Interactive Notation: Towards a Computer Model for Interactive Musical Composition

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Abstract. Here we present a preliminary study on the development of an interactive computer music method to create musical pieces based on the intervenient relation between a musician performer, a computer model and pre-interactive material, previously developed by a human composer. The aim is the establishment of a musical composition method, dynamic and in real-time, based on two premises: 1) the human interactive improvisation on notation 2) the computer-generated sound material, resulting from the interaction between computer, composer and interpreter.

Resumo. Apresentamos aqui um estudo preliminar sobre o desenvolvimento de um processo interativo de música computacional para a criação de peças musicais baseadas na inter-relação entre um músico interprete, um modelo computacional interativo e o material notacional, pré-desenvolvido por um compositor humano. Pretende-se com isso estabelecer as bases para um método de composição musical dinâmico e de tempo real, com base em duas premissas elementares: 1) a improvisação sobre notação interativa e 2) o material sonoro gerado pelo computador, resultante da interação entre compositor-computador-intérprete.

1. Introduction

It is a fact that we are in an age where computers are part of our daily routine. The processing capacity of such machines enables them to be ubiquitously used in computer music, as independent units, portable analyzers, virtual sound synthesizers, able to process and control sonic structures and music of great complexity and rich acoustics. At the same time, various types of data acquisition interfaces that retrieve information generated by body movement – the Gestural Interfaces - provide a wide range of interactive control for such artistic computational processes, thus facilitating communication between humans and machines. A major step was taken when, in conjunction to the extraordinary increase in processing power and computer memory, gestural interfaces were built with the capacity of acquiring and wirelessly transmitting real-time data.

In computer music, the dynamic process control in the sound material can occur through the manipulation of symbolic or acoustic data. They are directly related to the digital representation of audio generated and controlled by computer models. Symbolic Data are related to the control of the generational computer music processes of musical symbols and directly related to the semantic organization of music notation, rather than dealing with the representation of sonic (acoustic) material, organized into music, which is the acoustic data, as previously mentioned.

An interactive computational process notation can be used in many ways. One is the ability to generate original mixed compositional material (acoustic and symbolic) through the interaction with a human counterpart, being an instrumentalist performer, composer or an artist of another sort. The generation of mixed material in real-time brings the possibility of executing the symbolic material generated, sight-read by an interpreter. In a way, this material can be seen as a derivation of a written improvisation - which brings us to the concept of feedback of both parts in this musical process: the interaction between human and machine.

It could be argued that a composition performed on a system of this nature has at least three authors: 1) the Composer of the starting material, 2) the Computer, stratified in the computational model that dynamically creates musical score which the performer executes, and 3) the Performer, which executes the notation and thus adds his artistic aesthetic concepts, and feeds the computing process to keep generating– interactive musical notation. The final result is an artistic process created by a triad of human-machine-human (composer -algorithm-performer) each one with its own peculiarities, different elaborations and variations in the degree of contribution of each part.

For the actual construction of a system of generational interactive sheet music notation, one must first look into the problem of achieving real-time notation that is musically coherent. One could argue that the notation of European classical music is, in a sense, composed of a graphical structure that is very complex due to the need to formalize most of the musical parameters (pitch, dynamic, duration and timbre) unequivocally, unambiguous and consistently. Thus, traditional musical notation becomes, from the computational processing viewpoint, a costly procedure for the system here introduced. However, the so-called "graphic scores" often indicates greater flexibility and less formal rigor. These practices entails to free improvisation, rather than to the strict reinforcement of a musical structure, formalized into the compositional notation of a traditional musical score.

Thus, we need a interactive system that creates notation easy to perform, with low computational load (for the machine to process) and low cognitive load (for the perform to sight-read), but that, at the same time, allowing the expression of musical concepts with sufficient accuracy, concerning with the execution of musical prosody intended by the composer. In this article, we aim to introduce the basis of such interactive notational system.

