01101110 : An Audiovisual Installation Based on the Cellular Automaton Rule 110

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ABSTRACT

This paper presents and discusses in depth an interactive audiovisual installation created by the authors. The title of the work, *01101110*, corresponds to the number 110 and refers to the Cellular Automaton (CA) *Rule 110*. The installation is composed by a series of snapshots of the evolution of the CA, projected on white canvases, or directly on the wall, by custom designed and custom made projectors. The projected images, which the authors refer to as *shadow paintings*, are accompanied by an artificial soundscape, also based on the same automaton. When the visitors walk across the projected image, they interact with the sonic and the light output both physically and digitally by obscuring the projection and by making the light turn on and off. The outcomes and the process of the creation of the work are presented equally in a technical and aesthetic context. The minimalistic language of the piece may be traced back to the early pioneers of the visual arts such as Donald Judd or in music to composers such as Steve Reich.

1. INTRODUCTION

Cellular Automata (CA) have been the object and the inspiration of creative exploration repeatedly in the last decades. Amongst other algorithmic, generative and computational processes, they have been used both in the visual arts and the sonic arts. [1–3].

In the music domain, Xenakis was the first one to use them in 1986 for his orchestral piece *Horos* and in few other later compositions. Other notable composers that employed Cellular Automata in their work and have done considerable research on the topic are Peter Beyls [4] and Erduardo Miranda [5].

In the visual arts, examples of work based on Cellular Automata can be found in the work of Bill Vorn with his installation *Evil/Live* [1] and in Noyzelab [2] art/science music studio where composition and visualization processes were presented in a gallery context. Alan Dorin has created an interactive screen-based installation piece called *Liquiprism* [6] to produce polyrythmic patterns. Troika, a collaborative contemporary art group has used Cellular Automata in several painting-like pieces such as *Hierophany* [3] amongst others.

With the quite recent development of open source computer languages and toolkits for creative coding such as Processing and openFrameworks and with the emergence of the big communities around them, many more artists and designers have started creating work based on these algorithms too. Shared code has been proven extremely useful for the experimentation with such generative processes [7]. Equally in music, programming languages like Pure Data and SuperCollider along with their communities offered a very fruitful ground for creative development.

01101110 is a light-sound interactive installation [4] , echoing and celebrating the simplest mathematical model of computation : the automaton *Rule 110*. In contrast with most of the aforementioned works, it uses the most simple mapping for the generation of the visual and the sonic content following a minimalistic aesthetic. An overview of the installation can be seen in Figure 1.

In the first section of the paper, an analysis around the aesthetic choices of the work is given. Section two covers the technical description of the work: the design and the fabrication of the projectors, the sound design and finally the electronic circuits development for the light control and interaction with the audience. The final section offers a discussion around the exhibitions that took place in Ljubljana and in Copenhagen and some thoughts about the whole project in general.

2. AESTHETIC CONSIDERATIONS

011101110 is an audiovisual art installation which tries to bring together visual and sonic investigations at a very elementary and pure level. It aims to express in a direct, simple and hopefully elegant way the computational significance of this elementary Cellular Automaton which was introduced by Stephen Wolfram in 1983 and it is proven to be Turing complete [8]. Such an automaton can emulate a Turing machine and therefore can simulate the computational aspects of any possible real-world computer.

This artistic works celebrates this inspiring property as well as the more generic fact that in some systems, very

[1] http://billvorn.concordia.ca/robography/EvilLive.html
[2] https://www.noyzelab.com/

[3] https://troika.uk.com/work/troika-hierophany/
[4] https://onecontinuouslab.net/projects/#Rule110 https://onecontinuouslab.net/lab/#making-Rule110

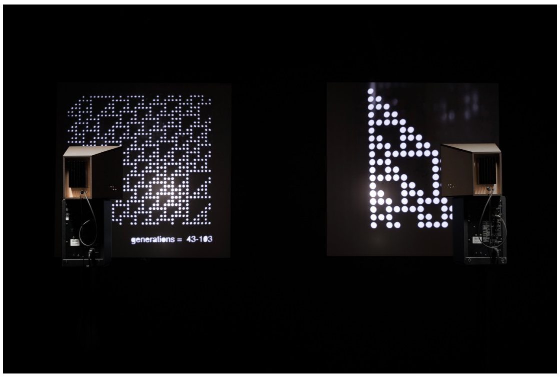

Figure 1. Rule 110 installation view - Image taken from the exhibition that took place in Ljudmila, Ljubliana on March 2019

simple rules can produce very complex results. By using extremely basic materials such as white light, shadows, pure tones and white noise, it has the aspiration to create an immersive and contemplative experience to the visitor which resonates with the ”logical beauty” of the algorithm.

