In Pursuit of Sound

by Chris Martin

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Georgia Institute of Technology, 2011

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Signature of Author ____

Department of Architecture
January 15, 2015

Certified by ____

Antón García-Abril PhD
Professor of Architecture
Thesis Advisor

Accepted by ____

Terry Knight,
Professor of Design and Computation,
Chair of the Department Committee on Graduate Students

Thesis Committee

Antón García-Abril, PhD
Professor of Architecture

Marc Downie
Digital Media Artist, OpenEndedGroup

Paul Steenhuisen
Composer

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Abstract

Architectural tools are built around visualizing our environment, however it is sound that paints the most accurate picture of our experiences. A glass wall feels more constricting than a opaque sheet, because when sound can reach our ears, our worlds are opened up. It is time that we leverage the technology that gives us so much insight into the science of sound, and start designing architectural experiences that can communicate visually what we understand sonically.

Historically we have relied on a known quantity of sound in order to generate space. Pythagoras unifies specific rules of harmony and proportion from sound in order to determine guidelines for pleasant spaces. Years later, Xenakis composes a musical score that informs the constructed surface of the Philips pavilion. Both pioneers of sonic architecture, and both pushing the technology of sound design. This thesis advances the theory of sound architecture by focusing on the smallest component of sound –the frequency– and translating that into the smallest component of form, –the gradient. Frequencies layer on one another to create an entire sonic composition, so must the gradients blend together to bring architecture into being.

The invitation to explore sonic movements as architectural experiences comes from the success of these gradients to convey imagined spaces among a flat image. It is through the production and implementation of this image that the architect can seek new control over visual forms that capture the ears as well as the eyes.

Thesis Supervisor: Antón García-Abril
Title: Professor of Architecture

Acknowledgments

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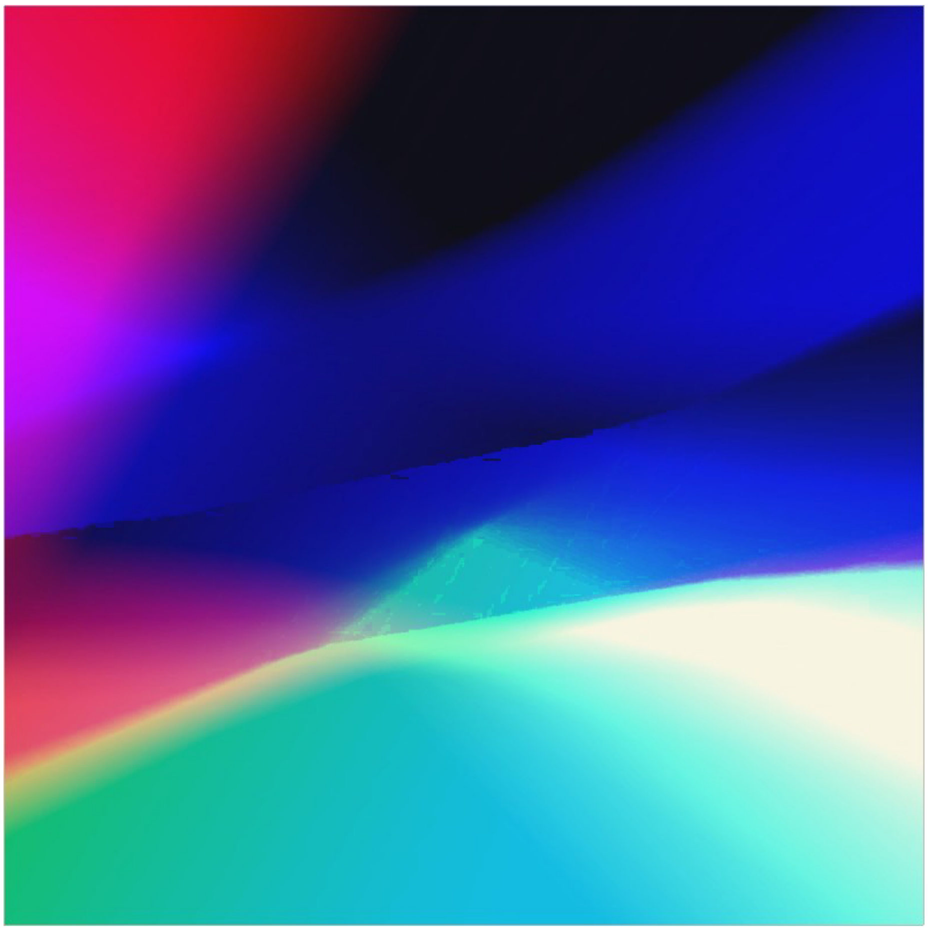
Thank you Gediminas Urbonas for putting together a wonderful class in which architects and musicians and engineers all came together to explore and create unique sonic experiences.

Thank you Larry Sass for asking me to discover what I wanted from architecture, and to pursue it sooner rather than later.

Thank you for my mom and dad who have always encouraged me to explore the world in new ways, and giving me such a strong foundation from which to build.

Finally thank you to my girlfriend who had to put up with the strangest sounds imaginable for the last few months, and for supporting my work, even when she was completely unsure of what I was doing.

Thank you for reading.



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Sound

“My favorite music is the music I haven’t yet heard. I don’t hear the music I write: I write in order to hear the music I have yet heard.”

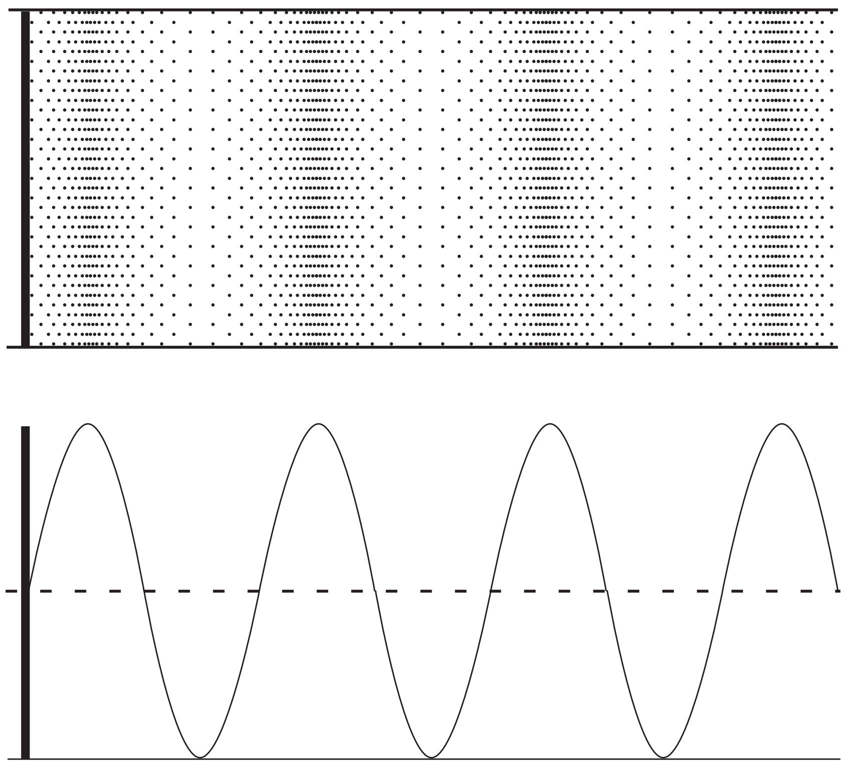
-John Cage

Sound is the spatial medium. Architecture is the art of making space. It is logical then, to conflate sound and space to uncover new experiences. Currently we are able to spatialize sound, but if we are to soundalize space - that is leave a sonic imprint by way of form and material- then we must uncover the potentials of sound through a new computational apparatus. This merging of the visual and the sonic domains in architecture has been prolific, however our reliance on our current tools has held us back. New technology can usher in new ways of thinking and working. Sound can become a common tool for future architects.

Literature professor Marshall McLuhan, in Understanding Media, does not make a distinction between the translation of knowledge and technology. He states technology [is] a way of translating one kind of knowledge into another. McLuhan goes on to describe this translation as hybridization of media, touting, “the meeting of two media is a moment of truth and revelation from which new form is born; for the parallel between two media holds use on the frontier between forms that snap us out of the Narcissus-Narcosis.” McLuhan employs the Greek myth of Narcissus to convey that we as a culture of media are numb from the fascination of any extension that we employ that is not of ourselves. Narcissus was numbed through his preoccupation with the reflection of his face. Not as a depiction of himself, but as an extension of his body’s ability to create a new being.

This slightly humorous depiction of a being in our technological society has some truth in it by way of architectural visualization. We are made inert by our reliance to our digital architectural models. They are an extension of our desire to experience space; however, their emphasis on a visual form in both creation and presentation has attenuated our reception to sound.

McLuhan does not present the method in which two media interact. For the hybridization of sound and space to be successful, I argue that their specificity in meeting must be configured. For this, I offer up Deleuze’s construct of the fold. Deleuze argues that with the fold, the Baroque did not invent, rather manipulate of domains from the orient –Greek, Roman, Romanesque, Gothic, and Classical. These manipulations –or folds– infinitely layer together to form the Baroque. These folds as I understand them are an infinite series of operations where the first act instantiates a new form and then a second act is a result of the first. The expressivity of the fold, and thus the nuance of the form occur through the near infinite transformations of sonic potential to visual actualization, and then back again.



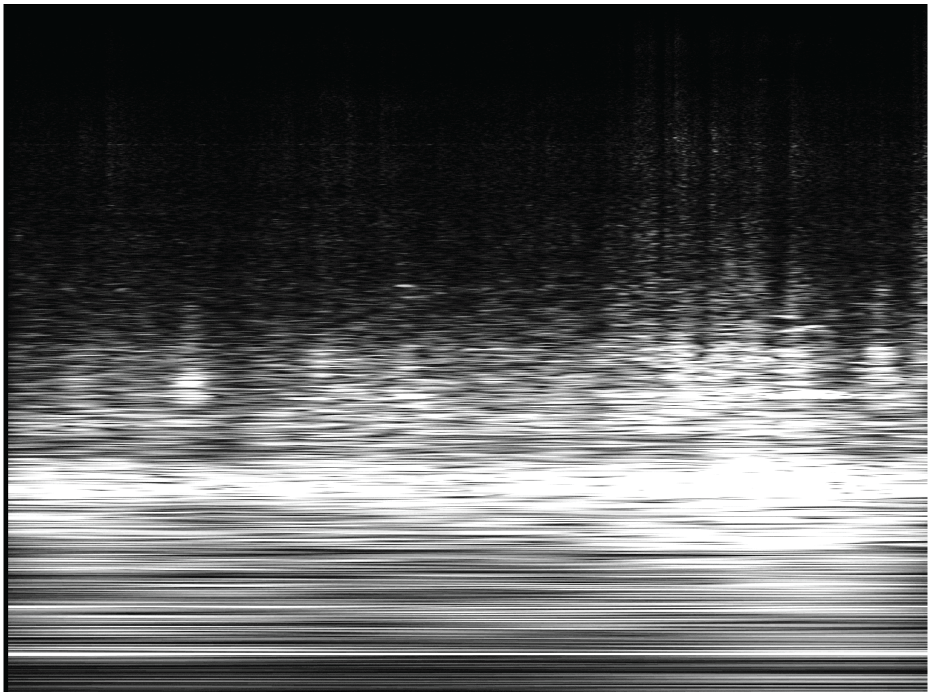
Sound wave visualization as particles moving in air

Sound Structure

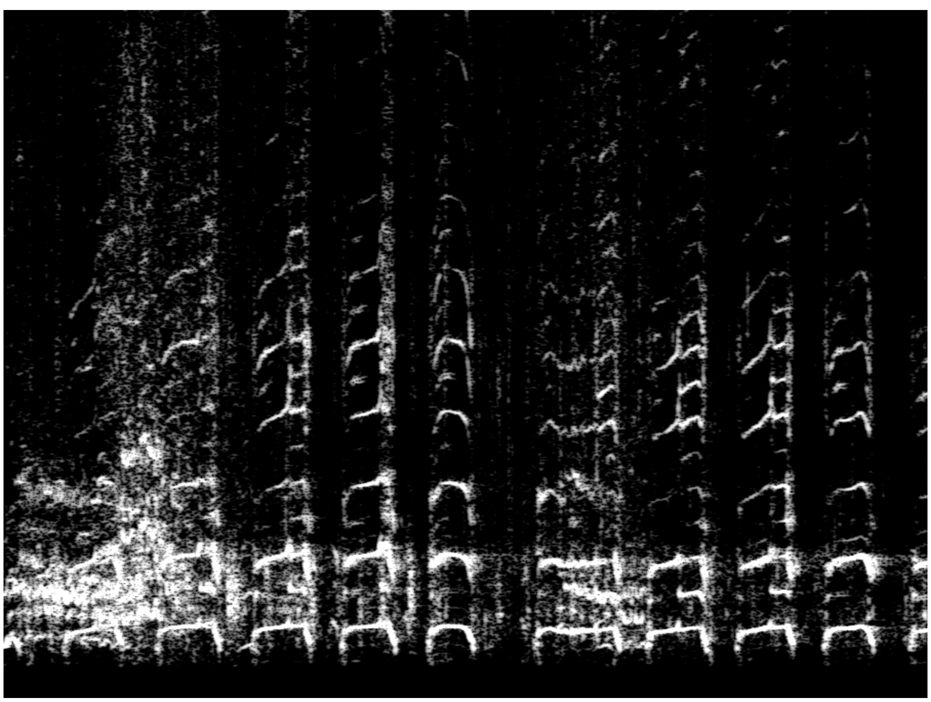
Sound is an excitement of air molecules that when entered into the ear create vibrations that the brain interprets as information. Before this invisible energy reaches us, it interacts with its surroundings. Materiality, temperature, density, and volume all act upon an almost instantaneous ripple in the air to produce and alter the information that we receive and interpret as sound. Today, we have an acute awareness of the impact that our environment has on our ears, and the science of acoustics explores how this can be optimized in order to produce specific sonic perceptions. However, the aim of this thesis is to rethink what we gain from our current knowledge of sound and what new patterns emerge when we disregard the cause of sound and only focus on the effect. This means that acoustics, although an unprecedented tool for manipulating sound, is not fully equipped to provide the answers to a most fundamental question concerning sound and architecture. What does sound look like?

In order to visualize sound we must know what it is composed of. Even though you can not typically see sound waves, the vibrations in the air follow a specific pattern. This pattern is typically revealed through an image called a sonogram, which plots frequencies on the X-axis, and time on the Y axis. Color is included to indicate the intensity or amplitude of the frequency. In many ways sounds can be categorized based on its sonogram. A low rumble will create a non distinct cloud on the bottom of the graph, while the sounds of a bird may create specific marks that lie in the middle of the page. The likelihood that you will be able to discern the individual sounds through your ears also relates to how easily it is to discern specific shapes. This relationship is known as fidelity, and it can be low, or high or anywhere in between.

The first step in using sound to create architecture is to be able to manipulate or parse the data found in the sonogram. The goal is to be able to discover patterns and parametric relationships found in the sound that can be mapped onto the architectural domain. An analysis method known as Fast Fourier Transform (FFT) allows the sonogram to be searched, for relevant information pertaining to the individual sound source.   First, the sound is divided into segments based on areas of high energy. These segments, or onsets, reveal the embedded structure of the sound. The texture, or timbre, of the sound is mapped by identifying the most used frequencies within the given onsets. The result is data points detailing, the onset, the duration, the frequency, and the amplitude of sound. Removing this data from the sonogram allows for new methods of visual mapping to search for new hierarchies.   The architecture of sound seeks to uncover a visualization apparatus that gives three dimensional form to this sonic data.

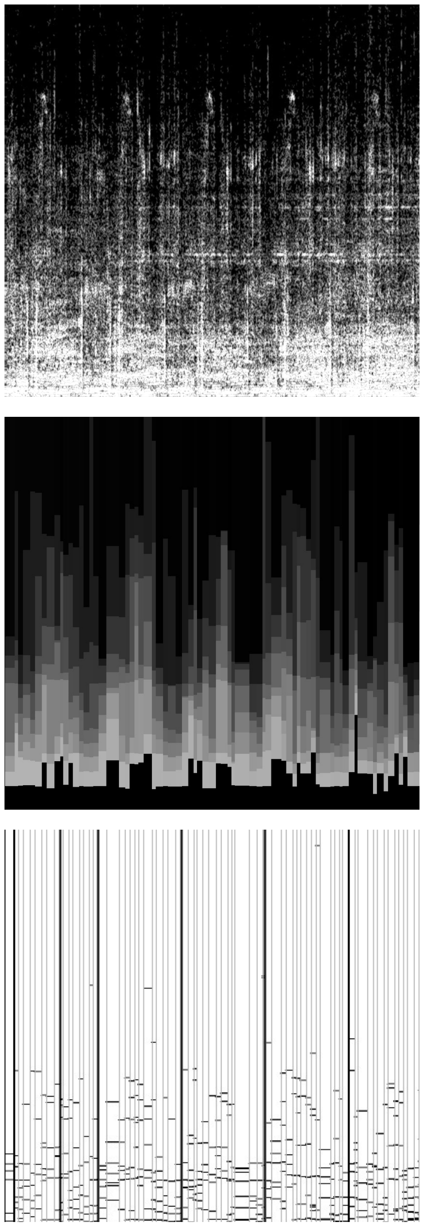


Spectrogram of a subway train



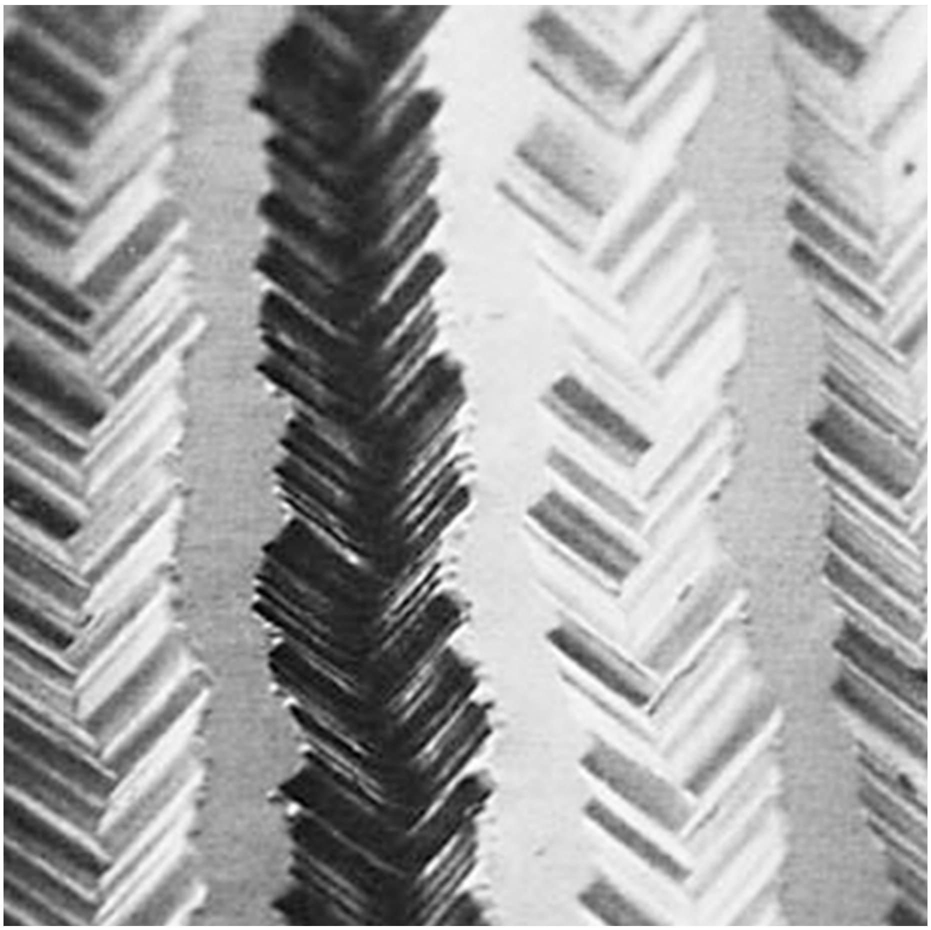
Spectrogram of a Herring Gull

New visualizations of spectrogram data as method for discovering patterns in sound



Assembly machine spectrogram

Rolling steel on table spectrogram

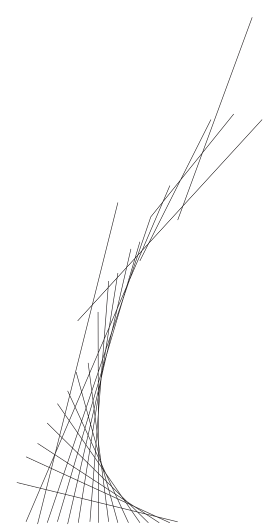


[1]

Sound Space

To create sound space is to develop an apparatus to translate sonic data into visible form. In order to define the apparatus, we can look to French philosopher Foucault. In an interview he clarifies that the apparatus "is a set of strategies' of the relations of forces supporting, and supported by, certain types of knowledge." In other words, it is a network that ties two elements, and in the case of this research, two media, together. Language arguably the oldest apparatus was given function by a need for communication. It is this "response to urgency," Foucault claims is the driver that necessitates the "manipulation of relations."

