

Noise Square: Physical Sonification of Cellular Automata through Mechatronic Sound-sculpture

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Abstract

As Burraston and Edmonds state, “creating patterns and sequences is necessary for the creative artist working spatially and temporally within a chosen medium”. [1] Accordingly, cellular automata’s capability of creating a wide range of evolutionary and generative patterns has made them of special interest to musicians and sound artists. While this has led to a great number of works of sound art and music that integrate generative patterns of cellular automata in one way or another, the sonic output of these works has been primarily retained within the realm of electronically produced sound. Followed by a concise overview on a selected number of these works, this paper presents a proposed audiovisual installation in which cellular automata is incorporated in the medium of mechatronic sound-sculpture, where the sound is generated physically and in the acoustic realm, through a mechanical apparatus.

Keywords

Generative Art, Cellular Automata, Mechatronic Sound-sculpture.

Introduction

Cellular Automata (CA) were originally introduced in the 1960s by Stanislaw Ulam and John von Neumann in the course of their studies on growth and reproduction processes. [2] They are a dynamic system in which time and space are discrete. Considering that music is a time-based system in which “a finite set of discrete values (e.g. musical notes, rhythms, etc.) evolve in space and time”, cellular automata are highly applicable to musical systems. [3]

Cellular automata are comprised of one or multiple dimensional arrays of cells. Each cell can have a finite number of states (e.g. dead or alive), which are determined by simultaneous local transition rules. Transition rules are extracted from configurations of a neighborhood of cells of specific length or range or the cell’s previous state. According to Dale Millen, in the context of a musical composition based on cellular automata, the composer can select or define each of the features above (i.e. the number of dimensions, cells, and states, the range, the type of transition rules, and the initial state of the system). [4]

The first instance of cellular automata used in music is perhaps Iannis Xenakis’ composition *Horos* (1986). According to Varga, Xenakis was particularly interested in

using the simplicity of cellular automata process to create complex and sophisticated results. [5]

Related Works: Cellular Automata in Music

An overview of different approaches in applying cellular automata to the production of electronic music and sound art is given in Burraston and Edmonds’ article in *Digital Creativity* journal, sound synthesis and MIDI sequencing techniques being the prominent methods. [1] LASy and Chaosynth are two noteworthy examples of using cellular automata in sound synthesis. The properties of these synthesizers are examined in detail by Miranda. [3]

The utilization of cellular automata in the MIDI domain is discussed in “Cellular Automata in MIDI based Computer Music” by Burraston et al. [7] There has been an extensive body of work dedicated to the design and development of MIDI-based cellular automata systems. Beyls, Millen, and Miranda were some of the early pioneers in this field who contributed to the movement from slightly different angles. As one of the first composers to experiment with cellular automata, Beyls investigated one-dimensional and two-dimensional cellular automata to develop systems equipped with a MIDI mapping process for both non real-time and real-time compositions and performances. [8][9][10] Millen and Miranda investigated systems (CAM and CAMUS) that were primarily based on two-dimensional and three-dimensional models of Conway’s Game of Life, this itself being the best-known example of two-dimensional cellular automata. [11] The characteristics and functionality of these systems, in addition to a number of other significant MIDI-based cellular automata compositional platforms are discussed and compared in detail in Burraston’s article. [7]

In an instance of using cellular automata in an audiovisual installation, Bill Vorn utilized a two-dimensional cellular automaton inspired by Conway’s Game of Life, in his work *Evil/Live* in 1997. [12] An 8×8 grid of cells represented by light bulbs were attached onto an aluminum structure, and the light patterns were constantly changed according to the cellular automata activity governed by the computer. Each light bulb also corresponded to an audio event that was generated by a sampler. The audio patterns were triggered via MIDI messages and played back

through the loudspeakers that were also attached to the aluminum structure. Vorn has expanded this work into *Evil/Live 2* and *Evil/Live 3* by increasing the number of matrices and cells and adding new levels of interaction.

Another example of using cellular automata in an installation work is Alan Dorin's *Liquiprism*. [13] *Liquiprism* was an interactive piece, based on the idea of generating polyrhythmic patterns through six different two-dimensional cellular automata that formed facets of a cube. Dorin's goal was to highlight the conceptual conflict between the inherent regularity and determinism of cellular automata, and the resulting complexity and fluidity that can be obtained by their interaction. Here, the sonification is accomplished through connecting *Liquiprism* to an analogue modeling synthesizer with the triggered sounds varying between simple squelchy tones and pure sine tones: "Each face of the cube is assigned a different MIDI channel and each of these is assigned a different voice on the multi-timbral synthesizer". [13]

In a rather rare instance of using cellular automata in an interactive live-performance involving musical robots, where the sonic output is a result of a physical process rather than a digital one, Jingyin He has applied the two-dimensional Game of Life cellular automata onto a grid-based MIDI controller in order to interact with a number of mechatronic idiophones and membranophones (The Kar-metik Machine Orchestra). [14][15]

In his 1990 article "Generative Processes and the Electronic Arts", Alan Dorin mentions the wind-chime as a physical example for such generative process-based systems. [16] Yet, referring to the physical processes as 'exceedingly complex' and difficult to control, Dorin argues that the computer "provides a practical alternative for the artist interested in exploring generative processes". [16] That is perhaps one of the main reasons underlying the occurrence of the great majority of the instances of using cellular automata in music in the electronic sphere.