The inspiration behind this work can be traced back to the early pioneers of the visual arts such as Donald Judd and Sol LeWitt or in music to composers such as Steve Reich or Terry Riley [9]. Equally, the visual part of the installation can go back to the eighteenth and nineteenth century where several apparatuses were invented to produce sound together with a visual representation. Those colour or optical organs signalled the beginning of visual music [10]. In *01101110* the designed and built device takes the simplest and purest form, echoing once again the ideals of minimalism in contemporary art and music. The light emitted by the diode is diffracted only by the perforated panels, keeping the process of the projection to its basic pure form, and no correction with any other obstacle, lens, stained glass or similar optical device is applied to the path of light. Therefore the projector in itself, as a sculptural element in the installation represents a piece of minimal design, and furthermore the projection in itself, represents a piece of minimal process.The natural simplicity of the process implies that the visitor is inclusively rendered as an another perforated panel, balancing between being an interfere and an observer. The visitor can never be completely in front of a *shadow painting* without being a shadow him/herself.

The installation creates two kind of spaces, the inner space of the projector and the outer space of the projection. People move and experience the second space, though they can sneak peek the first one also. The inner space is related to the abstract and immaterial nature of the algorithmic process, while the outer one to the experiential ways the automaton is revealed to our senses.The emitting light travels through and connects both spaces, creating a physical coupling between the two.

The installation is in accordance with Brian Enos' aesthetic values towards longer, slower, less dramatic and more sensual experiences [11]. Equally it has its roots in early La Monte Young works such as the *Dream House*. It may

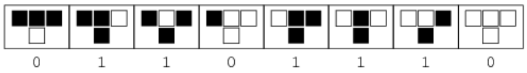

Figure 2. Rule of the Cellular Automaton Rule 110 (image taken from [8])

be seen as video stills or static frames of the evolution of the automaton. Similar to a photographer, the ambition of the authors was to capture the dynamics and ”life” of the evolution of this algorithmic ecosystem at specific times and locations. It is a landscape of pure shadow and sound, which becomes an environment when the visitors walk around the space, stand aside and in front of the *shadow paintings*, interfere with the work and explore at their own pace the space between the perforated panels and the room. Ideally, the work should be exhibited in a wide open dark space or a big gallery room where ten projectors and ten speakers can be installed. This setup gives more the impression of a photographic or painting exhibition than a new media one.

One of the ambitions of the the authors was to question and blend together disciplines such as architectural lighting design, music, science and media such as sound, space and light. This transdisciplinary approach is at the heart of the artistic, design and even technological investigations of their creative art-science collective [5].

The generative aesthetics are prominent in this artwork. Similar to the earlier movements of system art and process art, the artist focuses its creative forces in *meta-creation*: he/she designs processes rather than making the artefacts explicitly [12]. Clearly, processes having their roots in other disciplines such as physics, biology or computer science in the current case, may not maintain their interest when explored artistically or sonified and visualised. The authors believe that the pure mapping decisions they took, fulfil their creative intention especially in the context of minimal art. Similar to the case of phase music, they embrace Steve Reich's proposition that the processes must be perceptible [13].

3. TECHNICAL DESCRIPTION

The installation is generated by computational generative processes. Both the sonic and the light output is produced by the same computational system, the elementary one-dimensional automaton *Rule 110*. The extreme simplicity of this repetitious, dynamic procedure manifests both in the visual and the outcome: the same algorithm controls the digital fabrication process employed to create the perforated panels that cast the shadows and the sound synthesis engine that produces the sound and music. Figure 3 illustrates the mechanism of the installation as a block diagram. More details about each block will be given in the following subsections.

