ANGELIA: An Emotional AI for Electronic Music

Preprint · February 2023

DOI: 10.13140/RG.2.2.25416.39682

1 author:

Jean-Claude Heudin
Artificial-Creature.com
69 PUBLICATIONS **198** CITATIONS

SEE PROFILE

ANGELIA: An Emotional AI for Electronic Music

Jean-Claude Heudin
Artificial-Creature.com
Saint-Malo, France
jcheudin@artificial-creature.com

Abstract

This paper describes the principles of ANGELIA, an Art and Artificial Intelligence project for Electronic Music in the framework of the Hyperorchestration approach. ANGELIA is a hybrid emotional AI based on a dedicated music programming language that enables to use bio-inspired algorithms for composing and performing, such as neural networks, cellular automata, fractal development, and a corpus-based genetic algorithm. It includes also a feedback loop based on an "emotional metabolism" that modifies the expressiveness of the interpretation.

Keywords

Electronic Music, Artificial Intelligence, Bio-inspired Algorithms, Emotional Metabolism, Modular Synthesizer, Hyperinstrument, Hyperorchestration

Introduction

Most people and even musicians have a difficult time admitting that music can be represented and understood with algorithms. However, the history of music shows that algorithms and formal approaches have played an important role in the 20th century, with composers such as Stockhausen [1], Xenakis [2], Cage [3], to cite a few, but also before with Bach [4] and Mozart [5], among others.

Nowadays computer music is an active research field encompassing a wide range of approaches [6]. The works of David Cope with EMI (Experiments in Musical Intelligence) have shown that Artificial Intelligence can be successfully used for composing music in the style of prestigious composers [7]. More recently, the advances in Deep Learning have resulted in an increasing number of studies for music generation [8].

ANGELIA is an Artificial Intelligence research project for Electronic Music. This name is the contraction of "Angel" and "IA", the French acronym for Artificial Intelligence. The project was initiated during the summer of 2018 and its development has continued ever since.

An important axiom of ANGELIA is to place the artist at the center. Too often, the role of human is simply forgotten in AI projects, or at least unspecified. In contrast, our goal is to use AI for enhancing the creativity of the artist and not seeking to implicitly replace him. It is therefore imperative to integrate the AI in the artist's creative workflow, even if it will stimulate him to reconsider his approach towards composition and orchestration.

After four years of development, this paper describes ANGELIA's principles and approach. It first describes its hybrid architecture and the music-oriented programming language on which it is based. Then, it presents one of the main bio-inspired algorithms that can be used for composing and performing. A distinctive feature of ANGELIA is its emotional feedback loop. The next section describes the model of the "emotional metabolism" that modifies the expressiveness of the interpretation. During live performances, ANGELIA controls a dedicated 32-voice Modular Synthesizer. Together, they can be considered as a "hyperinstrument." The last section introduces the related Hyperorchestration approach.

Architecture Overview

ANGELIA is not based on a single algorithmic approach, such as Deep Neural Networks. Instead, it favors a hybrid architecture that enables to use different algorithms integrated in a dedicated high-level programming language.

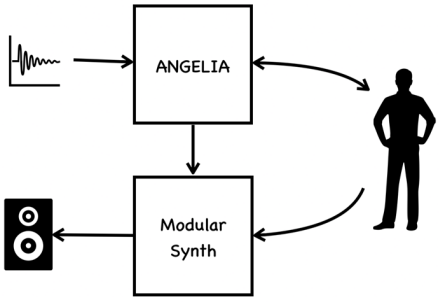

Figure 1. Overall architecture. During performances, the AI runs on a last generation tablet. The synthesizer is a 32-voice Eurorack Modular Synthesizer controlled via Midi and Control Voltage interfaces.

The architecture relies on three main parts: the artist, the AI, and the instrument. The artist interacts directly with both the AI and the electronic instrument. The AI is composed of a music generation engine and an emotional feedback loop whose purpose is to modify the expressiveness of the interpretation. The AI and the electronic instrument form together what we called a Hyperinstrument.

In fact, the boundaries between such an instrument and the instrumentalist are also subject to interpretation. We can consider them together as a hybrid being, a sort of "musical cyborg" composed of an organic part, the instrumentalist, and a machine part, the hyperinstrument, even if they are not physically merged. The concept of "musical cyborg" relies on the rejection of rigid boundaries, notably those separating human from machine [9].

Music Programming Language

The interaction between the AI and the artist is based on a dedicated programming language and a performance-oriented interface.