Using the apparatus theory as outlined above, we can identify and organize the historical arguments that have brought sound in conversation with architecture to discover a new expressivity.



Sound forms throughout history

[2]

[3] Chavin de huantar: Peru

[4] Chichen Itza: Mexico

When animals were marked on the surfaces of caves by prehistoric man, they were indications of the earliest link between sound and form. As the cave dwelling increased in size so did the number of paintings found on the wall. It was the deep resonance created by larger caves that stimulated the mind of the early artist and as the form of the cave changed so did the animals depicted on the walls.

. . .

Ancient Peruvians began to discover a relationship between the resonating frequency of the conch horn and the volume of a chamber. They discovered that a wall could be carved out in order for the sound of the horn to be amplified to increase the spatial understanding of the original sound. The structured pictured to the left was built so that a conch horn could be blown from between the crenelated walls and signal to those inside of a maze the proper path to exit.

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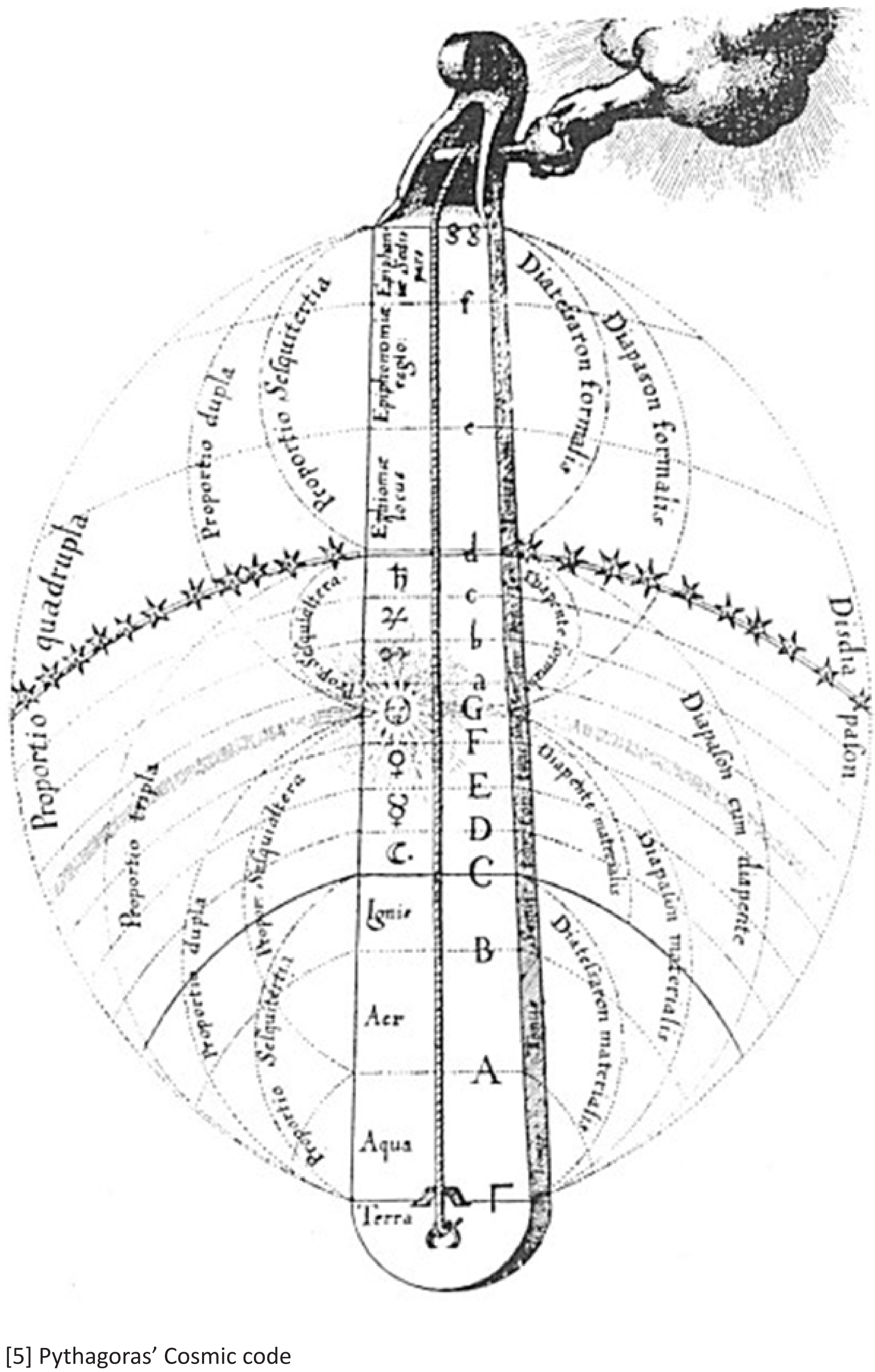
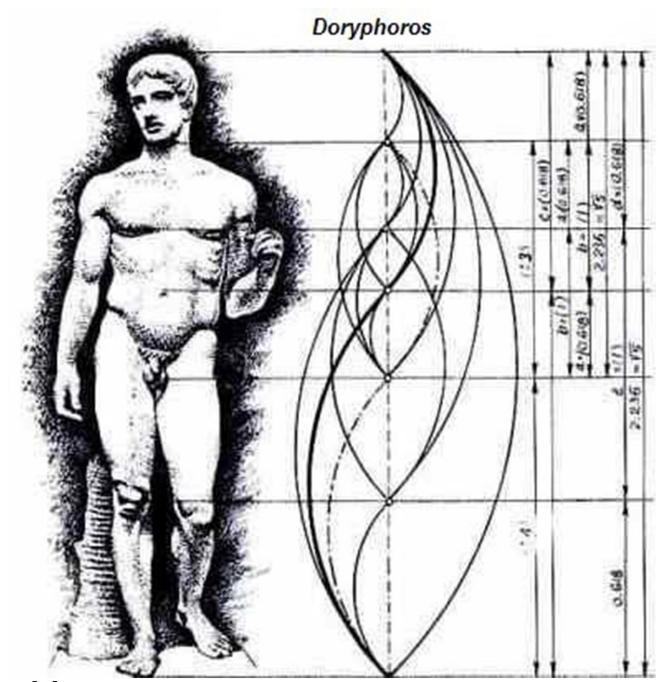
The Pyramid of Chichen Itza in Mexico carefully curates a performance where the shadow of the larger steps profile create a sinusoidal wave along the staircase wall. During spring equinox the shadow is perfectly aligned and a ceremony takes place on the temple courtyard. The chatter at the base of the pyramid reflect off of the stairs and create echoes that closely resemble the sound of a spiritual bird, the Quetzal. The wavy shadow is said to resemble the flight path of the bird coming down form the heavens, and combined with the tonal echo sound of the audience below creates an illusion of spiritual guidance.



[5] Pythagoras’ Cosmic code

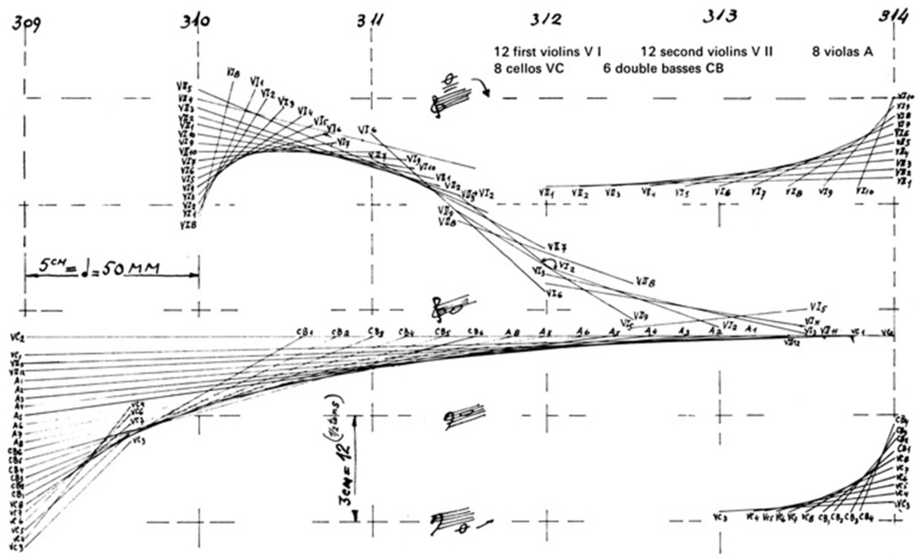
Certainly not the oldest, but the most influential was that of Pythagoras and the cosmic code. The cosmic code was a structure of harmony and proportion that was derived from the notion that number determined tone. Inspired by a blacksmith hammering with different weighted hammers, Pythagoras assigned harmonies to strings based on their lengths. The principal of number and tone was universally applicable. Pythagoras claimed that the distance that our planets had from the center of the solar system produced such an exquisite and harmonious tone, that our ears could not perceive them, yet these tones govern all temporal cycles on earth and all of the rhythms of nature.

Alberti, notable for the development of the first architectural notation system, expanded Pythagorean concept into the harmony of measured spaces. Here tones from a string were equated to measures of a room. He describes these measures by short middle and long areas. These are made up of proportional areas, which extend by a strict alignment with the change in pitch from measured string to measured string. Palladio expanded this further with a more rules of harmonious proportions of rooms, as well as the derivation of harmonious tones into a mathematical theorem for the arrangement of section and elevation.

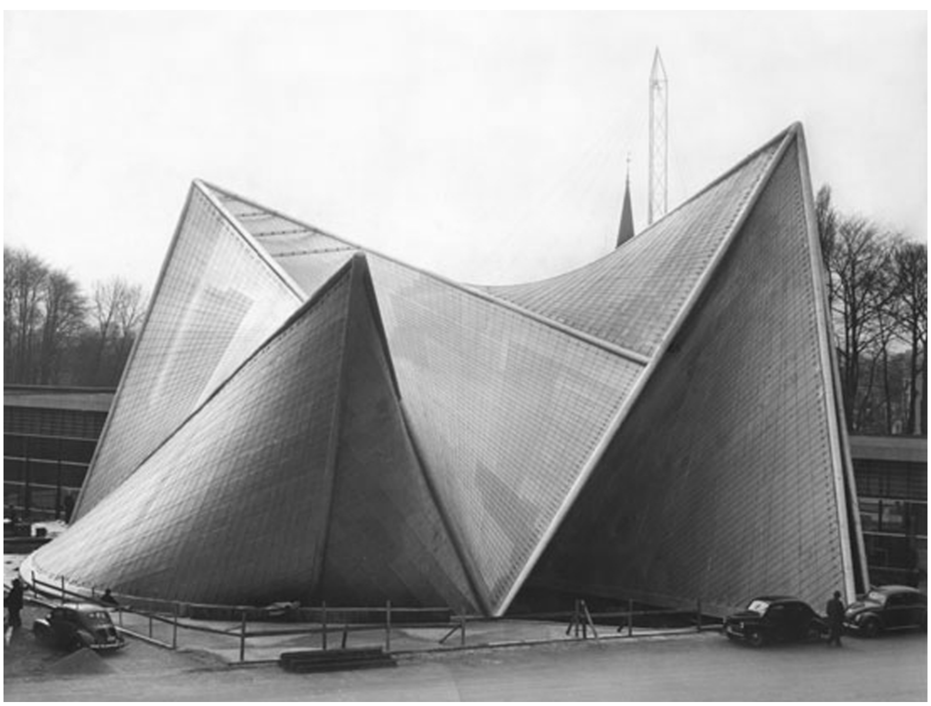


[6]

Our spaces are being used in more and more ways, and the expression of these spaces, is greatly varied. We need not prescribe to the pleasantry of sounds, as metaphors for pleasant space, but instead determine the sonic potential for all manners of sound and reevaluate our tools for the communication of space.



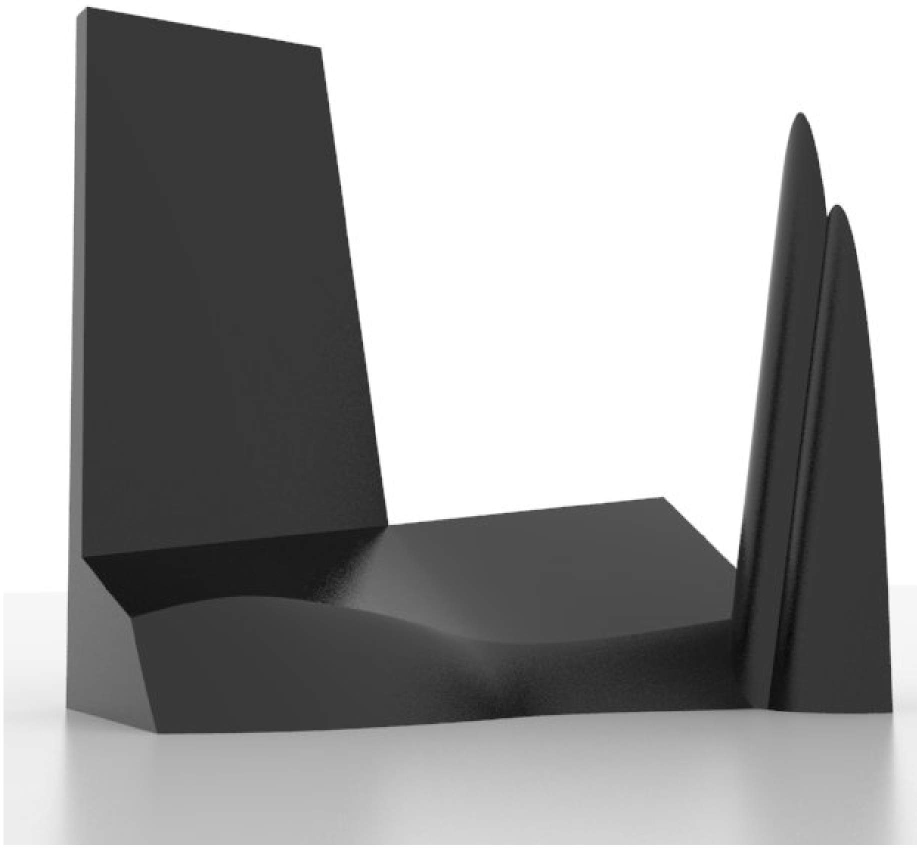
[7] Xenakis: Metastasis


[8] Philips Pavilion: Le Corbusier with Xenakis

An apparatus that hopes to overcome these strict constraints is notation. Notation is unique in that it does not follow any set of preordained rules. This means that the musical effect is not necessarily known beforehand, and the way in which sounds react to one another, following a certain principle of composition, generates the musical experience. If we are to accept that notation is a valid apparatus for architectural form, then we must be able to relate the sequences of sounds depicted visually, as a model for an instantiation into architectural experience. The Philips Pavilion is a relevant example for how space can be guided from sound.

Architect Le Corbusier guided by the mathematical and musical experience of Iannis Xenakis, designed and built a pavilion for the purpose of projecting film and video. The Philips Pavilion was formally designed after a composition by Xennakis entitled metastasis. This musical piece was a investigation into the spatial limits of the glissandi; “smooth pitched slides usually [performed] on a bowed string instrument.” Xenakis conjectured that if you were to repeatedly stretch out this glissandi, and interlace it with variations of the same, then you could create “sonic spaces of continuous evolution.” His basis for this idea was from the curved forms of the ruled surface.

Here we witness architectural form motivating a new conception of musical thought. As a primitive form of auralization, the sound experience that is expected from the Philips pavilion is first verified by Xenakis’ use of the formal characteristics of the ruled surface in his composition.



Sound Object

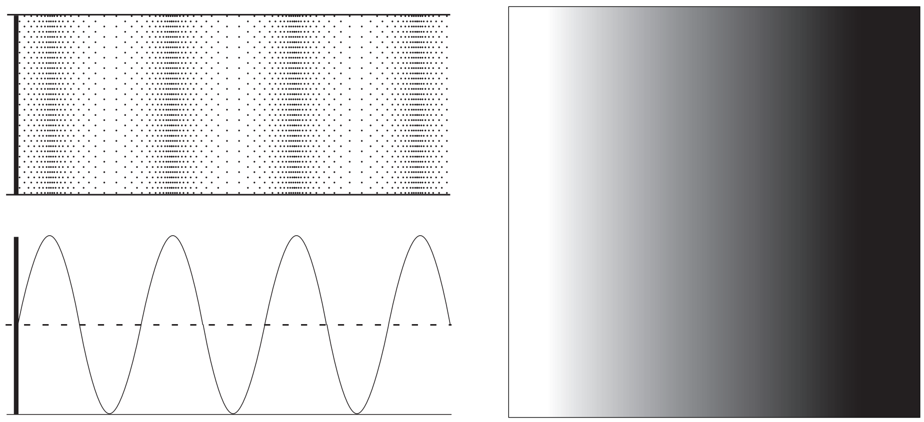
"Much of what we were hearing was in reality only seen"

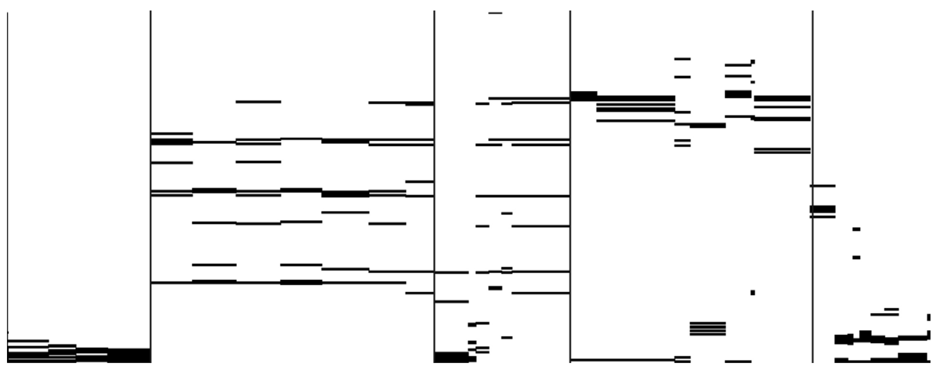
-Pierre Schaeffer

As the science of sound entered into the mid twentieth century, technological advancements allowed us to work with sound in a new way. The creation of the tape player allowed artists and musicians unprecedented control to altar sounds after they had been created. This new technology created a disembodiment to the sound, and asked its listeners to imagine what the source could be. However one musician Pierre Schaeffer was pioneering a new way of understanding sound.

Schaeffer, a French composer, was a front runner during a movement known as concrete musique. This was a new way of composing, using sound bytes as movements in a musical score. In order to advocate for found sound as a method for music composition, Pierre practiced what he called "careful listening." During careful listening he would replay the same 1-3 second sound sample over and over again, in an attempt to remove the initial impression of the sound source and just focus on the experience of the effect of the sound. He would also advocate for splicing the sound moments after the action of sound took place so as to not misinterpret what he was hearing with what he thought he was seeing.

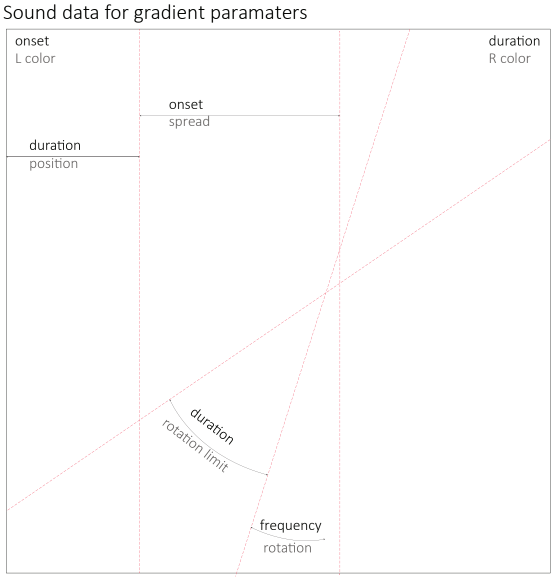
The data that I have retrieved from the sound samples, is not unlike the sound samples that Pierre was composing with. Each sound, has been broken down based on the energy levels, and subdivided into smaller groups. The difficulty is trying to express the similarities and the differences between sound samples in a way that creates a spatial and temporal experience similar to sound. Pierre Schaeffer discovered through his listening that sound can be organized by certain typologies. Further more, these typologies can be altered to create morphologies within a tight set. He would use this technique of creating objects from sound and then apply them in his musical compositions in order to transport the listener into a world defined by his method of making. In creating sound architecture I strive to quantify my work in a similar fashion.





