



Considering Stage Direction as Building Informed Virtual Environments

Alain Bonardi, Francis Rousseaux

► To cite this version:

Alain Bonardi, Francis Rousseaux. Considering Stage Direction as Building Informed Virtual Environments. *Journal of Virtual Reality and Broadcasting*, 2009, 6 (10). hal-01576773

HAL Id: hal-01576773

<https://hal.science/hal-01576773v1>

Submitted on 23 Aug 2017

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.

Considering Stage Direction as Building Informed Virtual Environments

Alain Bonardi, alain.bonardi@ircam.fr
Francis Rousseaux, francis.rousseaux@ircam.fr

Ircam, Centre Pompidou
1, Place Igor-Stravinsky, 75004 Paris, France
<http://www.ircam.fr/>

Summary: This article begins with some recent considerations about real-time music, inspired by the latest contribution of French composer Philippe Manoury. Then, through the case study of the scenic performance *La Traverse e de la nuit*, we analyse some perspectives for designing an Informed Virtual Environment dedicated to live show artistic domain.

Key-words: Informed Virtual Environments, Contemporary music, Virtual composition vs. improvisation, Score following, Ircam, Sensorial multimodality, Turning voice emotion into graphical movement, Husserlian retention/projection, Artistic performance and live show, Visual avatar of an oral emotion.

Introduction

Since its creation by Pierre Boulez about thirty years ago, the Institute for Music/Acoustic Research (Ircam, <http://www.ircam.fr>) has been at the center of what the composer Philippe Manoury calls in an article published in September 2007 "the split that electronics provoked in the world of music". This split immediately led the Parisian institute of research to the heart of the problematics of Informed Virtual Environments¹ ([Aubry et al.2007], [Herder et al.2007]), as many publications by research teams illustrate (<http://www.ircam.fr/equipes.html>), whether they are about 'instrumental acoustics' or about 'room acoustics' ([Caussé 2006], [Corteel 2007], [Viaud-Delmoal et al 2006]), about 'perception and sound design' ([Suied et al.2008]), 'analysis-synthesis' ([Vergez et al.2006]), 'music representation' ([Allombert et al.2005]), 'analysis of musical practices' ([Donin 2006]), or about 'real-time musical interactions' ([Ng et al.2007], [deLahunta et al.2007]).

The IVE approach remains at distance of immersion into virtual worlds ; its aim is modelling interactions rather than the world itself (objects, characters, situation models). The purpose is to provide users an experience that includes experimentation, simulation, training, collaboration and creation in the virtual world.

¹ Indira Thouvenin lends precision to this interpretation of EVI in her unpublished "mémoire d'Habilitation à Diriger des Recherches" : "we are interested in interactive modelization rather than world modelization (objects, characters, simulation models, ...). The aim is to enable users to live an experience that thus includes experiment, simulation, collaboration and creation in the virtual world".

Ircam main feature is to associate research and musical creations in its project teams ; no doubt that the most synthetic recent article about the situation of realtime music and about IVE for computer assisted composition.

In this paper, we will start from the statements and expectations of this composer to present the design and technical configuration of the multimedia theatre *La Traversée de la nuit*. We will show how this work constitutes a strong scientific proposition for IVE dedicated to contemporary creation, in the field of music as well as performing arts.

Considerations on the state of real time music²

If we have chosen to explore in more details Philippe Manoury's singular contribution, it is because it provides an exemplary overview of all the questions that IRCAM researchers have been asking about subjects closely related to Virtual Reality. His research provides us a quite complete background to precise our own work.

In his article ([Manoury 2007]), Philippe Manoury relates his fascination and his frustration facing the first attempts to bring together experimental electronic music and contemporary instrumental music. That was in the late 1970's and the experiment was limited by the set time imposed by magnetic tape on instrumentalists who were dependent on its inexorable progress. With Ircam's first successes in the 1980's, Manoury believed that real time synchronization of electronic music and instrumental playing would give the power of interpretation back to instrumentalists. He explains how as a musician himself he searched for an interactive interpretation of synthesised music to use his own instrumental playing.

At the time, the automatic tools for following scores were still missing. The interactivity between acoustic instruments and machines was only partially completed, "fragment by fragment", during limited and sporadic synchronizations between pre-composed parts of music that were unable to evolve during the performance.

According to Philippe Manoury, the conception of a reliable score follower in fact raises difficult questions: how to detect, recognize and analyze instrumental sounds and gestures in real time. Even though the situation is better for those who improvise without exactly trying to reproduce or notate their interactive works³, three main obstacles exist to achieve a score follower:

1° Notation of electronic music

Writing composers write down on a score the sounds in their minds ; a kind of "virtual real time" guides their intuition and imagination. To have the same effect with electronic music, not only must their calculations be done in real time, but relevant graphic interfaces must also exist for the expression and dynamic control of the composer to be expressed. Metaphors inspired by instrumental

² This excerpt is almost word for word what Philippe Manoury developed in his eponymous article.

³ According to Philippe Manoury, composing music consists in elaborating a complex musical discourse. The journey from invention to presentation involves memory, premonition, combining shapes, forming strategies, transitions, proportions and short-circuits. None of these can be improvised (cf. his own pieces Pluton, Neptune, En écho, Partita I.) And since nothing can be predetermined in this relationship between instrument and computer, the interaction may oscillate between complexity and a disarming simplicity. Spontaneous creation produces formal and standardized archetypes.

gestures (for instance variation of pressure of mouth or on the bow), or other sources out of the scope of the learned tradition have been developed over the years. But much remains to be done.