Music has its own language, in the form of music scores known to all. Musicians have proposed more graphic or flexible alternatives, like Iannis Xenakis [10] or Brian Eno [11] among others. But these representations are not directly adapted for algorithmic processing. In contrast, ANGELIA is based on a music programming language that is both understandable by the composer and interpretable by the AI. This approach also allows "live coding," a musical trend that has emerged in recent years where one can play live music with computer code [12].

The language is build on top of *JavaScript,* with an easy access to the source code, even in real-time. This code uses only one API to reduce dependencies: *WebMidi* for controlling Midi instruments [13]. The language syntax of ANGELIA inherits from trackers [14], but with a higher level of abstraction and algorithmic features. Here is an example of the language's syntax to show its main principles:

```
! Inhumane Etude #1
SONG: Prometheus
BPM: 120
BAR: 4
UNIT: 4
LENGTH: 90

INSTRUMENT: Piano "AUM" channel:1 vcurve:0.8
DEFINE: Sustain_On "ControlChange 64 data:127"

SEQUENCE: Mystic [C3 H F#3 Bb3 E4 A4 D5 C6]
LOAD: Bank0 Prometheus

0:0 Piano Sustain_On
0:0 Piano Play Mystic accent:classic intensity:0.6 humanize:0.5
...
! Improvise 4 bars using the Prometheus database
24:4 Piano Genplay Bank0 intensity:0.6 transpose:-3
...
80:0 End
```

Most of the syntax is self-explanatory. There are two sorts of expressions: directives and instructions. Directives are shown in capital characters. As an example, *DEFINE* is a preprocessor directive, inspired by the C programming language, specifying a name and a replacement text. This is useful for creating macros and extending the expressivity of the language. An important structure is *SEQUENCE*, which is basically an array of notes. It uses the classical letter notation with the special cases of R (rest), H (hold) and X (variable).

The language enables to represent a score by using instructions of the following form:

```
Bar:Pulse Instrument Instruction parameter:value ...
```

An example of a high-level instruction is *Genplay* that generates sequences using the corpus-based Genetic Algorithm (cf. previous code example).

The resulting program code can be uploaded in a performance-oriented web-based interface (cf. figure 2).

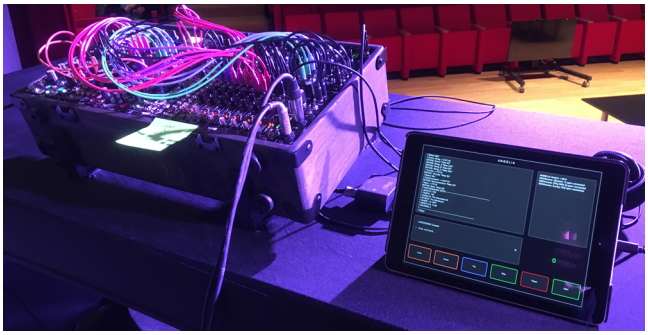

Figure 2. Hardware configuration showing the Modular Synthesizer and the tablet running ANGELIA. The performance-oriented interface includes a window displaying the script (top left); another one displaying the generated Midi flow (top right), and a live coding console (bottom left). In addition, there is a series of assignable buttons for controlling the execution (bottom).

Bio-inspired Algorithms

ANGELIA is not based on a single algorithmic approach. Instead, its programming language enables to choose for each instruction among different bio-inspired algorithms. It includes generative instructions based on the following kinds of algorithms:

- Procedural and stochastic generators,
- Evolutionary Algorithms,
- Cellular Automata,
- Fractal development,
- Neural Networks.

As an example, ANGELIA includes a dedicated Corpus-based Evolutionary Algorithm. One of the first Evolutionary Algorithms applied to music was *GenJam*, a Genetic Algorithm for generating jazz solos [15]. Like *GenJam*, our algorithm is inspired by natural selection among a population of individuals, the process that drives biological evolution [16]. By using this approach, a sequence of notes represents the "genetic code" of a melody or a chord progression. The population of musical sequences evolves over successive generation by breeding, through selection, crossover and mutation. Each genotype can be then developed to its phenotype, i.e. musical expression, in the envi-

ronment, i.e. the musical piece. The selection of a candidate, for reproduction and expression, depends on its fitness evaluation. The fitness function is a multi-parameter procedural function that scores each individual based on consonance calculation [17] and structural analysis [18].

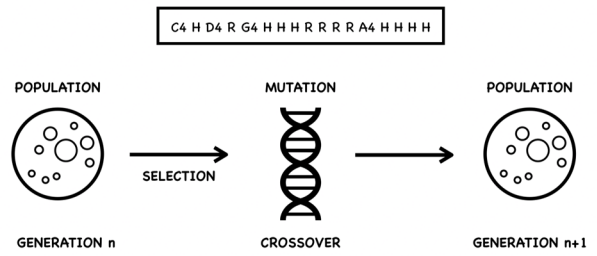

Figure 3. Simplified principle of the Genetic Algorithm. Individuals are 4-bar long sequences in the current implementation.

