



**HAL**  
open science

## Human centered processes

Philippe Lenca

► **To cite this version:**

| Philippe Lenca (Dir.). Human centered processes. pp.515, 1999. hal-01769544

**HAL Id: hal-01769544**

**<https://hal.science/hal-01769544v1>**

Submitted on 21 Oct 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# HCP'99



## Proceedings

Philippe Lenca (editor)

"Human Centered Processes"  
10<sup>th</sup> Mini EURO Conference

22 to 24  
September  
1999

Brest, France



CENTRE DE RECHERCHE PUBLIC  
CENTRE UNIVERSITAIRE



# **Human Centered Processes**

**Proceedings of the Conference Human  
Centered Processes (HCP'99),**

**Brest, France, September 22-24, 1999**

# **Local Editorial Board**

Philippe Lenca

Jean-Pierre Barthélemy

Sébastien Bigaret

Sébastien Iksal

Nathalie Lépy

Christophe Osswald



# Preface

The HCP'99 conference concerns professional users who are involved in human factors in companies and complex systems centered on human skills and abilities.

The study of operational strategies and processes used by human beings is the aim of Cognitive Science. It has been more or less recently applied in an industrial setting. For instance, the European Communities have supported a programme called Anthropocentric Production Systems, while in the US the notion of Human Centered Designs and Technologies has emerged and has become very popular. Such a movement is an important challenge for companies concerned with human beings in a workday context, because cognitive approaches, complementing more traditional ones, provide a great number of additional dimensions that allow design and analysis of more complete and complex systems.

The purpose of this conference is to bring together:

- Industrialists who deal with questions related to cognition.
- Researchers who are experts in Cognitive Science.
- Operation Researchers interested in discussing human centered approaches applied to complex industrial problems.

In view of this, the topics covered by the Conference concern industrially oriented themes where human centered approaches have already shown their usefulness; like planning, scheduling, decision making, quality control, project management, intelligent management of multimedia documents,...

This mini EURO conference has one of its motivations in the European COMAPS Brite-Euram project (Cognitive Management of Anthropocentric Production Systems, Be 96 - 3941).

About eighty papers are scheduled in the conference. Most of them are printed in these proceedings. The sessions are organized into seven streams (Applied Cognitive Science and Human Centered Systems, Knowledge Engineering and Management, Computational Linguistics, Manufacturing and Process Control, Decision Making, Multi-Modalities and Interactions, Methodology and/or Applied Mathematics). The conference includes: Keynote speakers talks (**Jean-Claude Falmagne** - University of California at Irvine – USA; **Henry Montgomery** - Stockholm University – Sweden; **James Shanteau** - Kansas State University – USA; **Kim J. Vincente** - University of Toronto – Canada), semi-plenary sessions (**Jean-Pierre Brans** - Vrije University – Belgium; **Dietmar Janetzko** - University of Freiburg – Germany), one invited session within the COMAPS Project (**Wolfgang Müller** - Fraunhofer Institute Information- and Data Processing – Germany), proposed sessions and regular sessions. Talks come from Europe in a broad sense (15 countries), from America (Chile, USA), Asia (Japan, Thailand) and from Africa (Cameroon).

Jean-Pierre Barthélemy, Chairman of Organization Committee,  
Raymond Bisdorff, Chairman of Programme Committee,  
Philippe Lenca, Editor of the Proceedings

# About HCP'99

The 10<sup>th</sup> mini-EURO Conference HCP'99 takes place in the Quartz convention center of Brest (France). It has received the "Haut Patronage of the Secrétariat d'Etat à l'Industrie". IASC Department (ENST Bretagne) is in charge of the organization of the conference.

## Programme Committee

Chairman: Raymond Bisdorff, CRP-CU (Luxembourg)  
Jean-Pierre Barthélemy, ENST Bretagne (France)  
Jean-Pierre Brans, VUB, Brussels (Belgium)  
Gilles Coppin, Thomson-CSF DETEXIS (France)  
Jean-Pierre Desclés, Université Paris-Sorbonne (France)  
Mehmet Göker, DaimlerChrysler (Germany)  
Alberto Greco, Laboratory of Psychology - Genova (Italy)  
Jean-Daniel Kant, LIP6, Paris VI (France)  
Marc Linster, IBA Consulting (USA)  
Benedetto Matarazzo, University of Catania (Italy)  
Franck Poirier, Université de Bretagne-Sud (France)  
Claus-Rainer Rollinger, Universität Osnabrück (Germany)  
Mike Sharples, University of Birmingham (England)  
Roman Slowinski, Poznan University of Technology (Poland)  
Marcus Spies, IBM Global Services (Germany)  
Gerhard Strube, Universität Freiburg (Germany)

## Organization Committee

Chairman: Jean-Pierre Barthélemy, ENST Bretagne (France)  
Assistant: Ghislaine Le Gall, ENST Bretagne  
Sébastien Bigaret, ENST Bretagne  
Philippe Lenca, ENST Bretagne  
Marie-Catherine Mouchot, ENST Bretagne  
Wonsil Park, ENST Bretagne  
Pierre Saunier, CRP-CU (Luxembourg)

## Sponsorships

**EURO** (Association of European Operational Research Societies)  
**The European Communities**  
**Air France**  
**Conseil Régional de Bretagne**  
**Conseil Général du Finistère**  
**Communauté Urbaine de Brest**  
**France Telecom**

**AFIHM** (French-speaking Association of Man Machine Interaction)  
**COMAPS Project** (Brite-Euram Be 96 - 3941)  
**CRP-CU** (Luxembourg)  
**ENST Bretagne**  
**ROADEF** (French Operational Research and Decision Aiding Society, a member society of EURO)

# Web Sites

<http://www-hcp99.enst-bretagne.fr/>

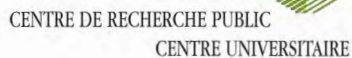
<http://www.crpgl.lu/>

<http://www-iasc.enst-bretagne.fr/>





# Sponsorships





# Table of Contents

## Part I - Applied Cognitive Science and Human Centered Systems

DSS Dedicated to Supervision: the Case of Air-Traffic Control.....	1
<i>Crévits I., Debernard S., Denecker P.</i>	
Cognitive Science for the IMSA Project.....	23
<i>Curé O., Cot N., Levacher M., Giroud J.P.</i>	
Informal Learning in It-Use Cognitive Support as an Operational Strategy.....	29
<i>Kavathatzopoulos I., Gulliksen J.</i>	
Modelling human activity for the purpose of flight analysis.....	37
<i>Le Blaye P., Wioland L., Chaudron L., Dehais F., Grau J.Y., Pénélaud O.</i>	
Post-Decision Editing of Auditors' Judgement.....	45
<i>Lundberg C. G., Nagle B. M.</i>	
Psychological Typologies for Management and for Management Science.....	53
<i>Müller-Merbach H.</i>	
A Districting Procedure for Winter Gritting.....	61
<i>Muyldermans L., Cattrysse D., Van Oudheusden D., Lotan T.</i>	
Socio-Cognitive Engineering: A Methodology for the Design of Human-Centred Computer Systems.....	67
<i>Sharple M., Jeffery N., du Boulay J.B.H., Teather D., Teather B., du Boulay G.H.</i>	
Human-Centered Systems Development and Use Inconsistencies.....	75
<i>Toffolon C., Dakhli S.</i>	
A macro architecture for human centred planning.....	85
<i>Vaccari E., D'Amato M., Caponetti L., Delaney W.</i>	
Ecological Interface Design: Supporting operator adaptation, continuous learning, & distributed, collaborative work.....	93
<i>Vicente K. J.</i>	
Integrating cognitive science and operations research techniques for building a better planning support system for a solid board factory.....	99
<i>Wanders H. L. T., Gaalman G. J. C., Jorna R. J. J., Sierksma G.</i>	

## Part II - Knowledge Engineering and Management

Adaptable groupware.....	107
<i>Alterman R., Landsman S., Introne J., Feinman A.</i>	



An architectural model compiler dedicated to archaeological hypothesis – An experiment on Krakow's Kramy Bogate.....	113
<i>Blaise J.-Y., Drap P., Dudek I.</i>	
Cooperation engineering for the extended enterprise.....	119
<i>Boughzala I., Zacklad M.I</i>	
Context-based decision making in incident management on a subway line.....	129
<i>Brézillon P., Pasquier L., Saker I.</i>	
Formal description of Human Machine (H-M) interactions derived from the application task graph.....	135
<i>Camilleri G.</i>	
Instrumenting collaborative writing and its cognitive tools.....	141
<i>Cerratto T. I.</i>	
Systems/persons correlation modeling. Application to noise/annoyance analysis.....	149
<i>Chaudron L., Boyer M.</i>	
Knowledge Management and Capitalisation as a Support for Innovation.....	155
<i>Ermine J.-L., Waeters A.</i>	
The Knowledge Capitalisation Problematic in Organisation from a decision aid point of view.....	161
<i>Fendri I., Grundstein M., Pachulski A., Rosenthal-Sabroux C.</i>	
Interaction with In-Vehicle Systems. A method to Evaluate the Performances of a New Input Device.....	163
<i>Kamp J.-F., Poirier F., Doignon P.</i>	
FELIX: An interactive rule mining interface in a KDD process.....	169
<i>Lehn R., Guillet F., Kuntz P., Briand H., Philippe J.</i>	
How a GroupWare based on a knowledge structuring method can be a collective decision-making aid: the MEMO-Net tool.....	175
<i>Lewkowicz M., Zacklad M.</i>	
Visualization in Data-Mining and Knowledge Discovery.....	183
<i>Poulet F.</i>	
Performance-based measures of expertise: How can you tell if someone is (or is not) an expert?.....	193
<i>Shanteau J. C.</i>	
Actions and Activities in Man-Machine disassembling systems.....	195
<i>Skaif A., Tian H., David B., Descotes-Genon B., Binder Z.</i>	
Expert system development in HRM: a case study in retailing.....	203
<i>Yildiz G., Erdogmus N.</i>	

## Part III - Computational Linguistics

The problem of transfer between verbal and iconic representations. Theoretical stake and practical applications.....	211
<i>Battistelli D., Valliez C.</i>	
Semantico-Cognitive Representation of Meanings - Application to Verbal Polysemy.....	217
<i>Djioua B.</i>	
Formal specifications building from specifications written in natural language.....	225
<i>Fougères A.-J.</i>	
Competitive Intelligence: extraction of relevant information with the contextual exploration method.....	233
<i>Goujon B.</i>	
A data processing sequence to extract terms and semantic relations between terms.....	241
<i>Le Priol F.</i>	
Information Routing in an Industrial Research Center: Using Textual Documents to build Researchers and Teams Profiles.....	249
<i>Pincemin B., Lemesle X.</i>	
SemIndex: A Human-Directed Textual Indexing of Image Content.....	257
<i>Thlivitis T., Kanellos I.</i>	
Representation of content using natural language processing.....	265
<i>Vinasse J.</i>	

## Part IV - Manufacturing and Process Control

On the Modelling of Production System.....	271
<i>Hadji S., Favrel J.</i>	
Dynamic adaptation of rules bases under cognitive constraints.....	277
<i>Lenca P., Le Saux E., Picouet P.</i>	
Conditional learning of expert's strategies.....	285
<i>Lépy N.</i>	
Workflow management - from chaos to synergy.....	293
<i>Leskovar R. T., Györkös J., Rozman I.</i>	
Machine learning methodology and cognitive modelling of human expert operators in anthropocentric processes.....	301
<i>Müller W., Wiederhold E.</i>	

Expert opinions on success factors for New Manufacturing Technology Deployment  
in Thai Automotive Industry..... 307  
*Paul H., Tritos L.*

Towards Reducing the Complexity of Process Modeling by Advisors, Explicit Context  
Modeling, and Visualization Techniques..... 315  
*Peter G., Rose T., Rupprecht C.*

Man Machine Interface for a Decision Checking Tool..... 321  
*Saunier P., Bisdorff R.*

## **Part V - Decision Making**

Ethics and Decision..... 327  
*Brans J.-P.*

GDSS-PROMETHEE.....329  
*Brans J.-P., Mosmans A.*

Modelling decision making with context-based reasoning and contextual graphs.  
Application in incident management on a subway line..... 331  
*Brézillon P., Pasquier L., Pomerol J.-C.*

Crisis management: optimal decision making as a method  
to prevent emergency situations and accidents in complex systems..... 337  
*Britkov V., Sergeev G.*

SOCRATE - SOCIetal Responses Analysis to environmenTal issues..... 345  
*Gadda A., Mazzeo Rinaldi F., Wolfler Calvo R.*

The supply chain management:  
operations research as a part of a decision making framework..... 353  
*Henig M. I.*

Cognitive Frames: An Integrative Tool for a State-of-the-Art Brand Management..... 355  
*Herrmann C.*

Human and social criteria for multicriteria Decision Aid in micro-credit:  
how to choose a CVECA installation site..... 357  
*Kala Kamdjoug J.-R.*

“Data Envelopment Analysis” versus “Multicriteria Decision Aid”.....365  
*Khamliche R.*

Using Agenda-Setting Theory for Strategic Marketing..... 367  
*Liebl F.*

Demystifying Expert Disputes with Cognitive Maps..... 369  
*Lumpkin C. A.*

STEEDES: a Strategic Transport/Energy/Environment Decision Support.....	377
<i>Mattarelli M., Moon D., Wolfler Calvo R.</i>	
A Multicriteria Decision Aid Methodology for the evaluation of the firms.....	383
<i>Montano Guzman L.</i>	
Performance Indicators Board.....	385
<i>Moreira J. M., de Sousa J. F.</i>	
Multicriteria Decision Aid for the budgeting of the Belgian health care system.....	393
<i>Mosmans A.</i>	
Strategic Performance Measurement: A Cognitive Approach.....	395
<i>Rughase O. G.</i>	
Order and Clustering.....	397
<i>Schweigert D.</i>	
Constructing quadratic objective functions from interviewing a decision maker.....	403
<i>Tangian A. S.</i>	

## **Part VI - Multi Modalities and Interactions**

How to use sounds in vocal servers?.....	413
<i>Chateau N., Botrel S.</i>	
Tools for product optimisation.....	419
<i>Fog C. L., Pedersen T. H.</i>	
The role of knowledge in WWW search: differences in IR skills and domain expertise...	425
<i>Hoelscher C., Strube G.</i>	
On-line multimedia Information System Adapted to Sailors.....	431
<i>Iksal S., Garlatti S., Kervella P.</i>	
Data and Knowledge Acquisition via Internet.....	437
<i>Janetzko D., Meyer H. A., Hildebrandt M.</i>	
Perceptual-based retrieval in large musical sound databases.....	445
<i>McAdams S., Misdariis N.</i>	
Systematic use of Internet based market research for mobility products.....	451
<i>Reinhold N.</i>	
Efficiency of WWW search engine user interfaces.....	453
<i>Röttgers H.</i>	
Intelligibility in Hypermedia communication: theory and research.....	455
<i>Storkerson P.</i>	

Actual Use and Judgement of the Usability of a Search Motor on the Web..... 463  
*Vom Hofe A., de Almeida V., Guibernao O., Legroux D.*

## **Part VII - Methodology and/or Applied Mathematics**

Neurosymbolic integration for industrial applications..... 469  
*Alexandre F.*

Epistemic Programming as an Operational Tool for  
Scientists to Program Their Epistemic Processes..... 475  
*Cheng J.*

Visual Languages for Linear Programming..... 483  
*Dombrovskaja L., Nussbaum M.*

Industrial applications of biomimetic adaptive systems..... 491  
*Donnart J.-Y., Jakobi N., Kodjabachian J., Meyer C., Meyer J.-A., Trullier O.*

A Primer on Media Theory..... 497  
*Falmagne J.-C.*

Modeling human cognition with artificial systems:  
some methodological considerations..... 501  
*Kant J.-D.*

Intervention Methodology for complex problems: the FAcT-Mirror Method..... 509  
*Le Cardinal G., Rigby J.*

Contributors Index..... 517

# **PART I**

## **APPLIED COGNITIVE SCIENCE AND HUMAN CENTERED SYSTEMS**

---





# DSS DEDICATED TO SUPERVISION: THE CASE OF AIR-TRAFFIC CONTROL

Igor Crévits, Serge Debernard, Pascal Denecker

Université de Valenciennes  
Laboratoire d'Automatique et de Mécanique Industrielles et Humaines  
Le Mont Houy – BP 311  
59304 Valenciennes Cedex

{Igor.Crevits, Serge.Debernard, Pascal.Denecker}@univ-valenciennes.fr

## Abstract:

*In the supervision of industrial processes, complex situations appear that only a human operator is able to grasp. This complexity comes from the size of the process and from the diversity of factors to master. Design assistances to the supervision operator is a mean to improve the mastery of this complexity. Then the complexity must be grasped by the designer of assistances. But in this context, the human operator introduces a additional difficulty. In order to master all the difficulties, several points of view, taking advantage of the results of various disciplines and technics, are necessary.*

**Keywords:** Supervision, human automation, modelling, cognitive mechanisms, air-traffic control

## 1 Introduction

The global objective of air-traffic control is to provide to airline companies crossing French airspace three kinds of services: the supervision of flights at airports, during approach and fly-over phases, the distribution of information to flights, warnings and assistance. The en-route control supervises aircrafts when they are outside of the approach zones of airports. This control has three objectives: to insure flight security, to regulate air traffic, and to allow flight economy. Particularly the security objective consists in avoiding collision between aircrafts, situations called conflicts.

To realize this control, French airspace is divided into five control regions, they are themselves divided into several sectors. A control center is associated with each region. Each sector manned by from one to three controllers, according to the quantity of traffic to manage. A plane crossing French airspace therefore passes from sector to sector.

To perform their work, controllers have technical procedures. Each control position is endowed with a radar view full of information about the aircraft. This information is provided by the CAUTRA system (Coordinateur AUTomatisé du TRafic Aérien - the French acronym for an automated air-traffic coordinator) from radar and from the flight plans registered by airline companies. This system also delivers paper strips to each control position, containing informations about the aircrafts crossing the sector, even before they appear. A strip contains four pieces of information: the call number of the plane, the route that it has to follow (a succession of points through which it must pass, so well as the estimated passage schedules for these points), the flight levels for entry and exit each sector, and the flight level required by the pilot, and the destination of the

plane. Controllers have also a radio system allowing them to contact the aircraft, and a telephone connecting them to the other control positions.

En-route air-traffic control functions are divided into two levels: tactical and strategical. The strategical level, called organic control, aims at managing the controlled sector periphery and realizing an air-traffic filtering. In a first time, the periphery management consists in modifying the enter flight levels on the request of the previous sector, role called *entry coordination*. In a second time, this management consists in negotiating the exit light level with the next sector, role called *exit coordination*. The *air-traffic filtering* consists in maintaining traffic load allowing to the second level to achieve their control objectives. This filtering is realized by coordination modifications limiting the number of conflits.

The tactical level, called radar control, aims at managing the sector interior and is decomposed into three roles. The *flight integration* seeks to maintain the global coherence, according to the control objectives, when new flight enter in the sector. The *traffic supervision* aims at verifying the traffic runs according to the flow foreseen by the flight plan or the controller. Finally the *flight guidance* consists in entering in contact with the aircraft in order to indicate them the operations they have to do to continue their route into the sector. Particularly this last role includes the management of conflicts which are avoided by modifications of flight parameters.

Highly dynamic situations appear in air-traffic. These situations submit the controllers, particularly the radar controller, to strong workload variations. Moreover this situation is enhanced by the air-traffic increasing [Mac Alindon, 1991], without the air-traffic security decrease.

For these reasons, we study the introduction of assistance to air-traffic control intended to regulate the controllers workload. This problematic, called dynamic task allocation, requires to master many human factors to design the assistances.

This paper is organised in three parts. The first part presents the different notions inherent in the dynamic task allocation. The second part presents the essential points of view of identification and modelling needed by the design of the assistances. Finally the third part presents the human factors used in the work of controllers and the investigations methods permitting to give them prominence.

## **2 Principles of Dynamic Allocation of Tasks between Human Operator and Support System**

### **2.1 Introduction**

Dynamic allocation of tasks is a sort of man-machine cooperation which consists in sharing dynamically all the tasks to be performed between a human operator (HO) and an automated system. The main advantage expected is the regulation of the human workload [Millot, 1988]. So, the automated system must be able to take care of some tasks, and provides a decision aid but also an action aid to the H.O.

This sort of man-machine cooperation is really suited to the process where the human workload changes a lot along the time because dynamic allocation allows to modify the degree of automation for adapting it to the human needs [Debernard and al., 1990]:

- When the human workload is low, all the the tasks are allocated to the H.O. for maintaining his own abilities.
- On the contrary, when H.O is unable to perform all the tasks because his workload is too high, some tasks (called shareable tasks) are allocated to the automated system.

The integration of this cooperation in a man-machine system requires to answer to different questions:

- Which tasks can be shared between H.O and automated system ? This question refers to the definition of all the tasks, and to the abilities of the automated system to set up.
- How allocating the shareable tasks ? This question refers to the definition of the structure of the man-machine system in view of characteristics process, and to the position of the H.O. in this structure. This question refers also to the algorithms and the criteria for choosing the tasks allocations.
- Which interactions between the H.O. and the automated system must be setting up to obtain an efficient cooperation ? How assessing this efficiency ? Which minimal interactions to be setting up between the two decision makers for building a common frame of reference for avoiding interferences on their current representation situation or diagnosis ? How showing this common frame of reference on man-machine interfaces and how update it in an optimal way for the H.O. (human model, automatic recognition of human intentions, etc.).
- How integrating in the automated system the specificity of the man-machine cooperation.

These different questions are treated now.

## 2.2 Structure of Dynamic Allocation

The general structure of dynamic allocation of tasks is given on Figure 1.

At the same level that H.O., the automated system (support system) controls the process only for the tasks which have been allocated to it. The allocations are decided by the task dispatcher and implemented by the task allocator. The latter has two functions [Debernard, 93]:

- Upstream the two decision-maker, it informs them about the allocations and how the tasks are performed by the other.
- Downstream the two decision-makers, it prevents one of them to perform a task allocated to the other.

The dynamic task allocation aims at modifying dynamically the allocations so as to optimize the process performance, but it is necessary to take into account the competences and the capabilities of the two decision-makers. For the H.O., these competences are considered as stable. But for the support system, some tasks normally in its competence may be not in certain case. So, it's necessary to determine on line for each task, the competences of each decision-maker.

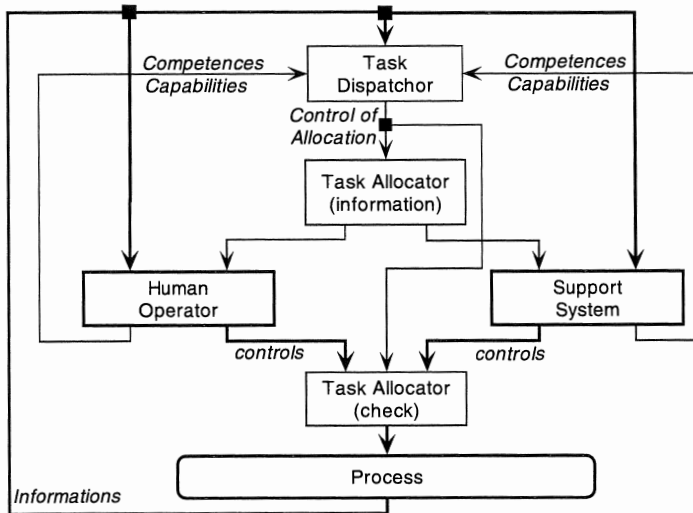


Figure 1: General structure of dynamic allocation of tasks

About the decision-makers capabilities of processing, we consider they are stable and known. Nevertheless, it's necessary to assess on line the human workload for avoiding underload or overload. Indeed, the underload can produce, in a short-term, a fall of vigilance and the H.O. can make some errors, [Jorna, 1991], and in a long-term a deterioration in human competences. The overload has some dangerous and immediate effects: errors, missing, delays, etc.

### 2.3 Interactions between H.O. and Support System

In a multi-task process, the different tasks to be performed are more or less independent. When the tasks are independant, the interactions between the two decision-makers does not exist. This is the ideal case and the only problem of the dynamic allocation of tasks to solve, concerns the tasks allocation.

When the tasks are not totally independant, some decisionnal conflicts can appear between the two decision-makers. These tactical conflits can appear, for example, when the treatment of one task allocated to the H.O. is constrained by the treatment of an another task allocated to the support system.

In the case of SPECTRA project [Debernard, 1993], [Crévits, 1996], the initial competences of the support system had been reduced for avoiding these situations. This support system called SAINTEX, has been produced by the CENA (french research center in air traffic control) [Angerand and Le Jeannic, 1992]. Now, SAINTEX is able to solve conflicts between only two planes, and these air conflicts are independent of the rest of the traffic. So the competences of SAINTEX are not stable in comparison with the number of possible situations.

## 2.4 The Task Allocator

The main function of the task allocator is the implementation of the allocations decided by the task dispatcher.

On one hand, the task allocator must inform each decision-maker about the allocation of each task. For example in SPECTRA project, on the radar screen, each plane which is part of a conflict allocated to SAINTEX, is showed with a specific color. On the other hand, for preventing tactical decisionnal conflict between the two decision-makers, the support system informs the H.O. about its decisions and actions. This permits to avoid two antagonistic actions which could create a new conflict between two planes. So, the functions of the task allocator are really important because it supports communication between the two decision-makers and its design enables human operators to increase partially their trust into the support system.

It exists an another kind of decisional conflict which could be qualified of strategic. These conflicts appear when difference exists between the effective allocation of tasks and the own human planning. Theses interferences are not due to the task allocator but to the task dispatcher which is going to be presented here after.

## 2.5 Types of Dynamic Allocation of Tasks

The function of the task dispatcher can be managed by the H.O. himself or by an automated system [Rieger and Greenstein, 1982]:

- The former is called explicit task allocation and the H.O controls the task allocator with a specific man-machine interface (Figure 2). So the H.O. uses its own criteria for allocating shareable tasks to the support system.
- The latter is called implicit task allocation and the task dispatcher is an automated system (Figure 3). The task dispatcher performs the allocations from an algorithm and criteria defined by the designer. These criteria can lead to assess some parameters of the man-machine system as human workload, task demand or global performance. The implicit task allocation presents the ergonomic advantage to decrease the human workload but the H.O. can't modify the allocations.

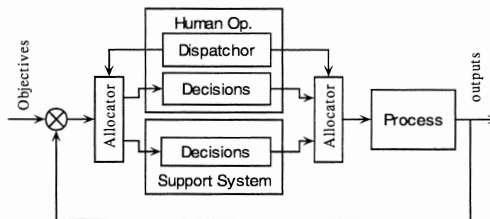


Figure 2: Explicit Task Allocation

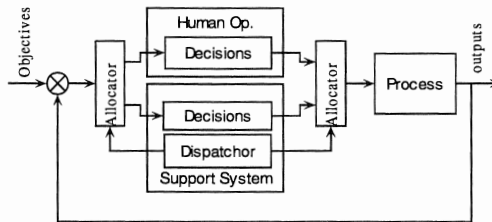


Figure 3: Implicit Task Allocation

These two types have been evaluated with a simulated process including independent tasks [Kamoun, 1989]. The results had shown an improvement of global performance with explicit and implicit allocation, and a good regulation of human workload [Kamoun and al., 1988], [Kamoun and al., 1989]. But for more complex process, the integration of a dynamic allocation of tasks is more critical for different reasons: the task complexity to perform, the assessment of the human workload when the tasks are cognitive, assessment of the global performance in line, human responsibility of support system's controls. In this last case, implicit allocation cannot be applied. However, it is possible to adopt an intermediate type of task allocation — the explicit assisted allocation — which consists of an automatic allocation by the task dispatcher, but the H.O. can modify the allocations if it's necessary.

## 2.6 External and Internal Allocation of Tasks

The tasks dispatcher, in a complex system where different levels or functions exist, can be situated at the same level than the H.O. and the support system which perform the tasks, or at an upper level, [Crévits, 1996]. In the first case, the dynamic allocation of tasks is qualified of internal, figure 4. In the other case, the dynamic allocation of tasks is qualified of external, figure 5. The advantage of the latter is to unload the "lower" level from the management of the allocations, because this level is overloaded in an explicit allocation for example, or because the "upper" level has better criteria for allocating the tasks. It is possible then to mix these two kinds of dynamic allocation to benefit from their respective advantages (mixed dynamic allocation).

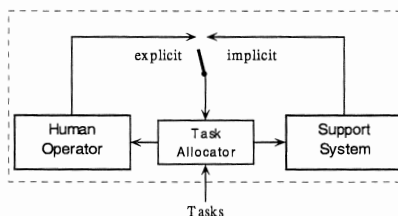


Figure 4: Internal dynamic allocation of tasks

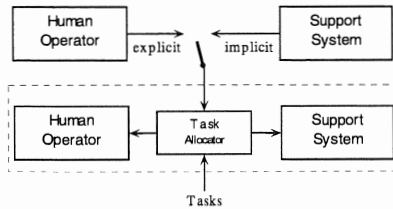


Figure 5: External dynamic allocation of tasks

## 2.7 The Task Dispatcher

In the implicit or assisted explicit type of dynamic allocation of tasks, the task dispatcher chooses the allocations of the shareable tasks. In complex process, one of the major problem is that the support system is not able to take always in charge some tasks under specific conditions. This is called dynamic shareability and it is necessary that the support system informs in real time the task dispatcher [Debernard, 93]. For example, in the case of SPECTRA project, a shareable conflict with two planes can become not shareable if the H.O. changes the trajectory of a third plane which interferes with the two others.

When the task dispatcher has chosen the first allocation for a task, it is possible to modify this allocation in certain case. The dynamic allocation is then qualified of pre-emptive [Debernard, 1993] and permits a better regulation of the chosen criteria. Nevertheless, if the task is too complex a modification of an allocation can be impossible because, for example, if the support system is unable to finish a task started by the H.O. In this case, dynamic allocation is qualified of non-pre-emptive.

Finally, the task dispatcher can work in a real-time mode or in a predictive mode.

In the case of SPECTRA, a real-time mode has been evaluated with nine qualified air traffic controllers from Athis-Mons Control Center and six engineers from the CENA. We have used an internal and non-pre-emptive allocation in explicit and implicit allocation. For the latter, the criteria used by the task dispatcher was based on a task demands estimator.

The main results have shown in implicit mode a decreasing of human workload and an increasing of performances [Debernard and al., 1992], [Debernard,, 1993]. These results are similarly the same? in explicit mode, but some dangerous behaviours appear because certain air traffic controllers don't use the support system in a good manner.

Nevertheless, these first results are not optimal about the human workload regulation. Indeed, in real-time the task dispatcher can not detect specific situations, and because the non-pre-emptive mode was used, some little overloads are appeared.

In a predictive mode, these problems are better treated. But it is necessary to predict all the tasks, the competences and the capabilities of each decision-makers. The major problem is then the reliability of the predictions.

This approach has been used in a second phase of SPECTRA project (SPECTRA V2). An external and explicit assisted allocation has been evaluated. The problematic is then more complex and it is treated in the next part.



### 3 Features needed to a distribution algorithm

#### 3.1 Introduction

The definition of task distribution respecting the features presented, requires the modelling of several problems in different ways. In order to master the complexity of this problem, we have used a procedure build around three models of the problem, the human operator and the resolution [Fréville and al., 1996].

#### 3.2 The problem model

The problem model seeks to identify a reference framework to the dynamic task allocation problematic. Here we have used the production management which provides hierarchical models of production functions translating the system refinement level by level (figure 6) [Dindeleux, 1992].

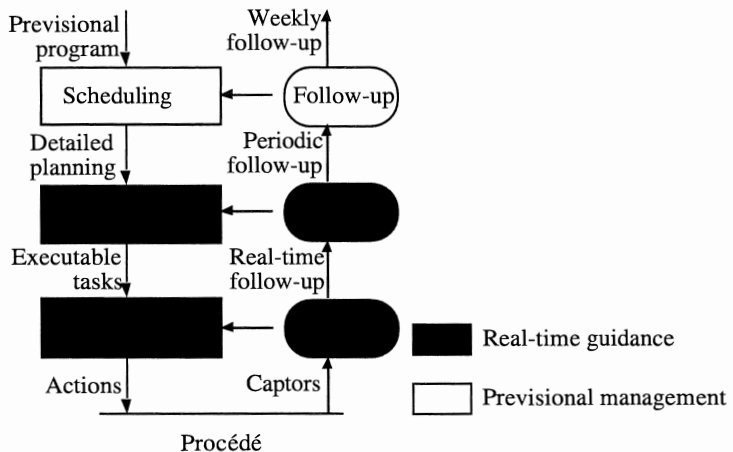


Figure 6: Production management functions

In this context, the three low levels are interesting. The scheduling level represents the lowest level of previsionnal management. It aims at optimizing the utilization of production means, satisfying their own constraints and respecting the production objectives. This level gives a work organization planning. The two lower levels constitute the real-time guidance. The control level aims at applying the planning given by the scheduling level. The order level, directly connected to the process, transmits the orders. In the context of dynamic task allocation, that is the human operator or the automated system.

Table 1 shows the correspondance between the dynamic task allocation functions and the production management functions. So the order level corresponds to the action level on the process, i.e. the human operator or the automated system. The control level corresponds to the task allocator because it applies the task distribution. The scheduling level defines the tasks to do. So this previsionnal level corresponds to the task prevision. Verify the constraints introduced by the human operator or the automated system enters also in the capacities of this level [Courtois and al., 1989], [Lamy, 1987]. Then this

level is able to continue the task prevision by the total or partial definition of the task distribution. In this case, there is an external or mixed dynamic task allocation. When no previsionnal distribution is defined, the dynamic task allocation is internal.

Production management functions		Dynamic task allocation functions		Air-traffic control functions	
Previsionnal management	Scheduling	External distribution	Prevision Distribution	Organic control	Air-traffic filtering
Real-time guidance	Control	Internal distribution	Distribution Allocation	Radar control	Aircraft guidance
	Order		Action		Orders to pilots

Table 1: Correspondance between dynamic task allocation functions, production management functions and air-traffic control functions

In the framework of the design of DSS for air-traffic control, the dynamic task allocation provides an appropriate structure because the production management is also a model of air-traffic control (table 1) [Crévits and al., 1993]:

- On the scheduling level, the air-traffic filtering is a strategical function which redefines as preventive the aircraft transition between sectors (coordinations), in order to reduce the number of conflicts, when it is necessary to reduce the workload of the tactical controller. On this level, the dynamic task allocation gives a mean to overpass the control capacities without penalizing coordinations with the others sectors. So the possible tasks to allocate to the automated system are simple conflicts between two aircraft only.
- The control level supervises the aircraft in the sector. On this level, the controller has to guide the aircraft. He can decide to modify some of the flight parameters of a plane when it is necessary, for instance, in case of conflict between two planes.
- The order level consists in contacting the aircraft when the controller implements the decisions concerning modifications of the planes trajectory (for example in the case of conflicts).

### 3.3 The human operator model

Providing a DSS is an operationnal mean for the operator to master the supervision difficulties. But the resulting interactions between human operator and DSS, also called man-machine cooperation, generate and introduce specific questions for the human operator, such as "how is the information perceived ?", "How are the situations evolved ?", "How should the decisions be taken ?" and "What action must be done ?". Because of these questions, the human dimension must be taken into consideration when drafting a model of the human operator. This model should be considered early on in the DSS development in order to improve the quality of the man-machine cooperation during the

problem resolution phase and decrease the divergences. From this point of view, the use of cognitive and artificial intelligence offers significant results.

In the case of dynamic task allocation, in function of the state of the process, the human operator has to do some actions to supervise it. So the definition of the task distribution is based on the prediction of the human operator's tasks during normal functioning. These ones come from events intervening in the process which can be classified in two categories:

- events after which a task can start,
- events before which a task must be finished.

Moreover, in the overloaded context of the dynamic task allocation, it is obvious to consider the quickest execution of tasks. So the human operator execute a task entirely when he starts it. On the contrary each interruption increases the global duration of the task. Then the tasks are non pre-emptive.

In the context of air-traffic control, the work of controllers comes from three types of events associated to aircraft: the enter of planes into the controlled sector, the conflicts and the exit of planes of the controlled sector. According to the human operator model, these events generate six types of tasks (figure 7) [Crévit, 1996]:

- the *assume* is the first task done by controllers, when the plane enters in the sector;
- the *order in level* is a modification of the flight level, forecasted by the flight plan between the enter and the exit;
- the *conflict solving* is a modification of flight parameters in order to avoid collision, between the enter time of the plane and the estimated time collision;
- the *flight parameters restoration* replaces the plane on its initial route when the conflict is terminated, between the estimated time collision and the exit time;
- the *plane supervision* is a task associated to each plane present in the sector;
- the *transfer* is the last task done by controllers to give the control to the next sector, when the plane exits from the sector.

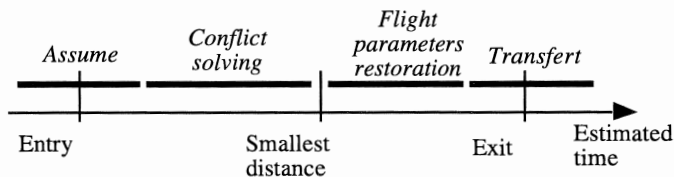


Figure 7: Tasks in the air-traffic control

In order to determine task distribution, it is necessary to first know the human operator's workload, particularly concerning overloads. This will allow to define a task distribution, if it is necessary, according to the tasks the human operator already has to do. Overload indicators are given by the single channel hypothesis [Welford, 1959] which translates the capacity of the human operator to process at least one task at any

moment. This hypothesis allows us therefore to determine if the human operator can respect the temporal constraints imposed by certain tasks.

The air-traffic management tries to master the air-traffic complexity reducing the size of controlled zones into regions, then into sectors. Controllers themselves reduce the complexity of situations they manage limiting the size of problems they treat. In this case, this limitation expresses in planes number. So controllers manage several independent problems, each ones composed of a reduced planes quantity.

The problem of dynamic task allocation is centered on the human operator. The human operator must be assisted when he needs it, without precisely scheduling his work. Moreover, the assistance must allow the human operator to remain the master of the entire process. Particularly information presented by the assistance must be understanding. In the case of dynamic task allocation, this information is based on events appearing on the process. But these events translate temporal information about the evolution of the process. Then the presentation of the decisions from the assistance is based on events and time to be efficiently inserted in the decisions of the human operator.

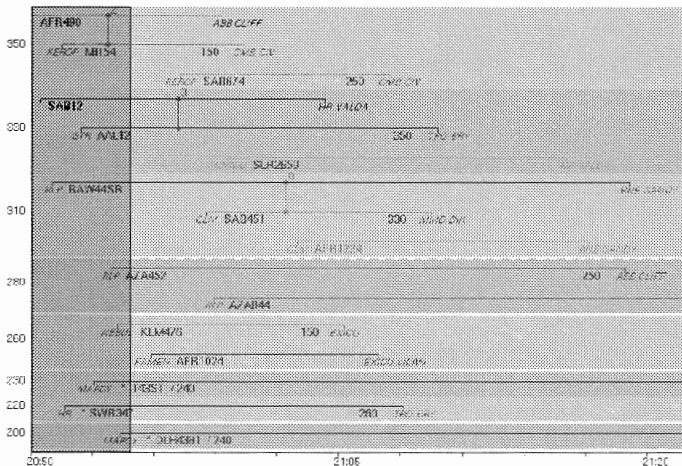


Figure 8: Interface of DSS for air-traffic control

The interface of controllers assistance is based on a temporal scale (figure 8). The interface recall the flight parameters (indicative, route, flight levels,...) and presents events to manage (modification of flight level, conflicts), information usually used by controllers. The assistance also gives informations on task distribution. Here shareable tasks are conflicts between two planes. The workload, particularly the overloads, is not an explicit information provided by air-traffic control means. The assistance introduces this kind of information putting in evidence time intervals where such overloads occur.

### 3.4 The solving model

After highlighting the different dimensions of the problem, the reference problematic still has to be determined taking into account the objectives to reach and the constraints

that to satisfy. This model is built around an AI/RO approach, hierarchised in time. Such an hybrid articulation helps to avoid the creation of a too simple and reductionist vision of reality, not compatible with the supervision problems studied.

By using the expressive power of these different models, the assistance provided to the operator is based on a resolution approach, including, for example, linear programming, multicriteria decision-making, graph theory, constraint handling programming, production scheduling or object-oriented programming,... and on a variety of exact or approximated problem solving techniques, such as branch and bound, metaheuristics, dynamic programming, referenced point multicriteria procedures, knowledge-based systems,....

As view in the problem model the task distribution enters in a scheduling problematic. Such a problem meets four notions: tasks, constraints, objectives and execution calendar [Gondran and Minoux, 1995]. In the case of the dynamic task allocation, the objectives are the same as the supervision which add to regulate the human operator workload.

On basis on events given by the human operator model, it is possible to define the tasks that the human operator has to execute to supervise the process. For each supervision situation, therefore a set of tasks is associated which is constituted of four parameters:

- the release date  $r$  before which the task cannot start,
- the due date  $d$  before which the task has to be completed,
- the processing time  $p$  of the task,
- the sharing indicator  $s$  comprising the *true* value when the task can be assigned to the automated system.

Both human operator and automated system represent the resources of the scheduling problem submitted respectively to the capacity constraint and sharing constraint as given by the human operator model.

Finally the specificity of the problem is seen when there is no pre-defined task execution calendar. The problem consists in mobilizing supplementary resources in order to avoid the human operator overloads.

The DSS is divided into three modules (figure 9). The first module, based on pattern matching technics coming from AI, generates tasks that the operator will have to do. The second module, based on explicit enumeration technics coming from OR, searches out overload subsets of task. To face the combinatorial complexity of this search problem, respecting the complexity limitation hypothesis of controllers, the exploration depth is limited to eight tasks subsets. If it is possible, the third module divides the overloaded sets of tasks into two separate subsets, one containing only tasks that the automated system is capable of processing, and the other, containing tasks for the human operator, who is no longer overloaded, because the task overload was shifted to the automated system. The last two modules have also been the subject of studies based on the linear programming in 0-1 variables associated to exact solving technics

[Crévits and al., 1994], and on constructive methods of scheduling associated to priority rules [Crévits and Fréville, 1997].

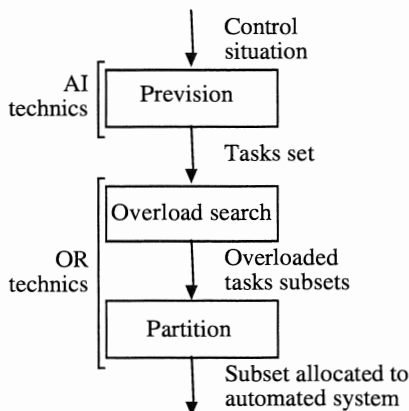


Figure 9: Structure of DSS for air-traffic control

## 4 Cognitive dimensions of supervision activities

### 4.1 Introduction

In process control, human activities need the construction of a plan to be guided. Planning plays a major role in cognitive activities and has two dimensions: anticipation and schematisation [Hoc, 1987]. In psychology, recent models of cognitive activities don't focus on the sequential structure of activities, as a strict expression of a plan. On the contrary, these models describe a global management of the updating of a current representation of the situation [Amalberti and Hoc, 1998b; Hoc, 1996; Endsley, 1995a; Sarter and Woods, 1991]. In complex systems, operators have to construct a mental representation of their multiple interactions, as in problem solving situations [Richard 1990]. These interactions are not only related to the supervised system, but affect all the human-system interactions. First, we will propose a definition of anticipation, not only centred on time management (explicit part of activities). That's why we will develop in a second part the importance of implicit cognitive mechanisms in risk, especially the role of metaknowledge to regulate the compromise between the mental workload demand and the quality/security optimisation of the system. In a third part, we will specify some methodological approaches to describe these implicit and explicit cognitive activities. In a last part, we will present some results to justify these theoretical aspects.

### 4.2 Characteristics of human operators' strategies in process control

Anticipation always played a major role in adaptive capacities of humans. This activity constitutes a distinctive characteristic of expertise [Amalberti, 1996; Grosjean, 1995; Roth and Woods, 1988].

Anticipation takes an important part in experts' activities, since these experts have a vast class of knowledge directly oriented to the objectives of the supervised systems. We can express the hypothesis that forecasts are integrated in the experts' knowledge.

We often mean by anticipation the notion of time management [Cellier, De Keyser and Valot, 1996]. Nevertheless, recent studies in process control have shown that this single aspect is not sufficient to explain all observed strategies. Indeed, we have to consider more variables if we want to take into account these related to the human (risk, workload) [Amalberti, 1996], and not only these related to the dynamic of the system.

Models of human activities usually describe a sequential ordering of non-decomposable activities. In considering only the temporal aspects, this conception has particularly reduced the definition of anticipation. This restriction probably comes from the methods, which only give the possibility to describe the explicit part of the behaviour (verbal report). However, several studies lead us to believe that anticipation and planning cannot be reduced to a symbolic form. Indeed, deeper mechanisms (implicit) play a major role in the regulation of human operator activities [Denecker and Hoc, 1997].

In the context of aeronautics, the notion of "situation awareness" describes several dimensions of human activities. This notion is distinguishable from others theories, as for instance mental models theory, insofar as the situation awareness does not consist of a finished number of elements or of a definite internal structure [Moray, 1990]. It must be seen as an opened system, according to a continuous movement of representations, which depend on the evolution of the process [Endsley, 1995a]. This "situation awareness" can be described as a complex process of perceptions and of recognition of patterns limited to the capacities of the working memory and the resource of the attentional processes. So, this notion allows us to define three types of integrated processes: the perception of the elements of the situation, the integration of the information, the comprehension and the forecasts of the future states of the process [Sarter and Woods, 1991; Endsley and Smith, 1996].

Therefore, the sub-symbolic cognitive activities have an important function in the construction and the updating of a representation of the situation. Thus, we have to modify our theoretical approach of anticipation to combine the symbolic and sub-symbolic aspects of the human cognitive activities. We distinguish in anticipation two part: forecasting and expectation [Denecker, in press]. Forecasting is the explicit component of anticipation, as plan with finite elements to guide the future activities. On the other hand, expectation is the implicit part of the activities. Its role is to prepare the organism to the future states of the situation. These expectations probably depend on expert knowledge in a domain, to identify the internal coherence of plan during time, and anticipate adapted responses.

### **4.3 Risk management and the cognitive compromise in the supervision**

The complexity of the situations and the uncertainty associated to their evolutions introduce supplementary constraints into the operator's activities. Consequently, the classical description of these activities is not sufficient to explain all the strategies related to the risk and the mental workload.

During supervision, human operator has to be able to manage risks. These risks can be external, when they are directly related to the systems, or internal when they depends on the human constraints. The maximal value of the internal risk is the loss of control [Amalberti, 1996; Amalberti and Hoc, 1998a].



To introduce his own constraints, human operator has to develop metaknowledge for an optimal regulation of human-system couple, and expectations play a major role in this regulation. In other words, the human operator has to integrate, to his own current representation of the states of the situation, all its cognitive possibilities, which can interfere with the dynamic of the system. These strategies have a special role in the regulation of workload, insofar as human operator has to be always able to reconstruct a plan to intervene on the system. Studies on fighter aircraft have shown that during the pre-planning step, operators anticipate many possible states, but also their capacity to deal with them [Amalberti, 1992].

Classical models used in experimental psychology seem to be poor to describe all these activities in complex systems, insofar as differences between situation in laboratory and natural situations are too important. Sometimes, to deal with the situation, operators have to diagnose and to forecast the state of variables with incomplete data or with a minimal definition of goals.

With Hoc and Amalberti, we can consider diagnostic and prognostic activities of supervision organised around a current representation of the situation [Amalberti and Hoc, 1998b; Hoc and Amalberti, 1999]. This current representation has to be seen as a central element, which organise all cognitive activities. It is a reference for diagnostic and prognostic and is a guide for the comprehension of the permanent changes in the supervised environment. All cognitive activities are involved in the construction of this current representation and in its updating [Hoc, 1996]. Then, human activities have to be seen through three complementary dimensions: parallelism/seriality dimension, autonomy/dependence dimension and the time of the event/differed diagnosis dimension. All these cognitive activities are related to the time of the situation to be synchronised in the time of the process, in the time of the task and in the time of the episode [De Keyser, 1990]. These dimensions are compatible with a model of diagnostic constructed on symbolic system of representations [Hoc and Amalberti, 1995].

This theoretical approach allows us to understand how operators introduce their own constraints (human limitations). To deal with these risks, operators have not always an algorithmic approach of the supervision, and produce errors that he can get back. Then, the anticipation of these constraints has to be considered to give a right description of mental workload.

#### **4.4 Methods to describe cognitive activities**

The access to the cognitive activities is not always easy, and methods used are often dependent, on the one hand on initial questions raised by the research, and on the other hand on the possibilities of investigation in the natural situation. Classically, we distinguish two main ways to describe these activities: the explicit part of behaviour (direct measure on variables), and the implicit part of behaviour (measure guided by the interpretation) [Hoc and Lemoine, 1998].

Several techniques are available to have access to these activities, for instance: physiological measures, performance measures, modification of the supervised environment, subjective measures, questionnaire. These methods could intervene in the course of activities or are not able to give a good description of the activities.

We can consider supervision as a situation of problem solving. Thus, verbal report analysis is a good way to access of operators' strategies [Amalberti and Hoc, 1998b], but not allows to access to the implicit activities. Endsley propose a method (SAGAT) to describe mechanisms of attention and its distribution, mental models, schemas, automaticity and limits of working memory [Endsley, 1995b]. This method consists on a succession of interruption during task and to question operator on all data he has in working memory. This gives a good description of the current representation of the situation and more by interpreting these data with verbal reports collecting during activities.

That is why, verbal report analysis and interruption of task, seem to us to be complementary. In our actual project (AMANDA), data are analysed according to this double point of view. In a simulation of ATC, we interrupted the traffic every two minutes. During interruption, we covered up the radar controller's screen, and give a hardcopy of a blind screen (controllers have just information about limits of the sector and positions of beacons). The radar had to draw positions and orientations of planes, which seem to him very important for the traffic. During the two kinds of experimentation (control and interruption), we have recorded all verbal reports.

In a first time, all data collected on hardcopy codes characteristics of the recall (planes represented in advance, differences between conflict angle, ...). These deformations of recall are signs of controllers' strategies to represent the situation [Bisseret, 1995]. In a second time, verbal report encoding was performed using a cognitive method introduced by Amalberti & Hoc [Hoc and Amalberti, 1999]. This method consists in inferring elementary cognitive activities from the behaviour, the context, a general architecture, and knowledge in the application domain. The verbal protocol is decomposed into elementary units, which are coded using a predicate/arguments format, with the help of the MacSHAPA software [Sanderson and *al.*, 1994]. In a first time, we have coded only the activities related to diagnostic and decision-making. The diagnostic activities are *inference* (INFHY) when controllers report uncertainty through an hypothesis, and *identification* (IDENT), when data of the situation are immediately categorised in a known problem. The decision-making activities are *schematic decision* (DECI-SCH) when the comprehension of the situation is not sufficient to act on planes, or to plan activities to organise the traffic. The other decision-making activities are the *precise decision* (DECI-PRS) when controllers decide to act on planes, the *action* (ACT) when controllers set on the action and the *evaluation of decision* (DECI-EVAL) to have a feedback on the global structure of the traffic.

We think that the conjunction of these different variables (implicit and explicit) will give us a global understanding of cognitive activities of air traffic controllers. The 15 interruptions during the simulation will give us the possibility to describe the dynamic evolution of the current representation. From a good description of this current representation of the different states of the situation, we will probably understand how controllers structure the traffic to act on it. In the following paragraph we will give first results to describe the expected results in a near future.

### 4.5 First results as example

#### 4.5.1 Distribution of cognitive activities

As we can see on the table 2 (average on 12 controllers), the activities of inference take on average a large place (32.4%) as actions (32.5%). For controllers, the comprehension and the construction of a operational representation of the problem (conflict) are very important activities.

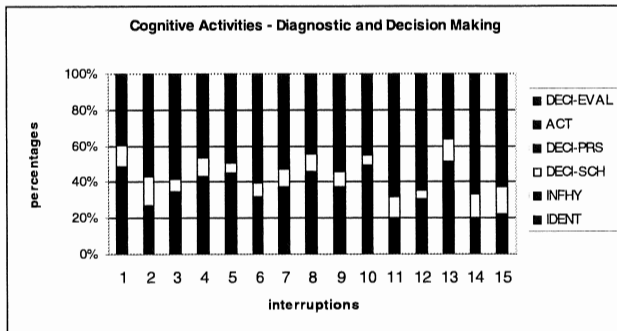


Table 2: distributions of diagnostic and decision-making activities

We can think that if the controller have a good comprehension of the situation, all decisions seem natural. The comprehension give the possibility to act following heuristic, because controllers prefer acting with few variety of action. More, this comprehension plays a major role to determine the context of the actions. Indeed, when the traffic increase, controllers report less inferences and more identifications (interruptions 8-12). During this period the precise decisions increase, and proportionnaly the schematic decision decrease. This is probably the sign that controllers have not the time to plan their traffic, and take some risks. This risk means that they have no possibility to deal with the situation when a problem occur.

#### 4.5.2 Precision of the recall

We present on table 3 the precision on the position of the reproduced planes. We can see at the beggining that all planes (more than 90%) are represented in advanced. For Bisseret [Bisseret, 1995], this a sign of heuristics used by controllers. During the simulation, we can define a same period of charge (last paragraph). During this period, the deformation of recall vary, and the proportion of planes in advance decrease (60%). We can hypothesis that controllers can not anticipate all the traffic, and focus on certain part of this one, without paying attention to other planes. In others words, the quality of planification decrease, and controllers are not able to deal with all the trafic.

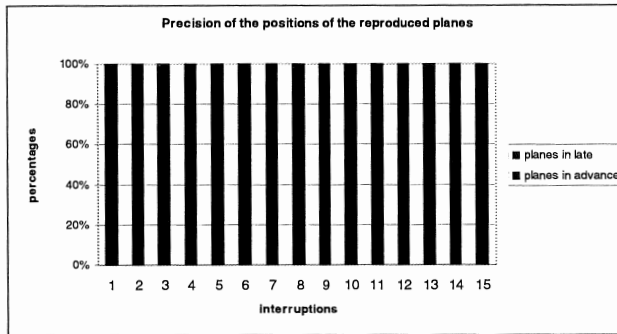


Table 3: Precision of the positions of the reproduced planes

If we are interested in representation of conflicts, table 4 presents the deformations of their representations. Before the eighth interruption, a large part of conflicts (more than 60%) are represented with an over representation of the angle. After this interruption, we can see that the distribution of correct and under representation of the angles increase. In the first part of the session, we can think that controllers represents through their deformations a part of their plan of actions. But, in the second part of the experimental session, this fact can't be observed. These decision are expressed during the control and do not correspond to a real plan of action. In other words, controllers do not need to express this plan because the time between the identification of the problem and its resolution increase under the control time (2 minutes).

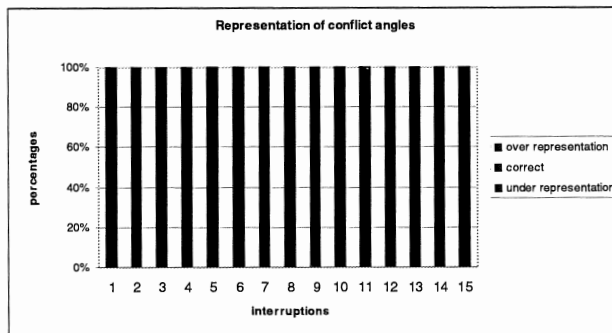


Table 4: Representation of the conflict angles

These firsts results just present an idea of the method we used to code all protocols. As we can see, the conjunction between explicit and implicit representation can give a more detailed representation of the strategies used by controllers.

## 5 Conclusion

In the context of the DSS dedicated to the supervision of industrial processes, the meaning of the term *modelling* is over the two usual signification: formulate in and solve.

On one hand, the single notion of equation restricts the term modelling to the context of mathematics or computer science. To define such models, required by the concrete realization of the assistance, other formalisms are necessary to express all the factors contributing to the decision.

In this way a systemic view allow to replace the decision in the global context of the process. Moreover the preponderant place the human operator takes in the supervision problems requires the utilization of models coming from the psychology in order to represent the mechanisms used by the operator.

On the other hand, to master the complexity of the problems, the formalization must be preceded by the identification of the decision it is necessary to assist, among all the activities of the operator.

Then the design of DSS dedicated to supervision requires a narrow collaboration between the decision and cognitive sciences. The major difficulty is the searched mechanisms are not always directly observable, but use no explicit phenomena.

## References

- [Amalberti and Deblon, 1992] Amalberti, R. and Deblon, F. (1992). Cognitive modelling of fighter aircraft's control process: a step towards intelligent onboard assistance system. *International Journal of Man-Machine Studies*, Vol 36, p. 639-671.
- [Amalberti, 1996] Amalberti, R.(1960). La conduite de systèmes à risques, Paris, Presses Universitaires de France.
- [Amalberti, 1998] Amalberti, R.(1998). Gestion dynamique des erreurs et contrôle de processus, XXXIIIème Congrès de la SELF, Paris, p. 261-270.
- [Amalberti and Hoc, 1998] Amalberti, R and Hoc, J.M..(1998). Analyse des activités cognitives en situation dynamique: pour quels buts? Comment?, *Le Travail Humain*, 61, p. 209-234.
- [Angerand and Le Jeannic, 1992] Angerand, L..and Le Jeannic, H. (1992).Bilan du projet SAINTEX, Note R92009, Centre d'Etudes de la Navigation Aérienne.
- [Bisseret, 1995] Bisseret, A.(1995). Représentation et décision experte: psychologie cognitive de la décision chez les aiguilleurs du ciel, Toulouse, Octarès.
- [Cellier and al., 1996] Cellier, J.M., De Keyser, V. and Valot. (1996). La gestion du temps dans les environnements dynamiques, Paris, Presses Universitaires de France,
- [Courtois and al., 1989] Courtois, A. Pillet, M. Martin,C. (1989). Gestion de production, Les éditions d'organisation.
- [Crévits and al., 1993] Crévits, I. Debernard, S. Vanderhaegen, F. Millot, P. (1993). Multi-level cooperation in air traffic control, Fourth International Conference on Human-Machine Interaction and Artificial Intelligence in AeroSpace (HMI-AI-AS'93), Toulouse, France, September 28-30.
- [Crévits and al.,1994] Crévits, I. Amrani, F. Fréville, A. (1994). Dynamic task allocation in a man-machine interface, EURO XIII, OR 36, Glasgow, Scotland, July 19-22.

- [Crévits, 1996] Crévits, I. (1996). *Répartition dynamique des tâches dans les systèmes complexes. Modélisation de la répartition anticipée. Application au contrôle de trafic aérien*, Thèse de Doctorat, Université de Valenciennes, France.
- [Crévits and Fréville, 1997] Crévits, I. Fréville, A. (1997). Constructive heuristics for a single-machine scheduling problem with time window constraints, International Conference on Industrial Engineering and Production Management (IEPM'97), Lyon, France, October 20-24.
- [Debernard and al., 1990] Debernard, S., Vanderhaegen, F., Debache, N., Millot, P. (1990). Dynamic task allocation between controller and AI systems in air-traffic control, 9th European Annual Conference on Human Decision Making and Manual Control, Ispra, Italy.
- [Debernard and al., 1992] Debernard, S., Vanderhaegen, F., Millot, P. (1992). An experimental investigation of dynamic task allocation of tasks between air traffic controller and AI system, 5th IFAC/IFIP/IFORS/IEA symposium on Analysis, Design and Evaluation of Man-machine Systems, The Hague, The Netherlands. June 9-11.
- [Debernard, 1993] Debernard, S. (1993). *Contribution à la Répartition Dynamique de Tâches entre opérateur et système automatisé: application au contrôle du trafic aérien*; Thèse de Doctorat, Université de Valenciennes.
- [Denecker and Hoc, 1997] Denecker, P. and Hoc, J.M. (1997). Analysis of the effects of a support to anticipation in the supervision of a long time-lag process: the blast furnace. In BAGNARA S., HOLLNAGEL E., MARIANI M., NORROS L., Time and space in process control - 6th European Conference on Cognitive Science Approach to Process Control, Roma, CNR, Istituto di Psicologia.
- [Denecker, sous Presse] Denecker, P. (sous Presse). Les composantes symboliques et sub-symboliques de l'anticipation dans la gestion des situations dynamiques, *Le Travail Humain*.
- [Dindeleux, 1992] Dindeleux E. (1992). *Proposition d'un modèle et d'un système interactif d'aide à la décision pour la conduite d'atelier*, Thèse de doctorat, Université de Valenciennes.
- [Endsley, 1995a] Endsley, M.R. (1995). Toward a theory of situation awareness in dynamic systems, *Human Factors*, 37, p. 32-64.
- [Endsley, 1995b] Endsley, M.R. (1995). Measurement of situational awareness in dynamic systems, *Human Factors*, 37, p. 65-84.
- [Endsley and Smith, 1996] Endsley, M.R and. Smith, R. P. (1996). Attention distribution and decision making in tactical air combat, *Human Factors*, 38, p. 232-249.
- [Fréville and al., 1996] Fréville A., Crévits I., Gandibleux X. (1996). Vers une approche multimodèle pour la résolution de problèmes rencontrés en conduite de systèmes automatisés complexes: démarche et illustrations industrielles, Congrès AFCET sur la modélisation des systèmes réactifs, Brest, France.

- [Garland, 1991] Garland, D.J.(1991). Automated Systems: the human factor, NATO ASI series, Vol. F73, Automation and Systems Issues in Air Traffic Control, pp 209-215.
- [Gondran and Minoux, 1995] Gondran, M., Minoux, M. (1995). Graphes et algorithmes. Editions Eyrolles.
- [Grosjean, 1995] Grosjean, V. (1995). Temporal strategies of operators dealing with numerous parallel processes: a field study, *International Journal of Human Factors in Manufacturing*, 5, p. 123-137.
- [Hoc, 1987] Hoc, J.M.(1987). Psychologie cognitive de la planification, Grenoble, Presses Universitaires de Grenoble.
- [Hoc and Amalberti, 1995] Hoc, J.M. and Amalberti, R. (1995) Diagnosis: some theoretical questions raised by applied research, *Current Psychology of Cognition*, 14, p. 73-100.
- [Hoc, 1996] Hoc, J.M. (1996). Supervision et contrôle de processus: la cognition en situation dynamique, Grenoble, Presses Universitaires de Grenoble.
- [Hoc and Lemoine, 1998] Hoc, J.M. and Lemoine, M.P. (1998). Cognitive evaluation of human-human and human-machine cooperation modes in air traffic control, *International Journal of Aviation Psychology*, 8, p. 1-32.
- [Hoc and Amalberti, 1999] Hoc, J.M. and Amalberti, R. (1999). Analyse des activités cognitives en situation dynamique: d'un cadre à une méthode, *Le Travail Humain*, 62, p. 97-130.
- [Jorna, 1991] Jorna, P.G. (1991). Operator workload as a limiting factor in complex systems", NATO ASI series, Vol. F73. Automation and Systems Issues in Air Traffic Control. pp 281-292.
- [Kamoun and al, 1988] Kamoun, A. Debernard, S. and Millot, P. (1988). Implicit dynamic allocation of tasks between man and computer based on the optimal control, 7th European annual conference on human decision making and manual control, Paris.
- [Kamoun, 1989] Kamoun, A. (1989). *Contribution à la répartition dynamique des tâches entre opérateur et ordinateur pour la supervision des procédés automatisés*, Thèse de Doctorat. Université de Valenciennes.
- [Kamoun and al, 1989] Kamoun, A. Debernard, S. and Millot, P. (1989). Comparison between two dynamic task allocations, 2nd European meeting on cognitive science approaches to process control, Sienna, Italy.
- [Keyser, 1990] De Keyser, V. (1990). Fiabilité humaine et gestion du temps dans les systèmes complexes, In Leplat, J. De Terssac, G. Les facteurs humains de la fiabilité dans les systèmes complexes, Marseille, Octares, p. 85-108.
- [Lamy, 1987] Lamy P. (19987). Ordonnancement et gestion de production, Manuel pratique, Editions Hèrmes.
- [Millot, 1988] Millot, P. (1987). Supervision des procédés automatisés, Edition Hermès, Paris.

- [Moray, 1990] Moray, N. (1990). A lattice theory approach to the structure of mental models, *Philosophical Transactions of the Royal Society of London*, B327, p. 577-583.
- [Rasmussen, 1986] Rasmussen, J. (1986). Information processing and human-machine interaction, Amsterdam, North-Holland.
- [Richard, 1990] Richard, J.F. (1990). Les activités mentales. Comprendre, raisonner, trouver des solutions, Paris, Armand Colin.
- [Rieger and Greenstein, 1982] Rieger, C.A. and Greenstein, J.S. (1982). The allocation of tasks between human and computer in automated systems", *Proceedings of the IEEE 1982 International Conference on Cybernetics and Society*, pp. 204-208, New York.
- [Roth and Woods, 1988] Roth E.M. and Woods D.D. (1988). Aiding human performance. I: Cognitive analysis, *Le Travail Humain*, 51, p. 39-64.
- [Sanderson and al., 1994] Sanderson, P., Scott, J., Johnson, T., Mainzer, J., Watanabe, L. and James, J. (1994). MacSHAPA and the enterprise of explanatory sequential data analysis (ESDA). *International Journal of Human-Computer Studies*, 41, 633-681.
- [Sarter and Woods, 1991] Sarter, N.B. and Woods D.D. (1991). Situation awareness: a critical but ill-defined phenomenon. *The international journal of aviation psychology*, 1, p. 45-57.
- [Welford, 1959] Welford A.J. (1959). Evidence of a single channel decision mechanism limiting performance in a serial reaction task, *Journal of experimental psychology*.



## COGNITIVE SCIENCE FOR THE IMSA PROJECT

O. Curé, N. Cot, M. Levacher, J.P. Giroud<sup>1</sup>

Laboratoire d'Intelligence Artificielle de Paris 5  
UFR de Mathématiques et d'Informatique  
Université René-Descartes  
45, Rue des Saints-Pères  
75006 Paris - France  
curo@math-info.univ-paris5.fr

<sup>1</sup> Chef de service de pharmacologie clinique de l'hôpital Cochin, membre de l'académie de médecine

### **Abstract:**

*The purpose of this paper is to present the IMSA Project. IMSA stands for Intelligent Multimedia System for Automedication and aims at providing a healthcare Internet tool for the end-user. IMSA proposes an environment that integrates on-line health information, a medical database and a knowledge base system for medical diagnosis. This provides public healthcare, medicine tutoring and general practitioner decision support services. Toward developing this system's Internet sites, we were concerned with developing an intelligent framework, ergonomics and providing a relevant level of medical information for a non-health expert.*

**Keywords:** Cognitive science, knowledge representation, Human-Computer Interfaces (HCI), public healthcare, automedication.

### **Introduction**

- The IMSA project proposes several healthcare services on the Internet such as:
- On-line health information,
- Tips to provide a good automedication,
- Access to a drugs database,
- A diagnosis for a single symptom and proposing a list of drugs that will help toward a better health.

Automedication could be defined as: « the use of drugs products that haven't been recently prescribed by a healthcare professional. » [Dictionnaire]. It's being used more and more by a large amount of people in France and Europe, and many medical conferences [QdM,1999] are now dedicated to it. Many doctors consider it's about time for them to get involved in this process. In fact, it's not useful to discuss whether automedication is appropriate or not because it's already there and growing. It's more important to bother on providing information to the patient's safe and relevant use of automedication.

Most of the time, drugs purchased in automedication are OTC (Over The Counter) products, which means that you can buy them on your own, without a doctor's prescription. The database of drugs in IMSA only involves OTCs.

With IMSA, the patient will have the opportunity to use a diagnosis module which, through a series of questions, will provide a therapeutic class of drugs that will help the end-user cure.

## 1 Cognitive work

The cognitive work is the heart of our system as far as IMSA could be defined as a Knowledge Base System (KPS) where the rules and facts are stored in a relational database system. Such as the well-known Mycin expert system [Shortliffe, 1976], the development of this tool needs a close collaboration with healthcare experts. We found the skills and motivations in the team of Professor Jean-Paul Giroud at the C.H.U. Cochin (Paris 5). Although Pr Jean-Paul Giroud is the pharmacology department chief at the C.H.U. of the Cochin hospital, he is also the author of books on healthcare and automedication [Giroud and Hagege, 1997].

With the help of doctors and pharmacologists, we were able to extract the knowledge that a practitioner uses during a medical consultation and which helps him to prescribe a drug.

The first important task of our teamwork was to select a list of mild symptoms where automedication of OTC drugs is harmless and effective. The cognitive work could be defined in different phases:

1. Work on the symptoms, considering the different forms a single symptom can take. For instance, cough was the first symptom studied and its forms are dry cough, productive cough, cough caused by smoking, cough due by a minor physical activity, etc.. The doctors helped us determined which forms need the assistance of a doctor and which could be cured with OTC drugs.

2. Work on drugs and their relations with symptoms. A close look at the contraindications of a drug or a therapeutic class was a very important step toward a safe proposition of healthcare products. In fact, it's necessary to study the active chemical component of each therapeutic classes and drugs to determine its correlation with a symptom. It's by far the most demanding task of the cognitive work.

3. Doctors also worked on all healthcare information provided in the site. All the on-line information definitions, questions and replies need to be understood easily by the end-user.

This cognitive phase emphasized that a symptom and a group of drugs are related by a therapeutic class which is determined by the active chemical component of the drug. This relation could be studied with medical books, doctors and pharmacologists.

## 2 Knowledge representation

Once the cognitive work was done for a dozen of symptoms, we started the development of a prototype. The knowledge representation was a major issue due to a constraint: the Internet supports the system, so the knowledge base and inference module needs to be implemented toward an effective and fast access. The amount of information available on the site is rather important:

1500 drugs descriptions with name of the product, price, rating efficiency by Pr Giroud, contra-indications, doses to prescribe, when to start and stop using the product, composition, etc.

Tenths of symptoms with definitions, causes of occurrence, extra information such as what to do first, etc.

Definitions and general information on healthcare.

Due to the amount of information and the need for a dynamic management of pages, a database approach was relevant. The use of a relational database system was then a must because it has been proved to work well on the Internet, which is not the case for Object Oriented database.

It was obvious that the medical knowledge used during a diagnosis can be easily represented via a decision tree. We had another constraint here: if the end-user spends too much time replying to question without a fast feed-back on drugs proposition, he will leave the site and never come back. The question always asked is how much is too much time? We don't intend to reply to this issue but our concern was that the end-user spends the shortest time in the diagnosis module and access a therapeutic class of drugs as fast as possible. To do so, we bundled together questions in classes. We ended up with three major classes of questions:

- Questions that detect whether the end-user's symptoms is mild or not. If any harm is possible, we invite the user to consult a doctor.
- Questions that help the system to detect which form of symptom the patient is suffering from.
- Questions that provide a list of drugs that are supposed to help the patient toward a better health. These questions are bound to the drug contra-indications.

For the diagnosis module, the medical knowledge is represented with a decision tree. The figure 1 offers a simple representation of the decision tree where the three levels of questions interact. With the questions of class 2, the system is able to display the right information on the symptom's form. With the questions of class 3, the end-user will know if some OTC drugs are available and efficient considering his symptom and contra-indications.

Let's consider an instantiation of the decision tree for cough :

- Choose upper body in the anatomic section.
- Choose cough among upper body symptoms.
- Display general information and probable causes of occurrence on cough.
- Reply to questions of class 1 (example : of a question your cough and spit blood).
- User clicked "Go on".
- Reply to questions of class 2 : Your cough is dry or productive (you spit).
- User clicks on Productive cough.

- Display Information on productive cough + Questions of class 3 on contra-indications.
- User clicks “Go on” because he doesn’t match the contra-indications..
- Display a therapeutic class list of drugs.
- User clicks on “ATOUCLINE expectorant”.
- Display all information for the product “ATOUCLINE expectorant”.

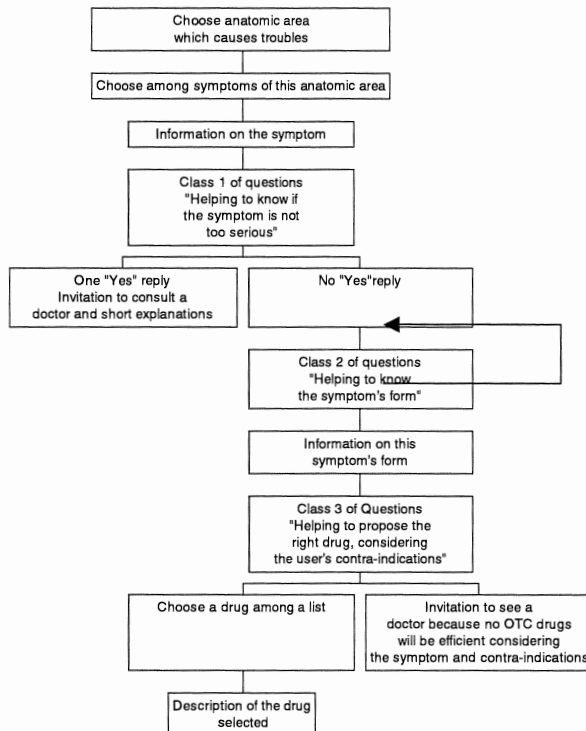


Figure 1: Simple decision tree for the diagnosis module

### 3 Human-Computer Interface

The main concerns during the development of the overall interface module were user-friendliness and efficiency. We learned a lot from all the sites and CD-ROMs we tested with healthcare professionals. Even if most of these systems were implemented toward a use by experts, we found that they weren't offering an efficient and logical navigation. Dialogues modes were ranging from the use of thesaurus to the analysis of a natural language [Winograd,1996]. In a technical domain like medicine, the analysis of

a natural language can be profitable to the expert but is not useful for the patient who ignores the terms of the medical domain.

Due to fast interaction between the system and the user, IMSA is using thesaurus dialogue mode and binary replies to all the questions asked. The end-user only uses the mouse click; it helps his navigation to be effective and fast, which is what's needed in an Internet site.

#### **4 Evaluation**

A prototype of IMSA has been developed with hundreds of OTC drugs and a dozen of symptoms, enough to have the system evaluated by a wide range of users (medicine students, doctors, automedication users and non users, computer scientists neophytes and experts). Tests were supposed to help us know about the interface ability to guide a patient from a symptom description to a drug proposition. To do so, we developed with our team of doctors a series of scenarios that would be played by the users. All scenarios would lead to a clear decision:

- Consult a doctor because the symptom's form is too serious.
- Consult a doctor because no OTC drugs are efficient for your symptom.
- Choose a drug (with the help of a rating and price) among a list.

After a user played all scenarios, a series of questions were asked. Replies from all users were compiled. It showed that:

- The IMSA project was well understood by most users.
- The navigation was clear and logical to all users, even for those who weren't user-friendly with the Internet.
- Medicine students found the tool interesting. They consider they do not spend enough time learning on benign symptoms. A system with more medical information could be a good tutoring tool for students.

#### **Conclusion**

The development of the IMSA project stands at the corner of medicine, multimedia interfaces and artificial intelligence. The main goal of this work is to prove the feasibility of a system providing healthcare information and diagnosis possibilities to the patient. Many tests with a wide range of end-users (healthcare professionals, computer scientists, Internet neophytes) more or less concerned with automedication confirmed that such a tool has a bright future.

IMSA proves that such a system can work efficiently using well-known technologies such as a CSQL programming through CGI, thesaurus and mouse click interface dialogue, general information and an expert system like decision tree stored in a relational database system.

Among the perspectives envisioned during our tests is the development of a tool conceived for the students in medicine or rookie practitioner. In fact, all the medicine student testers emphasized the point that such a system, with information correlated to

their skills, would be very useful during their final years of studies and their first years as general practitioners.

The IMSA projects showed us how important it's to have this kind of tools developed by computer scientists and healthcare professionals. This collaboration must be effective all through the project. Although a logical method could be used to get the information on drugs and their relations to symptoms, a doctor's point of view is always necessary.

### **References**

- [Dictionnaire] Dictionnaire des sciences pharmaceutiques & biologiques, Académie nationale de Pharmacie, page 192
- [Giroud and Hagege ,1997] Le guide de tous les médicaments, J-P Giroud et C. Hagege, Editions du Rocher, Paris 1997
- [QdM,1999] Le quotidien du médecin, Jeudi 21 Janvier 1999, N 6418 page 1-8
- [Shortliffe, 1976] Computer-Based Medical Consultations : MYCIN, F. Shortliffe, American Elsevier, New-York, 1976
- [Winograd,96] Bringing design to interfaces, T. Winograd, Addison-Wesley, 1996

# INFORMAL LEARNING IN IT-USE COGNITIVE SUPPORT AS AN OPERATIONAL STRATEGY

Kavathatzopoulos, Iordanis and Gulliksen, Jan

Department of Human-Computer Interaction  
Uppsala University  
Box 311, S-751 05 Uppsala, Sweden  
Iordanis@hci.uu.se & Jan.Gulliksen@hci.uu.se  
<http://www.hci.uu.se>

## Abstract:

The present paper describes research on informal cognitive learning and support among IT-users in industrial and office settings. Informal work organization structure and dynamics, i.e., cooperative relations and knowledge flows between IT-users, emanates from the shortcomings of formal organization, from IT-users' knowledge resources and from the demands of the task. Participation in formal educational programs before or during the use of new technology are not sufficient to provide all knowledge and skills necessary for optimal use in unexpected situations. Consequently the work organization restructures itself informally in order to take advantage of different individuals' cognitive resources and to transfer these to other individuals in the same work team who need guidance and training. Informal learning is a prerequisite for the successful use of information technology.

**Keywords:** Learning, competence, training, work-organization, information-technology

## 1 Informal learning and support

The interaction of information technology, humans, organization and work demands is very complex. It is therefore necessary to have highly competent users as well as an organizational environment which promotes learning and development. In this paper we attempt to give a description of how working teams function as a cognitive support unit in order to succeed in their work in a computerized environment. This knowledge is a prerequisite for effective work organization design and development of suitable educational intervention.

Any formal organization plan is not enough to describe the actual organization at a work place, that is, the way people are connected to each other and cooperate. As it turns out IT-users often reorganize themselves informally in forms that differ from the original formal organization plan, which means that other factors than the formal organization are also of importance. The informal structure is primarily seen as a result of the inadequacy of the formal organization to meet the work task demands. This perspective means that the grounds for the existence of informal organization should sought in factors related to the nature of the work, the formal work organization frame, and the competence of the work team members. The issue of interest is how the demands of the task affect the organization and how the organization shapes itself to meet these demands [De Keyser, DeCortis & Peree, 1985; Reinartz & Reinartz, 1989; Van Daele & De Keyser, 1991].

Besides formal education informal learning takes place in work organizations, especially when unexpected problems arise. Informal training is allowed or promoted by a formal organization if people who are experts in different areas are in connection with other people who are not experts in these areas. Continuous communication among these people has to be made not only possible but also easy. People must be close to each other geographically or at least they can use reliable communication technology in order to be able for the “expert” to get a picture of the problem situation and for the “novice” to receive instructions. They must also have time to communicate about such things and the authorization by the formal organization to experiment and test any new knowledge. All that means that the formal organizational frame has to be “loose,” and that it must not only allow informal communication and learning but also to support it.

### 1.1 Process industry

A study which was carried out in a control room of a sulfate pulp mill revealed an informal cooperative structure among the operators. This structure was related to informal cognitive support and learning [Kavathatzopoulos & Kuylenstierna, 1993].

The purpose of the informal cooperation structure was to transfer information, coordinate actions and to assist operators to fulfill their task, i.e. to supervise and control the process. The results showed that the form of the informal cooperation structure was similar in all shifts.

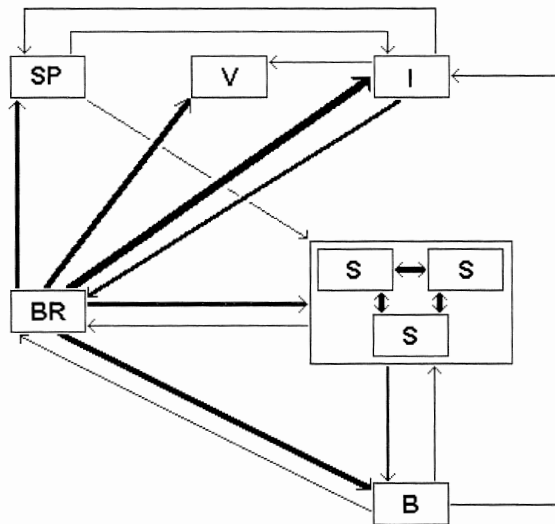


Figure 1: Direction of cognitive support in the control room. Thickness of arrows shows the frequency of support (The boxes indicate the placement and work task of individuals).

Looking at the dynamics of knowledge support we can see that operators in a certain department (BR) take a central position (fig. 1). These give informal support to all other



departments but most often to operators in difficult departments. Informal cognitive support and learning given by any other operator was correlated to previous experience in that department. The pattern for informal learning was consistent with the amount of formal training given to different operators. That is, operators in the above mentioned department had received more formal courses and hours of training than any other operator in the control room. They also had more experience from work in different departments in the control room than any other operator group. The structure of formal organization which placed these operators in the control room made them easily available to the other operators when they needed guidance and training. It may seem strange that regular operators who work in their departments every day and for many years should have anything to learn from others. However, the results showed that receiving informal education in many cases was very important because of unexpected events and situations.

## 1.2 Office setting

A second study [Lindgren, 1999] conducted in a department of the Swedish Tax Authority showed that users most often asked their colleagues for help when they confronted difficulties with the new system they worked with (fig. 2).

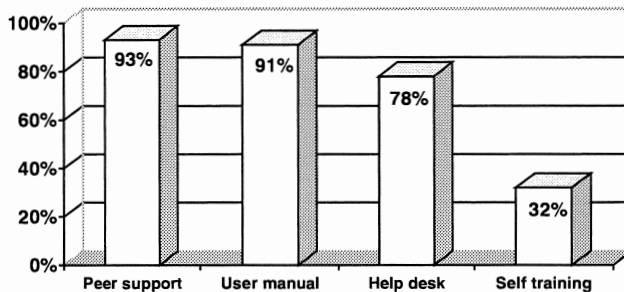


Figure 2: Percentage use of help to cope with problems arising from the interaction with the system.

Regarding the nature and the origin of the problems most of the users reported that the formal organizational frame created a lot of problems, such as difficulties in getting help, not enough time to ask and experiment, etc. The results point to the fact that organizational factors are very important to remedy any shortcomings. Continuous learning through the emergence of informal support structures is necessary for acquisition of competence to use the new system in an optimal way.

The point of departure for this study was the notion that informal work organization for development and competence may be accounted for factors related to the task demands, to the present level of competence of the team members and to the structure of formal organization. The results showed that an informal cognitive support and learning structure was present. The structure of this informal cognitive support and learning was consistent with the demands of the work task and the level of competence of IT-users.

## 2 Individual and organizational learning

The above findings have important implications. First, research on informal work organization must pay more attention to factors related to the fulfillment of the task. Second, because they suggest that informal support and learning emerges as an attempt to meet the task demands more efficiently, they should be of great interest to practitioners with the aim to design efficient work organizations and information/communication technology systems.

Informal cognitive support and learning can take place under the conditions of an open and supportive organizational frame, diversity of skills and competencies, free communication and enough time to experiment and communicate [Sefarty, Entin & Johnston, 1998; Salas et al, 1998]. It is very important that the organizational setting is arranged in that way. Planning for informal learning means that the kind and level of participants' expertise in different areas or aspects of the system has to be chosen, and placed in the work team. They can then support and train each other. An alternative solution could be to place there general and high level experts as instructors without demanding any high competence or specialization on the part of the trainees.

Learning is possible in situations where the learner has a real problem the solution of which is very important to him [Vygotsky, 1978; Nardi, 1996]. He has not to be indifferent or over motivated, i.e. emotionally blocked. The solution, however, must have some impact on his life or activities in order for him to be interested and activate himself searching for that solution. Furthermore, the problem's basic structure has to be understood by the person who has that problem. That means that this person or a group of persons know what the preferred solution is what they want to achieve, and they know that they have not yet solved it and they have not yet reached their target.

The solution, either as content or as a method to solve the problem, is transformed to the learner by someone who has this knowledge. Consequently this person has to be close to the learner in place and time, and give the necessary instructions to him. By guiding the trainee's thinking and action towards the solution the trainee gets informed about the new knowledge or the way of handling the problem. However, in order to internalize it and learn it the trainee has to test the proposed solutions and solving methods. The trainee can evaluate the information given to him by comparing it to his original target. This is the main criterion by which the degree of efficiency of instruction can be assessed. This training situation gives the trainee the possibility to make this comparison. Thus he is in a position to decide if the instructions are worth learning or not. If they help him to cope with his problem he internalizes the instructions, that is, learning take place.

What happens here is that the learner, when he confronts a problem, is in a condition of cognitive disequilibrium and the instruction helps him to re-establish equilibrium (see for example Piaget, 1980). Learning can take place in an environment where formal training in the form of an education program is given. People participate in different courses with the aim to learn how to use effectively the information technological equipment in their workplace. Such educational efforts must follow the above theoretical lines, that means that they have to provide problem oriented instruction as well as aiming at the establishment of equilibrium.

Besides formal education informal training takes place in work organizations. As we have seen above there is evidence of such informal communication structures aiming at cognitive support. We may say that informal training is allowed or promoted by a formal organization if people who are experts in different areas are in connection with other people who are not experts in these areas. That presupposes a high degree of specialization.

Continuous communication among IT-users has to be made not only possible but also easy. People must be close to each other geographically or at least they can use reliable communication technology in order to be able for the instructor to get a picture of the problem situation and for the learner to receive instructions. They must also have time to communicate about such things and the authorization by the formal organization to experiment and test any new knowledge. All that means that the formal organizational frame has to be "loose," and that it must not only allow informal communication and training but also to support it. The informal training must follow the above theoretical lines, which means that it has to be problem oriented. This is of course more natural for informal training than formal.

### **3 Planning the learning process during systems development**

In order to be able to define the objectives and the content of any educational intervention it is necessary first to describe the relationship, interaction and mutual influence of users' competence and skills on one hand, and on the other hand the features of information technology, organization structure and work task demands. Users' actual competence level and skills have to be mapped. Furthermore, the new skills demanded by new technology, organizational setting or work task must be defined [Kavathatzopoulos & Kuylenstierna, 1998].

Planning for informal education means that the kind and level of participants' expertise in different areas or aspects of the system have to be chosen, and placed in the work team. They can then support and train each other. An alternative solution could be to place there general and high level experts as instructors without demanding any high competence or specialization on the part of the trainees. Finally the educational process must be evaluated continuously. As a consequence the organizational setting has to change and adapt continuously, as well as the mix of competence and skills in trainers and trainees.

We know for a fact that the work tasks, the organization of the work, the human skills and experiences are very much influenced by the development of the technology support for the work [Leavitt, 1958]. To support this we need to let the development of IT be the engine in the process of developing the more humane parts of the IT supported work situation. How can this be done?

Traditional system development methodologies are extensively used in real life development settings today. These methodologies help establish the needed requirement specifications for efficient and effective development. Several problems have although been encountered in practical use of existing system development methods [Gulliksen & Lantz, 1998]. Some of these problems can directly be related to learning and organization factors as addressed above, but other important aspects contribute equally to these problems.

It is therefore important that the learning process, the development of the work situation as well as the necessary organizational changes can be planned for already during the system development process. By doing this it would even be possible to, to a larger extent, take the humane aspects into consideration when developing the systems and perhaps through this, change the appearance of the final system. There is a need to bring learning and organizational aspects into the system development processes, a need that is recognized by the system developers as well as the users. This is one of the focuses that we will pursue in our future work.

## References

- [De Keyser, DeCortis & Peree, 1985] De Keyser, V., F. DeCortis, & F. Peree (1985) Collective control in an automatized system as apprehended in verbal communications. I G. Mancini, G. Johannsen & L. Martensson (Eds.) *Analysis, design and evaluation of man-machine systems*. IFAC Proceedings Series, Varese, Italy.
- [Gulliksen & Lantz, 1998] Gulliksen, J. & Lantz, A. (1998) *User orientation - does it work or is it just an aggravation*. I3-magazine no.2, March 1998. The European Network for Intelligent Information Interfaces.
- [Kavathatzopoulos & Kuylenstierna, 1993] Kavathatzopoulos, I. & Kuylenstierna, J. (1993) *Informellt samarbete och kunskapsstöd: Operatörslaget i ett datoriserat kontrollrum [Informal cooperation and cognitive support: Operator teams in a computerized control room]*. Stockholm: NUTEK/DUP.
- [Kavathatzopoulos & Kuylenstierna, 1998] Kavathatzopoulos, I. & Kuylenstierna, J. (1998) *Kommunikationsteknikens egenskaper och arbetsorganisationens struktur [Features of communication technology and structure of work organization]*. Stockholm: NUTEK/SAMT.
- [Leavitt, 1958] Leavitt, H.J. (1958) *Managerial Psychology*. London: University of Chicago Press, Ltd.
- [Lindgren, 1999] Lindgren, M. (1999) *Datorutbildning i arbetet [Computer education at work]*. M.Soc.Sc. Thesis, Department of Education, Uppsala University.
- [Nardi, 1996] Nardi, B. A. (1996) *Context and consciousness: Activity theory and human-computer interaction*. Cambridge, MA: Mit Press.
- [Piaget, 1980] Piaget, J. (1980) *Experiments in contradiction*. Chicago: The University of Chicago Press.
- [Reinartz & Reinartz, 1989] Reinartz, S.J. & Reinartz G. (1989) *Verbal communication in collective control of simulated nuclear power plant incidents*. Proceedings of Second European Meeting on Cognitive Science Approaches to Process Control, Siena, Italy, October 24-27.
- [Salas et al, 1998] Salas, E., Cannon-Bowers, J. A., Church-Payne, S., & Smith-Jentsch, K. (1998) Teams and team work in the military. In C. Cronin (Ed.) *Military psychology: An introduction* (pp- 71-88). Old Tappan, NJ: Simon & Schuster.
- [Sefarty, Entin & Johnston, 1998] Sefarty, D., Entin, E. E., & Johnston, J. H. (1998) Team adaptation and coordination training. In J. A. Cannon-Bowers & E. Salas

(Eds.) *Making decisions under stress: Implications for individual and team training* (pp. 221-246). Washington DC: APA.

[Van Daele & De Keyser, 1991] Van Daele, A. & De Keyser, V. (1991) Distributed Decision Making and Time in the Control of Continuous Processes. I J. Rasmussen, B. Brehmer & J. Leplat (Eds.) *Distributed decision making: Cognitive models for Cooperative work*. Chichester: John Wiley & Sons.

[Vygotsky, 1978] Vygotsky, L. S. (1978) *Mind in society*. Cambridge, MA: Harvard Press.



# MODELLING HUMAN ACTIVITY FOR THE PURPOSE OF FLIGHT ANALYSIS

P. Le Blaye<sup>1</sup>, L. Wioland<sup>1</sup>, L. Chaudron<sup>2</sup>, F. Dehais<sup>2</sup>, J.Y. Grau<sup>3</sup>, O. Pénelaud<sup>3</sup>

<sup>1</sup> ONERA BA 701  
13661 SALON CEDEX AIR  
leblaye/wioland@onera.fr

<sup>2</sup> ONERA CERT  
31055 TOULOUSE CEDEX  
chaudron/deshais@cert.fr

<sup>3</sup> IMASSA -BP 73  
91223 BRETIGNY/ORGE CEDEX  
jygrau/openelaud@imassa.fr

## Abstract:

*ONERA and IMASSA are currently involved in a research program which aims at defining a methodology for the analysis of military aircrews' activity during everyday operations. The proposed methodology is different from the flight analysis processes currently used by airlines, for instance, as it is clearly focused on the human activity: it is based on a model of generic activity, built from aircrews' verbalisations and flight simulations, which is used as a reference to identify possible discrepancies between this generic model and the actions actually performed during the flight. Those discrepancies are then interpreted using a typology of typical safety relevant events, which was established by an extensive review of incidents cases.*

**Keywords:** human activity, aviation safety, flight analysis, cognitive modelling.

## 1 Introduction

ONERA (*Office National d'Etudes et de Recherches Aérospatiales*) and IMASSA (*Institut de Médecine Aéronautique du Service de Santé des Armées*) are currently involved in a research program called REX-FH, which aims at defining a methodology for the safety analysis of military aircrews' activity during everyday operations, using the data recorded on board the most recent aircraft.

This research program is supported by the Human Sciences division of the French MOD (DGA/DSP/STTC/SH), for the need of the French Air Force.

## 2 Background

Whatever the domain (aviation, nuclear power plants, other transportation means or industries), the study of the human operator's activity at work inevitably reveals its extreme variability. When trying to improve the safety or the performance level of such socio-technological systems, the measures undertaken on instruction, on ergonomics or on professional rules and procedures should carefully address this variability. The be-

haviour of the operators is obviously the visible expression of the variability, but it results primarily from the operators' knowledge and know-how. Through experience feedback, it becomes possible to collect and to analyse some relevant elements of knowledge and know-how in order to formulate some recommendations for safety improvement.

A review of existing experience feedback and on-line analysis processes has been conducted during a preliminary phase of the research program [Le Blaye and Doniat, 1996].

This review clearly showed that various systems already exist in most of the modern complex industries and transportation means, in order to better understand what are the difficulties actually faced by the operators in control of the processes. Mandatory or volunteer and confidential reporting systems are often used and obviously useful. Their efficiency for the improvement of safety widely depends on the level of confidence accorded to those reporting systems by the operators, but it is limited because of the subjective nature of the information provided.

Aviation has always given a particular attention to experience and "Human Factors" feedback. In order to get an accurate picture of the actual practices in flight, various tools are now emerging that tend to address not only the events revealed by a consecutive incident, but also less visible facts which could help understand what are the possible safety hazards of the socio-technological systems. One of the most systematic and objective tools is the day-to-day analysis of the flight recorded parameters which is now set up by most airlines with the corresponding hierarchical structure. These Flight Operational Quality Assurance (FOQA) programs offer a substantial amount of objective information and their safety benefit is high, especially if the aircrew involved in an event is able and agrees to participate to the analysis process.

However, these flight analysis systems are based on the detection of deviations from flight profiles or exceedances of parameters limitations, in order to detect well known and safety critical events. The analysis of the detected deviations is then left to a skilled specialist. The current tools look for deviations from a normative perspective of the crew activity. They provide useful data for safety improvement, but new ways are now open to better know the actual practises of the crew. By taking into account the intra- and extra-individual variability, an extended definition of the deviations in the aircrew behaviour may be proposed and addressed in order to establish more accurate safety recommendations.

Our approach refers specifically to theoretical and experimental studies carried by the department for Cognitive Sciences of IMASSA, concerning the cognitive aspects of the aircrew's activity and error mechanisms [Amalberti, 1996].

In the ecological approach of safety, the error is a natural element of human activity and it participates directly to the regulation of the activity [Amalberti and Wioland, 1997]. Then, the aim of a safety approach is not to suppress the errors but, rather more, to avoid that they could lead to an accident, i.e. to learn from them. That's the motivation to build an objective methodology to better know and understand what is actually done in the cockpit.



### 3 Objective

The objective of our research program is to develop a mock-up of a possible systematic flight analysis software for military aircraft that would be able to identify safety relevant events from a "human factors" perspective, using the available data recording of each mission. Those events will then be studied by a safety analyst who will formulate the appropriate safety recommendations.

The general purpose of the research program is to establish the necessary methodology to achieve this objective. The key of this methodology is to model the aircrews' activity and also the events which are thought to be safety relevant and that we intend to address.

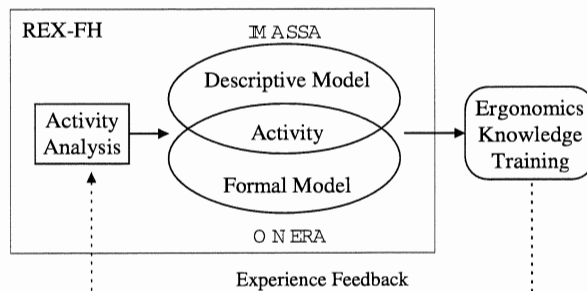
Those events will be identified as gaps between the actual activity and a reference norm. The criteria for human variability and the interpretation of the gaps in terms of safety depend directly on the definition of this reference norm [Grau and Bellet, 1992]. In the most classical approach, this norm may be defined as the prescribed task, as written in the documentation (legal requirements and recommended procedures). The norm may also consist of the usual practice, that may differ from one operator to another and also for one operator during his professional career. Last, the reference norm may be considered as the primary intent of the operator and a gap from this norm will be defined as a human error [Reason, 1990].

The choice of the reference norm has various implications from a safety point of view. Given the reference norm, it becomes possible to address not only the "negative" deviations and errors but also the difficulties that the operators have to face in normal operations and furthermore, particular mechanisms and "positive" behaviours that benefit to safety.

## 4 Methodology

### 4.1 Principles

In our methodology, the process for the identification of safety relevant events is based on the analysis of aircrews' activity. This analysis aims at establishing a typology of safety relevant events (SRE) and building an Activity Descriptive Model (ADM). This model is then implemented as an Activity Formal Model (AFM).



The model of activity is then used as a reference frame to rebuild and to identify some possible gaps in the activity as performed during the actual mission, using the flight parameters. Those parameters provide objective data on the aircraft state and parameters, systems in use, warnings to the crew and crew actions. They are recorded as a function of time by onboard equipment of the most recent military aircraft.

The identified gaps will then be interpreted using the typology of SREs.

#### 4.2 Identification of Safety Relevant Events (SRE).

This first step of the analysis of aircrews consisted of the study of incidents reports from the Air Force. Those reports deal with incidents which are not subjects of a detailed investigation. Given the current experience feedback practices in the Air Force, they represent the closest available information to what could be collected with a systematic analysis system. The study of 615 reports showed that the most safety critical phases of the mission are take-off and, moreover, landing. This study resulted in a typology of the gaps or errors, based on the phenotypic model of error production [Hollnagel, 1993]. The erroneous action is described as a gap with what should have been done, which is formally described outside of the actual situation, and generally based on the published procedures. The proposed typology are derived from an existing error categorisation [Swain and Guttman, 1983] with the adjunction of a temporal reference [Decortis and Cacciabue, 1988].

Four types of gaps have been identified:

- intrusion (*e.g. during approach, fuel tank dropping instead of landing gear down*)
- inversion (*e.g. tyre explosion at landing after a failure of the anti-slide system, because the pilot breaks before using the parachute, although the procedure is to use the parachute first*).
- omission (*e.g. the crew forget to report his position to the control before starting a descent*)
- erroneous time management, which can be detailed as:
  - \* too early (*e.g. landing gear down while speed still too high*)
  - \* too late (*e.g. thrust reduction too late, which results in a precipitated approach*)
  - \* too long (*e.g. thrust kept idle for a too long time, inducing an engine extinction*)
  - \* too short (*e.g. landing flare too short, causing a hard touch down*)

Those gaps can be identified among the elements of the descriptive model which is presented below.

#### 4.3 Building the Activity Descriptive Model (ADM).

The second step of the analysis of the activity consisted of detailed interviews of 5 qualified military crew members, on the basis of paper scenarios. The aim of these interviews was to capture the knowledge and the know-how of the crews in the take-off and landing phases. The transcription of the interviews help to build a preliminary descriptive model of the activity.

The ADM consists of a generic structure, based on the schema approach [Schank and Abelson, 1977]. This approach is now well accepted in cognitive psychology, among other formalisms used for knowledge representation in computer science.

The ADM allows to represent the crew activity with the following typology:

Phase > Schema > Module > Cue

The Phase is the highest level of description of a mission (e.g. "Take-off", "Landing"). It is defined as a sequence of schemas.

The Schema is a description of a particular goal-oriented activity (e.g. "Prepare landing configuration", see the example). A schema is an oriented graph of modules.

The Module is a typed consistent combination of Cues. Its type is either a Test, a Procedure, a Result or a Control (e.g. Procedure: {Speed 450 knots, Intercept 500 feet, Climb to pattern altitude}).

A Cue is a piece of information, a property or an elementary physical action (e.g. "Speed 450 knots").

The last phase of the analysis of crew activity consisted of mission simulations with military pilots in a realistic full-size simulator of a two-seats fighter aircraft. Four mission scenarios of one hour each were flown, including specific events in order to collect actual examples of deviations. Detailed debriefings with an analysis of video recording was conducted with the crew members. They were exploited to validate the MDA and the typology of SRE. The scenarios help to identify particular unknown practices that had not been explicitly described by the crews during the previous interviews. Numerous flight parameters were of course recorded during the simulations, to be used for the development of the software mock-up.

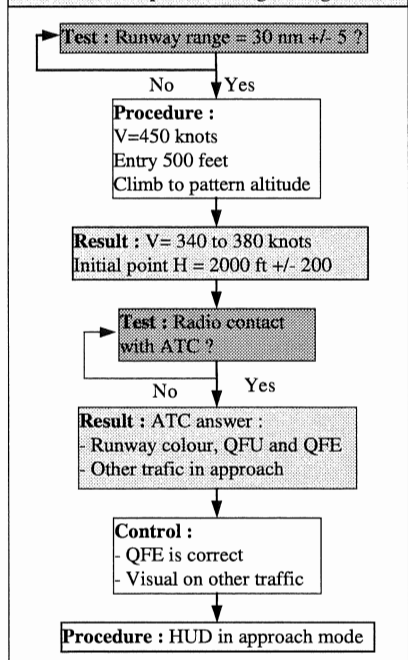
#### 4.4 Creating the Activity Formal Model (AFM).

The AFM is devoted to mathematically capture the ADM including software simulation functionalities. The requirements of the AFM are:

1) to provide a formal and computable representation of the activity characteristics as revealed and validated by the ADM,

2) to ensure the data connections between the elements of the activity and their corresponding effects on the flight parameters recorded by the on-board devices.

#### Schema 1 : Prepare Landing Configuration



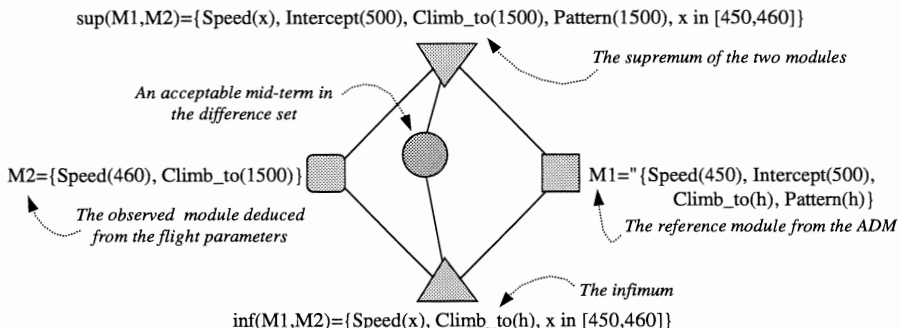
Indeed, a discrepancy feature which was assessed in the ADM (as it appeared relevant from a human factors analysis) must be consistently represented as a graph operator in the AFM. For instance, an ADM inversion of two Cues observed in a given activity should be captured by a specific permutation in the AFM, and the application of this operator should be confirmed by the correlation with the flight parameters. From a microscopic point of view, the informal notion of deviation to the activity described in the ADM, gets a corresponding definition as a structured difference between two pieces of knowledge.

Thus, the AFM aims at providing formal definitions of naive notions, such as the expression "addition of errors" which is frequently described by accidents investigators. Is the naive denotation "addition" formally relevant? Should it be considered that this "addition" is commutative, associative or distributive with other operators? The purpose of the AFM is to filter, to structure and to assess the amorphous knowledge in a consistent and relevant way.

From the theoretical point of view, the Cues are coded as constrained literals of the first-order logic (e.g. "speed(450)"), they represent the smallest piece of knowledge on which validity questions can be performed. Hence, the Modules are constituted of conjunctions of literals (e.g.  $M1 = \{\text{Speed}(450), \text{Intercept}(500), \text{Climb\_to}(h), \text{Pattern}(h)\}$ ).

An algebraic framework, called the Cubes model, is used to completely describe and capture the differences between pieces of knowledge such as different Modules. We think that such a skill is the key of activity deviation modelling. We previously established that the Cube model is a complete non-modular lattice [Chaudron et al. 1997]; all the symbolic fusion operators (supremum, infimum, etc.) are defined in the model and implemented in Constrained Logic Programming (CLP), more precisely in PROLOG.

For example, considering the Module  $M2 = \{\text{Speed}(460), \text{Climb\_to}(1500)\}$  deduced from the flight parameters of an actual mission, the Cubes model makes it possible to compare  $M2$  to  $M1$ , and to determine the symbolic difference set of these two pieces of knowledge.



The current research on AFM focuses on the integration of constraints into the Cubes model so as to fit closely to the actual expressions of both flight parameters and the refined modules of the ADM.

## 5 Possible extensions and conclusion

The next phase will be to extend the functionalities for the interpretation of the possible discrepancies between the generic model and the actual activity. The typology of SRE should integrate elements of expertise collected from flight safety officers.

The methodology could also be extended in order to describe the mechanisms dedicated to the adaptation of the mission plan in flight and the individual variability depending on the pilot's level of expertise [Wioland and Amalberti, 1998].

Based on a careful analysis of the crew activity, our approach should contribute to get a better information on everyday practices and to better understand how the crews face the operational constraints, how they regulate the errors inherent to their activity and eventually, how to avoid incidents becoming accidents.

## References

- [Amalberti, 1996] Amalberti R. (1996). La conduite des systèmes complexes. Collection Le Travail Humain. Editions puf. 1996.
- [Amalberti and Wioland, 1997] Amalberti R., Wioland L. (1997). Human error in aviation. Aviation safety conference. Rotterdam, Aug. 1997.
- [Chaudron et al., 1997] Chaudron L., Cossart, C., Maille N. and Tessier C. (1997). A purely symbolic model for dynamic scene interpretation. *International Journal on Artificial Intelligence Tools*, 6(4):635-664.
- [Decortis and Cacciabue, 1988] Decortis, F and Cacciabue, P. (1988). Temporal dimensions in cognitive models. 4<sup>th</sup> IEEE conference on Human Factors and Power Plants, June 5-9, Monterey, CA.
- [Grau and Bellet, 1992] Grau M.P., Bellet S.C. (1992). Bases théoriques de l'erreur humaine en situation de pilotage. Rapport IMASSA n 93-27. Décembre 1992.
- [Hollnagel, 1993] Hollnagel E. (1993). The phenotype of erroneous actions. *Int. J. of Man-Machine Studies*, 39, 1-32.
- [Le Blaye and Doniat, 1996] Le Blaye P., Doniat C (1996). Recensement des besoins et des méthodes de retour d'expérience sur les facteurs humains pour la sécurité de vol des aéronefs militaires. ONERA RT 3/5276 SY.
- [Reason, 1990] Reason J. (1990). Human error. Cambridge University Press.
- [Schank and Abelson, 1977] Schank R.C., Abelson R. (1977). Scripts, plans, goals and understanding. Hillsdale, N.J. Lawrence Erlbaum Associates Inc.
- [Swain and Guttman, 1983] Swain, D. and Guttman, H.E. (1983). Handbook of Reliability Analysis with emphasis on Nuclear Plants Applications. Nuclear REGULatory Commission, NUREG/CR-1278, Washington D.C.
- [Wioland and Amalberti, 1998] Wioland L. and Amalberti R. (1998). Human error management: towards an ecological safety model. 9<sup>th</sup> European Conference on Cognitive Ergonomics. Limerick University, Ireland.



## POST-DECISION EDITING OF AUDITORS' JUDGMENT

C. Gustav Lundberg<sup>1,2</sup> and Brian M. Nagle<sup>1</sup>

<sup>1</sup>A.J. Palumbo School of Business Administration, Duquesne University  
600 Forbes Avenue, Pittsburgh, PA 15282, USA  
LUNDBERG@DUQ.EDU & NAGLE@DUQ3.CC.DUQ.EDU

<sup>2</sup>Swedish School of Economics and Business Administration  
Arkadiagatan 22, 00100 Helsinki, FINLAND

### **Abstract:**

*Post-decision restructuring is the unconscious revision of what one saw and thought in the pre-decision stage as a result of outcome feedback. Professional auditors and auditing students participated in a post-decision restructuring (hindsight) experiment involving going concern judgments. Lack of feedback among professional participants invited more pronounced post-decision adjustments than access to feedback, in particular among participants who chose a going concern report. Whereas professionals were relatively unaffected by outcome feedback, novices were more likely to bolster their supportive signal ratings (and suppress the ratings of counter-indicative signals) following positive feedback. The findings are related to the effect of domain expertise on judgment heuristics.*

**Keywords:** Hindsight, Post-Decision Restructuring, Going Concern Judgment

### **1 Introduction**

Dynamic domains such as auditing may be particularly vulnerable to post-decision restructuring as experts rely heavily on rapid matches between what they observe and what they have made sense of in the past. Post-decision restructuring is the unconscious revision of what one saw and thought in the pre-decision stage as a result of outcome feedback. In short, the hindsight bias results from a projection of new knowledge into the past accompanied by a denial that the outcome information has influenced judgment [Hawkins and Hastie, 1990; Fischhoff, 1975]. The process of reducing dissonance involves considering, "reconsidering and re-evaluation of ... dissonant cognitions until adequate reinterpretations are invented or discovered" [Festinger, 1964, p. 157]. In contrast to earlier alternative-focused research, Svenson (1992) outlines an attribute-focused decision theory. Lundberg and Svenson (1993) found evidence for post-decision restructuring of facts among commodity traders.

The present study focuses on professional auditors' and auditing students' post-decision editing and on a hindsight judgment. The auditors were given relevant information based on an actual company and were asked to judge the company's viability. Our study may have several implications for the auditing profession. When an auditor is confronted with report decisions on separate clients with similar characteristics, s/he may be inclined to benchmark the latter audit report decision on the preceding decision. If the auditor is sued based on the merit of the audit, jurors (with

additional information subsequent to the audit) may have their opinions clouded by hindsight bias [cf. Anderson et al., 1997 and Kinney, 1993]. Also, during the audit review process a reviewer may be biased by the decision rendered by a manager. From a decision theoretic perspective, this study breaks new ground in that we (1) examine professional judgment in realistic settings, (2) work with the signals that each professional isolates, and (3) include both supportive and counter-indicative signals.

There is evidence that experts' judgments differ from those of non-experts. Smith and Kida's (1991) review indicates that the extent of the common biases investigated (anchoring and adjustment, representativeness, and confirmatory strategies) often is reduced when experts perform job-related tasks (as compared to students performing generic tasks or professional tasks for which they lack experience). Generally, auditors are asked to attest to the fairness of historical information which is contained in financial statements. In the US, 'Statement on Auditing Standards No. 59' [AICPA Professional Standards, 1989] has expanded the auditor's role in predicting whether the client has the ability to continue as a going concern for a reasonable period of time (generally one year); from that of a passive observer to that of an active seeker of going concern problems.

## 2 Method

Our participant pool consisted of 51 professional auditors –18 Partners, 6 Senior Managers, 8 Audit Managers, 12 Senior Accountants/Auditors, and 7 Staff Accountants– representing sixteen (large to small) accounting firms in the Pittsburgh, Pennsylvania area. The professional experience of the various auditors ranged from one year to 40 years, with an average of more than thirteen years. All participants were external auditors, and thus specialized in making *going concern modification - unmodified audit report* decisions. A second participant group consisted of 50 advanced undergraduate auditing students representing two Pittsburgh area universities. The individual participant was presented with relevant financial (including financial statements) and non-financial information of an actual company that we renamed ABC Corporation. We maintained references to the company's particular business sector. This procedure kept the realism of the task, while minimizing the risk of an auditor being directly familiar with the history of the particular firm. We chose a company that received an unmodified audit report, but filed for bankruptcy protection the next year.

The participants were asked: (1) to isolate signals –pieces of information about the company they believed to be critical to the unmodified audit - going concern judgment– and (2) to indicate what their report decision would be. This first phase involved: i) identifying prominent positive (supporting an unmodified audit report) and negative (supporting a going concern report) signals, ii) choosing between an unmodified audit report and a going concern report, and iii) choosing the three most positive and three most negative signals. For the first step, we asked the participants to mark/circle signals on the worksheet that suggest an unmodified audit report with a blue marker, and signals that suggest a going concern modification with a red marker. *Thus, each subject's successive judgments will be based on signals that s/he –not the experimenters– generated.* The participants were then asked to rate the strength of each signal with respect to their influence on their report choice; supportive signals (S1 to S3) ranging



from Neutral to Strongly For (their chosen report) and counter-indicative signals (C1 to C3) from Strongly Against to Neutral.

After completing Phase 1 –the original data collection– the participants were given a break of approximately 20 minutes. During this time, we transferred each participant's signal labels to an unmarked rating sheet. After the break, the participants assigned to the experiment group were informed that the actual auditing firm had issued an unmodified audit report, and that the company subsequently had filed for bankruptcy protection. Each subject was then asked to *replicate* their Phase 1 signal strength ratings. The explicit instructions to *replicate* the previous ratings –*as you recall your previous ratings*– were intended to minimize the risk that the subjects misinterpret the hindsight task as an assessment of current knowledge rather than of accuracy of recall or reconstruction of a previous knowledge state [cf. Fischhoff and Beyth, 1975]. The participants in the control group saw rating replication request forms without outcome information. We then compared the Phase 1 and Phase 2 signal ratings.

Finally, we asked the participants to assess the probability that the company received a going concern modification as well as the probability that the company received an unmodified audit report. 53 participants received outcome information: *At this point, you have received outcome information: you know what kind of report the Auditing Firm issued, and that the company filed for bankruptcy. However, we would like you to ignore what actually happened, and base your final decision on the preceding audit report only.* 48 participants (the control group) received no feedback.

The control groups guard against a general effect of regression towards the mean. We expected that the Phase 1 ratings of perceived degree of support for the ranked aspects and those given after the feedback would reveal a consistent downward revision of the most supporting aspects and an upward revision of the most counter-indicative aspects. Our focus on differences between the responses in the outcome groups, and in particular in relation to the control group, cancels regression effects.

### 3 Results

We begin our discussion of the results with the participants' assessments of the likelihood of each type of report. The professional participants in the feedback and the control groups rated the probability that *ABC Corporation received a going concern modification* very similarly, as 28% in the feedback group and 30% in the control group. However, both student participant groups rated the probabilities as 65% for a going concern report and 35% for an unmodified audit report. This difference in opinion between professionals and students is directly attributable to experience: in practice, a going concern report is issued much more infrequently than an unmodified audit report. Interestingly, 90% of the student participants chose a going concern report, compared to 37% of the professional participants. Since the company actually filed for bankruptcy protection within twelve months of the filing of the original report, the professional participants' experience does not serve them particularly well in this judgment [cf. Lundberg and Nagle, 1999].

Separating the groups into participants who chose a going concern modification and participants who chose an unmodified audit report reveal considerable differences in opinion. The professional experiment group participants who chose a going concern

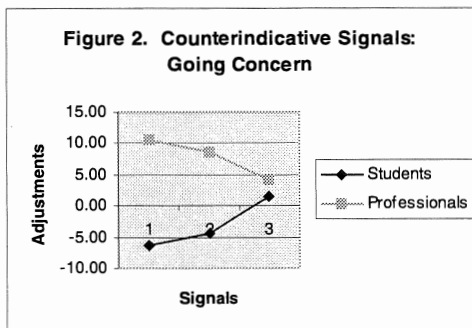
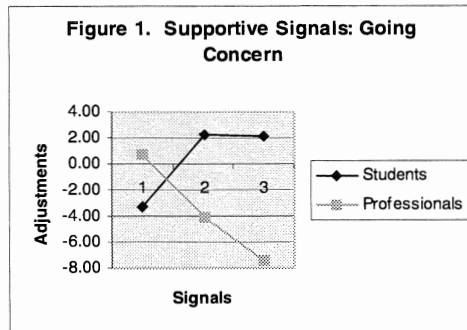
modification saw the probability that ABC Corporation received that type of report as lower (41%) than their control group counterparts (58%). This difference is significant ( $t = -1.69$ ,  $p\text{-value} = 0.0549$ ). The difference between the 'going concern likelihood' ratings of the student experiment group participants who chose a going concern modification (69%) and their control group counterparts (71%) is not significant. The difference in the ratings of the two professional groups who chose an unmodified report is also small (18.3/81.7 and 16.5/83.5, respectively).

The professional participants who *did not* receive outcome feedback, compared to the experiment group, saw a need to bolster their judgment. When selecting a relatively infrequently rendered report –one that may be challenged both internally and by the audited company– these auditors seem to draw support for their judgment from what they perceive to be their peers' standards. These auditing professionals may have assumed more cohesiveness in their domain than is warranted. Alternatively, the information that the original auditors issued an unmodified audit report may have led the experiment group participants to lower their GC-likelihood in retrospect. This explanation is less likely since they also learn about the company's subsequent trouble. It is interesting that a lack of feedback –more so than available feedback– leads to a more pronounced hindsight bias among professional participants. Professionals may be less vulnerable to a general hindsight bias than expected, but at the same time vulnerable to biases that stem from their specific task environment. The novice subjects on this task were largely unaffected by a hindsight bias.

We turn next to an examination of the participants' post-decision editing of the supportive and the counter-indicative signals. We expect a general tendency of regression toward the mean –a moderation of extreme ratings from the original to the recreated ratings. Therefore, we adjust the ratings in the two sub-groups in the experiment group –the subjects who chose a going concern modification and the subjects who chose a unmodified audit report– with the ratings of the subjects in the respective control group. Figure 1 depicts the post-decision changes in memory reproductions of earlier importance strength ratings as a result of outcome feedback/lack of feedback for the three most supportive signals, whereas Figure 2 depicts the changes in the three most counter-indicative signals. The figures reveal two drastically different patterns. When interpreting the figures it is important to note that the shifts in ratings are depicted in relative terms: *relative to the control group ratings, this is how the subjects in the experiment group responded*. Due to the small number of student participants who chose an unmodified report, the discussion focuses exclusively on going concern judgments. A two-way ANOVA of the adjustments to the supportive signals reveals that the *experience* factor (*students* versus *professionals*) is significant ( $p\text{-value} = 0.0193$ ), whereas the *signal* factor is not. There is significant interaction between *experience* and *signals* ( $p\text{-value} = 0.0063$ ). For the adjustments to the counter-indicative signals, only *experience* is significant ( $p\text{-value} = 0.0001$ ). In essence, experience/lack of experience significantly affects the post-decision adjustments.

A direct comparison of professional and student signal adjustments reveal that the differences between the averages are significant for all comparisons except for the third most important counter-indicative signals (C3). Whereas the two groups behave somewhat similarly –both making rather minor adjustments– with respect to the S1 and C3 reproductions, quite drastic deviations appear in the other ratings. The small

positive adjustments to S2 and S3 for the students, stem from positive adjustments due to positive feedback. The negative adjustments to S2 and S3 among the professionals in turn stem from sizable positive adjustments in the control group, not from negative adjustments in the experiment group. Whereas the student participants respond to



positive feedback by bolstering their supportive signals –as suggested by various hindsight theories– the professional participants do not appear to bolster their ratings based on positive feedback, but rather seem to bolster their supportive signals as a result of lack of feedback on a risky choice of a rather infrequently occurring report.

The relative adjustments to the counter-indicative signals among the students are a function of negative adjustments in C1 among participants with feedback. In the case of C2, the major adjustment is a bolstering among control group participants. As such, a negative adjustment of the most important counter-indicative signal following positive feedback is not surprising. Again, the positive adjustments to C1 and C2 among the professional participants are due to major negative adjustments among participants with no feedback. Thus, a pattern reemerges where a lack of feedback in conjunction with a relatively less frequently occurring, highly consequential choice leads to pronounced post-decision editing. We do not have an explanation for the strong bolstering in C3 for both students and professionals.

#### 4 Discussion

The expert participants displayed an ability –through sharper skills and/or mitigating heuristics– to counter the effect of outcome feedback on the memory of their choice. Smith and Kida (1991) argue that specialized judgment heuristics may be used for tasks within an expert’s domain, whereas general cognitive heuristics may be used in situations where the individual lacks information and/or expertise. In our case, knowledge of industry norms and patterns may lead to a simple heuristic: if you make a potentially controversial choice, be prepared to defend it. We found that auditors lacking feedback made a major effort to defend their choices to themselves. This process, we suspect, is related to the broader phenomenon of truth preservation in judgment and decision-making. Novices, on the other hand, revealed a tendency to bolster the ratings of their supportive signals following positive feedback, and (to some extent) to scale back the ratings for their counter-indicative signals. The findings suggest that experience plays an important role in hindsight judgments, and that lack of feedback may be as much a biasing factor as feedback. There is reason to be concerned about rating bolstering and suppressing tendencies that stem from making risky decisions without feedback (or with delayed feedback). The direct comparison of participants with various levels of experience suggests that there are situations where general hindsight biases occur –e.g., among our novice subjects– and others where they seem to be countered by mitigating, domain specific heuristics.

#### References

- [AICPA Professional Standards, 1989] AICPA Professional Standards (January, 1989). AU Section 341, The Auditor's Consideration of an Entity's Ability to Continue as a Going Concern. SAS 59, AICPA: New York.
- [Anderson et al., 1997] Anderson, J.C, Jennings, M.M., Lowe, D.J. and Reckers, P.M.J. (1997). The mitigation of hindsight bias in judges' evaluation of auditor decisions. *Auditing: A Journal of Practice and Theory*, 16(2): 20-39.
- [Festinger, 1964, p. 157] Festinger, L. (ed.) (1964). *Conflict decision and dissonance*. Stanford University Press, Stanford CA.
- [Fischhoff, 1975] Fischhoff, B. and Beyth, R. (1975). "I knew it would happen" - Remembered probabilities of once-future things. *Organizational Behavior and Human Performance*, 13: 1-16.
- [Hawkins and Hastie, 1990] Hawkins, S.A. and Hastie, R. (1990). Hindsight: Biased judgments of past events after the outcomes are known. *Psychological Bulletin*, 107: 311-327.
- [Kinney, 1993] Kinney, W.R., Jr. (1993). Auditor's liability: Opportunities for research. *Journal of Economics and Management Strategy*, 2(3): 349-360.
- [Lundberg and Nagle, 1999] Lundberg, C.G. and Nagle, B.M. (1999). Positive and negative biases among external auditors –The effect of experience on a high risk choice. *Proceedings of the Third International Stockholm Seminar on Risk Behavior and Risk Management*, Forthcoming, Stockholm, Sweden.

- [Lundberg and Nagle, 1999] Lundberg, C.G. and Svenson, O. (1993). Pre- and Postdiction of Commodity Prices, *Proceedings of the IAREP (International Association for Research in Economic Psychology) Conference*, pp. 346-357, Moscow, Russia.
- [Smith and Kida, 1991] Smith, J.F., and Kida, T. (1991). Heuristics and biases: Expertise and task realism in auditing, *Psychological Bulletin*, 109(3): 472-489.
- [Svenson, 1992] Svenson, O. (1992). Differentiation and consolidation theory of human decision making: A frame of reference for the study of pre and post decision processes. *Acta Psychologica*, 80: 143-168.



# PSYCHOLOGICAL TYPOLOGIES FOR MANAGEMENT AND FOR MANAGEMENT SCIENCE

Heiner Müller-Merbach

Universität Kaiserslautern  
Postfach 3049, D-67653 Kaiserslautern, Germany  
E-mail: hmm@sozwi.uni-kl.de

## Abstract:

*OR/MS in the service of “how to best design and operate man-machine systems” plays a responsible role in taking decisions for the people, by the people with assumptions about the people. Therefore, the understanding of people and their psyche is fundamentally important for OR/MS in practice. Four psychological typologies will be presented which are essential for (i) mutual understanding between OR/MS people and managers, for (ii) the composition of OR/MS teams and for (iii) the customer orientation of OR/MS groups.*

**Keywords:** Researcher and manager; converger versus diverger; motivation archetypes; functions of the brain; introvert versus extrovert; Environmental Interaction Theory.

## 1 The Need for Psychology in Operational Research and Management Science (OR/MS)

The need for psychology in Operational Research and Management Science (OR/MS) depends upon the understanding of OR/MS. For those who see OR/MS as narrow as a subset of mathematics, there is no need for psychology at all. However, there is a tremendous need for psychology for those who conceive OR/MS such as: *“Operations Research is concerned with scientifically deciding how to best design and operate man-machine systems, usually under the conditions requiring the allocation of scarce resources”* (ORSA, ca. 1977).

In this sense OR/MS has to serve the purpose of decisions

- *for* the people (those who depend upon the decision),
- *by* the people (the decision makers),
- with assumptions *about* the people, i.e. those who play a role in the man-machine system under study.

Therefore, it is not surprising to read – particularly in the very early OR literature – statements such as: *“Psychology is the key to successful OR”* (France 1971). Much earlier, Creelman and Wallen (1958) pleaded for an integration of psychologists in OR teams and reinforced their arguments by quoting first generation representatives of OR/MS such as Morse and Kimball as well as Churchman, Ackoff and Arnoff etc. A few years later, Churchman and Schainblatt (1965) pleaded for *“mutual understanding”* between the operations researcher and the manager.

People are different in many aspects: in their education, training and fields of interest, in their experience, in their psyche, and in their values. No individual equals any other. The spectrum of individuals is represented by the large numbers of terms characterising man in almost any language. Allport and Odbert (1936) collected e.g. 17,953 trait names in the English language.

In order to reduce the complexity of different personalities, a number of psychological typologies has been developed. Some of them will be presented here, particularly those which may help the OR/MS professionals.

The oldest psychological typology of the Western world goes as far back as to Hippocrates (ca. 460 – 370 B.C.) with his four temperaments: the *sanguine*, *choleric*, *melancholic* and *phlegmatic* type. This typology has endured all the epochs of thought since. Many other typologies were suggested more recently, mainly in the 20<sup>th</sup> century, but no one seems to be superior over the others in general. They all have their specific values.

The presentation of psychological typologies in this paper shall serve three main purposes:

- to develop a better understanding of one own's psyche,
- to develop a better understanding of other individuals, and
- to develop a better understanding of groups of individuals with different traits.

This paper is based upon former surveys by the author (in German), such as Müller-Merbach and Nelgen (1980) and Müller-Merbach (1986).

## 2 Four Selected Psychological Typologies

Four contemporary psychological typologies are selected to be presented here. All of them serve the purpose of making OR/MS studies in the sense of “*deciding how to best design and operate man-machine systems*” (ORSA, 1977; above) more effective.

### 2.1 Converging on the Left Side and Diverging on the Right: Researcher and Manager

Are there fundamental mental differences between OR/MS professionals on the one hand and managers on the other? When Churchman and Schainblatt (1965) reflected about the “*dialectic of implementation*”, they – at least implicitly – put the question if researchers and managers were different in their mental cognition and processing. An answer came from Henry Mintzberg (1976), easy to recognise by the title “*Planning on the left side and managing on the right*” hemisphere of the brain, followed by a more extensive study (Mintzberg 1979). This “brain-split” theory had predecessors, on the one hand authors from psychology such as Guilford (1956), Hudson (1966), Mitroff (1972) and Ornstein (1972), on the other hand the philosopher Immanuel Kant (1724-1804).

Kant spent much thought on the question: “*How do we know?*” One of his and his school's fundamental results was: “*(Pure) intuition without conception is blind, conception without (pure) intuition empty*”, originally: “*Anschauungen ohne Begriffe sind blind, Begriffe ohne Anschauungen leer.*” It is neither really possible to think, to reflect, to reason, to understand reality by pure intuition only (without conception), nor



by conception only (without intuition). However it may be that some people are stronger dominated in their thinking by intuition, others by conception (even if Kant did not discuss such psychological aspects).

It was Guilford (1956) who – without reference to Kant – suggested to distinguish between *convergent* thinking and *divergent* thinking. Hudson (1966) followed him and discovered that some people tend to think more convergently, others more divergently. Mitroff (1972) transferred this knowledge to the OR/MS literature. He reported: “*Convergers tend to prefer to work on manageable, well-defined problems for which there exists a single ‘best’ answer. Out of a set of many possible alternatives, they tend to converge on one and develop it in elaborate detail. Divergers tend to prefer to work on (and invent) vague and ill-defined problems for which there exist many alternative approaches. They prefer to multiply alternatives and possibilities rather than develop any single one in great detail. From a single stimulus, they produce many divergent responses. Convergers are analytical; they are ‘parts’ oriented. Divergers are synthetic; they are ‘whole systems’ oriented. Most scientists tend to be convergers; most arts and humanities students, divergers*” (Mitroff 1972, p. B-617).

Convergent thinking is based upon *reason*, it is *systematic*, it follows *rules* (including grammar, algorithms, structure), its targets are single, clear-cut (possibly optimal) answers. Its objects are well-defined problems, possibly even stated in mathematical terms. Its methods are *language, logic, computation*. It is dominated by *conception* (in Kant’s terminology, above).

In contrast, divergent thinking is based upon *holistic perception*, is *systemic*, it is *free* of any formal restrictions, its targets are to get something moved or – at least – to find acceptable and agreeable solutions which are practicable. Its objects are *messes* in the sense of problems without structure, possibly social systems. Methods in a formal sense are not used; discussion, exchange and integration of opinions, struggle for compromises etc. are the means to cope with messes; pictures of any kind are preferred over numbers. Divergent thinking is dominated by *intuition* (in Kant’s terminology, above).

It seems as if mankind represents a *continuum* between extreme *convergers* (with a high competence in convergent and a low competence in divergent thinking) on the one hand and extreme *divergers* (with complete incompetence in convergent thinking and high capabilities in divergent thinking) on the other hand. Even if extreme types are rare, most people seem to have a clear orientation toward convergent or divergent thinking, respectively. OR/MS professionals seem to belong to the party of convergers while managers (as well as politicians, even artists) to the party of divergers, as indicated by the title “*Planning on the left side and managing on the right*” (Mintzberg 1976).

The converger-diverger polarity found support through medical research. The left and the right hemisphere of the brain are connected by the „Corpus Callasum“ (CC). If the CC is interrupted, the left and right hemisphere can not cooperate anymore with one another. By a variety of experiments it was found that the left hemisphere (of right-handed persons) controls convergent thinking, while the right hemisphere of the brain controls divergent thinking. Test persons, for instance, could understand the term „square“ only on the left hemisphere and could explain the properties (four right angles, four edges of the same length etc.), but were not able to draw a square. On the right hemisphere, however, test persons could recognise a drawn square and reproduce it, but

were unable to find the term „square“ or refer to any properties. Thus, it seems that intelligence depends strongly upon the exchange between the left and the right hemisphere, i.e. mutual support between convergent and divergent thinking, i.e. reciprocal compensation between *conception* and *intuition* (in Kant's terminology, above). This is relevant (i) *intrapersonally* for each individual to better understand himself and others as well as (ii) *interpersonally* for the composition of teams and their guidance.

