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FORM-FINDING WITH EXPERIMENTATION ON NATURAL PERIODIC FORCES: THE SOUND MOTION STREAKS PROJECT

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Abstract

Today, many computational techniques of form-finding use the term design with the term research. Thus, architectural studios become more and more like laboratories for design experiments. This study proposes a design experiment called "The Sound Motion Streaks Project" where the sound can be used as generative computational data and applied to digital form finding studies. Design process relies on an idea that sound as an external force can produce or deform shapes according to its influence. The first phase of the process is to make

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physical experiments on the sound and see its influences on granular and fluid materials. We can say that, in these physical experimentations, there is a knowledge transmission from physical to digital medium that we can use as design parameters on software. In digital software, the sound can be a force field and manipulate digital matters such as particles, curves and meshes. The form-finding method of the Sound Motion Project is constituted by all physical and digital experiments, and applied in an urban area in order to discuss its architectural potentials. For instance, all material events in the area depend on duration and movement of digital tools, thus the notion of form and/or space become kinetic. Kinetic reactions bring out a new understanding of space and form which consists of motionless boundary, translatability, rhythmicity, differentiated densities and heterogeneity. Also this generative approach gives architects many potential solutions for architectural forms.

1. INTRODUCTION

Experimentation is the most important parameter for a scientific discovery. What about discoveries of forms in architecture? Nature has a lot of novel forms and patterns and produces new ones without stopping a moment. Thus, it is not a coincidence that the novel ideas in architecture usually come from experimentation procedures copying the processes of nature. To do this, architects need to understand how nature finds her forms and what her rules during the process of form generation. Our motivation in this study is a desire to create a form finding process called “the Sound Motion Streaks Method” in terms of experimentation on natural forces in order to find novel forms in architecture. The Sound is a natural force that we used in our study. The main objective of using sound is to see what sound looks like through interaction with matters. By doing this, we can produce a new notion of space which differentiates from the traditional Euclidian space and create a multi-sensory experience on users with the help of sound materialization. Throughout the paper, audience will see that there is no starting shape in this process, but there are different raw materials reacting to the sound influences. Therefore, this kind of formation processes will lead us to create a variety of topological geometry. Spaces emerging in this process are no longer static but dynamic, and this dynamism in the structure brings some kinetic properties to the form. In an animated form, the notion of “kinetic” reveals with a continuous motion through immovable structure of form. We can see the history of material movement under the influence of sound through transparent and overlapping structures of form. This illusion of movement called as “a frozen moment” and the designer becomes a person who “orchestrates” the whole process (Terzidis, 2003). The design process in this study is developed in four stages. First stage is to gain a general knowledge about the notion of form-finding process and physical sound properties. In this stage, additional to the literature review, we repeated physical sound experiments from the precedents -such as Cymatics- in order to strength our understanding of sound properties and material interactions. The second stage is to use this general knowledge coming from the first stage and constitute various digital experiments to examine the nature of digital materials and their reactions to the sound. Third stage is to generate our form-finding method and test it with different parameters in order to find a way for creating an urban scale prototype. Our final stage is to test this method in an urban area and discuss its architectural potentials through this way.

