Breeding Patches, Evolving Soundscapes

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ABSTRACT
This work describes the implementation of RePartitura, a processual multi-modal artwork that uses principles of Evolutionary Computation (EC) in the creation of a Pd patch that resembles the biological evolution of individuals within a population. This project was initiated with a collection of handmade drawings that share the common characteristic of being similar but never identical. This resemblance with a biological population of individuals, led us to its usage with the Evolutionary Sound Synthesis methodology. From each drawing we retrieved sonic features that were represented by a subpatch into the Pd system implementation. As Pd allows the development of patch generating other patches, this system acts as if they are individuals artificially living inside a population, were they grow, reproduced and eventually dye. This paper describes the technical aspects of RePartitura implementation; the mapping of drawings into sonic features, the design and breeding of individuals and the final sonic result of all individuals coexisting within the population, thus leading to the self-organization of dynamically evolving soundscapes.

Keywords
processual artwork, multimodal art, evolutionary algorithm, soundscapes, sound synthesis.

1.INTRODUCTION
The focus of arts throughout the Western History was the production of objects, the end product of an artist creation. However, in the second half of twentieth century, the artistic process replaced the materiality of the final product, resulting in a renewal of ideas and concepts. Lucy Lippard, analyzing the artist production of Sol LeWitt, said that his work was based on the premise that its "concept or idea is more important than the final object" [1]. This concept is similar to the one of generative art, which is defined as any form of art were "a system, with a set of defined rules and some degree of autonomy, is put on movement" [2].

Generative processes had already been explored in music, a few centuries ago. In 1650, the priest Athanasius Kircher wrote, based on the belief that musical harmony reflected the proportions of the universe, the book entitled: Musurgia Universalis, which describes a musical generative machine [3].

JJ Hummel published in 1793 a system to generate musical score, attributed to Mozart, in which music was generated in random order based on a dices game. This system embeds the majority of todays generative art elements. With this system, a musician could created a list of 176 pieces of music, from which16 were chosen, according to the result of a dices tossed, producing a new musical movement, althogether resulting in 1,116 distinct pieces of music. HPSCHD, a musical piece composed by John Cage and Hiller Lejaren, was influenced by Mozart's dice game algorithm [4].

Drawing can be defined as a process of registering ideas or actions (gestures) as an end in itself, or based on other representations. This media is analyzed by Walter Benjamin as from "another level within the human psyche. It is a locus for signs by which we meet the physical world" [5]. This aspect can be compared to the technical principle of computer language, as defined by Cramer, that is "controlling matter through the manipulation of symbols" [3].

The work of art, given by a system of generative process, is not restricted within a defined field, but in a multitude of different areas of knowledge, even beyond visual arts and music. Adaptive methods, such as Evolutionary Computation (EC) algorithms, might be seen as a technological strategy that fits the concept of generative artwork, due to their ability to turn an artwork process fluidic and immersive.

Here we describe the implementation of RePartitura, an artwork installation where handmade drawings beget soundscapes continuously created by an evolutionary sound synthesis process, as further described. This generative process is capable of continuously producing new sonic material, in constant evolution. This project is, therefore, based on the concept that the overall process is the actual artistic work.

As a multi-modal, generative processual artwork, RePartitura starts its sonic process from a series of similar, but never identical, handmade drawings. These are taken as a population of individuals, each one of them with its own genotype (i.e. determinant pictorial aspects of the drawing), mapped into sonic genotypes (determinant acoustic aspects) and implemented as Pd subpatches, each one of them being an individual into a dynamic population of an evolutionary sound synthesis process. These indiviuals undergo reproduction and selection, emulating the adaptive evolution of a biological population. The resulting sound, given by all coexisting individuals, is also similar but never repetitive, thus being self-organized into a soundscape.

2.EVOLUTIONARY SOUNDSCAPES
A soundscape can be seen as the acoustic correspondent of a landscape, which is a sonic environment that, in spite of constantly having original acoustical information, that never repeats itself, it has unique perceptual features in such a way that it is cognitively self-similar. - as it can be easily recognized and

distinguished by the average listener as a unique sonic ambient. We can hear examples of soundscapes in the sound naturally generated nearby waterfalls, within a tropical forest, by a traffic jam, in a crowded central station, and so forth. The manual designing of soundscapes, based on the parametric control of sound-source localization cues, have been approached by many methods, such as the ones described in [6,7,8], but they still differ from natural soundscapes as they are tailored by humans and not by a self-organized process, created by the interaction of sound-sources. In a systemic viewpoint, we consider soundscapes as open complex systems formed by a variant group of agents (i.e. sound-sources) that together present emergent cognitive self-similar properties.

