Metamodeling and Audio Signals Design Process, for the Encounter Between Sound and Changing Forms

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Abstract. The context of the following work arises from an exploratory interest around sound and forms, in order to be able to structure fictional architectural envelopes of an audio-reactive nature, whose materialization is achieved through digital visualization techniques, and generative software of art and design. This research implies an interdisciplinary development, between different categories of knowledge, through which unconventional processes are built, where sound is activated as an element that generates random values of information, and that have a direct impact on the configuration and changing behavior of the form and environment. Today, the boundaries that define creative territories are increasingly flexible and adaptive, which allows establishing knowledge networks that expand the ranges of action of design activities.

Keywords: Audio signals design process · Sound and changing forms · Experimental design processes · Fictional spaces

1 Introduction

The initial exploratory interest of this research, is around the possibility of working with sound as an element that allows configuring audio-reactive forms, which are built as fictional architectural envelopes and that are materialized through digital visualization resources. Likewise, in this paper, the relevance of the development of atypical creative processes is described, which allow establishing a set of actions aimed at the design of sonostructures, this broadens the possibilities of achieving a conceptualization of the form, from criteria of experimentation, where the poetic-aesthetic function is prioritized, before the functionality, or guidelines subject to the 'brifing' going outside of the commodity results of the standardized process of design.

Today, the options of approaching to design from perspectives that go beyond the dynamics of the problem - solution, allow setting up networks and associations, between multiple categories of knowledge, which in turn, offers the opportunity to raise thematic axes that they are not analyzed under this approach. This path of exploration does not

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replace, it intends to add new working methods incorporated as characteristic of design and worked from an experimental point of view. On the other hand, it is worth mentioning that, the sound allows incorporating in the forms, aspects of randomness that confers the envelopes, attributes of continuous transformation that are activated through the sound signals.

Generally, when recording audio directly from an open environment, this information has to be processed, through filters that enhance and clarify the quality of the data; therefore, technological interaction through programs that integrate programming code, allows cleaning up the interferences in the audible register, and thus, setting smoothed transitions in space. Similarly, the computer-aided modeling (CAD) tools are relevant, and allows the construction and visualization in 'real time' of each of the three-dimensional components of the envelope. It should be said that these computer media are, in principle, subordinate to parameters of usability, functionality, precision, among others. Fact that makes us recognize that we are not dealing with absolute randomness and brings us closer to experimental development processes. However, through experimentation and search for alternatives for use, it is possible to establish results that go beyond the usual practices, which are revealed in these platforms, which could be defined as metamodeling.

The referential framework to which it is intended to contribute, mainly revolves around design, sound, architecture, and digital arts. However, in order to structure the speech of this research, it is essential to get involved with an inter and transdisciplinary perspective, where philosophy and the arts, in combination with other disciplines, provide valuable information for the realization of the project.

2 Development

2.1 Encounters Between Sound and Form

Over time, many referents developed multiple creative approaches between sound and form, being a practice closer to architecture with an artistic orientation, due to the prioritization of symbolic, poetic, and aesthetic aspects, in the conceptualization of the works; for example, in the 'Philips Pavilion' by Iannis Xenakis, it is possible to see a strong influence of the graphic representation of experimental music, on the lines of the architectural envelope. One of the mainly results of the sound-architectural encounter, which (Marsden and Leadbeater 2017) point out, are the stimuli that they produce in the listener's memory, since they awaken specific memories of other places and other spatialities. "The strength of music in the listener is what gives meaning to memory… There are no limits in music or in the memory it evokes" (p. 160 - p. 161).

The famous architect Peter (Zumthor 2006), also participates in the sound evocation of memory, to build his concept of atmospheres in architecture. For him, the space is a musical instrument, which depends on the form and the materials, to produce a specific sound, which in turn, gives meaning to the ceremonial and daily experiences inside the space.

