Modelling the live-electronics in electroacoustic music using particle systems

André V. Perrotta
Catholic University of Portugal
School of Arts
CITAR
Porto, Portugal
aperrotta@porto.ucp.pt

Flo Menezes
Studio PANaroma
São Paulo State University
UNESP
São Paulo, Brasil
flo@flomenezes.mus.br

Luis Gustavo Martins
Catholic University of Portugal
School of Arts
CITAR
Porto, Portugal
lmartins@porto.ucp.pt

ABSTRACT

Developing the live-electronics for a contemporary electroacoustic piece is a complex process that normally involves the transfer of artistic and aesthetic concepts between the composer and the musical assistant. Translating in technical terms the musical, artistic and aesthetic concepts by means of algorithms and mathematical parameters is seldom an easy and straightforward task. The use of a particle system to describe the dynamics and characteristics of compositional parameters can reveal an effective way for achieving a significant relationship between compositional aspects and their technical implementation. This paper describes a method for creating and modelling a particle system based on compositional parameters and how to map those parameters into digital audio processes. An implementation of this method is described, as well as the use of such a method for the development of the work *O Farfalhar das Folhas (The rustling of leaves) (2010)*, for one flutist, one clarinetist, violin, violoncello, piano and live-electronics, by Flo Menezes.

1. INTRODUCTION

The use of technology and computers in musical composition and live performance can be considered a standard practice in contemporary electroacoustic music. This article will focus on the use of technology in the development of electroacoustic compositions in the contemporary music domain. More specifically, we present a method for modelling the live-electronics sounds and aesthetics of mixed music (i.e. in the genre of electroacoustic music which began with *Musica su due dimensioni* by Bruno Maderna in 1952, which congregates instrumental writing with electroacoustic devices and resources).

When composing a new piece that involves technology and acoustic instruments, the composer is faced with the challenge of articulating his aesthetic ideas with the required technical implementation. In order to achieve this goal, a mix of deterministic (i.e. structural) and heuristic (i.e. experimental) strategies is required. The sophistication and effectiveness of the final results of such an imbrication between structures and sonic events are determined by constraint factors such as time, resources and the composers proficiency in dealing with technology and computer programming. Due to the artistic and technical complexity of such a task, a very common strategy historically adopted by composers is to develop his/her composition in collaboration with a technology expert, which in this context is known as a musical assistant [1][2].

In the development of an artistic work that is carried on by an interdisciplinary collaboration between composer and musical assistant, an exchange of information, ideas and concepts takes place and becomes the interface through which the artistic work will be "materialized". This strategy directly affects the methodology and the final music piece. When impregnated by a speculative spirit, the main strategy is focused around the creation of new tools and models. These are based on the conceptual aesthetic ideas from the composer combined with the technical and technological skills provided by the musical assistant. On the contrary, in musical works where such a collaboration does not exist, the composer normally creates new musical and conceptual ideas based on well-established tools and methods, which brings him/her to a "comfort zone".

Despite the fact that the topics related to musical composition, aesthetics, musical informatics and audio processing are very well-established in the academic and commercial worlds, the work and practice of a musical assistant is not yet formally developed in terms of formalized theory and practice methodologies.

The methodology presented in this article describes a method for modelling the real time electronics of a musical piece using particles systems. The method tries to aggregate the advantages of a creative exploratory approach and, at the same time, to establish a basic structure that can be reused. This constitutes a basis for developing the live-electronics for different pieces by distinct composers and musical assistants.

