Formalization Using Organic Systemization in Musical Applications

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Abstract: This paper presents the application of Conway's Game of Life within the field of music in a live performance, addressing concerns such as setup, control and aesthetics. A discussion of selected works identifies the limitations in hardware and software, and explains the approach about these constrains to the realization of a system in a recent work.

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1. Introduction

With the advancement of audio technology since 1945, the shift in performance aesthetics of electronic music has been significant. This began with Pierre Schaffer's *Programme de la Recherche Musicale* (*PROGREMU*) in the late forties (Dack 1999); Karlheinz Stockhausen's *Gesang der Jünglinge* that is based on aleatory, serialism and emphasis on sound spatiality (Ungeheuer and Decroupet 1998) and Edgard Varèse's multimedia performance of *Poème électronique* during the mid-late fifties (Ouellette 1973); David Tudor's emergent behaviors within electronic circuits; and Iannis Xenakis's *Unité Polyagogique Informatique CEMAMu* (*UPIC*) system and his integration of probability, statistics and physics in music in the seventies (Xenakis 1971). It is evident that the introduction of new technologies extends the aesthetics of performance and composition in electronic music.

Within the field of generative music and the use of biological algorithms in composition, the aesthetics has been shifting towards its ability to self-organize and generate emergent behaviors (Dorin 2001). The use of artificial intelligence in musical systems allows us to explore the new and unexpected from the known (Rosenboom 1990). This may also be applicable in uncovering new aesthetics within the practice of contemporary sonic arts.

> The game made Conway instantly famous, but it also opened up a whole new field of mathematical research, the field of cellular automata... Because of Life's analogies with the rise, fall and alterations of a society of living organisms, it belongs to a growing class of what are called 'simulation games' (games that resemble real life processes). (Gardner 1970).

Since the publication of the *Game of Life* in 1970, there have been many variations of the system and its integration in other disciplines. One example of the integration of the *Game Of Life* is by a philosopher and cognitive scientist, Daniel C. Dennett. In his book, *Consciousness Explained*, he used the *Game of Life* as an analogy to illustrate how human's philosophical constructs, such as consciousness, can evolve based on the physical laws of our universe (Dennett 1991). Within the field of music, *Cellular Automata Music generator* (*CAMUS*) uses Conway's *Game of Life* to determine the two intervals between three notes (Burraston et al. 2004). *Automaton* by Audio Damage uses the *Game of Life* to drive modulation effects onto audio signal. Other musical applications that feature the *Game of Life* algorithm as a pattern generator include *Game of Life Sequencer Bank* by Grant Muller, *Newscool* in Reaktor by Native Instruments, *GlitchDS*, *Runxt Life* and Tehn's *Conway's life* for Monome.

Most applications focus their time in the use of *Game of Life* as a tool for composition and in post-production works, focusing less on its live performance aspect. Furthermore, a review (Burraston and Edmonds 2005) has been written on the historical and technical aspects of cellular automata in generative electronic music and sonic art. Many researchers in this field currently focus more on partitioning their time between different systems of cellular automata (often in its different applications in composition), and less on its performative aspect. Instead of following popular research or commentaries, this paper aims to discuss the aesthetics and methodology on utilizing Conway's *Game of Life* in a live performance setting.

Section 2 briefly reviews the basic concepts of Conway's *Game of Life* to allow sufficient understanding of the subject for this discussion. The third section presents the aesthetics and perspectives that motivate the idea. Thereafter, selected works are discussed in a chronological timeline leading up to the case study of a recent performance, *Bots Formalization*. *Bots Formalization* is the author's milestone in research and study of integrating the *Game of Life* in a live performance that involves human-robotic interactions. This paper concludes with a brief overview of future works and applications that extend the current research and practice.

