Elastic Transformations: a graphical rhythm transformation process

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ABSTRACT

This paper presents an algorithm and software that implements it for the gradual transformation of musical rhythms through graphical means, as well as the artistic installation Waiting for Response where it was first used. The transformation is based on the manipulation of the timeline of the input rhythm, which is treated as geometric form in constant transformation. The aim of the algorithm is to explore rhythmic relations in an evolutionary manner by generating transformations based on graphical and geometric concepts and independently of the musical character of the initial rhythmical pattern. It provides, relates and generates a genealogy of rhythms based on an initial rhythm, which may be perceptually unrelated. Waiting for Response is an artistic installation that employs the above transformation in the generation of sonic events to enter in an acoustical "dialogue" with the materiality of the exhibition space.

1. INTRODUCTION

Musical rhythm may be understood as a sequence of ordered events in time. While time is commonly represented as a straight line, repetitive rhythms have often been represented as polygons inscribed in circles, where time runs in a circular fashion folding onto itself and starting over with every repetition [1]. Let's now imagine a group of sonic events placed as fixed points on an elastic wire, which lies free on a cylindrical surface, where it continuously flexes, bends, folds and slides [1]. Let's further imagine that we walk on the bottom edge of that cylindrical surface, while vertically holding a stick that triggers those events when it hits them. As we go in circles, in a steady pace, while holding the triggering stick, as shown in Fig. 1, we realize that when the elastic wire stays steady the group of sonic events becomes a distinct pattern, but when the elastic wire starts to transform itself that pattern becomes gradually alternated. Moreover, depending on the deformation of the elastic wire, the resulting sequence of sonic events may gradually become perceptually unrelated to the initial perceived pattern, it can even reverse the time order of the initial pattern's events. Can we consider all the different appearances of the initial pattern as topologically equal in a musical sense? Can we consider them as one sonic pattern that is being transformed over time?

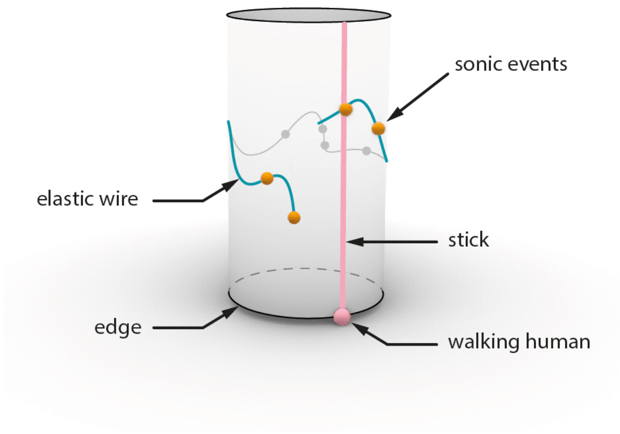

Figure 1. The geometric metaphor of Elastic Transformations.

In this paper, we will present a graphical rhythm transformation process developed as a *Max for live* device that puts in a sonic creative perspective the above geometric metaphor. The above metaphor can be considered analogous to gradual transformations and folds of the metric musical grid, which mainly is a mapping of time into itself. The core algorithm of "elastic transformations" generates rhythmic transformations by gradually manipulating the timeline on which the rhythmic events lie, effectively warping and folding time and distorting the durations between them. Moreover, we suggest a bridge between the parametric design of geometric forms on the one hand [2], and the generation of musical rhythms through the geometric representation of their timeline and events on the other [3], [4]. Our interest lies in utilising processes inspired by geometric principles in a musical/sonic context as a creative performance tool and methodology.

In addition, we will present the art installation *Waiting for Response*, which is the first implementation of that method [5] and places those elastic transformations in a creative perspective and dialogue with the materiality of an existing physical space. Furthermore, we will discuss future research and development based on the above graphical rhythm transformation process.

