

Temporal Transformations and Spatial Explorations in Sound-Light Art

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ABSTRACT

*This paper presents two art installations from an aesthetic, technical and art-science point of view. Both artistic works, *Waiting for Response* (2017) and *1/x* (2020) employ mathematical rhythmic transformations for the generation of sonic and light events in time. Two algorithmic processes, one graphical and one algebraic, are used for the creation of the pieces presented. The two pieces are in “dialogue” with the materiality of the exhibition space, expressed acoustically in *Waiting for Response* and optically in *1/x*. Time and time’s reflection in space are the basic concepts these works have been developed upon. The approach discussed in this paper, originates from a broader interest of the authors to express time articulation in space using simple formal devices in their artistic research.*

1. INTRODUCTION

This paper presents the mathematical concepts and the aesthetic foundation of two art installations created by the authors in the last four years. *Waiting for Response* is the participation of the authors in a site-specific walk-through light and sound installation, that focuses on interacting directly with the acoustics of the architectural void in the Jewish Museum Berlin. It is part of a larger artistic project created by the artist Mischa Kuball for the museum [1]. *1/x* is primarily a minimalistic light installation based on the singularity character of the $1/x$ function. The key characteristic that ties those works together is their time organisation approach and the way they activate space as an artistic parameter. Algorithmic rhythm processing and the instrumental use of space, for both the sound and light components of the two installations, are the common features of those works. Fig. 1 and 2 present the two installations¹.

Numerous compositions and sound art installations have been conceived for enclosed spaces with an emphasis on processes focusing on space rather than in time. Alvin Lucier has explored the resonances of spaces in several pieces, with the most celebrated one being probably the *I am sitting in a room* [2]. Max Neuhaus approached sound and place as an expanded instrument in most of his works [3]. Sound installations, bring naturally together sound and

¹ <https://onecontinuouslab.net/projects>

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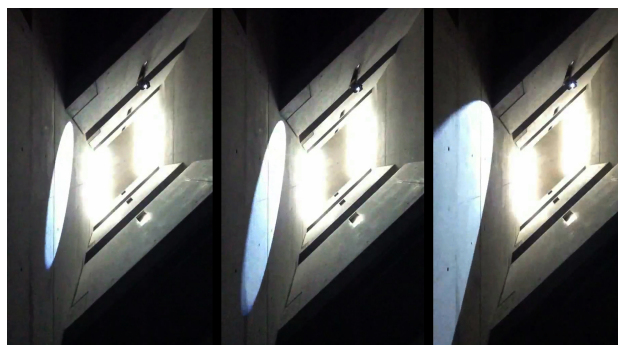


Figure 1. The architectural void in the Jewish Museum Berlin where *Waiting for Response* was exhibited as part of Mischa Kuball installation that took place in 2017

space, enriching the artists’ compositional vocabulary in that direction. Room acoustics is used as a compositional device: echoes, reverberation, resonances, created by the size and shape of the room and by the nature and texture of materials, become an artistic medium.

Similarly, formalised time articulation and algorithmic rhythm generation has a long history in electroacoustic and experimental music traditions. Many of the early pioneers in the field such as Lejaren Hiller and Leonard Isaacson, Iannis Xenakis and G.M. Koenig, have explored in their own personal way formalised rhythm. The electronic medium, both analogue and digital, has opened up enormous possibilities for accurate rhythmic design based on formal strategies [4].

Especially the advent of programmable sequencers, both analogue (generating control voltages) and digital (generating MIDI messages), offered a wide palette for rhythm experimentation. The generated sequences which controlled or triggered music parameters in real time, could be looped at different lengths and could be driven by various clocks. Moreover, the clocks could employ advanced clocking schemes (such as from Fibonacci series or prime numbers), incorporate clock processing modules (dividers, delays and other control logic routines) and include stochastic functions [5]. All these functionalities have been exploited extensively after the aforementioned first generation of pioneers, but their use was more rare in the form of sound installations.

This paper aims to offer an insight in our artistic research on time and space through the development of two art installations; The emphasis is more on the artistic approach and implementation of the artistic pieces, rather than in the technical analysis of the developed algorithms or on the engineering aspects of the projects in general. A brief present-



Figure 2. *1/x* as exhibited in Ljubljana in 2020 (above) and a discrete light impulse at the lower image (below).

tation of the two developed mathematical procedures will be presented in the second section of the paper. The third section of the paper is devoted to the spatial dimensions of the installations in relation to sonic and light contexts respectively. The artistic considerations behind how and why those mathematical devices were employed, along with a discussion concerning the exhibitions, will be exposed in the final section of this paper.