2. Background – Conway's Game of Life

The *Game of Life* is a two dimensional cellular automaton[1], devised by mathematician John Horton Conway. It is a simulation based on the births and deaths of living organisms in a system (Gardner 1970). A two dimensional cellular automaton is a mathematical model, in which cells are assigned a particular state, which then changes by turn according to specific rules conditioned on the states of the neighboring[1] cells. Two-dimensional simply notates the movement of the cells in both x and y–axis. (Krink 2003) Theoretically, the cellular automaton is based on an infinite square grid lattice; however, the size of the board is usually defined so that the number of cells present in the arrays is finite. In the automaton, a cell has two possible states: living or dead. These states are usually represented by colors. Black counters usually represent living cells, while white counters represent dead cells. (Gardner 1970) The state of the cells is determined by the state of the 8 neighboring cells surrounding it at every generation. The rules that determine the state of the cell for the next generation are as follow: (Gardner 1970)

Let the number of neighboring cells be n,

1. A dead cell becomes alive if $n \equiv 3$. **(Birth)**
2. A living cell becomes dead if $n \leq 1$ **(Death by exposure)**
3. A living cell becomes dead if $n \geq 4$ **(Death by overcrowding)**
4. A living cell stays alive if $n = 2$ *or* 3 **(Survival)**

The automaton begins with an initial pattern. Rules of birth and death are applied throughout the array to form the next generation. These rules are applied to the new generation that results from the initial pattern again. Here is an example of a simple pattern:

Let generation be g, hence at initial pattern, g=0

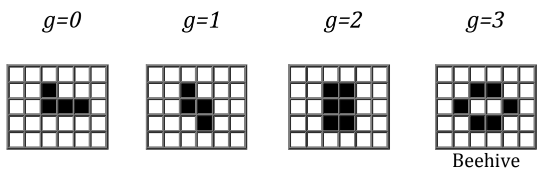


Fig. 1. Illustration of the 'life history' of a simple pattern. (Conway 1970).

1. Cellular Automaton is created by John von Neumann and Stanislaw Ulam to study the process of reproduction and growth. (Weisstein 2012)

Figure 1 (above) shows the life history of a simple pattern of tetrominoes, four rookwise–connected counters. (Gardner 1970) At g=3, the automaton ceases. This is because the resultant pattern of the cells in the subsequent generations is constant. This pattern produced is called a still life. The automaton will cease, when any of the following occurs (Gardner 1970):

1. All the cells on the board are dead.
2. The cells settle into a stable pattern that remains unchanged in the subsequent generations.
3. The cells oscillate in a cycle of two or more periods.

3. Aesthetics and Perspectives

While the aesthetics differs with its applications, it stays within its fundamental of formalization using organic systemizations, specifically Conway's *Game of Life*, to bring about structures. This extends to applications, the phenomenal of organic systemization in which an initial configuration evolves and brings about emergent behaviors based on the algorithm's grammar.

The outlook to performing and composing with the mentioned methodology can be explained in an analogy as such:

> The perfect rhythm of the last slogan breaks up in a huge cluster of chaotic shouts, which also spreads to the tail. Imagine, in addition the reports of dozens of machine guns and the whistle of bullets adding their punctuations to this total disorder. The crowd is then rapidly dispersed, and after sonic and visual hell follows a detonating calm, full of despair, dust and death. (Xenakis 1971)

The initial patterns can be perceived as the initial state of order. By starting the automaton and applying the rules of the game to all the cells on the board, the initial pattern breaks into chaotic generations of births and deaths. It ends in one of three ways: cells fading away completely, settling into a stable pattern that remains unchanged, or going into a stable oscillating phase with two or more periods of cycle. (Gardner 1970)

It is important to note that one has to have a good understanding of the *Game of Life* to utilize it strategically within compositions. (Burraston, Edmonds 2005) With the mastery of theory and practicum, one can alter the system to do the following: prolong or shorten the generations of births and deaths, resume lives, or put the system to a stop. If one is able to control the system amidst chaos, one should be able to manage a series of events, or in musical terms, articulate musical gestures eloquently. In such cases, the theory refers to the grammar and vocabulary of Conway's *Game of Life*, while the practicum refers to its performance — the deliberate strategy of making choices that are aesthetically successful within the composition and the *Game of Life* in a live performance.