Abstracted data from sonogram depicting freq sets, & objects

Sound data for gradient paramaters



Computational mapping parameters

If we consider a single frequency to represent the smallest component of sound, then to translate sound into form, we must discover the smallest component of space. I argue that the gradient is the most basic form of space and depth. The gradient implies a change in light value or a change in height. If sounds are made up of many frequency layered together then so must space be layered together with multiple gradients.

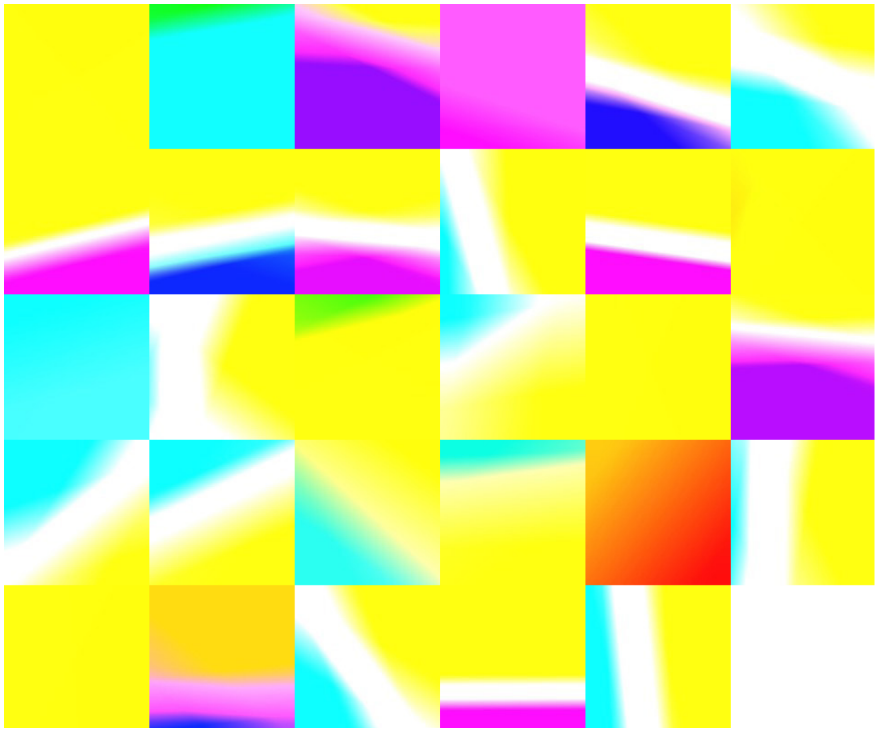
. . .

The data that is extracted from the sound is organized three major hierarchies. The first is the number of frequencies that make up a percentage of a second of sound. Several of these frequency groupings are ordered together to form what Pierre Schaeffer might refer to as an object. This object is determined by the lowest threshold of amplitude data from a sound source. Combining the frequency sets and the object recreates the entire sample of sound. The organization principle following these hierarchies corresponds also to method in which the gradient images are layered together.

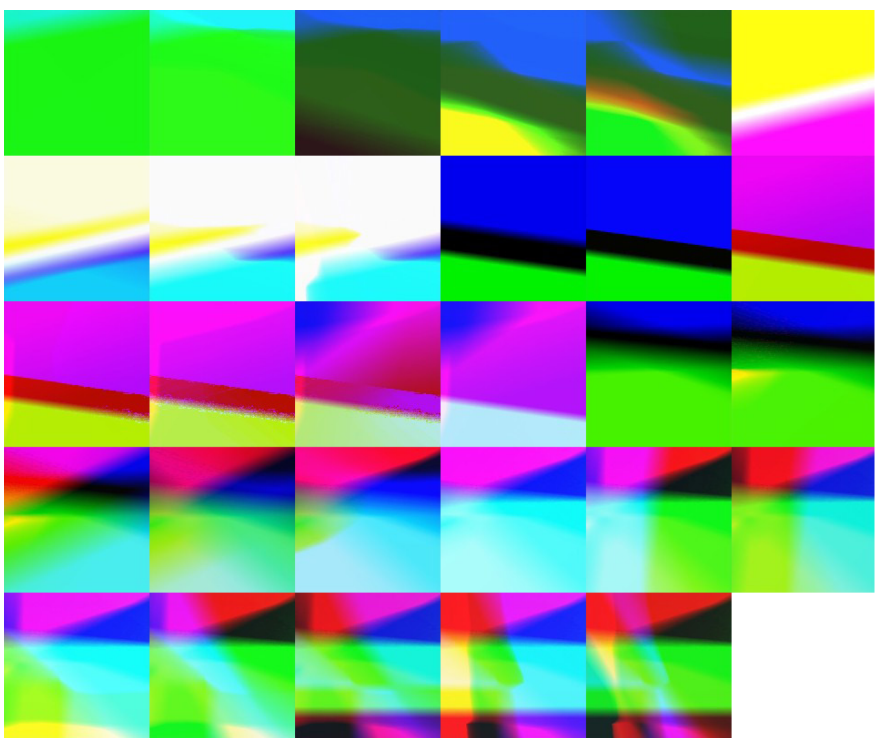
. . .

Each data point in the sound corresponds to a translation vector for the creation of a two toned gradient. The gradient is blended together to produce a new gradient that corresponds to the layering of frequencies in a small section of a sound. It is important to note that the blend method for these gradients is not order dependent. Meaning, no matter how the order of the images is stacked, the final result will be the same. This is important because the frequencies that they represent are not order specific.

After the sets of gradients are created, they are then re-blended following the order from the linear progression of sound. The new blend represents the passage of time and the change in energy level from second to second. The result of this method of image creation is a set of gradients that can be set to the structure of the sound, and as the tonal quality of the sound changes, so does the spatial perception of the image. The color in the gradients serve to expand the potential of blending one to another. The final product however, is reverted to black and white to ensure that the depth data is explicitly measurable.

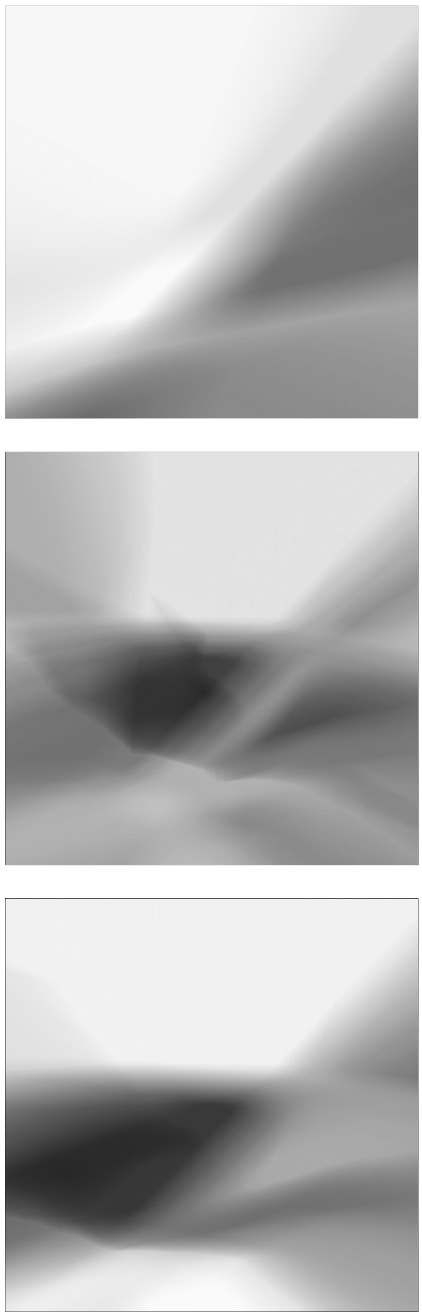


Frequency sets as layered gradients



Blending the above gradients together to achieve a mapping of the energy of sound

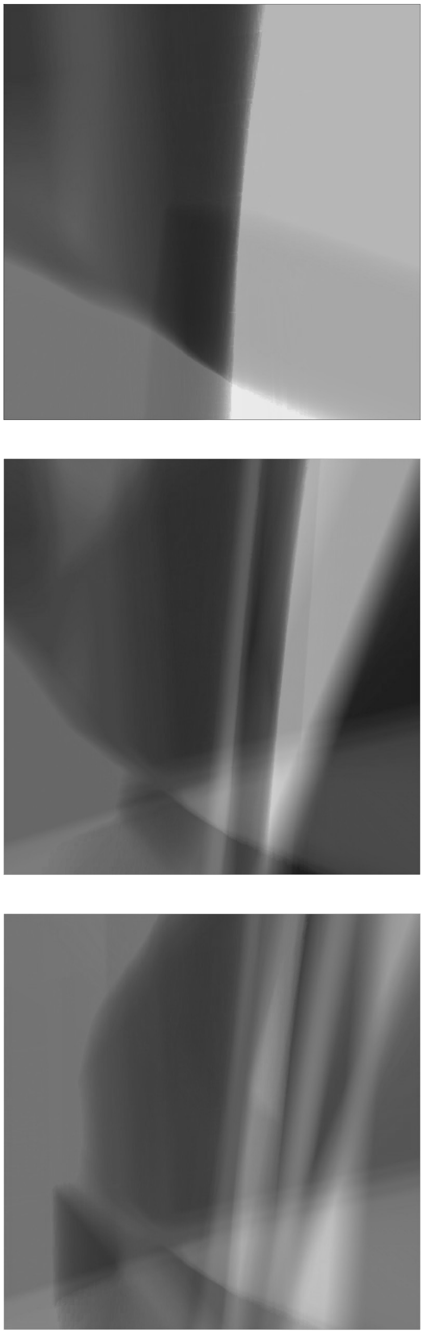
Sonic gradients



Morphology excerpt a: sound 1

Morphology excerpt b: sound 1

Sonic gradients

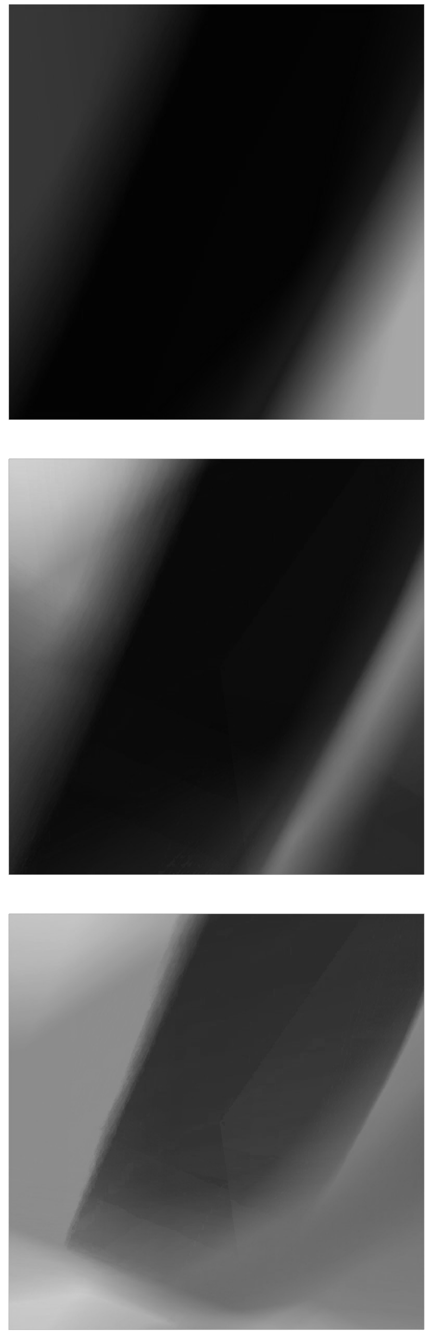


Morphology excerpt: sound 2

Morphology excerpt: sound 3

Sonic gradients

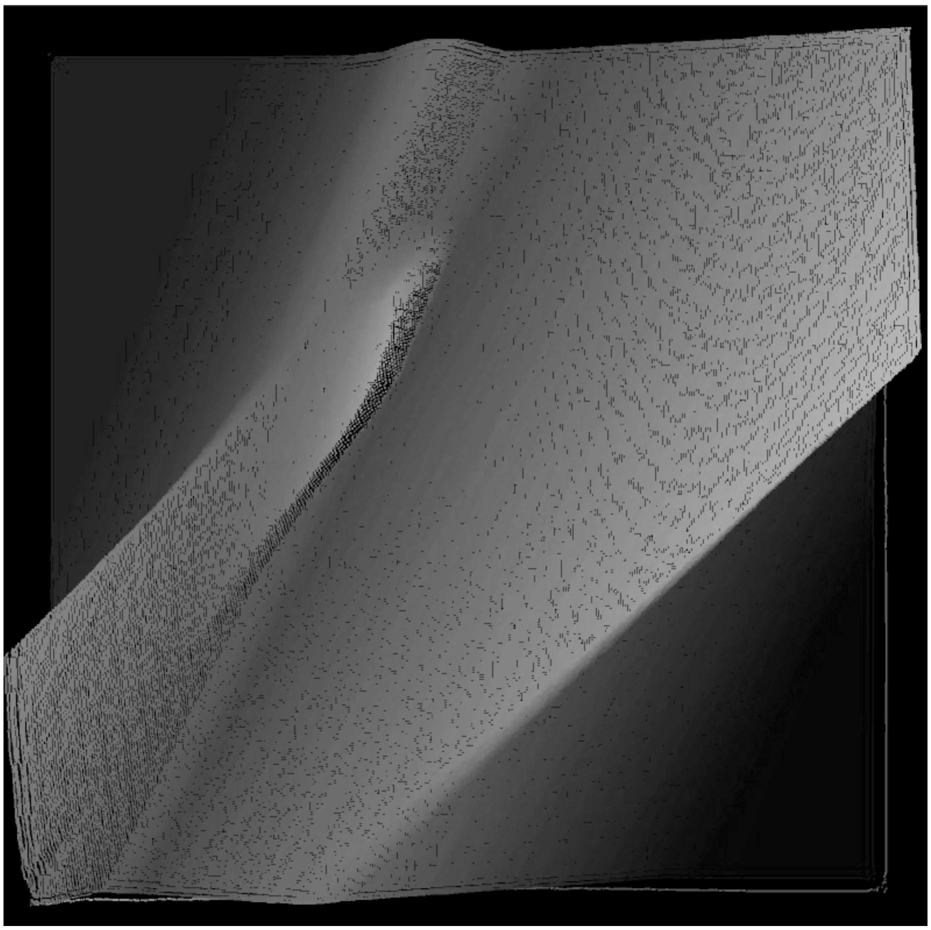
Morphology excerpts: sound 4



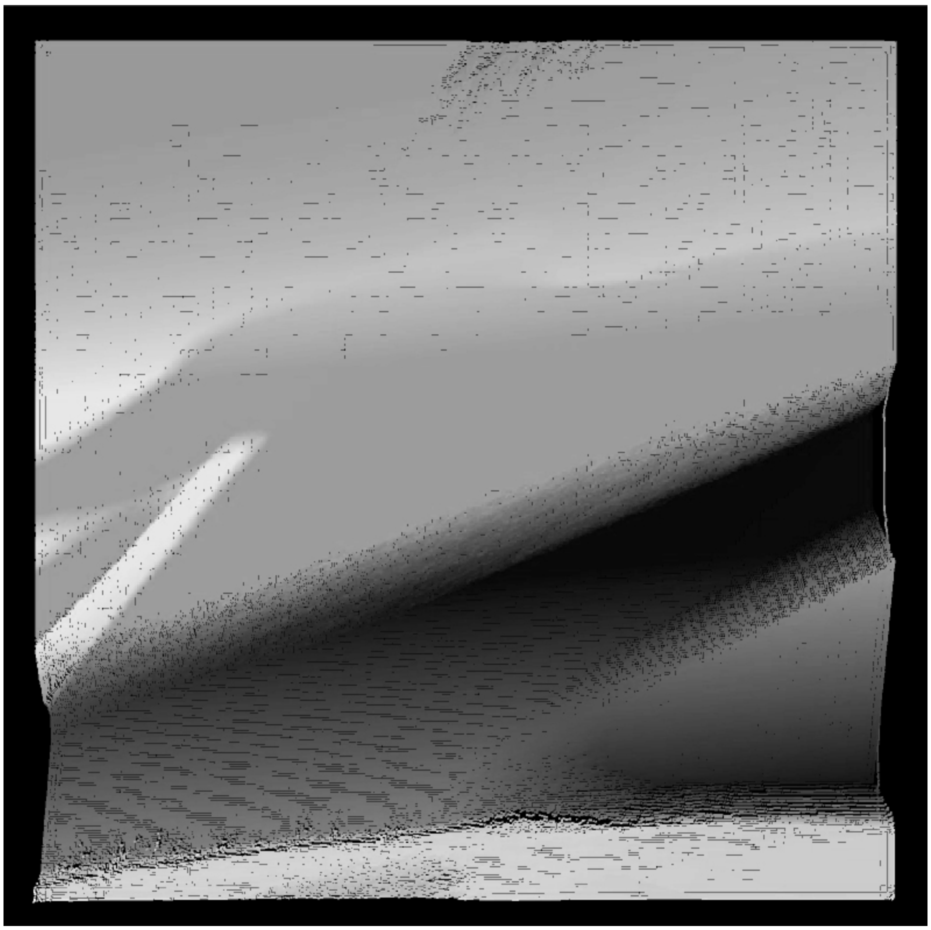
Morphology excerpts: sound 5

Architecture

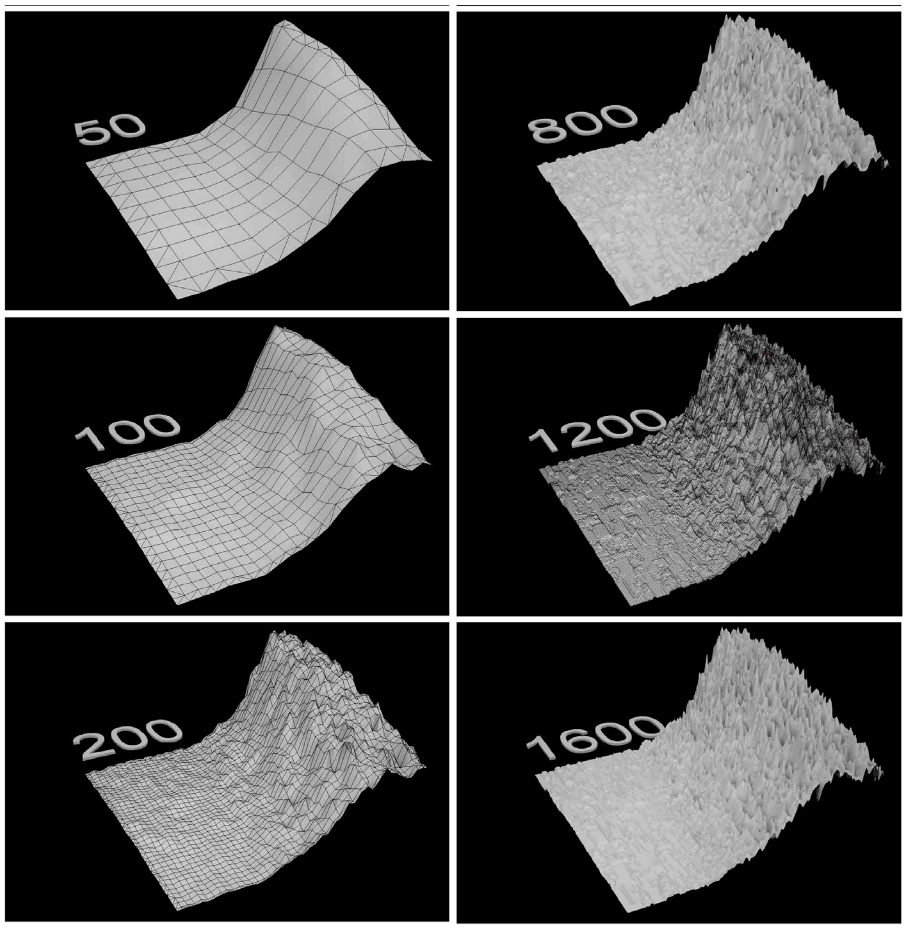
The methodology discussed in the creation of the sonic gradients reveals how capable sound can be as a tool for visualizing new space. The Images are developed sequentially from the sound data and create a hinge point into three dimensional form. The interpretation of these images, much like the interpretation of sound itself, is constantly changing. It is not the goal of the thesis to evaluate these images and find the correct method for architectural production, but rather to explore the possibilities that emerge when trying to capture, in a set of spaces, an unfolding of sound and time.



