

# Sound Visualization

Translating Soundscape into Spatial  
Experience through Responsive Installation

2026 MASTER THESIS

Author: Hui Chen

Supervisor: Kengo Skorick

Examiner: Jonas Lundberg

Chalmers University of Technology  
Department of Architecture & Civil Engineering  
MPARC-Master Program of Architecture and Urban Design



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY

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## Keywords

Soundscape; Sound Visualization; Spatial Experience; Responsive Architecture; Kinetic Surface; Behavioral Abstraction

## 1. Abstract

This thesis investigates how environmental sound can be translated into spatial experience through a responsive kinetic surface canopy. Sound is constantly present in public space but usually invisible, making it hard to sense the existence. Instead of treating sound as a acoustic information, the project explores how sound frequency can become a trigger for visible and bodily perceptible movement.

The research is inspired by cymatics and Chladni plates experiments, in which sound frequency generates visible patterns and forms with physical matter. The thesis refers to spatial experience of 'soundcube' from Leitner in 1969 and responsive architectural interface from Michael Fox in 1967.

The research combines sound recording, frequency analysis, digital modeling, and physical prototyping. Environmental sounds are collected and analyzed as relative frequency data. Meanwhile, a kinetic surface system is developed through iterative prototypes, testing how a flexible and segmented surface can produce feasible movable patterns. The principle that higher frequencies generate pattern of more complexity is applied, therefore, environmental sound frequency determines the complexity of the surface movement.

The final design proposal applied this catalogue to a responsive canopy installation in public space. In this design, eight Chladni pattern are selected as visual references for catalogue of kinetic surface patterns according to their complexity. Low-frequency sound activate simpler and broader surface movements, while higher-frequency sound trigger denser and more complex patterns. Through this application, the movement triggered by sound becomes spatial experience in public space that can interact with human.

The thesis contributes a design approach for translating environmental sound frequency into kinetic surface system. Through the use of Chladni patterns and frequency-based complexity principle, sound is transformed into visible patterns. The project positions sound visualization as an architectural process that connects cymatic phenomena with responsive installation and spatial experience.

## 2. Background

Sound is an essential part of everyday spatial experience. In public space, people constantly perceive traffic, footsteps, voices, wind, water and bird songs. These sounds influence atmosphere, pedestrian orientation and bodily awareness, but they usually remain invisible and instant. Unlike light, material or form, sound is difficult to read as a stable element. This creates a gap between the richness of acoustic environment and architectural design.

This thesis begins with an interest in sound visualization. Cymatics experiments, especially Chladni plate experiments, demonstrate how sound frequency can produce visible patterns through physical vibration. When a plate covered with sand is vibrated at different frequencies, the sand gathers along nodal lines and forms distinct geometric patterns. The pattern changes as the frequency changes, the higher the frequency is, the more complex the pattern will be. This phenomenon provides a clear relationship between sound frequency, matter and visual form.

However, Chladni patterns are usually understood as a static visual outcomes of acoustic vibration. In architectural design, the question is not only how sound can be visualized, but how the patterns can be transformed into bodily perceptible movement.

Responsive architecture provides a method to connect sound visualization with spatial transformation. Through sensors, movement systems and adaptive surfaces, architecture can react to environmental conditions and create changing relationships between body and space. In this project, environmental sound frequency is used as a trigger for selecting different Chladni-inspired movement patterns.

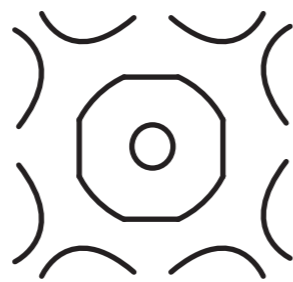


Fig 1. Pattern from Chladni Plate; own work

## 3. Research Questions

The thesis aims to explore how environmental sound frequency can be translated into responsive spatial patterns through a kinetic surface installation. The goal is to design a kinetic surface system that responds to different sound frequency conditions by activating a catalogue of movement patterns.

The main research question guiding this project is:  
-How can environmental sound be translated into spatial experience through an installation?

This main research question branches into several specific questions that shape the design process:  
-How can environmental sound be collected and analyzed to be input?  
-How can sound frequency and Chladni patterns be intergrated into the design?  
-How can a kinetic surface system transform patterns into spatial movement and bodily experience?

## 4. Delimitations

The thesis focuses on the architectural translation of sound frequency into kinetic surface patterns. It uses Chladni plate principles as a design reference, especially the relationship between frequency and pattern complexity, to explore a responsive surface systems based on actuation system with hybrid materials.

