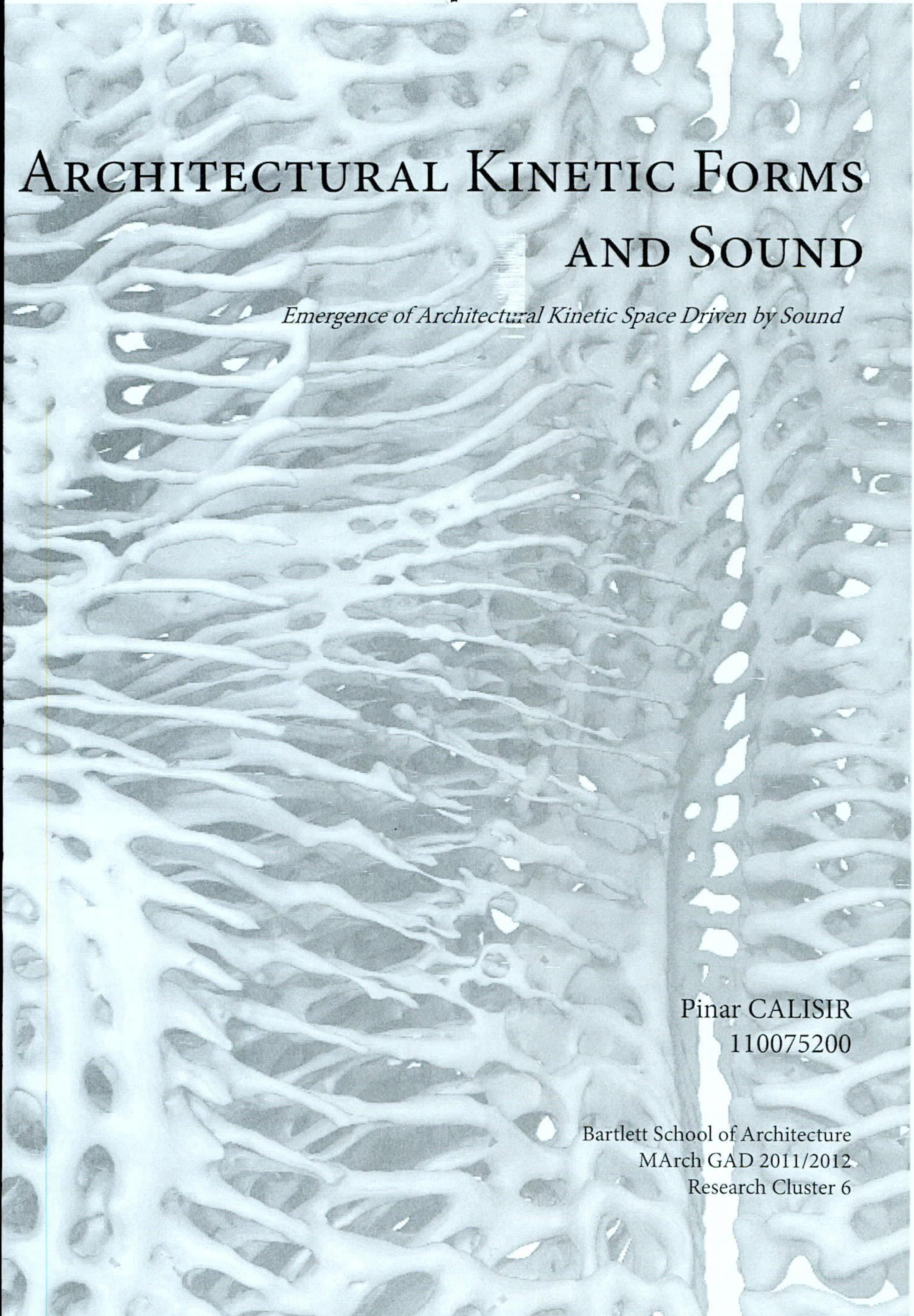

Architectural Kinetic Forms and Sound

Emergence of Architectural Kinetic Space Driven by Sound

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ABSTRACT

Music and architecture have shared a long relationship throughout history. Architects have designed different proposals to allude to this relation in their works. In this regard, this paper aims to propose another approach to producing architectural space with music and to examine the notion of space emergent in this approach. The paper begins with a history of music in architecture, even with music in the cosmos, so that the theoretical basis and aesthetic of this relation can be understood clearly. After historical reviews, the paper searches for a different method of using sound in order to create architectural space. This method relies on an idea which is to use sound as an external force which can produce shapes or deform shapes in order to its influence. After deciding the method, next phase of the experiment is to simulate sound as an influence. In digital software, sound can be a force field and manipulate tools such as particles, curves or meshes. The most important factor in this generative design method is time. Because all events depends on duration and movement of digital tools; the notion of form and/or space become kinetic and this 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.

From the Earth to the Moon	one tone
From the Moon to Mercury	one semi-tone
From Mercury to Venus	one semi-tone
From Venus to the Sun	one and a half tone
From the Sun to Mars	one tone
From Mars to Jupiter	one semi-tone
From Jupiter to Saturn	one semi-tone
From Saturn to the Fixed Stars	one semi-tone

Fig 1
Musical intervals between planets (Proust, 2009)

Introduction

From ancient times, analogies, coincidences and affinities have existed between musical and architectural compositions (Capanna, 2009). From the Renaissance to the era of modern architecture, music is sometimes an inspiration for architectural imagination, sometimes a direct image for illustration, or sometimes a proportional system for organising the elements of architecture. As the following part will outline, philosophers have interpreted even the cosmos itself to have been built with music.

The Cosmos and Music

One of the most significant discussions in ancient philosophy was about the relationship between the cosmos and music. In ancient times, philosophers sought to discover a relationship between natural phenomena, for instance the movements of the sea, the periodical reappearance of stars and sonic phenomena such as resonance and echo. The common point of these phenomena was the numerical orders that they have. Hence, philosophers used the harmony of music in order to describe the cosmos and to understand its initial material. For example, Pythagoras (532-497 BCE) asserted the cosmos to be a harmonic instrument based on mathematical relationships in musical harmonies. According to him, there were musical intervals between planets, which move around the world with a certain speed (Fig 1), and therefore musical harmony was the secret of the cosmos (Proust, 2009).

Fig 2
Athanasius Kircher, Musurgia Universalis: Pythagorean illustration of the Universe (Eggington, 2004)

Fig 3
Athanasius Kircher, Musurgia Universalis (Eggington, 2004)

In the seventeenth century, interest in musical harmony and the cosmos was continued by scholars such as Athanasius Kircher. In his encyclopaedia Musurgia Universalis (1650), he wrote not only texts about music of the seventeenth century, but also many philosophical ideas about the universe. He identified the cosmos in terms of musical ratios which exist in the harmony of music reflecting the harmony of God (Eggington, 2004).

In Musurgia Universalis, Kircher illustrated a number of sophisticated diagrams and visual materials about musical harmony in the cosmos. For instance, in Fig 2, he suggested a system of the cosmos based on Catholic doctrine and his philosophical points of view. In the Figure, Trinity is at the top of the triangle and is surrounded by nine angels singing a complex canon which is known as polyphony and which simulates cosmic harmony. The similar polyphony exists between the six planetary ratios and the six intervals in music (Eggington, 2004).

HISTORY OF MUSIC IN ARCHITECTURE

Architecture from Musical Ratios

Leon Battista Alberti

Leon Battista Alberti was not originally an architect but nevertheless authored the book De re aedificatoria libri decem (On the Art of Building), which laid out the most important architectural theory of early modern times (Nebois, 2011). Alberti was certainly influenced by music, most fundamentally while shaping his theories of proportion and perspective. Like Reynolds (1987) had put forward in his ideas, according to Alberti, architects should borrow all of their rules from harmonic relations and draw on the help of musicians, who are extremely well-known with regard to these sorts of numbers.

Additionally, in De re aedificatoria, Alberti used the harmonic ratios in order to define the limits of architectural elements, guaranteeing that the beauty of any man-made object can be guaranteed based up on these rules. The rules have two important fields of application: the determination of areas and the determination of volumes (Pintore, 2004)

The harmonies that Alberti uses to give structure to his harmonic areas are based on the Pythagorean scale. Pythagoras, according to a legend, found that there is a numerical ratio between two consonant sounds and the size of the instrument's component (e.g. string) producing them so that sounds are produced by two chords equal in material, thickness and tension but are of different lengths. From this law, the school of Pythagoras produced the Pythagorean musical scale, which has musical harmony according to mathematical ratios between the notes (Pintore, 2004).

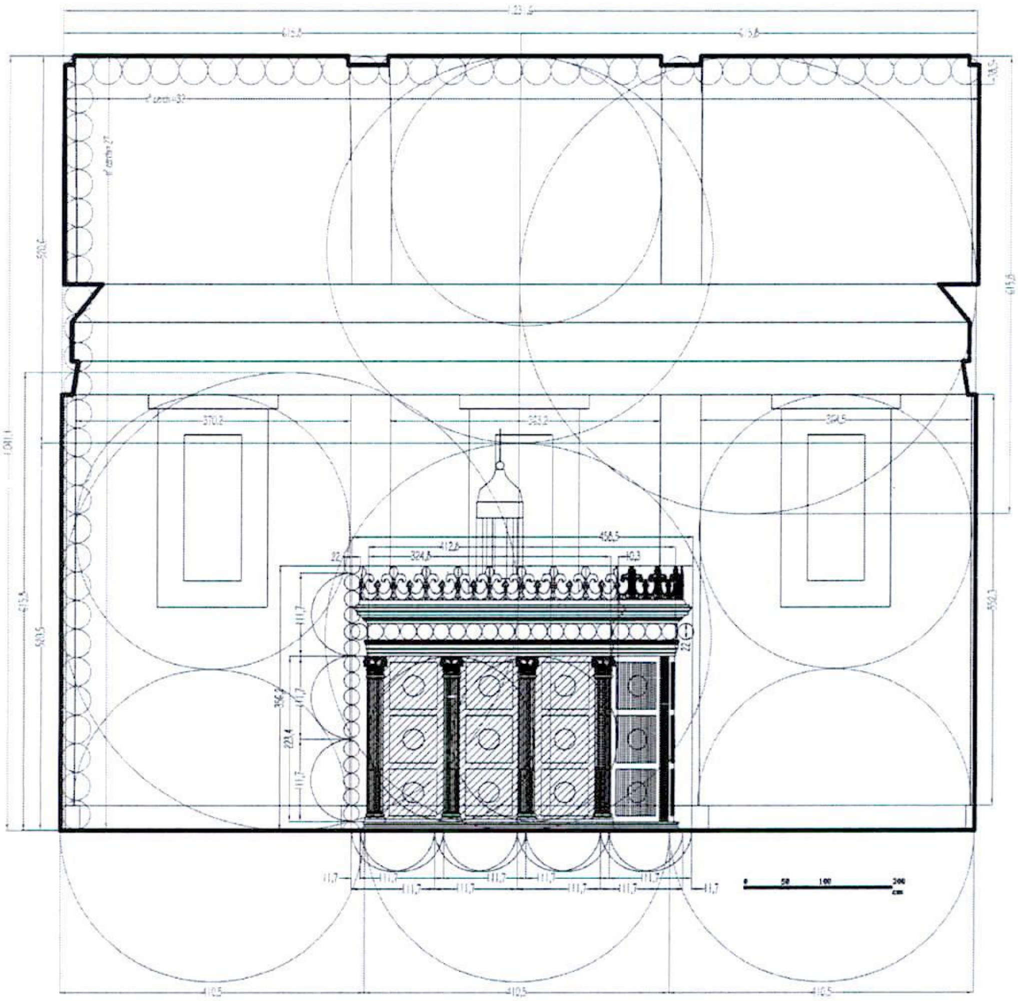


Fig 4
Geometric harmony analysis of the side elevation of Alberti's Chapel in Florence (Pintore, 2004)

Fig 5
Pythagorean diatonic scale on C

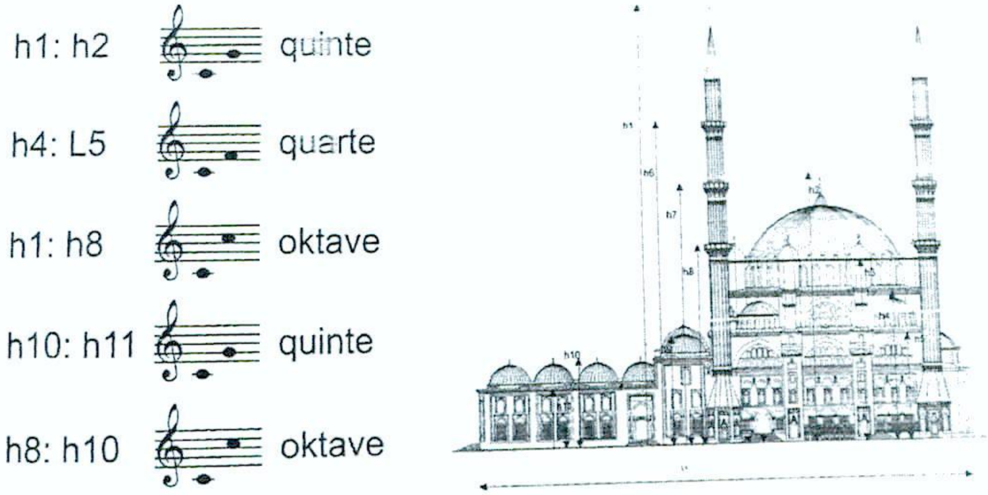
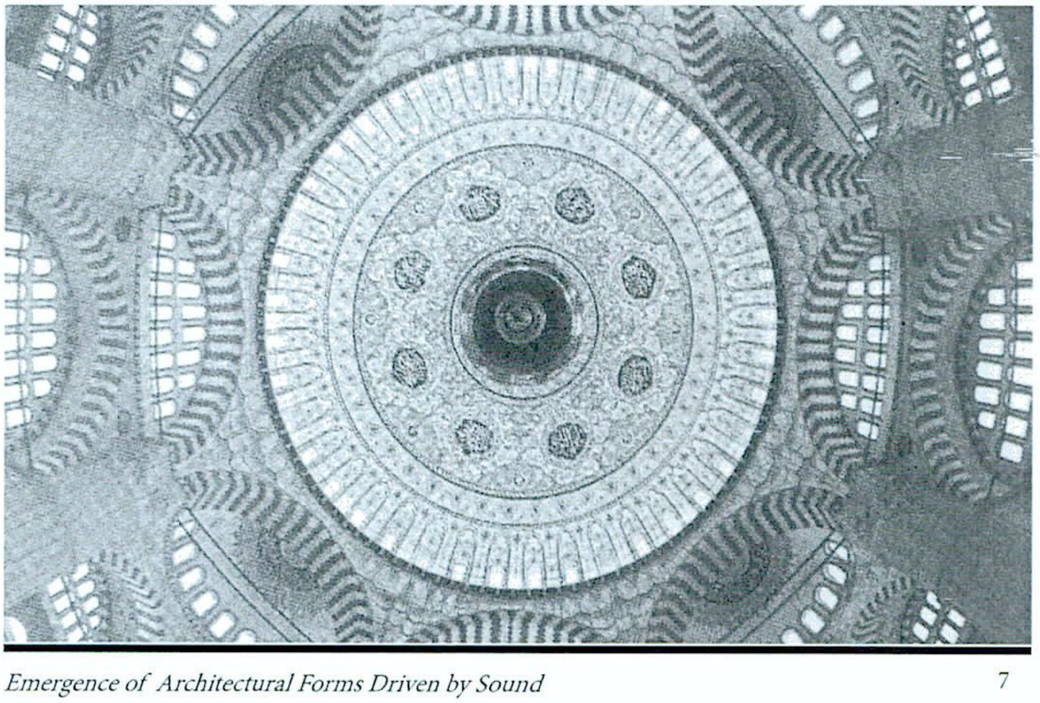


Fig 6

Architect Sinan-Selimiye Mousque harmonic proportions, Edirne/Turkey (Erozu, 2008)

Fig 7

Architect Sinan-Selimiye Mousque harmonic compositions of elements-inside, Edirne/Turkey (Erozu, 2008)



Architect Sinan

In Western culture, mathematics is undoubtedly an important tool of communication and something of a common language between music and architecture. It is interesting that a similar relationship and similar numerical ratios is also evident in the works of Architect Sinan, who was the famous Ottoman master of buildings, who took his inspiration mostly from Eastern culture but also knew the Western art of construction very well (Erozu, 2008).

Architecture from Musical Inspiration

Daniel Libeskind

Libeskind (2008) uses a number of inspirations while designing space, one of them which is certainly music because of his background. He studied music in Israel with a scholarship and became a virtuoso performer in New York before studying architecture. Musical inspiration is evident in many his works, but his early design Chamber works and most famous work, Jewish Museum are examined in this essay.

Chamber Works

In Chamber works, Daniel Libeskind's inspiration was chamber music, which consists of a few instruments; only those which can give logic to the musical composition. A set of 28 drawings completed in 1983 consists of a large number of lines coming together and producing a continuum form that Kurt W. Foster (Libeskind, 1991) defines as spatial music. The structure of drawings, lines and symbols represents an axial structure of sounds made from melodies and chords (Capanna, 2009).