2. UNDERSTANDING THE TERM FORM-FINDING AND THE SOUND PHENOMENA

2.1. Form-Finding

In 1806 Goethe introduced the term “Morphology”. He has a unique understanding on how forms emerge in nature and how the constant formation and transformation of forms related to environmental forces (Menges&Ahlquist, 2011). According to him generative processes in nature affect both organic and inorganic systems with the help of natural forces. He invented “Ur-forms” in order to explain “the foundational programs” in nature. These programs determine differences and similarities between forms in nature which is to say that similar forms (Urforms) should share a common foundational program (Aranda&Lasch, 2006). These foundational systems actually refer environmental forces which affect all forms in nature and cause a constant transformation throughout its lifetime. For instance, imagine different cracking systems in nature. The foundational program behind dry mud and dry paint is the same, therefore these cracking systems looks like identical. They are “Urforms”. Both are shaped by same environmental force which is “fluvial erosion” (Aranda&Lasch, 2006). D’Arcy Thompson explained similar ideas with Goethe in his book “On Growth and Form” in 1917. He proposed that there are environmental (external) forces in nature affecting shape of things. More importantly, he believed that we can solve this process with mathematics (Menges, Ahlquist, 2011). Similarly, Philip Ball (1999) stated that patterns and forms in nature are not only generated through biological coding, but also there are simple physical laws behind them. Therefore, we can repeat complex forms in nature by repeating these rules. From all these ideas, we can say that there are some natural forces in the world and they are acting on organic and inorganic things and determine their appearances. These external forces cause similarities and differences and we can repeat their effect on forms by repeating these physical forces. In the Sound Motion Streaks Project, our departure point is to use sound as an external force and find sound patterns and structures by means of form and force relations. Therefore, in the next chapter we examine some precedents works on sound phenomena and repeat some of their experiments in order to find the foundational program behind sound patterns and forms.

2.2. Sound Properties

To understand periodicity of sound we should understand the properties that create rhythmic vibrations. Sound is a kind of wave which passes through the air effecting particles back and forth and change their equilibrium positions, but it is the disturbance which travels not the individual particles in the medium [1]. The frequency is the number of occurrences of a repeating event (period) per unit time. The amplitude is the measure of a magnitude (energy transported) of oscillation of a wave [2]. If we find a sound analysis of a particular sound, we can see that, both amplitude and frequency reflects the periodicity of sound and rhythmicity (Figure 1).

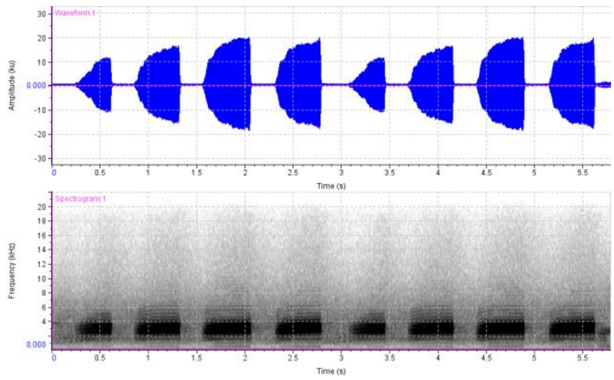

Figure 1. Nuthatch Sound Analysis: The image above illustrates the amplitude; the image below represents the frequency accordinf to time. (*Raven Pro 1.5 Beta*).

Figure 1

2.3. Sound as a Natural Phenomenon

Nature consists of complex systems constantly changing one assemblage of conditions to another-opposite one. These changing systems –animate or inanimate- create their own repetitive patterns and forms and their formation reveals hidden periodic forces which lay beneath them. A continual state of "vibration, oscillation, undulation and pulsation" gives these forces periodicity (Jenny, 2001). On the basis of vibrational phenomena, sound can be seen as another example. Taking information from its nature cannot be done with an eye or other senses except hearing. However, this does not give any visual data on the periodicity of the sound. Thus, since the eighteenth century, scientists have worked to make sound visible in order to explore its nature (Jenny, 2001). Ernest Chladni (1756-1827), who was one of the first physicist musicians, tried to simulate the vibrations of sound and make it visible. Chladni used a violin to vibrate metal plates covered with powder, and made the sound vibration process visible (Jenny, 2001). After Chladni, one of the important persons working in this area was Hans Jenny, a physician and natural scientist who founded Cymatics, which is a study of the vibrational character of sound and its hidden force on matters. Jenny's (2001) experiments, by putting matters such as sand, fluid, powder or salt on a metal plate, showed the hidden force of the sound on materials(Figure 2). He observed that in a kinetic-dynamic process based on sound vibrations, all patterned formations are generated and maintained by sound periodicity (Jenny, 2001). Overall, according to Jenny (2001), sound is physical force that can create vibrations and finally systemized pattern forms.