2. BACKGROUND

The relation between mathematical and musical structures has been long established. From the geometric properties of pitch and tonality in the days of Pythagoras or the

[1] As a cylindrical surface we consider an open right cylinder.

mathematically precise rhythms of Indian Classical Music (Tala), to the exploration of formalised rhythm from pioneer composers such as Lejaren Hiller and Leonard Isaacson, Iannis Xenakis, Milton Babbitt and G.M. Koening, mathematics play a central role in music practice around the world [6, 7]. The advent of programmable sequencers, both analogue and digital, expanded the possibilities for rhythm experimentation. Especially, the digital medium, through computer music languages such like *Max*, *Pure Data*, *Chuck* and *Super Collider*, has introduced immense possibilities for accurate rhythmic design and processing based on formal, mathematical and algorithmic strategies. On the other hand, commercial sequencers and digital audio workstations are focusing more on the generation and programming of rhythmic sequences and less on their processing. Sadly, very often efforts on the latter direction are part of the composers personal artistic dialect and have not being adequately documented or broadly published. In contrast to other type of symbolic processing or automatic rhythmic generation algorithms, only few textbooks in the computer music literature present rhythmic and timing processing functions.

Two timeshaping parametric methods, which implement a graphical interface are the *timewarp* external developed by John MacCallum and Andrew Schmeder [4], and the *cage.timewarp* object developed by Andrea Agostini and his colleagues [3]. The former aids in construction and management of polyphonic tempo maps, and the latter focuses on real-time computer aided composition.

Recently, George Sioros and his colleagues have developed a series of algorithms and software for the real-time manipulation of syncopation in a given pattern [8]. While these rhythmic transformations are based on a deterministic model of musical meter [9] rhythmic transformations may also be approached as a stochastic process [10].

In the seminal work of Godfried Toussaint [1], rhythmic structures are understood as geometric shapes and their musical properties reflect their geometric features. His models have found many applications in the generation of musical rhythms [11, 12]. However, beyond these applications, the geometric representation and manipulation of musical rhythms open up endless possibilities for the development of rhythmic transformations and processing that have not yet been fully explored. For instance, the parametric modeling of geometrical bodies gives rise to almost unlimited and continuous variations of forms by changing the values of a limited set of parameters, which creates a class and a genealogy of forms that can go even beyond topological similarities [2].

3. TECHNICAL DESCRIPTION

The programming environment that we used to put the geometric metaphor of Fig. 1 in a creative and practical musical perspective is Cycling '74's *Max*, and in particular its *Max for live* integration in the *Ableton Live* DAW. To create a simpler user interface that is closer to that of conventional music plugins we sought a convenient analogue of the above mentioned cylindrical surface. Having in mind that a cylindrical surface can be described topologically as a square in which top and bottom edges are given parallel orientations and the left and right edges are joined to place the arrow heads and tails into coincidence [13], we can unfold the cylindrical surface to a rectangular surface, and apply to it two perpendicular positive axes of time, *t* and *t ´*. Since, the initial group of sonic events is fixed on the elastic wire, our main consideration is how the latter is being mapped in time. A similar mapping can be achieved if we place and lay the elastic wire on the *t* axis, and introduce and utilize a new curve as the transfer function from *t* to *t ´*. In order to simulate the transformations that the elastic wire takes on the cylindrical surface through time, the introduced transfer function will have to move, bend, flex and slide in a similar manner. Now let's consider that the elastic wire on the cylindrical surface is at its "rest" position when it is parallel to the bottom edge of the cylinder. This means that when the length of the elastic wire spans the entire duration of the time domain of the *t* axis, then the "rest" position of our analogue will be the the diagonal line (0, 0) to (T, T').

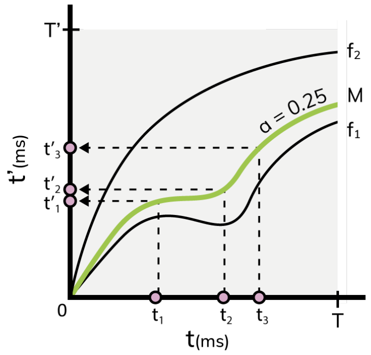

Figure 2. The gradual rhythm transformations morphing concept.

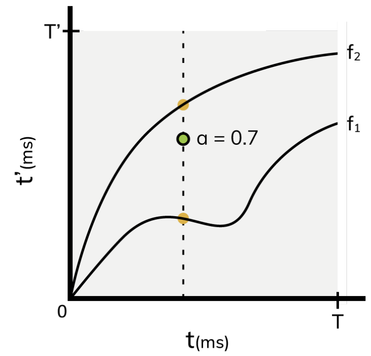

Figure 3. Weighted average interpolation between f1 and f2, with a weight value a=0.7.

