

TOWARDS A HOLON-PRODUCT ORIENTED MANAGEMENT

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Abstract : This paper describes research currently being carried out in the field of holonic Manufacturing Systems as a step towards holonic concept partial validation. The originality of the presented work deals with the idea that process management may be achieved not only by machines, operators, but also by part and product itself, carrying and managing its own information. Presented research work deals with STEP methodology and formal models to provide a product-holon behavior validation case for manufacturing control, based on information management. This paper demonstrates the feasibility of high level information structuration, based on product data definition, with advanced management technics on attached escort memories. Distribution of the information system onto each individual product requires tools and methods to manage and provide access to product related information for resources, automated systems and human operators. Automatic identification technology using electronic data carriers, Radio Frequency transponder, can provide such functionality and act as product information vectors to provide a generic support for holon-product implementation.

Keywords : Information technology, Process control, Data models, Holonic manufacturing, STEP, EXPRESS, Product Data Management

1. INTRODUCTION

Since the last decade, tremendous changes have occurred in the field of manufacturing systems considering production control and organization.

To manage product diversity and rapid changes in production demands, research effort of the eighties have been focused on manufacturing systems architectures satisfying productivity, flexibility, openness characteristics for integration aspect and cost reduction, widely based on automation increase (Dilts, 1991).

Originally represented by the CIM concept (Computer Integrated Manufacturing), new approaches have emerged to remedy the limits hit by such hierarchically and centrally controlled organization suffering from rigidity to fast production changes and adaptations.

Then, priority have been put on decentralization and distribution of decision-making activities and information flow with an expected downsizing of manufacturing systems. Fully distributed structures were proposed (Duffie, 1986) involving concurrent mechanism for job decision and coordination support, based on network communication procedures, contract nets. In this heterarchical architectures were promoted to provide manufacturing systems with decentralization, modularity, robustness and cooperative functionalities.

Beyond that approach characterized by system-based functionalities, strong demands appears for new formalizations of manufacturing systems to break off from conventional system organization to satisfy autonomy and individuality along with cooperation capabilities amongst all components of a

manufacturing system. Emphasis was put on coordination, self-organization, hyper-flexibility, adaptation and part-orientation.

2. NEXT GENERATION OF MANUFACTURING SYSTEMS

Several new paradigms for manufacturing system description were formulated drawing inspiration from the real world mainly over the two aspects of social organization of human societies and natural rules and environment.

Biological metaphor have been proposed by Okino (1994) to fit autonomous distributed manufacturing system description, so called *Bionic Manufacturing System* (BMS) in CAM-I/Japan.

BMS concept lays on a system theory involving self-organization rules over distributed components with quasi-life functions copying genetic behavior, allowing freely adaptive and flexible connections in response to changes of system conditions. Ueda (1994) specified a model of BMS as a pseudo ecosystem built around works and manufacturing cells thus mimicking biological organisms carrying DNA (Desoxyribo Nucleic Acid) gene type and BN (Brain and Neuron) type behavior and information. In a Bionic world environment, works are considered as organisms that grow up to become or generate products, and manufacturing cells are other type of organisms that process works. DNA type information is supporting inherited information and transformation as "growing up" objectives of products, while BN type information governs works activities. In this, a manufacturing system control behavior should be described by evolution strategies with mathematical model based expressions.

A social organization metaphor has been derived from the Hungarian journalist and philosopher Arthur Koestler (1989) proposition, specified early in 1971 in the prophetic book "The ghost in the machine", as the holonic concept. Based on the observation of self-regulation capabilities of social organization, a social holonic behavior involves very few characteristics supported by elementary entities named *Holon*, acting and cooperating to assume living of complex and ruled organization named *Holarchy*. Koestler adds that holonic argument can be applied to biological, social or cognitive hierarchy which manifests rule-governed behavior and structural consistency. The word Holon is build over the Greek root "Holos" meaning "Whole" completed by termination suffix "on" for "Particle" as encountered in the word neutron, to represent behavior properties of "a whole by itself and a part within other wholes".