An important feature of a soundscape is the sound localization of its agents. There are technologies that help to emulate the sonic localization field of a soundscape. Some of the most common ones are: Interaural Time Difference (ITD) [9], Interaural Level Difference (ILD) [10] and Head-Related Transfer Functions (HRTF) [11]. ITD cues refer to the time difference for the sound-waves, from one single sound-source, to arrive in both ears. Similarly, ILDs describe the difference of intensity between both ears. HRTFs, however, are a collection of spatial cues, described by digital filters, representing the sound processing of the listener's head-related anatomy, such as the shape of his/her head, outer ears and torso. ITDs and ILDs can be easily emulated by a computational model. ITDs can be assessed by the time-delay variation between audio channels and it delivers a convincing sound localization sensation. It was used in studies such as in a robotic sound source localization system [12].

The other important feature of a soundscape is it self-organization. It is known that adaptive methods, such as the evolutionary computation (EC), can produce emergent, self-similar complex systems [13,14]. We used this feature as premiss to develop a method for the automatic generation of soundscapes.

Since 2001, the researching group at NICS (Interdisciplinary Nucleus for Sound Comunication) have studied bio-inspired adaptive methods for sound design and music composition. Some of these techniques generated highly textured sonic outputs, which is a trademark of natural soundscapes [15]. We developed the *ESSynth*; a system using EC principles, in which a population of waveforms evolve in time, through generation steps, by the action of genetic operators and a fitness functions [16, 17]. Later, we incorporated sonic spatial localization cues to this method [18, 19]. These are based on the application of concepts from the theory of Complex Adaptive Systems (CAS) for the sound generation [20].

As described in [13], a CAS consists of a large number of agents with interconnected parameters that, altogether, exhibits coherent emergent properties. It is also known that a CAS can generate emergent properties by means of its agents competition and/or cooperation [14]. Its systemic behavior is the resultant of the interaction between a large number of its formant agents, leading to the process of self-organization, in which a CAS may pass through several organizational states [21]. We believe that this process can be emulated by an ESSynth model to generate soundscapes [22]. Originally, ESSynth was based on a population of waveforms (the "individuals"). Each individual had its own genotype: a group of acoustic descriptors that defines how its waveform is perceived and understood.

It is interesting to note that Schafer formally described soundscapes as "natural, self-organized processes usually resultants of an immense quantity of sound sources, correlated or not, but that conveys an unique sonic experience that is at the same time recognizable and yet always original" [23]. This definition is similar to the CAS one, as it is also an open complex system with self-organized emergent properties. Regarding the attempt of artificially creating soundscapes, Truax's comments are that: "soundscape composition might aim to computationally emulate self-organized biological or natural acoustic environments" [24]. This is one of the objective of this method.

Still in [23], Schafer defined three kinds of sonic elements that compound a soundscape. They are: 1) keynotes, 2) signals and 3) soundmarks. Together they compound the immersive sonic environment of a soundscape. Keynotes are the sonic elements that define a soundscape, even when they are not present or not consciously perceived (heard). Signals are the foreground sonic elements, always consciously heard. Soundmarks are the sonic elements unique to each soundscape that characterizes it and set it apart from other soundscapes.

In this work we aimed to apply an ESSynth method to generate emergent sonic properties based on external aspects. Our model of individual is a Pd patch whose genotype is described by few acoustic descriptors, initially mapped from the drawings and simple interactive rules to control the evolutionary process. Nevertheless, it suffices to the achievement of complex dynamical sounds. The system here presented may even use an interactive control, such as a motion sensor, to guide the evolutionary process for the dynamic creation and control of soundscapes.

