About the role of mapping in gesture-controlled live computer music

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Abstract. Interactive computer music proposes a number of considerations about what the audience experiences in relationship of what-is-going-on-on-stage and the overall musical result. While a traditional music instrument is a compact tool and "to play an instrument" has a precise meaning for everybody, 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 perceives and accepts these new paradigm. 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 the 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.
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 or a film, it makes great difference whether using a simple home one-small-loudspeaker TV-set or a Stereo-surround equipment since it affects the quality of sound and fidelity to the original design together with the intentions of the composer and the players.
The digital connections are more crucial. Controllers, or gesture recognition devices, produce data-flows used by the computer for producing sound [1]. 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.

1.1 The new instrument

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: this is the real novelty introduced by music performance. 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 [2],[3],[4],[5],[6],[7],[8] ,[9].
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 the audience is completely unaware about the crucial role of mapping and what actually the computer does during the performance for generating events in accordance with predefined music/acoustic material combined with information coming 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 has open 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 [10],[11].

2 The mapping paradigm as a creative tool

We shall give here some very basic ideas we usually take into consideration when using mapping as an aesthetic and creative tool for live gesture-controlled computer music performances. 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 implementing algorithmic mechanisms which dynamically put in relationship data coming from gesture recognition devices and algorithms which generate musical events and sound".

Consider a very simple example where the mouse is used as a gestural interface and a MAX-MSP [12] 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 [13] 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 The importance of the audience

For us the mapping paradigm is the real novelty in live performed computer 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 well known 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 are 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 the generated sound the performer hears [14]. 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 a completly new behaviour due to the number and the typology of elements involved. Actually, since the new instrument is indeed a system, knowledge about System Theory [15] 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*.

4.1 Instability and low controllability.

Instability means that a system under finite stimuli produces an infinite and non-decreasing response. Controllability indicates to what extent it's simple or not to control the system states and the 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, that is: performer->controller->sound; if present, it will appear and will be heard by the performer whenever the instrument is played (reverse path: performer<-sound).

4.2 Linearity.

In many kind of controllers most of the sensors used are typically not linear. But after all non-linearity is present also in traditional musical instruments even if not known in these terms: in the violin it is much more difficult to get the correct pitch when the finger gets closer to the bridge due to 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 using mapping, otherwise, as it 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 with a "threshold crossing approach" when the desired output is a trigger and the input is "continuous".

4.3 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.
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 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 [16].
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.

4.4 Latency

This is a well known concept in the computer music field and it 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 latency and the long time latency [17]. 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; this is always present in digital processing systems. When the delay between cause and effect is too high, the response is perceived in late and both the performer and the audience realize that the system does not *respond* promptly.
On the other hand, the long time latency can be used as a specific compositional tool as many composers do for implementing specific sound effects or data processing.

4.5 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 in order that they work 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.

4 Conclusion

In this article we focused attention on mapping from three different and complementary points of view and approaches: philosophical, technological and artistic. As said, it's not a matter of formalizing mapping but, rather, it's a matter of being aware as much as possible about the features mapping offers for expressive/artistic purposes. Since mapping also leaves space for improvisation [18] the presence of the audience is extremely important for its usage as a new tool for making music. And 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 for 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 that of composing and performing [18].
Technology *per sé* is not enough for novelty: from the iconography point of view there are not crucial differences between a rockstar singing and playing an electric guitar on stage using the most recent and sophisticated electronic equipment and a renaissance or medieval *menestrello* playing his lute and singing love and war songs. Mapping could be the true novelty.
We hope our considerations and results may be of some utility to some beginner in this fascinating territory of creative music.

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