> ¡Oíd! Todo espacio funciona como un gran instrumento, mezcla los sonidos los amplifica, los trasmite a todas partes. Tiene que ver con la forma y las superficies

> de los materiales que contiene y como se han aplicado… Por desgracia, hoy en día mucha gente no percibe los sonidos del espacio en absoluto. Sí, el sonido del espacio; personalmente lo primero que me viene a la mente son ruidos, los ruidos de mi madre trajinando los cacharros en la cocina cuando yo era niño. Me hacía feliz. (p. 26)

Now, besides memory, another meeting points can be established between sound and space. For this, many architects take this idea as a heuristic element, and make an encounter between the visuality of a musical score, to configure their projects; or in other words, they start from a musical image, to metaphorize architecture. Steven (Holl 2011), for the project called Hypo-Bank Block, takes as a creative trigger, the Gruppen Stockhousen score, where he organizes urban life, in three functional and temporal capacities. One was arranged for permanent residents, who live in the place, another semi-permanent, for office workers who travel from home to work; and finally, one for eventual buyers. Thus, Holl maintains that "just as we could take into the modern development of materials and technology, we could consider parallel progress when it comes to sound" (p. 16).

For this architect, the sound is an element that activates the tour experiences into the space; in fact, he assures that a sound sequentiality can even have a hypnotic effect, for this reason, he considers it vital to move through spaces not only with one's gaze, but also through listening.

In this regard, it is evident that a considerable part of architectural practices ensure that the aesthetic experience not only focuses on visuality, but is also in its haptic nature. For this reason, (Pallasmaa 2006), postulates that there is currently a domain of sight above the other senses, possibly due to the high number of visual stimuli, which gradually displace the other senses, such as hearing to a second plane. This is evidenced when people voluntarily interrupted the listen, for example, when they use headphones, which do not allow listening to the environment, something that would be difficult to imagine in other animals, which depend on their ears to survive.

Thus, the Finnish architect maintains that "we could reconstruct the space by diverting our attention from the visual, as established by resonant sounds, material vibrations, and textures" (p. 15).

If we return to the idea of space as an instrument that Zumthor propose, it should be noted that it is difficult to think of an architecture in total silence, since sounds are the product of some type of movement that occurs in the interaction of forms and materials, with external elements, which according to (Antenbi, et al. 2005), it's possible to say that acoustic singularities of the space, are defined through the sound in it.

> Yo creo que todo edificio emite un sonido. Tiene sonidos que no están causados por la fricción. No sé lo que es. Quizás sea el viento o algo así… Cuesta mucho conseguir que los espacios cobren sosiego y, desde el silencio, imaginarse cómo sonará el espacio con proporciones y materiales adecuados. ((Zumthor 2006), p. 31)

The multiple sound, visual, and tactile stimuli that come from a space and subject interactions; establish a unique link between experience and memory. To these architectural particularities, the subject being accesses through actions associated with the senses. Thus, by smelling, looking, touching, and listening, experiences are transposed to memory, which are activated through remember, to be later mentally reconfigured by people.

After this analysis, which marks a specific synthesis of the binding encounters between architecture and sound, several things can be concluded. One of them is that sound is the result of movement and continuous interactions between two or more parts, which are manifested and which determine the particularity of the soundscape. In that way, (Marsden and Leadbeater 2017), affirm that "nothing moves without producing sound; whether it is perceptual or not, to the human ear" (p. 162). For this reason, the evidence of change composes the acoustic singularity of the space, where diverse sound capabilities converge, which constantly incorporate new textures to the sonic-architectural spectrum of each place.

Another valuable aspect that is extracted from here is that architecture can be thought in terms of sound; either from a poetic approach, or as a result of a graphic interpretation of the sound impulses. Based on a paraphrase by Antenbi ((Antenbi, et al. 2005)), who defines sound as a type of sensory information (auditory and tactile), of a reflective nature, which refers to the medium through which it is propagated (message - metamessage), and also, describes the relationship that exists between spaces, activities, and materials; a clear link with architecture and sound is established.