Noise Square: an Audiovisual Installation¹

With the rapid developments of DIY technologies in recent decades, it is now possible more than ever before, to achieve a well-defined and highly controlled sonic output through a mechanical process and in a physical manner. The integration of mechatronic systems coupled with micro-controller programming in works of music and sound art has grown largely over the past few decades, and has led to an extensive body of work, ranging from complex robotic models of conventional musical instruments to reductionist and minimalistic sound-objects and sound-sculptures. [17][18] The programmability and autonomous capabilities of these systems, in addition to their high degree of responsiveness and predictable functionality calls

¹ Video documentation of the demo realization can be found at: <http://vimeo.com/114290748>

for their utilization in the context of generative art. The proposed installation, *Noise Square*, is an audiovisual work in which generative patterns of a 1D cellular automata are sonified through a set of four mechatronic sound-sculptures entitled 'Mutor', developed by the first author.

Mutor

Mutor² is a sound-sculpture in which "the sound of a DC motor is controlled and manipulated through mechatronics and microcontroller programming, in terms of frequency, timbre, and amplitude". [17] As shown in Figure 1, the instrument is comprised of a DC motor enclosed in a transparent acrylic cube with a pivoting side, a push-type solenoid attached to the edge of the pivoted side, and a small LED light panel mounted on the back of the cube. Micro-controller programming is used to control the motor's rotation speed, solenoid movements, and light panel's luminosity. The communication is performed via MIDI messages and different MIDI velocity values create different speeds of rotation, and therefore, a range of different buzzing tones, whereas solenoid's binary actuations fed by MIDI note-on and note-offs result in shutting and opening the door, modulating the amplitude and timbre of the noise in a rhythmic manner. The LED panel contains three bright LEDs that are connected in series and corresponds to the solenoid inputs, lighting the Mutor on and off synchronously.

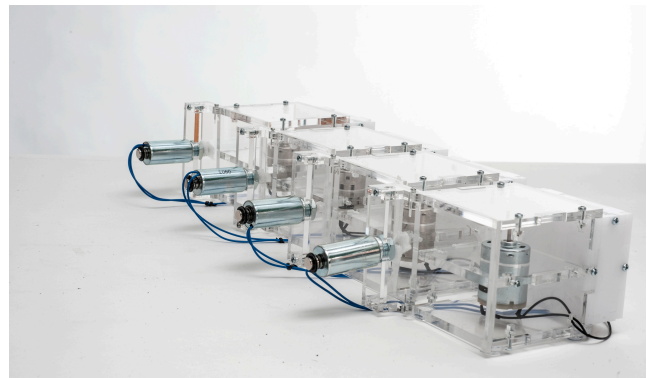


Figure 1. A set of four Mutors

The corporeal existence of Mutor as a sound-sculpture, in addition to its organic and bodily way of sound production, which is visually accentuated in synchronous LED light patterns, paves the ground for its placement in an installation setting, where physical and visual elements of the work are of great prominence. On the other hand, the privilege of autonomy provided by the use of mechatronics and microcontroller programming enables the possibility of having multiple units of Mutor programmed to function in an autonomous ensemble scenario. As a result, considering the grid-based structure, binary behavior, and outstanding visual manifestation of cellular automata, they can be exploited as highly harmonious compositional platforms in

² <http://www.m-h-z.net/mutor>

this context, creating the opportunity to employ an ensemble of Mutors in the self-governing and generative setting of an audiovisual installation.

Realization

Noise Square employs a set of four Mutors, placed next to each other in a row. A one-dimensional cellular automaton of four cells with the neighborhood range of one is used as the generative input source, each Mutor representing one of the cells. A grid of 4×15 cells—whose sizes are mapped to the dimensions of the Mutors—projected on a screen (or the wall) behind the Mutors, in addition to the row of Mutors itself, would be displaying the states of 16 sequential generations of the CA at all times (Figure 2).