An automaton consists of an array of cells and in principle Cellular Automata are used to model dynamic systems

[5] https://onecontinuouslab.net

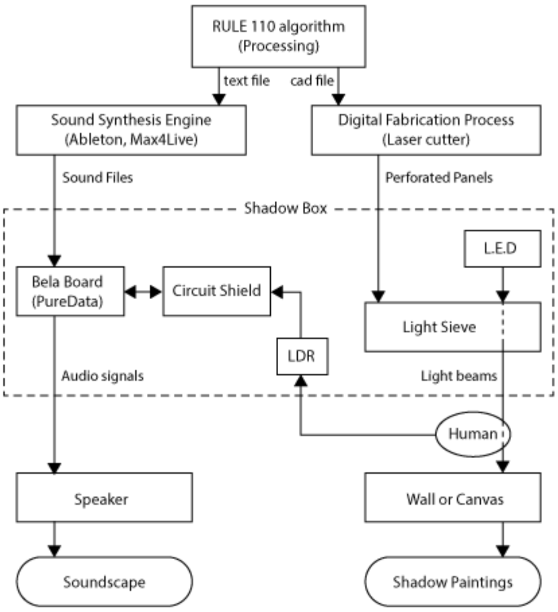

Figure 3. Block diagram of the installation

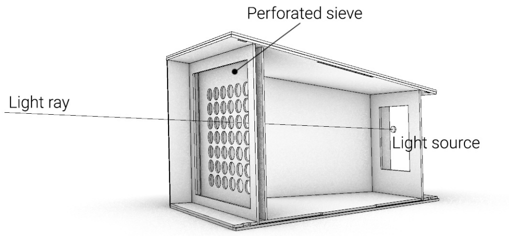

Figure 4. Concept diagram of the *shadow box*

that are discrete both in the time and spatial dimension. In this automaton each cell has two possible values; one or zero that may be represented visually by the black and white colours. The evolution of this automaton is defined by a set of rules which update the array on the next time frame.

The *Rule 110* algorithm was implemented in Processing programming language and was based on the code which accompanies the publication [7]. A function computes each generation of the automaton based on the simple rule illustrated in Figure 2 by simply examining its current state and its two neighbouring states. The number of cells of each generation and the geometrical characteristics of the two-dimensional image of the automaton are specified in the code. A different function generates a text file carrying information about the state of each cell for the selected generations used for the sonification and a CAD file that depicts the evolution of the automaton in two-dimensions for the digital fabrication of the perforated panels. Therefore the same snapshots of the evolution of the automaton generate all the media aspects of the art installation.

An important aspect of the creative process was the remote but synchronous collaboration between the authors. The one co-author was working in oneContinuousLab's studio in Athens, and the other on the installation site in Ljubljana. The challenge was to co-create remotely the physical object that would be installed into the specific exhibition space. The physical design of the *shadow boxes* was taking place in Athens, while in Ljubljana the more immaterial automaton implementation and sound programming was happening.

3.1 Custom Made Projectors

For the visual component of the work, a set of projectors were designed that emit the light diffracted by the perforated panels. Each projector is mounted on top of a loudspeaker placed on a stand. Moreover, the projector-speaker pairs are close enough to the wall where these shadows are cast, leaving nevertheless adequate space for the visitor to walk in front of them.

In relevance to the authors aesthetic considerations it was decided from early on that the projectors, or *shadow boxes* as the authors call them, should be as simple as possible, should create the inner space of the installation, and should have noticeable presence without being distracting. In addition, they should also be easily assembled and disassembled, lightweight, and fit in a carry-on suitcase. Moreover, following the fab-lab paradigm, given a simple instruction diagram and laser cut file, the *shadow boxes* should be easily reproduced in different parts of the world by different people [14]. The *shadow box* concept is illustrated in Figure 4.

At oneContinousLab in Athens, one of the co-authors was designing, making mockups and tests in order to find out the right parts, and metrical relations between those parts. The challenge was to make a compact *shadow box* containing a light source and a sieve that will produce a big sized *shadow painting* with sharp edges. During the experiments we realised that there are basically two factors affecting the sharpness of the projection. The first is the physical size of the light emitting source. The smaller the size of the light source the sharper the projection will be. Ideally a point in space emitting light, will create very sharp images and eliminate the importance of the next factor. The second are the distances between the light source, the sieve and the surface of projection. The bigger the distance between the light source and the sieve, the sharper the projection would be, but smaller in size.The shorter the distance between the sieve and the projection surface, the sharper the *shadow paint* will be, but smaller in size.