The main aesthetic of performance using Conway's *Game of Life* is driven towards the search and discovery of new aesthetics in contemporary sonic art practices. The use of *Game of Life* establishes a unified and equal field, setting decisions free from the boundaries of stylistic influences. The performers are able to perform music in the analogy of the *Game of Life*, blurring rhythmic rigidness, structure, while disregarding the unwavering radiance of tonality and harmony. The criterion of musicality is two-fold. The first is how two or more sonic materials interact with one another to create different sonic textures and timbres. The second is how these different sonic textures interact with each other. As such, the classification of music as being either ‘ugly’ or ‘beautiful’ is disregarded. This also implies that any interaction between two or more sonic materials can be considered musical. However, this should not be taken for granted, as the strategic choice of play used for the organizations and interactions are crucial points to yield a performance of valid musicality.

4. Case Studies

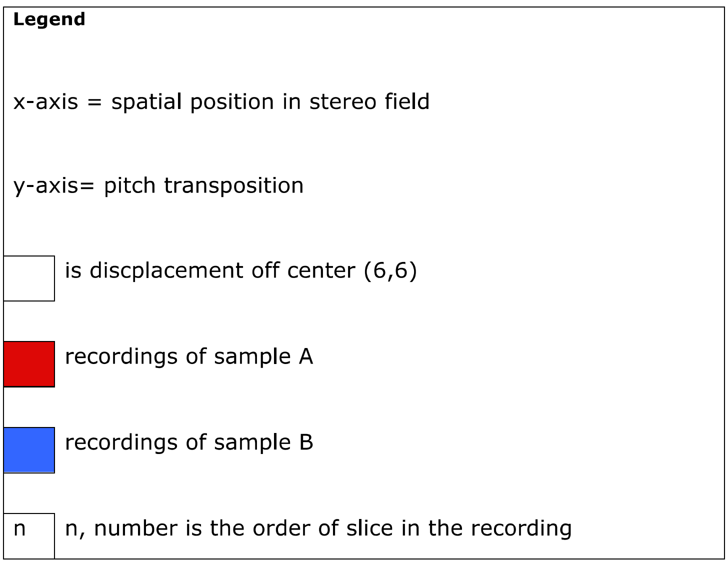
4.1. FD–2.111209

An initial musical application with the use of the *Game of Life* to further examine the plausibility of taking the *Game of Life* to a performance stage is *FD–2.121109*.[2] Created in 2009, *FD–2.111209* is an electronic composition based on the organization of musical motifs using Conway’s *Game of Life*. (Figure 2) While this work focuses on the compositional aspect; it set the foundations of studying to the *Game of Life* in a performance setting.

The main objective of *FD–2.111209* is to explore how events in the *Game of Life* relate to the intensity of musical events that takes place, and how parameters from the *Game of Life* can be mapped to musical attributes such as spatial location and pitch. In this work, two gliders set in a head-on collision path is used as the initial seed configuration, in an 11 by 11 grid array. The sequence lasts for 12 generations and ended with a 2 by 2 still life, more commonly known as ‘the block’.

FD–2.121109 further ascertains the importance of how certain cell configurations bring about different musical outcomes. *Parametrical Thinking* involves the use of variables from a systemization to control the values of musical attributes that are bounded by upper and lower limits. (Cope 1991) It brings to attention that *Parametrical Thinking* is an essential element to integrating the *Game of Life* in musical applications.