2° Capturing relevant information at the musical source

Sensors have been used to detect a flautist's fingering ; others have been put under the keys of a vibraphone. Video systems can analize the gestures of a percussionist, and aerials can measure the position of a bow. These methods combined can analyze the pressure on a string. Systems of captivation were at first mechanical and then used audio, video or radar methods, along with sensors, gravitation and acceleration. And we must not forget such ad hoc instruments as MIDI (Musical Instrument Digital Interface) keyboards.

3° Polyphonic analysis

Superimposed sounds mix their harmonics without the computer being able to discern their respective fundamentals. With the help of the techniques of analysing acoustic signals, these systems must become more "musical" even though this goal still remains, as a whole, out of reach.

Philippe Manoury makes two more important points, that will guide us for our own article:

1° When they compose, composers have to distinguish between instrumental interpretation and what cannot be changed by the musician. The composer might give more importance to improvisation by renouncing complex retroactive strategies. Computerized systems also have their own specific place in interpretation, as long as the composer renounces strict control over interpretation except if he gives more importance to improvisation by renouncing using strategies that are complex and retroactive in their mode of elaboration. This is the case when we ask synthetizers to receive information from the outside world and to process this information under partially defined rules. Interactive interpretation is thus the complex product of two indeterminate forces.

2° In conclusion, Philippe Manoury underlines the importance of the visual process used to predict the movement of musical time. This process still remains widely inaccessible to machines since it must combine two sensitive registers, putting them on an equal footing with human beings. In contrast to a machine that splits time into very small clock cycles, musicians keep time through bodily movements : nodding the head, tightening the diaphragm, tapping the foot. An orchestra conductor does all these and moves to communicate with the musician-interpreters. That's why it is so difficult for musicians and machines to share music in real time.

Placement for an exploratory research

Since they met at Ircam in 1997, the authors of this article have regularly collaborated in the field of Informed Virtual Environments ([Rousseaux & al. 2007], [Bonardi & al. 2005], [Rousseaux & al. 2004], [Bonardi & al. 2002]). Their goal: to try to lay out the foundations of cooperative musical interaction between musicians and 'intelligent' artificial systems.

Their collaboration is based on the common conception of stage 'scenographies' using computers (*Virtualis, Norma, Alma Sola, ...*) addressing research issues ;

the final realization being achieved by Alain Bonardi (<http://www.alainbonardi.net/>). These productions represent a real size experiment bringing closer to reality future, more responsive stage devices. Sometimes, when a show is popular enough with audiences to have a longer run, the stage device that carries it can substantially evolve. That was the case with *La Traversée de la nuit*, created in Enghien-les-Bains in November 2003⁴ and performed several times since then.

Le projet consistait à mettre en scène un dispositif de communication redondant et multimodal entre le public, un personnage et un système artificiel complexe, centré sur une circulation intense des émotions. L'austérité de la scénographie devait contraster avec la forte dramaturgie de la situation traitée, Geneviève de Gaulle Anthonioz racontant ses années de déportation à Ravensbrück pendant l'hiver 1944, après plus de cinquante ans de silence.

The idea was to play on duelling temporalities of sound and visual effects, working on different layers of memory to saturate the space between communication and liberty and forcing the actors and spectators to carve out, every night, a space where hope might live. The stage directions limit the play's artistic interpretation. For example, the schizophrenia of the central character is played by actors to show how she oscillates between despair and hope. One is an actress who speaks the lines, the other a dancer who moves with her and sometimes for her. And although the spoken lines themselves are to be rendered as neutrally as possible, a metaphorical representation of the narrator's mind is created in real time on a large screen at the back of the stage, in the actress' voice. The dancer and the actress both respond to the image, especially the dancer who, being freer, can vary her movements more.

De ces contraintes de mise en scène visant à amplifier la variabilité du spectacle découlent un certain nombre de choix artistiques :

Those dramatic choices echo Philippe Manoury's axiom about the composer's visual role in the conducting of a score. The device in *La Traversée de la Nuit*, for instance, involves a neuronal net that lets the voice of the actress be processed in real time while « recognizing» emotional states. Those emotions in turn, thanks to a multi-agent system, command the movements of mobiles arranged and projected on the wide screen at the back of the stage. Thus, in a way mysterious both to the audience and the actors, the voice's emotional variation produces a visual avatar.

Il est intéressant de remarquer que ces choix font directement écho à l'axiomatique de Philippe Manoury concernant le rôle du compositeur et la visualisation dans la conduite d'une partition. Précisons ce rapprochement en entrant peu à peu dans la définition du dispositif imaginé :

- Au moyen d'un réseau neuronal supervisé qui apprendra des catégories d'émotion, la voix de la comédienne sera traitée en temps réel de façon à y « reconnaître » des états émotionnels, qui prescriront à leur tour (au moyen d'un système multi-agent) les mouvements de mobiles agencés et projetés

⁴ This theatre play was performed on November, 2003, in the Centre des Arts, in Enghien-les-Bains (France). Stage direction: Christine Zeppenfeld; actress: Valérie Le Louédec; dancer: Magali Bruneau; multimedia design: Alain Bonardi and Nathalie Dazin; music: Stéphane Grémaud; lightning: Thierry Fratissier.

sur le vaste écran de fond de scène. Ainsi, d'une manière qui garde sa part de mystère tout en produisant des rationalités (les acteurs développent des affinités avec le dispositif, notamment lors des phases d'apprentissage), la variation émotionnelle de la voix donne naissance à un *avatar visuel*. Le dispositif propose une alliance mouvante entre training et surprise.

