MUME 2016 - The Fourth International Workshop on Musical Metacreation, ISBN #978-0-86491-397-5

Harmonic Constellation: An Audiovisual Environment of Living Organisms

Ana Rodrigues, Amílcar Cardoso, Penousal Machado
CISUC, University of Coimbra
(anatr, amilcar, machado)@dei.uc.pt

Abstract

We present a prototype for an audiovisual environment to aid a human user in the exploration of musical chords through a graphic language. More specifically, we intend to explore which aspects of music might influence visual aspects at a perceptual level and vice versa. Furthermore, we want to find out to what extent can these audiovisual associations be explored computationally. So far, we have created a system that evolves chords in an autonomous and systematic manner, while providing visual clues about the process. This system is based on a multi-agent simulation environment and springs simulation. A detailed reflection about the current approach and future developments is also included.

Introduction

Multi-agent systems have been widely explored in artistic and scientific fields, such as audiovisual applications and music In multi-agent systems, local interactions following simple rules often result in complex behaviors, which in turn result in the creation of patterns. We depart from this idea of rich pattern creation with agent simulation to interactively create, explore and share new ways of expression.

We cross three distinct fields of study: music, visual expression and science. In the field of music, we explore an algorithmic generation of chords. Then, we build an alphabet for the graphic representation of sounds based on previous studies about this crossmodal relationship. Finally, we build a computer prototype to express these concepts and associations between them. The current prototype evolves chords in an autonomous and systematic manner, but only considers chords in the root position and interaction is limited. Its aim is to explore both multi-agent systems' mechanisms for chord formation and visual representations for chords and notes. In a longer term, we intend to expand the environment to allow interactive construction and exploration of not only chords but also sequences of chords.

The remainder of this paper is organized as follows. We begin by presenting inspirational work in the section of "Related Work". The current state of our work can be found in "The System" section. Ideas and intentions for further developments are stated in the "Reflection" section, which is followed by "Conclusions".

Related Work

Automatic generation of musical harmony has been approached by different strategies such as grammar-based systems, knowledge-based systems, genetic algorithms, constraint satisfaction systems and neural networks (Bernardes et al. 2015). Bernardes et al. have implemented a system for real-time automatic generation of musical harmony through a navigation in a 12 dimensional Tonal Interval Space, where Euclidean distances equate with the perceptual proximity among pitch configurations as well as their level of dissonance, in a Tonnetz-like pitch organisation. (Bernardes et al. 2015). (Navarro et al. 2015) work on automatic generation of chord progressions was developed with the aid of an artificial immune system that automatically generates the next chord in the sequence taking the two previous chords as an input.

Various music systems were built exploiting swarm behavior (Whalley 2009). For example, in earGRAM (Beyls, Bernardes, and Caetano 2015) an exploration of algorithms inspired by biological systems was developed in order to obtain sound transformations driven by their dynamics. Furthermore, a collection of sounds was organized according to their perceptual qualities. For example, neighbour sounds were more similar than sounds that were far apart. In addition, sound was also explored with visualizations.

Although a lot of studies on sound and image have been done, most tend to be experimental studies without a deep concern on how humans perceive this audiovisual relation at a cognitive level (Giannakis and Smith 2000). Relevant experimental studies on visual music (Evans 2005; DeWitt 1987; Collopy 2000) using the computer include the work of John Whitney and Bill Alves (Alves 2005; 2012; Whitney 1994). Whitney reflected on the difficulty of achieving a formalism for color. To him, such a direct, synesthetic mapping of sound basic parameters (pitch, loudness, and so forth) as others had done, was not enough to capture the expressiveness of music. These studies of experimental mappings between sound and image features such as the harmony of form, color, and motion (Alves 2005; Whitney 1994) remain a relevant reference in our work in order to keep a sense of aesthetics in digital audiovisual environments. This directly relates to another very important field of study, computer art, which comprises the use of computer to produce artistic artefacts. This allowed artists to produce artworks with unpredictable results without losing too much time experimenting consciously (Noll 1966).

Lindborg and Friberg conducted an experiment with the aim of exploring associations between sound and image at a perceptual level, where they explored colour association with music mediated by emotions. Their experiments suggested that low energy (perceived as calm or boring) was expressed through the size of the object with smaller patches and associated with darker colors towards blue, where low-tension music (perceived as easy-going) was associated with lighter colors (Lindborg and Friberg 2015). In a different experiment, Ramachandran and Hubbard (Ramachandran and Hubbard 2001) explored the relation between sound and shape. In their *kiki and bouba experiment* they concluded that 95 percent of people would make the right association even though they had never seen these stimuli before. The reason to this was that the sharp changes in visual direction of the lines in the figure would mimic the sharp phonemic inflections of the sound kiki, while the rounded contours of the other figure would make it more like the rounded auditory inflection of bouba.