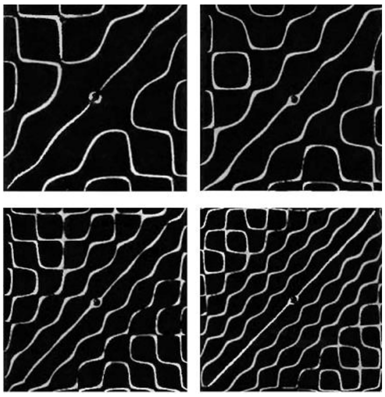

Figure 2

Figure 2. Chladni Experiments in Cymatics (Sand on a steel plate). Same topology of patterns emerges but numbers of patterns are growing as the pitch goes up. (*Jenny, 2001*).

2.4. Physical Experiments to Make Sound Visible

In this phase of the study, multiple physical experiments were generated from the Cymatics experiments, in order to deeply understand which parameters of sound actually create forms, deform shapes, or produce patterns. Water, non-Newtonian fluid made from water and starch and salt were used for physical experiments.

In experiment 1 and 2 (Figure 3), 40x40cm steel plates were used in order to materialize sound wave patterns. The left image shows the 1mm thick plate and the right image shows the 0.5mm plate. These square plates were clamped by the center with a speaker connected with an amplifier. Salt was sprinkled onto plates vibrating with sounds in different frequencies starting from 20Hz and gradually increasing to 80Hz with the help of the amplifier. As the plate vibrates, the salt begins to travel along the surface and salt particles interact with each other until they reach points along the plate that salt particles are not vibrating. These non-vibrating areas can be called as accumulation zones. We can see these zones as white lines on plates. When thickness of the plate increases, patterns on the surface blur, so that in the right image in Figure 3, we can see clearer patterns with a 0.5mm thick plate. Ultimately, every frequency has its own 2d pattern because of its unique vibrational character.

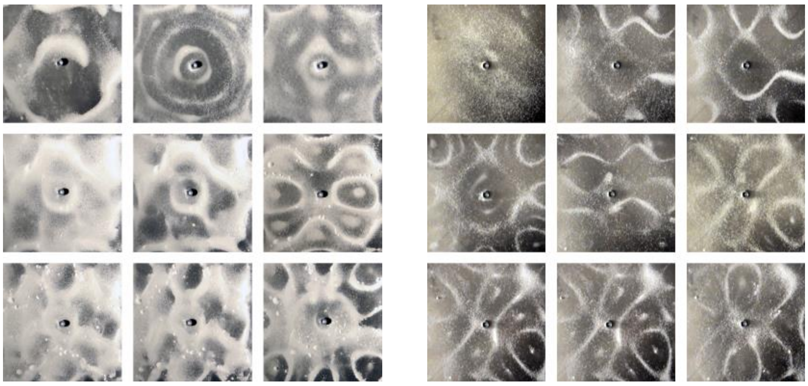

Figure 3

Figure 3. Experiment 1 and 2; Chladni Experiments. 1mm thick plate on the left and 0.5mm thick plate on the right. In both images, each pattern belongs to a particular frequency. Frequency used in these experiment starts from 200Hz and goes until 800 Hz. Material: Salt (*Calisir, 2012*).

In experiment 3 (Figure 4 - left image), we used corn-starch and water to experiment on a viscous fluid affected by a sound vibrations. This Non-Newtonian fluid behaves against the gravity and dances with the frequency played on the speaker. By the means of material behavior, viscous nature of the fluid tends to provide its surface continuity but irregularity of fluid molecules help to create 3d forms and patterns. Thus, this material has the capacity to create volumetric forms and patterns. In experiment 4 (Figure 4 - right image), we repeated previous experiment with water. Water maintains it surface continuity, therefore, it does not produce split patterns or 3d forms, instead the sound only can deform its surface. The higher frequency brings out the more complex wave-patterns.

Figure 4

Figure 4. Experiment 3: Non-Newtonian Fluid on the left image. Experiment 4: Water on the right image. Water experiment illustrates different frequency patterns between 200Hz to 800 Hz. On the contrary, in experiment 3, the whole motion emerges with a constant frequency-200 Hz. (*Calisir, 2012*).