- Les interactions primaires entre les spectateurs et le personnage-double s'en trouvent ainsi singulièrement complexifiées et mises en abyme, chacun pouvant voir l'émotion qu'il/elle entend par ailleurs, et réagir en conséquence, y compris spatialement pour les acteurs, qui peuvent être tentés de faire jeu avec les mobiles projetés. Les processus de prémonition, de mémorisation, de construction de formes hybrides, les stratégies de préparation et de conclusion, les transitions, les proportions, les courts-circuits évoqués par le compositeur Manoury ont ainsi prise dans le fil du temps narratif, spatialisé par le visuel qu'il suscite et éclaté par les interactions qu'il démultiplie.

On pense bien sûr aux processus de rétention/protention introduits par Husserl dans ses *Leçon pour une phénoménologie de la conscience intime du temps*, mais aussi aux figures d'un Whitehead tentant de décrire un cosmos naturaliste et génératif ([Husserl64] et [Whitehead04]). D'une certaine manière, c'est toute la théorie de l'*écoute réduite* qui est ainsi questionnée, telle qu'élaborée par Pierre Henri, Pierre Schaeffer, Michel Chion et d'autres, dont une hybridation avec les théories modernes de la perception visuelle se trouve ainsi requise : lire Maurice Merleau-Ponty bien sûr, mais aussi Marie-José Mondzain et Laurence Hansen-Love ([Mondzain96] et [Hansen-Love07]), dans la perspective d'une *théorie nativement multimodale de la perception*.

The Flagship Project: *La Traversée de la nuit*

Multi-modal interactions

The stage direction in *La traversée de la nuit* is based on an autarkic human to machine system: an actress, Valérie Le Louédec, tells the whole text. A dancer, Magali Bruneau, performs a certain number of gestures inspired by Nô theatre and there is a multimedia computer, as an artificial actor. However the two actresses on stage represent the two sides of the same character – conscious and unconscious, according to the traditional *shite* and *waki* in Nô theatre. The computer projects images onto a very large screen at the back of the stage (the actress and the dancer can see part of it at any time), provoking the reaction of the comedians who may adapt their play. At the beginning of the loop, the computer grasps the emotional states of the actress's voice.



Fig. 1. Example of image generation on the backstage screen in *La traversée de la nuit* (actress Valérie Le Louédec on the left, dancer Magali Bruneau on the right; photography: Julien Piedpremier).

Technical description of the human-machine system

The technical implementation of the human-machine system is based on a neural network to analyse the actress's voice as an input and a multi-agent system to generate projected images as an output. The whole system was coded using the real-time Max/MSP/Jitter platform.

The neural network was trained in supervised mode during several months. The actress would impose herself a list of emotional states and read the whole text using one of them. The input voice is computed one sentence after another. A twelve-component vector is computed from each of them: four components represent vowel pronunciation (formants), four of them have to do with rhythm (durations), and four of them have to do with its amplitudes. For each vector presented as an input, the neural network provides an emotional state "acknowledged".

The following video (to be embedded in the online version of the article) shows realtime processing of the voice, how the computer recognizes an emotional state (successive values that appear in the middle of the screen on the left: 14, then 10, then 7, etc.) at each drop of the sound level (for instance every end of sentence) thanks to the neural network.