3.RETRIEVING SONIC FEATURES FROM HANDMADE DRAWINGS

As mentioned before, our collection of handmade drawing shares the common feature of being similar but never identical, as seen an example, in the following Figure. Through the repetition of a gesture, the artist had created a great collection of similar drawings. We considered that as a natural metaphor for the ESSynth process in which there is a population of individuals that are, as well, similar but never identical. However, this population, differently from the drawing, could evolve in time, similarly to a biological population. It seemed interesting to develop a artwork in which these drawing would be mapped into individuals of a ESSynth system and whose evolution would create a dynamic soundscape.

The first step was to establish a method to map the drawing features into sonic features.

Figure 1. An example of a single drawing.

We considered three pictorial features that characterize each drawing in this collection. These are graphical elements presented in all drawings, that are similar but never identical, thus defining each drawing uniqueness. These graphical elements are the graphic correspondent of an individual genotype. They are here named as: *acúmulos* (cumulations), *repetições* (repetitions) and *fragmentos* (fragments). The following Figure shows the regions of occurrence of these elements. For the purpose of better viewing, they were underlined and presented in the same drawing previously depicted.

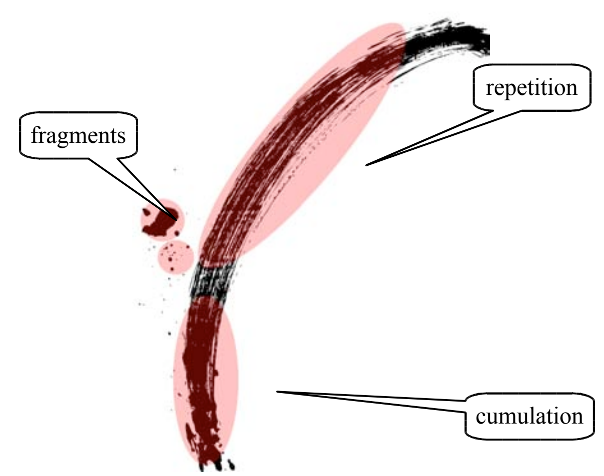

Figure 2. Graphical elements underlined in a drawing.

Following the proposal of this artwork, we related each graphical element with a single sonic aspects that seems to synesthetically represent, in the acoustic domain, each pictorial aspect of the drawings. We related cumulations to stochastic (noisy) lower-frequency sonic features, steady and of long duration. Repetitions were related to tonal (periodic) sounds, middle-ranged in frequency and time-frame variation. Finally, Fragments were related to short-time variations of stochastic or tonal material. With these in mind, we established the mapping between each aspect and its correspondent sonic features. This is seen in the following Table.

Table 1. Mapping of graphical elements into sonic features

Element	Drawing Aspect	Sonic Feature
Cumulation	Concentration of paint at the bottom of the paper drawing where the movement initiated	Stochastic, lower-frequency, steady
Repetition	Quasi-parallel traces at the middle of the drawing, generated by the back-and-forth movement of the bamboo-pencil	Tonal, pitch-variant, loudness-variant
Fragment	Paint dripped at the outlying parts of the drawing, due to the gesture intensity.	Sparks, Pulses, Short-time variations of Stochastic and Tonal material

We share the belief that any form of art should communicate concepts in three levels: 1) perceptual, 2) cognitive and 3) affective. Considering the sonic arts, perceptual aspects are the ones that describe the way in which sonic information is perceived by the auditory system. This is studied by the psychoacoustic. Cognitive aspects are related to the sonic features that can be understood and learned by the listener. Affective ones are the aspects related to the emotion evoked in the listener. The retrieval of these categories seem to related to the scale of time analyzed.

The psychologist William James was probably one of the firsts that touch the time scaling aspect of communication by defining the notion of “specious present”, in which he defines it as "the short duration of which we are immediately and incessantly sensible" [25]. One could argue that specious present is an extension of short-term memory, in which case it might well vary from person to person, and also from one sense of modality to another. Or it might be the interval in which information is experienced as a single unit, such as in a sentence, or musical phrase [26]. Some experiments had shown that in music, the specious present marks the time in which contextual information can be detected, which is in the order of three seconds [27].

Perceptual features are context-free. They can be retrieved in short time-scaling intervals (few milliseconds). Cognitive aspects can be retrieved within a time frame of about three seconds. Affective aspects are the ones related to the large time interval (thirty seconds or more) and may be related to the long-term memory, where it is considered its musical genre and style.