## 2.2 How to Motivate People: Spranger's Six Archetypes

The converger-diverger polarity is only one out of many ways to support mutual understanding between OR/MS professionals and managers. Spranger's (1914) six idealised archetypes of motivation are another way. They include:

- The *economic* men: Some people are only motivated by money. They judge everybody by his/her income and property, they weigh everything in monetary terms, they strive for monetary opportunities; their cause of motivation is simply: money.
- The *power* men: Others are excited by possibilities to have command over people and/or organisations. They love to be important. They tend to judge others according to their degree of influence. They strive for higher positions, and they are only motivated by opportunities to gain additional power. Even if higher power often corresponds with money, income and property are not their main motives.
- The *theoretical* men: Other people are fascinated by knowledge and understanding. They admire those who contribute to the understanding of our world, and they also want to contribute. They feel relieved by any new insight, i.e. by any theory (relevant for them) they have understood, and they are particularly proud about any part of theory they have contributed themselves. They may not mind money or power, but they may prefer not to care about their income and not to spend their time for leadership duties.
- The *aesthetical* men: Others are enchanted by beauty, harmony, and congruity. They may think in dichotomies such as beautiful versus ugly, harmonious versus dissonant, congruous versus discordant. They live for the beauty of arts, of music, of literature, of nature, of people, of products – from food arrangements to architecture, from internal structures to external appearance.
- The *social* men: Others are captivated by their social responsibility. If they seem misery and need they can not but try to help. They are always concerned about others, and they feel good if they had helped particularly those who were not able to help themselves.
- The *religious* men: Others try to live agreeable to God. They try to understand the will of God, and they try to arrange their lives accordingly.

The motivation of any real person is an individual *composition* of the six archetypes. Managers will have a prevailing economic motivation, while the power motivation may be dominating many politicians etc. As many empirical studies show (such as Guth and Tagiuri, 1965, and Tagiuri, 1965), there is empirical evidence of close relations between the roles of individuals in society and their prevailing motivations.

The task for OR/MS to “*scientifically deciding how to best design and operate man-machine systems*” (ORSA, 1977; above) in many cases implies consideration of the motivations of the people involved. Spranger’s typology may be of high relevance here.

### 2.3 The Human Brain: C.G. Jung’s Functions of Perception and Judgement

People are not only different due to their motivation structure, but also due to their functions of perception and judgement, according to C.G. Jung (1921). Jung (1875-1961) and many of his epigones (such as de Waele 1978) distinguished between two functions of *perception: sensation and intuition*, and two functions of *judgement: thinking and feeling*. They form a (two-dimensional) continuum:

- *Sensation*: The perception function of sensation is understood as perception by the *senses*, i.e. comprehension of those signals to which our senses are sensitive (extended by any kind of secondary information which can be measured by technology or empirical studies and is made available through any media).
- *Intuition*: In contrast to sensation, intuition (in quite a different sense as used by Kant, above) is understood as perception *beyond* (behind, beside, above, below, opposite etc.) sensation. Thus, intuition requires creativity, phantasy, imagination. Extreme intuitioners may not even be aware of what their senses realise, and their active brain always produces alternatives.
- *Thinking*: The perceived information can be processed by the judgement function of thinking, i.e. value-free rational processing only.
- *Feeling*: In contrast, the information perceived can be used for evaluation according to ethical values, such as good and evil, i.e. value-dependent (possibly irrational) judgement. This includes criteria such as responsibility and desirability

With reference to Churchman and Schainblatt’s mutual understanding: researchers may be more *thinking* oriented, while managers are more *feeling* oriented. Any function within each pair can be dominant, thus forming a matrix of four combinations.

Even if OR/MS professionals may tend towards *thinking*, the OR/MS task of “*scientifically deciding how to best design and operate man-machine systems*” (ORSA, 1977; above) requires a combination of all four functions: precise measurement of reality (i.e. “*sensation*”), the creation of alternatives (i.e. “*intuition*”) as well as rational processing (i.e. “*thinking*”) and ethical judgement (i.e. “*feeling*”).

### 2.4 EIT: Jung’s Introvert-Extrovert Typology, Extended by Ackoff

The psychological functions are only a section of Jung’s psychological typology. More well-known is his distinction between *introverts* and *extroverts*. Introverts are those who have little interaction with their social environment, while extroverts keep a lively interaction with others. But does interaction not mean flow in *two* directions: from the environment to the individual and from the individual to the environment? This is the set up point for Ackoff’s “*Environmental Interaction Theory*” (EIT). Ackoff (1978; Ackoff, Emery 1972) distinguishes – according to the flow intensity from the environment to the individual – between:

- *Objectiverts*: Some people are highly attentive to the environment and take notice of many things which are going on, i.e. the flow from the environment to the

individual is strong. They are influenced by the “*objects*” in the sense of everything outside of the individual subject.

- *Subjectiverts*: Some people seem to have no antenna for anything which takes place outside of themselves. They seem to rest in themselves. They take little notice of the objects around them and only concentrate on signs from their own interior, i.e. the “*subject*” itself. The flow from the outside to the individual is low.
- In a similar way, Ackoff distinguishes – according to the flow intensity from the individual to the environment – between:
- *Internalizers*: Some people prefer to change themselves and do not try to influence their environment. The flow from them to their environment is low. They “*internalize*” their ideas.
- *Externalizers*: Other people prefer to change their environment. They emphasise their influence on others. The flow from them to their environment is high. They “*externalize*” their ideas.

Any combination of high and low flow intensity is possible, thus forming a matrix of four types: Jung’s *introvert* is identical with Ackoff’s “*internalizing subjectivert*”, while Jung’s *extrovert* corresponds with Ackoff’s “*externalizing objectivert*”. These are the “*pure*” types with either both flows low or both flows high. In his empirical studies, Ackoff found that the majority of the white American population belongs to the mixed types where one flow is low and one flow is high, i.e. “*internalizing objectiverts*” and “*externalizing subjectiverts*” are more numerous than introverts and extroverts.

Ackoff evaluated *groups* as well and found that they tend to be stable and productive if the mean of the positions of the members is closed to the centre, i.e. to the “*centrovert*” position. This knowledge can be useful for the composition of OR/MS teams or any other groups.

### 3 Of the People, By the People, For the People

If OR is understood as a movement to help take decisions about “*how to best design and operate man-machine systems*” (ORSA, 1977; above), then it is related to the democratic leadership principle “*of the people, by the people, for the people*” as stated by Abraham Lincoln (1809-1865), the 16<sup>th</sup> President of the United States, in his famous “*Gettysburg Address*” on 19<sup>th</sup> November, 1863.

OR/MS – in my personal understanding – has to serve man. This includes the *understanding* of man as a prerequisite. A very basic foundation for such understanding are psychological typologies as presented here.

#### References

- [Ackoff and Russell, 1978] Ackoff, and Russel L. (1978), *The Art of Problem Solving*. New York.
- [Ackoff, Russell, Emery and Fred, 1972] Ackoff, Russell L., Emery, and Fred E. (1972) *On Purposeful Systems*. Chicago.

- [Allport and Odbert, 1936] Allport, G.W.; Odbert, H.S (1936) Trait-Names: A Psycholexical Study, *Psychological Monographs*, vol. 47, no. 1, Princeton, N.J.
- [Churchman, West and Schainblatt, 1965] Churchman, C. West; and Schainblatt, A.H. (1965) The Researcher and the Manager: A Dialectic of Implementation, in: *Management Science*, vol. 11, no. 4, pp. B-69 – B-87 (this paper was followed by an intensive discussion with several contributions in vol. 12, 1965, no. 2).
- [Creelman and Wallen, 1958] Creelman, G.D. and Wallen, R. (1958) The Place of Psychology in Operations Research, *Operations Research*, vol. 6, no. 1, pp. 116-121.
- [de Waele, 1978] de Waele, M. (1978) Managerial Style and the Design of Decision Aids, *OMEGA*, vol. 6, no. 1, pp. 5-13.
- [France, 1971] France, H. (1971) Psychology is the Key to Successful OR, *Operational Research Quarterly*, vol. 22, pp. 127-128 (italic pages).
- [Guilford, 1956], Guilford, J.P. (1956) The Structure of Intellect, *Psychological Bulletin*, vol. 53, pp. 267-293.
- [Guth, Wilhelm and Tagiuri, 1965] Guth, W.D. Tagiuri, R. (1965) Personal Values and Corporate Strategy, *Harvard Business Review*, no. 5, pp. 123-132.
- [Hudson, 1966] Hudson, L. (1966) *Contrary Imaginations*. New York 1966.
- [Jung, 1921] Jung, C.G. (1921) *Psychologische Typen*. Zürich (11. Auflage 1971), English Translation: *Psychological Types*. New York.
- [Mitroff, 1972] Mitroff, I.I. (1972) The Myth of Objectivity or why Science Needs a New Psychology of Science, *Management Science*, vol. 18, no. 10, pp. B-613-B-618.
- [Mintzberg, 1976] Mintzberg, H. (1976) Planning on the left side and managing on the right, *Harvard Business Review*, vol. 54, no. 1, pp. 49-58.
- [Mintzberg, 1978] Mintzberg, H. (1978) Beyond Implementation: An Analysis of the Resistance to Policy Analysis, *Operational Research '78*, ed. by K.B. Haley. Amsterdam 1979, pp. 106-162.
- [Müller-Merbach, 1986], Müller-Merbach, H. (1986) Psychologische Typen und Unternehmensführung, *Der Technologie-Manager* (technology & management), vol. 35, no. 4, pp. 42-47.
- [Müller-Merbach and Nelgen, 1980], Müller-Merbach, H., and Nelgen, D.W. (1980) Der Nutzen psychologischer Typologien für die modellgestützte Entscheidungsvorbereitung, *Proceedings in Operations Research 9*. Würzburg, Wien, pp. 622-629.
- [ORSA, 1977] *Carreers in Operations Research*. Providence, Operations Research Society of America (ORSA).
- [Ornstein, 1972] Ornstein, R.F. (1972) *The Psychology of Consciousness*. San Francisco.
- [Spranger, 1914] Spranger E. (1914) *Lebensformen*. (9. Auflage, Tübingen 1966), English Translation: *Types of Men.*, 1928.
- [Tagiuri, 1965] Tagiuri, R. (1965) Value Orientations and the Relationships of Managers and Scientists, *Administrative Science Quarterly*, June 1965, pp. 39-51.



## A DISTRICTING PROCEDURE FOR WINTER GRITTING

L. Muyldermans <sup>(1)</sup>, D. Cattrysse <sup>(1)</sup>, D. Van Oudheusden <sup>(1)</sup>, T. Lotan <sup>(2)</sup>

<sup>(1)</sup> Centre for Industrial Management, Research Group Quantitative Techniques, K.U.

Leuven, Celestijnenlaan 300 A, 3001 Heverlee, Belgium

Luc.Muyldermans@cib.kuleuven.ac.be

Dirk.Cattrysse@cib.kuleuven.ac.be

Dirk.VanOudheusden@cib.kuleuven.ac.be

<sup>(2)</sup> Ha'alón Street 14, Ra'anana 43572, Israel

### **Abstract:**

*Districing involves the partitioning of a large area into sub-areas (districts), such that each district contains at least one local center (depot) and is independently responsible for the operations performed within its borders. These operations typically involve different types of routing. In this paper, we present a heuristic approach for the districting problem, based on the partition of the road network into small cycles. We illustrate the procedure and discuss its merits for the salt spreading operations in the province of Antwerp.*

**Keywords:** Districting, Salt Spreading, Arc Routing.

### **1 Salt spreading and districting**

Salt spreading, also denoted winter gritting, involves the spreading of salt on roads when frost, ice, or snow have made them slippery. Routes for salt spreading operations are typically organized by districts and usually, a lot of attention is given to the problem of determining efficient routes within given district borders. On the other hand, the problem of districting, especially in the context of location and routing, is hardly addressed in the O.R. literature, or assumed to be solved a priori. However, many times significant, long-term savings can be achieved if more careful attention is devoted to the determination of the district borders. [Cattrysse et al., 1997] demonstrate the importance of districting for performing better routing. They define districting as a partition of a large area into sub-areas (districts) such that each district contains at least one local center (depot) and is independently responsible for the operations performed within its borders. The operations usually involve routing, with routes starting and ending at the depot.

From a planning point of view, there is a fundamental difference between districting and routing: whereas districting should be performed at the strategic and tactical level, routing is performed at the operational level. Thus districting should involve a more global view and is often related to the managerial and administrative levels. Furthermore, the same districts should allow support to different types of routing and possibly other operations performed within their borders. Hence whereas routes are more sensitive to specific constraints (e.g. time, capacity, etc.), districts should be more robust and not influenced by minor changes in the characteristics of the operations

performed within them. Obviously, good districting should be able to support good routing; however, there are other requirements which do not relate directly to routing. Good districting should result in balanced and compact districts whose borders define clear geographical sub-areas. Thus, whereas vehicle routes can cross each other, it is reasonable to expect that districts would not overlap.

Since districting should take into account the different tasks performed within the boundaries, careful enumeration of all planned activities and their related objectives is an important requirement. Furthermore, it is important to identify the most critical operation(s) in order to give it its proper weight. In the province of Antwerp mainly three types of operations are conducted from the same depots: preventive gritting, curative gritting and road maintenance. Since curative gritting has the most demanding requirements (it requires double the amount of salt), it is the most critical operation. Good districting for road maintenance operations is achieved by ensuring compact and balanced districts in which the depot is centrally located. Clearly, the districting problem requires a multi-criteria approach, even if a single kind of gritting is focused on (e.g. min. number of trucks, min. total or dead-mileage, etc.). Yet, in Antwerp, by performing a careful partition into compact districts and ensuring that all nodes are of even degree, the study can concentrate on the most important objective (min. number of trucks) for the most critical operation (curative gritting).

In this paper we propose a procedure for districting based on elemental cycles. Section 2 briefly explains the cycle approach. Section 3 is devoted to the heuristic procedure, while Section 4 presents the results of the districting procedure for the salt spreading operations in the province of Antwerp. Conclusions follow in Section 5.

## 2 The elemental cycle approach

The cycle approach, introduced by [Male and Liebman, 1978] in the context of routing waste collection vehicles, is based on the partition of a planar, Eulerian graph into cycles using a 'checkerboard pattern' (Figure 1). This partition into cycles is characterized by a large number of small cycles where every edge belongs to exactly one of them.

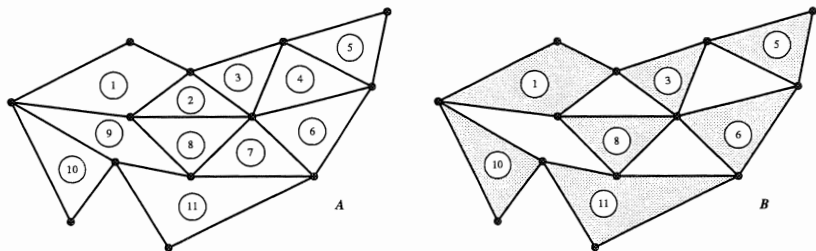


Figure 1: (A) A planar Eulerian graph; (B) Elemental cycles

Some of the inherent characteristics of the elemental cycle approach can lead to good districting according to the measures mentioned above. The existence of relatively small and many different cycles allows to aggregate them into districts so that districts are balanced and compact. A potential for good routing is maintained by ensuring that



districts constitute an Eulerian graph. Furthermore, the separability and additivity of cycles provides easy adjustment of the final partition to geographical or other 'secondary' constraints and considerations.

### 3 A districting procedure based on elemental cycles

The procedure builds all districts simultaneously by assigning elemental cycles to the depots and is divided into four stages, described in Sections 3.1 to 3.4.

#### 3.1 Stage 1: pre-processing

In the pre-processing, we partition the road network into elemental cycles and calculate the cycle weights and the ratios. The cycle weight denotes the total length to be serviced in a cycle, while the ratio  $R_{ij}$  relatively measures the average distance to reach cycle  $j$  from depot  $i$ . In addition, we specify the critical ratio for every depot. The value of the critical ratio is a benchmark, labeling cycles either as 'close' to a depot or not, and determines which cycles are considered in either Phase 1 or 2 of the iterative assignment procedure (3.3). From Section 2 it is clear that the elemental cycle approach requires a unicursal graph as input. If the graph corresponding with the road network is not unicursal, a minimal cost matching has to be solved prior to the partition into cycles. Since the matching edges receive weight zero, cycle weights can be calculated in different ways, for example such that cycles with the smallest and largest possible weight are created, which facilitates the construction of balanced districts. Finally, the ratio  $R_{ij}$  is defined as the average shortest path distance to reach cycle  $j$  from depot  $i$ , divided by the minimal average shortest path distance to reach cycle  $j$  from another depot.

#### 3.2 Stage 2: initial assignment

After pre-processing we are ready to initiate the district building process. Indeed, some cycles are immediately assigned since they are adjacent or very close to a depot node (indicated by a ratio smaller than 0.5). A ratio value smaller than 0.5 implies that all ratios for that cycle with respect to other depots are larger than 2, and thus, the average distance to reach that cycle from another depot is at least twice as long. By assigning cycles, other cycles may become isolated. For an isolated cycle all its neighboring cycles are already assigned to a single depot. It is eligible for one depot only and can be assigned directly. In that way we reduce the number of cycles to be considered in the subsequent stages and consequently speed up the assignment procedure. Next, we determine for every depot its eligible set, consisting of cycles not yet assigned and adjacent to a cycle already assigned to that depot. Only these cycles ensure connectivity in the next assignment step.

#### 3.3 Stage 3: two-phase iterative assignment

Stage 3 proceeds with the districting process in two phases, building all districts simultaneously in order to balance the total load. Phase 1 considers only cycles relatively close to the depots, indicated by a ratio-value smaller than the critical ratio. Focusing on the construction of balanced and compact districts, these cycles are assigned in a rather straightforward procedure, corresponding in some parts to the partitioning algorithm of [Bodin and Levy, 1991]. At any point in the procedure, the

district with the least amount of workload assigned to it so far, becomes the next candidate district for expansion. The cycle added to this district is the eligible cycle with the largest weight. After each assignment district weights and eligible sets are adjusted and a check for isolated cycles is performed. Phase 1 ends when no cycle can be found that is close enough to a depot and can be assigned directly without making the imbalance between the districts too large. This means either that different depots compete for the same cycle or, that different (conflicting) objectives need to be considered. Phase 2 therefore uses a multi-criteria approach. Three criteria are used: a measure for the 'closeness' of a cycle to a depot (since district compactness is facilitated by assigning the nearest cycles first), an estimate for the number of trucks required to grit all the roads (this is the most important objective of the underlying routing problem) and an indication for the (im)balance between the districts. For every depot the 'best' candidate cycle for assignment is selected, and a score based on the evaluation of the different criteria is calculated. The cycle-depot pair with the lowest score is assigned next. We repeat this procedure until all cycles are assigned.

### **3.4 Stage 4: improvement and user interaction**

This stage shifts or interchanges cycles between the depots, taking the connectivity into account and trying to decrease the number of trucks required. In this step geographical, climatical or other 'secondary' constraints are addressed. Obviously, these considerations can also slightly modify the decisions in the previous stages, for instance they can play a role whenever a tie occurs in the cycle assignment. No specific exchange procedure is developed for Stage 4, but very likely a user interactive procedure, where the decision-maker can suggest and evaluate certain changes, will give superior results. A visual representation of the districts will certainly help. It is clear that a lot of freedom remains; quite some trials can be explored, probably resulting in a more adequate partition. For example, other critical ratio-values affect the cycles considered in both phases of Stage 3. Other cycles or cycle weights are easily defined by considering other matching solutions or by averaging the edge weights over the cycles, instead of creating cycles with the largest and smallest possible weights. Finally, in the multi-criteria approach, the user can define the appropriate criteria for his own application, and carefully specify the evaluation.

In the next section, we illustrate our procedure by redesigning the existing district borders for the winter gritting activities in the province of Antwerp.

## **4 Districting in the province of Antwerp**

In 1996 the number of districts in Antwerp was reduced from nine to six, motivated by the need to reduce the operational costs. However, the new partition into districts did not take explicitly into consideration arguments related to the routing operations. Intuition was used, and district borders coincide to a large extent with irrelevant borders of communes. We applied our procedure to redesign the inter-district borders of four of these districts. The result is shown in Figure 2 and evaluated by considering the underlying routing problem for curative gritting. A truck has a capacity to spread approximately 35 km and in total 806.5 km of roads need gritting (highways not included).

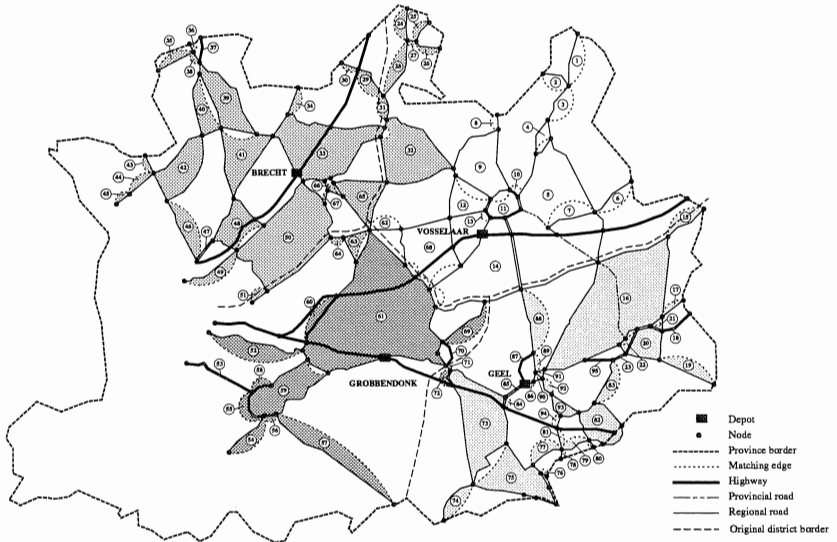


Figure 2: Elemental cycles and final district partition

Table 1 includes the load (total distance) and the number of existing tours for the original districts. Clearly, the average tour lengths in Brecht and Vosselaar are far below their 'optimal' potential length of 35 km. Hence, by improving the routing only, we were able to eliminate four tours. Column 5 indicates the total dead-mileage (dm) of the corresponding routing solution. The last section in Table 1 shows the operational results for the new district partition. Obviously, this new partition is not so well balanced as the original one. However, with the same number of trucks as in the improved routing situation within the original districts, we can grit the roads with approximately 80 km less deadheading, a reduction of about 14 %. A further reduction in the number of tours (from 25 to 24) seems to be difficult. District Geel is probably the best candidate for exchanging a cycle (trying to decrease the number of tours to six). However, such an exchange has a negative impact on the other districts. Comparing the new districts to the original situation, it is clear that important savings can be obtained using an appropriate districting and routing procedure. In addition, this improvement is achieved by redesigning the inter-district borders of four districts only. Hence larger savings can be expected when larger problem instances are solved and more borders are involved.

District	Original districts		Improved routing		New district & Improved routing		
	load (km)	# of tours	# of tours	dm (km)	load (km)	# of tours	dm (km)
Brecht	199.5	9	6	157.	262.	8	165.5
Vosselaar	195.5	7	6	155.	172.	5	110
Grobbendonk	178	6	6	144.	154.	5	117
Geel	233.5	7	7	129	217	7	113
Total	806.5	29	25	586.	806.	25	505.5

Table 1. Evaluation of the original and new districts

## 5 Conclusions

In this paper, we discussed the problem of districting associated with salt spreading and road maintenance operations and proposed a procedure based on elemental cycles. The approach is simple and flexible, and has the capability to deal constructively with multiple objectives. Many delicate tradeoffs among total workload, capacity, distance and geographical inputs can be addressed by the decision-makers during the different phases of the algorithm. The procedure was tested for the salt spreading operations in the province of Antwerp (Belgium), indicating considerable savings compared to the actual performance and proving the importance of a good districting procedure in the planning and organization of these services. Currently, careful attention is given to the further fine-tuning of the algorithm.

## References

- [Bodin and Levy, 1991] Bodin, L. and Levy, L. (1991). The Arc Partitioning Problem. *European Journal of Operational Research*, 53(3): 393-401.
- [Cattrysse et al., 1997] Cattrysse, D., Van Oudheusden, D. and Lotan, T. (1997). The Problem of Efficient Districting. *OR-INSIGHT*, 10(4): 9-13.
- [Male and Liebman, 1978] Male, J. and Liebman, J. (1978). Districting and Routing for Solid Waste Collection. *Journal of the Environmental Engineering Division ASCE*, 104(E1): 1-14.

# SOCIO-COGNITIVE ENGINEERING: A METHODOLOGY FOR THE DESIGN OF HUMAN-CENTRED COMPUTER SYSTEMS

M. Sharples<sup>1</sup>, N. Jeffery<sup>3</sup>, J.B.H. du Boulay<sup>3</sup>, D. Teather<sup>2</sup>, B. Teather<sup>2</sup>, G.H. du Boulay<sup>2,3</sup>

<sup>1</sup>School of Electronic and Electrical Engineering, University of Birmingham, UK

<sup>2</sup>Department of Medical Statistics, De Montfort University, Leicester, UK

<sup>3</sup>School of Cognitive and Computing Sciences, University of Sussex, UK

<sup>4</sup>Institute of Neurology, London, UK

Email: rad@cogs.susx.ac.uk

## Abstract:

*We propose a general framework for socio-cognitive engineering that integrates software, task, knowledge and organizational engineering. The framework has been refined and tested through a series of projects to design computer systems to support training and professional work. In this paper we provide an account of the least-explored part of the framework, that of organizational engineering. We describe a series of workplace studies of radiology training that have provided requirements for the design of a computer-based training system for neuroradiology. The structure of the workplace studies and the framework for socio-cognitive engineering can be applied widely to the design of human-centred technology.*

**Keywords:** human-centred systems design; organizational engineering; computer-based training; radiology.

## 1 Methodology: Socio-cognitive Engineering

We use the term ‘socio-cognitive engineering’ (or ‘human-centred systems design’) to indicate the process of describing and analysing the complex interactions between people and computer-based technology, so as to inform the design of interactive systems that support human learning, knowledge management, decision making and creativity. This builds on previous work in user-centred system design, soft systems methodology [Checkland and Scholes, 1990], socio-technical and cooperative design [Catterall et al., 1991], [Greenbaum and Kyng, 1991], [Sachs, 1995] and the application of ethnography to system design (see Rogers and Bellotti [1997] for a review). It goes beyond user-centred design in systematically drawing the cognitive, social and organizational sciences into the design process. We extend previous work by providing an integrated framework for socio-cognitive engineering.

## 2 Methods: “Building-block” Framework

We have developed a framework for socio-cognitive engineering (see table 1). It provides the system designer with a means to understand and organize the process designing human-centred technology. Rather than viewing the design process as a flow chart we have taken a “building block” metaphor. This has the advantage of showing clearly how the component activities of design can interlock and support each other.

The four “pillars” indicate the main processes of software, task, knowledge and organizational engineering. To construct a successful integrated system requires the designers to consider all the building blocks, but it is not necessary to build systematically from the bottom up. A design team may work on one “pillar”, such as knowledge engineering, up to the stage of system requirements, or they may develop an early prototype based on a detailed task analysis but without a systematic approach to software engineering. Each block specifies one type of design activity, but how that activity is carried out depends on the particular subject domain and training situation.

<i>Maintain</i>	Installed system	New task structure	Augmented knowledge	New organizational structure
<i>Evaluate</i>	Debugging	Usability	Conceptual change, skill development	Organizational change
<i>Integrate</i>	Prototype System			
<i>Implement</i>	Prototypes, Documentation	Interfaces, Cognitive tools	Knowledge representation	Communications, Network resources
<i>Design</i>	Algorithms and heuristics	Human-computer interaction	Domain map, user model	Socio-technical system
<i>Interpret</i>	System Requirements			
<i>Analyse</i>	Requirements	Tasks: goals, objects, methods	Knowledge: concepts, skills	Workplace: practices, interactions
<i>Survey</i>	Existing systems	Conventional task structures and processes	Domain knowledge	Organizational structures and schedules
	<i>Software Engineering</i>	<i>Task Engineering</i>	<i>Knowledge Engineering</i>	<i>Organizational Engineering</i>

Table 1. A “building block” approach to socio-cognitive system design.

The design activities are modular, allowing the designer to select one or more methods of conducting the activity, according to the problem and domain. For example, the usability evaluation could include an appropriate selection of general methods for assessing usability, such as heuristic evaluation or cognitive walkthrough, or it could include an evaluation designed for the particular domain.

One important aspect of the framework is that when a new technology, such as a training and decision support system, is incorporated into the workplace it will engender new knowledge, new tasks and ways of working, and new organizational structures. These become contexts for further analysis and design. Email is a prime example. The use of email in offices opens up new pathways of communication and access to new sources of knowledge. It can also profoundly affect the working day and the management of a company. These changes need to be analysed and supported through a combination of new technology and new work practices. Thus, the building blocks must be revisited both individually to analyse and update the technology in use, and through a larger process of iterative re-design.

### 3 Application: Computer-based Training in Neuroradiology

The domain in which we demonstrate the approach of socio-cognitive engineering is the design of a knowledge-based training system for neuroradiology. *MEDIATE* is a joint project between the University of Sussex, De Montfort University, Leicester, the University of Birmingham, and the Institute of Neurology, London. Its aim is to address a need identified by the radiology speciality for a more structured approach to reporting and training. One outcome of the project is the MR Tutor, a training system to assist radiologists in interpreting MR images of the brain, particularly images presenting diseases that are acknowledged to be difficult to differentiate. A prototype system has been developed in the Java programming language.

The MR Tutor combines an active tutor with a responsive support system. It is based on a constructivist approach to learning, in which the trainee is helped to acquire a well-structured method for describing abnormal features of images by engaging in an active process of case-based reporting. The *MEDIATE* team has devised a structured image description language (IDL) for MR neuro-images. The language is image-based, covering the visual appearance and anatomical locations of the image abnormalities. An archive of around 1200 cases, fully annotated using terms of the IDL and accompanied by clinical information and confirmed diagnoses, forms the knowledge base of the Tutor. At present some 40 of these cases have been included in the prototype system and we have recently developed a semi-automated method of transferring further cases and their descriptions.

The *MEDIATE* team has followed the socio-cognitive engineering methodology to develop a usable prototype training system. The software, task, and knowledge engineering aspects of the MR Tutor are described in [Teather et al., 1994], [Sharples, et al., 1995], [Sharples et al., 1996], [Sharples et al., 1997]. Formative evaluations of early prototypes of the MR Tutor have indicated its general usability and training effectiveness.

### 4 Organizational Engineering

This paper addresses the Organizational Engineering aspects of the design of the MR Tutor. The aim of the project was to investigate how the MR Tutor system could fit into the daily schedule of a trainee radiologist and to determine whether it might be accepted by the medical profession in the United Kingdom as an aid to training. Initial questions that the project addressed included: what would be the most appropriate configuration and location for a training system (portable?, based in the reporting room?, library?); to what levels of general or specialist medical training would the system be suited?; how does reporting of cases fit into other demands on the time of a trainee radiologist?; is there a standard method of teaching radiological reporting, within a hospital and across hospitals?; what do trainees and consultants perceive to be the main issues and problem areas in conventional training?

Similar questions face designers of technology for other areas of training and decision support and they often remain unanswered until the system is adopted for use, when the designers and adopters discover unforeseen problems, such as a lack of integration with the curriculum or an inappropriate location for the equipment. By

addressing these questions through workplace investigations, within a general methodology for analysing situated activities and how they might be assisted by technology, we have been able not only to provide answers to these specific questions but also to address more general issues of embedding computer-based systems in the workplace.

The project involved:

- a) developing practical and appropriate methods of organizational analysis;
- b) applying the organizational analysis through a series of workplace studies of radiology training in two UK hospitals;
- c) using the outcome of the studies to produce design recommendations for the MR Tutor.

Through the project we have developed a multi-level approach to organizational engineering, based on the work of Plowman et al. [1995], whose purpose is to inform the design and deployment of new technology in the workplace. It is descriptive, but is also concerned with the consequences of intervention (not just how the workplace is, but how it might be). It is designed for situations where there is limited access to the workplace, to experts, and to potential users.

The role of the fieldworker in organizational engineering is both to interpret workplace activity and to assist technology design and organizational change. This addresses the widely recognised problem of ethnographic approaches that, while they can provide an understanding of current work practices, they are not designed to explore the consequences of socio-technical change.

Table 2 shows a multi-level structure for organizational engineering, with level 1 consisting of a survey of the existing organizational structures and schedules, levels 2 and 3 providing an analysis of situated practices and interactions of those for whom the technology is intended, and level 4 offering a synthesis of the findings in terms of designs for new socio-technical systems.

The four levels of the approach give an overview of workplace activity leading to more detailed investigation of particular problem areas, with each level illuminating the situated practices, and also providing a set of issues to be addressed for the next level. These piece together into a composite picture of how people interact with technology in their working lives, the limitations of existing work practices, and ways in which they could be improved by new technology.



<i>Level 1</i>	<i>Work structures and schedules</i>
Activity:	study timetables, organizational structures, syllabuses, resources
Purpose:	to discover how workplace activity is supposed to be conducted
Outcome:	description of the existing organizational and workplace structures; identification of significant events
<i>Level 2</i>	<i>Significant events</i>
Activity:	observe representative formal and informal meetings and forms of communication
Purpose:	to discover how workplace activity, communication, and social interaction is conducted in practice
Outcome:	a description and analysis of events that might be important to system design; identification of mismatches between how work has been scheduled and how it has been observed to happen
<i>Level 3</i>	<i>Conceptions and conflicts</i>
Activity:	conduct interviews with participants to discuss areas of work needing support, breakdowns, issues, differences in conception
Purpose:	to determine differing conceptions of work; uncover issues of concern in relation to new technology; explore mismatches between what is perceived to happen and what has been observed
Outcome:	issues in working life and interactions with existing technology that could be addressed by new technology and working practices
<i>Level 4</i>	<i>Determining designs</i>
Activity:	elicitation of requirements; design space mapping; formative evaluation of prototypes
Purpose:	to develop new system designs
Outcome:	prototype technologies and recommendations for deployment

Table 2. Multi-level approach to organizational engineering.

## 5 Results

The MEDiate studies were undertaken by one researcher over a period of two years. This paper provides only a summary of the main results. The studies identified and clarified issues of importance to the design of computer-based training in radiology, including:

- the need to place computer-based training within a process of patient management. The teaching sequence and the presentation of individual cases should ideally take account of the content and quality of the case notes, and the recipients and purposes for which the radiological report will be used.
- providing a system that can be used within the limited and unpredictable time available for self-study, indicating the need for software implemented on a portable computer with the facility to rapidly save and resume a session;
- the need for a system that is authoritative, and perceived to be so by trainees and consultants. In general, radiologists have less confidence in the quality of computer-based material than information provided in book form.

## 6 Implications

The major contribution of the project reported in this paper has been to propose a framework for socio-cognitive engineering, as a contribution towards a science of interactive system design. We have described a realisation of the aspect of that framework that has been least explored, that of organizational engineering. The findings of the project are applicable at different levels of generality.

The workplace studies from the MEDiate project provide a clear set of recommendations for the design of computer-based (and conventional) training in radiology, indicating the importance of patient management, the perceived lack of authority of computer-based information, and the disputed role of case notes in the reporting process.

Each level of the studies was successful in providing an agenda of issues to be explored at each subsequent level, and for examining personal and organisational conflict in terms of mismatches of expectation between course managers and trainees, between the prescribed curriculum and situated practice, and in the differences in practice between institutions.

## Acknowledgements

The workplace studies were funded by grant L127251035 from the Cognitive Engineering Initiative of the UK Economic and Social Research Council. The authors wish to thank Leicester Royal Infirmary and the Institute of Neurology, London for their cooperation with the studies.

## References

- [Catterall et al., 1991] Catterall, B. J., Taylor, B. C., and Galer, M. D. (1991). The HUFIT planning, analysis and specification toolset: Human factors as a normal part of the IT product design processing. In J. Karat (Ed.), *Taking Software Design Seriously*. London: Academic Press.
- [Checkland and Scholes, 1990] Checkland, P., and Scholes, J. (1990). *Soft Systems Methodology in Action*. Chichester: John Wiley and Sons.
- [Greenbaum and Kyng, 1991] Greenbaum, J., and Kyng, M. (Eds.). (1991). *Design at Work: Cooperative Design of Computer Systems*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- [Plowman, Rogers and Ramage, 1995] Plowman, L., Rogers, Y., and Ramage, M. (1995). *What are workplace studies for?* Paper presented at the European Conference on Computer-Supported Cooperative Work.
- [Rogers and Bellotti, 1997] Rogers, Y., and Bellotti, V. (1997). Grounding blue-sky research: How can ethnography help? *Interactions*, May - June 1997, 58-63.
- [Sachs, 1995] Sachs, P. (1995). Transforming work: collaboration, learning and design. *Communications of the ACM*, 38(9), 36-44.

- [Sharples et al., 1996] Sharples, M., du Boulay, B., Jeffery, N., Teather, D., and Teather, B. (1996). *Interactive Display of Typicality and Similarity Using Multiple Correspondence*. Paper presented at the HCI '96 Conference on Human-Computer Interaction, London.
- [Sharples et al., 1995] Sharples, M., du Boulay, B., Teather, D., Teather, B. A., Jeffery, N., and du Boulay, G. H. (1995). *The MR Tutor: Computer-based Training and Professional Practice*. Paper presented at the World Conference on Artificial Intelligence and Education (AI-ED '95), Washington DC.
- [Sharples et al., 1997] Sharples, M., Jeffery, N., Teather, D., Teather, B., & du Boulay, G. (1997). *A Socio-Cognitive Engineering Approach to the Development of a Knowledge-based Training System for Neuroradiology*. Paper presented at the World Conference on Artificial Intelligence in Education (AI-ED '97).
- [Teather et al., 1994] Teather, B. A., Sharples, M., Jeffery, N., Teather, D., and du Boulay, B. (1994). Statistical Modelling and Structured Image Description for Intelligent Tutoring in MR Imaging of the Head. *Rivista di Neuroradiologia*, 7, 29–35.



# HUMAN-CENTERED SYSTEMS DEVELOPMENT AND USE INCONSISTENCIES

Claudine Toffolon<sup>1</sup>, Salem Dakhli<sup>2</sup>

Paris-Dauphine University, France

<sup>1</sup> E-mail: Claudine.Toffolon@dauphine.fr

<sup>2</sup> E-mail:: sdakhli@computer.org

## Abstract:

*The framework we describe in this paper provides a typology of human-centered systems development and use deviations and inconsistencies. This typology, based on four facets and three levels of abstraction (conceptual, detailed, technical), permits identifying another types of deviations and inconsistencies not considered in the literature. It may be useful to define methods and tools to manage inconsistencies in compliance with the organization's constraints, priorities and technical maturity.*

**Keyword:** deviation, human-centered system, inconsistency, project space, software actor, software model

## 1 Introduction

A human-centered system is one in which humans, supported by information technology, play a key role. Development and use of human-centered system involves actors, organizational structures, rule, procedures and computerized tools. Actors are humans who perform tasks in order to accomplish various categories of goals related to the business process supported by the human-centered system. Their role is characterized by three types of cooperation. On the one hand, they interact and cooperate among themselves (actor/actor cooperation). On the other hand, they interact and cooperate with the computerized tools (software, hardware, networks) which compose the human-centered system (actor/computerized tool cooperation). Finally, they interact with the organizational context composed of organization's internal and external constraints and priorities (actor/organizational context cooperation). Organizational structures, rules, procedures are instruments which permit actors either to interact among themselves or to cooperate with computerized tools and organizational context. Interactions and cooperation inherent in human-centered processes are either formal or informal. In recent years, many methods, techniques and tools have been proposed to support formal interactions. For example, workflow technology provides instruments to automate well defined sequences of actions performed by humans or machines. In particular, it automates formal procedures associated with actor/actor and actor/computerized tool cooperation. Informal interactions and cooperation either among actors or between actors and computerized tools are sources of various unexpected deviations and inconsistencies. Indeed, most processes governing these informal interactions cannot be completely specified in advance and once for all. A human-centered system inconsistency reflects a state of the software development or use process or a state of a software artifact resulting from this

process, and generally originates from a set of deviations. Inconsistencies and deviations were defined by [Cugola et al., 1996] and [Bandinelli et al., 1994]. [FERNSTRÖM, 1993] have proposed formal definitions of these concepts. A wide range of deviations and inconsistencies arise during the development of human-centered systems. For example, requirements engineering generate many kinds of inconsistencies related to the multiplicity of information sources. By another way, the use of such systems often results in deviations and inconsistencies related to the gap between the cognitive, organizational and sociological processes driving the actors behaviour and the representation of these processes in the human-centered system in use. Many researchers and practitioners [Balzer, 1991] [Ghezzi and Nuseibeh, 1998] [Nuseibeh, 1996] have proven that deviations and inconsistencies are inevitable in particular in complex human-centered systems. Moreover, in such systems, removal of certain inconsistencies can cause others to pop up. By another way, inconsistencies may be useful for focusing on aspects of human-centered systems which need particular attention. Consequently, management of human-centered systems inconsistencies must be integrated in the human-centered systems development and use processes. We think that to be managed, deviations and inconsistencies must be identified and the issues related to understanding why they occur must be addressed. In this paper, we propose a framework which:

- describes a typology of deviations and inconsistencies occurring during the human-centered systems development and use,
- permits understanding the causes of human-centered systems deviations and inconsistencies.

To be complete, the human-centered systems deviations and inconsistencies description and analysis must take into account firstly, the conflicting interests and points of views of all the organizational actors involved in human-centered systems development and use, and secondly all the aspects of software engineering . Therefore, our framework rests on a global model of software built using the economic agency theory [Alchian and Demsetz, 1972], the transactions costs theory [Williamson, 1989] and the software dimensions theory [Toffolon, 1999]. The remainder of this paper is organized as follows. Section 2 presents the global software model. In section 3, we analyze the causes of deviations and inconsistencies related to human-centered systems development and use, and describe synthetically a typology of these deviations and inconsistencies. This typology is described formally in section 4 using the Z specification language [Spivey, 1992]. Section 5 concludes this paper by listing the principal applications of the proposed typology in software engineering.

## **2 The software engineering model**

Applying agency theory in analyzing information technology role in modern organizations demonstrates that software engineering is governed by a set of contracts among actors concerned with the software system to be developed or maintained. At a given time, each actor plays the role of consumer (principal) or producer (agent) under the contracts which link him to the other actors. So, human-centered system development and use are a nexus of contracts among different actors with conflicting interests and points of view. The discrepancies between the actors objectives are partly the source of software engineering inconsistencies and related agency costs. By another

way, we notice that well established software development methodologies make a confusion between four businesses: the customer's business, the end user's business, the developer's business and the architect's business. To eliminate this confusion, we use the transaction costs theory to identify four different spaces representing respectively these four businesses:

The problem space where are defined the customers and users problems and their organizational solutions. This space represents the customer's business.

The solution or architectural space where are defined the computer solutions of the customer/user's problems. This space represents the architect's business.

The construction space where these solutions are implemented. This space represents the developer's business.

The operation space where are evaluated the software's usability from the user's perspective as well as its contribution to the organization's competitiveness. This space represents the end user's business.

Besides, each software project is represented in the four spaces by a static part, a dynamic part and actors. In each space, project's dynamic part relates to the software engineering process, project's static part is composed of software artifacts resulting from this process, while project actors are human resources concerned with this project. Each actor may have two categories of roles: producer (agent) or consumer (principal) of software artifacts. A role played by a project's actor in one of the four spaces is either principal or secondary. In each space, it is possible that a project has many actors assuming secondary roles, but there can be only one project actor involved in a principal role; moreover, an actor can play a secondary role in many spaces, but a principal role only in one (every actor plays the principal role in some space). The software dimensions theory permits taking into account all the aspects of the software as well as all the conflicting interests and points of view of the project actors. So, each project space is associated with a subset of the ten software dimensions [Toffolon and Dakhli, 1998].

### 3 The software engineering inconsistencies

In this work, we use the four project spaces to give more detailed definitions of software engineering deviations and inconsistencies by introducing the concepts of intra-space and inter-spaces deviations and inconsistencies. An intra-space (vertical) deviation is an event which causes a discrepancy either between the real and anticipated behavior of the process supporting one of the four project spaces, or between the real and anticipated behavior of a software artifact resulting from this process. An intra-space (vertical) inconsistency may be generated by an intra-space deviation and describes either the state of the process supporting one of the four project spaces, or the state of a software artifact resulting from this process. In the same way, an inter-spaces (horizontal) deviation is an event which disturbs interactions between two spaces. An inter-spaces (horizontal) inconsistency may be generated by an inter-spaces deviation, and describes either the state of inter-spaces interactions or the state of software artifacts concerned with these interactions. Vertical deviations and inconsistencies are related; on the one hand, to the activities of processes supporting the four project spaces and software artifacts they build; and on the other hand, to the communication problems associated with these activities. Horizontal deviations and inconsistencies depend on

vertical deviations and inconsistencies which can worsen them since the software artifacts resulting from the process supporting a given space are used in the information flows exchanged between this space and the three other project spaces. Vertical and horizontal deviations and inconsistencies are interdependent since, in each project space, the actor who plays the principal role is at the same time producer of software artifacts and consumer of artifacts coming from the three other project spaces.

Consequently, the software engineering deviations and inconsistencies constitute a spiral whose progression can be compared with a succession of chain reactions which explain the iterative character of the software development process, and the inadequacy of the conventional lifecycle. Figure 1 illustrates the software engineering inconsistencies metamodel.

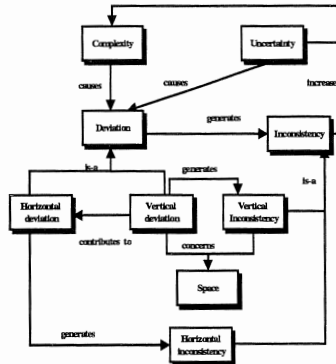


Figure 1: Software engineering inconsistencies metamodel

The definitions provided above give only a general view of software engineering deviations and inconsistencies. In particular, to cope with human-centered systems inconsistencies, we must take into account aspects related to human actors involved in such systems development and use. The typology we propose in this work aims to bridge the gap between on the one hand, human-centered systems deviations and inconsistencies and on the other hand, tools built to reduce their impacts. In that way, we consider that deviations and inconsistencies of human-centered systems are either formal or informal. Formal deviations (vs. inconsistencies) occur if a formal procedures or rules related to software processes or software artifacts are broken. Informal deviations (vs. inconsistencies) are related either to informal aspects of software development and use processes, or to software artifacts. The distinction between formal and informal deviations (vs. inconsistencies) is important since tools which permit coping with them are different. Indeed, it is possible to reduce formal deviations (vs. inconsistencies) impacts by defining tools based on existing formal procedures. By another way, tools needed to cope with informal deviations (vs. inconsistencies) are dependant on many factors like the nature of the deviation, the organization's maturity and the existing communication and coordination know-how. Consequently the *degree of formalism* is the first facet of the typology we propose. We note that we use the expression « *degree of formalism* » to stress that each human-centered activity is a mix composed of formal and informal tasks.



Secondly, we focus on the type of cooperation where deviations and inconsistencies occur. So, we distinguish the actor/actor and the actor/tool deviations (vs. inconsistencies). The first category splits into communications and coordination deviations (vs. inconsistencies) while the second is composed of user/tool and user/context deviations (vs. inconsistencies). Actor/tool deviations and inconsistencies originate notably from the inadequacy of the computerized tool with the end user cognitive process. It may result in inefficient contribution of end users to the organization's business processes. We note that the analysis of the tool/tool deviations (vs. inconsistencies) is beyond the scope of this paper which focus on the human aspects of human-centred systems. Consequently, the *nature of cooperation* is the second facet of the proposed typology.

The third facet of this typology, called « *localization* », relates to the project spaces where the deviations (vs. inconsistencies) occur. This facet reflects the vertical (vs. horizontal) nature of human-centered deviations and inconsistencies.

The second and third facets play a critical role in determining the appropriate tools to reduce deviations and inconsistencies impacts. Indeed, they permit taking into account the characteristics of the software projects spaces as well as the actors and processes concerned with the deviations and inconsistencies. In addition to actors directly involved in their development and use, human-centered systems interact indirectly with others organizational actors while cooperating with the organizational context and the external environment. Deviations and inconsistencies related to computerized tool/organizational context cooperation reflect notably human-centered system inadequacy with the organization's structure. Such deviations and inconsistencies are generally difficult to detect and their impact are observable notably through the organization's business processes dysfunctions. Because of the economic, organizational and social importance of these impacts, we consider that the *organizational aspects* constitute the fourth facet of the deviations and inconsistencies typology we propose in this work. This typology is composed of three abstraction levels: a conceptual level, a detailed level and a technical level. At the conceptual level, a deviation (vs. inconsistency) of a human-centered systems may be analyzed on the basis on the four facets described above i.e. (*degree of formalism, nature of cooperation, localization, organizational aspects*). The detailed level permits describing the characteristics of a given deviation (vs. inconsistency) four facets. This description includes notably the actors, the artifacts, the processes, the rules and the spaces concerned with a given deviation (vs. inconsistency). At the technical level, techniques, methods and tools which permit coping with deviations and inconsistencies are described. The next section provides a synthetic formal description of human-centered systems deviations and inconsistencies at the conceptual level.

#### 4 A formal model of inconsistencies and deviations

At a given date, we consider that a human-centered system  $S$  is composed of five parts:  $S = S_1 \times S_2 \times S_3 \times S_4 \times S_5$ . For  $i \in \{1, 2, 3, 4\}$ ,  $S_i$  is the representation of the human-centered system in the project space  $i$ .  $S_5$  is the coordination process between the four spaces. For  $i \in \{1, 2, 3, 4\}$ ,  $S_i$  is modeled as a state machine  $(SE_i^e, SE_i^r, STRANS_i^e, STRANS_i^r)$  where  $SE_i^e$  (vs.  $SE_i^r$ ) is the set of  $S_i$  expected (vs. real) states and  $STRANS_i^e$

(vs.  $STRANS_i$ ) is the set of  $S_i$  expected (vs. real) transitions. For  $i \in I = \{1,2,3,4\}$ ,  $SE_i^e$  and  $STRANS_i^e$  are known and determined by the project actors associated to the project space  $i$  in compliance with their requirements and the organization's technical maturity. For  $i \in I = \{1,2,3,4\}$ ,  $SE_i^r$  and  $STRANS_i^r$  are unknown and determined by the behaviour of  $S_i$ . Elements of  $STRANS_i^e \cup STRANS_i^r$  are functions  $t: SE_i^e \cup SE_i^r \rightarrow SE_i^e \cup SE_i^r$ . The coordination process  $S_5$  is presented in [Dakhli, 1998]. Formal description of  $S_5$ ,  $SE_i^e$ ,  $SE_i^r$ ,  $STRANS_i^e$ ,  $STRANS_i^r$  depend on the space, the actors, the support process and the artifacts associated with  $S_i$ . This description is provided in [Toffolon and Dakhli, 1999] as Z schemas noted respectively  $S_5$ ,  $SE_i^e$ ,  $SE_i^r$ ,  $STRANS_i^e$ ,  $STRANS_i^r$ . Using this notation, we define a human-centered system  $S$  as a the following Z schema  $S$ . This schema uses the following sets [ALPHA, THETA, SIGMA]. ALPHA (vs. THETA, SIGMA) is the domain of the states (vs. transitions, process) of any human-centered system  $S$ . ALPHA, THETA are related by a relation (partial function)  $\Pi$ : ALPHA  $\times$  ALPHA  $\clubsuit$  THETA. To take into account the concepts of formal and informal deviations and inconsistencies, THETA is partitioned in two subsets: THETA = THETA<sub>formal</sub>  $\cup$  THETA<sub>informal</sub> where THETA<sub>formal</sub> (vs. THETA<sub>informal</sub>) is the set of formal (vs. informal) transitions of any human centered system. STRANS<sub>i</sub><sup>e</sup> and STRANS<sub>i</sub><sup>r</sup> are partitioned in the same way: STRANS<sub>i</sub><sup>e</sup> = STRANS<sub>i,formal</sub><sup>e</sup>  $\cup$  STRANS<sub>i,informal</sub><sup>e</sup> and STRANS<sub>i</sub><sup>r</sup> = STRANS<sub>i,formal</sub><sup>r</sup>  $\cup$  STRANS<sub>i,informal</sub><sup>r</sup>.

$$\begin{array}{l}
 \cup S \\
 \rightarrow i: I, \\
 \rightarrow S_5: \Pi \text{SIGMA} \\
 \rightarrow SE_i^e, SE_i^r: \Pi \text{ALPHA} \\
 \rightarrow STRANS_i^e, STRANS_i^r: \Pi \text{THETA} \\
 \cap \\
 \rightarrow \forall r, s: \text{ALPHA} \rightarrow r, s \in SE_i^e \cup SE_i^r \bullet \Pi(r, s) \in \text{THETA} \\
 \rightarrow \forall r. SE_i^e \cup SE_i^r \exists s: SE_i^e \cup SE_i^r \neq \emptyset \bullet \exists t: STRANS_i^e \cup STRANS_i^r \bullet s = t(r) \not\Rightarrow r = t(s) \\
 \rightarrow \forall p: S_5 \exists i: I \bullet p \in (SE_i^e \cup SE_i^r) \times (STRANS_i^e \cup STRANS_i^r)
 \end{array}$$

Since the next definitions are applicable whatever the project space and the associated subsystem and process, we omit the index  $i$  in the following notations. According to the definitions provided in the previous section, inconsistencies are associated with a state while deviations are associated with a transition. If  $r$  and  $s \in SE^e \cup SE^r$ ,  $\Pi(r, s)$  is called a feasible transition. So, a transition  $t$  is not feasible iff  $\forall r, s \in SE^e \cup SE^r$ ,  $\Pi(r, s) \neq t$ . We note  $\Phi$  the set of the feasible transitions of any human-centered system. To provide formal definitions of deviations and inconsistencies, the concept of *action* must be defined: an *action* is a function which defines the set of feasible transitions associated with a given state. We consider two categories of actions  $A_e$  and  $A_r$ .  $A_e$  defines the set of expected transitions from a given state while  $A_r$  defines the set of real transitions from a given state. So, if  $r \in SE^e$ , a deviation occurs iff  $A_e(r) \cap A_r(r) = \emptyset$ . A deviation is formal if  $A_e(r) \cap STRANS_{\text{formal}}^e \neq \emptyset$  and informal otherwise. A *first order inconsistency* is defined as the result of at least one deviation. By another way, one deviation may result in many first order inconsistencies. An inconsistency not generated by a deviation is called *second order inconsistency*. The set of *first order* (vs. *second order*) *inconsistencies* of a human-centered system  $S$  is noted INCONSIST\_1 (vs. INCONSIST\_2). A deviation that results in at least one first order deviation is called *first order (active) deviation*. A *second order deviation* is a *passive deviation* i.e. a

deviation that generates no inconsistency. The set of *first order* (vs. *second order*) *deviations* of a human-centered system  $S$  is noted  $DEVIAT\_1$  (vs.  $DEVIAT\_2$ ). An inconsistency is formal if it results from one or more formal deviations and informal otherwise. The *degree of formalism* of an inconsistency depends on the number of formal deviations generating it. The *degree of formalism* of a deviation depends on the size of  $A_c(r) \cap STRANS_{formal}^e$ . Each human-centered system inconsistency  $\Lambda$  is associated with a set of initial states  $\Lambda\_ST\_Init$ . The information provide above is used to define the set of all deviations (vs. inconsistencies) of any human-centered system, noted  $DEVIAT$  (vs.  $INCONSIST$ ). The four facets of a deviation (vs. inconsistency) of a human-centered system are defined by the following four sets described in [Toffolon and Dakhli, 1999]: FORM, COOP, SPACE, ORG. Consequently, at the conceptual level, deviations and inconsistencies of a human-centered system  $S$  are modelled using the following Z schema  $DEV/INC$ . More information related to the detailed and technical levels of the deviations and inconsistencies typology are beyond the scope of this paper and are provided in [Toffolon and Dakhli, 1999].

$$\begin{aligned}
& \cup \underline{DEV/INC} \\
& \rightarrow S \\
& \rightarrow SFORM\_DEV, SFORM\_INC: PIFORM \\
& \rightarrow SCOOP, SCOOP: PICOOP \\
& \rightarrow SSPACE: PISPACE \\
& \rightarrow SORG\_DEV, SORG\_INC: PIORG \\
& \rightarrow SDEVIAT, SDEVIAT\_1, SDEVIAT\_2: PDEVIAT \\
& \rightarrow SINCONSIST, SINCONSIST\_1, SINCONSIST\_2: PIIINCONSIST \\
& \rightarrow \Lambda: SINCONSIST \\
& \rightarrow \Lambda\_ST\_Init: PIALPHA \\
& \rightarrow dev_{form} : SFORM\_DEV, dev_{coop} : SCOOP, dev_{loc} : SSPACE, dev_{org} : SORG\_DEV \\
& \rightarrow inc_{form} : SFORM\_INC, inc_{coop} : SCOOP, inc_{loc} : SSPACE, inc_{org} : SORG\_INC \\
& \cap \\
& \rightarrow SDEVIAT == SFORM\_DEV \times SCOOP \times SSPACE \times SORG\_DEV == SDEVIAT\_1 \vee SDEVIAT\_2 \\
& \rightarrow SINCONSIST == SFORM\_INC \times SCOOP \times SSPACE \times SORG\_INC \\
& \rightarrow SINCONSIST == SINCONSIST\_1 \vee SINCONSIST\_2 \\
& \rightarrow A_c \cdot SE^e \cup SE^e \clubsuit STRANS^e \\
& \rightarrow \forall (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) : SINCONSIST\_1 \exists (dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) : \\
& \rightarrow SDEVIAT\_1 \bullet (dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) \Rightarrow (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) \\
& \rightarrow \forall (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) : SINCONSIST\_2 \forall (dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) : \\
& \rightarrow SDEVIAT \bullet !(dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) \Rightarrow (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) \text{ ff} \\
& \rightarrow (\forall r : \Lambda\_ST\_Init \forall t : A_c(r) \bullet t(r)^M SE^e) \\
& \rightarrow \forall (dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) : SDEVIAT\_1 \exists (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) : \\
& \rightarrow SINCONSIST\_1 \bullet (dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) \Rightarrow (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) \\
& \rightarrow \forall (dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) : SDEVIAT\_2 \forall (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) : \\
& \rightarrow SINCONSIST \bullet !(dev_{form}, dev_{coop}, dev_{loc}, dev_{org}) \Rightarrow (inc_{form}, inc_{coop}, inc_{loc}, inc_{org}) \Rightarrow
\end{aligned}$$

## 5 Conclusion

The framework we describe in this paper provides basic instruments to cope with inconsistencies of human-centered systems. In particular, the proposed typology permits defining methods and tools to manage inconsistencies in compliance with the organization's constraints, priorities and technical maturity. So, it is compliant with the Simon's Bounded Rationality Principle [Simon, 1983]. By another way, the typology of inconsistencies and deviations proposed in this work permits identifying other types

of deviations and inconsistencies not considered in the literature. These deviations (vs. inconsistencies), called second order deviations (vs. inconsistencies) must be managed since they are source of uncertainty and are not compliant with many software quality principles like traceability and continuous improvement of software development process. A future research direction consists in using the formal description of the proposed typology to build a deviations and inconsistencies reduction process.

## References

- [Alchian and Demsetz., 1972] Alchian A.A., Demsetz H. (1972): «*Production, Information Costs and Economic Organization*», American Economic Review, 62(5): 777-795.
- [Balzer, 1991] Balzer R. (1991): «*Tolerating Inconsistencies*», in Proceedings of ICSE'13 Conference, Austin, Texas, USA, May 13-17: 158-165.
- [Bandinelli et al., 1994] Bandinelli S., Di Nitto E., Fuggetta A. (1994): «*Policies and Mechanisms to Support Process Evolution in PSEE*», In Proceedings of the 3<sup>rd</sup> IEEE International Conference on the Software Process, Reston, VA.
- [Cugola et al., 1996] Cugola G., Di Nitto E., Fuggetta A., Ghezzi C. (1996): «*A Framework for Formalizing Inconsistencies and Deviations in Human-Centered Systems*», ACM Transactions on Software Engineering and Methodology, 5(3), July 1996: 191-230.
- [Dakhli, 1998] Dakhli S. (1998): «*Prototyping*», PhD. Thesis, Paris-Dauphine University, France.
- [Fernström, 1993] Fernström C. (1993): «*State Models and Protocols in Process-centered Environment*», in Proceedings of the 8th ACM International Software Process Workshop, Wadern, Germany.
- [Ghezzi and Nuseibeh, 1998] Ghezzi C., Nuseibeh B. (1998): «*Managing Inconsistencies in Software Development*», Guest Editorial, Transactions on Software Engineering, 24(11): 906-907.
- [Nuseibeh, 1996] Nuseibeh B. (1996): «*To Be or Not To Be: On Managing Inconsistency in Software Development*», in the Proceedings of the 8<sup>th</sup> International Workshop on Software Specifications and Design (IWSSD'8), pages 164-169, Schloss, Velen, Germany.
- [Simon, 1983] Simon H.A. (1983): «*Models of Bounded Rationality*», (2 volumes), MIT Press, Cambridge.
- [Spivey, 1992] Spivey J.M. (1992): «*The Z notation: A Reference Manual*», 2<sup>nd</sup> edition, Prentice-Hall, Englewood-Cliffs, N.J..
- [Toffolon and Dakhli, 1998] Toffolon C., Dakhli S.(1998): «*A Framework for Software Engineering Inconsistencies Analysis and Reduction*», In the Proceedings of the 22<sup>nd</sup> Annual International Computer Software & Applications Conference (COMPSAC 98), IEEE Computer Society Press, pages 220-227, Vienna, Austria.

- [Toffolon and Dakhli, 1999] Toffolon C., Dakhli S. (1999): « *A Formal Process for Software Inconsistencies and Deviations Management* », Working paper, Paris-Dauphine University, France.
- [Toffolon, 1999] Toffolon C. (1999): « *The Software Dimensions Theory* », in the Proceedings of ICEIS'99 Conference, Setubal, Portugal.
- [Williamson, 1989] Williamson O.E. (1989): « *Transaction Cost Economics* », in « R. Schmalensee and R. Willig (Eds): Handbook of industrial organization », North-Holland, 1989.



## A MACRO ARCHITECTURE FOR HUMAN CENTRED PLANNING

Vaccari E., D'Amato M., Caponetti L., Delaney W.

Dipartimento di Informatica, Università di Bari, Italy  
E-mail: vaccari@di.uniba.it

### **Abstract:**

*A novel approach to cognitive modelling in the dynamic system theory (DST) paradigm is outlined and its capability to represent human centred decision making is discussed. The approach leads to the formulation of macro models conceived as a set of  $N$  generative DST models connected by a coupling scheme. The design criteria and the architecture of a software environment for the formulation and solution of such macro models is presented.<sup>1</sup>*

**Keywords:** cognitive modelling, descriptive complexity, autopoiesis, living organisations, structured DST models

### **1 Trends in cognitive modelling**

Cognitive modelling so far has been mostly performed in the computational paradigm known as computational theory of mind (CTM) on which classical Artificial Intelligence researches are based. Basic hypotheses underlying this paradigm are well known as well as its limitations and merits.

Let us simply recall that CTM is based on the assumed similarity between the mind and a universal Turing machine [Newell et al., 1958] from which the notion of a physical symbol system as an information processing device has been derived.

Knowledge is explicitly represented since the symbols can be given a semantic interpretation. Time has no significance in this approach. Computational models specify only a sequence of states that a system goes through and there is no concern about real amounts of time.

The last decade has been characterised by the awareness that dynamical system theory (DST) can offer a more realistic framework for cognitive modelling. In fact living systems behaviour is determined by the way in which the system states are changing in time and DST provides adequate formalism to describe these changes in time either in a continuous or in a discrete form. In this new perspective cognitive systems are considered in their globality and attention is focused on co-evolving, simultaneous processes unfolding in time.

While in CTM cognitive behaviour is viewed as the result of a computational process localised in the brain, in a system science perspective cognition is viewed as an emergent property arising from the interplay of brain, body and environment.

---

<sup>1</sup> This research has been funded by the MURST national project Evolution of the Concept of the City: Coherence between the Spatial Representation of the Planner and the Spatial Image of the Local Population

In a formal DST model, interactions among elements of a system are represented by means of mathematical expressions relating attribute's values of the related elements. The system state is described in the model by a set of variables representing attributes, whose values can vary with time. A state of the system is identified by a choice of values for each of the variables. Considering the variables as axes in an N dimensional space, each possible state will correspond to a point in that space, which is called the state space. The model's behaviour (which approximates the system's evolution in time) corresponds to a trajectory in the state space. A generative model is a dynamic model which can be used to generate a trajectory, corresponding to any initial state and any sequence of input values.

The total state of a DST model, representing the system' state, is changing from one time to the next. Instead computational models assume that most aspects of a system do not change from one moment to the next; change is assumed to be replacement of one symbol by another. The crucial difference between computational models and DST models is that in the former the rules that govern behaviour are defined over the entities that have representational status, whereas in dynamical models the rules are defined over numerical states, i. e. DST models can be representational without having their rules of evolution defined over representations.

The work of many researchers on living organisms contributed to the above mentioned shift of perspective focusing attention on the dynamical aspect of living systems and organisations both with respect to their inner dynamics and their dynamic interaction with a physical and sociocultural environment. In the theory of living systems called autopoiesis [Maturana and Varela, 1992], the organism reacts to disturbances/perturbations by means of a *self-referential dynamics*, so as to preserve its organisation; living systems are considered closed relatively to their operation but open in their connection with the environment and the connection behaviour-physiology is centred on the dynamic structural coupling between organism and environment.

Studies of evolution [Edelman, 1992], evidenced that living systems are capable of dynamically seeking the information they require and of selecting those behaviours that allow them to profit from their interaction with the environment. The internal dynamics of a living system unfolds in time as a function of its present state, of the perturbations from the environment and, according to Rosen [Rosen, 1979], of some predicted future state based on a wired-in internal model, i.e. a living system is an anticipatory system.

In short, living systems are viewed as dynamical systems composed of multiple dynamical subsystems which are simultaneously active and interacting.

## 2 Dynamic approaches to cognitive modelling

Dynamic frameworks within which to develop cognitive models currently include:

- The dynamic approach that Port and Van Gelder [Port and Van Gelder, 1995] propose as an alternative to CTM. It is based on the consideration that cognitive processes always unfold in time; thus a framework for their description must be able to describe not only what processes occur but how these processes unfold in time. The dynamic aspect is central. It is based on classical DST formalisms, their attitude in modelling a cognitive system is an holistic one, *the dynamics of central cognitive processes are nothing more than aggregate dynamics of low level*



neural processes described in higher level, lower dimensional terms. In this holistic approach, in order to manage descriptive complexity, the modeller has to make drastic assumptions and simplifications, with the result that often the original problem is only apparently solved. Although they recognise that a total system can be conceptually broken down into smaller dynamically interacting subsystems, their attitude is to freeze their interactions and study separately their independent dynamics which leads to the problem (not obviously solvable) of inferring global results from results obtained by modelling the parts in isolation. The approach can be used satisfactorily in simple contexts, but as we will discuss in the following section, it is difficult to imagine its use for modelling problems of organised complexity like cognitive processes.

- The biomimetic/animat approach Meyer [Meyer, 1995] This approach is based on a view of cognition as constraint satisfaction. The constraints are suggested by observations on animal behaviour in performing real life activities. The formalisms used include neural nets, simulation and heuristics inspired by biological, psychological and evolutionary theories. Positive aspects in Biomimetic/Animats applications reported in the literature regard the treatment of different phenomenological levels in the same overall model and the use of different formalisms. However it seems that the dynamic aspect, although present, is not central to the approach used and this may lead to problems regarding a correct time synchronisation when more realistic applications will be affronted.
- The macro DST model approach [Vaccari, 1998a, 1998b] discussed in section 4.

### 3 The need of hierarchical representations

The theory of autopoiesis defines a living system as a system which generates subsystems/component otherwise it disintegrates. If one wants to model such behaviour one needs a modelling formalism which foresees variable structure, i.e. systems having sub-systems which go in and out of existence as a function of the overall system dynamics. Hierarchical representations can be useful for modelling variable structure.

According to the theory of autopoiesis an organism is a self-organising system which contains its own control mechanisms. Including in a system's model its own control mechanisms requires the possibility to represent implicitly or explicitly hierarchical relations.

Autopoietic systems are considered closed with regard to their operation but open as regards their connection with the environment. The interactions with the environment change the state of the cognitive system which is in continuous evolution and it can pre-set its own behaviour by means of anticipatory models. Only a system which contains a model/representation of itself and/or of its environment can change its present state as a function of some predicted future state. Thus, a model of such a system will have a hierarchical nature, in the sense that it will *contain* a model of itself or of its context with faster dynamics.

It is clear from the above considerations that, in order to represent autopoietic, anticipatory systems, a formal dynamic model must foresee the possibility of representing hierarchical relations of different nature and different time scales at

different hierarchical levels. It is also necessary to manage the descriptive complexity without a drastic increase in uncertainty.

In the DST approach to cognition mentioned above, a model representing a cognitive process is formalised by means of one generative model thus it is not possible to manage descriptive complexity without a tremendous increase in uncertainty. Further the classical DST formalisms used to represent one generative DST model foresee neither hierarchical relations nor different time scales.

In order to overcome the above mentioned limitations we use modular macro models developed in the DST paradigm adopting an attitude where holism and reductionism are complementary [Delaney and Vaccari, 1989].

#### **4 A Macro DST framework**

In the following we use the expression “functional system” (FS) to denote an entity that is perceived as a “system” not because of what it is but because of what it always does (that is because of its invariant activity) where always means for all times and under all environmental conditions in a given environmental context.

Our DST approach to cognition is based: on the notion of functional system, on complementarity of holism and reductionism, on the development of discrete event simulation in the systems theory paradigm and on the possibility of using different formalisms in the same global DST model.

In this approach holism and reductionism are complementary in the sense that one cognitive system is represented as a structured model, i.e. a set of  $N$  generative DST models, connected by coupling input-output relations. Here the strategy adopted for reducing descriptive complexity is to conceptually break the cognitive system (that we conceive as a functional system FS) into appropriate functional sub-systems (FSS) amenable to being formally modelled separately and solved simultaneously taking into account their interactions. Conceptualising systems as structured systems/models refers to the process of structuring models (i.e. using composition) from a conceptual point of view and not simply at the implementation level by means of mathematical artifices.

The generative models forming a structured model might be structured models themselves; in such a case we obtain a second order structured model and it is possible to recursively define higher order structured models. This possibility to represent a sub-model, in turn, as a structured model allows hierarchical representations in a well established theoretical framework such as systems theory.

The sub-models mentioned above may represent either physical or conceptual FSSs eventually represented with different formalisms.

The above ideas have been incorporated in a systemic framework designed for the formulation and solution of structured dynamic models characterised by modularity and hierarchy [Vaccari et al., 1998].

#### **5 The Macro Architecture Overview**

The systemic framework we are developing consists of:

- The structured model, i.e. a set of  $N$  generative models and their coupling scheme. These sub-models may be specified at a ‘mathematical level’ with different (continuous/discrete) formalisms, while at the implementation level we use the discrete events formalism [Zeigler, 1976], which allows different time scales and can represent practically any continuous time / discrete time model.
- The nucleus which generates the global model solution by means of a discrete events simulation technique, i.e. an algorithm permitting the transitions to be treated as instantaneous events.
- The experimental frame specification, i.e. the set of conditions under which we solve the structured model and the set of required responses. Such specification is given in input in a declarative form.
- Graphical interfaces (under development) which provide a convenient way to input and visualise the structured model.

In the above framework the structured model to be solved is given in input in the form of a Bolck diagram specifying the names of the conceptual and physical Blocks (i.e. the sub-models representing either a conceptual FSS or a physical FSS) and their coupling scheme in terms of input/output variables. The invariant activities characterising the physical FSSs are specified in algorithmic form, while for the conceptual FSSs also the possibility to use a declarative form of specification has been foreseen (not implemented yet). A Block can incorporate alternative sets of equations for the evaluation of its state and output together with logic that permits the appropriate set of equations to be selected at each instant.

In the context of this paper very important features of the environment are modularity and hierarchy.

Modularity is an obvious characteristic of structured discrete events models, in that they are formed by combining together individual discrete events sub-models according to well defined rules, whereby outputs from certain sub-models become the inputs to other sub-models. Modularity also extends to structured discrete events models as wholes; i.e., two structured discrete events models can be coupled together by connecting outputs from one of them to inputs of the other one.

Modularity is very desirable in that it is useful for managing complexity and to implement hierarchical relations between functional subsystems.

“Authority hierarchies” are represented implicitly in the model, in the sense that one simply foresees conceptual sub-models (the controller) at the same level as physical sub-models (controlled subsystems) knowing that the outputs from the former will, in fact, constitute “controls/commands” in input to the latter. There are however situations in which it is convenient for hierarchy to be explicit in the model, i.e. we might find it desirable to explicate, in an overall structured model (A), both a first order sub-model (B) and its constituent higher order sub-sub-models (C(i)). We call such a hierarchy a “constitutive hierarchy”. Another form of hierarchy, called “reflexive hierarchy” is intended as a relation between an anticipatory FSS and the FSSs determining the predicted future state. Since the discrete events formalism used at the implementation level allows the representation of different time scales, the dynamics in the blocks

representing the anticipatory FSS may be slower than the dynamics in the blocks representing sub-FSS.

It seems reasonable to consider living systems behaviours as emerging from the interplay of many interacting functional subsystems (FSSs) characterised by some specific invariant activity in the system context. At an abstract level of analysis, we may identify different types of relations: a) Relations among elements of a FSS, b) relations among FSSs, c) relations between the system and its environment.

In our framework relations among elements of an FSS are taken into account by the specific invariant activities specified in the Blocks (i.e. sub-models representing FSSs) constituting the structured model; relations among FSSs which include relations between the system and its environment are taken into account by the nucleus which, using the coupling scheme and the experimental frame, given in input, defines how to generate new values for variables (pertinent to the global model) and when the new values should become effective. Foreseen relations between FSSs are functional relations and hierarchical relations. Functional relations are intended as causal relations and temporal relations between activities of FSSs. Hierarchical relations include: authority hierarchy, constitutive hierarchy and reflexive hierarchy. The latter is managed by means of a recursive call (prior to the transition state computation) to the nucleus in the physical block representing the FSS. Other basic features of the environment are: model specification in system theoretical terms; program architecture dictated by causality considerations; enforcement of strict separation of model and experiment-oriented specifications as input by the user.

## 6 Conclusions

Taking the point of view that human centred systems/organisation are autopoietic, anticipatory systems we discussed how hierarchical modelling based on structured dynamic models permits to represent many of their peculiar features i.e.:

- interacting conceptual and physical processes unfolding in time. at different time scales.
- variable structure and self-organisation.

Further structured dynamic modelling, based on the complementarity of holism and reductionism , allows to reduce descriptive complexity while minimising uncertainty.

## References

- [Delaney and Vaccari, 1989] Delaney, W. and Vaccari, E.(1989). Dynamic models and discrete event simulation. Marcel Dekker, New York.
- [Edelman, 1992] Edelman, G.M.(1992). *Bright Air, Brilliant Fire: On the Matter of the Mind*, Basic Books, New York.
- [Meyer, 1995] Meyer, J.A. (1995). The Animat Approach to Cognitive Science, in *Comparative Approaches to Cognitive Science*. Roitblat H.L. and Meyer J-A editors, MIT Press, Cambridge, MA.
- [Maturana and Varela, 1992] Maturana, H.R. and Varela, F. (1992). *Autopoesi e cognizione*, Marsilio, Milan.

- [Newell et al., 1958] Newell, A. Shaw, J.C. and Simon, H.A. (1958). Elements of a Theory of Human Problem Solving, *Psychological Review*, **65**, 151-166.
- [Port and Van Gelder, 1995] Port, R.F. and Van Gelder, T.(1995). It's about time: an overview of the dynamical approach to cognition. In Port, R.F. and Van Gelder, T.(eds), *Mind as Motion*, MIT Press, Cambridge, MA.
- [Rosen, 1979] Rosen, R.(1979), Anticipatory Systems in Retrospect and Prospect, *General Systems Yearbook*,**24**,11
- [Vaccari, 1998a] Vaccari, E. (1998). Knowledge as Modelling. *Cybernetics & Human Knowing*, **5**(2), 59-72
- [Vaccari, 1998b] Vaccari, E. (1998). Some Considerations on cognitive modelling. In R. Trappl (ed.), *Cybernetics and Systems'98*, vol.2 ,Austrian Society for Cybernetic Studies, Vienna, Austria, 663-668
- [Vaccari et al., 1998] Vaccari, E. D'Amato, M. and Delaney, W. (1998). Hierarchical Modelling: a Systemic Framework. Third International Conference on Emergence, August 98, Helsinki, Selected paper in *Acta Polytechnica Scandinavica* 178-184, G. Farre and T. Oksala (eds).
- [Zeigler, 1976] Zeigler, B.P. (1976). *Theory of modelling and simulation*, John Wiley and Sons, New York.



# ECOLOGICAL INTERFACE DESIGN: SUPPORTING OPERATOR ADAPTATION, CONTINUOUS LEARNING, & DISTRIBUTED, COLLABORATIVE WORK

Kim J. Vicente

Cognitive Engineering Laboratory  
Department of Mechanical & Industrial Engineering  
University of Toronto  
5 King's College Road  
Toronto, Ontario M5S 3G8, Canada  
Email: [benfica@mie.utoronto.ca](mailto:benfica@mie.utoronto.ca)  
URL: <http://www.mie.utoronto.ca/labs/cel/>

## Abstract:

*Operator support systems of the future will have to support operator adaptation to unanticipated events, foster continuous learning, and facilitate distributed, collaborative work. This paper describes Ecological Interface Design, a candidate framework for human-computer interface design that has the potential to fulfill these diverse demands.*

**Keywords:** ecological interface design, cognitive engineering, adaptation, learning, collaboration.

## 1 Introduction

As national and international economic competition has increased, process control industries of various types (e.g., nuclear power plants, fossil-fuel plants, and petrochemical process plants) are continually trying to “do more with less”. The need for continuous improvement in quality and productivity has increased drastically. This trend has caused engineering systems to become more complex than in the past, a trend that is sure to increase in the future [Pool, 1997; Vicente, 1999].

This increase in complexity has changed the demands experienced by operators of process control plants. There are three requirements in particular that are worth highlighting:

1. Adaptation to novelty;
2. Continuous learning;
3. Distributed, collaborative work.

Each of these points will now be described in turn.

An increase in complexity has led to a concomitant increased need to support *adaptation to novelty*, particularly to events that are unfamiliar to operators and that have not been anticipated by designers. Accident analyses have repeatedly shown that unanticipated events pose the greatest threat to system safety [see Vicente and Rasmussen, 1992 for a review]. In these situations, operators cannot rely on procedures

or automation provided by the designers because the event was not anticipated. Thus, operators must adapt to the new and unfamiliar situation and improvise a solution themselves. This is a demanding task, especially when we consider that the threat to equipment, the environment, and public safety is usually at its peak during these unfamiliar and unanticipated events. Thus, a framework for designing human-computer interfaces for process control systems must provide a way of identifying what type of information and support operators need in order to be able to deal successfully with unanticipated events.

A second challenge that has emerged in the process control industries is an increased requirement for *continuous learning*. Process plants are continuously striving to improve their operations by increasing the efficiency of existing processes, and by developing new processes that have valuable functionality. As a result, contemporary process control plants change much more frequently than in the past. These work environments are teeming with change and novelty, as continual attempts at quality improvement are being made. This trend means that there is an increased burden on operators to continually learn about the structure and behavior of the plant. Learning is not an activity that takes place once and for all during training and licensing because the process plant itself is continually changing. Therefore, a framework for designing human-computer interfaces for process control systems must foster continuous learning so that operators can keep pace with the turbulent change that characterizes their work environments.

A third challenge that has emerged in the process industries is the requirement to support *distributed, collaborative work*. As process control plants have become increasingly complex, there is a greater need to integrate different kinds of specialized knowledge (e.g., plant operations vs. plant management). More and more, these different types of knowledge will be held by different individuals, thereby creating an increased need for collaboration. Moreover, as control rooms have become increasingly centralized due to the power of information technology, there is a greater need to coordinate work activities across individuals who can be quite distant from each other geographically (e.g., control room operators vs. field operators). Thus, there is also a need for coordinating work activities across individuals that are distributed spatially.

Collectively, these challenges constitute a new set of design requirements. Operator support systems of the future will have to support adaptation to unanticipated events, foster continuous learning, and facilitate distributed, collaborative work if they are to meet the challenges imposed by today's competitive marketplace. In the remainder of this paper, I describe a candidate framework for human-computer interface design that has the potential to fulfill these diverse demands.

## 2 Ecological Interface Design

Ecological Interface Design (EID) is a theoretical framework for interface design for complex sociotechnical systems [Vicente and Rasmussen, 1990, 1992]. It is based on two seminal concepts from cognitive engineering research, the abstraction hierarchy (AH) and the skills, rules, knowledge (SRK) framework [Rasmussen, 1986]. The AH is a multilevel knowledge representation framework that can be used to develop physical and functional work domain models, as well as the mappings between them. It is used in EID to identify the information content and structure of the interface. The SRK



framework defines three qualitatively different ways in which people can process information: at the *skill-based* level, behavior is governed by a dynamic world model that allows people to engage in fluid perceptual-motor control; at the *rule-based* level, behavior is governed by rules which directly map perceptual cues in the environment to appropriate actions, without any mediating processing; finally, at the *knowledge-based* level, behavior is governed by a symbolic mental model which allows people to engage in analytical problem solving. The SRK framework is used in EID to identify how information should be displayed in an interface. The idea is to take advantage of operators' powerful pattern recognition and psychomotor abilities, allowing people to deploy everyday skills that have been honed through evolution. Thus, EID recommends that information be presented in such a way as to promote skill- and rule-based behavior, allowing operators to deal with task demands in a relatively efficient and reliable manner. Knowledge-based behavior is also supported by embedding an AH representation of the work domain in the interface. This provides operators with an external visualization of system structure and dynamics which offers support during novel situations requiring adaptive problem solving.

The EID framework consists of three principles. Each is intended to support a given level of cognitive control, as follows:

1. *Knowledge-based behavior* - represent the work domain in the form of an AH to serve as an externalized mental model that will support analytical problem solving;
2. *Rule-based behavior* - provide a consistent one-to-one mapping between the work domain constraints and the cues provided by the interface;
3. *Skill-based behavior* - support interaction via time-space signals, the operator should be able to act directly on the display.

For a detailed justification of these principles, see Vicente & Rasmussen [1990, 92].

Because the AH plays such an important role in EID, it is important to describe it in more detail. The AH is a multilevel representation format that describes the various layers of constraint in a work domain. Each level represents a different language for modeling the same underlying work domain. For process control plants, five levels of constraint have been found to be of use: the purposes for which the work domain was designed (Functional Purpose); the intended causal structure of the process in terms of mass, energy, information, or value flows (Abstract Function); the basic functions that the work domain is designed to achieve (Generalized Function); the characteristics of the components and the connections between them (Physical Function); the appearance and spatial location of those components (Physical Form). Higher levels represent *functional* information about work domain purposes, whereas lower levels represent *physical* information about how those purposes are realized by equipment.

### 3 Support For Unanticipated Events

EID provides a basis for helping operators cope with unanticipated events by using the AH to support problem solving. The rationale is very similar to that behind analytical redundancy techniques in control theory [Frank, 1990]. The AH represents the various layers of goal-relevant constraint that normally govern a process control plant when it is operating normally. When a fault occurs, one or more of those constraints will be violated, even if the fault is unfamiliar to operators and unanticipated

by designers. Because it is based on an AH representation, the interface will show the variables that enter into the goal-relevant constraints, thereby allowing operators to compare the behavior that is expected from the plant given the constraints with the current behavior of the plant. Any mismatch (i.e., a residual) is an indication that the work domain is not behaving as it should be [see Vicente, 1999 for more details].

#### **4 Support For Continuous Learning**

EID also provides a basis for continuous learning by mapping the goal-relevant constraints identified by the AH representation onto the perceptual features of the interface. By creating a transparent, visualization of otherwise opaque, abstract properties (e.g., mass and energy flows; chemical reactions), we are providing a rich source of feedback to operators about the structure and behavior of the plant. This feedback serves as an important input to learning processes. In effect, operators can learn every day on the job because the feedback they obtain from the interface provides them with a salient indication of how the plant responds to their or the automation's actions. In addition, feedback is also provided about the relationships that hold between variables under various operating regimes. Thus, as changes are made to the plant in the name of continuous improvement, an interface based on EID should foster continuous learning because operators should be able to update their understanding of the work domain based on the rich and salient feedback provided by the interface.

#### **5 Support For Distributed, Collaborative Work**

EID also provides a basis for supporting distributed, collaborative work by using the multiple levels of the AH to represent the varying information that is required by different stakeholders in the work domain. Each level of the AH provides a different language for modeling the work domain, and thus reveals different insights into the structure and behavior of the plant. This conceptual diversity provides a basis for accommodating the well-known fact that different individuals with different responsibilities tend to think about the plant in different ways. For example, plant managers tend to be concerned with meeting productivity and environmental regulation constraints, both of which would be represented in the Functional Purpose level of the AH. Plant engineers, on the other hand, tend to be more concerned with optimizing the production of the plant by thinking in terms of mass and energy balances, which are represented at the Abstract Function level of the AH. In contrast, control room operators tend to be more concerned with the status and configuration of plant functions and components, which are represented at the Generalized Function and Physical Function levels of the AH, respectively. Finally, field operators will frequently be more concerned with where particular components are located and what their appearance is, properties that are represented at the Physical Form level of the AH. These examples show that EID provides a global, shared representation – in the form of the AH -- that can support communication and coordination across individuals that are geographically distributed and that have diverse concerns, and thus, information needs.

#### **6 Conclusions**

The EID framework is a promising design framework for coping with the challenging trends that are being observed in process control industries. In this paper,

we have argued why there are good reasons to believe that EID can support operator adaptation, foster continuous learning, and facilitate distributed, collaborative work. Most of these arguments have been supported by data collected under representative laboratory conditions. The available experimental evidence shows that, compared to more traditional techniques, an interface based on EID can lead to: a) a better capability for coping with novelty [e.g., Pawlak and Vicente, 1996; Christoffersen et al., 1997; Xu et al., in press]; and b) a deeper understanding of the process [e.g., Christoffersen et al., 1998]. To date, however, no empirical research has been conducted to evaluate the claim that EID can effectively support distributed, collaborative work. This topic remains as an important issue for future research.

### Acknowledgements

This research was sponsored by research grants from the Natural Sciences and Engineering Research Council of Canada, NOVA Chemicals, and Honeywell Technology Center.

### References

- [Christoffersen et al., 1997] Christoffersen, K., Hunter, C. N., and Vicente, K. J. (1997). A longitudinal study of the effects of ecological interface design on fault management performance. *International Journal of Cognitive Ergonomics*, 1, 1-24.
- [Christoffersen et al., 1998] Christoffersen, K., Hunter, C. N., and Vicente, K. J. (1998). A longitudinal study of the impact of ecological interface design on deep knowledge. *International Journal of Human-Computer Studies*, 48, 729-762.
- [Frank, 1990] Frank, P. M. (1990). Fault diagnosis in dynamic systems using analytical and knowledge-based redundancy - A survey and some new results. *Automatica*, 26, 459-474.
- [Pawlak and Vicente, 1996] Pawlak, W. S., and Vicente, K. J. (1996). Inducing effective operator control through ecological interface design. *International Journal of Human-Computer Studies*, 44, 653 - 688.
- [Pool, 1997] Pool, R. (1997). Beyond engineering: How society shapes technology. New York: Oxford University Press.
- [Rasmussen, 1986] Rasmussen, J. (1986). Information processing and human-machine interaction: An approach to cognitive engineering. New York: North Holland.
- [Vicente, 1999] Vicente, K. J. (1999). Cognitive work analysis: Toward safe, productive, and healthy computer-based work. Mahwah, NJ: Erlbaum.
- [Vicente and Rasmussen, 1990] Vicente, K. J., & Rasmussen, J. (1990). The ecology of human-machine systems II: Mediating "direct perception" in complex work domains. *Ecological Psychology*, 2, 207-250.
- [Vicente and Rasmussen, 1992] Vicente, K. J., and Rasmussen, J. (1992). Ecological interface design: Theoretical foundations. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-22, 589-606.
- [Xu et al., in press] Xu, W., Dainoff, M., and Mark, L. (in press). Facilitate complex search tasks in hypertext by externalizing functional properties of a work domain on the user interface. *International Journal of Human-Computer Interaction*.



# INTEGRATING COGNITIVE SCIENCE AND OPERATIONS RESEARCH TECHNIQUES FOR BUILDING A BETTER PLANNING SUPPORT SYSTEM FOR A SOLID BOARD FACTORY

Henrico L.T. Wanders, Gerard J.C. Gaalman, René J.J. Jorna, Gerard Sierksma

University of Groningen  
Faculty of Management and Organisation  
PO Box 800  
NL-9700 AV GRONINGEN  
H.L.T.Wanders@bdk.rug.nl

## **Abstract:**

*In the past numerous planning support systems are built with Operations Research-based methods. These systems often function without the support of the planners.*

*We propose an alternative approach by embedding elements from both Cognitive Science and Operations Research. Our point of view is that integrating cognitive aspects of the human planner into the development process and consequently in the support system will lead to an enhanced and improved planning support system. We have performed an explorative study at a solid board factory to test the suitability of our approach.*

*The analysed solid board factory has two production locations. The planning decisions are made decentralised. There are four production planners and two final processing planners. At this moment, most short-term planning tasks are not supported by a computer system.*

*The purpose of this paper is to show the several phases we consider in the alternative approach.*

**Keywords:** production planning, computer support, task analysis, diagnosis, cognitive science, operations research, logistics

## **1 Introduction**

The use of management information systems in companies has increased in the last years. Nowadays there is a huge demand for good planning support systems that cooperate with the management information system of the company. A lot of those planning support systems function without the support of the planners. Developing planning support systems with an extended design methodology might increase the support within the company.

In general, two perspectives can be adopted to develop new planning support systems, namely:

- building systems that replaces the planner and his tasks, or
- building systems that adjusts to what the planner does (at this moment).

The first perspective implies that the system performs all planning tasks. Developers who adhere to this perspective believe that the planning task consists of a finite number of well defined and easy to automate subtasks. They believe that planning decisions could also be deduced by the system adequately.

This paradigm might be true in a simple and static environment. In reality the planner and/or support system act in a complex and dynamic environment. Other aspects become important, like the way a production plan is revised after changes or disturbances in the supply chain.

Information theory has its limitations because it could not explain adequately the complex, versatile, and active information processing that takes place within the human mind. Humans can increase their information-processing capacity, alter input, store it, reorganise it, retrieve material beyond the information given, make decisions and translate these decisions into action [Das *et al.*, 1996]. Thus a planner can manage complex and dynamic situations better than planning support systems do.

Therefore, we think that it is necessary to build a planning support tool complying with the requirements of the planners. So, we follow the second perspective, *i.e.* we want to build a system that adjusts to what the planner does.

Our goal in this project is to show that such an approach will lead to better planning support tools. We analyse both the tasks of the planner and the scheduling problem where the planner is faced with. We assume that integrating the tacit knowledge of the planner into a planning support tool, together with an algorithmic formulation of the 'base scheduling problems' lead to a better planning support tool.

This does not mean that the planning support tool supports all tasks of the planner. Those tasks that are relatively stable and are easy to formalise are performed by the planning support system. The planner performs those tasks that are often changed in time, or are being performed in a dynamic environment. But ultimately, the *planner* makes the definite decisions [Mietus, 1994].

To test the suitability of our approach we have performed an explorative study at a solid board factory in the Netherlands. We restrict our analysis to the production-planning domain.

The specific situation at the solid board factory is discussed in the next section. We continue with an analysis of the phases we consider in our approach to develop a new planning support tool. We will also show why our approach might lead to an improved planning support. Finally, we conclude with the results for the time being and the further research to be performed.

## 2 Specific situation at the solid board company

This research project has been performed at a solid board factory in the Netherlands. The factory has two production locations in the north of the Netherlands. Each location has two cardboard machines and one paper machine. We will describe the process flow for an order  $i$ . Figure 1 shows the flow schematically.

The customer orders arrive at the sales department. After commercial acceptance, the orders are offered to the planning department. The planning decisions are made decentralised. Each location has two production planners. The product types and

thickness are allocated to the cardboard machines in advance. This implies that each location has its own customer orders.

If the planning department accepts the customer orders, the orders are assigned to a run. A run shows all the customer orders of the same product type, the same thickness, and the same moisture percentage in a production week.

If the delivery time of the underlying orders of the run gets nearer, the production planner selects the run and plans the customer orders of the run against one another. At the end he has to determine the pallet need at the customer order level and order them.

Ready pallets are moved to the warehouse. The transportation planner decides when the order will be loaded and transported to the customer.

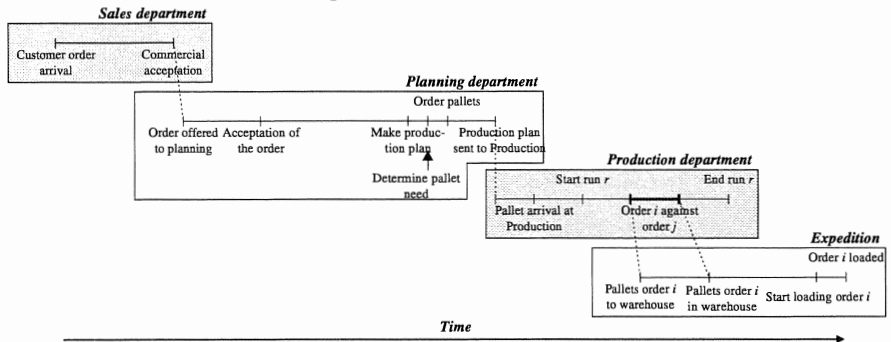


Figure 1: The process flow of order  $i$

### 3 Our alternative approach

The approach we have chosen to develop a new planning support tool for the production planning of a solid board company has a hierarchical structure. Figure 2 shows the stages in the hierarchy.

Our goal in this project is to build a planning support system by using elements from cognitive science, operations research and logistics. The logistics part is necessary to investigate the way the planning department is embedded in the whole organisation. Methods inspired by the Operations research (OR) are helpful in finding solutions for the underlying mathematical scheduling problems. Tools from Cognitive Science (CS) are used to analyse the planner's tasks, his reasoning and his behaviour.

In our opinion all these elements are necessary to build an appropriate support system. Other approaches either use the OR and Integration box, or the CS and Integration box only.

The Logistics box contains the analysis of the *supply chain* and the *production, planning and control* system. These two stages are performed, because a lot of aspects that are relevant in the planning task are determined at a hierarchical higher level in the organisation. For example, the operations manager decides what targets the planners must aim for. Besides this argument, an analysis of the organisation of the whole gives a better insight in the problems the organisation is faced with.

The *individual planning task level* gives an insight in the tasks the planner executes. Also important from a supporting perspective is the content of the planning tasks, the way the planner executes his tasks, and the strategies the planner follows to make a production plan.

The *mathematical formulation of 'base' scheduling problems* is made explicit in the following stage. In our opinion tasks that require intensive calculating can better be performed by a support system.

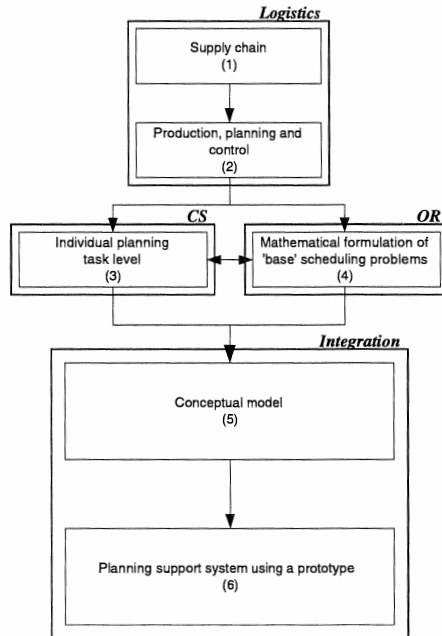


Figure 2: Hierarchy of the alternative approach

The Integration box contains the core of our approach. It consists of the *conceptual model* and the development of the *planning support prototype*.

All the knowledge of the preceding stages is merged in the *conceptual model*. The conceptual model consists of two modes: a 'zero state' and an 'adapted state' model. The 'zero state' model shows the current situation, whereas the 'adapted state' model the situation models that is used as a basis for the development of a planning support prototype. The specification of the 'adapted state' implies a (slight) change in the planning task.

The *planning support system* can be developed on the basis of the specified 'adapted state' conceptual model. The final stage consists of testing the appropriateness of our approach.



### 3.1 Supply chain

The target in this stage was to get a better insight in the overall process, that is a global survey over the material. The analysis was not restricted to the planning department, but also the sales and production departments have been taken into account.

One of the findings in this phase was that the company might improve its performance, if the supply chain management was changed. The followed strategy can be described as a make-to-order strategy, but for some markets or clients a make-to-stock strategy might lead to better results.

### 3.2 Production, planning and control

Planning is concerned with all the pre-operations activities whereas control is responsible for all the tasks and decisions to be made during the operation process [Hill, 1991]. Hoc (1988&1995) extended the theoretical framework by arguing that:

- plans are not necessarily action plans and can take more declarative forms,
- in complex situations, plans can lessen workload, and
- planning must not only be seen as plan generating, but also as plan execution.

### 3.3 Individual planning task level

To analyse the individual planning task level we performed think-aloud sessions with each of the four production planners. Think-aloud means that the planner verbalises all his thoughts during the execution of a task. The researcher analyses the protocols of the think-aloud sessions and derives common relations. For a complete analysis of verbal reports and protocol analysis, we refer to Ericsson and Simon (1990).

### 3.4 Mathematical formulations of the ‘base’ scheduling problems

The scheduling problems that emerge in the paper mill and cardboard industry have been extensively studied in the literature. In this section we only mention some example problems including their references.

On the cardboard machine the most dominant mathematical problem is the cutting stock problem to minimise the trim-loss of customer orders on the cardboard machine [Goulimis, 1990; Dyckhoff, 1992; Sierksma, 1996].

Laminated cardboard consists of three layers, an inner layer and two outer layers. The inner layer is produced on the cardboard machine; the outer layer on the paper machine. The problem is to find a composition of the layers such that the throughput time over the cardboard and paper machines is minimised [Sierksma and Wanders, to appear].

### 3.5 Conceptual model

The conceptual model consists of three layers, namely:

- *ObjectOriented-modelling of the domain,*
- *task analysis*
- *process description*

In the object-oriented modelling, all objects are introduced, defined, and described with the accompanying attributes and events. Following Yourdon and Argila (1996) we define an object as: *an independent, asynchronous, concurrent entity which “knows things” (i.e. stores data), “does work” (i.e., encapsulates services) and “collaborates with other objects” to perform the overall functions of the system (being modelled).*

The task analysis level describes the planning tasks at a macro level. We segregate the following tasks: administrate, count, tune, value, adapt, negotiate [Jorna *et al.*, 1996].

Both levels are united in the process description. We use flow chart techniques to describe the tasks the planner performs.

### 3.6 Planning support system using a prototype

We will use the conceptual model to construct a planning support prototype. The ‘adapted state’ model specifies which task the planner executes and which task the computer system executes.

## 4 Conclusions and future research

In this article we have shown the design of our alternative approach in order to build a better planning support system for a solid board company. We believe that our approach might lead to a better planning support tool. It is however not tested at this moment.

The construction of the prototype is the phase to be done. After that we might state some propositions about the appropriateness of our approach in relation to more traditional approaches.

## References

- [Das *et al.*, 1996] J.P. Das, B.C. Kar, R.K. Parrila, *Cognitive planning. The psychological basis of intelligent behavior* ( Sage Publications, New York, 1996).
- [Dyckhoff and Finke, 1992] H. Dyckhoff, U. Finke, *Cutting and packing in production and distribution* ( Physica Verlag, Heidelberg, 1992).
- [Ericsson and Simon, 1990] K.A. Ericsson, H.A. Simon, *Protocol analysis. Verbal reports as data.* ( The MIT Press, Bradford, 1990).
- [Goulimis, 1990] C. Goulimis, Optimal solutions for the cutting stock problem, *European Journal of Operational Research* 197 (1990).
- [Hill, 1991] T. Hill, *Production/operations management. Text and cases* ( Prentice Hall, New York, London, Toronto, Sydney, Tokyo, Singapore, 1991).
- [Hoc, 1988] J.-M. Hoc, *Cognitive Psychology of planning* ( Academic Press, London, 1988).
- [Hoc, 1995] J.-M. Hoc, Planning in diagnosing a slow process. Some implications of human operator computer support, *Zeitschrift fuer Psychologie* 203, 101 (1995).
- [Jorna *et al.*, 1996] R.J. Jorna, H.W.M. Gazendam, W.M.C. vanWezel, H.C. Heesen, *Plannen en roosteren, Taakgericht analyseren, ontwerpen en ondersteunen* ( Lansa Publishing, Leiderdorp, 1996).

- [Mietus, 1994] D. Mietus, Understanding planning for effective decision support. A cognitive analysis of nurse scheduling.(1994). University of Groningen: PhD.
- [Sierksma, 1996] G. Sierksma, Linear and Integer Programming. ed. 1st, (New York, Marcel Dekker, 1996) 0079-8177.
- [Sierksma and Wanders, to appear] G. Sierksma, H.L.T. Wanders, The Manufacturing of Heavy Weight Cardboard, *International Journal of Production Research*, to appear
- [Yourdon and Argila, 1996] E. Yourdon, C. Argila, *Case studies in object-oriented analysis and design* ( Yourdon Press Computing Systems, Englewood Cliffs, 1996).



## **PART II**

# **KNOWLEDGE ENGINEERING AND MANAGEMENT**

---



# ADAPTABLE GROUPWARE<sup>1</sup>

R. Alterman, S. Landsman, J. Introne, A. Feinman

Computer Science Department  
Brandeis University  
Waltham, MA 02421 USA  
alterman@cs.brandeis.edu

## Abstract:

*This paper presents a model of adaptable groupware that is motivated by developments in Cognitive Science. Adaptation of the system is tied to the behavior of users in managing the representation of common ground during the course of their joint activity. Our insight is that the explicit representations built by users to coordinate their behavior for a given problem are objects that the user will want to re-use in future problem solving sessions and over time some of these will become conventions of behavior that improve the performance of the participants in coordinating their behavior.*

**Keywords:** Adaptable Groupware, Common Ground, Shared Plans, Convention.

## 1 Introduction

The application domain of this work is groupware for distributed planning. Suppose that there are multiple users at remote locations who must plan out and execute a coordinated set of operations. Each of the users has different capabilities and duties. Their only resource for coordinating behavior is the computer. Users of the system work together at the same time but in different locations. The set of experiences that are generated in the course of the users' continued work over many sessions are a source of information that can be used to adjust the system's behavior to better fit the system to the users and the domain of application. Over multiple episodes of planning with the system, the practice that develops is a significant part of the performance in the person machine interaction. At issue is how to build a system that supports the development of practice in using the system to support the users' continued effort at planning for their domain of activity. The idea developed is that conventions of behavior naturally emerge from the ongoing practice of a community of users, are a part of the common ground that develops among regular users of the system, and are a basis for adapting a system to its environment of use.

For a test domain, the VesselWorld system was designed and built. In VesselWorld there are three users who must cooperate and coordinate their behavior. Each user is the captain of a ship. The task is to remove toxic waste from a harbor. Collectively the users must explore a large area to find and move all barrels of toxic waste to a large barge. The system is designed to support joint activity. A set of representations and operations manipulated by the users facilitate reasoning about common ground and shared plans.

---

<sup>1</sup> This work was supported by ONR (N00014-96-1-0440).



The system facilitates the development of conventions for coordinating on-line planning behavior within a community of users. These conventions will reduce user work in future planning sessions. Because conventions are regularities of behavior, they can also be converted into adaptations to the system.

To frame the discussion, this paper will draw on research in Cognitive Science. The adaptation of a system to the behavior of participants in managing the representation of *common ground* [Clark, 1996] during the course of their joint activity. Our insight is that explicit representations of *shared plans* [Grosz and Sidner, 1990] built by users to coordinate their behavior for a given problem are objects that the user will want to re-use in future problem solving sessions and over time some of these will become *conventions of behavior* [Alterman and Garland, 1998] that improve the performance of the participants.

## 2 Models of Human Computer Interaction and System Adaptation

There are two classic models of human computer interaction. The Norman model of the seven stages of human action details the mental stages involved in each user action [Norman, 1988]. Design is concerned with reducing the gulf between the intentions of the user and the commands provided by the system (the gulf of execution) and the gulf between the representations of the system state and their interpretability by a given user (the gulf of evaluation). The GOMS model of Card, Moran, and Newell (1983) provides a methodology for designing the user/system interaction in accomplishing a single task, which may involve multiple steps of action. Both of these models are used as tools for improving the design of the system. Neither of these models provides a basis for modelling changes and improvements (i.e., adaptations) in user/system performance that can only be achieved by continued practice. (See Alterman, Zito-Wolf, and Carpenter, 1998 for a practice-based model of device usage.) The set of experiences that are generated in the course of the users' continued work over many sessions are a source of information that can be used to adapt the system's behavior so as to better fit the user to the system and the system to the domain.

Adapting a system can require a mix of a user and system effort. The two extremes are the *adaptable system*, which is based solely on human effort, and the *adaptive system*, which automatically adapts [Oppermann and Simm, 1994]. The advantage of the adaptable system approach is that the user has a great deal of control over adaptations in the system; the disadvantage is that it requires considerable user work and skill. The advantage of the adaptive system approach is that expectations about user work and skill are lowered. The disadvantage of this approach is that the system builder is burdened with the task of building into the system a mechanism that is capable of accurately explaining the user's behavior --- an unsolved problem.

In the model of adaptable groupware that we describe, the work done by the user fits the following criterion: *It is work that directly benefits the user on the current problem.* The key idea is to tie the adaptation of the system to the behavior of the participants in the joint activity in managing the representation of common ground. Our insight is that the procedural representations built by users to coordinate their behavior for a given problem are objects that the users will want to re-use in future problem solving sessions (are likely candidates for conventions) and are consequently adaptations to the system.



### 3 Vessel World

In VesselWorld there are three users who must cooperate and coordinate their behavior. VesselWorld is a *groupware* system; users work at remote locations simultaneously. Each user is the captain of a ship. The task is to remove toxic waste from a harbor. Collectively the users must explore a large area to find and move all barrels of toxic waste to a large barge. Two of the users operate cranes that can be used to lift toxic waste from the floor of the sea. The third user is captain of a tugboat that can be used to drag small barges from one place to another. The cranes are able to individually lift and carry small or medium toxic waste barrels, jointly lift large barrels, and jointly lift (but not carry) extra large barrels. The tugboat cannot lift barrels, but can attach to and move small barges. Small barges may hold multiple barrels of various sizes.

In VesselWorld there are three mechanisms that help users to accumulate and monitor common ground: the State Of World map (SOW), a chat window, and a bulletin board of semi-structured notes. The SOW is used to monitor the current state of the joint activity. Figure 1 shows an example of a SOW for a crane operator. Only a portion of the virtual world is visible to each user at any time. The visible area is a circle of predefined radius around the actual location of the vessel. This area is represented in the interface by a darker circle surrounding the vessel. A small barge is represented by a diamond icon (sbrg1). Barrels of toxic waste are represented by a rectangular icon (lwaste1), the user's vessel is represented by a red circle (crane2), and other vessels are represented by white circles (crane1). Additionally, each vessel can also see all the large barges, which are represented by a triangle (e.g., brg2).

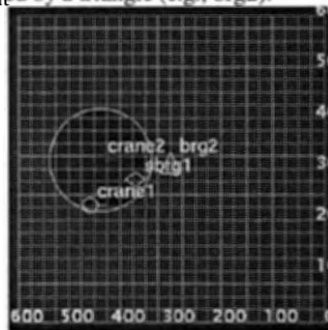


Figure 1: SOW map

### 4 Common Ground, Shared Plans, and Convention

Users of the VesselWorld system are engaged in a *joint activity* [Clark, 1996]. Joint activities have participants, who assume public roles. Joint activities require that the participants solve a set of coordination problems, advancing one increment at a time. Coordination of behavior requires common ground and communication. At any moment during a joint activity, what constitutes common ground (the jointly constructed context between users) has three parts [Clark, 1996: p. 43]: the initial common ground, the current state of joint activity, and the public events so far. The initial common ground is

the set of background facts, assumptions, and beliefs presupposed at the outset of the joint activity; conventions for coordinating behavior are an important part of the initial common ground. The current state of joint activity is where in the activity the participants presuppose themselves to be. The public events are those events presupposed by the participants as leading up to the current state of affairs. Common ground accumulates among participants during the course of activity.

The initial common ground between the two crane operators includes knowledge that some barrels of toxic waste require two cranes to be loaded onto a barge and that the crane operators must coordinate the loading (e.g., begin at the same time). The current state of the world must be monitored until both crane operators are in position and prepared to lift the barrel of toxic waste, and until the barge is in position and stabilized in rough weather. The public event of the tugboat captain stabilizing the barge signals the readiness of the barge for loading additional barrels.

Following Grosz & Sidner (1990) and Grosz & Kraus (1996), we will assume that for activities that involve shared planning, common ground includes a fourth element: a *shared plan*. The shared plan represents the participants' common understanding of what they plan to do in order to achieve their common goal. It develops during the course of the activity. It includes beliefs about actions that are to be taken and also the intentions of the participants.

Before the large barrel of toxic waste can be lifted the intentions of the tug boat captain and the two crane operators must be clarified. The plan to lift the large barrel of toxic waste onto the barge will only succeed if the tugboat captain intends to anchor a small barge close to the site of the barrel, and if both crane operators intend to lift the barrel at the same time.

Certain problems in coordination may re-occur. A *convention* is a solution to a recurrent coordination problem [Lewis, 1969]. Conventions are the regularities of behavior that develop among a community of actors with a tradition of common goals and shared activities. Alterman & Garland (1998) have developed a cognitive model of how convention emerges from group practice in circumstances where there is no ruling body of knowledge (as developed by prior generations of actors within the community) to draw on and to guide cooperative and coordinated behavior. An analysis of a large set of experiments shows that the development of convention has several important properties. New conventions for coordinating joint activities develop as a result of practice. The development of convention improves performance, while reducing communication and planning costs. These findings have significance for the development of systems for groupware planning. Adding adaptive components to a system that facilitates the emergence of convention as a part of initial common ground will result in improved performance, while reducing user effort.

In the domain of VesselWorld conventions develop over time for coordinating behavior between participants in a joint activity. Locations of objects are communicated between users using a certain notation scheme. Standardized procedures for loading barrels onto a small barge emerge that reduce the communication necessary to coordinate the lifting and loading of the barrel with the anchoring of the barge by the tug boat captain.

## 5 Adaptable Groupware

In VesselWorld, much of the coordination of behavior between participants is achieved by posting structured notes of information to a bulletin board. All notes posted to the window are WYSIWIS. The notes are semi-structured messages which participants may use to monitor and communicate current information, initial common ground, and shared intentions/plans. Semi-structured communication has been shown to be more effective than either unstructured or fully structured communication in coordinating complex activities [Malone *et al.*, 1988].

Three types of notes currently exist: definitions, planning grids, and object tickets. Definitions are representations for a term generated by users. Shared plans are created by the users to coordinate sub-problems encountered during the session. Object tickets are created to monitor the state of known toxic waste barrels. Figure 2 shows and example of a planning grid. All the vessels assemble at the location of the barrel (Step 0), the cranes must lift and carry the barrel of waste together (Steps 1-2). The tug must stabilize the barge while the cranes load the waste onto the barge (Step 3). The participants then carry out the steps of the plan, communicating where necessary to coordinate fine-grained actions not specified in the plan (such as the exact time the cranes must lift together).

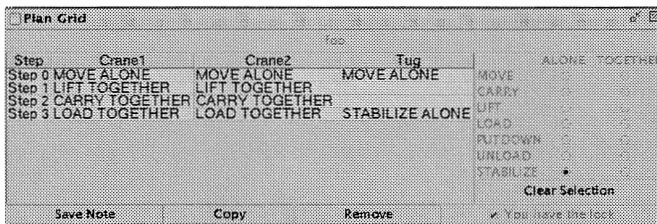


Figure 2: Plan Grid

Notes can be re-used within a problem-solving session and can be retained for use in future problem-solving sessions. For example, later problems requiring the tug boat operator coordinate with the two crane operators may re-use the same planning grid making minor modifications as the action proceeds. Re-used notes are the basis for the accumulation of initial common ground throughout the history of a community of actors using the system to coordinate activity. For regularly occurring problems of coordination in the domain of activity, planning grids will be re-used and develop into conventions that reduce the amount of work for the user in creating a shared plan for a regularly occurring problem of coordination.

## 6 Concluding Remarks

In the model of adaptable groupware that has been described, the use and re-use of planning grids benefit the performance of the users on both the current problem and future problems. The procedural representations built by users to coordinate their behavior for a given problem help the users manage their joint activity, and they are also objects that the user will want to re-use in future problem solving sessions (are likely candidates for conventions). Re-used planning grids indicate a regularity of behavior

and consequently are critical to the addition of *adaptive* features to the system. Space limitations have not allowed for the presentation of the adaptive features of the VesselWorld system. The key idea, however, is that given a regularity of behavior, the system can automatically perform some interface tasks for the user. Currently, the focus is on using the emergent conventions of group behavior (the re-used planning grids) to offload onto the system some of the work involved in managing information during the course of planning.

### References

- [Alterman *et al.*, 1998a] Alterman, R., Zito-Wolf, R. and Carpenter, T. Pragmatic Action. *Cognitive Science* 1998, 53-105.
- [Alterman and Garland, 1998] Alterman, R. and Garland, A. Conventions in Joint Activity. Technical Report CS-98-199, Computer Science Department, Brandeis University, 1998.
- [Card *et al.*, 1983] Card S., Moran, T., and Newell, A. *The Psychology of Human-Computer Interaction*. Lawrence Erlbaum Associates, Hillsdale, NJ, 1983.
- [Clark, 1996] Clark, H.H. *Using Language*. Cambridge University Press, Cambridge, 1996.
- [Grosz and Kraus, 1996] Grosz, B., and Kraus, S. Collaborative Plans for Complex Action. *Artificial Intelligence* 1996, 269-357.
- [Grosz and Sidner, 1990] Grosz, B., and Sidner, C.L. Plans for Discourse, in Cohen, P.R., Morgan, J., and Pollack, M.E. (eds.), *Intentions in Communication*. MIT Press, Cambridge, MA, 1990.
- [Lewis, 1969] Lewis, D.K. *Convention: A Philosophical Study*. Harvard University Press, Cambridge, MA, 1969.
- [Malone *et al.*, 1988] Malone, T.W., Grant, K.R., Lai, K., Rao, R., and Rosenblitt, D. Semistructured Messages are Surprisingly Useful for Computer-Supported Coordination, In Grief, I. (ed.), *Computer-Supported Cooperative Work*. Morgan Kaufmann Publishers, San Mateo, CA, 1988.
- [Norman, 1988] Norman, D. *The Psychology of Everyday Things*. Basic Books, USA, 1988.
- [Oppermann and Simm, 1994] Oppermann, R., and Simm, H. Adaptability: User-Initiated Individualization, in Oppermann, R. (ed.), *Adaptive User Support*. Lawrence Erlbaum Associates, Hillsdale, NJ, 1994.

# AN ARCHITECTURAL MODEL COMPILER DEDICATED TO ARCHAEOLOGICAL HYPOTHESIS AN EXPERIMENT ON KRAKOW'S KRAMY BOGATE

Jean-Yves Blaise<sup>1</sup>, Pierre Drap<sup>1</sup>, Iwona Dudek<sup>2</sup>

<sup>1</sup> gamsau umr map cnrs 694

EAML 184, av. de Luminy 13288 Marseille Cedex Cedex 09 France

Email (Jean-Yves.Blaise, Pierre.Drap) @gamsau.archi.fr

<http://moma.gamsau.archi.fr>

<sup>2</sup> Instytut Historii Architektury i Konserwacji Zabytków

Wydział Architektury Politechniki Krakowskiej

ul. Kanonicza 1, 31-002 Kraków, Poland

Email idu@gamsau.archi.fr

## **Abstract:**

*Our research addresses the question of how to handle the architectural knowledge in order to provide non-computer science specialists with a tool dedicated to the making and to the representation of archaeological hypothesis. Our approach of the architectural object is based on theoretical analysis and on elements of bibliography connected to specific buildings. Relevant hierarchy of concepts (individual elements of architecture that we call entities as well as relations linking them to one another) are formalised following the object oriented methodology in order to provide each element of vocabulary isolated as non ambiguous with a corresponding theoretical definition.*

*The "Hublot" application we present allows interaction with the theoretical model (create and arrange one's own set of entities) through a web browser in which textual data and VRML 2.0 (Virtual Reality Modelling Language) scenes are linked.*

*This research is connected with the ARKIW POLONIUM co-operation program that links the MAP-GAMSAU CNRS laboratory and the HAIKZ Institute of Kraków's Faculty of Architecture. The field of experimentation proposed is Kraków's Kramy Bogate (Cloth Hall) located on the city's main market square. Formalisation of the theoretical models and web interfaces are JAVA developments.*

**Keywords:** Knowledge extraction, web, archaeological hypothesis, Java, VRML.

## **1 Foreword**

Concern for the architectural and urban preservation problems has been considerably increasing in the past decades, and with it the necessity to investigate the consequences and opportunities opened for the conservation discipline by the development of computer-based systems. This clearly locates multidisciplinary as a central aspect of our research, and the enabling of distant web access to all the computer developments as a necessity. As an answer, we have formalised an object-oriented architectural model implemented to serve as a junction between the concepts and methods of the computer

scientist, and the knowledge and practice of the conservationist. This model is provided with formalisms enabling:

- A measurement of objects.
- An updating of the theoretical model contents.
- The representation of archaeological hypothesis (HUBLOT application)

In this paper we will focus on the HUBLOT application that has been experimented on Kraków's Kramy Bogate (Cloth Hall) located on the city's main market square.

## 2 Background and Context

The GAMSOU-MAP CNRS laboratory (Marseilles, France), specialised in the use of computer techniques, and the HAiKZ institute of Kraków's faculty of architecture, specialised in conservation, have initiated a research and exchanges program, named ARKIW, aiming at investigating the architectural evolutions of Kraków's main market square during its eight centuries of history.

### 2.1 Methodological background

In object-oriented programming, the field of knowledge is split into elementary concepts structured through refinements of classes. Since the architectural heritage clearly reveals elements of permanence and of variability, the knowledge to be represented and handled features both stable concepts (the roofing, the opening, etc.) and their historical variations. A thorough investigation of each of this evolution's steps by specialists of architecture and conservation is needed in order to identify and organise sets of non-ambiguous *objects* that we call architectural entities. It is therefore vital to provide an access to the architectural model itself both on the computer scientist side and on the conservationist side.

In addition to the architectural entity hierarchy approach of the building, we have developed a "grouping" mechanism that is used when applying the underlying model to fields of experiments. A LALR grammar based on the JAVA grammar allows a textual description of the field of experiment in which the building is seen as a set of entities and of relations linking them to one another. A compiler uses this textual description to represent the building as a collection of instances of the theoretical model's classes.

The "hublot" interface to this compiler gives a possibility to choose, modify or create a script in which the building is described. Following the compilation phase, the interface gives a direct access to the instances generated through the process and by a messaging mechanism allows the user to visualise the VRML representation or to get information on the model's instances data.

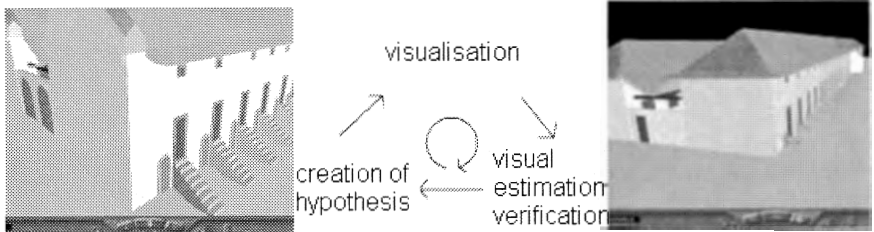
## 3 Objective of the experiment

### 3.1 Formalising the needs

Architects, historians of art, archaeologists and other professions that deal with the architectural heritage frequently face objects partly or totally destroyed. Most commonly destruction is the effect of time passing, but also of fires, floods, wars as well as

ignorance or irresponsibility. A detailed documentation that would provide information about form and structure of a despaired object is often lacking.

Therefore any reconstruction either purely theoretical or aiming for rebuilding or adaptation of the remains has to be based on comparisons and analogies. This however gives a place for the subjective point of view of the hypothesis' authors, and consequently in a majority of cases increases the amount of the possible propositions. When come the time for the authors of hypothesis to favour one solution, a visual comparative estimation plays an essential role.

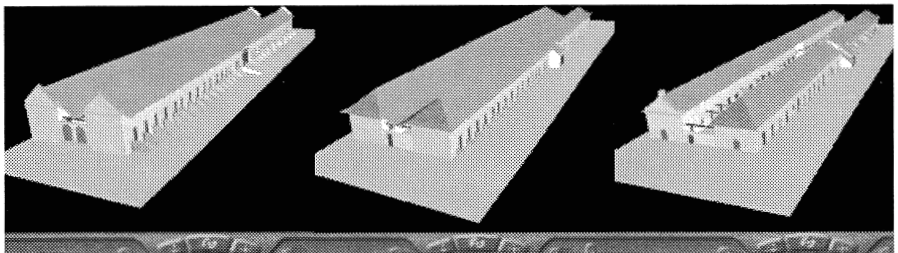


Creation of an hypothesis, as an act, is the result of an author's expertise. The next necessary step is a visualisation of the proposal in a perceptible form, its correctness and probability can then be verified by a visual estimation. This verification process is repeated until the satisfactory proposition is formulated.

Visualisation is a most tiresome and time-taking element in this process, it is therefore important to provide researchers with a knowledge-based tool that could help in authenticating, through the step of visualisation, the entire process of hypothesis building. Since the "hublot" interface represents a given hypothesis as the ordering of instances of the theoretical architectural model, it not only features a possible spatial solution for a given reconstruction problem but testifies of and gives access to the underlying architectural analysis.

### 3.2 Field of experiment

Kramy Bogate in Kraków is one of the structures that furnished the city's main Market Square. This Market Square, founded in 1257, is one of the biggest in Europe and it is listed as a monument of the UNESCO Cultural and Natural Heritage.



During more than five centuries Kramy Bogate filled the considerably big space of the citie's trade centre – dedicated to a cloth trade, they survived wars and fires to be demolished in sixties of the

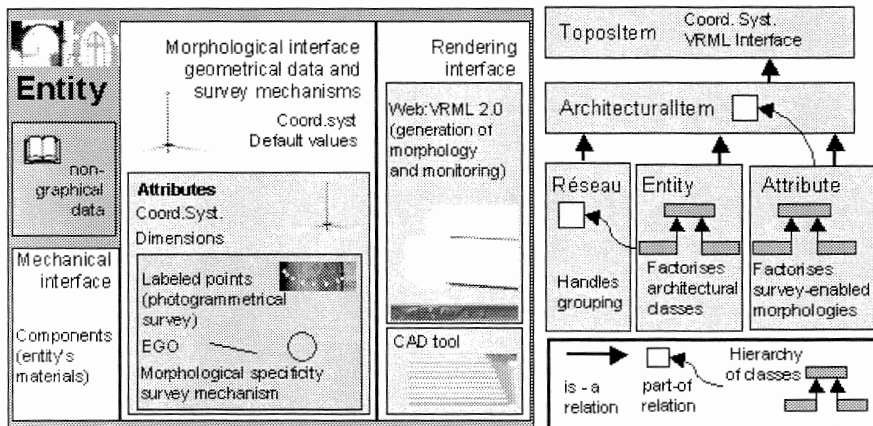
XIX century. Their cellars still exist under the actual level of the market square, but the location in the very centre of the city makes excavations difficult. Diverse historical documents (old maps, paintings, drawings, inventory descriptions, photographs, etc.) are preserved. From these data we can learn quite precisely the main shape of the object, its situation and general size - two parallel rows of brick shops with a covered gallery in between them. More detailed reconstruction requires the use of a general knowledge on particular elements of architecture. Therefore, Providing a tool for knowledge-oriented virtual reconstruction should bring to the fore a new opportunity for the construction and the interpretation of archaeological hypothesis.

#### 4 The hublot application

##### 4.1 The Architectural model: Definitions

Architectural concepts are described as entities, réseaux (arrays), attributes and relations and are gathered in the ItemTopos hierarchy. Elements of a building will be described as *entities* [Drap, 1997] providing that they meet two requirements:

- An entity is a unique " object " identified by a single element of the vocabulary.
- An entity has an obvious role in the physical structure of the building.



Architectural *entities*, structured by the inheritance of class mechanism are analysed from the point of view of intention. This means isolating object categories for which similarities of structure or behaviour can be observed. Once the properties of the architectural entity are described (both nature and behaviour) the relations between entities are formalised in order to organise the building. *Réseaux* are groups of entities and relations chosen in order to represent one specific combination. *Attributes* are items of vocabulary that correspond to a morphological specificity of one or several entities.

##### 4.2 The definition of a scene: La Demarche script language

A script based on our "La Demarche" script language defines how a given set of entities is organised in an array (*réseau*), and visualised in a scene. A first version of La Demarche, developed in 1997 with C++, had a strong drawback: its static aspect. As a

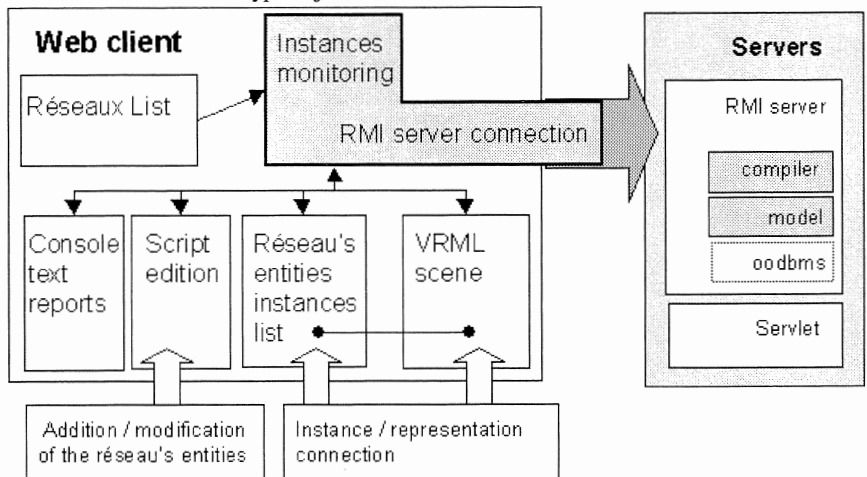


LALR type grammar, it used a LEX analyser and was therefore given a finite vocabulary after compilation. By choosing to develop in JAVA we could transform this language into a dynamic one that allows the integration of new concepts without compilation. With the introduction in the Java language of the metaclass mechanism it is possible to link the name of a class with its computer representation. It is therefore possible to gain access to each of the object's methods without writing tokens in a predefined dictionary.

We have also introduced in "La Demarche" the notion of mutable object, not implemented in Java but formalised in UML (Unified Modelling Language). Any instance of an object owns properties (attributes and behaviour) given by its class type. These properties, even though their actual content may vary during the instance's life, cannot disappear, and neither can new properties, not defined inside the class, appear. The addition of new attributes inside an instance implies a change of class type. This is not implemented neither in C++ nor in JAVA. Moreover, a mutation between sister classes cannot be done without facing the risk of an information loss (properties loss). We have therefore preferred implementing mutation in a restricted meaning : refinement of classes. The refinement operation allows the instance of a given class A to mute into an instance of a class derived from class A. We are therefore sure that after this operation all the attributes of the mutating instance will be informed. New attributes described in the derived class are given default values. This approach can prove useful when dealing with a group of architectural objects to be handled inside a common control structure. For example we group the ten beams (Solives) of a ceiling of which two are side beams (Muriere):

Solve ensSolve[10]; a 10 Solives array	ensSolve[0].refinement(Muriere); instance 0 is refined into a Muriere	ensSolve[9].refinement(Muriere); instance 9 is refined into a Muriere
-------------------------------------------	--------------------------------------------------------------------------	--------------------------------------------------------------------------

This La Demarche script defines a polymorph array of 10 Solive type objects of which two are Muriere type objects.



### 4.3 A web interface: the Hublot

A web interface dedicated to the edition and analysis of scenes based on our architectural model has been a strong requirement inside our research. The hublot

interface gives access to the LaDemarche compiler and to the architectural objects instanced through it. This interface allows diverse interaction with the model:

- addition or subtraction of entities in arrays (specific combination of entities and relations)
- modification of each entity's features like position, dimension, orientation, etc...
- on line computing and visualisation of the results in VRML (Virtual Reality Modelling Language) and of the textual reports in HTML (listing the characteristics of each entity in the scene), and connection between them.
- iterative action on each of these levels

## 5 Conclusion

The analysis of the architectural and urban evolutions of Kraków's Main Square is today a crossing point for historians, architects, archaeologists, etc.. Computer scientists are therefore confronted to a phenomenon in which both the concepts (the objects) and their representations for diverse disciplines evolve at high speed. Education and research in the scope of architecture and its history are in return questioned on how the development of information technologies can enrich their discipline. Consequently, the implementation of a theoretical architectural model positioned as a junction between diverse disciplines appears as a necessity. The hublot application uses the "representation" interface of such a model in order to allow on-line building up of archaeological hypothesis. Its experimentation on Kraków's Kramy Bogate (Cloth Hall) has shown the possible benefits of developing such a tool. More can still be done in order to ease the tool's use and to implement a JAVA-VRLML-OODBMS connection that will bring new perspectives and raise new questions for both the computer scientists and the architects collaborating in the research.

*The ARKIW co-operation is supported by a Franco-polish POLONIUM program.*

## References

- [Drap, 1997] P.Drap, M. Florenzano, J.Y Blaise (1997). PAROS, Photogrammétrie et modèles objet appliqués à l'étude de l'architecture construite, *L'Objet, logiciel, base de données, réseaux*, Édition Hermès, Paris. Volume 3 - n 1/1997, pp 27 à 52.
- [Kad, 1986] A.Kadhuczka (1986) Ochrona zabytków Krakowa, PAN Kraków , nr 400.
- [Luk, 1969] M. Łukacz (1994) The preservation priorities and the present problems of the historic preservation in Cracow. International Symposium Protection and Management of UNESCO Cultural World Heritage in East-Central Europe, September 14-18 1994, Warsaw-Zamość-Cracow, Poland.
- [Kad, 1995] A. Kadhuczka (1995), Relikty monumentalnej zabudowy Rynku Krakowskiego - ocena stanu zachowania i możliwości ekspozycji Ochrona zabytków, nr 1 (188), R. XLVIII, Warszawa 1995, ss. 13-19, and „International Symposium of Relicts of Medieval Monumental Architecture”, Warszawa-Lednica 1994, ss 17-25

# COOPERATION ENGINEERING FOR THE EXTENDED ENTERPRISE

Imed Boughzala, Manuel Zacklad

Laboratoire Tech-CICO (Technologie de la Coopération pour l'Innovation et le  
Changement Organisationnel)  
Université de Technologie de Troyes  
12, rue Marie Curie BP 2060  
10010 Troyes Cédex France  
imed.boughzala@univ-troyes.fr  
manuel.zacklad@univ-troyes.fr

## Abstract:

*Cooperation Engineering is Knowledge Engineering in the context of distributed activities not yet entirely formalised. It intervenes as an essential step for the operation of a Knowledge Management process adapted to the development of extended enterprises and to the building of Information System elements which facilitate communication and coordination (mailing, discussion forum, workflow, GED, semi-structured databases, EDI...).*

**Keywords:** Extended enterprise, Collective Knowledge Management, Cooperative Work, coordination, GroupWare, Information Technology

## 1 Introduction

In this article, we present the first elements of a methodological framework for the design of inter-enterprise coordination systems in the field of what we call an extended enterprise (cf. §2). These results lie within the research project ITCOM, knowledge engineering for mediated cooperative work leads at Tech-CICO laboratory, whose role is to give some methodological guides for the design of cooperative work mediation systems. **Cooperation Engineering is Knowledge Engineering in the context of distributed activities not yet entirely formalised.** It intervenes as an essential step for the operation of a Knowledge Management process adapted to the development of extended enterprises and to the building of Information System elements which facilitate communication and coordination (mailing, discussion forum, workflow, GED, semi-structured databases, EDI...).