2. BACKGROUND

2.1 General live-electronics system

The live-electronics used on a contemporary mixed music piece is based on the combination of distinct compositional, technical and technological methods. Figure 1 de-

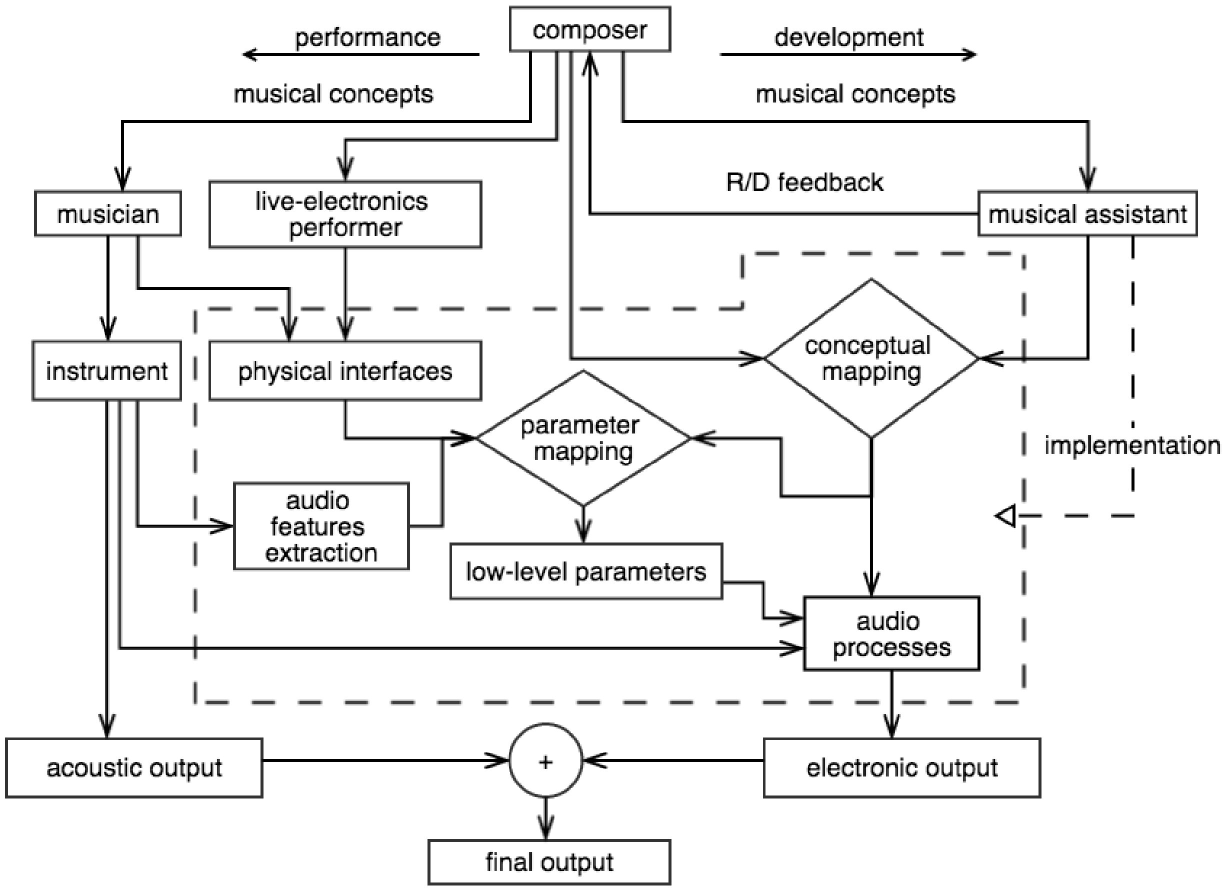


Figure 1: Block-diagram of a typical live-electronics system workflow.

scribes the flow of information that usually takes place in a live-electronics system, as well as the involved agents and processes [1].

With the current widely used dedicated programming environments such as Max [2], Pd [3] and Supercollider [4] it is possible for a proficient programmer to arrange, create and modify a considerable variety of distinct digital audio processing algorithms such as pre-composed sounds, real time synthesis, real time audio effects and real time spatialization. Each of these processes require a set of parameters that must be controlled during the performance by a dedicated performer (usually the composer himself and/or the musical assistant) and eventually also by the musician(s) on stage.

The decision of which type of audio processes to use and how to control their parameters must be a direct consequence of the musical ideas and concepts elaborated by the composer. The factors that influence these decisions are the conceptual relationships between the acoustic and electronic sources and the aesthetics of the final output.