2. https://soundcloud.com/ /jprecursor/fd-2-121109



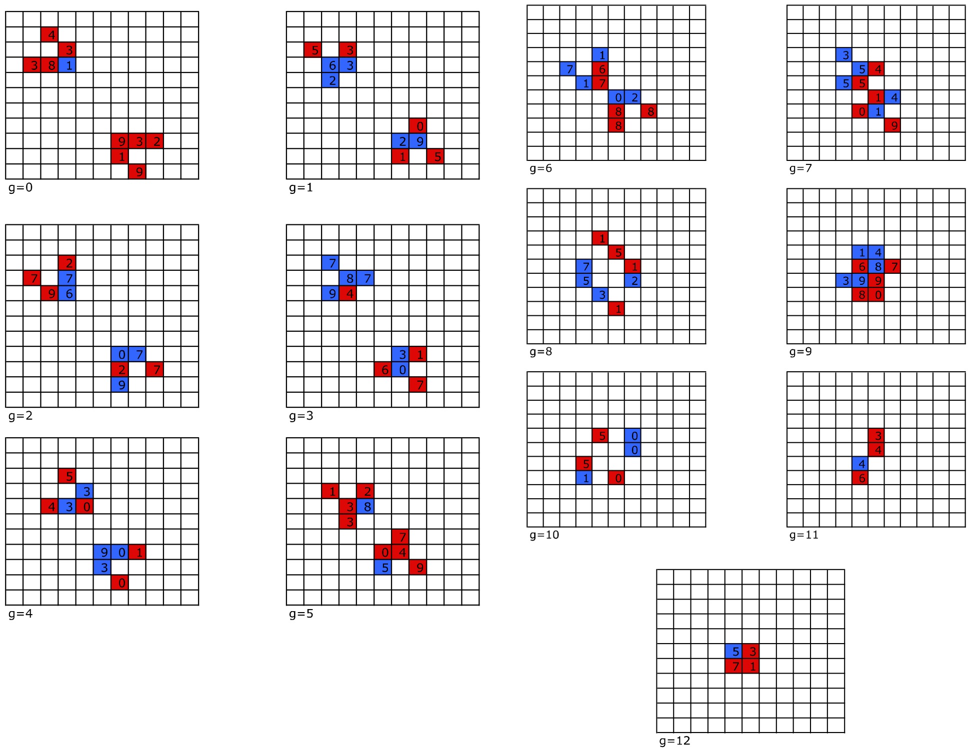


Fig. 2. FD–2.121109 Score Sequence.

4.2. Déboulerait

Prior to designing a unique system for performance utilizing the *Game of Life*, *Déboulerait*[3] utilizes the commercially available midi controller, Novation's Launchpad, and a port of the *Game of Life* algorithm — which was originally created for the Monome (Carbtree 2008). Based on the Monome's version of the code, a version specifically for the Launchpad was ported in *ChucK*. *ChucK* is a new (and developing) audio programming language for real-time synthesis, composition, performance, and analysis (Wang 2008). It is chosen for its highly precise scheduler that has no compromise on the dynamics and expressiveness of the control rates.

3. http://vimeo.com/19728681

Premiered at *COLAB 2010* (LASALLE College of the Arts Graduation Showcase, Singapore) with two performers, *Déboulerait* features the Conway's *Game of Life* as an instrument and focuses on its ability to play the game of life as an instrument during the piece. It consists of a sequential track of events that guides the performers in their improvisation by sending visual cues to the performers' instruments. Conway's *Game of Life* performs the role of an instrument in this piece. An overview of the system set-up is shown in Figure 3. The motivation drives towards the discovery and exploration of using the algorithm and the rules of an organic mathematical model as the basis of an instrument.

