Parallel lives, composing bio-inspired ensemble music by means of AI

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Abstract. The piece *Parallel lives*, for ensemble and mini-loudspeakers, is an artistic application of bio-inspired composition. It is based on AI and artificial life algorithms, focusing on a special type of cellular automata for membrane computing called P-system by Gheorghe Păun. These technological tools open up new solutions for musical creation, expanding the possibilities of computer assisted composition (CAC). This paper serves as a support to establish certain technical and aesthetic considerations which pose new challenges for the composer-researcher.

Keywords: AI, bio-inspired composition, cellular automata, CAC, membrane computing, P-system

1 Introduction

This paper focuses on the application of membrane computation, i.e., P-systems introduced by Gheorghe Păun, to the ensemble composition *Parallel lives*. These bio-inspired systems are part of Artificial Intelligence and simulate the behaviour of cellular membranes. They make possible the modelling of certain facets of the compositional work, in particular those of a mechanical or systematic nature, which need a big volume of calculation. In this case, the technological tools currently available become excellent assistants for the composer, the teacher and the researcher.

The research process is carried out from the point of view of musical creation. In this way, the composer makes his artistic and scientific work transparent and step by step detailed to the scientific community, offering tools that can be useful for students and other composers for the development of a personal artistic language. The results obtained allow widening the range of possibilities of algorithmic composition by using some of the relatively most recent branches of Artificial Intelligence.

A main topic of study is the generation of form and musical material based on algorithms and computational techniques that imitate natural processes at cellular level, specially at membrane level inside a single cell, applying concepts from auxiliary disciplines such as Biology, Genetics or Neurology.

The creative research does not only take into account the purely technical aspects, but also considers the aesthetical and stylistic dimensions, exploring ways to obtain interesting musical results and to serve the expression at the same time, framed in the current panorama of composition and pedagogical transmission.

2 Objectives

The main objective of this research is to apply bio-inspired techniques based on AI to a personal composition. Another objective is to explore the possible relationships between natural and musical processes, as well as the stylistic and aesthetic principles of these tools. At the end, it is intended to find generalizable application solutions of different types of P-systems (membrane computing).

3 Methodology

The methodology of this research project is based on a solid deductive theoretical framework that leads to prospects of applicability. Then, an inductive research process leads to a generalization of techniques from specific strategies. Finally, an auto-ethnographic approach is adopted, through the composition of the piece *Parallel lives* and the explanation of the process.

Some transversal axes of the research are intelligent agents and automatic learning, genetic algorithms (evolutionary computation: natural selection, mutation, crossover, mitosis, meiosis), neural networks, structure of DNA and proteins (biomolecular computing), Márkov chains, generative grammars, transition networks, chaotic algorithms, fractals, cellular automata and P-systems. Membrane calculation techniques are applied to musical composition by using seven different models of P-systems. In our P-system model we assign musical parameters to "vibrant" membranes, chemical compounds and applicable rules of evolution. To feed a musical P-system it is necessary an independent initial material and a categorization of compositional techniques, i.e., variation, expansion, compression, repetition and contrast. Each type of P-system is suitable for different compositional strategies and parameters.

4 Membrane computing and P-systems

Membrane computing is based on P-systems introduced by Gheorghe Păun (Păun 2020) and related to the fields of AI and artificial life. These systems (equivalent in computing power to Turing machines) simulate the behaviour of cell membranes, that is, the modes of operation of a cell as a living organism capable of processing and generating information. These are non-deterministic distributed, parallel and maximal type models that have a random component, allowing different solutions from the same input data. The calculations are carried out simultaneously in different parts of the system or algorithm and the maximum possible number of data is used at any time.

The basic requirement for a P-system to exist is the structural design of membranes so that they provide a hierarchy. This cellular structure is protected from the outside by a covering skin. The different compartments (membranes) that make up a cell allow the simultaneous execution of chemical reactions and the exchange of components. In addition, membranes have a certain permeability, they have the ability to be crossed by compounds or objects. This parameter is defined by polarization (semi-permeability), so that there can be irreversible flows, which work in one direction, but not in the opposite.

5 Applications to music composition: *Parallel lives*

The piece *Parallel lives* (2017) takes its title from Plutarch, who wrote a collection of biographies of famous Greeks and Romans, paired due to certain similarities. This idea is brought to music from the prism of Biology through bio-inspired musical composition techniques. In other words, processes of convergence, divergence and parallelism that appear in nature are worked timbrally, rhythmically and formally. Musical materials evolve as independent species that can develop similar characteristics. The musical dramaturgy is traced through a set of unions and branches that orient the hearing towards different levels of tension and energy. Progressively, the metaphor of a parallel ensemble appears on the stage that opens up a new listening space.

Two essential characteristics of P-systems are parallelism and maximum application of transition rules. These singularities are very rich for the development of harmonic, contrapuntal and timbrical processes in the piece, such as the evolution of textures, work with dynamic spectra, etc. A universal chronometer guarantees the synchronization of the processes which take place within the cell, and which allows the musical material to be sequenced in time.

The main focus of research is the generation of musical forms and materials based on algorithms and computational techniques that mimic natural processes within a single cell, by applying concepts from ancillary disciplines such as Biology, Genetics or Neurology. Therefore, an essential part of the process is mapping (Beyls, 2004), that is, the assignment of musical parameters to cellular parameters. It is necessary to foresee correspondences between sounds, transformations and processes such as the exchanges of chemical compounds, the dissolution, the creation or the division of the membranes. All the elements of a P-system (for example, rules, hierarchical structures or symbols of the alphabet) are likely to be modelled as musical elements, which could also be flexible depending on the needs of the composer to every moment.

6 Conclusions

In conclusion, we have studied the state of the art of Artificial Intelligence applications to musical composition, specifically natural bio-inspired techniques, and the stylistic and aesthetic principles of these tools. This leads us to investigate on possible relations between natural and musical processes to get results and conclusions from musical applications of membrane P-systems. Finally, by composing a new work based on these models, it is possible to prove that we can find analogies between compositional processes and natural processes at the cellular environment, that is, membrane computing can be used as tool to compose a bio-inspired piece for ensemble and mini-loudspeakers.

One of the main difficulties is the codification of musical parameters in the form of data structures which must be implemented and processed in a computer (mapping). This research is the first known study that applies a P-system (membrane calculus) to musical composition. Pre-existing bio-inspired models are almost always pitch oriented, while other parameters are omitted. This study focuses on the mapping of parameters such as timbre, rhythm and form.

This creative research aims to build tools to model elements of the personal musical language of a composer. In fact, planning the use of these systems is also part of the composition process. However, it should be kept in mind that the use of these techniques does not provide a guarantee of artistic result. It depends on the creator's ability to find analogies between musical and natural processes in the cellular environment, and then to come up with artistic creation from that. Finally, it is possible to continue research by creating new types of P-systems that simulate other interesting scenarios for musical composition.

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