In the scope of electroacoustic mixed music works, Mike Frengel[4] proposed a multidimensional framework to analyse the possible relationships between the acoustic and electronic sources. In his framework he organized those relational aspects into nine primary classifications: segregational, proportional, temporal, timbral, behavioural, functional, spatial, discursive and pragmatic. In what regards the technical implementation, the most important relationships are the timbral and temporal ones, representing the spectral and time domains, respectively.

The final desired sound aesthetics has a major influence on the decision of what kind of audio processes will be used. For example, if we consider a combination of spectrum conservation with isochronous time, a possible solution would be to apply a time-stretching effect, which is possible to be implemented using distinct algorithms. A phase-vocoder time-stretching implementation and a granular time-stretching implementation can fulfil the same conceptual choice but the final sonority is substantially different.

The universe of possibilities that emerge from the combination of all imaginable relationships between the acoustic and electronic parts is immeasurable. Moreover, it is also possible to interpret the different relational aspects as a continuum relational space, where one aspect can trans-

[1] This scheme does not consider the possible retroactive interaction between electronics and musical writing itself, as described so pertinently by the composer Philippe Manoury as "partitions virtuelles" (virtual scores)[3], since it surpasses the goal of our purposes here. It does not consider neither the number of performers nor the fact that not all the performers are necessarily submitted to the live-electronics processes in a mixed work with electronics in real time. The right side of the figure shows the development workflow and on the left side the performance workflow. The blocks inside the dashed lines represent the structures that need to be implemented by the musical assistant.

[2] www.cycling74.com

[3] www.puredata.info

[4] www.supercollider.sourceforge.net

form into another through any desired path. Rigorously, between instrumental layer and electroacoustic sounds there are distinct levels of interactivity going from maximum *fusion* to maximum *contrast*, as already discussed by the composer Flo Menezes[5].

These combinations and transformations must be translated into the live-electronics system by controlling the behaviour, dynamism and interactivity of the implemented audio processes through their respective control parameters.

In order to discuss the implementation of a live-electronics system, we present a technical formalization of the structures that need to be implemented by the musical assistant.

We define a unique configuration of audio processes including their respective control parameters as a *sonority state*. The conceptual transformations are translated into *sonority state transitions*. Thus we define:

A sonority state at any state *u*:

$$S^u \tag{1}$$

The group [5] of n audio processes that implement S^u:

$$P^{S^u} = \{p_1, \ldots, p_n\}, \forall n \in \mathbb{N}, n > 0 \tag{2}$$

The group of m low-level control variables (i.e. parameters) of each audio process p_i:

$$X^{p_i} = \{x_1, \ldots, x_m\}, \forall \{m, i\} \in \mathbb{N}, m > 0, 0 < i < n \tag{3}$$

Considering A and B distinct sonorities states of the live-electronics, we can define:

A sonority state transition:

$$T : S^A \to S^B \tag{4}$$

The group of n' audio processes that implement S^A:

$$P^{S^A} = \{p_1, \ldots, p_{n'}\}, \forall n' \in \mathbb{N}, n' > 0 \tag{5}$$

The group of n'' audio processes that implement S^B:

$$P^{S^B} = \{\bar{p}_1, \ldots \bar{p}_{n''}\}, \forall n'' \in \mathbb{N}, n'' > 0 \tag{6}$$

If the audio processes that constitute S^A are the same ones that constitute S^B ($p_i \Leftrightarrow \bar{p}_i, n' = n''$) [6], the transition T can be implemented by operating on the respective low-level control parameters:

$$T : S^A \to S^B \implies P^{S^A} \to P^{S^B} \tag{7}$$

$$p_i^{S^A} \to \bar{p}_i^{S^B} \implies X^{p_i^{S^A}} \to X^{\bar{p}_i^{S^B}} \tag{8}$$

If the audio processes that constitute P^{S^A} are different from the audio processes that constitute P^{S^B} statement 8 is not valid, and the transition must be solved by creating sub-states $S^{A'}$(a final state for S^A) and $S^{B'}$ (an initial state for S^B), where $P^{S^{A'}}$ is constituted with the same audio processes as P^{S^A} and $P^{S^{B'}}$ with the same as P^{S^B}, thus each sub-transition (right side of statement 9) can be implemented by operating in the low-level control parameters as shown in 8.

