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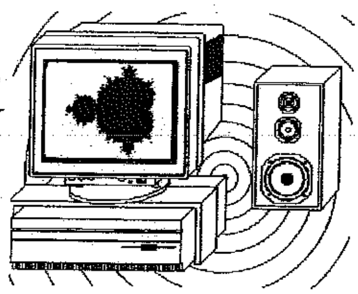

UNDERSTANDING AND CREATING MUSIC

Geometric algorithms and fractals, physical models and perceptive structures.

Caserta, November 2002, 21-25

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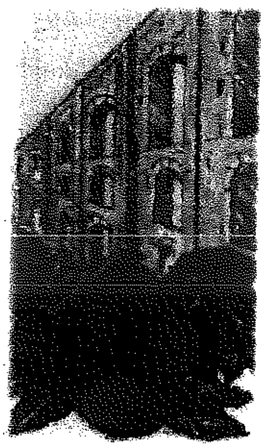

Pro Loco Valle di Maddaloni

SERIO

The mapping paradigm in gesture controlled live computer music

Leonello Tarabella, Graziano Bertini

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Abstract

No doubt music is the art of the sense of hearing. However, whatever the genre, in a concert executed with traditional instruments the visual aspect plays an important role for the emotional communication between the artists and the audience: dressing and behavior of performers on stage and spatial location of musical instruments directly controlled by the performers, guarantee the audience as to the reality and completeness of a human-to-human artistic communication. Here, everything happens as in Nature.
Interactive electro-acoustic music proposes a complete new scenario not only for the new sound palettes introduced but also for the new kind of relationships experienced by the audience between what-is-going-on-on stage and the final musical result.
While a traditional music instrument is a compact tool, the new electro-acoustic instrument is a system consisting of a number of spread out components: sensors and controllers, computer and electronic sound generators, amplifiers and loudspeakers. How to link information between the various parts of this exploded instrument is deeply correlated to new modalities of composing and performing in relationship with how the audience perceive and accept these new paradigms.
We here report our point of view and considerations about the role of "mapping" derived from our experience both in developing original controllers and in the realization of interactive electro-acoustic performances.

1. Introduction

A traditional music instrument is a compact tool which gathers together all the aspects (shape, ergonomics, mechanics and material) necessary for stating and determining timbre and for controlling pitch and nuances of sound. For some instruments it is also possible to personalize the acoustic response by choosing specific interchangeable crucial elements: mouthpiece (and reeds) for wind instruments, material and size of strings for string instruments. Besides, the physical structure of the instruments reflects the alphabet and syntax of reference for the music played (which in the case of western music is the well tempered scale and harmony) and reflects even the anatomic structure of the human body…maybe an alien civilization could derive the shape and structure of the human body by analyzing the complexity of musical instruments.
A question now arises: is the term "instrument" still appropriate and correct for the new equipment used in computer music? Compared to a traditional compact musical instrument the new one appears as an "exploded instrument" consisting of different elements: controller(s), audio-signal generator (the computer) and sound sources (loudspeakers) connected via different typologies of cables and signals.
There exist two main types of connections: the digital connection between controllers and computer and the analog connection between computer and loudspeakers. The analog path is related to rendering problems: regarding how to enjoy a video-clip, a film or a concert it makes a difference

whether using a simple home one-small-loudspeaker TV-set or Stereo-surround equipment because it affects the quality of sound and fidelity to the original design together with the intentions of the composer and players.

The digital connections are more crucial. Controllers, or gesture recognition devices, produce data-flows used by the computer for producing sound (Tarabella 2001a). The problem now consists in how to link, or better, how to *map* information coming from controllers to programs which generate complex musical structures and/or to synthesis algorithms which generate sound signals.

2. The new "instrument"

This is a real novelty in computer music performance. The composer/performer sets up a software mechanism which uses data coming from a controller to produce sound events: the performer "plays"...not precisely an instrument but rather a dynamic meta-instrument. From the point of view of the audience things become more difficult to understand especially when original controllers based on different kinds of sensors (pressure, acceleration, heat, infra-red beams, ultrasound, etc.) or gesture recognition systems based on realtime analysis of video captured images, are used by the performer.

In the computer music field a great variety of very sophisticated and complex gesture interfaces have been designed and realized using almost any kind of sensor. For a panoraminc overview on the argument we suggest that the reader use "gesture" as the keyword for browsing the Net (Tarabella 2001b, Wanderly 2000) and the proper references (Camurri 2000, Paradiso 1997, Poval 1996, Tarabella 1997).

