Composing musical geometry with sonic objects

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This article relates an experiment linking two types of forms: geometric forms generated from algorithms by mathematical functions and sonic forms generated from algorithms and linked to the first. In order to formalize a graphical and musical object called "sonic object", were used the following tools: the environment of a graphic program, the C# language and the Midi-dot-Net musical library. Diverse equations are used to generate the geometric shapes which generate periodical, cyclical and circular movements. Other equations used in the experiment are formulas adapted from the Edward Lorenz's Strange Attractor. Current research into the problem of the generation of patterns of movement, such as that of Jules Moloney, and research which deals with algorithms which generate shapes, such as that of Robert Krawczyk, have been taken as references and parameters for comparison for this work.

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INTRODUCTION

The generation of geometric shapes using mathematical functions in algorithmic processes has opened up a world of shape possibilities which seem to have no end. On executing the algorithms the computer produces a world full of spatial configurations which express the variables, parameters and formulas used. The images of trajectories, twists, loops, curves, inflections, spirals and spatial groupings which emerge from the generating process succeed in reminding one that beauty, order and symmetry are intimately related. It is impossible not to be moved when observing the images of the Shell, produced by Robert Krawczyk from the equations derived from the Lorenz Attractors (Sherbini and Krawczyk 2004).

The current work relates an experiment linking two types of forms: geometric forms generated from algorithms by mathematical functions and sonic forms generated from algorithms and linked to the first. Diverse equations are used to generate the geometric shapes which generate periodical, cyclical and circular movements. Other equations used in the experiment are formulas adapted from the Strange Attractors by Edward Lorenz (Krawczyk 2003). To these graphic organizations, which belong to the spatial domain the stimulus of which reaches us immediately by means of the eyes, were associated the sonic events, which have audition as the particular channel of perception, temporal succession as the development domain and movement as the factor of composition. The complete perception of the compositions generated combines both channels of perception. In this way the intention is to explore the relationship between geometry and music. The work intends to contribute to the field of contemporary architectonic projects with compositional elements of which the basis of expression is movement, interac-
tion and the confluence of the senses. Classic examples of this line of investigation are interactive mobile surfaces. One project on these surfaces which is currently at an advanced stage and widely known is the interactive panel project called Aegis Hyposurface (Burry and Burry 2010). Mark Goulthorpe and the dECOi design practice created this installation for the city of Birmingham's hippodrome. Goulthorpe characterized Aegis as an 'alloplastic' spatial solution, in other words, subject to reciprocal reactive transformations between the environment and man, in contrast to solutions which create autoplastic spaces (3). In the same line, the Dutch research group Hyperbody Research Group has been working on the materialization of interactive walls in which strategically placed sensors connected to actuating mechanisms produce movements which give shape to the surfaces, providing architecture with new dynamic elements to add to the formal repertoire. Current research into the problem of the generation of patterns of movement, such as that of Jules Moloney, and research which deals with algorithms which generate shapes, such as that of Robert Krawczyk, have been taken as references and parameters for comparison for this work.

THE FIRST TECHNIQUE. THE MUSICAL BOX
In previous years, work was carried out on the idea of translating numerical spatial coordinates into sound events defined as musical notes. To this end a mechanism was programmed which translated spatial coordinates of geometric elements into musical sounds. The mechanism, which was programmed in AutoLISP within the graphic environment AutoCAD, formed an interface with the Compo-Music musical functions library. Using this connection, the Musical Box was conceived as a geometric-musical translation process. The Musical Box technique involves the following steps:

1. Creation of a 3D model in AutoCAD
2. Graduation of the Cartesian axes with musical attributes (heights, durations and dynamics).
3. Capture and translation of the numerical coordinates of the model to musical coordinates with the Compo-Music syntax. For example (:C4 :8th :dyn 20) represented the note Middle C with the duration of an eighth and a dynamic of intensity Piano.
4. Creation of a LISP file with the sequence of translated coordinates
5. Reading of the LISP file in the interface of the Compo-Music to generate the MIDI file or the score.