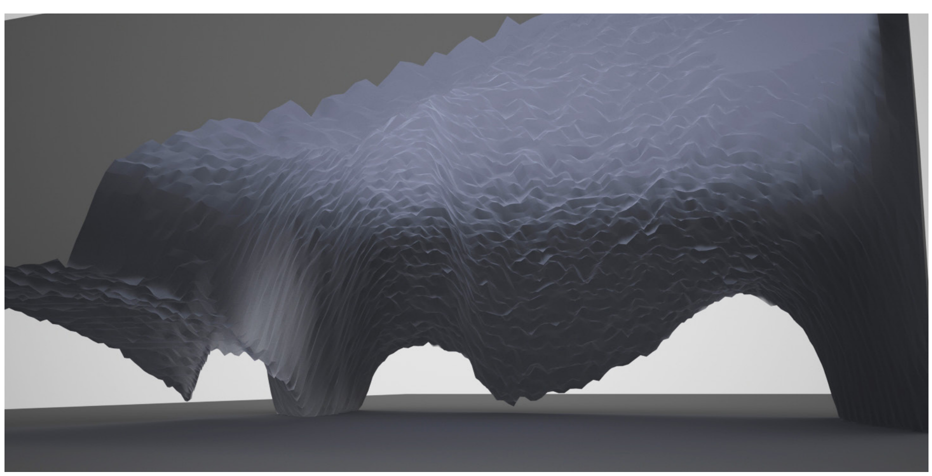
Height map



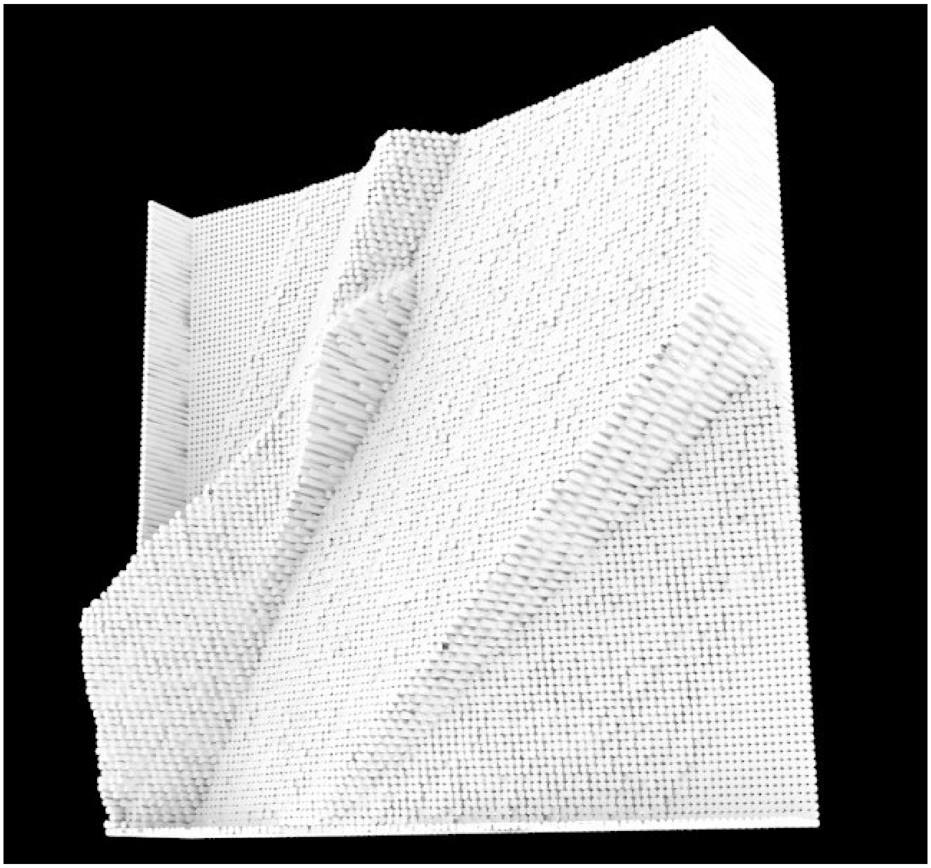
To visualize the depth found in the sonic gradients, image data can be remapped into a third dimension. The gray values of the images represent a height value at a specified scale. The number of pixels in the image represent the amount of detail that each surface contains. This method of 3d production can simulate folds in a surface, but due to the strict grid that the pixels follow, there can be no surface that lies behind or in front of another. This limits its architectural potential to a simple manipulation of surface height values.



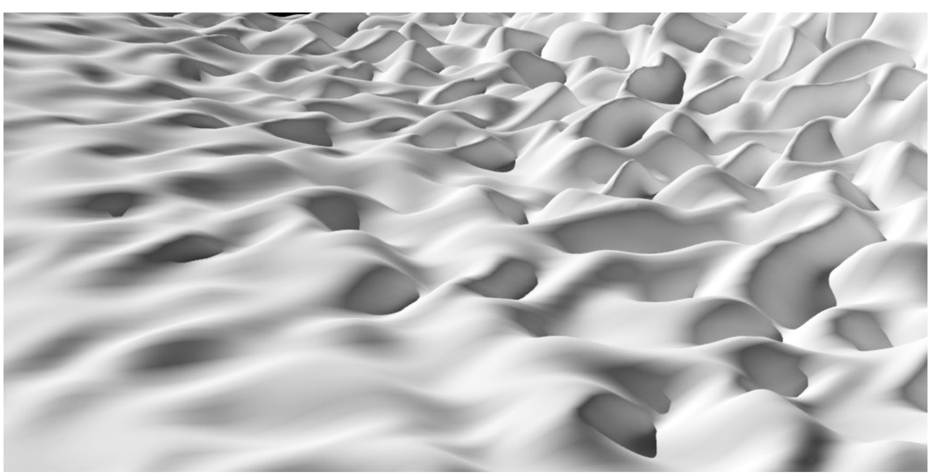
Resolution of height map to determine resolution of surface texture



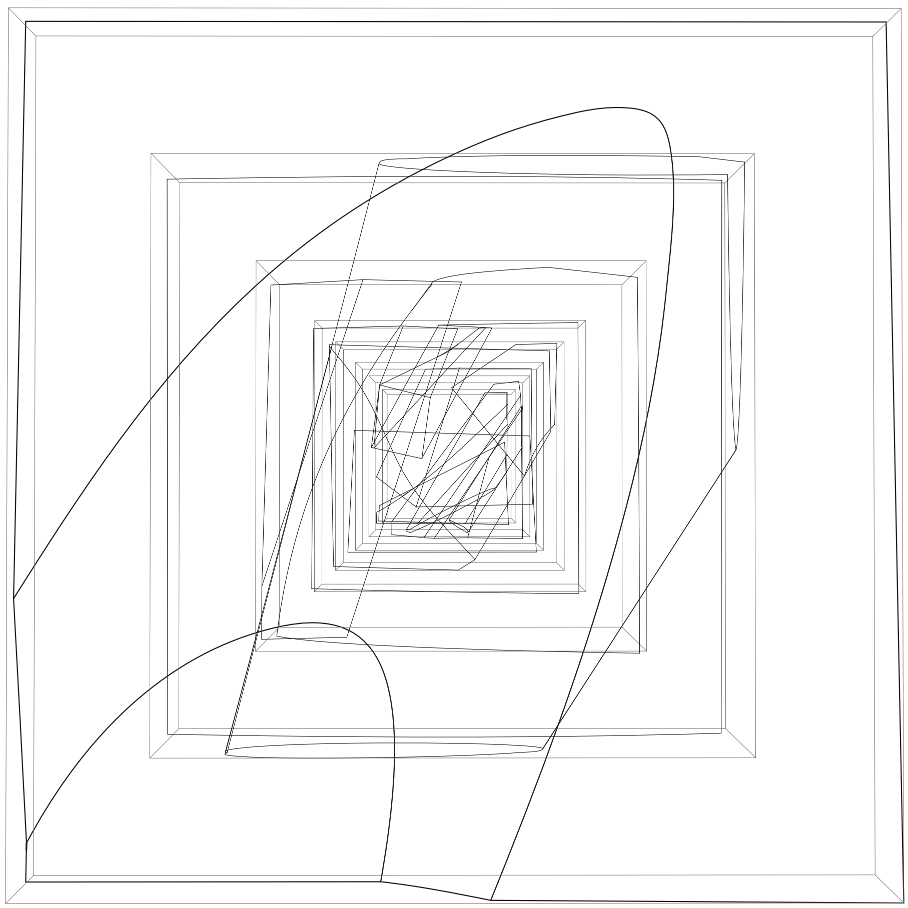
Ceiling condition generated from sonic gradient pixel values.



The pixels can be rescaled to alter the resolution of the surfaces. The areas of an image that contain the steepest slope will create the most dramatic surface texture.



Saturation values determine the scattering amount on surface



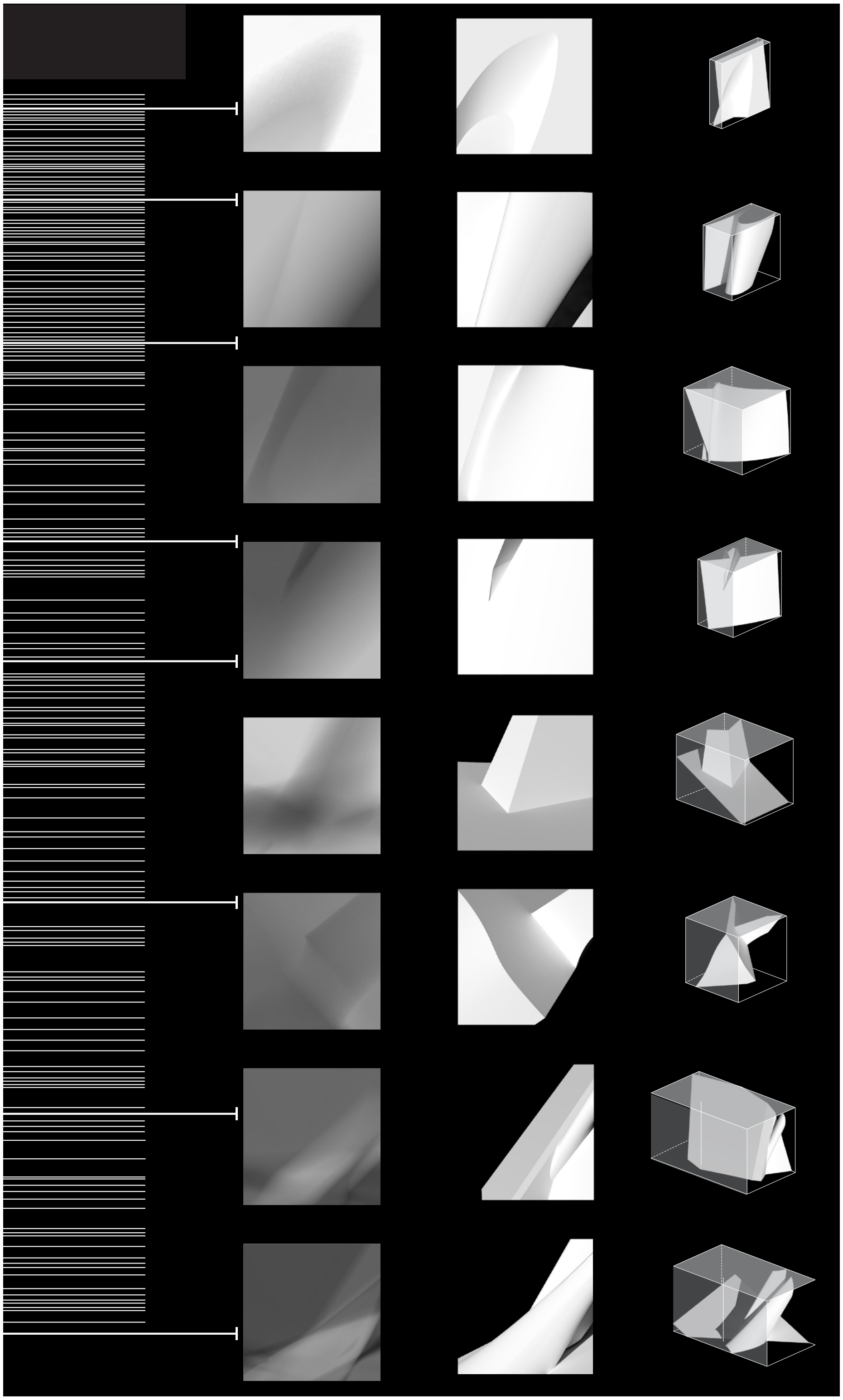
Sonic objects in wire-frame, layered along single perspective

Perspective

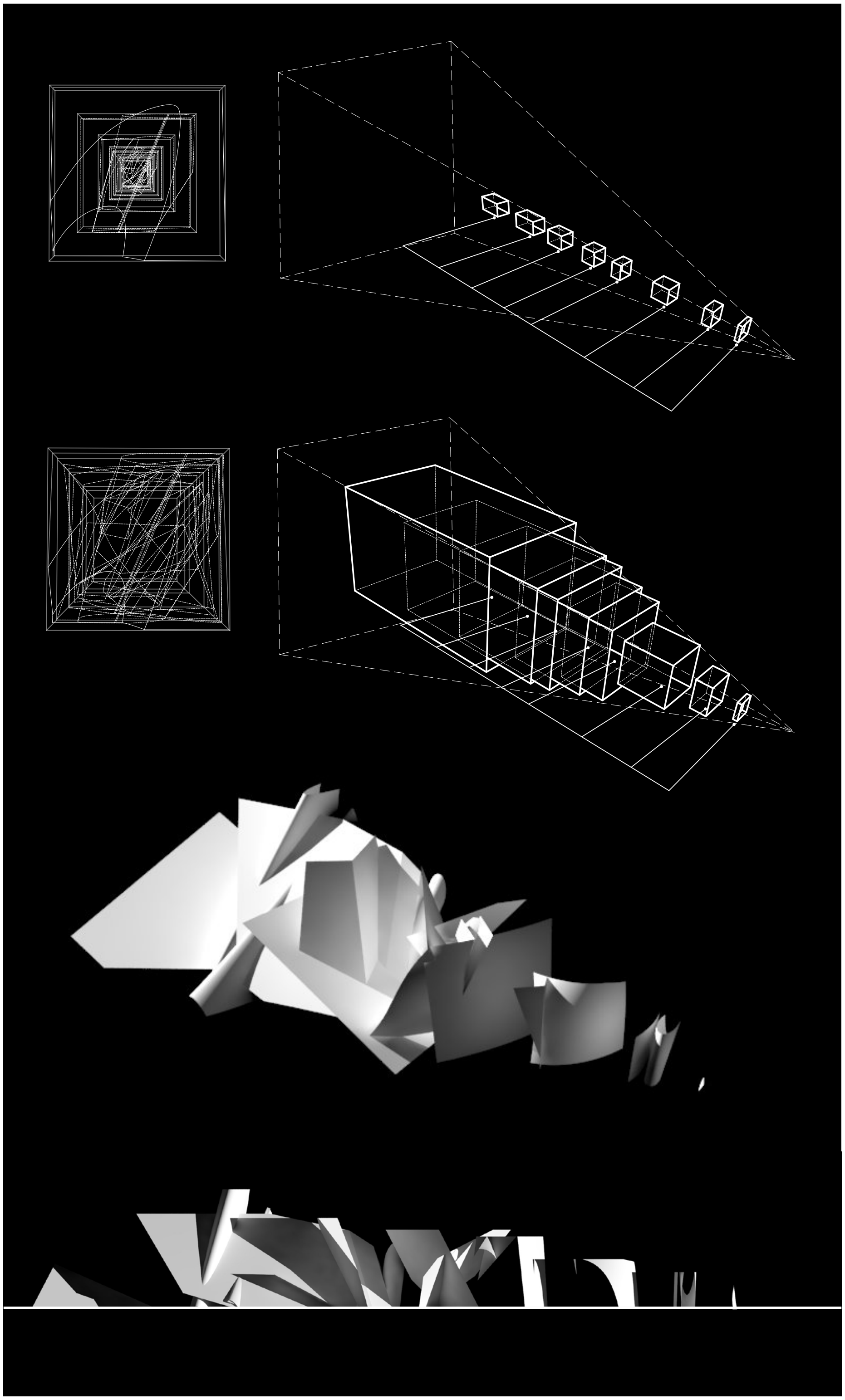
As a sound unfolds, our ability to accurately recall the past gets weaker. As we listen, we fabricate a memory of what we think we heard to better understand what is currently reaching our ears. The farther we move from the initial start of a specific sound the less likely that our memory of it is accurate. To capture the temporality of sound into architecture, the notion of duration and time must be explored. For this example, time is represented by a fixed perspective point that extends across a site. The duration of a sound is determined by the size and the location of sonic objects located along the line of sight from the perspective point.

From a singular vantage point, the objects on the site appear smaller the further away they are. Since the sound objects are placed in accordance with their position in a sound sample, the smallest perceived objects are also the objects that come later in the sound. As stated above, our memory of sound does not work linearly, so the objects themselves must undergo a transformation so that they represent more clearly the experience of sound.

To achieve this, each sonic object is rescaled form the center of the perspective so that its bounding box lines up with the bounding box of the closet object. Similarly to how previous sounds carry though to our interpretation of new sounds, so do architectural forms stretch across the site overlap one another and create a spatial experience that is greater than the sum of its parts.