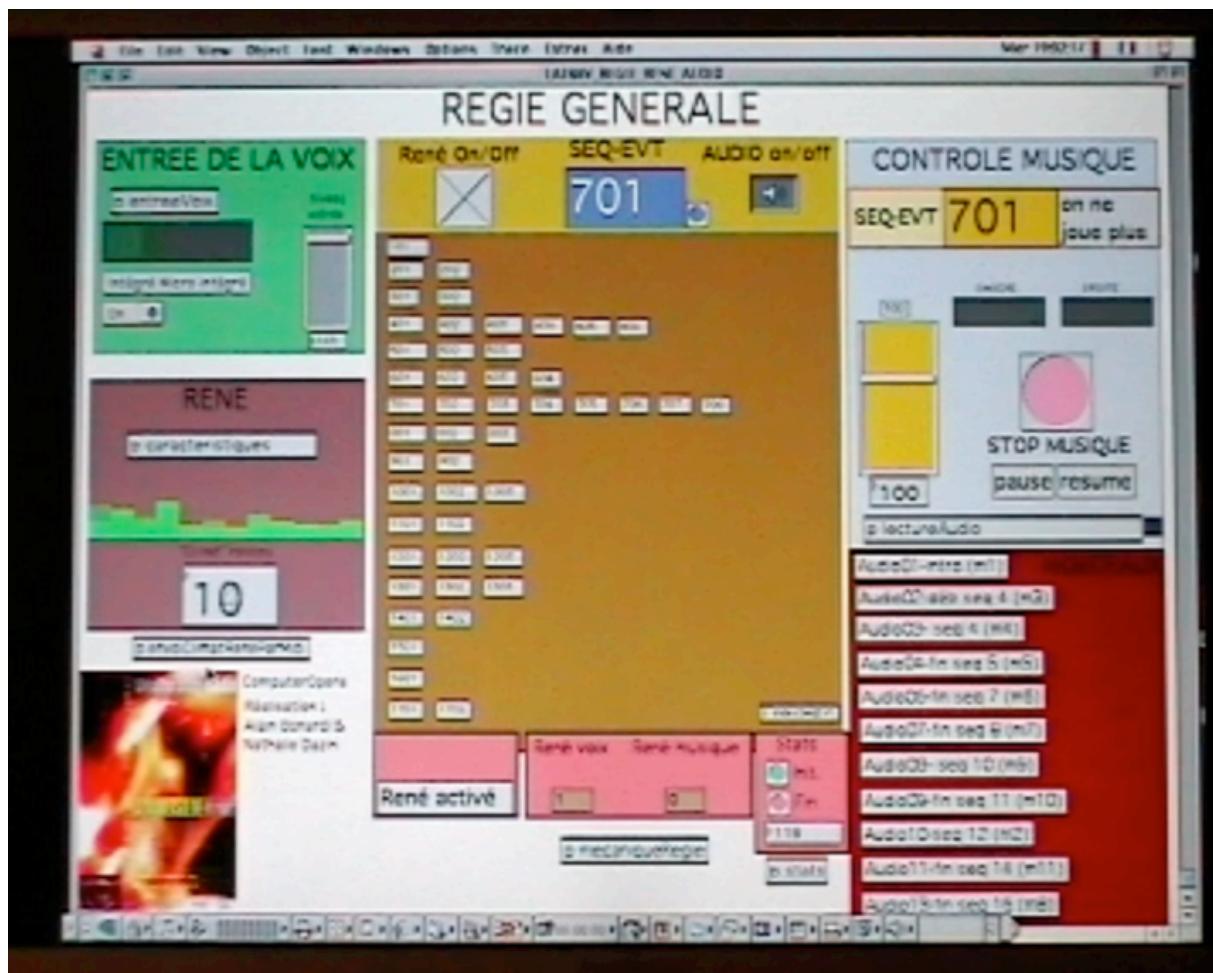


Fig. 2. Excerpt of a video snapshot of the Max/MSP real-time patch for voice analysis and emotional state recognition.

The multi-agent system ([Becket&al.03], [Pelachaud&al.02]) enables the real-time generation of images projected on a screen at the back of the stage. The agents may be compared to dynamic "billstickers" that would build together images always new (each of them carries a small part of image, still or animated).

- Each agent has a small psychological model of sensitivity (positive or negative), that reacts to the emotional states provided by the neural network according to the text sequences (that affect sensitivity weights). The result is a "mood" that conditions the agent willingness to achieve its goals.
- The agents cooperate towards one goal by optimizing an utility function computed from the appearance qualities of the images generated. There is one different utility function per text sequence. Agents may move, twist, enlarge, reduce, make more or less transparent their own small images.
- Agents are coordinated in the execution of these common goals in relationship with the emotional state acknowledged by the neural network by a "mood compensation" mechanism: the ones who are in a very good "mood" (high positive value) grant part of their willingness to the ones who are in a very bad "mood" (high negative value).
- Agents communicate together peer-to-peer by exchanging their "moods" at fixed periods.

The environment of agents includes the emotional states acknowledged by the neural networks, the event number indicating the current position inside the text, the loaded values for each text sequence, and the indications of an observer agent indicating the qualities of the global image generated.

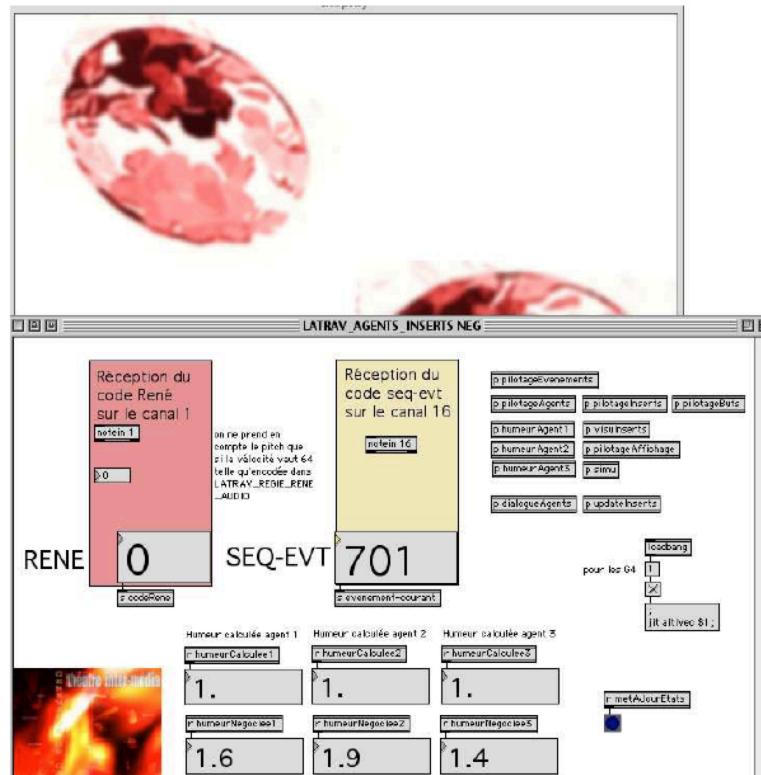


Fig. 3. Screenshot of part of the Max/MSP/Jitter patch in *La Traversée de la nuit*.