On the other hand, technological progress, and the development of new work interfaces around the assembly of audio-reactive installations through DMX (Digital Multiplex) controllers[1], and light projectors, open new opportunities, where spatiality it is delimited by robotic lights that generate displacements, rotations, intensity changes, and color, in correspondence with the sound input.

Among contemporary artists and designers, one could cite the work of Antoni Arola, who in his project 'Fiat Lux', uses lighting elements as construction materials, where he proposes immersive installations to awaken the senses and consciousness of visitors, and incorporate them into an illusory and 'non-existent' spatiality. In the same line are the works of Sergio Mora Díaz, Chilean artist and architect, who conceptually relies on the cosmos, information flows, and nature, to configure audio-reactive lighting environments, which accompany performative acts, and which are subsequently opened to the public so they can tour and experiment.

Returning to the previous concept of sound as an element that allows the configuration of audio-reactive forms, it is worth highlighting the designer and typographer Daniel Reed, who works under this paradigm in the field of visual communication. Reed, in his 2012 Musical Cymatics project, visually interprets, from an approach which at first might seem aesthetic-poetic, the forms generated by grains of salt on a sheet of paper when applying the vibration of the musical notes reproduced through the use of an amplifier. This project, originally speculative and experimental, and far removed from

[1] DMX (Digital Multiplex) controllers are communication protocols that allow the management of lighting devices, through a data network that comes from the computer, to the electronic systems.

the form-function concept, ends up concluding with a graphic result that, as well as aesthetic, ends up generating a set of combinable pieces that generate a visual version of the traditional musical notation code. With this, the designer goes from an aesthetic and experimental plane to endow the project with a functional and communicational plane.

Nowadays, the possibilities of incorporating the concept of adaptability and transformation as an attribute in the project result, has been evolving. In some cases, the objects require the human factor so that through interaction, they are able to configure the different compositions they offer; while, in the examples of Arola and Mora, the transformability and movement of intangible environments, are experimental and speculative, and that allows them to go a little further within the exploratory threshold, where the dynamism of the light projections depends on technological aspects. For this reason, to activate mobility in structures through sound, the human factor alone is not enough, but it is necessary to build, based on programming codes, the ways for this to happen. "Es innegable que en el refinamiento que tanto nos gusta haya ciertos elementos que están lejos de ser perfectos" (Tanizaki p, 28).

2.2 Metamodeling and Signal Processing

At this moment, the advancement and development of computer-aided modeling software, especially those that are directed to design and the arts, allows to go beyond the configuration of digital models or prototypes, which simulate a structure, materials, lighting, or the behavior of an object in a specific context, to define a particular process tree, which later becomes a new piece. In this way, the 'metamodeling' can be understood as that set of rules or parameters, which are associated under a singular sequence, and which in turn defines a model.

The management of programming codes, algorithmic functions, mathematical operations, among others, are possible thanks to the increase in friendly interfaces, which are developed with the aim of improving and enhancing user experiences, especially for people who are not familiar with computer languages, such as Python. These platforms use a system of nodes that can be associated in open networks, and to which new control or transformation parameters can be added at any time, which eliminates all types of compositional restriction in the program's workflow, although it should be noted that all calculations and analysis are subject to the processing capacity of the physical components of the computer. In this way, technology makes it possible for the computing canvas to become an experimental laboratory for developers. In this sense, Luciana (Parisi 2013) says (Figs. 1 and 2):

> Algorithms do not simply govern the procedural logic of computers: more generally, they have become the objects of a new programming culture. The imperative of information processing has turned culture into a lab of generative forms that are driven by open-ended rules. (p. 22)

Metamodeling is the base concept, for generative art and design programs, since the algorithms not only take care of the simulation of the properties of the digital components, but also allow the development of a new model that integrates the principle of '4A' for its acronym in Spanish (abstracto, autónomo, algoritmico, aleatorio). The '4A' is an integral