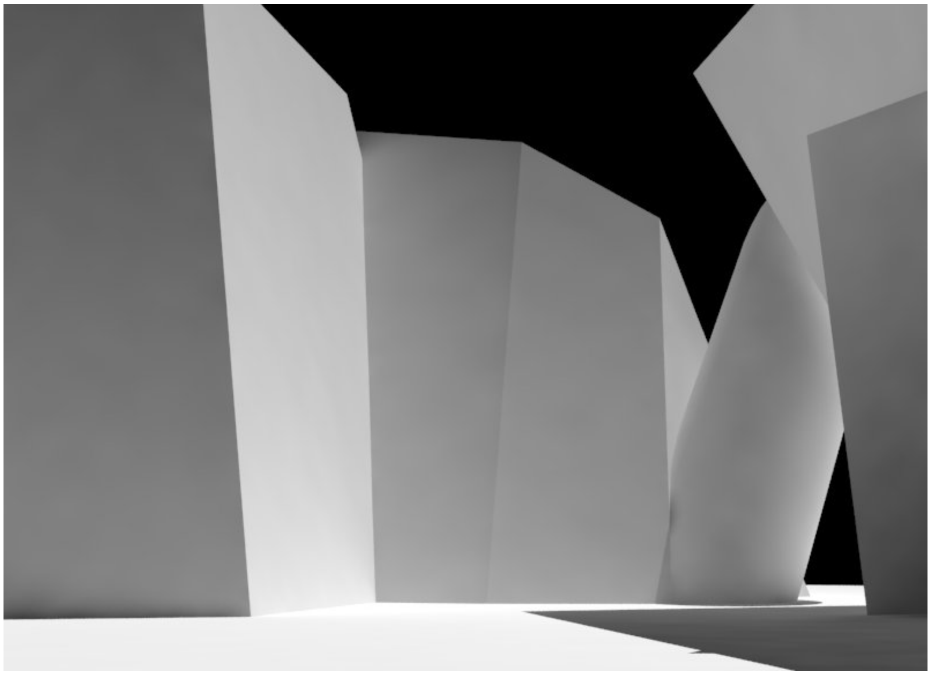


Interpreting the accurate depth of the sonic gradients to produce three dimensional sonic objects

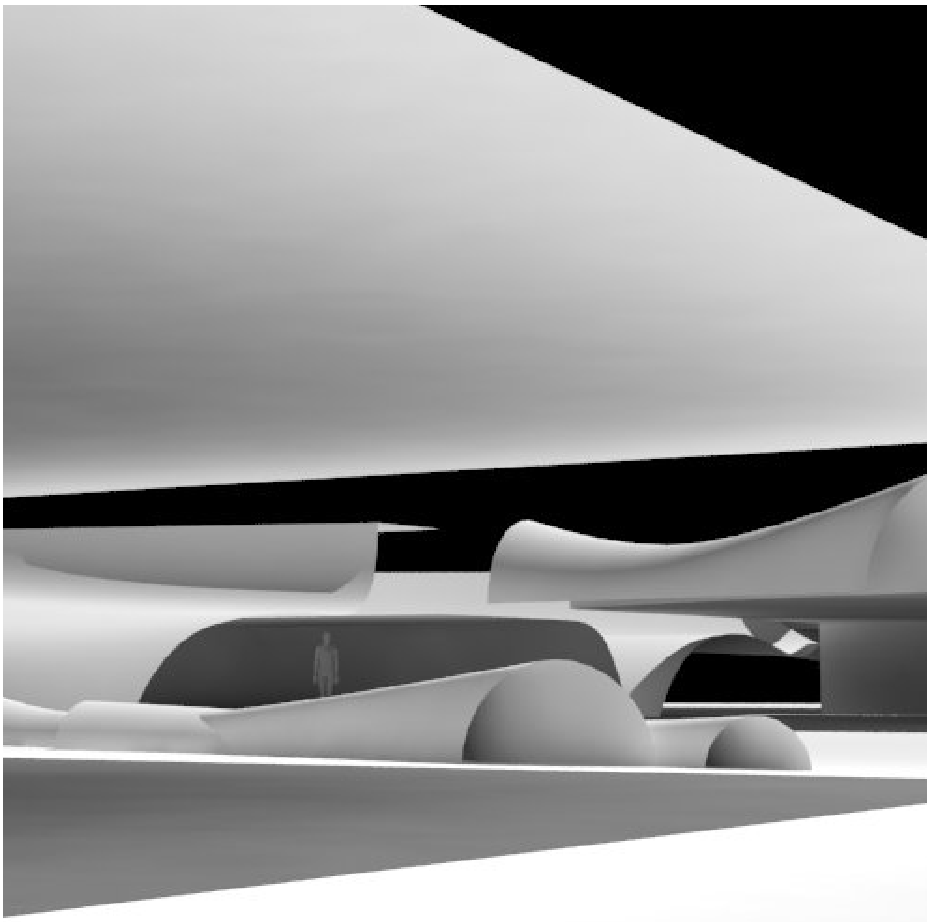


Placing and scaling sonic objects based on a singular camera view.   Axon and section of resulting scaled architecture

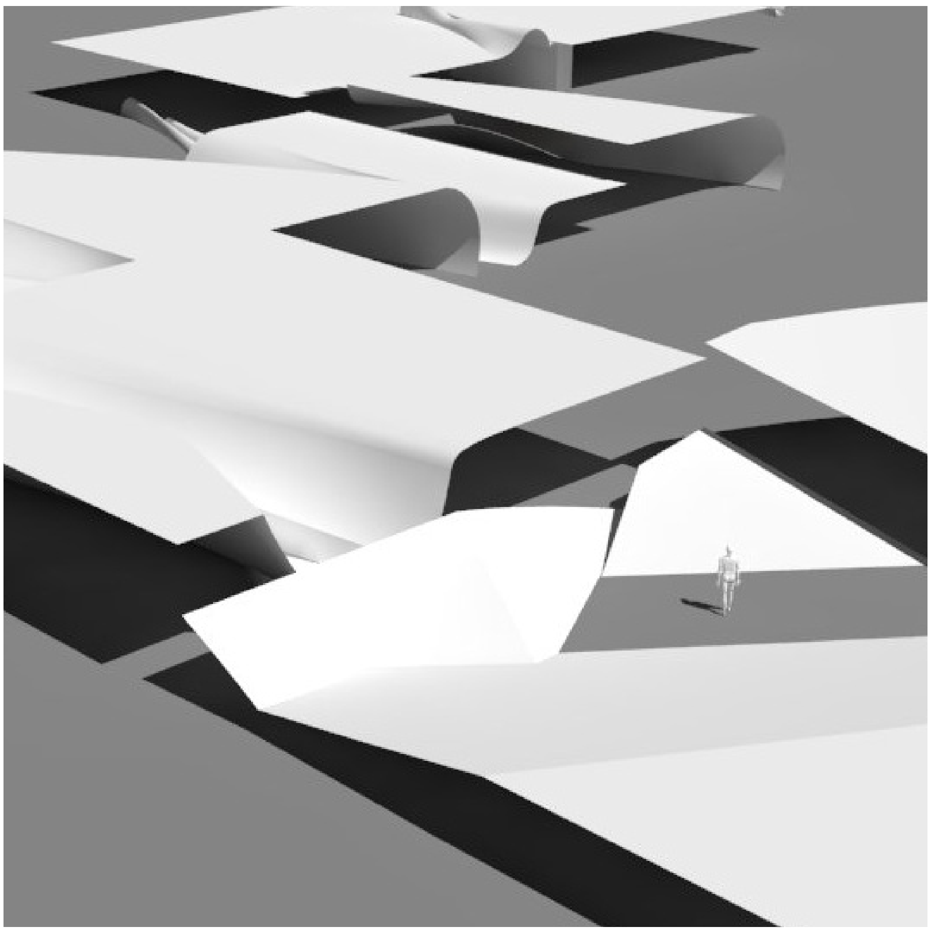
Floor plan of resulting scaled sonic objects. The increase in size of the surfaces corresponds to the view angle from the single perspective


Rendering of intersection scaled objects

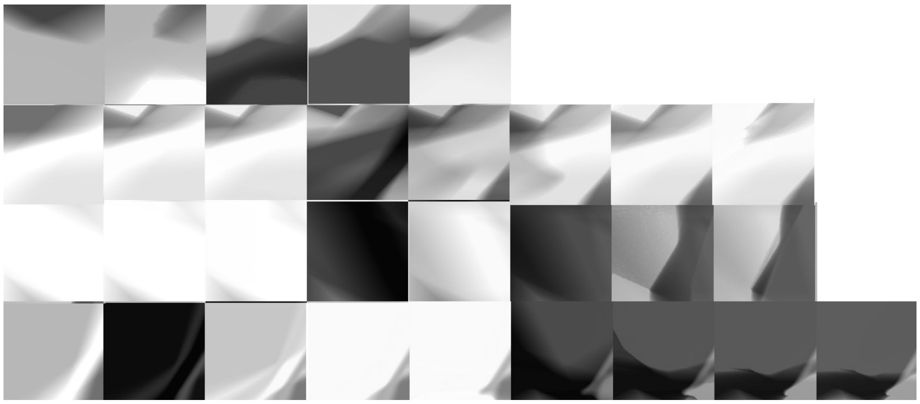
The methodology presented here is successful in establishing a connection between the organization of sound and the experience of space, however, due to the reliance on the perspective as organizational system, the resulting forms are not well controlled. Architecture generated form this process would always create a similar contour no matter what the original sound was. The sound objects themselves would be overshadowed by this larger gesture and all of the nuance of the original forms would no longer carry the weight that the sequence of individual gradient images did.



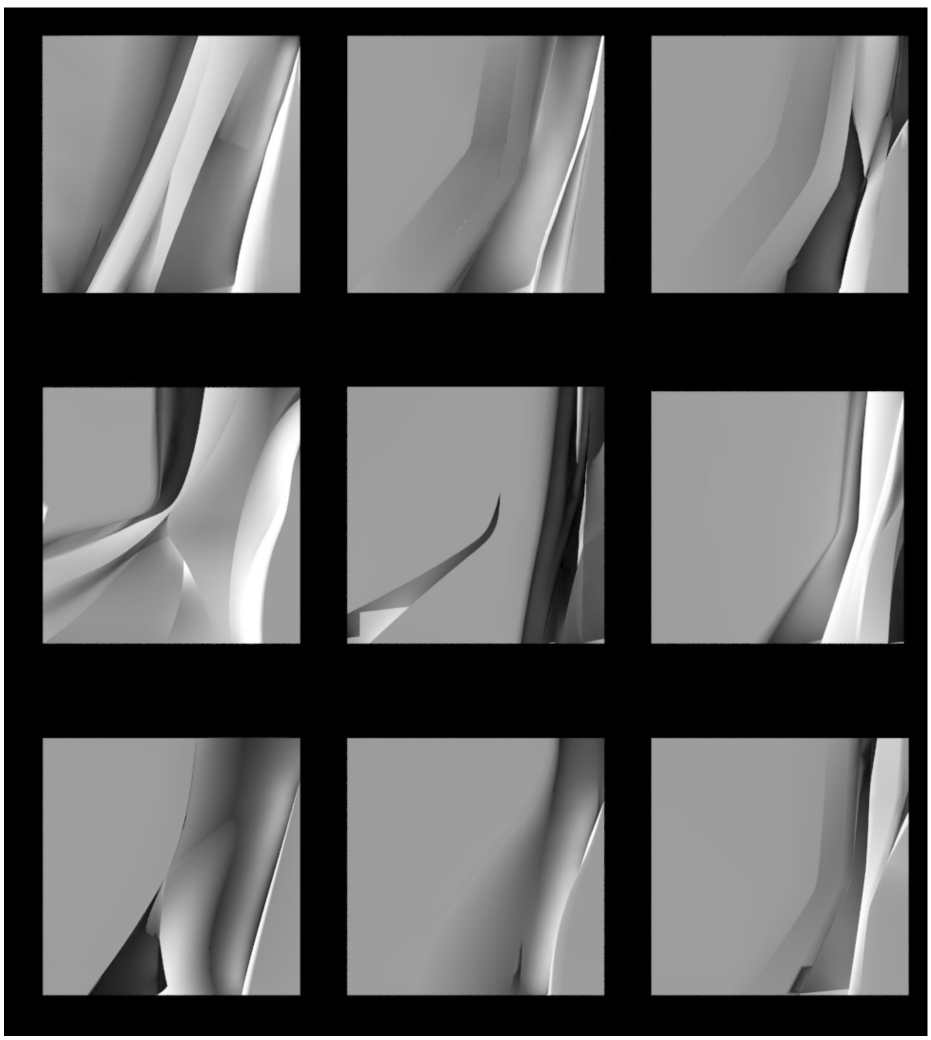
Field



One of the shortcomings of the previous prototype was that only certain gradients were represented. The sound source is composed of gradients for every onset from the spectrograph, and in order to fully describe a sound all of the gradients must be represented. This calls for a shortening of the original sound source and reorienting of the sonic objects produce from the gradients. The objects are modeled to act as canopy's to create enclosure as well as introduce a more flexible circulation path.

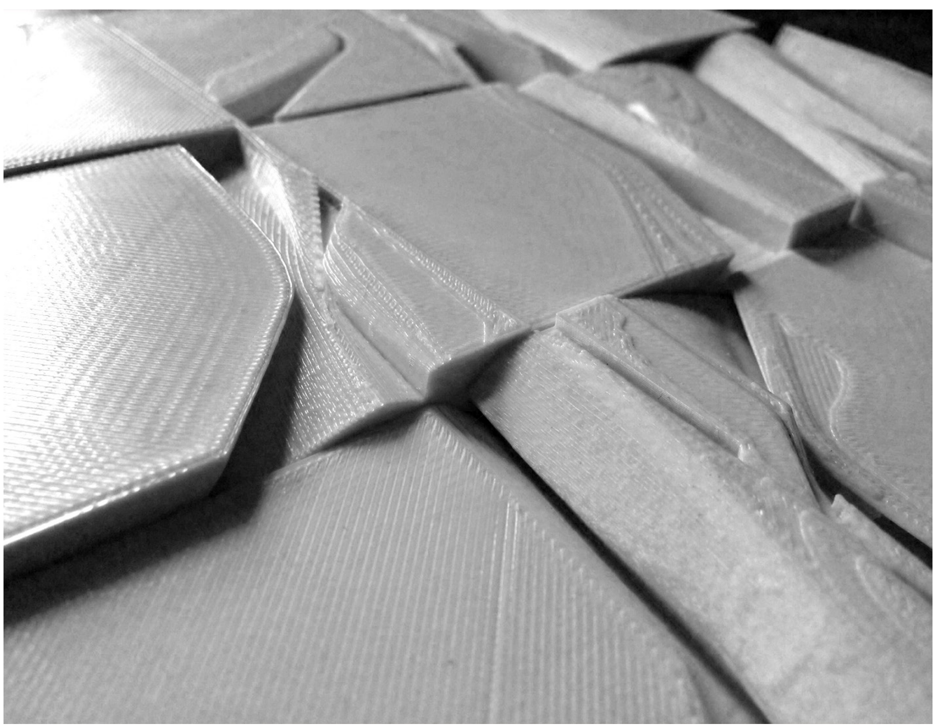


Sonic gradients as roof plan for an architectural field

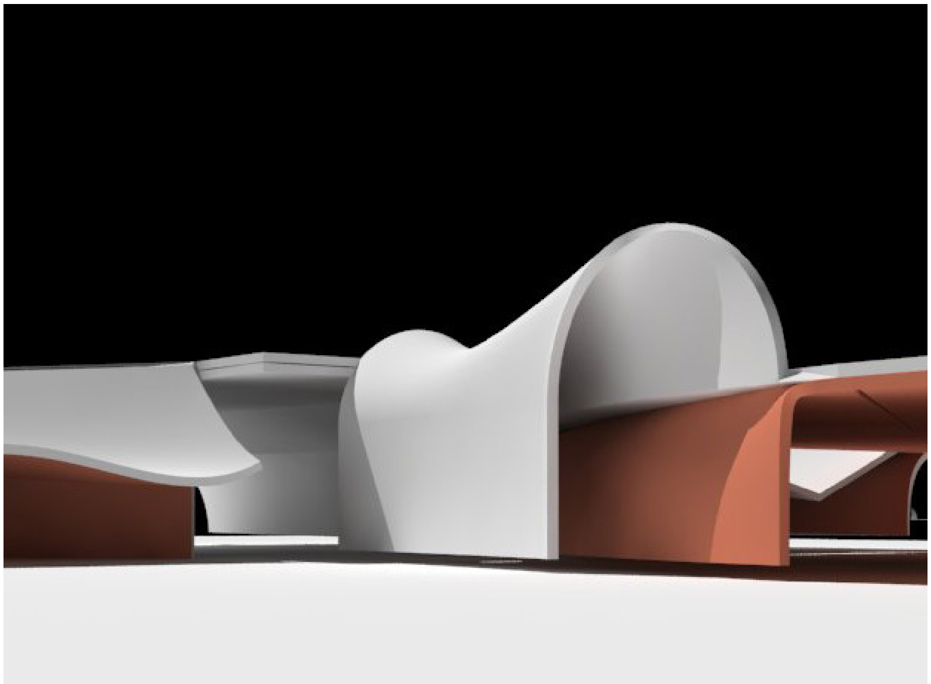


Three dimensional surfaces modeled after gradient grid

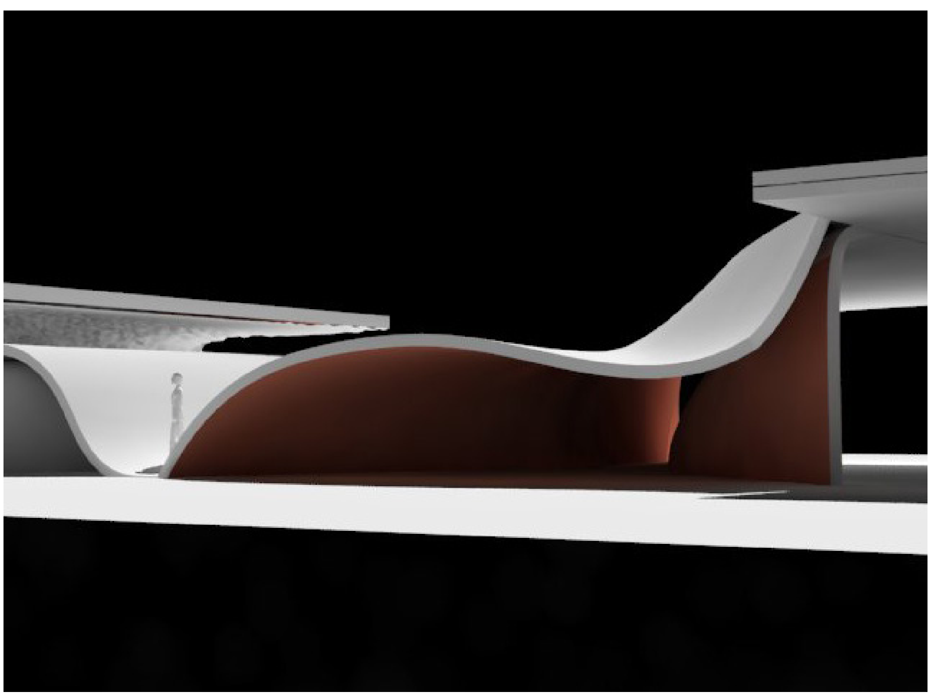
Overall field condition model



Model detail of continuities between several sonic objects

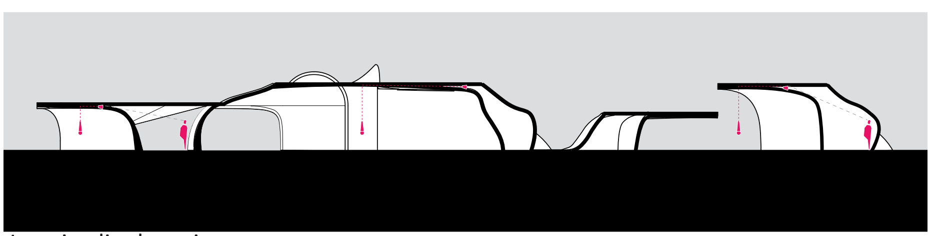


Layered surfaces representing passive and active acoustic surfaces

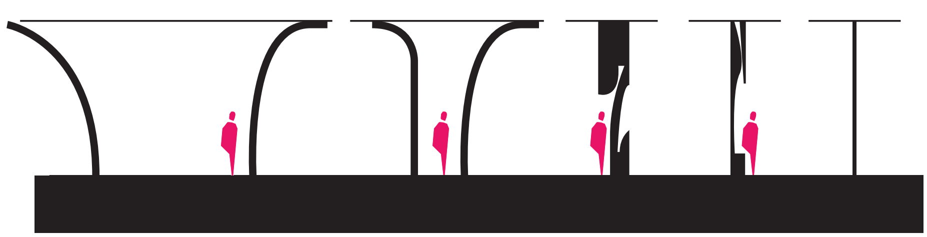


Leveraging the grid created from the proportion of the gradient images allows for two vectors of circulation to carry through. A path moving horizontally would describe a change in the morphology of the sound, and a path moving vertically would show a change in typology. The sonic objects would reflect this change based on a the change in continuity of the surfaces. Programmatically, this field condition would act as a sonic zoo; leveraging the surfaces as acoustic reflectors, altering the existing soundscape to create unique sound characteristics under each sonic object. Certain interior spaces would electronically project a filtered version of the soundscape based on the data that made that sonic object possible. The final result is a landscape that slowly reveals the link between form and sound, and creates a unique experiences based on the way that you traverse the grid.