In contrast with classical genetic algorithms, our implementation does not start from a random generated population, but is initialized using a corpus database. ANGELIA does not use large volume of data from uncited composers, like most Neural Networks approaches. The database includes a carefully curated corpus of patterns from both classical and jazz composers, including Chopin, Litsz, Bach, Debussy, Corea, Jarrett, among others.

Emotional Metabolism

In most AI music projects, the system generates music with no direct feedback from the produced sounds in the environment. In parallel with the generation of music, ANGELIA analyzes the perceived sound environment in order to generate stimuli that update an "emotional metabolism." This module in turn influences parameters that modify the expressiveness of the interpretation.

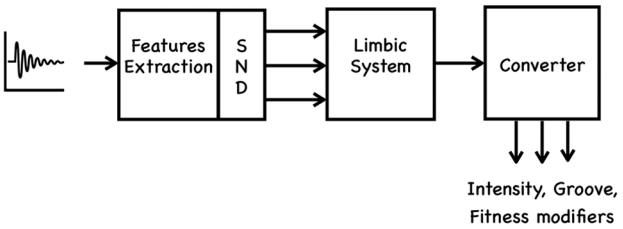

Figure 4. Block diagram of the emotional feedback loop based on three unsupervised neural networks. SND represents the three virtual neurotransmitters: Serotonin, Noradrenaline, and Dopamine.

The emotional metabolism is based on previous works about emotional virtual characters [19] [20]. It is composed of three main unsupervised neural network modules: the analyzer, the "limbic" system and the converter.

The analyzer extracts features from the perceived sound and transforms them into three virtual neurotransmitters: (1) *Serotonin* is an inhibitory stimulus that increases positive vs. negative feelings; (2) *Dopamine* is both excitatory and inhibitory, and related to pleasure and the reward-learning process; (3) *Noradrenaline* is an excitatory stimulus that is responsible for increasing active vs. passive feelings.

The limbic module is based on an emotional model inspired by works on the PAD(Pleasure-Arousal-Dominance) [21] and the Lövheim models [22]. It represents emotions, affects and moods in a three-dimensional space, where the three virtual neurotransmitters form its axes. Therefore, the current emotional state is a moving point in this 3D finite space, where the eight basic emotions, labeled according to the Affect Theory [23] are placed in the eight corners of the cube.

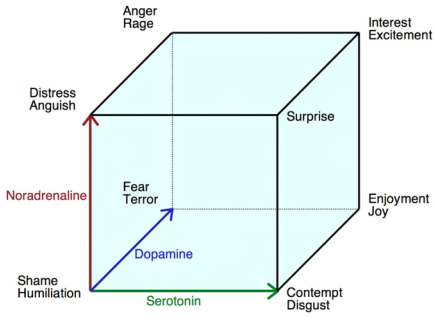

Figure 5. Mapping of the main emotional states on the three-dimensional space. The axes correspond to the three virtual neurotransmitters cumulated values.

The converter takes the coordinates of the current emotional state and converts them into values that updates the expressiveness of the interpretation, such as intensity, velocity, and swing parameters. In addition, it can be also used to modify fitness values when selecting melodic lines in the current population of the corpus-based genetic algorithm.

Hyperorchestration

ANGELIA can be defined as a Hyperinstrument: a musical instrument capable of playing multiple voices with extended composing and playing capabilities using Artificial Intelligence.

Sergi Casanelles coined the term "hypercorchestra" in his Ph.D. thesis [24]. He defined it as a new approach to the creation of contemporary music for audiovisual media. The term itself is derived from the concept of hyperreality, as defined by Umberto Eco [25], among others. Thus, the term is the portmanteau of "hyperreal" and "orchestra," which implies a musical ensemble that inhabits hyperreality. While his definition focused on contemporary movie music using sample libraries, we generalize the approach

in order to apply it in the larger context of electronic music creation.

Hyperorchestration expands the classical concepts of orchestra, orchestration and instruments. A classical orchestra can be generally broken down into four main primary groups: strings, woodwinds, brass, and percussion. In contrast, a hyperorchestra is composed of an arbitrary number of groups, each of them having a set of musical instruments, including hyperinstruments. Groups, instruments and listeners are not placed according to the typical orchestra-seating chart resulting in a conventional stereo field, but in a spherical virtual diegetic space. Thus, Hyperorchestration can be defined as the set of approaches, methods and guidelines in order to choose instruments, to place them in the hyperreal space, and to achieve a good cohesion and balance between them.