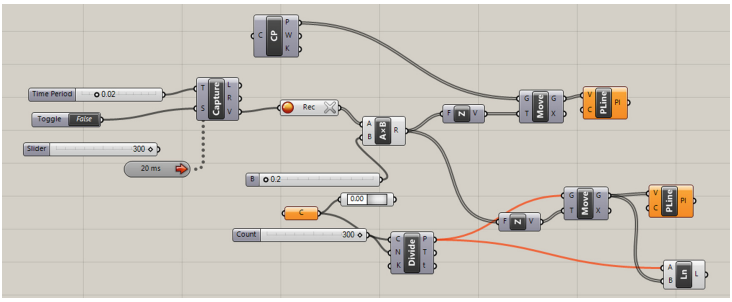

Fig. 1. Grasshopper nodes network screenshot - Alonso Peñaherrera.

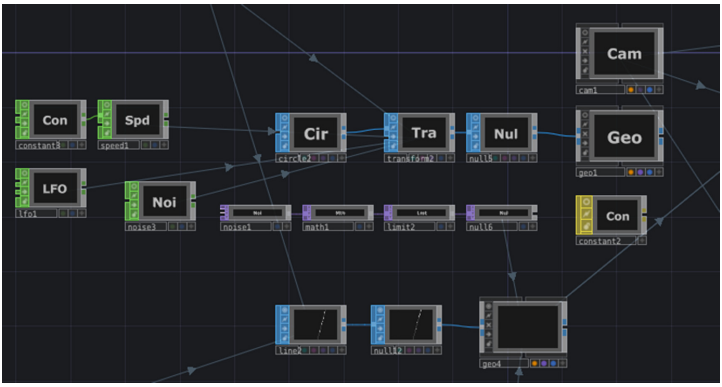

Fig. 2. Touchdesigner nodes network screenshot - Alonso Peñaherrera.

set of attributes, since to achieve the uniqueness of the design, it is necessary to establish a kind of collaboration with the machines; that is, the author does not develop each of the steps, but somehow, *autonomous* systems are structured where the program complements or executes actions, based on parameters that are previously set. In this case, human-machine communication is determined based on instructions, commands, or *algorithmic* data sequences, which generate figures, geometries, chromatics, and transitions in space, resulting in forms that are usually *abstract*, even when they start from figurative structures (Fig. 3). Finally, the *random (aleatorio)* factor is revealed when scenarios are established that evolve over time, and deliver changing aesthetic information, where the developers do not have total control of the changes. What generates a situation of uncertainty of its own and necessary in the design process, which seeks to get out of the obvious results.

On the other hand, according to Marek (Pícka 2004), metamodeling is an 'abstract language' that describes different types of data in constant interaction, and that also does not have a specific syntax or notation. In this sense, computer tools today not only enable the design of models through binary operations, but also allow the construction of the process chains that have a significant impact on the result. Likewise, it should be noted that the perspective of the computer industry, while addressing quantification and prediction parameters in the data flow, also incorporate patterns of randomness, and

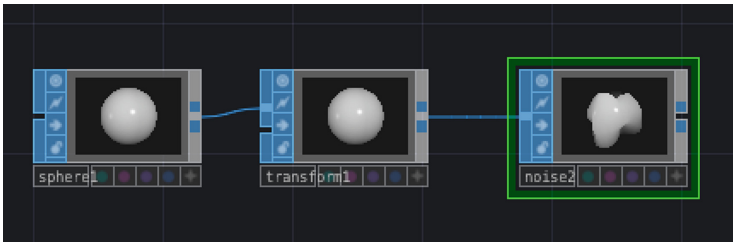

Fig. 3. Sphere and noise function - Alonso Peñaherrera.

calculations of information that come from various sources, to add values of novelty in the final product. "Metamodeling, therefore, describes how process becomes configuration, or how potentialities exceed preordained typologies" ((Parisi 2013), p. 25).