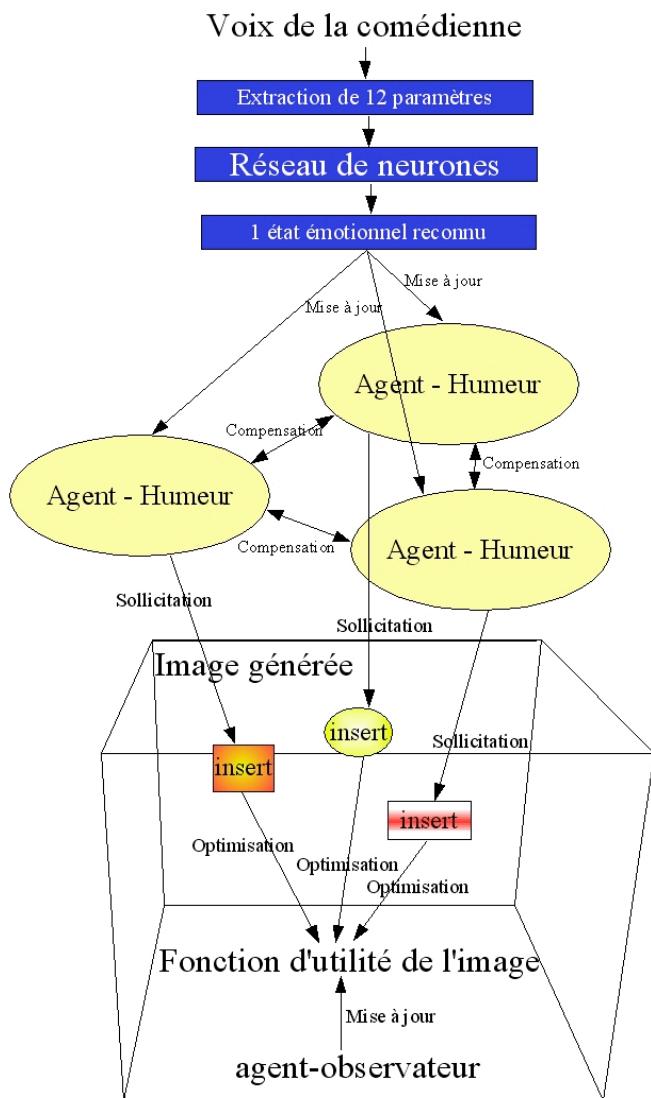


Fig. 4. Overall organization of the computerized processes in *La Traversée de la nuit*.

We show below on the two following video excerpts (to be embedded in the online version of the article) how the 'climate' of the voice can influence the movement of the agents. The same text ('[...] avant que retentisse la deuxième sirène de l'appel. Nous sommes le 29 octobre, et il ne fait pas encore très froid'⁵) is told with two opposite expressions ; we have voluntarily isolated two agents out of the total population and shown step by step their evolution. For the first video, the voice sounds quite 'soft' and 'intimate'. The two agents remain quite close. In the second video, the video sounds 'loud' and 'cold': the two agents move away from each other.

⁵ Possible translation of this text could be '[...] before the second call alarm rings out. It is October, 29th, and still not too cold'.



Fig. 5. Video snapshot of a first simulation with two visual agents driven by a 'soft' and 'intimate' voice.



Fig. 6. Video snapshot of a second simulation with two visual agents driven by a 'loud' and 'cold' voice.

Transforming Stage Direction Practices by IVE

Facing a theatre text, every stage director would like to propose his/her interpretation. Let us remind that the interpretation is not immanent to the text, in spite of the numerous indications (playwright foreword, stage indications, etc.). A text cannot exist on stage without an exegesis completed by the stage director.

This interpretation is always an effort to create forms. Let us try to understand this approach in a computer science viewpoint. The stage director process starts by setting a synthetic ontology of the drama: it describes the characters as types (19th century light comedies work with a small number of types, mainly three: husband, wife, and lover) and instantiations, by telling the name of the character, his/her situation at the beginning of the play, his/her costume, etc. During the play, there are instantiation variations⁶: the spectator discovers that such or such character is far different from what he/she imagined at the

⁶ *Instanciation* is a word often used by computer scientists, that comes from *instance*, and means *example, case*; an instantiation generalizes in a way the operation of affectation of a numeric value to a variable: to describe the real world, computer scientists instantiate abstract classes, stating that such or such entity is a particular case of a class, which is itself linked to other classes by generalization hierarchies and/or formal properties. This builds a set sometimes named *ontology*. Ontologies are claimed to describe parts of knowledge about the world and are very used in artificial intelligence. This can also be considered as an *object design* (an object design is based on heritage graphs in order to generate programs by simple instantiation of key-parameters).

beginning. These instantiation variations may lead to ontology revisions. It is for instance the challenge, as well dramatic as metaphysical, in the play *El Burlador de Sevilla* by the Spanish playwright Tirso de Molina (1630), inaugurating the Don Juan myth: may this character be saved by acknowledging his sins *in extremis* before his death ? May the character's ontology be modified at the very end of the play ? Let us notice that this approach may be applied to other forms of dramaturgical, no more based on characters but on situations (in this case, ontologies of situations would be considered).

In this traditional approach of theatre, the concept of similarity by the ontologies is essential. The director stages every scene considering it as an example in a set of cases provided by theatre literature. Explaining a character to an actor consists in pointing in the proposed ontology and link this ontology other ontologies, either of the same play or other ones. Sometimes two stage directions by two different directors can be considered as instances of the same ontology.