The holonic metaphor have been applied to manufacturing system organization by the International joint program IMS (Intelligent

Manufacturing System) with the thematic research consortium HMS (Holonc Manufacturing System) as a promising response to provide production systems with robustness and adaptability to condition changes and disturbances, modularity and flexibility capacities.

Underlying principles of holonic application to manufacturing systems have been defined as follows by the HMS consortium (Van Brussel, 1995) :

Holon : An autonomous and co-operative building block of a manufacturing system for transforming, transporting, storing information and physical object.

Holarchy : An assembly of holons which act in cooperation having a specific set of objectives and common goal.

Autonomy : Ability of an holon to control its own execution plan associated with its own strategy.

Co-operation : Capabilities of systems entities to communicate, negotiate and execute actions plans in order to reach an objective.

The previously presented paradigms are actually drawing up the next generation manufacturing systems to come in the next decades. Scientist community research activities have to cope with formalization and resolution of the aiming capabilities of the real world to validate and prove efficiency within the production world.

The following paragraphs will focus on a validation approach of the holon concept supported by part product and resources cooperating in a manufacturing environment.

3. PRODUCT ORIENTED MANAGEMENT

A common characteristic is revealed in both approaches BMS and HMS, with the duality of elementary organisms performing in complex systems. An holon consists of an information processing entity allied to a physical processing entity, as also biological organisms are unified entity of information and substance. This characteristic contributes to the emergence of an autonomous behavior appearance in complex systems.

Three types of basic building blocks in an holonic manufacturing system are: resource holons, order holons also call task holons and product holons (Bongaerts, 1995), co-operating to perform production (Fig 1.)

A resource holon consists of a physical part, namely a manufacturing resource in the HMS, powered by physical capabilities. It is an abstraction for the production means such as production machines, conveyors, ...

An order holon is an entity responsible for performing the work in a suitable and successfulness

way. It captures all information related to a job (Bongaerts, 1995).

Finally a product holon can be seen as an entity created by real or forecasted market demand. It holds all the necessary knowledge to assure the realisation of a product.

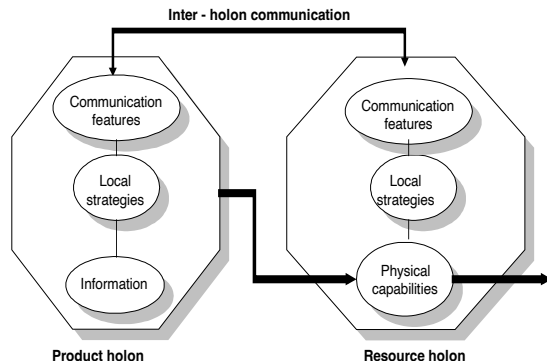


Fig 1. Resource and Product Holons structure.

Product information and knowledge is basically defined at the design level in words of functionality, shape, quality, manufacturing operations sequence, ... This knowledge is constructed step by step and structured through a life cycle product information model.

This product knowledge must be shared by all the actors tools used for the product design. In this field some work has been done in order to define both standardised product model, like STEP for instance, and integrated information infrastructure like AIT Integration Platform or Esprit NEUTRABAS platform.

At the manufacturing stage, this knowledge is conceptually duplicated to fit to each individual product or holon. One can say that product definition data set is cloned, and then follow its own life.

One of the major problem lies in the management of this information set associated to each holon. For instance Duffie (1986) proposed some computers, connected with each others, in order to play the role of products data manager. Some other authors (Upton, 1992) are proposing the use of electronic tags, but without any regards about integration problems.

In the following proposed approach, a product or any other holonic entity object carry its own information on a programmable tag which can be accessed in read/write mode by each user involved in its development process. Advantage of this approach is in machine capacities to focus on operations control (transport, measures, ...) and not on coherency maintenance of product related information, this point is conceptually assumed by each individual product. A dialog can be imagined inbetween machine and product as follows : *"Part 17843, where are you ?"* say the machine , *"I am currently at Machine 4 for a 10 minutes operation and I expect to be soon served*

by yourself " replies the product.

This leads to the emergence of claims contracts between customers and suppliers in a concurrent client/server formalism.