Roof plan showing change in morphology



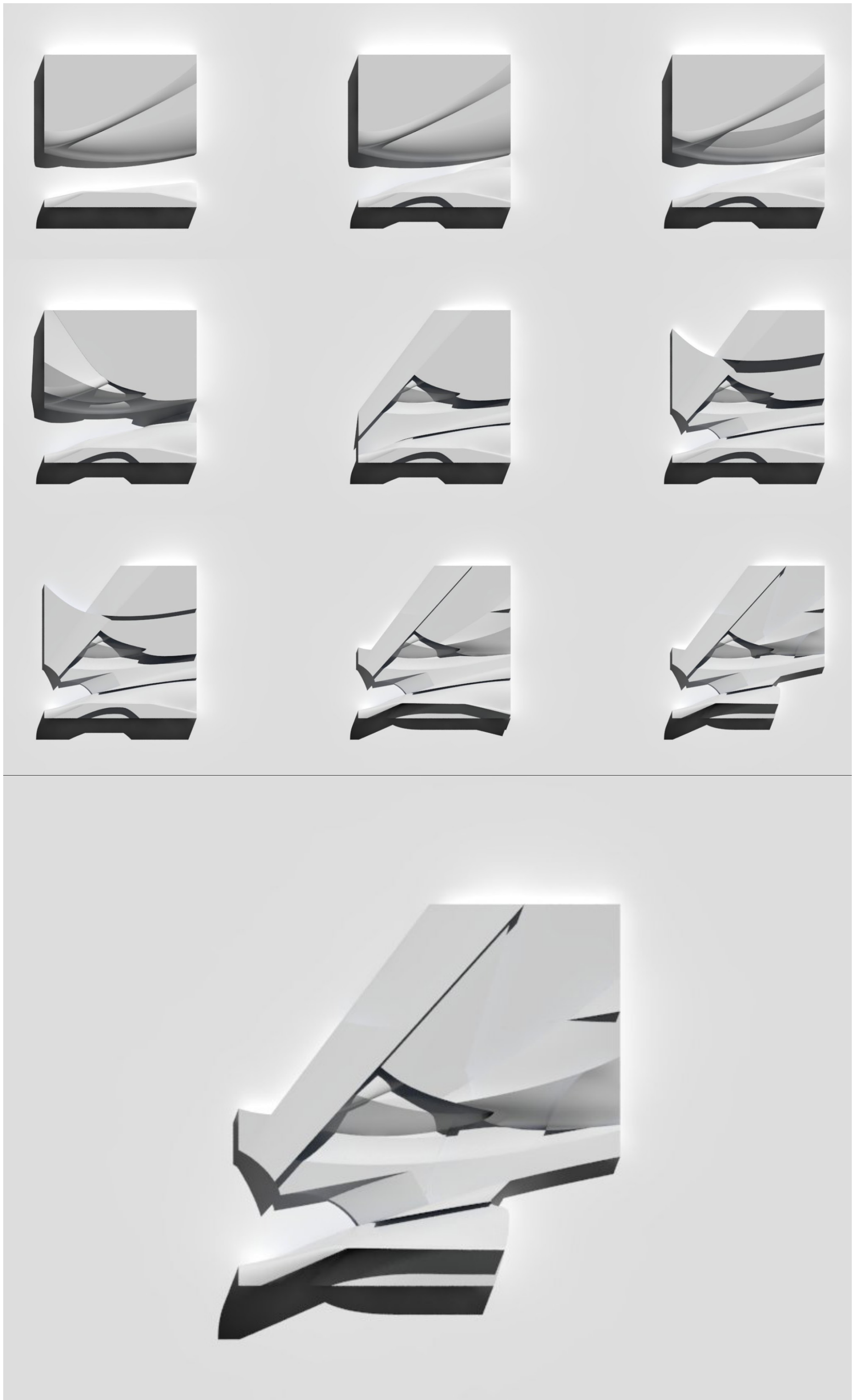
Longitudinal section

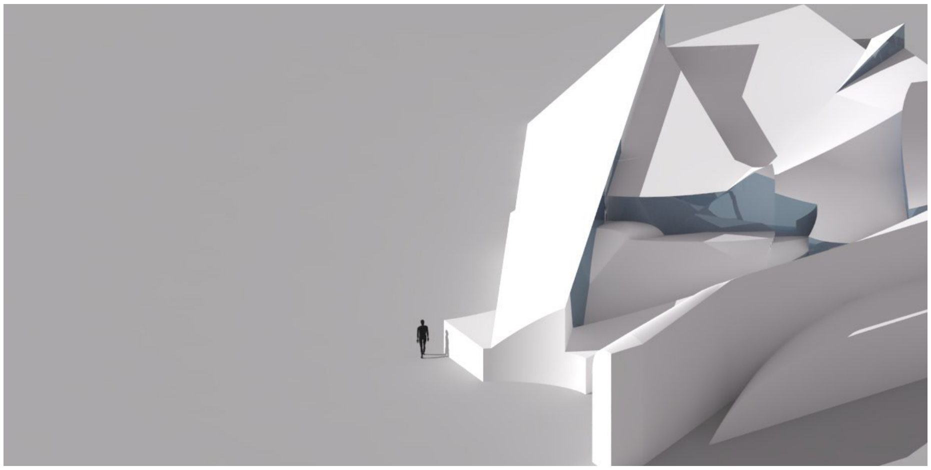


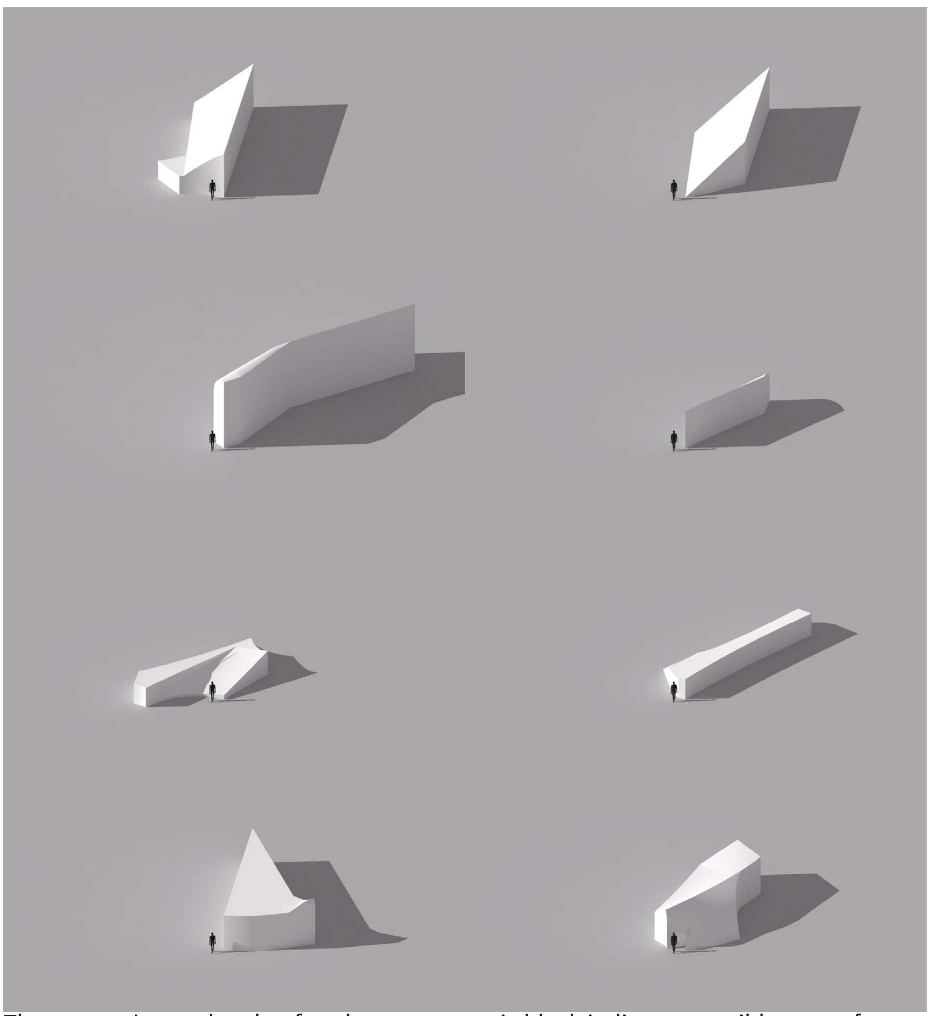
Sectional studies describing the scale of experience from elecroacoustic sound projected into the space

Transformation

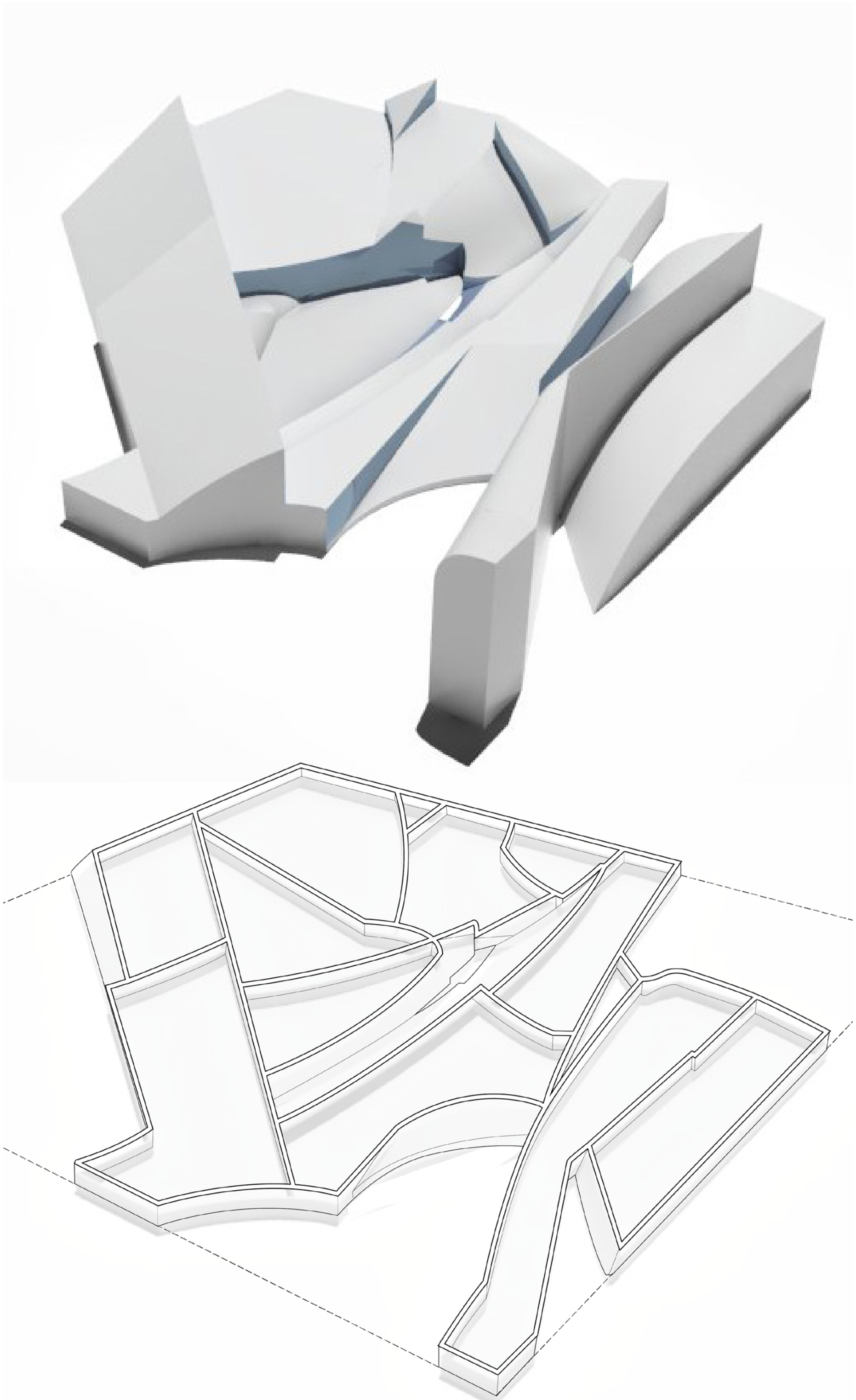
The sound gradients are created to ensure that the previous image is slowly altered by the next image. This ensures that as the sound progresses so does the spatial quality of the image. An entire sound sample is built from the sets of frequencies and the each set builds on top of one another. Animating this slow change reveals an unseen organization of static and morphing formal characteristics. The challenge for this last architectural experiment was to capture this ever changing form in a static architectural object. The result is a set of rules that build off one another based on the depth data from the sonic gradients.







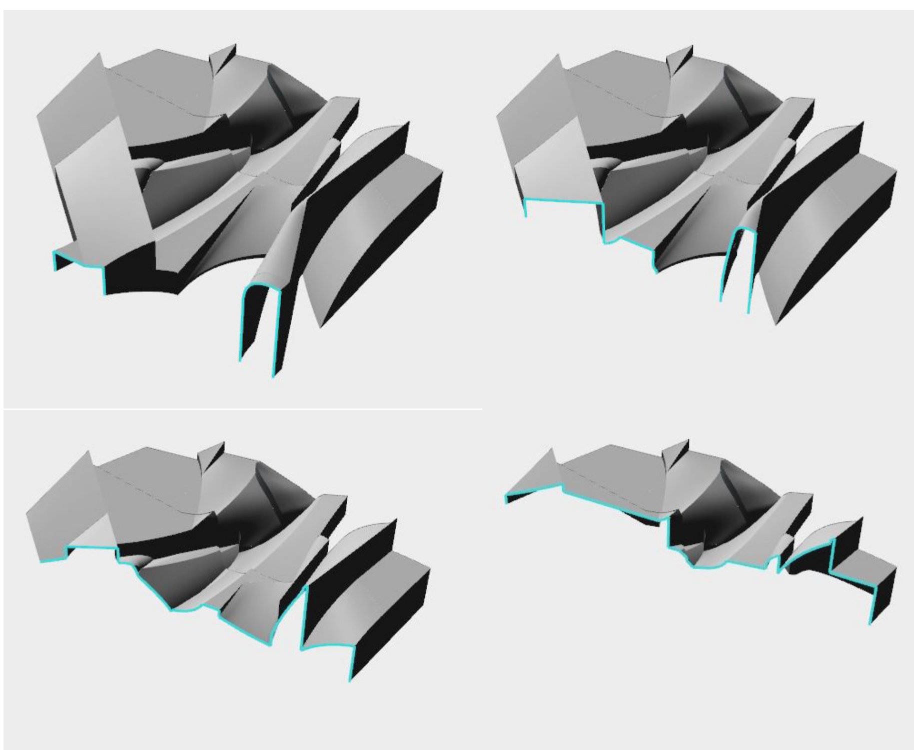
The proportion and scale of each programmatic block indicates possible usage for sound playback.



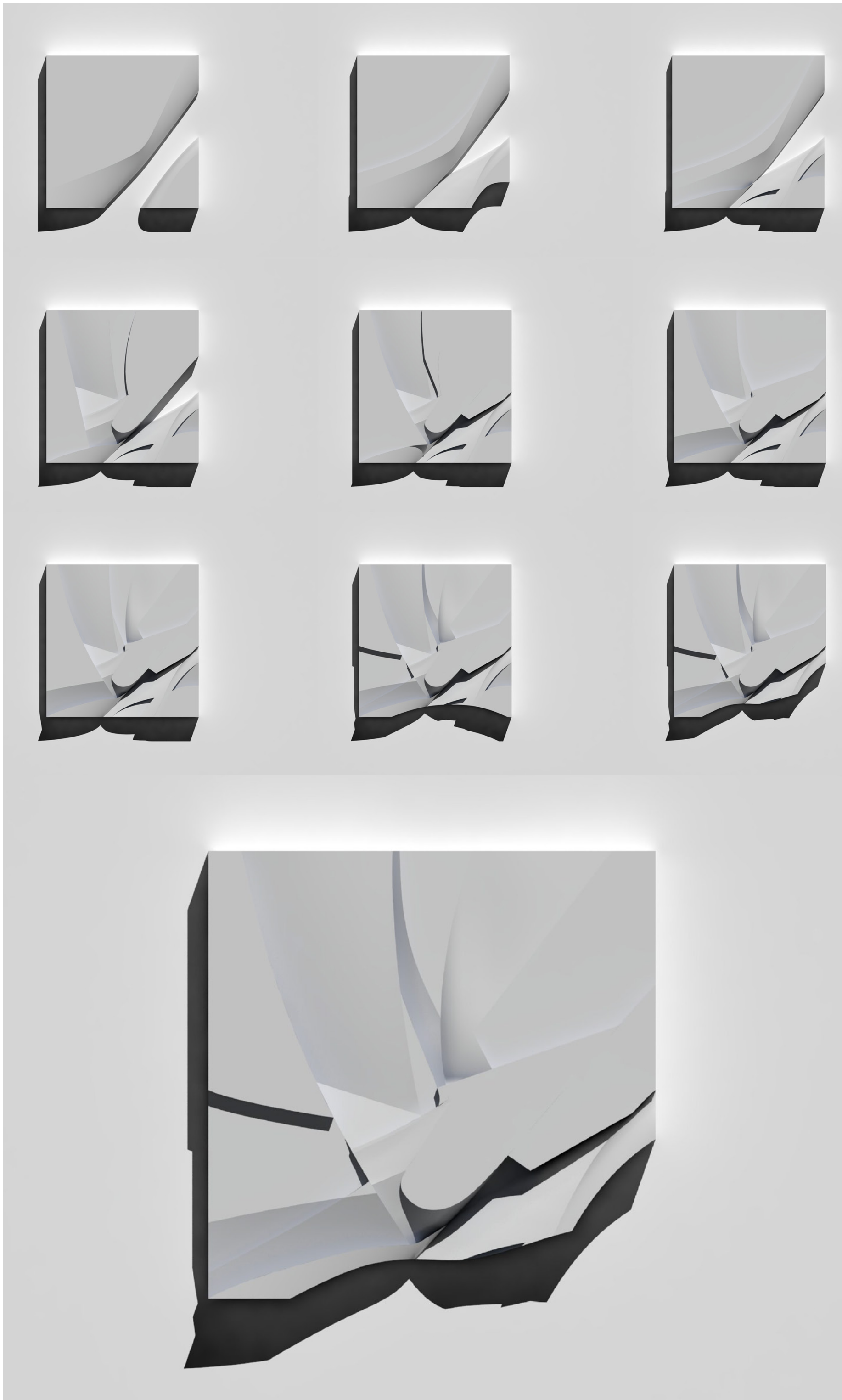
The variety of floor areas between the rooms, modify the original sound source to include a greater variety of resonance

The architecture consists of several programmatic blocks that fit together like a puzzle. Each block is a projection of the information described from the gradient images, and the blocks final form is not revealed until the last sonic gradient has been modeled. A solid mass is excited though sound to create an inhabitable form. The sound creates the architecture, but can the architecture begin to create the sound?

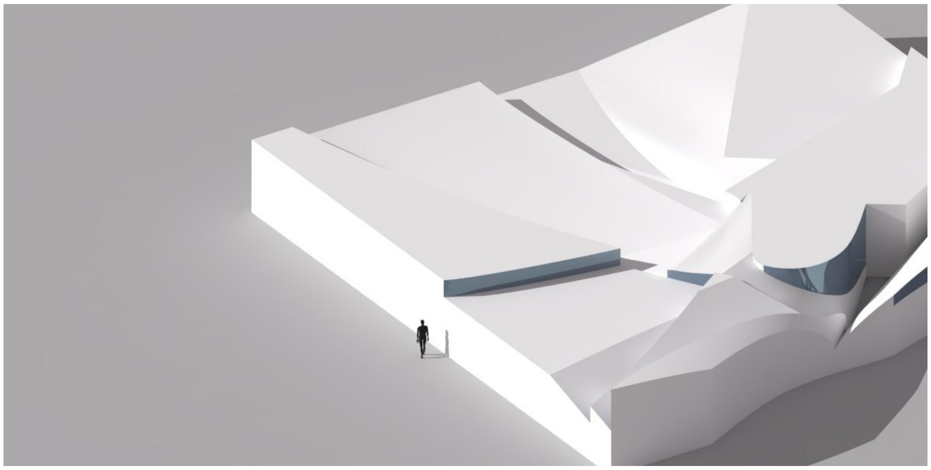
If we begin to understand the result of architecture, as data that can be remapped onto other domains, then it is possible relate the sectional contours of a volume to frequency modulation in sound. The resultant sound could then be remapped into an architectural space and feedback loop can begin, each structure informing the previous sound and vice versa. The architecture could slowly manipulate itself into finding a new stable state or oscillate between two different poles and generate a conflict of space and ideas.