Conclusion

In this paper, we have introduced the ANGELIA research project for Electronic Music. We have described its main principles and global architecture in the framework of the Hyperorchestration approach. Forthcoming papers will describe with more details each part.

Future developments includes the integration of new algorithms based on Markov Chains and advanced Neural Network models, but also additional corpus from both classical and jazz composers. Further developments and experiments on the emotional metabolism are also planned.

ANGELIA is not yet another AI project applied to music, but above all it is a Music project using AI. In this framework, we have released albums that retrace the artistic evolution of the project. They can be freely listened or downloaded on an independent and open music platform [26].

References

[1] Karl H. Wörner, *Stockhausen: Life and Work,* trans. Bill Hopkins (Berkeley: University of California Press, 1973).

[2] Iannis Xenakis, *Formalized Music: Thought and Mathematics in Composition,* 2nd revised edition (Sheffield: Pendragon Press, 1992).

[3] James Pritchett, *The Music of John Cage* (Cambridge: Cambridge University Press, 1993).

[4] Douglass R. Hofstadter, *Gödel, Escher, Bach: an Eternal Golden Braid* (New York: Basic Books, 1979).

[5] Lawrence M. Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (Oxford: Oxford University Press, 2002), 142–143.

[6] G. Papadopoulos and G. Wiggins, "Ai methods for algorithmic composition: A survey, a critical view and future prospects," (Edinburgh, 1999). *AISB Symposium on Musical Creativity,* 110–117.

[7] David Cope, *Virtual Music* (Cambridge: The MIT Press, 2001).

[8] Jean-Pierre Briot, Gaëtan Hadjeres and François Pachet, *Deep Learning Techniques for Music Generation* (Cham: Springer, 2020).

[9] Donna Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century" *Socialist Review* 80, (1985): 65–108.

[10] Anastasia Georgaki, "The Grain of Xenakis' Technological Thought in the Computer Music Research of our Days" (Athen, May, 2005). *Proceedings of the International Symposium Iannis Xenakis Proceedings,* 355–361.

[11] John T. Lysaker, *Brian Eno's Ambient 1: Music for Airports* (Oxford: Oxford University Press, 2018).

[12] Ge Wang and Perry R. Cook, "On-the-fly Programming: Using Code as an Expressive Musical Instrument" (New York, 2004). *Proceedings of the 2004 International Conference on New Interfaces for Musical Expression*.

[13] Chris Wilson and Jussi Kalliokoski, "Web MIDI API", The World Wide Web Consortium (W3C), accessed May 31, 2022, https://www.w3.org/TR/webmidi/

[14] "Music Tracker", Wikipedia, the free encyclopedia, accessed May 31, 2022, https://en.wikipedia.org/wiki/Music_tracker

[15] John A. Biles, "GenJam: A Genetic Algorithm for Generating Jazz Solos" (Aarhus, Michigan Publishing, 1994). *Proceedings of International Computer Music Conference*, 131–137.

[16] David E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning* (Boston: Addison Wesley Publishing Company, 1989).

[17] Norman D. Cook and Takefumi Hayashi, "The Psychoacoustics of Harmony Perception", *American scientist* 96, (Sigma Xi, The Scientific Research Society, 2008): 311–319.

[18] Kjell Bäckman, "Automatic Fitness in Evolutionary Jazz Improvisation" (Belfast, 2008). *Proceedings of the International Computer Music Conference*.

[19] Jean-Claude Heudin, "A Bio-inspired Emotion Engine in the Living Mona Lisa", *Proceedings of the Virtual Reality International Conference* (Laval, 2015): 1–4.

[20] Jean-Claude Heudin, "An Emotional Multi-personality Architecture for Intelligent Conversational Agents", in *Transactions on Computational Intelligence XXVIII* (Springer, 2018): 1–21.

[21] Albert Mehrabian, Pleasure-Arousal-Dominance: A General Framework for Describing and Measuring Individual Differences in Temperament", *Current Psychology* 14(2), (1992): 261–292.

[22] Hugo Löveheim, "A New Three-Dimensional Model for Emotions and Monoamine Neurotransmitters", *Med. Hypotheses* 78, (2012): 341–348.

[23] S. S. Tomkins, *Affect Imagery Consciousness* vol. I–IV (New-York: Springer, 1991).

[24] Sergi Casanelles, "The Hyperorchestra: A Study of a Virtual Musical Ensemble in Film Music that Transcends Reality", (Ph.D. diss., Steinhardt School of Culture, New York University, 2015).

[25] Umberto Eco, *Travels in Hyperreality* (New York: Mariner Books, 1990).

[26] Jean-Claude Heudin, "Angelia", accessed June 2, 2022, https://angelia.bandcamp.com/