2. Graphic notations

Several composers of the twentieth century explored different ways to express musical events. Consequently, they had to develop different forms of musical notation. Among them, Witold Lutoslawski and Morton Feldman significantly contributed in this process.

Their notational methods are here considered as possible solutions for our usage, or as an inspiration for the development of a computer model of interactive notation. Figure 1 shows two examples of graphical notation used by the composers mentioned above, made between the 1950s and 1960s.

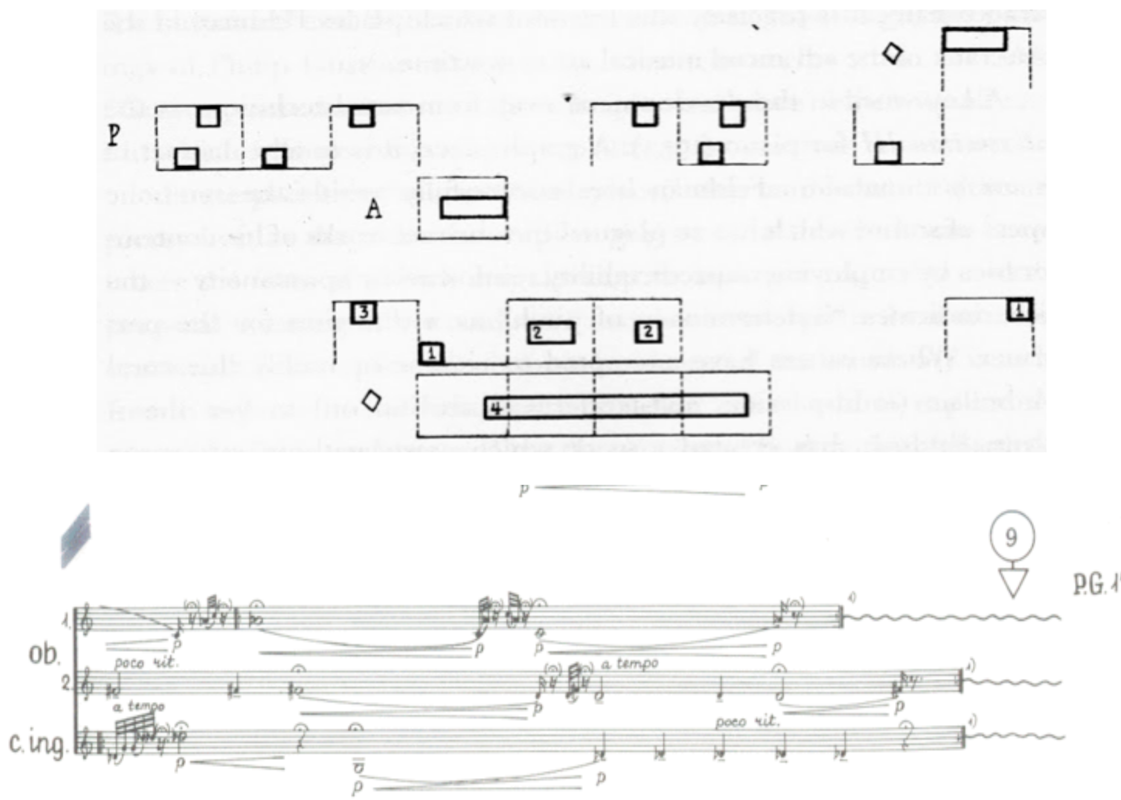

Figure 1. Example of the Graphical Notation of Morton Feldman (top). Excerpt from the second symphony of Lutoslawski, showing the aleatoric counterpoint (down).

Morton Feldman was an important American composer of the twentieth century, which pioneered on the usage of experimental musical notations. Its hallmark is the investigation of notational innovations, specially developed to create the characteristic freedom effect and to express one or rhythmic and melodic flow, often aiming to express complex sound patterns, whose sounds often metaphorically resembled the "fuzzy", or Asymmetric ideal [Feldman, 2000].