These experiments are important in order to understand different material behaviors against sound vibrations and find a process to materialize sound. For fluids, viscosity determines the embodiment of matter. On the other hand, granular materials are more interactive inside because of their particular nature. In the most general sense, sound frequency and amplitude stimulate matters, which cover a plate connected to a sound generator. However, the time and material features are also minor effects in producing the overall shape. Because materials have either viscosity or a granular system, they continue to change through more complex and heterogeneous formations over time until the process is over. From these physical experiments, three fundamental issues can be observed. First one is the behavior of natural force, the second one is material behavior and the third one is material capacity.

The digital medium is a place for representing natural world, obviously with the control of a human. Therefore, digital materials are always open to manipulation and sometimes we cannot foresee material behaviors. Thus, in order to build a form-finding system digitally, we have to create simulations and understand same principles in physical experiments in terms of digital matter. Therefore, findings coming from physical experiments become a guide for digital ones in this study.

3. DIGITAL EXPERIMENTS TO SIMULATE PHYSICAL DATA

From physical experiments, we know that sound spreads in the environment as a wave. Also, sound source produces rhythmic and periodic forces when it meets a surface. If there are particles upon the surface, they react to the sound force. These findings help us to constitute digital models of physical experiments in Autodesk Maya. In order to create an influence of sound amplitude or frequency as a dynamic force field in the Autodesk Maya, the Audio Wave node, which can read sound amplitude per second, was used. A dynamic force field is a force that manipulates digital matters such as particles, fluids, or polygons by pushing, pulling, splitting and so forth. Through the Hyper Shade (Figure 6), which is a relationship editor on Maya, dynamic connections between materials and forces in the scene can be controlled during the time.

Unlike physical experiments, both particles and fluids can be simulated through this process at higher level because the unpredictable behaviors of both materials can be kept under control. Hence, the digital process allows further evolution of forms and assemblies. From this understanding, the first digital experiment (Figure 5-left) was built in Autodesk Maya. There was a sound source in a container producing sound waves according to sound amplitude and particles in this container not only reacted to this periodic force but also to each other. Therefore, this system produced well-organized and regular patterns. More interaction between particles and higher amplitude caused more complex patterns. Second experiment (Figure 5-center) illustrates the surface deform behavior of sound from physical experiments and applies it upon continuous surfaces such as a sphere. Thus, sound active surfaces emerge. Third experiment (Figure 5-right) demonstrates the form generator features of the sound wave and produces volumetric forms within the harmony with sound amplitude.

Figure 5

Figure 5. Digital experiments: Left image: Sound becomes a Pattern Generator when it interacts with particles. Center image: Sound becomes a Surface Deformer with a continuous surface. Right image: Sound becomes a Form Generator with viscous fluids. We can see sound effects on different digital matters.
(*Calisir, 2012*).

According to these experiments, we can say that in digital medium (Maya) sound can generate patterns and become "Patterns Generator", deform existing shapes and become "Surface Deformer" and finally generate forms and become "Form Generator". Analyzing and synthesizing both physical and digital experiments help to create our own system which is the Sound Motion Streaks Project.

4. CONSTITUTING THE SOUND MOTION STREAKS METHOD

Learning from physical experimentation provides a deep understanding of sound and its nature. On the other hand, digital simulations of physical experiments provide a deep insight of how digital matters react to the sound when it is simulated by a dynamic force field as a wave. From these experiments, we construct knowledge on digital material behaviors and capacities and create our form-finding tool with the integration of different kinds of digital materials. There are several ways to create forms by taking information from sound and manipulating time. For instance, the Audio Node can be connected to particle emitters in order to change the quantity of particles released per second or manipulate their directions and scale. On the other hand, this process can be stated in terms of the logic of constructing linear elements produced by particle tracing and apply particle releasing based on curvatures. In order to get more control over the particle system, each particle converted into polygonal meshes, therefore, this new converted matter creates multiple structural formations. This mesh form has much more characteristic than the other, which is only created by particles. In the Sound Motion Streaks Method, three different digital tools are regulated together: the particle system, the linear curve system and the polygonal mesh system. Together the entire system fulfils its performative capacity with regard to these three systems. Spatial conditions have different levels of density. More articulated and characterized spatial shapes can be produced. Additionally, for the larger scale, architectural systems have the ability of response to multiple functional requirements in the site context.