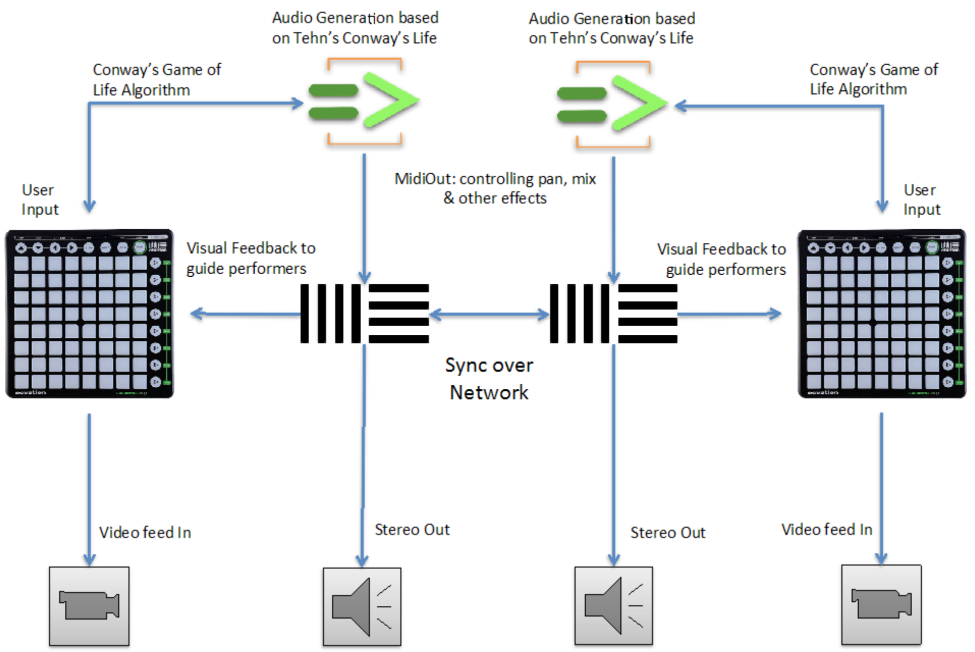


Fig. 3. Overview of the system: Déboulerait.

While in most electronic performance, the audience does not get to see what is happening on the screens and controllers of the performers. *Déboulerait* features a projected live video stream showing the performers on their instruments. This adds an additional element of visual performance aesthetics, as well as draws attention to the performers' aesthetic choices in the Game of Life during the structured improvisation.

The following limitations were found in the progress:

1. The interval between each generation is too consistent, resulting in the rigidity of rhythmic structure and texture.
2. The dynamics are either too consistent or chaotic (if a random function is in place), resulting the performance to be musically bland in color or too incoherent.
3. The grid array is finite, therefore limiting the performers in precision and diversity in control.
4. Only one instance of the *Game of Life* can be run on a singular device.

Henceforth, the above limitations became guidelines to the realization of a new performative setup in the most recent performance, *Bot Formalization*.

4.3. Bot Formalization

Bot Formalization sets out to test the newly customized performative system that integrates Conway's *Game of Life*. It explores the perform-ability through the formalization of custom-built robotic musical instruments. A designed systemization interfaces the mechanical onsets of actuators to a controller that breathes the *Game of Life*. This is similar to the agent-based system for robotic musical performance (Eigenfeldt 2008), but in addition to that, extends it to an array of robotic musical instruments with the use of the *Game of Life* cellular automata.

The custom-built robotic musical instruments[4] (Figure 4) residing in the Machine Lab at California Institute of the Arts (Kapur 2011) include seven independent robotic units

4. Further information: http://dev.karmetik.com/ /labs/robotics.

that have a total of 170 actuators, consisting of idiophones and membranophones. They are connected to a main server, communicating with the users in *Musical Instruments Digital Interface* (*MIDI*) through a Local Area Network.

Fig. 4. MahaDeviBot (left) and GanaPatiBot (http://www.karmetik.com/labs/robots)

The most important basis to the successful utilization of the *Game of Life* is mapping the automata's parameters to musical attributes as mentioned in the earlier section. These parameters from the *Game of Life* and the robotic instruments are shown in Table 1.