In this article we begin by presenting the current problematic of extended enterprise and the reasons for which Knowledge Management problematic is particularly critical. Then we define the notion of cooperative activity and of Cooperation Engineering, allowing us to introduce some hypotheses on the new forms of Information Systems adapted to cooperative work. These hypotheses guide us in our software specification activity for the inter-enterprise cooperation. Finally, we present the area in which we will experiment these solutions in the textile industry.

## 2 Extended enterprise

To respond to an economic and competitive environment which is becoming more and more complex, as well as to the internationalisation of markets, firms opt more frequently for the increase of alliances and partnerships developing new working forms “on network”. The emergence of the concept of extended enterprise or networked enterprise is the result of the desire of some firms to form alliance with others carefully selected and to set up durable and worthy exchange relationships, to escape from their own cumbersomeness. The network of firms keeps going from competencies which everyone brings to contribute to a common project. The participation of each one doesn't touch their legal independence (Paché 1993).

In this context the concept seems as if some firms showed capitalistic and legal independence which may be specialised in one task in the same values chain (Jarillo, 1988 ; Powell, 1990). When they multiply alliances, these firms give a greater place to the contractual growth than to the movable growth. So, they try to have more flexibility and reactivity with a light structure, and to preserve in fact their independence and chances to evolve constantly on the market.

The main idea of the networked enterprise or the network of enterprises is to limit internal activity of each enterprise to strategic competencies and to take out what is left. So, it confides it to suppliers, subcontractors or external partners. We define a networked enterprise as an enterprise which bets on certain key competencies in some activities for which it has knowledge, and which confides to others the execution of less strategic tasks (according to its competencies) for the achievement of the product expected by clients.

The criteria of the smooth functioning of the extended enterprise according to Aubrey (Aubrey, 1991) are:

- Autonomy of partners;
- Added value;
- Adapting to change;
- Mutual aid;
- Reciprocity;
- Shared values;
- Common vision.

In addition to that, the economic environment today requires new relationships between competitors. Relationships have changed and it is not unusual to see behaviours which are much closer to cooperation<sup>1</sup> and collaboration than competition. Who could believed that for the last few years IBM and Apple decide to cooperate on launching a compatible computer on the market working in the two environments, a behaviour that represent a new kind of cooperation between competitors.

---

<sup>1</sup> Here the term of “cooperation” is used in the sense of the game theory. We redefine it later in a more cognitive way.

According to many authors, the effectiveness of the network structure is highly dependent on the good use of the IT like EDI, WorkFlow and Internet which make easier the coordination of interdependencies between the different units of the network. However, network strategies rely, on the one hand, on all techniques linked to merchandise flow processing, and on the other hand, on Information Systems which allow an efficient coordination of operations between partners all along the added value line of a product or a service. Such techniques and such Information Systems which are built on the IT, represent according to Lorino (Lorino, 1989) "a strategic factor for the development and the success of enterprises". These tools favour the circulation mastery of material flows and techniques by information flows. They make professional links more efficient by allowing collective learning and knowledge transfer (Aliouat, 1996; Spitezki, 1995).

It is the importance of good Collective Knowledge Management that we will examine now for networked enterprise functioning, and for the specification of Information Systems of inter-enterprise cooperation.

### **3 Knowledge Management is a major stake for the extended enterprise**

As many authors have explained with conviction (Steels, 1993; Ermine, 1996; Grundstein, 1996), the pressure of technique and organisational innovations, the new management modes (project management), self-willed or constrained mobility of staff (transfers, redundancies, retirements) explains that Knowledge Management has become as such a major preoccupation in numerous organisations. We will take it up here from *Knowledge Systems Management's* point of view; which means that we focus on the artefact construction problematic facilitating the recall, transmission and access to the knowledge, but also like a preliminary step for the construction of Information Systems for cooperation (cf. infra). J.L. Ermine quotes in this way the quality handbook of CEA which defines Knowledge Management, in the sense evoked before, allowing:

- "to gather the knowledge and the know-how on easier accessible mediums,
- to facilitate their transmission in real time inside CEA and in delay time to our successors,
- to keep the trace of certain activities or actions on which the CEA should be asked in the future" (Quality handbook of CEA, 1996, p. 14, quoted by Ermine 1996 p. 16)

The Knowledge Systems Management is a major stake within big firms, and even more so in the enterprises integrated in the network which, when they are centred on their know-how, are extremely dependent on their partners to adjust their production and their innovation processes. These enterprises must be always up to date with their partner's evolutions to be better adapted and can anticipate (in) the new needs and constraints for the future.

According to Grundstein (Grundstein, 1996) Knowledge Management problematic can be tackled from four facets:

- locating the crucial knowledge (identification, location, characterization);
- its preservation (modelisation, formalisation, conservation);

- its valuation (access, diffusion, operating, combination, creation);
- and its currentness (updating, enrichment).

In our research context, we focus on the preservation and the valuation problematics. The preservation returns to a question of the implementation of modelisation processes of knowledge partly tacit. The valuation returns to a question of the elaboration of the software medium which allows the access and the distribution of mediated knowledge in the extended enterprise, or the specification of its Information System. Therefore, the originality of this research is double:

- the knowledge modelisation concerns not only job problem-solving knowledge but also knowledge allowing cooperation between partners.
- the distribution and operating knowledge tools, as Information Systems whose modelisation allows their specification, are not intended for use within the firm (intra-organisational use) but to support the relationship between different firms integrated in the network for a period possibly limited. This characteristic rises two important questions:
  - How to make coherent the Knowledge Management systems elaborated between different partners and how to make “inter-operate” the Information Systems specified.
  - How to solve problems linked to the sharing and the degree of confidentiality of the knowledge of different partners and so how to conceive an Information System able to manage such constraints (certain knowledge results from cooperation and can be considered as common, others are more private but shared, and finally others are private and confidential).

Cooperation processes study requires some theoretical principles and definitions which we will examine now.

#### **4 Cooperation engineering**

For K. Schmidt cooperative work “emerges when multiple actors, engaged in the realisation of a common task, are mutually dependent to their work and must coordinate and gather their individual production to be able to do the task which is confided” (Schmidt, 1994a).

For this author, cooperative work denotes exclusively collective work on a common object which corresponds to a principal collective goal. The need to coordinate such cooperative work generates a different specific work that Schmidt calls Articulation Work and which “is constituted of the need to restrain the distributed nature of complexly interdependent activities” (Schmidt & Simone, 1996).

We will not adopt the same definition of cooperative work which is, according to us a little restrictive. In accordance with Intellectual Transactions Theory (Zacklad, 1999) we consider that cooperative activities correspond to collective activities in which “cognitive interdependence” between actors is effective, which means that it has not

been to standardised<sup>2</sup>. According to us articulation work is included into cooperative work because the existence of the articulation activities being a necessary condition to define cooperation.

Still within TTI, we consider that there are two modalities which allow to increase the efficiency of cooperative activities by reducing cognitive interdependence between actors. The first consists in privileging the standardisation of actor relationships and corresponds to coordination (hierarchical relationships, client-supplier, project management...). The second consists in privileging the standardisation of knowledge used by the group and corresponds to the adoption of a common collective problem solving method. These two modalities are always complementary and interdependent: the standardisation of relationships allowing new opportunities of knowledge standardisation and vice versa.

To describe the Collective Knowledge in a decisional or a cognitive orientation (the description of the group activity according to the view point of the problem that it is trying to solve) one can use the modelisation techniques of problem-solving methods well known in Knowledge Engineering. To describe the standardisation of relationships one can use the results of the CSCW researches (Schmidt & Simone, 1996) which have defined primitives for the coordination from which different generic models can be built corresponding to various organisational configurations.

From an Information System's point of view, according to the renewed definition which we propose (cf. §4), these two standardisation modalities refer to different kinds of applications. The standardisation of relationships, which is based on the mutual commitments of actors, corresponds to the introduction of process management tools and workflow. The knowledge standardisation, which rely on the adoption of common representations of the intervention field, corresponds more often to the introduction of data bases which integrate a decisional component (management of production, of stock, of logistic processes) or decision-aid tools.

In the two situations, one has to build new socio-technical systems which are a mixture of organisational rules and of artefacts, principally computers, which facilitate the application of the rules by the actors of the organisation, systems called "coordination mechanisms" by Schmidt and Simone:

*"A Coordination mechanism is a construct consisting of a coordinative protocol (an integrated set of procedures and conventions stipulating the articulation of interdependent distributed activities) on the one hand and on the other hand an artefact (a permanent construct) in which the protocol is objectified"* (Schmidt & Simone, 1996).

---

<sup>2</sup> We can then suggest a definition of "cooperation": there is a cooperation between actors when the cooperative activity occurs in a context of cognitive inter-enterprise, the actors being obliged to commit themselves into intellectual transactions to reduce this interdependence. The cooperation concept is applied in the context of organised cooperative activities (as opposed to masses behaviour phenomenon) in which actors are "structurally independent".

## 5 MCPA Télécom

MCPA-Telecom is not yet proven methodological framework to design business processes using telecommunication services (more widely all services which rely on IT), which has been defined in CNET by the second author in order to guide the design of intra- and inter-enterprises coordination mechanisms. It aims to supply a design method corresponding to the need of cooperative IS. Without going into the details of this method, we can present some of its characteristics.

In accordance to Alquier (Alquier & Tignol, 1998), MCPA-Telecom declines differently the notion of IS according to a dimension called spatial by this author who distinguishes IS individual, departmental or collective IS. For Alquier, at the collective level, the IS is called “cooperative”, and it includes all the functionalities which come under GroupWare. Relying on the MadIn’Coop Method, in accordance with MCPA-Telecom, we can refine this notion of Cooperative IS by introducing three new IS’s points of view, according to the roles which they will play in the cooperation processes:

- A communication IS which supplies media facilitating synchronous or asynchronous, face to face or distance dialogs between actors
- A coordination IS which supplies media facilitating coordination between actors by relying on the concepts of roles, activities, tasks, responsibilities, means,...
- A Collective problem solving IS which relies on a first formalisation and standardisation of collective activities allowing the storage of data and the automatization of some processes. This IS meets to a large extent the “traditional” IS. However, it is nowadays open to less standardised cooperative activities than was the traditional IS: cooperative redaction, distributed CAO, distance teaching...

Of course, the use of artefacts contributing to determine their status, the same computing artefact could participate into these three IS according to the way they are used in the organisation. Complex computing environments can also offer different tools at the same time supplying these different functionalities. Finally, certain tools may associate two functionalities as for example a complex workflow, combining the cooperative redaction support (collective problem solving IS) collective validation processes support (coordination IS).

We also introduce a point of view close to Alquier’s spatial dimension which identify three levels of cooperative IS:

- The individual level;
- The small group level which corresponds to a project or recurrent processes which imply a limited number of actors who have a mutual knowledge of each others;
- The organisation or extended group level which imply a number of actors exceeding the possibilities of a mutual deep knowledge of each others;
- The inter-enterprise level which joins groups of actors (small or extended groups) belonging to the different partners of the extended enterprise and which is the aim of our research.



To study these different levels of activity and to specify the IS responding to their needs, MCPA-Telecom identifies three levels of modelisation, for which we will use different techniques of modelisation in the context of our study:

- A macroscopic level where firm processes are modelised job by job in an intra- and inter-enterprises context: to modelise the processes at this level we use the Aris Toolset language V 3.2a;
- A microscopic level in which we focus on particular process and its actors and artefacts. For this sharper specification, we rather use models issued from software engineering (for example UML) or from Knowledge Engineering (for example MKSM);
- A service's specification level which is different to the previous ones because it is only concerned with the description of software and/or telecommunication services which support actors in their work processes.

## 6 Conclusion: the application area of textile industry

To answer the research questions that we have raised (coherence of knowledge systems, IS inter-operating, adjustment of levels of confidentiality and sharing of knowledge, testing the MCPA-Telecom processes...), we will use an application ground provided by the textile industry in a regional environment.

In this industrial field, the extended enterprise corresponds to the different networked specialised enterprises (mill owner, knitter, dyer, clothing maker...) whose aim is to manufacture together a range of products at a lower price by reducing time and investment. The IT can be a factor that helps reducing time in the information exchange, and consequently, the manufacturing time thus ensuring better quality. But cooperation IS will be effectively introduced only if there is a willingness of the actors to share and to formalise knowledge. Textile industry is a difficult experimentation ground but most suitable for the following reasons:

- It is an industry strongly challenged at the international level, namely because the cost of workforce is higher than in the developing countries. We generally consider that a more efficient functioning of the network, would be a sine qua none survival condition, as illustrated the American experience which shows the importance of the IT for the re-localization of certain textile production activities (Abécassis, 1998);
- It is an industry in which job knowledge as well as inter-enterprise cooperation styles are both complex and informal. So, efficient implementation of Cooperation IS necessitate collective Knowledge Management activities.

Currently, we are studying the processes of this industry following the steps inspired by the MCPA-Telecom method:

- Macroscopic and generic modelisation of processes of the textile industry (functioning modes and decision processes);
- Application of this generic modelisation to a central partner in the industry: in this case the dyer;

- Selecting some target processes to be studied in detail for the specification of IT allowing for their improvement;
- Specification of services which rely on Intranet/extranet/Internet and the EDI and which will support these processes, knowing that these services can originate three innovations:
  1. Do what could not be done before (creation of new products and services);
  2. Do better what was already done (improvement of the production line);
  3. Do differently what was already done before (radical changing of an existing process).

## 7 References

- [Abécassis, C., Caby, L. and al, 1998] Information Technology and coordination modes: the case of the apparel industry in France and US, International Telecom Society, Stockholm.
- [Aliouat, B., 1993] Les stratégies de coopération Industrielle, *Economica*, Paris.
- [Alquier, A. M., Tignol, M.H., 1998]. Management des connaissances et management par projet, université de Toulouse 1, Toulouse.
- [Aubrey, B., 1991]. Les conditions de possibilités du réseau, *Les paradoxes du management*, Orgogozo, I. , Les Editions d'Organisation, Paris, p. 150-155.
- [Ermine, J.L., Chaillot, M., Bigeon, Ph., Charreton, B., Malacieille, D., 1996]. MKSM: Méthode pour la gestion des connaissances, *Ingénierie des systèmes d'information*, AFCET-Hermès, 1996, Vol.4, pp. 541-575.
- [Grundstein, M., 1996]. La capitalisation des connaissances de l'entreprise, une problématique de management, *actes des 5 eme Rencontres du programme MCX, Complexité: la stratégie de la reliance*, Aix-en-Provence, 4-5 juillet 1996.
- [Jarillo, C., 1988] On Strategic Networks, *Strategic management Journal*, Vol 9, n 1, p. 31-41.
- [Lorino, Ph., 1989] L'Economiste et le manager, Editions La Découverte, Paris.
- [Paché, G., 1993] L'entreprise en réseau, Presses Universitaires de France, Paris.
- [Powell, W.W., 1990] Neither market nor hierarchy: Network Forms of organisation, research in Organizational Behavior, Vol. 12, JAI Press, P. 295-336.
- [Schmidt, K., 1994] The Organization of Cooperative Work, Beyond the « Leviathan » Conception of the Organization of Cooperative Work, ACM Press, 1994.
- [Schmidt, K., 1994] Modes and Mechanisms of Interaction in Cooperative Work, Riso National Laboratory, P.O. Box 49, DK-4000 Roskilde, denmark, [RISO-R-666(EN)], 1994.
- [Simone, C., Schmidt, K., 1994] A Notation for Computational Mechanisms of Interaction, COMIC, Lancaster, UK, Computing Departement, Lancaster University, 1994.

- [Steels, L., 1993] Corporate knowledge management. Proceedings of the International Symposium on the management of Industrial and Corporate Knowledge, pp. 9-30, Compiègne, France, 27-28 Octobre 1993.
- [Spitezki, H., 1995] La stratégie d'entreprise: compétitivité et mobilité, Economica, Paris.
- [Zacklad, M., Rousseaux, F., 1996] Modelling Co-operation in the Design of Knowledge Production Systems: the MadeIn'Coop Method. Computer Supported Cooperative Work: the journal of Collaborative Computing, Vol.5, p. 133-154.
- [Zacklad, M., 1997] Méthode de Conception de Processus d'Affaire utilisant les services de Télécommunications, CNET France Télécom.
- Zacklad, M., (1999). La théorie des transactions intellectuelles, to appear in Intellectica, Paris.



## CONTEXT-BASED DECISION MAKING IN INCIDENT MANAGEMENT ON A SUBWAY LINE

Patrick Brézillon, Laurent Pasquier & Ilham Saker

Laboratoire d'Informatique de Paris 6, Case 169, Université Paris 6  
4, place Jussieu, 75252 Paris Cedex 05, France  
Tel: 33 1 44 27 70 08 - Fax: 33 1 44 27 70 00  
E-mail: Forename.Name@lip6.fr

### **Abstract:**

*The incident management on a subway line is a difficult task because context plays an important role in it. The SART project, which aims at the design of an intelligent support system for subway line traffic regulators, has to integrate this notion. We introduce a distinction between pieces of contextual knowledge according to the fact they intervene to limit the field of possible choices or not; If it limits the choice, it is called proceduralised context. These notions are represented in our application by decision graphs. We also take into account the operators' needs and waiting. For this purpose, they fulfilled forms and answered oral questions. We present in this paper the appraisal of their answers.*

**Keywords:** Context, Decision making,

### **1 Introduction**

The incident management on a subway line is a difficult task for several reasons. When an incident occurs, the operator has to: (i) retrieve rapidly a normal service on a complex and dynamic system; (ii) solve the incident and manage the train traffic on the part of the line that is not concerned by the incident; and (iii) tackle a wide number of parameters of various types in his decision making.

The SART project (French acronym for support system in traffic control) aims at the design and development of an intelligent system to support the operators who are responsible for a subway line, when an incident occurs [Brézillon *et al.*, 1997, 1998]. SART has a multi-agent architecture and is composed now of three agents: a line configurator, a traffic simulator and an incident manager. This paper focuses on results obtained for the incident manager for which we have to make context explicit.

The notion of context plays an important role in the incident management. We point out in [Brézillon and Pomerol, 1999] three types of context, namely the external context, the contextual knowledge and the proceduralized context. These types of context permit to model the variability of parameters type and the amount of information needed at each step of the incident resolution (see Section 2). Section 3 is dedicated to operators' needs for such a system, and Section 4 presents how we model the context-based reasoning of operators.

## 2 Context

We consider as context all information that may limit the possible decision field without directly intervening in the incident resolution. For example, the time of occurrence of the incident is not relevant considering the incident itself, but the resolution strategies observed are different whether it occurs at rush hour or not.

### 2.1 Contextual knowledge and proceduralised context

[Brézillon and Pomerol, 1999] define **contextual** knowledge as all the knowledge which is relevant for one person in a given situated decision problem and can be mobilised to understand this problem. Contextual knowledge is evoked by situations and events, and loosely tied to a task or a goal. Although the contextual knowledge exists in theory, it is actually implicit and latent, and is not usable unless a goal (or an intention) emerges. Contextual knowledge is considered as a part of the "context", the rest of the context, which is not relevant to the situation, is called external knowledge. During the proceduralisation process, contextual knowledge is evoked from known knowledge or acquired by the operators by any means.

When an event occurs, the attention of the actors is focused on it, and a large part of the contextual knowledge will be proceduralised. The proceduralised part of the contextual knowledge, at a given step of a decision making, is called the proceduralised context [Brézillon and Pomerol, 1999]. The proceduralised context is invoked, structured and situated according to a given focus. This is a more or less "compiled" knowledge which can be elicited by the usual techniques of knowledge acquisition. The representation of the proceduralised context is either evoked from the underlying contextual knowledge or built during the proceduralisation process.

At a given step of the decision making process, one has: proceduralised context which is the knowledge commonly known by the actors of the problem and directly (but often tacitly) used for the problem solving and which is one of the source of the proceduralised context; contextual knowledge which is the knowledge not explicitly used but influencing the problem solving; and external knowledge which is the knowledge having nothing to do with the current decision making step, but known by many actors of the problem. One can remark that the proceduralised state of contextual knowledge is dependent of the step of decision making process. Thus this state is dynamic and a contextual knowledge may be proceduralised at the next decision making step and retrieve the initial state after this.

### 2.2 Decision making in heavy contextual processes

At RATP, most of the incidents are well-known (object on the track, lack of power supply, suicide, etc.). Thus, the company has established mandatory procedures for incident solving on the basis of its experience. For example, [Brézillon *et al.*, 1997] discuss the procedure and the knowledge involved in the incident "Sick traveller in a train". In this case, the driver must continue up to the next station because travellers are safer in a station than in a tunnel. At a deeper level, the driver has to avoid stopping the train a long time in a tunnel because some travellers may have behavioural troubles such as claustrophobia and could leave the train to wander about on the track (and thus may generate another type of incident such as "Person on the track"). These pieces of knowledge, which are not necessarily expressed, result in more or less proceduralised actions that are compiled as parts of the proceduralised context. Very often many pieces

of proceduralised context are structured together in comprehensive knowledge about actions. As such, mandatory procedures are proceduralised contexts.

For simple incidents, a unique procedure is sufficient for the whole incident solving. For example, the incident "object fallen on the track", implies the procedure: power cut-off, an employee of the RATP goes down on the trackbed to remove the object, and once gone back on the platform, the power is re-established. However, there is no global procedure for complex incidents, only a set of procedures, each procedure solving a part of the incident. For example, when a train cannot move in a tunnel, there are procedures to evacuate travellers at the nearest station, for moving the damaged train by another train, etc. Some procedures are sequential, but others may be accomplished in any order. For example, when a train must push a damaged train, both trains must be empty but the order in which travellers of the two trains are evacuated is not important and mainly depends on the context in which trains are. What is important is that the two actions must be accomplished before the damaged train clearing. As a consequence, each operator develops his own practice to solve incidents, and one observes almost as many practices as operators for a given incident solving because each operator structures the set of procedures in order to take into account the current context, which is particular and specific. For example, is the next station a connecting one or not? Thus, cases that are similar in one context may be totally dissimilar in others as already quoted by [Tversky, 1977].

Another problem concerns non-written rules with which it is difficult to cope. In many working processes human beings develop genuine procedures to reach the efficiency that decision makers intended when they designed the system. Some parts of this practice are not coded [Hatchuel and Weil, 1992]. Such know-how is generally built up case by case and is complemented by "makeshift repairs" (or non-written rules) that allow the operational agents to reach the required efficiency. This is a way of getting the result whatever the path followed. The validation of this unwritten rules is linked more to the result than to the procedure to reach it. [De Terssac, 1992] spoke of logic of efficiency.

In our application, even if the decision making in the incident solving belongs to the operator who is concerned, there is a collective solving of the incident because other operators in the control room follow the incident solving and intervene, say, by recalling to their colleague something not to forget, by suggesting to ask information on a specific point. This part of the incident solving is not recorded and then cannot be considered in our modelling of incident solving.

### **3 Operators and context-based reasoning**

For the understanding of the ways in which complex incidents are solved, we have made three questionnaires. The goal was to define exactly how the system would be the most useful for operators in their decision making. The main conclusions are:

- Experience acquired by operators in past positions is an important element of the context of operators' decision making. As a consequence, SART will have to show concrete stuffs and go directly to what is essential for the operator.

- Each operator is highly knowledgeable with a given subway line and familiar with some others. As a consequence, SART must retrieve first incidents on the concerned line, after on similar lines and finally on all other lines.
- With an access to the traffic computer, SART should be able to detect by simulation the beginning of an anomaly of the traffic evolution and alert the operator. SART should also gather a large number of contextual data that define the context in which the incident is solved.
- Operators cannot be disturbed during their decision-making reasoning by a system asking for data. However, operators say to be interested by an off-line use of SART for helping them in:
  - repetitive tasks (e.g., the writing of the report on the incident) which SART can fill automatically a part of the report, pointing out missing information,
  - analyzing the incident that has just occurred,
  - facilitating intelligently the interaction between two operators discussing an incident (e.g. for a training purpose),
  - providing the history of events occurred before an operator begins to work,
  - giving a presentation of exceptional events that would help operators in his decision making or to enrich his experience,
  - providing an ordered list of incidents according to some criteria.

For being an efficient assistant, SART must deal with an explicit model of what context is for operators. Indeed, we have considered a context-based representation of the domain knowledge and a context-based representation of operators' reasoning during an incident solving. The former representation is discussed in [Brézillon et al., 1997], and we focus in the next section on the latter representation.

#### 4 Context modelling by decision graphs

Decision graphs are reasoning models derived from decision trees [Pasquier *et al.*, 1999]. They behave as their parents, but integrate the difference between contextual knowledge and proceduralised context and the dynamic switch of those knowledge states. In decision trees, branches diverge according to the possible choices and never converge even if the choice is no more relevant. This led to trees with identical action sequences on several branches. In such a case we decided to merge the common part of the branches. The structure is no more a tree but a directed graph, called **decision graph**.

The evolution from decision trees to decision graphs is based on the fact that a contextual piece of knowledge is proceduralised at the step where it intervenes in the choice. This choice generate several branches (representing the different possible action sequences). When the branches are merged, the proceduralised piece of context retrieve its contextual piece of knowledge state. We integrated also in this model some temporal notions such as precedence and independence, which are observed in our application field. As said in subsection 2.2, when a train must push an other train, both trains have to be empty. The evacuation of both trains is hardly represented by decision trees, but is easy modelled by a decision graph. In Figure 1, we present the decision tree modelling



the resolution of a train engine incident. The 15 last branches are the possible sequences of action for pushing a damaged train by another train. In the corresponding decision graph, they are replaced by the temporal branching showed in the slashed square. The explanations about the construction of both structures are in this book [Brézillon *et al.*, 1999].

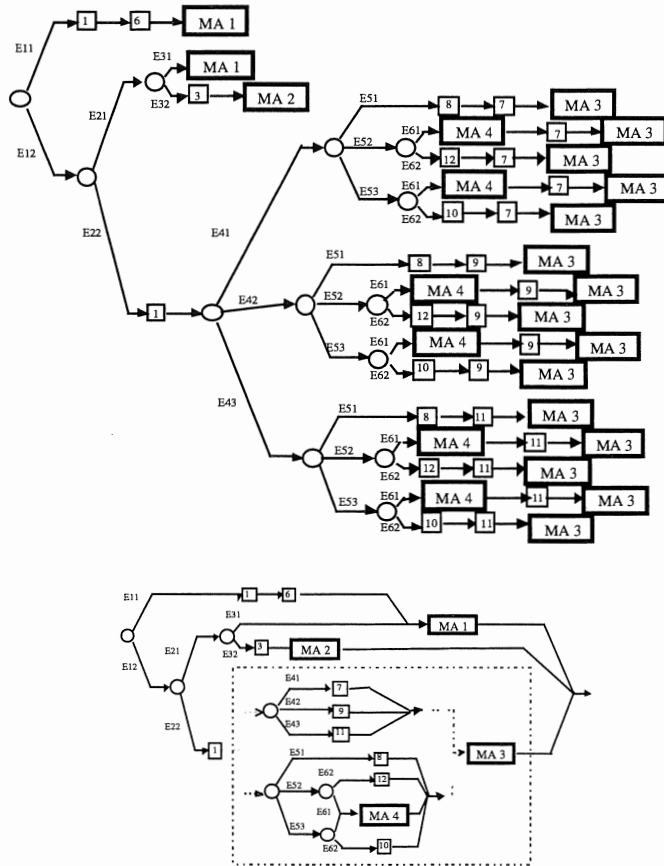


Figure 1: A decision tree and the corresponding decision graph

### Acknowledgements

The SART project enters a convention between two universities, the University Paris 6 (France) and the Federal University of Rio de Janeiro (FURJ, Brazil), a contract between the University Paris 6 and the French company of public transport in Paris (RATP), and another contract between the FURJ and Metrô-Rio that manages the subway in Rio de Janeiro. Grants are provided by RATP and COFECUB in France and CAPES in Brazil. We also thank J.-M. Sieur at RATP, and C. Gentile, I. Saker and M. Secron, Ph.D. students working on the SART project.

### References

- [Brézillon and Pomerol, 1999] Brézillon, P. and Pomerol, J.-Ch. (1999). Contextual knowledge sharing and cooperation in intelligent assistant systems. *Le Travail Humain*, 62(3), PUF, Paris, pages 223-246.
- [Brézillon *et al.*, 1997] Brézillon, P., Gentile, C., Saker, I., and Secron, M. (1997). SART: A system for supporting operators with contextual knowledge. In Federal University of Rio de Janeiro (Ed.), *Proceedings of the First International and Interdisciplinary Conference on Modeling and Using Context (CONTEXT-97)*, pages 209-222, Rio de Janeiro, Brazil.
- [Brézillon *et al.*, 1998] Brézillon, P., Pomerol, J.-Ch. and Saker, I. (1998). Contextual and contextualized knowledge: An application in subway control. *Special issue on Using Context in Application, International Journal on Human-Computer Studies*, 48(3) , pages 357-373.
- [Brézillon *et al.*, 1999] Brézillon, P., Pasquier, L. and Pomerol, J.-Ch. (1999). Modelling decision making with context-based reasoning and decision graphs. Application in incident management on a subway line. *Proceeding of the conference on Humen Centered Processes*, Brest, France (to appear).
- [Hatchuel and Weil, 1992] Hatchuel, A. and Weil, B. (1992), *L'expert et le système*. Paris: Economica.
- [Pasquier *et al.*, 1999] Pasquier, L., Brézillon, P. and Pomerol, J.-Ch. (1999). Context and decision graphs for incident management on a subway line. *Proceeding of the Second International and Interdisciplinary Conference on Modeling and Using Context (CONTEXT-99)*, Trento, Italy (to appear).
- [De Tersac, 1992] de Terssac, G. (1992). *Autonomie dans le travail*. Série Sociologie d'Aujourd'hui, Paris: Presses Universitaires de France.
- [Tversky, 1977] Tversky, A. ( 1977) . Features of similarity. *Psychological Review*, 84(4): pages 327-352.

# FORMAL DESCRIPTION OF HUMAN MACHINE (H-M) INTERACTIONS DERIVED FROM THE APPLICATION TASK GRAPH

Guy Camilleri

IRIT

Université Paul Sabatier, 118 route de Narbonne 31062 Toulouse Cedex France  
Camiller@irit.fr

## Abstract:

*To design interactive systems, a clear description of the interactions is required. A deep understanding of H-M interactions is necessary in order to formulate a useful description. The task graph (TG) structure and therefore the different tasks, which could be achieved by the system, appears essential for interaction specifications.*

*In this contribution, we propose a generic formalism, which can represent H-M interactions from any TG by determining constraints that it entails on the interaction. A formal and generic definition of the task, recipe and task graph concepts is required to represent generated interactions by any application. The interaction description depends on projected functionalities by an application and the way they are achieved. It is supplied by TG features. The tasks distribution (agents which perform them) and their realisation control (order of tasks performance) are two TG criteria which we determine as influencing interaction. Different methods can be applied for each TG type (which are defined with the two previous criteria) to specify the interaction. The utilisation of tasks which modify the TG, allows interactions to be described with the same formalism (task, recipe, TG and methods) out of any TG type of applicative domain (containing prescribed tasks).*

**Keywords:** Human machine interaction, task, transaction, Interaction formalisation.

## 1 Introduction

To design interactive systems, a clear description of the interactions is required. A deep understanding of H-M interactions is necessary in order to formulate a useful description. The task graph (TG) structure and therefore the different tasks, which could be achieved by the system, appears essential for interaction specifications [Sucrow, 1997]. TG represents the hierarchical decomposition of task performance. An example of the TG for the performance of a phone task is “pick up the phone”, then “dial the number” which is composed of “research the number” then “dial it”, then “speak”, and “hang up”.

In this contribution, we propose a formalism, which can represent H-M interactions from any TG. The TG is always built during the system design phase. Generally, this graph is implicit, but it is partially and often dynamically visible through the system Human Machine Interface (HMI). Throughout interactions, users build a mental TG, which represents the task hierarchy achievable with system. Therefore, one main

purpose of the HMI is to allow the user, during the interactions, to build a faithful representation of parts of TG.

A formal description of interactions derived from the TG depends on the graph nature and the formalism used to represent it. In the literature, the same formalism is often used for the TG and the interaction specification. A strong relationship exists between the TG and the interactions, the latter of which are derived from the TG for a given application. This is because the interactions depend on some application functionalities (prescribed tasks) and the way they are achieved (some parts of TG).

First, we define the concepts used to formalise the TG. Then we expose the features and the different TG types, which influence the interaction definition. Finally, we provide a simple formalism to describe interactions.

## 2 Task Graph definition

The TG definition following the applications often varies [Isténes, 1996]. Therefore, we propose an abstract TG definition which can be used in any application domain. We also choose a simple formalism to represent the concepts, which are easily expandable and customisable to match with the particular application needs.

### 2.1 Task

The task notion is used in several domains, often as primitive (axiom), therefore it is difficult to find a common definition. For experts systems, a task denotes an instance of a problem, a problem class, and both a problem class and an abstract description of a method of solving the problem [Chandrasekan and Johnson, 1992]. In knowledge acquisition, following the application domain and the acquisition method used, the task definition varies. For example, In KADS method [Schreiber et al 1993], a task is a composite action of problem solving entailing subtask decomposition, moreover a task can perform a particular goal. However, For MACAO method [Soubie, 1996], a task is an autonomous entity of treatment which allows to reach a goal from an input set of elements. In Fiona application a task is a concrete action, while in DSTM framework a task represents an objective to reach (a goal) [Isténes, 1996]. The task concept is also present in ergonomics. They mainly consider two task kinds, the prescribed and effective ones [De Montmollin, 1995]. The effective tasks are effectively achieved by an operator, by his activity. The main difference between prescribe tasks and effective tasks is: the prescribed tasks are defined by the designer, while the effective tasks are really performed by an operator.

In all these definitions, the action concept appears as a common notion (work to do, action to achieve, action of problem solving, and so on). Therefore, we propose below a task definition based on the action concept.

**Definition:** A task is an action in particular context, which is performed to reach a goal to satisfy a given intention.

Note: In the task definition, the intention term designates a forward-directed intention. Forward-directed intentions defined by Bratman in [Bratman, 1990] represent the agent desire to perform tasks not achieved but for which he is committed.

**Formal definition:** A task is composed of:

- Task's type
- Parameters list  $(p_1, \dots, p_n)$  with  $n \in \mathbb{N}$

Example: Phone(Jean,05-61-61-61-61,10h30) is a task where Phone is the task's type and (Jean,05-61-61-61-61,10h30) is the parameter list.

**Logical formalisation:** Tasks are represented by logical terms [Grosz and Kraus, 1996]. Then, they denote an element of interpretation domain. To access to the different parameters, we use the role functions, which are described, in our logical language by some function terms. For example, the role function agent(T) returns the agent which performs T.

## 2.2 Recipe

The recipe concept presented here is similar to the Grosz's recipe concept [Grosz and Kraus, 1996].

**Definition:** A recipe describes a task performance. It represents the hierarchical decomposition (at one abstraction level) of a task performance under appropriate constraints.

For example, a recipe for the performance of a phone task is “pick up the phone”, and then “dial the number”, and then “speak”, and “hang up”.

**Formal definition:** A recipe for the task T is a triplet made up of T, a subtask set  $\{T_{11}; \dots; T_{1n}\}$  and a constraint set  $\{C_1; \dots; C_m\}$ , noted  $(T, \{T_{11}; \dots; T_{1n}\}, \{C_1; \dots; C_m\})$ .

- Example: A recipe for the performance of phone task is (Phone(people,number, time), {pick\_up\_phone(T<sub>1</sub>); Dial\_number(number,T<sub>2</sub>); Speak(T<sub>3</sub>); Hang\_up(T<sub>4</sub>)},  $\{T_1 < T_2 < T_3 < T_4, \dots\}$ ).
- Graphical representation:



Figure 1: Recipe for task T

**Logical formalisation:** A complete and detailed presentation of the logical formalisation of recipe concept can be found in [Camilleri, 1999]. To represent the performed task, we use the DO operator introduced by Grosz [Grosz and Kraus, 1996].

A recipe for a task A composed of subtasks  $\{B_1; \dots; B_n\}$   $n \in \mathbb{N}$ , under the constraints  $\Gamma$  is represented by a logical entailment (or recipe axiom) as :

$$\forall x \text{ DO}(B_1(s_1(x))) \wedge \text{DO}(B_2(s_2(x))) \wedge \dots \wedge \text{DO}(B_n(s_n(x))) \wedge \Gamma \supset \text{DO}(A(x))$$

Where  $A, B_1, \dots, B_n$  represent predicates of task type and  $s_1(x), \dots, s_n(x)$  describe some decomposition role functions and,  $\Gamma$  conjunctive constraint set.

## 2.3 Task Graph

The task graph notion can be viewed as a kind of recipe library [Grosz and Kraus, 1996], or as a reasoning model which is a part of conceptual model used in knowledge acquisition.

**Definition:** A Task Graph is a collection of recipes hierarchically organised. It represents all possible decompositions (following the described recipes) of tasks performance.

- Graphical representation:

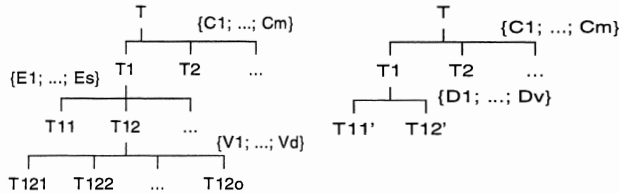


Figure 2: Task Graph

In the figure 2, the sets  $\{C1; \dots; Cm\}$ , ... represent the constraints set of their respective recipes. For example, a TG for the performance of a phone task is “pick up the phone”, then “dial the number” which is composed of “research the number” then “dial it”, then “speak”, and “hang up”.

**Logical formalisation:** A TG is represented by a conjunctive set of recipe axioms.

### 3 TG’s features influencing interaction

We identified two characteristics (tasks performance control and tasks distribution), which are important to define the interactions needed from the TG. To describe the interaction, we use the following notions [Post, 1996]: transactions which concern the transfer tasks of information ingredients between agents; transaction plans, which define the performance order of transactions.

#### 3.1 Tasks performance control

Generally, the transactional plans follow the control structure (tasks performance order) of the TG. In the above example (TG for the performance of a phone task), suppose that each task (pick up, dial, speak, hang up) needs a transaction, the hang up transaction completion requires the speak transaction achievement and so on. Therefore, transactions are achieved in the same order as the tasks performance.

#### 3.2 Tasks distribution

Tasks distribution represents all possible associations between agents and tasks. It can be modeled by doublets (agent, task) set. The tasks distribution is an important criteria to define the tasks needing a transaction. For example, consider the following TG (reduced here to a single recipe):  $(\text{calculating}((x+y-z)/2, R, T), \{\text{add}(x, y, r1, T1); \text{sub}_1(r1, z, r2, T2); \text{sub}_2(r2, t, r3, T3); \text{div}(r3, 2, R, T4)\}, \{T_1 < T_2 < T_3 < T_4; T_1 < T \dots\})$ . For  $d1 = \{(\text{user}, \text{add}); (\text{user}, \text{sub}_1); (\text{user}, \text{sub}_2); (\text{system}, \text{div})\}$  and  $d2 = \{(\text{user}, \text{add}); (\text{system}, \text{sub}_1); (\text{user}, \text{sub}_2); (\text{system}, \text{div})\}$  distributions, the transactions required are different. In the  $d1$  distribution only a transaction that presents the outcome  $r3$  ( $\text{sub}_2$  result) is needed. For the  $d2$  distribution, four transactions are required to present the

intermediate task result to the other agents. Thus, the possible set of distributions define tasks which require a transaction (and the nature of these transactions).

#### 4 Different TG types

A control is called static if and only if it is predefined (explicitly described in the TG), likewise a distribution is static if and only if the tasks distribution is predefined. We consider the following TG's types:

- Type 1 (Static Control (SC), Static Distribution (SD)) during the conception process, tasks requiring transactions are known (SD) in the same way as their achievement order (SC). We can define completely the required transaction plans. Therefore, all transactional plans are determined to the conception stage. Transactions can be bound to the TG. In [Sucrow, 1997], this TG's property is used to bind widgets to user goals.
- Type 2 (Dynamic Control (DC), SD) throughout the system conception, all transactions can be defined (SD). As we don't know the application order of tasks (DC), so the transaction order (thus transactional plans) cannot be determined. However, to achieve TG's tasks, the task control must be defined during the TG performance. This definition can require an explicit transaction or be determined by another task achievement.
- Type 3 (CS, Dynamic Distribution (DD)) at the conception stage, tasks needing transactions are not known (DD). As for the Type 2 TG, the distribution can be defined during the execution by an explicit transaction or by another task achievement.
- Type 4 (DC, DD) during the conception, tasks requiring a transaction (DD) and the execution order (DC) are not known. Therefore, during the TG execution these two features must be fixed either by some specific transactions or by tasks performance.

#### 5 Transaction plan formalisation

We represent a transaction by a task in our model. Therefore, a transaction plan is modelled by a TG containing transactional tasks.

This way to formalise transaction plans allows to unify the data manipulation mechanisms (TG is the only structure used) and to merge the domain TG with the interaction aspects of this TG. Moreover, the merged TG makes an explicit relationship between transaction tasks and related domain tasks. The method proposed above (to treat the type 2, 3, 4 TG) is modelled in this formalism by a transaction task, which modifies the TG. Thus, we need to construct another TG, which represents the system state.

#### 6 Conclusion

In this paper, we propose a generic formalism allowing to describe H-M interactions in any applicative domain from the TG by determining the constraints, which generate on interactions. The main advantages come from using the same formalism to represent

the TG and interactions. It facilitates their links and unifies the data manipulation mechanisms (TG is the only structure used).

The dissociation of the interaction description and its representation is an important point of interactive system conception [Camilleri, 1998]. Indeed, it clarifies the design and simplifies the system maintenance. A possible method to undertake the dissociation is to create an autonomous agent dedicated to interaction materialisation. Further work will attempt to use the link between the transaction tasks and the domain tasks to recognise user intentions.

### References

- [Bratman, 1990] Bratman, M. E. (1990). What is intentions?. In MIT Press, P.R Cohen, J.L. Morgan, M.E. Pollack, Intentions in communication, pages 15-31, Cambridge, MA, USA.
- [Camilleri, 1998] Camilleri, G. (1998). Description formelle de l'interaction Homme Machine. Internal Report 98-33-R, IRIT, Toulouse, France.
- [Camilleri, 1999] Camilleri, G. (1999). A formal theory of plan recognition adapted to discourse systems. Internal Report 99-16-R, IRIT, Toulouse, France.
- [Chandrasekan and Johnson, 1992] Chandrasekaran, B. and Johnson, T. (1992). Generic Tasks and Task structures: History, Critique and New Directions. In Springer-Verlag, J-M David, J-P Krivine, R Simmons, Second Generation Expert Systems, ISBN 3-540-56192-7, pages 232-272.
- [De Montmollin, 1995] De Montmollin, M. (1995). What is intentions?. In MIT Press, P.R Cohen, J.L. Morgan, M.E. Pollack, Intentions in communication, pages 15-31, Cambridge, MA, USA.
- [Grosz and Kraus, 1996] Grosz, B. and Kraus, S. (1996). Collaborative Plans for complex group action. *Journal of Artificial Intelligence*, 86(2): 269-357.
- [Isténes, 1996] Isténes, Z. (1996). Zola a language to operationalise Conceptual Models of Reasoning. *Journal of Computing and information*, 2(1): 689-706.
- [Post, 1996] Post, W.M. (1996). Cooperative emergency call-handling: Design and Realisation. COOP'96, pages 83-103
- [Schreiber et al, 1993] Schreiber, G. Wielinga, B. Breuker, J. (1993). Modelling Expertise. In Academic Press Harcourt Brace Jovanovich, G. Schreiber, B. Wielinga, J. Breuker, A principled approach to knowledge-based system development, ISBN 0-12-629010-7, pages 22-91.
- [Soubie, 1996] Soubie, J-L. (1996). Coopération et Système à base de Connaissance, Mémoire d'habilitation, UPS-Toulouse III, IRIT, France.
- [Sucrow, 1997] Sucrow, B. (1997). Formal Specification of Human-Computer Interaction by Graph Grammars under Consideration of Information Resources. In *Proceedings of the 1997 Automated Software Engineering Conference (ASEC'97)*, pages 28-35.



# INSTRUMENTING COLLABORATIVE WRITING AND ITS COGNITIVE TOOLS

Teresa I. Cerratto

University of Paris 8- Dept. Cognitive psychology  
2, rue de la Liberté - 93526 Saint Denis Cedex 02  
cerratto@gate.cnrs.fr

## Abstract:

*The purpose of this article is to discuss findings from case studies where 2 groups of students (16 academic students) have used traditional collaborative writing tools and synchronous cscw technology (Cf. Aspects<sup>®1</sup>). The article focuses on the cognitive transformations that are the result of the integration of a collaborative tool in a traditional collaborative writing task. Examining the effects of cscw technology on collaborative writing, on writing strategies and on the implication of students activities, I give some suggestions on what to preserve and what to change in the design of collaborative writing tools.*

**Keywords:** instrumental genesis, constructing meanings, collaborative activities.

## 1 Introduction

The relationship between humans and tools is central to an investigation of the process of mediated collaborative writing, when computer systems are designed to support both social and cognitive aspects. Although there has been a growth of interest in collaborative writing [Ede and Lunsford, 1990], [Saunders, 1990], [Zammuner, 1995], [Higgins et al., 1992] and in mediated collaborative writing [Kraut et al., 1990], [Beck, 1994], [Plowman, 1995] the fundamental relationship between tools and subjects in this context has overlooked, even though [Sharples and Peberton, 1988] and [Rimmershaw, 1992] have argued that writing experiences are transformed by the use of writing tools. The reasons for this have implications for the design of technologies to support collaborative writing, one of the main areas of interest for computer supported work [Sharples, 1993]. There is a history of discussions of the relationship between subjects and tools [Belisle et al., 1997]. [Norman, 1991] for example, referred to the power and importance of culture and artefacts to enhance human abilities and from this perspective he proposed in his well known presentation of cognitive artefacts that those external tools mediate cognitive process. Norman highlighted how cognitive artefacts completely transform the activities that they mediate (e.g. an airline checklist). From a learning point of view, [Jonassen, 1992] distinguished between 'delivery technologies' and 'cognitive tools', emphasising that the role of delivery technologies should be to

---

<sup>1</sup> Aspects is a commercial synchronous collaborative word processor, running on the Macintosh platform. Basically it allows the setting up of a common work space and a communication space. It also allows on-line writing and editing with each participant taking control alternatively over the shared document. To get more details, see <http://www.grouplogic.com/aspects/#new>

display thinking tools, tools that facilitate thinking processes. Rethinking cognitive tools, [Kuutti and Kaptelinin, 1997] criticised 'augmentation' perspectives, arguing that the potential impact of tools on human cognition is not enhancing some native capabilities, but, introducing new forms of mediation. The perspective adopted here is similar to these theoretical understandings of the nature of tools and processes underlying integration of technologies into human activity. However, collaborative writing is a specific cognitive and social activity. Therefore, two dimensions concerning human activities and then collaborative writing are still unclear. First, an understanding on how subjects integrate technologies as cognitive tools. From manipulating features to use them fluently and meaningfully : what happens in between ? Second, how do groups integrate cscw technologies into individual and collective activities ?

## 2 A cognitive approach of computer instrumented collaborative writing activity

Vygotsky's contribution demonstrates that the complex psychological processes cannot be explained without taking into account the important mediation role of psychological tools. According to [Vygotsky, 1934/1997] there are two kinds of tools : technical and psychological tools. Technical tools, such as for example a hammer, are oriented to transform an object, (e.g. to join pieces of wood together to build a chair ) while psychological tools are oriented to transform the subject himself or to influence other people, (e.g. a calendar to remind about dates). Adopting this distinction, different types of transformations can be obtained when using these material or symbolic tools. According to Vygotski's psychology and influenced by the Piagetian approach, [Rabardel,1995] extends these theoretical frameworks in an anthropocentered model he applies in the domain of ergonomics. For Rabardel, the distinction made by Vygotski is not pertinent to the effects of computer tools on cognitive and social activities. As [Kaptelinin,1995] has demonstrated, there are, at least, two features of computer tools which differentiate them from other tools. First, computer representations are active, and can be modified by computers according to their algorithms. Second, computer tools have the potential of implementing representation to reality. These two features of computer tools, indicate the possible function of computers as an extension of the internal plane of action as for [Kaptelinin,1992]. These two features are considered by Rabardel as characteristics of instruments. Instruments are these tools which are technical and psychological at the same time ; a sort of intermediate universe between subject and object and it transforms both. What is really important to understand is that instruments are mediated constructs that do not exist in themselves. They are constituted by an artefact -material- or symbolic-enriched with action schemes -specific cognitive and biological skills-. Instruments exist only inasmuch as the artefact used, has been associated with schemes<sup>2</sup> of use. The distinction between artefact and instrument is crucial to understand this approach suggesting that a machine or a technical system does not immediately constitute a tool for the subject. Adopting this approach, the study of mediated collaborative writing is the study of the instrumental genesis in collaborative writing with cscw technologies. That is a process which concerns the evolution of the use of the artefact and the elaboration of schemes by the user. In other words, it is the

---

<sup>2</sup> A scheme is a cognitive invariant, it can be defined as the structure common to all those acts which - from the subject's point of view - are equivalent

study of cognitive appropriation of artefacts which concerns a development of schemes associated 1- to specific features of the artefact, that is functions and technical properties, 2- to particular subject's goals of tasks, and 3- to interrelated social activities, that is interaction with other subjects.

## **2.1 Focus on collaborative writing**

Literature suggests that the introduction of computer tools to support collaborative writing will have a significant impact on the communication and on the negotiation of texts and collective activity which take place during the process of writing. Computer systems confront groups with a set of constraints which they have to identify, understand and manage in order to find the artefact usable. From this perspective I have conducted case studies with the objective to get a better understanding of the process of traditional collaborative writing and of transformations taking place during instrumental genesis.

## **3 Comparing traditional collaborative writing activities with computer supported collaborative writing**

I have selected academic students from a management school who were familiar with word processors and e-mail and with practice in writing reports in groups. 16 students distributed in two groups were video-taped, observed and interviewed. Both groups had four students using traditional collaborative tools and four students using Aspects® distributed into two computers.

### **3.1 The task : elaborating an argumentative report**

The task consisted in producing a 20 pages long academic report about decision making processes. Students had to evaluate a decision process by an expert systems and by a team of managers. Therefore the problem to solve was to argue about benefits and weakness of the integration of expert system in industrial decision making.

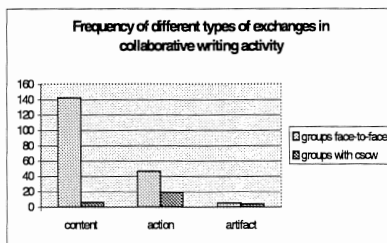
### **3.2 Methodology**

I have collected pre and post-questionnaires, interviews, drafts and final versions and I have videotaped 28 hours of student's collaborative writing activities. I have analysed verbal exchanges and messages exchanged through a chat-box of Aspects® and related it to the texts written. Two units of analysis has been used : paragraphs and exchanges. Paragraphs are the unit of analysis for the text. One paragraph is constituted by one or more sentences and it is delimited by one point obligating the change of current line. Exchanges are the unit of analysis for the dialogues : one exchange is equivalent to a turn-taking. A turn taking is composed by at least two utterances : initiative and reaction. An evaluative utterance can appear as a third component of the turn taking. Utterances have been coded by their semantic objects : 'action' -how do we do to write collaboratively ?- 'content' -what do we write for the common text ?- and 'artefacts' - how do we do with these technical features ?-. and in other ways. Comparisons between groups in the face-to-face situation and in the mediated situation have been done taking into account the first 30 minutes of collaborative writing activity.

#### 4 Analysis and Findings

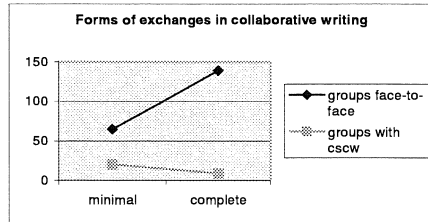
Observing how groups were elaborating different versions of the report, we found common characteristics in all groups : 1-students give priority to saving time in each meeting. To use time optimally is a criteria to continue to write with the same group in the future, 2-Students divide the task and writing evolves through individual contributions, 3- Students plan both the organisation of the groups and the organisation of the common text, 4- Students negotiate roles and semantic content at the same time. Looking at the differences, 1- the two csww groups needed in average 8.5 hours to complete the report, while traditional groups needed 4.5 hours. Csww groups had problems to identify paragraphs to be changed in the common file (e.g. group B needed 25 minutes to make sense of comments about a part of the common text). However, traditional groups using less time, obtained a better performance and a better understanding of the report. 2- groups using csww had problems to integrate the individual parts of the common text. Contradictions and repetitions of paragraphs showed that reports done with csww tools lack semantic coherence, 3- groups using csww tools had to use their collaborative activities to organise and to coordinate each others actions while traditional groups focused their collaborative activity on the semantic content of the text, 4- groups using csww had problems in negotiating roles and ideas compared to traditional groups. For example, to write one paragraph students developed at best 2 exchanges while traditional groups developed at best 12 exchanges -more exchanges can, of course, lead to more complicated ideas being expressed. In addition, groups using csww respected a prescribed plan of the report given by their professor and they tended to avoid structural changes during the activity. Decisions made were maintained in order to assure a common understanding of 'who is writing what and where'. Traditional groups showed a great flexibility and made changes as needed of pre-made agreements.

Looking at the distribution of exchanges:



Csww groups have oriented their exchanges towards actions, that is they have been more concerned with individual actions like coordination, checking and getting information about what is going on. Therefore, the content of the common text was neglected. The manipulation of the csww tool did not represent a problem in itself. Traditional groups were more focused on the content of the common text first, on their individual actions second, and on the use of traditional writing artefacts, third. These differences have important consequences for the common text. While traditional groups negotiate ideas and actions in order to construct text, groups using csww needed to check constantly that the collaborative activity, in itself works. These groups spent more

exchanges in getting information about effects of individual actions on the current collaborative activity than traditional groups. For traditional groups, getting information about current actions were implicit. The principal objective of the collaboration -to elaborate the text- has been transformed into a question of how to collaborate. From an instrumental approach, that is interpreted as a failure of collaborative schemes to write a text together. An instrumental genesis takes place when groups use csw and students have to manage in order to achieve a new organisation. Acquired cognitive and social schemes to write together have been transformed. The differences observed between traditional and csw collaborative writing activities, are understood as a sign of development of new organisations.



Forms of verbal exchanges showed that traditional groups were much more concerned with the task than the coordination of individual -collaborative- actions. The complete form of exchanges can be interpreted as an indicator of developed reflection on what it was been said by their co-authors. Groups using csw wrote a descriptive text and not an argumentative one. Putting much more attention on the transformation of strategies to collaborate through the csw tool, groups using csw tools have composed and reviewed their common text individually.

## 5 Discussion

From an instrumental perspective, differences observed indicate that csw groups were at the beginnings of their appropriation of the csw tool. They were trying to integrate the artefact into their old organisations which are associated with traditional schemes to write and to maintain relationships. Both social and cognitive routines are being transformed. In this active process, called instrumental genesis, students elaborate new ways to write together through a csw tool. Obviously enough, these results are still tentative, mainly because in the present study groups were observed only during 15 days. Future longitudinal studies are needed to analyse instrumental genesis over time in order to inform designers about how to support collaborative and cognitive schemes associated with 'co-elaboration' of argumentative texts. However our study helps designers to understand that collaborative writing is a complex cognitive and social activity entailing imagination, creation, discussion, negotiation, coordination, integration, communication and planning, composition and revision. Collaborative writing in educational environments, is a constant co-construction of meanings. This co-construction includes the effort to accept and give opinions, comments, suggestions and to integrate them in a way that has been accepted by the group. It is not only an exchange between questions and answers. It is not a production of a number of lines to fill pages. Collaborative writing is a socio-historical practise. There is a culture to write

together that depend on people, on tasks and on tools. Finally, collaborative writing is a cognitive and socially organised human activity. Artefacts do not become instantly instruments. Humans need time to develop and to re elaborate the new schemes that will be associated to artefacts in order to become useful means of actions.

## References

- [Beck, 1993] Beck, E. (1993). A survey of experiences of collaborative writing. In Sharples, M. (ed) *Computer Supported Collaborative Writing* Springer-Verlag London pp. 9-28.
- [Beck, 1994] Beck E. (1994). *Practices of Collaboration in Writing and their support*. Thesis in Cognitive Science. University of Sussex at Brighton. CSRP 340.
- [Belisle et al., 1997] Belisle, C., Zeiliger, R., Cerratto, T., (1997). *Integrated Cognitive Engineering at the Interface*, in proceedings of the Second International Conference on Cognitive Technology, CT'97, Aizu, Japan, Marsh, Hehaniv, Gorayska eds., IEEE Computer Society, Los Alamitos.
- [Ede and Lundsford, 1990] Ede, L., Lundsford, A. (1990). *Singular Texts/plural authors : perspectives on collaborative writing* : Southern Illinois University Press, Carbondale and Edwardsville.
- [Higgins et al., 1992] Higgins, L., Flower, L., Petraglia, J. (1992). *Planning text together. The rôle of critical reflexion in student collaboration*. *Written communication*, Vol. 9. No 1. January, 48-84.
- [Jonassen, 1992] Jonassen, D. (1992). *What are Cognitive tools ? in Cognitive Tools for learning*. Springer-Verlag, Chapter 1.
- [Kaptelinin, 1995] Kaptelinin, V. (1995). *Activity Theory : Implications for human Computer interaction*. In Nardi, B. (ed.): *Context and Consciousness : Activity Theory and Human Computer Interaction?* Cambridge : MIT. Press.
- [Kraut et al., 1990] Kraut, R., Egidio, C. et Galegher (1990) *Patterns of contact and communication in scientific research collaborations* pp. 149- 172 in *Intellectual Teamwork : Social and Technological Foundations of Cooperative Work* (eds. ) Galegher, Kraut et Egidio. LEA, Hillsdale' New Jersey.
- [Kuutti and Kaptelinin, 1997] Kuutti, K., Kaptelinin, V. (1997). *Cognitive tools reconsidered : from augmentation to mediation in in proceedings of the Second International Conference on Cognitive Technology, CT'97, Aizu, Japan, Marsh, Hehaniv, Gorayska eds., IEEE Computer Society, Los Alamitos.*
- [Plowman, 1995] Plowman, L. ( 1995). *The interfunctionality of Talk and Text*. In *Computer Supported Cooperative work*. Bruce, B. et Sharples, M. (eds) *Special Issue on Computer Supported Collaborative writing*. pp. 229-246.
- [Rabardel, 1995] Rabardel P. (1995). *Les hommes et les technologies, Approche cognitive des instruments contemporains*. Paris. Colin.
- [Rimmershaw, 1992] Rimmershaw, R. (1992) *Technologies of Collaboration*. In Sharples M (ed) *Computers and Writing : Issues and Implementations*. Kluwer. Dordrecht.

- [Saunders, 1990] Saunders, W. (1989). Collaborative writing tasks and peer interaction. *International Journal of educational research*, 13. 101-112.
- [Sharples, 1993] Sharples, M. (1993). Introduction in Sharples M. (eds.) *Computer supported Collaborative writing* Springer-Verlag London pp. 1-
- [Vygotski, 1934/1997] Vygotski, L. (1934/1997). *Penséé et Langage. La dispute*. Translated by F. Sève.
- [Zammuner, 1995] Zammuner, V. (1995). Individual and Cooperative Computer-writing and revising . Who gets the best results ? in *Learning and instruction*, Vol. 101-124.





## SYSTEMS/PERSONS CORRELATION MODELING. APPLICATION TO NOISE/ANNOYANCE ANALYSIS

Laurent Chaudron<sup>1</sup>, Marc Boyer<sup>2</sup>

<sup>1</sup>Onera, 2 avenue Belin 31055 Toulouse Cedex 04, France.

Tel: +33 (0)5 62 25 26 55, chaudron@cert.fr

<sup>2</sup>Tel: +33 (0)5 62 25 25, ext. 20 60, boyer@cert.fr

### Abstract:

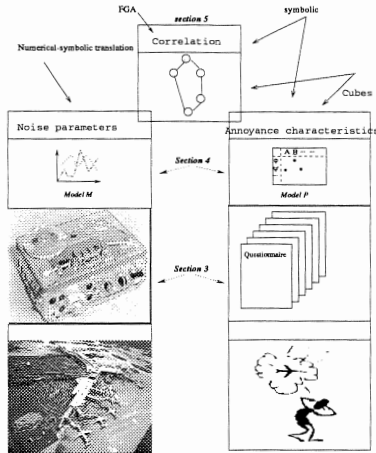
*The aim of this paper is to design a generic model of the correlation between aircrafts' noises and riparian persons' annoyance. This study is in keeping with Artificial Intelligence, and it focuses on the study of the relations between systems and involuntary users. Beyond a mere "noise level" → "annoyance" function, we aim at defining more precisely the causal relations between noise characteristics and the actual annoyance. Hence, we work both on annoyance cognitive models and on the general question of the correlation between artificial systems and human beings. In this paper, our contribution consists in the description of the first phase of the project: the experimental data collection program and the theoretical tools.*

**Keywords:** A.I., formal analysis, systems/unvoluntary-users correlation .

### 1 Introduction

Noise influence on annoyance is a widely studied problem. Many numerical approaches have been carried on in which statistics are used to represent general perception of phenomena [Vallet, 1996] (e.g. "In context  $c$ , a particular noise event ( $n > \sigma$ )dB exasperates 60% of population  $p$ "). Unfortunately, such kind of information does not express psychological annoyance, nor describes the correlations between noise and discomfort. In [FAA, 1985], the approach consists in designing a model based on physiological behavior of the auditive organs. In transport field, noise annoyance problems are identified [Leroux, 1998], but they often depend of the context [Remy, 1997] (roads' noise for example). Psycho-acoustic researches showed that categorisation (ability to recognize a sound) is opposite to continuous noise perception with just a few significant events. This approach, using cognitive science knowledge, seems to be a promising one (a human being is able to discern - and distinguish between - various noise aspects). In aeronautics, the control problem evolves faster than plane's characteristics [Rigaudias, 1997], however, companies modify take off/landing procedures in order to decrease noise effects. Finally the existing solutions consist in directly reducing the noise [Gaudriot and Martiant, 1998] [Valentin, 1997]. If it is clear that noise reduction (active or passive) is the simplest way to protect our sound environment, the idea is to analyse more precisely the causal links between the various parameters of noises and the characteristics of the resulting annoyance felt by persons.

## 2 Our Approach



Given an airport and riparian persons, if we want to understand the correlations between the noise generated by the aircrafts and the annoyance which is induced among the population, we need actual data to be collected. This is the purpose of Section 3. Then, thanks to a necessary simplification of data, we have to formalize the rough data so as to build a global knowledge base, this is described in Section 4. Finally, we have to correlate the noise information and the annoyance one within a synthetic model, the Formal Generalized Analysis, as a first sketch of model, is presented in Section 5.

As we try to design a global causal model, our objective is not to find a new physiological ratio. We have also to define a psychological annoyance cognitive model [Boyer and Chaudron, 1999], keeping the cause multiplicity and the actualy felt annoyance heterogeneous aspects. Moreover, at each step of our project, we try to reveal the actual links between noise parameters and annoyance characteristics. Thus the information and the correlation model have to be simplified in a first step and then they are hardly enriched.

## 3 Experimental phase

The aim of our experiments is to collect correlated sets of data: noisy events and simultaneous annoyance characteristics [Boyer and Chaudron, 2000] (we also try to design and validate the methodology). The first data collection experiment consisted in a two days (May 1999) measurements campaign (noise recording and annoyance expression) plan. A zone was chosen in a significant area near the the tracks' axis of the airport of Toulouse. A central point was equipped with a noise recorder while selected voluntary persons ( $n=10$ ) living around were asked to fill a questionnaire. Each time an aircraft was audible, predefined items and free fields allowed the volunteers to express various features of annoyance. The questionnaires were collected one day after and translated in a prolog database.

The acoustic device was a tape recorder *NagraIVSJ*. The data tapes are postprocessed so as to extract the significant value; many of them are not yet relevant (technical motor characteristics...) and in this first campaign we just took into account the noise level in dB.

It seems to be the first time these two kinds of data were recorded really simultaneously. Indeed, we made a direct link between each noisy event and pinpoint annoyance expressions. Generally, so-called noise-annoyance evaluation are mere links between average noise values (measured at time  $t$ ) and a vague discomfort expressions (time  $t'$ )<sup>1</sup>.

<sup>1</sup>Moreover we discovered that the smallest time deviation between mean noise measurements and annoyance polls, was:  $|t' - t| = 6 \text{ months!}$

Thus, for each event (an aircraft flight) time is the fundamental join parameter between the two sets of data.

#### 4 Data integration

The aim objective is to build a data base (implemented in Prolog) so as to structure knowledge as follows:

- the set of noisy event characteristics:
  - time (which we can aggregate by periods: morning, afternoon, evening, night),
  - noise characteristics (noise level in dBA for example, frequency, duration, number of previous noisy events);
- the set of the human features:
  - the person,
  - his activities,
  - his noisy environment (described by noisy events which are not aircraft ones),
  - his safety environment (did she or he see the plane?),
  - his annoyance expression (weak, medium, strong, very strong).

Example : Let  $Id_j$  be a noisy event which level is 75.7 dB. Its duration is 28 seconds. It took place the 29<sup>th</sup> of May at 17:45. The person  $p_i$  was strongly annoyed. He was reading a book in his garden and his noisy environment was quiet. This information can be symbolically translated into the formula:

$base(p_i, id_j, \{annoy(high), activity(intell), activity(outside), period(afternoon)\})$ .

While the noisy event is described by the following formula:

$ev(id_j, 29, 1745, \{level(75.7), duration(28)\})$ .

Thanks to the fact that: a small number of persons ( $\#=10$ ) and a small number events ( $\#=50$ ) are considered in this first experience, symbolic representation of knowledge is relevant. We must notice that numerical results are not ignored as they are encapsulated into symbolic predicates. At this point, the core of our problem is to analyze amorphous sets of symbolic knowledge in which typical classes and inferential links are searched for. For that kind of purpose, we designed an extension of a theory called "Formal Concept Analysis" allowing first-order logic properties to be captured, its basic principles are symmerized in the next section.

The empirical questions that will have to coped in the second phase of our study are the following:

- aggregation of individual annoyance features: in order to define a "symbolic mean" of annoyance so as to guarantee a standard annoyance symbolic scales, a **cognitive annoyance model** is needed. Collaborations with cognitive psychology labs in the frame of cognitive sciences actions is under construction.
- Non disruptive experiments for observed annoyance must be imagined and planed so as to collect data of observed annoyance: videos, drops of working performances...
- The various pre-categorization of the parameters of the global base must also be cautiously examined. This will allow greatest sets of events and persons to be considered.
- Finally an advanced level for symbolic representation of the data must be available (this is the purpose of the constrained cube model, in which the parameters will be recorded in terms of  $predicates(arguments) + Constraints(arguments)$ ). Such a model is suppose to be an optimal mid-term tool for numerical/symbolic treatments.

### 5 Theoretical frame: Formal Generalized Analysis

Our model is based on a well know approach: Formal Concept Analysis (say: FCA) which is a set-theoretical model for concepts that reflects the philosophical understanding [Arnaud and Nicole, 1662] of a concept as a unit of thought consisting in two parts: the *extend*, which contains all the entities (the objects, the examples...) belonging to the concept, and the *intend*, which is the collection of all the attributes (the characteristics, the properties...) shared by the entities. FCA is completely described the reference book [Ganter and Wille, 1996]. In FCA, the basic notion that models the knowledge about a specific domain is the formal *context* –described as a binary relation between two finite sets– from which concepts and conceptual double hierarchies can be formally derived so as to form the mathematical structure of a lattice<sup>2</sup> with respect to a subconcept-superconcept relation. FCA is used for self-emergent classification of objects, detection of hidden implications between objects, construction of concept sequences, object recognition, aggregation of data and information, knowledge representation and analysis. Based on a formal model for conjunctions of properties [Chaudron et al., 1997], we built an extension of FCA to first-order logic, called Formal Generalized Analysis (FGA) so as to deal with a natural expression of the knowledge involved in the noise↔annoyance problem.

**Definition A** cube is a conjunction of first-order logic literals. The set of cubes ( $C^r$  can be equipped with a struture of a lattice thanks to an extension  $\cup_c$  and  $\cap_c$  of the classical set operators.

Example: the cube  $c_1 = \{Level(inf80db), Period(Morning), Annoyance(Medium), Activity(\{Rest,TV\})\}$  captures the sound level and the main annoyance characteristics of a given noise event. If  $c_2 = \{Level(inf80db), Period(Morning), Activity(Manual)\}$  is the cube of event  $Id_{16}$ , then the common features of both events is captured by the cube:  $c_1 \cap_c c_2 = \{Level(inf80db), Period(Morning), Activity(V)\}$ , while the aggregation of both cubes is:  $c_1 \cup_c c_2 = \{Level(inf80db), Period(Morning), Annoyance(Medium), Activity(\{Rest,TV,Manual\})\}$  Thus, considering simultaneously different events, we can analyse the correlations between their cubes. Such a set of event is a context. As an example, let us consider the very simple context:

	Activity	Annoyance	Period	Level
Id1	rest	high	morning	inf80
Id3	intell, rest	low, medium	morning	sup80
Id5	tv, rest	medium	morning	inf80
Id16	manual	low	morning	inf80
Id20	rest, outside	low	afternoon	inf80

**Definitions** Such a table can be formally defined: a context is a pair  $(O, \xi)$  where  $O$  is finite set of objects, and  $\xi$  is a mapping from  $O$  onto  $C^r$ . Each object  $o$  in  $O$  has one and only one image  $p = \xi(o)$  in  $C^r$  which represents the set of properties of  $o$ . The dual operators ' and ° between  $O$  and  $\xi(O)$  are defined by:  $A' =_{def} \cap_c_{o_i \in A} \xi(o_i)$   $B^\circ =_{def} \{o_i \in O | B \leq_c \xi(o_i)\}$ .

<sup>2</sup>given two internal operators  $\sqcap$  (infimum) and  $\sqcup$  (supremum) on a set  $E$ ,  $(E, \sqcap, \sqcup)$  is a lattice, iff<sub>def</sub>:  $\sqcap$  and  $\sqcup$  are idempotent, associative, commutative and they verify the absorption law  $x \sqcap (x \sqcup y) = x$  and  $x \sqcup (x \sqcap y) = x$ . A lattice is always an ordered set: the relation  $\leq$  defined on  $E$  as:  $(x \leq y) \leftrightarrow_{def} (x \sqcap y) = x$  is an order relation for which  $\sqcap$  and  $\sqcup$  represent the greatest lower bound and the least upper bound

$A'$  is the set of attributes common to all the objects in  $A$ , and  $B^\circ$  is the set of the objects possessing their attributes in  $B$ .

As we have to determine the links between subgroups of event and the properties they share, we can define the generalised concepts as pairs of correlated objects (events) and their typical properties:

**Definitions** A generalised concept is a pair  $(A, B)$   $A \subset O$ ,  $B \in \mathcal{C}^r$  such that:  $A' = B$  and  $B^\circ = A$ .

The set of all generalised concepts defined by the context  $(O, \xi)$  is denoted as  $\mathcal{L}^1$  and it verifies:

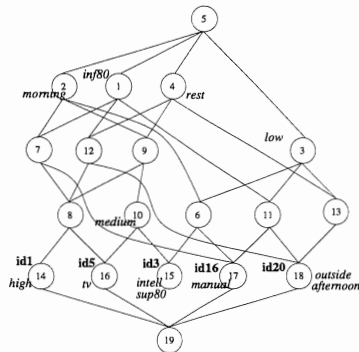
**Theorem** defining:  $\sqcup$  (supremum) and  $\sqcap$  (infimum) on  $\mathcal{L}^1$  as follows:

$$(A_1, B_1) \sqcup (A_2, B_2) =_{def} ((A_1 \cup A_2)^{\circ} \cdot B_1 \cap_c B_2)$$

$$(A_1, B_1) \sqcap (A_2, B_2) =_{def} (A_1 \cap_c A_2, (B_1 \cup_c B_2)^{\circ'})$$

We have:  $(\mathcal{L}^1, \sqcup, \sqcap)$  is a lattice.

Back to our example, such a diagram represents the symbolic dispersion (a kind of symbolic gaussian curve) of the knowledge as it is structured in the lattice  $\mathcal{L}^1$ :



Each node is a generalized concept, i.e. a stable couple (*events, features*) and two concepts have a supremum and an infimum. A given concept  $\textcircled{n}$  inherits all the properties which are linked above it in the diagram and  $\textcircled{n}$  is constituted of all the events which are linked below it. For example: concept  $\textcircled{6}$  is:  $(\{id16, id3\}, \{Annoyance(low), Period(morning), Level(V2), Activity(V3)\})$ .  $\textcircled{6}$  is the “class” of all events that looks like id16 and id3, characterized by the fact that they occurred in the morning and they induce a weak annoyance while activity and sound level were undefined (thus they are represented by variables).

Thus, the top-down subtree represents the emergent contextual classification of the events thanks to the labelling properties. The more events there are, the less characteristics they share and conversely. The relation between comparable concepts works like communicating vessels.

Such a flexible self-emergent classification suits our problem of amorphous knowledge mining. Indeed, thanks to the implementation of FGA, the context and the concept lattice can be considered as a global Prolog knowledge base  $C \cup L$  on which knowledge exploration experiments are performed. In particular, the knowledge base  $C \cup L$  is used so as to look for contextual dependencies (i.e. rules) between either objects or attributes. The induction of the context-based rules relies on a fundamental lemma:  $(\forall A \in P), \models (A \rightarrow (A'' - A))$ . Thanks to this result, a context rule generator based on a simple saturation algorithm was implemented. It allows to induce all the contextual rules generated by the considered events. For example, the following rule can be formally derived from our context:

$$(\text{Level}(\text{inf}80) \wedge \text{Activity}(\text{rest}) \wedge \text{Period}(\text{morning})) \rightarrow \text{Annoy}(x) \quad x \in \{medium, low\}$$

Which means that “if an event occurs in the morning and during rest, even if the sound level is less than 80 dB, the person feels an annoyance (at least at a medium level)”.

These different capabilities of knowledge mining and rules induction are still under study.

## 6 Conclusion

If the biological relations between noise and physiological relations are covered by a large amount of studies (thanks to which the various criteria dB, dBA,.. were defined), the simultaneous analysis of noise and psychological annoyance is little or none formally studied yet. Our approach aims at designing a generic causal model of the correlations between noise and annoyance, furthermore the model intend to captures the links between an artificial system and unvoluntary user.

## References

- [Arnaud and Nicole, 1662] Arnaud, A. and Nicole, P. (1662). *La logique ou l'art de penser*. Gallimard, 1992, Paris. in French.
- [Boyer and Chaudron, 1999] Boyer, M. and Chaudron, L. (1999). Projet MoCou : Modélisation du couplage personnes/machines. In *Actes du IIIe Colloque Jeunes Chercheurs en Sciences Cognitives*.
- [Boyer and Chaudron, 2000] Boyer, M. and Chaudron, L. (2000). Airport noise/annoyance analysis. In *International Council of the Aeronautical Sciences*. submitted.
- [Chaudron et al., 1997] Chaudron, L., Cossart, C., Maille, N., and Tessier, C. (1997). A purely symbolic model for dynamic scene interpretation. *International Journal on Artificial Intelligence Tools*, 6(4):635–664.
- [FAA, 1985] FAA (1985). Aviation noise effects. Technical report, Federal Aviation Administration Service.
- [Ganter and Wille, 1996] Ganter, B. and Wille, R. (1996). *Formale Begriffsanalyse: Mathematische Grundlagen*. Springer-Verlag, Berlin-Heidelberg. In German.
- [Gaudriot and Martiant, 1998] Gaudriot, L. and Martiant, J. (1998). Une nouvelle perspective de réduction de la gêne autour des aéroports : le lampadaire anti-bruit. *Acoustique et Techniques*, (16):61–63.
- [Leroux, 1998] Leroux, M. (1998). Les écrans acoustiques : Perception et représentation des riverains. *Acoustique et Techniques*, (16):29–32.
- [Remy, 1997] Remy, H. (1997). Les bruit aérodynamique des avions Airbus : état de l'art et programmes de recherche. *Acoustique et Techniques*, (10):12–20.
- [Rigaudias, 1997] Rigaudias, J.-B. (1997). Les besoins des compagnies aériennes en matière d'acoustique. *Acoustique et Techniques*, (10):5–8.
- [Valentin, 1997] Valentin, G. (1997). Ancas, un produit qui fait du bruit pour le réduire. *Acoustique et Techniques*, (10):51–52.
- [Vallet, 1996] Vallet, M. (1996). Annoyance after changes in airport noise environment. In *Proceedings of "INTER-NOISE 96"*, pages 2329–2334. INRETS.

# KNOWLEDGE MANAGEMENT AND CAPITALISATION AS A SUPPORT FOR INNOVATION

Jean-Louis Ermine<sup>1</sup>, Arnaud Waeters<sup>2</sup>

1 Commissariat à l'Energie Atomique, CEA/DIST, Centre de Saclay, France,  
ermine@cea.fr

<sup>2</sup> Kade-Tech, France  
kadetech.paris@wanadoo.fr

## Abstract:

*With the development of strategic Knowledge Management in a lot of companies, new prospective point of views have raised for understanding the complex process of innovation within the firm. We propose three main points of view, including theories, methodologies, and tools to give a new basis for managing the innovation process in a company*

**Keywords:** Knowledge management, Innovation, Business Intelligence, Knowledge Evolution

## 1 Introduction

Innovation is a fundamental process for companies in their competitive objectives. The innovation process is ill-defined, and attempts to support this process are only emerging.

Innovation can be seen as knowledge creation within the company, in a precise strategic perspective, and with a strong relationship with customers needs or problems. Hence, it is tightly linked to others activities as Knowledge Management and Business Intelligence, rapidly increasing now in companies .

Knowledge Management is the valuation of the Knowledge Capital of an organisation ([Evindson and Malone 97], [Strassmann.98], [Stewart 97], [OCDE 96]...), through main strategic actions. There are mainly three strategic axes for Knowledge Management :

- Management of the existing Knowledge Capital, essentially **capitalisation** (To know where you are in order to know where you want to go) and **sharing** (From individual intelligence to collective intelligence)
- Management of knowledge evolution, which comprises **capitalisation of former evolution** (To know where you come from), and **supporting future evolution** (Organise knowledge evolution)
- Management of the interaction of the Knowledge Capital and the (Competitive, Scientific, Technical ...) Environment, which means essentially **supporting the transformation of external information into internal knowledge**.

We will show how these three activities may be linked to innovation support, in what we call the spiral of innovation, illustrated in figure 1

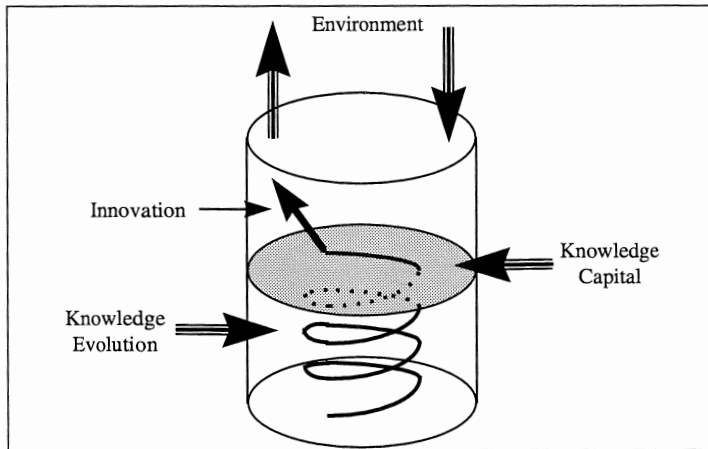


Figure 1: The spiral of innovation

## 2 Management of knowledge evolution

### 2.1 Capitalisation of former evolution

The capitalisation of former evolution is the justification for further evolution.

In that area, the well-known theories of evolution, adapted to artefacts, are good modelling supports to understand the way the firm has already innovated and will still do. The theoretical hypothesis are of two kinds ([Barthelmé et al. 98]) :

- Corporate knowledge is organised as a general system, not reducible to an already existing system (information system, documentation system, quality system etc.). This is the MKSM fundamental hypothesis, where Knowledge Capital is called Knowledge System (MKSM is an operational methodology for knowledge capitalisation, based on knowledge modelling [Ermine et al. 96]). Hence, corporate knowledge is ruled by the general laws of system evolution (Lamarck, Darwin, Piaget...). This leads to discover those general laws of evolution for knowledge as assimilation, accommodation, inhibition, mutation...
- A corporate knowledge system is not autonomous, because it has goals given by the organisational strategy. Therefore, it is more pertinent to refer to Lamarck axioms as adaptation to environment, transmission of acquired characters etc.

Based on these hypothesis, we can then build modelling tools to perform capitalisation of the former evolution. These models are filling the gaps in the standard MKSM macroscope, and are candidates to complete the method ([Barthelmé and al. 98]):

- History models, capitalising the contexts and the rationale (as for "Design Rationale" [Moran 96]) in which knowledge has evolved.



- Genetic classifications, describing the trees of technical objects or solutions which have been designed through time.

These models are illustrated in figure 2.

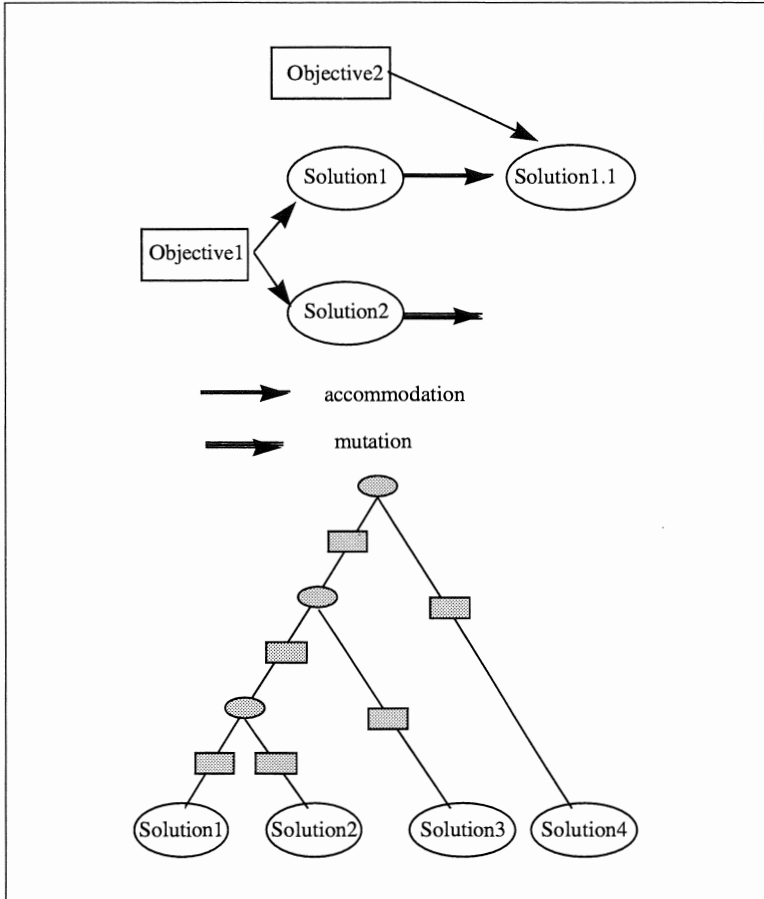


Figure 2: Models for capitalising knowledge evolution

## 2.2 Supporting future evolution

Evolution, knowledge creation is a chaotic process, in the sense of the mathematical "Deterministic Chaos". It is not predictable, and there is no hope to build a method to ensure knowledge creation or innovation. However, we can make assumptions on the system where knowledge evolution occurs, and derive some operational characteristics, in order, not to lead, but to support evolution. The theoretical hypothesis are of two kinds:

- There exists a sub-system to control (supervise) the evolution process. This system has a specific organisation, practices and procedures (cf. e.g. [Barthelmé and al. 98]).
- The only social community which has sound and validated practices to recognise, approve and disseminate innovative (even revolutionary) knowledge is the scientific community. Managing knowledge evolution must be inspired by those practices.

Based on these hypothesis, we can design a system, including organisation and procedures, according to the following requirements : observation of evolution from the existing knowledge, submission of significant evolution, peer validation, integration. That system can be formalised, for instance as in figure 3 and 4 (using the UML modelling technique), this point is detailed in [Besse and al. 99].

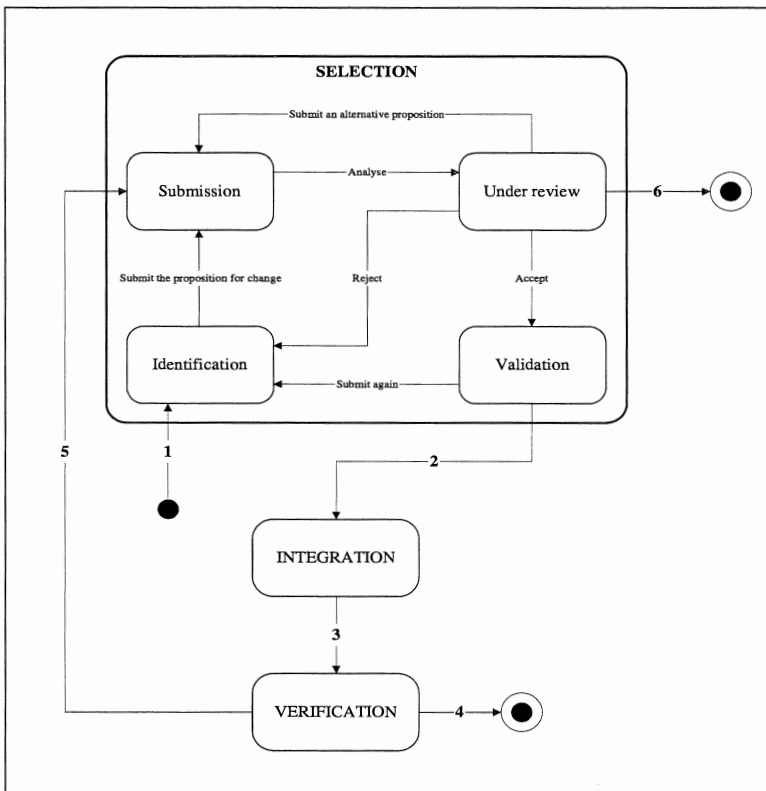


Figure 3: Procedures for supporting evolution (example)

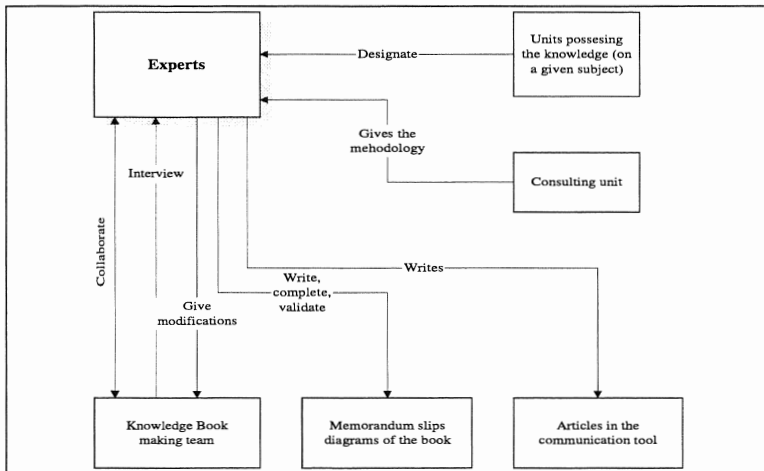


Figure 4: Organisations for supporting evolution (example)

### 3 Management of the interaction of the Knowledge Capital and the competitive environment.

Knowledge creation is for one part an internal (endogeneous) process and for another part an external (exogeneous) process. The external process is based on information retrieval from environment. It is a crucial point and organisations have designed a lot of adequate structures to optimise it (business intelligence, technological scanning ...). But in most of cases, the stress is put on information retrieval and analysis, which can lead to misunderstanding, cognitive overflows, information overflows etc. The main problem is to transform the information from outside into operational and/or innovative knowledge. Knowledge management is of great help in that sense ([Ermine 99]).

To understand how to use Knowledge Management (capitalisation and sharing) for supporting the external process of knowledge creation we need to make the following theoretical assumptions :

- The organisation and its Knowledge Capital are in constant relationship with its environment. This relationship is modelled by information and cognitive flows exchanged by the two different systems (we denote E for Environment, and K for the Knowledge Capital within the organisation)
- This relationship is not the result of an inclusion relationship (organisation into environment), but of an interactive process where the relation K2E is in equilibrium with the relation E2K. This symmetry is a fundamental stability factor for the organisation.

Based on these hypothesis, we need to model the interactive processes K2E and E2K. Managing evolution in that sense is to design methods and tools for supporting those two processes ([Ermine 99]).

The interaction K2E has three components :

- *Projection* : i.e. matching the tacit or explicit representation of a part of the knowledge system of the organisation (through its actors) with the perceived environment (or the part one can reach). This may be supported by a systematic construction of matching templates, which can be easily derived from knowledge models elaborated in knowledge capitalisation.
- *Distortion* : i.e. perception of a non-adequacy between the organisation and its environment. This perception can be optimised by shared argumentation.
- *Identification* : i.e. explicitation of the fundamental distortion factors (discovering the singular zones, or weak signals). This can be improved by a distributed interpretation among actors.

The interaction E2K has also three components :

- *Relevant feedback* : i.e. elimination of the singular zones which are obviously non pertinent. This can be supported by classical tools of information retrieval, and brain-storming sessions.
- *Representation* : i.e. mathematical or cognitive operations on the singular zones to obtain comprehensive grids. This is a part of the process which has a lot of supporting tools as information tools, infometric, statistic, linguistic tools...
- *Knowledge creation* : i.e. cross information, interpretation process, innovation. This is the most unexplored part of the process. Knowledge modelling is a good filter and a guide, as, in most of cases, the new knowledge has to be integrated in the knowledge system, in the way it has been capitalised

## References

- [Barthelmé and al., 98] F. Barthelmé, J-L. Ermine, C. Rosenthal-Sabroux, *An architecture for knowledge evolution in organisations*, European Journal of Operational Research, 109, 414-427, 1998
- [Besse and al., 99] A. Besse, J L Ermine, C. Rosenthal-Sabroux, *Modelling Organisation, Practices and Procedures for Knowledge Books Design*, Practical Application of Knowledge Management 99, Londres, 23-27 avril 1999, pp 175-193
- [Ermine and al., 96] J-L. Ermine, M. Chaillot, P. Bigeon, B. Charretton, D. Malavieille, *MKSM, a method for knowledge management*, Advances in Knowledge Management Volume 1, Jos. F. Shreinemakers Ed., pp 288 - 302, Ergon, 1996
- [Ermine, 99] J-L Ermine, *La gestion des connaissances, un levier de l'intelligence économique*, Revue d'Intelligence Economique, n 4, avril 1999, pp 98-111
- [Evinsson and Malone, 97] L. Edvinsson, MK. Malone, *Intellectual Capital*, Harper Collins Pub. 1997
- [Moran, 96] *Design Rationale* Lawrence Erlbaum Associates, Hillsdale, NJ, 1996.
- [OCDE, 96] *Employment and Growth in the Knowledge-based Economy*, OECD, Paris,
- [Stewart, 97] Stewart T.: *Intellectual Capital* New York, 1997
- [Strassmann, 98] P. A. Strassmann *The Value of Knowledge Capital*, American Programmer, March 1998

## THE KNOWLEDGE CAPITALISATION PROBLEMATIC IN ORGANISATION FROM A DECISION AID POINT OF VIEW

Iftikhar Fendri<sup>1</sup>, Michel Grundstein<sup>2</sup>,  
Alexandre Pachulski<sup>1</sup>, Camille Rosenthal-Sabroux<sup>1</sup>

<sup>1</sup>LAMSADE, Paris – Dauphine University  
{fendri, pachulski, sabroux}@lamsade.dauphine.fr  
<http://www.lamsade.dauphine.fr>

<sup>2</sup>MG Conseil,  
mgrundstein@mgconseil.fr  
<http://www.mgconseil.fr>

**Keywords:** Knowledge Capitalisation, Information System, Decision Support System, Tacit knowledge, explicit knowledge

From 1960 to 1940, the key concept of enterprise was information; it was the cybernetic era. From 1970 to 1980, the knowledge concept emerged with cognitivism and connectionism. In the beginning of 1990, the concept of knowledge capitalisation emerged but it was not until 1997 that knowledge management within organisation widespread and became more important as can be seen in everyday press, international conferences, product and services suppliers' commercial announcements...Today, enterprises are in a strongly competitive international context, that they have never experienced before. Products and technologies are bought and do not constitute differentiating elements any longer. The strongest weapon in the innovation race is knowledge.

Today's enterprises become aware of the necessity of knowledge management to improve their performance and competitiveness. The difficulty when enterprises don't manage their knowledge is that they may loose their expertise when an expert retire, loose their know-how, and experience difficulties to identify, transmit, share and exchange their knowledge. This is why today's enterprises turn towards knowledge management to avoid reproducing past mistakes and to take advantage from all the knowledge and the know-how used and produced within them. The aim of this study is to tackle knowledge capitalisation within organisation from a decision-aid point of view. In this paper we shall distinguish three research trends. Then we will describe the different facets (aspects) of knowledge capitalisation problematic. We place the decision-aid in relation with this problematic. Our approach will be illustrated by a case study and we will conclude on research perspectives.



# INTERACTION WITH IN-VEHICLE SYSTEMS. A METHOD TO EVALUATE THE PERFORMANCES OF A NEW INPUT DEVICE

J-F. Kamp<sup>1</sup>, F. Poirier<sup>1</sup>, Ph. Doignon<sup>2</sup>

<sup>1</sup>Université de Bretagne-Sud, Valoria Laboratory  
rue Yves Mainguy  
56000 Vannes - France  
(jean-francois.kamp, franck.poirier)@univ-ubs.fr

<sup>2</sup>Renault - Technocentre  
1, avenue du golf  
78288 Guyancourt Cedex - France  
philippe.doignon@renault.fr

## Abstract:

*In a driving context, the control of the in-vehicle systems is a very important problem since safety must be guaranteed. This paper presents a method to evaluate the performances of such control devices. The evaluation of the performances is made on the basis of a time criterion i.e., the time delay required to complete a task. In a concrete case, the method shows that, given a task T, the touchpad input device is 3 times faster than the push-button device.*

**Keywords:** Man-Machine Interaction, Evaluation, Task Execution Time, Input Device.

## 1 Introduction

This work is carried out in collaboration with Renault Research Department. In the near future, car manufacturers will propose on the market high-technology in-vehicle systems such as car phones, traffic information, route guidance systems etc. Most of these new systems require the user to accomplish complex manipulations: access to information, data input, system programming.

### 1.1 Problem

To execute a task, the driver manipulates an input device. These manipulations become a very difficult task since up to now the control devices are often reduced to small switches and push-buttons. For example, to select an item in a list, the user turns a rotary button and moves a cursor sequentially in the list: this is long and dangerous from a safety point of view.

### 1.2 Proposed Solution and Evaluation of the Performances

To solve this problem, we propose a new input interface to control in-vehicle systems. This new device is a touchpad of small dimensions (2.36 by 2.36 in.) with the purpose to record any gesture made by the user which is, in the present case, the drawing with the finger of a symbol, character or digit. The general idea is to recognise the symbol drawn by the driver and to match it with predefined patterns triggering specific actions for on-board systems.

In [Kamp et al., 1997], we showed that anybody is able to write characters on a small touchpad without looking at his finger and without visual feedback from a screen (so-called « blind condition »). In such « blind condition », the average recognition rate is 93% for letters. This result allows us to advocate the use of touchpads in vehicles because this type of interaction only slightly distracts from the driving task.

The purpose of this paper is to evaluate the efficiency of the touchpad and to compare it to push-buttons. The evaluation of the performances of such input devices is made on the basis of a time criterion i.e., the time delay required to complete a task. This criterion is very important since in-vehicle interaction must only marginally interfere with the driving task.

A first approach consists in carrying out a laboratory experiment [Coleman et al., 1991], [Paelke, 1993] to measure the time delay. This implies the participation of several subjects and the study of all the recorded data. The approach is very interesting but requires a lot of time and a staff of researchers.

Our approach is different and is part of the whole methods created for the evaluation of the user interfaces such as OPADE [De Rosis et al., 1994]. More precisely, our goal is to present a method well adapted to the measurement of the task execution time. This is exactly the same idea as the Keystroke-Level Model [Card et al., 1983] but our method fits better for on-board systems in general.

The second paragraph of the paper describes the method in detail. It is based on the finite state machine formalism. The third paragraph applies the method in a concrete case: the performances comparison of two input devices, touchpad and push-buttons.

## 2 Description of the Method

### 2.1 Finite State Automaton

To execute a task (searching for a name in a list for example), the user goes through a sequence of tree structured menus. In the context of on-board systems, one node of the tree menu corresponds to one image displayed on a small graphic screen. When the driver executes an action with an input device (pushing a button to select an item in the list), there is a change of image on the graphic screen, or, and it is equivalent, a change of node in the tree menu. Hence, it is natural to consider each node of the tree as the state of a finite state machine.

### 2.2 System Description

Let us remember that a finite state machine is [Dix et al., 1993]:

- a set of states  $S$ ,
- an initial state  $S_0$ ,
- a subset of final states  $F$  ( $F$  included in  $S$ ),
- a set of transitions which define a function  $S \times V \rightarrow S$  where  $V$  is a finite alphabet. On reception of an event, belonging to the  $V$  alphabet, the automaton goes from a  $S_i$  state to a  $S_j$  state.



Figure 1 illustrates the global structure of the system. The finite state automaton (3) supervises the man-machine dialogue.

When the driver manipulates the input device (1), an event (2) is sent to the finite state machine (3). Upon reception of an event, the responses of the automaton are:

- a transition between two states of the state machine,
- the emission of a specific control signal (4),
- the modification of the display (5).

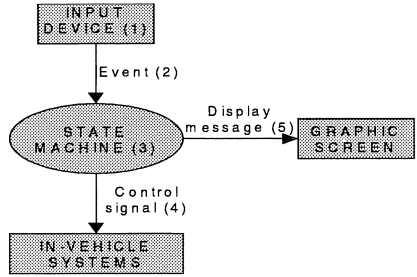


Figure 1: The global scheme of the system

Hence, a task completed by the driver begins at a starting state  $S_s$  and terminates at a final state  $S_f$ .

### 2.3 Performances Evaluation

Our goal is to build a model that would predict how much time a user would take to accomplish a given task with a given input device:

- Given:**
- A task (possibly involving several subtasks).
  - The input device (touchpad, push-buttons, ...).
  - The response time parameters of the system.

**Predict:** The time delay a user will take to execute the task, providing he manipulates the input device without error.

By definition, the time delay (TD) is the time needed to go from state  $S_s$  to state  $S_f$  (cf. section 2.2). Given a large task, the user will break it into a series of elementary actions. Such elementary actions consist, for example, in pushing a button to select an item in a list, or, in drawing a letter on the touchpad to write a name in an alphanumeric field. Each elementary action corresponds to one event sent to the state machine. Hence, if the production of a single event takes one time unit (TU), the total time delay needed to accomplish the task  $T$  is given by the following expression:

$$TD(D, T) = N(D, T) * TU(D) \tag{I}$$

where:

- $N(D, T)$  = the number of events needed to go from state  $S_s$  to state  $S_f$ . This integer depends on the input device  $D$  and the task  $T$ .
- $TU(D) = t_m(D) + t_r(D)$ , where:
  - $t_m(D)$  is the fingers manipulation time required to produce one elementary action with the input device  $D$ ,

- $t_r(D)$  represents the system response time and depends on the input device  $D$ : for example, the recognition of a symbol drawn on the touchpad takes much more time than the use of a button.

### 3 Input Device: Comparison between Touchpad and Push-Buttons

In this section, as an illustration of the method, we compare touchpad and push-buttons on the basis of the time criterion. To do this, we use expression (I) developed in section 2.3.

In a first step, the finite alphabets  $V_t$  and  $V_b$  are defined for the touchpad and the buttons respectively. This alphabet ( $V_t$  or  $V_b$ ) specifies all the events (or elementary actions) the device (touchpad or buttons) can produce.

In a second step, given the task  $T$ , we show the state machine built for the touchpad and the push-buttons respectively. We suppose the task  $T$  consists in selecting the town called “ARPAJON” in a list of 400 different cities (suburbs of Paris).

Finally,  $TD(\text{touchpad}, T)$  and  $TD(\text{buttons}, T)$  are calculated using expression (I).

#### 3.1 Finite Alphabets $V_t$ and $V_b$

##### Touchpad

Because the principle is based on character recognition, the touchpad can generate a lot of different elementary actions: letters (Let), ciphers (Cip), validation (Val), cancellation (Can), moving a cursor in any direction (Mov) etc. All these events belong to the  $V_t$  alphabet.

##### Buttons

In the automobile context, the number of buttons must remain low. Therefore the on-board push-buttons are limited to:

- a rotary button ( $R_b$ ) which allows the user to move a cursor in two different directions,
- a button to validate (Val) a selection and a button to cancel (Can) an action.

Hence, for the push-buttons device, “ $R_b$ ”, “Val” and “Can” are the only events which constitute the  $V_b$  alphabet.

#### 3.2 Finite State Machines

As a simplification, figures 2 and 3 show only the part of the state machine which concerns the selection of the destination town “ARPAJON” in a list. We suppose:

- the letters are introduced one by one,
- the first three letters “A”, “R” and “P” are sufficient to reduce the choice to one element which is “ARPAJON”.

##### Touchpad

In the “Destination” state (see figure 2), the user traces each letter “A”, “R” and “P” on the touchpad. The recognition process is error-free. Each recognised letter

corresponds to an event “Let”, belonging to the  $V_t$  alphabet, sent to the state machine. On reception of the “Let” event, the automaton stays in the same state “Destination” until “ARPAJON” is selected. Lastly, the user validates the town and the task  $T$  terminates on reception of the “Val” event.

Buttons

In the “Destination” state (see figure 3), the user turns the rotary button to go through the alphabet (in one direction or another) and to select the desired letter “A”, “R” or “P”. Then, the user must confirm the selection by pushing the validation button. Each rotation of the rotary button corresponds to an event “Rb” and each validation corresponds to an event “Val”, belonging to the  $V_b$  alphabet, sent to the state machine. On reception of “Rb” and “Val” events, the automaton stays in the same state “Destination” until “ARPAJON” is selected. Lastly, the user validates the town and the task  $T$  terminates on reception of the “Val” event.

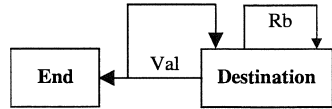
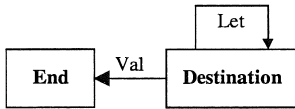


Figure 2: State machine of the touchpad

Figure 3: State machine of the buttons

**3.3 Computation of the Time Delay**

Using expression (I), we are now able to compute the time delay (TD) for the touchpad and the buttons respectively, given the task  $T$ .

Step	Events		Number of events	
	Touchpad	Buttons	Touchpad	Buttons
1	Let (“A” letter)	12 x Rb ( $M \rightarrow A$ ) <sup>1</sup>	1	12
2	/	Val (“A” letter)	0	1
3	Let (“R” letter)	5 x Rb ( $M \rightarrow R$ )	1	5
4	/	Val (“R” letter)	0	1
5	Let (“P” letter)	3 x Rb ( $M \rightarrow P$ )	1	3
6	/	Val (“P” letter)	0	1
7	Val (“Arpajon”)	Val (“Arpajon”)	1	1
		<b>N(D, T)</b>	<b>4</b>	<b>24</b>

Table 1. Sequence of events generated by the input devices, given the task  $T$

<sup>1</sup> ( $M \rightarrow A$ ) means that to select any letter (“A” in this case) the user begins at the default letter “M” (middle of the alphabet).

To execute task  $T$ , the user manipulates the input device (touchpad or push-buttons) and a series of elementary actions are generated. Table 1 contains, step by step, all the events sent to the state machine (see figures 2 and 3). The sum of the events (last line in the table) determines  $N(D, T)$ . Experimental measurements show us that  $TU(touchpad) \cong 1$  and  $TU(buttons) \cong 0.5$  second. Hence expression (I) gives us the following result:

$$TD(touchpad, T) = N(touchpad, T) * TU(touchpad) = 4 * 1 = 4 \text{ sec}$$

$$TD(buttons, T) = N(buttons, T) * TU(buttons) = 24 * 0.5 = 12 \text{ sec}$$

#### 4 Conclusion and Comments

As an illustration of the method presented in section 2, the comparison of two input devices gives the following result : to select the town called « Arpajon » in a list of 400 different cities, the touchpad is 3 times faster than the push-buttons. This result is obtained under the following assumptions :

- we do not take into account the ergonomic aspects such as training and ease of manipulation of the devices,
- the result also depends on the context in which the device is used and on the user himself.

In spite of these assumptions, the method seems to provide an interesting approach to compare the efficiency of input devices. It gives a first estimation of the time performance which is an essential criterion in the context of in-vehicle systems. Further experiments, in real conditions, must be carried out to validate the method.

#### References

- [Card et al., 1983] Card, S. Moran, T. Newell, A. (1983). *The Psychology of Human-Computer Interaction*, pages 259-311, Hillsdale, N.J.: Lawrence Erlbaum Associates.
- [Coleman et al., 1991] Coleman, M.F. Loring, B.A. and Wiklund, M.E. (1991). User Performance on Typing Tasks Involving Reduced-Size, Touch Screen Keyboards. In VNIS'91, pages 534-549, New York, NJ.
- [De Rosis et al., 1994] De Rosis, F. Cozza, M.T. De Carolis, B. Errore, S. Pizzutilo, S. De Zegher, I. (1994). Adaptive Interaction With Knowledge-Based Systems. In AVI'94, Bari, Italy, June 1-4.
- [Dix et al., 1993] Dix, A. Finlay, J. Abowd, G. Beale, R. (1993). *Human-Computer Interaction*, Prentice Hall Publ., pages 1-570.
- [Kamp et al., 1997] Kamp, J.F. Poirier, F. and Doignon, Ph. (1997). Un dispositif tactile pour la commande en véhicule: étude d'une utilisation à l'aveugle. In IHM'97, pages 175-181, Poitiers, France.
- [Paelke, 1993] Paelke, G. (1993). A Comparison of Route Guidance Destination Entry Methods. In Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, pages 569-573, Santa Monica, CA : The Human Factors and Ergonomics Society.

# FELIX: AN INTERACTIVE RULE MINING INTERFACE IN A KDD PROCESS

Rémi Lehn, Fabrice Guillet, Pascale Kuntz, Henri Briand, Jacques Philippé

IRIN/IRESTE  
BP 60601  
44300 NANTES  
Remi.Lehn@ireste.fr

PerformansSE SA  
La Fleuriaye  
44470 Carquefou

## **Abstract:**

*We present a highly interactive software for mining association rules from large relational tables. The software is composed of three components: a data base, a world wide web based interface which communicates with the base via SQL queries and which visualize relationships between rules via dynamic graph layouts and, a user-driven algorithm for searching relevant rules in a partial search space defined by user's requests and some statistical criteria.*

**Keywords:** Knowledge Discovery in Databases, Association rules, Interactive mining.

## **1 Introduction**

Generally speaking, Knowledge Discovery in Databases (KDD) aims at extracting non-trivial and previously unknown information, often represented by rules, in large databases (e.g. [Frawley 1992]). Due to the massive data -thousands of collected objects described by numerous attributes- the number of possible relationships is huge and prohibits the search for relevant rules by examining each of them. Since the beginning of the decade several knowledge discovery systems have been developed (see [Kodratoff 1999] for a recent comparison); they combine several data-mining techniques such as descriptive statistics, decision-tree induction, clustering, etc, but the majority of them let the users cope on their own with various diagrams and lists of results. As pointed out by Brachman et al. [Brachman 1996], most existing systems reported in the literature have been motivated mainly by new data-mining techniques rather than by the decision-maker's task. However, rule evaluation is a very sensitive task which requires a costly cognitive effort. And, in order to help the user efficiently the emphasis is now placed on the development of highly interactive tools focused on the user.

Besides the knowledge discovery wholly automatic, one can distinguish two approaches [Bandhari 1994]: the semi-automated discovery of knowledge in which a person guides a program to extract relevant information and, the so-called machine-assisted discovery in which a computer program guides a person to discover knowledge from data. The first one refers to the process of data analysts who are used to string

different heterogeneous algorithms together. The second one tries to include the analyst in the discovery loop and "requires that a model of interestingness be used to output data in a human-oriented form to an analyst who uses a specified model of interpretation to discover knowledge" [Bandhari 1994].

In this communication we present a rule mining process based on the second approach. It is composed of a highly interactive interface able to visualize quickly and intelligibly small parts of the large amount of data which are relevant for the user. The chosen representation model is similar to a Bayesian network where nodes represent some attribute conjunctions and arcs represent association rules whose quality is measured by statistical measures. The computation of the network is dynamic and is intrinsically dependent on the user's requests. Starting from a set of pre-selected global descriptions -few attributes-, the user can look for more specific ones. The corresponding states are then added to the network and new associations are computed on line. Conversely, he can focus on peculiar states and looks more general descriptions. In order to present the output data on a user-friendly form, we resort to a world wide web based interface.

The rest of the paper is organized as follows. Section 2 presents the main steps of the rule mining process involved in our software Felix. Section 3 describes the different pruning heuristics of the rule space. Section 4 recalls some cognitive constraints involved in a intelligible visualization and the drawing algorithm we have developed. We conclude in Section 5 with the Felix software structure.

## 2 Main steps of the rule mining process

The data to be analysed are assumed to be in the form of a relational table. The rows of the table describe a set of objects  $O = \{o_1, \dots, o_n\}$  and the columns are the attributes  $A = \{a_1, \dots, a_p\}$  -also called *items*- of these objects. We restrict ourselves here to presence/absence attributes which includes the case of complete disjunctive codings. In this case, each object  $o_i$  is described by an attribute conjunction or in a equivalent way by a subset  $X_i$  of  $A$  called an *itemset*:  $X_i = \{a_1, a_3, a_7\}$  means that only attributes  $a_1, a_3, a_7$  are present for  $o_i$  and, by reference to basket analysis, we say that  $o_i$  contains  $X_i$ . The objective is to extract from the database "relevant" relationships modeled by association rules  $X \rightarrow Y$  between pairs of itemsets.

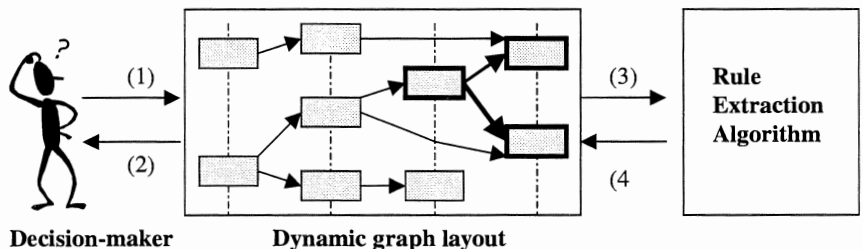


Figure 1: Rule mining steps

The rule mining process is a loop composed of four main stages (figure 1). At first step 1, the user focuses on some proposed descriptions of data which are automatically generated by a pruning heuristic and represented by vertices on a graph. Their selection –step 2- entails a rule extraction algorithm which generate more specific descriptions – i.e. with more attributes- and associated rules according to statistical criteria. Then (step 4), the graph layout is updated to take into account these new informations.

### 3 From data to significant association rules

In any real-world KDD task, the relevance of the rules is highly subjective as it implicitly involves the analyst's background knowledge about the studied domain. However, well-adapted criteria allow to focus his attention on small part of a large amount of data which is interesting. As purely logical properties are too much restrictive here, we resort to statistical measures which take into account counter-examples to some extent.

#### 3.1 Measures of statistical significance

Intuitively, a rule  $X \rightarrow Y$  between two itemsets  $X$  and  $Y$  is statistically significant if it is covered by a large number of objects and refute by few. Many coefficients have been presented in the literature to quantify these features (e.g. [Mingers 1989]) and discussion on their respective properties is far beyond the scope of this paper. From a comparison of Fleury et al. [Fleury 1995] and experimental tests in [Agrawal, 1996] and [Guillaume 1998] we retain three complementary measures.

*Support.* The support of the rule  $X \rightarrow Y$  is defined as a proportion of objects which contain the itemset  $X \cup Y$ . Let  $c: 2^A \rightarrow O$  be a function giving, for any itemset  $X$ , the subset of objects  $o_i$  of  $O$  containing  $X$  at least ( $X \subset X_i$ ). The support  $\rho(X \rightarrow Y)$  is the ratio  $|c(X \cup Y)|/|O|$ .

*Confidence.* The confidence  $\pi(X \rightarrow Y)$  of the rule  $X \rightarrow Y$  is defined as the ratio of the number of all objects which contain both  $X$  and  $Y$  to the number of all objects which contain just  $X$ :  $\pi(X \rightarrow Y) = |c(X \cup Y)|/|c(X)|$ . In inferential statistic this ratio is nothing else than the classical conditional probability.

The conditional probability is well-known to be independent of the sizes of  $O$  and  $c(Y)$  and to a proportional size increasing of  $c(Y)$  and  $c(X)$ . However, the rule  $X \rightarrow Y$  is more likely to be checked where the size of  $c(Y)$  increases or where the size of  $O$  decreases and, it is more meaningful where the set sizes increase in the same proportions. In order to take these variations into account in the rule selection, Gras et al. [Gras, 1993] have introduced an index, called *intensity of implication*, which measures the “surprise” of having few counter-examples for a rule as compared with a random draw.

*Intensity of implication.* Let us consider two randomly selected subsets  $U$  and  $V$  of  $O$  of size respectively equals to  $|c(X)|$  and  $|c(Y)|$ . Let  $N(U, V)$  be the random variable giving the number of objects into  $U \cap V$  and  $N(c(X), c(Y))$  be the number of objects containing  $X \cup Y$  - the number of counter-examples of the rule  $X \rightarrow Y$ . The quality of the implication is as the better as the number of observed counter-examples is small as

compared to the expected one i.e. as  $\Pr(N(U, \bar{V}) < N(c(X), c(\bar{Y})))$  is small. The exact value of this probability derives from the law of the random variable  $N(U, \bar{V})$ .

### 3.2 Extraction rule algorithm

The mining algorithm is an interactive version of the “Apriori algorithm” of Agrawal et al. [Agrawal 1993, 1996]. The basic version only takes into account measures of support and confidence ratio. It proceeds in two stages:

1. Reduce the search space by only keeping itemsets with a support rate larger than a fixed parameter  $\alpha$ . Let  $A_\alpha$  be the set of those frequent itemsets:  $A_\alpha = \{X ; c(X) > \alpha\} \subset P(A)$  with  $P(A)$  the set of all parts of  $A$ .
2. Find association rules between itemsets of  $A_\alpha$  that hold with a given confidence  $\beta$ .

The stage 1 is efficiently solved by a greedy algorithm. First the support for single items are computed and  $\alpha$ -large 1-itemsets are found. Then, iteratively for increasing sizes  $s = 1, 2, \dots$  potential  $s$ -itemsets are generated from the large  $(s-1)$ -itemsets of the previous step. Those which have a support greater than  $\alpha$  are used in the next step to generate itemsets of size  $s + 1$ .

The computation of the potential itemsets is based on the remark that for a  $\alpha$ -large  $s$ -itemset, all its  $(s-1)$ -subsets are  $\alpha$ -large. A similar property on a different search space is used at stage 2 to extract the significant association rules. And, the intensity implication criterium can be introduced at this stage [Guillaume 1998].

In our approach, the  $\alpha$ -large itemsets and the significant association rules are generated dynamically according to the part of the search space the analyst decides to mine.

## 4 Rule visualization

A property always required for drawing graphs which modelize abstract concepts is the readability. This covers physical constraints of the drawing support (e.g. standard size of computer screens) and aesthetic criteria. Aesthetics specify graphic properties that should help the reader to understand and remember the information embodied in the graph (e.g. [Purchase 1997]). They attempt to characterize readability by means of general combinatorial optimization goals. Common adopted criteria include minimize arc crosses and minimize the sum of the lengths of the arcs to avoid long lines which can create confusion.

In addition to these readability requirements, a drawing convention must be specified. For our KDD application, we consider polyline drawings with vertices arranged in vertical layers (figure 1). Each layer is associated with a degree of precision in the knowledge state: layers at the left correspond to general characteristics described by few attributes whereas layers at the right are more specific.

Due to the importance of this problem for many application fields, numerous efficient heuristics have been proposed. However, few of them take the interactivity with the user into account. In most algorithms a graph is given as an input and a drawing is supplied as an output. If a modification is performed (e.g. vertex and arc insertions) the algorithm runs again and produces a new drawing which may be thoroughly different from the previous one. But, important changes between consecutive layouts highly disturbs the



interpretation task and, a KDD process requires drawing methods which preserve the "user's mental map" as much as possible. For this reason, we have developed a genetic algorithm which is particularly efficient for this problem. By computing at each step a set of potential solutions genetic algorithms allow indirectly to approximatively solve a multicriterion problem: a set of potential solutions (i.e. the population) is computed according to aesthetics measured by the fitness and, a solution is selected in this set according to its resemblance with a previous drawing (we refer to [Guillet 1999] for details).

### 5 Software

The software is designed around an open-architecture involving three connected components :

- A *data-base manager*, to store data and discovered rules,
- A *knowledge discovery manager*, to compute rules from data in accordance with the user's requests,
- A *graphic user interface (GUI)*, for graph drawing and interaction managing.

Those three parts are autonomous and use standard protocols to communicate. In particular, any data base manager can be connected if it communicates using SQL requests with the knowledge discovery manager component. Our knowledge manager is built in Prolog, a well-adapted language to manipulate rules. We also made the choice to design an open-GUI by using the Web technology (Java, html, cgi scripts, client/server, and network capabilities). This universal Web interface offers many facilities: portability, java power, remote use, and also a standard protocol (http) between the knowledge manager and the GUI.

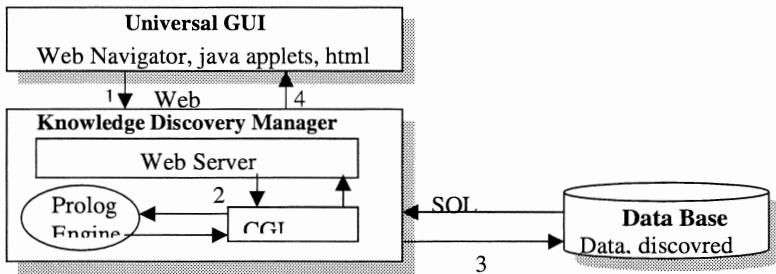


Figure 2: Software structure

A typical user's action is decomposed as follows: (1) A user's action triggers a Java graphic event that is sent to the knowledge manager. (2) The user request launches a CGI script on the web server that runs the local rule extraction algorithm on the Prolog engine. (3) The Prolog engine makes data base accesses and stores the computed rules via SQL requests. (4) The Java graph is updated with the new rules.

### References

- [Agrawal 1993] Agrawal, R. Imielinski, T. and Swani, A. (1993). Mining association rules between sets of items in large databases, In Proc. of ACM SIG-MOD Conf. on Management of Data, pages 207-216, Washington DC.
- [Agrawal 1996] Agrawal, R. Mannila, H. Srikant, R. Toivonen, H. and Verkamo, A. (1996). Fast discovery of association rules, In Advances in Knowledge Discovery and Data Mining, Fayyad U.M. and al. eds, pages 307-328, AAAI Press.
- [Bhandari 1994] Bhandari, I. (1994). Attribute focusing: machine-assisted knowledge discovery applied to software production process control, *Knowledge Acquisition*, volume 6, pages 271-294.
- [Brachman 1996] Brachman, J.R. and Anand, T. (1996). The process of knowledge discovery in databases: a human-centered approach, In Advances in Knowledge Discovery and Data Mining, Fayyad U.M. et al. eds, pages 37-58, AAAI Press.
- [Fleury 1995] Fleury, L. Briand, H. Philippe, J., and Djeraba, C. (1995). Rule evaluations for knowledge discovery in databases, In Proc. of the 6th Int. Conf. on Database and Expert System Applications, pages 405-414, London.
- [Frawley 1992] Frawley, W. Piatetsky-Shapiro, G. and Matheus, C. (1992). Knowledge discovery in databases: an overview, *AI Magazine*, volume 14, number 3, pages 57-70.
- [Gras 1993] Gras, R. and Lehrer, A. (1993). L'implication statistique, une nouvelle méthode d'analyse des données (in french), *Revue Mathématiques, Informatique et Science Humaines*, volume 120.
- [Guillaume 1998] Guillaume, S. Guillet, F. and Philippe, J. (1998). Improving the discovery of association rules with intensity of implication, In Proc. of the 2nd Eur. Symp. on Principles of Data Mining and Knowledge Discovery, Zytkow, J.M. and Quafafou, M. eds, Lecture Notes in Computer Science, volume 1510, pages 318-327, Springer-Verlag.
- [Guillet 1999] Guillet, F. Kuntz, P. and Lehn, R. (1999). A genetic algorithm for visualizing networks of association rules, In Proc. of 12<sup>th</sup> Int. Conf. on Industrial & Engineering Appl. AI & Expert Systems, Imam, I.F. et al. Eds, Lecture Notes in Computer Science, volume 1611, pages 145-154, Springer-Verlag.
- [Kodratoff 1999] Kodratoff, Y. (1999), Typologie des logiciels d'extraction de connaissances dans des bases de données, Journée Extraction de Connaissances à partir des Données, Personnel report, ESIEA, Laval.
- [Mingers 1989] Mingers, G. (1989). An empirical comparison of selection measures for decision-tree induction, *Machine learning*, volume 3, pages 319-342, 1989.
- [Purchase 1997] Purchase, H. (1997). Which aesthetic has the greater effect on human understanding ?, In Proc. of Graph Drawing'97, Di Battista, G. ed., Lecture Notes in Computer Science, volume 1353, pages 248-261, Springer-Verlag.

# HOW A GROUPWARE BASED ON A KNOWLEDGE STRUCTURING METHOD CAN BE A COLLECTIVE DECISION-MAKING AID: THE MEMO-NET TOOL

Myriam Lewkowicz, Manuel Zacklad

Laboratoire Tech-CICO (Technologies de la coopération pour l'innovation et le changement organisationnel)

Université de Technologie de Troyes

12, rue Marie Curie BP 2060

10010 Troyes Cédex France

myriam.lewkowicz@univ-troyes.fr

manuel.zacklad@univ-troyes.fr

**Keywords:** Collective decision-making, Design Rationale, groupware, Problem-Solving Methods

## 1 Introduction

Links between Decision-Aid and CSCW are mostly materialized by computer-based facilities for the exploration of unstructured problems in a group setting. There are for example GDSS (Group Decision Support System) aids for decision structuring, alternative ranking and voting tools. To parallel with Bernard Roy decision-aid problematics, these tools support sort, choice or arrangement. But the tool that we will propose is referring to description problematics by helping idea generation or issue analysis.

This kind of tool has to make materialize the arguments exchanged between decision-makers. Design Rationale researches are dedicated to formalization and memorization of the entire argumentative process that leads to decision in design situations. We have then studied this field and began with an empirical study in order to understand how long collective decision-making processes occur in design projects. This study permitted us to identify the limits of existing models.

We have then proposed to enrich Design Rationale models to take into account processes where solutions are not directly mentioned but rise up at different abstraction levels or took the form of constraints. In this paper, we are going to show how we enriched Design Rationale with concepts of Problem-Solving Methods in the DIPA model and how we implemented it in the MEMO-Net tool.

## 2 CSCW, groupware and decision-aid

The goal of groupware is to assist group in communicating, in collaborating and in coordinating their activities. Groupware may be seen as the multi-user software supporting CSCW systems or, as defined by Malone [cited in Coleman and Shapiro, 1992], "information technology used to help people work together more effectively".

CSCW may also be viewed as the scientific discipline that guides the thoughtful and appropriate design and development of groupware [Greenberg, 1991].

There are two ways of viewing the variety of groupware, a time space taxonomy and an application-level taxonomy. In the first one, synchronous is opposed to asynchronous and face-to-face (see the classical 2x2 matrix in [Ellis *et al.*, 1993] or [Bullen and Bennett, 1993]), in the second one we can list categories of applications (Message systems, GDSS and Electronic Meeting Rooms, Computer Conferencing, Coordination Systems...).

Traditionally, decision-aid is interested by GDSS, meeting rooms, and computer conferencing, which refer to asynchronous groupware. If we refer to Bernard Roy problematics [Roy, 1985], they correspond to choice, sort or arrangement. But we can't forget the description of the problem, of its context, of the whole project and the argumentation prior the decision. To understand a decision-process afterwards and to reuse its solutions, it is important to memorize all the evoked solutions and not only the ones that have been selected for the meeting. These preoccupations are closely to the fourth problematics of Bernard Roy: the description one: "*helping to describe actions and/or their consequences on a systematic and formalized way or to elaborate a cognitive procedure*" [Roy, 1985, p.88]. Our interest focuses then on another kind of groupware, which help idea generation or issue analysis.

Researchers who studied this field have concluded that if a groupware permits to record solutions' elaboration processes, it is not sufficient for an efficient knowledge management [Grudin, 1993]. It has to be completed by a method that structures exchanges for a better dialogue 's quality and for an ideas' management that would not be only chronological. These reflections have led to the IBIS method [Burgess-Yakemovic and Conklin, 1990], connected afterwards to Design Rationale researches.

### 3 Design Rationale: critics and ABRICo proposition

Design Rationale researches are interested in problems appearing through capture, articulation, representation and use of the rationale made explicit. The most known and experimented method is IBIS. IBIS and its different implementations (g-IBIS, it-IBIS...) have been experimented many times more or less successfully. In a general way, we can have two kinds of reservation about this method [Fischer *et al.*, 1996]: firstly, the non-representation of dependencies between issues, and secondly the ignorance of non-deliberated issues.

We have made partly similar criticisms of the QOC (Questions Options Criteria) method [MacLean *et al.*, 1996] and classical Design Rationale formalisms in our previous work [Lewkowicz and Zacklad, 1998-a, 1998-b]. Formalisms as QOC do not correspond to collective design situations that have to take into account the process' dynamics and the participants' roles. We had then proposed to represent these complex processes with an original formalism that we had called ABRICo (for the French words Accords, Buts, pRositions, Interprétations en Conception, that mean agreement, goals, propositions, interpretations through design).

We have tested this formalism by representing real complex collective decision-making situations. Seeing that this experimentation was conclusive, we built a first

version of a tool based on these concepts, MEMO-Net, and we submitted it to professional groups for a first evaluation. Unfortunately, the model proposed to users seemed to be too abstract for an easy comprehension, conclusion that re-opened the whole question of the ABRICo model and the first version of the tool.

One reason for the difficulty to implement ABRICo was, from our point of view, that the complex decision process formulation was too far from design situations which actors were confronted to. Where the traditional but simplistic Design Rationale models permitted an easy appropriation by actors, the ABRICo model, although more realistic from a cognitive point of view, appeared both too laconic and too far from concrete implementation's conditions in work situations for which we built it.

#### **4 The problem-solving methods contribution: the DIPA model**

In order to connect to the cognitive dimension of reasoning, we enriched ABRICo with problem-solving methods' concepts from knowledge engineering. This enrichment was translated into a new model, DIPA (for the French words Données, Interprétations, Propositions, Accord, which mean facts, interpretations, propositions, agreement). This model has itself two declinations according to the situations that lead the actors to give importance to analysis or synthesis processes (in the sense for example of KADS methodology [Wielinga, 1993]). This link with problem-solving method is, to our point of view, a natural evolution in our researches of more realistic Design Rationale models that fit to real projects' complexity.

The requirements of our goal to present both analysis and synthesis models to designers' teams that we were confronted to may seem amazing. Actually, it may appear natural at first glance to propose only synthesis models and their variants (routine design, configuration...). But our practical experience of design meetings showed us that analysis activities are also frequent. For example, as soon as a prototype has been developed, its functioning analysis will give important information that will be reintroduces in the process of solutions' generation.

These observations are also in accordance to cognitive ergonomic psychology [Darses, 1994] results that teach us that design situations in the organizational sense in fact generate two distinct phases in activity: solutions' generation and evaluation of these solutions phases. The first corresponds to synthesis problems in KADS sense and is close to design models in this method. The second corresponds to analysis problems whose diagnosis models are the most known.

It is also in accordance with an interpretation [Zacklad and Fontaine, 1996] of the Heuristic Classification of Clancey [Clancey, 1985]. These authors expose that analysis and synthesis are based on an heuristic reasoning that constructs a solution that is a justification of the possible causes of a state (analysis) or a justification of the compatibility of an outline with design constraints (synthesis).

The formalism used to describe DIPA is inspired by KADS' one [Wielinga *et al.*, 1993], [Schreiber and Wielinga, 1993] without strictly following these method's conventions on the way to represent inference structure.