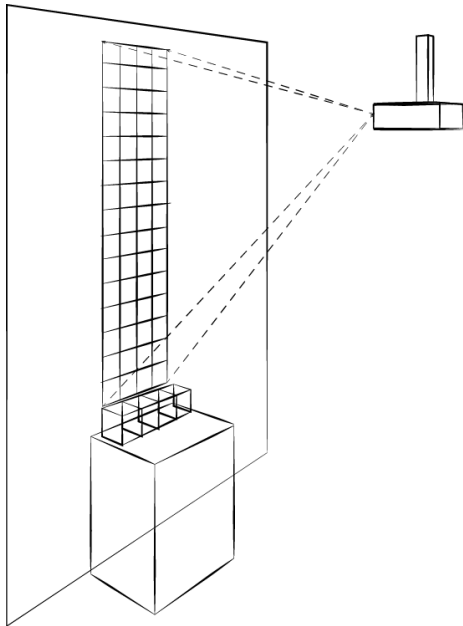


Figure 2. *Noise Square*: the set-up.

As the CA develops, the generations (rows) continuously step through the grid from the bottom (Mutors) row to the top of the grid, as the cell states in the bottom row determines the status of the Mutors. Therefore, four columns of the grid can be thought of as four vertical step sequencers constantly driving the instruments. Initially, a random rule-set (among the 256 possibilities) is applied to the CA, and its corresponding number is scaled down to the range of 0 and 127. This scaled number is then used as the input values for the motors, creating a rich and continuous drone chorus. A live (white) cell creates a MIDI message with the velocity of 127, which then lights the Mutor on, and causes the solenoid to push out and open the cube's door. A dead (black) cell creates a MIDI velocity of 0, turning the LED panel off, and returning the solenoid to rest position, which shuts the cube's door (see Figure 3). The CA develops at the rate of 8 generations per second, giving each step the duration of a 16th note in a BPM of 120. Every 64 steps, the CA rules is reset to another randomly chosen rule, changing the tone of the motors, and the CA's

evolutionary behavior that determines Mutors' rhythmic patterns.



Figure 3. *Noise Square*: demo realization.

Discussion

From a conceptual perspective, Mutor aims to draw attention to the sound of a DC motor by removing it “from its everyday context where it is unwanted and ignored”, flaunting its physical presence, and making it more accessible through the binary and metric rhythmic patterns. [17] Therefore, it can be argued that although using a different medium, Mutor somehow employs the same conceptual agenda as many contemporary examples of digital glitch music: that is to use grid-based and pulsating rhythms in order to bring the ignored and unwanted aural artifacts of modern technologies to the foreground, making them accessible, and appreciated. [19] Accordingly, the instrument is designed in a way that makes it perfectly capable of creating recurring motions and pulsating rhythms. The effect of these grid-based rhythms is perceived as subtle, but highly ordered timbral modulations of the motor's noise, and punctuated by the percussive sounds caused by shutting of the cube's pivoting door. In this way, Mutor aims to create a platform to explore the potential aesthetic values of a DC motor, by regulating its noise timbrally, and “musicalizing” it on a rhythmic grid. As noise philosopher Jaques Attali argues, what all kinds of music have in common is “the principle of giving form to noise”. [20]

With this in mind, in a context where grid-based rhythms are of essential prominence, the grid-based structure of cellular automata gives it an edge over the other algorithmic and generative methods. Cellular automata in fact share the very structural essence of the Mutor's temporal scaffold, i.e., employing basic binary elements to create a much more complex output. Furthermore, the minimalistic, cubic, and grid-based form of Mutor along with the synchronous square light panels sit perfectly with the black and white cells of the cellular automaton grids in terms of aesthetics. Considering the visual significance of an audiovisual installation work, this concrete and visionary connection between the instrument and the input source

can further strengthen the audiovisual expressivity and tighten the semantic-syntactic relationship.

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Authors Biographies

Mo H. Zareei is a sound artist and a music technology researcher. Born and raised in Iran, Zareei moved to the United States in 2010 to study at California Institute of the Arts, where he started to explore the world of electronic music. Using custom-built software and hardware, his experiments with sound covers a wide range from electroacoustic and electronic compositions to mechatronic sound-sculptures and installations. Striving to turn the harsh, unwanted, and unnoticeable into the pleasing and accessible, Zareei's work is particularly targeted at the point where noise meets grid-based structures. He is currently living in New Zealand, where he is pursuing his PhD research on noise music and mechatronics at Victoria University of Wellington.

Dale A. Carnegie has a BSc in Theoretical Physics and Applied Mathematics, an MSc with first class honours in Applied Physics and Electronics and a PhD in Computer Science. He is currently the Professor of Electronic and Computer Systems Engineering at Victoria University of Wellington where he is also the Dean of Faculty of Engineering. He heads Victoria University's Mechatronics Group, which specializes in Autonomous Mobile Robotics.

Ajay Kapur is currently the director of Music Technology at California Institute of the Arts. He received an interdisciplinary Ph.D. in 2007 from University of Victoria with a focus on intelligent music systems and media technology. Kapur graduated with a BS in Engineering and Computer Science from Princeton University in 2002. A musician at heart, trained on drumset, tabla, sitar and other percussion instruments from around the world, Ajay strives to push the technological barrier in order to explore new sounds, rhythms and melodies.