$$T : S^A \to S^B \implies P^{S^A} \to P^{S^B} \implies \begin{cases} P^{S^A} \to P^{S^{A'}} \\ P^{S^{B'}} \to P^{S^B} \end{cases} \tag{9}$$

The control over the low-level variables (X^{p_i}) can be done in three different ways: algorithmically, by reaction to acoustic parameters from the instrumental input using audio features extraction, by the use of physical interfaces (mouse, sliders, touch-screen, sensors, etc.). In order to link the chosen input data to the respective low-level variables, a mapping function must be implemented. Thus we define:

The group of l input variables of the live-electronic system:

$$Y = \{y_1, \ldots, y_l\}, \forall l \in \mathbb{N}, l > 0 \tag{10}$$

The mapping function m:

$$x_J^{p_i} = m_j(Y, t), \forall j \in \mathbb{N}, 0 < j < m \tag{11}$$

where t is time (absolute or relative).

The mapping functions (m_j) play a fundamental role on the overall implementation of the live-electronics. It must facilitate the technical link between different data formats and, at the same time, mathematically represent the path through which conceptual transformations are performed. Hence, in our live-electronics system we divide the mapping strategy into two different layers (as shown in figure 1):

- The conceptual mapping layer, where the aesthetic aspects and conceptual transformations are mapped into sonority states (S^u) and transitions (T) through audio processes (P^{S^u}) and mapping functions (m_j), respectively.
- The parametric mapping layer, where the mapping functions (m_j) are implemented and input data (Y) is mapped to the low-level variables of audio processes (X^{p_i}).

Despite the fact that parametric mapping is a widely researched and formalized topic, with implementation techniques ranging from as simple as one-to-one variable mapping with a deterministic linear function to many-to-many mapping with stochastic and chaotic distribution[6][7]. Conceptual mapping strategies and methods are not formalized and most literature on the topic represent the point of view of a specific composer or musical piece[8].

As a consequence, the conventional implementation strategy of a live-electronics system tends to be focused only on the low-level structures (audio processes and parametric

[5] Each audio process can have an independent role in the implementation of the sonority state, and the processes can be implemented to perform serially or in parallel.

[6] We can not use the mathematical equality "=", due to the fact that the parameters are not the same, hence, $p_i \Leftrightarrow \bar{p}_i$ means that p_i is equivalent to $\bar{p}_i$.

mapping functions); there is no direct algorithm modelling the dynamics of the conceptual transition. Additionally, each of the transitions needs to be implemented individually by a unique set of functions and variable values. Subsequently, the implementation of the audio processes and parametric mapping functions tends to be very codependent and the overall system turns out hermetically confined to the respective musical work.

2.2 Particle systems

Particle systems are widely used in several research areas for modelling and simulating complex events such as physical, natural, chemical phenomena, etc. Essentially a particle system is a useful modelling technique for describing systems that present highly dynamic and stochastic behaviours. In computer music, particle systems have been largely used for data sonification, physically based synthesis techniques, algorithmic composition and audio effects [9, 10, 11, 12].

A particle system is composed by a group of one or more particles that are confined within a definite environment. The dynamics of each particle is governed both by the rules and constraints of the environment and by the interaction with other particles. Each particle contains a set of attributes that controls how they react to the environment rules. Different sets of attributes will originate different types of particles. Attributes can be assigned stochastically and the particle system can have, at the same time, different types of particles as well as distinct individuals among the same particle group.

The system is regulated by a *particle system manager* structure. This structure is responsible for controlling the iterations, adding particles, removing *dead* particles and calling the functions that are common to all particles such as the set-up function where the initial values are assigned and the update function where attributes are updated at each iteration.

In the following section, we present an implementation strategy that uses particle systems for modelling the conceptual transitions and uses the model as the foundation for deriving mapping strategies and relationships between the low-level structures.