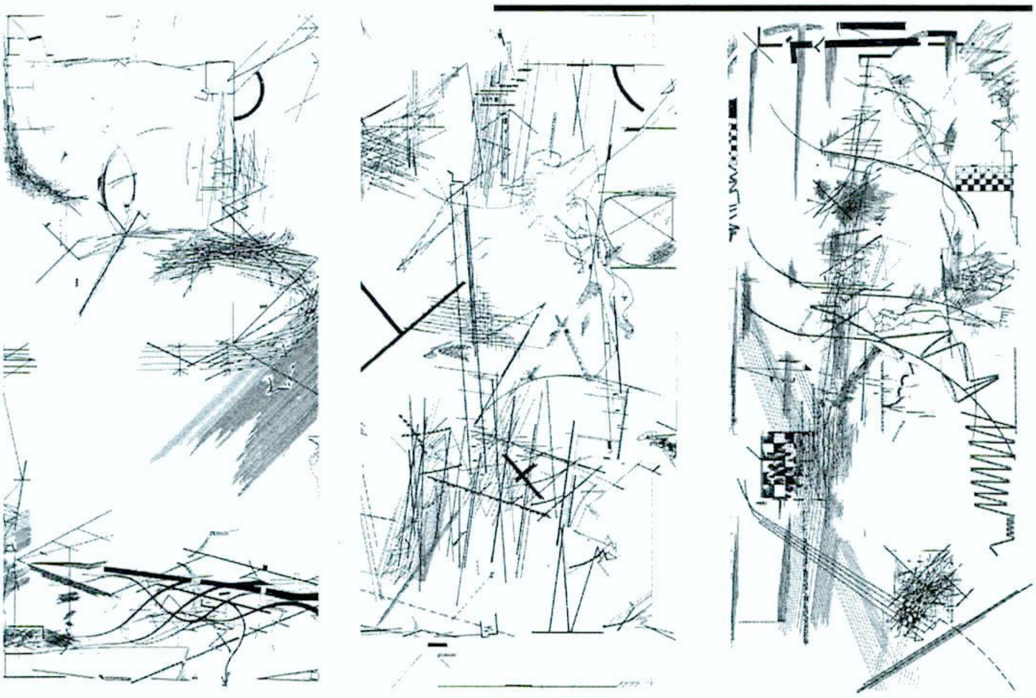


Fig 8

Daniel Libeskind, Chamber Works II-V / I-V / III-V (http://daniel-libeskind.com)

Jewish Museum

The same methodological process used in the Chamber Works, was also applied to the elevation of the extension project of the Berlin Museum's section dedicated to the Jewish Museum Department (Capanna, 2009). The real inspirations for this design though were history and of course Arnold Schönberg's intelligent composition: Moses und Aaron (Libeskind, 2008). Schönberg is the inventor of the dodecaphonic musical form which breaks the structural concord of music. His unfinished opera Moses und Aaron is the mixture of instrumental and vocal music which ends with the words: "Oh word, thou word, that I lack". In 2008, Libeskind expresses that: "It is true, most musicologists believe that the opera is finished with act 2 but there is of course act 3, which has no musical equivalent. Arnold wondered what music can be without the absence of God and humanity". Therefore, in his design, Libeskind tried to finish Schönberg's opera with an architectural response. Schönberg's idea concerned what happens if God himself dies and there is a huge emptiness after him. Libeskind incorporated this idea and design into some spaces which he called "the void". These spaces are not for exhibitions and they have no spatial function either. However, they represent the human soul without humanity. They were like the long pauses in the Schönberg opera or the eternal silence after the opera finishes.

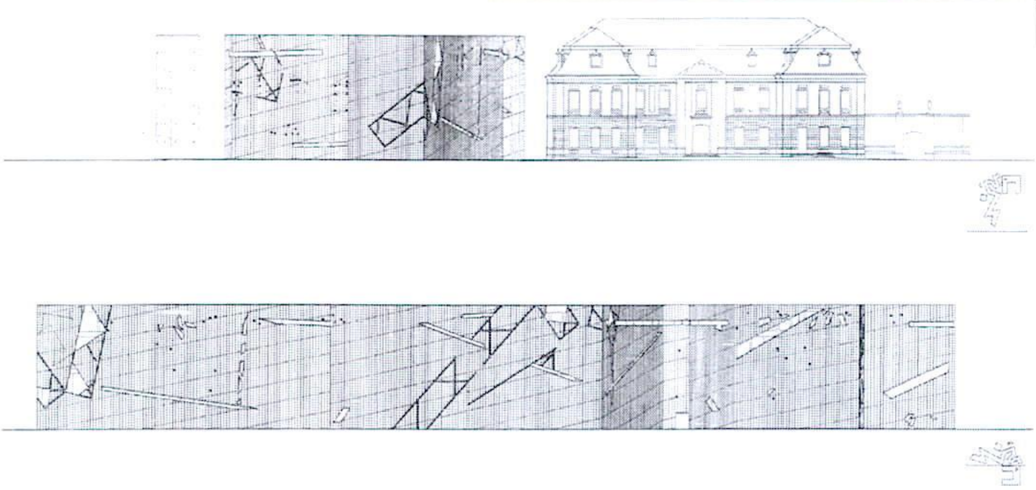
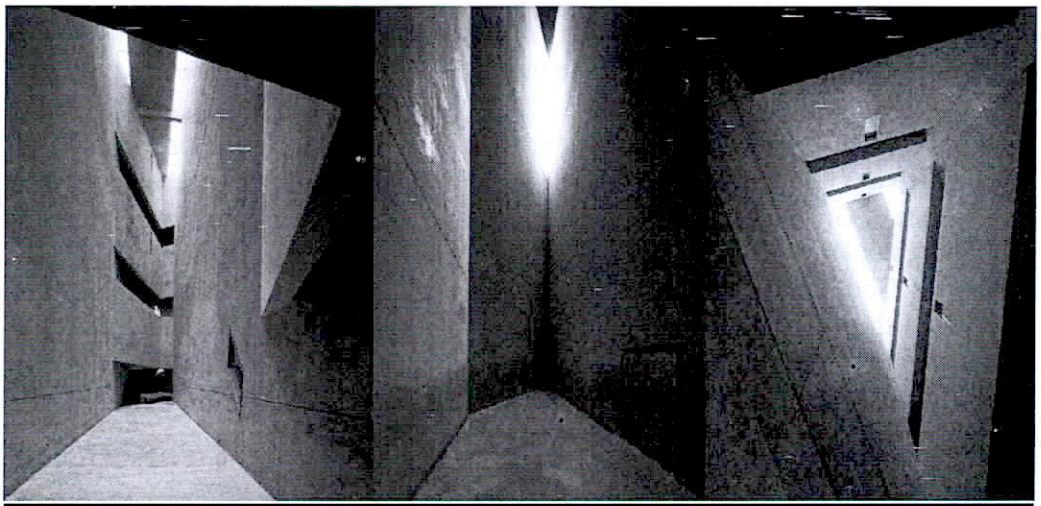


Fig 9

Elevations of Jewish Museum Extension- similarities with Chamber Works can be clearly seen (Capanna, 2009)

Fig 10

The Voids in the Jewish Museum (Capanna, 2009)



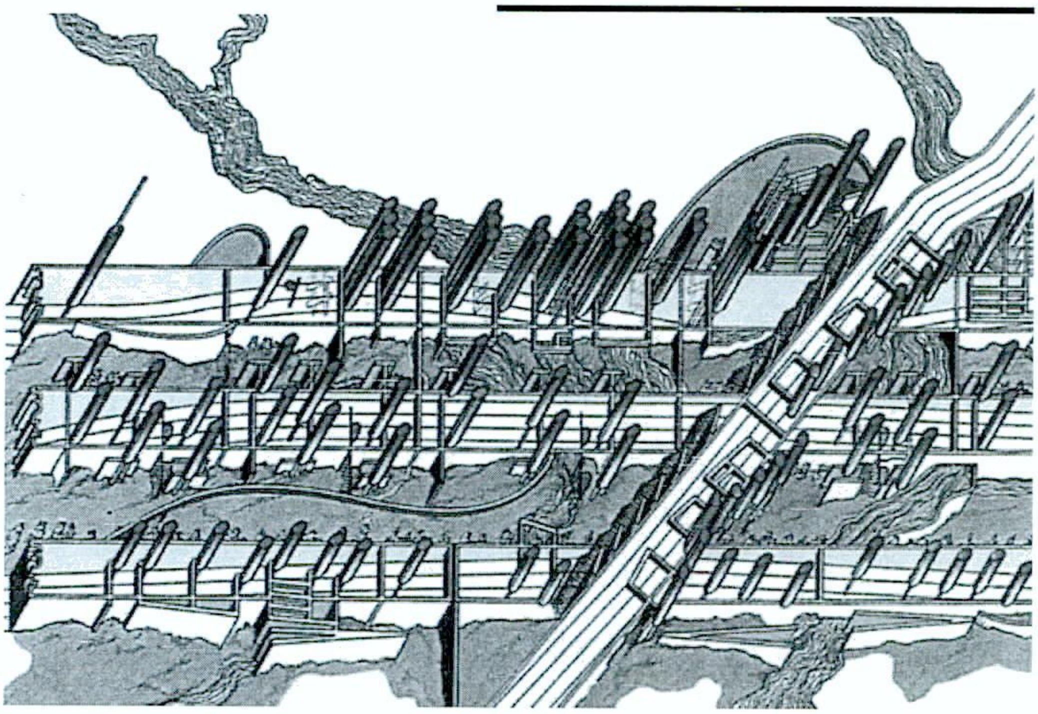


Fig 11

Peter Cook-Bloch City/ City with towers on musical writings (Capanna, 2009)

Architecture from Musical Writings

Peter Cook

Peter Cook is a founder of the historical group Archigram. His imaginary project, Bloch City, is an architectural transformation of Ernest Bloch's concert violin in order to plan an ideal city. Capanna (2009) quotes these sentences from Peter Cook: 'A simple exercise was the interpretation of a piece of a violin concerto by Ernest Bloch. Not a piece that I know, but one that looked tempting on paper. The notes become towers, the stave becomes a street, and supporting markings become walls. Around the time, I had set a series of short projects for students on idea of 'music' as a direct architecture [...] The notes on the staff represent the planimetric position of tall cylindrical skyscrapers while the musical lines are the urban highways of the 'great march'" (Capanna, 2009).

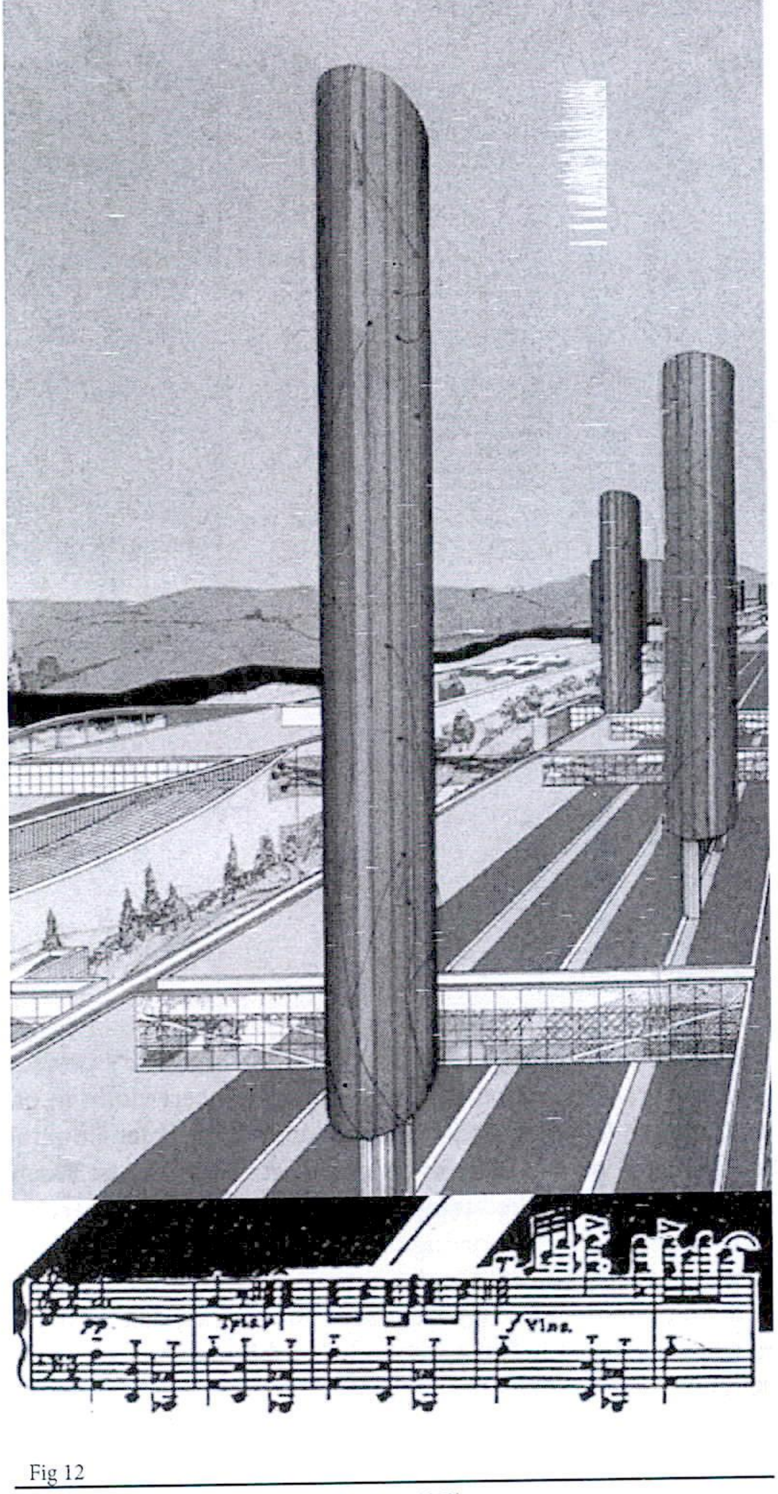


Fig 12

Peter Cook-Bloch City/ Street views (Capanna, 2009)

ARCHITECTURE FROM MUSICAL COMPOSITIONS

Le Corbusier/Iannis Xenakis

Two important projects from Le Corbusier's office can be elaborated while investigating the relation between music and architecture: La Tourette and Philips Pavilion, with the collaboration of Iannis Xenakis, who worked with Le Corbusier, and provided the musical quality of these buildings. Xenakis's musical intelligence was fed by complex techniques of mathematic and non-linear conception of form. Therefore, an architectural quality can be clearly seen in his musical compositions (Harley, 2011) and vice versa, he could adapt his musical talent and imagination into architecture.
In 1956, Le Corbusier had invited Xenakis to work on the monastery of La Tourette, applying the Modular proportional system to plan the musical spacing of the glass and mullions of the expanses of windows that faced the fields. The transition to a project rooted in geometry and music was natural (Varese, 1996). He was impressed with the numerical proportions of the Modulor and Xenakis had applied its divisions to his musical composition Metastasis, which explored the dissolution of the uniform and continuous duration of notes (Varese, 1996).

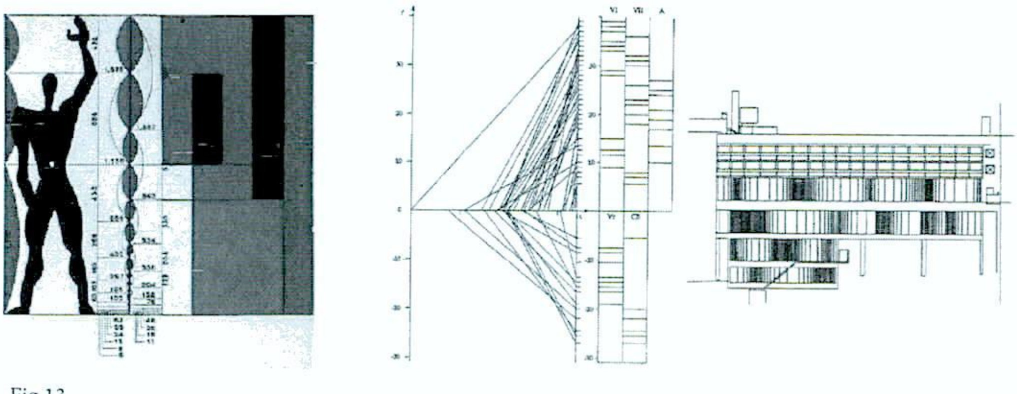


Fig 13

Modular by Le Corbusir, sheme of curves in Metastasis by Xenakis amd west Facade of La Touratte (Korkut, 2011)

In the winter of the same year, the Philips Company invited Le Corbusier to design a pavilion for the upcoming world's fair. Le Corbusier wanted to take a different approach for this proposal and presented them with 'an electronic poem', which has sound, light, colour, and rhythm inside (Varese, 1996).
Xenakis designed a geometric form for the pavilion because of his background as a mathematician. Xenais's graphing of the string glissando of the Metastasis resembled the ruled surfaces of hyperbolic paraboloid shells (Varese, 1996).