Another important aspect that affects the overall perception of sharpness, is the contrast of the projection. This contrast depends on the amount of light the light source emits, by the light reflection characteristics of the projection surface, and by the overall lightness of the room, which affects negatively the contrast of the projection. This meant that we should avoid unnecessary light escaping from the

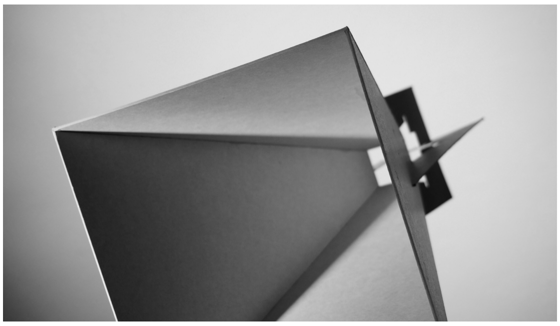

Figure 5. One of the first designs and mockups of an open form projector. oneContinuousLab, Athens February 2019

Figure 6. The first pilot prototype of the final shadow box. Ljudmila, Ljubjana, March 2019

projector to the room. The last one was in pace with our aesthetic decision to make an enclosure for the projector that will contain and co-note the inner space dimension of the installation. However, at an early stage of the design, we tested open formed projectors illustrated in Figure 5.

At the same time at Ljudmila laboratory in Ljubljana the other co-author was speculating and assessing the ideas on site in order to find issues and navigate the design decisions. Beyond spatial specificities, there were also time limitations affecting the material availability and the fabrication methods available there. At the end, the *shadow boxes* were made out of laser-cut 2mm MDF wood panels, which could be easily assembled and disassembled, in order to form a small and lightweight flat package. The electronics, described in the following section, were also placed inside the projectors. The final implementation of the *shadow boxes* can be seen in Figure 6.

3.2 Sound Design and Generative Process

The sound is generated principally by two basic sound synthesis modules found in most sound synthesis systems: a white noise generator and a sinusoidal oscillator. Each speaker diffuses either the sound of one oscillator tuned at a certain frequency or white noise modulated by a short envelope. These waveforms are triggered directly by the Cellular Automaton: each generation is scanned from left to right and if a cell has a value of one, it triggers a sonic event by sending a control signal to the sound synthesis modules.

The information regarding the state of each cell is given by a text file as described previously. A custom built Max For Live device reads the information and starts the sonification within Ableton Live Digital Audio Workstation. Each iteration of the automaton generate its own sonic sequence which thereafter is recorded as a separate sound file. Those files are then read by a program written in Pure Data programming language, where the simple interaction part with the gallery visitors and the projectors light control is developed.

An alternative solution would be to implement the automaton directly in Pure Data instead of using three separate programming environments for the sonic output. However since the same algorithm generated the files for the fabrication of the sieves, Processing language could not be avoided easily so the authors decided to use one language for the dynamics of the automaton (Processing), one language for the sonification process (Max For Live and Ableton) and another one for the interaction (Pure Data).

Every single projector-speaker pair produces its own unique soundscape and *shadow painting*. Each generation of the automaton is looped until the lighting conditions in front of the projector change. This may occur when visitors of the gallery walk in front of the speaker and the light is reflected and absorbed on them or in the presence of a flash light coming from a camera or any other light source. In that case, the sonification process moves randomly to a different generation of the automaton, bounded by the frame of the perforated panel - sieve of the projector (each of the sieves depicts a limited number of generations and does not necessarily cover the full length of the array). Therefore, only the projected iterations of the automaton are sonified. At the same time, the light of the projector turns on and off giving a more dramatic effect on the interaction.

In order to have the flexibility to position the projectors-speakers freely in the exhibition space and create a scalable installation, an embedded computing platform was used for each projector that could play the audio files, control the light and run the interaction algorithm. The Bela board open-source platform was used for that reason running the Pure Data program [15]. This board has the capability of sensor processing, direct audio output and of controlling other output devices such us the LED lights used for the *shadow paintings*.