With this in mind, we decided to map each drawing aspect to a sonic time-scaling. Cumulation are mapped into long time scale, representing affective aspects. Repetitions go into middle-time scale (i.e. the specious present), representing cognitive aspects. Fragments are mapped into short time scales, corresponding to perceptual aspects. Next Figure shows a detail of the mapping of the same image shown in previous Figures. Near each object there are three columns of numbers. The first one is a simple metric defined by: $m = (4*pi*Area)/(Perimeter^{2})$ to describe the roundness of each object. The more round is the object the closer is the value of m to one. The second number in the column is the object Area. The last two numbers are the position `(x,-y)` of its object, within the image mapping. This particular image has a total of 35 distinct objects. In this work, the object with the biggest Area is the Cumulation. The roundest objects (metric $m>=0.5$) are the Fragments. The stretched objects ($m<0.5$) are the Repetitions. As mentioned in Table 1, each of these objects will be mapped into corresponding Sonic Features, representing the individual genotype.

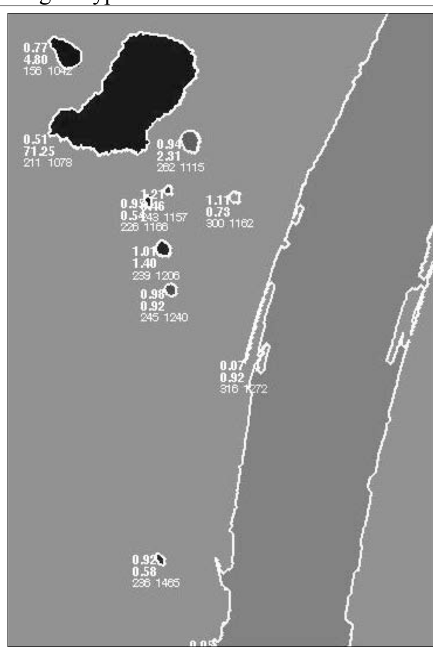

Figure 3. Detail of image mapping.

Each individual in this implementation is a Pd subpatch that has six arrays representing its genotype. These arrays control the individual parameters. Each individual subpatch is also compounded by two other subpatches: tonal and stochastic. The tonal subpatch has three parameters of control: 1) intensity, 2) frequency and 3) distortion. The stochastic subpatch has also three parameters of control: 1) intensity, 2) center-frequency and 3) bandwidth (Q). These six arrays correspond to the genotype of one individual. Each array represents a time series where the affective (cumulations), cognitive (repetitions) and perceptual (fragments) are mapped. The following Figure show the typical subpacth for the individual, compounded of the subpatches Tonal and Stochastic. On the top of this Figure, it is seen one of the six envelopes, that altogether compound the individual genotype.

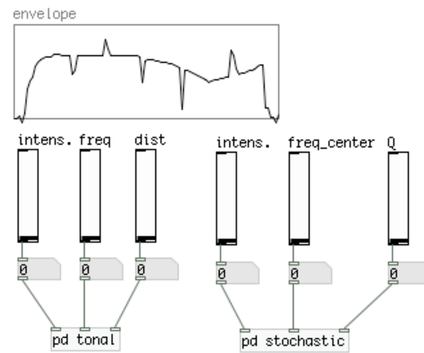

Figure 4. Implementation of the Individual as Pd subpatch.

4.PATCHES GENERATING PATCHES

An important feature found in Pd is the ability of developing patches that are able of manipulating and creating new patches. This touches the meta-programming paradigm, in which code is written by code, without human intervention. There are recent efforts in the development of objects better shaped for the meta-programming, such as the iemguts library, been developed by IOhannes Zmölnig, that aims the emulation of self-aware agent-systems [28]. Nevertheless, Pd is already capable of exploring the automatic generation of patches by other patches.

The evolutionary sound synthesis, as proposed in [16] has a population of individuals, a Target set and two evolutionary processes: 1) reproduction and 2) selection. The Target set guides the evolution process, similarly to the environmental pressure in biological populations. Selection applies a fitness function on the population individuals to find the best fitted one, according to the premisses given by the Target set. Reproduction uses the genetic operators: crossover and mutation to create new individuals, offsprings of each individual population and its best individual.