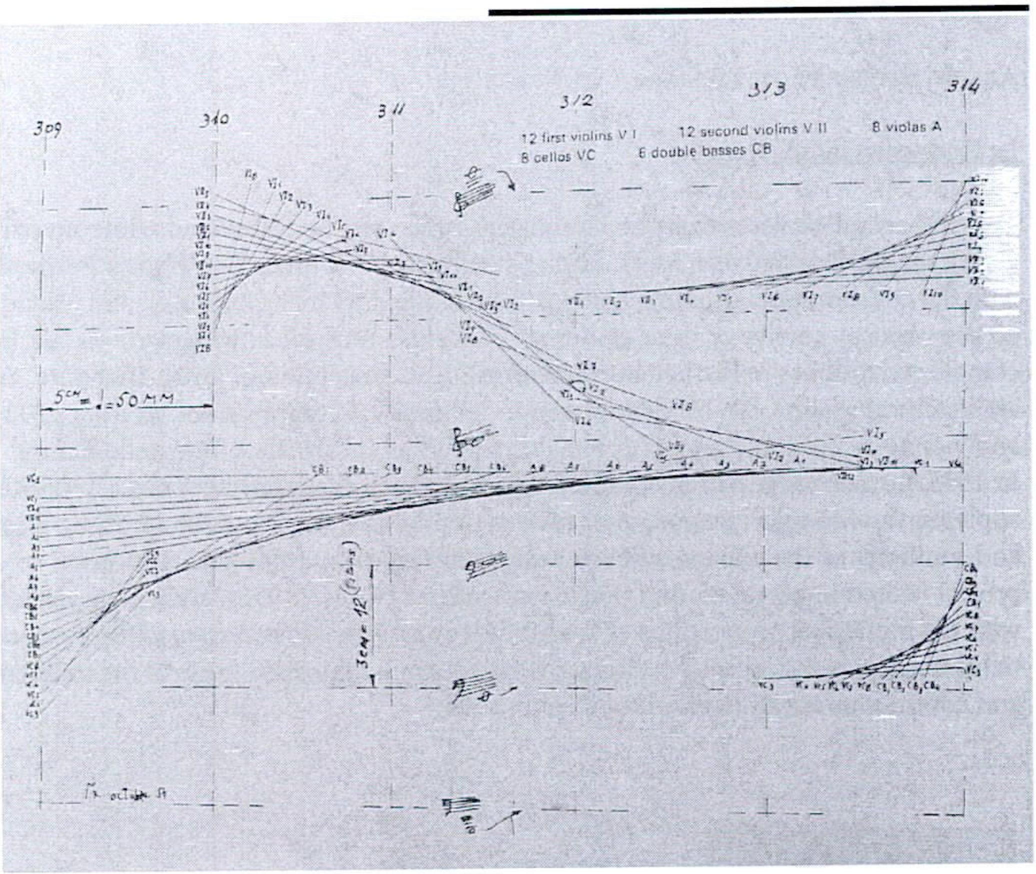


Fig 14
Hiperbolic paraboloid system in Metastasis by Xenakis (Varese, 1996)

Fig 15
Hiperbolic paraboloid system in Philips Pavilion (Varese, 1996)

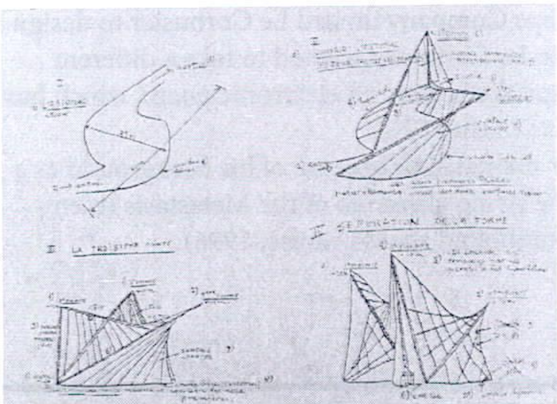


Fig 16
Philips Pavilion under construction (Varese, 1996)

Overall, as introduced so far, architects throughout history have used sound, generally music, in order to create their designs in many different ways such as a proportional system from mathematical structure of music or an inspiration and a metaphor, or an illustration that can be translated into architecture. However, the following part introduces images that present another and completely different method of using sound in architecture. In this method, forms and patterns in the images were created by sound directly, digitally and physically, instead of utilising it as an indirect element of design approach.

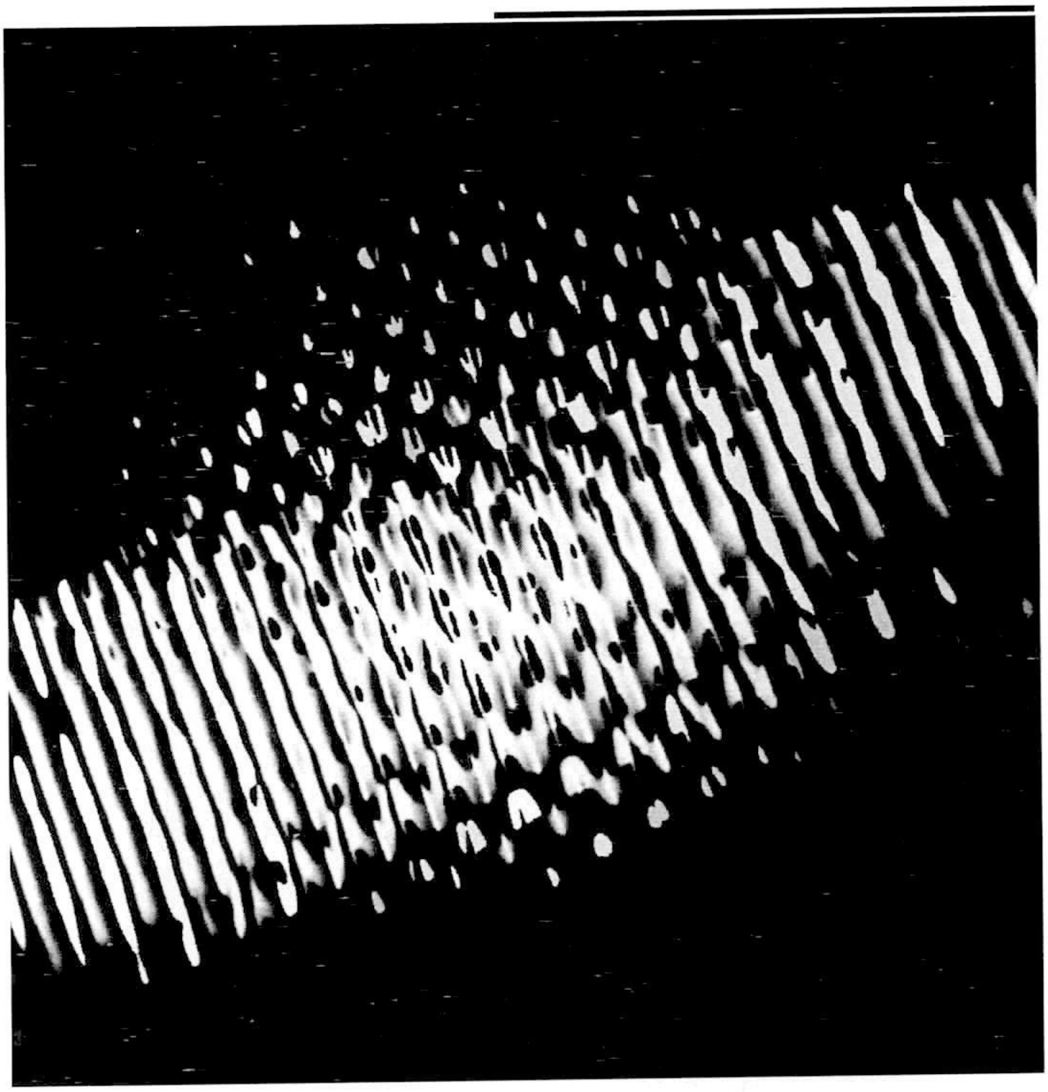


Fig 16

Sound vibrations on the surface of the water (Jenny, 2001)

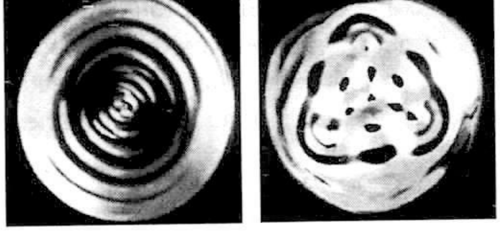


Fig 17

Sound vibrations on the surface of the water/first one is the initial wave and according to time surface is deformed into various different ways (Jenny, 2001)

ARCHITECURE FROM SOUND INFLUENCE

Nature has many different periodic systems constantly changing from one assemblage of conditions to another, opposite one. The processes of these circulations are regulated by natural forces that consist of rhythmic periods. From the smallest scale to the largest, a large range of repetitive forces can be found in nature. For instance, in the human body, the nervous system is operated by impulses which are basically simple serial frequencies, or in the muscle system, each muscle communicates with the others through simple vibrations. On the basis of vibrational phenomena, sound can be seen as another instance. 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 (Jenny, 2001).

Since the eighteenth century, scientists have been working 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 was thereby able to make the sound vibration process visible (Jenny, 2001).

After Chladni, the most important person working in this area was Hans Jenny, a physician and natural scientist who founded cymatics, which is the 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. For instance, in one of his experiments, the plate was attached to an oscillator that was controlled by a frequency generator capable of producing a wide range of vibrations. Through changing a dial on a generator, Jenny could create different sound patterns with different frequencies (Jenny, 2001).

Jenny tried different apparatus' and matters to discover sound deeply and found that all material experiences under the same physical forces and same stresses react with similar patterns. He observed three fundamental principles in his work. He held that these phenomena, based on sound vibrations, confronted us with patterned formations and kinetic-dynamic processes, all generated and maintained by sound periodicity (Jenny, 2001).

Overall, according to Jenny (2001), sound is physical strength that can create vibrations and finally systemised patterned forms.

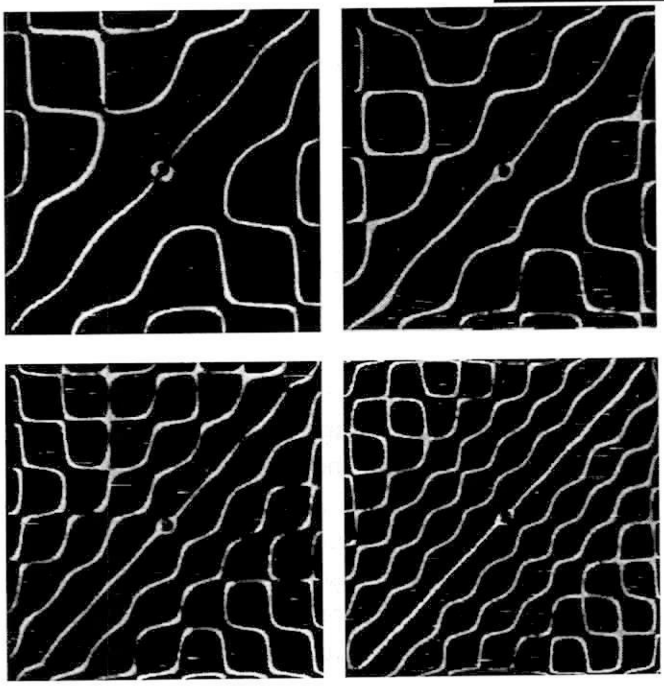
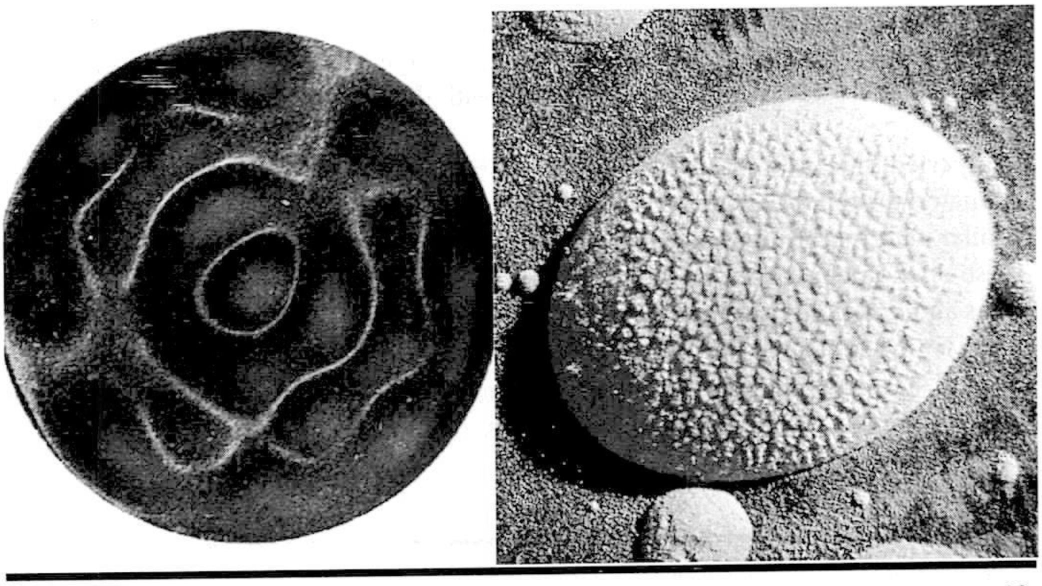


Fig 18

Chladni experiments in Cymatics/ Same topology of patterns but number of elements are growing as the pitch goes up (Jenny, 2001)

Fig 19-20

Chladni experiments in Cymatics/ Fig 19 is produced by speaking directly into tonoscope so that it represents particular sound in each frame. Fig 20 represents much more higher complexity which is generated in the system of Fig 18. According to duration of time, matter reacts in a different way and some of particles splits from the whole system (Jenny, 2001)



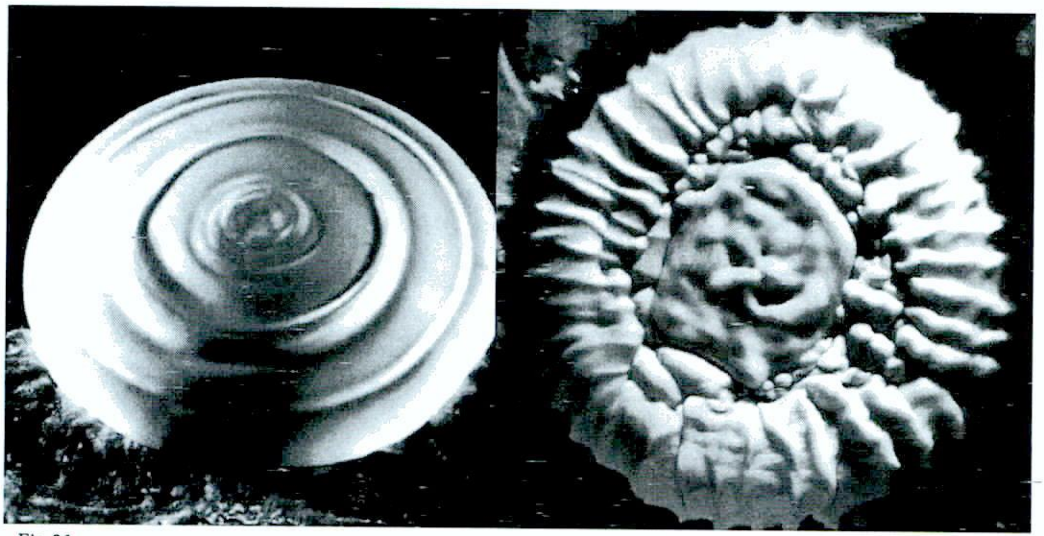
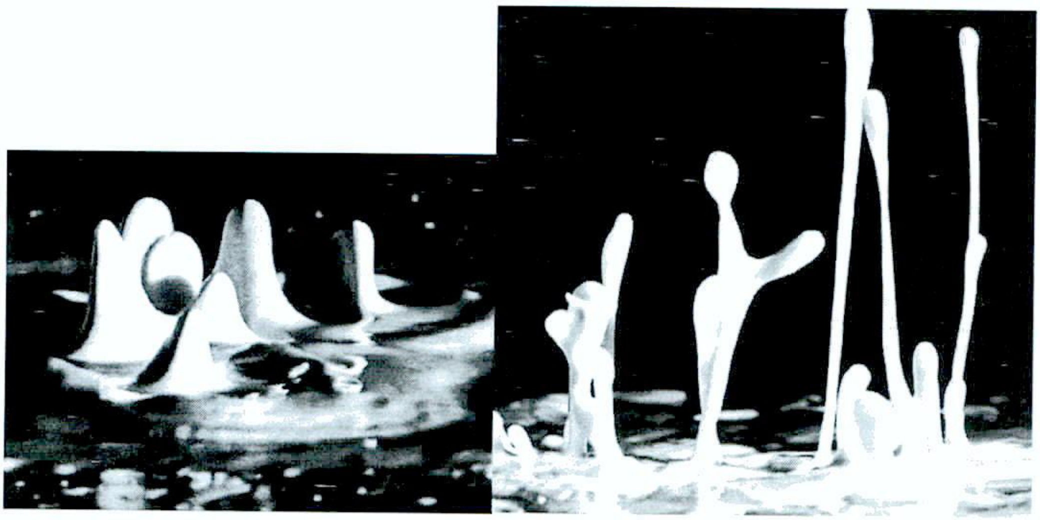


Fig 21

Cymatics Experiments: A Viscous Paste / Influence of sound can be seen as waves beginning from the center of the matter and according to time and amplitude it constantly changes its vibrational patterns (Jenny, 2001)

Fig 22

Cymatics Experiments: A Viscous Paste / Same process with Fig 21 but this time viscousity of matter is affecting the overal shape and create lighter structures(Jenny, 2001)