Now, it can be said that these computing environments like Grasshopper, Processing or TouchDesigner, where the reference points are articulated, from which objects are conceived, are relatively new, given that in recent years, several renowned designers, artists, coders, and creatives, have made these resources visible, despite the fact that they have been developing for some time. Even so, if the concept of metamodel is assumed as that set of parameters that are ordered in a systemic way, in coherence with an intentional approach to knowledge, this makes it possible to fix structures from outside the programming code language, so that the configuration of models, is subordinate to a system of analogous rules, but which are part of the metamodel. In this way, it is possible to reinterpret standard tools of a 'software', for the realization of an experimental and abstract model, to which, other types of modifiers can be added later.

Once the metamodels are defined in the design process, it could be said that these order structures help to understand the minimal context or the poetic and symbolic intentionality of the object. "A metamodel therefore describes the syntax of the models… with this representation of the syntax of models metamodels can also help to define the semantics of models" (Sprinkle et al. s. f., p. 58).

Now, regarding the configuration of the base envelope, the link between sound and form, in the first instance, is achieved through a process of recording and transforming sound information, which can be divided into four parts; firstly, it is necessary to identify the place where the sound sampling will be extracted; then, a recording must be made, with the help of a device with a microphone (it can be a mobile phone) to get an audio file. Subsequently, the data is analyzed through interaction with specialized computer programs, for example, Logic Pro, or Adobe Audition, which transform the previously obtained documentation into musical notation. In this sense, these four phases that are observed in Fig. 4, result in a melodic sequence, which serves to track the random changes in the pitch of the sound.

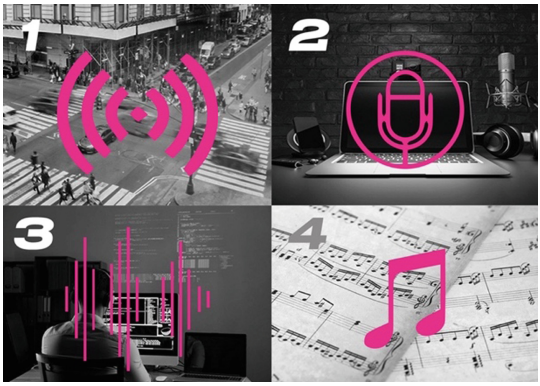

Fig. 4. Sound treatment phases - Alonso Peñaherrera.

Later, the series of notes is taken, and it is transferred to the three-dimensional diagram (Fig. 5)[2], which has six tonal levels distributed vertically, and at each of its ends, it has a representation of the twelve notes of the chromatic scale, starting from which, the tonal change can be detected; since its design allows to easily 'weave' the melodic sequence, due to the fact that it is mostly a hollow composition; the only solid part is in the center, which acts as a fixing support, and the place where the nomenclature of the notes are graphed. At the end of each circular part, there are two essential elements for the interpretation of the melodic series; one of them is a perforation that is located in the center, and that is where the filament passes and intersects, to build the shape of the tonal sequences. The second element consists of two rectangular fretworks, which are located on the sides of the rounded part of the structure, and have the function of representing the number of times that a note remains in the same place. In this way, the height of the fictional space is defined, so that it finally acquires audioreactive qualities, when it is sent to a signal recording and processing system, through programming code (Fig. 6).

Once the base structure is obtained, an audio-reactive metamodel must be built through the processing of sound signals, which moves the vertices and axes of the polygonal mesh, in harmony with the sound. It is usual that when working with this type of information, the audio data must be filtered to obtain a clean signal, and project smoother transitions in the space. There are several possibilities to treat the signals, but three of them are detailed below, which are effective, and also save computer resources.

The whole process starts from a module that collects the sound information, in the 'Touchdesigner', there are two possibilities, one with 'audio file in' or 'audio device

[2] In order to improve the processes of transformation of sounds to shapes, a three-dimensional diagram was designed, which takes the notes of the chromatic scale of a random sound, to set the height of the fictional envelope. These data are obtained when the audible register passes through.