3. METHOD

Our method is based on the concept that the live-electronics can be modelled by a particle system where each audio process (p_i) is represented by a type of particle. Sonority states (S^u) are represented by a specific configuration of particles in the system and state transitions (T) are achieved by controlling the dynamics of each particle on the system.

In order to implement the model, we create distinct types of particles, one for each audio process that needs to be represented. Each particle type is characterized by a set of specific and standard attributes. Specific attributes correspond to the low-level control variables of the respective audio process. Standard attributes describe the particles status and motion relative to the environments multidimensional coordinate system.

The basic standard attributes of a particle must be predetermined so that each particle can perform the dynamic behaviour required by the model. Usually this attributes are composed by: position, age, Time-To-Live (TTL) and status (dead/alive). The position is a vector with the same dimension as the coordinate system. When a particle is injected on the system it receives the *alive* tag and it starts with *age = 0*. At each iteration of the system the age is incremented and when it reaches a value bigger than *TTL*, the status is switched to *dead* and the particle is removed from the system.

Based on this "audio process ↔ particle" concept, we can adapt the formalization presented in section 2.1:

We define:

A particle that represents an audio process p_i:

$$\alpha^{p_i} \tag{12}$$

The group of r standard attributes of particle α^{p_i}:

$$A^{\alpha^{p_i}} = \{a_1 \dots a_r\}, \forall r \in \mathbb{N}, r > 0 \tag{13}$$

The group of q global attributes of the particle system (interactivity input variables, global constants, etc.) and the input variables Y.

$$G = \{g_1 \dots g_q, Y\}, \forall q \in \mathbb{N}, q > 0 \tag{14}$$

In order to implement a sonority state transition (T) by controlling the dynamics of the particles α^{p_i}, we need to implement a set of mapping functions that links the low-level attributes of an audio process to the standard attributes of the respective particle. Furthermore, we need to implement a set of functions that control the dynamics of the particle by operating exclusively on the standard attributes. Thus we define:

The function that maps a low-level variable to the standard attributes:

$$x_k^{p_i} = f_k\left(A^{\alpha^{p_i}}\right), \forall k \in \mathbb{N}, 0 < k \leq m \tag{15}$$

The function that controls the dynamics of the particle:

$$a_s^{p_i} = h_s\left(G, t\right), \forall s \in \mathbb{N}, 0 < s \leq r \tag{16}$$

where t is time (absolute or relative).

Considering the case where $p_i \Leftrightarrow \bar{p}_i$ and $n' = n''$ (same as statement 7). We can state that:

$$T : S^A \rightarrow S^B \implies P^{S^A} \rightarrow P^{S^B} \tag{17}$$

$$P_i^{S^A} \rightarrow P_i^{S^B} \implies \alpha^{P_i^{S^A}} \rightarrow \alpha^{P_i^{S^B}} \tag{18}$$

The addition of a new set of functions (h_s) to control the sonority state transitions serves two purposes. The first, is that by operating in h_s, we only deal with the same standard attributes, regardless of the audio process that will be affected. Also, the standard variables are a lot more intuitive to work with; changing position in space with a sophisticated gesture is a lot more "palpable" than controlling an abstract mathematical low-level variable. The second, is that the functions h_s can be used to model the conceptual transformations, thus offering a way for actually implementing the conceptual mapping layer.

In any case, the musical assistant always has the possibility of operating directly on f_k. This offers an increased flexibility to the implementation of the live-electronics system. Transitions that are very simple and obvious can be omitted from the particle system and implemented directly on the low-level variables, saving development time.

3.1 System implementation

In order to implement our method, we divide our live-electronics system into two distinct parts; the particle system and the audio processes system. This separation is justified by the fact that each system requires a different set of programming tools.

Regarding the particle system, the implementation of several types of particles that share a common base can be facilitated by the use of an object-oriented programming paradigm [13]. For that reason we opt to develop the particle system in the C++ language. Also, C++ offers the possibility of integrating several libraries for modelling and simulating complex dynamic systems such as Open Dynamics Engine [7] and Bullet Physics Library [8].