2. TIME AND RHYTHMIC TRANSFORMATIONS

The two installations explore mathematical ideas primarily through the use of a graphical procedure and algebraic functions. Those mathematical devices operate as processes for the rhythmic generation of the sonic and light events. In *Waiting for Response*, the procedure triggers exclusively the sonic events in a generative way. Symmetrically, in *1/x*, the function activates the flashing light events simultaneously with a sonic part of minor importance.

Sequencing technology, as we have seen in the first section of the paper, is more oriented on synthesis and programming of rhythms and less on the processing of existing rhythmic sequences. Contemporary computer music languages permit numerous possibilities on rhythmic processing. Unfortunately, often these efforts are part of the composers personal artistic dialect and have not being adequately documented in the academic literature. For instance, Robert Rowe presents very few modules on rhythmic processing in Max such the *accelerator* patch [6]. Similarly, Todd Winker's book on interactive composition covers very briefly timing processes [7].

In electronic music, it is not always easy to distinguish synthesis from processing procedures. In the audio signal domain this can become clear in sound synthesis. A straightforward example is subtractive synthesis which is primarily based on sound processing. Equally in the symbolic domain, the algorithmic generation of rhythm may

involve processing procedures.

Our generative method gravitates towards a purely processing approach. It is based on the undulation or extreme alteration of the metric time grid, which becomes perceptually absent. In both pieces the generated rhythms converge to the micro timescale. Therefore, perceptually the sonic output resembles the aesthetic of microsound compositions in a non-metrical manner as found in the works of Curtis Roads and Horacio Vaggione [8]. The main idea that lies behind the processes used in these projects is time based transformations of rhythmical events. That is, a mapping of time into itself, that changes dynamically. In *Waiting for Response* the transformations are made by graphical means, while on *1/x*, they are algebraic.

The concept of the graphical transformations can be seen in figure 3, where the system develops an output rhythmic sequence by processing the time locations of an input rhythmic sequence according to two curves defined graphically. The time variant transfer function that performs the desired transformation continuously interpolates between the two *target curves*. Those two *target curves* can have as many breakpoints as necessary. The whole system gradually (in time) morphs between two graphs, thus creating a metamorphose of associated rhythms. In this way we can achieve different types of gradual rhythm time transformations, including time reversal of all or part of the input events. It is obvious that this time operation prohibits the real time nature of the process since we are potentially dealing with anti-causal systems. In order to solve this problem we introduce a looping period for the input rhythmic pattern, and the transformations are calculated with a delay of one looping period. It is not the aim of this paper to expand on the graphical transformations algorithm. Another paper is currently under review which focuses exclusively on the technological dimension of the process which has been developed independently of the piece.

In *Waiting for Response* eight different impulse trains are rhythmically altered by the aforementioned time-warping graphical transformation process. After several experiments we decided to use as *target curves* two simple straight lines in order to achieve a simple rhythm time "mirroring". The two *target curves* can be seen at figure 4.

Similarly, in *1/x* where algebraic transformations used, the time reversal is prescribed by the very nature of the reciprocal function in study $f(x)=1/x$. Four impulse trains are processed independently this time, by four reciprocal functions. The output controls the DMX lights of the installation and create multiple decelerations of the rhythmic events. Since in this case we know beforehand the time-warping function, we can easily generate in real-time the output rhythm, considering that we decided to use as rhythmic input uniform impulse trains. That aesthetic decision took place in order to easier reveal to the visitor the nature of the reciprocal function. The developed algorithm is based on an iterative process that calculates all the time events by starting from the last one chronologically and moving towards the first one.

3. SPACE AND SONIC-LIGHT IMPULSES

The sonic material used for *Waiting for Response*, is a collection of designed impulses which were synthesised in the

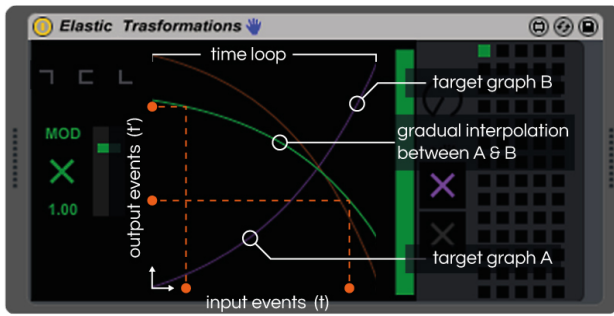


Figure 3. Graphical Rhythm Transformations concept

time domain directly by filling a 64 sample buffer-array. The array was filled empirically according to the sonic outcome in very large halls.