Following the formalization of this space-sound translation mechanism, various sonic results were obtained which were called "pseudo-music" or organized sounds. In spite of the fact that musical theorists and morphologists consider music to be a materialized shape for sounds organized according to specific rules, two reasons led us to add the prefix "pseudo" to express the sonic results obtained. In the first place, the creation of the work began from a starting point of minimum knowledge in terms of mastery of the techniques involved in the reading of music, its interpretation and composition. The second reason is connected to the fact that the sonic results have been obtained as a consequence of a process which was not completely the result of human intention, as the control was, in a certain way, shared between the order given by the algorithms and the arbitrary choices of the translation criteria. In terms of intentionality, it dealt with a process of generation which was almost random. It was more of a search in the dark regulated by some ordering elements than the result of decisions consciously taken by a creative will which theoretically imagines, writes and interprets melodies, harmonies and counterpoints. In other words, the results are not due to a subject’s creative desire. At the time, an experiment of comparative perception (geometry/pseudo-music) was carried out by interviewing various groups of people. The interviewees had to answer a questionnaire during a session in which they were exposed to the images of three states of the same geometric shape.
(original, averagely deformed and highly deformed) while simultaneously the audio obtained from these different geometric states was played. Identical musical parameters (scales, tempos, instruments, etc.) were used to translate the three geometric states. It was observed that using the translation method programmed in the musical box, the aesthetic state or the deformations applied to the geometric ordering of the raw material translated were irrelevant factors for the formation of the identity of the sonic results. This observation was based on the statistical counting of the responses given by the interviewees, who evaluated what they were seeing and hearing. The statistics led to the interpretation that the prevailing factor for the formation of the sonic identity of the translations was the combination of the programmed mechanism with the series of musical parameters used. According to the concepts of Iannis Xenakis (1992), one can say that this factor belongs to the domain "outside-time" and, from the results of the experiment, one can also aggregate outside-space, as the geometric order derived from and governed by spatial symmetries had a secondary or irrelevant role in the formation of the sonic result. It can be concluded then that the correlation geometry-pseudo-music was weak or non-existent (Menegotto 2009).

Therefore, coinciding with the observations of the philosopher Roger Scruton, we recognized the difficulty in establishing equivalences between musical movement and spatial movement. The first is understood as the perception of the passage between the notes of a melody and the second understood as movement in physical space. As Scruton has said it is a phenomenological truth that music moves but it is a truth that this does not correspond to a physical reality (Scruton 1979). However, these observations do not impede one from continuing to experiment with new approaches to composition involving both geometry and musical sound. The programming of other interfaces, such as the sonic object proposed here, intends to continue the work, while making it clear that the new experiments do not point towards discovering and providing a geometric explanation for music nor finding an exclusive musical or sound impromptu which characterizes each geometric configuration. Attention is focused on the imprecision of movement as an element of expression and gestural development.

THE SECOND TECHNIQUE. THE SONIC OBJECT.

On this occasion, sonic objects were programmed for the AutoCAD graphic environment in the C Sharp language on the platform .NET using the library of musical functions Midi-dot-Net. The first sonic object programmed is a circumference: a two-dimensional shape with a centre and radius. The first of these properties was represented by a numerical pair of coordinates X and Y. The second property is a numerical value which defines the size of the sonic object. The circumference was filled with hatch which gave the sonic object two more properties: colour and transparency, both represented by numerical values. For colour, three channels from the band between 0 and 255 were adopted. Each channel represents one of three channels of colours: Red, Green and Blue, or RGB. The transparency is represented by a numerical value between 0 and 100. The class of the sonic element is complemented with properties which represent three musical attributes present in the library of musical functions Midi-dot-Net: OutputDevice, Channel and Instrument. In this study, the other musical attributes, such as the pitch class, eighth, duration and dynamic, do not belong to the sonic object, although this is responsible for executing them using its spatial position as the parameter defining the note. The definition of the two-dimensional sonic object was enlarged to permit it to evolve in three-dimensional space. It was transformed into a sphere with the possibility of being positioned in any point of the space with the coordinates X, Y and Z. Colour, transparency and musical attributes remain the same for the two-dimensional and three-dimensional object. In the architecture of the programmed system, the sonic object class in-
The sonic cloud