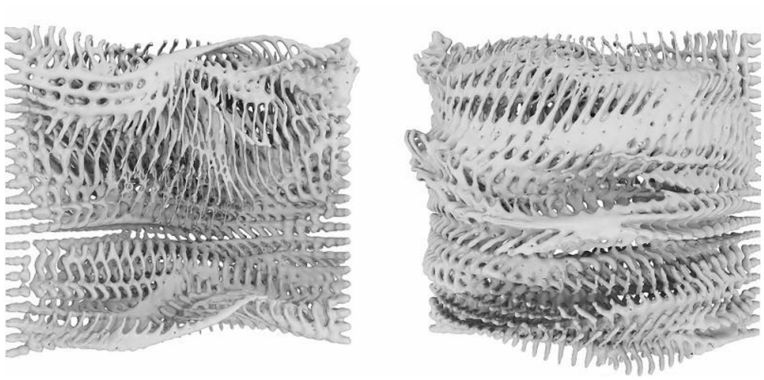

Figure 6

Figure 6. Elevations of the Sound Motion Streaks Project. In this test, a square boundary is created for the system. We can see the whole process of animation along the form.
(*Calisir, 2012*).

As hinted above, there are several ways to simulate sound driving forms in software applications, and it is a broadly acknowledged fact that software applications can cause coincidence results during the design process. To prevent this, it is necessary to understand the logic of the tools used and parameters that affect digital models. Hence, the following will focus on settings for 'the sound motion streaks method' in order to deeply understand the system, its architectural quality and make it a design tool.

4.1. Settings for Form Generation Method

As introduced above, the sound motion streaks method is based on three criteria: particles, curves and polygonal mesh. Particles are basically points that represent a collection of dots behaving like granular systems. Force fields such as air and gravity manipulate and organize this system based on the expressions or parameters. Similarly, a curve system lets one create dynamic curves so that natural movements and collisions can be created. Finally, polygons are a geometrical type that can be used to create three-dimensional structures in order to produce surface or architectural skin covering the systems.

Figure 7. Hyper Shade: Dynamic Relationship Editor. We can see connections on Hyper Shade for the Sound Motion Streaks Method on Autodesk Maya. We can change relations between digital matters and dynamic force fields through Hyper Shade.
(*Calisir, 2012*).

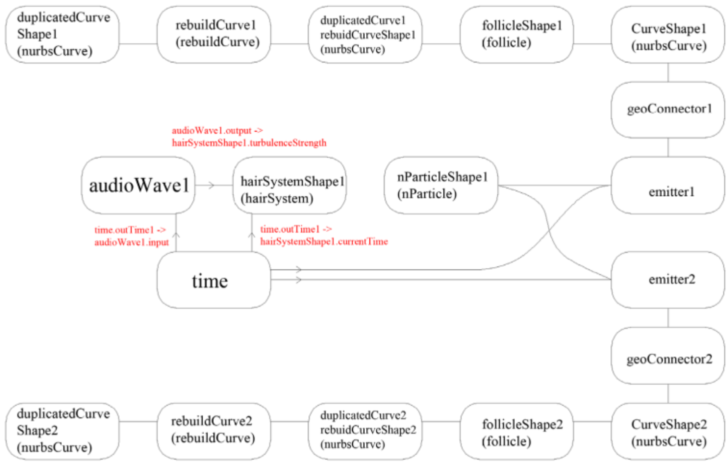

Figure 7

The whole system behaves like natural forms and like all forms in nature, they assemble themselves and also have the ability to gather their matter and interact with the environment under gravity or different fields. On the other hand, in order to produce these forms, the system must be run in a simulation. Simulations are essential for laying out complex architectural systems, in software applications and examining their behavior over extended periods of time. Also, simulations provide generative design processes (Hensel et al, 2010) and take advantage of motion movement and time. We can control dynamic relations between digital matters, dynamic force fields and time through Hyper Shade Editor (Figure 6). In order to discuss the potentials of the Sound Motion Streaks Method by the means of space and form we apply this method in an urban area.