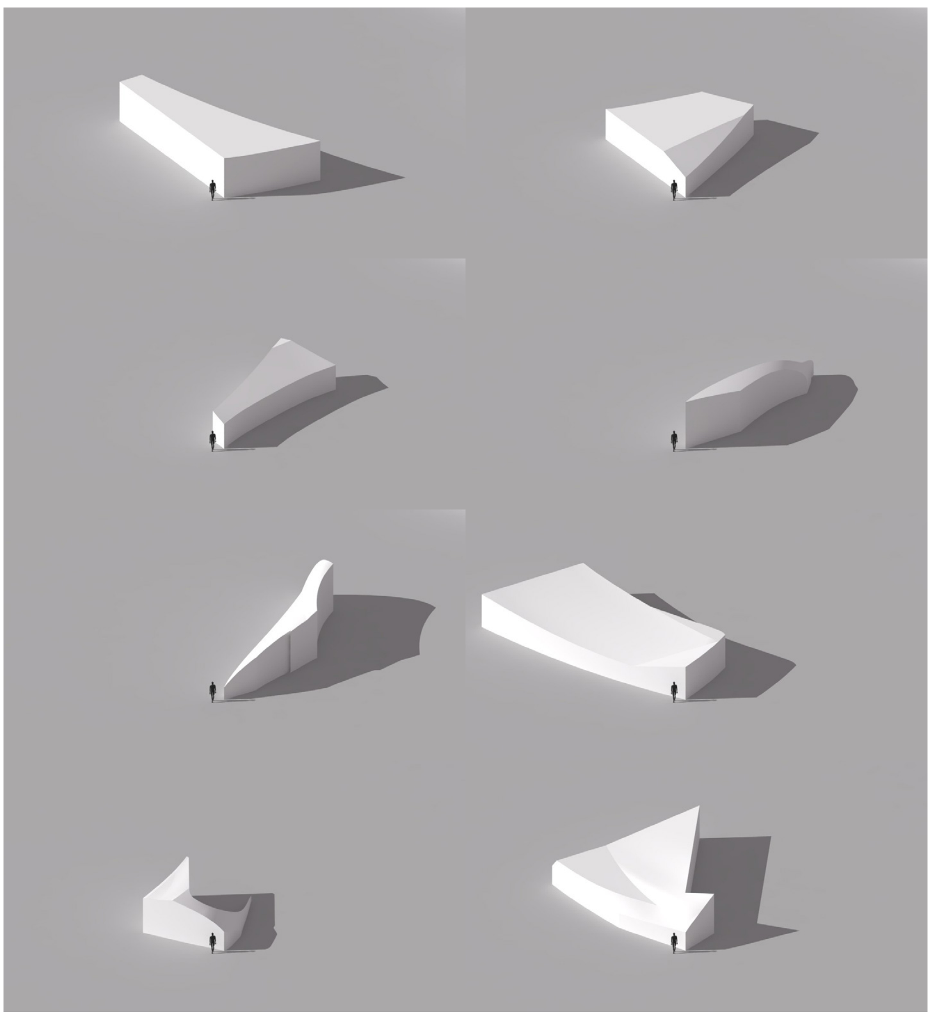


The sectional contour modifies the sound source to contain more modulation of frequencies

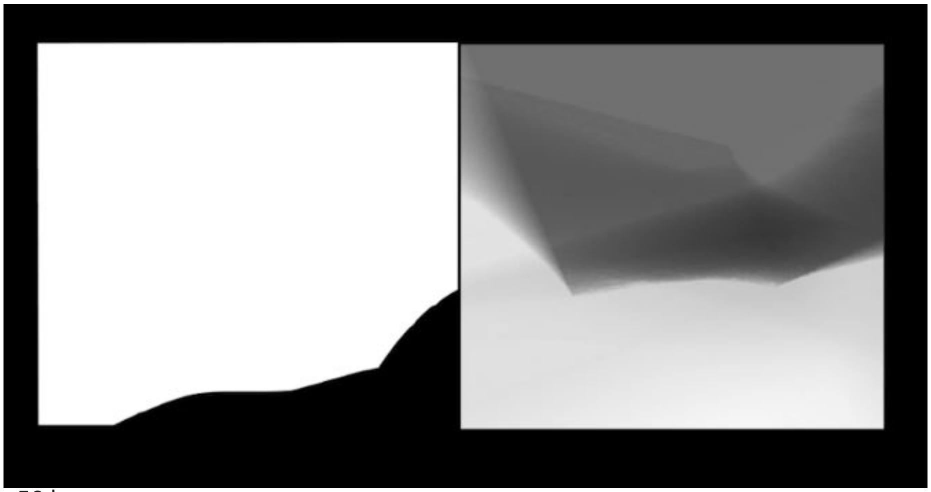


Transformation of sound with effects added form architectural features

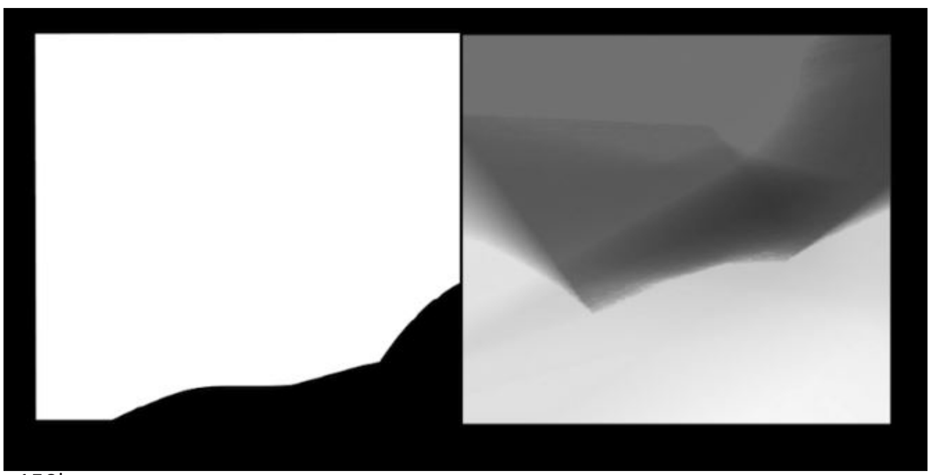




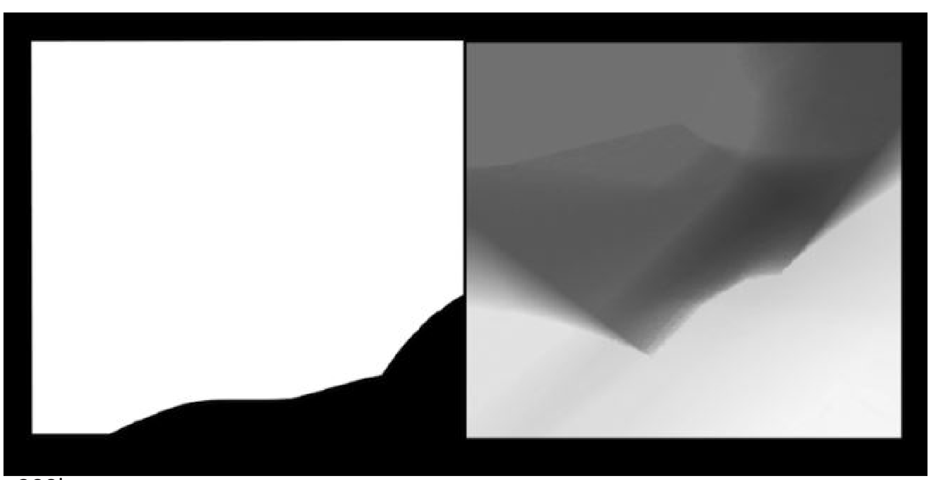
The programmatic blocks are more similar with this altered sound sample



+50 hz

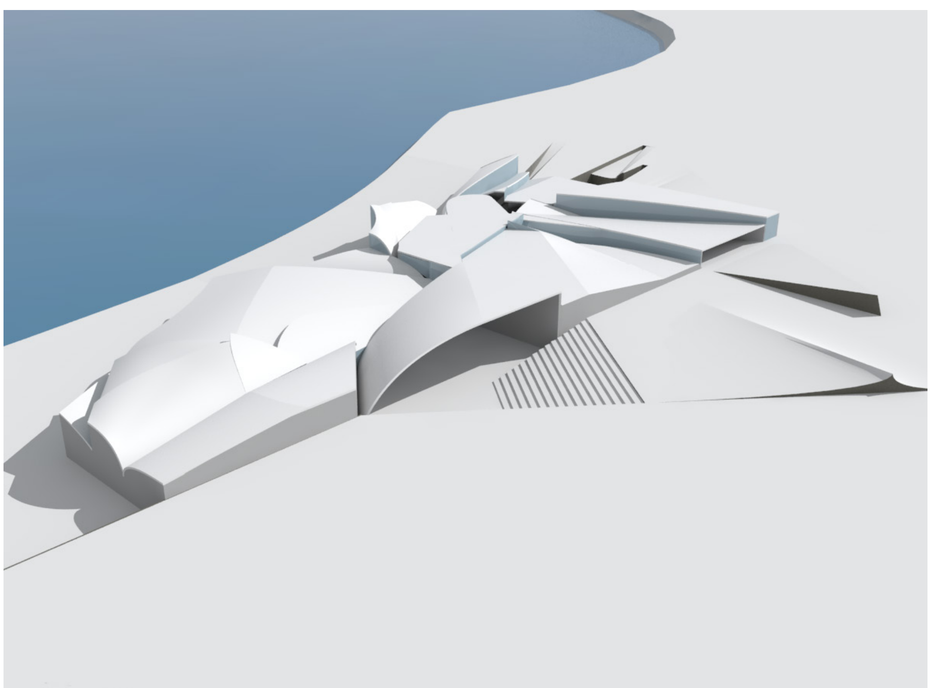


+150hz

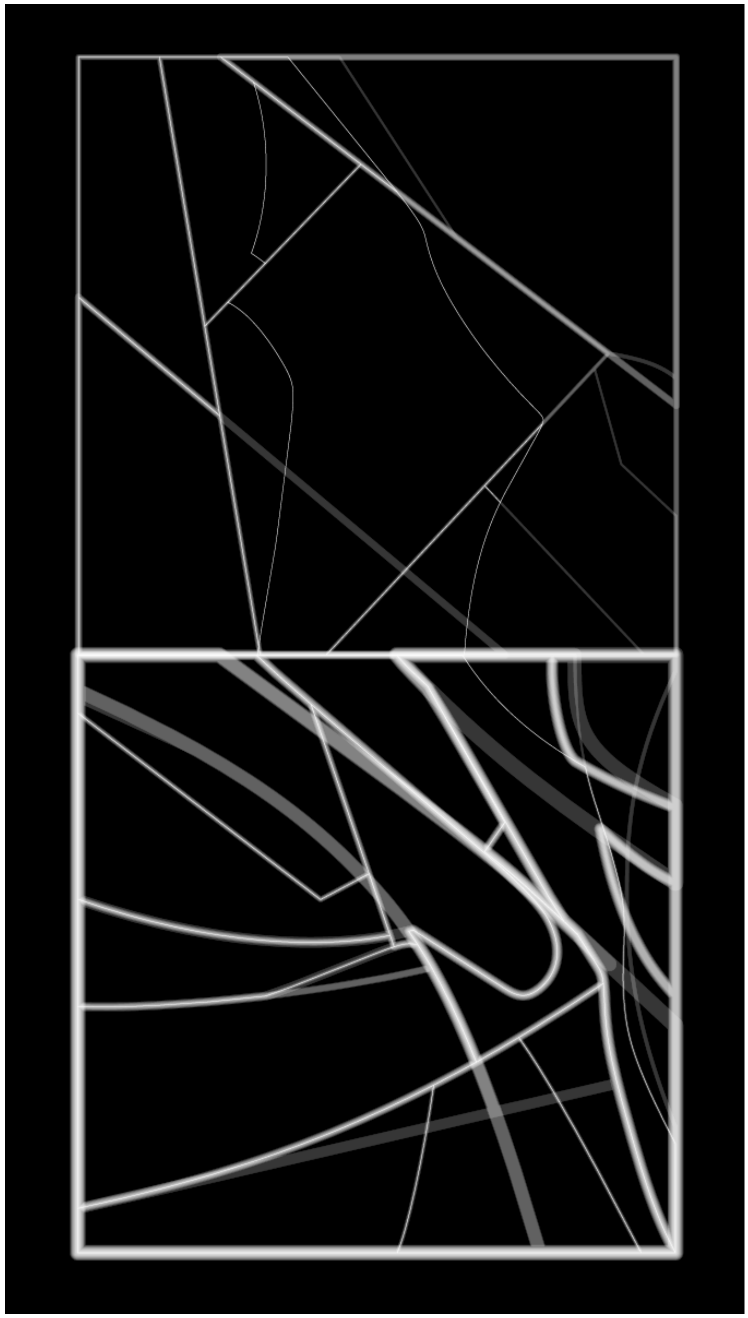


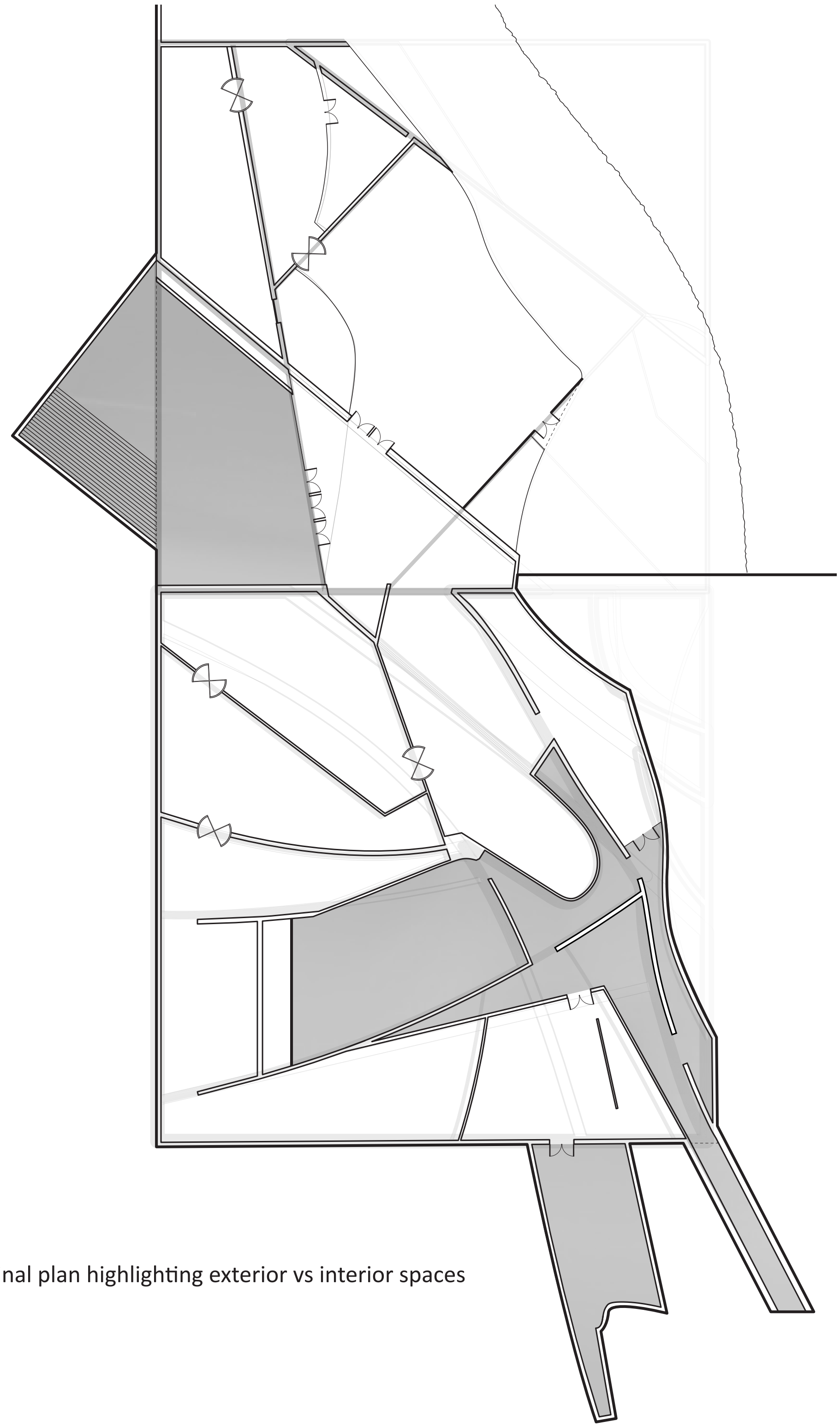
+200hz

To generate the additional component of the architecture the sound shifted frequency scales until the resultant gradient lined up with the boundary of the previous form.

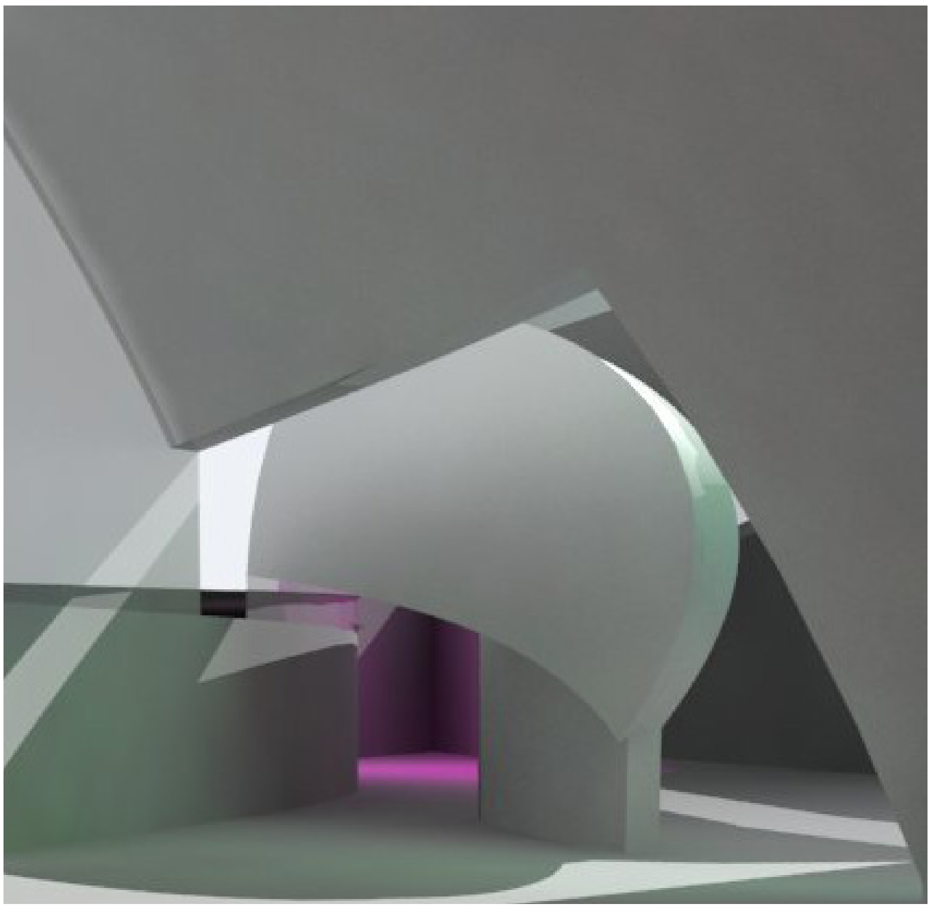


Resulting roof plan and site perspective. The site was modified to emphasize the major reference lines from the gradient images.