3.3 Light and Electronics

The light that gets diffracted by the sieves is emitted by a powerful light emitting diode (LED). The *Cree X-Lamp* was selected for its performance and its small size. An LED driver was used to power the LED light and to adjust the voltage output. The light was attached to a heatsink which was used to prevent the device overheating. All the electronics including the Light Depended Resistor (LDR) used to sense the light variations in front of the projector, was mounted on small circuit board, a custom made shield that could be easily connected on the top of the Bela board.

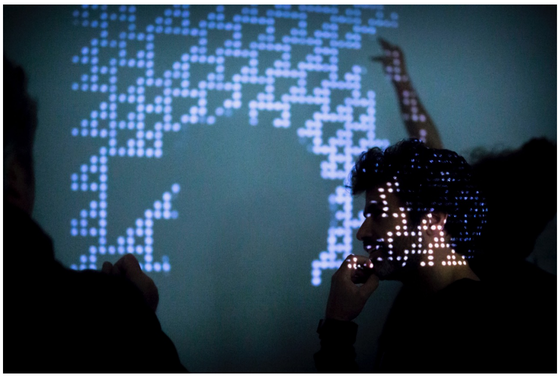

Figure 7. *01110110* exhibition in Copenhagen on May 2019

Both the board and and the shield was placed inside the projector. As it can be seen from Figure 6, the electronic parts were not visible, maintaining the minimalism of the projectors' design.

4. EXHIBITION AND DISCUSSION

The installation was first exhibited in the Ljudmila art-science laboratory in Ljubljana on March 2019. Four blank canvases were hanged on the black walls of the gallery space and in front of them the project-speaker pairs were installed. Soon after, a second exhibition took place in Copenhagen at Aalborg University. Instead of using white canvases this time, the shadows were cast directly to the white walls of the exhibition room. In both cases the gallery space was as dark and quiet as possible in order for the shadow patterns to be visible and the soundscape to be audible. The exhibition visitors were walking slowly around the gallery and were standing in front of the *shadow paintings* and inside the soundscapes. Figure 7 shows how the generated patterns are projected on the silhouette of the exhibition visitors.

From the two exhibitions it became evident to the authors that the attention of the visitors was captured by the clarity of the the "sonification-visualisation" process due the simplicity of the work and projectors - *shadow boxes*. Few visitors were trying to match the audible rhythmic patterns with the shadows, while other were trying to understand the technicalities of the work. We could argue that most of them were immersed in the contemplative experience offered by the gentle light of the space and the tranquil soundscape located around several spots in the gallery.

The challenge of this work is to conceptualise space and sound as the environment where the Rule 110 algorithm will reveal itself directly in the interplay of visitors' sensual experience. By expressing the same snapshot of the algorithm both as soundscape and *shadowscape* in a synchronous manner, a multi-sensory environment emerges were at its core lies the Rule 110 algorithm. What is in consideration here is the visitor to be attracted and experience the essence of the algorithm, and not merely to mathematically understand it or approach it only as tool for artistic outcome. But what can this essence can? How can we couple the scientific with the artistic and keep the underlying characteristics of both? In this specific case the simplicity and the minimalistic process of such a powerful algorithm was considered as its essence and was reflected throughout the installation and its experience.

Though light acts as a physical coupling medium between the inner space of the projector and the outer space of the projection, sound is generated and exists only in the space of the projection. A future development that will enhance the overall experience of the installation will be to find a way to make sound also act as a physical coupling medium.

The interaction did not work all the time due to the sensitivity of the sensors but that is something that can be improved by tuning more carefully the circuitry and the interaction algorithm. An adaptive threshold to detect brightness according to the ambient light condition would probably be an improvement in that direction.

We should point once again that the focus of the artists were not on the technological novelty but more towards the creation of a multisensory and meditative micro-environment that celebrates the computational elegance of the algorithm. The automaton *Rule 110* is the simplest known Turing complete system and *011011100* has the aspiration to offer a direct immersive experience of this remarkable property and reflects on the duality of complexity/simplicity.

Acknowledgments

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