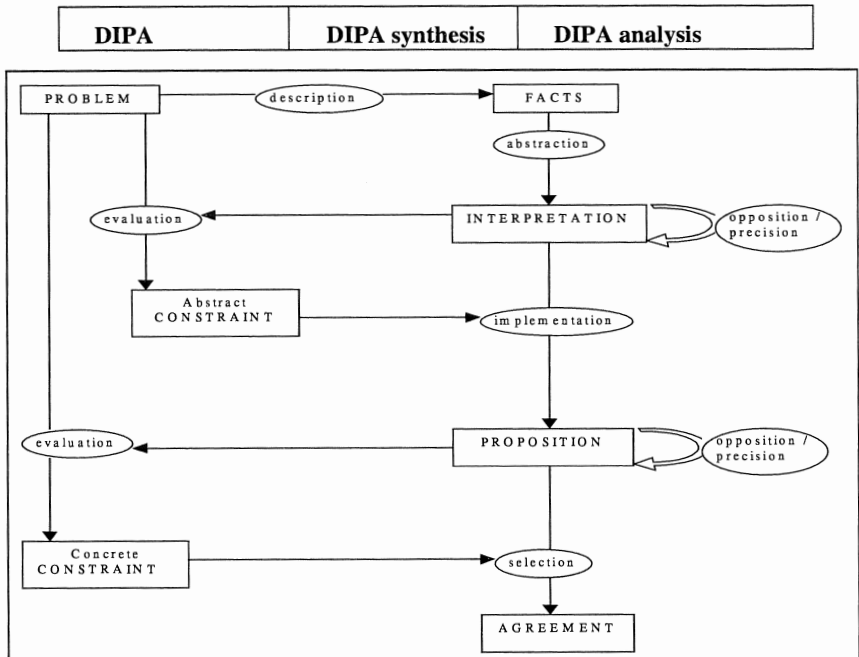


Figure 1: DIPA, an heuristic meta-model of design reasoning for analysis and synthesis

Problem	Goal	Dysfunction
Fact	Need	Symptom
Interpretation	Functionality	Cause
Abstract constraint	Constraint	Constraint
Proposition	Means	Repair
Concrete constraint	Constraint	Constraint
Agreement	Choice	Choice

Table 1. Implementation of DIPA meta-model for synthesis and analysis activities

### 5 MEMO-Net

We have implemented the DIPA model to build the MEMO-Net groupware. This system consists of two modules, one for synthesis phases (named "design" in the interface), and the other for analysis phases (named "diagnosis" in the interface). Its goal is to allow a project team to solve problems met during design by alternating the two types of activity on a cooperative way.

The exchanges' structure permits both to guide the solving process and to organize the arguments, particularly in arguments' capitalization perspective.

In the diagnosis module, actors of the project team identify a dysfunction and evoke symptoms, causes or repairs. In the design one, when the goal is expressed, the actors evoked needs, functionalities and means. To contribute, actors click on the following buttons (indicate a dysfunction, symptom, cause, repair) and then create the corresponding forms:

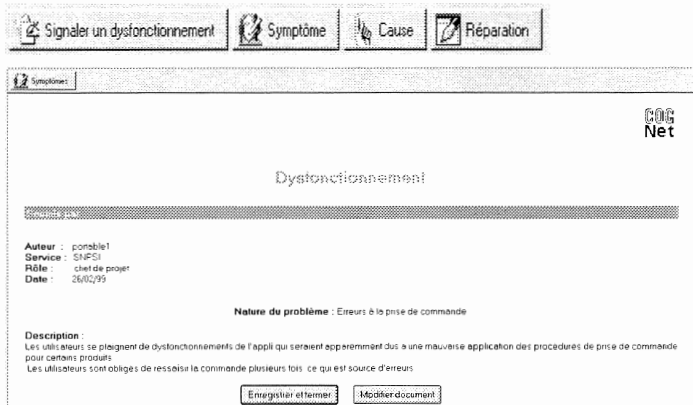


Figure 2: buttons to create new forms and form to describe a dysfunction

Contributions are classified chronologically or according to DIPA model categories, or to the authors' names, their roles, or their department.

The example that we are now going to describe is about a team of designers of a trading application. The dysfunction noticed is that application's users make many mistakes when they put in an order for some products. A first symptom seemed to be caused by interface's defaults, and improvement propositions are evoked, as well as a constraint: interface has already been modified twice. An other cause proposed is the lack of training, and two repairs are suggested: training seminars or free disposal of books with trade rules. In the screen copy below, one can see the chronological view of contributors' propositions:

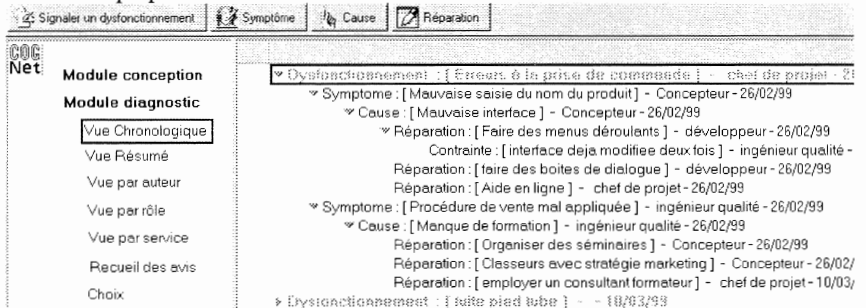


Figure 3: Chronological view of a diagnosis problem-solving method

When users have debated, it is possible to submit one of their propositions to the others for agreement, in order to collect their opinion and take a decision. This last step

corresponds to "selection" inference of DIPA model, which permits to reach a definitive agreement on the advisable proposition.

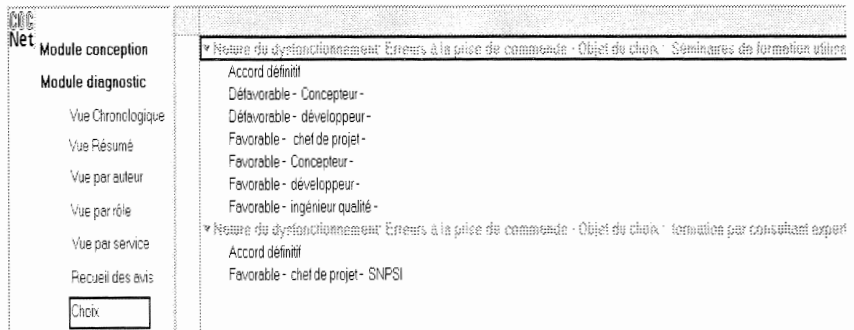


Figure 4: The "choice" view where one can see opinions gathered on a proposition.

## 6 Conclusion

We have shown in this paper that GDSS, meeting rooms and computer conferencing are useful groupware for a decision-aid based on sort, choice or arrangement problematics, but if we are interested in description problematics, we have to look at groupware that permit a memorization of the whole communication process. In order to allow the management of this memorized knowledge, it has to be structured. We then proposed the DIPA formalism to represent collective decision-making processes, inspired by Problem-Solving Methods in order to connect to cognitive dimension of actors' reasoning. The enrichment of groupware with a knowledge structuring method could permit both to guide collective work processes and to obtain useful knowledge.

We are now going to experiment DIPA model via MEMO-Net groupware, and we will evaluate the MEMO-Net influence on the speed of agreements obtaining and on the quality of the proposed solutions. We will also observe two groups of people solving several times the same problems, sometimes by using a non-structured groupware (a forum for example), and sometimes by using our MEMO-Net tool.

## References

- [Bullen and Bennett, 1993] Bullen, C.V., Bennett, J.L. (1993). Groupware in practice: An interpretation of work experiences, in Baecker, R. M. (Ed.) *Readings in Groupware and Computer-Supported Cooperative Work*, Morgan Kaufmann Publishers, Inc.
- [Burgess-Yakemovic and Conklin, 1990] Burgess-Yakemovic, K.C. and Conklin, E.J. (1990). Report on a Development Project Use of an Issue-Based Information System, in Halasz, F. (Ed.) (1990). *CSCW 90: Proceedings of the Conference on Computer-Supported Cooperative Work*. Los Angeles, Oct. 7-10, 1990. Association for Computing Machinery.
- [Clancey, 1985] Clancey, W. (1985). *Heuristic Classification*, Artificial Intelligence Journal, 27, pp. 289-350, 1985.



- [Coleman and Shapiro, 1992] Coleman, D. and Shapiro, R. (1992). Defining Groupware. Special Advertising Section to *Network World*, June 22, 1992
- [Darses, 1994] Darses, F. (1994). *Gestion des contraintes dans la résolution des problèmes de conception*. Thèse de doctorat, Spécialité Psychologie Cognitive. Paris, Université de Paris 8.
- [Ellis et al., 1993] Ellis, C.A., Gibbs, S.J., and Rein, G.L. (1993). Groupware some issues and experiences, in Baecker, R. M. (Ed.) *Readings in Groupware and Computer-Supported Cooperative Work*, Morgan Kaufmann Publishers, Inc.
- [Fischer et al., 1996] Fischer, G., Lemke, A.C., McCall, R., Morch, A.I. (1996). Making Argumentation Serve Design, in Moran, T. P. and Carroll, J. M. (Ed.) *Design Rationale Concepts, Techniques and Use*, Lawrence Erlbaum Associates.
- [Greenberg, 1991] Greenberg, S. (Ed.) (1991). *Computer-Supported Work and Groupware*. Academic Press
- [Grudin, 1993] Grudin, J. (1993). Groupware and Cooperative Work: Problems and Prospects, in Baecker, R. M. (Ed.) *Readings in Groupware and Computer-Supported Cooperative Work*, Morgan Kaufmann Publishers, Inc.
- [Lewkowicz and Zacklad, 1998-a] Lewkowicz, M., Zacklad, M. (1998-a). La capitalisation des connaissances tacites de conception à partir des traces des processus de prise de décision collective, *Actes de la conférence Ingénierie des Connaissances*. Pont-à-Mousson, mai 1998.
- [Lewkowicz and Zacklad, 1998-b] Lewkowicz, M., Zacklad, M. (1998-b). A formalism for the rationalization of decision-making processes in complex collective design situations, *Proceedings of COOP*. Cannes, may 1998.
- [MacLean et al., 1996] MacLean, A., Young, R.M., Bellotti, V.M.E., Moran P. (1996). *Questions, Options and Criteria: Elements of Design Space Analysis*, in Moran, T. P. and Carroll, J. M. (Ed.) *Design Rationale Concepts, Techniques and Use*, Lawrence Erlbaum Associates.
- [Roy, 1985] Roy, B. (1985). *Méthodologie Multicritère d'Aide à la Décision*, Economica.
- [Schreiber and Wielinga, 1993] Schreiber, G., Wielinga, B. (1993). *Model Construction*, in Schreiber, G., Wielinga, B., Breuker, J. (Eds.) *KADS a principled approach to knowledge-based system development*, Academic Press.
- [Wielinga et al., 1993] Wielinga, B., Schreiber, G., Breuker, J. (1993). *Modelling Expertise*, in Schreiber, G., Wielinga, B., Breuker, J. (Eds.) *KADS a principled approach to knowledge-based system development*, Academic Press.
- [Zacklad and Fontaine, 1996] Zacklad, M., Fontaine, D. (1996). *L'acquisition des connaissances classificatoires pour les systèmes à bases de connaissances*, in Aussenac-Gilles, N., Laublet, P., Reynaud, C. (Eds.) *Acquisition et Ingénierie des Connaissances*, Cepadues-Éditions.



# VISUALIZATION IN DATA-MINING AND KNOWLEDGE DISCOVERY

François Poulet

ESIEA Recherche  
Parc Universitaire de Laval-Changeé  
38 rue des docteurs Calmette et Guérin  
53000 LAVAL - FRANCE  
poulet@esiea-ouest.fr

## **Abstract:**

*In this paper, we describe data exploration and visualization techniques in data mining and knowledge discovery. The data sets we are interested in are very large and their components are multidimensional data. The representation of these data is done in a low dimensional environment. First, we present human perception capabilities: preattentive processing and regular processing. Preattentive processing is the study of visual features that are detected rapidly and accurately by the human visual system. We study how to use research results of human perception capabilities in data exploration techniques: what kind of geometric features are the best to use in visualization tools, what rules can be inferred from it, to built high quality visualization tools. Then we present a survey of existing visualization methods in knowledge discovery with a classification of these methods. The last part talks about human-computer interactions, that are of great quality, but mostly not interactive. We present some graphical interactive methods which allow such processing.*

**Keywords:** Multidimensional Visualization, Visual Data-Mining, Human-Computer Interactions, Pre-attentive Processing, Visual Perception.

## **1 Introduction**

First, we present some results of research in human visual perception and how to use them in data exploration visualization techniques. We focus on two different types of perceptions: what is called pre-attentive processing and regular human perception. We study graphical features recognition that is used for knowledge discovery and data-mining.

The second part of the paper is a brief survey of existing visualization techniques in data-mining and knowledge discovery with a classification of these methods. For each method, its advantages / disadvantages are discussed, and what type of data the method fits the best with.

In the final part, we deal with human computer-interactions. The existing visualization tools are of great quality, but the user cannot interact with the result of a visualization tool. We present an interactive visualization method that allows the user to perform an iterative process on the data, and another one to improve the comprehensibility of the results of non-graphical algorithms.

Then we conclude on this work and its extensions and applications in other topics where visualization appears.

## 2 Human visual system

For many years, vision researchers in cognitive psychology have been working to explain how the human visual system analyses images [Csinger, 1992]. A particular result has been the discovery of a small set of visual properties that are processed preattentively: very fast (typically accomplished within 100 ms to 250ms), very accurately and without any particular effort. We present some of these properties and how they can or cannot be combined together. We also study regular human vision processing : what kind of geometric features are the best to use in visualization tools (or the ones for which human perception is the best).

### 2.1 Preattentive processing

An example of preattentive processing (figure 1a) is the detection of a black square in a group of white ones. But the same black square cannot be detected preattentively in figure 1b because of the black circles (we call this: visual interference).



Figure 1: Preattentive or not

This simple example shows the main problem of using preattentive properties: if a property A and a property B are preattentive, when we use them together, the result is not necessarily a preattentive property or only one is always preattentive, and not the other one. A list of papers about two-dimensional features shown to be preattentive can be found in [Healey, 1996]. These features include boundary, length, thickness, texture, size, intersection, brightness, hue... We focus on techniques used in exploratory data analysis including target and boundary detections. Form and hue are two preattentive features, what happens if we mix them together? As shown in figure 2 vertical hue boundary is detected preattentively with different forms in both groups, but vertical form boundary is not detected preattentively because of random hue in both groups.



Figure 2: Interference between preattentive properties

Similarly, random brightness interferes with hue boundary but brightness boundary is preattentively detected with random hue in both groups. These examples show the difficulty of using several preattentive properties together. These properties should allow very outstanding visualization tools (a large amount of data can be visualised accurately and rapidly) when these interference problems are listed.

Lets now consider regular human vision processing.

## 2.2 Regular human vision processing

In this part we study geometric features used in graphical data analysis to show which ones are the best to use in visualization tools (or the ones for which human perception is the best), what rules can be inferred from it, to built high quality visualization tools. The first step is to try to respond to questions like: which graphical feature is detected rapidly, which one is accurately measured, how many features can we distinguish, how should color be used ... and then how to use the results to get high-quality visualization software.

Here again, we focus on techniques used in exploratory data analysis and to begin, we study absolute judgement of 1-D stimuli. The result is the number of distinct levels that the average participant can identify with a high degree of accuracy (measured in bits):

- position on a line (pointer at an arbitrary position between two markers) : 3.25 bits (10-15 levels)
- line geometry : - length: 2.6-3 bits  
- direction: 2.8-3.3 bits
- sizes of squares : 2.2 bits
- hue: 3.1 bits
- brightness: 2.3 bits

Mean value for 1-D signal is 2.6 bits.

The results of absolute judgement of multidimensional stimuli are :

- dot in a square: should be twice that of position on a line (6.5 bits), but measured at 4.6 bits.
- size, brightness and hue: 4.1 instead of 7.6

- hue and saturation: 3.6 instead of 5.3

It seems that having a little information about a lot of parameters is the way we do things (this agrees with linguistic theory).

These results are about an absolute measurement, in detection (relative measurement) we classify the ten following perception tasks:

- colour hue and saturation
- density
- length, angle, slope, area
- volume
- position along a common scale and along identical non-aligned scales.

Experiments showed errors in perception orderer in increasing error as follows:

- position along a common scale,
- position along identical, non-aligned scales
- length
- angle / slope
- area
- volume
- colour hue, saturation and density

These experiments show that colour, which is used intensively in all visualization tools, is one of the less accurate feature. We must keep in mind that relative judgement (detection) is more powerful than absolute one (measure) and that bit rates increases with dimensionality (up to 10).

### 3 Survey of visualization techniques

The second part of the paper is a survey of existing visualization methods in knowledge discovery with a classification of these methods. For each method, its advantages / disadvantages are discussed, and what type of data (symbolic or numeric, continuous or discrete, with a few or large number of attributes or items) does the method fit the best with. We only talk about visualization techniques used in data-mining and knowledge discovery. There are three different goals of data visualization [Keim, 1996]:

- explorative analysis,
- confirmative analysis,
- presentation.

In explorative analysis, the starting point is a set of data without hypotheses about the data, the process must be interactive and is a search for structures, boundaries..., the result is a visualization of the data which provides hypotheses about the data.

In confirmative analysis, the starting point is a set of hypotheses about the data, the process is a goal-oriented examination of the hypotheses and the result is a visualization that allows confirmation or rejection of the hypotheses.

In presentation, the starting point is a set of fixed facts, the process is the choice of an appropriate presentation technique and the result is a high-quality visualization of the data presenting the facts. We focus on the two first classes of visualization techniques: the explorative and confirmative techniques.

The first work on exploratory data visualization techniques was [Bertin, 1967] and later [Bertin, 1981] and [Tufté, 1983]. They have given general rules for layout, colour composition of data with inherent 2D/3D-semantics. Then techniques for a particular area (CAD, medical,...) with an underlying physical model were developed and more recently visualization techniques for arbitrary multidimensional data without any underlying physical model.

The data that are processed are:

- numerous
- of various types:
  - numeric, symbolic
  - discrete, continuous
  - relation between data
  - variation of the data

An simple example of the data sets processed in data-mining, from Clementine (a commercial data-mining software programme), is made of numerical and symbolic data (200 items). The attributes are:

- age, continuous
- sex, symbolic with the values: male, female
- blood pressure, symbolic with the values: high, normal, low
- cholesterol, symbolic with the values: high, normal
- Na: continuous
- K: continuous
- Class: drugX, drugY, drugA, drugB, drugC

An item of this data set is: 23, F, HIGH, HIGH, 0.792535, 0.03567, drugY

A classification of visualization techniques may be the following one:

- basic techniques,
- geometric techniques,
- symbolic techniques,
- hierarchical techniques,
- 3D techniques.

Basic techniques are the techniques used in various spreadsheets: pie charts, histograms, etc., their main advantage is comprehensibility but they can represent only simple relations between data.

Geometric techniques are the visualization techniques that perform geometric transformations and a projection. In these techniques we find 2D and 3D scatterplot-matrices [Andrew, 1972], projections views [Furnas and Buja, 1994], parallel coordinates [Inselberg, 1985]. Scatterplot-matrices can be used with a large number of items but the number of attributes is the dimension of the matrix (2 or 3D-matrix), and the attributes must be continuous or discrete with a large number of possible values for an efficient visualization.

In symbolic techniques, the basic idea is the visualization of the data values as features of icons. Two types of techniques can be distinguished: Chernoff-faces [Chernoff, 1973] and glyphs [Beddow, 1990], and stick-figures [Pickett, 1970]. Chernoff-faces and glyphs are used when a small number of attributes and items are to be visualized, stick-figures are used when a few attributes and a large number of items are processed.

In the last classes of visualizations techniques (hierarchical and 3D-techniques) we find specific visualizations algorithms like decision tree visualization or InfoCrystal [Spoerri, 1994] (specific for text-mining).

To conclude on these visualizations techniques we can say, there is no one which is the best, but the user of a high-quality visualization software must find all of them to be able to process any kind of data.

## **4 Human-computer interactions**

Interactions between the user and the computer are two-fold: from the user to the computer, the user gives instructions to the computer and the computer gives results to the user. The first way is Human-computer interactions and this area has made real progress in the last years: from a simple keyboard and black and white text screen to the keyboard/mouse/colour graphical windows systems we all use today. The second way is the interactions from the computer to the user, here, there was a great improvement too, from a simple text to multiple graphical visualizations. But in nearly all visualization tools, the user cannot interact with the result of a visualization. Using the result of a visualization as a new entry for a visualization tool or another kind of algorithm is impossible. This means there is only one tool that can be applied to the data, but in knowledge-discovery and data-mining, it is very difficult to get a significant result at the first step of data processing. Data-mining requires an iterative processing, where the miner applies successively different tools on the original data. We present some graphical interactive methods which allow such processing, that is what we call visual data-mining.

### **4.1 Interaction on scatterplot-matrices**

In explorative data analysis, a great visualization technique is the scatterplot-matrix, but in the existing commercial tools we get the result and we cannot do anything else. We added some interactive tools to scatterplot-matrices: removing an element, drawing the boundary of a set of elements belonging to the same class. etc. The user draws the



boundary (a line/plane or a 2D/3D-box) on the screen with the mouse (figure 3a), the equations of the corresponding frontier are calculated and can be used to create a new attribute, for example. In figure 3b we create a new attribute, and the result is used for a decision tree induction algorithm (C4.5), the size of the resulting tree goes from 19 nodes to 10 nodes and the prediction error goes from 7% to 0%, just because we added a new attribute that was, by the way of a simple visualization, obviously important (to classify the elements of a particular class).

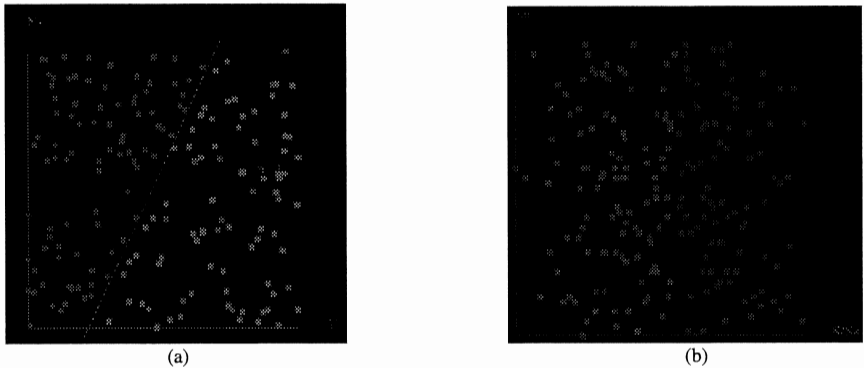


Figure 3: interactive definition of the boundary, creation of a new attribute

These kinds of graphical interactive methods can be used to discover / create « knowledge » from the data but they can also allow a better comprehensibility of the results given by a non-graphical algorithm.

## 4.2 Improving the comprehensibility of the results

Another way graphical visualization tools can help the user is the graphical presentation of the results given by a data-mining algorithm. For example, we use the decision-tree induction algorithm C4.5 on a well known simple data set from Irvine: iris. The result given by C4.5 is the following one:

```

petal_width <= 0.6 : Iris_setosa (50.0)
petal_width > 0.6 :
| petal_width <= 1.6 : Iris_versicolor (49.0/1.0)
| petal_width > 1.6 :
| | petal_length > 5 : Iris_virginica (17.0)
| | petal_length <= 5 :
| | | sepal_length <= 5.8 : Iris_virginica (2.0)
| | | sepal_length > 5.8 : Iris_versicolor (2.0)

```

This result is easy to understand for an expert in data-mining but for the person, expert in his own area, who try to use such an algorithm, this result may be surprising, not very meaningful. The same result can be graphically interpreted and give the following representation, that is easier to understand for everyone.

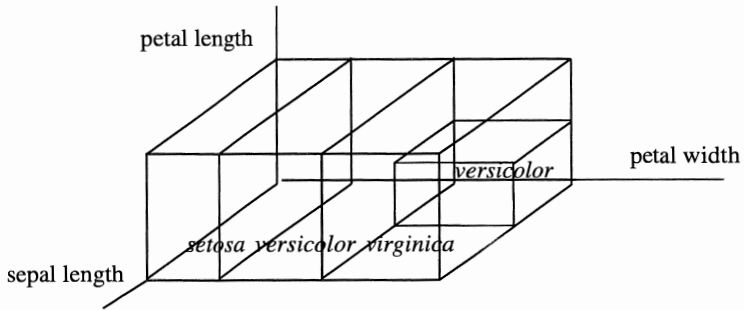


Figure 4: graphical representation of a decision tree

We have presented two different powerful methods to improve interactivity or comprehensibility in data mining tools. A better interactivity of data analysis visualization allows the user to perform an iterative mining of the data. Graphical visualization can also be used to improve comprehensibility of other non-graphical data-mining algorithms.

## 5 Conclusion

In this paper, we have described some improvements of visualization techniques in data-mining and knowledge discovery. The results of research in cognitive psychology, and more precisely in pre-attentive processing, can improve the efficiency of existing visualization algorithms. They should allow the user to process large data sets rapidly and with a great accuracy. These results are not used in the existing commercial visualization software in data mining and knowledge discovery, neither in other visualization software.

We have also shown that improved interactivity in visualization tools allows the user to perform an iterative mining of the data. We do not pretend visualization tools are the best methods for data mining and knowledge discovery, but we do think they are very interesting, and they can be used together with other (graphical or not) algorithms, for more interactivity, accuracy and comprehensibility of the results.

## References

- [Andrew, 1972] : D.Andrews (1972). Plots of High-Dimensional Data, *Biometrics*, vol(29):125-136.
- [Becker, 1997] : B.Becker (1997). Volume Rendering for Relational Data, to appear in *Proceedings of Information Visualization 1997*.
- [Beddow, 1990] : J.Beddow (1990). Shape Coding of Multidimensional Data on Microcomputer Display, *Visualization'90*, San Francisco, CA : 238-246.
- [Bertin, 1967] : J.Bertin (1967). *Sémiologie graphique*, Edts Gauthier-Villars, Mouton & Cie.
- [Bertin, 1981] : J.Bertin (1981). *Graphics and Graphic Information Processing*, Berlin.

- [Card et al., 1999] : S.K.Card, J.D.Mackinlay, B.Shneiderman (1999). Readings in Information Visualization, Using Vision to Think, Morgan Kaufman Publishers.
- [Chernoff, 1973] : H.Chernoff (1973). The Use of Faces to Represent Points in k-Dimensional Space Graphically, in Journal American Statistical Association, vol(68) : 361-368.
- [Csinger, 1992]: A.Csinger (1992). The Psychology of Visualization. Technical Report, Department of Computer Science, University of British Columbia, TR-92-28.
- [Furnas, 1986] : G.Furnas (1986). Generalized Fisheye Views, Proc. ACM CHI Int.Conf. on Human Factors in Software, CHI'86 : 16-23.
- [Furnas and Buja, 1994] : G.Furnas and A.Buja (1994). Prosections Views : Dimensional Inference through Sections and Projections, Journal of Computational and Graphical Statistics, vol(3), n 4 : 323-353.
- [Healey, 1996] : C.G.Healey (1996). Effective Visualization of Large Multidimensional Datasets, PhD thesis, University of British Columbia.
- [Inselberg, 1985] : A.Inselberg (1985). The Plane with Parallel Coordinates, Special Issue on Computational Geometry, The Visual Computer, vol(1): 69-97.
- [Keim, 1996] : D.A.Keim (1996). Databases and Visualization, Tutorial Notes, ACM-SIGMOD'96.
- [Pickett, 1970] : R.M.Pickett (1970). Visual Analyses of Texture in the Detection and Recognition of Objects, Picture Processing and Psycho-Pictorics, B.S.Lipkin, A.Rosenfeld (eds.), Academic Press, NY.
- [Spoerri, 1994] : A.Spoerri (1994). InfoCrystal : A visual tool for information retrieval and management in Human Factors in Computing Systems, CHI'94 Conference Companion pp11-12.
- [Tufte, 1983] : E.R.Tufte(1983). The Visual Display of Quantitative Information, Graphics Press, Cheshire, CT.
- [Tufte, 1990] : E.R.Tufte(1990). Envisioning Information, Graphics Press, Cheshire, CT.



## **PERFORMANCE-BASED MEASURES OF EXPERTISE: HOW CAN YOU TELL IF SOMEONE IS (OR IS NOT) AN EXPERT?**

James Shanteau

Professor, Department of Psychology  
Bluemont Hall 492  
1100 Mid-Campus Dr, Kansas State University  
Manhattan, KS 66506-5302

The identification of who is, and who is not, an expert is vital to any analysis involving expertise. If there are external criteria (ie, a correct answer), then the identification is straightforward. However, such criteria are typically unavailable in most domains where experts work. The initial purpose of this paper is to present three traditional approaches to the identification of experts (certification, peer nomination, and profiling). I will discuss applications and limitations of each approach. Then I will present the rationale for a novel approach (labeled CWS) for defining expertise in the absence of external standards.

To demonstrate the usefulness of this approach, I will show how CWS has been applied to three previously collected datasets involving experts. In each case, CWS provided new insights into the identification of expert. When applied to a study of auditing, CWS correctly identified differences in experience for professional auditors. In a study of livestock judges, CWS successfully distinguished between experts with different domains of specialization. And in a study of personnel selectors, CWS revealed that irrelevant attributes may be as informative (or even more informative) than relevant attributes in identifying experts. In the future, CWS may become a vital tool in research on experts and expertise.



## ACTIONS AND ACTIVITIES IN MAN-MACHINE DISASSEMBLING SYSTEMS

A. Skaf<sup>1</sup>, H. Tian<sup>1</sup>, B. David<sup>2</sup>, B. Descotes-Genon<sup>1</sup>, Z.Binder<sup>1</sup>

<sup>1</sup> Laboratoire d'Automatique de Grenoble (LAG) ENSIEG-INPG, B.P. 46,  
38402 Saint Martin d'Hères Cedex, France  
Tel: ++33 (0)4.76.82.64.06 ; Fax: ++33 (0)4.76.63.88  
e-mail: Ahmad.Skaf@lag.ensieg.inpg.fr

<sup>2</sup> Laboratoire ICTT-GRACIMP, Ecole Centrale de Lyon, B.P.163  
69131 Ecully Cedex, France  
Tel: ++33 (0)4.72.18.64.43; Fax: ++33 (0)4.78.33.16.15  
e-mail: Bertrand.David@ec-lyon.fr

### **Abstract:**

*This paper studies a semi-automatic dismantling system. A structure of the cell is presented, in relation with the actors taking part in the dismantling process. The idea to specify and classify the actions, in accordance with technical and ergonomic criteria, seems to be interesting for identifying the degree of automation and/or man-machine co-operation. This results in identification of all activities and their classification them in three zones (fully manual activities, fully automated activities and co-operative activities). The static or dynamic allocation of actions to the man or the machine is then possible by taking into account either the static role of each actor in the system or the dynamic instantaneous situation (taking into account actor overloading, operation complexity, .).*

**Keywords:** man-machine system, co-operation, action, activity, disassembly.

### **1 Introduction**

All over the world the need to recycle end-of-life products and to minimise pollution is increasing. One approach to recycling is disassembling. Generally, full automation of the disassembling process is very difficult. For this reason, human intervention and participation is often necessary. This leads to the study of man-machine systems, which are able to take into account Man-Machine Co-operation methods. The idea is to specify and classify the actions, according to technical and ergonomic criteria, in order to identify the degree of automation and/or man-machine co-operation. This leads to identification of all activities and their classification in three zones (fully manual activities, fully automated activities and co-operative activities). In the co-operative zone, allocation of an action to human, or to the machine is possible with respect to the situation of each actor in the system (static predefined capabilities) or instantaneous situation (dynamic occupancy of each actor).

## 2 Structure of man-machine disassembling systems

As already presented in [Binder et al., 1996] [Chevron et al., 1999], a disassembling system is a system which produces space parts from end-of-life products. The actors in a disassembling system are computer support system, human (supervisor, operator), and automated tools or robots. In such man-machine systems, all activities can be first divided into two groups, machine activities and human activities. For the sake of flexibility, intelligence, safety, or economics, some of the machine activities should be shared with a human. Likewise, for the sake of high capacity of data memory, speed of information processing, keeping human away from dangerous operations, some human activities should be shared with a machine [Millot et al. 1988]. This potential contribution of the machine to the human activities and/or the human to the machine activities creates, around the dividing line, a “co-operative zone” of activities (Figure 1).

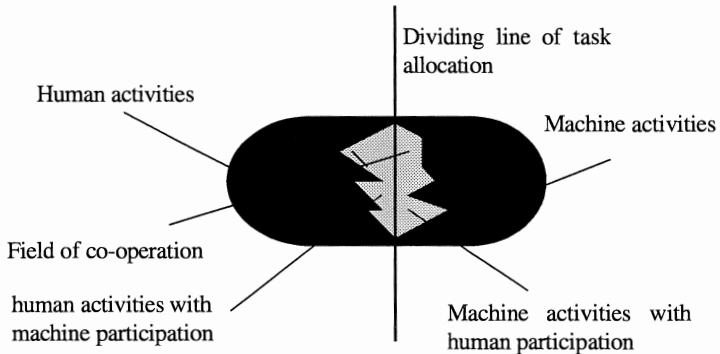


Figure 1: Type of activities and zone of co-operation

In order to study man-machine co-operation, an in-depth study of all activities in this zone is required. For this purpose, it is useful to distinguish two levels of man-machine co-operation, at decision level human Supervisor and Computer (S-C) jointly organise the operation process, at execution level human Operator and automated tool or Robot(O-R) jointly work on physical operations.

## 3 Actions in man-machine system

An action represents the given efforts to reach an objective. Each system is specified by a set of actions which transform the system from one given state to another. In automatic systems, these actions are executed by machines. In manual systems, the human is in charge of executing all actions. In semi-automatic systems (man-machine system), human and machine execute these actions individually or in co-operative manner. One of the man-machine system specifications is to allocate actions between two actors which are extremely: man with his human characteristics, and machine with its technical limitations. For this reason, all actions in this system must be specified from the point of view of ergonomics and technique.

To specify an action from man and machine implication point of view we use the following notation: each action “ACTION” has two parameters X and Y such as



ACTION(X,Y) ,where X∈[0,1] represents the degree of adaptation of action to the man, i.e. X=0 means that action is not adapted for human work, its execution by man is impossible, X=1 means that action is adapted for human work, and can only be done by man. Y∈[0,1] represents the degree of adaptation of action to the machine, i.e. Y=0 means that action is not adapted for the machine, its execution by machine is technically not feasible, Y=1 means the action is adapted to the machine, and is executed exclusively by the machine.

Therefore X and Y reflect man and machine involvement in an action, i.e. X and Y reflect ergonomic and technical criteria characterising the action. The question is how to determine ergonomic and technical criteria influencing X and Y. We assume that the initial value of X is X<sub>0</sub> and (A,B,C,D,.....,N) is a set of criteria which influence X by reducing its value. Let criterion A influence X by A<sub>X</sub> percent of X<sub>0</sub>, the reducing value of X will be:

$$V_X^A = A_X \cdot X_0 \tag{1}$$

In the same way for the remaining criteria, when the influence of all criteria does not exceed 100% of X<sub>0</sub>. Taking into account all criteria influences X, the value of X will be:

$$X = X_0 - (V_X^A + V_X^B + V_X^C + V_X^D + V_X^E + V_X^F + \dots + V_X^N) \tag{2}$$

Where  $(V_X^A + V_X^B + V_X^C + V_X^D + V_X^E + V_X^F + \dots + V_X^N) \in [0,1]$ .

The influence value of each criterion is statistically estimated by reference to known ergonomic factors (in particular the estimation of work load using Cooper-Harper scale [Millot, 1988]).

#### 4 Actions and Activities in a Disassembling Cell

Considering the structure of a disassembling cell in [CHEVRON, 1999], with four sub-systems (informational-decisional-operational-physical) and their three supervision, control, and execution processes, all actions can be enumerated. For a disassembling cell the proposed actions are: two supervision actions: to acquire (Ac), to guide (Gu); seven control actions: to calculate (Ca), to diagnose (Di), to decide (De), to follow (Fo), to pick up (Pi), to command (Co), to teach (Te); and six execution actions: to fix (Fi), to intervene (In), to rotate (Ro), to cut up (Cu), to unscrew (Us) to extract (Ex).

##### 4.1 Ergonomic and technical specification of actions in SC and OR systems

To specify the actions in Supervisor-Computer (SC) systems and Operator-Robot (OR) systems, two types of criteria are considered: technical criteria influencing Y are feasibility (FS) and cost (CO); and ergonomic criteria acting on X are workload (CT) (mental and physical), safety (ST), and reliability (FT) are considered.

Concerning the criterion of technical feasibility (FS), all actions of SC and OR systems are assumed to be feasible with a coefficient FS<sub>Y</sub>, for each action, as shown in Table 1. The values are estimated based the technical data of existing machines. For the second criterion CO, the influence of the cost is considered to be ignored for all the actions (CO<sub>Y</sub>=0%). With regard to ergonomic criterion CT, 10 subjects were questioned, guided by Cooper Harper modified scales, to determine the coefficient for each action (These scales reflect the difficulty associated with each action). The results

are transformed into influence  $CT_X$  as presented in Table 1. For the second criterion  $ST_X$ , We assume, for the actions of SC system, that the influence of safety on parameter X is ignored  $ST_X=0\%$ . On the other hand, for the actions of OR system, the influence of safety is estimated in relation to type of action and technology used. Finally, the influence of reliability on X is estimated in relation to purely human characteristics (long-term memory, short-term memory, quality of perceptions, etc.). From these influences, and using equations (1) and (2), the values of X and Y for each action can be calculated. The calculation results are given in the last two columns on the right-hand side of Table 1.

Action	Techniques Criteria		Ergonomics Criteria			X	Y
	FS <sub>Y</sub>	CO <sub>Y</sub>	CT <sub>X</sub>	ST <sub>X</sub>	FT <sub>X</sub>		
to acquire	20%	0%	80%	0%	5%	0.15	0.8
to guide	20%	0%	80%	0%	5%	0.15	0.8
to calculate	2%	0%	98%	0%	1%	0.01	0.98
to diagnose	60%	0%	40%	0%	5%	0.55	0.4
to decide	80%	0%	20%	0%	15%	0.65	0.2
to follow	40%	0%	60%	0%	10%	0.3	0.6
to pick up	30%	0%	70%	0%	10%	0.2	0.7
to command	7%	0%	93%	0%	5%	0.02	0.93
to teach	85%	0%	30%	0%	0%	0.7	0.15
to fix	10%	0%	10%	60%	5%	0.25	0.9
to intervene	100%	0%	10%	40%	10%	0.4	0.0
to rotate	10%	0%	10%	60%	5%	0.25	0.9
to cut up	10%	0%	10%	80%	10%	0.0	0.9
to unscrew	60%	0%	10%	50%	10%	0.3	0.4
to extract	85%	0%	10%	20%	5%	0.65	0.15

Table 1. Action specifications with regard to man and machine participation

If we observe the 9 actions of the SC system and the 6 actions of the OR system we can formulate the following comments. “to calculate” action with (0.01,0.98) is a machine action non-shareable with the man ( $X=0.01$  is ignored), the calculator must ensure its execution. On the other hand “to decide” action with (0.65,0.2) is a shareable action : X is not large enough, and Y is not ignored (non totally automatizable and difficult to be formed by the man alone). Thus, the human supervisor executes this action with an informational and guiding support from the calculator. Therefore for this action it is advisable to apply the type of co-operation known as “**vertical co-operation**” [Millot, 1996].

By representing all the actions of SC and OR systems on a 2D space with X (human contribution) axis X, and Y (machine contribution) on axis Y, we can determine four classes of action (Figure2):

- I. Not at all automatizable, and only man achievable actions. These actions are man oriented, without machine intervention.
- II. Automatizable, and not at all man achievable actions. These actions are completely machine achievable, without human intervention.

III. Automatizable, and achievable by man. They are the actions belonging to the co-operation zone (figure 1), and are the subject of a dynamic distribution called by [Millot, 1996] “horizontal co-operation”.

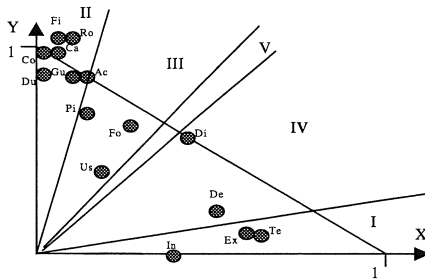


Figure 2: 2D distribution of actions in relation to man (X) and machine (Y)

IV. Not at all automatizable, and not easily achievable by man. They are the actions also belonging to the co-operation zone, and are thus shareable. For their execution man needs assistance tools. The execution of these actions is shared between man and the assistance tool, while leaving them under control of man.

This division is called by [Millot, 1996] “vertical co-operation”.

Between III and IV classes, class V of true man-machine co-operation actions can be found. Its actions are also in the co-operation zone (figure 1) and are the subject of future analysis.

#### 4.2 Activities in SC and OR systems

The actions described above are elementary low level actions. To achieve a global objective of the system we need higher level actions which involve more user oriented semantics. These higher level actions with their actors will be called activities. In a generic way we identified four actors: Supervisor (S), Operator (O), Computer (C), and Robot (R). To specify an activity, we give the actions, the actors and the end-of-life product (P) on which the actions are applied. Generally a activity takes the form:  $\{actor(s)\} \wedge \{action(s)\} \wedge \{product\}$ . Using this form, an activity as “Extraction one piece by unscrewing and cutting up” can be described as:  $\{S \wedge C \wedge R \wedge O\} \wedge \{Ac \wedge Gu \wedge Ca \wedge De \wedge Co \wedge Fi \wedge Us \wedge Du \wedge Ex\} \wedge \{P\}$  [Skaf et al., 1999].

Our interest is only directed towards the actions in the zone of co-operation, i.e. the action belonging to categories III, IV and V. To enumerate all activities in the zone of co-operation, it is necessary to find all realistic combinations (semantically significant configurations) from all possible combinations (combinations of 9 elements).

	n	S	O	C	R	Di	De	Fo	Pi	Us	P	?
ACTIVITIES	0	0	0	0	0	0	0	0	0	0	1	
	1	1	0	0	0	0	0	0	0	0	1	
	2	1	0	1	1	0	1	0	0	1	1	
	3	1	0	1	0	0	0	0	0	1	1	
	4	1	1	1	0	0	1	0	0	1	1	
	5	0	1	1	1	1	0	0	0	1	1	

Table 2. Activities based on actor-action-product configurations

Table 2 shows some of these activities, where “1” denotes that the actor, or action contributes to this activity, otherwise “0”. In the column furthest to the right(?), two symbols are used:

- “ ” indicates that the activity is accepted as a man-machine activity. For example, activity n 2,  $(\{S \wedge C \wedge R\} \wedge \{De \wedge Us\} \wedge \{P\})$ . This activity reflects that the decision “De” taken by the supervisor, using the assistance suggested by the computer, is intended to carry out a robot-like unscrewing.
- “ ” indicates that the activity is not accepted as a man-machine activity. For example, activity n 1 with no actors and no actions, activity n 3  $(\{S \wedge C\} \wedge \{De \wedge Us\} \wedge \{P\})$  “Us” is an action for robot or operator as actors, S and C can make an decision about unscrewing, but they cannot execute it.

### 5 Conclusion and outlook

A disassembling system has been presented, with focus on man-machine interaction and man-machine activities. A co-operative zone has been defined and a method of specification of the actions has been studied. This method makes it possible to identify two classes of actions (in the zone of co-operation): in the first case it is appropriate to apply vertical co-operation, in the second case it is more advantageous to apply horizontal co-operation. Finally, the method of enumerating all disassembling activities in the zone of co-operation has been illustrated.

Future work will consist of further examining the action and the activities in the zone of co-operation, and to improving the method of specification of the actions.

### Reference

[Binder et al., 1996] Binder, Z. Chevron, D. Spath, D. Tritsch, C. (1996). Modelling and Implementation of a Semi-Automated Disassembly Cell for Discarded Technical Products. IAR Annual Meeting. Karlsruhe, Germany.

[Chevron, 1999] Chevron, D. (1999). Contribution à l'étude de la Supervision d'une cellule de démontage de produits techniques en fin de vie. PhD thesis, LAG, Grenoble, France.

[Chevron et al., 1999] Chevron, D. Gerner, S. Skaf, A. Binder, Z. Descotes-Genon, B. David, B. and Dubois M. (1999). Disassembly System Modelling, Supervision and Control. 14<sup>th</sup> World Congress of IFAC. 5-9 July, Beijing, China.

- [Millot et al., 1988] Millot, P. Kamoun, A. (1988), An implicit method for dynamic allocation between man and computer in supervision posts of automated processes. 3<sup>rd</sup> IFAC congress "Analysis Design and Evaluation of Man Machine Systems". Oulu, Finland, 1988.
- [Millot,1988] Millot, P. (1988). Supervision des procédés automatisés et ergonomis. HERMES, Paris, France.
- [Millot,1996] Millot, P.(1996). De la surveillance à la supervision: l'intégration des opérateurs humains , Ecole d'été, Grenoble, France.
- [Skaf et al., 1999] Skaf, A. Tian, H. Descotes-Genon, B. David, B. Binder, Z. Dubois, M. (1999). Disassembling of end-of-life products and Man-Machine systems. International Symposium on Manufacturing Systems ISMS'99 of WMC'99 – Second World Manufacturing Congress 27-30 September 1999, Durham , U.K.



# EXPERT SYSTEM DEVELOPMENT IN HRM: A CASE STUDY IN RETAILING

Prof. Dr. Gültekin Yildiz, Dr. Nihat Erdogmus

Department of Management, Faculty of Economics and Administrative Sciences  
Sakarya University, Esentepe Campus, Sakarya-Turkey  
e-mail: erdogmus@esentepe.sau.edu.tr

## Abstract:

*A few studies have been conducted to develop expert systems (ES) in human resources management (HRM). One of the reasons behind this is that developing ESs in HRM is more difficult than other fields. The main difficulties in developing ESs in HRM are articulating expertise and representing knowledge. This study is an attempt to justify the employment of ESs in HRM and to discuss problems and shortfalls researchers face during ES development process. An illustrative case study in retailing industry is provided to demonstrate the feasibility of the ES development in HRM. Since store management is a key position in retailing industry, an ES used to identify store manager competencies is prototyped.*

**Keywords:** Expert System, Human Resources Management, Competency, Store Manager

## 1 Introduction

Managers use computers while doing their jobs such as planning, organising, coordinating and controlling. Since management problems are generally unstructured or semi-structured, using knowledge based computer programs raises the quality of management decisions. Disseminating expertise to non-experts by computer programs increases accuracy and efficiency of decision making process [Byun and Suh, 1994].

There are some attempts to develop ESs in human resources field [Byun and Suh, 1994; Sturman et al., 1996]. ESs developed in HRM are expected to aid managers in analysing and solving verbally stated problems which require expertise. So non-experts can use ESs to produce solutions by accessing to knowledge base (Lawler & Elliot, 1996).

In a few studies the limitations of ES development in HRM are discussed [Byun and Suh, 1994; Lawler and Elliot, 1996]. The reason behind limitations in this field is that developing ESs in HRM is more difficult than other fields. The main difficulties can be stated as articulating expertise and representing knowledge. In a different study, main barriers researchers face while developing ES were classified as company dependent and knowledge type [King and McAuley, 1991].

The first aim of this study is to emphasise limitations of ES development process in HRM. Second aim is to provide an illustrative case study in retailing industry to

demonstrate the feasibility of the ES development in HRM. Main focus of the study is to elaborate knowledge acquisition and knowledge representation steps of ES in the case.

## 2 Benefits of an expert system

An ES has two contributions in management field: a) disseminating expertise to enhance learning process and b) enhancing accuracy or efficiency of decision making [Ainscough et al., 1996]. Benefits of an ES are detailed in a study which classified benefits as feature benefits, task benefits and role benefits [Basden, 1994]. Feature benefit is related with technological features of functionality and user interfaces. Using ES to support a task is called task benefit. Carrying out supported tasks which user fulfill is named as role benefit.

In comparison with conventional programs, ES has some important advantages. Conventional programs depend on algorithm and data. Algorithms determine solutions by using given data [Hayes-Roth, 1990]. On the contrary, ESs carry out their jobs in a different way. The logic of ES is stated more precisely as the following: "The underlying principle of ESs technology focuses on separating the representation of the domain knowledge from the logical mechanism for processing and interpreting this knowledge. This allows knowledge relevant to a particular field to be easily updated, such modifications only affect the knowledge base" [Poo and Lu, 1991].

The main parts of an ES are; knowledge base, inference engine, user interface and explanation facility. *Knowledge base* consists facts and heuristics; *inference engine* makes interpretations or draws logical conclusions; *explanation facility* provides justification of how the system reached the conclusion; and *user interface* enables user to receive ES based explanation [Lado and Zhang, 1998].

In this study main focus is knowledge base, because difficulties of ES development in HRM are knowledge base related. In the next part of the study knowledge acquisition and representation of ESs in retailing are explained.

## 3 An illustrative case in retailing

Since retailing is a rapidly growing industry in Turkey [Arikbay, 1996], a retail chain was taken as a case. The retail chain has twenty six stores in different regions of Turkey. Every store operates in a different business environment. As it is very common in retail business, stores are geographically separated from central headquarters [Kelly et al., 1981].

The retail setting consists of both internal and external interfaces simultaneously [Babin and Boles, 1996]. In order to increase firm's performance, the impact of changing environmental factors should be assessed continually [Achabal et al., 1984]. Because of the distance from headquarter, control of store managers' performance is also an important concern in retailing [Lusch and Jaworski, 1991]. Not only managers' competencies but also the effects of environmental and organisational factors must be taken into account during performans controls.



### 3.1 Problem Domain

In retailing industry store management is a key position in success and failure of an organisation [Kelly et al., 1981]. It would not be wrong to say that store performance is mostly depended on the competencies of store managers [Lusch and Serpkenci, 1990]. Therefore to identify core competencies of store managers is critical. Developing an ES to determine core competencies of store managers will make top managers or human resources managers' job easy.

A store manager's role is called as boundary role. This can be stated as; "Chain store managers have a number of interfaces outside their individual unit, including customers, suppliers, district and territory managers, buyers, merchandise managers, representatives of advertising media, and executives from their corporate headquarters" [Kelly et al., 1981].

In retailing industry, retaining qualified personnel is an important human resources issue [Sonnenfeld and Peiperl, 1988]. Since store managers are critical personnel in this sector, to retain and motivate them, companies develop different human resources policies. Three human resources policies are very common in retailing: a) promotion from within, b) creating opportunities for mobility within organisation and c) promoting on the basis of performance and not seniority [Ganesan and Weitz, 1996]. It is also expected that store managers should be inner directed and high achievers [Lusch and Serpkenci, 1990]. From now on knowledge acquisition and knowledge representation procedure is discussed.

### 3.2 Knowledge Acquisition

Understanding and representing knowledge of the domain are the tasks which distinguish HRM from other domains [Byun and Suh, 1994]. Therefore new knowledge acquisition and representation methods are required to develop ES in this field. While developing ES, multiple knowledge sources (experts) and multiple methods should be used to acquire knowledge.

In this study, a new approach, 360 degree feedback, was used to gather knowledge. So expertise was acquired from different sources. General manager of stores, human resources manager, store managers, and store employees were sources who provided expertise during knowledge acquisition about store management position. Observation, interview and questionnaire were methods used in knowledge acquisition phase.

Knowledge acquisition process of the case was completed in three phases. First of all, a sample of stores from different regions were visited by researchers. During this visits, operations in stores and daily duties and relations of store managers were observed and the observations were recorded.

In the second phase, a group discussion was conducted in the headquarter of the chain. General manager of the chain, human resources manager, analysis and planning manager and four store managers from different regions participated to the meeting. Participants expressed their opinion about the needed competencies and their importance for store management. The meeting was directed by researchers. Group discussion was recorded by two assistants.

After group discussion, researchers combined the notes of observation and group discussion. These results were compared with management competency literature. At the end, a competencies list for store managers was prepared. The list consisted of 8 main competencies and sub competencies for each main competencies. The competencies in the list were randomly placed on a questionnaire form.

In the third phase, the questionnaire form was sent to 26 stores. Store managers were asked to give points for each main competency according to the importance of the competency for store manager's position. Points were given on the basis of 100. Store managers were also asked to divide total point given for a main competence into sub competencies according to importance. After return of questionnaires from stores, main competencies and sub competencies were put in order on the basis of the responses. The results can be seen in table 1. This table shows only main (core) competencies.

Core Competencies	Weight (100 p)
1. Leadership	94.4
2. Human Resources Management	90
3. Interpersonal Relations	85
4. Planning and Decision Making	83.3
5. External Relations	79.4
6. Operational Skills	76.4
7. Personal Development	73.9
8. Developing Subordinate	73.5

Table 1. Store managers' competencies

In order to acquire knowledge about environmental and organisational factors the same procedure as it was in knowledge acquisition about competencies was followed. First of all, a list of organisational and environmental factors was prepared on a questionnaire form. In development of the form, strategic management literature [Dinçer, 1998], general manager of the chain and a sample of store managers' opinion were taken into account. After completion of questionnaire, they were sent to stores.

Environmental and Organizational Factors	Order of Importance
Human Resources	1
Organization Structure	2
Market and Costumers	3
Competition and competitors	4
Socio-cultural	5
Effectiveness and Productivity of the organization	6
Suppliers	7
Economic conditions	8
Organization climate and culture	9
Business operations	10
Technology	11
Legal Regulations	12
Globalization	13

Table 2. Environmental & Organizational Factors Effecting Chain Store Manager's job

26 store managers were asked to put organisational and environmental factors in order on the basis of their importance for the store management position. At the end, responses of store managers were listed according to the order of importance (see table 2). After acquiring domain knowledge which are tabulated in table 1 and table 2, the most difficult step in ES development in HRM started: knowledge representation.

### 3.3 Knowledge Representation

A matrix was developed to demonstrate the relationship between core competencies and factors influencing these competencies. Vertically competencies, horizontally factors were placed on the matrix (see table 3).

Core Competencies	Environmental and Organisational Factors												
	Technology	Market and Customers	Suppliers	Socio-cultural Factors	Legal Regulations	Economic Conditions	Effectiveness and Prod. Of Org	Human Resources	Organisation Structure	Org. Climate and Culture	Business Operations	Competition and Competitors	Globalisation
1. Leadership													
2. Human Resorces Management													
3. Interpersonal Relations													
4. Planning and Decision Making													
5. External Relations													
6. Operational Skills													
7. Personal Development													
8. Developing Subordinate													

Table 3. Matrix of Store Managers' Competencies and Environmental-Organizational Factors

This matrix as a questionnaire form was sent to store managers and they were asked to determine the degree of relationship between competencies and factors. In the intersection point of competencies and factors store managers wrote the degree of relationship. Store managers were instructed to write 3, if degree of relationship between a competence and a factor is *very important*; 2, if relationship is *important*; and 1, if relationship is *not important*. 26 store managers completed questionnaire as it was mentioned above. After return of responded questionnaires, average of degree of relationship between every competence and factor was calculated. Finally, results as averages were put on the matrix.

The matrix was reviewed by a retailing consultant and two researchers. After review, this matrix was used to produce rules. One of 58 rules is shown below.

*If consumers and market factor is very important*  
 Then *Leadership\_Compentence=95*  
*Human\_Resources\_Management\_Compentence=90*  
*Interpersonal\_Relationship\_Compentence=85*

*Decision\_Making\_Planning\_Competence=80*

*External\_Relations\_Competence=75*

*Functional\_Competences=70*

*Personal\_Development\_Competence=65*

*Developing\_Subordinates\_Competence=60*

In rule production, the degree of relationship between competencies and factors was main criteria. Later, the prototype of ES of store manager competencies was developed.

#### 4 Conclusions

One of the contributions of the study is that in ES development multi-source and multi-method were used to acquire and represent knowledge. The development of an ES which has flexibility to take conditions of stores in different regions into consideration can be stated as main contribution of the study.

The ES of core competencies of store managers has two components: Core competencies of store managers and factors influencing these competencies. Firstly, in the ES, environmental and organisational factors determine ideal position requirements for store management position. Secondly, ES identified every candidates' development needs by comparing position competency requirements and candidate's competencies level.

The ES is designed to determine core competencies of store managers. While using the ES, there are the following steps. Firstly, there are choices about organisational and environmental factors. After choices, required competence level for a target store manager is reached as an output. Level of required competencies for store manager differs from store to store depending on regions/conditions in which store operates.

#### References

- [Achabal *et al.*, 1984] Achabal, D.D., Heineke, J.M. & McIntyre, S.H. (1984). "Issues and Perspectives on Retailing Productivity", *Journal of Retailing*, Vol 60, No 3, p. 107-127.
- [Basden, 1994] Basden, A. (1994). "Three levels of Benefits in Expert Systems", *Expert Systems*, Vol 11, No 2, p. 99-107.
- [Byun and Suh, 1994] Byun, D. & Suh, E. (1994). "Human Resource Management Expert Systems Technology", *Expert Systems*, Vol 11, No 2, p. 109-119.
- [Dinçer, 1998] Dinçer, Ö. (1998).  
Management &
- [Ganesan and Barton, 1996] Ganesan, S. & Barton A.W. (1996). "The Impact of Staffing Policies on Retail Buyer Attitudes and Behavior", *Journal of Retailing*, Vol 72, No 1, p. 31-55.
- [Hayes-Roth, 1990] Hayes-Roth, F. (1990). "The Knowledge-Based Expert System:A Tutorial", *Developing Expert Systems for Business Applications*, Eds. J.S. Chandler & T. Liang, Merrill Publishing Company, Columbus, Ohio, p. 3-24.

- [Kelly *et al.*, 1981] Kelly, J.P., Gable, M. & Hise, R.T. (1981). "Conflict, Clarity, Tension, and Satisfaction in Chain Store Manager Roles", *Journal of Retailing*, Vol 57, No 1, p. 27-42.
- [King and McAulay, 1991] King, M. & McAulay, L. (1991). "Barriers to Adopting Management Expert Systems: Case Studies of Management Accounting Applications Which Failed", *Expert Systems*, Vol 8, No 3, p. 139-147.
- [Lado and Zhang, 1998] Lado, A.A. & Zhang, M.J. (1998). "Expert Systems, Knowledge Development and Utilization, and Sustained Competitive Advantage: A Resource-Based Model", *Journal of Management*, Vol 24, No 4, p. 489-509.
- [Lawler and Eliot, 1996] Lawler, J.J. & Eliot, R. (1996). "Artificial Intelligence in HRM: An Experimental Study Of An Expert System", *Journal Of Management*, Vol 22, No 1, p. 85-111.
- [Lusch and Jaworski, 1991] Lusch, R.F. & Jaworski, B.J. (1991). "Management Controls, Role Stress, and Retail Store Manager Performance", *Journal of Retailing*, Vol 67, No 4, p. 307-419.
- [Lusch and Serpkenci, 1990] Lusch, R.F. & Serpkenci, R.R. (1990). "Personal Differences, Job Tension, Job Outcomes, and Store Performance: A Study of Retail Store Managers", *Journal of Marketing*, Vol 54, p. 85-101.
- [Poo and Lu, 1996] Poo, C.D. & Lu, H. (1996). "Multi-domain Expert Systems", *Expert Systems*, Vol 8, No 2, p. 67-73.
- [Sonnenfeld and Peiperl, 1988] Sonnenfeld, J.A. & Peiperl, M.A. (1988). "Staffing Policy as a Strategic Response: A Typology of Career Systems", *Academy of Management Review*, Vol 13, No 4, p 588-600.
- [Sturman *et al.*, 1996] Sturman, M.C., Hannon, J.M. & Milkovich, G.T. (1996). "Computerised Decision Aids For Flexible Benefits Decision: The Effects Of An Expert System and Decision Support System On Employee Intentions and Satisfaction With Benefits", *Personnel Psychology*, Vol 49, p. 883-908.



# **PART III**

## **COMPUTATIONAL LINGUISTICS**

---







# THE PROBLEM OF TRANSFER BETWEEN VERBAL AND ICONIC REPRESENTATIONS. THEORETICAL STAKE AND PRACTICAL APPLICATIONS

Delphine Battistelli, Cyril Valliez

C.A.M.S - La.L.I.C (Langage, Logique, Informatique et Cognition)

UMR 8557 - CNRS - EHESS - Université Paris-Sorbonne

96 bld Raspail 75006 Paris

E-mail : [battiste, valliez]@msh-paris.fr

## Abstract:

*The purpose of this paper is to show that the methodology implementation is not specific to a particular domain of knowledge but applies potentially to any type of text implying mainly movements of objects limited in space and time. More precisely, we will present a certain number of domains of varied applications showing how the level of abstraction and generality of the method allows to treat all of these problems in a unified manner. Furthermore, the practical interest of the transfer 'text - image' on the aspect of the ergonomics of applications will be developed, since images prove to be more immediately interpretable than the reading of a text. In fact, images give a synthetic and schematic vision of events described by the text.*

**Keywords:** Semantico-cognitive representations, spatial and temporal reasoning, iconic language, virtual reality

## 1 Introduction

The framework of our research is the study of *transfer relations* between semantico-cognitives representations of the language and visual representations, these ones being matched with iconic representations. From an operational perspective, we consider the problem of automating the construction of interpretations of texts in the form of sequences of fixed images

The particularity of our research comes from the designing of an original formal language of knowledge representation. This language is able to express intrinsic semantics of verbs which are independent from any specific domain. For example, a verb of movement like « arriver » (« to arrive ») can be used in road or air traffic contexts with the same meaning (ex.: *la voiture arrive dans le virage, the car arrives in the bend, l'avion arrive dans une zone de turbulences, the plane arrives in an area of turbulence*). In this paper, first we describe and explain why the methodology is independent of a specific domain of knowledge. Then potential applications are outlined to illustrate the power of abstraction of this method by processing differents problems in a unified way.

## 2 Building the semantico-cognitive representation of a clause

The Language of Semantico-Cognitive Schemes (LSCS) is able to express verbal meanings [Des, 1990]. These meanings are represented by using abstract structured frames organised with primitives. These primitives are semantico-cognitive units; that is to say, abstract units built from analysis of grammatical and lexical categorisations used in language but which are not lexicalised in a specific one.

Semantico-Cognitive Schemes (SCSs) are expressed by  $\perp$ typed expressions. For example, the verb « arriver » is expressed by :

[SCS of verb « arriver »]  $\lambda x. \lambda y. \text{CONTR}(\text{MOUVT}(\epsilon_0(\text{ex } loc) y) (\epsilon_0(\text{fr } loc) y)) y$

An entity  $y$  controls (CONTR) the oriented movement (MOUVT) between two static situations. In the first one,  $y$  is placed ( $\epsilon_0$ ) in relation to the outside (ex) of the location *loc*; in the second one,  $y$  is placed ( $\epsilon_0$ ) in relation to the boundary (fr) of this same location.<sup>1</sup>

After they have been evaluated, SCSs give rise to knowledge representations called SCRs — for Semantico-Cognitive Representations —. Each SCR is linked to a clause of the text. They are built from SSCs whose parameters are evaluated with the arguments of corresponding predicative relations. To illustrate this process, we consider two clauses (1) and (2) :

(1) *la voiture arrive dans le virage (the car arrives in the bend)*

(2) *le bateau arrive dans le port (the ship arrives in the port)*

The SCR of (1) is built from the underlying predicative relation (PR), which is <arriver\_dans, le\_virage, la\_voiture>, and from the linked SCS of « arriver », by matching the variables of the SCS with the arguments of PR, first /le\_virage/ then /la\_voiture/. The result is the SCR (1') :

(1')  $\text{CONTR}(\text{MOUVT}(\epsilon_0(\text{ex le\_virage})\text{la\_voiture}) (\epsilon_0(\text{fr le\_virage})\text{la\_voiture})) \text{la\_voiture}$

The building process would be the same for clause (2). In order to « visualize » the meaning of a proposition, primitives such as CONTR, MOUVT,  $\epsilon_0$ , ex, et fr are processed the same way than the arguments, that is to say, they are displayed as icons. Since these primitives are the cornerstone of our methodology and as they are not domain dependant, we are able to put forward a general methodology to visualise the meaning of clauses.

## 3 Characteristics of iconic representations

The following text (3) is an example of processed texts (those texts have been provided by an insurance company). From this text, consecutive images, illustrated by the figure 1, are built.

<sup>1</sup> For more details about SCSs, see [Abr, 1995].

(3) *Je roulais sur la partie droite de la chaussée quand un véhicule arrivant dans le virage a été complètement déporté. Serrant à droite au maximum, je n'ai pas évité la voiture.*

*(I was driving in the right lane of the road. A car arriving in the bend was carried completely out. Keeping to the right as much as possible, I did not avoid it)*

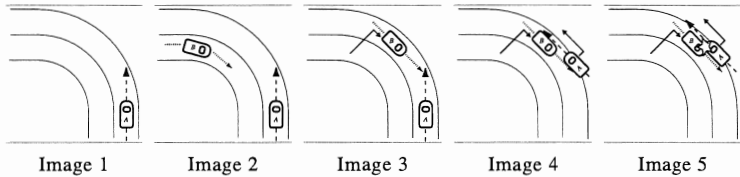


Figure 1: Iconic representation of text (3)

This kind of figurative representation does not aim to describe the real world. Each image displays a simplistic representation of a state of a micro-universe described by the text in a specific domain; in the domain of road traffic, it includes cars, roads, etc. This kind of representation does not exclude the possibility to display on a fixed image some sort of movement. For example, it is possible to show that an object is moving and that its movement is continuous. This format, called icon-symbolic, is interesting because it allows to display, with specific symbols, the intentional abilities of the speaker such as the capacities to control or to target a situation.

We are evolving towards a visualization of the « sense » of a narrative text that goes beyond the context of the simulation of spatio-temporal events to deal with more cognitive phenomena.

#### 4 Building the iconic representation of a text

In order to take into account the temporal relations of succession and concomitance between several clauses, all the SCRs must be organised. The building of semantico-cognitive representation of text relies on: (i) the identification of phases expressing modifications in the temporal referential in which the speaker is in charge : they are computed from the aspecto-temporal values of clauses and we call these phases *salient temporal phases* (STPs); (ii) the identification of information, encoded by the SCRs, which is validated on these STPs: these structures are called *salient spatio-temporal phases* (SSTPs). SSTPs are organised sequentially and define the Semantico-Cognitive Representation of the text [Bat 1999]. They aim to specify all the linguistic data which are necessary to display images. Their quantity determines the number of images displayed. Take, as an example, the SSTP<sub>3</sub> which is associated with the third image (fig. 1). From all the SCRs associated with clauses validated in this temporal area, it is possible to extract the following information:

- there are two entities A and B, localized relative to global location « virage »;
- A and B are under a controlled movement in progress;

- B is seen in the result of its swerve<sup>2</sup>.

An SSTP can then be visualized, by introducing elements of the knowledge domain and by translating the information the SSTP contains into an iconic language.

The building of images from SSTPs is carried out by applying infographic procedures on icons which represent the domain entities. These procedures visualize the relations coming from SSTPs: (i) in a iconic way for relation of location, orientation and direction of movement; (ii) in a conventional way for relations that are abstract and non directly visible. For example, in the image 3:

- the notion of control is represented in a classic way with the blue colour (we use red when there is no control) applied at icons representing vehicles A and B;
- the aspectual value of process is visualised by a dashed arrow which « goes through » the icons representing vehicles A and B;
- the aspectual value of event is represented by a dashed arrow which « leads to » the icon representing the vehicle B.

These kind of conventions of graphical representations lead us to write a set of exhaustive formal rules which define the LASCAR language[Bat, 1997b]. We omit the details in this paper. A comprehensive treatment may be found in [Bat, 1997a].

## 5 Potential applications

Processing a text in order to display images is at the heart of the conception of multi-modal interfaces. Most of the running applications are devoted to the assistance of the conception of three-dimensional scenes built from natural language sentences. An architect or town planner who wants to visualise a pictured scene describes it in simple sentences, which are translated by the software into graphic instructions. Consequently, they watch the building process interactively, but some limitations exist: sentences must describe static situations and they are translated one after another, that is to say, interaction between the user and software is a dialog. On the contrary, with our approach: (i) dynamic and static situations are processed; (ii) the text is considered as a whole, whereby sentences are not translated independently. In the following section, we present two potential applications; first Computer Aided Learning (CAL) then Computer Aided Translation (CAT).

### 5.1 Computer Aided Learning

The application of the «text-image» method for CAL is considered here as a tool for learning a second language, for example French. Two kinds of exercises must be considered: the learning of a new notion (a new vocabulary, a new grammatical structure, etc.) and the training in forming detached or linked sentences. In the first exercise, the utility of association between language and image is unquestionable. Because a large number of lexical and grammatical meanings are understood and

---

<sup>2</sup>Terms « movement » and « controled » are associated with primitives MOUVT and CONTR previously mentioned; expressions « in progress » and « result » are corresponding to the aspectual notions of « process » and « event » (see [Des, 1989]).

recorded more quickly and more efficiently when they are associated with images, many dictionaries and encyclopedias apply these pedagogic principles. But how does one illustrate verbs of movement and spatial prepositions? We think that using a semantic-cognitive representation is a way to deal with this problem. Relying on the same idea, to visualize the meaning of a temporal connector between two clauses, it is possible to display the connection between several clauses by visualizing the connection between several images.

One of the goals of the visualization used in the second exercise is to check and correct: the trainee makes one or several sentences, which must satisfy several conditions, and check, thanks to the visualization, the validity of his answer. For example, the trainee is being suggested a sequence of images (associated with a sequence of hidden sentences) and he (or she) must express the meaning of them by constructing a text in the language he is learning. This text is then translated by the software into a sequence of images. The trainee is able to compare the two sequences and therefore, correct himself. This kind of exercise seems to be well adapted to learning how to use the aspect-temporal category, which is particularly complex in texts made up of several sentences. We want to point out that our approach is interesting in the framework of text analysis and not for sentence analysis.

## 5.2 Computer Aided Translation

In order to answer a need of the global market, the idea is to use an iconic language to bypass the linguistic obstacles that occur, thanks to international pictograms. Therefore, using an «universal» iconic based on the same principles, rather than trying to translate integrally a text from one language to another, seems to be more realistic. The classic model of the automatic translation has to cope with two problems occurring in two consecutive stages. First, the building of a syntactic-semantics representation usually calls for an understanding of the text. Second, one has to deal with the automatic generation of a text from the structure previously built. The possibility to visualize the content of a text in an iconic way suggests a more simple process: the expert (in the target language) generates the text from the «universal» iconic representation. This approach seems to be well adapted for the needs of technical fields where two experts of the same domain are able to «speak» the same conceptual language but not the same spoken one. Since they use the same concepts, the same procedures, they deal with the same problems, difficulties, etc. The semantico-cognitive representation of the targeted text takes place exactly at the conceptual level.

## 6 Conclusion

From a theoretical point of view, our general analysis method proposes to describe the connections between linguistic and visual representations. Furthermore, the way a text is processed in a sequence of images is explained as an explicit transformation of representations. At last, our approach is not domain dependant but relies essentially on linguistic knowledge. Consequently, it is possible to apply this approach in other domains where spatial movements are crucial such as the transport domain. For example, harbour navigation, air, spatial and railway traffic could be processed in this way.

From an industrial point of view, our project finds a natural place in the multi-modal field. The practical interest of «text-image» transfer resides in the observation that images are easier to interpret than text. In fact, images give a synthetic and schematic vision of events described by the text. We've seen how in the fields of CAL and CAT this quality is indeed essential.

### References

- [Abr, 1992] Abraham M., Desclés J.-P. (1992), « Interaction between Lexicon and Image: Linguistic Specifications of Animation » in *Proc. of COLING-92*, Nantes, France, pp. 1043-1047.
- [Abr, 1995] Abraham M. (1995), *Analyse sémantico-cognitive des verbes de mouvement et d'activité, Contribution méthodologique à la constitution d'un dictionnaire informatique des verbes*, PhD, EHESS.
- [Bat, 1997a] Battistelli D., Desclés J.-P., Valliez C., Minel J.-L. (1997), « Building a sequence of images from a text », in *Proc. of NLPRS'97*, 2-4/12/97, Phuket, Thaïlande.
- [Bat, 1997b] Battistelli D., Valliez C. (1997), « De la représentation sémantico-cognitive d'un texte à sa représentation iconique », in *Proc. of FRACTAL'97*, 10-12/12/97, Besançon, France.
- [Bat, 1999] Battistelli D., Valliez C., Desclés J.-P. (1999), « Engendrer une séquence d'images à partir d'un texte: représentations sémantico-cognitives et raisonnements spatio-temporels », submitted paper to *TSI*.
- [Des, 1989] Desclés J.-P. (1989), « State, Event, Process and Topology », in *General Linguistics*, 29(3), pp. 159-200.
- [Des, 1990] Desclés J.-P. (1990), *Langages applicatifs, Langues naturelles et Cognition*, Hermès, Paris, France.

# SEMANTICO-COGNITIVE REPRESENTATION OF MEANINGS APPLICATION TO VERBAL POLYSEMY

Brahim Djioua

CAMS-LaLIC

96 boulevard Rapail 75006 Paris

djioua@msh-paris.fr

## **Abstract:**

*This communication describes the theoretical and practical tools that permit the automatic construction of a verbal lexicon in view of a didactic utilisation by linguists and an automatic treatment of written texts. Firstly we present the taken theoretical choices for the representation of the verbal polysemy in view of a practical utilisation; and secondly we present some elements of a semi-automatic tool (DISCC) that might help a semanticist in the construction of the semantic-cognitive representation associated with verb meanings*

**Keywords:** Verbal lexicon, polysemy, semantic-cognitive representation of meaning.

## **1 Methodological Preliminaries**

Debates on the definition of word meaning is have been taking place for a long time in various complementary disciplines. Theoretical and practical studies have evolved in interaction with one other. Several authors [Victorri, 96], [Desclés et al, 98] recognise the importance of the lexicon in the semantic representations and note, in particular, that semantics is insufficiently used in natural language processing computer systems.

To handle a text written with a computer, artificial intelligence used semantic networks, the logic of predicates and the semantic representation with features. The utilisation of features semantics can be adapted to describe the nominal substantives but with difficulty for the verbal constructions because it cannot deal with verbal polysemy in charge. The semantic networks and the theory of prototypes is often put back in reason for problems on the categorisation and the typicality [Desclés et al,91].

Syntax alone cannot reveal the semantics of lexicon. Verbal constructs with a same syntax can express different meanings. There are three examples in French::

- (1) Pierre touches the cupboard [*Pierre touche l'armoire*]
- (2) Paul receives a salary [*Pierre touche son salaire*]
- (3) The garden adjoins the house [*La jardin touche [à] la maison*]

Every sentence has the same syntactic construction (4): NP1 VS NP2, but their semantic representations are different. The first sentence describes a simple contact between "*Pierre*" and the "*cupboard*"; the second expresses the entrance in possession of "*a salary*" by an agent entity "*Paul*". The third sentence implies the presence of a fictional observer that, while scanning the "*garden*", conceptualise more and more near places until to get in contact with the place "*house*".

## 1.1 Processing polysemy

We can distinguish several methodological attitudes before the phenomenon of verbal polysemy. A first approach would be to consider that every senses of a verb is determined by the contextual environments ("effect of sense"), and therefore to refuse the oneness of "sense" for a verbal entity. The second attitude comes back to consider that, for every polysemic verb, there are as many distinct verbs and homonyms that of distinct senses [Atkins, 87]. Thus, the verb "*to touch*" would not have one senses but it exists several verbs "*to touch*" homonyms, each of this verbs are being identified by a semantic-syntactic diagram. This kind of approach can be applied for certain verbs homonymous like the French verb "*voler*" : "*voler<sub>1</sub>*" (to fly with wings) and "*voler<sub>2</sub>*" (to take something without being allowed). Another attitude would be to consider that it exists a "sense core" that would be common to all uses of one same verb and every particular sense would be determined then by the context. In this case every sense is derivable of the "sense core", either by addition of semantic features, either by metaphorical operations. This attitude is often the one used by lexicographers for the construction of dictionaries that distinguish the different senses of one same verb by opposition of "concrete sense" to the "figurative senses"<sup>1</sup>.

The approach adopted within the LaLIC team [Desclés,90] and [Abraham,95] is different of the presented previously attitudes. We supposes a comparable fundamental meaning to Picoche's "signifié de puissance" that would be to the source of the other senses. For Desclés, a polysemic verb has a "sense first" and its senses is analysed not from elementary linguistic predicates in the language in surface [Wierzbicka,92] but from more abstract elementary predicates, described in a cognitive representations level.

In this level of representation we uses some semantic and cognitive units (relaters and primitives) to construct some semantic and cognitive frames (SCF) associated to the verbal sense. [Desclés, 90] introduced a model, Applicative and Cognitive Grammar [A&CG], developed by the LaLIC team from the general works of the model of [Saumyan, 87] and of the cognitive extension of the model by [Desclés, 90]. The associate formalism to this model is a typed  $\lambda$ -calculus [Hindley-Seldin,86] and the Curry's combinatory logic with types [Curry-Feys, 58] with its combinators and its algebra. Indeed it has been shown by, among others, S.K.Shaumyan and by Desclés that combinators and types were excellent formal instruments of analysis linguistics, not only for the syntax but also for the verbal meaning representation [Abraham, 95]. This model articulates three levels of representations explicitly: a syntactic level, a predicative level and a semantic and cognitive level.

The first level is described by an extended categorial grammar [Biskri, Desclés 95]. The level two permits to formalise the predicative operations, of where of representations in term of predicates, arguments and role cases. The last level permits to represent meanings of predicates under shape of Sémantico-Cognitive Frames; these last are objects manipulated by our computer tool DISSC. The joint between levels is assured by a compilation process. Every level is described in a formal applicative

<sup>1</sup> For more details see [Desclés & alii.98]



language. The move from the middle to the lower level is a process of lexical integration.

SCF are semantic structures constructed with primitives. These primitives are defined by a basis semantic and cognitive types, static, kinematics and dynamic relaters and elementary operators as the topological operators on locations. The different static relaters are organised in an model of relaters more less specific of a location "archi-relateur" [Desclés, 87]. Relaters express different meanings (localisation, part-of, assignment, possession, identification,...) what one ordinarily designates in the semantic networks by the relation "is-a". These primitives have already been presented in several publications [Desclés, 85,90,98] [Abraham-Desclés,92]. SCF are described in a formal language with a specific grammar. Every SSC express a verbal meaning ; it is express either by a typed  $\lambda$ -expression, either by visual structures more accessible to the human users.

## 1.2 Semantic-Cognitive Frame Language

The conception of a design language supposes a definite grammar to basis of relaters and of primitive. The grammar of the SCFL defines a number of formal rules. The verification of the well formed applicative expressions is done by a functional typed system thus:

- (i) Let some basis types  $\{ \underline{J}$  (individuals: *Pierre, Paul, cupboard...*),  $\underline{C}$ (collective),  $\underline{L}$ (places: *garden, house...*),  $\underline{M}$ (massive),  $\underline{H}$ (propositions),  $\underline{stat}$ (static situations),  $\underline{cinem}$ (kinematic situations),  $\underline{dynam}$ (dynamic situations) } given
- (ii) If  $\underline{\alpha}$  and  $\underline{\beta}$  are types then  $F\underline{\alpha\underline{\beta}}$  is a functional type.
- (iii) If X and Y are expressions of the type  $F\underline{\alpha\underline{\beta}}$  respectively  $\underline{\alpha}$  then the application (XY) is of the type  $\underline{\beta}$ .

The static situations describe states. They are essentially described by the relation of location between a marked and a reference mark or by the relation of determination [Desclés,87]. Several static relations are defined between a reference mark and a marked. Relaters are typed; they are not compatible that with entities of a certain type. The static relaters, applied to typed entities, construct what one calls some static situations. Among the static relaters one finds the location "archi-relater" REP witch specifies himself in different relaters : the differentiation, localisation and the assignment.

To explain the dynamism of a situation that is expressed of a static way, we suppose a fictional observer that, while scanning a global place, conceptualise some real or mental places witch are joined according to an any gradient.

Kinematics situations describe movements in a referential spatio-temporal or of changes of states assigned to an object. The kinematics primitives express a modification between two static situations. Among the primitive kinematics we use the primitive MOUVT : the spatio-temporal movement of an entity passing a place to another (these places are not necessarily determined.)

The dynamic situations suppose an external constraint that gives back the possible kinematic modifications. The dynamic primitive express capacities of action from an

individual entity in relation to a situation as FAIRE (make : capacity to do an action), CONTR (capacity to control an action) or TELEO (to aim a goal to reach). An operator TRANS, got while composing the two dynamic operators CONTR and FAIRE, is used also to construct the dynamic situations expressing a semantic transitivity ( $\text{TRANS} \equiv \mathbf{W}_{(3)} (\mathbf{B}^2 \text{CONTR FAIRE})^2$ ). Of another side the linguistic statement "Marie touche au but" is a predicative structure witch can be reduced to a formal expression  $P_2 T^2 T^1$ ;  $P_2$  is a predicate with two arguments witch expressed in the lexicon by the verb "toucher-au",  $T^1$  the nominal term "le but" and  $T^2$  the nominal term "Marie". By a compilation (a program of abstraction), we can reduce the symbolic expression  $P_2 T^2 T^1$  to applicative expression (CONTR (FAIRE (MOUVTOR SIT1[x,y] SIT2[x,y] x) x)x). The semantic meaning of the lexical unit "toucher-au" is an expression defined by the "lexical law" :  $[P_2 \equiv \mathbf{B}^2_{(3)} \mathbf{W}_{(3)} \mathbf{B}^2 \text{CONTR FAIRE MOUVTOR SIT}_1 \text{SIT}_2 x]$ .

To every polysemic verb is associated a network of SSC bound between them by relations of specification/generalisation, of abstraction or of domain change. For certain networks it exists a root that represents the common abstract significance to all the meanings of the same verbal item; this root is a cognitive "archetype" analogous the "signifié de puissance" of [Picoche, 86].

## 2 DISSC: a tool to construct polysemic networks associated to a verb meanings

The construction, the manipulation and the consultation of the semantic-cognitive knowledge basis achieves itself in two big stages. The first task is to construct and to stock the SCF corresponding to the verbal items. A second stage consists in binding all its meanings by operations of fitting, be instanced or determination in order to construct networks between SCF translating the verbal polysemy. These two stages are processed very well separately either in parallel.

With this architecture (see figure 1), we recognise three levels of utilisation to the DISCC system.

- The administrator of the semantic-cognitive frame language, introduces and puts up to date relaters and the primitives of the SCF's language
- The semanticist can only create, modify and stock some SCF while using the only relaters and primitive definite by the administrator. The SCF, thus constructed, permit to construct networks of senses partners to polysemic verbs.
- The human user can consult the basis of SCF and networks. A system of text analysis that needs instances of SCF in a given context can either use it.

---

<sup>2</sup> The complex combinators  $\mathbf{W}_{(3)}$  and  $\mathbf{B}^2$  are respectively deferred and powers combinators. Deferred combinators are defined by a natural induction thus:  $\mathbf{X}_{(0)} \equiv \mathbf{X}$  and  $\mathbf{X}_{(n)} \equiv \mathbf{B} \mathbf{X}_{(n-1)}$ . Powers of combinators are defined by:  $\mathbf{X}^1 \equiv \mathbf{X}$  and  $\mathbf{X}^n \equiv \mathbf{B} \mathbf{X} \mathbf{X}^{n-1}$  [ $\mathbf{B} x y z \geq x (y z)$ ]. For more precision, see [Desclés,90].

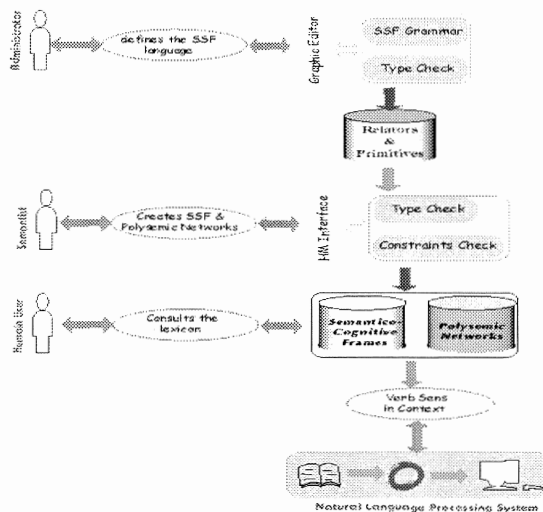


Figure 1: General Architecture of DISCC

The semanticist can, from a linguistic survey of meanings of a verb [Abraham,95] and [Desclés,98], to seize, to manipulate and to stock some SCF through the intermediary of the graphic publisher. The construction of SCF is made by a recursive way. The user chooses first a basis types, then static relators to construct some static frames. At the end of the SSF construction, the DISSC system proceeds to a semantic-logical type verification. If the SSC constructs thus is coherent, the system generate its applicative representation automatically under shape of a lambda typed expression; otherwise a message of mistake is sent back. This verification consists in an inferential calculation of types on the applicative expression representing the SCF thus constructed. To a semanticist demand, an "integration program" permits to produce the lexical predicate with its typed arguments under the shape of a follow-up complex combinator of relators, primitive and variables to be instanced by agents of the predicative relation.

While using the linguistic and cognitive analysis of the verb "to touch", we define all the SCF associated to the different meanings [Desclés, 98]. Then the polysemic network of the verb sense is constructed with abstraction / specification relations (see figure 2).

Research of information is done by a human user having access on the news visual more convenient than typed applicative expressions. Lexicon can be called also by a system as the automatic passage of a text on accidents reports toward a sequence of pictures [Battestelli-Valliez,97]. In some step of the semantic analysis of a text, it can need semantic value of a verb occurrence in order to "instanciate" a predicative relation.

This research in the lexicon can be done by a human user who want consult the lexical knowledge basis and see how are organised semantic categories of verbs. To title of example one can look for, for a given verb, and while taking account of the contextual information on the presence of a gifted agent of control in the predicative relation, all designs that are constructed according to certain constraints (with the

primitive CONTR only). The choice of a value on the "agentive" continuum (*continuum d'agentivité*) is based on a theory presented in [Desclés,94].

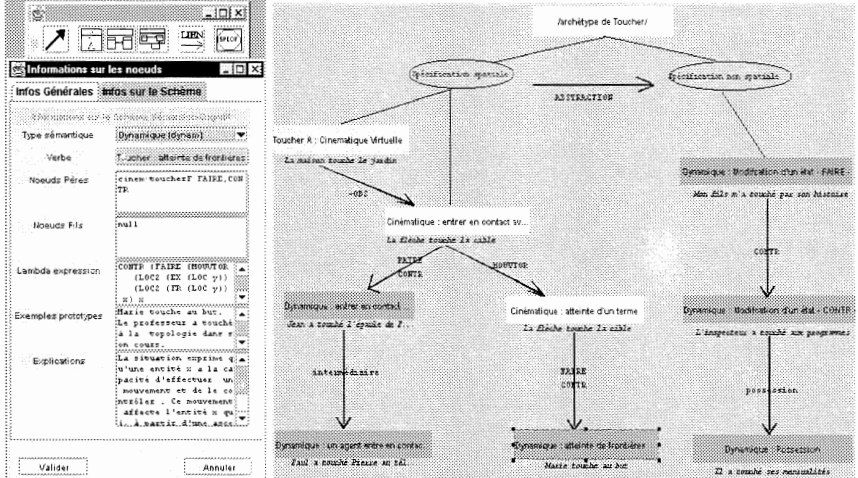


Figure 2: Creation of polysemic network of the verb " to touch "

### 3 Conclusion

We presented here, in the cognitive setting of our research, a methodology of verbal lexicon construction. The polysemic verbal is used by an automatic treatment of the natural language. The DISSC tool is realised with the SCFL witch use semantic and cognitive entities and typed primitives. DISSC is an interface programmed with Java™. During the development of the system, our first goal was to develop an isomorphism between a graphic language and typed applicative grammar in order to have a reliable system. The system is under evaluation and a future work is to determinate the contextual rules witch permit the correspondence between a context and a verbal meaning.

### References

[Abraham, 95] Abraham M (1995) *Analyse Sémantico-Cognitive des verbes de mouvement et d'activité, Contribution méthodologique à la constitution d'un dictionnaire informatique des verbes*, Thèse de Doctorat, EHESS, Paris

[Abraham and Desclés, 92] Abraham M, Desclés J-P (1992), " Interaction between lexicon and image : Linguistic Specification of animation», Actes de colloque, *COLLING vol 3* pp 1043-1047.

[Atkins, 87] Atkins, B.T.S (1987) Semantic ID Tags : Corpus evidence for dictionary senses. In Proc Third Ann. Conf. Of the UW Center for the New OED, pp 17-36 Waterloo, Canada

[Battestelli-Valliez,97] Battistelli D, Valliez C (1997), "De la représentation Sémantico-Cognitive d'un texte à sa représentation iconique ", *Colloque International FRACTAL 97*, 10,11,12 Décembre 1997, Besançon.

- [Biskri, Desclés 95] Biskri I, Desclés J-P (1995), "Applicative and Combinatory Categorical Grammar (from syntax to functional semantics)", *Acte du Colloque RANLP*, Bulgarie
- [Curry-Feys, 58] Curry, H.B., Feys, R., (1958) *Combinatory Logic*, vol I, North-Holland
- [Desclés, 87] Desclés J-P (1987), " Réseaux sémantiques : la nature logique et linguistique des relateurs", *Langages 87*, Larousse pp 55-78
- [Desclés,90] Desclés J-P (1990), *Langages Applicatifs*, Langues Naturelles et Cognition , Hermès, Paris.
- [Desclés et ali,91] Desclés J-P and Kanellos I (1991), La notion de typicalité : une approche formelle, *Sémantique et Cognition* sous la direction de D. Dubois, CNRS
- [Desclés,94] Desclés J,-P. (1994), "Relations casuelles et schèmes sémantiques", *Langages*, Vol. 113, pp.115-126
- [Descles et al, 98] Desclés J-P, Falgeul V, Kekenbosch C, Meunier J,-M, Richard J,-F., (1998), "Sémantique cognitive de l'action : une approche théorique et expérimentale" dans *Langages* (ed Guiglione, Desclés, Richard)
- [Hindley-Seldin,86] Hindley, J. R, Seldin, J. P, (1986) *Introduction to Combinators ans Lambda-Calculus*, Cambridge Univ. Press
- [Picoche, 86] Picoche J (1986), *Structures Sémantiques du lexique français*, Nathan, Paris
- [Saumyan, 87] Saumyan, S. K., (1987) , *A Semiotic Theory of Natural Language*, Bloomington, Indiana Univ. Press
- [Wierzbicka,92] Wierzbicka A. (1992), *Semantics, Culture and Cognition*, New York/Oxford, Oxford University Press
- [Victorri, 96] Victorri, B. (1996) *La polysémie : construction dynamique du sens*, avec la collaboration de C.Fuchs , Hermès



# FORMAL SPECIFICATIONS BUILDING FROM SPECIFICATIONS WRITTEN IN NATURAL LANGUAGE

Alain-Jérôme Fougères

LaRIS/UTBM

4, rue du Château Sévenans

90010 Belfort – France

Alain-Jerome.Fougeres@utbm.fr

## Abstract:

*Making specifications is taking more and more time; every day an enormous quantity of pages which, for the most part, is written in natural language. However the need to reduce the time needed in the development of the services is a priority. One method is to formalise the maximum number of specifications received. With this in mind, we will try to demonstrate the possibility of a certain automation in the passage from the informal to the formal, by means of methods and proven tools, available to assist an expert in specifications. For this end we propose a process of formalisation which relies on an intermediary representation of the specifications with the formalism of conceptual graphs before arriving at a formal description in Z of the initial specification.*

**Keywords:** knowledge representation, natural language, formal specifications.

## 1 Presentation

In the first phases of complex system development, such as for telecommunications, software specifications, services or hardware, are accompanied by long documents usually written in natural language. For the persons in charge of specifications, there are two dimensions to solving the problem: when producing specifications, are their procedures which could facilitate the development and writing of specifications? when managing specifications, what sort of help could be found to help in the archiving of the masses of data and in maintaining coherence during their development and exploitation?

### 1.1 The context of study

This research is motivated by desire to find methods of reducing the time needed to develop new services in computer science or telecommunications. It serves as a means to shorten all the stages in the cycle of development of each service offered. In this context, mastering the stage of functional specifications becomes of prime importance, since it facilitates the realisation of the service. Thus, each step which facilitates the writing of the specifications, whilst keeping the expected quality [Sommerville, 1992], contributes to a reduction of the time, inherent in this stage and, consequently in subsequent stages. Our objective consists of helping specification writers to formalise their specifications, by concentrating our attentions on the semantic aspects [Toussaint, 1992] of an informal specification. The *point de départ* for this procedure of formalisation arrives from specifications written in natural language, being converted in the terminology of software science with regard to the target, that must be determined

within the context of the not inconsiderable set of formal languages. There is a general consensus which states that you cannot reasonably envisage passing directly from natural language to formal representation; in the main this being due to the problems inherent in the use of natural language and, more particularly, in its interpretation (ambiguities, context). This has led us to select for the construction of an intermediary semantic representation defined in [Sowa, 1984]: the model of *conceptual graphs* (CG).

## 1.2 The procedure of formalisation

For this move towards formalisation, we propose a sequence of processes from informal specifications, likely to provide us with a formal description (fig.1).

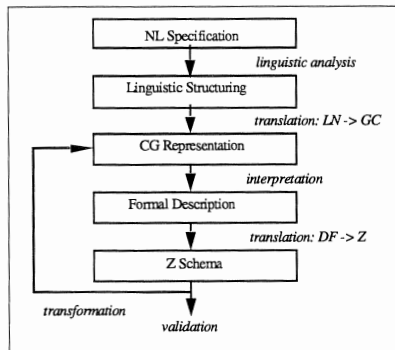


Figure 1: Different stages in the processing of specifications

## 1.3 Experimentation

Our experiments was based on the specification of *NEF*<sup>1</sup> and more specially on the tenth chapter detailing the *tarification*. The extensive nature of this specification and the linguistic complexities attached to it, have not permitted us, in this first approach to foresee a complete definitive path of formalisation. We settled, as an experimental protocol, on the realisation of the complete procedure in an incremental way.

## 2 Description of the work

### 2.1 Linguistic aspects

The processing of the language breaks down into two stages: a preliminary stage in which there is the acquisition of knowledge pertaining to the domain, and then the actual stage of linguistic analysis, itself. This second stage is generally sub-divided into five stages of analysis morphological, lexical, syntactic, semantic, pragmatic.

<sup>1</sup> NEF : *Normes d'exploitation et de fonctionnement* (rules of conduct and operation) of France Telecom, worked out at CNET (Centre National d'Etudes des Télécommunications)



### 2.1.1 The acquisition of knowledge phase

This preliminary stage consists of extracting lexical information contained within the text, in order to determine the preferred links that the words have between them. A simple study of the co-occurrence of words, based on an analysis of lexical proximity, thus enables us to reveal the presence of compound words, of expression, of predicative relationship and of schemas of phrases peculiar to the domain. The united use of this frequential analysis with techniques of statistical filtrage, such as the *mutual information*<sup>2</sup> permits refinement and improvement in the pertinence of the results.

A second phase of knowledge acquisition consists of extracting from the dictionary some definitions of terms retained as concepts, in order to describe them in a semantic dictionary in the form of conceptual graphs. In order to automate this task, we have adapted the algorithms of [Hernert, 1993] which allow us to detect the hyperonymic relationship contained in the dictionary definitions and to adjust them with terms modifying the definition. Once the content of the definition has been analysed, it is then possible to construct the corresponding CG and to include it in a canonical base.

### 2.1.2 The linguistic analysis phase

**The morpho-lexical analysis.** In the course of this phase, it is question of sequencing the analysed sentences in order to obtain a series of words after having identified the simple words, the compound words and the set expressions.

**The syntactic analysis.** Our aim here is not to set out the full array of numerous strategies for syntactic analysis but rather to set out clearly the formalism *Lexical Functional Grammars* (LFG) [Kaplan and Bresnan, 1982] that we have chosen. The LFG break down into three levels:

- the *c-structure* (analysis by components) described with rules of grammar out of context; it represents the syntactical structures in the form of a tree;
- the *f-structure* (functional description) comprises pairs of function-value, shows the grammatical functions such as subject, object, etc.;
- the *s-structure* (semantic structure), semantic projection based on the *c-structure* which only allows for predicate structure (predicates, arguments and modifiers).

LFG grammars add to the construction of the syntactic structure the formation of functional phrase structure (logic analysis), specified using patterns which are associated with grammar rules. But, the LFG analyser used does not have a sufficient linguistic range to analyse the more complex phrases frequently found in specification writing.

**The semantic analysis.** The selected formalism of representation of semantic knowledge, being the model of conceptual graphs, this analysis therefore consists of the semantic translation of the syntactical structure into the form of conceptual graph. For this, we have taken inspiration from the case grammars which determine the different thematic roles taken by the components of a phrase with the help of information

---

<sup>2</sup> When the number of couple of lexical unities observed becomes elevated, we estimates the probabilities of pertinent association by a method of likelihood:  $l(x,y) = \log \frac{n_{x,y}}{n_x n_y}$ , with  $n_x$  and  $n_y$  the number of occurrences of  $x$  and  $y$ . and  $n_{x,y}$  the number of occurrences of the couple  $(x,y)$ .

acquired about word-order, about prepositions, verbs and context. The analyser determines the way in which the nominal groups of a phrase are bound to the verbs: the semantic role specifying how an object participates in the description of an action.

## 2.2 The formalism of conceptual graphs

### 2.2.1 The elements of formalism

The world described by a formalism of representation of semantic knowledge is a collection of individuals and of relations between these individuals which specify a state which could be transformed. In the model of conceptual graphs [Sowa, 1984], the elementary objects are the *concepts* and the *relations*. Each proposition is represented by a CG built using oriented arcs connecting concepts and relations. Rules offering the possibility to join or disassociate are given. A formal correspondence with first order predicate logic is taken as a core. This basic description of CG shows the mixed qualities of this formalism: a graphic representation making it easy to read, and a system of mathematical proofs with solid axiomatic foundation which makes it formal.

### 2.2.2 Isomorphism CG and logic of the first order

Sowa defined the operator  $\phi$  which makes a formula in the predicates logic of the first order correspond to every conceptual graph. In the following example, the sentence *The system consists of transmitter* will have for equivalent the formula  $\phi(u)$ :

$$u : [\text{system: num1}] \rightarrow (\text{ConsistsOf}) \rightarrow [\text{transmitter} : *].$$

$$\phi(u) : \exists x, \text{system}(\text{num1}) \wedge \text{ConsistsOf}(\text{num1}, x) \wedge \text{transmitter}(x)$$

## 2.3 Towards a formalisation

### 2.3.1 Z language as the target language

A specification in Z [Spivey, 1992] is formed by a sequence of *paragraphs* comprising *schemas*, *variables* and *base types*. To every expression appearing in a specification in Z is associated a unique type. This type can be one of three sorts, a whole type, a cartesian produced type or still a schema type. The relations or the functions allow us to combine these three sorts of objects. A schema consists of a signature and of a property on this signature called *predicative part*. A signature is a collection of variables, each one possessing a type. They are created by the declarations and they provide the vocabulary necessary to the mathematical instructions expressed by the predicates. A predicate is the expression of a property which is characterised by the whole of the links for which it is true. The variables are of two sorts: the local variables which have a reduced scope on their schema of declaration and the global variable which form the object of a declaration outside the schema. Moreover, the formalism contains three standard *decorations* used in the description of the operations: “” to label the final state of an operation, “?” to label its entries and “!” to label its exits.

### 2.3.2 Building of a formal description

To build a formal description which corresponds to an informal specification, we worked by analogy with the construction mechanism developed by a human expert (fig.2). We begin by extracting the elements of the formal description, next we identify

and insert the indispensable elements which are not included in the module to be specified, then we establish the logic formulas (pre-conditions, post-conditions) corresponding to the collected elements and their links defined in natural language. The final phase is built by modelling in Z the CG based on the informal specification.

init : 1 CG by analyzed phrase.

Step 1 : join the graphs of one section :  $\text{Joint}(u1, \dots, un) \rightarrow u$ .

Step 2 : find the external references.

Step 3 : find the parameters, variables and relation of the description :

- . list the individual referent (object instances),
- . list the concepts in function of the referent type,
- . list the relations in function of the arity.

Step 4 : launch CG  $\rightarrow$  Z algorithm which gives Schema U.

Figure 2: Formal description construction methodology based on CG

The algorithmic elements of the translation of a conceptual graph in Z having been presented in [Fougères, 1997], we will essentially retain the two successive processes done on the concepts and on the relations. The referent of a concept becomes an element of the whole, represented by the type label; as for the relation, this is the object of a functional definition. The following figures illustrate the process of formalisation by presenting the three levels of representation of the specification of a simple transmission of messages between a transmitter and a receiver via a channel of transmission. We first applied the methodology on the phrases (1, 4 and 7) in figure 3 to obtain a unique graph  $u$  (fig.4, left). Then we calculated the corresponding logic formula, thus deducing the formal description and then we derived schema Z corresponding to  $u$  (fig.4, right).

- (1) System consists of a transmitter.
  - (2) System consists of a channel.
  - (3) System is consists of a receiver.
  - (4) Transmitter sends a message.
  - (5) Transmitter receives indication of loss p in channel.
  - (6) Channel receives message.
  - (7) Channel transmits message to receiver.
  - (8) Channel returns indication of loss to transmitter.
  - (9) Receiver receives message.

Figure 3: Simplified wording for "message transmission"

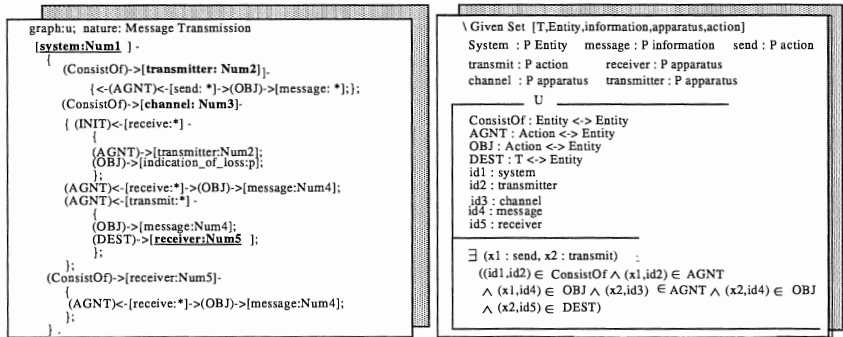


Figure 4: Fragments of the representation in the form of CG and specification in Z

### 3 Conclusion

We have proposed in this article an overall presentation of the procedure of formalisation of informal specifications expressed in natural language. It would be tempting, after having described the formalisation process, to postulate on the perspectives of making an "automatic specifier" [Balzer, 1985]. This however is not our point of view. We have not distanced ourselves from the perspectives of assisted specification, even if we have only briefly mentioned the problematics of assistance. Automation of the passage of NL specification to formal specification contains three types of problems:

- managing the intrinsic semantic irregularities of natural language;
- finding the quantity of expert information, of which abstraction is made in the source specifications – characterisation of the explicit and the implicit;
- compensating for the irreducible part of the passage from informal to formal – Newell clearly underlines the existence of a specific level of knowledge located outside of any formal system as well as the problem of transferring this informal knowledge into formal knowledge ("symbol level").

### References

- [Balzer, 1985] R. Balzer (1985). A 15 Year Perspective on Automatic Programming, in *IEEE Transactions on Software Engineering*, vol. SE-11, No 11, pages 1257-1268.
- [Davis, 1990] E. Davis (1990). Representations of Commonsense Knowledge, Morgan Kaufmann Publishers, San Mateo CA.
- [Fougères, 1997] A.-J. Fougères (1997). *Aide à la rédaction de spécifications formelles à partir de spécifications rédigées en langage naturel. Application aux spécifications de services de France Telecom*, PhD thesis of the University of Technology of Compiègne.

- [Hernert, 1993] P. Hernert (1993). *Un système d'acquisition de définitions basé sur le modèle des graphes conceptuels*, Phd thesis of the University Paris XIII.
- [Kaplan and Bresnan, 1982] R. M. Kaplan, J. Bresnan (1982). Lexical-Functional Grammar: A Formal System for Grammatical Representation, in J. Bresnan ed., *The Mental Representation of Grammatical Relations*, MIT Press.
- [Sommerville, 1992] I. Sommerville (1992). *Software engineering*, Addison-Wesley, Reading, MA.
- [Sowa, 1984] J. F. Sowa (1984). *Conceptual Structures: Information Processing in Mind and Machine*, Addison-Wesley Publishing Company, Reading, MA.
- [Spivey, 1992] J.M. Spivey (1992). *The Z Notation - A Reference Manual*, Prentice Hall International (UK) Ltd.
- [Toussaint, 1992] Y. Toussaint (1992). *Méthodes informatiques et linguistiques pour l'aide à la spécification de logiciel*, PhD thesis of the University Toulouse III.



# COMPETITIVE INTELLIGENCE: EXTRACTION OF RELEVANT INFORMATION WITH THE CONTEXTUAL EXPLORATION METHOD

Bénédicte Goujon

Bureau Van Dijk Ingénieurs Conseils  
57 boulevard de Montmorency  
75016 Paris

équipe LaLIC du CAMS, UMR 17  
(Université Paris-Sorbonne, EHESS, CNRS)  
96 boulevard Raspail  
75006 Paris  
goujon@msh-paris.fr

## Abstract:

*This article presents the VIGITEXT system. This system identifies extracts from patent abstracts in order to facilitate reading of a corpus of such documents in a Competitive Intelligence approach. The extracts are identified due to linguistic knowledge expressing general concepts, such as /improvement/, /modification/, /application/. Our approach does not require specific terminology nor statistical procedures to extract information from patent abstracts, and is usable in any field.*

*In this paper, the working context, based on the observation of a Competitive Intelligence step, is described, then the notions and the content of the extracts, as well as the VIGITEXT system, are presented.*

**Keywords:** Competitive Intelligence, Information Extraction, Natural Language Processing.

## 1 Introduction

In a Competitive Intelligence process, the most important sources of information are the patent abstracts. The use of bibliometric software permits the evolution and the recent trends to be identified in a specific field. However, one of the difficulties is to find interesting and surprising information in these technical documents.

We propose a method based on the identification of concepts independant of the field, for example /improvement/ (with linguistical indicators such as: improve, enhance, amelioration, ...), /modification/ (transform, alteration, modify, ...), /application/ (use to, application in, ...). These concepts, often used in patent abstracts to describe innovations, seem to give interesting information for an expert in Competitive Intelligence.

In this article, the working context, based on the observation of a Competitive Intelligence step, is described, then the notions and the content of the extracts as well as the VIGITEXT system are presented.

## 2 Competitive Intelligence and patents

In a Competitive Intelligence process, the most important sources of information are the patent references, which contain the description of research results. Some tools are used to analyse these kinds of resources.

### 2.1 Objectives and means in a Competitive Intelligence approach

In Competitive Intelligence, some of the objectives are to identify: the frequent subjects tackled by different groups of researchers, the leaders in a specific field, and the unexpected information of outstanding importance. In order to identify them, some electronic textual resources can be used: on-line data banks, Internet, Intranet. These resources contain full texts or abstracts.

According to specialists of Competitive Intelligence, such as Daniel Rouach [Rouach, 1996], the most important resources of information are patents. These resources are obtained in reference form, by interrogating specific data banks. Actually, these documents are checked by specialists (as opposed to Internet pages) and contain descriptions of inventions and research work.

For example, in a Competitive Intelligence approach, specialists obtain between 100 and 5000 patent references. The problem is to exploit such a corpus in the best way.

### 2.2 An example of a patent abstract

In order to propose another method to exploit the textual resources for Competitive Intelligence, we studied the textual content of patent abstracts. The patent references contain structured information in the fields « authors », « date », « key-words », and unstructured information in the fields « title » and « abstract ». Here is a short example of a patent abstract in the transgenic plants domain. Such abstracts usually contain 150 to 200 words on average.

<p>TI Transgenic plants expressing chitinase - with increased cold resistance or sugar content.</p> <p>AB Plants which have been transformed with chitinase-encoding DNA so that they express active chitinase and which (a) are resistant to cold damage or (b) have enhanced reducing sugar levels, are new. USE - The plants , especially tomato plants , have improved frost resistance or produce sweeter fruits. Dwg.0/2</p>
------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Figure 1: Example of a patent abstract

On the one hand, in order to exploit such information, we do not want to use a specific terminology of the field, because the fields of interest in competitive intelligence are always recent and not described. On the other hand, we do not want to use a statistical method as it does not permit non-frequent information to be identified.

### 2.3 Different methods and different results

The most usual systems to analyse these documents are statistical systems: they permit the identification of the most frequent words and concepts, and also the most important patent assignees. Some systems also apply multidimensional analysis, like



the Tétralogie system [Dkaki and al., 1997], which helps to identify collaborations between researchers. But those systems cannot identify rare but important information.

Other systems are adapted to extract terminology about technical texts. For example, ANA, developed by Chantal Enguehard [Enguehard and Pantéra, 1995], uses statistical procedures, a few heuristics and some knowledge to identify elements of the terminology of a domain, which can be used to index the texts. But those systems provide static terminology, which is not adequate enough to identify information.

### 3 Use of non domain dependant concepts

To obtain the following results, we observed a first corpus of 30 patent abstracts in English concerning transgenic plants [Goujon, 1999].

The principle is as follows: to describe an innovation, the writer insists on what is improved, on the new applications or possible uses, on modifications added or obtained. We exploit these concepts, and others identified in the patent abstracts, to locate interesting information.

#### 3.1 List of concepts

Presently, we are using twelve concepts, organized into two sets: on the one hand, a coherent set of concepts explaining a /change/ (with the general concept /change/, and four sub-concepts /improvement/, /deterioration/, /increase/ and /decrease/), on the other hand, a set of varied concepts introducing a result (/production/, /resistance/, /application/, /control/, /identification/, /effect caused/ and /destruction/).

These concepts are associated to sets of linguistic indicators, for example: transform, increase, application, resistance, etc.

Some rules permit the presence of a concept to be identified due to the indicators and some relevant clues.

The sets of indicators were obtained by using dictionnaires of synonyms, and the Beth Levin's classification of verbs [Levin, 1993] and by studying the content of the corpus.

The final extract must contain at least the indicator of the concept, and complementary information. For example, in the following sentence: «Plants which have been transformed with chitinase-encoding DNA so that ...», the ideal result explaining the /change/ concept contains the description of the element being under a transformation: «Plants which have been transformed».

#### 3.2 Results

As the user does not know which is the most important information on the corpus, he is not able to ask a specific question to obtain results. Our approach, which does not depend on predefined terminology of the field nor on weighting the interest of information according to its frequency, permits the user to discover potentially interesting extracts.

The users of VIGITEXT are scientists and experts in Competitive Intelligence, so the interface must be easy to understand and manipulate. In particular, the results are not organized into templates, or into multidimensional representations difficult to interpret.

The VIGITEXT system supplies extracts organized by concepts. Such results cannot be obtained with a search engine, because these systems are efficient in the identification of documents containing a term but not a concept. Also, a search engine provides a list of references, but the user is compelled to read each document to know the content.

### 3.3 A rule of contextual exploration

We use the contextual exploration method, developed by J.-P. Desclés and J.-L. Minel [Desclés and Minel, 1994]. This method has been used yet successfully for other tasks in French (automatic abstracting with Seraphin [Berri, 1996], identification of actions in texts with Coatis [Garcia, 1998],...). This method is adapted to proceed on technical texts containing a lot of unknown words, because it does not necessitate syntactical parsing.

The following rule of contextual exploration concerns the /resistance/ concept. The objective of the rules associated to this concept is to capture the description of the element against which there is a resistance felt.

Rule: R\_Res\_1

- Conditions : **L1** := { protect, protects, protecting }, **L2** := { against, from }

There is **indicator** element of **L1**, **clue** element of **L2** such as : DistanceInWords (**indicator,clue**) < 6, Position (**indicator**) < Position (**clue**)

- Actions : IdentifyBeginOfCIP ( RelevantWordAfter (**clue**) )

CreateExtractAfter (**indicator**).

Examples :

[1] « on the rind **protects** citrus fruit **against** freezing and chilling. »

[2] « plant defensive genes to **protect against** pests that feed on the plant . »

[3] « Used for **protecting** plants **against** attach by insects without the need for chemical insecticides »

[4] « ... can be used to **protect** animals, e.g. pigs, cows, sheep, goats, dogs or cats, **against** mucosal diseases, ... »

Table 2: Rule and examples on /resistance/ concept

In this rule, the distance between the indicator and the clue is 6 words at the most. In the first three examples, the conditions are verified, so extracts are created, but in the fourth example, the condition on distance is not verified, so no extract is created.

### 3.4 « Cutting out » of the extract

Actually, the cutting out is based on the punctuations, known verbs and a few prepositions. The previous rule obtains these results for each example:

[1] => /resistance/ - « **protects** citrus fruit **against** freezing and chilling »

[2] => /resistance/ - « **protect against** pests that feed on the plant »

[3] => /resistance/ - « **protecting** plants **against** attach by insects »

This method is not adequate in any case, for example in [4] the comma introduces examples which can be important and that do not divide the sentence into two clauses. In the abstract shown in Figure 1, this method is not very effective, because the sentences are quite long, and contain anaphora (« Plants which ... and which ... ») and interpolated clause (« The plants, especially tomato plants, have ... ») which are not taking into account yet.

Another difficulty is the length of the extract, which can be very heterogenous depending on the writer's style (some extracts contain about 30 words because of the absence of punctuation or known verbs).

### 3.5 Interest of the method in other kinds of documents

To evaluate the interest of this method in other kinds of documents, we tested it on a full-text patent in the transgenic plants field, and on a corpus of 10 abstracts of articles on health.

We obtained these results: 149 extracts were identified from the full-text patent, and 27 extracts were obtained from the 10 abstracts of articles. The evaluation of the quality of these results is not easy, but in any case it is interesting to note that the method is efficient on long documents, on abstracts of articles and on subjects other than « transgenic plants ».

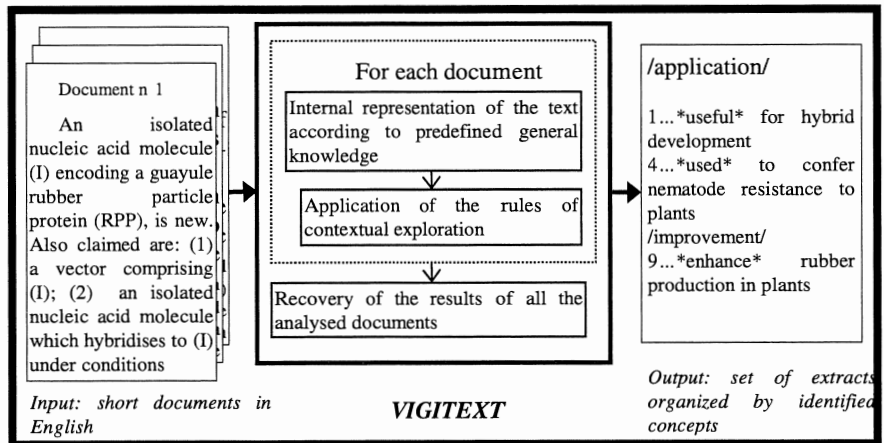


Figure 3: Architecture of VIGITEXT

## 4 The VIGITEXT system

VIGITEXT is programmed with the object-oriented language Java. It analyses documents contained in a data base, and allows a user to consult the information of the

corpus through the extracts on the interface. A gathering module permits the user to group the extracts according to his own knowledge.

#### 4.1 Architecture of VIGITEXT

As it is shown in figure 3, the analysis of a document consists first in the construction of an internal representation of the text according to linguistic knowledge. Then, the rules of contextual exploration are applied. Each identified context results in the creation of an extract. All the results are grouped by concepts on the user interface.

Actually VIGITEXT runs with about 70 indicators (that is to say about 200 forms) linked to the concepts (principally verbs, but also some nouns and adjectives) and about a hundred linguistic clues (prepositions, articles, forms of the verb « to be », etc.).

We have defined about 80 contexts which are identified by the rules of contextual exploration.

#### 4.2 Watching a document and its extracts

The screenshot shows a window titled 'Texte n°15'. The main text area contains the following paragraph:

An isolated nucleic acid molecule (I) encoding a guayule rubber particle protein (RPP), is new. Also claimed are: (1) a vector comprising (I); (2) an isolated nucleic acid molecule which hybridises to (I) under conditions represented by a wash stringency of 0.45 M NaCl, 0.04 M sodium citrate, 0.1% sodium dodecyl sulphate at 45 deg. C; (3) a transgenic plant containing (I) as a transgene; and (4) a plant host cell containing the vector of (1). USE - (I) can be used to induce rubber biosynthesis in organisms which do not ordinarily synthesise rubber. (I) can also be used to enhance rubber production in plants that already synthesise rubber.

Below the text, the interface displays the following information:

**Nombre d'extraits repérés : 8**

Notion	Chp	extrait
Amélioration	AB	*enhance* rubber production in plants
Production	AB	rubber *production*
Utilisation	AB	*used* to induce rubber biosynthesis in organisms
Utilisation	AB	*used* to enhance rubber production in plants

Figure 4: Interface showing a text with the associated extracts

To see the results, the user first selects a concept in the hierarchy shown on the interface. Then he obtains the list of extracts expressing the chosen concept (each extract is presented with the reference to the source document). If an extract seems to introduce important information, the user can select it to show the associated text.

On figure 4, the interface to see the text is presented: at the bottom, a table shows the extracts, which can be selected by the user, and at the top the text is in an area with the selected extract highlighted. With this interface, the user can quickly identify information about /application/ and /production/.

### 4.3 Organizing the extracts

We have developed an extracts gathering module. In fact, first the extracts are organized by concepts, statistically. But, seeing the extracts associated to a concept, the user quickly identifies extracts expressing similar information, or he locates uninteresting extracts. So, a gathering, as and when accessing to extracts, will permit the user to be more effective.

This module permits the user to create sets containing extracts from one or more notions.

For example, we carried out an experiment with a user, who created the group «insecticides », and associated to this group 8 extracts (corresponding to 6 patent references) identified from different concepts.

insecticides group:

- « plants with \*improved\* resistance to insect predation » - ref 200
- « \*control\* Lipidoptera esp » - ref 138
- « \*protecting\* a plant against an insect pest » - ref 142
- « lepidopteran-toxic proteins \*produced\* » - ref 140
- « \*Increasing\* the host range or toxicity of an insecticidal protein or a protein domain exerting its activity via interaction with the gut epithelium of insects within its host range » - ref 138

...

Figure 5: Results obtained with the gathering module

Such extracts may not be gathered by a classic search engine, as they do not contain a common terminology to express the information.

With this module, the user can: modify a group name, suppress a group, transfer one or more extracts from a group into another, and remove one or more extracts from a group. When a group is deleted or some extracts are removed from a group, the associated extracts are automatically associated to their initial concept.

In other respects, the resulting document groups can be statistically analysed.

## 5 Conclusion

The VIGITEXT system provides an original access to information described in patent abstracts, due to a hierarchy of general concepts associated to textual extracts. The classification is interactive, due to the extracts gathering module, which permits the user to organize the extracts according to his own knowledge.

### Acknowledgements

I am grateful to Jean-Luc Minel and Karen Nordberg for the careful reading of the manuscript and for comments.

## References

- [Berri and al., 1996] Berri, J., Cartier, E., Desclés, J.-P., Jackiewicz, A. and Minel, J.-L., (1996). SAFIR, système automatique de filtrage de textes. *actes de TALN-96*, pp.140-149.
- [Desclés and Minel, 1994] Desclés, J.-P. and Minel, J.-L., (1994). L'exploration contextuelle, in *Le résumé par exploration contextuelle., rapport interne du CAMS n 95/1, recueil des communications effectuées aux rencontres Cognisciences-Est, 25 novembre 1994*, Nancy, pp.3-17.
- [Dkaki and al., 1997] Dkaki T., Dousset, B. and Mothe, J. (1997). Mining information in order to extract hidden and strategic information., *RIAO 97*, pp.32-51.
- [Enguehard and Pantéra, 1995] Enguehard, C. and Pantéra, L. (1995). Automatic Natural Acquisition of a Terminology ». *Journal of Quantitative Linguistics*, vol.2, n 1, p.27-32.
- [Garcia, 1998] Garcia, D. (1998): Analyse automatique des textes pour l'organisation causale des actions. Réalisation du système informatique COATIS, Thèse de Doctorat, Université Paris-Sorbonne.
- [Goujon, 1999] Goujon, B. (1999). Extraction d'information techniques pour la veille par l'exploitation de notions indépendantes d'un domaine., *TIA '99, in Terminologies Nouvelles*.
- [Levin, 1993] Levin, B. (1993). English Verb Classes And Alternations., The University of Chicago Press, 1993.
- [Rouach, 1996] Rouach, D. (1996). La veille technologique et l'intelligence économique., PUF, p.37.

# A DATA PROCESSING SEQUENCE TO EXTRACT TERMS AND SEMANTIC RELATIONS BETWEEN TERMS.

Florence Le Priol

CAMS - LaLIC (Langage Logique Informatique et Cognition)  
UMR 8557 - CNRS - EHESS- Université Paris-Sorbonne  
96 bd Raspail - 75006 Paris  
tel: 01 44 39 89 61 fax: 01 44 39 89 68  
lepriol@msh-paris.fr

## Abstract:

*Extraction processing systems of terms or concepts give different results according to their strategy of search. The systems using statistical methods can treat a lot of texts but do not allow a very rich interpretation of results. The systems using linguistic methods allow a finer semantics but treat with difficulty a lot of texts. Coupling these two approaches allows the treatment of a lot of texts and in this way answer better the present needs. These structured knowledge can be used, for example, in "knowledge management".*

*IOTA is founded on a morpho-syntactic analysis and on the selection of the most representative term according to statistic criterion. SEEK-JAVA uses a semantic method (the contextual exploration) without syntactic analysis for the extraction of semantic relations between terms. The integration, in the data processing sequence ECoRSé, of IOTA and SEEK-JAVA, is carried out for the construction, from large corpus, of terminology in which the links between terms are interpreted. The relations identified by SEEK-JAVA (hierarchy class / subclass, attribute / value, instances of class, relation between an object and its part) build a terminological network giving semantic labels with relations between terms detected by IOTA. They are inserted in an organized system of meaning. The subjacent linguistic model is Applicative and Cognitive Grammar.*

**Keywords:** Contextual exploration, knowledge extraction and capitalization, semantic relations between terms.

## 1 Introduction

According to their strategy of search the information processing systems of terms or knowledge extraction give different results.

Systems using statistical methods, sometimes coupled with a morpho-syntactic analysis [Daille, 1995; Enguehard, 1993; Bruandet, 1989; ...] and systems using connectionist methods [Seffah and Meunier, 1995; ...] can treat a lot of texts but the results give much noise. These systems provide many information which do not always represent the domain. Systems which seek links between the detected terms do not propose interpretations of the relations between terms.

Systems using linguistic methods cannot be used for the treatment of a lot of texts. Most of the time, the analysis consists of a morpho-syntactic analysis [Bourigault 94].

On the other hand, some systems [Jouis, 1993; Le Priol, 1998] use a semantic method that allow the identification of the semantic relations between terms.

To couple a system using a statistical method (IOTA) and a system using a semantic method (SEEK-JAVA), allows the treatment of a lot of texts. The semantic relations identified by SEEK-JAVA increase the possible complexity of a terminological network by giving semantic labels to the relations between terms detected by IOTA. However, to know the nature of links between terms can be an help for an expert at the time of the terminology validation.

## 2 SEEK-JAVA: extract semantic relations between concepts

### 2.1 System structure

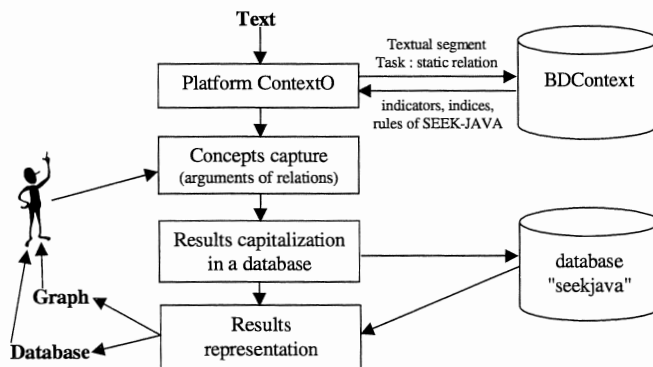


Figure 1: SEEK-JAVA in FilText project

SEEK-JAVA objective is a knowledge extraction and organization on the basis of text using contextual exploration method. It allows semantic relations extraction between concepts, knowledge organization in a data base and give results in form of graphs.

SEEK-JAVA (Figure 1) is an element of FilText project. Contextual exploration engine ContextO, associated with linguistic knowledge data base BDContext [Crispino *et al.*, 1999] allows "the decoration" of text by semantic labels specifying relations. Knowledge, triplet concept-relation-concept, are capitalized in "seek-java" data base then represented in form of graphs for a better interpretation.

### 2.2 Semantic relations

Semantic relations aimed by SEEK-JAVA are expressed by linguistic marker of "leave-all", ingredience, attribution by membership with a class, inclusion between class, localization, identification and identity relations.



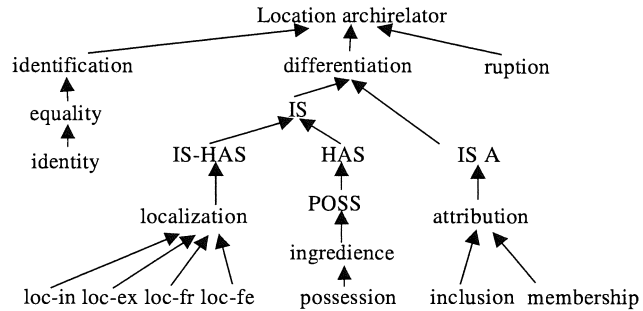


Figure 2: "architectonie"

In French, these static relations are attached to linguistic expression of primitives "is" and "has" [Desclés, 1987]. They are organized in a location network called "architectonie" (Figure 2).

Location function is the establishment of a location linked between a located entity and a locates entity. The semantics of each static relation correspond to intrinsic properties: the functional type (semantic type arguments of relation); algebraic properties (reflexivity, symmetry, transitivity...); layout properties (combination) with the other relations in a same context (i.e. in a given static situation).

### 2.3 Contextual exploration

Contextual Exploration [Berri, 1996; Desclés, 1997] consists in the seek in texts giving indices which play "release" role then in the seek of complementary indices in "release" context. When the "release" of the complementary linguistic indices are identified, it is possible to conclude on the semantic relation. "Release" indices, complementary indices and conceptual exploration rules constitute a linguistic knowledge base which remains relatively independent from the domain. Indeed, selected linguistic indices belong vocabulary to general language and not to a particular domain.

<b>Head</b> : Ringrdvrs09	
<b>Release</b> : relation statique	
<b>Comment</b> :	
<u>classe de l'indicateur</u>	<u>Exemple prototypique</u>
&IetreLingVerbPpasDivers4	Les œufs de Pâques <i>dont sont garnies</i> les poules en chocolat.
<b>Body</b>	
E:= créer_espace(DonnerAnterieures(I))	
L := &dont	
<b>Condition</b>	
Il_existe_un_indexe x appartenant_à E tel_que classe_de x appartient_à (L)	
<b>Action</b>	
1. attribuerEtSem(PhraseParent_de I, "ingrédience")	

Figure 3: rule Ringrdvrs09

A rule (Figure 3) is made up of five characteristic parts: "Head" is used to indicate the rule name; "Release" allows the indication of the contextual exploration task concerned (for SEEK-JAVA, it is a "Static Relation" task); "Comment" gives the possibility to provide some information as a class indicator which activate rule, a

prototypic example and possibly an additional explanation in natural language; "Body" gives contextual indices class, search space and rule condition; "Action" allows the attribution of semantic relation to the treated statement.

### 2.4 Linguistic knowledge Organization

Accumulated linguistic knowledge is stored and managed in the data base BDContext [Crispino *et al.*, 1999]. They are structured in tree tables (Figure 4).

The first table groups information concerning the linguistic markers (name, class, type...),. The second table allows grouping in "étiquette hors contexte" column , markers class labels. The third table groups rule indications. These three tables are dependent between them by "Classe" or "ClassIndicateur" fields.

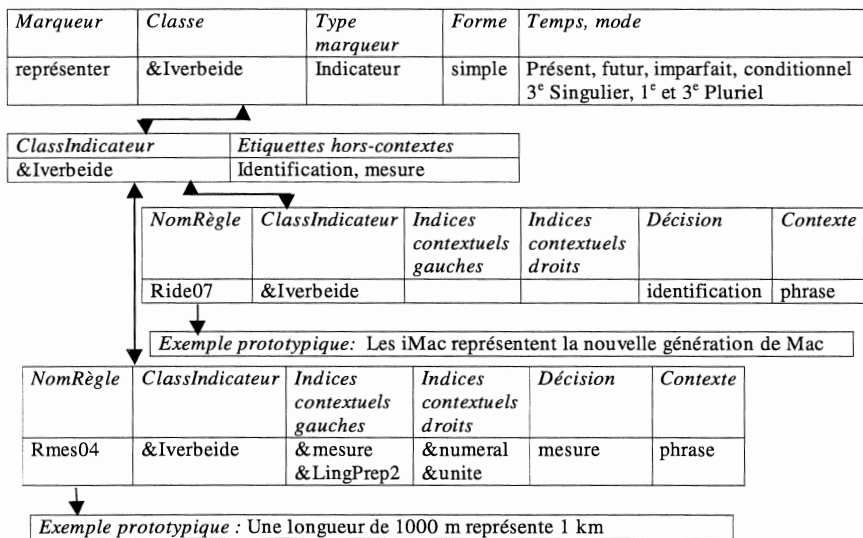


Figure 4: linguistic knowledge organization: the marker "représenter"

### 2.5 Knowledge capitalization and representation

Semantic relations and their arguments are capitalized in a data base. User can thus simply handle the data (Figure 5).

	argument_gauche	relation	argument_droit	corpus
GRAPHE	gravures rupestres	inclusion	corniformes	C:\VisualCafedbDEIProject...
	gravures rupestres	inclusion	armes et outils	C:\VisualCafedbDEIProject...
GRAPHE...	gravures rupestres	inclusion	figures anthropomorphes	C:\VisualCafedbDEIProject...
	gravures rupestres	inclusion	figures géométriques	C:\VisualCafedbDEIProject...
rechercher	gravures rupestres	inclusion	figures non représentatives	C:\VisualCafedbDEIProject...
	figures non représentatives	ingrédience	cupules isolées	C:\VisualCafedbDEIProject...
ajouter	figures non représentatives	ingrédience	groupes de cupules isolées	C:\VisualCafedbDEIProject...
	figures non représentatives	ingrédience	plages	C:\VisualCafedbDEIProject...
supprimer	figures non représentatives	ingrédience	barres	C:\VisualCafedbDEIProject...
	figures non représentatives	ingrédience	figures inclassables	C:\VisualCafedbDEIProject...
imprimer tout	figures géométriques	ingrédience	cercles	C:\VisualCafedbDEIProject...
	figures géométriques	ingrédience	croix	C:\VisualCafedbDEIProject...
enregistrer tout	figures géométriques	ingrédience	étoiles	C:\VisualCafedbDEIProject...
	figures géométriques	ingrédience	réticulés	C:\VisualCafedbDEIProject...
imprimer...	figures géométriques	ingrédience	spirales	C:\VisualCafedbDEIProject...
	figures anthropomorphes	ingrédience	figures simples	C:\VisualCafedbDEIProject...
enregistrer...	figures anthropomorphes	ingrédience	figures complexes	C:\VisualCafedbDEIProject...
	figures anthropomorphes	ingrédience	corniformes anthropomorp	C:\VisualCafedbDEIProject...
FERMER	figures anthropomorphes	ingrédience	réticulés anthropomorphis...	C:\VisualCafedbDEIProject...
	armes et outils	ingrédience	poignards et lames	C:\VisualCafedbDEIProject...
ajouter	armes et outils	ingrédience	hallebardes	C:\VisualCafedbDEIProject...
	armes et outils	ingrédience	faucilles	C:\VisualCafedbDEIProject...
supprimer	armes et outils	ingrédience	haches	C:\VisualCafedbDEIProject...
	armes et outils	ingrédience	armes diverses	C:\VisualCafedbDEIProject...
rechercher	armes et outils	ingrédience	claviformes	C:\VisualCafedbDEIProject...