Figure 8. This image illustrates different phases of form evolution. Time manipulation gives us a chance to freeze the moment and materialize a specific time.
(*Calisir, 2012*).

Figure 8

5. AN URBAN SCALE PROTOTYPE

For an urban scale prototype, an old bridge in Limehouse in London was chosen (Figure 8). The bridge is a kind of extension for Dockland Light Railways(DLR), but now is neglected and separated from DLR from a barrier. The whole area is affected by the rhythmic noise of DLR (Figure 9).

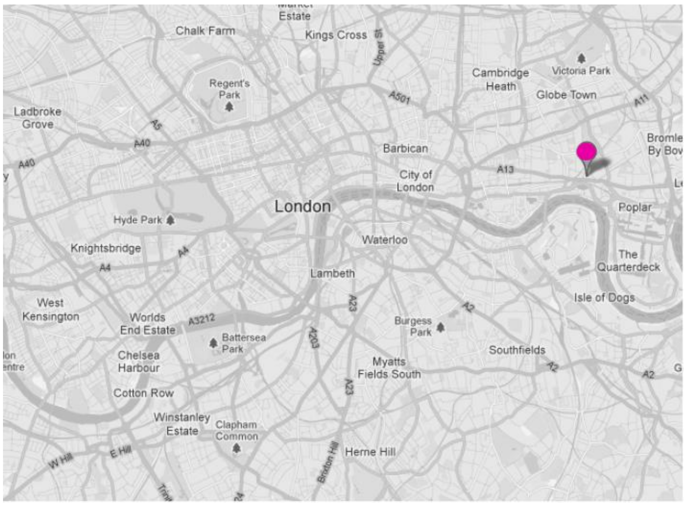

Figure 9

Figure 9. The city map of London. City center and Limehouse Neighborhood location .

In order to make visible the sound-scape of this area-a sound that is unique to an area- and produce sonic awareness, the sounds of this particular site in London were recorded and translated into an architectural proposal. The idea is to "see what the sound looks like in a particular place" and through this, to provoke a multi-sensory experience in the user.

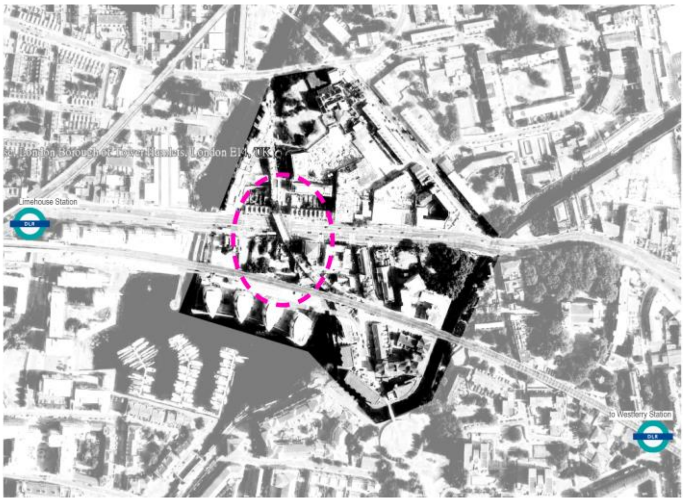

Figure 10

Figure 10. Google Earth İmage of Limehouse Area. Dashed line represents the neglegted bridge and its surrounding area.

The proposal is an urban path and connector between two different "sound areas" and making use of an abandoned rail bridge, this construction crosses a busy road to a quiet area behind the new railways. To make possible the sound visualization, the sound was captured and recorded on real time. It means that the sounds used in this proposal, present the exact differentiation of the noise/calm areas as they were captured along the path. For the urban prototype we do not fix curves in the space, instead, the sound curves travel following the path, and are influenced in accordance to the area they are passing.