Regarding the audio processes system, the technical development of the "audio process $\leftrightarrow$ particle" concept implies that each audio process must be implemented as module, and the system architecture must allow for the dynamic management of any number of instances (i.e. voices) of each module. Our solution for this problem relies on the use of the Max programming environment for the implementation of the audio processes modules [14]. Each audio process is encapsulated using the poly~ object, which provides automatic voice allocation, voice management and individual or general voice access.

The integration of both systems can be achieved in two distinct ways: The particle system is implemented as a stand alone C++ application and the transfer of data between both systems is done using the OSC communication protocol[15]; the particle system is implemented in C++ and compiled as a Max object, hence the transfer of data occurs internally in the Max application.

3.2 System features

3.2.1 Modelling vs Mapping

We define our strategy as modelling instead of mapping due to the fact that a mapping strategy presupposes that all variables are defined. As opposed to our modelling strategy, where we do not need to know or define all elements beforehand. In our context, a mapping strategy assumes that the audio processes, low-level variables and input variables must be defined so that we can make logical links between them. In our modelling strategy we may not know the audio processes or the interaction input variables, but we can still design a particle system for modelling the conceptual transformations and musical gestures, and from that model we can derive conclusions on what kind of audio processes and interactivity would better suit our needs.

[7] www.ode.org

[8] www.bulletphysics.com

3.2.2 Micro-modulations, stochastic transitions

The overall behaviour of a particle system is controlled by the particle dynamics and also by adding and removing particles. Adding particles of the same type with a stochastic control over their attributes generates a cloud of particles that "floats" around a focus point. This means that several instances (as many as the computer can handle) of the same audio process hovering around definite parameter values can be generated. Thus creating a very dynamic and organic sense of micro-modulations on the timbre and sonority.

With this same principle, it is also possible to create stochastic transitions between sonority states, by controlling the injection of particles in the system with a probability distribution that changes over time. Favouring one type of particle in the beginning and migrating to a second type of particle towards the end of the transition.

3.2.3 Spatialization

The model of a sonority state creates a direct relation between audio processes and the coordinate system. We can take advantage of this relation and use it for audio spatialization, therefore linking the dynamic behaviour of the particles to spatialization coordinates.

3.2.4 Re-usability

Implementing the particle system and the audio processes as audio modules allows the development of different music projects using the same framework. Reusing the particle system structure for different works allows for the musical assistant to dedicate more time in formulating the musical gestures rather than spending time with technical related programming issues.

4. EVALUATION

4.1 *O Farfalhar das Folhas*

In order to discuss the relationship between musical ideas and their technical realization in view of musical informatics in the composition of *O Farfalhar das Folhas* [9] by Flo Menezes, an electroacoustic piece for ensemble (one flutist (flute in C, in G and piccolo), one clarinetist (clarinet in B flat, in E flat and bass clarinet in B flat), violin, violoncello, piano) and electronics, it is advisable to understand the original conception of this work.

Composed in 2010, this piece consisted on a homage to the memory of the brother of the composer, the poet Philadelpho Menezes. One of his most inventive poems is inserted in the border of a catalogue of poems, and, being read in the counter-sense of reading, reveals itself as something uncertainly inserted amid the leaves, as a kind of imponderable intromission inside the printed catalogue. By

[9] *O Farfalhar das Folhas* was commissioned by MISO Music Portugal and was first performed on July 3, 2010, in Lisbon, by the Sond'Ar-Te Electric Ensemble conducted by Jean-Sébastien Béreau, with Flo Menezes, Paula Azguime and André Perrotta controlling the live-electronics.

manipulating this poem – classified by him as an *intersemiotic* one, crossing its visual, verbal and sonic aspects –, we realize the image of an insect that wings against a glass window. The sound of a /r/ emerges as an uncertain inserted phoneme in the middle of the word “insect” (*inseto* = *insect*; *inseRto* = *inserted*), while one discovers the poems verse: “An insert moves swiftly against the laws of writing”.