In *RePartitura* we take a slight different approach. We start our population with few individuals, direct mappings from a selected group of drawings. A population is grown out of these initial individuals. Each individual is a variant sonic event. The coexisting of all individuals gives the overall output sound, thus creating the dynamic soundscape.

5.EC POPULATIONS AS DYNAMIC SOUNDSCAPES

Individuals are implemented as abstractions in Pd. The initial arguments are used to pass its unique name to all six arrays belonging to each individual genotype. Using the ITD sound location technique, as described in section 2, we emulate the individuals dynamic location, as if they were moving inside of a spatial position field. The casual encounter between individuals raises the chances of an offspring creation. This process entails to a varying-size population, different from the initial ESSynth method, were the population had a fixed size. Another distinction is that the output sound in ESSynth was given by the queue of best individuals of each population generation (audio samples of several ESSynth simulations are available at the following link:

www.nics.unicamp.br/~fornari). In RePartitura, the sound output is given by all individuals coexisting at each moment with the variant population. This also creates the possibilities of population extinction, by the reducing of its number of individuals to zero, as well as to reach a super-population plateau, in which all computational resources of the machine running this Pd patch would be in jeopardy. We can set thresholds to avoid these two extreme scenarios but the natural variation of population size inside these limits is enticing and welcome for this artwork perspective.

Similar to the ESSynth original method, RePartitura implementation also delivers the paradigm of variable similarity. The sound output, resulting of all individuals within the population set, will naturally describe a dynamic soundscape.

6.DISCUSSION

The drawings that gave birth to the project RePartitura were conceived by the creation of hand gestures, imprinted as a drawing. These gestures were executed every day during a period of approximately 10 months, where each drawing took about 10 seconds to be created. The material used were nankin paint, a bamboo pen and thick papers. These were chosen because they seem to better fit for the registration of the artist's movement expressivity. The intention was to identify in these registers (i.e. the imprinted drawings) the expressive transformation throughout the progression of time (e.g. an initially narrow movement was stretching, as time went by) and the artist's mood changes interferences in the creation (i.e. accidents that left the drawing paper with more fragments seems to be related to periods in which the artist was undergoing an anxious mood). These two temporal scales (e.g. large: 10 months, small: 10 seconds) used to create the drawings correspond respectively to the above mentioned affective aspects and cognitive aspects of arts (section 3). These time scales also infer the processual nature of this artwork, as the drawings creation were adapting and evolving along time, as well as generative (the more stochastic were the drawings created, the more anxious was the artist state of mind).

Later, these drawings were analyzed and their graphical aspects were mapped into sonic features. An evolutionary computation method was used to emulate individuals whose genotype are compounded by these sonic features. The dynamical changing population of these individuals, created a soundscape and representing acoustical methaphore the original gestures, captured as drawings, and the whole process of its creation.

7.CONCLUSION

The implementation in Pd of RePartitura brought several technical advantages that enable the dynamic process of its installation in real-time. The ability given by Pd to easily implementing routines able to replicate and tailor subpatches dynamically was a paramount in making feasible the creation of this artwork. As mentioned, this implementation derives from the ESSynth method, in which there was a population of waveforms evolving in time according to a Target set, representing the pressure of environment conditions found in any adapting biological population. However, in the Repartitura implementation shown here, there is no Target set. This is due to the fact that as population is growing out of very little individuals (i.e. two initial individuals) we thought that any restricting conditions could jeopardize the chances of getting a rich soundscape. Nevertheless, we plan to implement few conditions that will enable the external interaction with the evolutionary process of individual creation and extinction. One of them is the usage of sensors and/or gesture controls. Motion sensors and web-cams can be easily used in Pd to emulate external conditions that interfere with the evolutionary process. One idea that we plan to implement is the concept of energy intake (i.e. food) for the individuals, where they should seek and compete for it. The concept of sexuality and gender was also not fully implemented. We plan to experiment with other kind of mappings where some graphical aspects could be related to the notion of gender. Having gender and sexual reproduction, we might as well implement a childhood period for the individuals, when they would not be able to generate new individuals but could be externally influenced (i.e. learning). As it can be seen, there is a myriad of enticing possibilities to use the ESSynth method to create new implementation in Pd that can be turned into artwork installations as well as used in art performances. We plan to keep developing processual artwork creations in Pd, exploring the multi-modality and interactivity aiming to reach immersive sonic experiences.

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