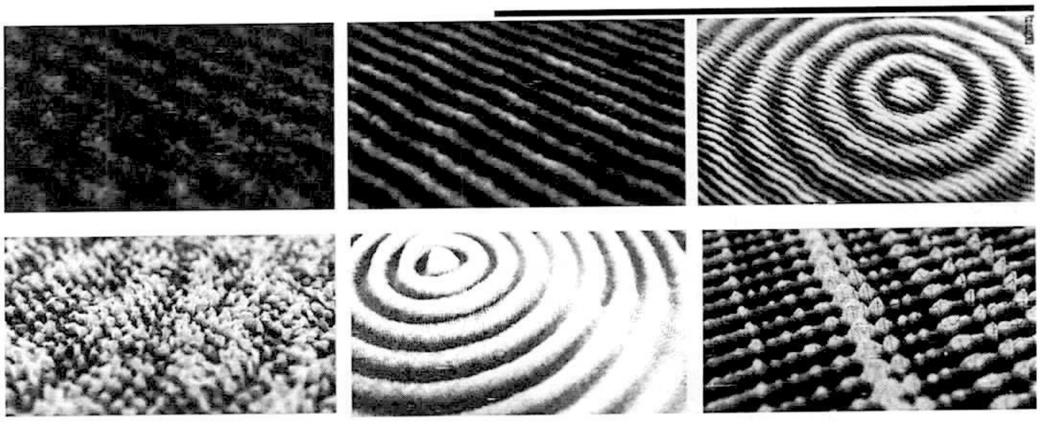
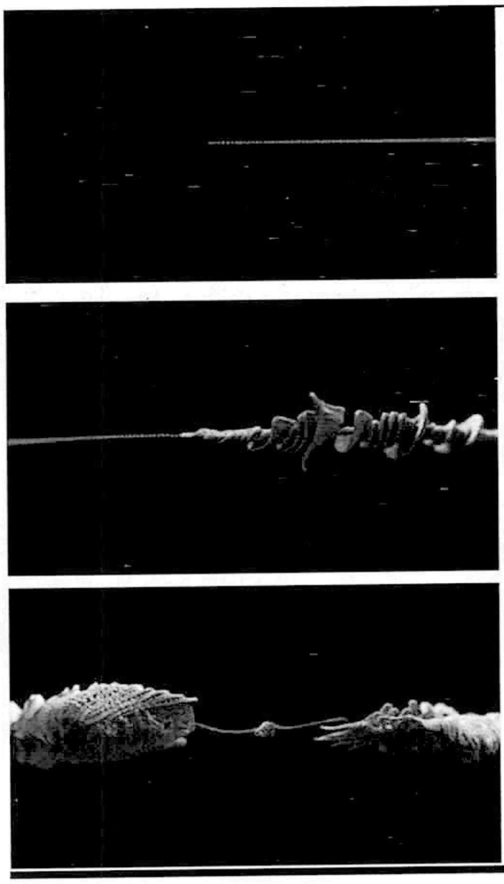


Fig 23

20 Hz - visual project / visualisations from different frames of the video generated directly by sound of the upper atmosphere (http://www.semiconductorfilms.com)

Fig 24

Balance - visual project / visualisations of different frequencies of sound and its effects on granular matters (http://www.korb.lt)



DESIGN PHASES

1. Understanding the Influence of Sound

Multiple physical experiments are generated in this phase, in order to deeply understand which parameters of sound actually create forms, deform shapes, or produce patterns. Water, sticky fluid made from water and starch, salt are used for physical experiments. 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 the 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 all of materials either have viscosity or a particular system, they continue to change through more complex and heterogeneous formations over time until the process is over.

From the physical experiments it can be said that the parameters of sound which cause changes on the matters are frequency and amplitude. The frequency is a quantity of waves that pass from a certain point in a second and determine the sharpness of the sound; on the other hand, the amplitude is the height of the sound wave and determines the violence of the sound.

Furthermore, according to these experiments, material behaviours (one is fluid and the other is particles) can be observed over a period of time under the influence of sound parameters. For particles, their granular nature causes a discontinuity of form boundaries and instability of aggregate formations, but more importantly a lack of understanding of their physics. Thus, particles under a kinetic movement seem to be an unlikely candidate for use in architecture (Hensel, Menges & Weinstock, 2010). Similarly, it can be said that fluid systems also have these kinds of features based on their common behaviours during the experiments.

Overall, in physical experiments, three key determinants of material behaviours and the geometry of form arrangements can be determined: the mechanical properties of materials, the influence of sound and time.

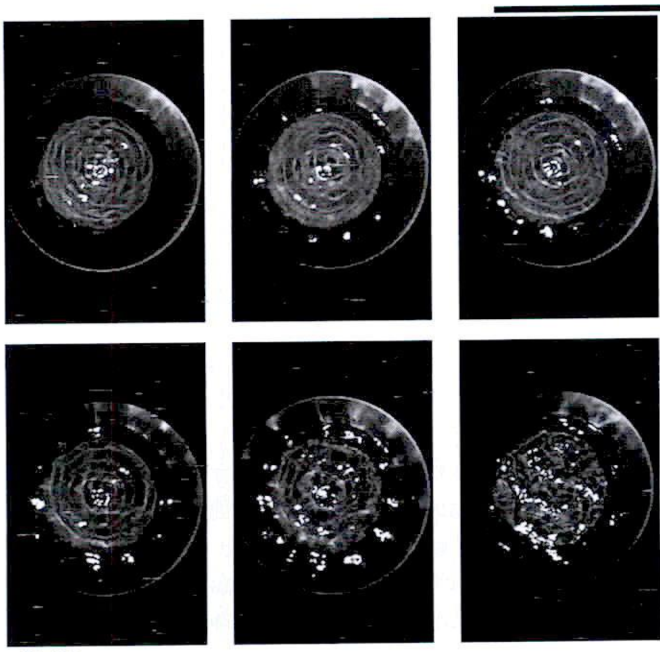
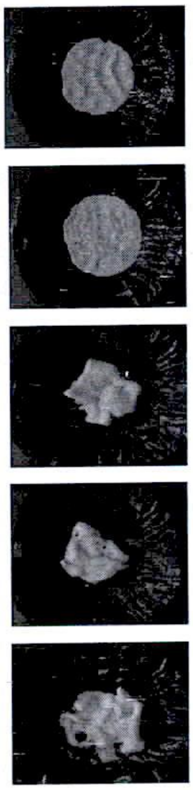


Fig 25

Physical Experiments with water, according to amplitude and frequency different patterns emerge on the surface

Fig 26

Physical Experiments with sticky fluid, according to amplitude and frequency different patterns and spaces emerge



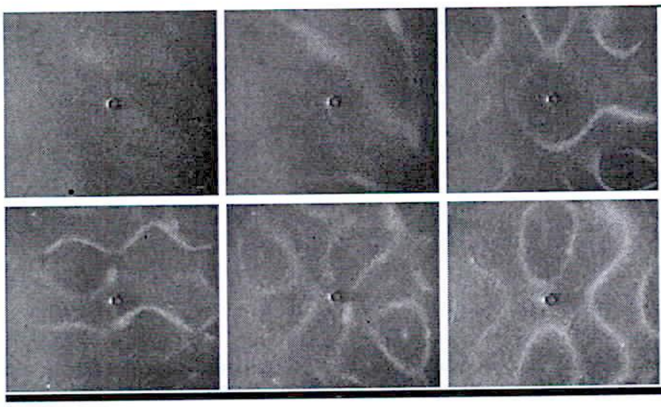


Fig 27

Physical Experiments with salt, according to amplitude and frequency different patterns emerge

Fig 28

Experiments with salt-Differentiated matter from the whole

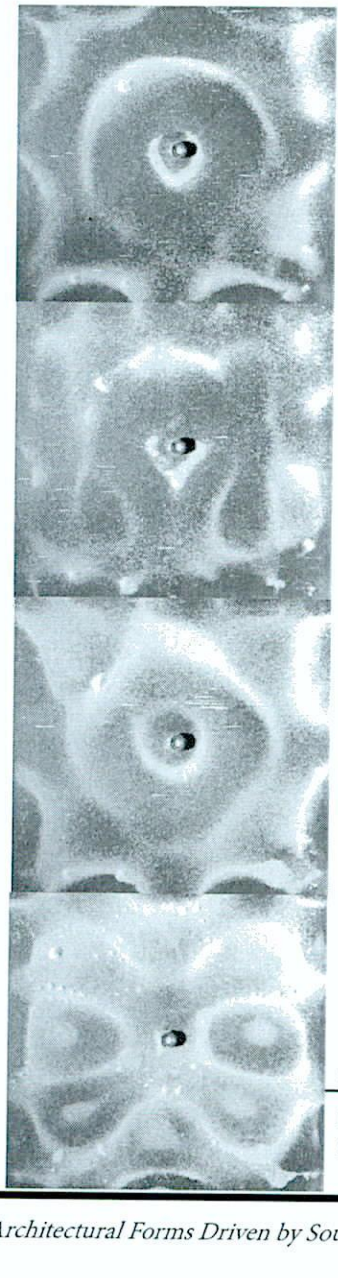


Fig 29

Experiments with salt-Transition phases from one pattern to another

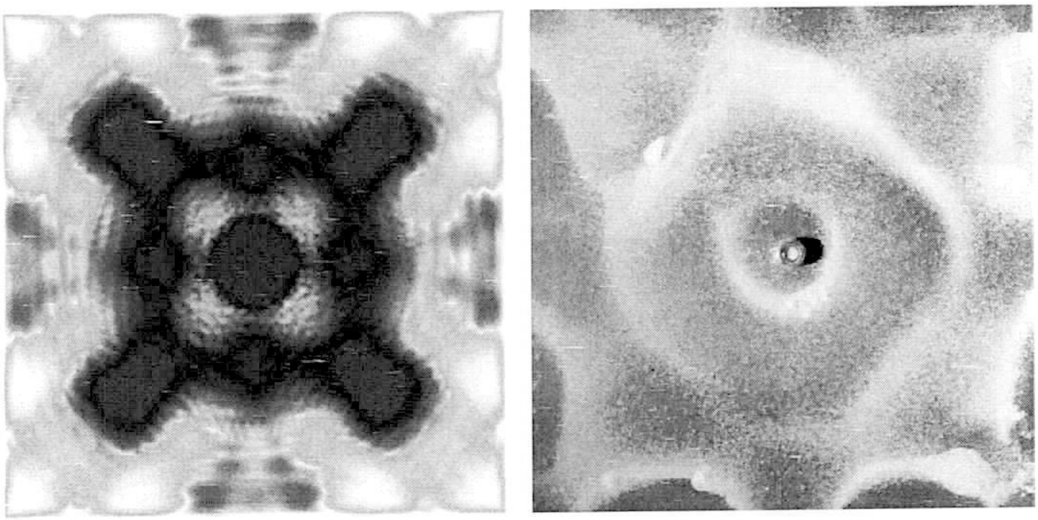


Fig 30

The effet of sound on the digital and physical matter

2. Simulating the Influence of Sound as a Map

The second phase of the research is based on digital experiments. Under the influence of extrinsic forces _in this case, sound_ digital simulations give a higher degree of control over the design process. Firstly, the sound waves are demonstrated digitally with constraints in order to explore the capacity of adaptation and integration in the site context. An initial set of experiments seeks out different arrangements of sound sources and geometrical configurations and also interactions between two different sound waves in the same foursquare volume. It can be clearly seen that site boundaries and different waves produce different patterns during the time. In other words, patterns give adaptive responses to changes in their environments. These experiments are also similar to the digital demonstrations of Chladni plates, but with the utilisation of more than one sound wave.

Fig 31

A sound source and a foursquare volume creating sound map (red dot represents sound source) (made by Ines Gavelli)

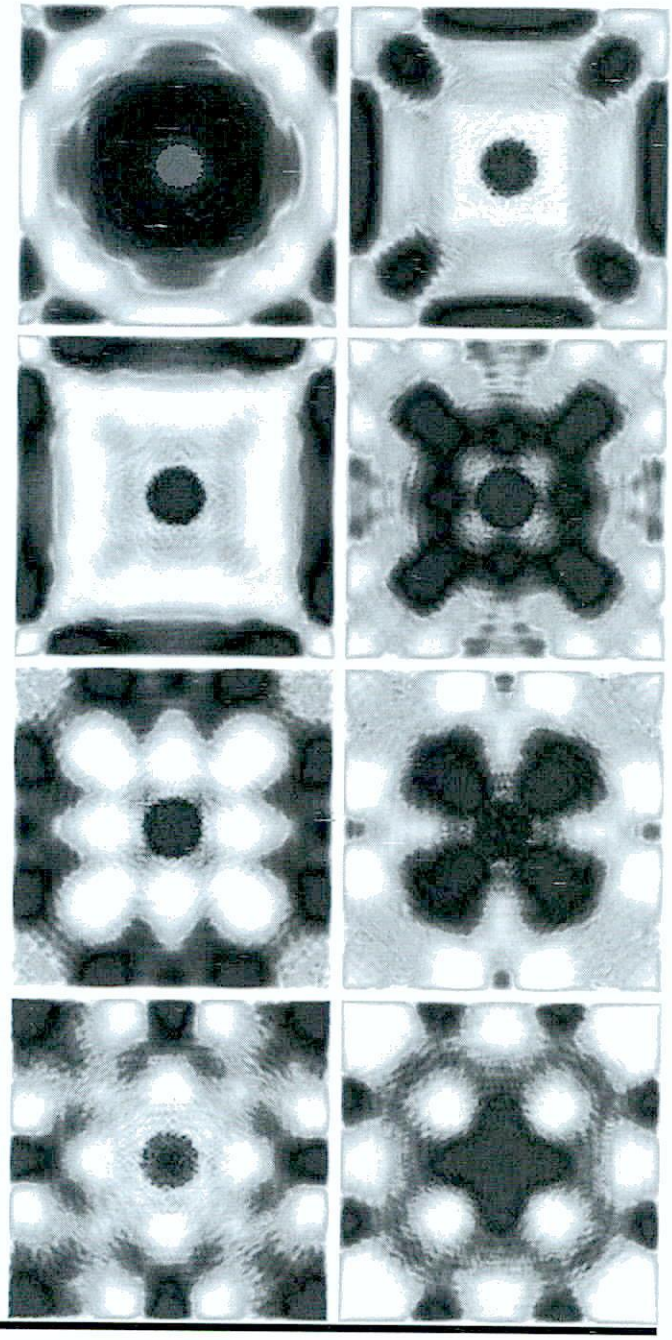


Fig 32

Two sound sources and a foursquare volume creating sound map (red dot represents sound source) (made by Ines Gavelli)

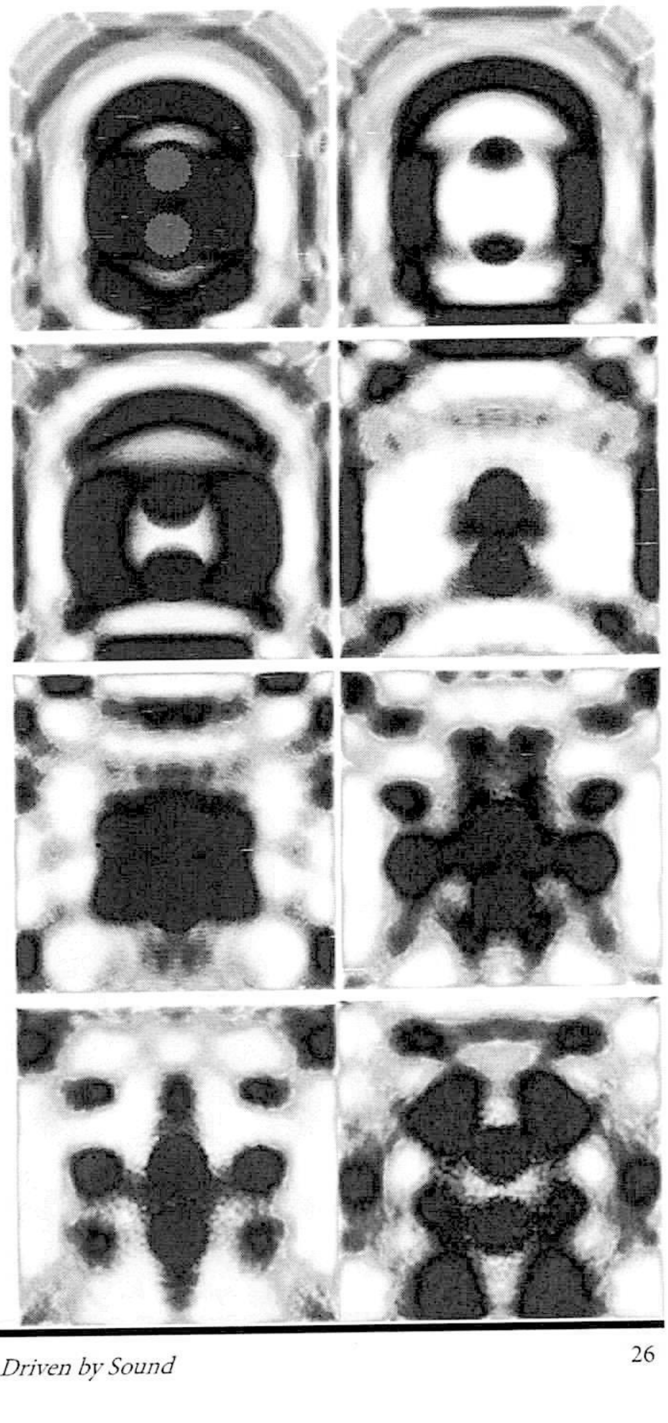
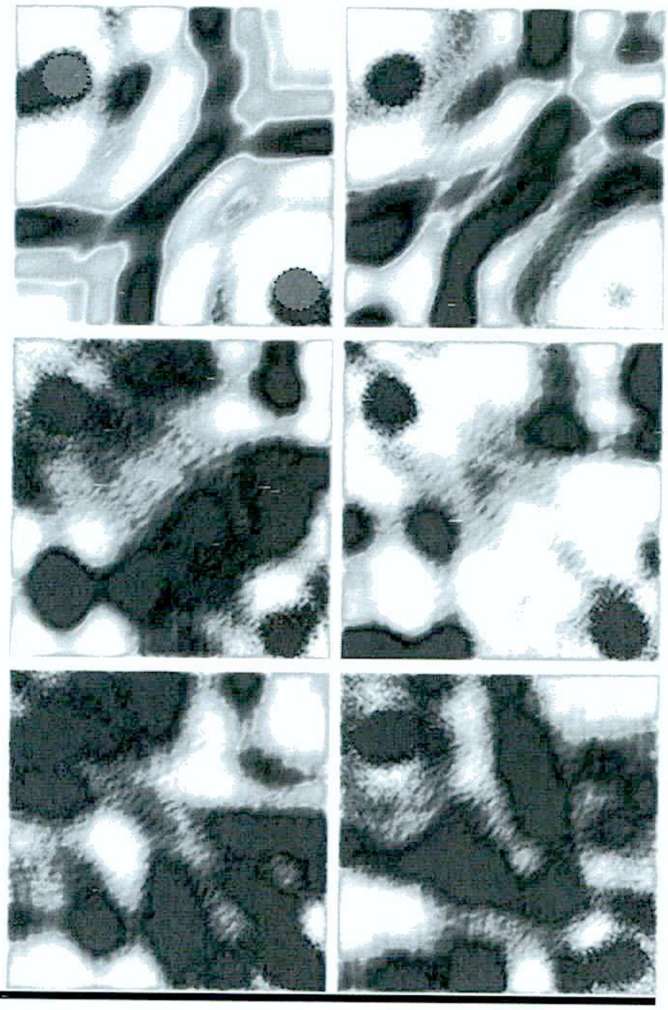