At the core of the elastic transformations lies the transfer function *M* that continuously morphs between two target functions f_1 and f_2 (Fig. 2). The resulting function *M* is the weighted average:

$$M = a \times f_2 + (1 - a) \times f_1 \tag{1}$$

where *a* stands for the weight value (Fig. 3).

By drawing the two target functions as free form curves between the axis *t* to *t ´*, the above method results in a graphical process for producing gradual rhythm transformations. Those transformations can even result in time reversal of the input events that are placed on the *t* axis. In or-

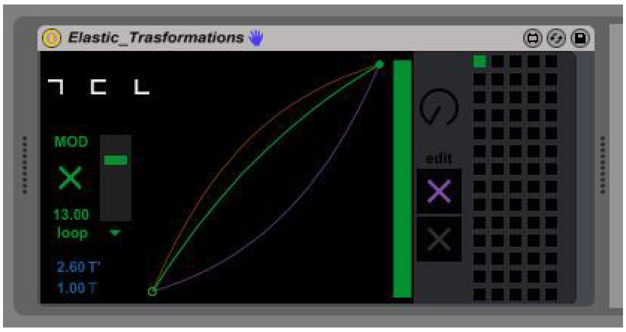

Figure 4. The Elastic Transformations Max for live device.

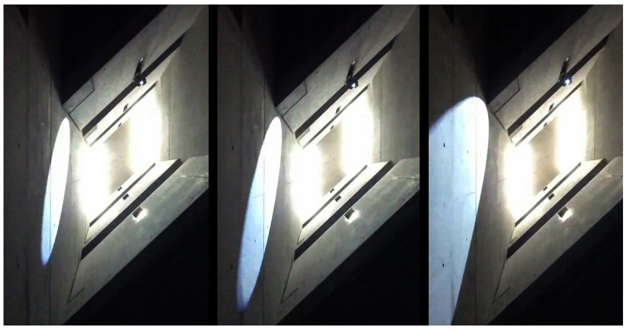

Figure 5. The architectural void in the Jewish Museum Berlin where *Waiting for Response* was exhibited as part of Mischa Kuball installation that took place in 2017.

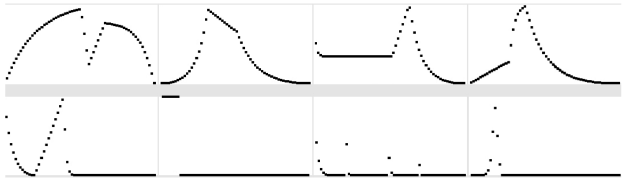

Figure 6. The eight impulses constituting the sonic material used in *Waiting for Response*.

der to overcome this time reversal in a live performance situation, we utilized the following approach. First the MIDI events are "recorded" in real-time over a time period of T and are stored in the device's memory as the input pattern. Then, the transformation of the entire recorded input pattern takes place over a time period of $T\,'$. This process introduces a delay between the MIDI input and the generated output. The function M maps the initial sonic event's time position t that lie within the duration T of the input loop, to a time position $t\,'$ within the output loop duration $T\,'$. The morphing weight a can be manually controlled and modulated directly from the graphical user interface (GUI) of the device or it can automatically oscillate between 0.0 and 1.0 at a rate set by the user. T and $T\,'$ can be also specified by the user. The functions f_1 and f_2 are inserted by the user as curves through the GUI, and can be stored and recalled as presets. The transformed rhythmic pattern is updated either at some regular interval (e.g. at the beginning of every loop or bar) or continuously, incorporating any changes in the values of parameters as they occur (e.g. the value of the weight a). Fig. 4 shows the *Max for live* device and how it appears inside *Ableton Live*. Sound examples demonstrating the graphical rhythm transformation process can be found online [2], where, also, the *Max for live* device "Elastic Transformations" can be freely downloaded.