Witold Lutoslawski was a noted European composer of the twentieth century. In his works "Chains I," "Mi-Parti", "String Quartet no. 2 ", Lutoslawski used a compositional technique he named "Aleatoric Counterpoint "[Rae, 1999] with the writing of musical passages inserted into "boxes" with traditional notation, which could be implemented at different *tempi*, with each performance. Lutoslawski created a process of controlled randomness, in relation to the temporal synchrony, but without allowing an unrestrained freedom for other parameters. This is why such boxes are represented with traditional notation, containing precise pitches and rhythms.

It is also worthwile to mention the scores of visual listening (Visual Listening Scores) by Rainer Wehinger, created in the 1970s. Wehinger developed that type of score for the piece "Artikulation" of György Ligeti.[1]

Since the first decade of this century, many artists have developed music notation with the aid of computer. Some of them also created computer models of real-time processing, to represent the structure of their musical pieces. A typical example is shown in Figure 2, which brings an excerpt from the piece Solitude[2], by Hans-Christoph Steiner, composed in 2004, and written in PD (Pure Data)[3].

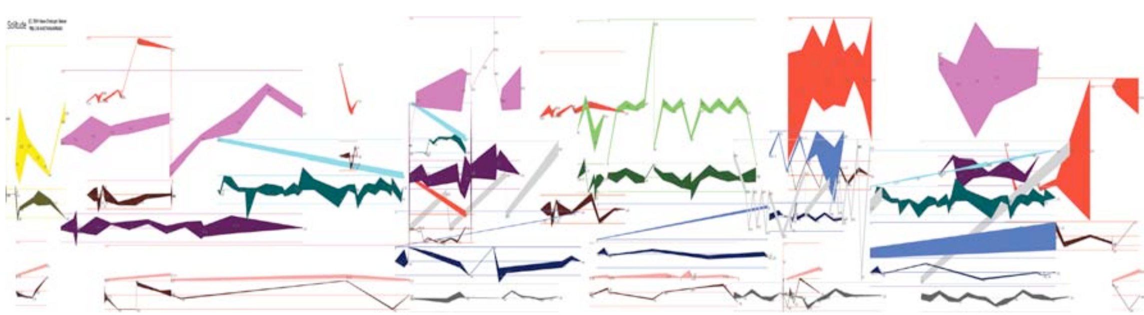

Figure 2. Excerpt of the graphical musical notation *Solitude*, from Hans-Christoph Steiner, entirely created in PD.

1 http://www.youtube.com/watch?v=71hNl_skTZQ&feature=related
2 http://at.or.at/hans/solitude/
3 http://www.puredata.info

The graphical score shown in Figure 2 resembles a natural extension of the notation proposed by Wehinger, for pieces by Ligeti, but with the advantage of being fully compounded of virtual notation, not written on paper but displayed in a computer screen, which gives total mobility and plasticity for such structure. This score provides the procedural steps of the computational model on the digital processing of a pre-recorded sound material. The steps are described in PD structures of language, through the different colors, representing the distinct procedural transformations of the sound source, along the horizontal timeline, from left to right, following the same orientation of a graphical spectrogram as well as the traditional (western) musical notation.

3. Interactive Notation

The concept of interactive notation here proposed is to create a virtual graphical score, as in Figure 2, with easy access, fast computer processing and easy understandability, so that musicians can sightread the notation created in real-time through the interaction with the performer, without the need for synchronization note-by-note, but block-by-block, as inspired by Lutoslawski's approach. So it's enough that the musicians begin each "Box" at the same time. For that, one can use a human conductor or a computational process that synchronizes each section. A score of interactive music notation can use these types of strategies to circumvent common technical problems, as the realization of a score which is: Consistent, Complete, Easy of reading, Comprehensible, Applicable, and created in Real-time. Here, in this preliminary study, we investigate a computer implementation of segments "blocks" of a musical composition. In our model, these symbolic fragments are pre-composed and can be organized inside of "boxes", in order to facilitate the HMI – the Human-Machine Interaction – thus creating an environment where one can explore the concepts of: Interpretation, Improvisation and Real-time composition. Here we draw a formal distinction between Improvisation and Composition. Improvisation is here seen as the elaboration of musical ideas in real time, without necessarily writing any final notation. Composition, however, necessarily assumes the development of musical concepts of real-time, formalized in musical notation, so that another performer can play them. It is worth noting that the control and decision for the beginning and end of the segments, and the form of composition is left to the musician (or group of performers), since this system may allow the interaction of multiple musicians, interconnected by several computer models of interactive music notation.