Fig 33

Two sound sources and a foursquare volume creating sound map (red dot represents sound source) (made by Ines Gavelli)



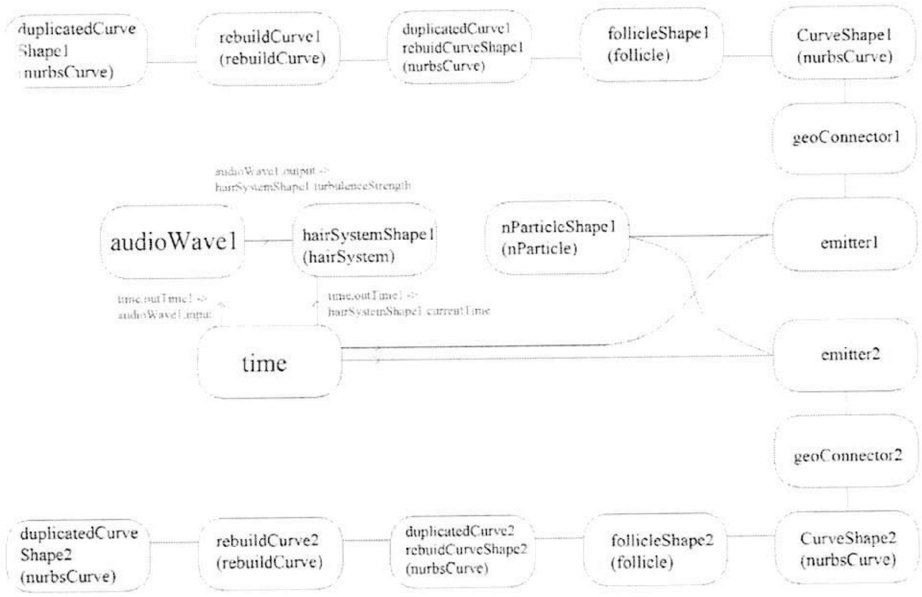


Fig 34

Representation of AudioWave node and Connections in HyperShade

3. Simulating the Influence of Sound as a Dynamic Force

The third setting for digital experiments is to find a way to create influence of sound amplitude or frequency as a dynamic force field in software. A dynamic force field is a force that manipulates digital tools such as particles, fluids, or polygons by pushing, pulling, splitting and so forth.

In order to create sound influence in the following experiments, the AudioNode, which can read sound amplitude per second, was used. Through the HyperShade, which is a relationship editor on the software, 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 levels because the unpredictable behaviours of both materials can be kept under control. Hence, the digital process allows further evolution of forms and assemblies.

Fig 35

Surface Deform on a sphere/sequent images illustrate the effect on AudioWave which can read amplitude of sound and transform it into a integer. Different amplitudes create different surfaces

4. Sound as a Surface Deformer

One of the first digital attempts is to use sound as a surface deformer. Observations of the effect of motion and amplitude can be stated clearly. During the time, different amplitudes are applied on the same surface of matter and because of the continuum of this process; every step of deformation produces different patterns. Therefore, surface-active forms and a wide range of topological geometries of the same form are created. In regard to amplitude and time, it was also observed that higher amplitudes have more capacity to deform surfaces and are much more effective over the long term. Vice versa, low amplitudes and a short time influence surface deformation much less. In summary, the length of the motion and strength of the amplitude offer different pattern formations on the surface.

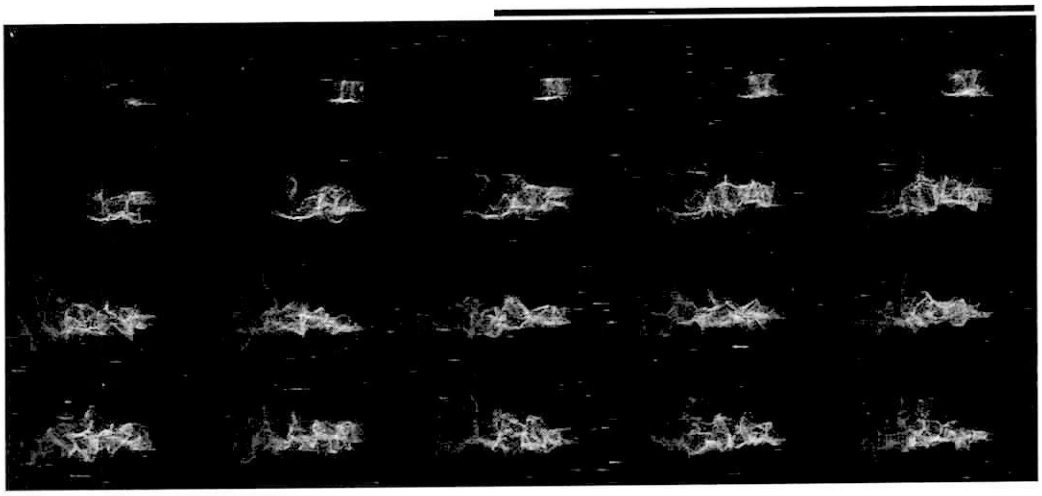
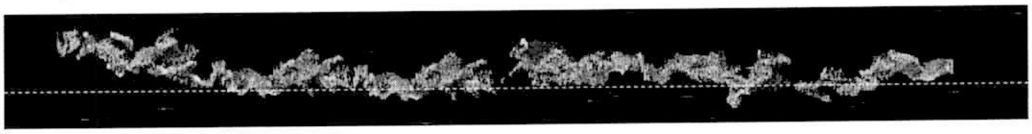


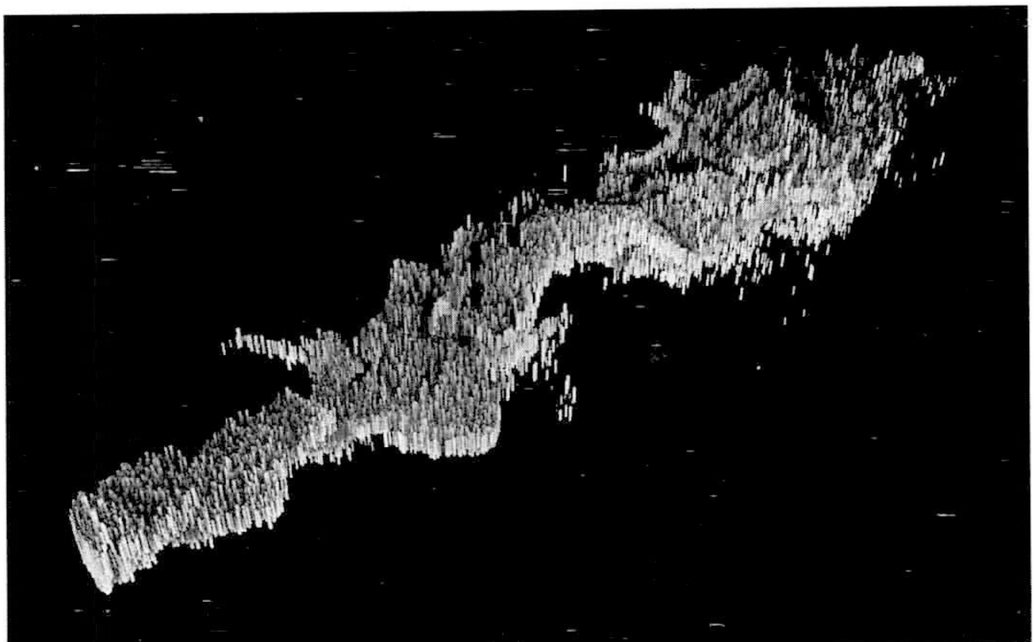
Fig 36

Images represent only particle systems.According to amplitude particle releasing and position of each particle are affected. However, the system is unstable and has no constraints (made by Weiwei Wei)

Fig 37

Same particle system with instances (made by Weiwei Wei)





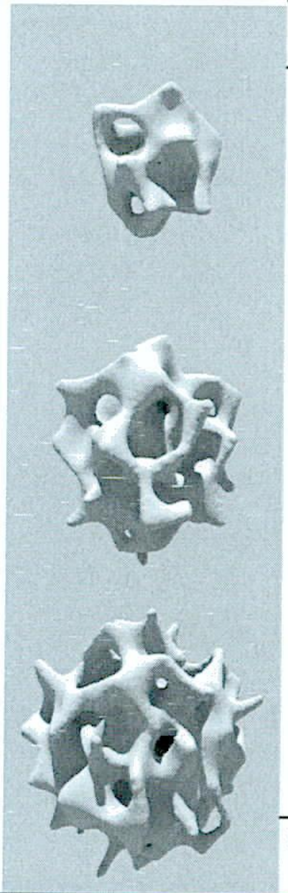
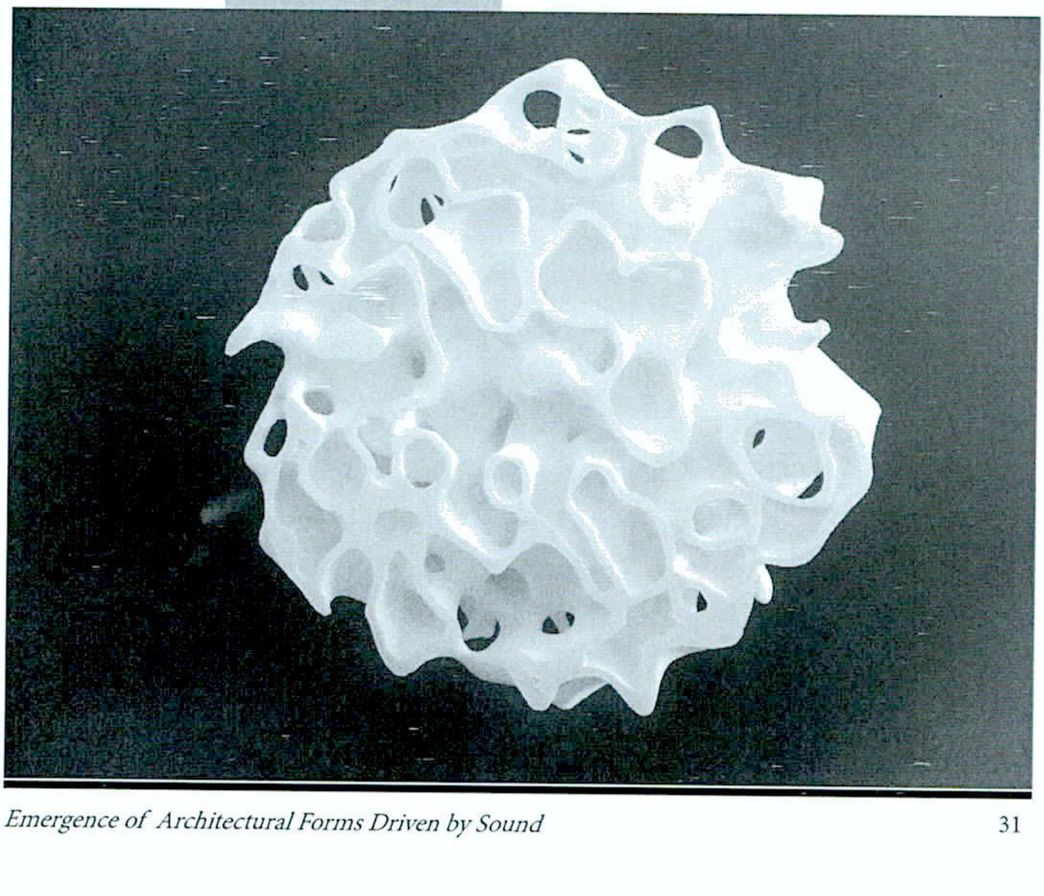


Fig 38

This process only has particle and mesh systems. According to AudioWave, particle rate is affected and the system evolve through a higher degree (made by Ines Gavelli)

Fig 39

Section of 3d model of this process. Spatial potentials can be seen clearly



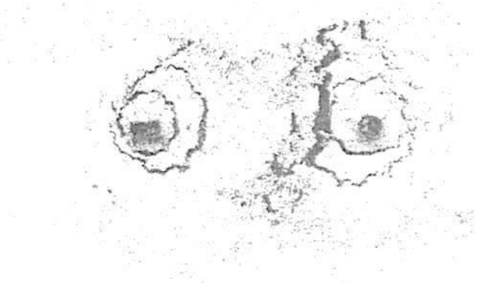


Fig 40

particles' rate based on AudioWave node. According to amplitude rate is changing constantly (made by Ines Gavelli)

Fig 41

particles' rate based on AudioWave node. According to amplitude rate is changing constantly (made by Ines Gavelli)

Fig 42

particles' rate based on AudioWave node. According to amplitude rate is changing constantly and particles tracing their paths (made by Ines Gavelli)

Fig 43

particles' rate based on AudioWave node. According to amplitude rate is changing constantly and particles tracing their paths. Overall shape is emerged from mesh system (made by Ines Gavelli)

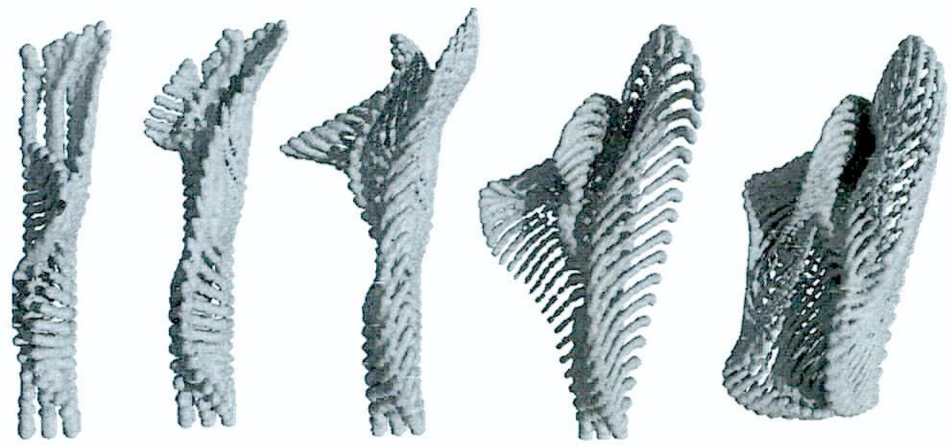


Fig 44
Sound Motions Streaks Process /streaks are animated according to AudioWave and at te same time releasing particles and tracing their paths. Sequent images show the form in different time frames.

5. Sound Creates Forms

The other attempt for the digital process is to create form itself from the beginning instead of deforming existing shapes. Taking information from sound and time already showed that there are several ways to create forms. For instance, the AudioNode 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 systems, each particle converted into polygonal meshes, therefore, this new converted matter creates multiple structural formations. This mesh form is much more characteristic than the other, which is only created by particles. In this process, 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 characterised 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. This design approach can be called 'sound motion streaks'. 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 'the sound motion streaks method' in order to deeply understand the system, its architectural quality and make it a design tool.