Grill and Flexer (Grill and Flexer 2012) investigate perceptual studies between sound and image and then apply it to a digital media tool. Their goal was to develop an intuitive screen-based interface representing large collections of sounds, where sound manipulation would be facilitated by the exploitation of cross-modal mechanisms of human perception, like we aim to do in this work. They used metaphoric sensory properties that are shared between sounds and graphics, and constructed a meaningful mapping of auditory to visual dimensions. However, they restricted their focus to textural sounds, i.e., sounds that appear as static events, instead of evolving over time.

In a previous work, we have exploited a bio-inspired approach in which L-Systems evolve graphically and musically according to processes of mutation and cross-over guided by an user (Rodrigues et al. 2016).

The System

In this section, we present an agent based system and its interactions. An interplay between music and visual expressions is the core basis for the evolution of our system (see Figure 1). To implement the environment we resorted to Processing and Max/MSP. A demonstration video of our experimental application can be seen at: http://bit.ly/1TnJIJZ

System's behavior

We have two types of agents in our environment: notes and chords (see Figure 2). Both are initially displayed in the environment randomly. Chords are initially empty and wander in the environment looking for notes within their vision field that might be "absorbed" by the chord according to a set of musical rules. The field of view is defined by an angle and a distance depth (see Figure 3).

Figure 1: Prototype's application environment overview. Dark objects in the background represent note agents. Connected objects with springs in the foreground represent chord agents.

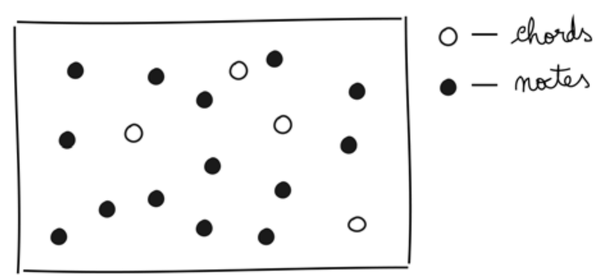

Figure 2: Two agents present in the system: notes and chords.

In the current version of the prototype, chords are formed in root position. Additionally, notes are positioned in relation to the root at intervals that are multiples of thirds. When a note forms an interval with the root that does not meet that condition, it still may be included in the chord, but only after being transposed up or down one or more octaves in order to meet the condition. For example, a note forming a 2nd with the root may be transposed one octave up to form a 9th and thus be included in the chord.

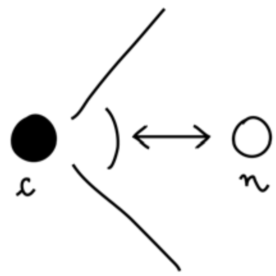

Figure 3: Chord (c) - note agent (n) field of view example.

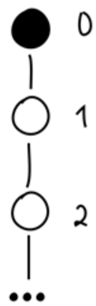

Figure 4: Note collection criteria for chords.

Note interval	Probability
3	90%
5	10%
7	70%
9	60%
11	40%
13	20%

Figure 5: Note interval and its corresponding probability of being caught.

A chord agent starts empty. Once a first note is caught up, it assumes the role of the chords root (see Figure 4). Subsequent notes seen in the vision field can be caught according to probabilistic rules that take into consideration the upward interval they form relative to the chords root (see Figure 5). If a note forms an upward 3rd interval with the root, there is a high chance (of 90 percent) that the note will be caught. Notes that form intervals of 7th, 9th, 11th and 13th, can also be caught, but with decreasing probabilities. 5ths are not favoured, but can also exist in the chords (lower probability). In brief, we are allowing chords to be formed as (possibly incomplete) sequences of 3rds counting from the root, up to the 13th (see Figure 5). We should clarify that these probabilistic rules are not based on systematic empirical work, so they are quite arbitrary, although trying to roughly reflect the musical practice in current popular styles.

Moreover, these rules do not distinguish major from minor intervals, neither perfect from diminished/augmented fifths intervals, as we do not want the impose additional constraints to the chord space to explore.

Crossmodal associations

In this environment, visual representation of chords and notes is performed by geometrical objects. This geometrical approach is inspired by Bruno Munari expressive drawings and diverse shapes explorations (Munari 1968) with the objective of building a modular and dynamic visual feedback.