This form extends in a linear site, and unfolds as a vault that varies with the urban sound. The resulting form is dynamic with differentiation of spaces, densities and textures. The linearity is broke were the sound is higher because higher sound creates voids between the layers that could be used to accommodate internal spaces. The spaces are articulated with the continuity of the shape, as a linear and kinetic space, encourages the user to flow along it. The sound as the creator of the space is frozen in time and allows the user to witness and become aware of the acoustic environment. Wall, roof, and floor are all blend together, giving a sense of continuous space and enhanced perceptual experience. Nothing in this form is predictable; everything is opened to be discovered by the self-experience.

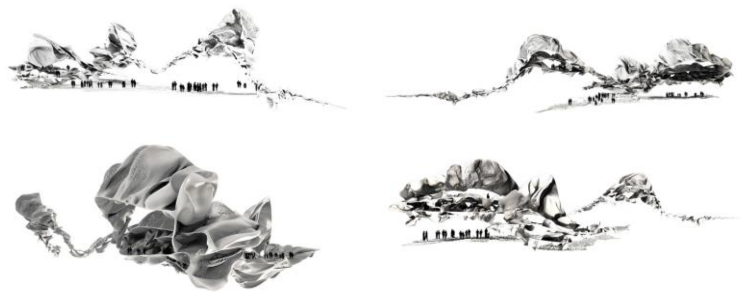

Figure 11. An Urban Scale Prototype: Elevations. Different elevations show the whole path adaptation to the different sound areas. Linear parts are in the calm areas and volumetric parts reflect areas with higher voice. (*Calisir, 2012*).

Figure 11

6. DISCUSSION/ARCHITECTURAL CONSEQUENCES

It became clear that all kinds of patterns and forms are being manufactured by not only frequency and amplitude but a generative design method which also incorporates time and the site context. All these parameters pose advance settings for digital control systems which evoke three-dimensional and responsive architectural forms (Lally and Young, 2007). Therefore, this kind of digital production of form is more sufficient and yields a variety of topological geometry. Also, what is worth noting here is the creation of kinetic space in addition to time and to give more architectural features to forms. Before going further, it is necessary to define the term kinetic. Kinetic is a term that can be expressed with the word motion in most cases. The term “motion” is a process of changing position or place over time (Terzidis, 2003). According to Terzidis (2003), “while time is involved in motion as a measurement of change, the form itself does not involve time. Thus, the kinetic form represents a motionless boundary and an extension of the notion of architectural form.”

6.1. The Term Kinetic in Art and Architecture

Before architecture, the kinetic had a long history in the art, especially after the 1950s when it was used in the movement of kinetic art (Terzidis, 2003). The history of kinetic art begins with the realist manifesto published in Moscow in 1920 by Gabo and Pevsner. They proposed that the traditional elements of plastic and pictorial arts are denied and that in these arts, a new element, the kinetic rhythms, will be claimed as the basic forms of our perception of real time (Rickey, 1963). Marcel Duchamp's sculpture Mobile wheel and his painting Nude Descending the Staircase can be given as examples. These art pieces are not three-dimensional but four-dimensional which is time as an interpretation of the actual movement (Rickey, 1963).

In architecture, on the other hand, the representation of motion is usually achieved with an abstract formal arrangement which depends on the relation between "cause and effect". Cause and effect relations can be created by different digital tools and simulations. Digital tools can be animated in simulations which are essential for not only designing kinetic processes but also for designing complex material systems and for analyzing their behavior over extended periods of time. Air, sound, wave and nuclear physics are commonly available simulations (Hensel et al, 2010). Another simulation that has been mentioned so far is sound. The movement in the sound motion streaks process is provided by Audio Node and its connection with time. Small variations in the Audio Node in each sequence may produce changes in the development of each component at many different scales. Hence, as time goes on, architectural form continues emerging through much more complex and articulated space. Terzidis (2003) posited that in this complexity of form, users' eye can catch the virtual movement and the physical stimuli which forms have. Furthermore, from all digital experiments, it can be said that apart from the complexity of kinetic form, all shapes driven by sound have in common rhythmicity, motionless boundaries and changeability over time, no matter their different materials, causes or functional mechanisms. Therefore, in this design process, form is literally a product of matter. It is actually an abstract entity to which process gives certain geometric and kinetic characteristics (Terzidis, 2003).

