Towards an Emergent and Autopoietic Approach to Adaptative Chord Generation through Human Interaction

Francisco de Paula Barretto[1], Suzete Venturelli[1], and Gabriel Gaudencio do Rego[2]

[1] Computer Art Research Lab, University of Brasilia, Brasilia, Federal District, Brazil
{kikobarretto,suzeteventurelli}@gmail.com
[2] Laboratory of Cognitive and Social Neuroscience, Mackenzie Presbyterian University, So Paulo, Brazil
gabrielgaudenciorego@gmail.com

Abstract. This poster describes a transdisciplinary practical-theoretical on-going research, which address on the discussion about the possible applications of Artificial Intelligence (AI) techniques, such as genetic algorithms, which underlie the Maturana and Varela's autopoietic concept considering the achievement of emergent results as heuristic to creativity. Through human interaction using neuronal bio-feedback it is possible to provide more natural fitness function to such algorithms.

Keywords: autopoiesis, emergence, bio-feedback, creativity, genetic algorithms.

1 Theoretical Framework

1.1 Autopoiesis

The concept of autopoiesis, as the organization of the living, originated in the work of Chilean biologists Humberto Maturana and Francisco Varela in the 1970s [1] . This idea was developed in the context of theoretical biology and was early associated with the artificial life simulation long before the term "artificial life" have been introduced in the late 1980s in [2] .

Autopoiesis (from the Greek auto which means itself and poiesis which means creation) describes the autonomous systems, able to self-reproduce and self-regulate, while iterating with the environment. This environment iteration might unroll, only in an indirect way, changes on the autopoietic systems internal processes and structures that might lead to a deterministic-emergent transition.

Today the concept of autopoiesis continues to have a significant impact in the field of artificial life computing. Pier Luisi presents a good review in [3]. Furthermore, there was also an effort to integrate the notion of autopoiesis to the field of cognitive sciences.

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To be more precise, an autopoietic system is organized as a production processes network of components (synthesis and destruction) which: (i) continuously regenerate themselves in order to form a network able to reproduce components and (ii) this network constitutes the system as a distinct unit in the domain in which it exists. In addition to these two explicit criteria for autopoiesis, we can add another important point: that identity self-constitution implies on the creation of a relational domain between the system and its environment. Froese and Ziemke describes this relational domain in [4]. This emergent domain is not predetermined but possibly co-determined by the system and environments organization. Any system that meets the criteria for autopoiesis also generates its own domain of interactions while its identity emerges.

The concept of self-organization can be interpreted in many different ways, but in terms of autopoietic is worthy of being presented by two aspects: (i) determining local-to-global, so that the process has its emerging identity global constituted and constrained as a result of local interactions and (ii) determining global-to-local and global identity where its ongoing contextual interaction constrain local interactions [5].

Finally, autopoietic systems are also autonomous systems since they are characterized by such a dynamic co-emergence but are specified within a specific domain. It is important for the creativity of a system that it's changes and adaptations of the internal mechanisms are not performed directly by an external agent, but through an internal self-regulation mechanism.

1.2 Emergency

The emergent behavior can be defined, according to Peter Cariani [6] , as something fundamentally new, that could not be predicted before it happened, such as natural evolution. This characteristic might be seen as a useful heuristic towards achievement of creative behavior. Being the human not only a part of the autopoietic system's environment, but also an active agent, the interaction occurs in a higher cognitive level, influencing the artificial agent cognitive construction.

In general, emergence designates a behavior that has not been explicitly programmed in a system or agent. Pfeifer and Bongard [5] point out three kinds of emergence: (i) a global phenomenon arising from a collective behavior, (ii) individual behavior as the result of an interaction between the agent and the environment and (iii) emergence behavioral from a time scale to another.

The artistic installation named La Funambule Virtuelle [7], from Marie-Hlne Tramus and Michel Bret, where a virtual acrobat evolves to keep up on a tightrope, reacting to the movements of the public. The character tries to reproduce the position of the iterator while trying to stay on the rope. In this installation, through a ANN, the balancer is able to learn to remain on the rope during the user interaction. From the learned gesture, a new behavior emerges through movements that were not taught, endowing the character of what the artist calls the ability to improvise. This is a nice example of the individual behavior as the result of an interaction with the environment.

A deeper level of emergence called epistemic emergence involves, of course, the emergence of new perspectives intrinsically linked to the sensorial changes. The improvement or development of new sensorial organs allows an organism to evolve into another lineage, along with new world perspectives. This kind of development also occurs in our technological evolution as we build artifacts such as thermometers, clocks, telescopes, and that extend our senses or reactions as an extension of our natural biological functions.