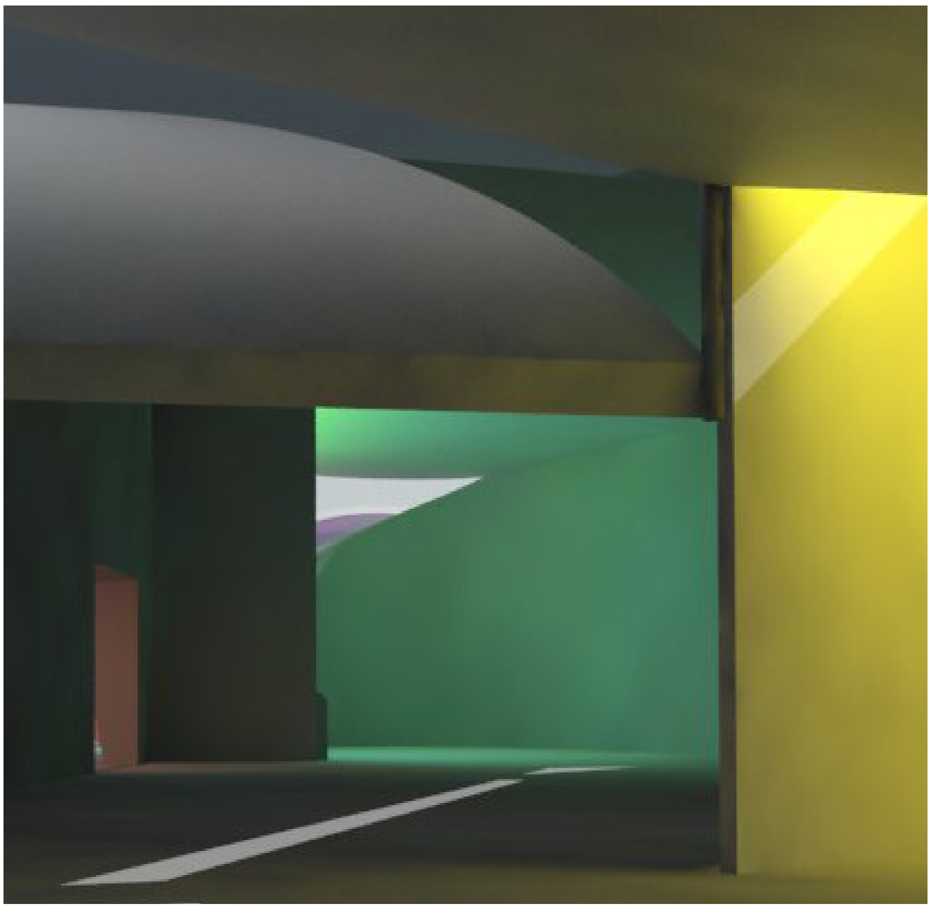




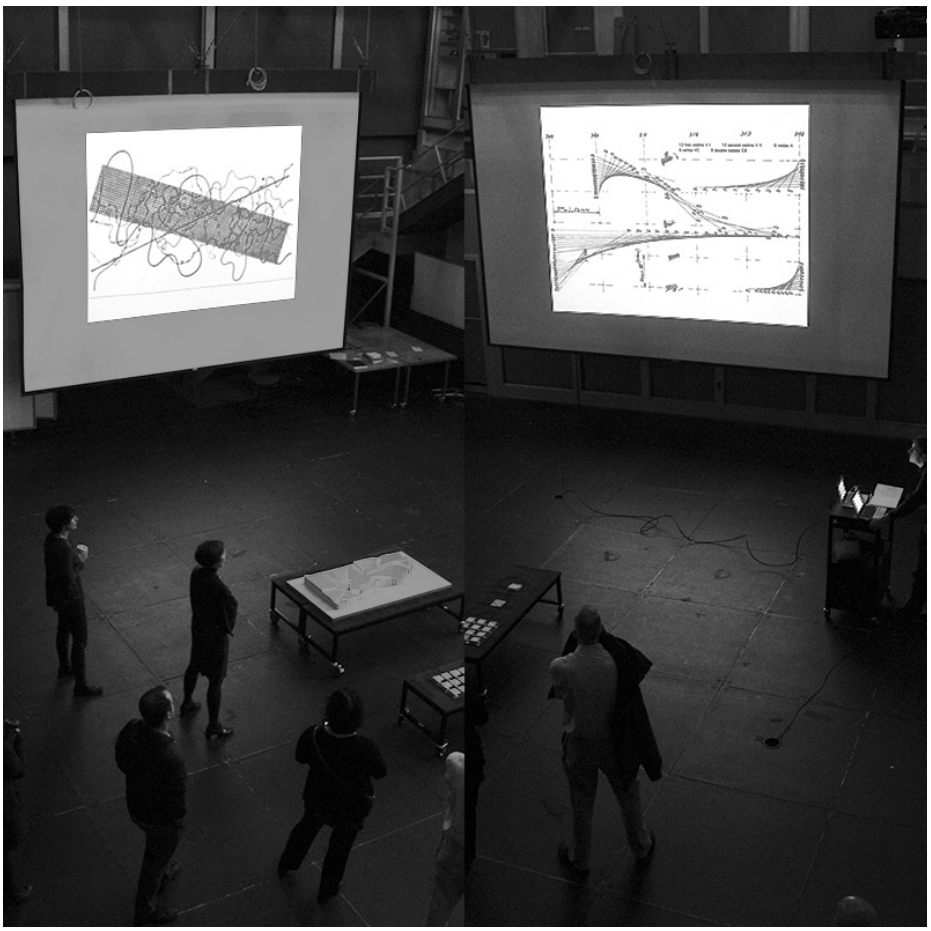
Final plan highlighting exterior vs interior spaces



Interior rendering 1
Color represents possible sonic experiences within the undulating forms



Interior rendering 2
Color represents possible sonic experiences within the undulating forms



Presentation

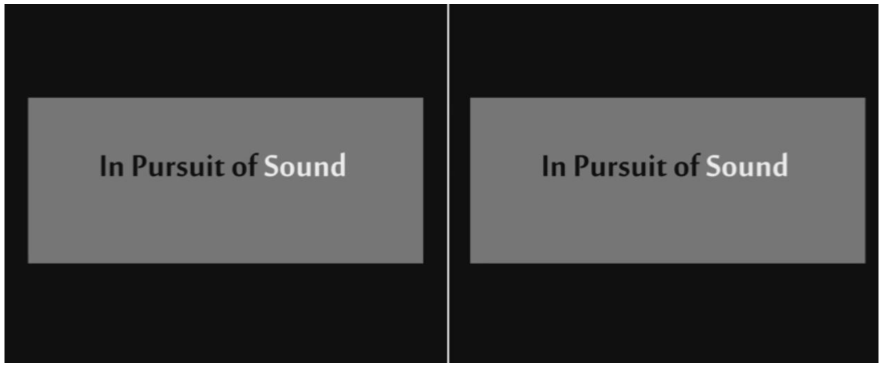
The following pages are excerpts of my thesis presentation. The video I created summarized the points i made in this research book, and included the sounds that inspired me, and generated the architecture that is referenced.

The video is on-line at https://www.youtube.com/watch?v=_8h0_OwL2Cs&feature=youtu.be
The final presentation was filmed across two screens in the old media lab at MIT.

What is clear from this research is that sound is manipulated to challenge our perceptions of the environment, but we do not recognize how fleeting these experiences can be. Architecture built from sound could manage these temporary perceptions and organize them in to create lasting experiences that expand our understanding of our spaces and inform us on the importance that sound has in our daily lives.

. . .

This pursuit is followed thorough to organize my passion for sound, into an apparatus for the creation of permanent spaces of sonic enjoyment and reflectance.



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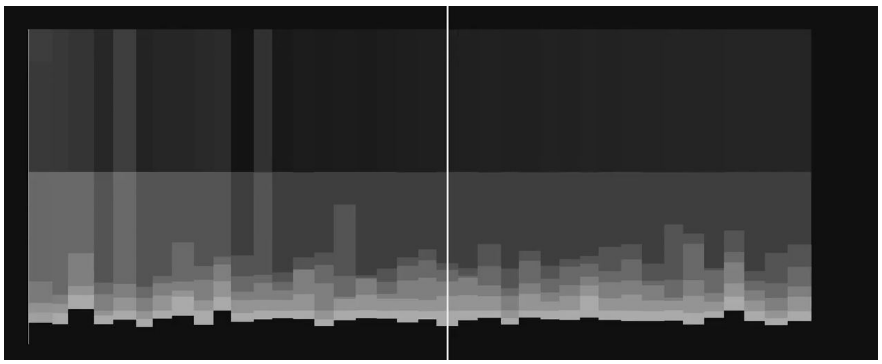
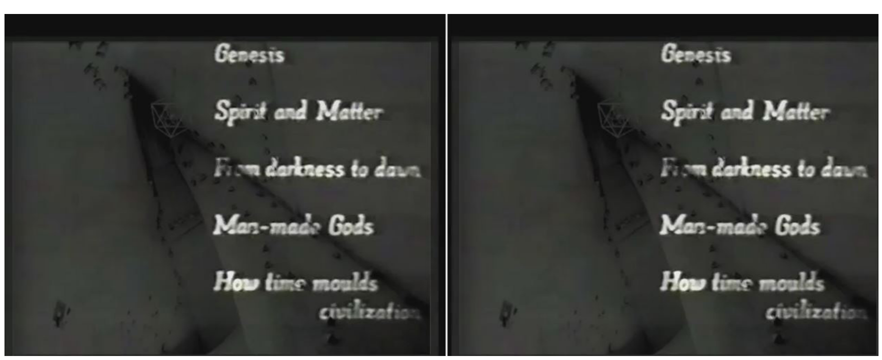

1:02


2:07



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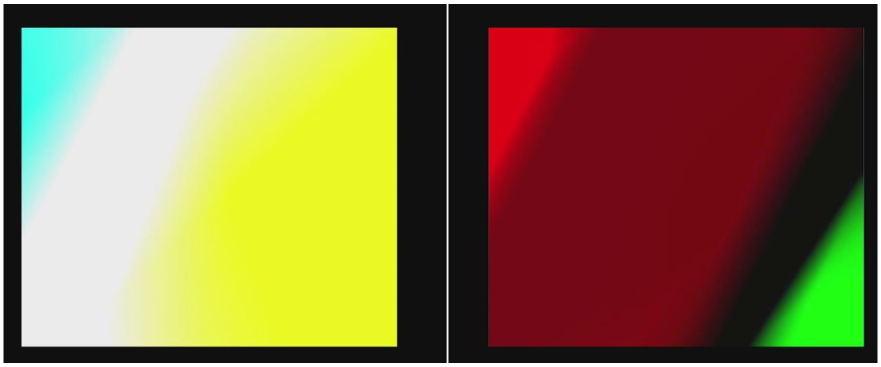

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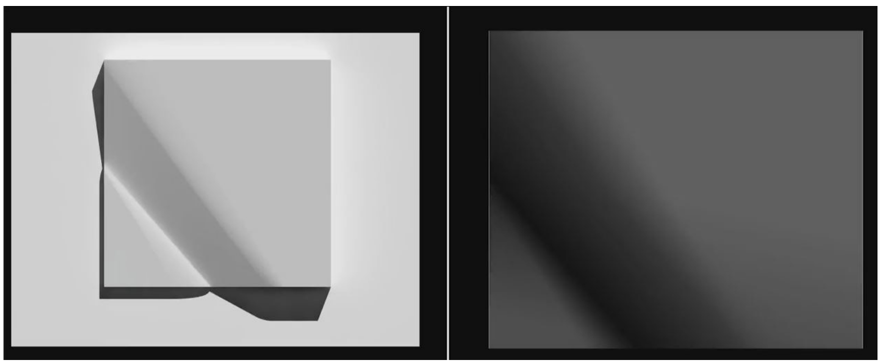

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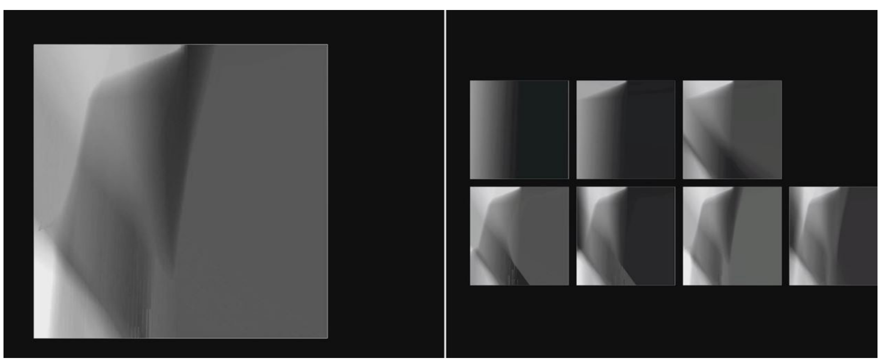

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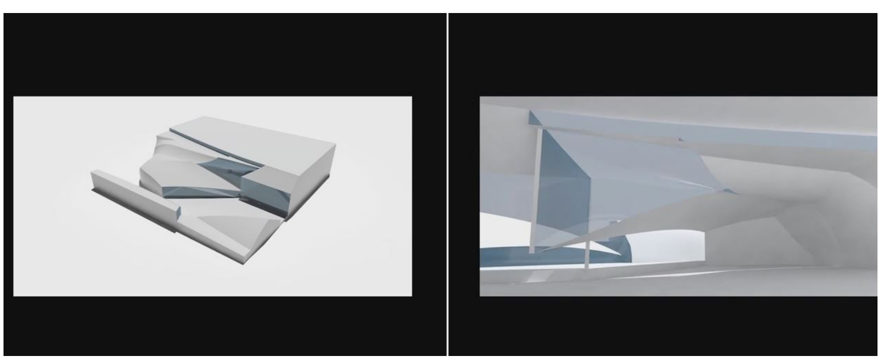

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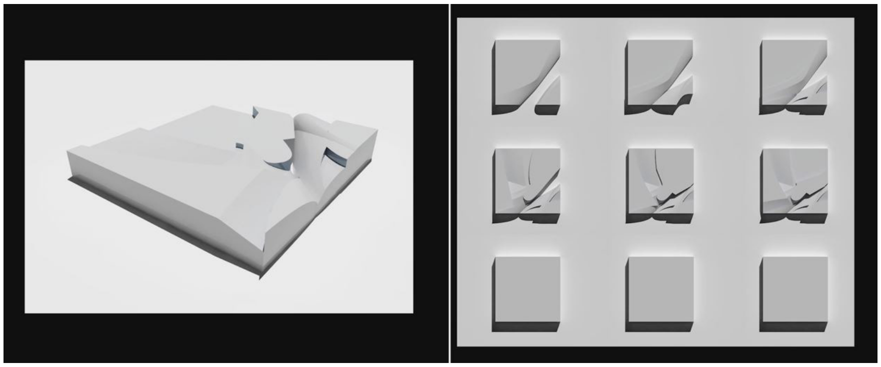

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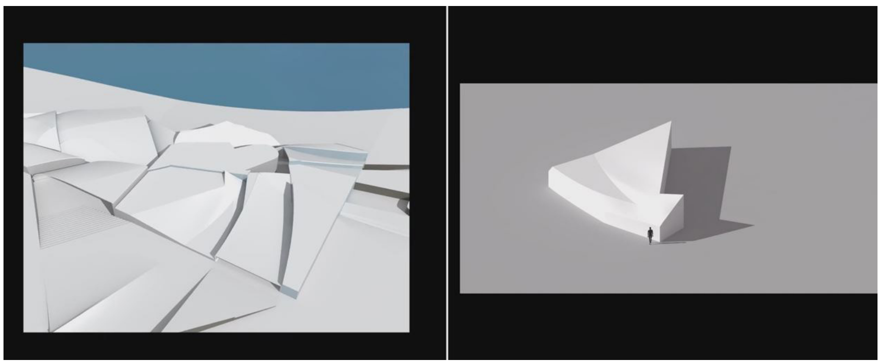

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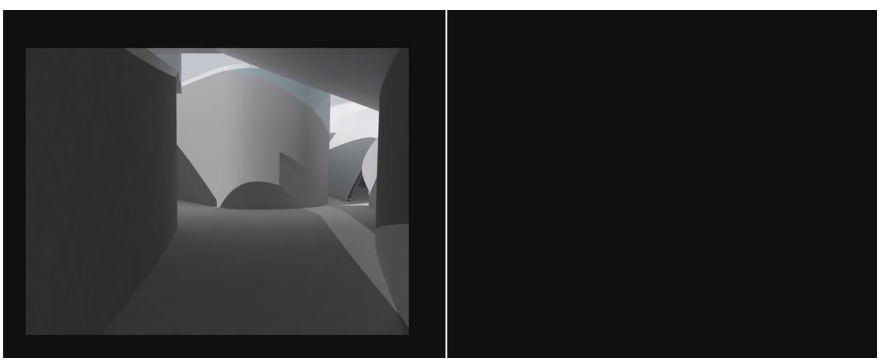

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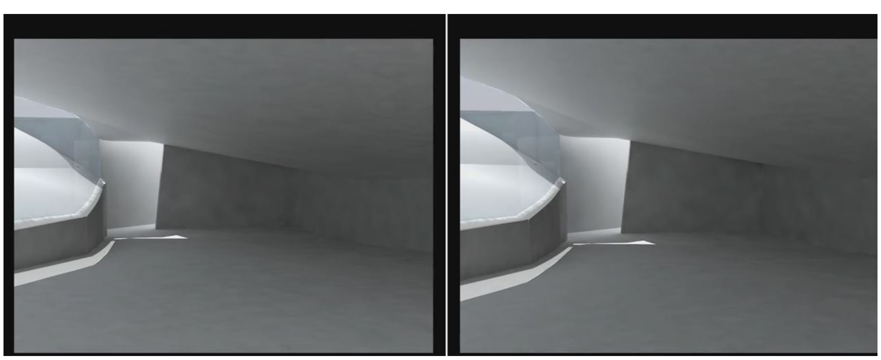

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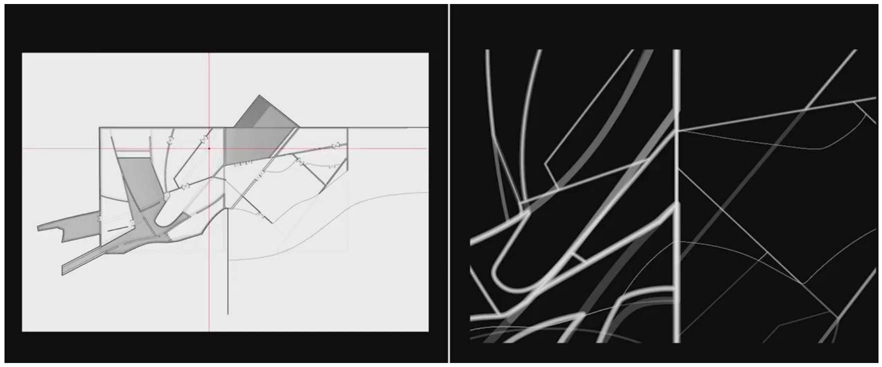

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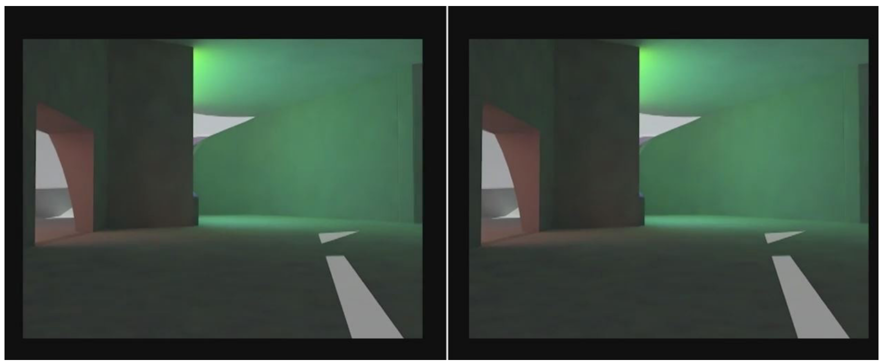

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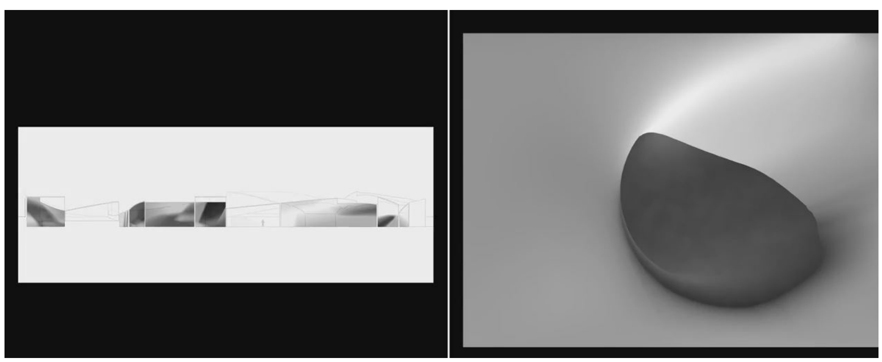

11:28

Image Credits

[1] Recordgroove. Digital image. Vinyl Revinyl. N.p., n.d. Web. <http://www.vinylrevinyl.com/2008/10/02/how-to-maintain-your-vinyl-records/>.

[2] Lascaux1. Digital image. La Borie CHic. N.p., 2015. Web. <http://laboriechic.com/dordogne-attractions/cave-paintings-of-lascaux>.

[3] Huaraz-peru-chavin-main-temple. Digital image. Dawn on the Amazon. N.p. Web. <http://dawnontheamazon.com/blog/2009/12/20/out-of-huaraz-peru-to-chavin-de-huantar/>.

[4] Pyramid shadow. Digital image. Study Blue. N.p. Web. <https://www.studyblue.com/notes/note/n/history-of-arch-201-300-exam-iii/deck/6768104>.

[5] Music of the spheres. Digital image. Global Astrology. N.p. Web. <http://globalastrologyblog.blogspot.com/2011_01_01_archive.html>.

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