4. WAITING FOR RESPONSE

Waiting for Response [3] is part of the light and sound installation *res·o·nant* created by Mischa Kuball for the Jewish Museum Berlin in 2017 [4]. The installation incorporates two of the five vertical voids that perforate the Museum's Libeskind building. On each of the two 24-high meter voids, there is a speaker attached to a rotated light projector. The speaker plays back in loop a series of 60-second-long sound clips - so called Skits - which were composed specially for the piece by more than 50 musicians. In Fig. 5, three still frames show the view of Mischa Kuball's installation where *Waiting for Response* took place.

Waiting for Response consists of a sound clip - Skit - that aims at interacting directly with the acoustics of the architectural void, revealing it and being revealed by it. The sonic material used for it, is a collection of 8 designed impulses, as shown in Fig. 6, which were synthesised directly in the time domain by filling a 64 sample buffer-array. Such impulses are used as excitation signals and generate the acoustic response of architectural spaces, thus revealing the geometry and materiality of those spaces. Therefore, space can be "performed" and articulated musically in the artistic process.

Furthermore, such short impulses act as a metaphor for the spatial void. The idea that lies behind the aforementioned impulses is to act as a trigger/sound stimuli that is completely a-spatial, that is, clean of any possible spatial characteristic. Anyone who has ever shouted in an an-echoic chamber realises how weak and different the uttered voice is. The an-echoic chamber tries to assemble the a-spatial. In this sense, the aforementioned 8 impulses are waiting to be revealed through the specific space, and in the same time the space is waiting to be revealed by the sonic impulses. Both space and sound are "waiting for response".

Our aim is to interact with the space in a most direct and neutral way. To this end, eight different impulse trains were produced from the above eight impulses, which in turn they were rhythmically processed by the elastic gradual transformations algorithm. In this case the graphical rhythm transformations happen by gradually morphing between two functions f_1 (t)= c·t and f_2 (t)=T´- c·t, to achieve a simple linear time-reversal of the input events. As the initial rhythmic pattern is an isochronous pulse, the rhythmic result at the two extremes (a=0 or a=1, eq. 1) is the same. However, interesting patterns and relations emerge as the morphing between the functions continuously takes place.

In *Waiting for Response* the introduced rates on modulating the morphing weighted averages don't share a least common multiple between the different impulse trains. This produces mathematically controlled phase-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

[2] www.oneContinuousLab.net/projects/#ElasticTransformations
[3] https://onecontinuouslab.net/projects/#WaitingForResponse
[4] http://www.mischakuball.com/works.html

sound impulses, reveals the structure of space (voids) by its reflections and reverberation. The asynchronous vertical alignment of the continuously 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 perceived repetitions.

Despite the fact that the piece was composed to be part of the larger installation and had to be 60 second long, it is not designed to be bounded in time. The generative process was set up in a way that it could unfold over time without repeating itself in any perceptible way [14]. 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.

5. DISCUSSION - FUTURE WORK

So far, the elastic transformations algorithm, has shown us that is very easy to experience a multitude of rhythmical patterns with a set of few initial events and parameters. Tweaking and adjusting those parameters becomes the medium for exploring a morphing fluidity between rhythms that are not usually related. The parametric manipulation of the timeline as a geometric form is the fundamental link between all the generated rhythmic variations which range from subtle to extreme. Simple graphical transformations can conceptualize and organize sound events from the micro- to the meso- and to the macro- time scale. It is a methodology that focuses more on the transformation of the rhythm rather than on the rhythm itself, and seeks unexpected relations that may emerge through rhythm's gradual manipulation.

The above process and the installation, is part of a larger exploration of the artists-authors to articulate time and space in their work, which goes even beyond the media of sound to that of light, movement or pure pressure [5] . The crossover between architecture - music composition - lighting design and the duality between material and immaterial media drive their creative practice and research endeavours.

The algorithm presented here consist only the first step towards a broader research question that tries to link ideas and processes from computational design with the field of sound and music computing. Our aim is to associate concepts from analytic geometry and 3D modelling processes with music elements such as rhythm or the audio features of the sound objects. In the case of rhythm processing the next step is to approach timespace as 3D form, moving to more complex geometries and to further integrate principles and methods from parametric design.

Acknowledgments

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