Such impulses are used as excitation signals and generate the acoustic response of the architectural spaces. Enclosed spaces behave acoustically as Linear - Time - Invariant LTI filters. Such filters can be represented mathematically in the time domain by their response to impulse signals. Therefore, space can be performed and articulated musically in the artistic process but with fewer elements of control. Impulses, one of the simplest signals for exciting enclosed spaces and make them reverberate, are used widely as part of the measurement methodology in room acoustics. Bursting balloons and pistols create adequate bursts of energy to “activate” spaces. We decided to interact with the space in both installations in a similar fashion, as we will see below, in the most direct and neutral way.

In $1/x$, a complementary concept of impulses of light, similarly to the impulses of sound mentioned before, determines the “optical material” used for the composition of the work.

From a technical point of view, four white DMX lights are controlled via MIDI messages. A DMX/USB interface is linked to a DMX control software, which in turn is communicating internally via MIDI to Max programming language. MIDI events, generated by the time-warping algorithms presented in the previous chapter, are responsible for the light behaviour of the installation.

$1/x$ was also exhibited with a sonic element which played a secondary role in the overall experience. In order to create the illusion that the sound was produced by the electrical circuit of the lights, speakers were collocated with the lights, in a way that were not visible to the visitor. Similarly to *Waiting for Response*, a simple impulse was used, in complete synchronisation with the optical output. The unit sample function also called the Kronecker delta was employed and filtered through statically tuned band pass filters. Each speaker was diffusing sonic rhythmic patterns processed and coloured by a different filter setup. An important aspect of the installation, which draws from our previous work, is that it was designed to be scalable according to the number of light / speaker pairs [9].

It is interesting to mention the similarity between geometrical acoustics and geometrical optics as mathematical models to describe sound and light propagation. Geometrical acoustics, offer a simple perceptual model to analyse the acoustic behaviour of enclosed spaces. Numerical simulation of such models may give an idealised acoustic

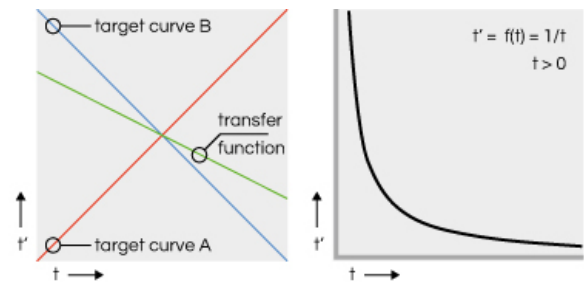


Figure 4. The curves used for *Waiting for Response* at the left side, and visualising the reciprocal function of $1/x$ at the right side.

behaviour of the room. Geometrical optics offer an analogous method in studying light propagation. These similarities have an impact on the evolution of our work which is in dialogue with scientific concepts and often assimilates and embraces the precision of scientific thinking.

In that sense we could argue that the two pieces are complementary: we treat sound and light in a reciprocal way. Since the rhythmical transformation mentioned in the second section applies to both domains, they become instrumental for the development of our approach.

4. EXHIBITIONS AND DISCUSSION

Waiting for Response was part of the light and sound installation *res-o-nant* created by Mischa Kuball for the Jewish Museum Berlin in 2017². The installation incorporated two of the five vertical voids that perforate the Museum’s Libeskind building. On each of the two 24-high meter voids, there was a rotated light projector. A speaker was placed on each projector, that rotated along with the projector and looped a series of 60-second-long sound clips - so called Skits - which were composed specially for the piece by more than 50 musicians.

Our work, consisted essentially of a sound clip - Skit - which focused on interacting directly with the acoustics of the architectural voids, by revealing them and being revealed by them. We eliminated any spectromorphological characteristics to the minimum, in order the walls of the voids not only to shape the architectural spaces but to equally shape the perceived sonic context as well. For this reason, it was composed exclusively by the 8 aforementioned sound impulses. Every impulse is articulated and distributed in time by the graphic transformations described in section 2.