The three musical features explored (pitch, loudness and note interval), are translated into four visual features (shape, lightness, size and line width). Pitch is represented by the notes' shapes (see Figure 6). Inspired by Ramachandran and Hubbard study of kiki and bouba where the softness of a sound is associated with round object shapes, we define that the higher the pitch the sharper is the shape (Ramachandran and Hubbard 2001). The loudness of a note is associated with the lightness and size of the note's shape as a metaphor for the energy of the sound. The less energy a note has, the dimmer and smaller it will be (see Figure 7). This mapping is based on previous studies that correlate these musical and visual characteristics (Lindborg and Friberg 2015).

Figure 6: Types of shapes according to the note's pitch. Higher pitches correspond to sharper shapes, lower pitches are associated more with rounded shapes.

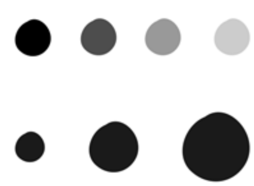

Figure 7: The energy that an object contains (loudness) is translated into lightness and size. The more energy it has the bright and luminous it is.

As for the interval between two successive notes in a chord, we translate it into a direct mapping corresponding to the length of the connection between their objects' shapes. (see Figure 8). On the top of all of these feature associations, a springs system is applied to each chord (see Figure 9).

Figure 8: Distance between notes of the same chord.

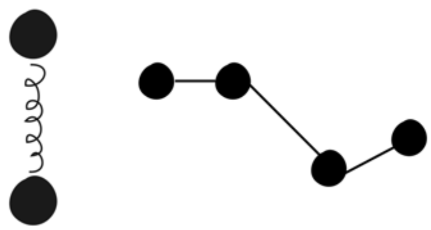

Figure 9: Springs system example.

Reflection

Currently, our system produces chords using simple rules. The current visual representation for music lets us distinguish sounds' pitch and energy or loudness with clarity. Furthermore, the notion of intervals between notes in a chord is provided by the notes' physical distance in the corresponding spring system. In the current prototype the user can listen to each chord and move it in the environment. Although we present a functional prototype, further developments still need to be done.

One of the limitations of our system is that once the notes are absorbed by the chord they remain stuck to that chord making the system predictable and static. Our solution to this problem will be an implementation of an algorithm that allows the loss of some notes according to some criteria. Plus, notes should be attracted by other chords and move to a different chord whenever that could make more sense in musical terms. These features will ensure that the system will have its own dynamic and is able to be creative in the formation of chords.

Chords are currently distinguished graphically by their shapes, length and brightness. However, in the future we aim to distinguish chords visually in a more detailed way. For example, we intend to represent dissonance through the color of the chord. To this end we may turn to some findings on emotions, colour and music features (Baumgartner, Esslen, and Jäncke 2006; Lindborg and Friberg 2015; Partesotti and Tavares 2014; Plutchik 2001; Vink 2001; Webster and Weir 2005).

We also may experiment other ways of note aggregation (see Figure 10), and other textures that might have more plastic and modular proprieties or may just be more expressive at a perceptual level. The user should be able to associate specific textures to certain kinds of chords (see Figure 11), which could prove to be a facilitator in the mediation of crossmodal associations between audio and visual features.

The location of chords in the environment is also an important aspect that we might taken into account so the user can easily perceive relations and similarities/differences among them since it is just arbitrary in the current system.

In addition, inverted chords shall also be implemented. Chords should also be able to exclude notes under probabilistic conditions. This last feature will limit stagnation in our musical organism.

We aim as well to build a system of preferences to guide the user in the formation of chords as if it was a project that he can give continuity to. Given this, we expect the user to evidence their preference for certain kind of chords and, in that way, change the system organization order.

Finally, we shall implement the possibility of combining chords either by user choice combined with a computational approach or in an autonomous way by the system. With the introduction of user actions in the, system we will be able to transform a probabilistic agent-based system to an adaptive system, since the user user choices will guide the evolution of the system in the formation of chords.

In the end, a qualitative evaluation of the system, either in terms of functionality and regarding user experience, will be conducted and will include user tests. One of the aspects to cover is the comparison between two modes of operation: interactive versus autonomous evolution.

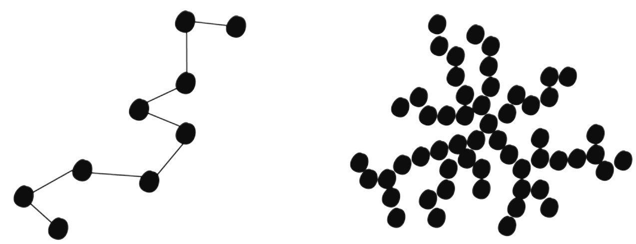

Figure 10: Left image: current aggregation system (springs), Right image: future experimentation aggregation system (dla-diffusion limited aggregation).