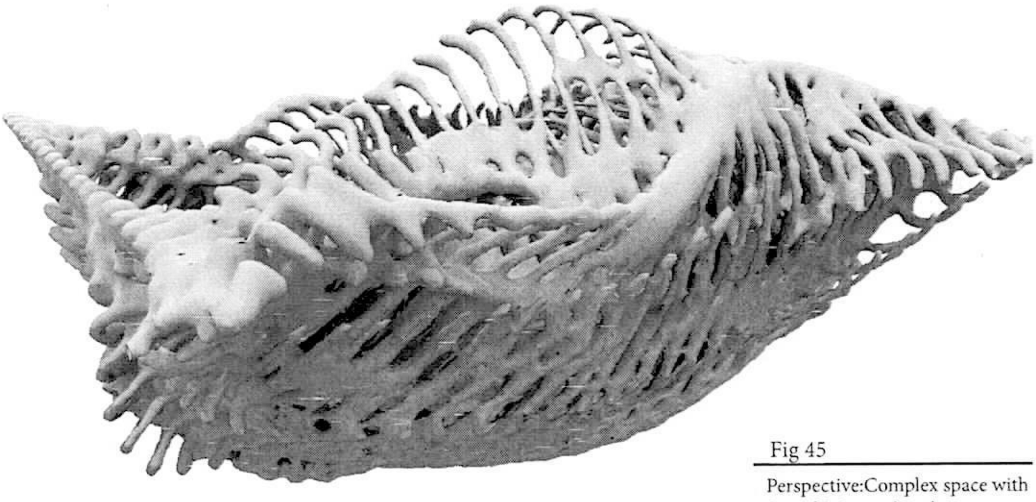


Fig 45

Perspective:Complex space with Sound Motion Streaks

6. 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, spheres, streaks, and so forth. They behave like granular systems in nature. Force fields such as air and gravity manipulate and organise this system based on the expressions or parameters that they have. 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. 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. They can self-organise under stress or create non-linear forms. They also have an elastic behaviour determined by the specific influences and can accept large stresses and deformations (Hensel, Menges & Weinstock, 2010).
On the other hand, in order to produce these forms, these three tools must be used in a simulation. Simulations are essential for laying out complex architectural systems, in software applications and examining their behaviour over extended periods of time (Hensel, 2010). Also, simulations provide generative design processes (Hensel, Menges & Weinstock, 2010) and take advantage of motion-movement and time.

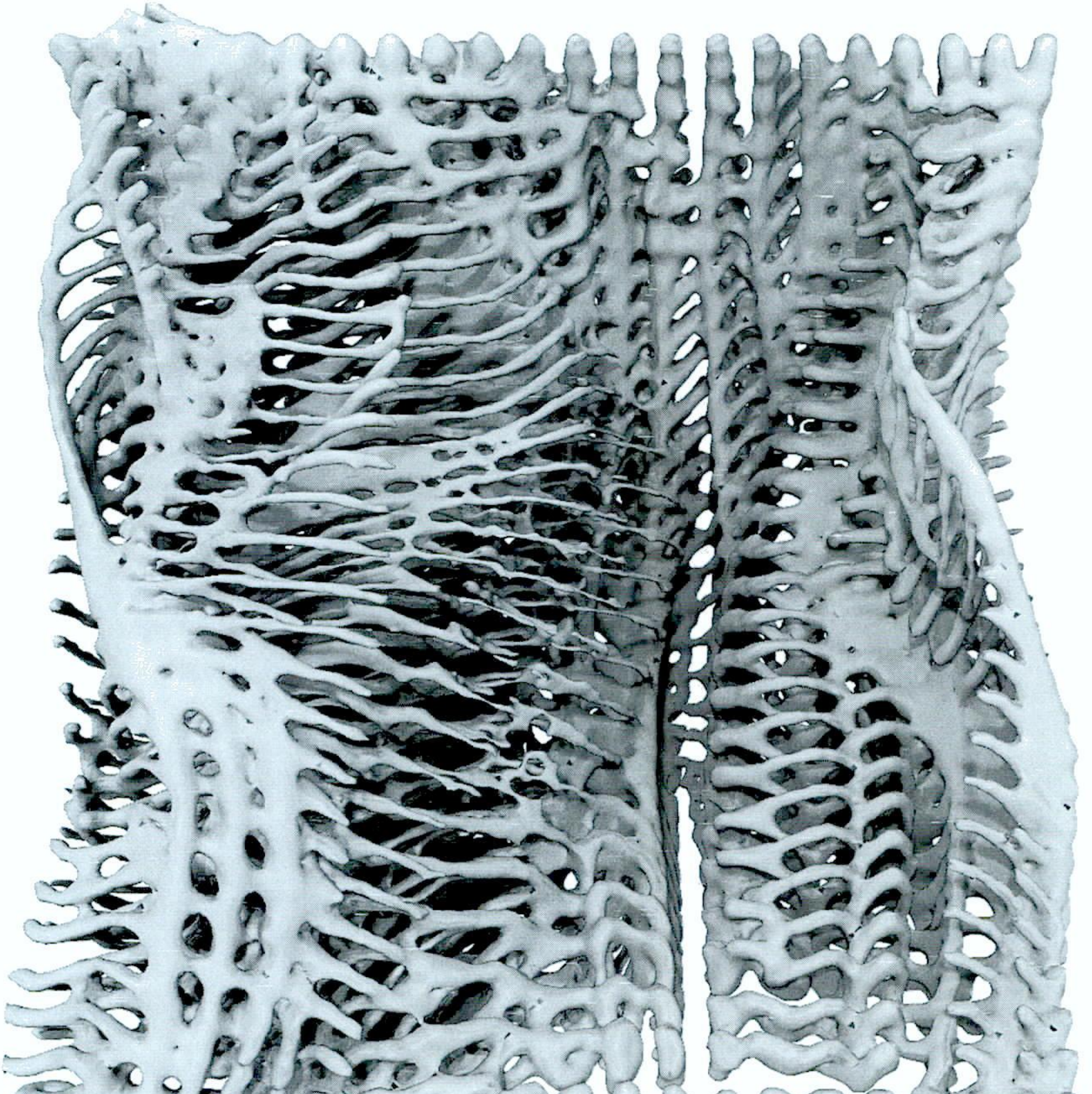


Fig 46

Top view: Complex space with Sound Motion Streaks: Streaks determines the constraints of the form and they are animated by amplitude at the same time curves tracing their movement in the space by releasing particles. The final particle system produce meshes and overall, the system has different densities, layers and mesh geometries.

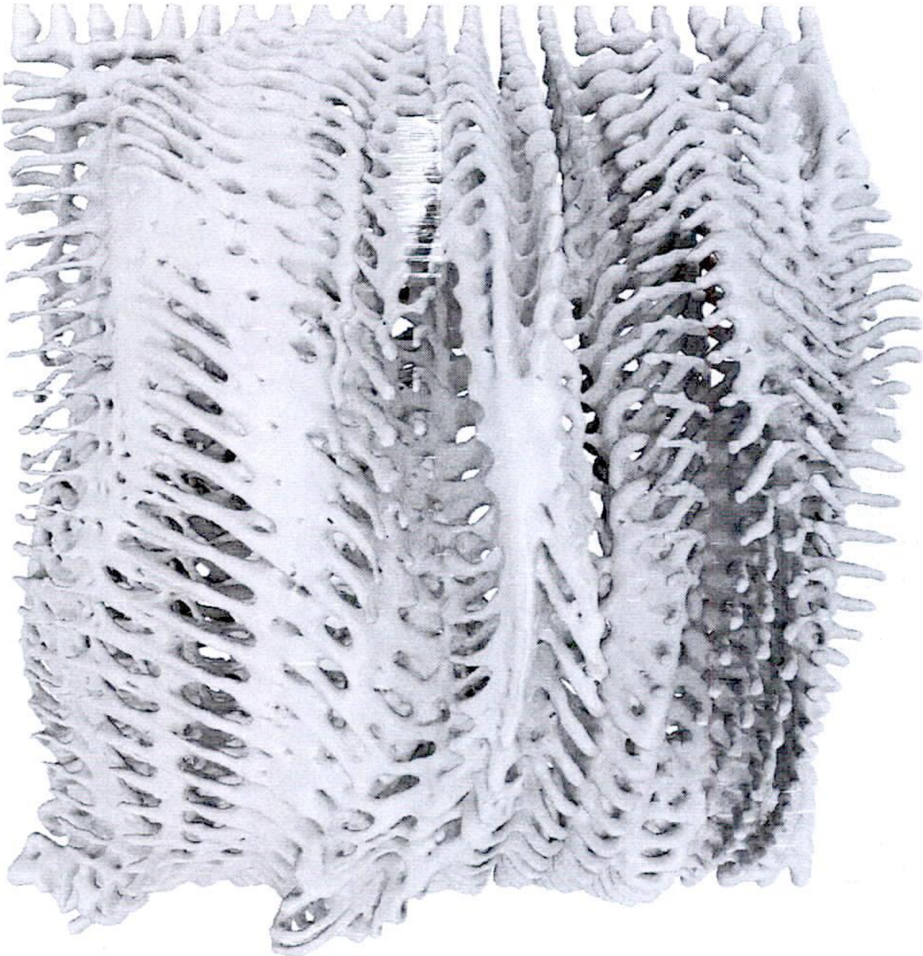


Fig 47

Bottom view

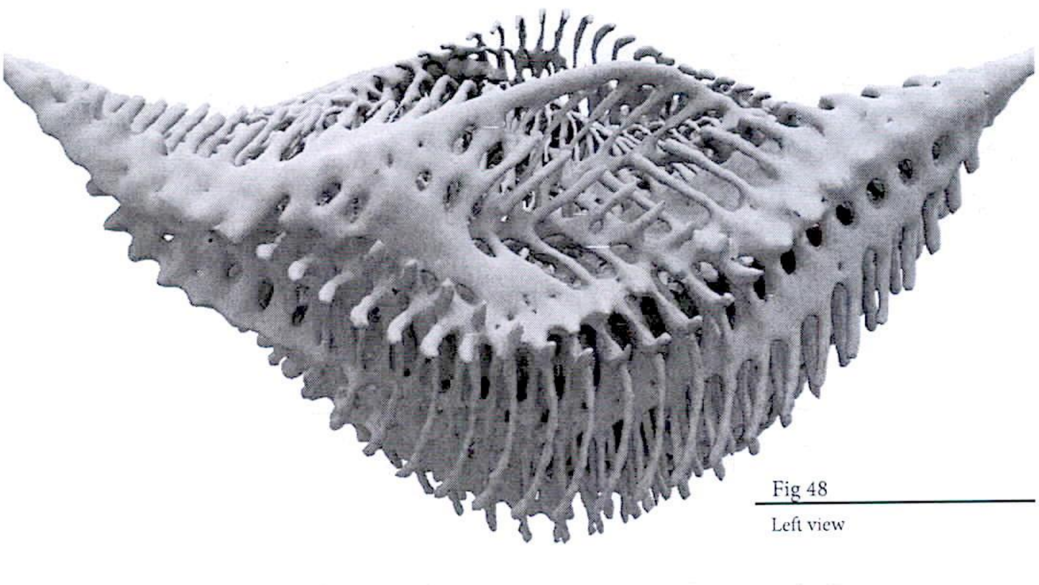


Fig 48

Left view

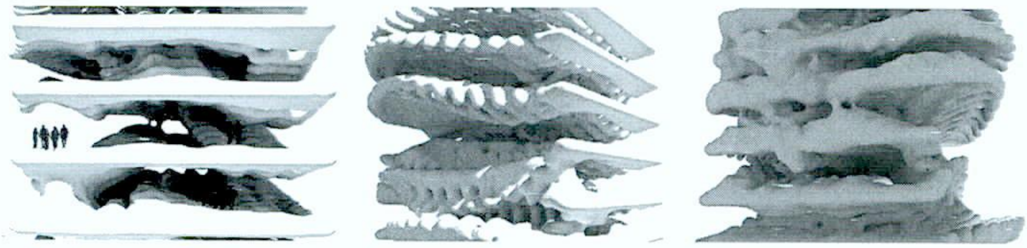


Fig 49

Different arrengements of streaks/ Curves are top of each other and creates its own vertical boundary

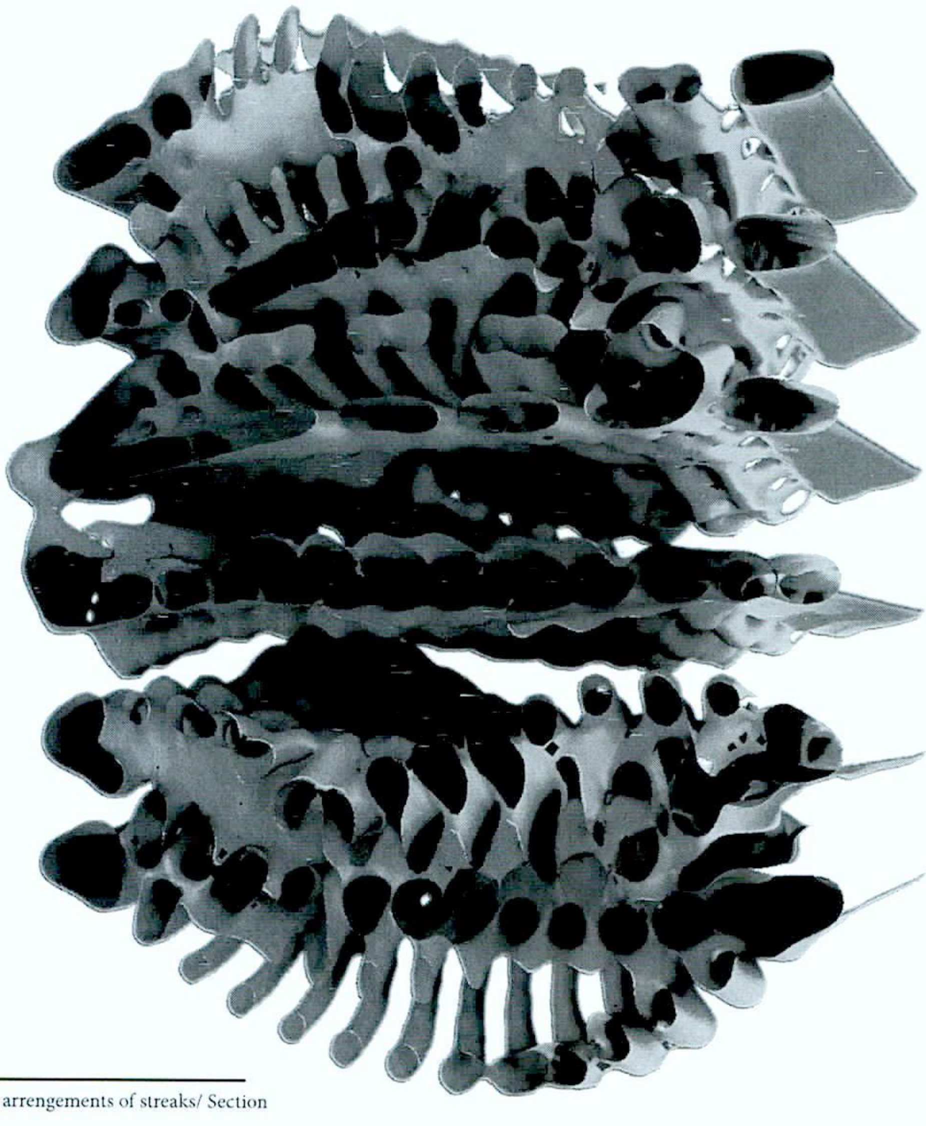


Fig 50

Different arrengements of streaks/ Section

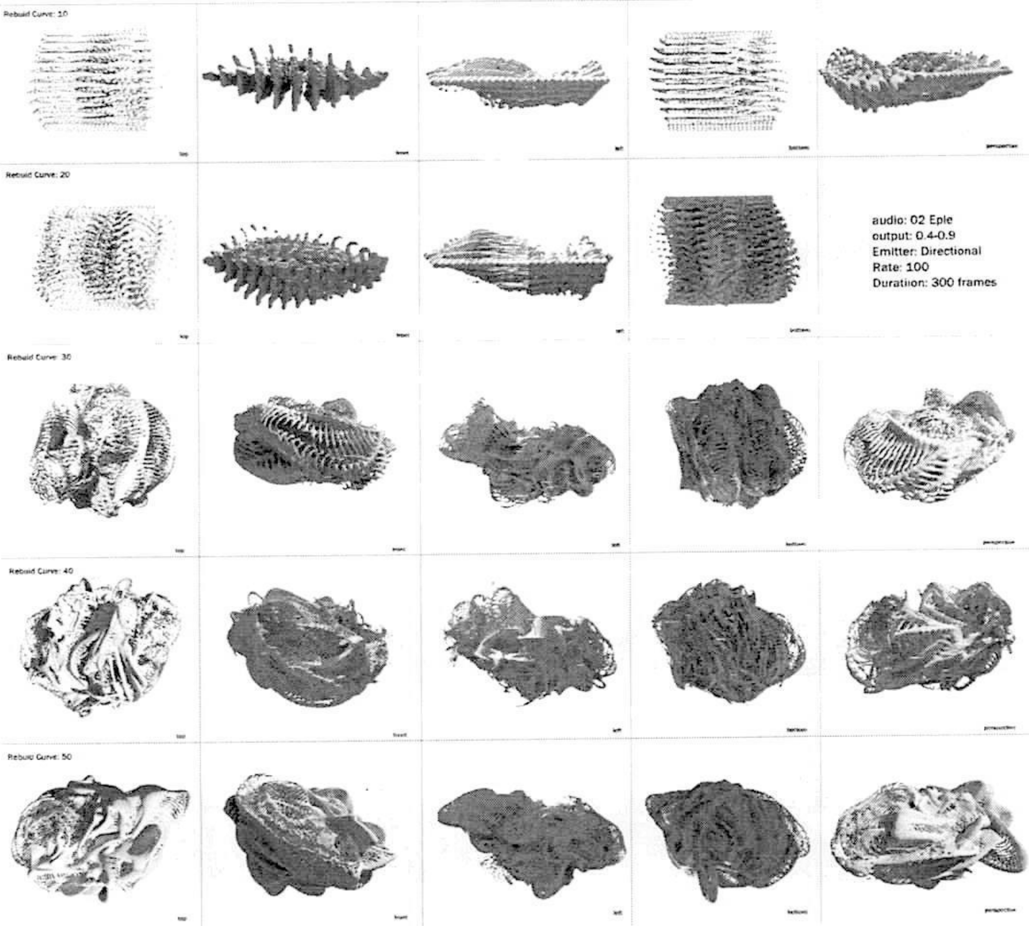


Fig 51

Reconstructing streak structure generates different spatial systems. If curve structure has less section the system behaves calmer. Based on the number of sections, system evolves through much more complex and heterogenic space.