From our experience, in particular regarding impressions and questions coming from the audience after our concerts, we argue that people usually can appreciate and understand that what is going on musically comes from the presence and the movements of the performer, but in general are unable to understand the complex cause-effect relationships and usually think the controller **is** the instrument. And usually they are completely unaware about mapping and the crucial role of the computer during the performance, as it generates events in accordance with predefined music/acoustic material combined with information from the controllers a performer is acting on. The simple one-to-one mapping rule valid for traditional instruments leaves room for a theoretically infinite range of mapping rules definable by the composer for a specific piece and even for each part of that piece. The mapping is a part of the composition.

This approach opens a complete new and wide territory to explore for composition, and especially, for live performance. It is no longer a matter of playing an instrument in the traditional sense, but rather playing a specific piece of music in terms of activating and controlling during the live performance musical/acoustic material and algorithms prepared during the compositional phase (Serra 2001, Rowe 2001, Tarabella 2000).

3. The mapping paradigm as a creative tool

We shall give here some very basic ideas which constitute a good approach to using mapping as an aesthetic and creative tool for live gesture controlled computer music performance. We think it's hard to formalize rules and/or strategies about mapping since we are here facing the realm of creativeness and it appears rather difficult to try to follow and/or fulfill a specific syntax while composing. Anyway we give here an informal but usefull definition of mapping as *the possibility of implement algorithmic mechanisms which dynamically put in relationship data coming from gesture recognition devices and algorithms which generate musical events and sound.*

3.1 An example of mapping

Consider a very simple example where the mouse is used as a gestural interface and a MAX-MSP (Winkler 1999) patch generates sound in accordance with these simple rules: vertical position of mouse sets pitch of sound, horizontal position controls harmonics content, button-down starts sound, button-released stops sound. Another situation could be: pitch is random, timbre is fixed in advance, vertical position controls the attack time, horizontal position controls the amount of reverberation. A further situation maybe…maybe you, the reader, at this point has devised some different and smarter ideas.

As a consequence of the many ideas and arrangements one can think of how to link the simple and standard functionality of the mouse, we can claim that mapping and composition make part of the same creative activity at both micro level of timbre and macro level of musical melodic and rhythmic patterns.

In (Sapir 2002) Silviane Sapir wrote that mapping should be neither too simple nor too complex since in the first case the real power of the computer turns out to be not so well used; in the second case the audience is not able to understand what is happening and cannot appreciate completely the artistic content of the performance.

Having direct experience of that, we strongly agree with this observation and, further, we think the rule can and must be extended as follows: we experienced that if a complex mapping situation is reached after a growing-up complexity started using simple (close to one-to-one) mapping, the audience willingly accepts it even if highly complex to be understood. It's important however that the "training" phase has a *per sé* aesthetical and musical meaning.

After one or two episodes like that, it is possible to use the opposite path, that is from a very complex mapping situation to a simple one. This will be accepted by the audience because in some way people are faithful that something will happen to "explain" (artistically speaking) what is going on; often it happens that someone starts the guess-the-riddle game in his/her mind. And after a number of episodes like those described, also sharp changes from simple to complex and vice-versa, mapping proves to be of interest and well accepted by the audience.

3.2 The importance of the audience

For us mapping is the real novelty in live performed computer generated music. For that we take the audience into great consideration as the opposite pole of the composer/performer.

In an avant-garde concert executed with traditional musical instruments, the audience is requested to understand and taste the musical language and musical content proposed. A default for the audience is that musicians play musical instruments, that is that they use mechanical "tools" for producing sound, in the same manner a speaker is expected to use his/her mouth: attention is focused on the content. In a tape-electronic music concert, the artistic message is accepted as an opera prepared in studio, in the same manner as a film or a video-clip, no matter how the composer reached the result.

But in a live computer music concert the visual component is of great importance when the new "exploded" instrument is used because attention of the audience is also focused on the relationships between gesture of the performer and the music they are listening to. And people want to understand the rules of the new game, beside tasting and appreciating the musical result.

It is important then to plan a storyboard of different situations each one characterized by well defined musical-acoustic micro-worlds inside of which well balanced "amounts" of simple and complex mapping arrangements between gesture and music should be used.

Our attention shifts now to technical problems and proper solutions related to gesture recognition systems and to mapping.