Figure 5: "seek-java" data base

The table presentation allows fast and simple handling (tri, search...) but does not allow fast interpretation for lack of legibility. Knowledge representation in graphs, based on the semantic networks formalism, comes to supplement the table representation (Figure 6).

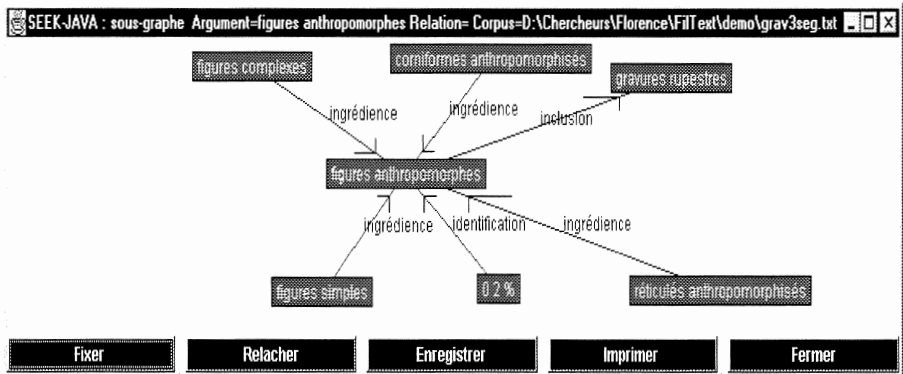


Figure 6: graph obtained starting from a corpus on "gravures rupestres"

### 3 Data processing sequence ECoRSé

#### 3.1 Data processing structure

IOTA and SEEK-JAVA integration is carried out using large corpus, for terminologies construction in which the links between terms are interpreted. Principal

interest of data processing sequence ECoRSe (Figure 7) is the complementarity of the two systems. IOTA works using large corpus. It allow the extraction of terms and not labelled relations between terms (cliques). SEEK-JAVA works using short texts. It detects semantic relations between terms but the terms are not automatically located.

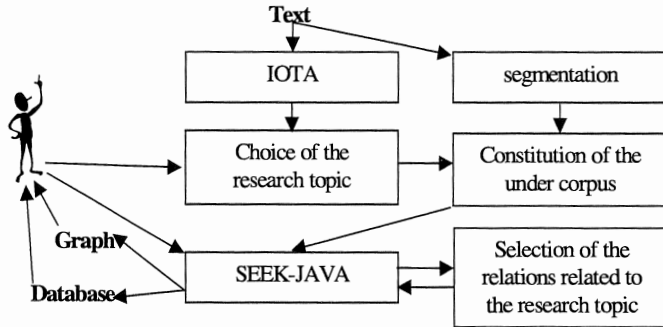


Figure 7: Data processing sequence ECoRSe

After cliques constitution by IOTA, user chooses his study topic by selecting a clique. Corpus sentences having made it possible to build the selected clique constitute user sub-corpus. Sub-corpus size is reduced (maximum tree or four pages for each sub-corpus) that is appropriate for SEEK-JAVA.

### 3.2 IOTA

IOTA [Chiarabella, 1986] is a Search Information System (SIS). To increase SIS performances (relevance of found documents by system) and to reduce system silence, a thesaurus is often used. IOTA approach consists in automatically building thesaurus using texts. It is thus a more restrictive vision of thesaurus. We regard as thesaurus terms only concepts found in the corpus.

Subjacent assumption amounts considering that two terms which present frequent co-occurrences in a same sentence are dependent or at least relate to the same concepts. Measurement that we defined [Bruandet, 1997] is founded at this lexical distance between two lemmatised terms and take into account:

- occurrences number of terms couple,
- pseudo-syntactic information.

It is obvious that associations between certain word categories such as prepositions have no interest for knowledge acquisition. Thresholds of values are defined for various syntactic categories which are substantives, initials and/or proper names, adjectives, verbs and prepositions and/or conjunctions (Figure 8).

This method implementation supposes a morpho-syntactic analysis adapted to the SIS. At the end of this analysis phase, lemmas (called simply terms) are extracted and associated with syntactic category.

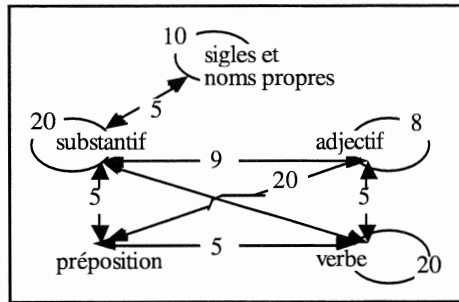


Figure 8: Graph of the syntactic categories

Measurement values are recorded in a term-term matrix. Graph associated with matrix is difficult to interpret and analyse. It is thus necessary to extract from it information more easily interpretable and corresponding better to the knowledge expression. We extracted from this graph the complete maximum sub graphs called *cliques* (sub graphs whose nodes are inter-connected between them). These cliques bring information to connections between terms. They represent, for a given term, "strong" contexts found in text.

#### 4 Conclusion

IOTA allows well to release terms dependent between them but links nature remain completely unspecified. In other words, IOTA determines potential relations and SEEK-JAVA must use these terms as arguments of semantic relations which it detects. However all the links between terms built by IOTA do not generate a relevant semantic relation between concepts detected by SEEK-JAVA.

The semantic networks built by ECoRSe can be used for different tasks:

- To consider more "semantic" indexing strategies of documents; selected elements not being only nominal groups but terms or nominal groups semantically dependent.
- Semantic relations facilitate networks interpretation by user (user is for example an expert charged to validate a proposal for an automatically built terminology).

#### References

- [Berri, 1996] Berri J. (1996), "*Contribution à la méthode d'exploration contextuelle, applications au résumé automatique et aux représentations temporelles. Réalisation informatique du système Séraphin*", Thèse de doctorat, Université de Paris-Sorbonne.
- [Bourigault, 1994] Bourigault D. (1994), "Extraction et structuration automatiques de terminologie pour l'aide à l'acquisition des connaissances à partir de textes" in *Actes du 9<sup>e</sup> Congrès Reconnaissance des Formes et Intelligence Artificielle*, Paris, pp 397-408.
- [Bruandet *et al.*, 1997] Bruandet M-F., Chevallet J-P., Paradis F. (1997), "Construction de thesaurus dans le système de recherche d'information IOTA: application à l'extraction de terminologie." in *Actes des Premières Journées Scientifiques et Techniques (JST'97)*, FRANCIL, AUPELF-UREF, Avignon, avril 1997, pp. 537-544.

- [Chiarabella *et al.*, 1986] Chiarabella Y., Defude B., Bruandet M-F; Kerkouba D. (1986) "*IOTA: a full text information retrieval system.*" Proc. of Sigir Conference on Research and development in Information Retrieval. Pisa, Italy, pp 207-213.
- [Crispino *et al.*, 1999] Crispino, Gustavo; Ben Hazez, Slim; Minel, Jean-Luc(1999), "Architecture logicielle de ContextO; plate-forme d'ingénierie linguistique" in *TALN (Traitement Automatique des Langues Naturelles)*; juillet 1999, Cargèse, France.
- [Daille, 1995] Daille B. (1995), "ACABIT: une maquette d'aide à la construction automatique de banques terminologiques monolingues ou bilingues" in *IV<sup>e</sup> Journées scientifiques de l'AUFELF-UREF: Lexicomatique et Dictionnairiques*, septembre 1995, Lyon.
- [Desclés, 1987] Desclés J-P. (1987), "Réseaux sémantiques: la nature logique et linguistique des relateurs" in *Langages*, n 87, septembre 1987.
- [Desclés, 1997] Desclés J-P. (1997), "Les systèmes d'exploration contextuelle" in *Co-texte et calcul du sens*, ed. Guimier, Presses de l'Université de Caen, 1997, pp 215-232.
- [Enguehard, 1993] Enguehard C. (1993), "Acquisition de terminologie à partir de gros corpus", in *Informatique & Langue Naturelle (ILN'93)*.
- [Jouis, 1993] Jouis C. (1993), "Contributions à la conceptualisation et à la modélisation des connaissances à partir d'une analysis linguistique de textes. Réalisation d'un prototype: le système SEEK", Thèse de doctorat EHESS, Paris.
- [Le Priol *et al.*, 1998] Le Priol F., Chevallet J-P., Bruandet M-F., Desclés J-P. (1998) "Intégration d'un système statistique (IOTA) et d'un système sémantique (SEEK) dans une chaîne de traitement permettant l'extraction de terminologies." *Ingénierie des Connaissances (IC'98)*, 13-15 mai 1998, Pont-à-Mousson, France, pp 33-40.
- [Seffah and Meunier, 1995] Seffah A., Meunier J-G. (1995), "ALADIN: un atelier orienté objet pour l'analysis et la lecture de textes assistée par ordinateur" in *International Conférence On Statistics and Texts*, Rome.

# INFORMATION ROUTING IN AN INDUSTRIAL RESEARCH CENTER: USING TEXTUAL DOCUMENTS TO BUILD RESEARCHERS AND TEAMS PROFILES

Bénédicte Pincemin<sup>1</sup>, Xavier Lemesle<sup>2</sup>

<sup>1</sup> INaLF, équipe Sémantique des Textes  
benie@club-internet.fr

<sup>2</sup> EDF - Division Recherche et Développement  
1, avenue du Général-de-Gaulle - 92141 Clamart cedex  
xavier.lemesle@edf.fr

## Abstract:

*Many new information systems rely on the definition of profiles. This paper presents the application DECID, based on profiles characterizing all the activities and skills in a research center. A critical review is made about human factors linked to the use of profiles, especially in the context of information sharing and dissemination.*

**Keywords:** human factors, DECID, electronic documents, information filtering, selective dissemination of information, user model.

## 1 Introduction

### 1.1 Organization of the paper

With the Web development, the volume of available and exchanged information keeps growing. Moreover, the computing powers have reached scales that allow new application opportunities. These two main factors, at least, have contributed to the interest for any kind of personalization for information systems, with the success of notions like *filtering*, *routing*, and *user profiles*. Among the diversity of propositions, we would like to stress the major models used, and the common questions encountered by applications relying on profiles. Actually, profiles are here a key element in the relation between human and computer.

We will then present DECID, a kind of routing application, running for 3 years in an industrial environment. DECID is characterized by 3 features, that make its strength and its novelty: (i) automation and place given to human interpretation, (ii) central use of texts, (iii) collective meaning of profiles. Grounded observations can now be collected and analysed, regarding human factors in the setting and usage of such a targeted distribution of information application.

### 1.2 Personalized information systems

#### 1.2.1 Profiles as queries

SDI (Selective Dissemination of Information) is the classical technique which consists in defining a sophisticated long-term query about a particular topic, with the help of a professional librarian. This query is then used to periodically alert about new

documents on the topic. The professional investment required to build a profile generates two limitations: either only some people can afford defining their interest profiles, or general strategic topic are chosen and corresponding profiles are defined, to which people can subscribe –but these are no more personal profiles. As new technologies have arisen, three modern versions of SDI have appeared: routing, filtering, and personal agents.

Routing has been defined as a complementary task towards adhoc retrieval [Belkin & Croft, 1992]. In the routing task, the query may be improved knowing the relevance judgement of the user for already seen documents. Actually, it is assumed that every user is implied enough to provide systematic assessments. But relevance feedback may be different in the context of long term queries, in order to avoid converging on one arbitrary subtopic, and to “forget” what’s no more in the present interests [Allan, 1996].

In the filtering perspective, one receives information by a certain “pipe” (e-mail, newsgroups) but one judges that part of it is irrelevant, and that it would be a great help to reduce the number of items presented [Lutz & al., 1990]. The danger is obvious: either you check the eliminated information, and gain no time; or you are exposed to any failure of the system, which may be especially serious for nominative information.

As for research about personal agents, it is above all concerned with spreading and cooperation strategies to explore the net. Moreover, queries are more rules to *extract* predetermined information than open queries to *discover* new matter.

### 1.2.2 Profiles as context for information processing

There are also profiles that are not queries themselves, but add information to process queries. User models have been studied for a few years, and their conditions of acceptance and limits are known [Allen, 1990].

Electronic Documents Management Systems offer different views and accesses to a big unique document collection, according to parameters that are defined by the administrator of the document base (parameters like project, area of responsibility, etc.).

More generally, some profiles are used to reduce the access to information, instead of enriching it. If the search area is too focussed, this goes against open-mindedness and useful knowledge of the environment. Such profiles may be like blinkers.

### 1.2.3 Profiles as searchable representation of people’s activities

A third way to conceive profiles is to characterize people’s activities and skills, for every person of a community, so as to be able to find every person concerned with a question [Harvey & al., 1994] [Streeter & Lochbaum, 1988]. Specific human aspects of these applications will be detailed in § 2.2.

## 2 The DECID system

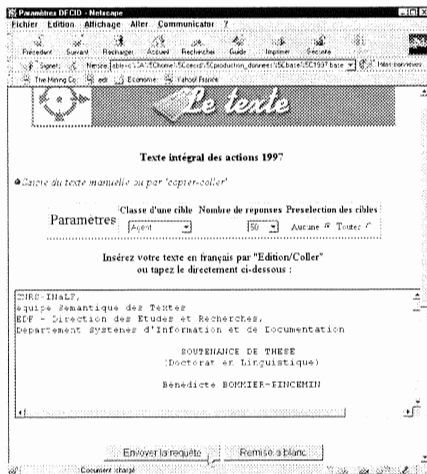
### 2.1 Defining characteristics

#### 2.1.1 DECID overall description

DECID stands for *Diffusion Electronique Ciblée d’Informations et de Documents*, “targeted electronic distribution of information and documents”. DECID is a document



routing system for selective dissemination of information throughout the research center of EDF, the French electric power company. The system is available via the Web on the Intranet, so that everybody in the company can use it easily without installing any specific software. DECID has worked for 3 years, and it has about 500 users and receives 10 to 20 queries a day.

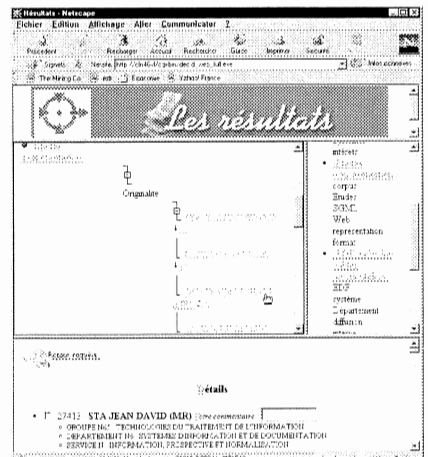
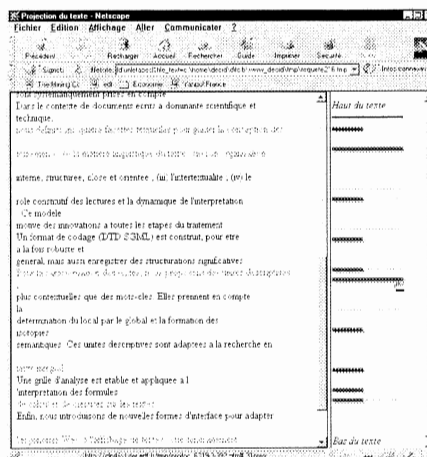


DECID is used to find people concerned by a document, or experts on a topic. The text of the document is directly submitted, for example with a copy/paste command. After a few seconds, DECID displays a list of selected researchers or teams, in relevance order and with detailed explanations for each proposal. The user can save his/her selection in a file, or e-mail the document to the people s/he has chosen.

The three main features of the targeted distribution are: (i) automatic processing and place given to human interpretation and decision; (ii) the use of texts both for querying (instead of keywords), and for characterizing people interests and skills (profiles are based on a corpus of research programs texts); (iii) the set of profiles represents thoroughly the research center activities.

### 2.1.2 Complete automation and interface for human interpretation

The complete automation allows the building and management of a large number of profiles, which is a must for the interest of the application and for its scalability. Here we characterize 1,200 researchers, 180 Groups, 35 Departments and 7 Services. These profiles are updated twice a year, when there is a new version of the research programs.



The automatic processing of the query is fast, so that the search is interactive and efficient. It allows the circulation with no delay of public or confidential information, and escapes from the contingent hierarchical organization which usually channels and compartmentalizes the information exchanges. The user who seeks for people concerned by a document keeps a key-role: the computer can *suggest* people, but cannot determine what is *relevant*: relevance is an *interpretative* judgement. That's why great attention has been devoted to building an interface adapted to the presentation and the navigation in the texts (texts as input, when the document is submitted, and texts as output, for the explanation of the selected profiles). The results' topical classification also allows a non restricted number of propositions (*silence* reduction) without wasting time because of some irrelevant ones (*noise* neutralization) [Bommier-Pincemin, 1999].

### 2.1.3 The key role of texts

All DECID inputs are texts: texts representative of a person's current activity for the profiles, and texts of the documents to be compared with profiles. So, there is no need learning a query language to use DECID, and no need "translating" the document with some information loss. For robustness considerations, the system does not assume some special structure or layout of the text. The process considers fundamental textual properties, and can also take into account knowledge about some main texts genres.

For the profiles, everybody can be equally characterized, as soon as one can collect for example all existing texts establishing the research activities for the year. Therefore, no involvement is required from the people to build their profile.

Moreover, using texts instead of keywords gives more semantic to the search: the *noise* is reduced (because the text brings disambiguating context to the words it uses), and the *recall* is raised (the text develops the subject, varies the vocabulary, refers to the domain shared background, and mentions some related questions). More semantic indexing units, adapted to full-text, can be defined [Bommier-Pincemin, 1999].

### 2.1.4 Collective meaning of profiles

All the profiles together provide a fair view of the activity of the research center. DECID can thus really help not to forget anyone concerned by an information, or to find the expert(s) on a question if s/he exists in the center.

The significance of every profile is related to its environment among other profiles. The profiles are not independent from one another, like in SDI systems. As there is an intertextuality among the texts of the corpus used for the profiles' definition, there is an interdefinition of the profiles representing people of the same organization. For example, the profile brings out the person original skills and professional experiences.

## 2.2 Human factors in targeted distribution of information

### 2.2.1 Effects on the organization of work

When they get to know DECID, people often worry about the increase of information amount in mail boxes: "the easier it is to route information, the more information one will receive". On the contrary, DECID's aim is to reduce excessive disseminations, which are to be replaced by targeted distributions. People then receive much less

irrelevant documents, and a few new accurate information they may have missed without the system. DECID is even more used to find people than to send documents.

One of the main current dissemination practice concerns the internal reports. The author of the internal report wants to know the list of persons to whom the report is to be sent. These people are not only the ones directly concerned by the topic: people who pay for the work, officials, colleagues of the team, experts, friends. DECID can be a help for the author not to forget some concerned people, but it would be a disaster if used to compute lists of names without the author's supervision.

### 2.2.2 Information exchanges and relationships

The reasons to send or to want a document are often a mix of rational and irrational motives: there is useful information, but also clear conscience information, relationship information, reassuring information ("just in case"), affective information (for example, about an old project one used to be very implied in).

Sending a document is not trifling: it is a social and meaningful action. Some implicit rules regulate exchanges: for example, usually one doesn't forward a document which seems to be of poor quality. Conversely, there is a social pressure towards information transmission, via the accusation of withholding information. Among hierarchic ranks, information exchanges are codified. A document received from a superior may be interpreted as "something one ought to read". A document sent to a superior may be partly interpreted as a means to attract his/her attention.

(French) social proprieties restrict sending a document to someone unknown: this might be seen as an intrusion or fawning. The role of DECID is then to give a good description of the activity of indicated persons, so as to make the first meeting easier, if the opportunity arises. Could the sender be anonymous? This would have two drawbacks. The sender would feel less responsible of the quality of the routing. And for the addressee, a great part of the value of the document s/he receives lies in the fact that a colleague personally has thought s/he could be interested by the document.

DECID serves the top managers purposes: a better coordination in the company, a reduction of duplicate activities, a more reactive organization. For middle managers, DECID takes a part of their job. They are the ones who used to pass information on, and some of them may feel stolen from one of their special tasks. But the ones who receive lots of information –because their name or position is well known– appreciate DECID anyway, because it helps them being efficient in all this information redistribution.

Sharing information is not spontaneous. Information owning is linked to power, it can make you indispensable. That's why managers have to practically encourage communicating attitudes. In the case there are tension or conflicts between two teams, which are in competition within the company, each team may try keeping its significant information for itself. Furthermore, individual benefits have to be considered as well as collective benefits. The direct and personal benefits for the user must be commensurate to the invested efforts.

### 2.2.3 Ethical concerns

For the DECID system, profiles are computed without telling it to the researchers or involving them. At least, people are curious to know how they have been described:

“How has my profile been made?” Two points must be clarified so as to make the system acceptable. First, it must be clearly explained which data have been used, and in what way they are processed for the profiles’ building. In DECID home page, it is specified that all the information used comes from the “textes d’Action”, which are written by the researchers for the managers in order to plan the center activities for the year to come. Knowing that the profiles are issued from these particular documents is essential, not only to understand one’s profile, but also to properly interpret the results of a DECID search. The second point which has to be clarified, is that a profile stands for someone’s professional activities and skills, and not for the person his/herself. Some users would like to add or rectify information in their profile. From experience, we have decided not to allow these interventions: it would be very costly (because of the time spent to do it, and because it would be better doing it with an expert of the system), and it might deteriorate the regularity and the homogeneity of the overall representation.

Users may also worry about the interference of an automatic system in the human relationships: “Do we set a world where people are closed in their office and just communicate by sending electronic documents via the nets?” Of course not! Everybody knows how important are informal talks and word of mouth information spread, and how essential are the relationship networks for the smooth running of a company. The role of DECID is actually to reinforce these exchanges by suggesting new people to meet, by recalling people one might have forgotten, by decompartmentalizing the organization. Typically, a good use of DECID is not to directly send a document to everybody more or less concerned, but to find a few good starting points, that is people from different teams who can pass on the information accurately (the system is not perfect) and who feel personally implied.

Another worry of users is the fact DECID might take the place of some workers and generate unemployment. But DECID makes a job which did not exist before, because it is no human job: a man cannot have a comprehensive and detailed view of all the current activities of several thousands of researchers. Conversely, DECID cannot be used without implying a human intelligence: DECID displays results, which have to be interpreted with judgement. Indirectly, DECID contributes to a more efficient work organization. This improves the dynamism and the competitiveness of the company, and should decrease long-term unemployment.

### 3 Conclusion

From the beginning, the DECID project has two main targets: (i) decompartmentalizing the research center, by helping people finding other researchers working on any given subject; (ii) creating a new dynamic for information distribution, with documents exchanges that would be faster, more accurate, and with overall less waste of time, of paper, and of energy.

After 3 years of use, one can say DECID has reached its first target, but that we are still under way for the second target. We have confirmed how much one has to take into account numerous and diversified human factors, as regards systems dealing with texts, information and communication. We have also stressed the relevance of the technical principles of DECID: the direct use of texts (with a richer semantic than non librarian

keywords representations), and the cooperation between complete automatic computing and human necessary interpretation through an elaborate interface.

### References

- [Allan, 1996] Allan, J. (1996). Incremental Relevance Feedback for Information Filtering. In Proc. SIGIR'96, 270-278.
- [Allen, 1990] Allen, R.B. (1990). User models: theory, method and practice. *International Journal of Man-Machine Studies*, 32: 511-543.
- [Belkin & Croft, 1992] Belkin, N.J., and Croft, W.B. (1992). Information filtering and information retrieval: Two sides of the same coin? *Communications of the ACM*, 35 (12): 29-38.
- [Bommier-Pincemin 1999] Bommier-Pincemin, B. (1999). Diffusion ciblée automatique d'informations: conception et mise en œuvre d'une linguistique textuelle pour la caractérisation des destinataires et des documents. PhD thesis, Univ. of Paris, France.
- [Harvey & al., 1994] Harvey, C.F., Smith, P., Lund, P., and Bell, G. (1994). The Word-of-Mouth Emulator - Representing expertise and interest in a research and development environment. In Proc. 18<sup>th</sup> Int. Online Information Meeting, 423-436.
- [Lutz & al., 1990] Lutz, E., v. Kleist-Retzow, H., and Hoernig, K. (1990). MAFIA - An active Mail-Filter-Agent for an Intelligent Document Processing Support. *SIBOIS Bulletin*, 11 (4): 16-32.
- [Streeter & Lochbaum, 1988] Streeter, L.A. and Lochbaum, K.E. (1988). Who knows: a system based on automatic representation of semantic structure. In Proc. RIAO'88, 380-388.



# SEMINDEX: A HUMAN-DIRECTED TEXTUAL INDEXING OF IMAGE CONTENT

Théodore Thlivitis<sup>1</sup>, Ioannis Kanellos<sup>2</sup>

<sup>1</sup>École Nationale Supérieure des Télécommunications de Bretagne  
Theodore.Thlivitis@enst-bretagne.fr

<sup>2</sup>École Nationale Supérieure des Télécommunications de Bretagne  
Ioannis.Kanellos@enst-bretagne.fr

## Abstract:

*We present a human-centered process for indexing image content. By image content we understand high-level interpretative information as opposed to information extracted by automatic image processing. We have developed an interactive application which guides a user in his/her extraction of semantic information from images. Multiple descriptions of the same image and easy extension of the description schemas were two of the main goals of the SEMINDEX application. We also present some results and guidelines taken from our own experience using the SEMINDEX process.*

**Keywords:** semantic indexing, content description, human/computer interaction, interpretative semantics

## 1 SEMINDEX in context

It is not possible to unify semiotic domains. It is not possible, for instance, to create images as you create text, to understand oral speech using image items etc. We don't even have to develop complex arguments in order to sustain such a statement. An anthropological or purely historical or cultural observation is merely sufficient : if translation between two different semiotic domains were possible and somehow equivalent, a cognitive economy principle (even if always obscure) would erase one in favour of the other.

Nevertheless, in the case of information retrieval, one needs not to dispose of the whole semiotic content of the image. On the other hand, *textuality* seems to possess two particular features that make it preponderant for any demand addressing the meaning of an item such as an image or a sound. Firstly, it is notorious that natural language can be used to say everything that is not ineffable, with the precision one wishes. Secondly, natural language uses symbolic data that may be largely exploitable by machines, and still be understandable by users.

In line with these assumptions, the SEMINDEX project aims at offering assistance means for a *non-expert* user, both in *textualizing* and *recovering* information of images. In other words, SEMINDEX develops two modules for *guiding* a user in rendering *descriptive*, *plastic* and *interpretative* features of an image or of several images, and/or in *retrieving* images from an image data base.

From this point of view SEMINDEX joins an *anthropocentric* computer system paradigm. For the *indexing* module, the textualization is mainly produced by the human agent. This is opposed to automatic image processing techniques. Those techniques (such as IBM's QBIC [IBM Almaden Research Center, 1999]) aim an automatic indexing of images and a retrieval based on image-to-image similarities. SEMINDEX is opposed to but not incompatible with such techniques.

In fact, a *bottom-up* approach, such as the automatic indexing methods, may actually give some hints to the human agent about the corpus organization, some color or texture details, etc. He may use this or other external aids in different steps of the SEMINDEX process. But since SEMINDEX aims a *semantic* description of the image which is governed by a *top-down* meaning process, entering the indexing cycle of SEMINDEX means that all semantic decisions are up to the user; and no automatic technique should replace these user's choices.

## 2 From Image to Text: the SEMINDEX process

SEMINDEX does not force a unique description schema. It takes into account the fact that *indexing processes* and *description needs* vary enormously inside different application environments. Consider for example the totally different kind of indexing process and objectives existing between a press agency employee, faced with dozens of photos to index a day, and an employee of the indexing service of a museum, mainly offering image retrieval services students and professionals.

By understanding this diversity, we focused on an *open architecture* which is easily adaptable to specific indexing needs. Instead of presenting our resulting description schemas details for a specific corpus<sup>1</sup>, we shall show the way we have proceeded to *converge* on these description schemas. We give also some useful guidelines for future applications on different domains.

Here are the main steps of the process underlying the SEMINDEX proposal:

1. The process begins when the need for a semantic indexing of one or more image corpus occurs, cf. fig. 1. We suppose that the initiator of this indexation demand

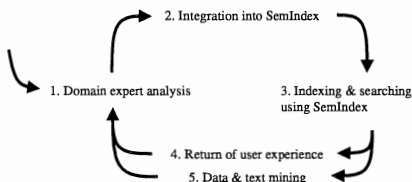


Figure 1: Outline of the underlying SEMINDEX process.

is a department related to image archival storage and that there exists an expert in

<sup>1</sup>In fact, we have been given a *celebrities* photos corpus, mainly made up of images accessible through the web. The main reason for this choice has been the current demand for such images, which seems to be the second most demanded kind of information in some web search engines.



image archiving<sup>2</sup>, e.g. a *researcher* working for the archival section of a newspaper or of a magazine or of a press agency; a *curator* of a museum; etc.

We call that person the *domain expert*.

Given some excerpts of the corpus to be indexed, the *domain expert* produces a first set of *prototype* image descriptions, using the SEMINDEX *meta-description schema*.

For simplicity and exchangeability reasons we have chosen a standard *meta-description*, the *XML Document Type Definition* (DTD). This means that the domain expert may use any XML validating editor<sup>3</sup>, load it with the SEMINDEX DTD and extend the standard (by default) SEMINDEX *prototype* image descriptions, cf. fig. 2.

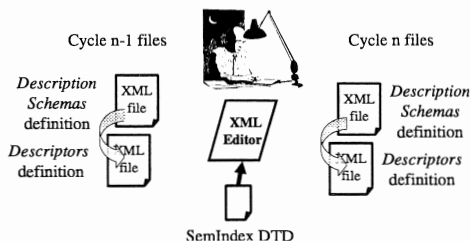


Figure 2: The domain expert uses the SEMINDEX DTD to extend the standard prototype descriptions XML file. He produces two new XML files, one for the *descriptors* and another for the *description schemas*, the second making references to the first one.

The current version of the SEMINDEX meta-description is described in appendix A. SEMINDEX acknowledges the importance of the *domain expert* for the success of this step. We want just to mention that our approach regarding the construction of the *description schemas* was based on the *Interpretative Semantics* theory [Rastier, 1987] as extended and operationalized in [Thlivitits, 1998].

2. The integration of the two fundamental XML files — the one containing the *Descriptors* and the other the *Description Schemas* — in SEMINDEX is immediate, since the SEMINDEX application reads those files during start-up, cf. fig. 3. In case of modifications to the *Description Schemas* (cf. later on), this means that all possible errors in the construction of these start-up files will appear during this phase. The *domain expert* has thus the opportunity to validate his or her modifications before the indexing phase. During this phase, all existing indexations are automatically transformed to correspond to the new description schemas, cf. later on the actions that can be undertaken.
3. Then comes the “real” indexing phase. We do not enter in the details of the user interaction. *Simplicity* and *efficiency* have been two major requirements during the

<sup>2</sup>Of course if a person having a sufficient experience with the indexing of a certain corpus does not exist, SEMINDEX suggests some default description schemas.

<sup>3</sup>We used IBM’s Xena XML editor. cf. <http://www.alphaWorks.ibm.com/tech/xena>

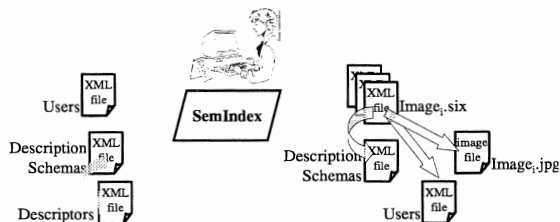


Figure 3: The main configuration files used upon start-up of the SEMINDEX application are: the “Users” XML file contains information for logging in the users who have the right to modify the indexations; this information is also used to mark out “who has changed what” during the indexing phase; the “Descriptors” XML file contains the hierarchy of the descriptors, the type of each descriptor (*free text* or *enumerated values*) as well as the *possible values* for all *enumerated* descriptors; the “Description Schemas” XML file contains the *prototype descriptions* defined by the *domain expert*, as shown in appendix A. The XML file representing the image and its semantic content points to the image file, to the SEMINDEX DTD, and contains identifiers taken from the *Users* configuration file as well as the two main *meta-description* files, the *Descriptors* and the *Description Schemas* XML files.

design, since one of SEMINDEX’s main goals is to *guide non-expert users* during the indexing (and of course the retrieval) phase.

The output of the indexing phase is a set of XML files containing the indexations of the images. To an image corresponds one XML file (the name of the image suffixed by “.six”) which contains all the indexations for that image, cf. fig. 2. The “.six” file alone has thus all the information relative to an image. XML enabled browsers could read directly the “.six” file and extract both the image file and the content description (which may be null if the image has not been indexed). During the initialization of the SEMINDEX application, “.six” files are automatically created for all new image files.

4. After the indexing phase of a set of images, it may be necessary for the *domain expert* to review the validity of the *Description Schemas* and/or the *Descriptors*. Two possible ways appear on fig. 1: an *automatic* extraction of rules and regularities from the indexed images, or a more *user-oriented* return of experience.

We will only discuss a case of “user-oriented” return of experience. It is based upon using the SEMINDEX application for a two months period. This is of course a simple case study. In professional indexing conditions a more elaborate *return of experience* protocol should be established.

For our experimental purposes, we were mainly interested in the following points:

- the *Descriptors* use and the “enumerated” descriptors’ *possible values* use: in fact, some of them were not used at all. Some of them were less used inside the context of a *Description Schema*.
- overall descriptive coverage: a few enumerated descriptors’ values were missing.

Remarks of this kind can lead to some modifications of the *meta-description schema*. In concrete terms, at the beginning of the second cycle of the SEMINDEX process the *domain expert* may need to proceed to one or more of the following actions on the *meta-description schema* XML files:

- (a) add a new *Description Schema* or a new *Descriptor*: these actions can be done at any moment with no loss of data
- (b) modify an existing *Descriptor* by:
  - i. modifying its name: this can be done at any moment with no loss of data (links between XML files are based on unique identifiers)
  - ii. adding a *possible value* to an *enumerated* *Descriptor*: this can also be done with no loss of data
  - iii. modifying a possible value's *name*: no problem, since indexations point to a *Descriptor*'s *possible values* using unique identifiers
  - iv. deleting a possible value from an "enumerated" *Descriptor* : of course, if one deletes this value from the *Descriptor*'s definition, all of this value's uses in indexations will also be deleted. Since this should normally happen if this value has not been sufficiently used, we have not implemented a replacement policy for deleted values.
- (c) modify an existing *Description Schema*: this means one of the following:
  - i. modify the name of *Description Schema*, which can be done at any time and will be taken into account at the next start-up of the SEMINDEX application
  - ii. add, modify or delete *Descriptors* from the Schema: cf. those actions themselves
- (d) delete a *Descriptor*: the consequences of such an action are double. Firstly, all *Description Schemas* pointing to that *Descriptor* should be manually modified, cf. fig. 4. Secondly, all indexations based upon these *Description Schemas* will loose the value of the deleted *Descriptor*. In any case this is not a recommended action, unless early in the SEMINDEX process. It is not a necessary action neither, since only the *Descriptors* that are actually used by at least one *Description Schema* will appear in the SEMINDEX application.
- (e) delete a *Description Schema*: this can be done at any time, but of course all indexations made using this Schema will be lost. It should normally be limited during the early stages of the SEMINDEX process.

The details above should at least point out the *extensibility* principle of SEMINDEX, cf. appendix A. Since the description needs to evolve rapidly over time, SEMINDEX was designed to fulfill such needs as simply as possible. The semantics of a modification are evident and no action is undertaken unless a user makes an explicit demand. All possible errors are reported during start-up, in such a way that the *domain expert* can always validate the new schema before the indexing phase.

### 3 Conclusion & perspectives

SEMINDEX lets *domain experts* easily and rapidly define, use and extend the *Description Schemas* as needed by the image corpus and the specific needs and experience

of the users of the indexation and retrieval systems. Using these *Description Schemas* the SEMINDEX application *guides* the users in efficiently indexing (and later retrieving images from) one or more image corpus. SEMINDEX supports a multi-user indexing environment with the possibility to have multiple descriptions for the same image, according to different *points of view*, i.e. *Description Schemas*.

We have a first return of experience from indexing an image corpus which has led to a number of corrections of the *Description Schemas* according to the SEMINDEX process. These modifications will be integrated for a second cycle validation. Hopefully only a few values were missing. The major part of the modifications concerned combining existing *Descriptors* and *Descriptor's values*. Some new *Description Schemas* may also be created.

We plan a thorough data-mining of existing indexations to search for rules and regularities which could further assist the user interaction. We also consider using natural language processing tools to enhance the choice of *Descriptors* and enumerated *Descriptor values* during both the indexation and retrieval phases. NLP and statistical tools can also be used for an off-line structuring of the textual values of the non-enumerated *Descriptors*.

#### A SEMINDEX meta-description schema

The SEMINDEX meta-description schema has been created according to 3 main objectives:

**extensibility** so the *domain expert* can extend the description schemas easily and with no modifications to the existing indexed images.

**simplicity** the *domain expert* is not (in principle) a computer scientist

**genericity** support for different application domains and multiple descriptions of the same image

Those principles gave rise to a meta-description schema shown in fig.4. The *Descriptors* follow a hierarchy structure. The standard hierarchies provided with SEMINDEX cover the following main aspects of an image:

1. the *plastic* aspects, like the “centering” of a photo, the fact that a photo is “fine” or “coarse grained”
2. the *description* and *interpretation* aspects, which contain the most important semantic information
3. the image *identification* aspects, like the “creator” or “date of creation”

#### Acknowledgments

This work is funded by the CNET (France Telecom’s center for research and development). We would like to thank François Rastier for his work regarding the semantic structure of a celebrities corpus, based upon the Interpretative Semantics theory [Rastier, 1987]. We would also like to thank Florence Knorst and Angélique L’Henoret for their fruitful remarks on indexing a corpus of images.

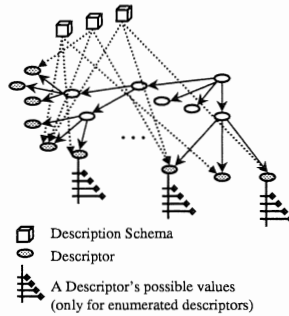


Figure 4: The generic structure of all *Description Schemas*. *Descriptors* are defined independently from the *Description Schemas*. They are organized in description hierarchies, an actual *Descriptor* being a leaf of the hierarchy. If the *Descriptor* is of *enumerated type* then the *possible values* are also attached to the leaf-*Descriptor*. The *Description Schemas* consist of a set of leaf-*Descriptors*.

## References

- [IBM Almaden Research Center, 1999] IBM Almaden Research Center (1999). Query By Image Content (qbic). <http://www.qbic.almaden.ibm.com/>.
- [Rastier, 1987] Rastier, F. (1987). *Sémantique Interprétative*. PUF, Paris.
- [Thlavitit, 1998] Thlavitit, T. (1998). *Sémantique Interprétative Intertextuelle : assistance informatique anthropocentrée à la compréhension des textes*. PhD thesis, Université de Rennes 1.



# REPRESENTATION OF CONTENT USING NATURAL LANGUAGE PROCESSING

Jérôme Vinesse

France Télécom — CNET/DSM/GRI  
jerome.vinesse@cnet.francetelecom.fr

## **Abstract:**

*This paper gives an overview of the studies in CNET concerning the representation of content of natural language documents of any kind. It also gives arguments in favor of the use of text as a convenient way to explicit non-textual contents.*

## **1 Introduction**

France Telecom, as a telecommunication operator, gives to his customers access to a great amount of information, and wishes to make it easier for them to localize and manipulate such information. A large proportion of that information is textual, and for that reason natural language processing has been studied for years in CNET, the R&D center of France Telecom.

Our claim in this paper is that natural language is a relevant way of representing non textual information as well, in order to index and retrieve it.

In the first part, we will explain our motivations for using natural language as a way to explicit content. The second part exposes the expected qualities of the content formal representation we would like to extract from texts. The third part is an overview of available features and work on progress in CNET in the field of content representation, especially for information indexing and retrieval.

## **2 How interesting is it to explicit content in natural language ?**

While natural languages are an excellent way of expressing content in human communication, because centuries of changes gave them lots of convenient qualities, one often prefers artificial languages — like programming languages, or keywords lists — when the content has to be processed by computers, because automatic processing of natural language is a very complex task. In contexts where both human and computer are involved in the processing of content, it is worth examining the drawbacks and advantages of natural language as a format for stocking content.

### **2.1 Drawbacks of natural language**

Drawbacks of natural language, in our context, are the properties that prevent it from being automatically interpreted.

#### ***It contains ambiguity***

One great problem of natural language as a representation system is ambiguity, and more precisely the fact that a piece of information in that system — a word, a phrase or even a sentence — may have several meanings. While a human reader might in most cases find out which of the meanings was intended by the writer, thanks to the context,

computational interpretation is much less likely to reach such a result, as the process of interpretation is extremely complex and little known so far.

### ***It allows multiple formulations***

A second problem, exactly opposite to the first one, is that there are multiple ways to express the same content. This constitutes a drawback because it makes it harder to automatically match contents that are similar, as far as they may look completely different.

This phenomenon appears at various levels of linguistic content. At the lexical level, we can use synonyms to designate the same reality. Furthermore, the same idea may be expressed by words of different parts of speech. At the syntactic level, ideas in a sentence can follow different orders without any clear change of meaning.

If we cross the boundaries of one language, it is also obvious that we can express nearly the same content in two languages, and that in such a case the way in which information is coded in the two languages may be completely unrelated.

### ***It mixes content and structure***

The third problem we will discuss is the fact that natural language is used for expressing bits of information that play very different roles in a document : description of a situation; subjective viewpoint on that situation; quotations; name, function and address of the author of the document; structure of the document; and so on. When building one application, all these elements of content should not necessarily have the same interest or use, and sorting them from a unique flow of text may be a complex task. If the application were to be built on the basis of a structured database, much of the above elements would have been put into separate fields in order to facilitate their use.

## **2.2 Advantages of a natural language**

Apart from the fact that it is largely spread, natural language as a representation system has a lot of qualities, which are very difficult to gather in a unique, stable artificial language.

### ***It allows subtle nuances***

Formal languages have a limited lexicon and a strict syntax, both because they are generally oriented towards a precise task and because they must obey strict constraints of interpretation.

On the contrary, natural languages possess a very large and even open lexicon, which enables to express a lot of similar but not completely equivalent senses. Furthermore, and though the syntax a natural languages obey rules, these rules are flexible and numerous enough to allow a huge amount of combinations. Both lexical and syntactic possibilities of natural languages thus allow us to express almost anything we mean, with as much precision as we need.

### ***It suits any kind of content***

Natural language covers all fields of knowledge, allows representation of abstract as well as concrete things, is suitable for descriptive, interpretative and evaluative discourse. In a word, it has no subject limitation.

### ***It is a durable standard***



Formal languages have two drawbacks concerning their status as standards. First, they are not shared by a great community of users. Secondly, they may become obsolete.

For natural languages, those two drawbacks disappear. They are known and used by a lot of people, each language being shared by a large community which is able to give equivalent meanings to the same expressions. Natural languages thus constitute a set of standard representation systems. Consequently, the amount of data available in natural language is extremely valuable, and describing non-textual information with texts is a good way to allow a common access to heterogeneous content.

Moreover, natural languages are not likely to become obsolete. They are naturally enriched when necessary, which makes them change, but slowly enough for the users and the automatic interpretation systems to integrate the changes.

### **3 What should be the ideal content representation to be extracted from texts ?**

Since we think that the advantages of natural language are valuable, it is worth using it as a content stocking system. We then need to get rid of the quite serious drawbacks we noticed : this should be done by automatically converting texts into a formal content representation system, which wouldn't share the drawbacks of natural language. This section presents the ideal qualities expected from such a representation system.

#### ***A surface-free representation***

While natural language allows multiple representations of the same idea, a formal content representation system designed for automatic processing should not.

The representation of content should not depend on the lexical choices made by the writer of the document. Synonyms and periphrases should have a similar or close representation, regardless of the vocabulary actually used in the sentence.

At the same time, the way the discourse is constructed should not influence too deeply the representation if the sense is the same.

Finally, the representation of the content should be close if two documents express the same idea in different languages.

#### ***An unambiguous representation***

The representation to be produced from the text must be as unambiguous as possible. The reason for that is that it will be used to match other representations : for example, the one produced during indexing will be matched to the one representing the query. Ambiguity would have serious drawbacks, close to those of keyword indexing : matching would be possible even if the content is different.

#### ***A treatable representation***

Some formal operations on content representation may be useful for information retrieval.

First, it should be possible to compare two representations that do not exactly match, in order to determine how close they are. This is necessary because natural language expresses lots of nuances, and in a lot of cases it is relevant to match slightly different contents.

Secondly, it may be useful to be able to produce representations close to a given one. For instance, if a query gives no results, we may wish to extend it in several ways to increase the chance to obtain results. One way of extension is generalization and a second one is approximation.

#### **4 What can we manage to do for content indexing and retrieval ?**

It must be clear that we are far from being able to convert texts in natural language into such an ideal content representation. It is even clear that specifying such a representation is a difficult task, and that processing a correct (non ambitious) linguistic analysis on unrestricted text is still not easy. This section gives a rapid overview of what has been developed in CNET in terms of linguistic processors usable for content indexing and retrieval, and also outlines the current directions of research in that domain.

##### **4.1 Available features**

The languages treated are French and English.

##### ***A typographic segmentation***

Segmentation is a necessary step in linguistic analysis because it determinates the list of words to be processed out of the string containing the sentence. But it goes much further into content analysis in identifying or pre-identifying a whole set of specific entities of the text : email addresses, URLs, times, dates, smileys, telephone numbers, and so on.

Giving a semantic type to the typographic entities of the text will avoid misinterpretations that would occur if, for instance, parts of URLs were to be interpreted as meaningful words.

This is done by a set of rules processed by the adequate engine.

##### ***A lexical analysis***

Lexical analysis consists in identifying in the text known entries of the lexicon. This is useful in two ways for content indexing and retrieval.

First it allows to have a common representation (called lemma) for the various forms of a word, like plural and singular forms. This demands a lexicon for each language, in which all existing forms are represented. Through the lexicon, all the forms can be reduced to the lemma, which will serve as a unique symbol to represent the variable word. This is very useful for information retrieval, as it reduces silence, even if it is only the very minimal form of surface-free representation.

Secondly, it makes it possible to detect the presence of compounds or phrasal lexical units, and to represent them as a whole, rather than as separate meaning elements, which would be totally irrelevant in most cases. Namely, the problem of those lexical units is that they are made of words which kind of lose their meaning when included in that context. For example, "it rains cats and dogs" has nothing to do with animals, and this may cause noisy answers for a query about cats in an information retrieval system. Using a lexicon of compounds or phrasal lexical units should then decrease noise.

##### ***A syntactic disambiguation***

We apply a method of shallow parsing, which builds groups of words (phrases) according to a grammar, and obeying a set of constraints, such as gender or number agreements. This step of analysis reduces the number of lexical hypothesis for each word of the text, and thus gives a more precise idea of the content.

Apart from the fact that some irrelevant possible lemmas might be discarded at this step, the result of syntactic analysis makes it to possible to filter the words according to their parts of speech. Nouns are generally relevant for information retrieval, while pronouns are not. A word like “mine”, which has among others those two parts of speech, can be filtered when necessary to avoid noise in retrieval.

### ***A thematic tagging***

Thematic tagging consists in attaching one or several semantic fields to a text or a portion of text. It is based on a large-scale lexicographic database, available for French and partly for English, associating a semantic field to each word sense. It uses a statistical method to determinate the most relevant fields.

Thematic tags can be used to restrict the information retrieval process to thematically relevant documents. This is a way to reduce noise while complete word sense disambiguation is not available.

## **4.2 Uncompleted features**

A lot of work is currently done in our team on semantic data and procedures.

### ***A search by concept***

One of the objectives of our projects is to be able to query a textual or textually represented database for a concept rather than for a word. This would be completed if we were able to build an ideal unambiguous surface-free representation of textual data. That being not the case, there is ongoing work on the subject.

To go further that mere thematic tagging, which constitutes a first way of reducing the effects of ambiguity, we are working on word sense disambiguation on the basis of semantic networks and argument structures.

In addition, we are studying the way to represent in our semantic database conceptual entities, mainly constituted of cross-linguistic synonym sets associated with their derivational families. For those entities to be effectively used, we also need to progress on word sense disambiguation.

### ***A search by extension***

Generalization is necessary to extend the scope of query if it was too precise to give interesting results. This demands a semantic taxonomy, on which we are working.

An alternative to searching by generalization is searching by approximation. This means that the query is extended to the closest concepts, and this again demands an adequate semantic network, which is also studied in our team.

## **5 Conclusion**

The quantity of information available in texts, as well as its quality, makes natural language processing a very promising technique. Yet, a lot of work remains to be done, especially in the field of semantics, in order to take a real advantage of linguistic

analysis. CNET is continuing research in that domain, for such applications as information retrieval, automatic abridgement or information extraction, in order to make relevant access to textual or textually described content on the Net a feasible task for the customers of France Telecom.

# **PART IV**

## **MANUFACTURING AND PROCESS CONTROL**

---





## ON THE MODELLING OF PRODUCTION SYSTEM

Souad Hadji, Joël Favrel

INSA-IF, Bât 502, PRISMa  
20, avenue Albert Einstein, 69621 Villeurbanne Cedex, France  
shadji@ifhpserv.insa-lyon.fr

### **Abstract:**

*We propose in this article to attach to the nominal supervisory control reactive modules to disturbances in a goal of functioning maintenance under disturbance. This type of reactivity remains adapted to the engaging of the degraded functioning from the detection of a disturbance. The insurance of production flow continuity is based on the commutation of adapted modes to the detected dysfunction. It means, the replacement of a module by an other in case of anomaly and, insurance intermode passages (nominal functioning, degraded functioning). If an event qualified as relevant appears, the behaviour of the system goes from nominal functioning to a type of specified degraded functioning. The first part of our contribution aims to at providing a formalism to model change mechanisms between working modes. This formalism should help us in nominal and degraded working mode validation. The second part of our contribution will consist in developing an approach based on the principle of supervisors commutation, for the robust control of discrete-events systems (DES).*

**Keywords:** Automaton, Statechart, Supervisory control, Alphabet Partition, SED.

### **1 The proposed structure**

#### **1.1 A first proposition**

The idea of the structure is to couple, not only one, but several supervisors to the process. Indeed, our motivation is linked to the unpredictable and exceptional character of perturbations and, to the necessity to process critical perturbations not taken in account a priori. Generally, most current perturbations are integrated into the nominal functioning. If expected in advance, these perturbations lose in a certain manner their abnormal character. One of the main difficulties met when using of such an approach (called integrated approach), resides in the fact that the designer needs to a priori envisage which symptoms are likely to appear and anticipate their processing. In our approach, Supervisors do not work simultaneously, contrarily to the modular supervision. They work towards to the global supervision of the process. Figure 1 illustrate the proposed structure.

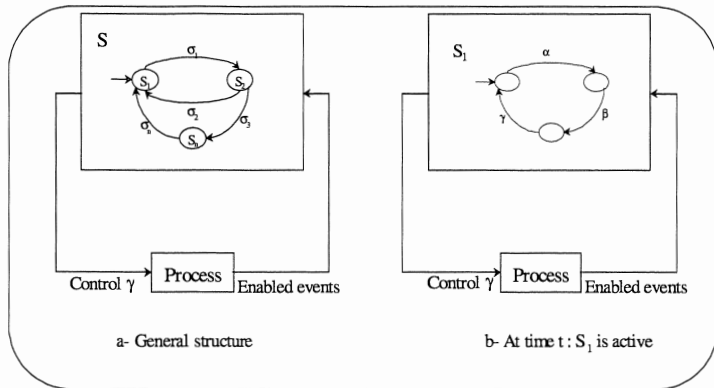


Figure 1: Diagram of supervision structure

Such an approach is interesting in the sense it simplifies complex problem resolution. Indeed, as the complexity of the different supervisors is lesser than the unique supervisor complexity of a centralised supervision. On one hand, supervisors can more easily synthesise. On the other hand, in the case where a specification has to be added or modified, it is not necessary to modify the global strategy of control. Only the calculated supervisor for this specification will be added or modified. Each supervisor acts alone on the process in a certain context. It means that in this context, it has a global and total information. However, the global supervision results from the work of the whole supervisors, independent some of others. The replacement of a block by an other is made by commutation following the occurrence of an event characterised as relevant ( $\sigma_i$ ). Let us  $\sigma_i$  ( $i = 1..n$ ), the events that switches the system from a functioning mode to another.

## 1.2 A second proposition based on mixed model: Statechart-Automatons

The automaton is a graphical language used to specify the control of discrete-event systems. When trying to use this tool beyond its preferential application field, for example to specify working modes, we rapidly meet problems triggered by the complexity of what it is necessary to describe and by the important size of descriptions. It becomes essential to structure specifications, by exploitation of the concept of hierarchy. In our proposed structure, our first constraint is the ability to commute from a supervisor to an other. That is to say to know how to switch from a set of states or activities to an other set of states or activities, during the commutation of the different blocks. We should be able to empty an automaton (to block it) and to activate an other automaton, that will control at one's turn the system. This is not allowed by automaton. We associate to automatons a related graphical language, the Statechart, that offers an interesting representation of the notion of hierarchy. According to our objectives, Statechart is a more efficient tool. The Statechart allows us to deactivate some modules and launch some others, according to the workshop configuration. Thus we define a precise job framework for each of the two languages. Statechart defines the working modes and describes the logic of evolution between these modes. Automatons refine the



expected behaviour when a mode is reached and mainly realise the efficient control. In other words the Statechart ensures the passage from the nominal mode to a degraded mode (and inversely). When the nominal mode or a degraded mode is reached, automatons ensure the supervised control, following the classic theory of Ramadge-Wonham (RW), [Ramadge and Wonham, 1988], [Ramadge and Wonham, 1989], [Wonham, 1995] and [Ramadge and Wonham, 1987]. Figure 2 illustrate the second proposition.

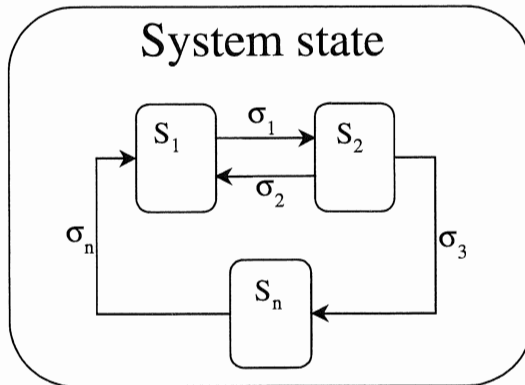


Figure 2: Partial specification Statechart showing only working modes

In our first proposition, only one supervisor attacks the process at the same time. In figure 2, at time  $t$ , only one supervisor is active at the same time in the model of the Statechart.

**Corollary 1:** The structure is an automaton, because in the theory of automatons, only one state is active at the same time.

### 1.3 Interest of the model

Hierarchical control is used when system management becomes too complex and/ or in presence of strongly dependent modules [Long, 1993]. Our approach is based on a global system subdivided in a set of sub-systems. This method leads to successive resolution of acceptable dimension problems. The efficiency of an hierarchical approach depends on the conception of levels and mechanisms of information return. Our architecture allows a decomposition of the problem in two levels by giving autonomy to each module. This hierarchy does not express only a hierarchy for decision but also a hierarchy for abstraction because the vision of the process is not the same at the different levels. This architecture is suitable to our approach, that will consist in giving to the system strong flexibility and reactivity under disturbances. By taking in account criteria of choice for the model tool, the mixed model Statechart - Automatons seems the most adapted. Indeed, the Statechart allows to fulfil the gap concerning the impossibility of automatons to express the hierarchy (in term of aggregation) [Harel, 1987]. More, for the purpose to obtain a more complete and power graphical tool, Statechart allows in particular to approach more efficiently the description of working modes. The proposition to couple to the automatons the Statechart language, which

belong to the same family, offers a graphical mechanism associated to the concept of hierarchy [Sahraoui and Ould Kadour, 1993].

## 2 Two-levels model

The proposed model is constituted by two levels. The high level is modelled by a Statechart and the low level by an active state of the Statechart . The transition of the high level to the low level is made by refinement. To the opposite, the transition of the low level to the high level is made by abstraction. On a formal point of view, the model is characterised by different workings according to the context in which we are. In this structure, we have two states of the Statechart and N supervisors. We burst the system in several sub-systems (figure 3).

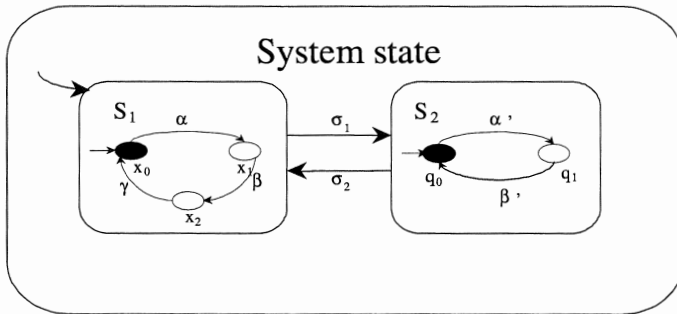


Figure 3: Two-levels model

### 2.1 Alphabet partition and proof

Our concept is based on the partition in two sub-sets of the global alphabet. We define a new partition of  $\Sigma$ , such that  $\Sigma = \Sigma_n \cup \Sigma_d$  with  $\Sigma_n \cap \Sigma_d = \emptyset$  (figure 3).

$$\Sigma_n = \{\alpha, \beta, \gamma, \alpha', \beta'\} \text{ and } \Sigma_d = \{\sigma_1, \sigma_2\}.$$

An event can be generated by the supervised process if it can be generated by the alone process and if it is allowed by the active supervisor. The working of a process G coupled to the supervisors S<sub>i</sub> is equal to the language  $L(G) \cap L(S_i)$ . The global working of the system is equal to the sum of the  $L(G) \cap L(S_i)$  for i go from 1 to N. Our goal is to validate the global structure. This partition implies that the global proof (Spec) is equal to the sum of separated proofs (S, S<sub>1</sub> and S<sub>2</sub>).

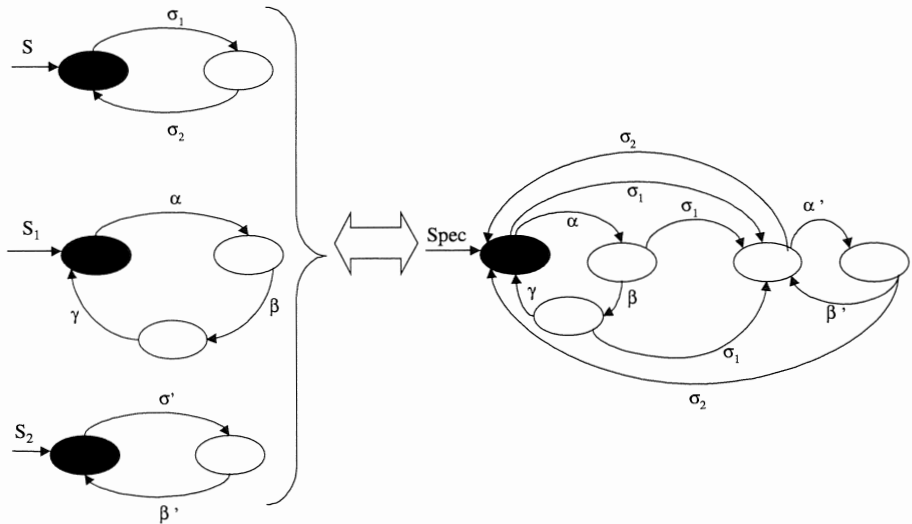


Figure 4: Global proof

**2.2 Construction of the reduced automaton: the global supervisor (S of figure1)**

At time  $t$ , only one supervisor is coupled to the process. Thus, if we look each supervisor as a particular state of the Statechart, there is only one state that is active at the same time. According to corollary 1, we can say that the structure is an automaton. The next step will be to replace each supervisor by a state, in order to realise the synthesis of the high level. The reduced automaton corresponds to the supervisory control when we are in the maximal abstraction level. To simplify the description, we use Statechart, which offers a talkative representation of the studied system behaviour. In this structure, we are interested only in the events that are qualified as relevant ( $\sigma_i$ ). For instance, if we took a production workshop, we should make abstraction of events "beginning of work" of a machine  $M_i$ , "end of work" of the machine  $M_i$ ... We would be interested by breakdown and repair event, for example. This reduced automaton corresponds to the supervisory robust control.

**2.3 Toward a maximal refinement**

To the basis, the technique of description used states-transitions diagram. In the figure 3, the diagram shows that the studied system will be in one of the two states " $S_1$ ", or " $S_2$ ". Labelled and oriented arcs describe the logic of state change: transiting from " $S_1$ ", or " $S_2$ " when the event " $\sigma_1$ " appears. And inversely, transiting from " $S_2$ ", or " $S_1$ " when the event " $\sigma_2$ " appears. The default entry serves to identify the state considered as present at the departure (initial state). At the departure, the system is in the state " $S_1$ ".

### 3 Conclusion

We have proposed to use jointly two graphical languages, Statechart and Automaton, to specify the supervisory robust control of automated production systems. We have defined a precise action field for each of them. The Statechart describes working modes and the logic of mode changes; automaton describes the detailed behaviour on the control system when it would have reached a particular mode following the occurrence of particular event. They will be used, in a first time, to refine "leaf" states (elementary states) of the Statechart defining modes and, in a second time to realise effective control. This approach presents many advantages. In particular it allows:

- to set up working modes of the studied system by showing graphically structural bonds (modes / sub-modes) ;
- to exploit the force of the Statechart thanks to its primitives that are simple to use.
- to describe the logic of mode change in a synthetic manner and very expressive manner, thanks to the power of evolution mechanisms associated to the concept of hierarchy and the generalisation of the notion of transition. For instance, it becomes possible to describe in a very concise manner that the progress of a mode will be interrupted if an event acting at a superior level occurs;
- to model in a formal manner, the mode changes on automaton that manage the progress of these modes.
- To propose a validation of the two levels of the model, for the global proof.

### References

- [Harel, 1987] Harel, D. (1997). Statecharts, a visual formalism for complex systems, *Science of Computer Programming*, North-Holland, n 8, pp 231-274.
- [Long, 1993] Long, J. (1993). *Sur la conduite hiérarchisée des systèmes flexibles de production*, Thèse de doctorat de l'INP Grenoble.
- [Sahraoui and Ould Kadour, 1993] Sahraoui, A.E.K. and Ould Kadour, N.(1993). on SART and Statecharts for reactive systems specification, 12<sup>th</sup> IFAC Congress, Sydney, 1993, vol5, pp317-320.
- [Ramadge and Wonham, 1988] Ramadge, J.G. and Wonham, W.M. (1988). Modular supervisory control of discrete event systems, *Mathematic control, Signals and Systems*, Vol.1, n 1, pp. 13-30.
- [Ramadge and Wonham, 1989] Ramadge, J.G. and Wonham, W.M. (1989). The control of discrete event systems, *IEEE Transaction on Automatic control*, Vol. n 1, pp. 81-98.
- [Ramadge and Wonham, 1987] Ramadge, J.G. and Wonham, W.M. (1987). Supervisory control of class of discrete event processes, *SIAM J. Control and Optimisation*, Vol. n 25, pp. 206-230.
- [Wonham, 1995] Wonham, W.M. (1995). Notes on control of Discrete-Event, ECE 1636F/1637S, System Control Group, University of Toronto.

# DYNAMIC ADAPTATION OF RULES BASES UNDER COGNITIVE CONSTRAINTS

Philippe Lenca, Elisabeth Le Saux, Philippe Picouet<sup>1</sup>

<sup>1</sup>Département IASC - ENST Bretagne - BP 832  
F-29285 BREST CEDEX

## Abstract:

*In the framework of the COMAPS (COgnitive Management of Anthropocentric Production Systems) project (Brite Euram BE 96-3941) this paper presents an algorithm dedicated to the updating of a rules base under cognitive constraints. These constraints come from the assumption that the rules are reasonable "approximations" of those used by a human expert.*

**Keywords:** cognitive modeling, knowledge acquisition, process control

## 1 Introduction

This paper is dedicated to a cognitive approach for industrial process control and to its use for designing an expert decision support system: the COMAPS tool. The COMAPS tool is based on a rather simple observation about the life cycle of man-machine cooperation in the management of an industrial process [Barthélemy et al., 1995]. Such a cycle can be decomposed into three periods (fig. 1). During the learning period, the human operator comes from the state of novice to the state of expert [Shanteau, 1988]. In the maintenance phase, the expert operator applies his/her know-how and adapts his/her rules to control the process. At the revision period (breaking period), either the expert and the physical system have evolved in drastically different ways or some important structural changes occur. In any case, simple adaptation of rules is not enough any more and a learning phase has to be initialized once more.

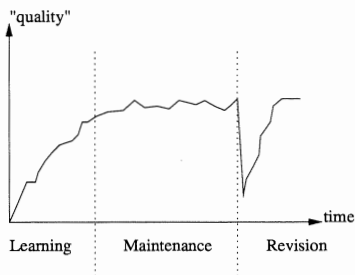


Figure 1: Life cycle of a process

Such a scheme inscribes in the framework of Anthropocentric Production Systems (Wobbe) the forms of advanced manufacturing which depend upon a balanced

integration between human skills, collaborative work organisation and adapted technologies. This kind of approach is also a way to capitalize knowledge and to adapt transfers of expertise.

The COMAPS tool is itself articulated into three phases: an offline learning phase, an online maintenance phase and a conflict solving phase. The learning phase extracts a set of initial rules from a sample. The learning algorithm is based on decision tree paradigm [Müller and Wiederhold, 1999]. The maintenance phase updates the rules according to new incoming information [Le Saux et al., 1999]. The conflict solving phase [Saunier and Bisdorff, 1999] is called when no acceptable modification can be recommended by the maintenance phase algorithm. This part of the COMAPS tool is the one that needs to fully interact with the expert operator and all the COMAPS man-machine interface is designed conjointly with it.

This paper emphasizes on the second phase. In section 2, we first describe the cognitive model we shall use; in section 3, we discuss some formalization issues. The main features of the maintenance phase are presented in section 4 and some concrete results are discussed in section 5.

## **2 Cognitive and methodological approach**

### **2.1 Methodological aspects**

Our methodology is based on an on-line non intrusive acquisition of the operator's behavioural strategies. It involves three main features:

1. The expertise modelling and the strategies extraction techniques follow cognitive principles like bounded rationality [Simon, 1979], parcimony [Barthélemy and Mullet, 1986] ...
2. The expert operator is in the loop of the process control, even in the aim of the strategies convergence towards a meaningful set of rules.
3. The protocol and the algorithm techniques are specific to the incremental and iterative aspects underlying the maintenance phase.

In the COMAPS framework, the expert is directly observed, on real situations, when performing decision making tasks.

### **2.2 Cognitive model**

In order to learn the decision maker's strategies, we follow Montgomery's principle of search for a dominance structure [Montgomery, 1983] instanced as the moving basis heuristics (MBH) [Barthélemy and Mullet, 1986, Barthélemy and Mullet, 1992].

The cognitive model assumes that the decision maker (DM) shows rationality in the way that something is optimized. But this rationality is bounded by his/her cognitive abilities (stocking and computing in a short term working memory) and his/her satisfaction features. As a consequence, he/she uses a not too large collection of stable strategies but involving a small amount of information. These strategies are assumed to be stored in a long term memory. They have been constructed from the DM experience.

In addition, the DM is supposed to use some combinations of information rather more frequently than others.

According to the above observations, the MBH integrates three main cognitive principles:

- *parsimony*: due to his/her short-term memory capacity, the DM manipulates a small amount of information [Aschenbrenner and Kasubek, 1978, Johnson and Payne, 1985],
- *reliability/warrantability*: the processed information that leads to a choice has to be large enough (in quantity and/or quality) for individual and/or social justification [Montgomery, 1983, Ranyard and Crozier, 1983],
- *decidability/flexibility*: the DM decides after a sequence of changes in term of processed information until a decision is made at a relatively short notice [Huber, 1986, Montgomery, 1983, Svenson, 1979].

### 2.3 Algorithmic consequences

As a consequence of the MBH, COMAPS tool searches for classical rules: “if condition then decision”. Main differences with the usual machine learning approach are that the “condition” involves always a small amount of information and that the expert does not use a “large” set of rules.

## 3 Formalisation

### 3.1 Data and rules

We are concerned by:

- A set  $X = \{X_1, \dots, X_p\}$  of  $p$  control parameters. Each parameter  $X_i$  has a values domain (numerical or nominal)  $V_i$ . The global domain is the set  $V = \prod_{1 \leq i \leq p} V_i$ .
- A set  $Q = \{1, \dots, q\}$  of labels denoting the decision outcomes. An element  $x$  of  $V \times Q$  is called a control situation (*cs*).
- A rule is tuple  $R = (W_{i_1}, \dots, W_{i_q}; j)$  with  $W_{i_k} \subseteq V_{i_k}$ , and  $j \in Q$ . The rule  $R$  will be sometimes written under a conjunctive form as:  $[(X_{i_1} \in W_{i_1}) \wedge \dots \wedge (X_{i_q} \in W_{i_q})] \rightarrow j$ . The first term is the condition of  $R$  and the second term its label. The dimension,  $\dim(R)$ , of a rule  $R$  is the number of control parameters occurring in its condition.

Let  $H \subseteq V \times Q$  be a set of *cs* and  $B$  be a set of rules we say that:

- The *cs*  $x = (x_1, \dots, x_p; l)$  is covered by the rule  $R = (W_{i_1}, \dots, W_{i_q}; j)$  whenever  $x_{i_k} \in W_{i_k}$ . If moreover,  $l = j$ ,  $x$  is said to be well covered by  $R$ .
- $B$  applies on  $H$  whenever each  $R \in B$  covers at least one *cs* in  $H$  and each  $x \in H$  is covered by at least one rule in  $B$ .  $B$  is consistent with  $H$  whenever  $B$  applies on  $H$  and every  $x \in H$  is well covered by some rule in  $B$ .

We can restate the COMAPS problematic in term of updating a set of rules  $B$  and a set of  $cs$   $H$  under three constraints: ( $C_1$ ): each rule has a “small” dimension; ( $C_2$ ): the number of rules is “not too large”; ( $C_3$ ): the rules constitute a set which is consistent with the current set of  $cs$ .

### 3.2 Complexity issues

The conditions  $C_1$ ,  $C_2$ ,  $C_3$  above correspond to NP-complete problems (for NP-completeness issues we follow the terminology from [Garey and Johnson, 1979]).

**Theorem** - Let  $v \geq 2$  be an integer. The following problem is NP-complete:

Name[v-COMAPS] (v-dimensional-COMAPS)

Instance: a set  $H$  of  $cs$ , an integer  $m$ .

Question: does it exist a set  $B$  of rules such that  $B$  is consistent with  $H$ ,  $|B| \leq m$  and  $\text{Max}_{R \in B} \text{dim}(R) \leq v$  ?

*Sketch of proof:* the set of  $cs$  covered by the rule  $R = (x_{i_1} \in W_{i_1} \wedge \dots \wedge x_{i_k} \in W_{i_k} \rightarrow j$  constitutes a so-called cylinder of  $H$  with basis  $W_{i_1} \times \dots \times W_{i_k}$ . The set of rules  $B$  is consistent with  $H$  if and only if the corresponding cylinders constitute a partition of  $H$ . The result is then obtained, with standard arguments, by reduction from the clique partitioning problem in graphs [Garey and Johnson, 1979]).

This remark assigns to the maintenance phase another role: correct eventual errors from the learning phase and correct its own errors ...

### 3.3 Some relaxations

In fact conditions  $C_1$ ,  $C_2$  and  $C_3$  appear as much too strong. In particular:

1. some inconsistencies (i.e.  $cs$  covered by a rule  $R$ , but not well-covered by  $R$ ) can appear sporadically without seriously affecting the robustness of a rules set.
2. “waiting before updating”, in order to find an efficient solution, could be better strategy than “change the rule at the first observed inconsistency”.
3. some observed inconsistencies can be just the result of priority between rules. This is the case when the CS  $x$  is well-covered by  $R$ , covered by  $R'$  and the DM uses  $R$  prioritary to  $R'$ .

To account for these three remarks, we introduce a priority relation  $\Pi$  on a rules set applying to  $H$ ; the notion of outer-covered  $cs$ , a certainty factor  $\gamma(R)$  of the rule  $R$ .

- $\Pi$  is a reflexive, acyclic relation on  $B$
- $x \in H$  is outer covered by  $R \in B$  whenever  $x$  is covered by  $R$  and if  $x$  is well-covered by  $R'$  then  $R' \Pi R$  ( $R'$  has priority on  $R$ ).
- $\gamma(R) = \frac{|\{x \in H: x \text{ is well covered by } R\}|}{|\{x \in H: x \text{ is covered by } R\}|}$

Another notion, *Promising Combination of Aspects*, is also usefull to increase the efficiency of the maintenance phase. It is discussed in [Lépy, 1999]. In any case, with these materials, condition  $C_3$  can be weakened into: ( $C'_3$ )  $B$  applies on  $H$  and  $\text{Max}_{R \in B} \gamma(R) < \sigma$  with  $\sigma < 1$  a threshold



## 4 Maintenance algorithm

We shall describe this algorithm in a rather approximate way (but sufficient to understand its main features). For more substantial details the reader can refer to [Le Saux et al., 1999].

### 4.1 Principles

The algorithm starts with a set  $H_0$  of  $cs$ , a set  $B_0$  of rules and a priority relation  $\Pi_0$  on  $B_0$  fulfilling the conditions  $C_1$ ,  $C_2$  and  $C_3'$ . According to new incoming  $cs$  arriving at time  $1, \dots, t, t+1, \dots$  that added to  $H_0$  constitute the sequence  $H_0, H_1, \dots, H_t, \dots$  of histories, it updates the rules and the priority relation in order to get a sequence  $B_0, B_1, \dots, B_t, \dots$ ;  $\Pi_0, \Pi_1, \dots, \Pi_t, \dots$  such that any triple  $(H_t, B_t, \Pi_t)$  satisfies to  $C_1$ ,  $C_2$  and  $C_3'$  (algorithmic updating of  $H_t$  and some other points are omitted).

### 4.2 Updating the rules base

Three cases can occur when a new  $cs$   $x$  arrives:

1.  $x$  is well-covered by at least one rule  $R$  and badly covered by none.
2. no rule in  $B_t$  covers  $x$ ,
3.  $x$  is badly covered by at least one rule  $R$  in  $B_t$ .

In the first case, set  $H_{t+1} = H_t \cup \{x\}$ ,  $B_{t+1} = B_t$ ,  $\Pi_{t+1} = \Pi_t$ .

In the cases 2 and 3, the algorithm uses, hierarchically, six functions that have been implemented to adapt  $B_t$ :

1. generalize an existing rule to cover a set of CS that are not or badly covered, by the following operations: removal of one dimension over a rule to extend it, extension the domain of a control parameter occurring in the rule.
2. create a new rule to cover a set of  $cs$  that are not or badly covered.
3. from a badly covering rule, create a “subrule” on the same control parameters as the initial rule ones in order to cover the  $cs$  well.
4. create a new rule with control parameters complementary to parameters involved in the bad covering rules.
5. add a new control parameter and its values domain in a rule  $R$ .
6. change the priorities between the rules.

The parameters of the algorithm are the maximum dimension  $m$  of a rule and the threshold  $\sigma$ . The operations (1) up to (6) are tested hierarchically, the first one for which  $Max \gamma(R) \leq \sigma$  and  $Max dim(R) \leq m$  is used to update  $B_t$ . When they all fail, two possibilities remain: parameters  $\sigma$  or  $m$  are tuned or the third phase starts.

## 5 Current results

Real data being confidential, we've been testing the algorithm through a mockup with coded data. The first tests have been led without the expert, dividing the coded data set into a training set for the learning phase and an incoming situations set for the maintenance phase.

With one of the pilot sites data, we had the possibility to test the behaviour of the maintenance phase facing a known evolution of the process control. Starting from a set of 6 institutional rules and an history of 1086 *cs*, the rules set has been updated according to 556 new *cs*.

The results according to the quality of the rules are summarized in Figure 2, the last column corresponding to the type of modification applied according to the list presented in 4.2. All the results have been shown to the expert and they were validated.

Rule	$\gamma$ Before	$\gamma$ After	Modification
1	0.41	1	
2	0.84	0.87	
3	0.56	0.87	5.
4	0.57	0.69	6.
5	0.89	0.87	5.
6	0.70	0.88	5. and 6.
7		0.84	4.
8		0.86	4.

Figure 2: Quality of the rules

We wait for a prototype, now under development, to be installed for benchmarking to be able to make some more tests, but this time in a real decision context and not only with *a posteriori* validation.

Some comparisons between classical machine learning tools, and especially decision tree learning tools like ID3 [Quinlan, 1986] and C4.5 [Quinlan, 1993] are also under way.

## References

- [Aschenbrenner and Kasubek, 1978] Aschenbrenner, K. and Kasubek, W. (1978). Challenging the custing syndrome: multi-attribute evaluation of cortison drugs. *Organizational Behaviour and Human Performances*, (22):216–234.
- [Barthélemy et al., 1995] Barthélemy, J.-P., Coppin, G., and Guillet, F. (1995). Smelting process control: from experimental design to acquisition of expertise. In *International Conference on Industrial Engineering and Production Management*, volume 2, pages 2–11.
- [Barthélemy and Mullet, 1986] Barthélemy, J.-P. and Mullet, E. (1986). Choice basis: a model for multi-attribute preference. *British Journal of Mathematical and Statistical Psychology*, (39):106–124.

- [Barthélemy and Mullet, 1992] Barthélemy, J.-P. and Mullet, E. (1992). A model of selection by aspect. *Acta Psychologica*, (79):1–19.
- [Garey and Johnson, 1979] Garey, M. and Johnson, D. (1979). *Computers and intractability, a guide to the theory of NP-completeness*. New York:Freeman.
- [Huber, 1986] Huber, O. (1986). Decision making as a problem solving process. In Brehmer, B., Jungermann, H., Lourens, P., and Sevón, G., editors, *New directions in research on decision making*.
- [Johnson and Payne, 1985] Johnson, E. and Payne, J. (1985). Effort and accuracy in choice. *Management Science*, (31):295–314.
- [Le Saux et al., 1999] Le Saux, E., Lenca, P., Picouet, P., and Barthélemy, J. (1999). An anthropocentric tool for decision support. In *The Sixteenth International Joint Conference on Artificial Intelligence*, pages 338–343, Stockholm, Sweden.
- [Lépy, 1999] Lépy, N. (1999). Conditional learning. In *Human Centered Processes*.
- [Montgomery, 1983] Montgomery, H. (1983). Decision rules and the search for a dominance structure: toward a process model of decision making. In Humphrey, P., Svenson, O., and Vari, A., editors, *Analyzing and Aiding Decision Process*, pages 471–483, Amsterdam:North Holland.
- [Müller and Wiederhold, 1999] Müller, W. and Wiederhold, E. (1999). Machine learning methodology and cognitive modelling of human expert operators in anthropocentric processes. In *Human Centered Processes*.
- [Quinlan, 1986] Quinlan, J. R. (1986). Induction of decision trees. *Machine Learning*, 1(1):81–106.
- [Quinlan, 1993] Quinlan, J. R. (1993). *C4.5: Programs for Machine Learning*. Morgan Kaufmann, San Mateo, CA.
- [Ranyard and Crozier, 1983] Ranyard, R. and Crozier, R. (1983). Reasons given for risky judgment and choice: a comparison of three tasks. In Humphrey, P., Svenson, O., and Vari, A., editors, *Analyzing and Aiding Decision Process*, North Holland.
- [Saunier and Bisdorff, 1999] Saunier, P. and Bisdorff, R. (1999). Man machine interface for a decision checking tool. In *Human Centered Processes*.
- [Shanteau, 1988] Shanteau, J. (1988). Psychological characteristics of expert decision maker. *Acta Psychologica*, (91):203–215.
- [Simon, 1979] Simon, H. (1979). *Models of thought*. Yale University Press, New Haven.
- [Svenson, 1979] Svenson, O. (1979). Process description of decision making. *Organizational behaviour and human performance*, (23):86–112.
- [Wobbe, ] Wobbe, W. Anthropocentric production systems: A strategic issue for europe. volume 1 of APS Research Paper Series (FAST). European Communities, Brussels.



## CONDITIONAL LEARNING OF EXPERT'S STRATEGIES

Nathalie Lépy<sup>1,2</sup>

<sup>1</sup> ENST Bretagne – Département Intelligence Artificielle et Sciences Cognitives  
Technopole Brest Iroise – B.P. 832 – 29285 Brest Cedex – FRANCE  
E-mail: Nathalie.Lepy@enst-bretagne.fr

<sup>2</sup> Centre de Recherche Public – Centre Universitaire  
13, rue de Bragance – L-1255 Luxembourg – LUXEMBOURG

### Abstract:

*We present a method which can be used to influence or to condition an automatic-expert-strategies-learning algorithm, by limiting as much as possible the interaction with the expert, which is a potential biases source. We introduce here two innovative concepts: conditional learning and Promising Combination of Aspects (PCA). The term "conditional" is used in order to account for the fact we have preliminary knowledge on the expert's strategies which are going to condition the learning and/or the acquisition: the system learns rules knowing that the expert uses preferentially such or such promising combination of aspects. This article is particularly centered on the validation of the PCA concept.*

**Keywords:** conditional learning, automatic learning, knowledge acquisition, ecological validation, decision-making model.

**Acknowledgement:** this work is financed by a grant from the *Ministère de l'Education Nationale et de la Formation Professionnelle* at Luxembourg.

### Introduction - Research context

The work presented in this article fits into the European project BRITE EURAM n° BE 96-3941 COMAPS (COgnitive Management of Anthropocentric Production Systems). Five firms collaborate on this project : Circuit Foil (copper leaf manufacturing) at Wiltz (Luxembourg), Thomson (PCB manufacturing) at Brest (France), Textar (break pad manufacturing) at Leverkusen (Allemagne), Camtec and teamwork at Berlin, and three academic partners : ENST Bretagne, CRP-CU at Luxembourg, Fgh IITB at Berlin.

The aim of this project consists in studying and applying the use of knowledge and technics coming from Cognitive Science in industrial field and, more specifically, in decision-aid problems, concerning quality process control. The cognitive model used is the Moving Basis Heuristic (MBH) [BARTHÉLEMY and MULLET, 1986, BARTHÉLEMY and MULLET, 1992], this model relies on three fundamental cognitive principles: *parsimony*, *reliability* and *decidability*.

A number of Knowledge-Based Systems (KBS) were already developed to assist the expert in his decision-making task. These systems gave rise in turn to hopes and disappointments to industrials and the general public. Two main difficulty sources can be listed: knowledge acquisition from an expert's know-how [LÉPY, 1997] and, on account of this know-how is evolutive, the maintenance of the acquired-knowledge base. To get

round the problems met during the knowledge acquisition, in particular the biases coming from the verbalization of his knowledge by the expert, some attempts were made to equip systems with automatic-symbolic-learning abilities: induction learning from examples and counter-examples, deduction learning, analogy learning, ..., to only name the more classical tendencies. The concerned applications are restricted to sectors where system use needs a strong interaction with the expert who confirms or rejects the suggested solutions. Interactivity has raised numerous questions concerning the expert and his/her integration in the assistance process, that is the reason why we were more particularly interested in designing a tool of *conditional expert-strategies learning* limiting, as much as it can be, the expert/system interaction. The term "conditional" is used in order to account for the fact we have preliminary knowledge on the expert's strategies which are going to condition the learning and/or the acquisition: the system learns rules knowing that the expert uses preferentially such or such combination of aspects which seems promising to him. We call *aspect* a value or a values set on one attribute. Our decision-making model was developed around this central concept of *Promising Combination of Aspects* (PCA) and by adapting the Montgomery's model [MONTGOMERY, 1983] of the search for a dominance structure to a judgment situation, instead of a choice one. Figure 1 synthesizes our modeling.

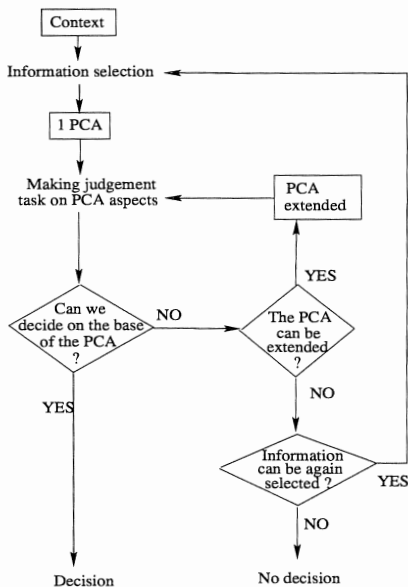


Figure 1: Decision-making modeling.

## 1 PCAs: ecological validation

A knowledge acquisition was made in parallel in our three industrial sites. We examine only one in the present report, it is sufficient to illustrate our matter.

The aim of this classical phase in the building of any KBS, was not to obtain a domain modeling by rules and facts directly injectable in the system (biases risk, cf. [LÉPY, 1998]). but to use this collected knowledge to appreciate the

This whole modeling is obviously built on the existence of PCAs, that is, they quite correspond to a cognitive reality in the thought decision-making processes. First, an ecological validation<sup>a</sup> [LÉPY, 1998] of this concept was performed. We present it in the first section. Next, we show how we formalized this PCA notion by linking it to a category already recognized in cognitive psychology. The third section presents the different means envisaged to find the PCAs underlying an expert decision-maker's strategies. We conclude by emphasizing how this concept could be a powerful "algorithmic accelerator" as a part of an expert-strategies learning tool.

<sup>a</sup>By ecological validation, we mean a validation on the field relying on the life, the actions of the human being in decision situation.

*Remark* : what we call *context* of the decision in our model, corresponds in fact in the Montgomery's one (cf. [MONTGOMERY, 1983]) to the feeling that it would have a *promising alternative*.

the ones our system computes (*ecological knowledge validation*) and, more generally, to validate our model and the concepts on which it is built. We restrict ourselves to the ecological validation of the PCA concept.

### 1.1 Knowledge acquisition: method practically used

This section presents the way we carried out the knowledge acquisition on one of our industrial sites. Three possible information sources were at our's disposal: a set of documents describing the production process, an expert and a daily meeting where experts act in concert to make the suited decision concerning the quality control of the process.

Documents were read and translated when it was necessary, in order that there was no misunderstanding about the technical terms used. Translations were also read and corrected/updated by the expert. Interviews were done, aiming at obtaining answers to the questions coming from this reading phase.

The daily meeting was the subject of audio and video recording. These observation sessions were immediately followed by an interview with the expert to collect: his comments about the meeting, some precisions about the decision made and the reasoning followed, divers comments about the production process. Each audio/video recording were faithfully and completely transcribed. So as to avoid the biases linked to knowledge verbalization, we insist on the fact that in the transcriptions, we accurately wrote down the right words used by the expert and not what we thought we had understood. The ecological validation of the collected information depends on this strictness. Another interview with the expert was then possibly done when the transcriptions made needed some precisions.

The reading of the recording transcriptions being difficult enough to be used as it was, a content analysis was done from the observations and interviews, the oral documents constituting a raw reference to which to refer when needed.

### 1.2 Evidences for PCAs

We define a *decision situation* as the set of parameters<sup>1</sup> values or *aspects* from which the expert<sup>2</sup> makes his decision.

About the industrial process studied, from the document read and the interviews made, we listed more than some forty parameters. However the observation sessions revealed that the expert have not all of them in front of his eyes when he makes his decision. According to the context and the difficulty of the decision to be made, he can possibly ask to consult the value of some "hidden" parameters. Moreover, from the content analysis made from our observations, it clearly emerges that some parameters are much more evocated than others during decision making, and the number of the different parameters considered in a same time to make a decision is three on average (it is not always the same three for the whole decision situations). In this way, the expert has some "parsimonious" and "reliable" combinations of aspects which he preferably examines and which bring him to make a decision or which direct him to study another set or a complementary set of parameters (decidability criterion).

Thus, the three fundamental cognitive principles: parsimony, reliability and

<sup>1</sup>We use *parameter* term in a general meaning: every important element the knowledge of which explains the characteristics of a set or a question (cf. *Le Petit Robert*)

<sup>2</sup>In the considered company, the *expert* is an entity which groups three physical people together, but we indeed take place in an uni-decision context. these people having to converge towards a common decision.

decidability, on which our model is built, and the PCA concept was well validated in the framework of the considered application. To make his decision, the expert draws on the smallest number of aspects as possible (*parsimony*), the judiciously chosen combination (*reliability*) of whose allows him to make the “best” decision as possible (*decidability*). In other words, he relies on a *Promising Combinations of Aspects*, of a minimal size (*parsimony*), which he will extend if necessary (to satisfy his *reliability* and *decidability* criteria).

The results coming from our observation analysis convince us of the relevance of a conditional-learning approach which in our case would be built on the PCA notion. Because the expert leans on the PCAs during his decision process, knowing them could allow any learning algorithm to keep the strategies compatible with the considered PCA set as a priority. The resulting rules set obtained would be therefore more representative of the expert’s decision strategies.

However, if the use of PCAs as a decision making support could be observed, on the other hand it is not possible to draw up a “sufficiently complete” list (sufficiently complete so that the learning algorithm is well “conditioned”). The observation duration needed to cover all the situations the expert can meet, would be probably higher by far than the fifteen days made. Adding that the analysis of this observation period and of the complementary interviews needed around four work months...

To ask directly the expert can not be either considered: “tell me, what are your PCAs?”. Biases being the result of this kind of direct asking are unavoidable. We developed therefore some methods for the automatic PCAs extraction (see section 3).

## 2 PCAs: from the development to the formalization

For describing more formally what we mean exactly by PCA, we started from a conceptual approach of the problem. The expert’s limited working-memory abilities [BARTHÉLEMY and MULLET, 1986] do not permit him/her to memorize the situations met. For this reason, he must both synthesize them and be able to generalize this expertise to the similar situations. Thus, it is by conceptual learning that he gets his decision-making strategies.

A concept can be seen as an objects class or category which have some common characteristics and each class can be connected with one or several specific behaviours (here: the decisions to be applied).

Initially the categories were described in term of attributes and sometimes in term of *features* (or *aspects*). That is to say that a list of attributes or features was drawn up which indicated if an object belonged or not to a given class. This point of view gave rise to the NSC (Necessary and Sufficient Conditions) model. However, a category can not be only described *in extension*, that is, it can not be merely seen as an instances collection. The concept give us an *in intention* category description (that is to say a mental representation associated to the category).

In 1953, [WITTGENSTEIN, 1961] pointed out that all the elements in the category did not concern all the same attributes, as it had been said in the previous view (NSC). She exhibited that it was the matter of grouping together elements which present some similarities, that is some common features, but not all: later, Rosch will speak about *family resemblance* which groups together the different common elements.

Afterwards, [ROSCH, 1973] introduced the *prototypy* notion which had been already



mentioned by [POSNER and KEELE, 1968] and highlighted in a lot of experimentations. In the Rosch's initial standard model the prototype could be defined as *the object which have the greatest number of common elements among the different instances in the considered category*.

She was got to revise this first model on account of experiences results which refuted some of her theses. In particular, in 1978, she [ROSCH, 1978] introduced the notion of the *validity of a feature  $f$* . This notion permitted her to define a  *$C$  category predictor*, that is the conditional probability  $P(C|t)$  that an object was classified in the  $C$  category knowing that it had the feature  $f$ . The *typical features* are those which have a maximum validity. They summarize the outstanding properties.

So, Rosch made a shift in her definition: the prototype is no more defined by a category instance, but by a mental construction, coming from *cognitive operations* on the typical features. In this new version, the prototype can not correspond to any real object of the category (fact experimentally demonstrated). It is a set of typical defining features. A category can be therefore defined by a Typical Combination of Features (TCF), notion from which we made a shift in meaning, from "typical" to "promising". Indeed, the TCF are the category representatives calculated more in intension than in extension, it is the reason why we prefer to speak about PCF (Promising Combination of Features), or about PCA, because we use the term "aspect" rather than "feature".

### 3 PCAs: how to compute them ?

After the formalization of the PCA concept, we elaborated two PCAs-extraction methods. In any case, we start from an historic of decision-making situations with the associated decisions made. These situations synthesize as it were the decision-maker/expert behaviour.

#### 3.1 PCAs extraction by statistical computation

We postulated that the promising combinations are used more frequently than any other no-promising combination. So, our first idea was to design a purely statistical extraction method. Our algorithm makes a study of the appearance frequencies of all the possible combinations of aspects in order to make the ones the user considers as the most promising to be emerged. As by the most promising we mean here the most used, we have chance to miss the PCAs which are more rarely used, because of the rarity itself of the situations they could support.

To reduce the space of the combinations to be examined and thus to avoid a calculating explosion, we took into account the cognitive principles of the MBH model.

#### 3.2 PCAs extraction by connexionist cognitive network

We said it was not possible to make sure that the PCAs set obtained by running the previous algorithm was complete (PCAs will be reliable, but they will be able to not cover all the space of the expert's decision strategies). Moreover, this algorithm took into account the cognitive principles underlying our model only for the pruning of the space to be explored (in order to have a "reasonable" algorithmic complexity). So this algorithm accounts for only one aspect of our cognitive approach. The second algorithm we propose, makes use of the cognitive principles of our model in the designing itself. We drew our's inspiration from a connexionist cognitive network which models an elementary

categorization task: CATEG\_ART, cf. [KANT, 1996], network coming itself from the ART network of [CARPENTER and GROSSBERG, 1987]. One of the interests of this network is that it constitutes in fact a connexionist version of the choice MBH model, applied to a categorization task. We already mentioned (cf. section 2) the fact that a decision-making task can be regarded as a categorization operation: expressing a given decision about a decision situation can be interpreted as classifying this same situation in the category labeled with the decision made, the PCAs constituting the *resemblances* between the situations in a same category.

#### 4 Conclusion

Because the knowledge acquisition phase is a real *bottleneck* for the designing of any KBS, resulting in part of the knowledge verbalization, we worked on the achievement of an automatic-expert-strategies-learning tool in which the interaction with the expert is limited as much as possible. However, the learning can be influenced by a set of indications on the decision-maker's *a priori* knowledge and on the promising research areas in the space of the whole possible strategies. In this spirit, PCAs constitutes a powerful algorithmic accelerator for a learning algorithm. We have introduced therefore the concept of *conditional learning*: the system learns rules knowing that the expert uses preferentially such or such promising combination of aspects.

The PCA concept was ecologically and formally validated. Even though the direct observation gives reliable and relevant indications, it does not permit to determine the PCAs, so we presented briefly the two automatic-extraction methods we developed.

The results obtained by our algorithms on the data of the process described in section 1 will be presented.

#### References

- [BARTHÉLEMY and MULLET, 1986] BARTHÉLEMY, J.-P. and MULLET, E. (1986). Choice basis: A model for multiattribute preferences. *British Journal of Mathematical and Statistical Psychology*, 39:106–124.
- [BARTHÉLEMY and MULLET, 1992] BARTHÉLEMY, J.-P. and MULLET, E. (1992). A model of selection by aspects. *Acta Psychologica*, 79:1–19.
- [CARPENTER and GROSSBERG, 1987] CARPENTER, G. and GROSSBERG, S. (1987). A massively parallel architecture for a self-organizing neural pattern recognition machine. In *Computer Vision, Graphics and Image Processing*, volume 37, pages 54–115.
- [KANT, 1996] KANT, J.-D. (1996). *Modélisation et mise en oeuvre de processus cognitifs de catégorisation à l'aide d'un réseau connexionniste*. informatique, Université de Rennes I.
- [LÉPY, 1997] LÉPY, N. (1997). Expertise et acquisition des connaissances en intelligence artificielle. In SPI'97, école doctorale SPI, université de Rennes I.
- [LÉPY, 1998] LÉPY, N. (1998). Validation écologique des connaissances et concepts sous-jacents à la construction d'un système cognitif d'aide à la décision en milieu industriel. In SPI'98, école doctorale SPI, université de Rennes I.

- [MONTGOMERY, 1983] MONTGOMERY, H. (1983). Decision rules and the search for a dominance structure: toward a process model of decision-making. In *Humphrey P.-C., Svenson O., Vri A., Analyzing and aiding decision process*, pages 343–369, Amsterdam North-Holland.
- [POSNER and KEELE, 1968] POSNER, M. and KEELE, S. (1968). On the genesis of abstract ideas. *Journal of Experimental Psychology*, 77:353–363.
- [ROSCH, 1973] ROSCH, E. (1973). Natural categories. *Cognitive Psychology*, 4:328–350.
- [ROSCH, 1978] ROSCH, E. (1978). Principles of categorization. In E., R. and B.-B., L., editors, *Cognition and categorization*, Hillsdale (N.J.). Erlbaum.
- [WITTGENSTEIN, 1961] WITTGENSTEIN, L. (1961). *Investigations philosophiques*. Gallimard, Paris. Traduction (ed. allemande: 1953).



# WORKFLOW MANAGEMENT - FROM CHAOS TO SYNERGY

Robert T. Leskovar, József Györkös, Ivan Rozman

University of Maribor

Faculty of Electrical Engineering and Computer Science; Institute of Informatics

Smetanova 17; SI-2000 Maribor; Slovenia

{RLeskovar, Gyorkos, I.Rozman}@uni-mb.si

## Abstract:

*Modern companies tend to maximize customer and employee satisfaction, respect their individuality, and maximize profit and minimize costs and risk simultaneously. They tend to define and optimize their processes, make them human centered and, especially bigger companies, spread their business (products and services) all over the world. Global enterprises and virtual organizations are showing up. The workflow technology, as an answer and a solution to these tendencies, pervades different application domains. Therefore demands for the efficient and robust workflow management system (WfMS) and for the interoperability of existing WfMSs and tools from different vendors are natural phenomena. The Workflow Management Coalition (WfMC), Object Management Group (OMG) and different individual researchers and developers have done much in this direction but there is no general and final solution, yet. Standard architectures are being built and different new methods are being developed which try to satisfy workflow-specific demands. New approaches include also application of intelligent agents and domain content languages on the basis of the Extensible Markup Language (XML).*

**Keywords:** Workflow Technology, Workflow Management Systems, Workflow Standards.

## 1 Introduction

Organizations and companies in application domains such as banking, insurance, telecommunication, finance, health care and others have been using special centralized, tightly coupled information technology (IT) architectures, together with proprietary components and tools, for several years. These components and tools could be classified into several groups like document management, image processing, e-mail processing, groupware or project support tools.

Such applications have greatly increased productivity and provided better services. Despite their success they have also drawbacks which are growing through the influence of distributed, heterogeneous environments where e-commerce and dynamic workflows are placed today. Major drawbacks are unadaptable, hard-coded business policies and information accesses. This is inadequate for today's dynamic business processes where activities and resource allocations have to change at run-time. Second major drawback is isolated application execution. Older applications were developed for the specific platform and operating system to solve specific problems. Occasionally they have used

simple message exchange mechanisms but they were still isolated information and process islands.

## 2 Workflow Management Systems

Workflow has been proposed to solve the problems mentioned in the introduction. It is intended to separate business process management logic from other application logic like database management systems did with the database logic. This omits the need to rewrite applications when changes in procedures occur.

According to the definition, the workflow is the automation of a business process, in whole or part, during which resources, information or tasks are passed among participants for action, according to a set of procedural rules [WfMC-RM, 1998]. As business processes are automated, production can increase dramatically. A workflow system is used for this purpose, namely it is used to define, manage and execute workflows according to the computer representation of the workflow logic.

The market for workflow has evolved from requirements across the whole IT industry, with a wide range of products focussed on one or more particular aspects of the overall workflow requirement. This multiplicity of products increases the need for standards within the industry to enable different products to work together and integrate within a consistent overall architecture. Through the global connectivity and e-commerce the world is becoming a huge organization with a spectrum of products and services it offers. Inside this organization there are thousands of departments with different purpose, products, knowledge, services and the IT infrastructure which enables implementation of these entities. Therefore the most needed standards are those for the interoperability of workflow systems. Let us take a look first at the general features of the workflow systems:

- *understandable process definition representation* – a process definition consists of a network of activities and their relationships, starting and terminating conditions of the process, and information about the individual activities, such as participants, associated IT applications and data, etc. A workflow modelling tool as a part of the workflow system provides on one hand a graphical process view to non-programmers such as business analysts, re-engineering experts, end-users and others, and on the other hand a computer-understandable representation that is interpreted and executed.
- *distributed, heterogeneous architecture* – workflow systems have to run on multiple platforms since business processes often span across multiple locations (distributed departments of a company, company and its subcontractors, etc.) which generally use different platforms. Because of this the workflow system often employs three-tier client/server architecture. Special stress should be laid on the effective event management service (as proposed in [Eder and Panagos, 1999]) since there are many events and groups of events in the business environment concerning management of time, IT and human resources and costs.
- *data model* – we can classify workflow data in many ways. In the WfMC workflow reference model (see section 3.1) three kinds of workflow data have been identified: (i) workflow control data - the workflow enactment service

maintains internal control data to identify the state of individual process or activity instances and to support other internal status information; (ii) workflow relevant data – used by both the application and workflow management system; and (iii) application data - used by the workflow application only.

- *user model* – user model specifies each user's role and thus separates the roles (specifications of capabilities needed to perform a task) from the physical resources, which may change during the workflow enactment. Specific resources that have the required capabilities will be assigned to the task at the process execution time. Often the user model is represented by the organizational structure in the organizational directory.

### 3 Standards that enable interoperability of Workflow Management Systems

#### 3.1 Workflow Management Coalition and The Workflow Reference Model

In August of 1993 major corporations formed a Workflow Management Coalition (WfMC), a non-profit international organization of workflow vendors, customers and analysts with the charter to address the problem of standardization regarding the interoperability of workflow systems and components.

The WfMC has identified five functional interfaces to a workflow service as part of its standardization program – the Workflow Reference Model (figure 1) [WfMC-RM, 1998]. Specifications of these interfaces represent a firm, general workflow system architecture without implementation constraints regarding workflow service.

The core of the Workflow Reference Model is *the workflow enactment service*. It is a software service that may consist of one or more workflow engines in order to create, manage and execute workflow instances. Applications may interface to this service via the Workflow Application Programming Interfaces (WAPI).

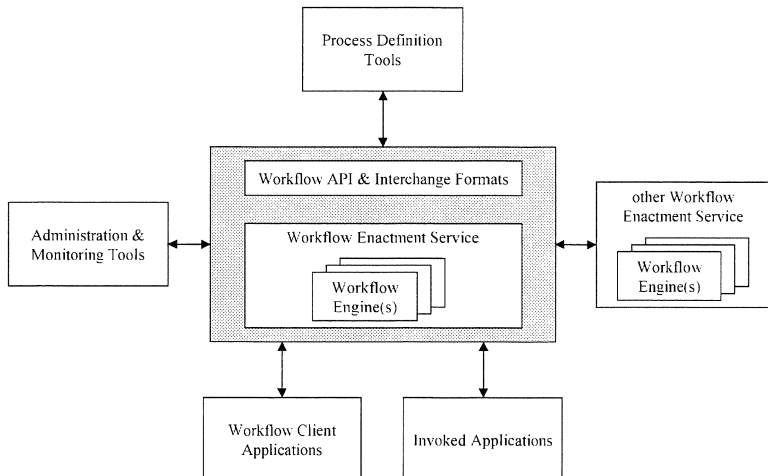


Figure 1: The WfMC's Workflow Reference Model

A variety of different tools may be used to analyse, model, describe and document a business process. *Interface 1* defines a common interchange format, which supports the transfer of workflow process definitions between separate products and workflow service. Interface 1 includes a common meta-model for describing the process definition and a textual grammar for the interchange of process definitions (Workflow Process Definition Language - WPDL) and APIs for the manipulation of process definition data.

*Interface 2* specifies standard workflow management Application Programming Interfaces (API) - WAPI. With the support of these interfaces in workflow products developers can implement front-end applications that need to access workflow services.

*Interface 3* defines an interface mechanism between workflow management systems and any other application. This mechanism is based on the so-called "Tool Agents" that can handle the application control and information exchange. They can communicate with applications by using DDE commands, by protocols like OLE or CORBA or any other concept. The suggested interface defines the way a Tool Agent can be used by a workflow application, e.g. a worklist handler or the workflow engine; it does not define a direct application control mechanism.

*Interface 4* provides an abstract specification that defines the requests and responses that two or more workflow engines must exchange to be capable of supporting processes that interoperate across a network. WfMC has also defined a binding that gives concrete type definitions and message formats for the realization of the abstract specification, using Internet e-mail with MIME encoding as the transport mechanism. At the 1998 AIIM show in Anaheim (California), there was a major press event illustrating the capabilities of this interface in a live interoperability demonstration.

Specification of the *interface 5* specifies what information needs to be captured and recorded from the various events occurring during a workflow enactment. It does not define how the data is stored, but what information is to be gathered and made available for analysis. The purpose of this interface is the ability to use one monitoring application with different workflow services from different vendors.

### **3.2 Object Management Group and the Workflow Management Facility**

The submission to the Object Management Group's (OMG) Workflow Request For Proposals from a consortium of 19 companies, backed by 23 potential users of the specification, including the Workflow Management Coalition, is known as the Workflow Management Facility (WMF) [OMG-WMF, 1998].

Ever since it has been published in 1995, the Common Facilities part of the Object Management Architecture (OMA) had a placeholder for an architectural component that "provides management and coordination of objects that are part of a work process" – the Workflow Facility [Schulze, 1997].

The Workflow Management Facility specification uses the ISO Interface Definition Language (IDL) to define its core interfaces. By means of these interfaces the workflow engine can be plugged as a component in the different workflow environments and interact with other business objects. The reality is not so simple, though, but firstly it is important that the facility is standardized and adopted.



The Workflow Management Facility has been adopted in the beginning of 1999 by the OMG. It is a great accomplishment for both the OMG and WfMC members since it achieves the goal of being able to build large-scale, stable and easy to maintain applications in a controlled manner, according to opinions of working groups' members.

### **3.3 Internet Engineering Task Force and the Simple Workflow Access Protocol**

In May 1998 a working group was set up to develop a Simple Workflow Access Protocol (SWAP) for use over the Internet. Workflow services provide sequencing of other services, and thereby need a way to start an external generic asynchronous service, and to be told when it completes.

SWAP uses the Internet Uniform Resource Identifier (URI) of a process definition to generate process instances, retrieve instance states and for other requests. The process originator may provide the process instance with the URI of an observer. When the process instance is completed it will send an HTTP request back to this URI in order to notify the originator. This allows the originator to be put to sleep, freeing up operating system as well as network resources while waiting for the process instance to complete.

Because the service generates a unique process instance object for every invocation of the service, many invocations can be performed at the same time, a very important feature when the service may take several weeks to complete, as is sometimes the case in the long-running Internet applications.

SWAP uses W3C's Extensible Markup Language (XML) to provide parameters for the messages sent using the HTTP protocol. Request responses are also encoded using XML. Agreement on the final specification of this protocol is expected in 1999.

## **4 Technologies of influence**

### **4.1 Agent technology applied to the workflow environment**

Agents have characteristics that are synergetic to circumstances in the organisation [Jennings et al., 1997]. Most important are: (i) distributed, autonomous behaviour for distributed problem solving; (ii) social skills for information sharing, coordination and negotiation; and (iii) responsiveness to changes for unpredictability in the business process and proactively taking of opportunities.

Since such agents employ knowledge repository and various reasoning and planning mechanisms they can contribute to the optimization of the workflow and consequently of the business process in the organisation. This may improve the maturity and overall quality of the business process.

Another important aspect of agents is adaptability to the demands and individual characteristics of users. They can act as personal assistants (manage schedules, adaptively search for specific information, etc.) and allow humans concentrate on creative work.

### **4.2 Using Extensible Markup Language as the basis of the workflow language**

Today there is a trend in different communities to create their common languages on the base of The Extensible Markup Language (XML) [W3C-XML, 1999]. XML makes

it much easier to develop and deploy new task or domain specific markup, enabling the automation, parsing and processing of such data. It provides its documents (data collections) with the attributes of extensibility, defined structure and validation. Therefore it would be probably useful to define a standardized workflow description language on the basis of XML.

In the workflow world there are already many approaches to describe workflow data in XML - in the section 3.2 we have seen how SWAP employs XML; [Eder and Panagos, 1998] expressed intention to use XML for workflow-specific data; etc. XML parsers are already built in some Web browsers. This means that users of a workflow system will be able to connect to the system from any location using the browser and exchange their task information without the need for other applications and tools (they can effectively use notebooks or even PDAs when participating in a workflow).

## 5 Conclusion

Workflow technology is going to pervade through different application domains and, consequently, impact the whole information society. It has many advantages and potentials over traditional, legacy systems but it can also integrate with them. Companies can cooperate effectively by using this technology and this is also the working attitude of the groups and individuals in the next millennium. Competition does not produce such results as the synergy of cooperating environments. It is important that the Object Management Group and the Workflow Management Coalition shape common standards. By the end of 1999 it is expected to see first compliant products from member vendors. The workflow technology is relatively new and pretty sophisticated and needs further research regarding implementation aspects, like distributed task execution and transaction processing. It is useful to integrate it with new, emerging technologies, like Extensible Markup Language, intelligent agents and the new generation of middleware.

## References

- [Eder and Panagos, 1999] Eder, J. and Panagos, E. (1999). Towards Distributed Workflow Process Management. *Workshop on Cross-Organisational Workflow Management and Co-ordination*. San Francisco. California.
- [Jennings et al., 1997] Jennings, N.R., Faratin, P. and Johnson, M.J. (1997). Agent-based business processes management. The IBS Research Group. Intelligent business systems. <http://www.labs.bt.com/projects/ibsr/papers/aew/papers.htm>.
- [OMG-WMF, 1998] Object Management Group. (1998). Workflow Management Facility Revised Submission. <http://www.omg.org/pub/docs/bom/98-06-07.pdf>.
- [Schulze, 1997] Schulze, W. (1997). Fitting the Workflow Management Facility into the Object Management Architecture. *OOPSLA '97*. <http://www.tiac.net/users/jsuth/oopsla97/schulze.html>.
- [W3C-XML, 1999] World Wide Web Consortium. (1999). Extensible Markup Language, <http://www.w3c.org/XML>.

---

[WfMC-RM, 1998] Workflow Management Coalition. (1998). The Workflow Reference Model and Specifications of its interfaces. <http://www.aiim.org/wfmc/standards/docs>.



---

# MACHINE LEARNING METHODOLOGY AND COGNITIVE MODELLING OF HUMAN EXPERT OPERATORS IN ANTHROPOCENTRIC PROCESSES

Wolfgang Müller<sup>1</sup>, Eckhard Wiederhold<sup>2</sup>

<sup>1</sup> Fraunhofer Institute Information- and Data Processing  
Project Office Berlin  
Mollstraße 1  
D-10178 Berlin  
Wolfgang.Mueller@pbb.iitb.fhg.de

<sup>2</sup> Fraunhofer Institute Information- and Data Processing  
Project Office Berlin  
Mollstraße 1  
D-10178 Berlin  
ecky@cs.tu-berlin.de

## Abstract:

*Within this paper some aspects of the BRITE-EURAM Project COMAPS (cognitive management for anthropocentric production systems) are presented. The entire COMAPS-system is an online decision support system to control dynamically changing industrial production processes. This contribution is focussed only on the initialisation phase by machine learning methods providing a snapshot of the current knowledge on the control policy of the expert operators. Especially emphasised is the adoption of the production rules produced by ML techniques to the cognitive model of expert's control practice. The applied algorithms to obtain a quasi optimal rule set as a model of the intensional representation of the expert knowledge were tested by real world applications (printed circuit board, foil and brake pad production). The results of one application is presented.*

**Keywords:** Online-systems, decision trees, cognitive modelling

## 1 Introduction

The COMAPS-system is designed for online support of experts in control of anthropocentric production processes. By setting technological process parameters, the industrial (anthropocentric) production process delivers products, which will be assessed according to given quality indications. Since the quality parameters and the process environment evolve, the human operator's expertise is essential for controlling the production process so that the quality indication of the products is optimal or at least satisfactory. Normally, there exist several tunable process parameters leading to a multi decision problem. The operator support of the COMAPS- system is based on a model, called DOAM (dynamic operator action model) in the sequel. This model should reflect the mental representation of the production process being the basis for rational decisions of human operators.

The DOAM contains two parts: a control reference (CR) as extensional and an "optimal" rule set (RS) as intensional representation of the expert knowledge. The CR contains relevant control situations (CS) from the past. A CS consists of the measured values of physical process parameters, measured or observed environmental parameter values, quality indices and decision values according to a special product. It contains both physical process parameters (attributes) and subjective discrete decision values. From the physical point of view the CR can be considered as a set of points in a multi-dimensional state (feature) space. The number of dimensions corresponds to the number of relevant parameters. The decision outcomes are represented by the different labels.

The rule set (RS) represents a generalisation of all CS collected in the control reference (CR). It is formulated as a set of production rules, consisting of a condition and a conclusion part. The condition part is a conjunction of aspects. An aspect consists of values of attributes. Discrete aspects are defined by a set of associated values, and continuous ones by their intervals. In the context of the COMAPS algorithm a production rule is called elementary rule (ER). From the cognitive point of view an ER represents a certain control strategy, called atomic control strategy of the human expert. A disjunction of elementary rules with identical conclusion parts describes the generalised control strategy according to the correspondent conclusion value and the complete control strategy includes those for each conclusion value of each decision outcome.

Before starting the COMAPS- system the model has to be initialized. An initial CR can be filtered from a raw data set containing the entire number of CS collected in the past. The correspondent initial RS can be generated by using machine learning approaches.

## **2 Machine Learning Approaches for initialization of the DOAM**

Machine learning is generally taken to encompass procedures, that learn a task from a series of examples (in our case control situations) [Michie et al, 1994]. An example is described by a vector of attribute values with a class value attached, that has to be established beforehand. In terminology of machine learning this is called supervised learning. Each attribute may have either unordered (categorical) or ordered (e.g. continuous) values. Most of the machine learning tasks can be mapped onto a classification problem. Machine learning in the close sense intends to generate classifying impressions simple enough to be easily understood by a human. Their algorithms generate decision trees (e. g. CAL5 [Müller and Wysotzki, 1994], CART [Buntine and Caruana,1991], C4.5 [Quinlan,1993] ), exception trees (ripple down method [Scheffer,1995] ) or production rule sets (like Cn2 [Clark and Niblett,1989] ). The reason for the suitable legibility is that these classifiers split the entire feature space into axis parallel class regions and it is easy to derive production rules reflecting the decision behavior of the human operator. Statistical methods (e.g. discriminant analysis) and neural networks construct and optimize weighted sums of all the original features for the sake of classification. These weighted sums correspond to new (transformed) features which become now the basis of classification. So the original features are "hidden", the classifier is not legible and they do not mimic human reasoning to provide insight into the decision process.

For the initialisation of the DOAM decision tree algorithms are used for following reasons:

- The results are legible by the human experts (performance of all machine learning algorithms in the close sense)
- The training time is normally not as high as for CN2 and the classification results are mostly better [Michie et al, 1994].

For the learning step two different decision tree algorithms are used: CAL5 [Müller and Wysotzki, 1997] and a C4.5 like Algorithm [Quinlan, 1993]. CAL5 mainly delivers well generalized decision trees at the expense of the correctness while the behaviour for the trees delivered by the C4.5 algorithm is vice versa. Therefore both algorithms are applied.

From each decision tree a rule set, representing the different control strategies, can be derived. The conjunction of all tests ( in DOAM they are called aspects) along a path from the root to a leaf node define the condition part of the production rule and the correspondent leaf label is its conclusion part.

### 3 Discussion of the results of machine learning algorithms

The generation of the production rules of all leafs is more or less a physical model of the production process including the real actions of the human operators. From the cognitive point of view, apart of the empirical observed CS, there is no direct formal access to the cognitive expertise of the human operator. But the rule set delivers a discussion basis and allows a cognitive reflection upon his practice. Thus, it can be considered as hypotheses of his control strategies. Thereby the generated rule of one leaf represents an atomic control strategy.

From the machine learning point of view a decision tree covers the complete feature space and delivers a rule set, which allows to formulate hypotheses that assign a class label to each point within this space. But the hypotheses are only reliable in these points, describing the observed CS. Thus, the rule set derived from the decision tree should be adopted to the original control reference (CR). It does not need to cover the complete feature space. There are sub areas in the feature space, where no experience according to any control strategy exists; they are empty. The coverage of such an empty state space by a rule would correspond to a more or less satisfying prediction according to the control strategy. That does not correspond to the desired intensional representation of expert knowledge.

In the case of sub areas containing CS with different values of the decision outcome (class values), a coverage of different elementary rules with the corresponding class label attached is needed. An original RS derived from **one** decision tree is not able to satisfy this requirement. For that reason a large variety of elementary rules (atomic control strategies) should be available from which a final rule set, nearly reflecting the control strategies of the experts, can be derived. In the COMAPS initialization procedure, a certain amount of decision trees can be produced and the ER of each of them are collected in a common original rule set. This rule set is then adapted to the cognitive model, representing the intensional expert knowledge.

#### 4 Realisation of a quasi optimal model

To increase the quality of rule sets that can be achieved by decision tree algorithms we merge several rule sets that originate from applying these two decision tree methods mentioned above, with different parameter settings to the same data set<sup>1</sup> (control reference). The quality is measured by means of compactness and reclassification capability (correctness - defined below). In this sense a rule set consisting of just one rule for each class containing one aspect would be called optimal if there reclassification rates would be 100%. Unfortunately this can not be reached in practice.

Now after production of this huge ( but probably redundant) rule set<sup>2</sup>  $RS$ , consisting of a lot of elementary rules this rule set has to be reduced to one of a reasonable size and reclassification capability. Therefor, two measures -the correctness and completeness- are introduced:

Let  $CR$ , the control reference (all collected control situations), and  $CR_k$ , the control reference according to one class  $k$ , be sets of control situations with  $CR_k \subset CR$ . An elementary rule  $ER_{ik}$ <sup>3</sup> that is supposed to model an atomic control strategy belonging to class  $k$  can be viewed also as a (potentially infinite) set of control situations situated in the correspondent sub space and assigned to the class label  $k$ . Now, the correctness and completeness can be defined as:

$$cor(ER_{ik}) = \frac{\| ER_{ik} \cap CR_k \|}{\| ER_{ik} \cap CR \|} ; com(ER_{ik}) = \frac{\| ER_{ik} \cap CR_k \|}{\| CR_k \|}$$

With these formulae the rule set can be restricted to a quasi optimal rule set. First, the number of elementary rules is reduced applying the following algorithms: “drop elementary rule  $ER_{ik}$  from rule set  $RS$ , if there exists an elementary rule  $ER_{jk}$  with  $ER_{ik} \subseteq ER_{jk}$  and  $cor(ER_{ik}) \leq cor(ER_{jk})$ ”; “drop elementary rule from  $RS$ , if  $cor(ER_{ik}) < mincor$ ” or if  $com(ER_{ik}) < mincom$ ”, where  $mincom$  and  $mincor$  are user defined thresholds.

Secondly, we apply a simplify method based on [Quinlan, 1987] to reduce the redundant aspects in an elementary rule: Let  $AS_m$  be an aspect of an elementary rule  $ER_{ik}$  and  $ER_{ik}^m$  the same elementary rule without that aspect. If  $cor(ER_{ik}) - cor(ER_{ik}^m) < \Delta S$  (whereas  $\Delta S$  is a predefined threshold), then  $AS_m$  is redundant and can be dropped. Finally, a quasi optimal rule set from the remaining rules is selected by calculating ranking tables for elementary rules of one class (for each class one ranking table) by the formula  $rank(ER_{ik}) = cor(ER_{ik})(I - \xi) + com(ER_{ik}) \xi$  where  $0 \leq \xi \leq 1$  represents the desired generalisation factor. From these ranking tables elementary rules are selected

<sup>1</sup> Optional the multiple-class problem is transformed into a two-class problem. Therefore the data set is spliced into  $n$  data sets (for each class one), rules for this class are generated by applying decision tree algorithms and then this rules are added to the merged rule set.

<sup>2</sup> This is optional even increased by combining aspects of elementary rules to new elementary rules. It is not reasonable to apply this part of the algorithm in any case, as it may produce a combinatorial explosion.

<sup>3</sup> Index  $i$  reflects the fact that a class  $k$  may be modelled by more than one elementary rule



consecutively if they contain control situations that are not modelled by any other elementary rule yet.

For modelling purposes of expert behaviour according to *CS* situated in unstable sub areas of the state space, the priority relation is introduced. Let  $ER_{ik}$  and  $ER_{jl}$  be two elementary rules modelling parts of different class areas in the state space and an intersection  $I_{ijkl} = ER_{ik} \cap ER_{jl}$  exists. If  $\|I_{ijkl} \cap CR_k\| - \|I_{ijkl} \cap CR_l\| > \Delta P$ , then  $ER_{ik}$  is said to prior  $ER_{jl}$ , where  $\Delta P$  is a predefined priority threshold.

## 5 Example

As an example several rule sets were generated based on the same data set<sup>4</sup> applying different methods to delete redundancies. Table 1 shows a list of the generated rule sets with some statistics about their reclassification and generalisation capabilities.

Rule Set	Number of correct modelled control situations	Number of false modelled control situations	Number of not modelled control situations	Number of elementary rules contained in the rule set	Number of elementary rules containing one aspect	Number of elementary rules containing two aspects	Number of elementary rules containing three aspects	Number of elementary rules containing four aspects	Number of elementary rules containing more than four aspects	Main value of aspects for an elementary rule
01	99	9	0	34	0	2	10	4	18	4.2
02	100	8	0	34	8	8	8	10	0	2.6
03	88	3	17	22	2	4	6	10	0	2
0A	94	14	0	126	10	38	28	16	34	3.4
0B	100	5	3	34	8	6	10	10	0	2.6
0C	89	12	7	22	14	2	4	2	0	1.7
0D	83	16	9	10	8	0	2	0	0	1.4

Table 1. Rule Set Statistics

The rule set 01 is directly derived from only **one** C4.5 like decision tree [Quinlan, 1993] and the set 02 is result of the application of redundancy elimination method based on [Quinlan, 1987] to the set 01. To this set the selection function was applied (set 03), where a convenient compromise between correctness and generality is desired.

<sup>4</sup> printed circuit board production with two decision outcomes.

The next series starts with a rule set that derives from merging several rule sets produced by some decision trees just eliminating covered elementary rules (first mentioned method). Rule set 0B was yielded by the selection function with a very small generalisation factor. The sets 0C and 0D were produced by further increasing the generalisation factor.

## 6 Conclusions

This paper deals with the BRITE-EURAM project COMAPS. In general, it is developed as an online decision support of human centered production processes. It is based on a dynamic operator action model, consisting of two representations: an intensional (case based oriented) and an extensional (production rule oriented) representation of operators control experience. This contribution especially emphasizes the initialization phase because of the application of machine learning approaches to produce a convenient initial model for the maintenance phase of the COMAPS-system. Based on decision tree classifiers a method is developed for producing a quasi optimal production rule set. The production rules, generated by decision trees has to be considered as a physical static qualitative model of the production process which can serve for checking hypotheses of the control strategy of the human operators. Based on an enlarged (by merging production rules from a lot of decision trees) original rule set methods are developed to detect redundancies and to select a quasi optimal rule set according to the adaptation of a cognitive model of humans control practice. Note, that a heuristic selection method is used and better rule sets could be achieved. An example demonstrates the benefits of the developed production method of the quasi optimal rule sets in comparison with an rule set derived from only one decision tree.

## References

- [Clark and Niblett, 1989] P. Clark and T. Niblett, The *cn2* Induction Algorithm, *Machine Learning*,3:261-283, 1989.
- [Scheffer, 1995] T Scheffer, Learning rules with nested exceptions, in J Zizka and P. Brazdil, *Proceedings of the International Workshop on Artificial Intelligence Techniques*, Brno, P: 203-210, 1995.
- [Müller and Wysotzki, 1997] W. Müller and F. Wysotzki. The Decision Tree algorithm CAL5 Based on a Statistical Approach to Its Splitting Algorithm. In G. Nakhaizadeh C.C Taylor (eds), *Machine Learning and Statistics, The Interface*, John Wiley & Sons, 1997.
- [Quinlan, 1993] J.R. Quinlan. *C4.5 Programs for Machine Learning*. Morgan Kaufmann Publishers, 1993.
- [Quinlan, 1987] J.R. Quinlan. *Generating Production Rules From Decision Trees*. *Proceedings IJCAI –Milan, Italy*, 1987.
- [Buntine and Caruana] W. Buntine and R. Caruana, *Introduction to IND and Recursive Partitioning*, User's manual, NASA Ames Research Center, 1991.
- [Michie et al., 1994] Michie, D. Spiegelhalter, D.J. and Taylor, C.C. (1994) *Machine Learning, Neural and Statistical Classification*. Ellis Horwood Limited, Hertfordshire, UK.

# EXPERT OPINIONS ON SUCCESS FACTORS FOR NEW MANUFACTURING TECHNOLOGY DEPLOYMENT IN THAI AUTOMOTIVE INDUSTRY

H. Paul<sup>1</sup> and L. Tritos<sup>2</sup>

<sup>1</sup> Professor  
School of Management  
Asian Institute of Technology  
PO Box 4, Klongluang,  
Phatumthani, 12120, Thailand

<sup>2</sup> Lecturer  
Industrial Engineering Department  
Thammasat University  
Klongluang, Phatumthani, 12121, Thailand

## Abstract:

*Appropriate managerial efforts prior to and after adoption of New Manufacturing Technology (NMT) are the key requirements for successful NMT deployment. In this study, we identify factors related to the success of NMT deployment. After reviewing the literature, we developed interview protocol and used it to interview twenty managers of ten automotive manufactures. The managers are working in quality and production engineering departments of the first-tier suppliers of two major automobile assemblers. Fifty items were identified through the interview process representing the perspective of the managers toward factors for successful NMT deployment. Finally, we asked ten experts to classify of those fifty items into four categories of the model of Quality Management System. The four categories are management responsibility, resource management, process and/or product realization, and measurement, analysis and improvement. The experts were chosen from academia, industry, registrar of ISO/QS9000, and NMT system vendor. We found that fourteen of fifty items can be classified into the four categories with hundred per cent of consensus rate from experts. The results imply that one could use the concept of Quality System Management to enhance the success of NMT deployment.*

**Keywords:** Quality Management System, Expert Opinion, New Manufacturing, Technology (NMT)

## 1 Introduction

As the competition intensified, concerns over declining productivity, flexibility and quality of manufactured autoparts in automobile supply chain have activated profound interest in the adoption, and implementation of manufacturing practices such as new manufacturing technology, quality management system, just-in-time production system. To achieve this competition, the model of quality management is always recommended both in literature and by practitioners. Many firms adopt this model in management of their business operations and manufacturing. The complexity of NMT has made the technology difficult for firms to implement and to achieve expected benefits from the

technology. The objectives of this study, therefore, are (1) to report on the success factors for NMT projects in Thai automotive industry and (2) to identify the relationship between the success factors for NMT deployment and QMS concepts. The results of this study would provide information about the managerial efforts that can bring about the success of NMT deployment in Thai automotive industry.

## 2 Research methodology

### 2.1 Experiment design

We first reviewed the literature of NMT deployment and developed interview protocol for data collection. The data collected for this study was opinions of managers on key factors that made NMT deployment success in their companies. Second, we interview twenty managers of ten automotive manufactures. The managers are all working in quality and production engineering departments and have experiences in NMT implementation. All managers were asked for key factors that made NMT deployment success in their companies. Third, we set a panel of ten experts in the fields of QMS and NMT implementation. We then asked the experts to classify the key factors into four categories of quality management model based on the content validity of the factors. The four categories are management responsibility, resource management, process and/or product realization, and measurement, analysis and improvement. All experts were given a copy of ISO/CD2 9001:2000 for used as a reference. The purpose of this process is to synthesize the managerial effort for successful implementation of NMT with the quality management concepts. After conducting two rounds of the expert opinion process, we summarized the key factors classified by four categories of quality management concepts that relating to the success of NMT deployment.

### 2.2 The samples and experts

The companies selected as samples for this study were the first-tier suppliers of two major automobile assemblers. They were owned by Thai and/or Japanese and were both ISO/QS9000 certified and non-certified companies. The selected companies can be classified into three groups: subsidiaries of large companies, jointed venture with Japanese, and Thai companies. The characteristics of the ten companies are shown in Table 1.

Manufacturing process		Ownership	Existing QMS	Size
Machining	(6)	Thai owned (3)	Obtained ISO/QS9000 (5)	Less than 200 (7)
Fabrication	(3)	Japanese owned (4)	Pursuing ISO/QS9000 (2)	More than 200 (3)
Assembly	(1)	Thai-Japanese (3)	None (3)	

(x): the number of companies

Table 1. Characteristics of interviewed companies

The experts selected for this study must either well understand the model of quality management system (ISO9000) or have experiences in implementing of NMT or be an academic in ISO9000 and NMT. The panel of experts consisted of two academics, four practitioners, two assessors of ISO/QS9000, and two vendors of NMT system. The summary statistics of the selected experts are as follows:

- Average age		42	years old
- Average years of experience in NMT or QMS		7	years
- Education background:	Bachelor degree	4	persons
	Master degree	4	persons
	Doctoral degree	2	persons

### 3 Research findings

#### 3.1 Expert Opinions on Success Factors for NMT Deployment

The data was collected during the fourth quarter of 1998. The interviewees consisted of factory managers, production managers, quality control managers, and quality management representatives. We found that most managers identified about 12-15 key factors relating to the success of NMT deployment. We then group all factors together and found that there are a total of fifty different factors that the managers thought important for the success of NMT deployment. Table 2 shows the fifty success factors and the number of experts who identified those factors.