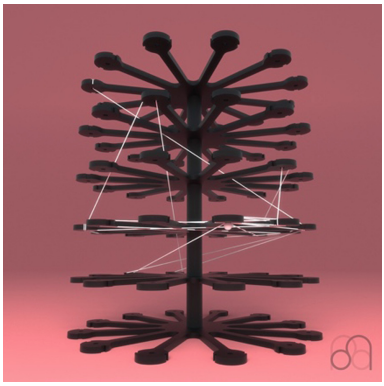

Fig. 5. 3D diagram and sound fabric - Alonso Peñaherrera.

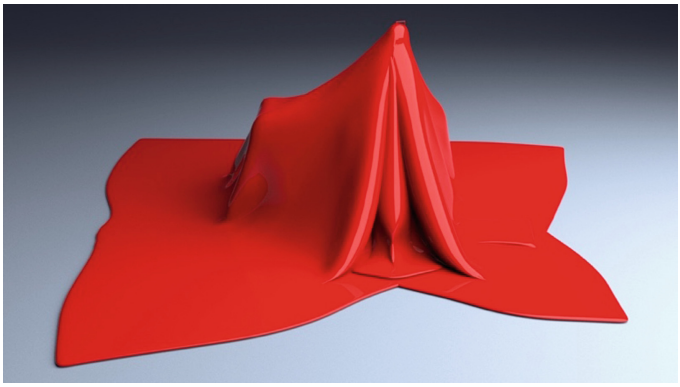

Fig. 6. Digital architectural envelope - Alonso Peñaherrera.

in'[3]. After this, a 'select' is added to take a single channel, and then, connect it to a 'math', which is a mathematical operator that allows the signal to be amplified when it is weak. Finally, the modules that smooth the signals are added, and they can be a 'lag', 'trail' + 'analyze' or 'filter'.

The first operator 'lag' (Fig. 7), generates a delay in the signal, and by default it comes with a value of 0.2, however, you can write any number in this parameter, but to be more precise in data latency control, it is preferable to work with a numerical range that goes from 0 to 1, to generate a minimum lag, in the analysis of information in real time. The second 'trail' element (Fig. 9) produces a retrospective history of the signal, from the entry point of the current frame, backwards, and combined with an 'analyze' (Fig. 10), gives an average of all the values of the 'trail' channel, and returns in a single value, which allows a stabilization of the information. Usually, these two chains of modules are

[3] If you work with 'Processing', you could use an 'Audio Input', which allows the recording of audio signals, and then, you should also add a 'Select Input' to select only one channel of audio, and finally, put an 'additive mathematical operator' to amplify the sound signal.

enough to clean the signals (Fig. 11), however, there is a third option that is called 'filter' (Fig. 12), which is used with registers where the signal is very dirty. The parameters of this resource must be controlled very carefully, since its filtering process is very intense, and at times it could completely suppress the original signal. It is worth mentioning that this last technique, is useful when working with Kinect's sensors, especially when data is taken from people's heads or faces (Figs. 8 and 13).

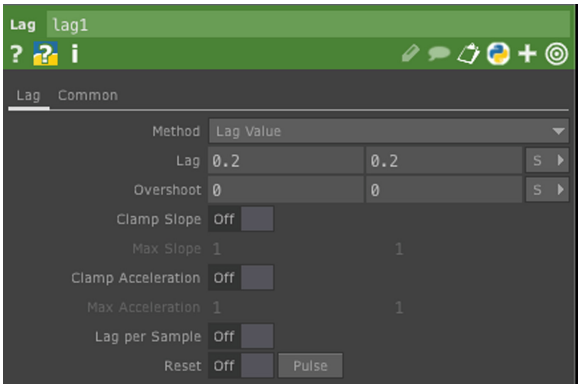

Fig. 7. Lag values box - Alonso Peñaherrera.

Fig. 8. Lag chain - Alonso Peñaherrera.