In a more general point of view, this is a formal approach, where the example is represented as an instance of a general structure grasping all cases, and one looks for similarities by varying the instantiation. The obvious advantage is to provide an explication of the "similar to the example" side of the proposition, and even a distance measure – this is the way to create a recapitulatory concept in *intension*. Ontologies enable to look for the similarities of an example by staying inside a concept, even if it means to move to the immediate more general concept when the search is unsuccessful. This kind of approach that has to do with pre-organization necessities evoked by Manoury. In the field of digital arts, artistic installations as well as virtual worlds usually implement highly structured and completely predefined ontologies that model the environments, the objects, the users, etc.

In a computer science viewpoint, there is another way to deal with the question of similarity ([Perrot94]): it is the interactive data-mining approach, where the example is represented as a specialization of a set of cases. One looks for other neighbouring specializations, but without having at disposal a pre-defined ontology. The user accepts to shape an *ad hoc* ontology at his/her hand with the interactive help of computers. This is an approach by extension: shaping a similarity consists in shaping a list of contents of similar form by successive amending actions. It uses computing in an interpretative and interactive way, with amending actions on contents and their forms (on the user's side, who is provoked by the proposals of the computer).

In the case of the staging of *La Traversée de la nuit*, we have built a dramaturgical IVE system. It first means we have designed a virtual world with its multi-modal interfaces and its feedback loop: voice (actress) to image (population of kinds of sprites on screen), image to movement (dancer), image to voice (feedback to the actress), movement to voice (dancer to actress). We come to an IVE, since dramaturgical knowledge is handled by the actor to machine relationship in our system. This knowledge is not a set of predefined ontologies that would "translate" the text into static structures. It is centred on a set of interactions that let the performers play with the system as an instrument but providing at the same time some surprise. If we come back to necessities expressed by Manoury:

- We deal with writing and interpreting strategies developed by the author and the stage director: memory, premonition, etc. are overexposed by the

association of voice, movement and image.

- We keep separate the two levels of predetermination (text, music, banks of images pre-selected, indications of staging) and what belongs to interpretation (voice, part of movements, images).
- We do not have such precise time requirements as musicians, but we have organized time coordination thanks to voice inputs and visualisation that provide important synchronisation or trigger information, both for performers and to the audience (telling there is an important change).

Conclusion: Towards Tools for Collaborative Man to Machine IVE

We are currently working on a theatre creation named *Les petites absences*⁷ that is also a research in collaboration with the Realtime Musical Interactions Team at Ircam, managed by Frédéric Bévilacqua, and the comedians of the *Théâtre du Signe* in Caen. During this project, we put the emphasis on having enough time to test ideas about a future possible dramaturgical working station for performers and stage directors. We name it 'Virtual Assistant for Performers and Stage Directors'. We discussed such issues as dramaturgical knowledge emergence or fuzzy mapping between scenographic inputs and outputs. We show below a screenshot of a sketch of one aspect of the 'Virtual assistant'. We start from audio and video capture of performers (dressed in black in contrast with a white backstage wall). Their silhouettes are surrounded with bounding boxes. Descriptors about gesture (quantity of movement, surface of contraction, etc.) and about voice (pitch, loudness, brightness, etc.) are computed for each frame. Then aggregators can be computed for each descriptor: for instance, average value, variance, minimum and maximum values. This gives a 45-component vector that characterizes each sequence.

We therefore constitute a stack of vectors. The most important aspect for us is to arouse the emergence of dramaturgical knowledge thanks to man to machine dialogue. We therefore let the user (for instance a stage director) organize collections of sequences that seem quite close to him/her. From this intuitive personal collection, we infer thanks to a Principal Component Analysis the most significant aggregators (among the 45 present) for the collection. This enables to avoid pre-defined modelling of performing situations.

⁷ This play will be created in December 2008 at the *Comédie de Caen*.