Success Factors for NMT Deployment	N. of Experts
1. Encourage activities that improve customer satisfaction.	20
2. Include technology issues in the company policies.	20
3. Deploy the company policies through the plant and employees	20
4. Emphasize the roles of project champion of NMT implementation	20
5. Concentrate on long-term planing rather than short-term planning	20
6. Appreciate the roles of the responsibility and authority of technology project team for implementing NMT.	19
7. Provide an adequate technical training program for NMT users prior to and after adopting the system.	19
8. Provide re-training program for the user after implementing NMT for a period of time.	19
9. Consider the importance of preventive maintenance schedule for the adopted NMT to achieve effective implementation.	18
10. Understand control parameter in the process and product prior to adopting NMT.	18
11. Involvement of customer in providing technical assistance in adopting NMT.	18
12. Select system vendor based on technical capability, serviceability, and price rather than price alone.	18
13. Review the success of NMT implementation process and conduct performance evaluation of implemented NMT to take corrective action in the future project	17
14. Consider both product and overall system performances including the level of customer satisfaction prior to and after adopting NMT.	17
15. Realize the importance of benchmarking with respect to the competitors in your industry about their adopted NMT.	17
16. Rely on single vendor of NMT system for maintenance & upgrading in the future	17

17. Negotiate long-term technical support with system vendors.	17
18. Encourage the employees to suggest about changing and improving the existing process by adopting improved tools and NMT	17
19. Review the NMT implementation project at schedule interval.	16
20. Consider the importance of adoption and implementation of NMT to achieve the customer satisfaction in term of quality of products and processes performances.	16
21. Consider the importance of operation procedure or work instruction of each adopted NMT for users.	16
22. Top management support in terms of finance and time for MT implementation	16
23. Concentrate on multi-functional team for implementing NMT.	15
24. Middle management support in terms of time and supervision for NMT implementation project.	15
25. Appreciate the roles of the authority of technology project champion for implementing NMT	15
26. Top management views employee involvement as crucial in implementing NMT	15
27. Communicate the impact of NMT implementation on the job security of employees	14
28. Consider the compatibility of NMT with infrastructure (e.g. work space, supporting services, workforce skill).	14
29. Involve system vendor in product and process development prior to the adoption of NMT	14
30. Appraisal of system and product performances is not used for ranking employee	14
31. Include discussion in continuous improvement at all level of the company	14
32. Encourage employees to express new ideas to improve their working Environment and customer satisfaction	14
33. Consider an adequacy of adopted NMT to its applications	14
34. Employees understands the company strategy and policy	13
35. Consider the impact of adopted NMT on working environment	12
36. Consider the important of customer's feedback that used for an improvement	12
37. Consider the important of modifying or upgrading of an existing technologies	12
38. Operation procedures are developed based on the complexity of NMT	12
39. Multi-justification techniques are used for decision making prior to adopt NMT	11
40. Top management commit to continuous improvement as a primary goal	11
41. Involving employees from a variety of departments in technology decision	10
42. Consider the experience with pilot project prior to implementation of NMT	9
43. Linking the process and NMT design with product design	8
44. Linking the manufacturing strategy with business, and marketing strategy	8
45. Establishing the multi-skilled employees to operate and control NMT	7
46. Establishing multi-disciplinary planning and making a decision	6
47. Giving employees more managing and planning responsibility	6

48. Improving direct labor training prior to and after adopting of NMT	5
49. Top management encourage employees involvement in manufacturing process	5
50. All key department managers within the company concern about responsibility for quality improvement	4

Table 2. Expert Opinions on Success Factors for NMT Deployment

### 3.2 Relationship of the Success Factors for NMT Deployment and QMS concepts

The fifty factors were used in the experts' opinion process. In this process, we asked ten experts to classify the success factors into four categories of quality management system (QMS) concepts. The classification was done based on the content validity of the factors to each QMS concept. After conducting two rounds of the classification process, we found that fourteen of fifty items can be classified into the four categories of QMS concepts with one hundred per cent of consensus rate from the experts. Table 3 shows the list of the factors that have a hundred per cent of consensus rate. We also show in Table 4, 5 and 6 the list of factors that have 80%, 70% and 60% of consensus rate from our experts. The results of this study imply that key factors for the successful NMT deployment are related to the QMS concept. Therefore, one could use the concept of Quality Management System to enhance the success of NMT deployment.

<b>Category 1: Management responsibility</b>
1. Encourage activities that improve customer satisfaction.
2. Include technology issues in the company policies.
3. Deploy the company policies through the plant and employees.
4. Emphasize the roles of project champion of NMT implementation.
5. Concentrate on long-term planning rather than short-term planning.
6. Appreciate the roles of the responsibility and authority of technology project team for implementing NMT.
<b>Category 2: Resource management</b>
7. Provide an adequate technical training program for NMT users prior to and after adopting the system.
8. Provide re-training program for the user after implementing NMT for a period of time.
<b>Category 3: Product and/or service realization</b>
9. Consider the importance of preventive maintenance schedule for the adopted NMT to achieve effective implementation.
10. Understand control parameter in the process and product prior to adopting NMT.
11. Involvement of customer in providing technical assistance in adopting NMT.
12. Select system vendor based on technical capability, serviceability, and price rather than price alone.
<b>Category 4: Measurement, analysis and improvement</b>
13. Review the success of NMT implementation process and conduct performance evaluation of implemented NMT to take corrective action in the future project

14. Consider both product and overall system performances including the level of customer satisfaction prior to and after adopting NMT.

Table 3. Success Factors for NMT Deployment classified by QMS concepts with 100% consensus rate

<b>Category 1: Management responsibility</b>
1. Realize the importance of benchmarking with respect to the competitors in your industry about their adopted NMT.
<b>Category 2: Resource management</b>
None
<b>Category 3: Product and/or service realization</b>
2. Rely on single vendor of NMT system for maintenance and upgrading in the future
3. Negotiate long-term technical support with system vendors.
<b>Category 4: Measurement, analysis and improvement</b>
4. Encourage the employees to suggest about changing and improving the existing process by adopting improved tools and NMT

Table 4. Success Factors for NMT Deployment classified by QMS concepts with 80% consensus rate

<b>Category 1: Management responsibility</b>
1. Review the NMT implementation project at schedule interval
2. Consider the importance of adoption and implementation of NMT to achieve the customer satisfaction in term of quality of products and processes performances
<b>Category 2: Resource management</b>
None
<b>Category 3: Product and/or service realization</b>
3. Consider the importance of operation procedure/instruction of each adopted NMT for users.
<b>Category 4: Measurement, analysis and improvement</b>
None

Table 5. Success Factors for NMT Deployment classified by QMS concepts with 70% consensus rate

<b>Category 1: Management responsibility</b>
1. Top management support in terms of finance and time for NMT implementation.
2. Concentrate on multi-functional team for implementing NMT.
3. Middle management support in terms of time and supervision for NMT implementation project.
4. Communicate the impact of NMT implementation on the job security of employees.
5. Appreciate the roles of the authority of technology project champion for implementing NMT



<b>Category 2: Resource management</b>
6. Top management views employee involvement as crucial in Implementing NMT.
7. Consider the compatibility of NMT with infrastructure (e.g. work space, supporting services, workforce skill).
<b>Category 3: Product and/or service realization</b>
8. Involve system vendor in product and process development prior to the adoption of NMT.
<b>Category 4: Measurement, analysis and improvement</b>
9. Appraisal of system and product performances is not used for ranking employee.
10. Include discussion in continuous improvement at all level of the company.
11. Encourage employees to express new ideas to improve their working environment and customer satisfaction.

Table 6. Success Factors for NMT Deployment classified by QMS concepts with 60% consensus rate

#### 4 Conclusions

In this study, we identify factors related to the success of NMT deployment by interviewing twenty managers of ten automotive manufactures. The managers were working in quality and production engineering departments of the first-tier suppliers of two major automobile assemblers. Fifty items were identified through the interview process representing the perspective of the managers toward factors for successful NMT deployment. We then asked ten experts to classify of those fifty success factors into four categories of QMS concepts. We found that 32 of fifty factors can be classified into the four categories with at least 60% of consensus rate from experts. The results imply that one could use the concept of Quality System Management to enhance the success of NMT deployment within Thai automotive industry.

#### References

- [Boyer et. al., 1997] Boyer, K.K., Leong, G.K., Ward, P.T., and Krajewski, L.J. Unlocking the potential of advanced manufacturing technologies, *Journal of Operations Management*, Vol. 5
- [Millen and Sohal, 1998] Millen, R. and Sohal, A.S., Planning process for advanced manufacturing technology by large American manufacturers. *Technovation*, Vol. 18, No. 12
- [Small and Yasin, 1997] Small, M.H. and Yasin, M.M., Advanced manufacturing technology: Implementation policy and performance. *Journal of Operations Management*, Vol. 5
- [Sohal, 1996] Sohal, A.S., Assessing AMT implementation: an empirical field study, *Technovation*, Vol.16, No. 8
- [Swamidass and Kotha, 1998] Swamidass, P.M. and Kotha, S., Explaining manufacturing technology use, firm size&performance using a multidimensional view of technology, *Journal of Operations Management*, Vol. 17



# TOWARDS REDUCING THE COMPLEXITY OF PROCESS MODELING BY ADVISORS, EXPLICIT CONTEXT MODELING, AND VISUALIZATION TECHNIQUES

Gerhard Peter, Thomas Rose, Christian Rupprecht

Research Institute for Applied Knowledge Processing (FAW)

Helmholtzstraße 16, 89081 Ulm, Germany

{Gerhard.Peter | Thomas.Rose | Christian.Rupprecht}@faw.uni-ulm.de

## Abstract:

*The need for effective knowledge asset management has carried process modeling to a new sphere. The goal is to design corporate processes as a sustainable resource for improving a company's competitiveness. In this paper, we present an approach to support human interactions with process networks that draws upon the duality of formal reasoning and mental assessment. First, advisors provide interactive assistance in the design of process models. They care about specific features of processes that are based upon formal theories. Second, visualization techniques are employed to support process engineers in cases where any formal theory about process characteristics is missing. That is, an engineer's perceptual capabilities are exploited for the assessment of processes.*

**Keywords:** Advisors, Visualization Techniques, Process Modeling.

## 1 Motivation

In a global market place, the competitiveness of any enterprise will ultimately rely on the ability to carry out and govern system development processes, which constitute the very root of industrial value creation. Much of the communication in design processes even changes to electronic media. Thus, many aspects of process experience that used to be implicit in the organizational culture, need to be made explicit and even transferable. The goal of our approach is to design corporate processes as a sustainable resource for improving a company's competitiveness. Just imagine the effort it takes to model a real-world process that consists of several thousands process steps (not only in terms of time required but also with respect to the mental effort); rather the norm than the exception in domains like plant construction or automotive design.

The prime objective of our research is to elevate the capability to capture and maintain process know-how at a level of accuracy that brings enterprises into a position to operate in virtual engineering networks. In this context, virtual engineering networks refer to intra- as well as inter-organizational structures. In particular, we aim at providing a synergy between formal theories and the perceptual capabilities of humans. We focus on support tools for process engineers who themselves are experts in the engineering domain, i.e. there are no third party champions involved that formally represent the process following a sequence of interviews.

In this paper, we present an approach to support human interactions with process networks. First, advisors provide interactive assistance in the design of process models.

They care about specific features of processes, that are based upon formal theories (so-called *microtheories*).

Tool support built upon formal features, however, comes a step short. There is a rather large share of know-how, sometimes violating textbooks, that cannot be expressed in formal rules. Here it is, where we promote an intuitive user interface to process networks as second part of our approach. Layout algorithms allow one to visualize processes with respect to a set of predefined characteristics. It is up to an engineer to judge the quality of a process with regard to her personal understanding of the domain.

Our contribution is based on experiences gained in two large companies in the utility plant engineering and automotive sectors.

## 2 Human-centered Process Modeling

Process management constitutes a prime competence to value generation. We define a *process* as a dynamic system of temporally and logically ordered activities intended to reach a goal and augmented with concepts for agents, roles and artifacts. Processes are generated from positive as well as negative experience about certain ways-of-working accumulated by process participants. The complexity of a process is determined by the number and diversity of its elements and relations. The spectrum of managing processes ranges from the formal representation of processes, over assessment and re-engineering activities, up to the execution and control of processes. In this paper, we focus on the modeling part, i.e. how to support the capture and maintenance of process models.

Process modeling has emerged as a standard instrument for coping with the increasing complexity of process management tasks. A *process model* is an abstract description of an actual or proposed process. We understand process models as a result of sophisticated mental construction rather than a pure mapping of attributes from a real process [Schütte, 1998]. A process is not per se existent as a system in the real world. Even the representation of an actual process is always based on subjective perception and interpretation. Hence, a complete process model comprises not only the formal representation, but also pragmatic aspects, i.e., aspects of subjectivity (for whom), time (when), and goals (what for). The assignment of a process model to an original (actual or proposed) process is only valid in the context of these pragmatic aspects.

A special feature of process models that distinguishes them from other types of modeling in computer science is the fact that “many of the phenomena modeled must be enacted by a human rather than a machine” [Curtis et al., 1992]. Thus, one of the major objectives of process modeling should be to “provide guidance, suggestions, and reference material to facilitate human performance of the intended process” [Curtis et al., 1992].

## 3 Means of Process Modeling Support

The specific intention is to offer dedicated support to process engineers who themselves are experts in the engineering domain. However, due to the subjective character of process models, which cannot be eliminated entirely, process experience can only be formalized up to a certain degree. Hence, process modeling and

maintenance needs to be supported by explicit, automated guidance as well as by visualization techniques that exploit the perceptual capabilities of humans.

### 3.1 Automated Process Modeling Advice

Advisors for process modeling identify failures or weak points, indicate potentials for improvement, show consequences, and generate proposals for modeling activities (e.g., with respect to completeness or consistency). They provide explanations and draw conclusions based on the specific context and their own knowledge. Advisor support can be provided before, during and after conducting a process modeling task. An advisor can be defined as a program that supports a user for solving a problem. Each advisor is based on a microtheory [Gruninger and Fox, 1994]. A microtheory captures the expertise of a limited domain; it comprises a set of formal statements (e.g., in predicate logic) and a description of the context for which the statements are valid.

Syntactical correctness of a process model can be supported by advisors automatically. This can be achieved by checking consistency and completeness of a given process model with regard to the underlying meta-model. But, checking the syntactical correctness of a formal representation does not indicate whether the process model really reflects the original (actual or proposed) process to be represented.

Due to the subjective nature of process modeling in light of the already mentioned pragmatic aspects, it is rather difficult to find a common understanding of a process' structure and to define formal metrics for assessing the semantical correctness of process models. However, by capturing and reusing process modeling experience, i.e., the reasons for process design decisions in a specific context, automated guidance can also be provided for supporting the semantical correctness. In our approach, a model of selected constraints and requirements describes the specific context of a process model explicitly [Rupprecht et al., 1999]. Constraints and their relationships are captured at a generic level in terms of an ontology. Experience in process modeling is broken down into single design decisions that are captured in terms of dependencies among constraints and process fragments represented as generic construction rules (microtheories). By applying these construction rules to a specific model of constraints and requirements, proposals for adaptations to the process model are generated. By collecting and maintaining such dependencies from different engineers, process modeling experience can be reused for specific process modeling cases.

This approach allows one to tailor process models in accordance with project-specific requirements, as it is especially relevant for process models in the domain of complex system engineering [Negele et al., 1999]. Figure 1 demonstrates the basic principle of advisor-based guidance with an example for the project-specific adaptation of a plant construction process model. It shows how an advisor derives the suggestion to insert a generic process fragment ("*apply for export permission*") before another process fragment ("*decide: bid or no bid*") due to a specific legal constraint ("*export certification necessary*"). In figure 1, dashed arrows represent generic dependencies and solid arrows represent advisor conclusions.

Amid modeling, an engineer selects constraints from the constraint ontology. Each selection or later change in a constraint may trigger an advisor, which (1) highlights the parts of the process where potential alterations arise due to the change, (2) generates advice on how to conduct the alterations, and (3) provides a textual explanation.

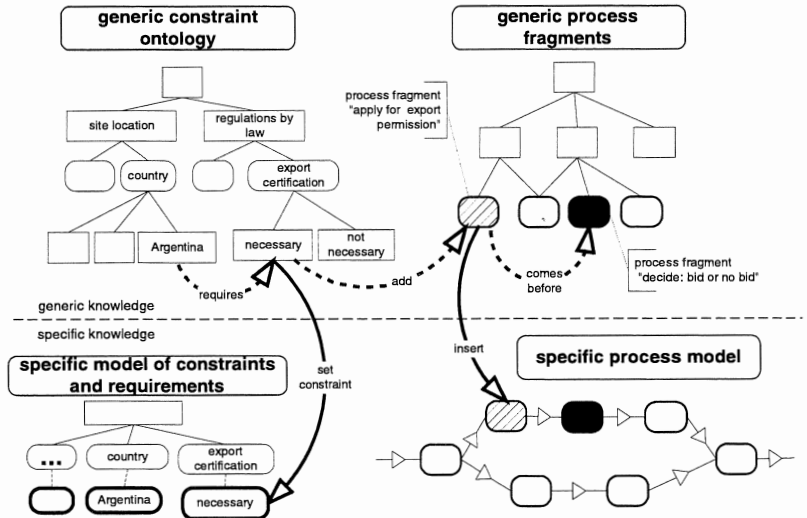


Figure 1: Advisor mechanism for process model adaptation

Beyond automated guidance for syntactical and semantical correctness, advisors can provide assistance for optimizing and redesigning a process model with respect to specific goals (e.g. time or cost reduction). We have developed a process modeling and execution environment in which advisors point to potential improvements of a process based on a dynamic analysis by simulation (e.g. bottle-necks encountered during simulation trigger an advisor that generates the proposal to parallelise activities in order to shorten total lead time) [Kratz and Rose, 1997]. Once again, such a tool requires formal rules that are derived from expert knowledge.

The microtheories cannot necessarily be expected to be complete, i.e., to cover any potential problem that may arise during process modeling and analysis. As compensation we utilize the capabilities of the perceptual system of humans as shown in the following subsection.

### 3.2 Visualization Techniques for Process Model Assessment

Humans readily impart meaning into what is seen and are excellent at perceptual organization. By looking at a drawing representing a process a user can point out potential problems that concern a process as a whole, thus compensating for the limited scope of advisors which focus on formalizable aspects of a process. Such problems are indicated by odd layouts, whereby ‘odd’ depends on the personal understanding of the domain by an engineer. Odd layouts are caused, for instance, by missing or incorrect logical dependencies among activities, missing or incorrect document relationships, huge heaps of documents in late phases of the process, or the sparse spreading of documents [Rose, 1998].

To support an engineer, visualization techniques are employed that generate dynamic layouts for process models according to different criteria. Currently, three layout options are distinguished:

- Temporal: Activities are ordered along the x-axis depending on their respective starting time.
- Logical: Activities are ordered according to the logical sequence of activities.
- Informational: Activities are ordered according to the informational input-output relations between activities.

Figure 2 presents an example of a structural flaw in a network of logical dependencies between the elements of a process model (the paper symbol denotes documents and the other symbols indicate different types of activities). Several indications give reason to check the correctness of the process structure. Firstly, there is a parallel line of activities not synchronised with other activities. Secondly, this line of activities starts without any task which is typically represented by a document. Thirdly, a closer look at the kind of activities, i.e. the icons, involved unveils, that this line of activities is about tooling which rather belongs to late phases of an engineering process. The flaw is caused by a missing logical dependency between activity 1 and activity 2. In the layout option of temporal dependencies this flaw would not be that obvious.

Note, it is the process designer who judges the correctness of such patterns. Visual support offers additional decision criteria.

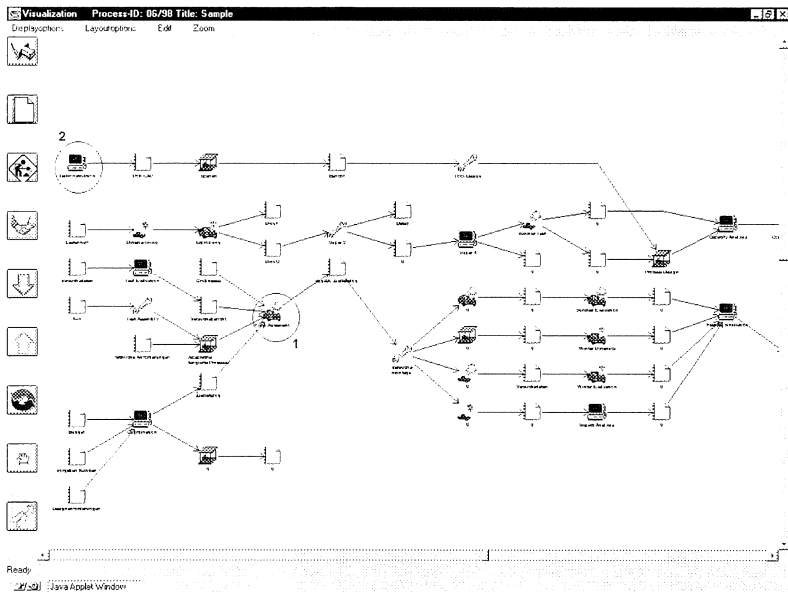


Figure 2: Flaw in the process structure (adapted from [Rose, 1998])

#### 4 Discussion

We have presented an approach that draws on the duality of formal reasoning and mental assessment. The former is utilized by advisors while the latter is supported by

different visualization techniques that enable a user to view an entire process model from different perspectives.

Having no formal theories in visualization is one of its biggest strengths but also one of its biggest weaknesses, i.e., it is solely up to an engineer to decide when to use what layout option. Process model visualization is certainly not limited to the three layout options introduced above. Many other visualization aspects influence the subjective perception and interpretation (e.g. choice of icons, setting filters to focus on specific process elements, zoom factors for different sizes of process elements). For maximum flexibility, it is necessary to offer specific combinations of all these option settings for specific needs or assessment goals. Still, it is up to an engineer to encounter flaws by interpreting a process model once appropriately visualized. But she has a better, i.e., “problem-specific”, basis for succeeding.

The question arises of how to combine layout options. The ultimate goal is an ontology of layout options. Each combination reflects experience on identifying potential flaws in the structure of the process. The ability to express local constraints for layouts will help in elaborating layout options. Eventually, the selection of suitable orchestrations of layout options will be advisor driven. A layout advisor will check the process model for types of flaws and propose suitable options. This will turn our visualisation method into an active stance, where it points to potential flaws when an engineer may not even be aware that a problem exists.

## References

- [Curtis et al., 1992] Curtis, B., Kellner, M. I. and Over, J. (1992). Process modeling. *Communications of the ACM*, 35(9) : 75-90.
- [Gruninger and Fox, 1994] Gruninger, M. and Fox, M. (1994). The role of competency questions in enterprise engineering. In *Proceedings of the IFIP WG5.7 Workshop on Benchmarking - Theory and Practice*, Trondheim, Norway.
- [Kratz and Rose, 1997] Kratz, N. and Rose, T. (1997). Modelling and analyzing processes in production and administration. In Tzafestas, S. G., editor, *Management and Control in Manufacturing Systems*, pages 118-142. Springer-Verlag, Berlin.
- [Negele et al., 1999] Negele, H., Fricke, E., Schrepfer, L. and Härtlein, N. (1999). Modeling of integrated product development processes. In *Proceedings of the 9<sup>th</sup> Annual International Symposium of INCOSE Systems Engineering: Sharing the Future*, Brighton, UK.
- [Rose, 1998] Rose, T. (1998). Visual assessment of engineering processes in virtual enterprises. *Communications of the ACM*, 41(12) : 48-53.
- [Rupprecht et al., 1999] Rupprecht, C., Peter, G. and Rose, T. (1999). A model-driven approach for context-specific individualization of process models (in German). *Wirtschaftsinformatik*, 3.
- [Schütte, 1998] Schütte, R. (1998). *Grundsätze ordnungsmäßiger Referenzmodellierung – Konstruktion konfigurations- und anpassungsorientierter Modelle*. Gabler Verlag, Wiesbaden.



# MAN MACHINE INTERFACE FOR A DECISION CHECKING TOOL

Pierre Saunier, Raymond Bisdorff

CRP-CU Luxembourg

13 rue de Bragance

L-1522 LUXEMBOURG

E-mail: [saunier@crpcu.lu](mailto:saunier@crpcu.lu), [bisdorff@crpcu.lu](mailto:bisdorff@crpcu.lu)

## Abstract:

*In this paper we present a part of the COMAPS research project. This project introduces a new kind of decision help for an industrial operator in charge of a production machine. The tool constructs and maintains a model of the user's decision practice. For each new operator's decision, the COMAPS tool informs the operator of the fitting of the new decision inside the formal representation of the past decision practical. A decision, which does not fit, is decorated in different colours according to the type of conflict between the decision and the decision model.*

*After a short presentation of the COMAPS project, this paper presents the "check as you decide" paradigm i.e. a way to assist the operator in his/her every day decisions.*

**Keywords:** Decisions help, Industrial process, Rule basis.

## 1 Introduction

This paper presents a part of the Brite-Euram BE-96-3941 European project COMAPS (COgnitive Management for Anthropocentric Production Systems).

The purpose of the project is to build a tool that assists an industrial operator in charge of tuning a production machine. The global context is illustrated in figure 1. First, from observable control behaviour  $\mathbf{B}$ , a control reference  $H$  is build by encoding and filtering the raw data. Then the tool build an initial control theory  $C$ . This control theory will be used to inform the user if a new incoming tuning is conform or not to the operator past decision practice. The new incoming tuning is also used to maintain the control theory in order to detect slight changes in the cognitive control theory  $H$ , changes that will be revealed in the observable control behaviour. The way used by the tool to inform the decision-maker is analogous to a classic spelling or grammar checker. A decision which does not fit into the represented past decision practice is underlined in different colours according to the type of conflict between the decision and the control theory: this is the "check as you decide" principle. Contrary to the common "check as you type" principle, the checker is not using a static proofing reference, i.e. a dictionary and a grammar. In the COMAPS tool, this checking reference is continuously updated ([R. Bisdorff, 1999], [E. Le Saux *et al.*, 1998]).

This paper is divided into two parts. First, we shortly present the cognitive principles of the COMAPS design and the usual way of using the tool. Then we show how the COMAPS tool organises the dialog with the operator.

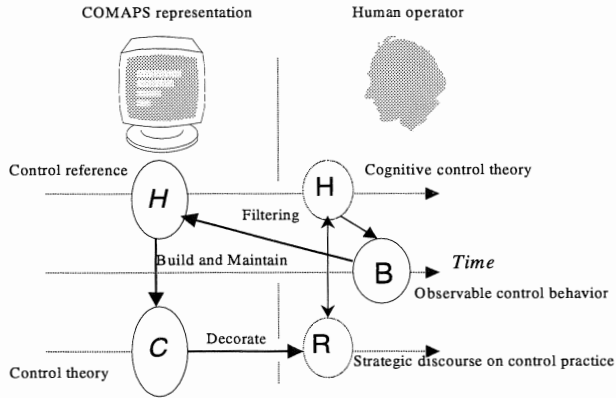


Figure 1

## 2 Check as you decide

We call **control situation** (CS) the parameters, or attributes, used by the operator to take his/her decision as well as the decision itself. We note  $d(x)$  the decision associated with a CS  $x$ . A set of control situations relevant for describing a decision practice is called a control reference  $H$ . On the basis of this control reference, the COMAPS tool builds and maintains a control theory  $C$ .

### 2.1 Use of the tool

The main principle of the tool consists in “checking for a given decision-maker, if his decision is conform to his practice” as it is known to the tool through the given control reference. Once initialised, the tool is used as follow:

- 1 A new CS arrives, *i.e.* a set of parameters with the associated operator’s decision (a tuning for the machine he/she is in charged for instance).
- 2 The decision is decorated (underlined with different colours) if the decision is not well covered by the tool’s representation of the user practice.
- 3 For a decorated control situation, the operator can :
  - Request an explanation why the decision is decorated ;
  - Keep his/her decision : the tool has to take into account this new CS, *i.e.* the tool adds this CS to the control reference and updates correspondingly its internal representation of the decision practice ;
  - Change his/her decision: the operator eventually realised he/she made a mistake.

In order to be flexible, the control theory is build upon generic cognitive principles, not depending on domain relevant engineering principles, *i.e.* the tool builds a behavioural model of the cognitive control strategies of the expert. This allows the tool to be generic and therefore adapted to different kind of industrial process control contexts. Let’s present shortly the underlying cognitive principles. A deeper description can be found in [E. Le Saux *et al.*, 1998].

## 2.2 Cognitive principles

In J.P. Barthélemy and E. Mullet [J.P. Barthélemy and E. Mullet, 1994] introduce their cognitive model of decision-making called the Moving Basis Heuristics (MBH).

This model is governed by three principles:

- Parsimony: the decision-maker (DM) processes a small subset of information. This is directly linked to limited rationality introduced by Simon [H.A. Simon, 1995].
- Reliability / warrantability: the DM uses a subset of information large enough to be meaningful.
- Decidability / flexibility: the way of choosing the subset is flexible enough to achieve a decision.

The MBH model is essentially a descriptive approach to decision-making. Therefore an important methodological point is given by the fact we are doing decision checking and not decision prescription. In this sense, the model of the user practice is not a mapping one to one from parts of the description space to possible decisions. The cognitive model and the checker paradigm lead us to represent the operator's practice by a set of "short" rules (they are constraint on at most 4 premises) and priorities between this rules. We called  $d(R)$  the decision associated with the rule  $R$ , and we note  $R_1 > R_2$  if  $R_1$  has the priority over  $R_2$ ,  $R_1 = R_2$  if none has priority over the other.

We say that a CS is **covered** by a rule when the CS parameters satisfy the premises of the rule. If the CS  $x$  is covered by the rule  $R$ , we note this  $x \in R$ , even if  $d(R) \neq d(x)$ . We say a CS  $x$  is **well classified** by a rule  $R$  if  $R$  covers  $x$  and  $d(R) = d(x)$ .

A rule is a part of the parameter space associated with a decision. We call the CS of  $H$  that satisfies a rule, the **support** of the rule.

## 2.3 Decoration

As said earlier, the decoration mechanism gives immediate feedback about the fitting of new incoming CS into a given the control theory. Three cases are possible. If a control situation  $x$  is not covered by any rule of the control theory, there is a "**no covering rule**" or "*unknown practice*" decoration for  $x$ . This case can arise when the parameters of the CS are unusual. The second case is when  $x$  is covered, taking into account the priorities, by a rule or several rules of same decision value. The tool then uses a "**well covering rule(s)**" or "*usual practice*" decoration. This decoration says that the CS is conform to the past decision practice. The last decoration, "**wrongly covering rule(s)**" or "*unusual practice*" decoration, appears when *a rule or rules with different decision values solely cover  $x$* . This decoration warns the operator of a decision value that appears unusual for the given control situation.

The decoration algorithm is summed up in figure 2.

$ \{ R / x \in R. \}  = 0$	$\Rightarrow$	<b>no covering rule</b> decoration	
$ \{ R / x \in R. \}  = 1$	$\Rightarrow$	if $d(R) = d(x)$ then <b>well covered</b> else <b>wrongly covered</b> decoration	
$ \mathfrak{R} = \{ R / x \in R. \}  > 1$	$\Rightarrow$	$\mathfrak{R} = \{ R_j, \dots, R_p \}$	
		one rule has priority: $\exists i : \forall j \neq i, R_i > R_j$	if $d(R_i) = d(x)$ then <b>well covered</b> else <b>wrongly covered</b> decoration
		no rule has priority: $\forall (i, j), R_j = R_i$	If $\exists i : d(R_i) = d(x)$ then <b>well covered</b> else <b>wrongly covered</b> decoration.

Figure 2

Figure 3 introduces a simple example. There are two possible decision values:  $\square$  and  $\circ$ , and two rules  $R^\square$  and  $R^\circ$  that intersect. If there are no priorities ( $R^\square = R^\circ$ ), the five CS in the intersection are *well covered*, each CS supporting the rule of the same decision. If rule  $R^\square$  has the priority, the three CS, which decisions are  $\circ$ , are decorated with a *wrongly covered* decoration.

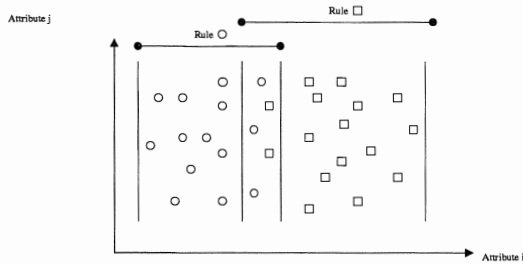


Figure 3: Priorities

After this short presentation of the “check as you decide” principles, we present now a second feature of our man-machine interface for a decision checking tool.

### 3 Computing Related Control situations

When a user wants to know some explanations about the particular decoration of a given control situation, following our cognitive design principles, the tool can't show decision rules. Indeed, it is known from cognitive psychology, that when deciding, the operator generally refers to typical reference cases, not to general decision rules. These latter are used, from a cognitive point of view, not for actually deciding, but for explaining and discoursing upon a decision practice. So in terms of effective decision support, showing decision rules won't be useful for him/her. As an alternative approach, we propose to show instead the user a limited set of reference control situations illustrating the user's past decision practice when tackling related similar or related control situations.

To assess similarity or neighbourhood descriptions among control situations, we define distances inside the attribute dimensions. On the one hand, if an attribute is nominal, only the same and different values are admitted. If an attribute is ordered or numeric, then a classical distance function used. These distances are aggregated in order

to find a small set of “nearest” control situations in a geometrical point of view in the past decision practice. A well or wrongly covered decorated CS is always covered by rules, and each covering rule has normally a support. The premises of the covering rules will give the context of the decision (*i.e.* the set of attributes to take into account), and the support of the covering rules will give related samples. In order to select a few CS among the support, the distance on attributes will be used. For each attribute of a rule, the selected subset of CS are recursively reduce to the nearest CS on the considered attribute. As the result is related to the order in which the attributes are taken into account, the selection is run many times, with a different order of considering the attributes. Then, all the selected subsets are merged. If there are too many CS in the union, the oldest in time are removed. If there are too few CS, we start again the search for related CS.

Two starting points for computing related CS, depending on the type of decoration, are distinguished.

### 3.1 A single rule covers the CS

In this case, the decoration arises when there is only one rule  $R$  that covers  $x$  or a single rule  $R$  covers the point  $x$  with a clear priority over all other rules that cover  $x$ , and  $d(R) \neq d(x)$ . In this case, we start to search the related CS in the support of  $R$ . The following pseudo-code describes the algorithm. We note  $a(R)$  the attributes used in the premises of  $R$ ,  $|X|$  the cardinal of the set  $X$  and  $R(H)$  the CS that support the rule  $R$ .

There are two global parameters:

- $n_{\min}$  : the minimum number of CS to be presented to the user,
- $n_{\max}$  : the maximum number of CS to be presented to the user.

```

{y1, ..., yn} = getRSamples(CS x, Rule R, CsSet H)
Ex = ∅
While(|Ex| < nmin)
  for p = 1 to |a(R)|
    B = R(H) - Ex
    for each i ∈ a(R)
      B = {y ∈ B / d(yi, xi) is minimum}
    endfor
    roll(a(R))
    Ex = Ex U B - (Ex ∩ B)
  endfor
endWhile
if |Ex| > nmax : too many CS,
then remove the oldest situation until |Ex| = nmax
endif
return Ex

```

### 3.2 No rule covers the CS

In this case, we don't have a covering rule, so we don't know on which attributes we must focus our attention. One way of dealing with this missing information is to compute the set of attributes used in all the rules, and then to proceed the same way as previously. This process is described by the following pseudo-code.

```

{Y1, ..., Yn} = getSamples(Cs x, RuleBase ϕ, CsSet H)
Ex = ϕ
a(ϕ) = ( a1, ... , an)
while(|Ex| < nmin)
  for p = 1 to |a(ϕ)|
    B = H - Ex
    for each i ∈ a(ϕ)
      B = {y ∈ B / d(yi, xi) is minimum}
    endfor
    roll(a(ϕ))
    Ex = Ex U B - (B ∩ Ex)
  endfor
endWhile
if |Ex| > nmax : too many CS,
then remove the oldest situation until |Ex| = nmax
endif
return Ex

```

This concludes our brief presentation of the “related control situations” feature of our man-machine interface for checking decision support.

#### 4 Conclusions

In this paper, we have outlined two essential features of the man-machine interface for checking decision support implemented in the COMAPS tool. The first feature presents our “check as you decide” principle, helping the decision-maker to confront his actual decision practice with the observed past decision practice. A second feature of our interface presents the generation of related samples of decisions in order to explain a given decision with the help of similar cases from past decision practice.

#### References

- [Barthélemy and Mullet, 1994] J.P. Barthélemy and E. Mullet, Expert Individual decision: the moving basis heuristics, *Collection des rapports de recherche de Télécom Bretagne*, RR-94005-IASC, 1994
- [Bisdorff, 1997] R. Bisdorff, Cognitive support methods for multi-criteria expert decision making, special issue of EJOR of EURO XV INFORMS XXXIV Conference (Barcelona, 1997), L. Valdares Tavares & B.D. Dean (ed.), EJOR, to appear summer 1999
- [Le Saux *et al.*, 1998] E. Le Saux, P. Lenca, J.P. Barthélemy and P. Picouet, Updating a rule base under cognitive constraints: the COMAPS tool, 7<sup>th</sup> European Annual Conference on Human Decision making and manual Control, 1998-11-04
- [Simon, 1995] H.A. Simon, A behavioural model of rational choice, *Quarterly Journal of economics*, 68, 1995

# **PART V**

## **DECISION MAKING**

---







## ETHICS AND DECISION

Jean-Pierre Brans

VUB/ULB Universities of Brussels  
Pleilaan, 2-1050 Brussels  
BELGIUM

OR searchers own a considerable decision power through the models they propose to investigate Human Real World situation. This power is comparable to the one held by the scientists and the engineers facing Natural Real World phenomena and developing technologies.

Similarities, but also fundamental differences, exist between their respective investigations.

It is essential to develop both Human and Physical models in an Ethical framework. The quality of our way of life, of our future, of our environment is involved !

In the field of OR single criterion models often do not allow considering all the Human requests for a Harmonious Decision-Making. Only one feature is considered and optimized. On the other hand Multicriteria Analysis seems to be quite appropriate to take into account all Human aspirations and therefore seems to offer quite more Ethical reliability.

The Multicriteria PROMETHEE-GAIA methodology allows obtaining a graphical visual view of the Brain and Freedom of the decision-makers with regard to their decision problem. On the other hand it is also possible to visualize an Ethical Behavior and to control if some possible decision fits both the aspirations of the decision-makers and Ethical requests.

Such Ethical and decision investigations should from now on be associated to all OR modelisations.



---

## **GDSS-PROMETHEE**

Jean-Pierre Brans, Alain Mosmans

VUB/ULB Universities of Brussels  
Pleilaan, 2-1050 Brussels, Belgium  
jpbrans@vub.ac.be

The PROMETHEE multicriteria methodology has been extended to the multiple decision makers context. In this case, several decision makers are confronted to a decision problem involving a common set of possible actions. Once each decision maker has formulated a specific set of criteria and of preference parameters to evaluate these actions, the PROMETHEE methodology can be used to facilitate the group decision process.

PROMETHEE I and II rankings can be obtained not only for each decision maker separately but also for the group as a whole.

The GAIA method is extended in order to display the possible conflicts between the decision makers. It is then possible to detect the origins of these conflicts, to explain them and eventually to achieve a consensus decision after some decision makers have modified their evaluations.



# MODELLING DECISION MAKING WITH CONTEXT-BASED REASONING AND CONTEXTUAL GRAPHS. APPLICATION IN INCIDENT MANAGEMENT ON A SUBWAY LINE

Patrick Brézillon, Laurent Pasquier & Jean-Charles Pomerol

Laboratoire d'Informatique de Paris 6, Case 169, Université Paris 6  
4, place Jussieu, 75252 Paris Cedex 05, France  
Tel: 33 1 44 27 70 08 - Fax: 33 1 44 27 70 00  
E-mail: ForeName.Name@lip6.fr

## Abstract:

*Decision trees allow the modelling of event-dependent reasoning, but do not consider the dynamics of contextual knowledge. In the framework of the SART project, which aims at the design of an intelligent support system for subway regulators, we have to model high-contextual reasoning. We propose to introduce the notion of contextual graph, derived from decision trees, in order to take into account temporal and context-based reasoning. This model leads not only to a graphical simplification, but relies on observed reasoning modes in which context and its dynamics are essential. Our formalism also considers action structures as independent entities which are more or less similar to cognitive schemes and the graphic representation is reminiscent to conceptual graphs.*

**Keywords:** Context-based reasoning, Contextual graphs.

## 1 Introduction

The representation presented in this paper is used in the SART project (SART is the French acronym for support system in traffic control. Information is available at <http://www.lip6.fr/SART>). The SART project aims at the design and development of an intelligent system to support the operator who is responsible for a subway line at RATP (the French company of public transport in Paris) when an incident occurs [Brézillon *et al.*, 1997].

The modelling of operators' reasoning is a difficult task because operators use a number of contextual clues in the application of the procedures. Our model associates case-based reasoning and decision trees and includes an explicit representation of contextual knowledge. In Section 2, we introduce the notions used to model the context. Then, we present our work on contextual graphs and their application into subway line control.

## 2 Context and reasoning

Many efforts have been made to take context into account, see [Brézillon, 1999] for a survey. In a series of recent papers we have tried to clarify the notion of context, at least for the sake of using it in engineering. Hereafter, we define **contextual knowledge** as the part of context which is relevant in a given situation for a given operator [Brézillon

and Pomerol, 1999]. This may be seen as the subset of the context in which the operator can find every piece of knowledge for reasoning or explaining the situation [Brézillon *et al.*, 1999a]. The complementary part in context is called external context.

[Brézillon and Pomerol, 1999] define also **proceduralised context** as the proceduralised part of the contextual knowledge that is considered explicitly, with causal and consequential links, at a given step of the problem solving. Indeed, operators do not consider at each moment all contextual pieces of knowledge during an incident solving; the proceduralised context is the part of the contextual knowledge operators are focusing on at a given step of the incident solving. This notion is relative to each operator, to the current situation and to the moment at which the operator is working. The proceduralised status of the context is dynamical since a contextual piece of knowledge is proceduralised when the operator focuses on it and goes back to its initial state when he does not need it anymore.

### 3 Representation by decision trees

We initially modelled the possible sequences of actions by decision trees [Raïffa, 1968]. The nodes represent possible states of nature according to context (circles in Figure 1), and the actions to execute are on the corresponding branches (square and rectangular boxes in Figure 1). Common sub-sequences of actions were grouped in macro-action structures (the rectangular boxes in Figure 1) and almost all the actions are postponed at the end of the branches [Brézillon and Pomerol, 1998]. For example, Figure 1 presents the decision tree obtained in case of a failure of one or several motor coaches<sup>1</sup>. In such a case, the driver have to try to restart the failed motors. If all motor coaches restart, the train continues its run. If not all motor coaches work but enough engine power is available, the train continues its run only if there is no steep incline, otherwise it restarts without travellers. Finally, if there is not enough motor coaches available, a train (usually the next one) pushes the damaged train up to the end-station.

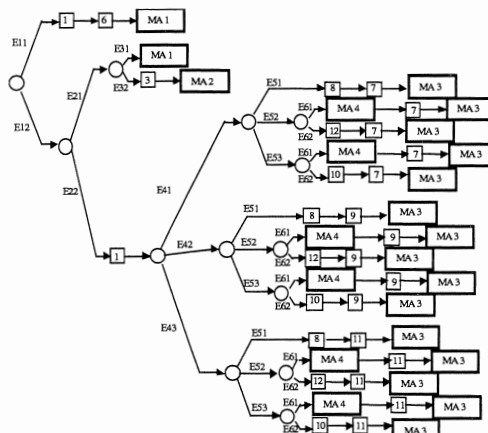


Figure 1: An example of decision tree

<sup>1</sup> A typical five-cars train is made up of 3 motor coaches and 2 trailers

Actions		Events	
1	Residual traffic regulation	E11	Immediate repair possible
2	Damaged train continues with travelers	E12	Immediate repair impossible
3	Damaged train continues with travelers until a steep incline	E21	Enough motor coaches available
4	Damaged train restarts without travelers	E22	Not enough motor coaches available
5	Stable damaged train at end station	E31	No steep incline between damaged train and end station
6	Repair damage	E32	Presence of steep incline until end station
7	Exit of the travelers out of the damaged train		
8	Exit of the travelers out of next train	E41	Damaged train at station
9	Exit of the travelers out of damaged train via available cars	E42	Damaged train under tunnel
10	Exit of the travelers out of next train via available cars	E43	Damaged train partially at station
11	Exit of the travelers out of damaged train via track		
12	Exit of the travelers out of next train via track	E51	Next train at station
13	Next train joins damaged train	E52	Next train under tunnel
14	Link both trains	E53	Next train partially at station
15	Convoy return to end station		
16	Disassemble convoy	E61	Presence of a station between damaged train and next train
17	Next train goes to next station	E62	No station between both trains

Table 1.

Macro-actions		Actions lists
MA 1	Damaged train continues service	Actions 2 and 5
MA 2	Damaged train stops service	Actions 7, 4 and 5
MA 3	Make a convoy with damaged train and next train	Actions 13, 14, 15, 5 and 16
MA 4	Empty next train at a station	Actions 17 and 8

Table 1. List of actions, events and macro-actions used in the decision tree

In our application, the final goal of all branches of the decision tree are the same: "Fast return to a normal operating mode" and the branches express only different means to reach the final goal according to the state of nature. Actually, in our representation (Figure 1 and Table 1) the so-called event nodes in decision trees are here used to specify the context. At this step there is no probabilities on the events, the main purpose is to describe, with the maximum of parsimony, all the possible contexts in which the decision has to be made. For example  $\{E_{12}, E_{21}, E_{32}\}$  describes a context in which there is no immediate repair possible, but enough motor coaches is still available and a steep incline. For this reason we will talk hereafter of context nodes instead of event nodes and of context instead of nature's state. As observed in [Brézillon *et al.*, 1998], the action postponement observed in Figure 1, amounts to relating each decision to a state of nature, here a context described in the branch.

The above representation can be simplified by observing that some actions tends to relate contexts each other. In other words, the regulators try to undertake remedial actions to temporary, or definitively, return to a more normal operating mode. Thus, some paths in the tree can converge after remediation. This is why we introduce hereafter the notion of **contextual graphs**. A contextual graph is an oriented graph that represents the decisions to undertake according to the context.

### 4 Contextual graph representation

As explained in [Brézillon *et al.*, 1999b], the proceduralisation of the contextual knowledge is a process that makes explicit the links, especially the causal and consequential links, between contextual knowledge pieces and as such the links become a part of the proceduralised context. Consequently, the above decision tree (Figure 1) can be regarded as representing proceduralised context, because for each context represented by a sequence of context nodes the implicit reasoning about causes and consequences implies that the action to undertake is defined without ambiguity. Thus, the contextual graph implicitly represents the reasoning involved in the proceduralised context (Figure 2).

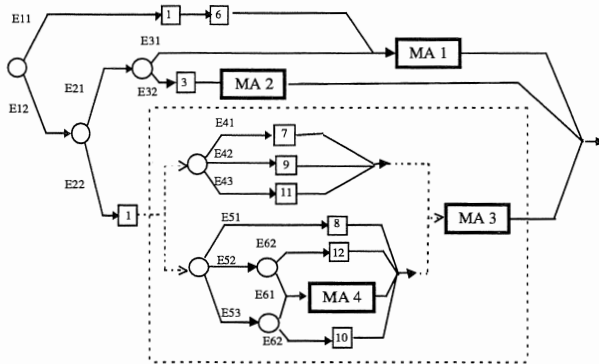


Figure 2: The contextual graph corresponding to Figure 1

We have already mentioned that, after a remedial action, different paths of the graph converge in a unique path. In some sense, these actions, if they are successful, abolish the problem related to a given proceduralised context. For example, the proceduralised context 1 and 2 in Figure 3 are respectively solved by actions 1 and 2. A new context then enters the focus of attention (context 3). Thus, our representation takes into account the dynamics of the proceduralisation.

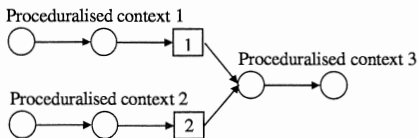


Figure 3: Converging contexts

The evolution from decision tree to contextual graphs is not only a graphical simplification. Decision trees deals with uncertainty whereas contextual graphs replace uncertainty by the knowledge complexity of the context of decision. When a piece of contextual knowledge is proceduralised in a tree representation, its status stays the same up to the end of the branch, even if actions have successfully solved the problem. On the contrary, in a contextual graph, the proceduralised knowledge evolves continuously. In



such a dynamical domain (subway line control), it is fundamental to accurately represent the dynamics of operators' reasoning.

The fact that our model is now based on graphs broadens the modelling capabilities of operators' reasoning. Another problem of modelling by trees concerns parallel action sequences. In our application, the order in which some actions are executed may be indifferent. For example, when a train must push a damaged train, both trains must be empty but the order in which the trains are emptied is not important and depends mainly on the context in which the trains are. As the contextual pieces of knowledge are too numerous to be exhaustively considered, we have introduced a new splitting in contextual graphs, called **temporal branching**. A temporal branching figures several branches that may be run independently and in any order. This idea is inspired by industrial project management. Without such a representation we should be obliged to multiply the number of paths, one for each order of possible inverting.

This structure is shown in Figure 2 (in the slashed square). One can see the opening and closing square bracket in dashed lines between action 1 and macro-action MA3. Both branches are composed of a contextual sub-graph. The upper one tells how to empty the damaged train, the lower show the same for the emergency train. The actions of both sequences are locally and independently executed. To detect such temporal branching in real applications, one has to detect action sequences that are actually indifferently undertaken in an order or another. For example, if you see that sometimes the operators decide to do a sequence "A-B" and sometimes the sequence "B-A", one can suppose that actions "A" and "B" are time-independent, but must be accomplished before a given step. Such situations are easy to automatically detect from records.

In Figure 2, the structure in the slashed square have a proper signification. It can be thought as an independent strategy named "assistance to a damaged train." This strategy has a goal (to push a damaged train with another train up to the end-station) and an explanation about the way to carry it out. This explanation may be represented as a contextual graph, which looks like the contextual sub-graph shown in Figure 2.

The introduction of the notion of contextual sub-graphs simplifies the representation. To explain the way to solve an incident, the system now presents a contextual graph in which some actions structures are simple actions and others are sub-strategies whose explanations may be expanded in contextual sub-graphs. This representation is reminiscent to Sowa's conceptual graphs [Sowa, 1984] with their mechanisms, e.g., of aggregation and expansion. Macro-actions are then considered as a particular case of action structure in which the contextual graphs are simple action sequences.

## 5 Conclusion

Using contextual graphs, we can model notions that are not modelled by decision trees. The main one is to make context explicit and to take into account the dynamics of the proceduralisation. Another advantage of contextual graphs is their ability to deal with large structure usually encountered in industrial applications. This representation is easily understood by operators (and designers) and well accepted by them and their hierarchy.

## Acknowledgements

The SART project enters an agreement between the University Paris 6 (France) and the Federal University of Rio de Janeiro (FURJ, Brazil), a contract between the University Paris 6 and the French company of public transport in Paris (RATP), and another contract between the FURJ and Metrô-Rio that manages the subway in Rio de Janeiro. Grants are provided by RATP and COFECUB in France and CAPES in Brazil. We also thank J.-M. Sieur at RATP, C. Gentile, I. Saker and M. Secron, Ph.D. students and A. Trinity and S. Roux, MsB students working on the SART project.

## References

- [Brézillon and Pomerol, 1999] Brézillon, P. and Pomerol, J.-Ch. (1999). Contextual knowledge sharing and cooperation in intelligent assistant systems. *Le Travail Humain*, 62(3), PUF, Paris, pages 223-246.
- [Brézillon and Pomerol, 1998] Brézillon, P. and Pomerol, J.-Ch. (1998). Using contextual information in decision making. In: Chapman & Hall. Widmeyer G., Berkeley D., Brézillon P. & Rajkovic V. Eds.: *Context-Sensitive Decision Support Systems*, pages 158-173.
- [Brézillon *et al.*, 1997] Brézillon, P., Gentile, C., Saker, I., and Secron, M. (1997). SART: A system for supporting operators with contextual knowledge. In Federal University of Rio de Janeiro (Ed.), *Proceedings of the First International and Interdisciplinary Conference on Modeling and Using Context (CONTEXT-97)*, pages 209-222.
- [Brézillon *et al.*, 1998] Brézillon, P., Pomerol, J.-Ch. and Saker, I. (1998). Contextual and contextualized knowledge: An application in subway control. *Special issue on Using Context in Application, International Journal on Human-Computer Studies*, 48(3) : pages 357-373.
- [Brézillon *et al.*, 1999a] Brézillon, P., Pasquier, L. and Saker, I. (1999). Context and decision making. Application in incident management on a subway line. *Proceedings of the Conference on Human Centered Processes*, Brest, France (to appear).
- [Brézillon *et al.*, 1999b] Brézillon, P., Pasquier, L. and Saker, I. (1999). Context-based reasoning and decision graphs: Application in incident management on a subway line. *Proceedings of the Seventh European Conference on Cognitive Science Approaches to Process Control*, Villeneuve d'Ascq, France (to appear).
- [Pasquier *et al.*, 1999] Pasquier, L., Brézillon, P. and Pomerol, J.-Ch. (1999). Context and decision graphs for incident management on a subway line. *Proceeding of the 2nd International and Interdisciplinary Conference on Modeling and Using Context (CONTEXT'99)*, Series Lecture Notes in Computer Science, Springer Verlag.
- [Raïffa, 1968] Raïffa H. (1968). *Decision Analysis*. Mac Graw Hill.
- [Sowa, 1984] Sowa, J.F. (1984). *Conceptual Structures: Information Processing in Mind and Machine*. Addison Wesley Publishing Company.

# CRYSIS MANAGEMENT: OPTIMAL DECISION MAKING AS A METHOD TO PREVENT EMERGENCY SITUATIONS AND ACCIDENTS IN COMPLEX SYSTEMS<sup>1</sup>

Vladimir Britkov, Gleb Sergeev

Institute for Systems Analysis, Russian Academy of Sciences  
9, prospect 60-let Ocyabria, 117312, Moscow, Russia,  
E-mail: lis@isa.ru

## Abstract:

*Among a host of human-oriented activities several should be singled out which lay important roles in the prevention of substantial economic losses and loss of human lives in the course of everyday work. In the first place it should be applied to the activities to assure safety in technological, societal and environmental spheres, to prevent emergency and crisis situations, and reduce levels of risks of human activities. Several important factors affect the solution of numerous problems connected with these tasks.*

**Keywords:** Decision support systems, Societal factors, Emergency situations

## 1 Human factors

Centralization and automation, two general trends in modern industrial sphere, do not eliminate people engaged in the technological processes. They are usually moved only to other, more responsible positions, and fulfill other, mostly decision-making, supervisory and controlling functions. This results in that human decisions and actions in the process of their work are becoming more important and authoritative, affecting general safety of technological and other activities. At the same time the basis for human decisions, which also are becoming more complicated, becomes more fuzzy and vague, but the time-span for taking decisions shorter.

All this has sharply increased the number of various stresses and psychological difficulties for managing and operational personnel, that practically is becoming an inseparable component of "man-machine" systems, often without any regard to their psychological, physiologic and other human properties (and their limitations!). This separation in some cases may explain unaccountable erroneous human decisions and actions in the course of the fulfillment of their functions (especially in the emergency conditions and in time of critical events, both of technological, as well as social nature) [Meadows et al., 1992].

It is of interest and operational attention that human error contribution to MAJOR industrial accidents occurs to be greater than to less serious failures. Whereas the human errors resulting in general technological failures amount to 10-30 % of all causes, in major accidents they are estimated to be in the range of 60-80 % [Gittus, 1987]!

---

<sup>1</sup> The research of this paper was carried out under support of the Russian Humanitarian Scientific Foundation (Grant N 98-03-04452)

It has been firmly established that industrial accidents (in particular, major hazards) do not arise in isolation of non-technological developments, among which factors of societal nature are of exceptional importance. They, in fact, add new requirements to the needs of effective management, decision making in particular, and informational support, converting measures connected with securing safety, both technological, societal, and environmental, into anthropocentric and human oriented. Now a great many tasks connected with the decision making (in a general sense of the term) in the course of various operations (during emergencies, and otherwise) could be solved only by the use of the most modern managerial methods. They include also information support, processing of large volumes of diverse information and data, and the employment of computerized information systems and techniques.

One of the main conclusions from the analyses of industrial accidents of any type and kind, especially those with catastrophic consequences, which occur from time to time in the industrial countries, is that various hazards do not arise in isolation from other, non-technological, factors. In that respect societal dimension of numerous human activities is, in particular, of exceptional significance [Richardson, 1991]. It adds a new and important aspect to the industrial safety problem *per se*, turning it into a complex multi-aspect phenomenon with important and significant societal (human-oriented) connotations.

Major accidents on the industrial installations (particularly technological catastrophes) are actually the results of numerous factors performing in close conjunction with each other, mainly with those of societal nature (regulatory and controlling mechanisms, economic considerations, legal factors, motivations of people in the course of industrial activities and many others). All of them often exert significant impact on the state and tendencies in the formulation of socially acceptable levels of safety in any country.

A number of important social factors of significance can be named which could play important, sometimes decisive roles in the technological safety sphere. The role of economic factors, in particular in such hazardous industries, as nuclear power or chemical plants, should be stressed, as economic considerations very often impose strict (and sever) limitations on the realization of safety programs and prevention of emergencies. Among other social factors should also be mentioned here the state of general social or economic stability (or rather instability) in a country or a region, or a professional or educational level of the workforce. For example, the issue of personnel competence and accordingly of personnel **choice**, in particular of managers and operators, acquires a new significance for the effectiveness of the measures directed at the prevention of industrial, especially major, emergencies and accidents. One of the obstacles in this sphere is that there is not much guidance concerning "correct" personnel selection methods. This is due mainly to the difficulty of defining criteria for optimal successful managers' or operators' performances.

Among many important societal factors **deficient**, often-obsolete systems of personnel choice, especially for responsible managing and operating positions, should be accentuated. To oppose this in some countries there are legally binding requirements that the operators, in particular in nuclear industries, should prove their competence and abilities, permitting them to occupy the positions they strive to get (for example, through examinations or some other methods).

To properly comprehend this approach some general specifications of modern technological safety activities should be noted:

- Among the causes of various industrial accidents, the emphasis is usually made on the factors, mainly of technological nature, in particular, equipment failures and mistakes of operators, leaving aside less noticeable factors, which, nevertheless, affect the course of events before and during crises.
- Short-term consequences (economic, social, ecological) of industrial accidents could now be assessed with the help of latest analytic and modeling techniques with sufficient degree of reliability. This cannot be said, however, of probable long-term societal consequences, including a wide range of lasting harmful impacts on the health and welfare of the population and plant personnel. They very often remain outside the attention of appropriate authorities and public organizations.
- In complex technological systems with strictly balanced processes, and hazardous by the nature of their activities, major accidents depend on intricate chains of events. They, in fact, are the end results of hardly predictable coincidence of the operations of many factors. Among them - technological and social play a most important role (equipment failures, managerial faults, maloperations of personnel, defective designs, often absence of feedback of operational experience, problems with the choice of personnel, etc.). In real life the whole array of causes usually cannot be easily discovered, as many important data are often irrevocably lost, ignored or even intentionally hidden.
- Major accidents are often preceded by smaller incidents ("near misses") due to non-technological factors, mostly social. Taken individually these events are fairly frequent, giving enough ground for important conclusions, which in real life are, alas, usually not taken into serious consideration.

The experience has proved that specific features of emergency situations or accidents compel to look at the phenomenon from a much broader point of view: major technological catastrophes with unpredictable *a priori* causes and consequences in most cases have other, more concealed and deep-rooted causes than direct technological, engineering or managerial faults, however decisive they might look. Regrettably, **indirect** causes of major technological accidents, which appear to a cursory observer not to be connected with the technological safety (in technical sense of the term) often, remain unidentified.

This, of course, does not mean that societal factors have been altogether ignored during the analyses or investigations of accidents. Sufficiently wide research has been made to that effect, but to a conspicuous degree it concentrated on social aspects of the final consequences - that is on what happened **after** the accidents. It seems much more important to detect factors, which could lead to the development of the undesirable events **before** serious accidents would actually happen on the plants.

So, the main point is - **societal** factors, in the broadest sense of this term, should be included in the number of probable, sometimes decisive, though not very noticeable, causes of major industrial and other accidents. This should be understood in the sense that powerful factors of societal nature (in conjunction with others) create general **preconditions** for human-made calamities. In fact, ANY major industrial accident,

should be treated as a complicated **socio-technological** event, the end result of the interplay of many technological, societal and other factors, in particular the attitudes, motivations and actions of people participating in industrial activities, directly **not** connected with the industrial safety as such.

Among the most important factors of societal nature several should be singled out, characterized and analyzed, that seems to play most influential roles in assuring technological safety. Among them:

- Safety regulatory functions and mechanisms. The world experience has proven that developed safety regulatory mechanisms constitute a prime prerequisite for the effective prevention of industrial accidents. Indeed, rapid technological development and increasing environmental pollution have required serious organizational efforts in the reconstruction of regulatory agencies in the majority of industrial nations. Safety mechanisms, as a rule, have been transformed into highly specialized administrative systems, which deal with various aspects, societal including, of industrial safety.
- Legal systems, that is the existence of developed legislation and execution of laws which creates the basis for the effective measures to raise the level of safety (in the general sense of the term). It is expedient to note an important tendency here - the **internationalization** of safety legislative activities, begun by the so-called "Seveso directive" of the EEC with subsequent addendum's. [Kleindorfer. and Kunreuther, 1987]. Now an interstate system of cooperation and interaction on a continental level has been created to accumulate, assess, and analyze data concerning potential risk of serious accidents and appropriate measures directed at their prevention and mitigation of negative consequences. For the first time in the legislative history and practice an international normative basis connected with the prevention of serious industrial accidents and emergencies, has been created.

## 2 Information needs and systems of decision support

World experience has amply demonstrated that effective management in the technological safety sphere constitutes a prime prerequisite for the prevention of emergency situations and, as a consequence, of serious accidents of various types and their negative consequences [Britkov and Sergeev, 1998a]. As the technological systems become more complex, hazardous and environmentally harmful, industrial management practices require still more sophisticated and effective operational and analytical methods and instruments. This transforms technological safety activities into highly specialized systems of their own, based to a significant degree on computerized processing of large volumes of diverse and highly professional information and data.

The difficulties and the necessity to improve management practices led to the design and construction of information systems, based on the use and interpretation of "knowledge", i.e. information accumulated in the course of experience (negative including). These systems ("decision support systems" - DSS) are designated to distribute the accumulated, and processed information in the form of "instructions" for the decision makers who can then take appropriate and final decisions [Britkov, 1997]. The DSS seem exceptionally useful in the cases when the time lag for appropriate and preferably optimal decision in the given conditions is severely limited but the risk of serious losses is high ("emergency situations").

The possibilities to employ modern telecommunication means and to build information centers (regional, for example) accumulating knowledge concerning similar industrial complexes (though spatially separated) or analogous tasks or events ("emergency situations). This optimization of the decision-making processes constitutes an important element of the DSS, separating them from other (mainly "object-oriented") decision support systems.

The DSS are especially useful when there are firmly fixed tasks (functions), but the algorithm of their solutions is absent. In other words, the main purpose the DSS is the optimization of the management practices in the result of a better understanding and formulation of the tasks, that results in a better assessment and choice of the solutions of the tasks appearing in the course of decision making [Britkov and Sergeev, 1998b].

The key point here is that the difference between the poorly, or semi-poorly, structured and well-structured problems affect the methods of their solutions. The latter is usually understood as the process of decision making possessing a routine and reiterative features. The former is that where there is no known and proved method of a solution, as the problem, *as such*, appears for the first time or it posses a very complicated and unclear nature.

If the method of the information processing might be presented in the form of an algorithm, then the process of decision making may be structured and accordingly incorporated in the computer program and the solution of a problem automated. In real life the situations usually are much more complicated. There are many problems, in particular in the financial sphere, when though management tasks are evident, the process of their solutions cannot be fully automated, as many poorly structured factors should be taken into consideration for taking a final decision (for example, in the credit sphere).

Generally speaking, the number of situations where the problems to be solved cannot be programmed is extremely large and the persons to take final decisions are not always known thus, turning the decision making process into a more and more complicated activity. Thus, it is clear that one of the main specific features of the situations, suitable for the employment of the DSS, is the possibility of a simulation of a problem. The tasks of financial dealers who often are compelled to take decisions within a few seconds are a most evident and illustrative example of this point. So, the time considerations are usually an important factor to use the DSS.

### **3 New Hi Tech problems**

The points raised above and the trends mentioned, as well as the events in the countries undergoing deep politico-economic changes show that negative consequences, which often accompany them, have been mainly the results of inability to timely introduce long needed changes in the technological, societal, or in many cases of environmental safety activities, as they ceased to correspond to the requirements of a human oriented and highly developed societies.

The occurrence of technogenic catastrophes, in fact of any serious technological or social negative events, provide a convincing answer to the question why an emphasis should be made upon the factors, societal including, that affect the level of safety in complex societal or industrial societies. Only well organized ("well structured") and

democratically run societies, where developed administrative, legal and many other mechanisms, specific of the level of modern development, can create appropriate conditions necessary for the optimization in the safety sphere and cope with hazards characteristic of many industrial and other activities.

It should be stressed that the techno-scientific progress continues at an ever-increasing rate. Radical technological and societal innovations carry with them not only new benefits for the societies, but also new, unprecedented dangers. The developments in the electronic and telecommunications areas may provide a good example of that.

With the approaching the XXI century a sinister and probably hazardous threat appears before the humanity – the so-called “Problem of 2000<sup>th</sup> year”(Y2K) [<http://www.2000.com/>, <http://www.y2k.com/>].

The scientists, in particular specialists in the electronic and communications sphere, as well as statesman or public institutions are now becoming anxious that the numerous computers may fail to properly switch over to the dates of the 2000<sup>th</sup> year. The problem is considered by many experts as a probable result of the inability of technical, particularly programming, means to assure a “smooth” transfer of numerous management systems based on the use of computers to the dates of the next century [<http://www.coalition2000.org/>, <http://www.2000.ru/>, <http://www.millennium.ru/>, <http://www.year2000.ru/>]. In the opinion of many specialists that may lead to serious, in some areas catastrophic, consequences of socio-economic and environmental character. They may also acquire not only local or national, but also in many cases also global proportions.

The modern safety problems could be successfully coped with only if all the relevant factors, SOCIETAL including, are considered in their entirety, as a SYSTEM of realistic and optimal decisions and actions, serving a common purpose - to prevent non-trivial industrial accidents or at least to considerably mitigate their destructive socio-economic losses and environmental impacts.

So, the points submitted here seem to give sufficient ground for a general conclusion that at the present stage of industrial development it is not so much the techno-engineering aspects that could contribute to the safe operation of complex industrial systems. It is the societal factors, which, in the long run, might decide the success of the industrial, and other safety activities. A wide range of various societal mechanisms and instruments is now at the disposal of scientists and managers and it is up to them to use them effectively.

## Reference

[Britkov, 1997] Britkov, V. (1997). Communication Emergency Decision Support Systems Integration. In.: The International Emergency Management Society Conference. National and International Issues Concerning Research and Applications. Ed. V. Andersen, V. Hansen. Copenhagen, Denmark, pp. 395-403.

[Britkov and Sergeev, 1998a] Britkov, V. and Sergeev, G. (1998). The role of societal factors in decision support processes of emergency engineering. In.: The international Emergency Management Society Conference "Disaster and Emergency Management: International Challenges for the Next Decade", Edited by J.Harald and G.Shaw. Washington, DC, pp. 413-420.



[Britkov and Sergeev, 1998b] Britkov, V. and Sergeev, G. (1998). Risk management: role of social factors in major industrial accidents. *Safety Science*, v.30, PERGAMON, Elsevier Science Ltd., Delft, The Netherlands, pp. 173-181.

[Gittus, 1987] Gittus, J. (1987). The Chernobyl nuclear accident: its consequences and lessons. Paper at the PSA conference. Zurich.

[Kleindorfer and Kunreuther, 1987] Kleindorfer, P. and Kunreuther H. (eds.) (1987). *Insuring and Managing Hazardous Risks: From Seveso to Bhopal and Beyond*. Springer-Verlag, Berlin.

[Meadows et al., 1992] Meadows D., Meadows D.L. and Randers J. (1992) *Beyond the Limits*. Chelsea Green (US), Earthscan (UK), McClelland (Canada).

[Richardson, 1991] Richardson G. (1991). *Feedback: Thought in Social Science and Systems Theory*. University of Pennsylvania Press, Philadelphia, PA.



# SOCRATE - SOCIETAL RESPONSES ANALYSIS TO ENVIRONMENTAL ISSUES

A. Gadda<sup>1</sup> F. Mazzeo Rinaldi<sup>2</sup> R. Wolfler Calvo<sup>3</sup>

<sup>1</sup>Università di Milano – Faculty of Political Science  
Via Conservatorio, 4 Milano 20100  
anna.gadda@iol.it

<sup>2</sup>University of Catania Faculty of Economics,  
Corso Italia 55, I-95129 Catania, Italy  
francesco.mazzeo@jrc.it

<sup>3</sup>DEI-Politecnico di Milano,  
P.za L. da Vinci, 32 – 20133 Milano  
wolfler@elet.polimi.it

## Abstract:

*The Use of focus groups as a tool to better understand societal responses to environmental issues is widespread. However the generation of heterogeneous groups in order to cover the widest range of social opinions is still a critical point. In this article an original methodology, called SOCRATE, is proposed to support the Decision-maker in defining the different 'citizen's categories' and in choosing the focus groups' participants. Neural network and ant system methods are used.*

**Keywords:** Interpretative frames, neural networks, ant system.

## 1 Introduction

In society, development can be portrayed as a process of interaction among socio-economic, cultural, natural and technology systems. The interactions can be considered along different spatial and temporal scales - from local to global. At each scale one can consider the local community or system, for itself and also in relation to its exchanges with other communities and systems [Dematteis, 1994]. These considerations shape the sustainability of the interaction between people and their environment. In particular, they refer to the value of local knowledge in inventing solutions to collective problems.

Thus a sustainable decision has to resolve the potential of social conflicts and take into account the legitimacy of knowledge of civil society.

The use of Focus Groups to reduce social conflicts in environmental management problems is a well-known approach and has been successfully applied numerous times. But one of the main 'problems' of the Focus Group approach that still remains (when the citizens are the main actor) is the choice of participants.

In this contest the use of a methodology based on the concept of interpretative frames seems rather attractive.

Through the use of interpretative frames, it becomes feasible to explain, describe and analyse problems based on each person's perception. For instance, according to the

interpretative frames concept, everyone has a different perception of the issue of "future generations", which plays a main role in environmental problems.

The scope of this work is to give a useful tool to decision makers to understand societal responses to an environmental issue. The tool is called SOCRATE - SOCIetal Responses Analisis to enviromenTal issuEs.

There are two main objectives of SOCRATE. The first is to support the Decision-maker in understanding and identifying the different 'citizen's categories' according to interpretative frames; the second is to support the choice among the persons who have to be invited to participate in the Focus Group in order to have the best possible change of representative person's prospective.

The concept of interpretative frames and their importance are described in section two. In section three the context in which SOCRATE has evolved is introduced. The methodology is presented in section four, where the use of neural networks, an ant system algorithm and a questionnaire are justified.

## **2 The reality through interpretative frames**

SOCRATE's philosophy is based on the concept of interpretative frames. Individuals, through interpretative frames, make predictions and inferences, understand phenomena and decide which action to take. The concept of "frames" refers to the everyday use of unique personal frames that make social reality meaningful. Each frame has its own rationality in reaching different conclusions (definition of a solution) from different introductory statements (definition of a problem). Each interpretative frame selects and justifies the options to be taken into consideration, the consequences, and the evaluation criteria. Each culture (or better each sub-culture) provides an inexhaustible collection of interpretative frames, which relate persons to social reality [Borgna, 1995].

Three ideal typical frames are used as compasses to move along the collection of interpretative frames: the individualist-materialist, the self-ecologist and the egalitarian perspective. The three perspectives are based on the distinction between material and post-material values introduced in [Inglheart, 1983] and the cultural perspectives [Douglas, 1985] [Swchwarz and Thompson, 1993].

In the individualist-materialist perspective (IM), security needs (crime prevention, law enforcement, etc.) and economic needs (stability of the economy, economic growth, struggle against inflation, etc.) are primary. The environment is a simple physical habitat, detached and external to man. The relation man-nature is supreme: man is external and superior to the environment. It is a vision that justifies and motivates an attitude of *laissez-faire*.

At the base of the egalitarian perspective (EG) lies global interdependence of society and the impossibility of analysing single aspects of society without considering their connection with the other aspects (environment, economy, etc.). Here, man is an element of the environment, one component among many. This perspective is concerned with defining objectives of society that structure daily life, production, exchange and consumption methods.

The last perspective is the self-ecologist (SE). Since primary needs of a person are satisfied; individuals turn to the satisfaction of secondary needs. The attitudes of

individuals are dictated by anxiety for their personal well-being and not by the problems of ecosystem equilibrium. Nature is seen as an object of pleasure, as space for amusement. Man uses the environment; the relation man-nature is of domination.

Each perspective involves different representation of the meaning both the social system and nature. It also involves a different representation of temporal and spatial dimensions.

### **3 Temporal, spatial and personal dimension**

The interpretative frames selected by individuals are the product of many components, both personal (psycho-physic state, personal history and the role played in society) and related to temporal and spatial contexts where his "persona" is inscribed. The choice of the individual's frames depends directly and indirectly on the spatial context. The history of the individual intersects with the history of the place through a dynamic interconnection of personal, social, cultural, economical and environmental factors.

The spatial context is an integration of global and local dimension [Magnaghi, 1997]. Different aspects of a local context (cultural, economical and political) have to be seen in relation to each other. At the same time each aspect of a local context is in a strict relation with a more global dimension. With current information and transport systems even the smallest isolated village is connected with the global village: it receives messages from outside and elaborates them in a particular way.

The spatial context taken into account in this work can be seen as a network of different "regional" areas, in which metropolitan and non-metropolitan areas may be identified. The cities are evolving into city-regions in an urban continuum that goes beyond the municipal borders.

According to what has been said before, it has been decided to consider a minimal spatial resolution called MHUA - Minimum Homogeneous Urban Area. MHUA can be regarded as a subset or a combination of different metropolitan areas (Inner City, Central District, Suburban District and Periphery) always preserving homogenous criteria. MHUA is a record of constitutive activity; it includes many different aspects (cultural, historical, socio-economic, environmental), as a unified whole.

### **4 SOCRATE methodology**

SOCRATE is based on two principal assumptions. The first is between interpretative frames and some individuals' characteristics. The second assumption is between frames and MHUA. The main steps in making SOCRATE are:

- data collection on interpretative schemes, characteristics of people and their urban area. Information will be collected through questionnaires and national/regional databases;
- formalisation of the two assumptions, by using the neural network described in 4.2.1 and with an algorithm called ant system as described in 4.2.2.

#### 4.1 Data capture

Through the questionnaire it will be possible to gather information about the interpretative frames for each of the possible combinations of cultural, social, economics, environmental characteristics of MHUA.

The interpretative frames are complex concepts formed by the combination of different indicators. For the choice of the indicators we refer to the three perspectives (individualist-materialist, self- ecologist, egalitarian). By using their principal characteristics we are able to fix the main dimensions of interpretative frames to investigate:

- the temporal and spatial perception;
- the equilibrium between individualisation and identification;
- the combination of satisfaction of primary or/and secondary needs;
- the representation of economic system;
- meanings of development;
- representation of interaction among economic system, natural system and social-cultural system.

The individual characteristics considered are the principal variables helpful to define the role of the individual: sex, age, occupation, instruction, etc.

The characteristics of MHUA taken into account are the principal social, cultural, economics and environmental factors (e.g. occupation, traffic, level of pollution).

The indicators are the results of the historical path, but they could also be seen as the engine of the history. The dynamic behaviour could be due to either a conflict between those indicators or an external event which acts on one or more of them. Thus, the characteristics of MHUA are also considered in an historical perspective to capture the interpretative frames resulting from the temporal dynamic of the context.

#### 4.2 Interpretative frames and structural characteristics

In order to find the relation between the responses obtained by the questionnaire (interpretative frames) and the structural variables, a neural network will be designed and used. Moreover, we are interested to connect the frames to the temporal evolution (dynamic behaviour) of the spatial context. The used of an ant system, described below, seems rather interesting in facing this latter problem.

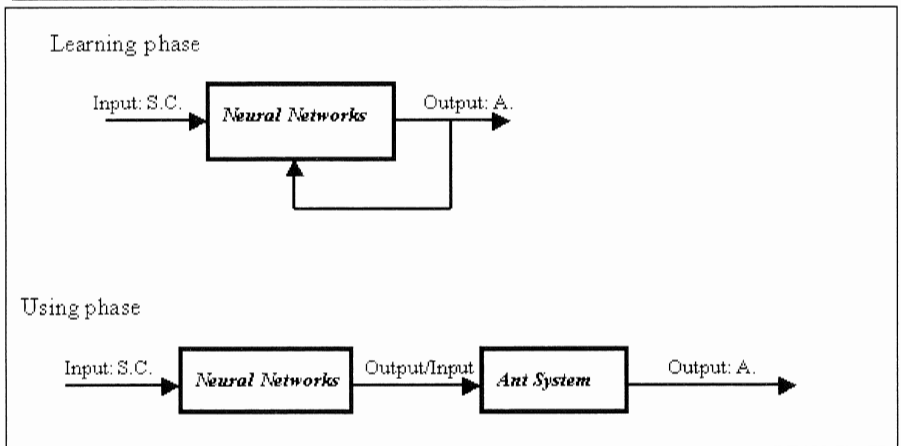


Figure 1: The scheme of SOCRATE

The two steps require a different set up. The neural networks needs a learning phase on a specific data set. Completed the learning phase, the neural networks provides as output a set of answers according to the set of structural (personal and territorial) characteristics given in input (see fig. 1). The ant system, in this context, has the purpose to 'readdress' the answers (interpretative frames), obtained as output from neural networks, in case of recent MHUA structural characteristic modification. The 'readdress' is obtained exploiting all the information contained in the database of MHUA. The two methodology are briefly explained below.

#### 4.2.1 The neural networks

In social sciences, the problem of inferences and analysis is due to a relative large amount of information, but insufficient knowledge of rules and meaning among data. The traditional quantitative methods based on statistical models suffer from rigidity, since they apply a predefined mathematical model to relate independent with dependent variables.

Given that the Neural Networks are adaptive systems, they allow a different approach to statistical modelling. The relation input/output is approximated starting from data, without been predefined in input. The neural networks approximate the function through a learning process. In the use of neural networks, the user gives a certain number of exhaustive examples (input/output). If the examples given are different (independent), the net will be able to learn without mixing them. When similar cases are met (examples), the net will only learn their typical characteristics. After the training phase, the net should be able to give correct answers as output even for those cases, which are not been observed in the learning process.

The expected result of the neural network is an approximation of the function, which links the structural characteristics with the answers. The questionnaires are used to support the learning process of the neural networks. The neural network has as input the set of structural characteristic (urban area and individual) for each interviewee and as output the set of answers given by each of them.

#### 4.2.2 The ant system

Observations on the biological behaviour of ant colonies have inspired a new heuristic method to search the optimal value of a combinatorial problem called ant systems. In this evolutionary technique, introduced by Dorigo et al. [Dorigo et al., 1996], simple agents explore a region of the search space and share information gathered throughout their individual searches. Each individual (ant) generates a feasible solution by means of a constructive algorithm. At each step of the construction, the ant has to be 'able' to decide how to make one more step towards a complete solution.

The choice is based on the two following factors.

- A trace factor (pheromone) which guides the ants to choices that gave good results in early constructions. The intensity of the factor informs the ants about the quality of the solutions which could be reached by making the corresponding choices
- A desirability factor which guides them to choices which induce the best value of the objective function.

This method takes into consideration a unknown percentage of ants behaviour introducing a casualty factor. Indeed, each ant anytime makes a probabilistic decision in among the best possible choices.

The expected results of the ant system is a 'path' which connects the first set of answers (neural network output) with a new set of answers by the interpretative frames space.

### 5 Final remarks

SOCRATE creates a link toward the potentialities that integration between qualitative and quantitative research could offer to decision-makers.

The idea of SOCRATE starts from the belief that focus group experiences have proved to be a useful approach to understand the needs, the behaviours, the knowledge of a local population, which have to be considered in a sustainable decision process. In this context SOCRATE offers a preliminary picture of the whole interpretative frames essential to define the actors attending a "face to face" focus group.

The methodological thoughts for finding innovative methods have allowed outlining a tool -SOCRATE – based on both operational research and social science methods. The way, in which the integration of the aforesaid scientific fields is proposed here, seems to offer a novel approach, which allows decision-makers to better understand societal responses to environmental issue.

#### References

- [Borgna, 1995] Borgna P. (a cura), 1995, Corpi in azione. Sviluppi teorici e applicazioni di un modello dell'attore sociale, Rosenberg & Sellier, Torino.
- [Dematteis, 1994] Dematteis G., Global network, local cities, in *Flux* n.15, January March 1994, pp. 17-23.
- [Douglas, 1985] Douglas M., 1985, Risk Acceptability According to the Social Sciences, Russell Sage Foundation, New York.



- [Inglheart, 1983] Inglheart R., 1983 *La Rivoluzione silenziosa*, Milano, Rizzoli Editori.
- [Magnaghi, 1997] Magnaghi A., *The Territory Like Complex System. The dialectic Local/Global*. Paper presented at "Advanced Study Course. Systemic Complexity and Eco-Sustainable Development", Erice, Sept. 1997.
- [Swchwarz and Thompson, 1993] Swchwarz M. and Thompson M., 1993, *Il rischio tecnologico. Differenze culturali e azione politica*, a cura di E. Bianchi, Guerini Associati Editori.
- [Dorigo et al., 1996] Dorigo M., Maniezzo V., Colomi A., *The Ant System: Optimization by a Colony of Cooperating Agents*, IEEE Transactions on System, man and Cybernetics-Part B 26,1996, 29-41



## **THE SUPPLY CHAIN MANAGEMENT: OPERATIONS RESEARCH AS A PART OF A DECISION MAKING FRAMEWORK**

Mordecai I. Henig

Tel-Aviv University  
69978 Tel-Aviv, Israel  
henig@post.tau.ac.il

The challenge of supply chain management is to consider the chain in its entirety, not just the sum of its various parts. Most standard inventory and production planning models, which assume long-term stationary demand to solve decomposable sub-problems, are inappropriate to the turbulent and complex environment of modern manufacturing. These unstructured and quantitative models are incapable of suggesting innovative alternatives to the problem of assessing the full impact of uncertain demand on the supply chain.

Objective functions are but facets of the broader corporate values. Some of them, like certain measures of customer satisfaction or even maximizing annual profit, may drive the corporate into unwanted corners. Constraints, are sometimes artificial and deter real progress and positive change of direction. Modern manufacturing approaches such as JIT and TQM demonstrate the difficulty of traditional Operations Research methods in triggering innovative ideas and forming a creative decision-making process.

At first, the many multi-criteria methods that began to appear in response to this difficulty only extended Operations Research models. Later, they began to take a more subjective perspective, to include management's knowledge and experience.

Our conclusion is that essentially supply chain management must represent a decision-making process that incorporates an understanding of management's preferences and is able to suggest innovative alternatives. To achieve these goals we suggest upgrading Operations Research methods and including them as part of a decision-making framework.



## COGNITIVE FRAMES: AN INTEGRATIVE TOOL FOR A STATE-OF-THE-ART BRAND MANAGEMENT

Christoph Herrmann

Bonhoffer Ufer 2  
D-10589 Berlin, Germany

Apart from the fact, that combinations of qualitative and quantitative methods are still fairly seldom in marketing science, many researchers still concentrate on behavioral instead of cognitive studies. While analysing past and present market behavior they forget to look for new opportunities and to appraise them. Moreover, many marketing models still proceed from a very idealistic basis, neglecting the real conditions of decision-making in practice. In his doctoral thesis, the author has tried to overcome this dilemma, showing how cognitive science may successfully influence brand analysis and management decisions.

It is important to bear in mind, that brands do not only have a monetary value. They also dispose of a high cognitive value. Through complex cognitive representations they guide the decision behavior of consumers as well as of marketing managers. To manage brands successfully, brand managers should focus their decisions more strictly on developing and influencing these cognitive schemes. Unfortunately most of the existing evaluation strategies do not suffice to fulfill this task. Whereas quantitative brand research only focuses on hard facts such as evaluating how much a brand is currently worth or how single brand features should ideally be weighed, qualitative research tries to discern the hidden image of a brand, often referring to a static and one-dimensional view of a brand's personality.

Cognitive science can help managers to get a more clear, flexible and efficient view of the current perception of their brand as well as of possible future changes than current marketing research does. The frame model for example, which has been developed by Marvin Minsky to describe complex objects of perception and has since then found wide-spread recognition in artificial intelligence and in operations research, furnishes an ideal ground for brand analysis and brand evaluation. The typical frame structure recommended by Marvin Minsky (slots, fillers, links) is not only easily to be transferred to brand representations. It also allows to integrate qualitative and quantitative research strategies on a highly efficient basis. By considering typical image attributes as slots, brand-specific meanings as values and perceptionary references as links, one even gets a scheme, which makes it possible to estimate a brands potential for resonance and thus the probability that a certain management decision may increase or reduce a brands potential for success. By this way managers do not only get important information on the status quo of their brands but are also able to test new brand strategies and their influence on brand recognition.

In this paper, the autor will explain what marketing experts can learn from cognitive science. He will show how closely management opportunities are linked to the way consumers as well as managers frame their perceptions and decisions. Moreover, he would like to discuss why cognitive science represents a favourable ground for

---

integrating qualitative and quantitative research in marketing and how the frame-based brand management system works in practice.

# HUMAN AND SOCIAL CRITERIA FOR MULTICRITERIA DECISION AID IN MICRO-CREDIT: HOW TO CHOOSE A CVECA INSTALLATION SITE

Jean Robert Kala Kamdjoug<sup>1</sup>

<sup>1</sup>Université Catholique d'Afrique Centrale - Institut Catholique de Yaoundé  
BP 11628 Yaoundé - Cameroon  
irkk@camnet.cm

## Abstract:

*The decision processes in micro-credit imply many criteria. Some of them are classical like financials criteria, but these processes involve also human centered criteria like socio-cultural and intuition of decision maker ... This paper is devoted to the study of multicriteria decision aid tools (ELECTRE III and IV) adapted to human, social, cultural and economic criteria and dedicated to the selection of sites of CVECA (Caisse Villageoise d'Épargne et de Crédit Autogérée or Self-managed village savings and loan banks) by the PPCRD (Projet Pilote Crédit Rural Décentralisé) in the regions of Nyong Et Mfoumou and Haute Sanaga (South Cameroon).*

**Keywords:** Multicriteria Decision Aid, Human centered processing, human, social and cultural criteria, Micro-credit.

## 1 Brief introduction to micro-credit

In an absolute way, the country areas of Cameroun are not that poor. The annual incomes of the farmers allow them to develop a good financial activity of saving and credit. But the quality of these services gives problems. The exclusion of the poor and of the inhabitants of country areas from formal financial structures has made easier the development of a very active informal substitution sector, characterised by: the predominance of cash transactions; the lack of recording and regulation; the restricted scale of the operations; the very high credit rates; the lack of long term financing; the fact that the warranty of these credits is mostly based on the social pressure (the cultural and social proximity and the relations personalization furthers solidarity and confidence between the parties). Usually in these areas, incomes are periodic and they correspond to drafts. The time between two drafts is very difficult for the rural populations because all their reserves are in general exhausted before the new draft arrival, and this makes easier the development of usurer practices held by a few wily and unscrupulous fellows.

Due to these particular characteristics, the financial system adapted to these areas is the one of microfinance, which is not only a credit and saving service but a set of services for people having low incomes. Microfinance is a unique of its kind financial system because it performs a social task using commercial tools [Microcrédit, 1997].

Several approaches of microfinance exist, the main ones are the following: the mutualistic or cooperative system (inspired by Raffesein's model [Humbert, 1994]); the joint and several credit system (inspired by the Grameen Bank principles

[Humbert, 1994]); the CVECA system ([Diop, 1994]); tontines are rotating credit systems between the members of social group ([CCCE, 1988]).

The success of microfinance systems is dependent on giving solutions to several problems. Here is a non exhaustive list of these problems: the credit-risk management for the micro-credit institutions *refunding*, the identification of "poorest" or micro-credit customers and the selection of institutions installation sites, the micro-credit participants training and the evaluation of micro-credit institutions. These problems appeal to several, often conflicting, points of view to be taken into account.

In this article, we will focus on the problem of choosing a CVECA installation site.

## 2 Selecting a CVECA installation site

To select an area to install a CVECA, the MIFED (Microfinance and Development) relies on two surveys, in the potential areas led by the "operators". The interval between the two surveys is of approximately two years and this allows to verify the validity of the collected informations. These surveys allow to determine the feasibility of a CVECA in the area. These feasibility conditions gather the existing frame conditions, the social and economical situation of the area, the opportunity of a CVECA network settlement, the interest and the motivation of local population for such an undertaking. These conditions allow to bring out a set of criteria presented below.

### 2.1 Methodology used to determine criteria and parameters

ELECTRE III [Roy and Bouyssou, 1993] that we use in this study, is a method base outranking on a noncompensatory logic without a unique criteria of synthesis. This method performs the problems in terms of ranking, considers pseudo-criteria, veto power and criteria weight in his structure.

The parameters have been obtained after several training sessions with MIFED experts. We submit the model results to experts, who give us back their viewpoints, therefore we make corrections for a new cycle of "*perform-correction*".

The ranking of criteria in importance order by experts helps us as basic information for the weight perform. In this importance order the *ex æquo* have the same weight. Then from discussions with experts, the weights have been adjusted with the respect of previous establish order importance of criteria.

In the cases of threshold and vetos, with the help of expert knowledges and collected data, we have defined the adapted values of these parameters. First of all, we ask the experts individually to propose the values of the parameters, then we retain the ones which give the greatest compromise of expert point of view and data collected.

### 2.2 Sites selection criteria

We now describe the retained criteria for a CVECA installation site (cf. Table 1).

The expert knowledge and the collected data have ensure us that the criterion family respects the cohesiveness axiom, the exhaustiveness axiom and the not redundancy axiom. Unfortunately we can't ensure the respect of these axioms in all potential regions, but these criteria can be used in all regions, with a new one in special conditions.



### 2.2.1 Possibility of developing viable savings and credit services

This criterion concerns the indicators that can reassure on the capacity of the region to develop a solid activity of savings and credit. These indicators are:

- *the individual saving capacity* including the average amount collected per member by the tontines;
- *the collective savings capacity*, which corresponds to the average amount of funds that have not been used during several weeks. This information is obtained in the accounts books of the groups;
- *the will of savings or of deposit at the bank*: it is estimated qualitatively from indicators on the existency of savings practices, on the commitment of individuals and groups to deposit their savings at the funds, the joining and saving amounts future customers envisage;
- *the capacity of the system to start with his own resources*: the aim is to know if the joining funds and deposits collection can cover the credit needs.

### 2.2.2 Existency of developpable economic activities

To ensure a lasting savings and credit service, the following indicators need to be of a good quality: existency of "developpable" activities without strong constraints and will of the inhabitants to develop these activities.

### 2.2.3 Technical feasibility

The aim is to have a look if it exists in the area the funds should cover human resources (cashiers and internal auditors) who are needed for the fund management, to have a look at the communication substructures, to know if the area is opened up, and at the ONG support capacity to develop a micro-credit system adapted to the institution environment.

### 2.2.4 Commitment and quality of the existing social groups

The existing social organisations are determining supports for the success of a village bank. On the preliminary survey to the installation of a CVECA, one searches for:

- *the existency of functional groups* that would like to commit themselves in the system and if they exist their number and their members number. However, on one makes sure that these groups fulfill the following criteria: regular meetings, concrete and verifiable realisations shown, commitments respected by the members and stability on the previous years;
- *the existency of jointy liable groups* likely to be the base for the fund;
- *the assurance of the groupings reliability within the fund*: the aim is to make sure that the group cohabit and this can be checked by their visible realisations, their habit to work together and the lack of conflict between the groups.

### 2.2.5 Presence of a social guarantee

The micro-credit services are intended to poor populations, that can not provide the property warranties that commercial banks require. One of the most important warranties for this kind of people is the social pressure. To install a fund, the following items are to be verified:

- the existency of persons with a well-know authority and/or influence and that are interested in the system and potentially driving;
- the existency of social pressure means within the groups or within the village. One can verify that the groups are governed by regulation texts and that it exists a practice of social pressure;
- the existency of social regulation practices, for the disputes settlement at the village and groups level.

### 2.2.6 Populations interest and motivation

The feasibility surveys allow to determine the interest of the populations, future customers of the fund, have for the project. These informations are obtained during meetings organised by the interviewers with the future customers. The relevant indicators coming out are the following:

- presence during the meetings, clear formulation of the interest the villages find in the fund settlement;
- the formulation by the future customers of the difficulties to settle a fund;
- the quality of the future customers proposals concerning the fund functioning;
- the assurance that the amount the populations propose to join the fund is at least greater than the one for a tontine;
- the active taking part of the future customers, the promise to take part in the construction of the fund buildings.

### 2.2.7 Number of potential customers for the funds

The number of potential customers is essential to decide of a fund installation because behind this criterion are hidden several determining parameters for the institution durability. Below a certain number of customers, the fund will not be able to be financially autonomous and will never be able to collect the funds needed for the initial loans. Micro-credit experts say that the number of customers needed to have a viable fund is about 80 to 100 and so it's necessary at the beginning to have a minimum of 60 members.

## 2.3 Criteria evaluation method

### 2.3.1 Criteria evaluation grid

The scales that we have used in this study is not absolute, its depend of social and economic characteristics of location region of CVECA sites. For example, the

Criteria	Evaluation scale
possibility of developping viable savings and credit services	0-9
<i>the individual saving capacity</i>	0-3
<i>the collective saving capacity</i>	0-3
<i>the will of savings or of deposit at the bank</i>	0-3
existency of developpable economic activities	0-6
<i>existing activities</i>	0-3
<i>the will of developping these activities</i>	0-3
technical feasibility	0-6
<i>communication substructures</i>	0-3
<i>existency of people able to manage the fund</i>	0-3
commitment and quality of the existing social groups	0-9
<i>the existency of functional groups</i>	0-3
<i>the existency of jointy liable groups</i>	0-3
<i>groupings reliability within the fund</i>	0-3
presence of a social guarantee	0-9
<i>existency of persons with a well-know authority and/or influence</i>	0-3
<i>existency of social pressure means</i>	0-3
<i>existency of social regulation practices</i>	0-3
populations interest and motivation	0-3
number of potential customers for the funds	20 and more

Table 1: The criteria and evaluation grid

appreciation of criteria, *number of potential customers for the funds* has done differently in Mayo Danay<sup>1</sup> and Nyong Efoumou, 30 is enough in first region and 60 in second.

### 2.3.2 Criteria parameters

Num.	Criteria	$\beta$	Veto	Weights
1	Possibility of developping viable savings and credit services	3	4	2
2	Existency of developpable economic activities	2	3	2
3	Technical feasibility	2	3	3
4	Commitment and quality of the existing social groups	3	4	1
5	Presence of a social guarantee	3	4	1
6	Populations interest and motivation			2
7	Number of potential customers for the funds	10	30	1

Table 2: The paramaters of project

There is not veto on "*Populations interest*", because this criterion can change fastly after the creation of CVECA.

<sup>1</sup>This region of CVECA belongs to North Cameroon

### 3 Results

	Cr01	Cr02	Cr03	Cr04	Cr05	Cr06	Cr07
KAN	6	5	6	7	3	1	160
BIKAN	5	4	4	5	5	2	120
TOMBO	8	5	4	6	3	2	220
AKAK	4	4	3	4	5	1	120
EYECK	4	4	4	5	3	1	200
FAN-BILOUN	4	4	3	6	4	1	200
MENGANG	6	4	5	3	2	2	200
BERKONG	7	5	6	4	3	3	200
MVEBEKONG	4	4	4	4	4	1	50
BITAM	6	3	4	5	4	1	100
MEBOLO	5	3	4	7	7	3	130
MENGUE-KOM	5	2	6	5	6	3	150
BIBEY	7	4	7	6	6	3	210
EKAK''	5	4	5	5	3	1	150

Table 3: Table of action performances

In the graph [Figure 1] we observe that, the best sites in the conclusions of complementary survey take the first places in ranking. These sites had presented the best conditions of CVECA installation.

There are incomparable sites due to the fact that, it is difficult to give the preference to one by resting on the social criteria, which have the greatest weight. For example, FAN-BILOUN and MEBOLO are incomparable.

Some sites for which the experts give objections in the complementary survey issues have been ranked in the middle of graph, but not in last rank like we expect, it is the case of EKAK and MENGANG. And some sites that the experts have recognized to have satisfied conditions, take the last places in ranking graph (cf. Figure 1). This result is due to veto on the criterion "*number of potential customers for the funds*" for the EKAK site, and, for BITAM, the imbalance in the performances of criteria justifies this position in the ranking: the site has good performances on the first and the fourth criterion, and poor performances in others, like we can see in [Table 3].

### 4 Short conclusions

These informations have been collected in a feasibility phase involving in micro-credit operators. They have been used in the choice of CVECA which are up to now functional.

The information processing by ELECTRE III show us that are very close to decisions taken by PPCDR. The aim of study was particularly oriented to the detection of situations where it is necessary to make a close control during the realization, for sites of CVECA which have a poor evaluation in mentioned criteria. This result encourage us to explore the development of multicriteria decision model for suggesting an aid in the evaluation of CVECA site.

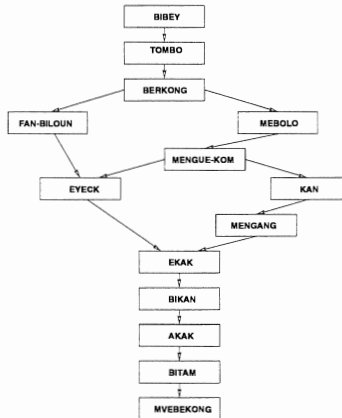


Figure 1: The ranking graph of the sites

The process has allowed to reponsibles of project to detect some faults in their selection system. It is the case when they have discovered that, some sites that they have evaluated as “very good” presented failures in some criteria, and some sites that they have found average had in reality advantages.

## References

- [CCCE, 1988] CCCE, editor (1988). *Les tontines en Afrique rôles et évolution*, chapter Les tontines : définitions, organisation et fonctionnement, pages 2–11. CCCE.
- [Diop, 1994] Diop, M. (1994). *Systèmes d'épargne et de crédit décentralisés*, chapter Les caisses villageoises autogérées au pays Dogon et dans l'Oudalan, pages 75–82. Ministère Français de la Coopération.
- [Humbert, 1994] Humbert, L. (1994). *Les systèmes d'épargne et de crédit decentralisés*, chapter Prise en compte du milieu. Ministère Français de la Coopération.
- [Microcrédit, 1997] Microcrédit, S. (1997). *Déclaration et plan d'action adoptés au sommet sur le micro-crédit*. Sommet du microcrédit.
- [Roy and Bouyssou, 1993] Roy, B. and Bouyssou, D. (1993). *Aide multicritère à la décision : méthodes et cas*. Gestion. ECONOMICA.



**« DATA ENVELOPMENT ANALYSIS » VERSUS  
« MULTICRITERIA DECISION AID »**

Rachid Khamliche

Université Libre de Bruxelles  
Service de Mathématiques de la Gestion et Institut de Statistiques  
Boulevard du Triomphe - CP 210/01  
B-1050 BRUXELLES - Belgique  
Fax : + 32 2 650 59 70

**Keywords:** Data Envelopment Analysis, Multicriteria Decision Aid, Efficiency, PROMETHEE.

Data Envelopment Analysis allows the decision maker to assess and control, in an objective way, the efficiency of a set of organisational units that are under its management task. In a parallel way, the MCDA approach and particularly the PROMETHEE method also focuses to highlight the strengths and weaknesses of this set of units according to the decision maker's preference structure. In this context of duality, this paper shows how competing or complementary these two approaches are, outlines their respective strengths and weaknesses and presents a new way for combining these objective and subjective approaches in order to yield more information and a better insight into the real and complete productive performance of each unit under evaluation.





## USING AGENDA-SETTING THEORY FOR STRATEGIC MARKETING

Franz Liebl

Universitaet Witten/Herdecke  
Alfred-Herrhausen-strasse 50  
D-58448 Witten, Germany  
FranzL@uni-wh.de

There exist many attempts to combine marketing and public relations in order to provide integrated corporate communications – which merely remained a nice metaphor. However, taking the notion of communications seriously bears fundamental implications for strategic marketing and the models employed for decision support. Communications research and cognitive science have much more to offer than simple sender-receiver frameworks that regularly turn out to be too superficial. Particularly agenda-setting research can give important insights for marketing decisions.

The agenda-setting hypothesis is not new in marketing research; it used to command that a brand should be made a top-of-head phenomenon by continuously providing news value to the public. However, this is rather a mere imperative than an analytical tool. We will show that marketers may considerably profit from exploring the large body of agenda-setting research which regularly draws on cognitive science approaches.

If corporate communication is understood as agenda setting, strategic marketing and public relations are tantamount to analysing strategic issues and managing a strategic-issue agenda. In this paper we will show what the elementary cognitive components of an issue are and what the cognitive dynamics of an issue look like on an individual and societal scale. Frames are used as a modelling device including, for example, stakeholders, problem symptoms, solutions, media coverage and proposed alternatives.

The basic issue model that had originally been developed by the author for analysing complex societal problems will be generalized and applied to a strategic marketing context. Now the themes and issues marketing communication is emphasizing, product design is alluding to and brands are standing for can be analysed within a single framework. This will provide insight if there are dissonances that in the end may spoil the consistency of a company's marketing strategy. On the other hand, one can discover if the consistency is rather trivial because the connectivity of issues and themes is too low or lacking complexity.

When the configuration of a marketing strategy has been analysed in depth, it has to be confronted with the structure and the dynamics of the external environment, i.e., target groups and socio-cultural trends. As trends and issues of public discourse can be modeled by the same approach, it is possible to find the correspondences between the external and internal configurations of themes. Now strategic marketing options can be tested in different scenarios enabling a truly prospective approach to managing trends.



## DEMYSTIFYING EXPERT DISPUTES WITH COGNITIVE MAPS

Cristina A. Lumpkin

The TERRA Team  
12, Res. Aber Ildut  
Rue Joseph Le Velly  
29290 Saint Renan, France  
C.Lumpkin@wanadoo.fr

### Abstract:

*Decision makers receive conflicting expert testimony, particularly when dealing with controversial issues. In this case study of Oahu's Waiahole Ditch Water controversy, cognitive maps were used to analyze the scientific disagreement between two scientists debating the impacts of proposed streamflow changes upon an estuary. The scientists first mapped their individual views of the system, then used the maps to discuss points of agreement and disagreement. Areas of disagreement were analyzed further, to determine whether such disagreements were caused by apparent differences or real differences of understanding. A final collaborative cognitive map shows areas of agreement and remaining areas of disagreement. The study shows this cognitive mapping technique can be used as a communication and negotiation tool, allowing scientists to discuss individual points within their arguments*

**Keywords:** cognitive mapping, science court, scientific dispute, modeling ecosystems, uncertainty.

### 1 Introduction

Decision makers frequently receive conflicting expert testimony, particularly when dealing with controversial issues. Interest groups buttress their policy arguments with the science which best supports their respective causes. In such cases, decision makers often find themselves unable to distinguish between genuine scientific dispute and the mere appearance of dispute. Their response can be to disregard the scientific arguments as being too inconclusive to be of value, as happened in Oahu's Waiahole Ditch Water controversy. The science presented in a contested case hearing lasting nine months was deemed inconclusive by the Hawaii State Commission on Water Resource Management (CWRM), which allocates water in the island state [CWRM, 1997a].

Was the science truly insufficient to aid the Commission in assessing the effects of changing streamflows upon receiving waters, or was the science lost in the pseudo-legal forum in which it was presented? To what degree do scientists disagree on "the facts" rather than merely failing to communicate with each other? Miscommunication can create false conflicts which frequently become politicized and fan the flames of divisiveness and litigation. Improved communication may educate decision makers and the public and eliminate or dissolve what in retrospect might be seen as phantom conflict. Several ways have been proposed for dealing with scientific dispute in policy

making. Table 1 compares three different methods, including the one demonstrated in this paper, a cognitive mapping process designed to show where scientists agree and where they disagree.

Method	Pros	Cons
Consensus-based methods (e.g., environmental mediation) [Ozawa and Susskind, 1985]	<ul style="list-style-type: none"> <li>• scientists debate the issues</li> <li>• consensus is politically attractive</li> </ul>	<ul style="list-style-type: none"> <li>• mixes science with value-laden policy issues</li> </ul>
Science court idea [Mazur, 1993]	<ul style="list-style-type: none"> <li>• scientists debate the issues</li> <li>• separates science from policy</li> <li>• reveals areas for further research</li> </ul>	<ul style="list-style-type: none"> <li>• never tested</li> <li>• non-experts have to interpret debate</li> </ul>
Cognitive mapping process	<ul style="list-style-type: none"> <li>• same as for science court</li> <li>• semi-graphical language easy to understand by non-experts</li> </ul>	<ul style="list-style-type: none"> <li>• time-consuming interview process</li> </ul>

Table 1. Comparison of ways of dealing with expert disagreement.

In this study, cognitive maps were used to analyze the scientific disagreement between two scientists who testified in the Waiahole Ditch Water contested case hearing about the impacts of additional flow in windward streams upon the estuary in Kaneohe Bay. The scientists first mapped their individual views of the system, then exchanged maps and discussed their points of agreement and disagreement. Areas of disagreement were analyzed further, to determine whether such disagreements were caused by apparent differences (such as definitional differences) or real differences of understanding. The scientists produced a final collaborative cognitive map showing their areas of agreement and issues which remain disputed.

The cognitive mapping method proposed here can enable decision makers to "unpack" scientific disputes, taking the map reader through each expert's arguments point-by-point. The scientists' assumptions and value judgments are revealed, allowing decision makers to decide for themselves whether those judgments are the same ones they would have made, and whether the assumptions are reasonable. Perhaps the greatest value of these maps is obtained in the second step, in which the disputing experts negotiate and collaborate to create a joint map. This process can help decision makers decide whether the expert disagreement is more apparent than real, if remaining disagreement centers on key issues in the decision context, and where to concentrate further research efforts.

## 2 Methods

Cognitive maps are a means of graphically displaying information, using text in a map-like structure [Fiol and Huff, 1992], with cause-and-effect relationships indicated by the direction of an arrow between mapped concepts [Eden et al., 1992]. Such maps can enhance our understanding of how an individual mapper sees the world. In this study, cognitive maps were used to articulate a natural system, the relationship between streamflow changes in Waiahole Stream and the health of the estuary in Kaneohe Bay, Oahu.

For this study, I used a type of cognitive map called *cause maps*, directed graphs constructed of short text “concepts” and arrows or lines showing the direction of cause or linkages between the concepts [Eden et al, 1992]. Such maps are elicited in open-structure interviews and attempt to show in words how a system works. In this way the maps act as models of a system, with concepts linked together to form an argument (such as “increased streamflow leads to increased fish productivity”).

### 2.1 Elicitation method

I first met with the scientists individually, explaining that the mapping process was intended to articulate their understanding of how the system worked. According to Eden et al [1983], the cognitive map is not meant to portray the system in an objective way, but to “be a representation of a part of the world as a particular person sees it” [p. 44]. Both mappers<sup>1</sup> seemed to understand the process easily with a brief explanation.

I asked both mappers the same initial question: “what is the relationship between the amount of streamflow of Waiahole Stream and the health of the estuary at Kaneohe Bay?” To record the maps, I drew them on a large tablet of paper as the mapper spoke, making a tape recording of the proceedings and taking notes to prevent loss of data. To increase the richness of the maps and clarify any apparent contradictions within them, I frequently asked the mappers questions throughout the process.

### 2.2 Iterative nature of the process

After creating computer-generated versions of their maps, I both met with the mappers and sent them edited maps, asking for comments and clarification. I urged the mappers to be certain the maps reflected their own views and told them to make any changes until the map represented their view of the system. Changes in the maps included clarifications of arguments, deletions and additions of concepts, and retractions of statements. After eight to nine iterations, the number of changes in the maps diminished to one or two edits, at which point the mappers said they felt satisfied that the maps accurately portrayed their understanding of the system, and the maps were considered to be “confirmed”.

### 2.3 Joint mapbuilding

The resulting cognitive maps by the experts were used to communicate the disputing scientists’ views of the natural system, in an effort to examine the roots of the dispute.

---

<sup>1</sup> The term mappers is used to refer to the scientists as the substantive generators of their maps.

After the individual maps were confirmed, joint meetings of the scientists were held in which they identified shared elements of the maps and used these as a starting point for negotiating a final collaborative map. In these meetings the experts identified their areas of agreement and disagreement, which I represented on a joint map.

### 3 Case Study: The Waiahole Ditch Water Controversy

The scientists in this study gave opposing testimony in a high-profile water allocation dispute on the Hawaiian island of Oahu. Since 1916 water has been diverted from where it naturally falls on the windward side of Oahu to the dry leeward side [Tummons, 1994]. The Waiahole Ditch tunnel system extends approximately 27 miles from the water's source to the Ewa-Kunia area, where the water was used to irrigate sugar cane on large plantations. With the demise of this industry on Oahu, debate over the best allocation of the newly available water ignited between those who wanted to retain use of the Waiahole water on the leeward side of the island and those who wanted the water returned to windward streams.

Proponents of continued diversion of the water argue that the water recharges the Pearl Harbor aquifer, Oahu's most important source of potable water, and that the water is needed for diversified agriculture slated to take the place of sugar cane [Tummons, 1994]. Arguments for returning the water to the windward side include stream restoration for ecological and recreational purposes, irrigation for cultivation of taro (a Native Hawaiian food staple), and improved productivity of the Kaneohe Bay fishery [Pa Martin, 1995].

Hawaii's Commission on Water Resource Management (CWRM) released a final allocation decision on December 24, 1997, after a nine-month contested case hearing involving 24 parties. The Commission's decision allocated 14.03 mgd to various leeward users, and 12.97 mgd to windward streams [CWRM, 1997b]. Despite extensive scientific testimony heard in the hearing, the Commission has called for yet further scientific studies to be done to guide future allocation of the Waiahole water. One reason for this was the apparently profound disagreement among scientists regarding the impacts of different amounts of freshwater flow to the various ecosystems involved. The Commission ruled that the science presented in the contested-case hearing was insufficient to determine the impacts of proposed alternatives on the affected streams and receiving water.

A major source of uncertainty in the Waiahole case stems from scientific disagreement over the ecological effects of enhanced freshwater influxes to the Kaneohe Bay estuary. Using cognitive mapping, I worked with two scientists who gave conflicting testimony in the contested-case hearing before the CWRM. Expert I, a fisheries biologist with expertise in marine ecology, testified on behalf of the windward parties to the case. Expert II, a biological and chemical oceanographer, testified on behalf of the Bishop Estate, which sought to keep the ditch water flowing on the leeward side of Oahu.

The cognitive mapping study took place in two stages: the initial stage involved mapping both scientists' individual views of the system; the second stage was a joint mapbuilding exercise in which they created a collaborative map showing areas in their

arguments where they agreed and where they disagreed. For the individual mapping, the elicitation method suggested by Eden et al. [1983] was used to help the scientists articulate their views of the stream-estuary relationship. The initial question asked of both scientists was "what is the relationship between the amount of streamflow of Waiahole Stream and the health of the estuary at Kaneohe Bay?" Both experts interpreted the imprecise word "health" to mean the *productivity* of the estuary, although they later agreed they had interpreted productivity differently.

After confirming that the experts' individual maps accurately represented their views of the system, I brought the two scientists together in facilitated joint meetings in which they presented and explained their individual maps to each other. These meetings presented the experts with their first opportunity to discuss the science of the Waiahole case with each other. Previously, they had not interacted with each other directly, although Expert II had given a rebuttal to the testimony of Expert I in the hearing. After the experts debated at length, they were directed to list the agreed-upon elements from their individual maps. They then listed those elements with which they did not agree.

During those proceedings the experts debated and negotiated the wording of agreed elements and the meanings of others, resulting in an expansion of the list of agreed elements from the original set of eleven to the final set of sixteen. These areas of agreement and disagreement between the two experts are represented in simplified version of the joint map (Figure 1) which resulted from these sessions. Those items which are accepted only by Expert I are shown within elliptical borders. Those items accepted by Expert II only are enclosed in hexagonal borders. Agreed-upon elements are in plain text, without borders.

Key differences in the experts opinions center on how they define *productivity*, a difference which causes further disagreement about what inputs to the estuary affect productivity. To a large degree, this definitional difference explains the large area of Expert I-only concepts on the left side of the joint map. Expert I agrees with most of Expert II's argument, but felt he was leaving out the most important productivity inputs. Expert II, on the other hand, disagrees that Expert I's arguments are substantiated enough to be presented as part of the map. Both experts agreed, however, that experiments could be devised to clear up the uncertainty in the argument. Another difference is Expert I's observation that endemic species will thrive more than alien species in a higher streamflow environment. Expert II did not disagree with this point, but he felt it reflected a value judgment on Expert I's part, as increased productivity could include both alien and endemic species.

The joint map shows clearly where the experts agree and where they disagree, depicts the reasons for such (understanding which was enhanced by dialogue generated during the joint mapping sessions), and can be used by decision makers as an aid to interpreting disputed science.

#### 4 Conclusion

This study illustrates a process which can be used to aid policy makers faced with expert dispute. Individual experts' arguments are represented via cognitive maps. These maps can be used to aid in understanding the scientific basis for their conclusions. The

semi-graphical language used in this process creates maps which provide an easily understood overview of the technical content for decision makers.

Rather than listening to hours of testimony in a question-and-answer format or reading endless pages of written testimony, decision makers can simply follow the cause-and-effect arguments presented in a single map. The assumptions underlying these arguments become clear as well, allowing map readers to draw their own conclusions about the soundness of the science. The maps can be as simple as those presented here, or, by integrating the cognitive mapping process with an overall computerized decision support system, the maps could be hyper-linked to supporting materials and/or additional explanation.

The joint map allows decision makers to refine their understanding of where and why expert dispute exists. In the case of this study, I discovered that the experts disagreed much less than was originally apparent (both to the experts themselves and to several reviewers familiar with their testimony). The core element of their disagreement was isolated, and the experts agreed that with some additional experimentation, the remaining uncertainty surrounding the disputed argument could be resolved.

## References

[CWRM, 1997a] Commission on Water Resource Management (1997a), Department of Land and Natural Resources, State of Hawaii. "Water Commission Issues Proposed Decision on Waiahole Ditch." July 15, 1997 press release.

[CWRM, 1997b] Commission on Water Resource Management (1997b), Department of Land and Natural Resources, State of Hawaii. "Decision and Order." December 24, 1997.

[Eden et al., 1983] Eden, C., Jones, S. and Sims, D. (1983). *Messing about in problems (Frontiers of operation research and applied systems analysis; volume 1)* Pergamon Press, New York.

[Eden et al., 1992] Eden, C., Ackermann, F., and Cropper, S. (1992). "The analysis of cause maps." *Journal of Management Studies*, vol(29:3): 309-324.

[Fiol and Huff, 1992] Fiol, C. and Huff, A. (1992). "Maps for Managers: Where are we? Where do we go from here?" *Journal of Management Studies*, vol(29:3): 267-285.

[Mazur, 1993] Mazur, A. (1993). "The Science Court: Reminiscence and Retrospective." *Risk - Issues in Health & Safety*, vol(4): 161-170.

[Ozawa and Susskind, 1985] Ozawa, C., and Susskind, L. (1985). "Mediating science-intensive policy disputes." *Journal of Policy Analysis and Management*, vol(5:1): 23-39.

[Pa Martin, 1995] Pa Martin, E. (Ed.) (1995). "Ditch's preliminary environmental assessment report is challenged." *Ke Kia'I*, vol(6:1), January 1995, p. 10.

[Tummons, 1994] Tummons, P. (1994). "Waiahole Water: Where will it go when the cane fields are gone?" *Environment Hawaii*, vol(5:3), September, 1994, : 1-7.



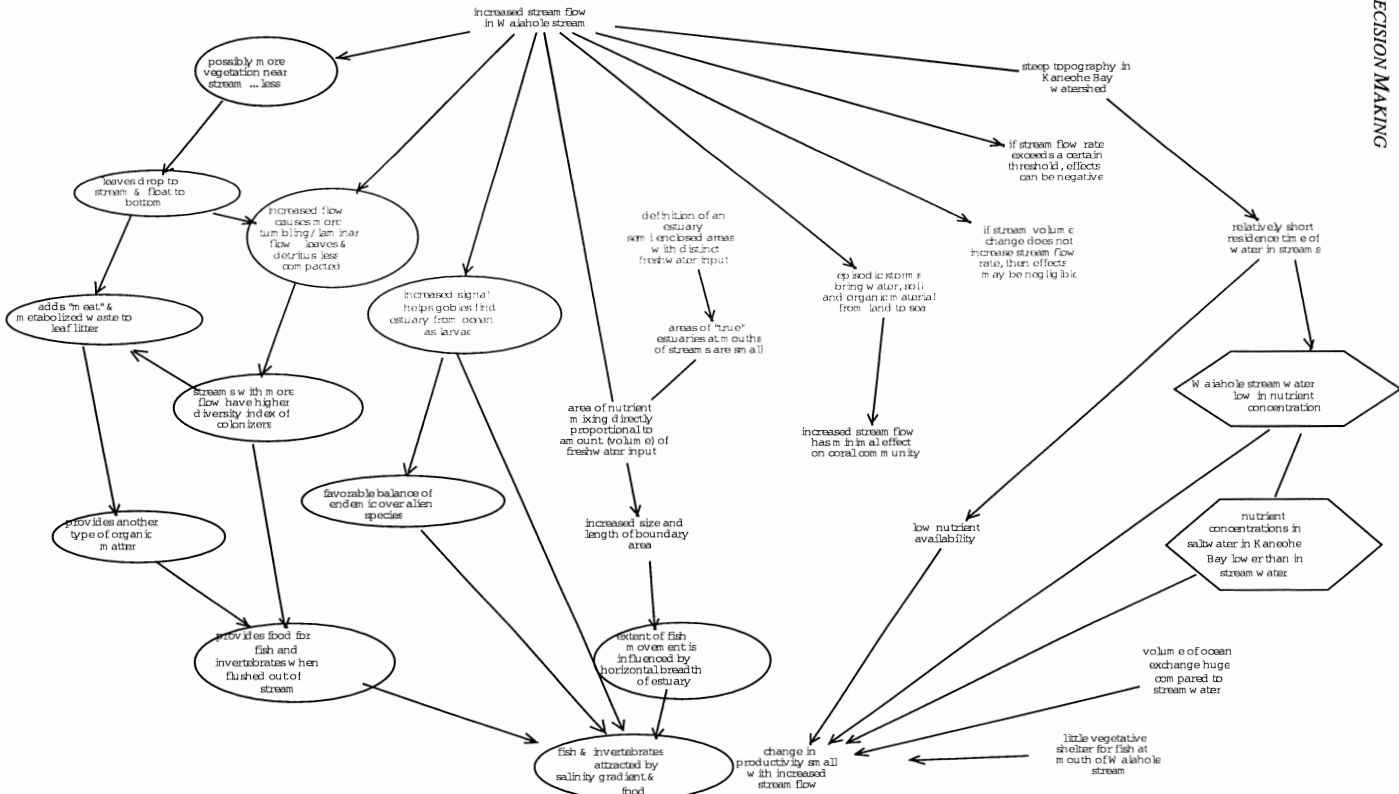


Figure 1: the experts' joint cognitive map



# STEEDS: A STRATEGIC TRANSPORT/ENERGY/ENVIRONMENT DECISION SUPPORT

M. Mattarelli<sup>1</sup>, D. Moon<sup>2</sup>, R. Wolfler Calvo<sup>1</sup>

<sup>2</sup> AEA Technology plc,  
Oxfordshire, UK  
david.moon@aeat.co.uk

<sup>1</sup> European Commission, Joint Research Centre  
Ispra, Italy  
[roberto.wolfer, marina.mattarelli]@jrc.it

## Abstract:

*Resource constraints, improved availability and quality of information, and increasing public awareness are all contributing to severe difficulties in arriving at acceptable decisions in such areas of public policy as choice of energy technologies, environmental management and transport planning. The paper describes a European research project called STEEDS (Strategic Transport Energy Environment Decision Support). The project is aimed at developing an advanced Decision Support System (DSS) able to assist the policy makers in the evaluation of future technology and policy options for the European transport system. The system allows decision-makers to evaluate complex choices on the basis of enhanced access to large amount of information generated by an integrated set of models and using a newly developed multicriteria decision aid module.*

**Keywords:** DSS, Transport, Energy, Environment

## 1 Introduction

In the STEEDS (Strategic Transport EnergyEnvironment Decision Support) project<sup>1</sup> a computer-based Decision Support System (DSS) in the context of transport-energy-environment interactions has been developed and validated [Moon, 1996].

The STEEDS DSS is a software-modelling system evaluating future policy and technology options for the European transport system. STEEDS is a tool intended to assisting decision-makers and strategic planners in public authorities and transport supply industries, especially at European and national levels in the comparative analysis of transport-energy-environment policy options. It enables decision-makers explore the long-term projections on market take-up of different transport technology mixes under the influence of different policy and technology options and exogenous macro-economics contexts and to assess their energy and environmental impacts. STEEDS assists decision-makers in the comparative analysis of these alternatives future policy, enabling them use their own criteria and value judgements.

The STEEDS tool covers all modes of transport (road, rail, water and air), including passenger and freight movements. It generates annual projections over a time horizon of

---

<sup>1</sup>The project is a shared-cost action partially funded by EC-DGXII

36 years (from 1995 to 2030), producing national-level results (with disaggregation by route type) for individual EU Member States (as well as Norway and Switzerland for completeness) and for Europe as a whole.

The paper concentrates on the description of the overall framework of the STEEDS DSS and how it works in supporting users in transport-environment-energy related decision-making processes.

In the following, a description of the architecture of the STEEDS DSS is given. Following this, a description of the use of tool, its processing stages, its features and benefits to the users are given. After that, a short description of two case studies (still on-going) is reported.

## 2 STEEDS Architecture

The STEEDS tool is designed around of the following components (Fig.1):

- a set of alternative scenarios which describe a range of possible external political and socio-economic developments envisaged to 2030
- a set of policy options including fiscal measures, regulatory measures and voluntary targets
- five linked models of the transport-energy-environment system, on a European level
- a Data Visualisation tool, for the viewing of the modelling results,
- a decision aid module based on a Multi-Criteria Decision Aid (MCDA) evaluation method.

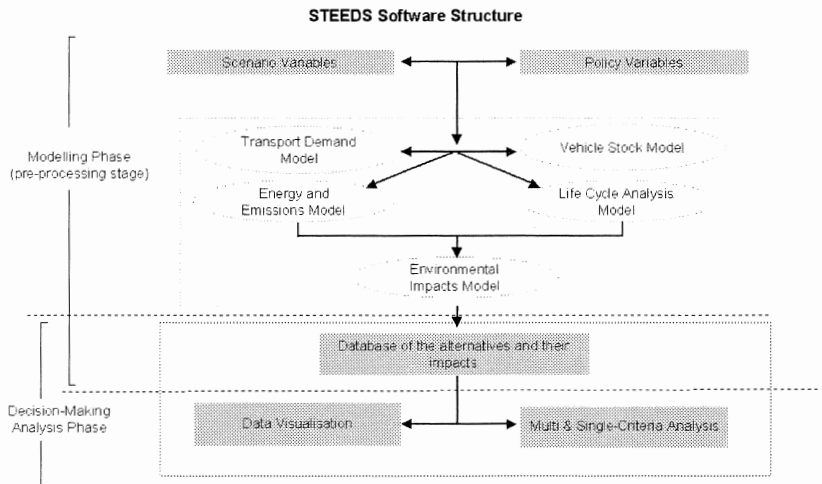


Figure 1: The STEEDS Software Structure

The *set of alternative scenarios* describes a range of possible external political and socio-economic developments envisaged to 2030. In STEEDS four scenarios [Dreborg et al., 1997] have been developed as four internally consistent possible “future worlds”, and from these visions of possible futures, variables describing factors within those “worlds” have been devised. These include GDP projections and factors such as overall global energy prices, which may affect the outcomes of the models, while being outside the control of transport/energy/environment decision-makers. The purpose of the scenarios is to provide a series of contexts within which the European transport system may develop.

The *policy options* include fiscal measures such as vehicles and fuel taxes, regulatory measures such as vehicle emissions and fuel quality standards and information programmes and voluntary targets.

The five linked models describe the transport system and calculate their impacts. They are: the Transport Demand Model, the Vehicle Stock Model, the Transport-Energy-Emissions model, the Life-Cycle analysis Model and the Environmental Impacts Model.

The Transport Demand Model (TDM) calculates the overall level of transport activity, in each country in Europe. The Vehicle Stock Model (VSM) tracks the changes in the vehicle park brought about through new vehicles, potentially using new propulsion technologies, entering the stock to replace older vehicles. The Transport Energy, Emissions and Noise Model (VEEM) calculates the emissions and energy consumption due to the different vehicle technologies that have entered the vehicle fleet. The model produces information on energy consumption and the emissions and noise produced by the vehicles. The Life Cycle Analysis Model calculates the energy consumption and pollutant emissions, which are due to the manufacture, maintenance and disposal of vehicles over their lifetime. The Environmental Impacts Model takes the data on overall levels of emissions and uses them to provide a series of ‘impact indicators’, such as global warming potential, as well as monetary valuation of the damage associated with such emissions levels (external costs).

The tool for the *Data Visualisation* is a sophisticated graphic user interface, which supports the visualisation of the year by year trend data for all the transport/environment/energy indicators calculated in the modelling stage for each of the user-defined inputs.

The *Decision aid* module supports user in the evaluation of the alternative transport policies set through the comparison of their impacts with respect to multiple and single criteria. The evaluation is performed in three forms: Single-Criterion Alternative Comparison, Alternative Comparison by Target and the MultiCriteria Analysis. The MultiCriteria analysis is based on a new MCDA approach developed by Munda (reference).

The schema in Fig. 1 shows also the whole STEEDS processing phases. The schema is based on the splitting of the DSS framework in two processing phases. The first phase is a modelling pre-processing stage in which the input is defined and the data concerning the specific decision context (depending on the user) are prepared for the analysis phase. The analysis phase allows the user to view the data generated and run decision analyses on selected sets of variables (alternatives/criteria) according to the his/her specifications

### 3 The Modelling Phase - Input definition and generation of the alternatives and they impacts

Two blocks compose the STEEDS DSS inputs: the scenario definition and the policy/technology options definition. The user is asked, assisted by a consultant, to define a set of technology or policy options (or combination of them, by defining a package of options) on the base of the policy variables modelled and to define one (or more) macro-scenarios, by selecting one of the predefined ones or creating a new one. The user is asked also to indicate the country and the time horizon to be considered

After the phase of input definitions, a large number of separate runs of the linked models are used to generate the transport-energy-environment impacts (related to the specific time frame and an indicated country) of different possible policies or policy combinations set by the user. The models calculate a large set of indicators. For example, the TDM and the VSM calculate the annual projections of the transport demand growth for passenger and freight movements and the corresponding vehicle market composition. This provides the decision-maker with indications of the effects of the policy and the macro-scenarios on the overall growth of the level of the transport activity, on the relative trend in each single sector (road, rail, water and air), the forecast demand for each single vehicles, etc.. In the meantime, the time-variation of the vehicle stock allows the user to get indications on how a policy incentive can affect the market penetration of new propulsion systems (ex. Electric vehicles, fuel cell vehicles, compressed natural gas fuelled vehicles, etc....) and to demote the use of conventional technologies, and many other market aspects. The energy use impact projections, calculated by the VEEM model allows the decision-maker to get a view of the fuel consumption and primary energy requirement associated to the transport system evolution. The impacts of the alternatives generated are then explored and evaluated in the decision-making analysis phase.

### 4 Decision-Making Analysis Phase- Exploration of the transport-environment-energy effects of the policies modelled and their comparison analysis

The tool for the *Data Visualisation* (in Fig.1) supports the visualisation of the annual projections of all the transport/environment/energy indicators calculated in the modelling stage for each of the alternatives generated. This tool helps the decision-maker to understand the implications of the transport policy/technology options set for his/her specific case. The effects of these policies are explored in the transport-environment-energy dimensions, in their interrelations and in their dynamics over time. Related to the environmental impacts, a wide range of indicators are visualised (at various level of desegregation) to allow the decision-maker to analysis the policy consequences from this prospective. A large set of direct emissions is visualised to allow the user to assess the direct impact of the vehicles on the environment and on the human health, including acoustic pollution caused by noise. Moreover many indirect emissions are provided to the user to have a perception of the impacts due to the maintenance, disposal of the vehicles, many impact indicators are also given together with a parallel cost quantification of the environmental damage in term of external costs.

A decision aid module supports the user in the comparative analysis of the transport policies. The Single-Criterion Alternative Comparison allows the user to an easy

understand of the difference between the impacts of the alternatives in inputs with respect to a selected transport-environment-energy indicator, over the time and for a selected year.

The MultiCriteria Decision Analysis performs the comparison of the various alternatives with respect to multiple energy-environment criteria, taking into account of the decision-maker judgement values, suitably modelled. The MultiCriteria analysis is performed on a consistent subset of the alternatives and a subset of the evaluation criteria of interest for the end-user. The system allows the decision-maker to evaluate a wide range of different decision problems (varying the alternatives in play and the evaluation criteria from the range of those quantified) focused on different issues (air quality, energy-saving, urban mobility, etc.). For each decision problems supported, a ranking of the alternatives considered is provided as output, with an indication of the distance between them. In STEEDS, the method adopted for the MCDA analysis is a relative new approach developed by Munda [Munda, 1995]. This is a discrete evaluation method based on a pairwise comparison technique, with allows the use of information affected by uncertainty and models the user preferences through the use of fuzzy relations. For more details, see Munda [Munda et al., 1995]

## **5 Case Study**

Two case studies have been developed to test and validate the tool.

The first case study models the introduction of new propulsion systems, for UK out to year 2020, under to scenarios of GDP growth, comparing the current fuel duty policy with a hypothetical package of technology incentives, which includes a 33% purchase subsidy and a 50% cut in annual vehicle tax for alternative-fuelled vehicles.

The second case study looks at the effects of different policy packages with non-technological objectives (carbon tax package, air quality package, urban modal shift package) as well as the technology incentives package. The time horizon is 2010, offering less scope for technology change then in the first case. The results are provisional. The calibration within the models are still being checked against industry data. After this phase, all the results will be re-generated and the STEEDS DSS will be demonstrated.

## **6 Conclusion**

The STEEDS tool brings together many different aspects of transport, energy and environmental impact modelling to paint a picture of the possible impacts of the European transport system on energy consumption and the environment, with the potential to look as far ahead as the year 2030. To deal with the complexity of the options that decision-makers may be interested in exploring and assessing, a complex system has been developed, based on the integration of transport models, a decision aid module and an easy-to-operate graphical user interface. The tool is used to help decision-makers explore a large set of decisional problems, allowing a multiple and single-criteria comparison of the options considered, supporting users in strategic decision-making processes.

The STEEDS tool is currently in the process of testing through the modelling of case studies and will be completed and demonstrated through to mid-1999. The STEEDS project will be finished in July 1999.

### **Acknowledgments**

The STEEDS project is funded by EC-DGXII in the framework of the Non Nuclear Energy Programme Joule III. The STEEDS project consortium, who together are developing the tool described in this paper, are: ETSU (UK), TÜV Rheinland (Germany), Institute for Systems, Informatics and Safety, JRC Ispra (Italy), IER University of Stuttgart (Germany), Environmental Strategies Research Group, FOA (Sweden), BG plc (UK), GBN Europe (The Netherlands), University of Bremen (Germany).