The poet himself explains: “The reading of this poem must start from the last pages and end in the initial ones, and the pages must be rapidly manipulated with the fingertips, making up a kind of motion picture. Movement will then assign order to its Alexandrine verse. The produced sound of the rustling of leaves emerges primarily as a mere noise against the reading of the phrase but is actually transfigured into the despair of an insect facing the misleading transparency of a glass window, materialized here by the intersemiotic de-codification process” [16].

The composition by Flo Menezes does not set in music the poem, but is based on it as a kind of intersemiotic intersection. *O Farfalhar das Folhas* (*The Rustling of Leaves*), a *sine littera* work in which the poem, projected on a transparent leaf, cohabits the same space of the musicians without being literally “intoned” by the piece, deals therefore with three human conditions, continuously moving, even if not always in a linear way, towards the last one – the greatest of all human desires: *constraints*, the *libertarian* act, and finally the aimed *freedom*. All those human conditions of living are structurally exposed in the main profile of the piece, which is based on one of the harmonic techniques of the composer, namely on his *cyclic modules* [17] as shown in Figure 2.

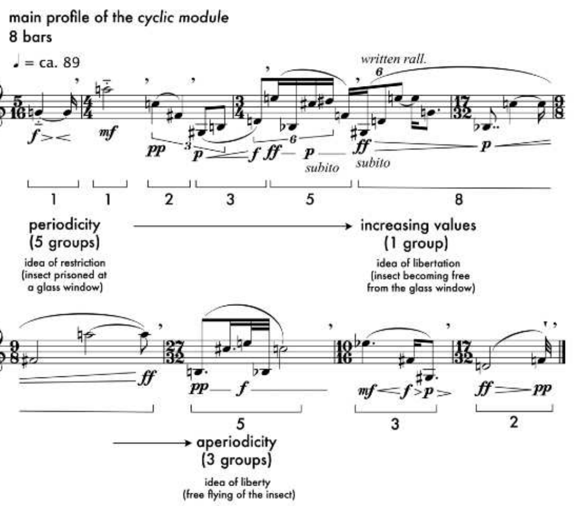


Figure 2: Cyclic module of *Farfalhar das Folhas*.

For the world première of the work in Lisbon on July 3, 2010 and, three days later, in London, Flo Menezes wrote some indicative words concerning its poetics: “Amid of this aim of liberty, as utopian as necessary, the imponderable is unexpectedly inserted and struggles against the constraints given by the conditioning of our own writings. Quantum claustrophobia tends to limit gestures in space-time (compressed intervals and rhythmic values, fragmentary interceptions). The libertarian act tends to expansion: an insect that, becoming free of the misleading transparency of that glass arresting it, rediscovers an infinite time and space. And finally one can enjoy the many resonances and correspondences flying freely in the air, no more as a liberated insect, but now as coloured butterflies tracing interesting trajectories in space.

But amid this process, that initial state was already reflected into the freedom itself, since the noise of that insect winging against the glass window is indeed very similar to that one of the wind freely rustling the leaves in a libertarian forest, in which every difference makes sense, for Ezra Pound said once in a very pertinent way: “The human beings differ from another as the leaves of trees ”.

To these three human states – *restriction*, *liberation*, and *freedom* – the piece associates respectively micro-articulated textures, extended durations, and finally resonances with their loosing itineraries, to which correspond three spectral treatments in real time: distorted shuffling with ring-modulation; time-stretching; and synthesis in real time controlled by the musicians themselves.

4.2 About the live-electronics

The live-electronics for *O Farfalhar das Folhas* (*The Rustling of Leaves*) was developed with the main objective of solving the problem of creating a synthetic resonance that would follow the harmonic paths developed throughout the piece with an ever-changing superposition of harmonic pertinent frequencies. The resonance should also react to the musicians and highlight the most important notes as they were played on the instruments. Additionally the composer asked for specific audio processes (shuffling, ring modulation, time-stretching) that make punctual appearances at specific moments.

In order to match the challenge, the musical assistant utilized the method for modelling the transitions using particle systems.

The idea of an ever-changing superposition of frequencies can be thought of an analogy to a swarm of bees flying around a point of interest in an endless motion. From this analogy we created the relation that each bee in the swarm is a particle on the system and each particle represents an audio process implemented as a simple sinusoidal oscillator with frequency and amplitude as low-level variables. Therefore our swarm is in fact a representation for an additive synthesis and each particle holds the standard attribute set plus frequency and amplitude attributes.