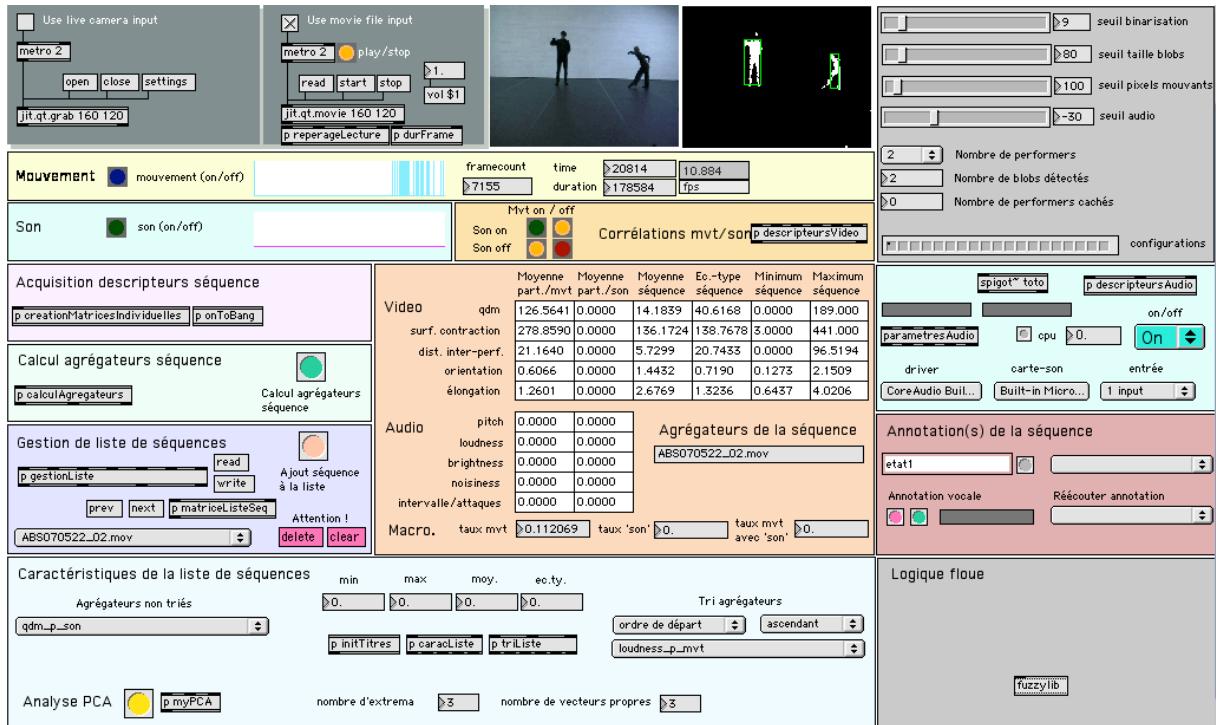


Fig. 7. Screenshot of a sketch of the acquisition interface for the 'Virtual Assistant for Performers and Stage Directors'.

Second step, we are developing a real-time (for Max/MSP) fuzzy logic⁸ engine able to handle uncertain reasoning. This give us the opportunity of thinking of fuzzy mapping between the inputs and the outputs of the scenography. For instance, how can we link the presence of the actor on stage (corresponding to the surface of contraction he/she occupies on the screen capture) to the level of red lightning ? First idea would be to write in Max/MSP (that can handle all device for stage command) a predefined mathematical function giving the level of red according to the presence of the actor. Our idea is to let some ambiguity in the mapping thanks to fuzzy logic, and to be able to build a feedback loop using fuzzy modifiers. For instance, let us consider a fuzzy rule like 'if the actor is very present, the level of red should be high'. From the first empirical observations, we can adjust the rule using fuzzy modifiers, to remain on a semantic level.

⁸ Project lead with the collaboration of researchers of the Laboratory of Advanced Computing of Paris 8 University: Isis Truck and Nicolas Jouandeau.

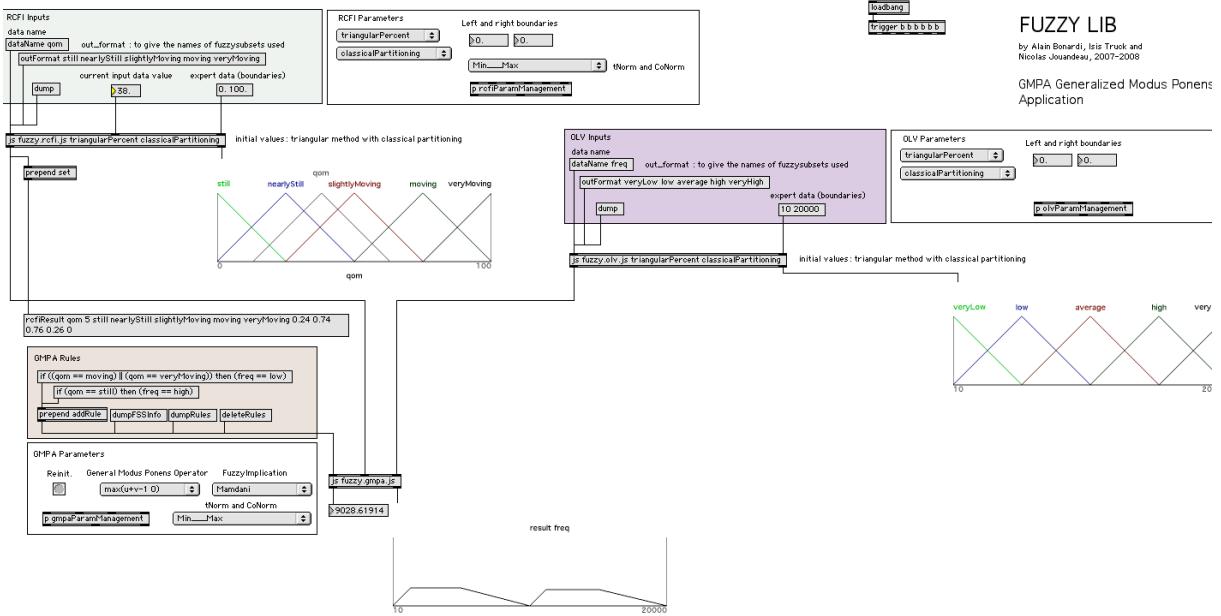


Fig. 8. Screenshot of a sketch of the real-time Max/MSP fuzzy logic engine to link inputs and outputs of scenographic and dramaturgical 'systems'.

This research provides sketches of tools to implement various aspects of IVE systems dealing with stage scenography and dramaturgy.

Bibliography

A. Allombert, M. Desainte-Catherine, *Interactive scores: A Model for Specifying Temporal Relations between Interactive and Static Events*, Journal of New Music Research, vol. 34, n° 4, Décembre 2005

S. Aubry, I. Thouvenin, D. Lenne, S. Okawa, *Knowledge Integration for Annotating in Virtual Environments*, International Journal of Product Development, Inderscience eds, 4(6):533-546, 2007

M. Becker Villamil, S. Raupp Musse, L. Paulo Luna de Oliveira, *A Model for Generating and Animating Groups of Virtual Agents*, Intelligent Virtual Agents, 4th International Workshop, IVA 2003, Kloster Irsee, Germany, September 15-17, 2003

A. Bonardi, I. Truck, H. Akdag, *Building Fuzzy Rules in an Emotion Detector*, 11th International Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU'2006), actes pages 540-547 (vol. 1), Paris, juillet 2006.