Unfortunately, electronic tags are by now not easy to integrate in an enterprise information system. It is for instance impossible to read or write structured information on these systems because they use elementary data handling protocol instead of high level and semantic information manipulation dialogue. In this field, the MONOLIN project (MOBILE NOdes in Logistics and Industrial Network, EP 6936) develops the basic requirements for a standard identification systems network interconnection interface allowing integration : the Escort Memory System - Application Programming Interface so called EMS-API (Monolin, 1994).

Significant validation of a such approach can be foreseen, taking into account that ANSI X3T6 subcommittee is actually working on an Radio Frequency identification devices (RFID) interoperability standard, information structuration will follow (ANSI X3T6, 1996).

An Holon-Product Information management approach is proposed in the following chapter as a logistic support to manufacturing system control. Holon-Product specification will assume both vertical integration (link with the design level) and the horizontal integration by supplying methodology and support tool allowing that each part carrying electronic tag, can act as a communication vector of process information system, in charge of the overall application management, and information coherency, consistency and reachability.

4. PRODUCT-HOLON INFORMATION MODELLING

One of the most significant approach today in product modelling is the development of ISO 10303 standards called STEP (STandard for Exchange of Product model data) which define models, database access and neutral data files format for representation and exchange of product data. The goal is to define complete models for product life-cycle in a CIM context, as well as the means for exchange of data between enterprise functions along a product life-cycle definition (from CAD to production, maintenance, ...).

EXPRESS is a formal modelling language, object oriented, that models the knowledge about information used by an information system. It provides the words, syntax and grammar needed to describe an application field. EXPRESS is designed to satisfy basic requirements as modelling of the information and processing objects; definition of the constraints rules; definition of the operations

performed by objects; be readable by an human operator as also be automatically computed.

5. PRODUCT-DRIVEN MANUFACTURING

5.1. Product/Process Interrelationship

In the presented model, every product is acting as a real actor within its process able to :

- manage itself its characteristics like shape, design version, ...
- has knowledge of its evolution through its

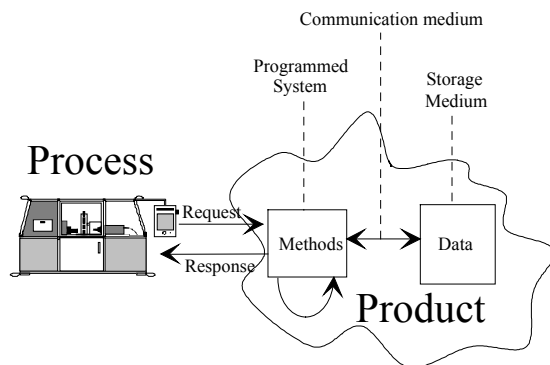


Fig 3. Process/product relationship based on the client/server model.

operation sequence

- store its history in the holonic process.

Figure 3 points out the concept adapted from the client/server model we chose in order to respond to these objectives. In such a case each product is the manager of its own information and gives them to the process after it received a service request : "What is the next operation to be proceed on yourself" for example.

On the basis of a client/server relationship between product and process, user requests - i.e. process requests - are sent to an interface supporting product access methods in an object-oriented interrogation form such as *Object_Selector.Message (Parameters)* or *SystemMessage (Parameters)* :

- COLOR.GETVALUE ();
- COLOR.PUTVALUE (Red);

The data storage medium, in our case, consists of identification tags carried by products or by pallets and also an optional network database. Explanation about the choice of two possible storage medium is made in sub-paragraph 5.3.

5.2. Product Model Translation for Manufacturing Control Services

The major problem, related to this model (Fig 3.) is

the integration of tags in the information system which necessitates :

- reference conceptual models to put the information about the products themselves on tags;
- tools to implement these models and to access the information.

For the purpose of the presented work, it is assumed that a logical data model of product for manufacturing operations exists and is defined in the EXPRESS language (this model could be a STEP application protocol or a specific model).

Figure 4 shows the STEP-based methodology allowing translation of product model, described in the EXPRESS formalism (entities, attributes, functions, rules) :

- to a product-information access library supporting a direct requesting of target application on the EXPRESS schema data;
- to the optional database structure definition.