For the elaboration of the audiovisual simulation table, some parameters defined by the content disseminators in digital media of TouchDesigner, "Paketa12"[4] y "Bileam Tschepe"[5], are used, to which the filtering chains that are previously detailed, are added. Later, the fictional envelope is collocated, in 'wireframe' view, to identify the points on the surface that change in tune with the audible register. In this case, the node links are inside 'containers' (Fig. 14) that allow grouping each component, within a specific folder, to simplify and organize the amount of information in the systems.

The result is an audiovisual measure box (Fig. 15)[6], in which at the top, the fictional envelope is shown being altered by the sound in real time, while below, multiple graphic meters of the audible register are evidenced, which in the first place, it has a status bar, then, in the lower left corner, the sound spectrum is located. Subsequently, two graphic

[4] User profile: https://www.youtube.com/user/paketa12.
[5] User profile: https://www.youtube.com/user/nose2bear.
[6] Audiovisual mesuare box: https://youtu.be/hwSuNWbOwf8.

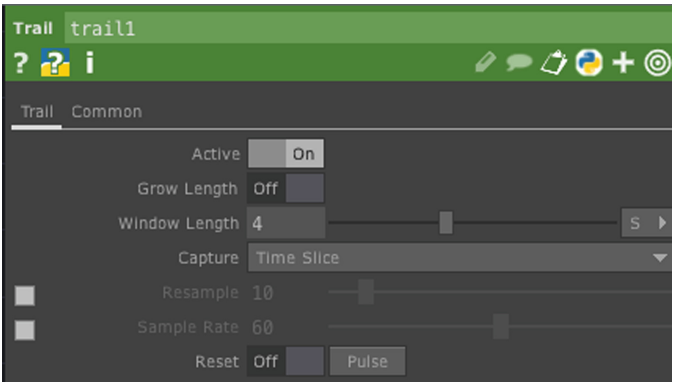

Fig. 9. Trail values box - Alonso Peñaherrera.

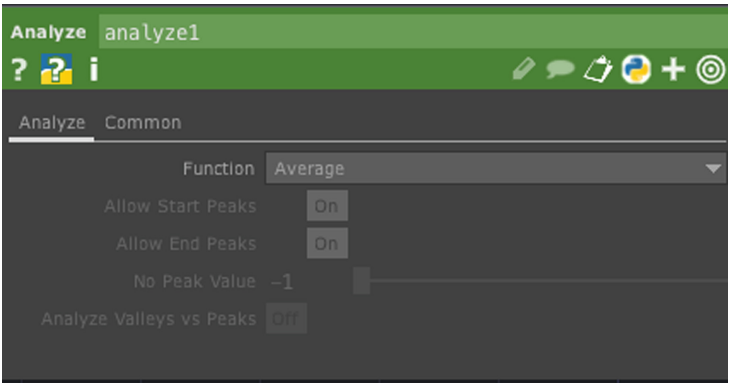

Fig. 10. Analyze values box - Alonso Peñaherrera.

Fig. 11. Trail and Analyze Chain - Alonso Peñaherrera.

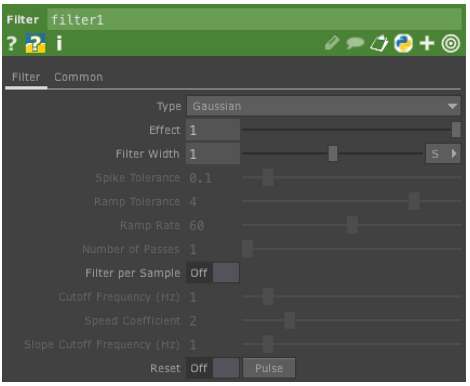

Fig. 12. Filter values box - Alonso Peñaherrera.