A. Bonardi, Th. Bouaziz, F. Rousseaux, *A style of theater production inspired by interactive content data mining*, Human System Learning Who is in Control?, ISBN 2-909285-33-2, Editions Europia, décembre 2005

A. Bonardi, F. Rousseaux, *Composing an Interactive Virtual Opera: The Virtualis Project*, LEONARDO Volume 35, Issue 3, MIT Press, juin 2002

R. Caussé, *Instruments de musique virtuels et modélisations physiques*, Découverte, n° 340, Juillet 2006

E. Corteel, *Synthesis of Directional Sources using Wave Field Synthesis, Possibilities and Limitations*, EURASIP Journal on Advances in Signal Processing, special issue on Spatial Sound and Virtual Acoustics, Janvier 2007

S. deLahunta, F. Bevilacqua, *Sharing Descriptions of Movement*, International Journal of Performance and Digital Media, vol. 1, n° 3, 2007

N. Donin, *Vers l'annotation multimédia d'informations musicales*, L'inouï, revue de l'Ircam, n° 2, 2006

L. Hansen-Love, *Les images peuvent-elles mentir ?*, PhiloSophie, 2007

J. Herder, K. Garbe and I. Herbst, *Spatial Audio for Augmented Reality*, 10th International Conference on Human and Computer, Duesseldorf/Aizu-Wakamatsu/Tokyo, pp. 53-58, December 2007

E. Husserl, *Leçons pour une phénoménologie de la conscience intime du temps*, PUF Epiméthée, 1964

Ph. Manoury, *Considérations [toujours actuelles] sur l'état de la musique en temps réel*, Collection é prospectives, Ircam, Septembre 2007

M.-J. Mondzain, *Image, icône, économie*, SEUIL, 1996

C. Pelachaud, I. Poggi, *Multimodal Embodied Agents*, The Knowledge Engineering review, Vol. 17:2, 181-196, 2002

J.-F. Perrot, *Des objets aux connaissances*, Journée Méthodes objets et Intelligence Artificielle : Frontières, Ponts et Synergies, Paris RIA, June 1994

F. Rousseaux, A. Bonardi, *The Emergence of Knowledge in the Secrecy of our Musical Collections*, 4th Sound and Music Computing Conference, Lekfada, Grèce, juillet 2007

F. Rousseaux, A. Bonardi, *Music-ripping : des pratiques qui provoquent la musicologie*, MUSICA SCIENTIAE, Irène Deliège éditions, European Society for the Cognitive Sciences of Music, page 111-124, numéro spécial 2003-2004

C. Suied, P. Susini, S. McAdams, *Evaluating Warning Sound Urgency with Reaction Times*, Journal of Experimental Psychology, 2008

C. Vergez, P. Tisserand, *The BRASS Project, from Physical Models to Virtual Musical Instruments: Playability Issues*, Lecture Notes in Computer Science, vol. 2006, n° 3902, Mai 2006

I. Viaud-Delmon, O. Warusfel, A. Seguelas, E. Rio, R. Jouvent, *High Sensitivity to Multisensory Conflicts in Agoraphobia Exhibited by Virtual Reality*, European Psychiatry, vol. 21, n° 7, 2006

A.-N. Whitehead, *Modes de pensée*, VRIN, Analyse et philosophie, 2004

L. A. Zadeh, *The Concept of a Linguistic Variable and its Application to Approximate Reasoning-I*, Information Sciences 8, 199-249 (1975)

L. A. Zadeh, *The Concept of a Linguistic Variable and its Application to Approximate Reasoning-II*, Information Sciences 8, 301-357 (1975)

L. A. Zadeh, *The Concept of a Linguistic Variable and its Application to Approximate Reasoning-III*, Information Sciences 9, 43-80 (1975)

Short biographies of the authors

Since they have met in 1997 at Ircam, Francis Rousseaux and Alain Bonardi regularly collaborate in the field of Informed Virtual Environments (IVE).

Francis Rousseaux est ingénieur en informatique, 'full professor' depuis 1997. En appui de sa recherche de PhD, il a créé en 1990 le système apprenti d'aide à l'éducation de l'oreille *Le Musicologue*, puis il a participé à la coordination de deux projets IST (http://www.ircam.fr/projets_europeens.html?L=1) dans le domaine de la fouille de pièces musicales (*Cuidado et SemanticHiFi*). Francis Rousseaux travaille actuellement à l'Ircam sur le projet IST Caspar. Il est aussi membre du groupe DiGiArts de l'Unesco.

Alain Bonardi is an artist as well a researcher. Parallel to an engineer training in the Ecole Polytechnique, he has studied musical composition with Emmanuel Nunes, Michel Philippot and Hacène Larbi. His creations in the field of opera deal with musical composition (digital opera in an open form *Alma Sola*, chamber opera *Du/Tri-plicata* – grant from the Beaumarchais Association), as well as digital scenography (virtual scenography of *Norma* by Bellini) or the association of artificial intelligence with stage arts (theatre plays *La Traversée de la nuit* by Geneviève de Gaulle-Anthonioz, *Sur la lecture* by Proust). Alain Bonardi is a senior lecturer at Paris 8 University.