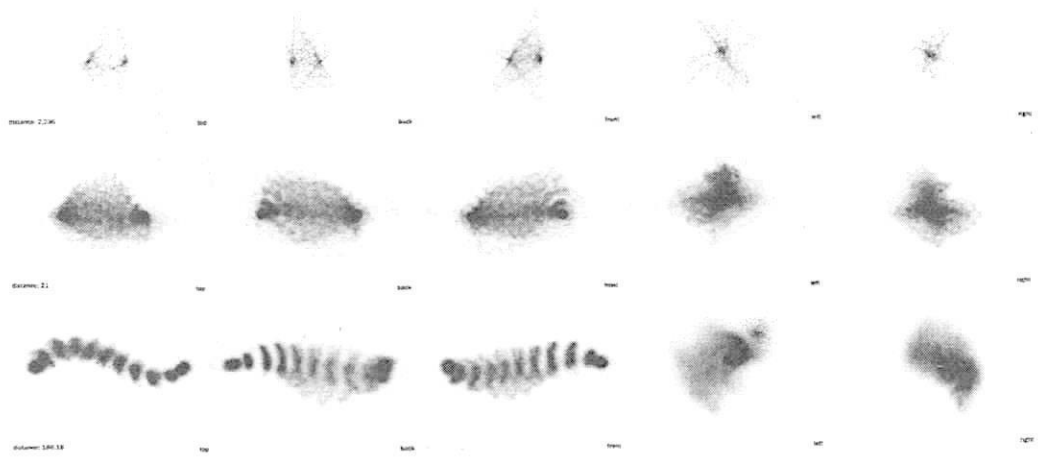


Fig 52

Distance from sound source also generates different spatial systems. This effect can be controlled by this expression:
hairSystemShape1.turbulenceStrength = (audioWave1.output*1000)/distanceDimensionShape1.distance
Rebuild 10 times/ Duration: 680 Frames

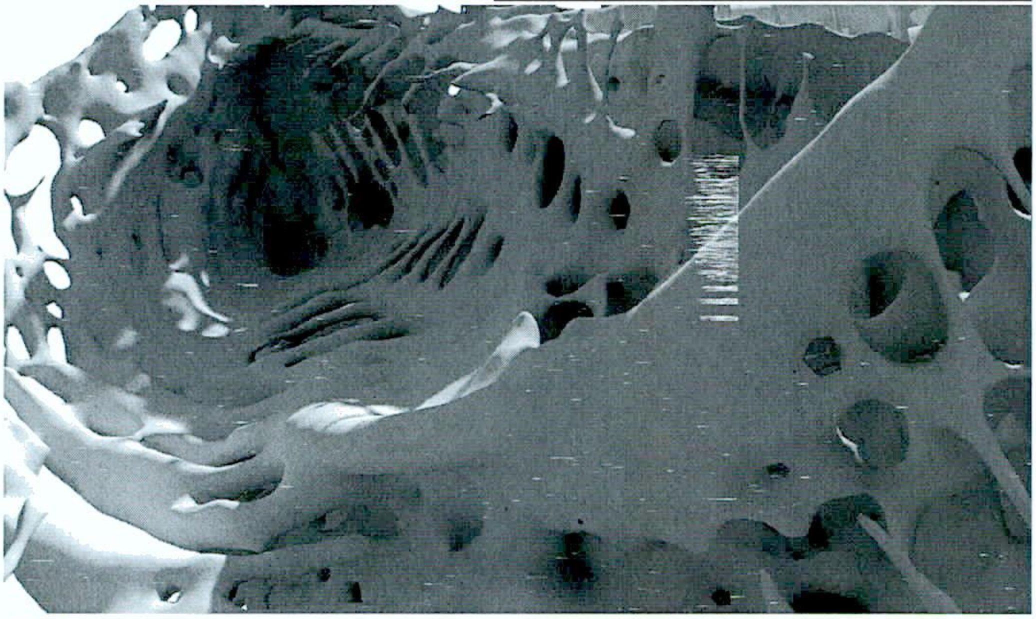


Fig 53

Sound motion streaks generates space

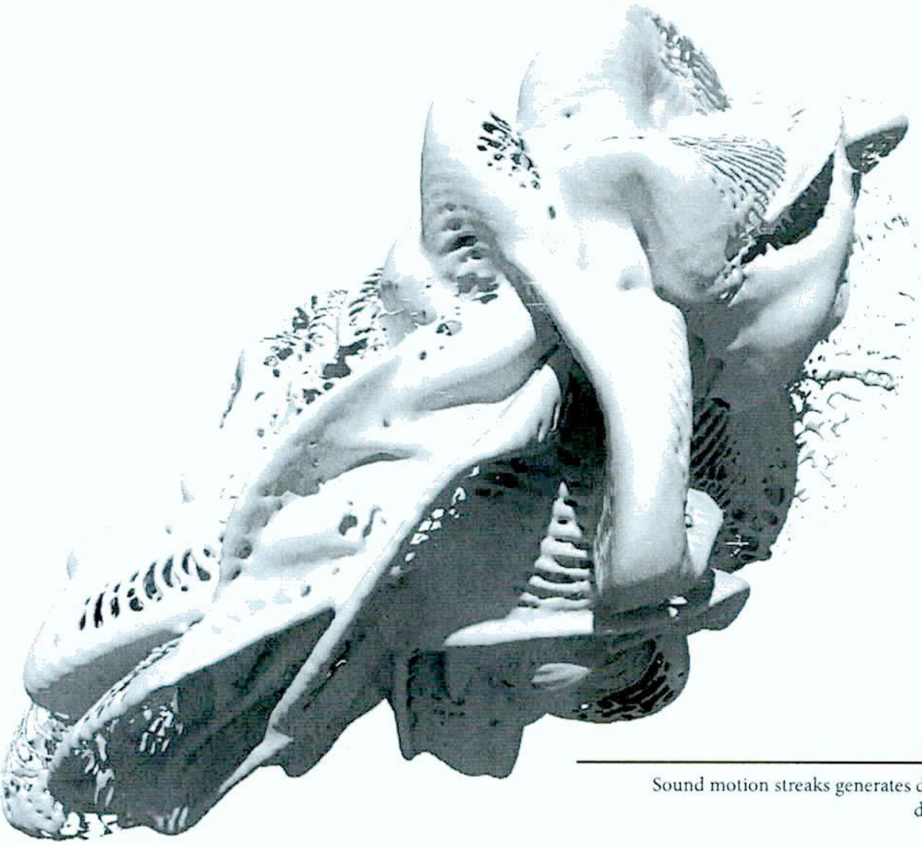


Fig 54

Sound motion streaks generates different densities

6. An Urban Scale Prototype

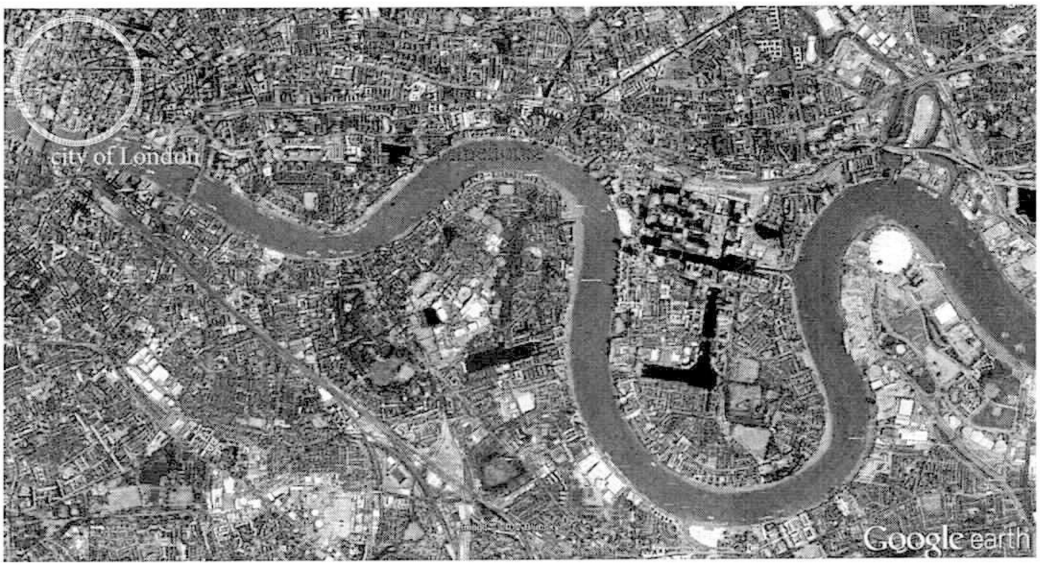


Fig 55

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

Fig 56

From the different parts of the site, the noise produced by DLR is recorded in order to produce a sound map. This sound map determines the noisy places, the constraints based on surrounding buildings and streaks. Finally sound motion streaks process is imposed and architectural kinetic space emerges. Yellow dots represent the areas where sound is recorded.

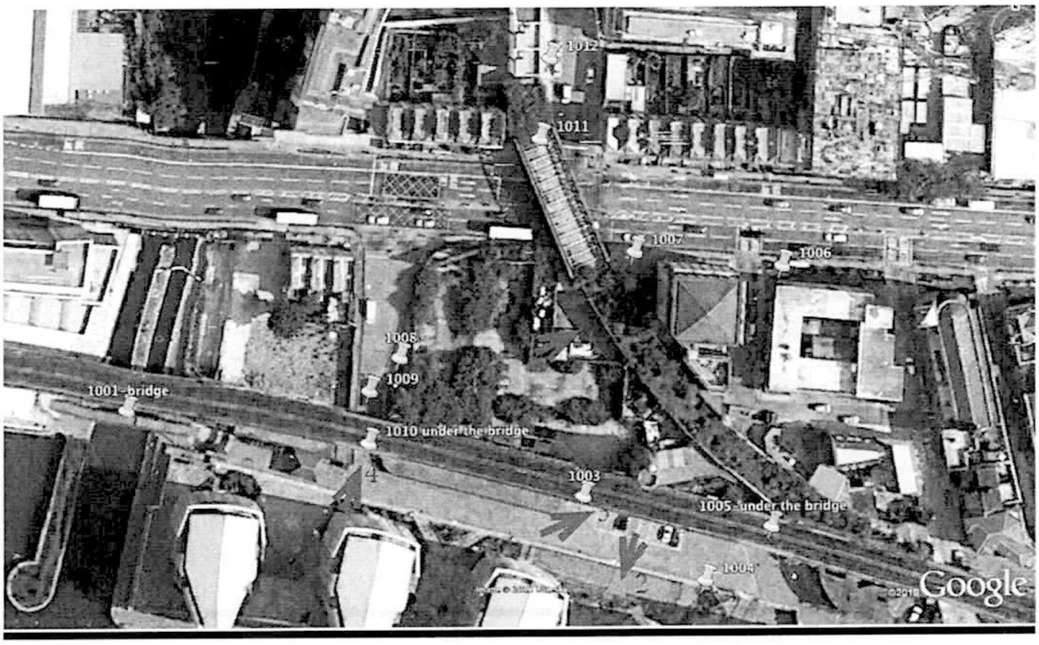
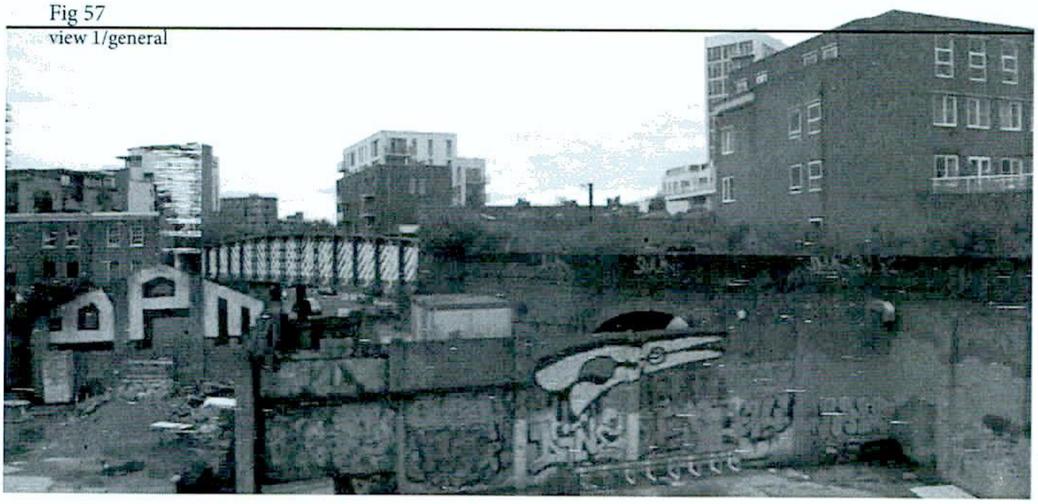