### **References**

- [Moon, 1996] Moon, DP, (1996) STEEDS Project Deliverable D1: User Requirements for the STEEDS Decision Support System, EC-DGXII, Contract JOE3-CT96-0037
- [Dreborg et al., 1997] Dreborg, KH, Eriksson, EA, Wouters, A (1997) STEEDS Project Deliverable D2: External Scenarios for the STEEDS Decision Support System, EC-DGXII, Contract JOE3-CT96-0037
- [Munda, 1995] Munda, G (1995), "Multicriteria Evaluation in a Fuzzy Environment – Theory and Applications in Ecological Economics", Physica-Verlag, Heidelberg
- [Munda et al., 1995] Munda G., Nijkamp P. and Rietveld P. (1995), Qualitative multicriteria methods for fuzzy evaluation problems, European Journal of Operational Research, N. 82, pp.79-97.



## A MULTICRITERIA DECISION AID METHODOLOGY FOR THE EVALUATION OF THE FIRMS

Linett Montano Guzman

Service de Mathématiques de la Gestion (S.M.G.)  
et Institut de Statistiques et de Recherche Opérationnelle (I.S.R.O.)

Université Libre de Bruxelles

CP 210/01

Boulevard du Triomphe

Bruxelles, Belgium

Email : lmontano@smg.ulb.ac.be

**Keywords:** Multicriteria Decision Aid ; Sorting problematic ; Aggregation operators ; Fuzzy measure ; Evaluation of the firms.

For the evaluation of the firms the most methods consider only quantitative criteria (financial ratios); however qualitative criteria and their synergy also affect the performance of the firms. This paper presents a multicriteria decision aid methodology which incorporate in the evaluation : qualitative variables and fuzzy integral, the last one is able to represent a certain kind of interaction between criteria.



## PERFORMANCE INDICATORS BOARD

João Mendes Moreira<sup>1</sup>, Jorge Freire de Sousa<sup>2</sup>

INEGI - FEUP, Rua dos Bragas, 4099 Porto Codex, Portugal  
<sup>1</sup>jmoreira@fe.up.pt; <sup>2</sup>jfsousa@fe.up.pt

### Abstract:

*The Performance Indicators Board (PIB) is a top level oriented module for mass transport companies. The objective of PIB is to collect and to show the planning and control information to support the decision making process. In this paper, the authors describe the indicators identification process and the logic architecture of the module, in particular its query tool.*

**Keywords:** Key Performance Indicators, Transportation, Data Mart, OLAP.

### 1 The GIST system

The GIST system [4,3] is a computer application for supporting operational planning in public transport companies. It was developed as a decision support system which aims to help transport companies to improve the operation of critical resources, such as vehicles, drivers and planning staff. The system is also an important software tool to support tactical and strategic management studies regarding companies operations. A consortium of 5 leading Portuguese transport companies (CARRIS, STCP, Horários do Funchal, Empresa Barraqueiro and Vimeca) and 2 R&D institutes (INEGI-FEUP and ICAT-FCUL) is responsible for the GIST system. The companies involved in this consortium operate daily about 6000 vehicles, corresponding broadly to half of the road public transport market in Portugal, including Madeira and Azores.

The GIST system was successfully installed in those companies in 1996. Nowadays, the upgrades of this application are being developed under the name of GIST98/EUROBUS. This evolution represents both an improvement to the GIST present functions and an extension of its functionality.

### 2 The GIST98/EUROBUS system

The GIST98/EUROBUS system contains the following modules:

- Network Module, allowing the definition of the transportation network;
- Gist-Line Module, the route information module;
- Trip and Vehicle Scheduling Module, allowing the trip timetable definition and the vehicle scheduling information management and optimisation;
- Crew Scheduling Module, the crew scheduling information management and optimisation module;
- Rostering Module, in which is defined who will do each duty each day and in which various optimisation algorithms are applied to the roosting rules;

- User Information Module, an user-oriented module which provides information to the users of public transports;
- Performance Indicators Board Module, a top level oriented module which gives performance indicators to support the decision making process;
- Hiring Management Module, the module that manages the renting vehicle activity.

The first 3 modules are upgrades of the present GIST modules. The Crew Scheduling Module, the Rostering Module, the User Information Module and the Performance Indicators Board Module belong to the EUROBUS project that has been financially supported by a public institution named 'Agência de Inovação'. All these modules together with the Hiring Management one form the GIST98/EUROBUS system.

### **3 The Performance Indicators Board Module (PIB)**

The PIB Module filters the information derived from the other modules so that the operational managers can access, in an easy way, the relevant information for the decision making process. The main problem in structuring a PIB Module is to define those indicators which are significant to the managers and those that are important to the planners but not necessarily to the managers. The PIB Module just contains the information useful to the operational managers. All the other information is included in the corresponding module. As the GIST98/EUROBUS is a decision support system to the operational planning, the information we can get from it is essentially planning information.

The first questions we tried to answer were: "Which are the big groups of indicators that operational managers need?" and "Which indicators must be included in each group?".

The results presented in this text are derived from the study accomplished at the STCP Company (the Oporto Public Transport Authority) and also from the U.S. Bureau of Transportation Statistics [2].

#### **3.1 "Which are the big groups of indicators that operational managers need?"**

Taking attention to the information that GIST98 contains and to the big areas that operational managers work with, we have defined two main groups of performance indicators: service indicators and crew indicators. The first group gives information about the level of service that the company is offering, which is specially important to the marketing department while the crew indicators give information relevant to the human resource department.

#### **3.2 "Which indicators must be included in each group?"**

The answer to this question is not easy. The complexity involved in the definition of those indicators creates problems in a systematic approach. The way we solved this question will be explained in the next section.

#### 4 The process of defining the service indicators

The first thing to do was to collect information from the companies. It was a long, interactive process between the analysts and the companies' staff. The service reports produced monthly were another major source of information.

Based on the information collected it was possible to notice that each potential indicator has no more than 4 parameters. This means that it is possible to identify a specific indicator by answering to 4 questions: "Which is the indicator denomination?", "Which entity does the indicator refers to?", "Which is the aggregation level used?" and "Which aggregation function does it represent (in other words, is it an average, a maximum or any other kind of function)?". As an example: if we want to know the average width of trips per route, the indicator is the width, the entity is the trip, the aggregation level is the route, and the aggregation function is the average. Using this methodology it was possible to identify the indicators group, the entities group and the aggregation function group. The aggregation level was more complex to define. In fact, using the example above, the trips can be aggregated by route, by line, by period of the day, by day, by line and by period of the day at the same time, i.e., they can be aggregated by one entity or by a combination of entities. The first thing we observed was that when an indicator can be aggregated by one entity it can also be aggregated by more generic entities. In the example, if routes can aggregate trips, lines can also aggregate trips (notice that a line is a set of routes). The step forward was to define the different dimensions to be used. Each dimension refers to a sequence of entities. The order by which they appear on table 2 is defined by their degree of detail. This means that the first entity of each dimension is the most specific one and the last one is the most generic. In other words, the entity referred at the last column of each dimension is a set of the entities referred at the previous one, and so on.

Service Indicators	Dimensions					Planned vs. Real
	Space	Day type	Time	Vehicle	Roster	
Number of routes	x					
Routes width	x					
Number of lines	x					
Lines width	x	x	x	x	x	x
Number of trips		x	x	x		x
Number of vehicles used	x	x	x	x		x
Number of vehicles used at the same time	x	x	x	x	x	x
Total distance	x	x	x	x	x	x
Commercial distance	x	x	x	x	x	x
Non commercial distance	x	x	x	x	x	x
Commercial time	x	x	x	x	x	x
Non commercial time	x	x	x			x

Table 1: Service Indicators

Space	Segment	Route	Line	Gist-line	Depot	Network
Day type	Day	Day type				
Time	Day	Week	Month	Quarter	Year	
Vehicle	Trip	Vehicle	Depot	Network		
Roster	Duty period	Duty	Duty type	Roster	Depot	Network

Table 2: Dimensions

Tables 1 and 2 present part of the results obtained by this methodological approach (the aggregation functions were ignored just for the sake of simplicity).

## 5 The PIB's logic architecture [5,1]

The data for PIB is stored in an appropriate database. This is an important feature for several reasons. Some companies operate in several towns and they may have a GIST98/EUROBUS system working at each town; if the managers want to know indicators concerning all the company, and not just a part of it, the PIB has to work at the same time with information from several databases in order to provide the right indicators. Moreover, the information that is stored is not necessarily the same that is used to support the operational planning. Sometimes, specific statistics based on that information are enough. So, the information is read from different databases with a given periodicity and only the one that is relevant to the PIB Module is stored.

To extract and load the data to the PIB database, a load manager has been built. The load manager's function is to extract the information from the source databases (just the relational ones considered) and load it to the PIB database. It is also a function of the load manager to perform simple transformations in order to adapt the source data to the PIB database. The extracting and loading functions can be scheduled in order to avoid the overloading of the computer during the working period.

As the companies often just need to keep data during a certain number of years, it is important to have a manner of storing the data older than a given date in a proper device. That data must be available whenever the users need it.

The two main components of the PIB module perceptible to the users are the query tool and the report tool. The query tool allows the definition of the indicators. It is a user-friendly interface allowing the construction of complex queries by non-skilled users. This tool will be described in detail in section 6. The report tool is oriented to the construction of reports. It is possible to include a set of indicators in a report and to format it. There is a set of different layouts for the indicators available to the user. It is possible to define parameters to the reports. The report is a Microsoft Excel file that can be opened and changed using this software.

The main problem of this type of systems is the large amount of information they have to manage. The relational database management systems were traditionally designed to optimise the use of device's space. Roughly we can say that the paradigm was: "The less is the space needed to store the data, the better is the database design". During the last years the information won an increasing strategic importance in the companies and the storage devices became cheaper. This has driven to a change of paradigm. Nowadays the ability to manage huge amounts of data with good performances is a crucial factor for the companies. So, in the design of a database, the performance factor must be studied. How should we design the database to speed up queries? One of the crucial factors to reduce the query's response time is the number of tables used. The ideal to speed up queries is to design the tables according to the queries to be done. Usually, a compromise option between these two paradigms is used. The information is stored in the third normal form and, according to the most frequently queries, temporary tables are created to improve performances. As the most frequently

asked questions are not the same along the time, the management of temporary table is dynamic. This is the job of the warehouse manager.

The warehouse manager updates the structure of the database but, to optimise the performance of the queries, we need to read the information from the database in the most efficient way. This is the function of the query manager.

Figure 1 shows how those six components interact with each other.

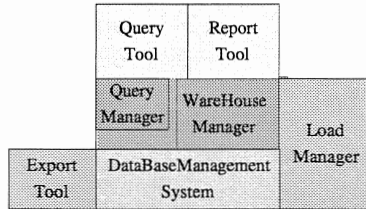


Figure 1

## 6 The query tool

In section 4 we saw that it is possible to identify a specific indicator by answering to 4 questions. The query tool uses that kind of questions to create a sequence of user-friendly windows.

### 6.1 Entity

Firstly, the entity is chosen. All the other windows depend on this choice. The entity choice can be seen as the answer to the question: "Which entity does the indicators refers to?" or "From which entity do I want to get information?".

### 6.2 Indicators

The second step is the selection of the indicators. The indicators available are those that refer to the entity chosen previously. These choices can be seen as the answer to the question: "Which is the indicator denomination?". In this window, the user can also define the aggregation function that he wants to use with each indicator. By doing this, he is answering to the question: "Which aggregation function does the indicator represent?".

### 6.3 Aggregation levels

Then, the user must choose the aggregation levels he wants, i.e., the dimensions. It is the answer to the question: "Which are the aggregation levels used?". The dimensions available depend on the chosen entity. If there are several identifiers for each dimension, the user must select one of them. When the user finishes this step he has identified the required indicator(s).

### 6.4 Layout

The layout is defined in a matrix format. The user can set the rows and the columns.

## 6.5 Constraints

By default, all the records are displayed. To impose constraints the user can write conditions or/and select exhaustively the required data. The window where this is done can be reached by pressing a single button. This is done to hide from the users optional windows that are used only by skilled users.

## 6.6 SQL statement

Finally, the user can access the SQL statement and change it, if he wants. In the same window, he gives the name to the indicator created so that he can use it later.

With this type of interface it is possible to generate any SQL statement. In order to accomplish this task it has been necessary to add some options to the windows described above such as: to ignore similar rows (DISTINCT clause), to order the data by a given criteria (ORDER BY clause), to operate set operations like union, intersect and minus, or to use sub-queries. Skilled users can edit the SQL statement and write it directly using that language. Any basic SQL statement using the optional clauses WHERE, GROUP BY and HAVING can also be done with this interface. These clauses form a large percentage of the queries most frequently done by the users.

## 7 Conclusions

In this paper we described a computer application for supporting operational planning in public transport companies. The main feature of the PIB Module is to display the information the system holds in a useful layout to the managers, hence reducing the documentation production costs. PIB is not a competitor of OLAP (On Line Analytical Processing) tools. The decision of developing our own OLAP tool was taken by the consortium based on a cost/benefit analysis.

The methodology used in the Performance Indicators Board Module was user-oriented. During the development process, analysts and developers had to interact with the final user in order to adapt the module design to the user needs. As a consequence, changes were successively done to previous plans. This interactive process is essential by several reasons: the involvement of the companies in the development is strong, the redesign effort is minimum, the definition of short-term goals speeds up the development, and companies become more capable to understand technical difficulties. All these features increase the probability of success.

In November 1998 Microsoft launched the SQL Server 7 that includes the OLAP Server, all at a price around \$1400 for 5 users. With this announcement our strategy was altered because the cost of this software is clearly lower than the PIB's development cost and because this tool is better to achieve the purpose of our work.

## References

- [Anahory, Sam and Murray, Dennis, 1997], *Data Warehousing in the Real World*, Addison-Wesley
- [Bureau of Transportation Statistics (BTS) of the U.S. Department of Transportation, 1997], *National Transportation Statistics 1997*.



- [Cunha, J.F., Sousa, J.P., Galvão, T. and Borges, J.L., 1993], A Decision Support System for the Operational Planning at Mass Transport Companies, 6<sup>th</sup> International Workshop on Computer-Aided Scheduling of Public Transport, Lisbon, Portugal.
- [Sousa, J.P., Sousa, J.F. and Guimarães, R.C., 1988], Un système informatique d'aide à la génération d'horaires de bus et de chauffeurs, Gestion de l'économie et de l'entreprise - l'approche quantitative, Editions CORE, Série Balises, De Boeck, Brussels, pp. 477-492.
- [Thomsen, E., 1997], OLAP Solutions: Building Multidimensional Information Systems, John Wiley & Sons, Inc.



## MULTICRITERIA DECISION AID FOR THE BUDGETING OF THE BELGIAN HEALTH CARE SYSTEM

Alain Mosmans

Service de Mathématiques de la Gestion (S.M.G.)  
et Institut de Statistiques et de Recherche Opérationnelle (I.S.R.O.)  
Université Libre de Bruxelles  
CP 210/01  
Boulevard du Triomphe  
Bruxelles, Belgium  
Email : amosmans@smg.ulb.ac.be

**Keywords:** Multicriteria Decision Aid, sorting problematic, fuzzy sets, health care

Three years ago, the Belgian Ministry for Social Affairs asked the department of Operational Research (SMG) of the Université Libre de Bruxelles to develop multicriteria tools aimed at helping the INAMI's actuaries (National Institute of Insurance against Disease and Handicap) to understand health care budgets consumption in order to reduce the overspendings they were regularly facing. The paper will deal with the results of that research : the construction of a multicriteria fuzzy assignment procedure of the insured Belgians to some "pathological channels", its computational implementation and a practical example.



## STRATEGIC PERFORMANCE MEASUREMENT: A COGNITIVE APPROACH

Olaf G. Rughase

Universitaet Witten/Herdecke  
Alfred-Herrhausen-strasse 50  
D-58448 Witten, Germany  
olafr@uni-wh.de

Traditional strategic performance measurement systems mainly refer to financial and maybe some non-financial indicators (e.g. Shareholder Value or Balanced Scorecard). These systems may indicate that a chosen strategy is possibly wrong, but hardly what the organization should do exactly or how a complex set of activities should be modified. At this point, a decision-oriented tool for strategic performance measurement is needed.

Only the customer himself will define the success of the unique value mix, because competitive advantages are formed in the minds of customers. Finally, the customer's perception will decide, how well the "strategic fit" of the organization was designed. There are many techniques that describe a customer's perception and expectations, buying criteria, experiences or customer value. But as single techniques they are barely able to describe of a complex competitive advantage based on a set of different activities, which are in interaction with each other. Storytelling as the "preferred sensemaking currency of human relationships" (Boje) among customers and organizations could be the connection between these techniques and may close the gap. Positive and negative stories of the customer represent unique experiences with organizations and thereby form a strategic identity of the organization. Frames and meanings can be identified as well as the background of motivation and acting in order to understand the customer's perception in-depth.

A decision-oriented tool for strategic performance measurement should be based on these stories. Therefore, our instrument contains qualitative and quantitative elements heavily influenced by cognitive science. An in-depth interview (narrative/problem-oriented) represents the most important part of the instrument. During these interviews, customers are having the opportunity to express their experiences (stories) in their own words.

All interviews are analysed by an intersubjective content-analysis to get a detailed cognitive map of the customer. Not only the elements within these cognitive maps are important, but the relations between the elements. The relations will demonstrate the customer's associations and complex perception of unique value (such as competitive advantages). Perhaps not every customer were able to experience competitive advantages intended by the organization. For that reason, a questionnaire follows the interview, containing (open & standard) questions about certain properties of different activities. This mainly quantitative information is complementary to the qualitative interview and should always be interpreted in reference to the cognitive map. As a result, the entire set of different activities, which is intended to create a competitive advantage, can be detailed measured by cognitive maps and supporting quantitative information.

This instrument was already used in many industrial applications and has been proven to be very effective. Because of the detailed strategic performance information, many companies modified their "strategic fit" (if needed) and got a lot of intentions for new appropriate activities, which hit the cognitive world of their customers and will shape their strategic identity.

# ORDER AND CLUSTERING

Dietmar Schweigert<sup>1</sup>

<sup>1</sup>Fachbereich Mathematik, Universität Kaiserslautern  
D-67653 Kaiserslautern, Germany  
e-mail: schweigert@mathematik.uni-kl.de

## Abstract:

*To compare is a human process. Every likes to decide what is good or bad for him. During this process the comparison comes before the measure.*

*Therefore the intension of this paper is to replace the role for the distance function in clustering by partially ordered sets. We avoid scaling and compare distances between the data whether one is larger than the other or equal or even incomparable. By this comparison we get a partially ordered set of distances. After a processing of this partially ordered set we apply a well-known cluster algorithm and discuss the advantages and short-comings of this new approach.*

## 1 On partially ordered sets

An order relation of a set  $A$  is a binary relation  $\vartheta \subseteq A^2$  which is usually denoted by  $a \leq b$  if  $(a, b) \in \vartheta$ . This relation is reflexive, antisymmetric and transitive.

We consider a partially ordered set or a poset  $P$  to be a pair  $P = (P; \leq)$ . We take  $a, b \in P$  with  $a \neq b$  and say  $a$  and  $b$  are comparable in  $P$  when either  $a < b$  or  $b < a$  in  $P$ . On the other hand,  $a$  and  $b$  are incomparable in  $P$  if neither  $a < b$  nor  $b < a$  in  $P$ . We say  $a$  is covered by  $b$  when  $a < b$  in  $P$  and there is no element  $c \in P$  for which  $a < c$  and  $c < b$  in  $P$ . A poset  $P = (P; \leq)$  is called a chain if every distinct pair of elements from  $P$  is comparable in  $P$ .

Small partially ordered set can be presented in the form of a Hasse diagram. The advantage of this diagram is that we can work by symbolic computing not only with measuring.

## 2 A cluster algorithm of orderings

The set of objects are given by  $x_1, \dots, x_n$  and the distances by  $d_{ij}, i, j \in \{1, \dots, n\}$ . We assume that the distances have the properties  $d_{ii} = 0$  and  $d_{ij} = d_{ji}$  for every  $i, j \in \{1, \dots, n\}$ .

We do not measure for distances but compare it as the partially ordered set. We will point out on a small example.

We will present the Hassediagram of the partially ordered set  $d_{ij}$  by distances.

Let us mention that the distance  $d_{13}$  is minimal and that the distances  $d_{45}, d_{15}, d_{24}$  are non-comparable.

	$x_2$	$x_3$	$x_4$	$x_5$
$x_1$	$d_{12}$	$d_{13}$	$d_{14}$	$d_{15}$
$x_2$		$d_{23}$	$d_{24}$	$d_{25}$
$x_3$			$d_{34}$	$d_{35}$
$x_4$				$d_{45}$

Table 1: Matrix of distances

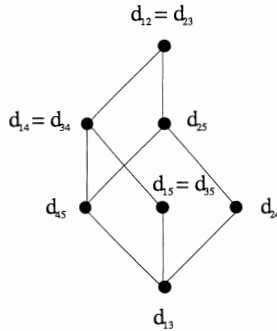


Figure 1:

### 3 Algorithm of ordered clustering

**Input:** A symmetric distance matrix  $D_1 = (d_{ij})$  where the distances form a partially ordered set.  $k := 1$ .

**Step 1:** Begin with the partition  $C_1$  which consists of  $n$  clusters containing a single element.

**Step 2:** Determine  $d_{pq} = \min_{i \neq j} \{d_{ij}\}$  in  $D_k = (d_{ij})$ . In the case there are more minimal elements take the lexicographic order. Merge the two clusters which contain  $x_p$  and  $x_q$ . Put  $d_{pq} := \infty$  in  $D_k$  and put  $k := k + 1$ . Denote the new partition by  $C_k$ .

**Step 3:** Stop, if number of the required clusters is obtained. Otherwise goto step 2.

**Output:** Clustering  $C$  with the required number of clusters.

#### 3.1 Example

Let us begin with step 2 and determine  $d_{pq} = \min_{i \neq j} \{d_{ij}\}$ . We have  $d_{13}$  and we will merge the two clusters  $x_1$  and  $x_3$ . Now we have to consider the non-comparable pairs  $d_{45}, d_{15}, d_{24}$ . We take  $d_{15}$  of lexicographic order and merge the clusters  $d_{15}$  and  $d_{35}$ . In this phase of the algorithm we have the clusters

$$\{x_1, x_3, x_5\} \{x_2\} \{x_4\}$$

where we have the minimal elements  $d_{45}$  and  $d_{24}$ . We take the lexicographic order and we have  $d_{45}$ .



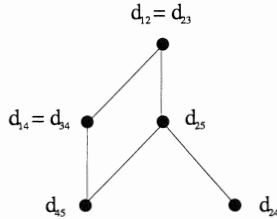


Figure 2:

### 3.2 Result

**Iteration 0:**  $\{x_1\}, \{x_2\}, \{x_3\}, \{x_4\}, \{x_5\}$

**Iteration 1:**  $\{x_1, x_3\}, \{x_2\}, \{x_4\}, \{x_5\}$

**Iteration 2:**  $\{x_1, x_3, x_5\}, \{x_2\}, \{x_4\}$

**Iteration 3:**  $\{x_1, x_3, x_5\}, \{x_2, x_4\}$

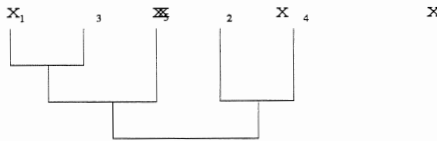


Figure 3:

**Remark.** If one change the lexicographic order then the algorithm will produce other solutions.

### 4 The subroutine for the minimal elements

We present the partially ordered set of distances from the tables 3.1 and 3.2 as a matrix in  $\{0, 1\}$ . We put 1 for  $d_{ij} \leq d_{kl}$  and 0 for  $d_{ij} \not\leq d_{kl}$ . If the distances  $d_{ij}$  and  $d_{kl}$  are equal  $d_{ij} = d_{kl}$  we use the same row and column

### 5 Algorithm for minimal elements

Input: Partially ordered set of distances as a matrix  $C_0$  with  $\{0, 1\}, m$ .

Step 1: Initialize  $k := 0$ .

Step 2: Determine a column  $a^j$  in  $C_k$  with a minimal number of 1<sub>g</sub>. If there is more than one column  $a^j$  choose the lexicographical first one. The distances  $a^j$  are minimal.

	$d_{23}, d_{12}$	$d_{13}$	$d_{34}, d_{14}$	$d_{35}, d_{15}$	$d_{24}$	$d_{25}$	$d_{45}$
$d_{23}, d_{12}$	1	0	0	0	0	0	0
$d_{13}$	1	1	1	1	1	1	1
$d_{34}, d_{14}$	1	0	1	0	0	0	0
$d_{35}, d_{15}$	1	0	1	1	0	0	0
$d_{24}$	1	0	0	0	1	1	0
$d_{25}$	1	0	0	0	0	1	0
$d_{45}$	1	0	1	0	0	1	1

Table 2: Matrix of the poset of distances

Step 2: If all minimal elements have been put out then delete the column  $a^j$  and the row  $b_i$  which belongs to these distances. Put  $k := k + 1$  and denote the new matrix with  $C_k$ .

Goto Step 2.

Step 3: Stop, if  $k = m$ . If  $k < m$  then goto Step 2.

### 6 Example of order and clustering

We take the data from the book [Everitt, Dunn, 1991] and respectively [Hartigan, 1975]. The data relate the number of crimes of different types per hundred of thousands population in several American cities. For us it is sufficient to restrict the table in page 42 and 116 in [2] to the data of four cities to see enough.

	Murder	Rape	Theft
Atlanta	16.5	24.8	905
Boston	4.2	13.3	669
Hartford	2.5	8.8	724
Honolulu	3.6	12.7	1102

Table 3: Crimes

The algorithm provide it for two minima  $d_{23}$  and  $d_{24}$ . Now we have the following dendrograms

The interpretation of the results can be understood by the data.

	$x_2$	$x_3$	$x_4$
$x_1$	$d_{12}$	$d_{13}$	$d_{14}$
$x_2$		$d_{23}$	$d_{24}$
$x_3$			$d_{34}$

Table 4: Matrix of the poset

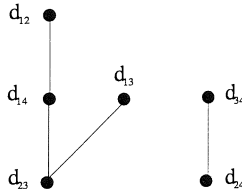


Figure 4:

$\{x_1\} \{x_2x_3\} \{x_4\}$  respectively  $\{x_1\} \{x_2x_4\} \{x_3\}$   
 $\{x_1\} \{x_2x_3x_4\}$   $\{x_1\} \{x_2x_3x_4\}$

Table 5: Clusters

**References**

[Barthelemy, Guenoche, 1991] Barthelemy, J. P., and A. Guenoche, (1991) Trees and proximity representations, John Wiley, New York

[Everitt, Dunn, 1991] Everitt, B.S. and Dunn G, (1991), Applied multivariate data analysis Arnold, London

[Hartigan, 1975] Hartigan, A., (1975), Clustering Algorithms, John Wiley, New York

[Müller-Merbach, 1975] H. Müller-Merbach, (1975), Modelling techniques and heuristics for combinatorial problems, in B. Roy (ed) Combinatorial programming, Methods and applications (1975) Dordrecht, Boston, 3-27

[Schweigert, Trinkhaus, 1996] Schweigert, D. and H.Trinkhaus, (1996), Clusteranalyse zur Bestimmung einer kostenoptimalen Vertriebsstruktur, ZWF91, 168-171.



# CONSTRUCTING QUADRATIC OBJECTIVE FUNCTIONS FROM INTERVIEWING A DECISION MAKER

Andranik S. Tangian<sup>1</sup>

<sup>1</sup>University of Hagen, D-58084 Hagen, Germany  
Andranik.Tangian@FernUni-Hagen.De

## Abstract:

*We develop a model for constructing quadratic objective functions in  $n$  target variables. At the input, a decision maker is asked a few relatively simple questions about his ordinal preferences (to compare two-dimensional alternatives in terms 'better', 'worse', 'indifferent'). At the output, the model mathematically derives a quadratic objective function used to evaluate  $n$ -dimensional alternatives. The model is provided with operational restrictions for the monotonicity of the objective function (= either only growth, or only decrease in every variable) and quasi-concavity of the objective function (= convexity of the associated preference). Constructing a monotonic quasi-concave quadratic objective function from ordinal data is reduced to a least squares problem with linear and polynomial inequality constraints.*

*In illustration, we construct a quadratic objective function of ski station customers. Then it is used to adjust prices of 10 ski stations in the South of Stuttgart.*

**Keywords:** Decision theory, decision support system, optimization, quasi-concave utility functions, quadratic control, quadratic performance indices, quadratic programming, restricted least squares, nonlinear programming, management.

## 1 Introduction

Recall that most optimization models include three constituents: (a) space of alternatives where alternatives are represented by  $n$ -dimensional vectors, (b) constraints represented by a system of equalities and/or inequalities, and (c) a scalar-valued objective function which represents the preference of a decision maker on the space of alternatives. Finding the optimal solution is equivalent to finding the maximum of the objective function subject to constraints.

A great effort has been made for decades to develop methods for constructing econometric equation systems which can form the constraints of an optimization model. On the other hand, relatively little has been done to develop practical methods for constructing scalar-valued objective functions. In the 50ies the so-called 'linear-quadratic' approach has been introduced with a quadratic objective function being optimized subject to linear constraints; see Frisch (1964) and Theil (1964). Recall that a quadratic objective function in  $n$  target variables has the following form

$$f(u_1, \dots, u_n) = \sum_{i=1}^n a_i u_i^2 + \sum_{i < j} b_{ij} u_i u_j + \sum_{i=1}^n c_i u_i + d, \quad (1)$$

where at least one of the coefficients  $a_i, b_{ij} \neq 0$ .



together with their utility indices

$$\begin{aligned} y_1 &= f(P_1) \\ &\dots\dots\dots \\ y_m &= f(P_m) \end{aligned} \tag{2}$$

where at least two  $y_i, y_j$  are different.

The quadratic extensions  $x'_1, \dots, x'_m$  of vectors  $P_1, \dots, P_m$  are collected in the following  $(m \times N)$ -matrix

$$X = \begin{pmatrix} u_{11}^2 \dots u_{11}u_{12} \dots u_{11} \dots 1 \\ \dots\dots\dots \\ u_{m1}^2 \dots u_{m1}u_{m2} \dots u_{m1} \dots 1 \end{pmatrix} ,$$

and the corresponding utility indices  $y_1, \dots, y_m$  are collected in the  $m$ -vector  $y' = (y_1, \dots, y_m)$ . Then (2) is written as the following linear system:

$$y = X\beta \tag{3}$$

As in regression analysis, if  $m > N$  then we assume that the above equality holds approximately, that is,  $y = X\beta + \epsilon$ , where  $\epsilon$  is the error vector. The vector  $\beta$  of the coefficients of a quadratic objective function  $f$  should minimize the vector of errors  $\epsilon$ :

$$\|y - X\beta\|^2 = \sum_{k=1}^m (y_k - x'_k\beta)^2 \rightarrow \min_{\beta \in \mathcal{R}^N} \tag{4}$$

The solution  $\beta^*$  to this minimization problem is found from the system of normal equations

$$X'X\beta = X'y \tag{5}$$

The following theorem states that if the input alternatives  $P_0, \dots, P_m$  are supposed to be located at two utility levels then the output ordinal preference is independent of a particular numerical representation, that is, the model is ordinal.

**Theorem 1 (Tangian and Gruber 1997: Uniqueness of ordinal preference)** *Suppose that utility indices  $y_1, \dots, y_m$  take exactly two values  $y' < y''$  and that system (5) has a unique solution  $\beta^*$ . Transform  $y' < y''$  into arbitrary  $z' < z''$ , and correspondingly redefine the utility index vector  $y \rightarrow z$ . Then the system  $z = X\beta$  for the new cardinal utilities  $z$  has a unique solution  $\beta^{**}$ , and the ordinal preference, corresponding to  $\beta^{**}$ , is the same as the ordinal preference, corresponding to  $\beta^*$ .*

### 3 Monotonicity restriction

An objective function and the associated preference are called *monotonic* in  $U \subset \mathcal{R}^n$  if after an inversion of some axes ( $u_i \rightarrow -u_i$ ) the objective function is nondecreasing. This means that, for every target variable, the preference either only increases along this target variable at every point of  $U$ , or only decreases.

**Theorem 2** *Let  $f$  be a quadratic function (1) on a convex polytop  $H$  with the set of vertices  $V$ .*

- **(Nondecreasingness)**  $f$  is nondecreasing over  $H$  if and only if its first derivatives are nonnegative at the vertices  $V$ .
- **(Monotonicity)**  $f$  is monotonic over  $H$  if and only if each of its first partial derivatives has the same sign at all the vertices  $V$ :

$$s_i f'_i(\mathbf{u}) \geq 0, \quad i = 1, \dots, n, \quad \mathbf{u} \in V, \quad (6)$$

where

$$s_i = \begin{cases} -1 & \text{if } f \text{ decreases in } u_i \\ 1 & \text{otherwise} \end{cases},$$

$$f'_i(\mathbf{u}) = 2a_i u_i + \sum_{j<i} b_{ji} u_j + \sum_{j>i} b_{ij} u_j + c_i. \quad (7)$$

#### 4 Quasi-concavity restriction

A function  $f$  over a convex domain  $U \subset \mathcal{R}^n$  is called (strictly) *quasi-concave* if it represents a (strictly) convex preference, in other words, if the upper level sets

$$V = \{\mathbf{u} \in U : f(\mathbf{u}) \geq C\}$$

are (strictly) convex for every constant  $C$ .

Let  $f$  be a quadratic function as defined in (1). Denote by

$g(\mathbf{u})' = (f'_1(\mathbf{u}), \dots, f'_n(\mathbf{u}))$  the gradient of  $f$  at the point  $\mathbf{u}$ , see (7);

$$G = \begin{pmatrix} 2a_{11} & b_{12} & \dots & b_{1n} \\ b_{12} & 2a_{22} & \dots & b_{2n} \\ \dots & \dots & \dots & \dots \\ b_{1n} & b_{2n} & \dots & 2a_{nn} \end{pmatrix} \text{ the Hessian matrix of second derivatives of } f;$$

$g_r$  the  $r$ -vector obtained from  $g$  by keeping only the first  $r$  elements;

$G_r$  the  $(r \times r)$ -matrix obtained from  $G$  by keeping only the elements in the first  $r$  rows and the first  $r$  columns;

$|\cdot|$  the determinant of a square matrix;

$\pi$  a permutation of the first  $n$  integers;

$g^\pi$  the vector obtained from  $g$  by performing the permutation  $\pi$  on its elements;

$G^\pi$  the matrix obtained from  $G$  by performing the permutation  $\pi$  on its rows and the permutation  $\pi$  on its columns.

**Theorem 3 (Quasi-concave quadratic functions)** *Let a quadratic function (1) attain its infimum in a convex open set  $U \subset \mathcal{R}^n$  at its boundary point  $\mathbf{v} \in \bar{U} \setminus U$ , where  $g(\mathbf{v}) \neq 0$ .*

- **(Quasi-concavity)**  $f$  is quasi-concave over  $U$  if and only if

$$(-1)^r \left| \begin{matrix} G_r^\pi & g_r^\pi(\mathbf{v}) \\ g_r^\pi(\mathbf{v})' & 0 \end{matrix} \right| \geq 0, \quad \forall \pi, r \geq 2. \quad (8)$$



- **(Strict quasi-concavity)**  $f$  is strictly quasi-concave over  $U$  if and only if (8) holds for  $v$  and in addition for some point  $w \in U$  holds

$$(-1)^r \begin{vmatrix} G_r & g_r(w) \\ g_r(w)' & 0 \end{vmatrix} > 0, \quad \forall r \geq 2. \quad (9)$$

- **(Sufficient condition of strict quasi-concavity)** If (9) holds for  $v$  then  $f$  is strictly quasi-concave over  $U$ .

By virtue of (7), each determinant in (8) or (9) is a polynomial of degree not higher than  $n + 1$  in the coefficients of a quadratic function.

## 5 Quasi-concavity under monotonicity

To satisfy the assumptions of Theorem 3, one must be sure that the function  $f$  really attains its infimum over  $U$  at its boundary point  $v$ , where  $g(v) \neq 0$ . If the “worst” point  $v$  is indicated erroneously, the quasi-concavity is guaranteed only in the domain, containing the points preferable to  $v$ . If  $g(v) = 0$  then the quasi-concavity is not guaranteed at all. This problem is solved automatically if the function  $f$  is monotonic in a domain somewhat larger than  $U$ .

Consider two points  $v, w \in \mathcal{R}^n$ , where  $v = (v_1, \dots, v_n)$  and  $w = (w_1, \dots, w_n)$ . We write

$$v \ll w \quad \Leftrightarrow \quad v_i < w_i \quad \text{for } i = 1, \dots, n.$$

Let  $v, w \in \mathcal{R}^n$  such that  $v \ll w$ . An open  $n$ -dimensional *parallelepiped* is

$$H = (v; w) = \{u \in \mathcal{R}^n : v \ll u \ll w\}.$$

**Theorem 4 (Quasi-concave monotonic quadratic functions)** Consider two open  $n$ -dimensional *parallelepipeds*  $H = (v, w) \subset H' = (v', w')$ , the former being strictly embedded in the latter:  $v' \ll v \ll w \ll w'$ . Let a quadratic function  $f$  be monotonic over the larger *parallelepiped*  $H'$ . Then  $f$  is quasi-concave (strictly quasi-concave) in  $H$  if and only if the condition (8) (the condition (9)) holds for the Pareto-worst vertex  $z$  of  $H$ .

## 6 Model for constructing quadratic objective functions

Taking into account inevitable rounding errors in applications, in practice there is no great difference in requiring non-strict or strict quasi-concavity. On the other hand, the sufficient condition in Theorem 3 can be considered as “almost necessary”, in the sense that a preference, satisfying (8) but not (9), is a limit of preferences which satisfy the both conditions. Therefore, in practice we can use the sufficient condition for strict quasi-concavity (9) instead of condition (8) with the gain in computational efficiency:  $n - 1$  instead of  $2! + \dots + n!$  constraints.

**Theorem 5 (Constructing monotonic quasi-concave quadratic objective functions)** Constructing a quadratic objective function which is monotonic and strictly quasi-concave over a *parallelepiped*  $H \subset \mathcal{R}^n$  is reduced to solving the following restricted

least squares problem:

$$\begin{cases} \|\beta - \beta^*\|^2 \rightarrow \min_{\beta \in \mathcal{R}^N} \\ A'\beta \geq 0 \\ (-1)^r \begin{vmatrix} G_r & g_r(v) \\ g_r(v)' & 0 \end{vmatrix} > 0, \quad r = 2, \dots, n, \end{cases} \quad (10)$$

where  $\beta$  is the  $N$ -vector of the objective function coefficients to be estimated;  $\beta^*$  is the unconstrained solution to (5);  $A$  is an  $(n \cdot 2^n \times N)$ -matrix, representing constraints (6) for  $n$  partial derivatives in each of the  $2^n$  vertices of the  $n$ -dimensional parallelepiped;  $v$  is the Pareto-worst vertex of parallelepiped  $H$ .

## 7 Example of application

We consider the problem of improving the performance of an association of 10 mountain ski stations by adjusting their prices. The stations are located in the Alps 220–270 km south of Stuttgart, the inhabitants of which are their main customers.

In our approach we adjust the prices of the 10 ski stations by means of a simple model. The market equilibrium with a complicated interaction of agents is not introduced in the model explicitly but it remains in the background. We suppose that customers have no fixed budget constraints. If a customer is convinced that the services are really good he may pay extra money for an additional quality, and vice versa. Therefore, the central item of our approach is the *quality-to-price ratio* which is identified with the utility.

According to the philosophy of market economy, all the ski stations should have approximately the same quality-to-price ratio. If some station has a higher quality-to-price index than others, it has a better competition standing and therefore its price can be somewhat increased. Conversely, if a station has a lower quality-to-price ratio than others, it has a worse competition standing and therefore its price should be reduced.

Therefore, the price adjustments should be aimed at bringing the utility index of all the 10 ski stations approximately to the same utility level (to make the stations equivalent with respect to the customer's preference). For this purpose, we construct an objective function of an "average" Stuttgart skier in the following three target variables:

$u_1$  — Price of the day ticket, in DM.

$u_2$  — Accessibility, characterized by the distance from Stuttgart in km.

$u_3$  — Quality, characterized by the length of pistes in km, assuming that the services are better at bigger stations.

According to the requirements of our model, every person interviewed has to select several equivalent points in the three-dimensional space Price  $\times$  Accessibility  $\times$  Quality. In practice, a person interviewed has been given the questionnaire shown in Table 1. The top line contains a reference vector  $P_0$ , corresponding approximately to the existing station Grasgehren (24 DM/Day, 230 km from Stuttgart, 12 km of pistes). At the bottom, one finds an auxiliary 'reference improvement vector'  $P_9$ , which is strictly Pareto-better than  $P_0$  (better in every target variable). Each row displays a vector  $P_k$ , which is a deviation from the reference vector  $P_0$  in one of the coordinate planes. The coordinate indicated

Coordinate plane	Alternatives	Price $u_1$	Distance $u_2$	Length $u_3$	Utility index
Ref. vector	$P_0$	25	230	12	0
$U_1 \times U_2$	$P_1 \rightarrow$	40	<input type="text"/>	12	0
	$P_2 \rightarrow$	35	<input type="text"/>	12	0
	$P_3 \rightarrow$	20	<input type="text"/>	12	0
	$P_4 \rightarrow$	0	<input type="text"/>	12	0
$U_1 \times U_3$	$P_5 \rightarrow$	40	230	<input type="text"/>	0
	$P_6 \rightarrow$	30	230	<input type="text"/>	0
	$P_7 \rightarrow$	20	230	<input type="text"/>	0
$U_2 \times U_3$	$P_8$	25 $\rightarrow$	250	<input type="text"/>	0
Ref. impr. v.	$P_9$	20	200	20	1

Table 1: Questionnaire

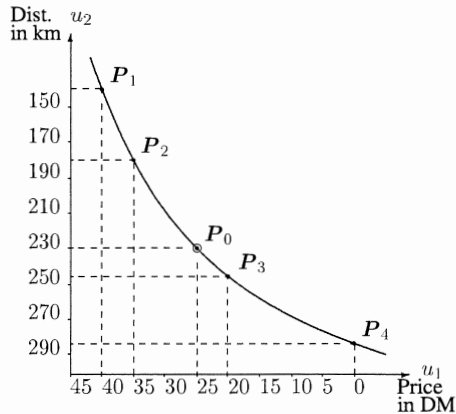


Figure 1: Customer’s indifference for two variables

by an arrow is changed, and another coordinate is replaced by an empty frame. A person interviewed has to fill in the empty frames to make every alternative  $P_k$  equivalent to the reference alternative  $P_0$  (reflected in the questionnaire by the same utility index 0). For instance, an increase in price to 40 DM/Day can be compensated by a reduction of the distance to 150 km.

It is not required to specify the altitude of the utility hill but to trace the level curve going through the reference vector (Figure 1). The questionnaire asks to indicate the intersections of several vertical lines with the imaginable indifference curve going through the reference vector  $P_0$ . Note that to select an equivalent alternative from a line is as selecting an indifferent alternative from a continuous menu. For this purpose, no estimation of cardinal utility of alternatives in the lines is needed but rather ordinally comparing them with the reference alternative in terms ‘better’, ‘worse’, or ‘indifferent’.

Station	Price in DM	Distance in km	Pistes in km	Utility index	Rank	New price	New utility index	New rank
Balderschwang	20	220	7	174	2	32	1.0	7
Fellhorn	39	260	20	28	9	29	0.8	8
Grasgeheren	24	230	12	146	4	32	3.1	3
Hindelang	19	240	32	312	1	43	3.9	2
Ifen 2000	42	260	30	48	7	36	1.8	5
Kranzegg	30	225	20	159	3	40	0.5	9
Lechtaler Alpen	31	237	7	57	6	26	2.1	4
Nebelhorn	39	265	12	0	10	21	4.7	1
Rettenberg/Kranzegg	30	223	2	68	5	27	1.5	6
Tannheim	32	250	8	34	8	23	0	10

Table 2: Adjusting prices for 10 ski stations

After a quadratic objective function has been constructed by our computational model (Tangian 1996), the utility indices of the 10 stations have been evaluated by plugging their data into the objective function. The resulting ranks of the stations are shown in Table 2. A high utility index signalizes that the price at the given station is underestimated, and vice versa. Adjusting prices have been made by the following iterative cycles:

- The price for the top-ranked station is made 1 DM higher.
- The price for the bottom-ranked station is made 1 DM lower.
- The ranking is updated.
- If the bottom-ranked alternative has become top-ranked then stop, otherwise return to the beginning of the cycle.

As one can see in column ‘New utility index’ of Table 2, the range of utility indices over the 10 stations is reduced from 312 before the price adjustment to 4.7 after the adjustment. This means that now all the ski stations are located close to the same indifference hypersurface. Therefore, they have the same quality-accessibility/price ratio, and under the new prices the supply should better meet the demand. We do not mean that the prices computed should be taken literally but rather as a hint for their possible correction: Which stations can make their prices higher, to which extent, and which stations should retain or even lower their prices. For instance, the cheapest station, Hindelang, becomes the most expensive after our price adjustment. This is an evident indication at a significant underestimation of its price earlier. The overall performance of the association of the ski stations after the price adjustments with applications of our method has improved by almost 8%.

## 8 Summary

- We have developed a model for constructing quadratic objective functions in  $n$  target variables from data based on ordinal measurement of preferences.
- Computationally manageable conditions for monotonicity and quasi-concavity of a quadratic function are formulated

- A model for fitting a quadratic objective function with monotonicity and/or quasi-concavity restriction is reduced to the least squares problem with linear inequality constraints for the monotonicity and polynomial inequality constraints for the quasi-concavity.
- The computer program developed can be used in research and applications. In particular, we have described its application to price adjustments of ski stations.

## References

- Arrow, K.J. and A.C. Enthoven (1961). Quasi-Concave Programming. *Econometrica*, **29**, 779–800.
- Chew, S.H., L.G. Epstein, and U. Segal (1991). Mixture Symmetry and Quadratic Utility. *Econometrica*, **59**, 139–163.
- Debreu, G. (1952). Definite and Semidefinite Quadratic Forms. *Econometrica*, **20**, 295–300.
- Diewert, W.E., M. Avriel and I. Zang (1981). Nine Kinds of Quasiconcavity and Concavity. *Journal of Economic Theory*, **25**, 397–420.
- Frisch, R. (1964). An Implementation system for optimal national economic planning without detailed quantity fixation from a central authority, *Proceedings of the 3rd International Conference on Operations Research, Oslo, 1963*. Dunod–English University Press, Paris–London.
- Gruber, J. (1991) (Ed.). *Econometric Decision Models. New Methods of Modeling and Applications*. Springer, Berlin (Lecture Notes in Economics and Mathematical Systems 366).
- Leroux, A. (1984). Other Determinantal Conditions for Concavity and Quasi-Concavity, *Journal of Mathematical Economics*, **13**, 43–49.
- Tangian, A.S. (1996). *A WINDOWS Program for Constructing Objective Functions. Version 1.0. User's Guide*. FernUniversität, Hagen (Discussion Paper 233).
- Tangian, A.S. (1997a). *A Fast Algorithm for Restricted Least Squares and Quadratic Programming*. FernUniversität, Hagen (Discussion Paper 242).
- Tangian, A.S. (1997b). *Constructing Quadratic Objective Functions Under Monotonicity Restriction*. FernUniversität, Hagen (Discussion Paper 243).
- Tangian, A.S. (1998). *Constructing Quasi-Concave Quadratic Objective Functions*. FernUniversität, Hagen (Discussion Paper 263).
- Tangian, A.S., and J. Gruber (1997). Constructing Quadratic and Polynomial Objective Functions. In: *Constructing Scalar-Valued Objective Functions* (Tangian A.S., and J. Gruber, Eds.), pp. 166–194. Berlin: Springer (Lecture Notes in Economics and Mathematical Systems 453).
- Theil, H. (1964). *Optimal Decision Rules for Government and Industry*. Amsterdam: North-Holland.



# **PART VI**

## **MULTI MODALITIES AND INTERACTIONS**

---







## HOW TO USE SOUNDS IN VOCAL SERVERS?

Noël Chateau, Solenn Botrel

France Télécom – Centre National d'Etude des Télécommunications  
Direction des Interactions Humaines  
2, Avenue Pierre-Marzin, 22307 Lannion Cedex  
noel.chateau@cnet.francetelecom.fr / solenn.botrel@cnet.francetelecom.fr

### **Abstract:**

*This paper deals with the pertinence of introducing non-speech sounds in telephone-vocal servers. The impacts of such sounds in terms of perceived identity and usability of the service are discussed and a methodology aiming at evaluating these two aspects is proposed.*

**Keywords:** sound identity, usability, psychoacoustics, ergonomics, vocal server

### **1 Introduction**

Each year, hundreds of millions of phone calls are addressed towards vocal servers in France. These servers cover main sectors of activity, ranging from banking services to leisure (e.g., games, horoscope). For many years, the type of access to the servers (classic wired phone) and the type of the tree structures utilised to deliver information have not much evolved. Today's diversity of the situations of access (e.g., mobility, classic phones, computers) to larger and larger databases (e.g., phone-based Web access) implies that vocal servers have to provide users with efficient interfaces to access information in a simple and rapid way. To achieve this goal, a possible evolution of vocal servers is to make use of non-speech sounds to facilitate navigation, as proposed by Brewster [Brewster, 1997].

Considering vocal servers, three major classes of dialogue between the man and the machine can be observed: 1) DTMF (Dual Tone Modulation Frequency) command via the keypad of the phone, 2) voice command based on human-voice recognition and 3) intelligent dialogue based on both voice-recognition and voice-synthesis technologies. This paper will only deal with today's mostly used servers, namely DTMF vocal servers but the proposed methodology might be extended to other services.

The audio messages delivered by the vocal server can be help messages (resulting from user's request or inactivity), navigation messages (informing on possible actions) and information messages (answer to the initial user's request). These messages consist in speech and non-speech signals, such as validation beeps. Although these messages are devoted to provide relevant semantic information, they also convey identity content through the style of voice, music and sounds chosen. One of the main concerns of vocal-servers designers is to judiciously provide audio messages that offer the best usability to users and convey a specific identity of the service (and of the company behind it).

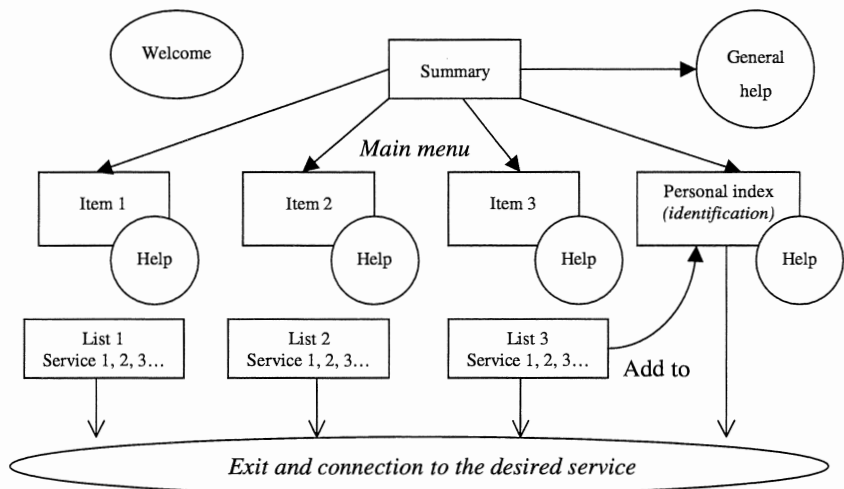
Although a lot of work has been already done on the use of non-speech sounds in human-machine interfaces (see [Gaver, 1997] for a review), few has dealt with

telephone-based interfaces (*e.g.* [Rosson, 1985]). In all cases, these studies addressed the question of usability of services by introduction of non-speech signals or investigated the representation of tree-structures by such signals (*e.g.* [Brewster, 1997]). Our present work aims at studying the impact of non-speech sounds on the usability of vocal servers while considering the important aspect of perceived identity. This paper will propose a general framework combining psychoacoustics and ergonomics adapted to the dual evaluation of perceived identity and usability of vocal servers.

## 2 Research framework

### 2.1 The vocal server

DTMF vocal servers are characterized by a tree structure of information. Users have to navigate in this structure using the keypad of telephone to interact with the system and find the desired information. This structure of information is made up of different functional units: welcome, summary, main menu, help, user identification, list, exit, connection to other services... The diagram of a "classic" server is proposed on figure 1 below. This diagram represents the structure of *Audiotelis*, a service whose aim is to propose a selection of useful vocal servers to users and to allow them to create a personal index where they can store services of their choice. The selection is organised in three separate lists. When listening to the presentation of a given service, the user can either store it in its personal index or get connected to it by pressing one key.



### 2.2 Identity and usability

#### 2.2.1 The identity of sounds

The identity of a sound might be viewed as its intrinsic capability of evoking particular feelings, or moods, when no context is considered. One of the first researchers who investigated this field was Solomon [Solomon, 1958]. He presented 20 recordings of sonar sounds to a population of 50 listeners who had to judge them on 50 semantic-

differential scales such as power (powerful - weak), familiarity (familiar - strange) or tension (relaxed - tense). By means of a factor analysis, he found that the sonar sounds could be fairly represented in a 7-dimensional space, each dimension being significantly correlated to one or a few of the 50 scales. Solomon's work was followed by several researchers who applied a similar method to other problems, such as the quality of sound-reproduction systems [Gabrielsson and Sjögren, 1979], the timbre of sounds [von Bismark, 1974] or the identity of car sounds [Chouard, 1999].

Although the semantic-differential method has shown to be fruitful, it presents two major drawbacks that have to be mentioned. First, this method dictates a specific vocabulary to subjects to describe sounds and second, it assumes that the perceived identity of sounds is a linear combination of several dimensions. To avoid these problems, other methods such as (dis)similarity judgement or free categorisation have been proposed. In the case of similarity judgement, subjects listen to every possible pairs of sounds of a corpus and each time give a number related to the degree of (dis)similarity between them [McAdams, 1994]. A matrix of (dis)similarity is obtained and submitted to a multidimensional Scaling (MDS) analysis in order to reveal possible dimensions along which sounds might be ordered. Concerning categorisation, subjects listen to a corpus of sounds and are asked to cluster them in homogenous groups [Maffiolo et al., 1998]. Afterwards, these groups are labelled by subjects with their own words. A subsequent tree analysis furnishes the representation of structured categories corresponding to means of the groups created by subjects.

In most of studies cited above, sounds are analysed and described by physical parameters (level, spectrum, onset duration, etc.); then, correlation are computed between these descriptors and homogenous categories or dimensions found in the subsequent analysis of psychoacoustic tests. All previous work has provided numerous results which help us to understand what are the main parameters of sounds to manipulate in order to control their perceived identity.

A last, but not least aspect under which sound identity might be tackled is music. Music is probably the most efficient way to convey feelings and generate specific moods by non-speech sounds. It may be considered, in this regard, as a language. Music can introduce a desired atmosphere by its style (the identities of vocal servers with bossa-nova or techno music are probably different!), but can also create specific moments of tension and looseness within a melody according to those notes played in a given musical scale [Bigand, 1994]. Music can also stop and give place to silence which can "dramatise" the situation. Therefore, music has to be considered as a premier sound component to create and control a desired identity of a vocal server.

### 2.2.2 The usability of a vocal server

From the user's point of view, vocal services could be "characterized by a labyrinth of invisible and tedious hierarchies" [Yankelovich et al., 1995]. They can encounter difficulties to navigate in the service and localise themselves in the tree structure. In this context, ergonomics is interested in studying and minimising these potential problems of usability.

Usability is a central concept in ergonomics: the IEEE Standard Computer Dictionary defines it as "the ease with which a user can learn to operate, prepare inputs for, and

interpret outputs of a system or component” [IEEE, 1990]. More accurately, the ISO 9241-11 standard [ISO 9241-11, 1998] emphasises that usability is commonly considered as a multidimensional entity that depends on:

- effectiveness: precision and fulfilment of the task;
- efficiency: ratio between consumed resources (workload, time...) and effectiveness;
- satisfaction: the user’s feeling about his interaction with the system;
- context of utilisation: this includes users, asked tasks, equipment, and all social and physical conditions;
- “learnability” : facility of apprehension of the system by naive users.

These generic principles are specified by several authors as “rules” that have to be applied to services design. We can cite the ergonomics guide design of Scapin [Scapin, 1986] or Nielsen’s [Nielsen and Mack, 1994] heuristics which are applicable on oral man-machine dialogue.

To test these different aspects of usability, ergonomics draws three main categories of methods: experts reviews, user tests and inquiries. Experts reviews consist in evaluations of interfaces carried out by experts without users being involved. In user tests, “real” users work and interact with the service and are observed and recorded. In inquiries, users are asked for their experiences, meanings and feelings about the service. Preferably, user tests are conducted during the design phase in order to collect relevant data and readjust the specifications of the server.

### 3 Scientific approach

This section describes the proposed methodology to evaluate the contribution of non-speech sounds to the usability and the identity of vocal servers. This evaluation might be carried out by combining psychoacoustic and ergonomic approaches. Concerning psychoacoustics, the most appropriate way to evaluate the identity of non-speech sounds in this context is to use the semantic-differential method. Indeed, when a given service is proposed to clients, the marketing division defines vectors on which it wants to communicate in order to promote the service (*e.g.*, simplicity, efficiency, rapidity). Additionally, the communication division gives general values identifying the company that should be encountered through the use of the service (*e.g.*, proximity, warmth, dynamism). Therefore, a number of adjectives describing a *target identity* are fixed and might be used for the evaluation. These adjectives have to be completed by others to form a sufficient number of scales on which listeners will give their opinion. Once the sounds having the closest perceived identity to the target identity of the service will be determined, they will be implemented in the vocal server at different degrees.

Brewster [Brewster, 1997] has shown that non-speech sounds such as earcons (combination of musical tones) can be used to represent the hierarchy of a tree structure used by vocal servers. Although seducing, his results are not a sufficient to prove that non-speech sounds can improve the usability of vocal servers. To our opinion, the contribution of non-speech sounds has to be evaluated within the frame of a dynamic situation and not a static one, as used by Brewster. Therefore, it is proposed to use

four interfaces of the same vocal server and to evaluate their effectiveness with four different groups of subjects. The vocal server under test will be Audiotelis, which is described in section 2.1. The four interfaces can be described as follows:

- 1) The reference interface: non-speech sounds are not implemented;
- 2) The earcon-based event interface: short non-speech sounds (earcons of 2 or 3 notes) are played when the status of the system resulting from a specific event has to be described (validation of the identification of the user, success, error...) and as items separators in lists. No music is used;
- 3) The music-based localisation interface: music is played in a coherent way to represent the tree structure of the server. One piece of music is chosen per level in the hierarchy and different excerpts of the same piece are selected to represent the different nodes in that level. No earcons are used;
- 4) The comprehensive sound interface: this interface is the combination of interfaces 2 and 3 where music is used for localisation and earcons are used for events feedback.

The usability of the four different interfaces will be assessed by user tests based on the realisation of 7 scenarii of utilisation of the service. The scenarii will be:

- 1) Free discovering of the service;
- 2) Connection to a service proposed in one of the three lists of items (see fig. 1);
- 3) Creation of a personal index;
- 4) Adding of a proposed service to the personal index;
- 5) Adding of two other services to the personal index;
- 6) Deletion of a service in the personal index;
- 7) Connection to a service from the personal index.

The behaviour of users will be recorded and analysed to extract data such as the success rate and the time used to complete each task. Following, a questionnaire will be proposed to users where they will have to give their opinion on the identity of the server on the same semantic-differential scales as those used for isolated sounds. In order to test short- and long-term memorisation, users will be asked to associate the different keys and sounds to functions and loci in the hierarchy found in the server immediately after the test and one week later.

#### **4 Conclusion**

This paper proposes a methodology whose objective is to assess the relevance of the use of non-speech sounds in vocal servers. The approach combines psychoacoustics and ergonomics in order to evaluate the perceived identity and usability of such servers. The large body of data which is expected to be obtained will allow us to derive rules for designing easy-to-use vocal servers with controlled identity.

## References

- [Bigand, 1994] Bigand, E. (1994). Contributions de la musique aux recherches sur la cognition auditive humaine. In McAdams, S. and Bigand, E. editors, *Penser les sons, Psychologie cognitive de l'audition*, PUF, pages 157-173, Paris, France.
- [Brewster, 1997] Brewster, S.A. (1997). Navigation telephone based interfaces with earcons. In *Proceedings of BCS HCI'97*, pages 39-56, Bristol, UL.
- [Chouard, 1999] Chouard, N. (1999). A semantic differential design especially developed for the evaluation of interior car sounds. *Acustica united with Acta Acustica*, 85, S354, Proceedings of Forum Acusticum 1999, Berlin, Germany.
- [Gabrielsson and Sjögren, 1979] Gabrielsson, A. and Sjögren, H. (1979). Perceived sound quality of sound-reproducing systems. *J. Acoust. Soc. Am.*, 65(4), 1019-1033.
- [Gaver, 1997] Gaver, W.W. (1997). Auditory Interfaces. In Helander, M.G., Landauer, T.K. and Prabhu, P. editors, *Handbook of Human-Computer Interaction*, 2<sup>nd</sup> edition, Elsevier Science, Amsterdam, The Netherlands.
- [IEEE, 1990] Institute of Electrical and Electronics Engineers. *IEEE Standard Computer Dictionary: a Compilation of IEEE Standard Computer Glossaries*. New York, 1990.
- [ISO 9241-11, 1998] ISO 9241-11 (1998). International Organization for Standardization. *Ergonomic Requirements for Office Work with Visual Display Terminals, Part 11, guidance on usability*.
- [Maffiolo et al., 1998] Maffiolo, V., Castellengo, M. and Dubois, D. (1998). Qualité sonore de l'environnement urbain : Sémantique et intensité. *Acoustique & Techniques*, 16, 14-21.
- [McAdams, 1994] McAdams, S. (1994). La reconnaissance de sources et d'événements sonores. In McAdams, S. and Bigand, E. editors, *Penser les sons, Psychologie cognitive de l'audition*, PUF, pages 157-173, Paris, France.
- [Nielsen and Mack, 1994] Nielsen, J. and Mack, R. L. (Eds.) (1994). *Usability Inspection Methods*. John Wiley & Sons, New York, NY.
- [Rosson, 1985] Rosson, M.B. (1985). Using synthetic speech for remote access to information. *Behaviour Research Methods, Instruments and Computers*, 17, 250-252.
- [Scapin 1986] Scapin, D. L. (1986). Guide ergonomique de conception des interfaces homme-machine. *Rapports techniques 77*. Institut National de Recherche en informatique et en automatique.
- [Solomon, 1958] Solomon, L.N. (1958). Semantic approach to the perception of complex sounds. *J. Acoust. Soc. Am.*, 30(5), 421-425.
- [von Bismarck, 1974] von Bismarck, G. (1974). Timbre of steady sounds: A factorial investigation of its verbal attributes. *Acustica*, 30, 146-159.
- [Yankelovich et al., 1995] Yankelovich N. Levow, G.A. and Marx, M. (1995). Designing speechActs: Issues in speech user interfaces. *Human Factors Computing Systems*, 369-376, Proceedings of CHI95, Denver, USA.

## TOOLS FOR PRODUCT OPTIMISATION

Carsten L. Fog & Torben Holm Pedersen

DELTA Acoustics & Vibration  
Building 356, Akademivej  
DK-2800 Lyngby, Denmark  
clf@delta.dk, thp@delta.dk

### **Abstract:**

*This paper discusses the importance of the sound from a product for the perception of the overall quality of the product. Test methods based on subjective assessments are essential for the evaluation of the product sound quality and some preliminary considerations about these methods will be presented. A definition of Product Sound and Product Sound Quality is given, and a general process of product optimisation is described by using a model called "The Product Sound Wheel". Some practical applications will be discussed for product optimisation within the automotive and consumer goods markets. The key issue is that the product sound has been improved and hence the acceptability to the users. Finally, the application for quality control in the product is suggested.*

**Keywords:** Acoustics, Human Perception, Listening Test, Product Sound Quality

### **1 Introduction**

In modern society people are almost constantly surrounded by products, whether they are at home, at work, on vacation, or on their way. We suggest that one essential determinant of "quality of life" is the noise or the sound produced by these ubiquitous sound sources. A product that rattles, rumbles, or screeches unpleasantly has a very different effect than one that puts out the various signals and sounds that the user expects. Quality of life is based on a range of values, which are expressed as basic needs that must be fulfilled for a person to experience a high quality of life.

As we see it, the increased interest in product sound is not only due to the psychometrics of product sound perception or the mechanical design, but also to the fact that it is only during the last few years we have begun to realize the importance of product sound to the user assessment and satisfaction and hence also to the market acceptance of the products. There is a rubbing-off effect from marketing of one type of product to marketing of a completely different type. As product sound has more and more become a sales factor as far as cars are concerned, this has been transferred to a large number of other products, first and foremost on the consumer market and especially regarding every conceivable "electrical product", as e.g. vacuum cleaners, dishwashers, hair dryers, small fans, audio products, etc., etc.

Thus, manufacturers wanting to keep their market position have on most markets gradually been forced to be sensitive as to how their customers feel and are affected by the sounds from the products. Or put in other words:

**"We buy with our ears, too."**

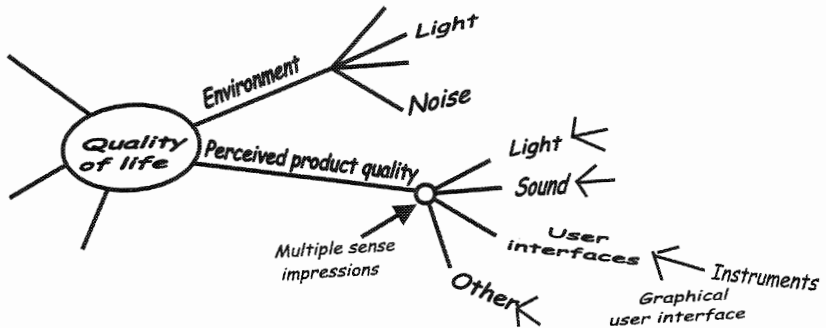


Figure 1: Perceived product quality – one element of quality of life

How the quality of a product is perceived by users and other observers in the vicinity of the product depends of course on a number of product attributes such as appearance, response to user activities, function, noise/sound, weight, smell, taste/flavour, and tactile characteristics. We may even talk about the sound quality, the visual quality, the tactile quality, the quality of user interfaces, etc., See Figure 1.

Product sound optimisation is a method for making “optimal product development” in a broad sense. It contains disciplines within perception psychology, psychoacoustics, and acoustics especially in relation to mechanical design.

The overall objective in the product development is to utilise future consumers’ attitudes, expectations, and preferences so that the sound from a product becomes a positive attribute to the user instead of an annoying problem. As all hearing persons can perceive acoustic quality and thus can be said to be experts, there is a need for good acoustic design and development. Totally, this represents a special opportunity to make sure that the product has the desired success with the users.

## 2 Measurements Involving Human Subjects

Until now two mainstreams have directed acoustic measurements involving human subjects: *Psychoacoustics* on one hand where any kind of bias from the subjects’ expectations, mood, preferences, etc., is avoided or minimized, and *consumer surveys* on the other hand where mainly preferences are sought. In the field of product sound quality a basic understanding of the underlying psychoacoustics phenomena – also for rather complex signals – is essential. But in contrast to the pure psychoacoustics research the influence of stimuli from other senses and influence from the listening panel’s preferences are not regarded as unwanted bias.

Figure 2 gives a simple illustration of the concepts. With our technical measuring devices we are measuring at the input to “Filter 1” (point 1). With the instruments we can measure the finest details, but we do not know if they are relevant for the perception and preferences. The input to “Filter 2” may be measured by psychoacoustic methods and is an *objective* measurement. By carefully planning and performing the tests, we can obtain reproducible results. From this kind of measurements we will know which kind of



can be heard. The measurements at point 3 are purely *subjective*. The measurements will tell us what a certain group of people will hear and what they will prefer. The result will depend on the selected group.

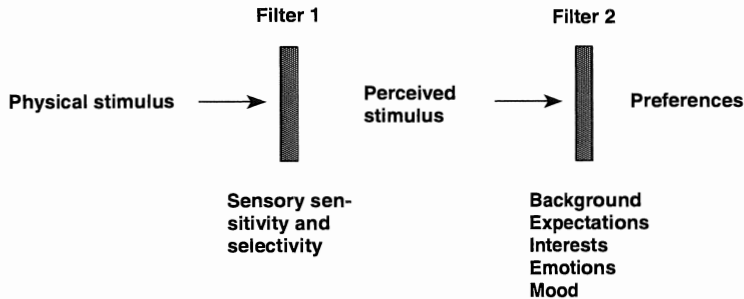


Figure 2: From stimuli to preferences

In designing and developing new methods involving human subjects a clarification of these phenomena is essential for assessing the product sound quality. The same goes for evaluating the annoyance of noise.

At DELTA Acoustics & Vibration we are working for the time being with a project addressing the below four phenomena of human perception of sound:

1. Perception directly related to the physics of the sound
  - How to establish a simple correlation – for instance a loudness value – between the physics and the perception (measurement point 2) which can be measured with sound analysis equipment
2. Perception of complicated phenomena of the sound, common to humans
  - Needs measurements based on human subjects and cannot be measured with instruments
3. Multimodal perception
  - Other senses as moderators of the sound perception or combined stimuli (part of filter one)
4. Perception influenced by mental processing
  - This is the output of the preferences at measurement point 3

One aim is to establish general principles for the coupling between the acoustic perception and the product design.

### 3 Definitions

Product sound can be thought of as a kind of symbolic language that varies with culture, context, and a variety of other factors. Furthermore, it has a tendency to change over time, partly because of technical advancements, but also because of changing tastes and fashions. This means that the task of optimising product sound is a highly iterative process.

We define *Product Sound* as the perceived sound from a product.

The term *Product Sound Quality* refers to the adequacy of the sound from a product. This is evaluated on the basis of the totality of the sound's auditory characteristics, with reference to the set of desirable product features that are apparent in the user's cognitive and emotional situation.

*Product Sound*, *Product Sound Quality*, and *Sound Quality* are often used indiscriminately to refer to a variety of related qualities. We choose to use the term *Product Sound* as defined above to emphasize that we are concerned with a characteristic of the product. This is different from "sound quality" or other terms that refer to the performance of speakers, telephones, amplifiers, and other products that are specifically built to reproduce sound.

We have also defined the following categories of *Product Sound*:

*Passive Sounds* are the sounds that are produced when the product is touched (knocked, pressed, etc.).

In contrast, *Active Sounds* are put out by the product itself. These active sounds can be further categorised as *Running/Operating Sounds*, *Action Sounds*, and *Signal Sounds*. These terms are best illustrated by an example using a washing machine:

The machine generates a *Running/Operating Sound* when it is in a given part of its cycle (wash, spin, rinse, etc.). The sounds may vary with the different stages of the cycle, and they may be continuous, stationary, or irregular.

When switching from the wash stage to the spin stage, the machine generates an *Action Sound* that has to do with its inner workings and is not intended as a direct signal of anything. This kind of sound can be continuous or impulsive, but is not generally stationary over long periods of time.

A washing machine puts out a humming sound at the end of the cycle. The primary purpose of this sound is to indicate that the machine is finished, and therefore the humming is a *Signal Sound*.

#### 4 Sound in Design: The Product Sound Wheel

We have created a model for product sound optimisation, see Figure 3.

The outer path in the *Product Sound Wheel* describes the fundamental process of optimising the Product Sound Quality. First, alternative sounds from a product, simulated sounds, or sounds from similar products are presented to a test panel. The panel gives their response either in answering forms prepared for statistical computations or directly, e.g. by setting sliders or pressing buttons. The same sounds are measured by analysers, software, etc., and a number of metrics for each sound is the result. The metrics may be any relevant traditional noise measure or may be more psychoacoustically related as loudness, sharpness, fluctuation, strength, roughness, etc., or any combination of these.

By graphical or statistical methods the connections and correlations between the two kinds of measurements are sought, and usually it is possible to describe the preferred sound by objective metrics. By analysis of the physical characteristics of the sound-generating mechanisms, the necessary design changes to obtain the defined values of

the metrics may be implemented. Tools for “sound tailoring”, sound editing, and simulation exist, and the lower inner path is often an attractive shortcut to test different versions of possible sounds for further analysis or subjective tests.

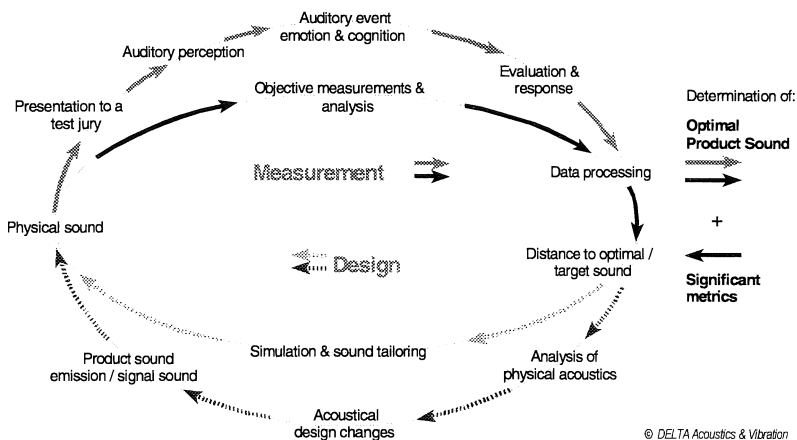


Figure 3: The Product Sound Wheel – a model for optimising Product Sound Quality

## 5 Practical Applications

During presentation a practical application will be discussed for products within the automotive and audio market.

- A carmaker wanted a silent power steering with a faint quality sound. The sub-supplier asked for an analysis of the sound from the existing power steering systems, and specifications of the desired “sound” and suggestions to design changes. As a result of this project, new owners of that make can pride themselves on the quiet and harmonious sound of their power steering.
- All CD-players contain movable parts and, hence, all produce some small amount of noise. Whether this noise is heard or not depends on two things: How loud it is and how it is composed. Even when noise levels measured may be the same, certain combinations of frequencies can be annoying while others are scarcely audible. Even in low background situations using a team of trained listeners it was possible to come up with a set of metrics which reflect the findings of these listeners. So, now introduction of an on-line QC-system in the production based on these metrics is under consideration for this new product.

The key issue is that the product sound tools with listening tests as a central part have been used to design changes into the products in order to improve their product sound and hence their acceptability to the users.

## 6 Conclusion

In summation, a properly designed product sound is an effective form of communication providing information about the quality, function, and condition of a product. The optimisation of product sound is a multidimensional process with physical, psycho-acoustic, and psychological aspects.

Product sound design tools are being used more and more to solve sound-related design problems and to develop products that yield a higher level of customer satisfaction. At the same time, product sound is emerging as an important marketing factor, as is the case with the famous Harley Davidson motorcycle sound, for example. The Product Sound Wheel is a useful aid in keeping product specifications as close as possible to the desired values throughout the iterative process of product sound design.

Whether a product sound is attractive is not determined by the sound alone and its relation to the function, but also by what the user is accustomed to, what the competitors' products do, and not least important, what the surroundings are willing to accept.

So, when discussing perceived product quality we must accept that it is a multi-dimensional discipline. For the combined stimuli more research is needed in order to describe the total response as indicated in our paper.

At DELTA Acoustics & Vibration we will work intensively in research during the next year on how to make measurements with test persons an efficient tool in the optimisation of perceived product quality.

### References

- [J. Bernsen, 1999], *Sound in Design*, Danish Design Center, Copenhagen.
- [J. Blauert & U. Jekosch, 1996], *Sound Quality evaluation – a multilayered problem*, EEA-Tutorium, Antwerpen.
- [C.L. Fog, 1998], *Optimal Product Sound: Design and Construction Guidelines for Developing Products with Desirable Sound Characteristics and Minimal Noise*, Report SPM 144 (in Danish), DELTA Acoustics & Vibration, Copenhagen.
- [C.L. Fog, 1999], *Use of Product Sound Optimisation Tools*, 6th International Conference on Sound & Vibration, Copenhagen.
- [C.L. Fog and T.H. Pedersen, 1998], *Introduction to Product Sound Quality*, Nordic Acoustical Meeting, Stockholm.
- [T.H. Pedersen and C.L. Fog, 1998], *Optimisation of Perceived Product Quality*, Euro-Noise 98, München.
- [H. Stone, J.L. Sidel, 1993], *Sensory Evaluation Practices*, Academic Press, San Diego.

# THE ROLE OF KNOWLEDGE IN WWW SEARCH: DIFFERENCES IN IR SKILLS AND DOMAIN EXPERTISE

Christoph Hoelscher<sup>1</sup>, Gerhard Strube<sup>2</sup>

<sup>1</sup>Center for Cognitive Science, Institute of Computer Science and Social Research  
University of Freiburg, Friedrichstr. 50, 79098 Freiburg, Germany  
hoelsch@cognition.iig.uni-freiburg.de

<sup>2</sup>Center for Cognitive Science, Institute of Computer Science and Social Research  
University of Freiburg, Friedrichstr. 50, 79098 Freiburg, Germany  
strube@cognition.iig.uni-freiburg.de

## **Abstract:**

*Searching for relevant information on the World Wide Web often is a laborious and frustrating task for casual and experienced users. To help improve searching on the web based on a better understanding of user characteristics, we investigate what types of knowledge are relevant for Web-based information seeking, and which knowledge structures and strategies are involved. Two experimental studies are presented, which address these questions from different angles and with different methodologies. In the first experiment 12 pronounced Internet experts are first interviewed about search strategies and then perform a series of realistic search tasks on the WWW. From this study a model of information searching on the WWW is derived and tested in a second study. In the second experiment two types of potentially relevant types knowledge are compared directly. Effects of Web experience and domain-specific background knowledge are investigated with a series of search tasks in an economics-related domain (introduction of the EURO currency). We find differential and combined effects of both Web experience and domain knowledge. Costs and benefits of the various methods of data collection are discussed.*

**Keywords:** Internet/Web expertise, Internet Search Engines, Logfile Analysis, Novice Expert Comparison.

## **1 Introduction**

The ever faster growth of the World Wide Web has turned the Internet into an immense information space with diverse and often poorly organized content. Online users are confronted with rapidly increasing amounts of information as epitomized by the buzzword "information overload." While skills necessary for browsing individual websites seem to be available to users after only minimal training [Hurienne and Wandtke, 1997], considerably more experience is required for query-based searching [Pollock and Hockley, 1997] and inter-site navigation.

The underlying question of the research presented in this paper is, what types of knowledge are relevant for Web-based information seeking, and which knowledge structures and strategies are involved. Two experimental studies are presented, which address these questions from different angles and with different methodologies.

Search engines such as Altavista or Excite are a central part of information seeking on the Internet, requiring sophisticated knowledge for their efficient use. They were chosen as a focus for our investigation because they have a prominent position among Internet resources.

Investigations on the search behavior of both expert and novice Web users have several practical applications. First and foremost a model of search behavior can serve as the basis for improving interfaces and functionality of existing search systems. The different needs of experts and novices can be identified and catered to by more sophisticated future systems. Also, help-systems and Internet education (e.g., courses and tutorials) can also benefit from a better understanding of users' difficulties with the search process.

## **2 Experiment 1: Exploratory Investigation of Expert Knowledge and Search Behavior**

Experiment 1 investigates "Internet expertise", which we defined as the technical knowledge and skills necessary to utilize the WWW and other Internet resources successfully in solving information problems.

### **2.1 Phase I: Interviews.**

First the participants were asked to describe their experience with the available search services, their search behaviour and their intentions and rationales for using certain sources and strategies. With the help of *mental walk-throughs* the process of searching for online information was then discussed step by step.

To reveal those experts' conceptual structures, the interview was augmented with a specialised card-sorting task [Janetzko, 1998; Strube et al., 1996]: During the interview, relevant terminology and actions were made explicit by recording them on colour-coded cards. Afterwards, the experts were asked to build a graph structure with these cards. This structure is supposed to represent an expert's personal conceptualisation of the search process. To support the participants in this task, some appropriate concept categories and relations were predefined and presented to the experts.

### **2.2 Phase II: Web-based information-seeking tasks.**

In the second phase of this expert study, a number of real-life information-seeking tasks were employed that had to be performed by the experts on the Internet. Examples: "Which finger is unaffected in RSI?" or "Find a sound archive for the VIRUS music synthesiser".

All inputs to the computer were mediated through an assistant of the experimenter who had to be orally instructed by the expert for each action. This procedure forced the expert to make every step of the interaction process verbally explicit, including those that might otherwise be missed because of rapid interaction sequences. Additionally, the experts were asked to think aloud about their search activities. This method can be categorised as being in between a classic thinking-aloud scenario and *teach aloud* [Ericsson and Simon, 1993]. All utterances were audio-taped and later transcribed for the analysis. Web-page requests and search queries were also included in the protocol.

## 2.3 Results of the expert study

### 2.3.1 Interviews.

The experts reported a wealth of Internet-related knowledge, much of it being highly idiosyncratic. Therefore, expert statements relevant to the search process were collected from the transcripts and entered into a matrix to determine which concepts, heuristics and strategies were common to the majority of the experts. Likewise, the concept-card models were inspected for inter-individually common knowledge structures. The statement matrix and the card models were aggregated into an initial process model of information seeking with search engines. This model describes the search process from the experts' shared perspective.

### 2.3.2 Web-based information-seeking tasks.

We distinguish two levels of data analysis, the level of information seeking steps and the level of individual search queries. For the analysis of information seeking steps, a set of rules was derived from the experts' process model for segmentation and categorisation of the protocol into action units. A total of 56 information problems was tackled by the subjects, two thirds of these successfully. A total of 1956 action units were identified, each corresponding to a step in the process model. The matrix of transition probabilities between all steps of the mode was computed<sup>1</sup>, allowing for an analysis of interaction sequences. The main results are summarized below.

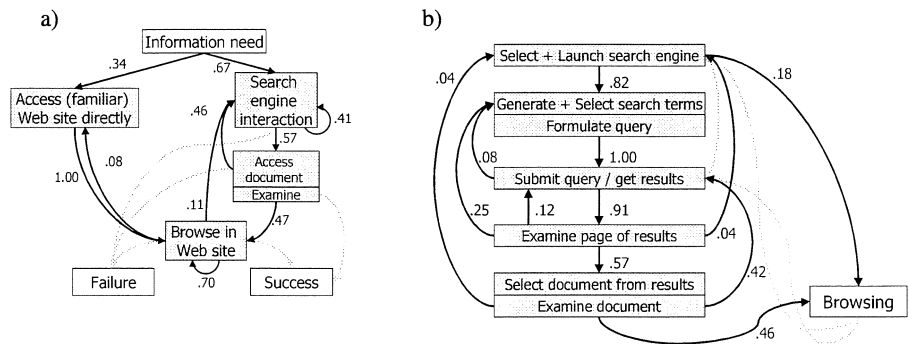


Figure 1: a) Global level of the process model of information seeking .

b) Close-up of direct interaction with a search engine.

(percent values represent transition probabilities to the next unit. Transition probabilities of .03 and below are omitted to reduce visual clutter)

Figure 1a shows that in two thirds of the search tasks, the experts initially choose to use a search engine. Only in one third of the cases they opted for browsing as the initial

<sup>1</sup> The sum of all transitions going out from one node equals 1.00 in this analysis

strategy. Finding potentially relevant documents with a search engine led to browsing episodes of varying length in about 47 percent of the cases. This in turn could lead directly to a solution, but often enough, a return to the search engine for further queries was observed. This indicates that the experts in our study quite frequently switched back and forth between browsing and querying if necessary.

Figure 1b gives a close-up of actions directly involved in Search Engine interaction. We found that the experts react quite flexibly if relevant documents are not found in the first attempt, namely with frequent re-formulations or re-formatting of existing queries, starting over, requesting additional result pages as well as backtracking to earlier result pages<sup>2</sup>. Again we observe opportunistic behaviour making use of all the options a search engine provides.

Individual search queries were analysed as well, and compared to available data on user behavior. [Jansen et al., 1998] report a quantitative analysis of a large sample of search requests from the EXCITE search engine, representing the search queries of the average Internet user. A corresponding sample about German search engine users was made available to us by the managers of the FIREBALL search engine. A comparison of these data sets with the experts' queries in our study indicates that web experts make use of advanced search options like formatting, Boolean operators, etc., much more frequently than the average user.

This first expert study confirms the high importance of media-specific skills of Internet users and gives a detailed picture of Internet expertise. While IR skills were the focus of this study we did find numerous hints to the importance of content specific knowledge. Experts frequently complained about lacking relevant domain knowledge regarding individual search questions and were highly aware of this obstacle while being rather sure of their technical competences.

### 3 Experiment 2: The EURO study

Experiment 2 is designed to directly compare the contributions that technical Internet skills and content-area specific domain knowledge make to the search process.

A current topic from the domain of economics – the European Monetary Union – was chosen for this laboratory experiment. The subjects were given a set of information-search problems from this domain. A 2 x 2 design of the independent factors *Web expertise* and *domain knowledge* results in four experimental groups. Participants with domain knowledge were recruited from students of economics. Web expertise was assessed by interview and a pre-test. In the experiment, two kinds of tasks were used, simulated search tasks and tasks that had to be performed live on the Web.

Based on the process model developed in section 2, complex search tasks were broken down into sub-tasks corresponding to individual steps of the process model like *Generate & Select Search Terms* or *Evaluate Result Pages*. The resulting sub-tasks allowed for a focused investigation of the direct effects that different types of expertise

---

<sup>2</sup> The large proportion of browsing steps directly following the selection of a search engine represents browsing in the directory structure of hybrid web catalogues / search engines like Yahoo! and have been refined into a distinct coding category for study 2.



have on individual steps of the model. For example, controlled result pages can be given to all subjects, while in real-life Web interactions rarely any two users come up with exactly the same search request and, therefore, usually do not evaluate the same result pages. In order to shed some light on the criteria of query formulation, the participants also had to judge prefabricated search requests and give frequency estimates of potential search terms.

In the second part of the experiment, the actual Web searches, we tried to make as few restrictions as possible, and did not employ thinking aloud techniques. Browsing and searching behaviors which manifest in the interaction sequences during the search are compared to identify differences in information seeking strategies and tactics.

Analysis of the data from the actual Web searches were divided into 3 parts. First transitions between stages of the model were compared in similar fashion to experiment 1. While across all four experimental groups the behavioral pattern of web searchers was largely confirmed<sup>3</sup>, a comparison between the novice and expert groups revealed a number of differences. They begin with different choices in initial behavior (e.g., only web-savvy students of economics try to access relevant known web-sites directly, while others always rely on search engines first) and carry on into most stages of the search process. The temporal information in the log-file was also analysed, showing individual and combined effects of Web experience and domain knowledge on intervals between page access. The third part of data analysis again investigated formal aspects of query formulation like using Booleans and formatting as well as the number and source of search terms, once more pointing at differential effects of Web-savvyness and domain knowledge and even compensatory interactions between the two.

The above analysis of actual Web searches will be complemented by results from the simulated search tasks, analysis of which is currently pending.

#### **4 Methodological issues**

A mix of data collection techniques is employed in this study allowing for a comparison of different methods for recording and modeling behaviors and knowledge structures. In experiment 1 interaction sequences and search statements are reconstructed from the audio protocol of the thinking aloud tasks. In experiment 2 the same measures are recorded directly with a proxy-server installed on the client computer. The proxy logfile contains a wealth of information like the date and time of each access, the Uniform Resource Locator (URL) of each file viewed and its length. Additionally we have the HTTP result code (indicating, e.g., if the file to be accessed was physically unavailable) and for most cases also the Referrer URL that indicates from which URL a users requests another page and is an important tool for reconstructing the behavioral trace. The logfile data can be processed to reveal the majority of the users interaction. Nonetheless a traditional observer protocol is written to complement the logfile, because it is assumed that certain interactions are not adequately recorded in the proxy logfile due to drawbacks in the HTTP protocol. The

---

<sup>3</sup> These differences were largely due to apparently increased task difficulty even for expert participants in comparison to the first study and a refined coding scheme.

categories for the observer protocol were derived from the process model as described in section 2 above. We will discuss the costs and benefits using the more labor-intensive audio / observer protocols on the one hand and the automatically generated proxy logfiles on the other hand. It is already clear that proxy logfiles alone would not have sufficed as a basis for revealing all relevant group differences reported in this paper but overall has been very helpful for the analysis.

### References

- [Ericsson and Simon] Ericsson, K. A. & Simon, H. A. (1993). *Protocol analysis: verbal reports as data*. Cambridge, MA: MIT Press.
- [Hurtienne and Wandke, 1997] Hurtienne, J., & Wandke, H. (1997). Wie effektiv und effizient navigieren Benutzer im World Wide Web? Eine empirische Studie [How effectively and efficiently do users navigate in the WWW? An empirical study]. In D. Janetzko, B. Batanic, D. Schoder, M. Mattingley-Scott & G. Strube (Eds.), *CAW-97: Workshop Cognition & Web*. (pp. 93-104). Freiburg. IIG Berichte 1/97
- [Jansen et al., 1998] Jansen, B. J., Spink, A., Bateman, J., & Saracevic, T. (1998). Real life information retrieval: A study of user queries on the Web. *SIGIR Forum*, 32(1), 5-17.
- [Janetzko, 1998] Janetzko, Dietmar (1998). *Card-sorting and knowledge elicitation*. unpublished manuscript.
- [Pollock and Hockley, 1997] Pollock, A., & Hockley, A. (1997). What's wrong with Internet Searching. *D-Lib Magazine*. [Online] Available: <http://www.dlib.org/dlib/march97/bt/03pollock.html> [1998, March 4]
- [Strube et al., 1996] Strube, G., Janetzko, D., & Knauff, M. (1996). Cooperative construction of expert knowledge: the case of knowledge engineering. In P. B. Baltes & U. M. Staudinger (Eds.), *Interactive minds* (pp. 366-393). Cambridge: Cambridge University Press.

# ON-LINE MULTIMEDIA INFORMATION SYSTEM ADAPTED TO SAILORS

S. Iksal<sup>1</sup>, S. Garlatti<sup>1</sup>, P. Kervella<sup>2</sup>

<sup>1</sup>Laboratoire IASC, ENST Bretagne  
ZI de Kernevent, BP 832, 29285 BREST Cedex, France  
Email: Serge.Garlatti@enst-bretagne.fr

<sup>2</sup>Atlantide, Technopôle Brest Iroise,  
Site du Vernis, CP n 2, 29608 BREST Cedex, France

## Abstract:

*Due to new technologies in telecommunication, most of computer-based systems are available through Internet or Intranet. Web servers supply with hypermedia tools for user-driven access to information. They provide a new information retrieval mechanism based on browsing into database or information systems instead of writing queries. On-line information systems used to have huge hyperspace and then the user may become hopelessly lost in hyperspace. Users only access a fragment of information space according to their current goal. Consequently, the task model enables us to assist the user for browsing and to determine the relevant information space which corresponds to certain concepts of the domain space. For hyper-document comprehension, coherence and cognitive overheads are the main factors. Domain and task models give local and global guidance to the users in order to convey the overall document structure to them and then to increase the document coherence and decrease the cognitive overheads in enhancing orientation and navigation.*

**Keywords:** on-line information system, adaptive web server, user modeling, task model, domain model.

## 1 Introduction

Due to new technologies in telecommunication, most of computer-based systems are available through Internet or Intranet. They are based on one or more Web servers. Web servers supply with hypermedia tools for user-driven access to information. They provide a new information retrieval mechanism based on browsing into database or information systems instead of writing queries. One of the main advantages of browsing for users, in general, is that they are better to recognise the information they search that to characterise it in advance [Vassileva 1996].

SWAN project aims to design an adaptive Web server for on-line information systems about nautical publications. First of all, we present the SWAN project and its requirements. Secondly, on-line information systems by means of adaptive hypermedia are analysed and discussed. Next, user modeling and user interface are described and finally, some discussions and perspectives are considered.

## 2 SWAN Project

SWAN project (Adaptive and Navigating Web Server) is a joined project between the IASC laboratory and a private company called Atlantide. The project is funded by the west council and supported by the French naval hydrographic and oceanographic service. At present, sailors have to find out the relevant pieces of information in different categories of publications (sailing directions, lists of lights and fog signals, tide and streams publications and radiosignals publications, ...). These multimedia publications are composed of texts, photos, tables, drawings, charts and plans. The on-line information system will provide nautical information for different classes of sailors and vessels to prepare a maritime navigation or to navigate on oceans.

Free and directed interviews showed that sailors have a common set of tasks which are stables and are achieved in very similar way. We found out four common goals sufficiently general, which are used to design the adaptive Web server [Garlatti, Iksal et al. 1999].

## 3 On-line information systems

In cognitive science, the comprehension of a document is often characterised as the construction of the mental model that represents it. The readability of a document can be defined as the mental effort spent on the construction process [Kaheneman 1973; Thüring, Hannemann et al. 1995]. In a way of increasing the readability of the hyper-document, it is necessary to assist the user in the construction of his mental model, for instance, by favouring concepts useful for the process and by weakening those which disturb it. For this purpose, two main factors are considered, *coherence* and *cognitive overheads* [Thüring, Hannemann et al. 1995]. A document is coherent if a user is able to build a mental model from it that corresponds to facts and relations in a possible world [Jonhson-Laird 1989]. To increase coherence, it is necessary to provide cues. These cues help the user to identify the major components of the hyper-document and how the overall structure is composed. For reducing the mental effort of document comprehension, it is not sufficient to impose a coherent structure ; it is also necessary to convey that structure to the user. It can be accomplished by providing overview of the document components and their relationships in terms of graphical maps or browsers. Conklin characterises cognitive overheads as the additional effort and the concentration needed to maintain several tasks at the same time [Conklin 1987]. This phenomenon is essentially due to the limited capacities of the human process for information processing [Kaheneman 1973]. With hypermedia, these efforts concern orientation and navigation. In a way of avoiding the disorientation, readers may know the overall document structure, then it is necessary to give some tracks of their moves through that structure. Indeed, comprehension and orientation are closely related.

Adaptive hypermedia for on-line information systems are dynamic hypermedia ; all pages are computed on the fly instead of defined previously. To increase the document coherence and to decrease cognitive overheads, static and dynamic hypermedia do not need the same tools. A static hypermedia is a collection of pages with fixed links between them. Generally the system offers a map to the user, such as the linear structure of a book's table of contents which gives an access to the hypermedia's structure and all its pages. This structure can be represented by a directed acyclic graph which can be

used to browse the hyperspace. In dynamic hypermedia, it is not possible to represent the hyperspace in such a way. Generally, the hyperspace is represented by the domain model which is a high level structure providing all the concepts of the domain and their relationships. The most advanced domain models are semantic networks. The least ones are only a list of terms.

On-line information systems used to have huge hyperspace and then the user may become hopelessly lost in hyperspace [Conklin 1987]. So, it is not sufficient to give him guides by means of the domain model for two main reasons : first of all, the domain model may be too complex - a concept can be connected to each other - and secondly each concept may contain too much data. Then, other criteria have to be used to determine the relevant information space and to assist the user for navigation. In on-line information systems, users used to only access a fragment of information space according to their current goal. Consequently, the task model enables us to determine the relevant information space and to assist the user for browsing. The relevant information space corresponds to some concepts of the domain space.

#### 4 User modeling

SWAN Project is based on two main models, first the user's model which is composed of a user's class, a task model and an individual model, and next the domain model which structure the information contained in nautical publications (Figure 1). The structure of our user's model is similar to Hynecosum's [Vassileva 1994; Vassileva 1996].

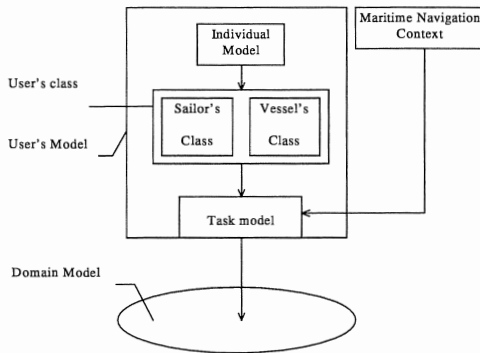


Figure 1: User modeling

The user's class consist of a sailor's class and a vessel's class. The former has only one feature, the sailor category which can be professional or yachtman. The maritime navigation context consists of a set of navigation condition features. The user's individual model enables the sailor to choose an adaptation method for a particular task or to specify some parameters of an adaptation method. It takes into account some user's preferences too. The domain model determines the domain concepts and their relationships which are well-known for advanced and expert sailors.

Task analysis of user's goals showed that it is quite natural to represent them by a hierarchical task model

In our model, we have two kind of tasks : abstract and atomic.

- Firstly, abstract tasks are used to declare the navigation process. An abstract task is decomposed into sub-tasks which can be abstract or atomic. A control structure using standard operators determines the sub-tasks ordering. The operators are the following : sequence (and), selection (or) and a specific selection which allows to have one task in abeyance.
- Secondly, atomic tasks are used for information retrieval and communication. They are not composed of sub-tasks, in fact they are leaves of the hierarchical task model. An information retrieval task computes a hypermedia views allowing the user to browse in a small hyperspace. It determines the relevant domain concepts. A communication task gives some explanations to the user, specifies some user's needs and gathers data or information from users.

The goals of adaptation, adaptation technologies, user's features and the strategy to define spatial views depend on each class of tasks.

The hierarchical task model is very convenient for the designer to define the navigation support and also to provides relevant cues to the user. It is based on a composition relationship between tasks which can take four possible states : opened, closed, in abeyance or in use. Indeed, the different states of the tasks and the paths in the corresponding sub-domain model may provide cues to the user.

### 5 User interface

Domain and task models help us to give local and global guidance to the users in order to convey the overall document structure to them and then to increase the document coherence and decrease the cognitive overheads in enhancing orientation and navigation.

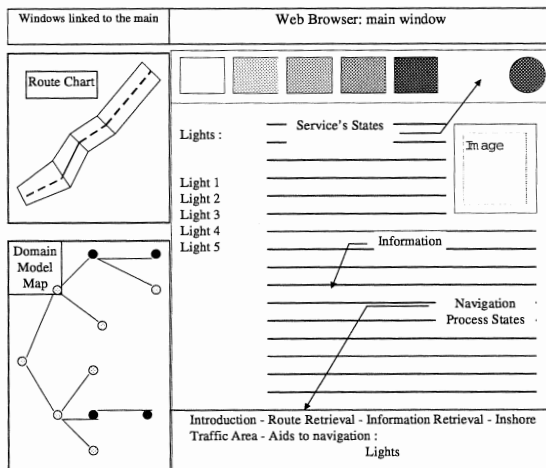


Figure 2: User Interface

In order to help the user in browsing, the task model is presented always with the same structure. We propose a stable architecture for all the adaptive application. The main tasks, called services, are displayed at the top of the main window (Figure 2). We use annotation methods to explain which is the current service, and what service is in abeyance. During the navigation process, the tracks of the user's paths are displayed at the bottom of the main window; annotation is used for showing the sub-task states in the current service: previous sub-tasks opened - already visited, task in use, next sub-tasks closed, next sub-tasks opened - already visited.

When the user selects an information retrieval task (Figure 2), he first chooses a route section and the corresponding part of the domain model is shown. This kind of atomic tasks works like a « door through the domain model ». The domain model is presented as a graph. Each leaf is a category of information we develop in the central part of our interface. We use annotation (colors) to display the relevant categories and the non-relevant ones according to the context. In the central area, we propose all the elements corresponding to the selected category, the context and the geographical area.

## 6 Discussions and perspectives

Our approach assumes some hypotheses about domain model and task model. Indeed, we assumed that the domain model extracted from sailing directions is well understood by the sailors. We used the domain model to give local guide to the user because it is an abstract and stable view of the domain. We plan to add a mechanism able to only select the well understood concepts of a user or a user's class by masking some sub-concept « a kind of overlay model. For instance, naive sailors could have some difficulties to cope with the entire domain model. Then naive sailor could have a wrong representation of the domain.

At present, the task model is masked to the users because we assume that the user's background is insufficient to deal with the complexity of the task model, its modifications and its design. But maybe, it is important to enable some users to manage the task model and to create new tasks.

Some aspects of the current version of this on-line information system is intentionally simple. Indeed, all future users don't make a habit of utilising computer-based systems to achieve their daily tasks. Consequently, it is important to firstly design a software which is not too far from the current software in nautical domain. The purpose of the first version is also to show the benefits of adaptive on-line information systems to sailors, to acquire new goals for the systems and to suggest sailor propositions and comments before going further.

In the next stage, we plan to add some features in our adaptive web server : user's preferences for adapting the task model and the strategy to define hypermedia views, more sailor and vessel classes, new tasks, maybe specific to some user's classes. We thought about other features, but we need to evaluate the current version before modifying.

## References

- [Conklin, J. 1987] Conklin, J. (1987). "Hypertext: An introduction and Survey." IEEE Computer.
- [Garlatti, S., S. Iksal, et al. 1999] Garlatti, S., S. Iksal, et al. (1999). Adaptive On-line Information System by means of a Task Model and Spatial Views. Second Workshop on Adaptive Systems and user Modeling on the World Wide Web, Toronto and Banff.
- [Jonhson-Laird, P. N. 1989] Jonhson-Laird, P. N. (1989). Mental Models. Foundations of Cognitive Science. M. I. Posner. Cambridge, MIT Press: 469-499.
- [Kaheneman, D. 1973] Kaheneman, D. (1973). Attention and Effort. Englewood Cliffs, Prentice Hall.
- [Thüring, M., J. Hannemann, et al. 1995] Thüring, M., J. Hannemann, et al. (1995). "Hypermedia and Cognition: Designing for Comprehension." Communication of the ACM **38**(8): 57-66.
- [Vassileva, J. 1994] Vassileva, J. (1994). A practical architecture for user modeling in a hypermedia-based information system. User Models and User Adapted Interaction, Fourth International Conference on User Modeling.
- [Vassileva, J. 1996] Vassileva, J. (1996). "A Task-Centered Approach for user Modeling in a hypermedia Office Documentation system." User Models and User Adapted Interaction(6): 185-223.



# DATA AND KNOWLEDGE ACQUISITION VIA INTERNET

Dietmar Janetzko<sup>1</sup>, Herbert A. Meyer<sup>2</sup>, Michael Hildebrandt<sup>3</sup>

<sup>1</sup> Center for Cognitive Science, Institute of Computer Science and Social Research  
University of Freiburg, Friedrichstr. 50, 79098 Freiburg, Germany  
dietmar@cognition.iig.uni-freiburg.de

<sup>2,3</sup> Department of Psychology  
University of Kassel, D-34109 Kassel  
<sup>2</sup> hameyer@hrz.uni-kassel.de, <sup>3</sup> hilde@hrz.uni-kassel.de

## Abstract:

*The Internet provides new possibilities for data collection both in academic research and for industrial applications. While most of the methods used in this field are relatively straightforward on a technical level, the methodology for successful data collection and investigation are not. In this paper, we provide a survey of the methodological requirements necessary to exploit fully the Internet's potential for data acquisition and online research.*

**Keywords:** Online-Research, Empirical Methods, Data Collection, World Wide Web, Internet, Questionnaire.

## 1 Introduction

Network environments provide unprecedented possibilities to access information. We can search in databases or access almost any type of information via the World Wide Web (WWW). With more and more people using network environments these systems also turn into a means of data collection: Internet users are not only accessing information, but, in doing so, also *provide* information. The first aspect, user as a information seeker, is obvious. The second one, user as a provider of information, however, is relatively new and has drawn much attention recently to methods for online data collection [Janetzko, 1999a]. As a matter of fact, it is always risky to make predictions about the future development and usage of technologies. There are, however, good reasons to assume that acquiring data in network environments will play a major role in areas such as Web site evaluation, market research, ergonomics, the social sciences, to name but a few.

Direct marketing relies on collecting data both in open (e.g., questionnaires, WWW forms) and covert (e.g., log file analysis) ways. In E-commerce, the users' activities are already precisely recorded with in order to predict future activities. In distance education, data are collected online for evaluation purposes. More and more, public opinion is strongly influencing political decision-making in western democracies. For this reason, political polls will increasingly make use of Internet surveys (e.g., for on-the-spot-surveys to capture a first trend in public opinion). In psychological and sociological research, collecting data is playing a small but increasingly important role.

On a more general level, recording data by using technical means has become part of our daily life. For instance, weather reports or economic decision making rely on it. The Internet has introduced some genuine methods, and also new varieties of old techniques. In what follows, we deal with data recording from interaction with open network environments such as WWW (thus, we will not deal with, e.g., recording temperatures in factories for monitoring purposes). The type of non-technical data acquisition we will discuss has its own peculiarities. Self-selection and repeated participation (in online surveys or experiments, for instance) are examples of problems unknown in more technical types of data acquisition, but well-known in online-investigations. The goal of this paper is to present a survey of approaches to data acquisition in network environments. This topic has many aspects, technical, methodological, legal, psychological, sociological. In what follows, we will concentrate on the methodological issues. For a more complete discussion of this topic, see Janetzko (1999a). Tools and techniques used in online-research are described in Janetzko (1999b).

## 2 Basic Concepts in Data Acquisition

Collecting data is not a means in itself. It is always done to provide an answer to a question. This question can be spelled out very precisely or in a rather vague way. In both cases we want to know something about a particular set of entities, e.g., a group of people. Using more technical terms, we can say that we are interested in a descriptive characteristic or parameter of a population (e.g., mean or standard deviation).

Imagine a researcher who wants to know to how consumers of a particular brand of corn-flakes like the new package of this brand. Usually, we can not investigate the whole population of subjects because it is too large, not available or too costly. Instead of examining the whole population (e.g., the set of all aficionados of a particular brand of cornflakes), we investigate only a part of it, which is called *sample*. We want the sample to be very similar to the population. A sample of this kind is called *representative sample*. To have a representative sample is very important. Only then can we generalize from the behavior of the sample to that of the population. Basically, a representative sample can be selected from a population in two ways. In *random sampling*, each element of the population has the same probability of becoming part of the sample. In *stratified* or *quota sampling*, elements of the population are selected in proportion to their frequency in the subgroups. (Note that a representative sample is not required if we have the chance to investigate all elements of a population. This, however, is a rare occasion).

## 3 Drawing Samples in Online-Research

If we want to generalize from the results of the sample to the population, a representative sample is needed. The set of all Internet users is not well described, and it is surely not representative of the general population of a country. However, recent surveys indicate that the set of Internet users is gradually becoming similar to the general population. (At least the proportion of women and elderly people is increasing).

There are various possibilities to recruit participants for online-investigations. An investigation may be announced by entries in search engines or search indexes, postings

to newsgroups, by online-research Internet directories (cf. Tab. 1) or simply by advertisements in conventional media like newspapers.

- Ulf-Dietrich Reips' *Experimental Psychology Lab*, Zürich und Tübingen  
<http://www.genpsylab.unizh.ch>
- Online Lab for Social Psychology, Jena <http://www.uni-jena.de/~ssw/labor.htm>
- Online Psychology Lab Padua  
<http://www.psy.unipd.it/personal/laboratorio/surprise/htmltesi/>
- Experimental-Server Trier <http://cogpsy.uni-trier.de:8000/TESeve.html>
- Max-Planck-Institut für biologica Cybernetics, Tübingen  
<http://exp.kyb.tuebingen.mpg.de/web-experiment/index.html>
- Internet Psychology Lab <http://kahuna.psych.uiuc.edu/ipl/>
- Psycholinguist Laboratory Scotland <http://surf.to/experiments>

*Table 1.* Collection of Online-Labs in Europe

#### 4 Controlling for Distortions

Distortions may have three different sources, all of which lead to a non-representative sample. First, the Internet users are simply not representative of the general population. We mentioned this issue in the preceding section. Second, an investigation might push off people. This, in turn, may have different reasons (e.g., usage of non-standard technologies, clumsy style of presentation, etc.). Clearly, everything has to be done to prevent this (e.g., by using standard Internet technologies clear presentation etc.). Third, an online investigation may also attract particular types of people (e.g. people on the lookout for incentives, or students). This may also lead to repeated participation of the same person in the online investigation. The more general term for this phenomenon is *self-selection*. More than in conventional investigations, subjects in online investigations are prone to self-selection. This means they decide which investigation they work through. At least with respect to repeated participation there are various techniques for control. But in general, the tendency to participate repeatedly in an online investigation seems low.

#### 5 Reactive and Non-Reactive Methods

There are various ways to classify techniques for collecting data. One major classification draws a line between reactive and non-reactive ways of collecting data. Using reactive methods, the subjects are aware that they are part of an investigation. Thus, they can react to this fact in various ways, for instance by trying to present themselves in a positive way. During data analysis it is very difficult or even impossible to separate subjects' 'genuine' reaction from the biased responses due to reactivity. A

online-questionnaire is an example of a reactive method. In contrast, Hänze, Hildebrandt & Meyer (1998) conducted a psychological field experiment. They incorporated an experimental manipulation into a well-established Web site (an icon archive), thus 'recruiting' every Web site user as an (involuntary) subject. Methods like this, where subjects are unaware of their participation, are called non-reactive.

There is no clear-cut distinction between both reactive and non-reactive methods. Even when non-reactive methods are used, people may assume that their data are being recorded. Thus, they may 'react' to this situation. By contrast, when reactive methods are used people easily forget (at least for a while) that they are being investigated. Note that cookies may be considered as both reactive or non-reactive. Many people consider non-reactive methods as a form of deceiving people. Thus, these techniques raises ethical issues.

## 6 Interview, Survey, Field Study, and Experiment

The distinction between reactive and non-reactive methods is only one of many possible ways to classify methods used for carrying out investigations. A different classification used in this field is between the classical types of investigations, the most important of which are interview, survey, field study, and experiment.

Interviews can be carried out in a structured way by using chat-bots [Janetzko, 1999c]. These systems use canned text to ask questions to the user. The answers can be easily recorded. Chat-bots conducting interviews have much in common with elaborated online-surveys that present follow-up questions depending on the preceding answer (adaptive testing).

In *surveys*, questionnaires are used to address research questions in written or oral form. Questionnaires can be set up in a rather ad hoc style by collecting those questions that seemingly relate to the question to be investigated. They can, however, be carried out in a highly sophisticated manner, as it is done in item response theory (e.g., Thissen & Steinberg, 1988).

*Field studies* are observations in a natural setting. The investigator does not introduce or manipulate particular conditions (variables). The WWW can be considered a natural environment, and people may be observed as they act in this setting. The *field experiment* mentioned above [Hänze, Hildebrandt, Meyer, 1998] is half way between a field study and an experiment, as an experimental manipulation was incorporated into a 'natural' situation.

The *experiment* is the most precise research method. In an experiment, one (or many) independent variables (i.e., something that may produce an effect) are varied and the effect on one (or many) dependent variables (i.e., something that is affected) is studied. For instance, if we are interested whether or medication affects attention or not, an experiment will provide an answer to this question. We may form two (or more) groups, e.g., male and female. Each group can be further divided into two subgroups. The first subgroup of men and women receives a particular amount of the medication. The second subgroup of the men and the women receives a placebo. This way, we varied the two independent variables (sex and medication). We may then study the effect of those on attention. There are particular tests for measuring attention. Attention is the

dependent variable. In an experiment, we will usually test hypotheses that specify a relationship (e.g., between medication and concentration), or a difference in the field under study. The experiment is the only type of investigation that allows us to investigate causal relationships. In *Web-experiments* all conditions are realized by technical means. The assignment of subjects to experimental conditions is also done in an automatic way.

<b>Reactive Methods</b>	<b>Non-Reactive Methods</b>
Cookies	Cookies
Online-Survey / Questionnaire	Log-File Analyzes
Web-Experiment	Environment Variables
Chat-Bots	Field Study / Field Experiment

Table 2. Reactive Methods and Non-Reactive Methods in Online Research

## 7 Comparison of Techniques

Researchers evaluating the quality of data collected in open networks are particularly interested in studies comparing different online methods. Such comparisons can be done within the group of online techniques (e.g., data acquisition via E-Mail versus data acquisition via WWW). It may, however, also be carried out between online methods and standard methods (e.g., laboratory experiment versus Web-experiment, surveys via E-Mail versus surveys via surface mail).

*Surveys carried out via E-Mail or via Surface-Mail.* Both types of surveys are usually considered *push media*. This means the participants are not actively seeking to participate in an investigation. Instead, the investigator approaches them. Both types of investigations can be conducted in different ways. In particular, the types of incentives vary widely. Problems arise as participants' familiarity with the medium Internet is hard to assess. Hence, it comes as no surprise that results of studies evaluating these types of investigations differ. Earlier studies indicate that there is a greater response rate when surface-mail was used. This is true even when the sample under study had a strong technical background [Mehta & Sivadas, 1995]. However, in their meta-analysis of more recent studies, Krantz & Dalal (in press) found that the response rates of surveys conducted via E-mail and via surface mail are on the same level.

*Web-Experiments versus Lab-Experiments.* Comparisons of Web-Experiments and lab-experiments are fraught with methodological problems when they are carried out post hoc. This is due to the fact that upon closer inspection seemingly similar experiments may in fact vary enormously. There is, however, evidence both from post hoc meta-studies [Krantz & Dalal, in press] and from studies particularly set up to compare both approaches, that they produce similar results [Reips, in press]. A critical discussion of technical and methodological issues in Web-experiments can be found in Hildebrandt & Meyer (1999). Clearly, we have to wait for further evaluation studies. But at least robust effects may be found both in conventional and online investigations.

## 8 Discussion

Data collection in network environments relies on a suite of methods that have pros and cons. An online investigation is not the method of choice if the subject has to be strictly controlled (e.g., to decide if one or several people are working through an investigation). On the other hand, investigations can profit in many ways from online techniques:

- Researcher can take advantage of automatic data analysis and presentation.
- Huge sample sizes can be addressed by net-based methods of data acquisition.
- By employing online methods, researchers can reach people they usually cannot reach with conventional methods.
- Whenever necessary, time measurements can be recorded down to the level of milliseconds. This way, the researcher has a clear-cut criterion for outliers who are not focusing on their task.
- Data acquisition can be done so that that particular methodological deficiencies (e.g., sequence effects in questionnaires) may be alleviated (e.g., by presenting items in a randomized way).

Some of the aspects mentioned above can also be achieved with standard computer-based techniques for data acquisition. However, full set of advantages will only be available by using net-based methods. The effort necessary to set up such instruments depends of course on the skills of researcher and on the complexity of the instrument that is needed to collect data.

## References

- [Hänze, M., Hildebrandt, M. & Meyer, H. A, 1998] Hänze, M., Hildebrandt, M. & Meyer, H.A, (1998). Field experiments on the World Wide Web: Effects of mere exposure on information retrieval. *Psychologische Beiträge*, 40, 363-372.
- [Hildebrandt, M. & Meyer, H. A., 1999] Hildebrandt, M. & Meyer, H. A. (1999). *Experimenting on the Data Highway: Full speed or speed limit?* Available via <http://www.psych.uni-goettingen.de/abt/1/hilde/>
- [Janetzko, 1999a] Janetzko, D. (1999). *Statistische Anwendungen Im Internet - In Netzumgebungen Daten erheben, auswerten und präsentieren*. München, Addison-Wesley.
- [Janetzko, 1999b] *Collecting, analyzing, and presenting data via Internet - A collection of tools, resources, and references*. Available via <http://cogweb.iig.uni-freiburg.de/SAI>
- [Janetzko, 1999c] Janetzko, D. (in press) Chat-bots. In B. Batinic, B., U. D. Reips, M. Bosnjak, M. & A. Werner. *Online social science*. Toronto: Hogrefe & Huber
- [Krantz, & Dalal, in press] Krantz, J. H. & Dalal, R. (in press). Validity of Web-based Psychological Research. In M. H. Birnbaum (Ed.), *Psychology Experiments on the Internet*. San Diego, CA: Academic Press.

- [Mehta & Sivadas 1995] Mehta, R. & Sivadas, E. (1995): Comparing response rates and response content in mail versus electronic mail surveys. *Journal of the Market Research Society*, 37; 429-439.
- [Reips, in press] Reips, U.-D. (in press). The Web Experiment Method: Advantages, Disadvantages, and Solutions. In M. H. Birnbaum (Ed.), *Psychology Experiments on the Internet*. San Diego, CA: Academic Press.
- [Thissen & Steinberg, 1988] Thissen, D. & Steinberg, L. (1988). Data analysis using item response theory. *Psychological Bulletin*, 104, 385-395.





# PERCEPTUAL-BASED RETRIEVAL IN LARGE MUSICAL SOUND DATABASES

Stephen McAdams<sup>1,2</sup>, Nicolas Misdariis<sup>1</sup>

<sup>1</sup> Institut de Recherche et de Coordination Acoustique/Musique (Ircam-CNRS),  
1 place Igor Stravinsky, F-75004 Paris, France

<sup>2</sup> Laboratoire de Psychologie Expérimentale (CNRS), Université René Descartes,  
EPHE,  
28 rue Serpente, F-75006 Paris, France  
email: smc@ircam.fr, misdariis@ircam.fr

## Abstract:

*Large sound databases pose the problem of retrieving appropriate sounds based on their perceptual and semantic properties. Perceptually relevant dimensions and features of musical sounds, determined by empirical studies, can be used for direct requests or to compute a similarity metric between an ideal target sound and the sounds in the database. A model of the perceptual distance between two sounds is based on perceptually relevant acoustic parameters. This model, developed on data from a small set of synthesized sounds, was adjusted to work on IRCAM's Studio OnLine natural-sound database. Future directions of research for other kinds of access are discussed.*

**Keywords:** auditory ergonomics, psychoacoustics, content-based retrieval, sound databases

## 1 Introduction

Musicians, sound engineers, and sound designers confronted with extremely large databases of sound samples have the problem of retrieving appropriate sounds. Categorical indexing in terms of musical instrument, pitch and dynamics played, and articulation style can reduce the search. However, it still requires the user to have an idea of what the samples sound like in order to formulate the request. Another approach is to use perceptually relevant dimensions and features of musical sounds as determined by empirical studies in order to directly access sounds having a particular perceptual property, or to compute a similarity metric between an ideal target sound and the sounds in the database. Several studies dealing with the perception of musical timbre have found significant correlations between acoustical parameters of sounds and their subjective dimensions. We will describe this work and its adaptation to content-based retrieval.

## 2 Multidimensional distance model of musical timbre

### 2.1 Psychophysical basis

Musical timbre is a complex auditory attribute for which multidimensional scaling techniques (MDS) have usually been employed to reveal the main underlying perceptual dimensions. From dissimilarity judgments on pairs of sounds, an MDS analysis builds a low-dimensional space in which sounds are located with regards to their mutual timbral

differences [McAdams, 1993]. Direct judgments of dissimilarity by listeners are processed by an algorithm that fits a distance model to them in which the distances between sounds have a monotonic relation to the judged dissimilarities [Winsberg & De Soete, 1993]. In this context, the study of [Krumhansl, 1989] on a set of 21 synthesized sounds of musical instruments and the derived study of [McAdams et al., 1995] on 18 stimuli of the same set were used as the basis for the present work. The K89 set was obtained with the EXSCAL model which contains both a euclidean component (euclidean distance between sounds in an n-dimensional space) plus a specificity component which may be conceived as either an additional dimension along which only one timbre varies or as a unique feature present on that sound which increases its distances from all other sounds. This distance model in K-dimensional space is represented by:

$$d_{ij} = \left[ \sum_1^K (x_{ik} - x_{jk})^2 + s_i + s_j \right]^{\frac{1}{2}}, \quad (1)$$

where  $d_{ij}$  is the distance between sounds  $i$  and  $j$ ,  $x_{ik}$  is the coordinate for sound  $i$  on dimension  $k$ , and  $s_i$  is the specificity on sound  $i$ . The M95 set had a large number of listeners and so analysis of latent classes of listeners could be included in the modeling. In this case each latent class has a set of weights applied to each dimension and to the set of specificities:

$$d_{ij} = \left[ \sum_1^K w_{kc} (x_{ik} - x_{jk})^2 + v_c (s_i + s_j) \right]^{\frac{1}{2}}, \quad (2)$$

where  $w_{kc}$  is the weight for listener class  $c$  on dimension  $k$  and  $v_c$  is the weight for class  $c$  on the whole set of specificities. In both cases, the analysis led to a timbre space with three common dimensions. These will be referred to as 'K89' and 'M95', respectively.

[Krimphoff *et al.*, 1994] attempted to quantify the perceptual axes of K89 in terms of acoustic parameters. The derived parameters were subsequently tested on M95. Both spaces gave similar results for two of the dimensions, which fit with Spectral Centroid (average over the sound duration of the instantaneous spectral centroid within a running time window of 12 ms) and Log Attack-Time (the logarithm of the rise time measured from the time the amplitude envelope reaches a threshold of 2% of the maximum amplitude to the time it attains this maximum amplitude). As for the third dimension, the most significant correlation occurs, for K89, with Spectral Irregularity (log of the spectral deviation of component amplitudes from a global spectral envelope derived from a running mean of the amplitudes of three adjacent harmonics) and, for M95, with Spectral Flux (average of the correlations between amplitude spectra in adjacent time windows). The values of the correlation coefficients are shown below in Table 1.

	Spectral Centroid	Log Attack-Time	Spectral Irregularity	Spectral Flux
K89	88%	88%	75%	
M95	88%	88%		29%

Table 1: Correlation coefficients between perceptual dimensions and physical parameters for the two original timbre spaces.

## 2.2 Derivation of a distance model

The main objective of this study was to build a multidimensional distance model from the relations among the perceptual criteria obtained by MDS analyses and the calculated physical parameters. This approach was first reported in [Misdariis *et al.*, 1998]. First, the subjective data, i.e. the coordinates of the sounds along each perceptual axis, were normalized to make the results of the two original studies comparable: a multiplicative factor of 1.93 was applied to K89. Afterwards, a mathematical relation between these subjective data and the values of the corresponding parameter was obtained by a linear regression method: the slopes of the resulting six straight lines could then be considered as proportionality coefficients between the perceptual and the physical dimensions (e.g. Figure 1 shows the regression of position along Dimension 3 of K89 onto spectral centroid).

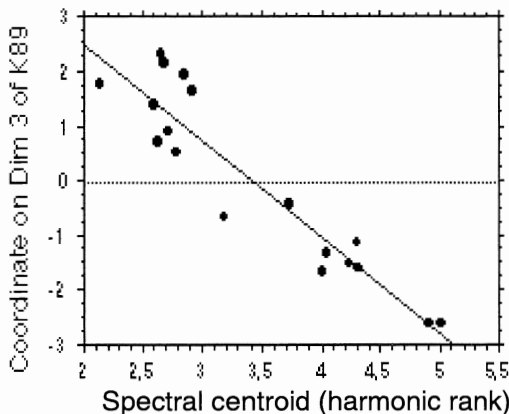


Figure 1: Regression of the third dimension of K89 onto spectral centroid (represented as harmonic rank).

Finally, these coefficients were used as weighting factors for the four acoustic correlates in a Euclidean distance formula representing the perceptual distance, as described in Equation 1:

$$\text{DIST} = \sqrt{\alpha \cdot \Delta \text{SC}^2 + \beta \cdot \Delta \text{LAT}^2 + \gamma \cdot \Delta \text{SI}^2 + \delta \cdot \Delta \text{SF}^2}, \quad (3)$$

where

Attack-Time ( $\log_{10}(s)$ ), Spectral Irregularity (dB), and Spectral Flux (unitless), respectively, and DIST is the resulting distance between two sounds in this acoustic parameter space weighted by their individual coefficients. The coefficients for SC and LT were derived from the mean of the values from K89 and M95.

### 2.3 Application of the model to the SOL database

The global aim of this work is the development of a search engine within the Studio On Line (SOL) database of recorded musical sounds (<http://sol.ircam.fr/>). However, the initial studies from which the model was derived were based on a restricted set of sounds equalized in pitch, duration, and loudness. To the contrary, the database upon which the model is expected to make predictions covers at present fifteen instruments recorded over their entire pitch range, at all dynamics and using almost all playing techniques of each instrument (normal, flutter tonguing, staccato, multiphonics, etc.). Therefore, a validation step was necessary both in the definition of the perceptual dimensions and in the method for calculating the parameters.

For the time being, we have focused on the problems of parameter extraction when processing acoustically produced sounds rather than synthesized ones, such as a nonnegligible signal-to-noise ratio, natural or forced inharmonicity, high non-stationarity, etc.. To illustrate a typical problem often encountered, Figure 2 presents the Spectral Centroid as a function of the physical level (RMS) over the duration of a Bb0, staccato, trombone sound. Note that these two parameters are not independent of one another and that several covariation relations of this type exist between other pairs of parameters. Also note in particular that the existence of areas where the Spectral Centroid estimate is clearly false is quite obvious.

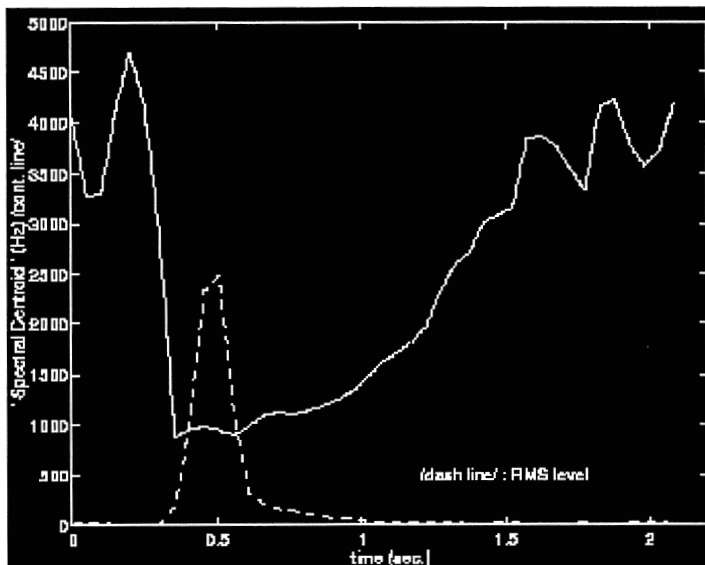


Figure 2: Spectral Centroid vs RMS level of a Bb0, staccato trombone tone.

The adjustments suggested by this kind of investigation have been made directly within the parameter calculation procedures: different ways to calculate a given parameter have been tested and elements like noise-gate modules in the generation of spectral data have been implemented.

On the basis of this set of perceptually calibrated physical parameters, the user of the SOL database can then perform a filtering operation to select a small subset of samples to be listened to (Figure 3). A categorical choice between continuously and percussively excited sounds is performed. The user can also constrain the search to given pitch and dynamic (loudness) values. Once these two constraints are applied, one can zoom into a certain part of the database on the basis of brightness (SC), richness (SI), and attack (LAT). The zoom process allows one to adjust the relative perceptual importance of each dimension.

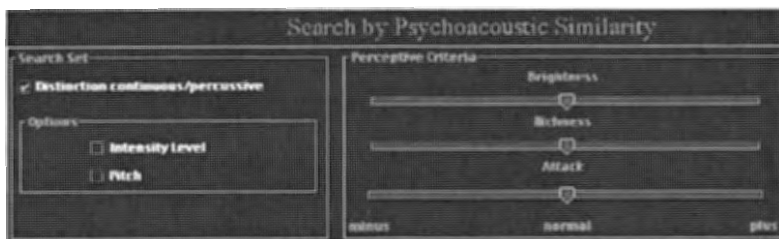


Figure 3: SOL user interface for defining a similarity search in the sound database.

### 3 Future directions

Since the modified model in its present state gives encouraging results, the next step of development will be to quantify empirically different perceptual scales, such as roughness, in order to establish more accurately and more exhaustively the relation between the distances in perceptual and physical parameter spaces and to develop a richer palette of acoustically quantified timbral parameters. We are also interested in developing a semantic access to the database in which correlations have been established between verbal descriptors such as "bright", "rough", "rich", both with the perceptual spaces derived from multidimensional scaling studies and their underlying acoustic parameters. In this latter vein we are particularly interested in the future in developing algorithms which allow the system to learn the acoustical meaning attached to certain verbal descriptors by a given listener.

### References

- [Krimphoff *et al.*, 1994] Krimphoff, J., McAdams, S. & Winsberg, S. (1994). Caractérisation du timbre des sons complexes. II: Analyses acoustiques et quantification psychophysique [Characterization of the timbre of complex sounds. II: Acoustic analyses and psychophysical quantification. *Journal de Physique*, 4(C5), 625-628.
- [Krumhansl, 1989] Krumhansl, C. (1989). Why is musical timbre so hard to understand? In S. Nielzén & O. Olsson (eds.), *Structure and perception of electroacoustic sound and music*. Excerpta Medica, Amsterdam, pp. 43-53.
- [McAdams *et al.*, 1995] McAdams, S., Winsberg, S., Donnadieu, S., De Soete, G. & Krimphoff, J. (1995). Perceptual scaling of synthesized musical timbres: Common dimensions, specificities, and latent subject classes. *Psychological Research*, 58, 177-192.
- [McAdams, 1993] McAdams, S. (1993). Recognition of sound sources and events. In S. McAdams & E. Bigand (eds.), *Thinking in Sound: The Cognitive Psychology of Human Audition*. Oxford University Press, Oxford, pp. 146-198.
- [Misdariis *et al.*, 1998] Misdariis, N., Smith, B. K., Pressnitzer, D., Susini, P. & McAdams, S. (1998). Validation of a multidimensional distance model for perceptual dissimilarities among musical timbres. *Proceedings of the 16th International Congress on Acoustics, Seattle*, pp. 2213-2214.
- [Winsberg and De Soete, 1993] Winsberg, S. & De Soete, G. (1993). A latent class approach to fitting the weighted euclidean model, CLASCAL. *Psychometrika*, 58, 315-330.

## SYSTEMATIC USE OF INTERNET BASED MARKET RESEARCH FOR MOBILITY PRODUCTS

Nicole Reinhold

Daimler Chrysler  
Research and Technologie 2  
Goldsteinstraße 235  
60528 Frankfurt/Main  
Germany

Phone : 0049-69-6679-481

nicole.n.reinhold@daimlerchrysler.com

Lab 11 Concepts for Railsystems and Aircraft as component of the Daimler-Chrysler research deals with methods of the innovations-management at the interface marketing/sale and development. The customer orientation is the main focus, already in the early phase of the conception of new splinting vehicles. First market research studies for products of the public passenger transport for the splinting vehicle manufacturer Adtranz have shown different difficulties and specific requirements on market research.

There is a demand on the development of new methods doing marketing research. The internet provides here interesting features as:

- International realization of studies
- Fast and low-cost data collection
- Automated data processing
- Realization of multi-media elements in the survey design

Problem causes as a countermove particularly:

- Self-selected samples
- Unknown total population
- As well as insufficient distribution of internet accesses.

First results from a project which examines the systematic usage, of the internet as a marketing research tool will be presented. In detail the contribution deals with:

- Chances and risks of online marketing research
- Prerequisite for the successful realization of online market research
- Position of online marketing research within the complete marketing research strategy.
- Strategies for a long term use of online marketing research.

A part of the results will be used in the context of my master thesis at the department of sociology at the University of Frankfurt/Main.





## EFFICIENCY OF WWW SEARCH ENGINE USER INTERFACES

Heike Röttgers

Department of Library and Information Science  
Media Documentation Studies  
Grindelhof 30  
D- 20146 Hamburg  
heike.roettgers@cityweb.de

**Keywords:** World Wide Web, search engines, user interface, logfile analysis.

World Wide Web search engines are improving on technical and conceptional fields. But often the end-user and his attentions on web-based information retrieval are ignored.