4. Interactive Self-Organized Notation

Distinct from Traditional and Grapical notations, the Interactive notation, as proposed in this article, is a dynamic and adaptive notation, which is based on selected musical aspects and computationally mediated through the interaction between the real-time action of the human performer with the material previously developed by the composer. Therefore, it seems that the development of a computational model for interactive notation must take into account both aspects of music given by online (performance) and offline (composition) data. Music is often defined (quoting Edgard Varèse) as the art of "Organized Sound". Such organization is perceived by the human mind in three distinct levels: 1) sound sensation, 2) musical context understanding (Music Cognition) and 3) the emotion evoked by its listening or making. The sound sensation, or contextually-free perception, is related to aspects of human hearing, its natural limits and nonlinearities on the perceived acoustic information. This has been studied at least since the works of [Helmholtz, 1912] and is mostly held by the area of science known as Psychoacoustics.

Cognition has been formally studied in music since the 1980s, by researches aiming to create mathematical models to emulate the mind process of musical information retrieval, in a broad range of areas, such as: 1) expressive performance , 2) musical memory, 3) compositional processes, and 4) gestural data. These aspects have been studied by several research groups, such as the Society for Music Perception and Cognition[4], ESCOM - European Society for the Cognitive Sciences of Music and the magazine music Perception[5]. Some of these studies aims to create musical descriptors, which are computer models that – to a certain extent – can predict musical aspects that are free of context (psychoacoustic) or based on context (cognitive). Although music cognition usually deals with the analytical understanding of the emotional musical aspects, a sub-area of study that has recently gaining momentum is the research of emotions evoked by music [Meyer, 1957]. This is the type of emotion that is involuntarily aroused by music in the individual mind and can only be acknowledged by its possessor. Nevertheless, there are physiological signals (biosignals) that seem to be associated with the variation of emotions state and can be retrieved by non-invasive sensors, such as the variation in skin condutance (Galvanic Skin Response - GSR), heart rate, measured by an electrocardiogram (ECG), or a photoplethysmograph (PPG) that, from the outer skin, measures the variation of light reflexion in a blood vessel, which is associated with oxigen rate changes, thus related to the variation of respiratory rate. In terms of musical cognition, such biosignals can describe both evoked emotional range of studies of short-term (Affects) as the long-term (Moods) [Barbas, 2000]. Affects are related to short chunks of music, around three to five seconds long, considered by some scholars as the feeling of present, or "now" in music. Moods are usually evoked by longer exposition to

4 www.musicperception.org
5 www.escom.org

music material; a more extensive musical piece, such as a symphony or a complete concert (usually longer than one hour). These emotional effects persist for long periods of time and can be seen in the variations of biological rhythms, such as the circadian cycle [Moore, 1982]. The informational content, given by the emotion evoked by music, and correlated with biosignals, permeates and connects three interdependent systems: Structuring, Evaluation and Performance. From this systemic interconnection, music derived from the Composer-Computer-Performer interaction, which is here described as a self-organized process with emergent regularities in the informational flow of musical aspects detected, from which habits (as conceptualized by Charles S. Peirce[6]) emerge, thus pointing to its musical meaning. Figure 3 describes the self-organization of music through the process described above.