Table 1. Parameters from Game of Life against robotic musical instruments

Game of Life		**Robotic Musical Instruments**	
State of cell	On / Off (0, 1)	**No. of Actuators**	170
Coordinates of cell	x– axis / y– axis (integer)	**Volume**	soft–loud
Interval between generations	time (float)	**Speed**	slow–fast

The *Game of Life* is setup in the program to send and receive either *MIDI* or *Open Sound Control* (*OSC*) messages. The outcome of each cell can either be its position coordinates and current state (x, y, state) or a cumulative message consisting of position coordinates converted to midi notes and the state scaled to midi velocity (midi note, velocity).

This allows the communication between the *Game of Life* and an external device. The use of a controller interface bridges the user and the game itself, while enabling the performer to figuratively 'play' away from the computer screen. The interface controller used in this setup is the grayscale64 by Monome. It consists of 64 buttons and an accelerometer that registers 2 axes. (Figure 5).

Fig. 5. The Monome Grayscale64. (http://www.monome.org)

To further extend the compatibility of the controller closer to the number of actuators in the robotic instruments, the controller is setup to run 2 instances of *Game of Life* synchronously and independently.

Table 2. Overview of Mapping

Controller	Game of Life	Robotic Instruments
Buttons (64 × 2)	Cells	Actuators (128)
Accelerometer: x–axis	Duration of each generation / State	Speed of Actuators / Hitting Velocity
Accelerometer: y–axis	State / Duration of each generation	Hitting Velocity / Speed of Actuators

In summary, the buttons are mapped to the cells in the *Game of Life*. The additional accelerometer sensors in the grayscale64 allow us to add further control to the *Game of Life* system. In this case, the x–axis is mapped to the time duration of each generation and y– axis is mapped to the *MIDI* velocity. The mapping of the axes is switched in the second instance of the *Game of Life*. The state of each cell also acts as a gate to allow the passing of accelerometer data for *MIDI* velocity (Table 2). These mappings give the user additional control to dynamics and rhythm, which increases the articulation.

Bot Formalizations[5] is driven towards a structured improvisation of the analogy mentioned above in Xenakis's quote of the series of events that proceed one after another from the state of order. It also aims to explore the discovery of new organization in timbres and rhythm using the *Game of Life*.

5. Selected Video Excerpt of Performance: http://vimeo.com/channels/vie/55973717.

5. Conclusion

The system used in *Bots Formalization* overcame the limitations mentioned in Section 4.2. Dynamics and the fluidity in rhythm and structure are achieved by mapping the temporal and velocity attributes to a volatile parameter in the *Game of Life*. By increasing the number of instances of the *Game of Life* that runs synchronously and independently, the restriction of diversity in control is reduced.

In San Francisco (1996), Brian Eno referenced *Metaphors We Live By* by George Lakoff and Mark Johnson. Eno mentions that the use of different metaphors for a situation will change one's perspective towards the situation. (Eno 1996) The metaphorical representation of living organisms will evoke different insights to performance, uncovering vibrant dynamics within human–*Game of Life* interaction. This may also extend to influence the creation of different timbres and textures, as well as rhythmic structures that one may overlook during conventional process.

This paper addresses the live performance aspect of using the *Game of Life* automata, bringing crucial elements such as dynamics and temporal parameters into discussion, which are often not discussed. Focusing more on the perspective that resulted when using the *Game of Life* in a live performance, a discussion of selected works[6] leads to the realization of a designed systemization[7] that addresses the limitations of array size, dynamics and rhythmic structures.

Future works include designing a universal system that works in MIDI and OSC, extending this further to other forms of cellular automata and perhaps its integration and application other performing arts, and pedagogy for performance using Conway's *Game of Life*.

By way of conclusion, while there may be areas of considerations that may be omitted in this discussion, this paper presents a specific methodology and perspective that leads to the realization of a tool that brings the musical application of Conway's *Game of Life* to a live performance setting.

6. Other applications that extend further the ideas mentioned during this discussion can be found at: https://vimeo.com/ /channels/vie/

7. All works mentioned are to date as of December 31st, 2012.

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