4. Mapping and acoustic feedback

In gesture controlled electro-acoustic musical performances a big role is played by the psychoacoustic feedback that is the loop created by the performer's movements upon the controllers and then the sound generated that is heard (O'Modhrain 2000). We know that in traditional wind and bow instruments, feedback is related to the continuous control of sound characteristics (pitch, intensity, timbre, articulation etc.) during the generation by means of continuous modifications of the physical synthesis parameters. The importance of feedback can be easily experienced when it lacks i.e. by playing an instrument with the ears closed or while wearing headphones playing different sounds or music at an high volume; in these cases the intonation and the timbre result differently from those desired because even tough the movements and postures of the body onto the instrument are close to the "correct" due physical values, little parameter differences cause audible sound differences.

Acoustic feedback is equally important in realtime controlled computer generated music; however, as seen before, the "new instrument" entails here a complete new behaviour due to the number and typology of elements involved. Actually since the new instrument is indeed a system, knowledge about System Theory (Marro 1997) can be applied for a pertinent investigation and usage of the input and output data-flow. In this field we know that the typical concepts to take into consideration are: *instability*, *controllability* , *linearity* and, in presence of digital devices, *sampling rate*, *quantization, latency* and *multiple triggering*.

- **Instability and controllability.** Instability means that a system under finite stimuli produces an infinite and non-decreasing response. Controllability indicates to what extent it is simple or not to control the system states and output by varying its input. Controllability can be low or high: low controllability, which for traditional instruments could be translated into "difficult to play", typically consists of bad features in the direct path; if present, it will appear and will be heard by the performer whenever the instrument is played.
- **Linearity**. In many kind of controllers typically most of the sensors used are not linear. But after all, non-linearity is present also in traditional musical instruments even if not known like that: in the violin it is much more difficult to get the correct pitch when the finger gets closer to the bridge just because of the non-linear response of the pitch versus the finger position...and no violin player complains of that. Anyway when non-linearity is a problem, proper methodos can be used for linearization of mapping, otherwise, as happens for volume or pitch controls, values can be directly used. Both behaviours can be avoided or used depending upon the artistic and creative needs: for example discontinuity should be implemented in mapping when the desired output is a trigger and the input is "continuous".
- **Sampling and quantization.** We can assume that all gesture controlled musical systems have a digital part; in order to convert analog into digital signals we know it is necessary to use two types of processing: sampling and quantization also called Analog-to-Digital conversion (A/D). The gesture capturing systems have low sampling rates, about some ten Hertz. If we try to directly control low level sound synthesis with such a low rate signal we will hear a lot of clicks; some precautions must then be taken into consideration in order to avoid them, as explained in the following.

The second step in A/D conversion is quantization, where a finite and limited number of bits are to be used, typically 8 or 10, for representing values coming from controllers. Even in this case it is usually unwise to directly control low level synthesis parameters, since the "steps" in the sound signals can be heard, especially when controlling the pitch.

Oversampling and related interpolation techniques are used to solve both of the above mentioned problems, in order to increase the time and the amplitude resolutions (Oppenheim and Schafer 1975). The resulting signal is "more continuous" or, better, "less discrete" from a practical point of view since it amounts to an higher sampling frequency and uses a greater number of bits than the original. When necessary (for example in pitch or timbre variations) it's so possible to control sound synthesis without audible clicks and steps.

- **Latency** is a well known concept in the computer music field and is generally defined as the delay between the stimulus and the response. While in traditional instruments there is usually no latency since the effect (sound) is emitted as soon as the stimulus (bow movement, key hit etc) is started, in the new instrument two types of latency are present: the short time and the long time ones (Wessel and Wright 2001). Short time latency (10 ms order of magnitude) depends on the audio-signal buffers size, on the sampling rate and on the different kind of data processing, and is always present in digital processing systems. When the delay between cause and effect is too high, the response is perceived late and both the performer and the audience realize that the system does not *respond* promptly. On the other hand, the long time latency is specifically a compositional tool used by many composers for implementing specific sound effects or data processing.
- **Multiple Triggering.** Another important point for mapping, especially when triggering sound samples, is the anti-bouncing algorithms. When a sound sample is triggered from a signal coming from the gestural recognition device, it can happen that instead of only one single trigger several of them come one after another. In this case the multiple triggering, if not filtered, will make the sample start many times, and lots of "clicks" will be heard at audio level. In order to avoid multiple triggering it is necessary to filter out the triggering signal once the sample is started for a time depending upon the sample duration. This problem, called *synchronisation*, does not appear in musical interfaces only, but it is typical of the interfacing between analog and digital circuits; anti-bouncing hardware or algorithms are always implemented in the keyboards of calculators, computers, mobile phones etc..