For the version developed for the Jewish Museum, the desired duration of the periodicity of the gradual “mirroring” interpolation for each impulse train is unique. The durations introduced don’t share a least common multiple. This produces mathematically controlled time-shifting relations between the 8 different impulse trains, resulting in an overall metamorphosis of periodicities. This metamorphosis of periodicities, together with the unique characteristic of the sound impulses, reveal the structure of space (voids) by its reflections and reverberation, and with the periodicity of the slowly rotating speaker in space, creates a unique spectrum of interleaved actions, an organism, so to speak, that is experienced by the visitor as an emergent

² <http://www.mischakuball.com/works.html>

unique speciality, characteristic of each spatial void. The asynchronous vertical alignment of the chronically altered impulse trains makes them appear on the mesoscale time-frame as chords of rhythms that come and go like waves. Extreme expansions and contractions of time are present without repetitions.

Despite the fact that the piece was composed to be part of the larger installation and had to be 60s long, it was not designed to be time-bounded. The generative process was set up in a way that it could unfold over time without repeating itself in any perceptible way [10]. The emphasis of the piece was not on its macro-scale, since it does not have a fixed form, but rather on the emerging relations of the generative soundscape and the space. The architectural space had very strong visual presence and dramatic acoustical behaviour.

I/x was premiered in Osmo/za Gallery Space in Ljubljana in 2020, but the piece was initially conceived in the same period with *Waiting for Response* in 2017. As a consequence the authors couldn't be there to setup the installation since it was during the Covid-19 pandemic. However, they were in contact with the curators, in order to oversee remotely the installation process. Fortunately the first author of the paper was familiar with the space from a previous project that took place in the same space.

The scope of *I/x* was to achieve a spatial perceptual exposition of the inherent characteristics of the reciprocal function articulated in time. The approach is very similar with *Waiting for Response* but the focus here was in the direction of time articulation through the medium of light and an “ever-lasting” generative piece. In this piece, we introduce rhythmically controlled flashing lights that instantly illuminate the installation visitors and the space: a fully darkened room with neutral white walls. The lighting positions and angles are selected in such a way to shed light on the visitors of the exhibition and cast multiple shadows on the walls in an alternating manner. Moreover, an echo of bright light in darkness is experienced by each visitor because of the afterimage phenomenon, which appears when the eye is exposed to bursts of bright light. An afterimage is an image that continues to appear in one's vision after the exposure to the original image has ended. This physiological phenomenon was so intense that we had to appropriately diffuse the light source in order that the visitors would not visualise the structural array of the LED light source. Moreover, a warning sign for people prone to epileptic seizures or other photo sensitivities was placed at the entrance of the installation room.

In retrospect, other more complicated rhythmic sequences could have been used in the creation of *I/x*. These sequences would create a more complex rhythmic discourse which once again can be found in the particle-based works of Curtis Roads. The authors preferred to stay closer to a minimalistic aesthetic; the intention was to make the process transparent and perceptible. Therefore, the piece echoes Steve Reich's concepts of music as a gradual process [11].

In *I/x*, the “dialogue” between the visitors silhouettes, the flashing lights and the shadows on the white walls creates an intense and often uncomfortable environment. The installation is completed with the actual presence of the visitors in situ and the way their bodies interfere with the lights. In *Waiting for Response*, in a symmetrical manner,

the “dialogue” that transpires is between the rapid sound repetitions, their reflection on the walls of the enclosed space, and the visitors navigation in that dense environment. The visitors are immersed in a dynamic optical rhythmic field in the first case and in a dynamic sonic rhythmic field in the second case. Moreover, in *I/x* the perceived sensual space seems to shrink towards the visitor, while in *Waiting for Response* seems to expand towards the borders of the space. As the *I/x* installation is designed to be scalable, the authors speculate that it would have a great experiential effect if were to be exhibited in a large and clear white walled dark space.

Acknowledgments

I/x has been created with the support of the European Art - Science - Technology Network for Digital Creativity (EASTN-DC), a network co-funded by the Creative Europe program of the European Union³. We would like to thank Gregor Lersch (head of exhibitions and curator at the Jewish Museum Berlin) for inviting us to participate with our piece *Waiting for Response* in the *res-o-nant* exhibition.

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