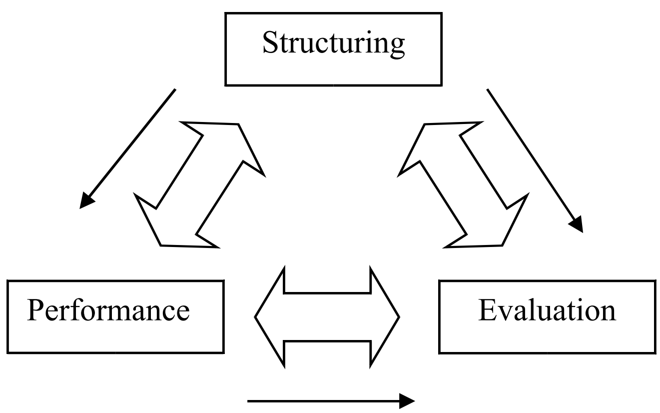

Figure 3. Self-organized process of informational flow through the music of the emotion evoked in the interaction of: Structuring, Evaluation and Performance. The unilateral and thin arrows refer to the traditional sense of emotional information flow.

Traditionally, the notational structure remains unchanged while evalutaion (listening) or performance are happening. This is because the structure is the result of self-organization

6 http://www.philosophy.uncc.edu/mleldrid/SAAP/CLT/PD04.htm

of the musical process given by the composer's psychological universe. This one, as an open and complex, suffer the influence of external agents (here named inspirations) that will define the final shape of the musical structure. However, there can be cases where the musical structure is not fixed, but dynamically changed throughout the performance. Examples of such processes are found in improvisations, such as the one of jazz and other popular music genres, or even in artistic “happenings” or sessions of algorithmic compositions, such as Mozart's dice game [Chuang, 1995].

5. The Computational Model

From Figure 3, we see that there are four elements to be considered for the creation of interactive notation. They are: 1) Structure, 2) Performance 3) Evaluation and 4) Information Flow. The information flow of the emotion evoked is determined by both behavioral data (because of its correlation with biosignals) and the predictions of acoustic descriptors. Biosignal data can be retrieved from musician performers or the listeners, in particular through the usage of data acquisition devices; electronic portable equipment, non-invasive and wireless. The structure can be fixed (typically given by the musical notation) or dynamically created, through the use of computer models developed in open-source environments (such as PD) that handle biosignals data related to the informational flow and control the parameters of audio processes and/or re-structuring musical algorithms, in a dynamic model of the musical score, that is played by the performer, while its structure is being recreated. Musicians will perform by playing this type of music with various degrees of freedom, that can be extended since from the improvisations, until the execution of large scores, dynamically built by the computer model, where both musicians and listeners can interact.

We tested a HRMI (Heart Rate Monitor Interface), a USB adapter that converts ECG signal captured by Polar Electro Heart Rate Monitor[7] (HRM) transmitter and is captured by the algorithm written in PD. Through this system, we can control an algorithm to create soundscapes through evolutionary synthesis [Fornari et. al., 2007] using data collected from a dynamically biossinal (ECG) changes associated with the emotional state of short (Affects) and long (Moods) musical duration.

6. Conclusion

This paper presents the ongoing project of creating a system of interactive computer music notation. Through composer-computer interaction we intend to use musicians in several formations to create processes of notation and improvisational music, characterizing it as a self-organized system. We aim to do this through the use of musical descriptors for the prediction of aspects of emotion evoked by music, such as biosignals, and associate them with data retrieved from behavioral reactions of musical emotion. The process is mediated by computer models developed in PD, that will create structures for the dynamic performance of musical works of the emergent Informational Flow, given by the descriptors and biosignals dynamically retrieved during the performance of musicians. The resulting musical piece can be recorded in digital audio and its generated structure can then be written as formal music notation, resulting in a score that can be played again by musicians, as a traditional piece of music. This is the outcome of an emergent process of self-organized interaction mediated by interactive relation between Composer, Computer and Performer.

7 www.polarheartratemonitor.org

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