While in specific technical application all these problems must be taken into account and must usually be solved for working properly, in the creative artistic context the composer/performed is requested to be aware of them; they should be taken into consideration but it is not strongly requested to solve them since if sometimes they can cause unwanted results, at other times can be used for reaching specific artistic goals and often they must even be emphasized.

5. Conclusions

Writing this article forced us to place order on and to clarify the knowledge we gained on mapping from our experience from three different and complementary points of view and approaches: philosophical, technological and artistic.
As said, it's a not matter of formalizing mapping but rather of knowing as much as possible the features mapping offers for expressive/artistic purposes. And after all Harmony has been formalized after musicians have produced thousands and thousands of compositions, the syntax of a language is usually formalized after it has become a well defined communication tool and lot of literature has been produced, books on jazz improvisation has been written and schools of jazz was founded when the history of jazz were almost concluded.
Since mapping also leaves space for improvisation (Tarabella 1995) the presence of the audience is extremely important for the development of mapping as a new tool for making music: direct human-to-human artistic communication gives back useful information for that.

The MAX and MAX/MSP languages allows the philosophy of mapping as a new territory of creative activity to be put to work. While Max is a de facto standard, at the moment there do not exist standards for gesture tracking systems and it seems that the activity of designing and carrying out personal and original interfaces is particularly rich as is that of composing and performing.

6. Aknowledgments

Special thanks are due to Massimo Magrini and Gabriele Boschi who greatly contributed in developing the proper communication and audio synthesis software and the true implementation of gesture tracking systems at the cART project of CNR, Pisa.

7. References

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09.30 – 10.00: A. Fleischer *(Technical University of Berlin)*, A model of metric coherence

10.00 – 11.00: D. Cope, *(University of California, Santa Cruz)*, Computer Models of Musical Creativity.

11.00 – 11.30: (Library) coffee break

11.30 – 12.00: D. Casali, G. Costantini, M. Salerno *(University of Rome "Tor Vergata")*, Automatic musical chord recognition.

12:00 – 13:00: G. Buzzanca, *(Conserv. "Niccolò Piccinni")*, A Neural Network for Musical Style Recognition

13:00 – 13:30: C. Buteau, *(Dep. of Math. ETH Zurich, ETH Zentrum)*, RUBATO's MeloTopRubette for Topological Analysis of Melodic Paradigms

13:30 – 13.40: Panel

13.40 – 14.30: (Library) Farewell party

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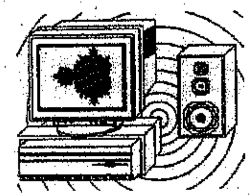

November 2002, 21-25
Caserta

Polo Universitario
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Thursday 21st November
8.30 – 11.00: registration

Session I
11.00 – 11.30: Opening session

11.30 – 12.30: J. Haluska *(Mathematical Institute, Slovak Academy of Sciences)*, Classification and structure of tone systems and the uncertainty knowledge-based information theory.

12.30-13.00: P. Di Lorenzo *(Seconda Univ. Napoli)*
Chaos and order in recorded monodic music via nonlinear time series analysis.

13.00 – 13.30: P. Di Lorenzo, G. Di Maio, M. T. Scarpa *(Seconda Univ. Napoli)*, Fractal musical signals compression: a new reliable method?

13.30 – 15.00 (Library) Welcome party

15.00 – 15.30 V. Cafagna, D. Vicinanza, *(Univ. di Salerno)*, Audio synthesis by means of elliptic functions.

15.30 – 16.00 B. Meudic, *(Ircam - Centre Pompidou)*, A causal algorithm for beat-tracking.

16.00 – 17.00: B. Riečan *(Slovak Academy of Sciences)*
Mathematical models of uncertainty and Music.

17.00 – 17.30: (room M) coffee break

17.30-18.00: G. Barbasso, G. Costantini, A. Uncini
(Univ. di Roma "Tor Vergata"), An adaptive filter for real-time room acoustic response simulation.

18.00 – 18.30: S. Busiello *(Seconda Univ. di Napoli)*, Music and images.