The product definition within the STEP neutral file is used :

- to create the tag memory image, for the first

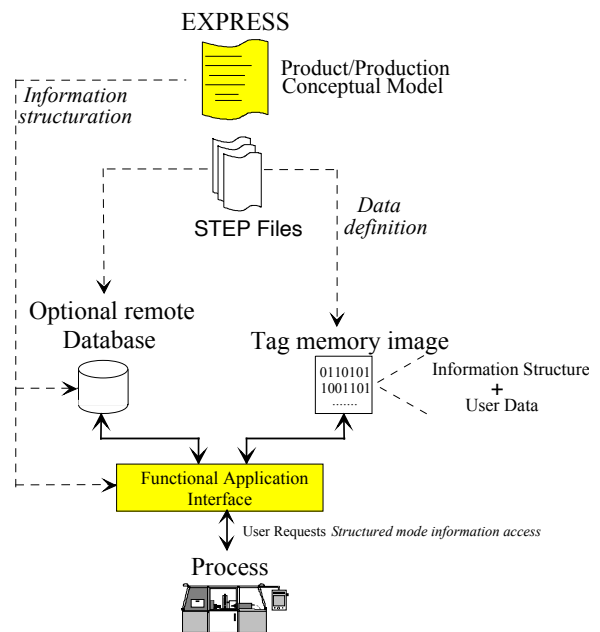


Fig 4. From EXPRESS schema to customers requests management at the shop floor.

state of a product associated to the current phase of its life cycle in the manufacturing environment;

- if needed, to populate the previously created database schema.

5.3. Remote Database Reachability

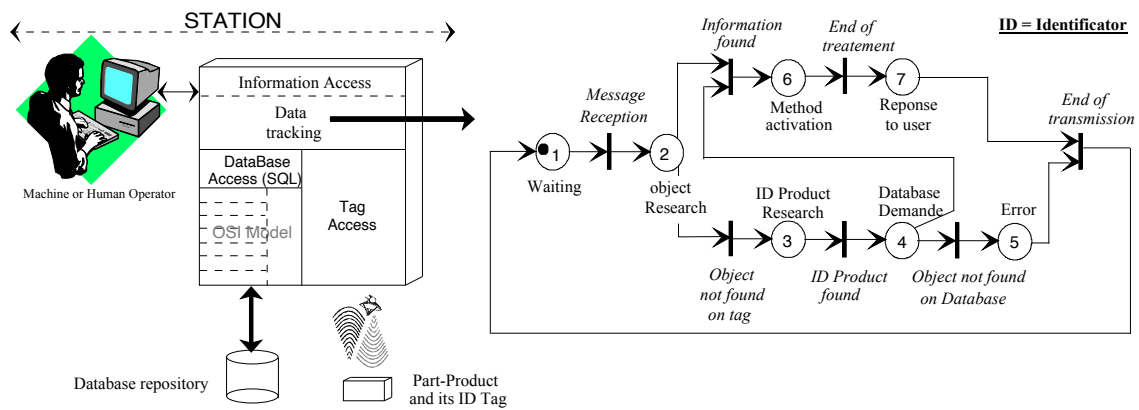


Fig 5. State graph of product data remote access from a process point.

Tags are of course limited in capacity, and storing complex structures needs more memory than only storing the contents (Attributes value). Today, tags tend to have higher storage capacity (up to 128 Kbytes) but in some cases (like automotive industries) this may not be enough, so if it is relevant for the application a part of the data could be stored on other medium.

A network database in client/server mode seems to be the natural architecture to manage the overflow of data :

- we need to have a persistent computer storage in order to manage EXPRESS schema population and translation;
- it stores and manages high volume of data;
- time response is efficient for most of the applications;
- enterprises are already trained with such an architecture.

The presented approach has the same philosophy as distributed database (Morris, 1992) that is, "users do not have to know where data are stored to access to them". The system performs data locating, formatting and transferring through the structure (see Fig 5.). In fact, when we populate the schema, we specify where EXPRESS entities must be (on tags or remote database). Afterwards, the user can send a request to

the system, without specifying the location of the objects he wants to access.