2 The Evolutionary Chord Generation Case

Genetic algorithms are an Artificial Intelligence technique proposed by John Holland [8] and uses a metaphor based on the theory of natural evolution. In the genetic algorithms, the solutions for the problem are evolved through multiple generations, improving the solutions prior to each new iteration. Just like in natural evolution, genetic operators such as mutation and recombination allow each new generation of individuals to improve the previous generated potential solutions. This evolution towards the "best" solution is given by a fitness function that calculates the degree of adaptation of the individual and its neighbors, inferring the most likely to reproduce and therefore which variations are more able to extinction.

These populations of individuals composed by a genotype and a phenotype. The genotype is the individual coded information, like our chromosomes and is composed by some alleles. The information coded in the individual genotype is represented by the phenotype. For example, the color of our eyes (phenotype) are coded into our DNA (genotype).

For example, in one possible approach to chord formation, we must consider that there are many standards and rules that define various categories of chords as major, minor, diminished or increased and that these patterns are usually represented by intervals between notes, expressed in semitones, and we can, from a note, build several different chords using other notes at specific intervals. So,as a first experiment there was implemented a Genetic Algorithm (GA) chord generator.

In this experiment the individuals chromosome are formed by 4 alleles and each one of these alleles contains a musical note. Groups of 4 notes forms a chord. The fitness function, in this case evaluates the distance between chromosomes, considering the notes contained in alleles in relation to the notes required for formation of a major chord, classifying individuals with interpolated values between 0 and 100 (maximum fitness).

Once an initial population randomly generated containing 10 individuals were performed 100 rounds using two genetic operators with different rates probability for this population: crossover and mutation. For the crossover operator there was applied a percentage rate of 80

At each round played the individual sound (phenotype) with the highest fitness. This mapped chromosome (genotype) evolution allowed us to realize that, while not struck a major chord, all the other types of chord system emerged.

Even with a fixed and hard fitness function, the application of recombination and mutation operator has enabled the emergence of chords not provided as minors diminished and augmented, for example, suggests an emergent behavior of the autopoietic system.

3 A Human-Guided Evolutionary Chord Generation Experiment

It is possible to use human bodys physiological signals as a fitness function, which could indicate cognitive and affective processes relevant for the implemetation of a human-computer interface (HCI). In the specific case of a musical experiment, two classes of physiological signals could be used to assign: (1) affective processes, like emotional states [9]; or (2) cognitive processes, like error detection in the harmonic field expectation [10]. The first proposed class is being subject of intensive research since the last decade, resulting in systems with acceptable accurate rates that can identify and classificate a subjects emotion only using his physiological responses [11]. In the other hand, the second proposed class got less attention from researchers, mainly because the subjacent complexity in tracking and using its signals in accurate online systems for HCI. Only in the last few years some papers proposed online systems based in error detection signals, but yet with low accuracy rate or with better accuracy rates, but limited by the kind of the task [12], that is different from the experiment proposed in this research.

However, the use of cognitive process like error detection (which represents a biological feedback system) opens a broad branch of HCI possibilities and, in this particular experiment, it serves as an innovating way in creative interaction, where the fitness function is not oriented by a determined function leading to a final state, but it develops to a endless state oriented by a constant homeostasis process.

As said before, there are some eletrophysiological potential related to cognitive processing of music in human beings, like the Early Right Auditory Negativity (ERAN) detected by Electroencephalography (EEG). The ERAN is related to the detection of violations in the harmonic patterns, taking in count some harmonic scale which a person has familiarity (such as Western music) [10]. The problem is that ERAN potential is well detected by offline (post-analysis) and multi-trial processing, such as ERP experiments. But, by this moment, the literature lack conclusive studies about the use of ERAN in a online (real-time) system. There are studies with similar potentials, like ERN (Error-related Negativity) [12], which behaves in a similar way of ERAN and are detected in similar spacial distribution of electrodes (frontal lobe).

4 Conclusion

In the research, we propose a system that could integrate the musical genetic algorithm with a HCI based on a feedback detection using error signals, like

ERAN. To potentialize the signal detection, the analysis process will be designed to a user-dependent system, which requires training of the user to optimize the algorithm detection of the system according to individuals error signal characteristics. There are also the possibility to integrate different physiological signals, like pupillometry, skin conductance or electromyography that could be involved with error and feedback detection (yet this assumption still lack conclusive studies), or affective responses (like tension, arousal or unpleasantness) that could compound a integrative system for the HCI system proposed in this study.

This approach might seem simple at first sight but opens several doors to the development of adaptative interfaces based on bio-feedback, for exemple. In the other hand it can provide to natural-based artificial intelligence techniques evaluation functions more natural than the rigid ones used today.

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