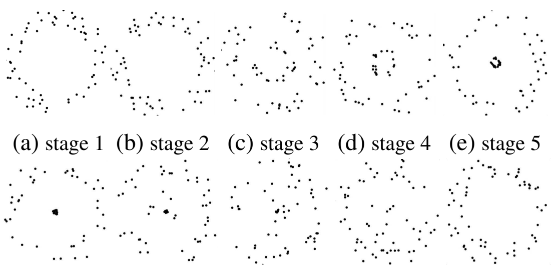
The ever-changing timbre sensation effect was achieved by creating a relationship between the motion of the particles, the interaction with the musicians, the volume and spatialization of each of the oscillators. Our particle system is implemented in two dimensions, the particles perform a standard circular motion around the center of the system with a randomized radius limited so that they are usually far from the center. They also have random angular velocity and can move freely in the clockwise direction. The amplitude attribute of each particle is mapped to be inversely proportional to the radius of the circular movement. In the center of the system (radius = 0) the amplitude is maximum. Additionally the amplitude attribute of each particle is mapped to the geometric distance of the corners of the system, hence each particle is independently spatialized in the quadraphonic sound diffusion system.

Each particle (or bee) is assigned with a harmonic pertinent note, chosen by a probability distribution function. For each part of the piece the universe of possible notes would change accordingly. The particles keep their birth note until an interaction event happens. The interaction events were: the soloist instrument (different parts of the music had different soloists) plays a highlight-intended note (we detect the note by means of pitch tracking); the digital performer interacts manually on the system and inputs the highlight-intended note.

When an interaction event occurs, particles that hold the highlight-intended note start a different movement. The idea is to use this motion to highlight and detach the specific note from all others creating a sense of pitch resolution in the resonance. This is realized by forcing the particle to move towards the center of the system by operating on the radius attribute. When the particles reach the center, they stay there for a brief instance of time and then return to their usual peripheral movement. Due to the fact that the amplitude attribute reaches the maximum value in the center, during the period of time that the particle is moving to the center, staying there and moving back, their amplitude is a lot bigger than the amplitude of the peripheral particles, hence achieving the desired effect.

On the end of this detachment movement, when the particle reaches the usual peripheral trajectory, the frequency attribute of all other particles (that did not participate on the movement) is reset to a new value using the probability function. This redraw of the frequency values creates the sensation of an ever-changing harmony that in fact always hold the same interval relationships, as determined by the composer.

Figure 3 shows a complete detachment event.



(a) stage 1 (b) stage 2 (c) stage 3 (d) stage 4 (e) stage 5

(f) stage 6 (g) stage 7 (h) stage 8 (i) stage 9 (j) stage 10

Figure 3: Detachment event provoqued by an interaction event applied on the system

5. CONCLUSION

Contemporary composers are always seeking for new paths for transgressing the boundaries of the current paradigms. In this continuous evolution, the bond between art and science becomes increasingly prominent. The musical assistant must find new tools and strategies to fulfill the ever growing variety of aesthetics and concepts explored by the artists.

The method presented in this paper proposes a new point of view to the work of the musical assistant: it addresses not only pragmatic problems such as re-usability and modularity of implemented software, but also addresses the fundamental problem of translating art into math.

The method has already been used in several compositions for different composers (*O Farfalhar das Folhas* by Flo Menezes, *A Laugh to Cry* by Miguel Azguime [10] , *Changeless I and II* by Paulo Ferreira Lopes [11]).

The implementation of the method implies that the musical assistant have advanced programming knowledge and mathematical skills, therefore, the development of a user friendly framework for implementing this method integrated in the most commonly used computer music programming platforms (Max, Pd, Supercollider) would be a very important task for the evolution of this method. Additionally, the elaboration of a library of algorithms and respective musical gestures would create an easier introduction and a starting point for using particle systems in the development of live-electronics systems.

Acknowledgments

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