User interfaces are complicated in what concerns input of search queries, and output of the retrieved data. Difficulties with the use of search engines include: no recall, too many hits, loss of orientation, incomprehensible options, inadequate data for criteria of relevance, overestimation of database contents, ineffective help contents.

This study focuses on the evaluation of existing user interfaces, in order to design a new model for search engine user interfaces based on an evaluation catalogue.

This catalogue represents the results of a query-logfile analysis of Germany's biggest search engine Fireball. More than six million queries have been analysed and interpreted. A statistical analysis of the query-logfile reveals that people often do not understand the possibilities that search engines offer (boolean operators, truncation, detailed search etc.) and hence do not make use of the full potential of these systems.

Possible optimizations of user interfaces will be presented. This concerns not only the input of search queries, but also the output.

Current applied research in the fields of visualization of search results and different kinds of ranking methods will be presented and discussed with respect to improving today's WWW search engines.



# INTELLIGIBILITY IN HYPERMEDIA COMMUNICATION: THEORY AND RESEARCH

Peter Storkerson

Ph. D. Candidate  
Institute of Design  
Illinois Institute of technology  
350 North LaSalle Street  
Chicago, IL 60610  
email: pstork@tiac.net

## **Abstract:**

*This paper proposes a theoretical perspective for describing a communication and an experimental method for conducting user research in hypermedia. It operationalizes on the level of sensory configuration at which a designer operates. It proposes a model of intelligibility which relates user interpretation to sensory variables according to cognitive processes. It's experimental method can be used or adapted to isolate a wide variety of variables and hypotheses.*

**Keywords:** hypermedia, multimedia, cognition, perception, rhetoric

## **1 Introduction**

Published documents address unknown persons across time and space. Communicators present content they want to be received in predictable ways and they marshal communicative resources to do so. Communications are configurations of these resources. Taking “design” to be making the choices that configure a communication, designers confront questions about how their choices affect content and effectiveness. Hypermedia complicates what is already a confusion by mixing symbolic and depictive modes, often with combinations of disparate materials.

Experiential domains of time and space are unavoidable (image, video or text, navigational structure, etc.), and design choices governing experiential domains are themselves communicative resources. Designers need an operational understanding of their work, but design has little theory of its own. Its integration of the conceptual and the material place it between artistic, intellectual and practical pursuits. Even the relevant insights of other disciplines often don't function operationally in design's domain. Observing characteristics as they appear *in situ* to build “theories of the middle range,” risks reifying preconceptions. We need to look deeply enough to avoid begging the questions that must be asked, and build a design centered knowledge.

## **2 Theory**

The experiments described below reflect a general theory of communication in a rhetorical and constructivist frame that sees knowledge not as “truth” but invention [Corbett]. The invention is not arbitrary, but extends and/or revises the state of

knowledge or practice it addresses. States of knowledge vary between persons, but they are built using a species wide set of cognitive procedures [Anderson *et al.*, 1993] to which they are accountable and which make communication possible. We can use those procedures to organize our thinking about communicative goals, to relate them to spatio-temporal variables, and build operational, testable models of communicative performance.

Here are some critical aspects of the theory as axioms:

1. The first requisite of a communication is its intelligibility or potential for sense-making. It is intelligible when a receiver (reader, viewer, etc.) is able to construct an interpretation or reading which makes it coherent both internally and in context. That reading is what appears as communication itself.
2. The communication does not merely transmit, but prompts and guides the perceiver in altering his or her cognitive organization. At its heart are unstated concepts or frames that the receiver needs to make it intelligible. Though unstated, they can be detected. For example, we know something is understood not when it can be repeated but when it can be cognitively manipulated, e.g., “‘The road is bumpy’ so we drive slowly.”
3. The more the communication is attached to cognitive procedures, the more its interpretation can be stabilized. The use of those procedures in the spatio-temporal organization of the communication guides interpretation. States of knowledge and beliefs vary but cognitive procedures are far more consistent. Second, presentation according to a procedure supports and implicitly suggests that procedure as a line of reasoning. It is a ready-made pattern for the receiver to follow and extend. Its relations can induce in the receiver a corresponding interpretation.
4. Knowledge is rhetorical.[Scott, 1967] Rhetoric embodies thinking as spatio-temporal procedures. It is how we convince others, how we question ourselves and how we come to our own conclusions. Its core is the use of analysis and synthesis to disassemble something and reassemble its parts into something different or new.[Cicero, M.D.LIX] It is not merely persuasion. It constructs content by its analytic and synthetic use of selection and organization. Presentation makes assertions related to underlying data ( Figure 1) .
5. Any communication begins in spatio-temporal experience. The receiver’s perception organizes experiential flow into discrete entities using integration, segregation, and selection. Perception is further developed by cogitation or “thinking.” The reading that results is a record of the cognitive work: a lasting recollection that informs subsequent perceptions by cognition.
6. Hypermedia extend the rhetorical possibilities of individual modes by combining and juxtaposing “symbolic”(e.g. language based) and “depictive” [Kosslyn, 1994] (spatio-temporal and sensory) modes of presentation. In hypermedia, characteristics of perception, perceptual cognition, and cross-mode cognition as well as thought are critical to rhetoric. Depictions by themselves show only individuals and lack attribution. Symbolic systems are

built from categories, but they can only render experiences by attribution. Multimedia can produce stable meanings by linking across depictive and symbolic modes. In



“The press was using John, but John was also using the press.”

7. Figure 2, with image and text, we know whose hand is out, and what it means, just as we know what is meant by “using”.
8. The fundamental unit of interpretation is the event which expresses change and the attributions that specify it. It is the first point of conclusion, when the interpretive process gives a satisfactory return. “My glove,” is not an intelligible utterance, but “I shield myself with my glove,” is. Interpretation begins as something perceived, immediately and on a perceptual spatio-temporal scale. Interpretations develop by combining perceptions into larger units and relations, extending perceptual grasp. We hear a note, then a phrase, then a melody. Hypermedia’s use of sound, animation, and the sequencing of specific locations or pages follow this pattern.
9. Cognitive change as learning extends perception, both in visual complexity and temporal scale by combining current perceptual units into fewer, more complex ones. There are three broad levels of cognitive extension corresponding broadly to pattern recognition, narrative and theory: Pattern repetition such as rule governed relation, rhythm or rhyme which produce expectation, the larger sequential whole such as narrative or production sequence which serves as a frame to hold smaller units together, and theory as an explicit set of links holding units together. In communication pattern is mnemonically powerful in inducing stable long term memory. That retention supports , comprehension and interpretation.
11. Sensory modes are directly linked to experience via perception and sense based cognitive systems with their own distinct properties, e.g., we can most directly manipulate visual stimuli visually (rotate, rescale, move around, etc.) [Marr, 1982] We know that thunder and lightning are parts of the same phenomenon, but if there is a time difference, we do not perceive them as one thing [Bregman, 1990]. Sensory credibility follows sensory cognition. The experiential structure of a communication is a means of exercising sensory cognition to guide interpretation. It is also the means by which the communication indicates what it is. For it to be what it is, it must be perceived as what it is, thus it must depict itself. Finally, it is its depiction of itself.
12. Reception can be considered as retention and integration. Memory is long term retention, comprehension is the completeness of retention, and interpretation is the selectivity and associative structure of retention. The levels of integration are pattern recognition or the association of perceptual units into stable groups, the narrative or production sequence as a series of

elements with an order and conclusion or outcome, [Casey, 1987] and semantic integration or theory, the association of elements by explicit qualitative links into a manipulable structure. If I know how much you remember, and its pattern, I can know a great deal about your comprehension and interpretation.

13. Interpretation, memory and comprehension are prompted by a communication's patterning. [Rubin, 1995] Structuring of presentation is mnemonically powerful. Patterns of presentation, matched to temporal and spatial aspects of perception and cognition can be used to prompt retention, comprehension, and interpretation.

### 3 Experiments

From this theoretical frame, I have proposed a testing procedure and a set of three initial experiments relating interpretation to spatio-temporal structure. All three are built from the same module: the movie as a video and a spoken text, each comprised of a single event or statement, followed by questions probing the receiver for their integration and retention. In each experiment the receiver is seated at a computer presenting a series of movies with video and spoken text used to manipulate a variables (Figure 3).

The first experiment varies semantic distance, [Molinor *et al.*, 1989] and the second varies temporal relations between text and video including order, separation and overlap. Questions probe the receiver's cognitive integration. The third uses a sequence of movies. Here, questions probe for patterns of memory and that reflect cognition of the sequence of presentations as an entity distinct from any one of them. Experiments are fully automated, and the computer automatically records times responses and latencies. A video camera mounted on the computer screen records gestures and eye movements.

In the first experiment, there are 40 movies of each one 8 to 16 seconds (Figure 3: four categories of semantic relation

). After each movie, receivers choose first whether the video and text "make sense together" (integrate) or not, and second, how "confident" they are of their choice: high, medium or low. They are allowed 10 seconds for each.

After the set is presented, ten movies that the receiver reported made sense together are repeated. After each repetition, two more questions are asked. Do the text and video seem in themselves, to be about the same thing (integrated) or if they are separate but conjoined by putting them together (linked). Then, receivers are asked to "Say what you can about the communication. Summarize it or tell us what it's about if you can... or indicate what it was that brought the text and video together."

The 40 movies are organized a priori into four groups based on analogic relations: group 1 movies can be seen to share subject matter, group 2 share an explicit concept, group 3 conjunctions are indirect, and group 4 conjunctions have little or no intelligible relations. By the grouping criteria, group 1 movies will have high scores in integration and confidence, with short latency indicating perception. Group 4 will be lowest, with

high confidence and short latency. Groups 2 and 3 should fall in between in integration, with low confidence, and high latency indicating thinking.

At the time of this writing, the sample consists of 40 persons with a total N of 1176 records. All statistics were compiled using SPSS. Nevertheless, the data presented are preliminary and strictly illustrative.

The mean integration score of each category was group 1: 1.3, group 2: 1.55, group 3: 1.65, group 4: 1.8 with significance of .007. They were then categorized by the integration scores they received. The correlation between the a priori and empirical categories was .620 correlation using Spearman's rho, significant at .000.

#### 4 Results

While the a priori taxonomy is closely related to the measured the integration score, the fit is not perfect. Sorting movies by integration scores provides a better measurement of the consistency of receivers' integration. The scores have a mean of 1.501, and a standard deviation of .275. The twenty-fifth percentile is at 1.3, and the 75th percentile is at 1.68. Scores in the middle indicate different interpretations. If that is caused by the communication, we would expect the confidence scores to have a corresponding U-shaped curve. Confidence scores vary from 2.0 to 2.6, (out of 3) on such a u-shaped curve. A quadratic regression indicates with a .000 significance that 44% of the variance of confidence scores can be explained by integration scores alone. This indicates that we are looking largely at characteristics of the communication, not the receivers. We would also expect the decision time to be shortest for movies with low and high scores, but here, while the curve is the expected inverted u, the  $r^2$  is only 1.85 with a significance at the 2.3% level. When confidence latency is plotted against integration latency there is no relationship, indicating perhaps that confidence level is known by the time the integration is decided upon.

The first experiment asks if semantic relations are relevant in the ability of receivers to conclude that a text and a video make sense as two parts of the same thing. The above is what results can look like. The algorithm used is good, though others could be tried. Some movies are consistently interpreted in the same ways in both integration and confidence. Latencies indicating perceiving thinking correlate with confidence and with variability of interpretation. The lack of relation between integration latency and confidence latency indicates where certain judgments are being made.

The goals of the first experiment are very simple. To develop some baselines for understand and measuring integration or cross-mode cognition as an event. The second experiment uses "moderately interpretable" conjunctions and varies them temporally to study integration temporally, and consider the relative importance, of mode and precedence.

The third experiment begins to model some characteristics of hypermedia in ways that are recognizable. Sequences to test longer term memory and thresholds for the comprehension of something a larger whole that is not asseccible. Here, too self reports will be minimized in favor on recognition, or sorting tasks.

More generally, these analyses are based not on entities but procedures, and interpretation as their output. They can be measured and cued. They may be pointed toward a hypothesis which, to overstate it, could argue that "If I know what you remember in what associative configuration, and I know what you had to pay attention to and think about, I know a great deal about your interpretation because I know how you *can* think about. I can guide interpretation by structuring cognitive tasks and possibilities by manipulating juxtapositions, time, space.

Many different manipulations could be tried. The video records eye movement that could be used to probe for cognitive methods. The analysis can be extended to interactivity especially through such resources such as affect control theory. Thus, by making basic and grounded decisions and distinctions – perception and thought, the event as intelligible unit, the extension and stabilization of cognition by patterning – it is possible to build a protocol can probe other variables.



## References

- [Anderson *et al.*, 1993] Anderson, John R., Frank Bellezza. *The Rules of the Mind*. Hillsdale, N.J.; : L. Erlbaum Associates, 1993.
- [Bregman, 1990] Bregman, Albert S.: *Auditory scene analysis : the perceptual organization of sound*: Cambridge, MA; MIT Press, c1990. 773 p.
- [Casey, 1987] Casey, Edward S. *Remembering: A Phenomenological Study*. Bloomington Indiana; Indiana University Press. 1987, 359 p.
- [Cicero, M.D.LIX] Cicero, Marcus Tullius. *Ciceronis De oratore libri. iii. De optimo genere oratorum. De claris orationibus*. Venetiis, M.D.LIX.
- [Corbett] Corbett, Edward P. *Classical Rhetoric for the Modern Student*. New York. Oxford University Press.
- [Kosslyn, 1994] Kosslyn, Jeffrey. *Image and Brain*. Cambridge; MA. MIT Press. 1994. 516 p.
- [Marr, 1982] Marr, David. *Vision*. Cambridge; MA. MIT Press. 1982. 397 p.
- [Molitor *et al.*, 1989] Molitor, S., S.-P. Ballstaedt, Heinz Mandel. *Knowledge Acquisition*. Mandel, Heinz, Joel R. Levin, eds. *Knowledge Acquisition from Text and Images*, Amsterdam. North Holland, 1989. pp. 3-37
- [Rubin, 1995] Rubin, David C. *Memory in Oral Traditions*. New York. Oxford University Press. 1995. 390p.
- [Scott, 1967] Scott, Robert. *On Viewing Rhetoric as Epistemic*, *The Central States Speech Journal*. Central States Speech Association. V.18:1, Feb. 1967, pp. 9-17
- [Waltz, 1981] Waltz, David L. *Toward a Detailed Model of Processing for Language Describing the Physical World*, *Seventh International Joint Conference on Artificial Intelligence*, Vancouver, CA; University of British Columbia, 1981, p. 1-6

## Figures

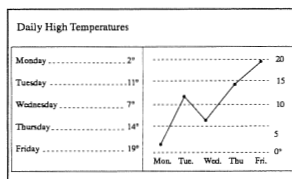


Figure 1: data and visual narrative



“The press was using John, but John was also using the press.”

Figure 2: Image and text combined to produce stable interpretation.

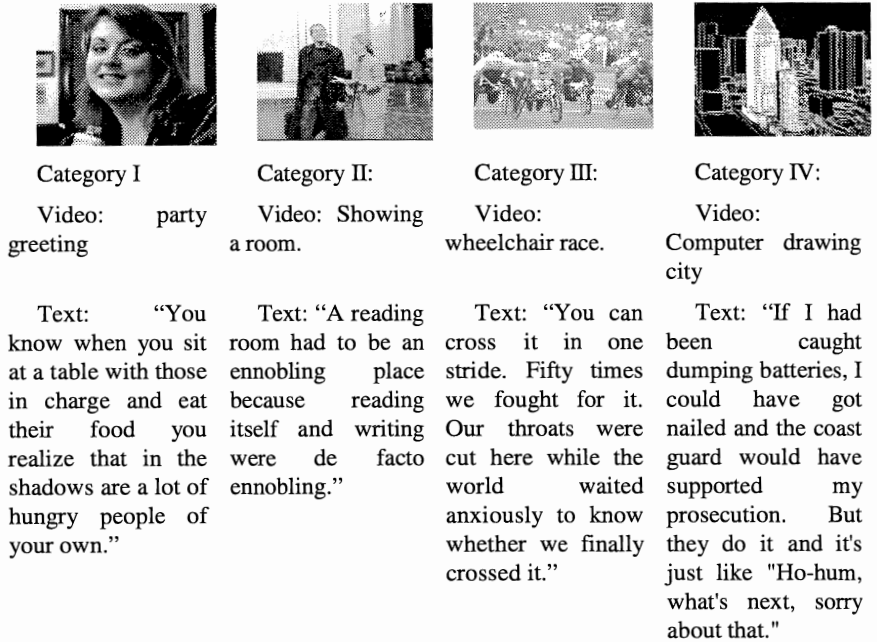


Figure 3: four categories of semantic relation

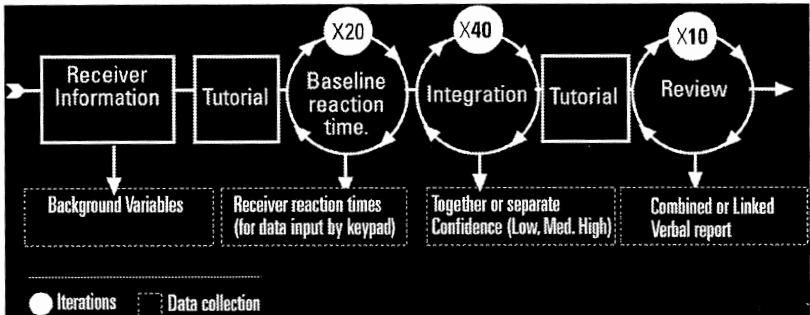


Figure 4: experiment 1

# ACTUAL USE AND JUDGEMENT OF THE USABILITY OF A SEARCH MOTOR ON THE WEB

Alain Vom Hofe<sup>1</sup>, Valérie de Almeida, Olivier Guibernao, Delphine Legroux

PSY.CO Laboratory (EMC2)

University of Rouen

<sup>1</sup> vomhofeal@aol.com

## Abstract:

*This research investigated the actual practice of novice Web users with a search engine requiring Boolean querying. The relative frequency of use of each response modality (unique key word / 2 or more key words connected by boolean operators), for three types of search task, and six knowledge themes was evaluated. In addition the relationship between real use and usability judgement of query modalities was examined. The results showed that querying varies greatly according to both theme and task, as well as with their interaction. The lack of relationship between actual practice and judgements was discussed in terms of « encapsulated » procedures. For ergonomics the results observed lead us to the conclusion that the design of user interfaces cannot be uniquely task-oriented.*

**Keywords:** World wide web, search tasks, users, cognitive psychology, ergonomics.

## 1 Introduction

The WWW allows the diffusion and consultation of numerous documents coming from many and varied areas. Whilst a major information source, the web, however, is not “the universal panacea for all users performing any information seeking task” [Steinberg, 1996]. The question of the usability of the web is today a recurrent one which much research has attempted to answer. From the point of view of cognitive ergonomics, this question drives at distinguishing the different task types and cognitive activities. On a general level it is possible to distinguish “searching tasks”, which require the user to find information from one place in the information structure, and “exploratory tasks”, which require the user to find related items of information within the structure [Smith et al., 1997]. Exploratory tasks, possibly the most typical web tasks (the navigational approach), arise principally from browsing activity, and are assisted by navigation aids in the form of graphical browsers. However browsing is not appropriate when the user has a well-specified aim and it is also inappropriate when the user needs a “credible” starting point, from which he can explore the data realm. Here we are concerned with the logic of a search activity, and the facilities provided by the search engines (eg, Altavista, Hotbot) and subject catalogs (eg, Yahoo). The specialized literature supports the notion of the search box as a useful facilitator, but this tool often generates dissatisfaction in novice users, notably with regard to the syntax used for querying; for example in the case of the well known Altavista, the manipulation of boolean operators.

If what is required is an analysis of errors and thus a detailing of effective help systems taking into account the diversity of users, an analysis of the various user

strategies employed during the learning process is essential. Herein lies one of the principal research objectives of cognitive psychology and ergonomics. However before precisely analysing user strategies, it is necessary to gather descriptive data. These were collected in this research in which we studied the actual practice of novice users, using Boolean querying. We evaluated the relative frequency of use of each response modality (unique key word / 2 or more key words connected by boolean operators), for three types of search task, and six knowledge domains (themes). Then in the knowledge that incorrect representations are often at the origin of incorrect tool usage, we were interested by the relationship between real usage of a response modality -- for a given task and a given domain, and the representation that the subject had of the usability of this modality.

In order to respect the constraints of ecological validity of experimental research, we firstly defined several types of search tasks and secondly designed a simulation of the web.

## **2 Method**

### **2.1 Subjects**

18 novice users, i.e. subjects who had already used a computer (notably for text treatment), but who had never navigated on the Net. The subjects (average age: 22. 4 years) were all university students. They each received a remuneration of 100FF.

### **2.2 Material, tasks and procedure**

- Three types of search tasks were selected:
  - i) finding a precise item of information (T1). For example: What is the height of the Eiffel Tower?
  - ii) finding several precise items of information, for comparison (T2) : For example: What is the cheapest snowmobile in the supplier catalogues presented on the web?
  - iii) finding information on a theme (T3). For example: What are the advantages and disadvantages of gene manipulation?
- Six domains of knowledge were chosen: Space (D1), Monuments (D2), Travel (D3), Genetics (D4), Health (D5), Religion (D6).

#### **2.2.1 Computer device**

We know that the configuration of the Web is in a constant state of change due to the integration of new sites and the modification of old ones. The results of querying by the search engines are directly affected by these changes, notably the URL list. Consequently for obvious reasons of experimental control, we designed a fixed micro internet. A certain number of sites were selected from the Internet that subjects could visit, and these were stocked locally by means of a 'proxy-cache'. To best simulate the web environment, we designed a search motor based on the functioning of Altavista. This motor allowed searching by key words with several operators activated as follows: "space bar" functioned as "OR", "+" functioned as "AND" and "-" as "EXCEPT". Page indexing was based on a count of the occurrences of the words present on each web

page. Thus on submitting a word to the motor the first URLs proposed were those where the word appeared the most frequently.

The following data were examined:

- the number of queries
- the occurrence of the different modalities: unique key word / OR / AND / EXCEPT

Questionnaire: Judgement of the usability of query modalities

The responses obtained from this questionnaire serve to demonstrate whether or not there is a similarity between the way in which novice users judge the usability of each response modality and the way in which they use them depending on the type of search and domain.

The construction of each item resulted from the crossing of the factor “search task type” and the factor “query modalities”. 12 items were presented in the same way at the conclusion of each of the 6 sessions. Each item was presented alone, on a sheet of paper at the bottom of which there was a continuous and graduated (10 gradations) response scale

Example of item: In order to find a precise item of information; the use of a single key word is:

not at all appropriate..... very appropriate

### 2.2.2 General procedure

The experimental conditions resulted from the crossing of the factors “search type” (3 modalities) and “domain of knowledge” (6 modalities) were applied to all subjects in two different orders so as to evaluate an eventual order effect whilst allowing the calculation of between-subjects correlations. The experiment consisted of 6 sessions (each of 90 min). During each session the three task types were presented, each one being associated to a different field of knowledge.

The 12 questionnaire items were presented in random order at the end of each session.

## 3 Results and discussion

### 3.1 Actual use of motor : total number of queries and choice of query modalities.

The modality “except” was only very rarely selected, and thus separated out and excluded from the comparisons.

A general analysis of variance (Anova) was conducted on each dependent variable with a 18 (“subjects”) X 2 (“order”) X 3 (“task type”) X 6 (“domain”) experimental design. The effect of the factor “order” was insignificant and therefore excluded from the following analyses.

Total number of queries was found to be dependant on the factor “domain” ( $F(5, 85)=22,00$ ;  $p<,000$ ), the factor “task type” ( $F(2, 34)=22,49$ ;  $p<,0001$ ), and the interaction of these two factors ( $F(10, 170)=17.84$ ;  $n<.000$ ).

Results for the use rate by querying modality and task type were as following. For the dependent variable "occurrence of a single key-word", the effect of "task type" was significant ( $F(2, 34)=11,51$ ;  $p<,0001$ ) as was that of the factor "domain" ( $F(5, 85)=11,78$ ;  $p<,000$ ). The "task type 'X' domain" interaction was also significant ( $F(10, 170)=5,001$ ;  $p<,000$ ). Similar results were observed for the dependent variables "occurrence of AND" as well as "occurrence of OR" (excluding, for this last variable, a main effect of the "task type" factor). From the group of post-hoc comparisons, an initial cluster emerged for the "domains" 4, 5 and 6. These themes had the following characteristics: (a) little or no difference between the occurrences observed for tasks 1 et 3; (b) some noticeable differences (note a large difference for the fourth area) between the occurrences observed for task 2, on the one hand and tasks 1 et 3, on the other. Task 2 was distinctive for these three domains by a number of more significant occurrences.

The second possible cluster concerns the domains 1, 2 and 3, the major common characteristic being a low number of occurrences (with the exception of the second domain for the dependent variable "unique key-word") and consequently an absence of task differentiation.

### 3.2 Usability judgements

Ratings of usability on the linear scale formed the raw data which were subjected to statistical analyses. We observed the following hierarchy of usability: (1) "unique key word" ( $M=6, 6$ ), (2) "AND" ( $M=6, 15$ ), (3) "EXCEPT" ( $M=5, 90$ ), (4) "OR" ( $M=5,42$ ). This demonstrates that subjects considered the modality "EXCEPT" to have greater usability than the modality "OR", although the former was very rarely used.

An Anova was performed on these data with 18 ("subjects") X 6 ("domains") X 4 ("query modalities") X 3 ("task type") factors. The effects of both the factors "domains" ( $F(5, 85)=3,14$ ;  $p<,011$ ) and "query modalities" ( $F(3, 51)=10,63$ ;  $p<,000$ ) were significant, whilst "task type" factors were not ( $p<,92$ ). The second-order interaction effect for the first two of these factors was also significant ( $F(15, 255)=2,28$ ;  $p<,005$ ), as was the interaction between "task type" and "query modalities" ( $F(6, 102)=19,53$ ;  $p<,000$ ). This last interaction reveals the highly complex nature of judgement making, as for these two factors (essential for interpretation in cognitive psychology terms): the curves for modality "unique key-word" and modality "EXCEPT" appear "as a mirror image" of each other, and for the modality "AND" and the modality "OR", as two lines in opposite directions (ascending and descending). If one adds to this that the factor "domain" interacts with the two preceding factors, it appears that subjects judgements, having to integrate numerous parameters, differ greatly.

One also observes that the only curve obtained for the modality "unique key-word" is very close to the one obtained for this same modality in the real use condition; for the two other modalities where it is possible to compare real use and usability curves (i.e. "AND" and "OR"), one notes very divergent shapes. This absence of correspondence, for the mean scores obtained during the six sessions (10 practice hours), is striking in the knowledge that the quality of learning depends on the degree of precision of the representation of the task requirements. But this vital question, can be better addressed using between-subjects correlations.

### 3.3 Interindividual correlations between real motor use and usability judgement variables

In this case we investigated the degree of similarity between subjects ranking of each of the variables in each session. Where high, this infers a correspondance between these variables. Due to the fact that the number of subjects ex æquo for certain variables was not negligible, we used a *gamma* correlation coefficient. In learning terms one can assume that the number of statistically significant correlations will increase with the sessions. The results were enlightening: from the many correlations calculated, only 9 were significant! Moreover their distribution over the sessions does not support the learning hypothesis.

## 4 Conclusion

Although “search activity involves a rather focused, intentional action on the part of the user”, differing from browsing which “is much more exploratory, and generally driven by the attractiveness of the links encountered during exploration” [Duchastel, 1998], the cognitive approach to search activity is extremely complex. The study here presented shows that whatever the dependent variable, the variance of the scores is quasi systematically attributable to all the experimental factors and to the interactions between these factors. The factors manipulated in this research involve as much, according to Anderson's terminology (1995), declarative knowledge (ie the What issue) as procedural knowledge (ie, the How to issue). For the former, it is principally a question of knowledge of the different themes and task categorisations but notably also of the successive “states of the world” linked to the action of querying. For the latter, it is principally a matter of process (ie. both the progression and the way in which results are achieved). Seen globally these results therefore constitute an indication of the coherence of the procedures used by subjects. Users are capable of choosing a response modality according to the characteristics of the situation and the task. However there is no evidence that this choice is the most appropriate or that is conscious. Based on the assertion in this study of a lack of relationship between real use and usability judgement of query modalities, one must consider that subject activity remains implicit and “encapsulated” in some procedures. This is a true problem because one of the principal determinants of the learning of complex technical systems is the understanding of the logic of the functioning of the system. It is necessary for the novice user, to become able, like the expert, to take into account the rules which govern the activity and therefore to be able to explain why a certain procedure is applicable in one context and not in another, and why the same procedure can attain very different objectives perhaps even opposing objectives.

For the psychologist, in these learning by doing situations the construction of functional representations is therefore one of the principal concerns. From the outset of learning it is important that the user can both process the task and form a mental model of the situation. But in many cases the cost of this double activity is too high. Wherein lies a recurrent problem for ergonomists. A solution may reside in the design of systems, involving on the one hand a delegation of a part of the task to intelligent agents allowing a personalised use of the web based on user profiles [see Kamba et al., 1997], and on the other hand a safeguarding of the autonomy of the user as the cognitive

activities required for the search - comprehension, reasoning, evaluation - are too complex to be fully automated.

### References

- [Anderson, 1995] Anderson, J.R. (1995). Learning and Memory. An Integrated Approach. Wiley, New York
- [Duchastel, 1998] Duchastel, P. (1998). Knowledge interfacing in cyberspace, *International Journal of Industrial Ergonomics*, 22, 267-274.
- [Smith et al., 1997] Smith, P.A., Newman, I.A. and Parks, L.M. (1997). Virtual hierarchies and virtual networks: some lessons from hypermedia usability research applied to the World Wide Web, *International Journal of Human-Computer Studies*, 47, 67-95.
- [Kamba et al., 1997] Kamba, T, Sakagami, H. and Koseki, Y (1997) ANATAGONOMY: a personalized newspaper on the World Wide Web, *International Journal of Human-Computer Studies*, 46, 789-803.
- [Steinberg, 1996] Steinberg, S.G., (1996). Seek and ye shall find. *Wired*, 4, 61-103.



# **PART VII**

## **METHODOLOGY AND/OR APPLIED MATHEMATICS**

---



# NEUROSymbOLIC INTEGRATION FOR INDUSTRIAL APPLICATIONS

Frédéric Alexandre<sup>1</sup>

<sup>1</sup>LORIA/INRIA-Lorraine  
BP 239  
F-54506 Vandoeuvre  
falex@loria.fr

## Abstract:

*Today, symbolic and connectionist artificial intelligence have proved their complementary efficiency for various aspects of cognitive processing. Both approaches can be seen as complementarily acting on specific parts of information, namely data and knowledge. Such a dichotomy can also be observed as one consider real world applications. A general theory is rarely available to build a complete knowledge based system. Conversely, data can generally be extracted from the problem but never cover the whole problem. Accordingly, the idea has emerged that the combination of symbolic and connectionist tools could be a way to benefit from the advantages of both approaches. Neurosymbolic integration that will be presented here is the domain whose goal is to define strategies and propose tools for the cooperation of symbolic and connectionist artificial intelligence.*

**Keywords:** neurosymbolic integration, hybrid approach, unified approach, industrial application, cognitive aspects.

## 1 Introduction

What is the nature of relationship between human cognition and real world applications? We will try to contribute to answering to this question through our recent experience on such typical applications and the corresponding cognitive modelization.

### 1.1 First example

The first experience is an industrial application in the steelmaking domain. The problem is to predict the rolling force of a roll-mill to accurately preset the machine and improve the quality of the resulting sheet of steel. Different investigations were driven. The first one was driven from an engineer point of view. The goal was to exhaustively enumerate the parameters in the process, the rolling force was depending on. Then, various engineers from such domains as physics, thermics and other steel making related domains, gathered and wrote down physical equations relating those parameters with the rolling force. A physical model resulted from this modeling step, that was able, from the expert knowledge about the process, to compute the theoretical rolling force [Roberts, 1972].

The second investigation was driven from a statistical point of view. Sensors of the process allowed engineers to build up data bases gathering thousands of examples, each corresponding to the values of the critical parameters and the corresponding rolling force

Then, a statistical analysis, involving a multilayer perceptron, allowed to predict the rolling force, as a function of the input parameters [Pican et al., 1993]. Here, except from the selection of the pertinent parameters, no knowledge was incorporated in the model, only built with measured data.

Both models were implemented on the process and respectively yield an average error of 25% and 17%. It was then possible to conclude that a data-based approach was more efficient than a knowledge-based approach. Nevertheless, a more accurate analysis showed that large errors in both models were not committed on the same cases. It was then possible to imagine that a clever combination of both models could yield an even better result.

## 1.2 Second example

The second experience is concerned with the autonomous navigation of a robot. This example is more academic, though industrial applications can also be envisaged in this framework. As for the previous example, knowledge-based and data-based approaches have also been reported for this problem, where the goal is to propose at each moment the best action for the robot that will optimize its reward, as a function of its environment, perceived through sensors, and of its past history, memorized within the system.

Knowledge-based approaches are derived from classical artificial intelligence techniques, where objects and relations between them are represented by symbols. In models like [Donnat and Meyer, 1996], a rule based classifier system can control the navigation of a simulated robot with complex reasoning abilities. Nevertheless, it is much more difficult to ground the symbolic structures defined here on real numerical perceptions.

Conversely, data-based approaches like [Bühlmeier et al., 1996] are built in a bottom-up way, from the sensors. Here, the associative properties of hebbian learning are used to learn correlations between elementary numerical events. Such models are thus very efficient in tasks like obstacle avoidance, but are limited to reactive behaviors.

## 2 Neurosymbolic integration

We have evoked above knowledge-based and data-based approaches to real-world applications. Accordingly, Artificial Intelligence (AI) can be also divided in symbolic and numerical AI. Symbolic models offer good performances in reasoning, are able to give explanations and can manipulate complex data structures, but they have generally serious difficulties in anchoring their symbols in the perceptive world. By contrast, numerical models like neuronal models are often selected for pattern recognition and have such qualities as generalization and learning abilities, whereas they have not been reported as efficient for deduction tasks.

As a consequence, neurosymbolic integration has emerged and try to combine symbolic and neuronal AI to benefit from advantages of both approaches. Among various strategies for neurosymbolic integration, two are clearly identified.

The hybrid strategy is an opportunist approach which proposes to combine classical models from neuronal and symbolic AI. Here, the point is to wonder about possible cooperations between such models and to emulate the corresponding platforms, able to ensure parameter and data structure exchanges between the models [Hilario et al., 1994].



Another point corresponds to deciding, for a given application, which combination of symbolic and numerical models could yield a good performance. Such a general methodology and the corresponding tools were proposed during the european MIX project [Alexandre, 1997].

The unified strategy proposes that the characteristic properties of the symbolic AI can emerge from distributed local computations of a neuronal model. Among several ideas, biologically-inspired modelization of brain-like systems are of particular interest here. In this framework, complete cognitive functions, from the perceptive to the reasoning or planning level, are modeled from a neuromimetic point of view, from the neuron level up to the structural level of the nervous system [Edelman, 1987, Alexandre et al., 1991].

It is also worth noticing that neurosymbolic integration has been also justified from a cognitive point of view [Lallement et al., 1995]. Basically, the idea is to identify in human intelligence, on the one hand, low-level operations mostly concerned with perceptual tasks, best carried out by neuronal models, and on the other hand, high-level operations rather concerned with reasoning, best treated by symbolic models. It is then straightforward to state that most complex cognitive human tasks involve both types of operations, hence the need for the combination of the corresponding models.

Concerning the two types of strategies of integration evoked above, we now illustrate them to the light of the applications presented at the beginning of the paper.

### **3 The hybrid approach**

An hybrid strategy was chosen for the steelmaking application. In addition to the two physical and neuronal modules described above, another prediction module with fuzzy logic was also built. Then, in addition to these basic modules, two kinds of higher-level modules were defined. First, a Kohonen map was used to estimate, for each basic module and each input data, a prediction of its error. Second, a case-based reasoning module was implemented, whose goal was to choose, for each input data, the best combination of modules to apply. All these modules were gathered on a multi-agent platform, in charge of their communication and parameter exchange. As a result, an average 10.5% error was obtained [Alexandre, 1997].

### **4 The unified approach**

The autonomous navigation of a robot has been tackled with a biologically-inspired unified approach. As a connectionist model, the model developed here [Frezza-Buet and Alexandre, 1998a] has such characteristics as hebbian learning, classical neuronal activation, etc. It has also specific biologically-inspired mechanisms as feed-back control activation and lateral excitation. More interestingly, this model also includes specific knowledge, like the definition of specific maps with topology and coding derived from cortical data. This multi-map model has been proven very efficient for the learning of the behavior of an autonomous robot, from the perceptive level up to the level of the selection of action in an unknown environment [Frezza-Buet and Alexandre, 1998b].

## 5 Discussion

Both hybrid and unified strategies are grounded on the same idea of combining symbolic and neuronal AI principles to get their advantages. Our experience with these strategies makes us discuss now about their interest for industrial applications but also for the better understanding of human cognition.

The hybrid strategy consists in combining current classical models from both symbolic and neuronal approaches. Here, the point is to build a platform allowing for a fruitful dialogue, parameter exchange and other adaptive processes between connectionist and symbolic models. As our industrial experience illustrates and as confirmed by similar experiences made in our group, it is clear that the hybrid strategy is a rather simple and pragmatic approach, using classical AI tools. As such, it can be easily used for complex real-world tasks. Concerning its cognitive orientation, the hybrid strategy underlines the dual aspect between expert knowledge and statistical estimation obtained from data. It is thus an attempt to reconcile to typical human processes: trying to understand, explain, formalize and giving an unconscious estimation from experience. While implementing our modules in the steelmaking plant, we have particularly observed that this dual approach was very well understood by the technical staff. We believe that this point is very important for such a new tool to be accepted and used in a plant.

The unified strategy claims that the connectionist formalism alone can perform cognitive tasks and emulate the corresponding properties. Inspiration from neurosciences domains is often used in such a framework. Here the cognitive orientation is clearly anthropomorphic. Instead of modeling its reasoning strategy like in the hybrid way, the idea here is to mimic the human substratum for perceiving and reasoning. Even if this approach is clearly potentially powerful, it is not as mature as the hybrid one. It is also not directly applicable to any industrial application, except when the topic is to modelize human behavior. Nevertheless, local properties and mechanisms of such models could be more directly exploited in an information processing point of view, without consideration of the biological framework.

As a conclusion, we think that, even if the hybrid approach is more tractable in a short term point of view and the unified approach is more generic, they tend toward the same goal and can illustrate complementary aspects of cognition.

## References

- [Alexandre, 1997] Alexandre, F. (1997). Tools and experiments for hybrid neuro-symbolic processing. In *Ninth International Conference on Tools with Artificial Intelligence (ICTAI'97)*, pages pp. 338–345, Newport (California). IEEE Computer Society.
- [Alexandre et al., 1991] Alexandre, F., Guyot, F., Haton, J.-P., and Burnod, Y. (1991). The Cortical Column: A New Processing Unit for Multilayered Networks. *Neural Networks*, 4:15–25.
- [Bühlmeier et al., 1996] Bühlmeier, A., Manteuffel, G., Rossmann, M., and Goser, K. (1996). Robot learning in analog neural hardware. In *Proceedings of the International Conference of Artificial Neural Networks*, pages 311–316.

- [Donnart and Meyer, 1996] Donnart, J.-Y. and Meyer, J.-A. (1996). Learning reactive and planning rules in a motivationally autonomous animat. *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics*, 26(3):381–395.
- [Edelman, 1987] Edelman, G. (1987). *Neural Darwinism: the theory of neural group selection*. Basic Books.
- [Frezza-Buet and Alexandre, 1998a] Frezza-Buet, H. and Alexandre, F. (1998a). A model of cortical activation for robot navigation. In *International Conference on cognitive and neural systems, Boston, USA*.
- [Frezza-Buet and Alexandre, 1998b] Frezza-Buet, H. and Alexandre, F. (1998b). Selection of action with a cortically-inspired model. In *Seventh European Workshop on Learning Robots, Edimbourgh*, pages 13–21.
- [Hilario et al., 1994] Hilario, M., Pellegrini, C., and Alexandre, F. (1994). Modular Integration of Connectionist and Symbolic Processing in Knowledge-Based Systems. In *Proceedings International Symposium on Integrating Knowledge and Neural Heuristics, Pensacola Beach (Florida, USA)*.
- [Lallement et al., 1995] Lallement, Y., Hilario, M., and Alexandre, F. (1995). Neurosymbolic Integration : Cognitive Grounds and Computational Strategies. In DeGlas, M. and Pawlak, Z., editors, *Proceedings World Conference on the Fundamentals of Artificial Intelligence*, Paris.
- [Pican et al., 1993] Pican, N., Bresson, P., Alexandre, F., Haton, J.-P., and Couriot, E. (1993). A Perceptron with Optimized Backpropagation Learning Algorithm to Preset a Temper Mill Machine. In *Proceedings Int. Conf on Neural Networks and their Industrial and Cognitive Applications, Nîmes*.
- [Roberts, 1972] Roberts, W. L. (1972). An approximate theory of temper rolling. *Iron and steel engineer*.





# EPISTEMIC PROGRAMMING AS AN OPERATIONAL TOOL FOR SCIENTISTS TO PROGRAM THEIR EPISTEMIC PROCESSES

Jingde Cheng

Department of Information and Computer Sciences, Saitama University  
255 Shimo-Okubo, Urawa, 338-8570, Japan  
cheng@ics.saitama-u.ac.jp

## Abstract:

*In order to provide scientists with a computational methodology and computational tools to program their epistemic processes in scientific discovery, we are establishing a novel programming paradigm, named 'Epistemic Programming', which regards conditionals as the subject of computing, takes primary epistemic operations as basic operations of computing, and regards epistemic processes as the subject of programming. This paper presents our fundamental observations and assumptions on scientific discovery processes and their automation, and an outline of our research project of Epistemic Programming.*

**Keywords:** Scientific discovery, Conditional, Primary epistemic operations, Epistemic programs, Computational methodology.

## 1 Introduction

Scientific discovery, in particular, various epistemic processes in scientific discovery, has always been surrounded by an aura of mysticism. Can we have a “science” and/or an “engineering” of scientific discovery? The term ‘science’ means the state or fact of knowing or cognizing some class of things, i.e., objects or phenomena, by the observation, identification, description, experimental investigation, and theoretical explanation of the objects or phenomena. The term ‘engineering’ means the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems in order to make these artificial objects have desired properties and therefore function well. Thus, if we can eventually have a “science” and/or an “engineering” of scientific discovery, then, what are its fundamental observations and assumptions, conceptual foundation, scientific and mathematical principles, and operational tools?

In various mathematical, natural, and social scientific literature, it is probably difficult, if not impossible, to find a sentence form that is more generally used to describe various definitions, propositions, theorems, and laws than the sentence form of

---

<sup>1</sup> This work is supported in part by The Ministry of Education, Science, Sports and Culture of Japan under Grant-in-Aid for Exploratory Research No. 09878061 and Grant-in-Aid for Scientific Research (B)

'if ... then ...'. In logic, a sentence in the form of 'if ... then ...' is usually called a **conditional proposition** or simply **conditional** which states that there exists a relationship of sufficient condition between the 'if' part and the 'then' part of the sentence. Mathematical, natural, and social scientists always use conditionals in their descriptions of various definitions, propositions, theorems, and laws to connect a concept, fact, situation or conclusion and its sufficient conditions. Indeed, the major work of almost all scientists is to discover some sufficient condition relations between various phenomena, data, and laws in their research fields.

In general, a conditional must concern two parts which are connected by the connective 'if ... then ...' and called the **antecedent** and the **consequent** of that conditional, respectively. The truth-value of a conditional depends not only on the truth-values of its antecedent and consequent but also more essentially on a necessarily relevant and conditional relation between them. The notion of conditional plays the most essential role in reasoning because any reasoning form must invoke it, and therefore, it is historically always the most important subject studied in logic and is regarded as the heart of logic [Anderson and Belnap, 1975]. When we study and use logic, the notion of conditional may appear in both the object logic (i.e., the logic we are studying) and the meta-logic or observer's logic (i.e., the logic we are using to study the object logic). In the object logic, there usually is a connective to represent the notion of conditional. On the other hand, in the meta-logic, the notion of conditional is usually used to represent a logical consequence relation. From the viewpoint of object logic, there are two classes of conditionals. One class is empirical conditionals and the other class is logical conditionals. For a logic, a conditional is called an **empirical conditional** of the logic if its truth-value, in the sense of that logic, depends on the contents of its antecedent and consequent and therefore cannot be determined only by its abstract form (i.e., from the viewpoint of that logic, the relevant relation between the antecedent and the consequent of that conditional is regarded to be empirical); a conditional is called a **logical conditional** of the logic if its truth-value, in the sense of that logic, depends only on its abstract form but not on the contents of its antecedent and consequent, and therefore, it is considered to be universally true or false (i.e., from the viewpoint of that logic, the relevant relation between the antecedent and the consequent of that conditional is regarded to be logical). A logical conditional that is considered to be universally true, in the sense of that logic, is also called an **entailment** of that logic. Indeed, the most intrinsic difference between various different logic systems is to regard what class of conditionals as entailments, as [Diaz, 1981] pointed out: "The problem in modern logic can best be put as follows: can we give an explanation of those conditionals that represent an entailment relation?"

Any scientific discovery must include an epistemic process to gain knowledge of or to ascertain the existence of some empirical or logical conditionals previously unknown or unrecognized. As an applied and technical science, Computer Science should provide scientists with some epistemic representation, description, reasoning, and computing tools for supporting the scientists to suppose, verify, and then ultimately discover new conditionals in their research fields. However, no programming paradigm in the current computer science focuses its attention on this issue. In order to provide scientists with a computational methodology and computational tools to program their epistemic processes in scientific discovery, we are establishing a novel programming

paradigm, named '*Epistemic Programming*', which regards conditionals as the subject of computing, takes primary epistemic operations as basic operations of computing, and regards epistemic processes as the subject of programming [Cheng, 1996b].

## 2 Fundamental Observations and Assumptions

To define what is scientific discovery is a difficult task which concerning many disciplines such as history of science, philosophy of science, philosophical logic, philosophy of logic, psychology, and cognitive science. Historically, scientific discovery is the most important subject studied in history of science and philosophy of science from very different viewpoints, and just recently, it became the research subject of some cognitive scientists and computer scientists who believe that the process of a scientific discovery can be described and modeled in a normal way and therefore it can be simulated by computer programs automatically [Langley et al., 1987], [Shrager and Langley, 1990], [Simon, 1995].

We present here some fundamental observations and assumptions, which underlie our research direction, on scientific discovery processes and their automation as follows:

(1) Specific knowledge is the power of a scientist: Any scientist who made a scientific discovery must have worked in some particular scientific field and more specifically on some problem in a particular domain within the field. There is no universal scientist who can make scientific discoveries in every field.

(2) Any scientific discovery has an ordered epistemic process: Any scientific discovery must have, among other things, a process that consists of a number of ordered epistemic activities that may be contributed by many scientists in a long duration. Any scientific discovery is neither an event occurs in a moment nor an accumulation of disorderly and disorganized inquiries.

(3) New conditionals are epistemic goals of any scientific discovery: Any scientific discovery process must include an epistemic process to gain knowledge of or to ascertain the existence of some empirical or logical conditionals previously unknown or unrecognized. Finding some new data or some new fact is just an initial step in a scientific discovery but not the scientific discovery itself.

(4) Scientific reasoning is indispensable to any scientific discovery: Any discovery must be unknown or unrecognized before the completion of discovery process. Reasoning is the sole way to draw new conclusions from some premises that are known facts or assumed hypotheses. There is no scientific discovery that does not invoke scientific reasoning.

(5) Scientific reasoning must be justified based on some sound logical criterion: The most intrinsic difference between discovery and proof is that discovery has no explicitly defined target as its goal. Since any epistemic process in any scientific discovery has no explicitly defined target, the sole criterion the epistemic process must act according to is to reason correct conclusions from the premises. It is logic that can underlie valid scientific reasoning.

(6) Scientific reasoning must be relevant: For any correct argument in scientific reasoning as well as our everyday reasoning, the premises of the argument must be in

some way relevant to the conclusion of that argument, and vice versa. A reasoning including some irrelevant arguments cannot be said to be valid in general.

(7) Scientific reasoning must be ampliative: A scientific reasoning is intrinsically different from a scientific proving in that the purpose of reasoning is to find out some facts and conditionals previously unknown or unrecognized, while the purpose of proving is to find out a justification for some fact previously known or assumed. A reasoning in any scientific discovery must be ampliative such that it enlarges or increases the reasoning agent's knowledge in some way.

(8) Scientific reasoning must be paracomplete: Any scientific theory may be incomplete in many ways, i.e., for some sentence 'A' neither it nor its negation can be true in the theory. Therefore, a reasoning in any scientific discovery must be paracomplete such that it does not reason out a sentence even if it cannot reason out the negation of that sentence.

(9) Scientific reasoning must be paraconsistent: Any scientific theory may be inconsistent in many ways, i.e., it may directly or indirectly include some contradiction such that for some sentence 'A' both it and its negation can be true together in the theory. Therefore, a reasoning in any scientific discovery must be paraconsistent such that from a contradiction it does not reason out an arbitrary sentence.

(10) Epistemic activities in any scientific discovery process are distinguishable: Epistemic activities in any scientific discovery process can be distinguished from other activities, e.g., experimental activities, as explicitly described thoughts.

(11) Normal scientific discovery processes are possible: Any scientific discovery process can be described and modeled in a normal way, and therefore, it can be simulated by computer programs automatically.

(12) Specific knowledge is the power of a program: Even if scientific discovery processes can be simulated by computer programs automatically in general, a particular computational process which can certainly perform a particular scientific discovery must take sufficient knowledge specific to the subject under investigation into account. There is no generally organized order of scientific discovery processes that can be applied to every problem in every field.

(13) Any automated scientific discovery process must be valid: Any automated process of scientific discovery must be able to assure us of the truth, in the sense of not only fact but also conditional, of the final result produced by the process if it starts from an epistemic state where all facts, hypotheses, and conditionals are regarded to be true or valid.

(14) Any automated scientific discovery process need an autonomous forward reasoning mechanism: Any backward or refutation deduction system cannot serve as an autonomous reasoning mechanism to form or discover some completely new things. What we need in automating scientific discovery is an autonomous forward reasoning system.

The above fundamental observations and assumptions are significant because they not only underlie our research direction but also distinguish it from others.

### 3 Epistemic Programming

Based on our fundamental observations and assumptions on scientific discovery processes and their automation, in order to provide scientists with a computational methodology and computational tools to program their epistemic processes in scientific discovery, we have to investigate the following research problems from various viewpoints: What logic system can satisfactorily underlie scientific reasoning and epistemic processes in scientific discovery? How is a formal theory, which may be paraconsistent and infinite, organized, represented, and constructed? How is the current belief state of an agent represented? What should be taken as primary epistemic operations of an agent? How are primary epistemic operations by an agent or some agents, which are collaborating on the same subject, on a formal theory organized and ordered as an epistemic process? How can we define that an empirical theorem found in an epistemic process is new and interesting formally? How can we find new and interesting empirical theorems in a formal theory automatically? How can we establish a computational model of epistemic processes in scientific discovery? What programming primitives should be provided for scientists to program their epistemic processes?

The fundamental logic that can underlie epistemic processes in scientific discovery has to satisfy at least two important essential requirements. First, as a general criterion for validity of reasoning, the logic must be able to underlie relevant reasoning as well as truth-preserving reasoning in the sense of conditional. Second, the logic must be able to underlie paracomplete and paraconsistent reasoning; in particular, the principle of Explosion that everything follows from a contradiction cannot be accepted by the logic as a valid principle.

Classical mathematical logic or its various classical conservative extensions and traditional (weak) relevant logics cannot satisfy all the above two essential requirements for the fundamental logic. We have adopted predicate strong relevant logic **EcQ**, which was proposed by the present author in order to establish a satisfactory logic calculus of conditional to underlie relevant reasoning, as the fundamental logic to underlie epistemic processes [Cheng, 2000]. **EcQ** can certainly underlie relevant reasoning as well as truth-preserving reasoning in the sense of conditional better than traditional weak relevant logic as well as classical mathematical logic. **EcQ** is free of not only implicational paradoxes but also conjunction-implicational and disjunction-implicational paradoxes. Therefore, **EcQ** assure us of the relevance and truth of a belief in the sense of conditional in any epistemic state, if all premises in the primary epistemic state are true or valid. Since **EcQ** is paraconsistent, it allows inconsistent belief set and does not require the belief set must be consistent at any time.

We have proposed a strong relevant logic model of epistemic processes in scientific discovery [Cheng, 2000]. We distinguish explicitly known knowledge and implicit consequences (in the sense of strong relevant logic) of the known knowledge, and use a set of sentences (i.e., premises  $P$ ) rather than the deductive closure of that set of sentences (i.e., formal theory  $T_{\text{EcQ}}(P)$ ) to represent the current belief state of an agent. We take epistemic deduction of knowledge, explicitly and implicitly epistemic expansions of knowledge, and explicitly and implicitly epistemic contractions of knowledge as primary epistemic operations, define an epistemic process as a sequence epistemic states of an agent and these primary epistemic operations on the epistemic

states, and define various classes of epistemic processes such as consistent, inconsistent, paraconsistent, monotonic, and nonmonotonic epistemic processes. We model a belief revision as a process (i.e., models a belief revision as an epistemic process which consists of a sequence of primary epistemic operations) rather than a function. Some reasoning form such as simple induction and simple abduction can also be defined in terms of epistemic operations.

We only define an epistemic process as a sequence of epistemic states and primary epistemic operations on the epistemic states but say nothing about what order the sequence should have. As we mentioned in Section 2, a fundamental conjecture of the present author is that the order of epistemic process in any scientific discovery is field, domain, and problem dependent, there is no generally organized order of scientific discovery processes that can be applied to every problem in every fields. It is the working scientist who knows the best way to make scientific discovery in his / her particular research domain, and therefore, it is the task of the working scientist that determines and organizes the order of his / her epistemic process. What should we do is to provide scientists with some way and tools to aid them in their work. The way and tools we want to provide are a novel programming paradigm, Epistemic Programming, and computational tools to support the programming paradigm.

An *epistemic program* is a sequence of instructions such that for a primary epistemic state given as the input, an execution of the instructions produces an epistemic process where every primary epistemic operation corresponds to some instruction and every epistemic state is the result of the execution of the instruction, in particular, terminal epistemic state is also called the result of the execution of the program. We say that an epistemic program *replayed* a scientific discovery if the execution of the program produced the same result as that discovered by the original discoverer in history when as input the program takes the same initial conditions as that the original discoverer did. We say that an epistemic program *created* or *made* a scientific discovery if the execution of the program produced a result that is new, important, and interesting to the scientists working on the particular domain under investigation. From the viewpoint of scientific discovery, we are particularly interested in establishing an epistemic programming methodology to develop epistemic programs that can certainly create or make scientific discoveries.

From the viewpoint of computation, a key point to Epistemic Programming is that we have to develop some mechanism to find new, important, and interesting empirical theorems in a formal theory automatically according to an epistemic program. The present author has proposed a relevant logic approach to automated theorem finding in scientific discovery [Cheng, 1995] and developed an automated forward deduction system for general-purpose entailment calculus, named 'EnCal', as a fundamental tool to support automated theorem finding in scientific discovery [Cheng, 1996a].

#### 4 Concluding Remarks

Many works on this new research direction of Epistemic Programming are still in their early stages and some problems are still completely open until now. We are constructing a computing model for epistemic programs and designing an epistemic programming language and its system. The ultimate goal of our research project is to

provide scientists with a computational methodology and computational tools such that they can program their creatively epistemic processes in scientific discovery, and therefore, to make scientific discovery become a “science” and/or an “engineering”.

### References

- [Anderson and Belnap, 1975] A. R. Anderson, A. R. and Belnap Jr., N. D. (1975). *Entailment: The Logic of Relevance and Necessity.*, Vol. I. Princeton University Press.
- [Anderson, Belnap, and Dunn, 1992] A. R. Anderson, A. R., Belnap Jr., N. D. and Dunn, J. M. (1992). *Entailment: The Logic of Relevance and Necessity.*, Vol. II. Princeton University Press.
- [Cheng, 1995] Cheng, J. (1995). *Entailment Calculus as the Logical Basis of Automated Theorem Finding in Scientific Discovery.* In *Systematic Methods of Scientific Discovery – Papers from the 1995 Spring Symposium*, Technical Report SS-95-03, pages 105-110, AAAI Press.
- [Cheng, 1996a] Cheng, J. (1996). *EnCal: An Automated Forward Deduction System for General-Purpose Entailment Calculus.* In Terashima, N. and Altman, E. (Eds.), *Advanced IT Tools, Proc. IFIP World Conference on Advanced IT Tools, IFIP 96 – 14th World Computer Congress*, pages 507-514, CHAPMAN & HALL.
- [Cheng, 1996b] Cheng, J. (1996). *Epistemic Programming – Toward a New Programming Paradigm for Scientific Discovery.* In *Proc. 1996 IEEE-SMC Annual International Conference on Systems, Man, and Cybernetics*, Vol. 3, pages 2400-2406.
- [Cheng, 2000] Cheng, J. (2000). *A Strong Relevant Logic Model of Epistemic Processes in Scientific Discovery.* In Kawaguchi, E., Kangassalo, H., Hamid, I. A. and Jaakkla H. (Eds.), *Information Modelling and Knowledge Bases*, to appear, IOS Press. (An early version appeared in *Proc. 9th European-Japanese Conference on Information Modelling and Knowledge Bases*, pages 179-198, 1999)
- [Diaz, 1981] Diaz, M. R. (1981). *Topics in the Logic of Relevance.* Philosophia Verlag.
- [Langley et al., 1987] Langley, P., Simon, H. A., Bradshaw, G. L. and Zytkow, J. M. (1987). *Scientific Discovery – Computational Explorations of the Creative Processes.* MIT Press.
- [Shrager and Langley, 1990] Shrager, J. and Langley, P. (1990). *Computational Approaches to Scientific Discovery.* In Shrager, J. and Langley, P. (Eds.), *Computational Models of Scientific Discovery and Theory Formation*, pages 1-25, Morgan Kaufmann.
- [Simon, 1995] Simon, H. A. (1995). *What is a Systematic Method of Scientific Discovery?* In *Systematic Methods of Scientific Discovery – Papers from the 1995 Spring Symposium*, Technical Report SS-95-03, pages 1-2, AAAI Press.





# VISUAL LANGUAGES FOR LINEAR PROGRAMMING

Liubov Dombrovskaja and Miguel Nussbaum<sup>1</sup>

Departamento de Informática, Universidad Técnica Federico Santa María,  
Casilla 110-V, Valparaíso, Chile,  
liuba@inf.utfsm.cl

Departamento de Ciencia de la Computación, Pontificia Universidad Católica de Chile,  
Casilla 306, Santiago 22, Chile  
mn@ing.puc.cl

## Abstract:

*The development of the graphic languages for modelling of linear problems has began, when the graphic capacities of the computers became widely used, This research presents the state of art in visual modelling languages and also makes an analysis on the effectiveness of their support of the modelling process. The graphic representation seems to offer potential for externalising those “objects of thought” allowing a more direct map among the internal and external representations. The graphic representation does not guarantee the clarity for itself, it depends on its secondary notation that means relationship between the perceptible clues and the important information.*

**Keywords:** modelling language, visual language, linear programming

## 1 Introduction

The development of modelling languages for Linear Programming (LP) has followed the computers' evolution, but it has been slower than the development of the algorithms. First languages were computational representations of the mathematical model that the solver could read and process; that is, these languages are oriented to solvers [Fourer, 1983]. The development of the analyst's oriented languages, such as algebraic languages, allowed more efficient formulation and maintenance of linear models. With the progress of bigger and faster computers, the size of the problems manageable with LP has grown. Also, the visual capacities of the computers allowed developing graphic languages that represent the model in visual form instead of textual notation.

The construction of modelling languages is constrained by the limited cognitive capacities of human beings and the complexity of modelling process leading to the need of extensive training of the analyst. Although all LP languages are equivalent due to the existence of transformations from one language to the other, they are essentially different from the point of view of the quantity of work, ability and understanding required from the analyst. On the other hand, expert analysts are highly trained people. They are able to learn how to use any representation and any new software to solve problems. The question is how to make their work easier. If we have the computational technology to build friendly tools, the question becomes more practical: what representation is more useful to analysts?

---

<sup>1</sup> The authors are grateful to Chilean National Science Foundation (FONDECYT) for its partial support in this research under grant 2980010

## 2 Visual Modelling Languages

The authors of [Murphy *et al.*, 1992] concern about the impact of the language on the effectiveness of the modelling process in six dimensions (two of them are out of scope of this paper):

**Declarativity:** the definition of the problem as it is, the opposite to the construction of the declaration of the model.

**Work intensity:** the required quantity of the user's detailed work that is the function of the complexity of the representation.

**Concreteness:** the analogies with the objects of the real world and relations among them, the opposite to the specification of the abstract objects and relationships.

**Conceptual Modularity:** the strategies of the problem's resolution that reduce the cognitive complexity. First, the representation has to support hierarchical abstraction, in which general concepts capture the essential details of multiple instances. Second, the representation has to support a decomposition top-down. Third, the representation should facilitate the bottom-up strategy of problem modelling that involves the reuse of previously defined models and model's fragments. Finally, users can define small pieces and allow the computer to infer the non-defined elements of the model to build the complete model. The latter concept is referred as the piece-meal approach.

An existing variety of visual languages can be classified by the objects used for model construction into a modelling scheme: algebraic, based on entity-relationship diagram, graph-based, etc. This section shows how different visual languages support the modelling process.

### 2.1 Algebraic languages

The development of the algebraic languages has been the great advance in the OR. In the algebraic languages the model is seen as a collection of variables, related by the system of linear constraints with the objective to minimise or to maximise a linear form. A graphic notation of the algebraic representation has been developed by Collaud [Collaud, 1998]. The basic elements of this representation are the components of the algebraic model, the connectors and sub-model's elements that allow visualising them as a single component. This language provides the view of the general structure of the model, the hierarchical decomposition and the composition bottom-up. It is non-procedural and concise. Algebra includes abstract concepts with little connection to the real world, so the language is not concrete. The work intensity is improved in comparison with the textual algebraic languages, because of the clarity of the structure of the model. The conceptual modularity has certain support.

### 2.2 Structured Modelling

The principles of the structured modelling (SM) have been developed by Geoffrion [Geoffrion, 1987] as a formal frame for the development of tools. There are three structures defined for each model: an elementary, generic and modular structures. The elementary structure is based on primitive and compound entities, attributes, functions and tests. The generic structure tries to capture the natural grouping of the elements, while the modular structure tries to organise the generic structure hierarchically based on the semantics of the problem. Due to the hierarchy of the modular structure, SM

allows graphic implementations, such as MEL [Chari and Sen, 1996]. The genus graph is drawn with difficulty for fairly big problems, what makes difficult to discern the physical structure of the model. In terms of the concreteness, the declaration of the model and the graphs are quite abstract [Murphy *et al.*, 1992].

### 2.3 Graph Based Modelling

The graphs are nets of activities with inputs and outputs in which the nodes represent restrictions and the arcs represent flow of resources. The contribution of the studies [Jones, 1990], [Jones, 1995] is to apply the graph grammars to the modelling. Basically, the model is represented as a graph, nodes and arcs of which are divided into different types with the associated values or attributes. The graph grammars consist on a group of operations that can be applied to a graph, what forces the definition of graphs consistent to the desired type. The implementation of graph grammars is Networks [Jones, 1990] that is a graph editor, in which the operations are also represented as graphs.

The graph is abstract in the sense that the nodes and arcs of the graphs correspond directly to the algebraic objects (lines and columns of the LP tableau) and only accidentally to the physical objects. The graphs can be quite complicated to draw what implies the use of some aggregation techniques to simplify the problem for the user. The conceptual modularity is provided only through the hierarchical abstraction.

### 2.4 Block-schematic languages

The block-schematic scheme sees the model as processes with their inputs and outputs, which is represented as a table with classes at the beginning of columns and names on the side. While the names in the intersections of columns and rows refer to a non-zero, non-one element of the LP tableau, the ones represent the connection with other blocks of the model.

In LPFORM icons are used to represent graphically the blocks of the elements of a block-schematic view of linear problem [Ma *et al.*, 1989], [Ma *et al.*, 1996]. The model in LPFORM is seen as a diagram, in which the blocks represent the sub-models, and the connections among them represent the flow between the blocks. So the blocks are an abstract collection of activities and restrictions that cannot be represented as nets. Because of the analogies with the real objects, the icons as a specification of sub-models are an efficient method to specify linear problems of great scale. Although it seems that this representation lacks necessary level of details to understand the problem, since it is not seen what attributes are involved in the relationship. By definition, the LPFORM is relatively concrete and offers the complete conceptual modularity. The LPFORM representation is more efficient for LP with the net structure.

### 2.5 Languages based on the Entity-Relationship Diagram

The proliferation of databases in organisations and the extensive use of these data in the mathematical models are the reasons to expand the entity-relationship diagram to the linear problems under the supposition that it is "natural" to integrate models and data with tools to manage both. A diagram notation for the LP models offers a unified notation for the definition of the model and the manipulation of the data [Choobineh, 1991]. The disadvantages are the same of the algebraic languages, the most important is being abstract and not concrete, and it does not support the conceptual modularity.

## 2.6 Knowledge-Based Languages

Artificial Intelligence tries to imitate the human reasoning in computing systems. Although, words like expert systems and knowledge-based systems seem to be too much misused, the importance of these efforts remains. PDM is a textual notation for the production, distribution and inventory problems [Krishnan 1991], and MODFORM [Raghunathan, 1993] is a language for the domain of planning and production problems. The PDM has been also enlarged toward the domain of linear problems with a graphic interface NetworksPM [Jones, 1994]. A person not necessarily having the knowledge in OR specifies the model graphically in terms of sets, relationships and functions. From this specification, the mathematical model is inferred automatically, building the appropriate graph. The system manages both models, declarative and mathematical in the same way, in form of graphs with attributes. In a way, the use of graphs diminishes the concreteness of this language.

Another example of this representation type is MGPL [Dombrovskaja *et al.*, 1998]. The basic constructors of this language are entities, links and relationships. An entity is visualised as an icon and encapsulates the knowledge on the real world object. The attributes of the entity represented by links allow the entities to be related with others. The MGPL infers the algebraic representation of the model from the graphic definition.

Basically, the knowledge-based languages are oriented to the decision-makers, since they infer the mathematical model starting from the problem at hand. So, these languages are declarative and concrete. Also, they support the conceptual modularity through reuse of existent models, although they do not contain top-down decomposition. Probably, they are not intensive in work.

## 2.7 Multiple Representations

The choice of the representation scheme depends on the problem, as well as on the particular user involved. Students, engineers, decision-makers and the experts in IO have different necessities and they may want to use multiple representations for the same model during the course of its development or use. The study [Greenberg and Murphy, 1995] shows that among the algebraic, block-schematic, based on graphs and structured modelling schemes, none possesses enough information to build automatically another representation for some linear problems. This leads to the definition of a high level frame that supports an multiple representations architecture.

The advice of limiting the availability of the options goes against the current tendency in the software development under the discovery that this type of flexibility can be more harmful than profitable for the analyst [Vessey and Galetta, 1991]. We should concentrate on determining the characteristics of the tasks that analysts performs, and to support those tasks with the appropriate representations and tools.

## 3 Conclusions

Although the representations of the linear problems discussed earlier are equivalent due to the existence of the representation's transformations to the other one, they are essentially different from the point of view of the quantity of work, ability and understanding required from the user. As you can appreciate in the previous chapter,

none of the discussed representation schemes possesses all the characteristics that reduce the cognitive complexity.

The need of visual graphic languages is supported by the heuristic nature of the process of problem resolution [Srinivasan and Te'eni, 1995], which is manifested in the need to visualise the general structure of the model and to make the details accessible in order to change the level of abstraction. Although, any graphic representation is better simply because it is graphic. The graphic representation doesn't guarantee the clarity by itself [Petre, 1995]. Good graphic depends on the secondary notation that means relationship between the perceptible clues and the important information. It is suggested that if the relationships are visually near, it is easier to derive a mental model of the structure of the system from the graphic representation than from a textual representation.

Cognitive capacity of human beings is limited, and the analyst needs to see the general structure of the model, as well as the details. Many details hinder the understanding of the general structure, while few details are not enough.

An icon is a powerful tool for the analogy with the real world object, which has been used in LPFORM and MGPL. This power exploited by Microsoft and Apple is supported by the phenomena of mental imaging, which is the mental creation and manipulation of images related to the concept of thought [Conway and Wilson, 1988].

As it has already been mentioned, the conceptual modularity of the problems representation reduces the cognitive complexity through hierarchical abstraction, top-down decomposition, bottom-up composition and piece - meal approach. These requirements are strongly leaning on the evidence found in the studies [Srinivasan and Te'eni, 1995] and [Willemain, 1995].

Studies in Cognitive Psychology reveal that the human efficiency depends on the representation of the problem. If there is the correspondence among the problem to solve and its representation – cognitive fit – the problem is solved quicker and more effectively that is related with the intensity of the work [Vessey and Galetta, 1991]. So, there is a need of experimentation with a representation in order to determine which one corresponds to the mental model and modelling process of the analyst. The visual language is to be designed and tested carefully in order to determine the ease of use and appropriateness for the analyst and the decision-maker, so the complete modelling process can be improved.

## References

- [Chari and Sen, 1996] Chari K. and Sen T.K. (1996) An integrated modeling system for structured modeling using model graphs, Working paper, Virginia Polytechnical Institute & State University, Blacksburg, VA, USA
- [Choobineh, 1991] Choobineh J. (1991) A diagramming technique for representation of linear models. *OMEGA International Journal of Management Science*, 19(1), 43-51
- [Collaud, 1998] Collaud G. (1998) A hypertext environment for linear optimisation. *Decision Support Systems*, 23, 111-131
- [Conway and Wilson, 1988] Conway T. and Wilson M. (1988) Psychological Studies of Knowledge Representation, *Approaches to Knowledge Representation: An*

- Introduction, Eds. Ringland G.A. and Duce D.A., Research Studies Press Ltd. and John Wiley & Sons Inc., England
- [Dombrovskaja *et al.*, 1998] Dombrovskaja L., Rodríguez P. and Nussbaum M. (1998) Knowledge Based Modeling Tool for Linear Programming, Computers and Operations Research, 25(5), 379-388
- [Fourer, 1983] Fourer, R. (1983) Modeling languages versus matrix generators for linear programming. ACM Transaction on Mathematical Software, 9, 143-183.
- [Geoffrion, 1987] Geoffrion A. (1987) Introduction to structured modeling. Management Science, 33, 547-588.
- [Greenberg and Murphy, 1992] Greenberg H.J. and Murphy F.H. (1992) A comparison of mathematical modeling systems. Annals of Operations Research, 38 (1-4), 177-238.
- [Greenberg, 1993] Greenberg H.J. (1993) Modeling by object-driven linear elemental relations: a user's guide to MODLER, Kluwer Academic Publishers, Boston, USA
- [Greenberg and Murphy, 1995] Greenberg H.J. and Murphy F.H. (1995) Views of mathematical programming models and their instances, Decision Support Systems, 13, 3-34
- [Jones, 1990] Jones, C.V. (1990) An introduction to graph-based systems, part 1: overview. ORSA Journal on Computing, 2, 136-151.
- [Jones and Krishnan, 1994] Jones C.V. and Krishnan R. (1994) A Visual, Syntax-Directed Environment for Automated Model Development. Working paper, School of Business Administration, University of Washington.
- [Jones, 1995] Jones, C.V. (1995) Developments in graph-based modeling for decision support. Decision Support Systems, 13, 61-74
- [Krishnan, 1991] Krishnan, R. (1991) PDM: a knowledge-based tool for model construction. Decision Support Systems, 7, 301-314.
- [Ma *et al.*, 1989] Ma, P., Murphy, F.H. and Stohr, E.A. (1989) A graphic interface for linear programming. Communications of the ACM, 32, 996-1012.
- [Ma *et al.*, 1996] Ma P.-C., Murphy F.H. and Stohr E.A. (1996) An implementation of LPFORM. INFORMS Journal on Computing, 8(4), 383-401.
- [Murphy *et al.*, 1992] Murphy F.H., Stohr E.A. and Asthana A. (1992) Representation schemes for linear programming models, Management Science, 38(7), 964-991.
- [Petre, 1995] Petre M., (1995) Why looking is not always seeing: readership skills and graphical programming. Communications of the ACM, Vol. 38 (6), pp. 33-44
- [Raghunathan, 1993] Raghunathan, S., Krishnan, R. and May J.H. (1993) MODFORM: A knowledge-based tool to support the modeling process. Information Systems Research, Vol. 4(4), 331-358.
- [Srinivasan and Te'eni, 1995] Srinivasan A. and Te'eni D. (1995) Modeling as constrained problem solving: an empirical study of the data modeling process. Management Science, 41(3), 419-434

- 
- [Vessey and Galetta, 1991] Vessey I. and Galetta D. (1991) An empirical study of information acquisition. *Information Systems Research*, 2(1), 63-83.
- [Willemain, 1995] Willemain T.R. (1995) Model formulation: what experts think about and when. *Operations Research*, 43, 916-932





# INDUSTRIAL APPLICATIONS OF BIOMIMETIC ADAPTIVE SYSTEMS

Jean-Yves Donnat<sup>1,3</sup>, Nick Jakobi<sup>1,3</sup>, Jérôme Kodjabachian<sup>1,3</sup>, Christophe Meyer<sup>1,2</sup>,  
Jean-Arcady Meyer<sup>1,3</sup>, Olivier Trullier<sup>1</sup>

<sup>1</sup> Mathématiques Appliqués SA (MASA)  
24 Boulevard de l'Hôpital, 75005 Paris, France  
[first\_name.last\_name]@animaths.com

<sup>2</sup> ACASA Lip6  
8 rue du Capitaine Scott, 75015 Paris, France  
[first\_name.last\_name]@lip6.fr

<sup>3</sup> AnimatLab Lip6  
8 rue du Capitaine Scott, 75015 Paris, France  
[first\_name.last\_name]@lip6.fr

## Abstract:

*This paper describes how some mechanisms underlying adaptive behaviors in animals and men may be employed in artificial systems and in industrial applications. Such mechanisms may range from simple reflexes to highly cognitive processes. In particular, the paper describes how current knowledge about motivational systems in animals may be used to build a behavioral engine that is used to animate video-games characters. It also shows how a pedagogical engine capable of modeling human cognitive capacities in a given learning task may be applied to the automatic generation of exercises that fit a child's current knowledge and needs. Finally, the paper suggests how it is possible to automatically generate neural controllers for satellites or walking robots, which may reconfigure themselves to cope with sudden environmental changes or with internal breakdowns.*

**Keywords:** Adaptive behavior, reflexes, cognitive processes

## 1 Introduction

Animals and men are able to survive in changing and more or less unpredictable environments, and numerous research efforts are aimed at unraveling the highly efficient adaptive mechanisms they use for such purpose. When any such mechanism begins to be elucidated, it is usually quickly incorporated in a variety of industrial applications, either because of its life-like flavor or because of its mere efficiency.

In particular, numerous biomimetic mechanisms generating adaptive behaviors have been described and exploited in the literature concerning so-called *animats* (Meyer and Wilson, 1991; Meyer et al, 1993; Cliff et al., 1994; Maes et al., 1996; Pfeiffer et al., 1998). An animat is an artificial animal or a real robot that is equipped with sensors, with actuators and with a motivational system that selects which action to perform, in the service of which goal. Such motivational systems may call upon simple stimulus-response connections – that directly link the animat's sensors to its actuators - or they

may involve more cognitive mechanisms with, for instance, memory, planning, anticipation, or modeling capacities. They may improve over time through individual learning, or through the evolution of successive generations (Meyer, 1997).

Although the animat literature is mostly devoted to fundamental issues – e.g., understanding how human cognition evolved from basic adaptive behaviors in its animal ancestors – this article describes some industrial applications of animat research that are currently developed at MASA, a French start-up company devoted to Adaptive Objects Technology. These applications concern the development of two software engines: the DirectIA® SDK (Direct Intelligent Application) and the Evolver Platform that will be described in turn.

## 2 DirectIA®

DirectIA® is a variety of C++ libraries for Windows platforms that may be used to endow an animat or autonomous agent with a motivational system that generates behaviors closely resembling those of animals and humans. Such agents may be simple reactive agents or very sophisticated characters. In the latter case, they are able to learn, to elaborate plans, to build models of the agents they interact with and to anticipate the behaviors of these agents. They are even able to communicate. Finally, they may be incorporated into very large populations.

DirectIA® is designed to be used in :

- Video games, on-line games and virtual worlds
- War games and role-playing games
- Complex system simulations (Ecosystems, human societies...)
- Animation of assistants, avatars and pet companions
- Interactive animated stories, entertainment game software.

In particular, DirectIA® has been used to develop Peacemakers (Figure 1), a proprietary wargame in real-time 3D. This software addresses all the weaknesses found in traditional real time strategy games: deterministic gaming from the PC opponent, absence of autonomy and bad coordination amongst units, no adaptation to the user's skill, repetitive game concept.

Likewise, DirectIA® is exploited in a variety of educational softwares that use current knowledge in psychology to model the skills a child needs to perform a given task. This allows the automatic construction of a model of the child that represents an evaluation of the level of his/her skills. In turn, the model allows to personalise the software to each particular child and to enhance its educational functionalities.

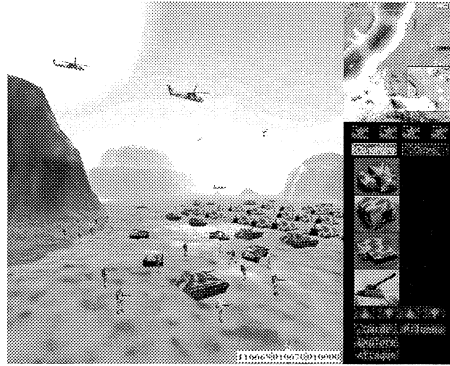


Figure 1

In the case of Figure 2, for instance, the software assumes that a child knows that a mouse is naturally motivated to get to a piece of cheese or to hide in its nest. It also assumes that the child knows that the mouse is not able to see an object from which it is separated by a sharp corner. In order to test the validity of such assumptions, it devises a solution that the child could imagine if he/she were asked to attract the mouse to the nest by way of disposing of a piece of cheese somewhere in the environment.

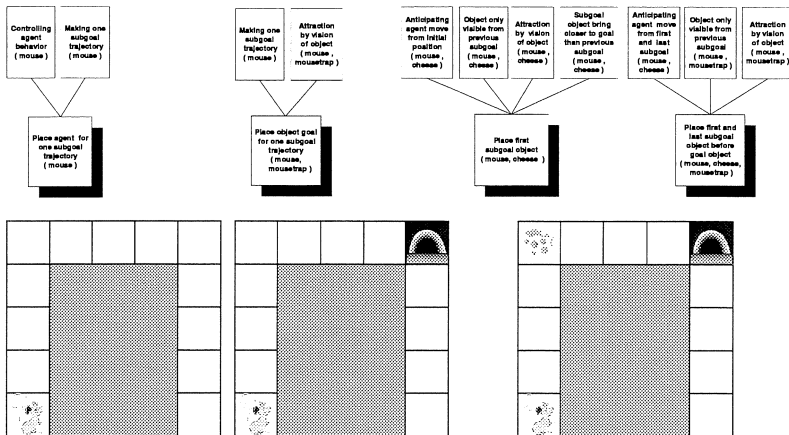


Figure 2

If the solution proposed by the child turns out to be incorrect, as in Figure 3, the software is able to infer that the child got the idea of using the cheese to bring the mouse closer to the nest, but that he/she didn't realize that the mouse would still not see the nest from the place where the cheese has been deposited. Then, the software can devise another experiment to help the child correct his faulty knowledge.

Finally, DirectIA® makes possible the development of on-board architectures for a new generation of robot toys currently under development. Like the software just mentioned, the toys will be able to model and anticipate the behavior of a child in real

time so that the robot's interest for the child, and thus its educational capabilities, will be optimized.

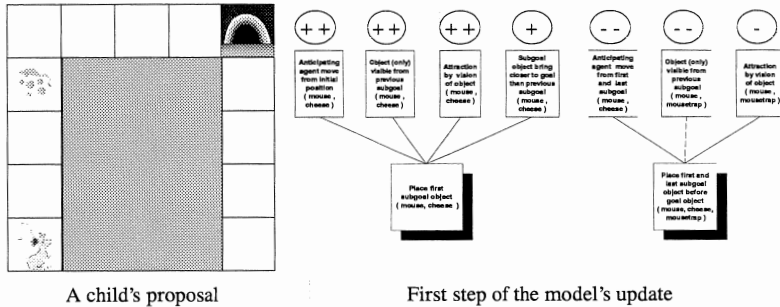


Figure 3

### 3 Evolver platform

In the natural world, complex adaptive control architectures arose through processes of variation, selection and evolution. Over successive generations, primitive architectures gave way to those that were more complex and better suited to their survival needs. As a result, such architectures are robust, dynamic and adaptive.

The Evolver platform implements an artificial selection process that automatically designs and optimises any structure that can be described as a directed graph. Such a process doesn't need to know *how* to solve a problem: it just needs a way of selecting good solutions from bad. Moreover, it may remain active in the background while the structure it generates is at work, thus making it possible to *dynamically adapt* to new situations and to find solutions to new problems as and when it is needed.

Objects such as robots and unmanned vehicles equipped with controllers designed by the Evolver platform are robust, modular and adaptive. The same robot, originally programmed to do no more than walk for example, can rapidly acquire new capacities (vision, navigation etc.) without having to modify its walking controller, by the simple addition and evolution of new modules. The sudden breakdown of sensors or motors may be handled automatically by a reconfiguration of the architecture in such a way that the whole will form a practically Unbreakable Machine.

Figure 4 shows a hexapod robot (from Applied AI Systems, Inc.(c)) and part of a neural controller that has been automatically designed through the use of the Evolver platform. Such a controller allows the robot to walk according to an efficient tripod gait, and to avoid obstacles. Current work aims at evolving an additional module that will be responsible for light-following.

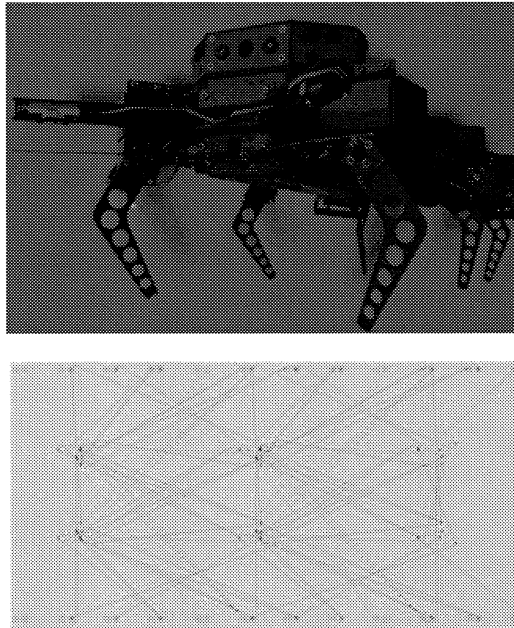


Figure 4

Other applications of the Evolver platform concern the on-line control of a satellite and the automatic recovery of its nominal trajectory in case of breakdowns in one or several of its motors. Scheduling problems afford other important applications of the Evolver platform, notably in the areas of resource allocation, time-tabling and job-shop scheduling.

#### 4 Conclusion

Adaptive biomimetic processes already lead to a variety of applications, notably in the fields of video-games, of robotics, of educational software and of industrial process optimization. In our opinion, this new artificial life leading edge technology opens the way for the introduction of adaptive behaviors to objects of the future.

#### References

- [Cliff et al., 1994] Cliff, D., Husbands, P., Meyer, J.A. et Wilson, S. From Animals to Animats 3. Proceedings of the Third International Conference on Simulation of Adaptive Behavior. The MIT Press/Bradford Books. 1994.
- [Maes et al., 1996] Maes, P., Mataric, M., Meyer, J.A., Pollack, J. and Wilson, S.W. (Eds.). From Animals to Animats 4. Proceedings of the Fourth International Conference on Simulation of Adaptive Behavior. The MIT Press/Bradford Books. 1996.

- [Meyer, 1997] Meyer, J.A. From Natural to Artificial Life: Biomimetic Mechanisms in Animat Designs. *Robotics and Autonomous Systems*. 1997, 22, 3-21.
- [Meyer et al., 1993] Meyer, J.A., Roitblat, H. et Wilson, S. From Animals to Animats 2. Proceedings of the Second International Conference on Simulation of Adaptive Behavior. The MIT Press/Bradford Books. 1993.
- [Meyer and Wilson, 1991] Meyer, J.A., et Wilson, S. From Animals to Animats. Proceedings of the First International Conference on Simulation of Adaptive Behavior. The MIT Press/Bradford Books. 1991.
- [Pfeiffer et al., 1998] Pfeiffer, R., Blumberg, B., Meyer, J.A. and Wilson, S.W. (Eds.). From Animals to Animats 5. Proceedings of the Fifth International Conference on Simulation of Adaptive Behavior. The MIT Press/Bradford Books. 1998.

## A PRIMER ON MEDIA THEORY

Jean-Claude Falmagne

University of California, Irvine

The family of all semiorders on a finite set has an interesting property: any semiorder  $S$  can be joined to any other semiorder  $S'$  by successively adding or removing pairs of elements, without ever leaving the family. Moreover, the minimal number of such steps is exactly equal to the (symmetric difference) distance between  $S$  and  $S'$ . Various other binary relations share that property (e.g. partial orders, interval orders, biorders; cf. [Doignon and Falmagne, 1997]; for definitions and study of these concepts, see [Luce, 1956; Monjardet, 1978; Roberts, 1979 ; Fishburn, 1985; Trotter, 1992]. A similar kind of property is true for the family of linear orders and for some families of weak orders [Falmagne, 1996; Falmagne *et al.*, 1997].

Gathering all these examples and others in an abstract concept leads to define a particular type of semigroup of transformations on a finite set of states [Falmagne, 1997; Falmagne and Ovchinnikov, 1999]. We introduce some terminology inspired by the primary application of this concept to date, which is to the evolution of individual preferences under the influence of the flow of information from the media. The transformations are called 'tokens' (of information), and any composition of tokens is a 'message.' We call 'effective' for a state  $S$  a token  $t$  such that  $St$  is distinct from  $S$ . A message is 'stepwise effective' for a state if all its tokens are (successively) effective. A 'reverse' of a token is another token undoing its action, that is,  $t'$  is a reverse of  $t$  if for all distinct states  $S, T$ , we have  $St = T$  iff  $Tt' = S$ . A message is said to be 'consistent' if it does not contain both a token and one of its reverses, and 'straight' if it is both stepwise effective and consistent. We state four axioms informally here.

- [1] Each token has a unique reverse.
- [2] The semigroup is transitive: any state can be transformed into any other state by some consistent message.
- [3] Any stepwise effective message  $m$  transforming a state into itself is 'vacuous', that is, its set of tokens can be partitioned into pairs of tokens  $t, t'$  such that one is a reverse of the other.
- [4] Two effective and consistent messages  $m, m'$  producing the same state are jointly consistent; that is,  $mm'$  is consistent.

Any semigroup satisfying these axioms is called a 'medium.' We mention a few illustrative results.

- Axioms [1]-[4] are independent.
- A token is never a one-to-one function.

The 'content' of a state  $S$  is the set of all tokens appearing in any straight message producing  $S$ .

- For any state  $S$  and any token  $t$ , either  $t$  or its reverse belongs to the content of  $S$ . Accordingly, all the contents of states have the same number of tokens, which is equal to half of the total set of tokens.

We also introduce the concepts of 'orientation' and of 'closure' for a medium and derive various consequences.

Applications of media theory are many and diverse. The set of all semiorders (resp. partial orders, interval orders, biorders) on a finite set provides an example of an oriented medium.

An example of a non oriented medium in convex analysis is as follows. Any finite collection  $C$  of hyperplanes in a Euclidean space induces a partition of the space, one class of which is the union of  $C$ , and the other classes are the open, convex polyhedral regions bounded by hyperplanes in  $C$ . (Some, or all, of these regions may be unbounded.) We regard each polyhedral region as a state. From one state  $S$ , it is always possible to move to another adjacent state by crossing some hyperplane including a facet of  $S$ . (We suppose that a single hyperplane is crossed at one time.) We can formalize these crossings in terms of transformations of the states. To every hyperplane corresponds two ordered pairs  $(H, H')$  and  $(H', H)$  of open half spaces  $H$  and  $H'$  separated by the hyperplane. These ordered pairs generate two transformations  $t(H, H')$  and  $t(H', H)$  of the states. Applying  $t(H, H')$  to some state  $S$  results in some other state  $V$  if  $S$  is included in  $H$ ,  $V$  is included in  $H'$  and the polyhedral regions  $S$  and  $V$  share a facet which is included in the hyperplane separating  $H$  and  $H'$ ; otherwise, the application of  $t(H, H')$  to  $S$  does not change  $S$ . Clearly, the application of  $t(H', H)$  reverses the action of  $t(H, H')$  whenever the latter was effective in modifying the state. Note however, that  $t(H, H')$  and  $t(H', H)$  are not mutual inverses. It is easily verified that the semigroup of transformations  $t(H, H')$  satisfies Axioms [1]-[4].

These theoretical results can be applied, in a suitable stochastic framework (where the set of states of the medium is the state space of a random walk), to the statistical analysis of opinion polls (cf. [Falmagne *et al.*, 1997]). An application to polling data concerning the 1992 US Presidential Election is described by [Regenwetter *et al.*, 1999].

## References

- [Doignon and Falmagne, 1997] DOIGNON, J.-P. and FALMAGNE, J.-Cl. Well-graded Families of Relations. *Discrete Mathematics*, 1997, Vol.173, pages 35-44.
- [Falmagne, 1996] FALMAGNE, J.-Cl. A stochastic theory for the emergence and the evolution of preference structures. *Mathematical Social Sciences*, 1996, Vol. 31, pages 63-84
- [Falmagne, 1997] FALMAGNE, J.-Cl. Stochastic Token Theory. *Journal of Mathematical Psychology*, 1997, Vol 41(2), pages 129-143.
- [Falmagne *et al.*, 1997] FALMAGNE, J.-Cl., REGENWETTER, and GROFMAN, B. A Stochastic Model for the Evolution of Preferences. In *Choice, Decision and Measurement: Essays in Honor of R. Duncan Luce* (Ed. A.A.J. Marley), 1997, Erlbaum: Mahwah, NJ.
- [Falmagne and Ovchinnikov, To appear] FALMAGNE, J.-Cl. and OVCHINNIKOV, S. Media Theory. *Discrete Applied Mathematics*. To appear



- [Fishburn, 1985] FISHBURN, P. C. Interval Orders and Interval Graphs, 1985. Wiley: New York.
- [Luce, 1956] LUCE, R. D. Semiorders and a theory of utility discrimination. *Econometrica*, 1956, Vol. 24, pages 178-191.
- [Monjardet, 1978] MONJARDET, B. Axiomatiques et Proprietes des Quasi-ordres. *Mathematiques et Sciences Humaines*, 1978, Vol. 16(63), pages 51-82.
- [Regenwetter *et al.*, 1999] REGENWETTER, M., FALMAGNE, J.-Cl. and GROFMAN, B. A Stochastic Model of Preferences Change and its Application *Psychological Review*, 1999, Vol. 106, pages 362-384.
- [Roberts, 1979] ROBERTS, F.S. Measurement Theory. In Gian-Carlo Rota (Ed.), *Encyclopaedia of mathematics and its applications*, Vol. 7. Mathematics and the social sciences, 1979, Addison-Wesley: Reading, Ma.
- [Trotter, 1992] TROTTER, W. T. *Combinatorics and Partially Ordered Sets: Dimension Theory*, 1992, The Johns Hopkins University Press: Baltimore, Maryland.



# MODELING HUMAN COGNITION WITH ARTIFICIAL SYSTEMS: SOME METHODOLOGICAL CONSIDERATIONS

Jean-Daniel Kant

LIP6 (Laboratoire Informatique Paris 6)  
Université Paris 6, Case 169, 4 Place Jussieu, 75252 Paris Cedex 05  
Jean-Daniel.Kant@lip6.fr

## Abstract:

*We present here some methodological considerations about the modeling of human cognition. First, we discuss the cognitive plausibility of the rationalist perspective which still prevails in Artificial Intelligence and Cognitive Science. Second, we follow the framework of information processing systems and introduce the psychomimetism approach that helps to assess the cognitive plausibility of a cognitive model. Third, we show that both classical artificial intelligence approaches (e.g., expert and knowledge-based systems) and connectionism are not satisfactory to model high-level human cognition because they do not account for the situatedness of cognition. To tackle such an issue, we propose a methodology based on neuromimetic (i.e. biologically-inspired) neural networks within the framework of computational neuroscience.*

**Keywords:** cognitive modeling, cognitive plausibility, situated cognition, computational neuroscience, artificial neural networks

## 1 Introduction

This paper deals with modeling human cognition. Yet we strongly believe that the better we understand how humans behave in an intelligent way, the better we can design artificial intelligent systems that mimic this intelligent behavior and/or interact with humans in an intelligent and natural way. But what do we mean by human cognition ?

The major activity of a *cognitive agent*, whether human or animal, is to adapt to a continuously changing environment in order to achieve some goals (survive, find food, make reliable decisions, etc.). Artificial adaptive systems are aimed to study, model and implement such adaptive activities. Depending on (i) the *level of the task* we try to model (from a low-level close to perceptual and motor processes to a “higher” level close to symbols and natural language), (ii) *the agent’s nature* (e.g., human, insects, non primates, primates) and (iii) *the inspiring cognitive theories* (e.g., psychological, neurobiological, ethological, sociological), adaptive systems could take different form: artificial neural networks, animats, autonomous robots, etc. [Meyer and Wilson, 1991]. In this paper, we propose some methodology to design adaptive systems to study high-level human cognition. We will show that the classical artificial intelligence approaches (e.g., expert and knowledge-based systems) are not satisfactory, and propose a methodology based on biologically-inspired neural networks. Let us start with what we mean by classical artificial intelligence.

## 2 The rationalist perspective

According to traditional Artificial Intelligence (AI), the human cognition uses abstract symbols to represent the environment features or some internal states (e.g., beliefs, goals, knowledge, emotions, desires, etc.). As a theory of cognition, traditional AI is based on what has been called the *rationalist* perspective [Winograd and Flores, 1986]. The rationalist perspective assumes that the environment can be described objectively and that from these objective representations rational (usually synonymous with optimal) solutions can be deduced. Experts systems design nicely illustrate the rationalist perspective. Some knowledge is extracted from human experts (step 1), and is formally described and stored as logical rules (step 2). The agent is seen as a problem solver, and acts by applying the rules of inference (step 3) to produce an output (solution). Recent knowledge-based systems follow this methodology as well, where more complicated structures are added to the set of logical rules (e.g., object-oriented ones, frames, scripts, scenari, etc.). Another example of the rational perspective is what we call the *classical theory of decision making*, where the decision maker is assumed to maximize an utility function [Edwards, 1954]. Here, the decision maker needs to enumerate all the possible scenari (i.e possible actions and their consequences and the consequences of the consequences, etc.), and to value them in order to build the utility function (step 1). Then, the utility function is maximized (step 2) and the action that receives the maximal utility is taken (step 3).

The rationalist perspective implies a type of rationality that strongly differs for what we know about human cognition. We address two major types of criticisms to support this claim: (i) *weak cognitive plausibility* and (ii) *lack of situatedness*. We now go into these two issues more closely.

## 3 Cognitive plausibility

Cognitive plausibility is difficult to assess, because it strongly depends on the level of analysis and on the theories we believe in. However, even if we are far from having understood the human cognition, the progresses made in psychology and biology give us a better insights into the cognitive processes. Once they are strongly established by several scientists, the psychological and biological data give us a lot of facts that a model should not refute to be considered cognitively plausible. We now introduce a methodology that may help to assess the cognitive plausibility of a model.

### 3.1 Psychomimetism

We have introduced in [Kant, 1996, chap. 2] a methodology, called *psychomimetism*, in order to design cognitive models within the framework of the *information processing* approach. Such an approach gave birth to cognitive psychology in the late 1950s and still prevails in today's cognitive theories. Broadly speaking, it views a cognitive agent as an information processor which receives inputs from the environment, processes the information by manipulating elementary information units and produces some outputs.

Psychomimetism prescribes some design principles for an artificial system aimed to model human cognition. It assumes that we have a *cognitive model*, i.e. a set of principles that describes the way the cognitive agent processes the information, and a *description language*, i.e. a way to represent the information (e.g., using well-defined features). A psychomimetic artificial system has to:

- PM1 implement all the principles of the cognitive model in order to perform numerical simulations of the model and validate it on experimental data.
- PM2 produce structures, whether outputs or internal representations, that are interpretable in terms of elements of the description language
- PM3 implement a learning mechanism compatible with the cognitive model, in order to model the processes that produced the structures prescribed by the design principle PM2

The design principle (PM1) emphasizes *implementation*. It means that the functional architecture of the artificial system and the way this system processes information are both compatible with the principles of the cognitive model. (PM2) emphasizes *intelligibility*. Instead of being a black box, a psychomimetic artificial system processes information meaningfully, so that an external observer could interpret its behavior and its outputs in terms of elements of the description language (e.g., symbols of natural language). (PM3) emphasizes what we call the *structure-process coupling* issue. Biology and psychology reveal that the representations used by a cognitive agent and the processes that have produced and transformed them are strongly interdependent. This implies that one should not study the representations involved in human cognition independently of the processes that produced these structures [Kant, 1996, p. 7].

Now that we have introduced a methodology, let us examine how it helps to assess the cognitive plausibility of two dominant approaches of cognitive modeling: the rationalist perspective and connectionism.

### 3.2 Cognitive plausibility of the rationalist perspective

The rationalist perspective gave birth to artificial systems that are psychomimetic. For instance, knowledge-based system could be considered as psychomimetic: (PM1) the description language is a set of well-defined properties of objects and the cognitive model usually relies on logical reasoning, (PM2) symbolic machine learning techniques based on inference mechanisms provide intelligible logical rules, (PM3) which are actually learned by the system (PM3) [Michalski et al., 1983]. But the cognitive plausibility of this approach is very questionable. First, a lot of experiments in psychology have shown that people do not follow the principles of formal logic, like in syllogistic reasoning. Hence, even for reasoning tasks, the plausibility of formal logic inferences is controversial and may suggest that other structures and processes are needed [Anderson, 1990]. Second, symbol-based systems need a large amount of information to be processed (e.g., browse all the rules to update the system's knowledge) and a lot of computations (inferences, optimizations, etc.) to learn the symbolic structures. Therefore, they do not take into account the *bounded rationality* of human cognition that Simon pointed out in the late 70's [Simon, 1979]. Since then, it has been widely confirmed in experimental psychology that humans have limited capacities of information storage and limited capacities of computation.

### 3.3 Cognitive plausibility of connectionism

Connectionist networks resolve many of the problems of traditional symbol processing: they are fault and noise tolerant, they have a certain ability for generalization, and they integrate learning in a natural way as they learn from the environment.

*process coupling* issue. Indeed, connectionist networks are in a sense closer to the brain than symbol processing systems, since they are made of a large number of nodes (called neurons) that are interconnected with adjustable connection weights and that process information in parallel (for more details on connectionist networks, see e.g. [Levine, 1991]). Moreover, currently popular connectionist network architectures, whether supervised (like the multi-layer perceptron) or unsupervised (like the ART neural network [Carpenter and Grossberg, 1987]), have shown to be able to learn arbitrary categorizations and build stable representations of the categories, even for objects described with qualitative features. However, when we want to interpret these internal representations as a set of symbolic structures, separate rule-extraction algorithms are needed [Kant and Levine, 1997]. Hence, learning and rule formation productions are two separated processes, and the structure-process coupling issue is not solved.

We have proposed a connectionist network, called *Categ\_ART*, that follows our psychomimetic methodology, and therefore solves the structure-process coupling issue. *Categ\_ART* models decision making and categorization processes of data described by qualitative features [Kant, 1995, Kant, 1996]. It implements a cognitive model for categorization and decision making based on the Moving Basis Heuristics [Barthélemy and Mullet, 1986]. *Categ\_ART* has been tested for a set of experimental data, where 7 experts and 20 customers from a French bank had to categorize 180 savings schemes into 4 categories ranked by attractiveness. There were four features to describe the schemes: fiscality, availability, minimal warranty and expected yield. In this experiment, *Categ\_ART* was able to account for all the categorization made by a subject and usually with parsimony so the produced decision rules were in accordance with the bounded rationality of the subjects. Thanks to *Categ\_ART* simulations, we have shown that all the cognitive principles of our model were consistent with the data. Moreover, its intelligibility as a psychomimetic system allowed us to make some predictions of two heuristics that accounted for a large majority of the subjects in this experiment [Kant, 1996].

Our experience with the *Categ\_ART* network has shown that the psychomimetic methodology enables to use a connectionist network to assess the cognitive plausibility of an information processing model. However, information processing systems as models of human cognition have been recently criticized because they do not account for situatedness. We present now this second central issue in cognitive modeling.

## 4 Situatedness

### 4.1 Situated cognition

The concept of “*situatedness*” has attracted a lot of interest among researchers in cognitive science and artificial intelligence in the mid-eighties, since it strongly challenged the rationalist perspective. It is derived from a cognitive theory, called *situated cognition*, that we briefly summarize, following Clancey’s recent book [Clancey, 1997]. Situated cognition can be understood from three perspectives:

*functional (i.e. social)*: a human agent is socially situated, and his/her behavior is regulated by his role, place and identity within the society he lives in. Social relations, interpersonal perceptions and actions, community’s history, etc. strongly influence the representations and the meanings of actions.

*structural (i.e. biological)*: perceptions, conceptions and actions are coordinated and structurally coupled. Therefore, we must take these three aspects of cognition into account at once when we aim to model a cognitive agent.

*behavioral*: behavior is reflective and continuously adjusted, individual actions are time-sensitive and take into account local feedback from the environment.

The rationalist perspective, and more generally all information processing approaches, do not take into account the situatedness of human cognition. It is mainly because they took the computer as a reference for cognition. As Maturana pointed out in 1970 [Maturana, 1970], a biological system is *structurally closed*. The system's history determines what is a pattern in the environment, using *learning*, *interaction* and *feedback* to select the relevant information and to adjust its behavior. In contrast, the rationalist approach views the cognitive agent as an *open* information-processing systems that is *in-structable* [Clancey, 1997, p.90]: information structures come in, they are objectively coded into the system and from these structures, an output is produced. This output will have eventually an impact on the environment, but there is no direct feedback into the system. To sum up, information processing systems, whether they are symbol-based systems or connectionist networks, are not enough integrated within their environment. Moreover, what is relevant in the current situation (e.g. object features) is hard-wired in the system by its human designer. Consequently, information processing systems suffer from fundamental problems, like the "frame problem" and the problem of "symbol grounding" [Pfeifer, 1996].

Obviously, Situated Cognition is a seducing approach but it seems very difficult to follow, especially if we want a model to account for its three perspectives at once. Therefore, situated cognitive models have usually focused only on some of them. In the field of workplace design and computer systems design, the social perspective has been tackled by approaches that perceive the final user as a situated agent in interaction with its working environment, and propose incremental methods where the user is involved in each step of the design process (e.g. see the "situated design methodology" [Lueg and Pfeifer, 1997], or the Brite-Euram European project COMAPS [COMAPS]). Situated robotics [Pfeifer, 1996] or the animat approach [Meyer and Wilson, 1991] tackle both structural and behavioral perspectives by designing autonomous robots which interact on their own with their environment. However, to our knowledge, situated robots have been successfully designed for tasks that do not require symbolic processing like navigation or motor-perception coordination. Hence, the question arises if it is possible to design situated cognitive model for higher level of cognition that are specific to humans, like reasoning and decision-making. We believe that computational neuroscience may help to solve this issue.

## 4.2 High level situated cognition: a computational neuroscience approach

In order to address situatedness, we claim that a shift is needed from connectionist networks back to *neuromimetic*, i.e. *biologically-inspired artificial neural networks*. Connectionist networks are information-processing systems so they also failed to address situatedness because (i) even if they integrate learning mechanisms symbols are still derived from a hard-encoded input layer made of other fixed stored symbols (e.g., well defined features), and (ii) they do not enough integrate feedback and adaptation of behavior

The *Computational neuroscience* approach appeared in the early 1990's and is aimed to "understanding the information content of neural signals by modeling the nervous system at many different structural scales, including the biophysical, the circuit, and the systems levels" [Churchland and Sejnowski, 1992, p.vii]. This approach has already proposed neuromimetic models that have attained a certain degree of success to model pattern recognition and classification and motor control, for example. The capability of artificial neural networks in performing symbolic reasoning and inference tasks, however, is still somewhat controversial (e.g., [Levine and Aparicio IV, 1994]). Yet our brains constitute an "existence proof" that neural-like structures are capable of symbolic reasoning, however imperfectly. Moreover, it is generally believed that the brain structures involved in high-level cognition differ in complexity from those involved in perception and motor control, but are organized according to many of the same principles. Hence, it seems likely that connectionist principles that have already proved successful in perceptual and motor tasks should, in different combinations and with greater complexity, also provide explanations for symbolic reasoning and other processes that have been the domain of classical artificial intelligence. Some of these principles have been identified by authors like Grossberg and Levine and have been used in various combinations to model cognitive tasks (e.g., see [Levine, 1991] for a review).

## 5 Conclusion

We claim that a better consideration of neurobiological facts and knowledge will help to design artificial neural networks that will tackle both structural and behavioral perspectives of situated cognition for high-level cognitive tasks. In particular, and among others, we think that several issues should be studied: (i) what does it mean to represent something in the environment, (ii) how object features are extracted from the environment, (iii) how such a feature construction process influence the system's behavior, (iv) what are feedback signals (e.g., reward, punishments) and feedback mechanisms, (v) how contextual effects, like motivation or emotion, influence cognition.

As a first step toward, Levine and I have proposed the RALF (Reinforcement and Attentional Learning Framework) neural network that models *rule formation* [Kant and Levine, 1997]. RALF tackles issues (iii) and (iv), but still departs from a hard-wired input layer. Future works will be devoted to the others problems listed above, and especially the problem of feature construction processes.

## References

- [Anderson, 1990] Anderson, J. R. (1990). *Cognitive Psychology and its implications*, 3<sup>rd</sup> edition. Freeman, New-York.
- [Barthélemy and Mullet, 1986] Barthélemy, J.-P. and Mullet, E. (1986). Choice basis: a model for multi-attribute preferences. *British Journal of Mathematical and Statistical Psychology*, 43:106–124.
- [Carpenter and Grossberg, 1987] Carpenter, G. and Grossberg, S. (1987). A massively parallel architecture for a self-organizing neural pattern recognition machine. *Computer Vision, Graphics and Image Processing*, 37:54–115.
- [Churchland and Sejnowski, 1992] Churchland, P. S. and Sejnowski, T. J. (1992). *The*



- [Clancey, 1997] Clancey, W. J. (1997). *Situated Cognition: on human knowledge and computer representations*. Cambridge University Press.
- [COMAPS] COMAPS. See <http://www.comaps.de/> to get details on the COMAPS Project.
- [Edwards, 1954] Edwards, W. (1954). The theory of decision making. *Psychological Bulletin*, 51:380–417.
- [Kant, 1995] Kant, J.-D. (1995). Categ-ART: A neural network for automatic extraction of human categorization rules. In *ICANN 95 Proceedings*, volume 2, pp. 479–484.
- [Kant, 1996] Kant, J.-D. (1996). *Modélisation et mise en œuvre de processus cognitifs de catégorisation à l'aide d'un réseau connexionniste*. Unpublished doctoral dissertation, Université de Rennes I, France.
- [Kant and Levine, 1997] Kant, J.-D. and Levine, D. S. (1997). A neural network for decision making under the influence of reinforcement. In *Proceedings of the International Conference on Neural Networks*, volume I, pp. 558–563, Houston.
- [Levine, 1991] Levine, D. S. (1991). *Introduction to neural and cognitive modeling*. Lawrence Erlbaum Associates, Hillsdale.
- [Levine and Aparicio IV, 1994] Levine, D. S. and Aparicio IV, M., editors (1994). *Neural networks for knowledge representation and inference*. Lawrence Erlbaum Associates, Hillsdale, NJ.
- [Lueg and Pfeifer, 1997] Lueg, C. and Pfeifer, R. (1997). Cognition, situatedness, and situated design. In *Proc. of the 2<sup>nd</sup> Int. Conf. on Cognitive Technology (CT'97)*, pp. 124–135.
- [Maturana, 1970] Maturana, H. (1970). Biology of cognition. Reprinted in Maturana, H. R. and Varela, F. J., editors, *Autopoiesis and Cognition: the Realization of the Living*, Reidel, 1980, pp. 2–62.
- [Meyer and Wilson, 1991] Meyer, J.-A. and Wilson, S. E., editors. (1991). *From Animals to Animats: Proceedings of the First International Conference on Simulation of Adaptive Behavior*. The MIT Press/Bradford Books.
- [Michalski et al., 1983] Michalski, R. S., Carbonell, J. G., and Mitchell, T. M., editors (1983). *Machine Learning, an artificial intelligence approach*. Tioga Publishing Company, Palo Alto, CA.
- [Pfeifer, 1996] Pfeifer, R. (1996). Symbols, patterns, and behavior: towards a new understanding of intelligence. *Proceedings of the Japanese Conference on Artificial Intelligence*, pp. 1–15.
- [Simon, 1979] Simon, H. (1979). *Models of thought*. Yale University Press, New-Haven.
- [Winograd and Flores, 1986] Winograd, T. and Flores, F. (1986). *Understanding Computers and Cognition: A New Foundation for Design*. Ablex.



# INTERVENTION METHODOLOGY FOR COMPLEX PROBLEMS: THE FACt-MIRROR METHOD

Gilles Le Cardinal<sup>1</sup>, Julie Rigby<sup>2</sup>

<sup>1</sup> Professor of Information and Communication Sciences,  
University of Technology of Compiègne  
Gilles.Le-Cardinal@utc.fr

<sup>2</sup> PhD student, University of Technology of Compiègne  
Julie.Rigby@utc.fr

## Abstract:

*We describe a new intervention methodology for awkward, difficult and/or recurrent situations, leading to pertinent, robust and reliable solutions. A framework is created which overcomes the contradictions, antagonisms and paradoxes created by the confrontation of multiple strategies, and the differences which exist between the different stakeholders. Founded on the principles of a strategy of trust, emerging from the Prisoner's Dilemma, the method's originality lies in describing all the interactions at work by making an inventory of the Fears, Attractions, and Temptations that each participant could feel in relation to the other's action in the situation concerned. With a new common representation of the problem, the stakeholders produce structured recommendations, leading to a process of empowerment and allowing co-operative action.*

**Keywords:** complexity, paradox, co-operation, empowerment, trust.

## 1 Introduction

When a bothersome, perturbing or catastrophic event occurs in a complex system, it is a sign that the communications, regulations and traditional circulations have ceased to function. It is therefore necessary to rely on the functioning of the system and to reintroduce new communications and regulations.

## 2 Simple, complicated, complex problems

When confronted with a thorny or intractable problem, that is to say a problem where simple, complicated and complex problems are embroiled, what approach is the most appropriate in order to disentangle it?

Finding a solution involves identifying:

- the simple problems for which all that is required is to think, where anybody can find the simple and immediate solutions which are the most appropriate;
- the complicated problems, correctly identified, which are characterised by the fact that information, training or expertise needs to be introduced, by an instructor, or an expert;

- the complex problems, which necessitate the co-operation of all the participants in order to identify and introduce innovative and co-operative solutions.

We propose a precise, structured and operational approach to this type of problem.

### 3 Approaches to avoid

Let us specify first of all what the method is not, in contrast to other approaches:

- It does not consist of assigning blame or applying new punishments or penalties, hoping that the fear of sanctions will force a change in behaviour. When rules exist already and are not respected, the problem will not be resolved by, "doing more of the same thing", as Paul Watzlawick remarks (Watzlawick, 1972).
- It does not consist of naming a "Mr thorny problem", a neutral party, who is allocated a mission, limited in time, for which he/she is provisionally transferred powers in order to deal with the immediate consequences of the problem.
- It does not consist calling upon an expert, who, after an audit, will be able to propose a plan to resolve the complicated problem for which he/she is an expert. Faced with a complex problem which, by definition, cannot be dealt with solely by one person, his/her approach consists of identifying a complicated problem for which he/she is the expert, and proposing solutions, proven to work elsewhere.

It does involve creating a manageable and secure situation where the various participants can work together. Conditions are created that favour an in-depth investigation of the area concerned and translate into the setting up of communicational processes which are well defined, leading to a set of propositions drawn up in situ by the persons involved, making a solution to the problem possible.

### 4 The democratic debate of Jurgen Habermas

Communication theoreticians, have for many years reflected on the conditions necessary for the establishment of a meaningful debate.

The first step consists of carefully selecting the stakeholders in the task of considering the problem in such a way that they represent all the sensibilities and the strengths present.

The second difficulty to overcome consists of making the protagonists work together in such a way that it is possible to associate a great number of differences in a co-operative effort: differences of culture and profession, differences of rationality and logic (substantive or procedural), differences of projects.

Jurgen Habermas (Habermas, 1986) studied in particular the conditions for the possibility of democratic debate and mutual understanding. He developed a critical thought in the area of communication. The approach presented in this article shares the following convictions with Habermas:

- that it is necessary to give the right to speak to all the stakeholders and,
- that it is necessary to respect their liberty and to call on their sense of responsibility.

The authors do not share the optimism of Habermas concerning the possible absence of hidden interests. However, on the contrary, it is considered that a thorny problem always conceals paradoxes and dilemmas which quickly result in confusing the debates, transforming them instead into opposition, into competitiveness, or into open conflict according to a dynamic easy to explain and to understand.

## 5 Strategies in paradoxical situations according to Yves Barrel

How can these commonly occurring situations be resolved? By better structuring the meeting, securing it, and initiating processes that can be managed, keeping away from the dangers that have just been identified.

Because of the hidden presence of dilemmas in all thorny problems, the method presented here has striven to integrate strategic conditions to be respected in paradoxical situations that have been reformulated based on the works of Yves Barrel (Barrel, 1979) and Catherine Chevalier (Chevalier, 1996):

The five rules identified in all the strategies in paradoxical situations are:

- To divide time and space and identify in time and space, specific strategies adapted to a well defined situation,
- To specify the frequency with which it is necessary to alternate changes of strategy and working areas,
- To work on the language to construct a common representation of the problem which is understood by everyone and which constitutes common ground,
- To multiply the observations and the points of view to make the complexity of the system emerge,
- To be creative and innovation because solutions do not preexist.

## 6 The specificity of the method

In order to succeed in what is the risky task of the construction in the group of a common representation of the thorny problem, it is necessary to take as the object of the study not the people, but the interactions between the principal stakeholders involved in the problem. Indeed, experience shows that if one decides to speak about people, the approach of all work groups slowly but surely moves towards the designation of persons who are accused of not doing their work well and who will be rapidly identified as guilty parties. René Girard (Girard, 1972) explained how this rapid and inevitable designation of the scapegoat occurs, where certain persons will be identified as being the only guilty party, a behaviour which is very practical for welding together a group. It is sufficient to exclude or to sacrifice the guilty party in order to momentarily resolve the difficulties encountered.

By focusing on the interactions, the state of affairs is completely changed. Instead of looking for a guilty party, attention is drawn to the malfunctions or ideally to their sources that are the relational dilemmas inherent in the system identified study.

How, therefore, can a discourse be made possible concerning the nature, the quality and the dangers which the interactions between the participants conceal? To answer this, the Game Theory provides a useful and powerful indication

Indeed the Games Theory provides a pertinent, though it be simple, representation of the interaction situation. The prisoner's dilemma (Axelrod, 1992) is the archetype of the strategic paradox which appears between two participants who can gain a reward (R) if they co-operate, who suffer a punishment (S) if they refuse to co-operate, but who are tempted not to co-operate, exploiting the eventual co-operation of the other. This allows them to gain a temptation payoff (T) but inflicts on the other the 'sucker's pay-off' (S). Gain, punishment, temptation payoff and 'sucker's pay-off' are often difficult to identify with precision in a real situation, especially before entering into the interaction.

On the other hand, the feelings of the participants submitted to such a dilemma can be easily anticipated (Le Cardinal et al., 1997). Each individual experiences feelings, but each in a specific way:

- the Fear of being betrayed and of suffering the consequences,
- the Attraction of achieving mutual co-operation because they want to win together,
- the Temptation to betray the other, to benefit from the betrayal bonus.

Whereas it is difficult to evaluate the outcomes of a real interaction, it is very easy to talk about the fears, the attractions and the temptations felt by each given participant in relation to another. The situation changes from being quantitative and exterior to the participants, to qualitative and interior to the participants, from mathematics to human sciences, from the economic area to the existential area.

## 7 Conditions for meaningful and co-operative work

These three feelings in all the important interactions identified are expressed in a brain-storming workshop. Here we escape the pitfalls of a sterile discussion or poor justification. What is said is legitimate, which in no way stops one of the participants making an opposing statement. All the statements are taken into account. The logic of AND is substituted for the logic of OR.

Each participant will have to make an evaluation by attributing a mark, anonymously, personally and therefore subjectively, to each proposition according to his/her consideration of its degree of importance for the best resolution of the problem. Next, the marks of the participants are integrated by taking the average of the marks obtained for each statement.

This huge quantity of qualitative and quantitative information (between 200 and 1000 statements according to the problem and the time spent) collected from the participants in reply to only three questions "what are the fears, the attractions and the temptations of the participants in relation to each other?" should next be reviewed and structured before being exploited in the search for solutions.

## 8 Construction of a common representation

After stating the **FAcTs** (**F**ears, **A**ttractions, **T**emptations), their notation and obtaining the general classification, the group operates firstly a closing operation by regrouping the statements by affinity, called 'unavoidable themes'. Between 10 and 20 different registers are opened, called 'unavoidable themes' of the problem. To give a name to each of these themes constitutes an extremely important conceptual operation.

It is due to a rigorous common effort on the language that the thorny problem is broken down into smaller problems clearly identified by an ordered list of **FAcTs**.

The list of the names of the unavoidable themes constitutes a true common linguistic representation of the thorny problem, broken down by a extremely precise and transparent process carried out in the group. This common representation of the problem in the form of precise unavoidable themes cannot be obtained until after the initial creativity phase.

Theoretically, this is due to the following reasons:

1) The statements of all the possible fears of the participants could little by little construct a totally negative representation of the problem. If all the fears are justified and correspond to real dangers, the addition of all the possible dangers generates a very pessimistic view of the situation.

2) The juxtaposition of all the attractions possible as a result of the co-operation of all the participants, on the contrary generated an optimistic image of the situation, more positive than any of the participants could have imagined on their own. Paul Watzlawick<sup>1</sup> (Watzlawick, 1972) indicates indeed, that a characteristic of communication is that every situation can be restated either positively or negatively. This is exactly what has been found by successively stating the fears and the attractions.

3) The temptations allow us to understand the relation of continuity which exists between the catastrophic situation and the idyllic situation. Indeed, if the different participants give in to the different identified temptations, the processes generating the catastrophe set in. No-one is accused of giving into these temptations. Understanding better the possible reasons for failure, the representation that each participant constructs of the problem becomes more complex and more intelligent.

Regis Ribette (Ribette, 1997) gave the name of double constructivism to this double process of complexification of the inherent individual representations and the construction of an explicit common representation.

## 9 Construction of the recommendations

At this point, it is convenient to explain the logic of the elaboration of the recommendations. Once again, the rules of the game are precise. The animator first of all reads the whole list of fears, the attractions and the temptations making up a theme.

In a creativity workshop the animator asks the group to consider:

- how to suppress or reduce the fear studied, by reducing the danger which it causes,
- how to realistically obtain what was expressed as a potential attraction,
- how to limit the temptation or make more difficult and less advantageous a betrayal, (that is to say, giving in to the temptation)

In this way, each recommendation has a precise origin. We know precisely the use of each measure stated, to which part of the initial problem it contributes the most and which danger it has the purpose of reducing or bringing under control. Dozens of

recommendations are produced to improve the smaller problems linked to the unavoidable theme. We observe that certain recommendations can be contradictory since coherence is not required by the constitution even of the creativity workshop. This is why the final phase of the method consists of regrouping the recommendations, either into coherent scenarios, amongst which one must choose, or axes of actions which it will be suitable to put into practice in an ordered manner.

The participants emerge from this work better informed, having more complex representations of the problem but they are also able to assume new responsibilities, since each one knows what he/she has to do in order to improve the situation. Each person will be motivated by this process of empowerment and commit themselves when it is a case of finding the people responsible for putting into practice the different actions.

## 10 Conclusion

From a situation of despair in the face of a task previously considered as impossible which had led to a loss of hope and the anxiety of inaction, we have moved on to a situation where there is more illuminating information empowering the participants and allowing new possibilities for action which translates into multiple actions, possible to put into practice and for which we understand the sense and the effects. The follow-up of the application of the recommended measures will make up part of the checklist which constitutes the inventory of the unavoidable themes.

The various processes involved culminate in the construction of the sense of a project and the trust in a team: the ultimate objectives of the FAcT-Mirror method.

## 11 Applications

This method has been used in over one hundred situations involving:

- in administration: the development of partnerships between organisations working in the same region (creation of jobs),
- in industry: the design of a complex product (metallurgy, automobile), fusion between firms, improvement of quality & security, resolving conflict (trade unions) encouraging co-operation between university and industry.

## References

- [Axelrod, 1992] Axelrod, R. (1992). *Donnant-Donnant, Théorie du comportement coopératif*, Odile Jacob, Paris.
- [Barrel, 1979] Barrel, Y. (1979). *Le paradoxe et le système*. PUG, Grenoble.
- [Chevalier, 1996] Chevalier, C. (1996). *Conflit et théories des systèmes*. Thèse UTC, Compiègne.
- [Girard, 1972] Girard, R. (1972). *La violence et le sacré*. Grasset.
- [Habermas, 1986] Habermas, J. (1986). *Morale et communication*. Le Cerf, Paris.
- [Habermas, 1987] Habermas, J. (1987). *Théorie de l'agir communicationnel*. Fayard, Paris.



- [Le Cardinal et al., 1997] Le Cardinal, G. Pouzoullic, B. and Guyonnet, J.F. (1997). *La Dynamique de la Confiance*. Dunod, Paris.
- [Ribette, 1997] Ribette, R. (1997). *Vers un nouveau genre managérial*, ISERIS, 1997
- [Watzlawick, 1972] Watzlawick, P. (1972). *Une logique de la communication*. Seuil, Paris.



# CONTRIBUTORS INDEX

---



# Contributors

## Index

### A

Alexandre F.	469
Alterman R.	107

### B

Battistelli D.	211
Binder Z.	195
Bisdorff R.	321
Blaise J.-Y.	113
Botrel S.	413
Boughzala I.	119
Boyer M.	149
Brans J.-P.	327, 329
Brézillon P.	129, 331
Briand H.	169
Britkov V.	337

### C

Camilleri G.	135
Caponetti L.	85
Cattrysse D.	61
Cerratto T. I.	141
Chateau N.	413
Chaudron L.	37, 149
Cheng J.	475
Cot N.	23
Crévits I.	1
Curé O.	. 23

### D

D'Amato M.	85
Dakhli S.	75
David B.	195
De Almeida V.	463
Debernard S.	1
Dehais F.	37
Delaney W.	85
Denecker P.	1
Descotes-Genon B.	195
De Sousa J. F.	385

Djioua B.	217
Doignon P.	163
Dombrovskaia L.	483
Donnart J.-Y.	491
Drap P.	113
Du Boulay G. H.	67
Du Boulay J. B. H.	67
Dudek I.	113

### E

Erdogmus N.	203
Ermine J.-L.	155

### F

Falmagne J.-C.	497
Favrel J.	271
Feinman A.	107
Fendri I.	161
Fog C. L.	419
Fougères A.-J.	225

### G

Gaalman G. J. C.	99
Gadda A.	345
Garlatti S.	431
Giroud J. P.	23
Goujon B.	233
Grau J. Y.	37
Grundstein M.	161
Guibernao O.	463
Guillet F.	169
Gulliksen J.	29
Györkös J.	293

### H

Hadji S.	271
Henig M. I.	353
Herrmann C.	355
Hildebrandt M.	437
Hoelscher C.	425

### I

Iksal S.	431
Introne J.	107

**J**

Jakobi N.	491
Janetzko D.	437
Jeffery N.	67
Jorna R. J. J.	99

**K**

Kala Kamdjoug J.-R.	357
Kamp J.-F.	163
Kanellos I.	257
Kant J.-D.	501
Kavathatzopoulos I.	29
Kervella P.	431
Khamliche R.	365
Kodjabachian J.	491
Kuntz P.	169

**L**

Landsman S.	107
Le Blaye P.	37
Le Cardinal G.	509
Legroux D.	463
Lehn R.	169
Lemesle X.	249
Lenca P.	277
Le Priol F.	241
Lépy N.	285
Le Saux E.	277
Leskovar R. T.	293
Levacher M.	23
Lewkowicz M.	175
Liebl F.	367
Lotan T.	61
Lumpkin C. A.	369
Lundberg C. G.	45

**M**

Mattarelli M.	377
Mazzeo Rinaldi F.	345
McAdams S.	445
Meyer C.	491
Meyer H. A.	437
Meyer J.-A.	491
Misdariis N.	445
Montano Guzman L.	383
Moon D.	377

Moreira J. M.	385
Mosmans A.	329, 393
Müller W.	301
Müller-Merbach H.	53
Muyldermans L.	61

**N**

Nagle B. M.	45
Nussbaum M.	483

**P**

Pachulski A.	161
Pasquier L.	129, 331
Paul H.	307
Pedersen T. H.	419
Pénélaud O.	37
Peter G.	315
Philippé J.	169
Picouet P.	277
Pincemin B.	249
Poirier F.	163
Pomerol J.-C.	331
Poulet F.	183

**R**

Reinhold N.	451
Rigby J.	509
Rose T.	315
Rosenthal-Sabroux C.	161
Röttgers H.	453
Rozman I.	293
Rughase O. G.	395
Rupprecht C.	315

**S**

Saker I.	129
Saunier P.	321
Schweigert D.	397
Sergeev G.	337
Shanteau J. C.	193
Sharples M.	67
Sierksma G.	99
Skaf A.	195
Storkerson P.	455
Strube G.	425

## T

Tangian A. S.	403
Teather B.	67
Teather D.	67
Thlivitis T.	257
Tian H.	195
Toffolon C.	75
Tritos L.	307
Trullier O.	491

## V

Vaccari E.	85
Valliez C.	211
Van Oudheusden D.	61
Vicente K. J.	93
Vineste J.	265
Vom Hofe A.	463

## W

Waeters A.	155
Wanders H. L.T.	99
Wiederhold E.	301
Wioland L.	37
Wolfler Calvo R.	345, 377

## Y

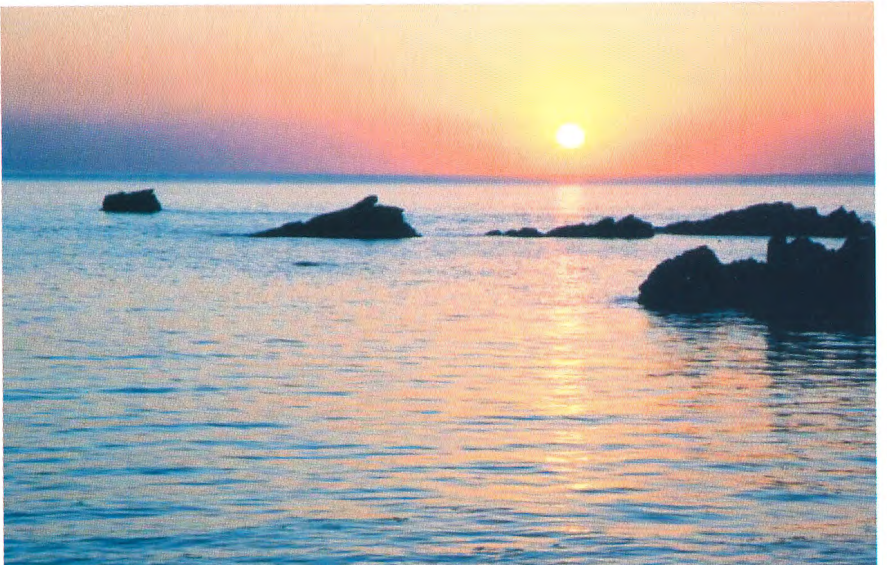
Yildiz G.	203
-----------	-----

## Z

Zacklad M.	119, 175
------------	----------















## Human Centered Processes

The HCP'99 conference concerns professional users who are involved in human factors in companies and complex systems centered on human skills and abilities.

The study of operational strategies and processes used by human beings is the aim of Cognitive Science. It has been more or less recently applied in an industrial setting. For instance, the European Communities have supported a programme called Anthropocentric Production Systems, while in the US the notion of Human Centered Designs and Technologies has emerged and has become very popular. Such a movement is an important challenge for companies concerned with human beings in a workday context, because cognitive approaches, complementing more traditional ones, provide a great number of additional dimensions that allow design and analysis of more complete and complex systems.

The purpose of this conference is to bring together:

- Industrialists who deal with questions related to cognition.
- Researchers who are experts in Cognitive Science:
- Operation Researchers interested in discussing human centered approaches applied to complex industrial problems.

In view of this, the topics covered by the Conference concern industrially oriented themes where human centered approaches have already shown their usefulness; like planning, scheduling, decision making, quality control, project management, intelligent management of multimedia documents,...

This mini EURO conference has one of its motivations in the European COMAPS Brite-Euram project (Cognitive Management of Anthropocentric Production Systems, Be 96 - 3941).

About eighty papers are scheduled in the conference. Most of them are printed in these proceedings. The sessions are organized into seven streams (Applied Cognitive Science and Human Centered Systems, Knowledge Engineering and Management, Computational Linguistics, Manufacturing and Process Control, Decision Making, Multi-Modalities and Interactions, Methodology and/or Applied Mathematics). The conference includes: Keynote speakers talks (**Jean-Claude Falmagne** - University of California at Irvine - USA; **Henry Montgomery** - Stockholm University - Sweden; **James Shanteau** - Kansas State University - USA; **Kim J. Vincente** - University of Toronto - Canada), semi-plenary sessions (**Jean Pierre Brans** - Vrije University - Belgium; **Dietmar Janetzko** - University of Freiburg - Germany), one invited session within the COMAPS Project (**Wolfgang Müller** - Fraunhofer Institute Information- and Data Processing - Germany), proposed sessions and regular sessions. Talks come from Europe in a broad sense (15 countries), from America (Chile, USA), Asia (Japan, Thailand) and from Africa (Cameroon).

Jean-Pierre Barthélemy, Chairman of Organization Committee,  
Raymond Bisdorff, Chairman of Programme Committee,  
Philippe Lenca, Editor of the Proceedings