The sonic cloud (figure 1) is formed by the successive appearance of a graphic unit composed of two-dimensional sonic objects, positioned in a curved or-
dering which turns and moves in a linear fashion in the horizontal and vertical directions. The values of the translation vector and the angles of rotation are stipulated randomly. All of the numerical adjustments of the movements of translation and rotation, as well as the definition of the parameters of colour and transparency which each group of sonic objects acquires, form part of the aesthetic process of artistic choice of the final composition. The grouping of the sonic objects is ordered in circles of increasing radius. The modes defining the evolution of the visual and sonic shapes which participate in the compositions is an aspect of the process which is subject to continuous changes, being a key moment of aesthetic choice. In the cloud study, the evolution of the sonic phenomenon and the graphic phenomenon is not synchronised although they share the same temporal space. On hearing the result it can be clearly noted that there are moments in which the graphic elements, evolving in an increasing and continuous movement, lose the accompanying sounds. These sound pauses were not intentionally placed silences in the composition. The silent image on the paper does not manage to express the composition completely. It expresses only one part of the composition sought. The unified and complete result of the image and sound can be seen at: https://sites.google.com/a/poli.ufrj.br/dc_menegotto

In this exercise the sonic shape of the composition is defined by uniform temporal segments which express the same cyclically repeated sound theme, alternating the musical scales in each segment of the repetition. In order to define the quality of each note of the sound theme, the musical scales are used alternately in the following order: chromatic, major, minor, pentatonic, scales of odd and even whole tones. The composition presented here did not make use of any specific rules from the tonal system or from the twelve-tone technique method. The duration is randomly defined in a list of tempos which are transformed in milliseconds before being passed to the object which administers the duration of Threads of the system. The instruments chosen for the compositions are also randomly defined within the set of traditional MIDI instruments. In general, a subjective evaluation produced better auditory results for percussion instruments than for instruments whose flow of sound is continuous, such as the string instruments and wind instruments. This subjective appreciation led to the decision to use the piano, vibraphone, glockenspiel and other percussion instruments. An observation of the configuration of a sonic cloud shows that while visual evidence of formal geometric ordering exists it is difficult to find. There is the impression of a chaotic ordering which is not governed by any rule. The greater density of red and grey colours visible in the centre of the composition is perhaps the only visual evidence which manages, in a certain way, to suggest the presence of the regularity of the generating movement. In the auditory sphere, the cyclical repetition of the sonic theme can reinforce the perception of the existence of an order which controls the generation. Nevertheless, the observation of the visual and sonic evidence requires at-
tention or the perception of the clues develops at different moments.

Sonic Mandalas

The series of studies presented next differs from the studies carried out with the clouds. Observing these examples provides the certainty that there is a law of movement. Configurations of this type, such as Crova’s Disk and Naylor’s PI Flowers were explored by Krawczyk (1). Figure 2 presents the first three-dimensional composition studied for this work which responds to the following cyclical formula

```java
public Point3d Circular(double x, double y, double z, double radio, double ang) {
    double seno = System.Math.Sin(ang);
    double cose = System.Math.Cos(ang);
    double x1 = x + radio * cose;
    double y1 = y + radio * seno;
    return new Point3d(x1, y1, z);
}
```

In order to form the Mandala the angle is incremented at each cycle. The construction process of the formal composition and its corresponding sonic translation is initiated by the launching of sonic objects to the space R3. Immediately, the algorithm makes a reading of the position X,Y,Z of each centre and play a synchronized sound obtained by the translation of these numerical values to the qualities of the pitch of the musical note. As the sonic objects are temporarily stored in a list, the sequential order of which corresponds to the moment of generation, the sequencing of the reading becomes an element which permits aesthetic choice and selection. The list of points can be read sequentially n, n+1, n+2..., or by producing some type of alternation or specially programmed jump which will have an influence on the sonic result of the composition. In figure 2, two moments of the formal geometric and sonic evolution are presented. During the translation process, the transparency of the sonic object is connected to the values of the dynamics. The translation criterion of the centre coordinate is arbitrary. For these studies the qualities of the notes were defined in the following way:

1. Abscissa X establishes the measurement of pulsation and a value of the dynamic
2. Ordinate Y defines the pitch class and a tonic note used as an initial reference, although tonal system modulation rules are not applied
3. Height Z is translated to a value of an eighth defining the tone of the note