Kinetic form evokes generative processes and the concepts of interactivity, modifiability and continuous evolution with the help of time (Tierney, 2007). In terms of time, kinetic forms produced by sound change over time and this motion either freezes the moment or makes complete. In both ways, kinetic form has great architectural value because it consists of agitated surfaces, compressed planes and penetrated spaces in both ways. Even though movement is frozen, the unique characteristic of architectural space remain; that is both dynamic and static (Terzidis, 2003). According to Terzidis (2003), it is dynamic because the design process provides an elastic essence and manipulation of entities. It becomes static when it has to freeze in order to be built. Therefore, it contains a large collection of forms from which architects find the most suitable in terms of function, architectural space and environmental context.

Figure 12. An Urban Scale Prototype. A view from surface. Voids break the linearity of the path and create internal spaces. (*Calisir, 2012*).

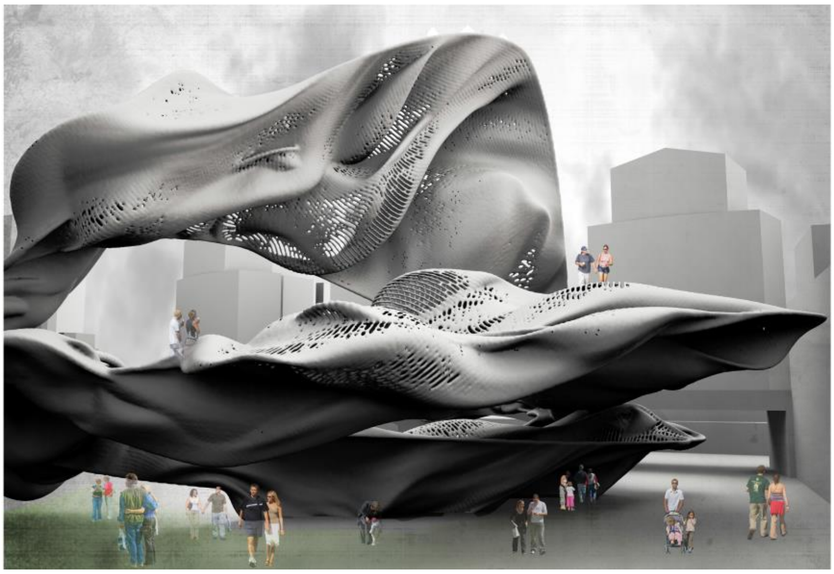

Figure 12

6.2. Conclusion

This paper proposes a method to create forms and patterns in a dynamic-kinetic process by using sound as an external force. To create this method, first physical, then digital experiments are done to understand the sound phenomena and its influence on materials. After these phases, we construct our method with 3 different tools in Autodesk Maya-curves, particles and polygonal mesh-. Sound affects this hybrid material system and we manipulate time-sound and material properties through Hyper Shade. The ultimate form emerging in this process depends on time therefore we can track the whole process along the form and this brings kinetic properties to spaces created in the Sound Motion Streaks Project. The value of this kinetic process is its changeability and endless topology. Moreover, in this animated space, users discover sound with their eyes and become aware of the sound-scape of the area. Through this multi-sensory experience, users can not only hear the sound in the environment but also see and touch therefore, the perceptual experiences are enriched and enhance.

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[1] http://www.acs.psu.edu/drussell/demos.html

[2] http://www.physicsclassroom.com/class/sound

Software Using:
Autodesk Maya
Raven Pro 1.5 Beta Version: Interactive Sound Analysis Software