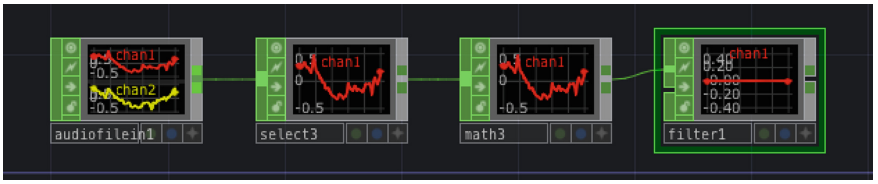

Fig. 13. Filter chain - Alonso Peñaherrera.

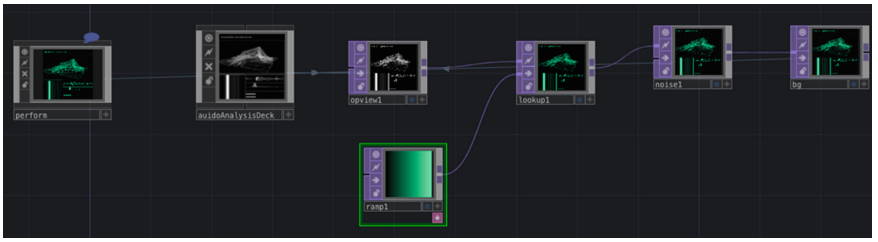

Fig. 14. Container chain - Alonso Peñaherrera.

stripes were placed, all of them, exhibits the wave of the sound, to finally insert a band that represents the left and right channels. In this way, the technical description of the fictional envelopes in continuous iteration is complemented.

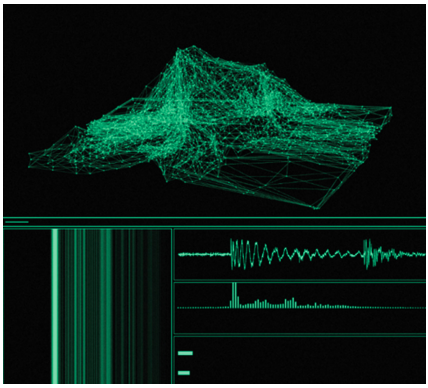

Fig. 15. Audioreactive frame - Alonso Peñaherrera.

3 Conclusions

It is interesting to think architecture in terms of sound, since from this perspective, it is possible to link poetic, symbolic, and aesthetic aspects, which give the envelope a new sensitivity, based on intangible qualities of sound, such as memory, movement and multiple relational encounters, which together with visual and tactile elements, project the singularity of the spaces. Technological advances facilitate the materialization and construction of these ideas, and also provide the possibility of building audio-reactive and interactive experiences, through the design of metamodels and the use of light devices or movement sensors.

On the other hand, signal processing are perfectly combinable structures, each designer or developer could configure them from their perspective, however, these sequences of modules provide a reference base to work, since sometimes programming through nodes is very broad and it is difficult to know how to start, and define a metamodular structure for signal cleaning.

Likewise, it can be mentioned that the three types of filter chains 'lag', 'trail' + 'analyze' and 'filter', can be used to control any type of signal, whether they are coming from a motion capture sensor. Kinect, Realsense, or Leap Motion, as well as for MIDIS devices (Musical Instrument Digital Interface), DMX, OSC data, among others. In addition, it must be said that with any of these filters, it is possible to combine each other to generate more rigorous cleaning processes, for example, mixing a 'lag' with a 'trail' and 'analysis'.

Regarding disruptive creative processes, it can be said that they allow us to travel new territories of design, outside of the problem-solution constraint. It allows us to consolidate experimental processes where development is more relevant than the result itself. This

typology of processes generates a structure for reflection to detect opportunities in various fields. The concept of non-absolute randomness and constantly changing context allows us to walk through an expanded vision of design. If we understand change as a survival action itself and it generates sound, the simple crossing at the system level of these concepts proposes a generator axis of exploration. On the other hand, the alternative and its fiction are necessary to move from an increasingly egalitarian material environment and result from patterned processes used as identical, based on usual data, and demand-market parameters.

This research is the result of a combinatorial experimentation in a fictional environment based on the relationships established between sound, space, and form in relation to the subject and constant change.

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