Friday 22nd November
09.00 – 09.30: M. Olivetti Belardinelli *(Univ. di Roma "La Sapienza" – ECONA)*, Research lines in cognitive Psychology of Music.

09.30 – 10.00: A. R. Addessi *(Univ. di Bologna)*, Perception of the "Macroform" in the Quartetto per Archi in due tempi (1955) by Bruno Maderna.

10.00 – 10.30: T. Noll, *(Univ. of Berlin)*, Tone Apperception and Weber-Fechner's Law.

10.30 – 11.00: M. Reybrouck *(Catholic Univ. of Leuven, Belgium)*, Understanding and creating music between measurement, computation and control: symbolic thinking and theexperiential approach.

11.00 – 11.30: (room M) coffee break

11.30 – 12.00: F. Delogu, R. Brunetti M. Olivetti Belardinelli *(Univ. di Roma "La Sapienza")* How do melody and rhythm go together? A new performance-task based experimental approach.

12.00 – 12.30: M. Karasseva, *(Computer Center Moscow State Conservatory)* Understanding Music Language through Synesthesia as Means for Music Cognition.

12.30 – 13.00: J. Kiss *(Université Paris VIII)*
The esthetic influence of the paradigms of cognitive science within musical creativity.

13.00 –13.30: A. Damiani , P. Di Lorenzo, G. Di Maio, M. Olivetti Belardinelli *(Univ. di Roma "La Sapienza"– ECONA)*, A Mathematical Model to classify the musical patterns of listened melodic pieces.

13.30 – 15.00: Lunch time

15.30 – 16.30: I. Deliège, *(URPM - Centre de Recherches musicales de Wallonie Université de Liège)*, Emergence, Anticipation and Schematization Processes in Listening to a Piece of Music.

16.30 – 17.00: F. Delogu, C. X. Rodriguez , N. Hernandez, M. Olivetti Belardinelli, *(University "La Sapienza" Rome)*, Influences of metric and melodic accent structures on expressive rhythmic performance.

17.00 – 17.30: (room M) coffee break

17.30 – 18.00: A. Padova, L. Bianchini, M. Lupone, M. Olivetti Belardinelli, *(Univ. di Roma "La Sapienza")*, A Contribute about the relation between Musical Timbre and Emotions in the Listeners.

18.00 – 18.30: G. Sica, *(Univ. di Napoli, Gruppo AC.EL.)*, Micro and macro-processing elements in Max MSP environment.

18.30 – 19.00: F. De Felice, F. Scagliola, F. Abbattista *(Univ. di Bari, VALIS group)*, GenOrchestra: Towards a creative musical behaviour.

Saturday 23rd November
09.00 – 09.30: V. Cafagna, F. D'Eliso *(Univ. di Salerno, Conservatorio di Napoli)*, A special nonlinear distortion synthesis device based on McAdams functions.

9.30 – 10.30: G. Nottoli *(Conserv. di Frosinone, Univ. di Roma "Tor Vergata")*, Computer aided musical composition, a survey.

10.30 – 11.00: R. Santoboni, *(Conserv. di Bari, Accademia Musicale Pescarese)*, Matrix procedure for the generation of musical structures.

11.00 – 11.30: (room M) coffee break

11.30 – 12.00: M. Clementi, R. Santoboni, A. R. Ticari, *(MARR Software)*, Virtual Composer: an integrated tool for musical composition.

12.00 – 12.30: P. Monopoli, Cellular Automata and musical composition: an experience.

12.30 – 13.00: L. Tarabella *(C.N.R., Pisa)*, The paradigm of mapping in gesture controlled live computer music

13.00: poster session, H. Suzuki, *(Keio University Yokohama)*, Grouping of Music by Self Organization of Neural Network

13.00 – 14.30: Lunch time
15.00 – 18.30: Guided tour: Casertavecchia middleage city
19.30: Concert

Sunday 24th November
9.30 – 12.30: Guided tour: Royal Palace and Gardens
12.30 – 15.30: Lunch time
15.30 – 19.00: Guided tour: Royal Palace and Gardens
19.30 – 21.30: Gala Dinner

Monday 25th November
09.00 – 09.30: F. Rousseaux., A. Bonardi, *(IRCAM-CNRS)*, Knowledge Discovery as Applied to Music: Will Music Retrieval Over the Web Revolutionise Musicology?