Figure 3 presents other 3D composition studied which responds to the following formula

```java
public Point3d Lorenz_A(double x, double y, double z, double dis, double ang, double r, double s, double b, double t) {
    Lorenz lor = new Lorenz();
    double seno = System.Math.Sin(ang);
    double cose = System.Math.Cos(ang);
    Point3d po = new Point3d(0.0, 0.0, 0.0);
    double xa = po.X + dis * cose;
    double ya = po.Y + dis * seno;
    double za = po.Z + dis * seno;
    double x1 = xa + lor.Calcula_dx(xa, ya, za, t, r, s, b);
    double y1 = ya + lor.Calcula_dy(xa, ya, za, t, r, s, b);
    double z1 = za + lor.Calcula_dz(xa, ya, za, t, r, s, b);
    return new Point3d(x1, y1, z1);
}
```

In order to carry out the numerical translation modular congruents are applied in accordance with the necessary quantities for each case. For example, in order to find the pitch class in the chromatic scale was used 12 as modulus of congruence. To produce and distribute modular ostinatos, which maintain a constant pitch of the note, the modulus of congruence must be 1. The Mandalas can be processed in between 1 to 5 stages. Stages 2 to 5 reproduce the movement of stage 1 with some pre-programmed dislocation. The example of figure 4 shows a Mandala
Figure 2
Two moments of the graphical and sound evolution in a circular Mandala (1000 sonic objects)

Figure 3
Strange Attractor Mandala (1000 sonic objects)
of circular movement in 5 stages in which each stage is directed to a quadrant of the Cartesian system and dimensioned with a factor of specific scale.

CONCLUSIONS

The expectation of discovering a kind of invariable musical impromptu (outside-space) in the geometric configurations had been discarded during the experiments with the musical box. Since then, we have sought methodological pathways which permit better understanding of how to deal with the relationship between movement derived from the geometric shape and movement derived from the musical form. The questions which arise are related to the modes of modelling regularities and formal dynamic characteristics. In view of the current stage of developments in kinetic architecture, it is believed that it is important to understand how to order, relate and maintain some control between the dynamic architectural elements and the musical events. Stating that the objective was not to provide a geometric explanation for music does not mean abandoning the scientific treatment of the question, merely a change of focus towards the problem opting for freer methods of exploration between the two forms of composition, whose raw materials and development domains are different: architecture/music, geometry/sound, space/time. In this way, we agree with the observation by Steve Holl for whom the problem of comparison between architecture and music is: The question would not simply be "how to compare?" but what unmarked routes to investigate and what experiments to perform (Holl 1994).

The experiments with musical geometry permit us to combine compositional procedures as well as to accumulate observations with the aim of detecting possible kinetic and sensorial relations. The design of the experiments faces us with the dilemma of whether to focus our attention on the rigorous observation of the events or on the aesthetic decision on the artistic configuration. We have mentioned the difficulty in relating the physical movement to the musical movement. This difficulty is observed, for example, when trying to define the direction of a simple translation in musical terms. In spite of there not being physically equivalent movements, it is difficult to deny that music, in the same way as architecture, has the capacity to stimulate and guide motor impulses. It is strictly in this sense that one seeks to explore the movement understood as impulse or gestural development. In the comparative observations between the geometric shape and its sonic evolution it is possible to note certain gestural or perceptive equivalence, especially in the examples with very characteristic geometric configurations as presented in the examples. However, this equivalence seems to be so subtle that we can understand it using the $y$-Condition concept which Elizabeth Martin suggested on the connection between architecture and music. The $y$-Condition notion refers to the subtle phonetic transition between the letter i and the letter e in the word "quiet" (Martin 1994). With the construction of the mandalas formed by sonic objects we took up once more the research begun with the musical box. Experimenting with the mandalas gave us the opportunity to update the programmed system and compare the results obtained with both methods. One of

![Circular Mandala in 5 stages (1000 sonic objects)](image)
the advantages found with the programming tools used in the studies presented, in which the C Sharp language and the Midi-dot-Net library were used, instead of the AutoLISP language associated with the Compo-Music library, was the possibility to carry out the sonic translations directly synchronised with the graphic elements within the modelling environment. This integration in the unified environment permits geometric and sonic experimentation at the exact moment of the conception of the project. It is believed that this possibility of integration, in addition to benefitting the observations, permits an increase in the range of questions. We hope that these benefits can be transferred to the architectural project, both in its aesthetic aspect, as well as being incorporated into aspects which relate to its functionality and the sonic qualification of the space.

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