The search for physical storage of objects is made after each user request reception, as shown in the state graph model exposed in the Fig 5.

5.4. Application Tool

A prototype Tag-STEP (see Fig 6.), running under MS-Windows, uses a standard computer to generate a **Mobile Database Nodes** structure. It is connected to a relational network database management system (ORACLE 7) through SQL_NET-TCP-IP-Ethernet protocols.

The EXPRESS schema is converted in a relational schema which has to be put on the ORACLE database. In this case each EXPRESS entity is translated to a relational entity - i.e. a table - and to a view in order to manipulate sub-typing. The schema is then converted as a C program to generate the Functional Application Interface as explained before. This program is able to read or write data independently on tags or on the database. To populate the schema we use a STEP neutral file provided by the product definition phases.

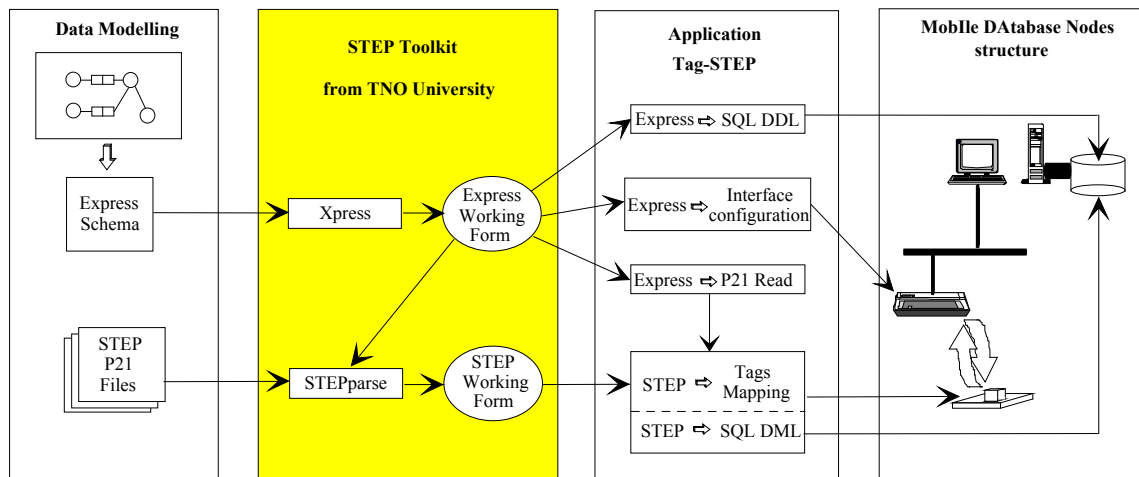


Fig 6. STEP based methodology for holon product definition and management

6. CONCLUSION

The presented work is a step toward holonic concept validation. This new approach for information management and decision making necessitates methodological framework for Information System implementation as well as interfacing tools based on international standard definitions. Dealing with STEP formal models, the paper has demonstrated the feasibility of high level information structuration, based on product data definition, with advanced management technics on attached escort memories.

Emerging technologies and standards for intelligent automatic identification systems are coming up with local processing capabilities, and also full object language characteristics of Express with methods and algorithms, should allow to upgrade this methodological approach for a full holonic characteristic implementation.

Expected benefits in manufacturing systems organisation and management are:

- better data distribution in the overall manufacturing system allowing real time tracking of products. Each holon-product is an element of a distributed manufacturing database allowing immediate consultation by other process actors;
- simplification in the production machine structure and software capabilities. A generic interface is defined to link different kinds of users to the structure in the product coupled memory. There will be a gain in the production system modularity and modifiability, ...

One of the most significant extension of this concept concerns its application to cover the full product life cycle data management from production to after sale services and recycling. This is actually in progress in the field of a research contract between the CRAN and a French cars manufacturer, to provide a holonic approach car management all along the vehicle life-cycle (Lonc, 1996).

Basically, STEP could be the general framework used for vehicle data management and as recommended by AIT research program. Linking between different phases - i.e. different data models - will be realised through models described in EXPRESS-X, for the creation of views on a model and mapping data from one model to another.

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