Fig 57
view 1/general



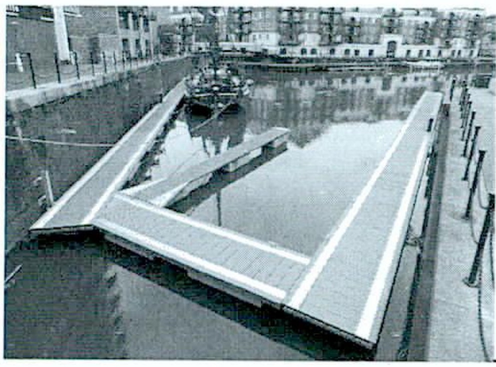


Fig 58/view 2

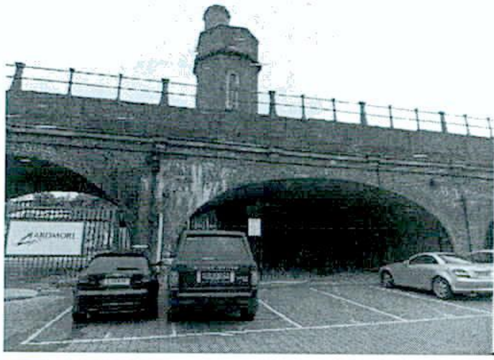


Fig 59/view3

Fig 60/view 4

Fig 61

Sound map according to chosen places where sound is recorded

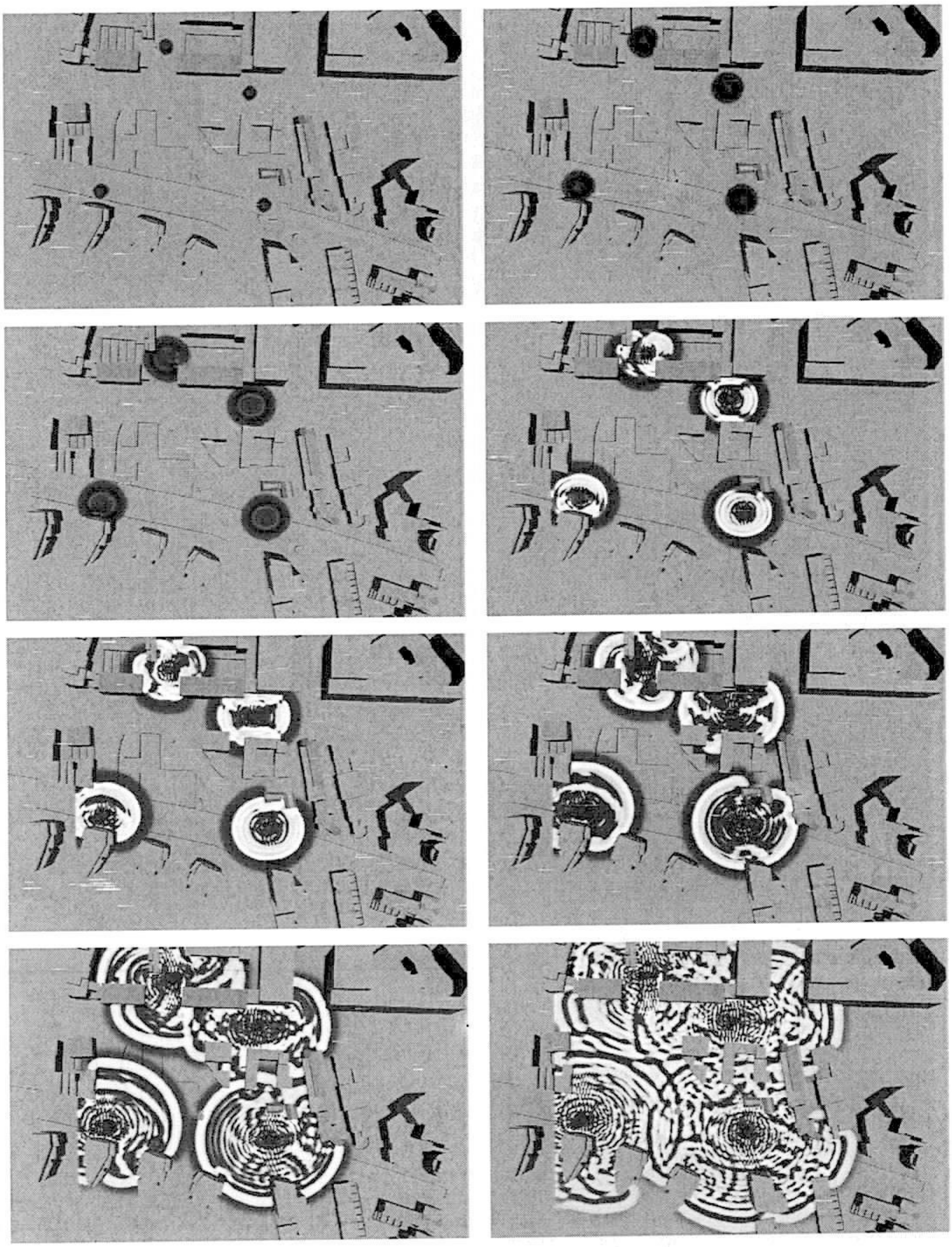


Fig 62

Overall form, after sound motion streaks process is applied

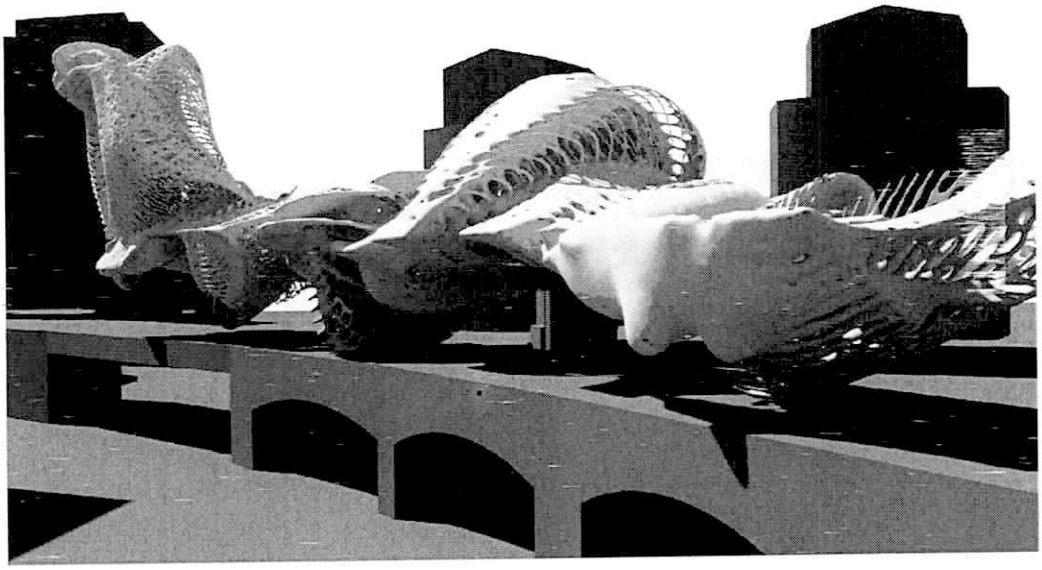
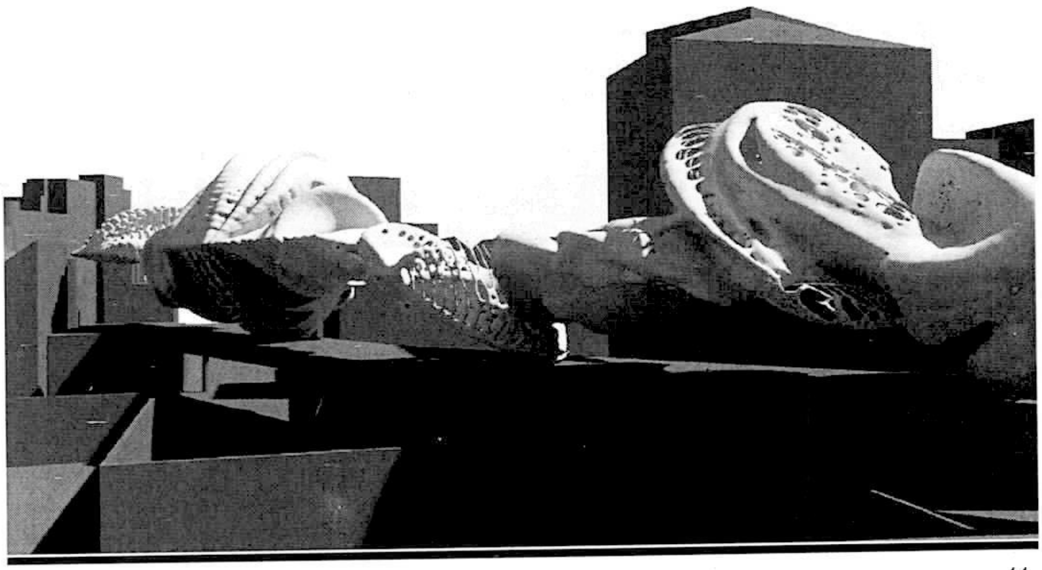


Fig 63
Perspective

Fig 64
Perspective



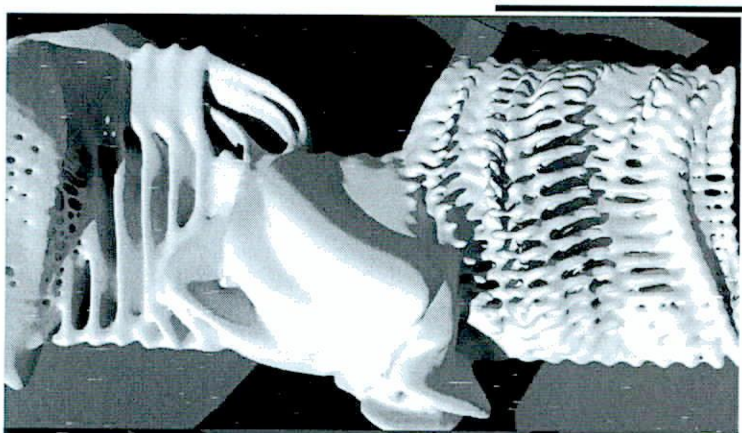


Fig 65
Top view detail

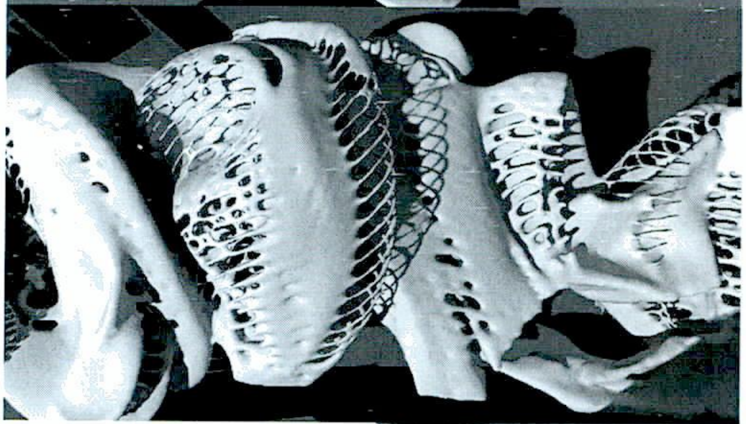


Fig 65
Top view detail

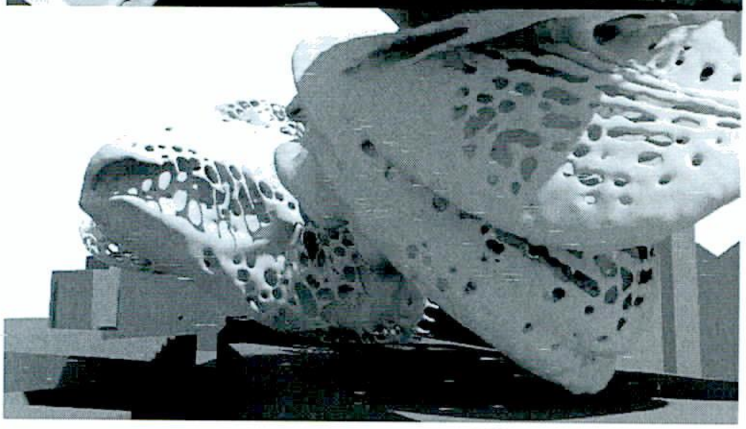


Fig 65
Surface detail

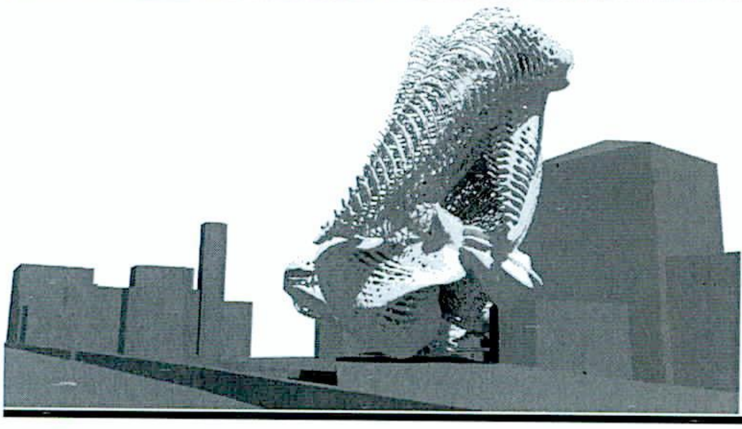


Fig 65
Surface detail

Architectural Consequences

It became clear with the later digital experiments 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 fabrication 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. Motion is an act or process of changing position or place over time (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 (Terzidis, 2003).

Kinetic Term in Art

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). In other words, this new understanding of art is based on rhythm and movement so that time may employ illusion and a limitless dimension to traditional art. 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. This gives abstraction, articulated and imaginary forms and space to traditional art (Rickey, 1963).

Representation of Kinetic in Architecture

In architecture, on the other hand, the representation of motion is usually achieved with an abstract formal configuration which depends on the relation between cause and effect. Architects use different digital tools to create cause and effect relationships such as displacement, reduction, suppression, amputation, miniaturisation, augmentation, addition, extension, amplification, substitution, absence, contamination, dissociation, dislocation, friction, and penetration (Terzidis, 2003). Furthermore, these digital tools create simulations which are essential for not only designing kinetic processes but also for designing complex material systems and for analysing their behaviour over extended periods of time. Air, sound, wave and nuclear physics are commonly available simulations (Hensel, Menges & Weinstock, 2010). Another simulation that has been mentioned so far is sound.
The movement in the sound motion streaks process is provided by AudioNode and its connection with time. Small variations in the AudioNode in each sequence may produce changes in the development of each component at many different scales through the reorganisation and recombination of the overall shape (Hensel, Menges & Weinstock, 2010). In other words, external forces (AudioNode output) influence the nature of the evolution of form and this process, which is the most dominant model in architecture, represents the movement in forms (Terzidis, 2003). 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). In terms of architectural skin, kinetic form also alludes a new definition which does not mean closed material layers but a system that air can enter and spread through the layers (Lally and Young, 2007).

In generative design, kinetic characteristics of form are no longer static according to Manuel de Landa (cited in Tierney, 2007). It is no longer homogenous, either. Its behaviour cannot be imitated by solid modelling because it takes its properties from all of the digital tools used. Therefore, 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.

Perpetuating Particles project one of the example projects in the book SoftSpace edited by Lally and Young (2007). In this project, a number of particles released in a site that they can move independently. The direction of their release was under the control of digital tools but another external force, collision also affected particles randomly so that while they are travelling along the determined direction, they organise and create a continues surface. Thus, this project is similar to the sound motion streaks method in terms of external forces and the time-movement relation in the site, Despite the fact that the system only has a particle system, individuals produce a much more complex systems over time and the overall shape of matter remains undecided until the moment that the movement stop taking information from the process (Lally and Young, 2007).

Notion of Space in Kinetic Form

According to Tierney (2007), the definition of image in traditional architecture has no relationship with time and space. It was fixed and static. But in reality, all forms produce are being produced in a space and also expanded in time. Digital applications can represent the form while they are concurrently revealing themselves in the space depending on time. Therefore, simulations on digital software, brings a new definition of architectural image and at the same time, space (Tierney, 2007).

With the sound motion streaks process, not only is the notion of form changed but also that of space. The notion of space has carried a significant emptiness and this aspect has not been changed for a long time. From that point of view, space is not varying while environmental or cultural conditions are always changing. But this constant space cannot be further abstracted. Similarly, the time in modernity is comprehended as homogeneous and stable. It is not conceived as an entity which is produced in various ways, but like space, it is understood as infinite and undefined. However, the generating effects of time and space can break this aspect and expand the architectural horizon. Time and space are no longer homogeneous. A new understanding of the generative design processes make space curved, expands and contracts and changes with time, which simultaneously gives space uncertainty and unpredictability (Berkel and Bos, 1992).

On the other hand, kinetic space consists of some other qualities based on digital applications. Translatability (Tierney, 2007) and heterogeneity (Kiendl, 2008) can be given as an example. It is translatable because same settings can be constructed another site and translated into multiple forms with infinite scalability (Tierney, 2007).

It is heterogeneous because it has many differentiated elements and different densities reflecting movement and time (Kiendl, 2008). Therefore, with the notion of space which kinetic form bring forward, architecture evolve to the more complex heterogeneous and translatable systems which give architects many potential geometric topologies.

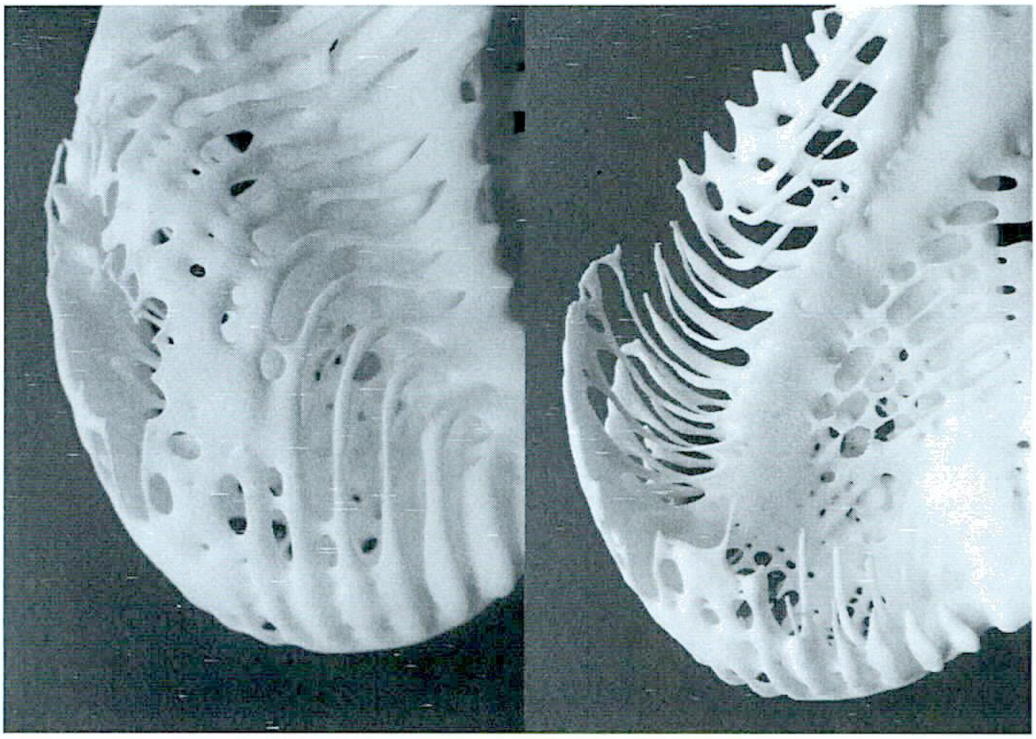


Fig 66
Surface detail from 3d print model

CONCLUSION

This paper has analysed the long relationship between music and architecture and proposed a new way to create architectural space with music. It also has argued that the architectural spaces and forms created by music are kinetic because they are representations of movement brought out by musical sounds. The approach used for making these spaces is based on computational design methods. Software analyses the sound's amplitude and frequency and creates a force in order to deform existing shapes or make a new form from the beginning. The value of this kinetic process is its changeability and endless typology. Moreover, spaces are not only static but also dynamic due to this process. Therefore, it is a new understanding of a traditional approach, which is only based on static forms and spaces.

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