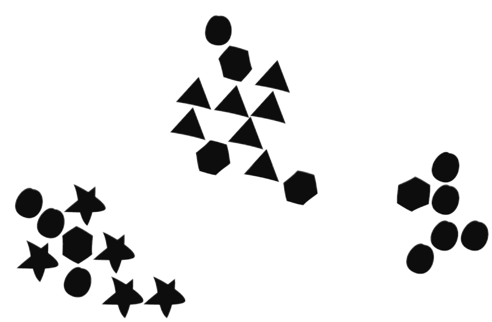

Figure 11: Example of chords' visual distinction using different textures.

Conclusion

We presented a prototype where the local interactions of a multi-agent system guide the emergence of visual patterns to facilitate the creation and exploration of musical chords. The main aim is the creation of an interface to aid a human user in the exploration of musical chords. Although it is a work in progress and we still need to do a lot more of experiments and improvements, the prototype already provides important cues about visual representations for the chords and about how chords can be evolved in a multi-agent system.

References

Alves, B. 2005. Digital harmony of sound and light. *Computer Music Journal* 29(4):45–54.

Alves, B. 2012. Consonance and dissonance in visual music. *Organised Sound* 17(2):114–119.

Baumgartner, T.; Esslen, M.; and Jäncke, L. 2006. From emotion perception to emotion experience: Emotions evoked by pictures and classical music. *International Journal of Psychophysiology* 60(1):34–43.

Bernardes, G.; Cocharro, D.; Guedes, C.; and Davies, M. E. 2015. Conchord: An application for generating musical harmony by navigating in a perceptually motivated tonal interval space.

Beyls, P.; Bernardes, G.; and Caetano, M. 2015. eargram actors: An interactive audiovisual system based on social behavior. *Journal of Science and Technology of the Arts* 7(1):43–54.

Collopy, F. 2000. Color, form, and motion: Dimensions of a musical art of light. *Leonardo* 33(5):355–360.

DeWitt, T. 1987. Visual music: searching for an aesthetic. *Leonardo* 20(2):115–122.

Evans, B. 2005. Foundations of a visual music. *Computer Music Journal* 29(4):11–24.

Giannakis, K., and Smith, M. 2000. Auditory-visual associations for music compositional processes: A survey. In *Proceedings of International Computer Music Conference ICMC2000, Berlin, Germany*. Citeseer.

Grill, T., and Flexer, A. 2012. Visualization of perceptual qualities in textural sounds. In *Proceedings of the International Computer Music Conference (ICMC 2012)*. Citeseer.

Lindborg, P., and Friberg, A. K. 2015. Colour association with music is mediated by emotion: Evidence from an experiment using a cie lab interface and interviews. *PloS one* 10(12):e0144013.

Munari, B. 1968. *Design and Visual Communication. Contributions to a Teaching Method*. Laterza.

Navarro, M.; Caetano, M.; Bernardes, G.; de Castro, L. N.; and Corchado, J. M. 2015. Automatic generation of chord progressions with an artificial immune system. In *Evolutionary and Biologically Inspired Music, Sound, Art and Design*. Springer. 175–186.

Noll, A. M. 1966. Computers and the visual arts. *Design Quarterly* (66/67):64–71.

Partesotti, E., and Tavares, T. F. 2014. Color and emotion caused by auditory stimuli.

Plutchik, R. 2001. The nature of emotions. *American Scientist* 89:344.

Ramachandran, V. S., and Hubbard, E. M. 2001. Synaesthesia–a window into perception, thought and language. *Journal of consciousness studies* 8(12):3–34.

Rodrigues, A.; Costa, E.; Cardoso, A.; Machado, P.; and Cruz, T. 2016. Evolving l-systems with musical notes. In *Evolutionary and Biologically Inspired Music, Sound, Art and Design*. Springer. 186–201.

Vink, A. 2001. Music and emotion: Living apart together: A relationship between music psychology and music therapy. *Nordic Journal of Music Therapy* 10(2):144–158.

Webster, G. D., and Weir, C. G. 2005. Emotional responses to music: Interactive effects of mode, texture, and tempo. *Motivation and Emotion* 29(1):19–39.

Whalley, I. 2009. Software agents in music and sound art research/creative work: current state and a possible direction. *Organised Sound* 14(02):156–167.

Whitney, J. 1994. To paint on water: The audiovisual duet of complementarity. *Computer Music Journal* 18(3):45–52.