The project does not develop a complete real-time mechanical control system or full-scale engineering solution. Sensors, actuators and control logic are considered conceptually as part of the responsive installation system, while the main focus remains on spatial experience translation and digital surface movement.

The design proposal is developed as an transferable installation system rather than a site-based permanent design. The selected site is used as an application scenario to test how the kinetic surface could respond and interact with the environment and how the visual effect would be. The thesis prioritizes design method, prototype development, and spatial representation over mechanism and technical detailing.

## 5. Concept Mapping

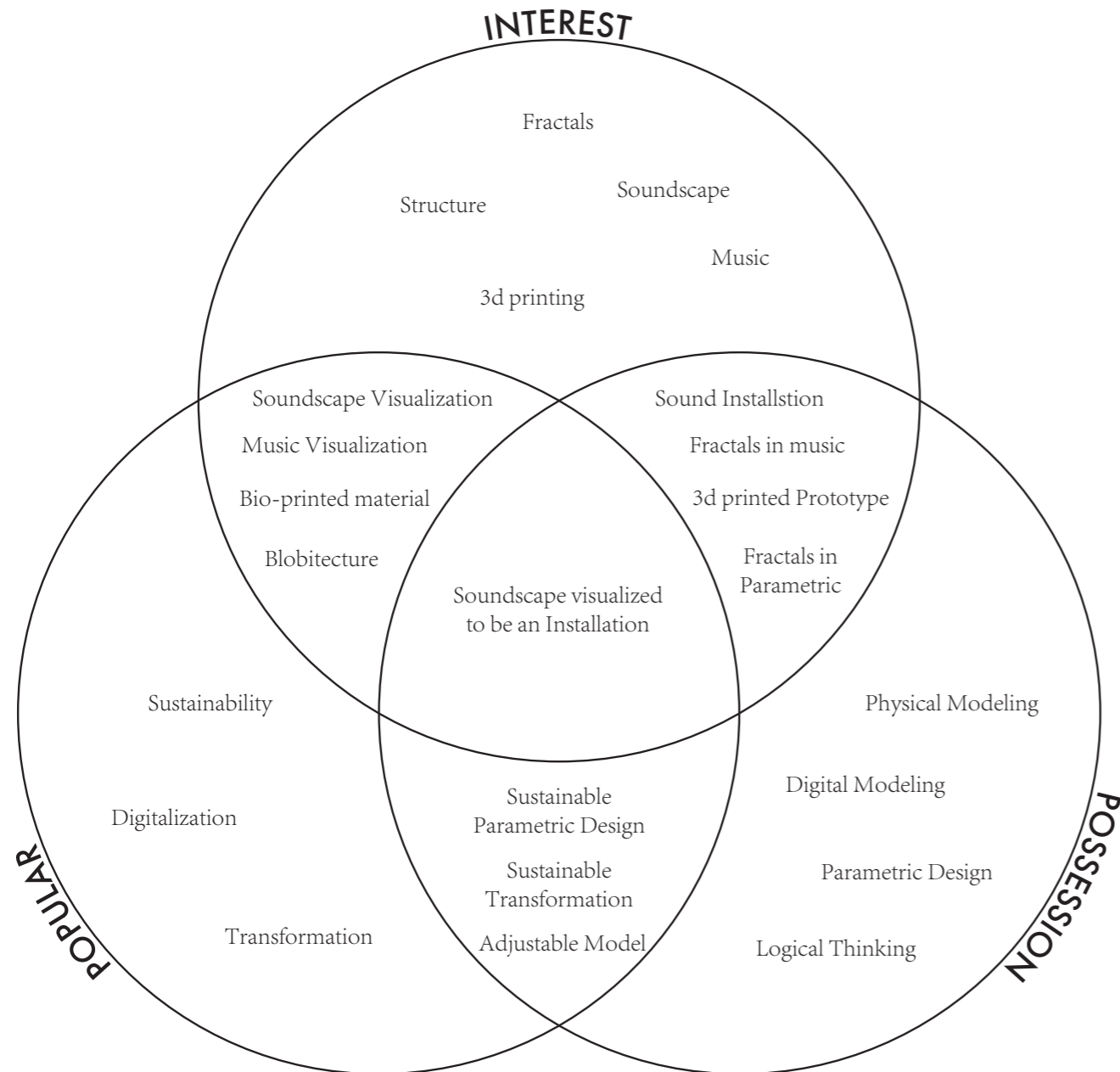


Fig 2. Concept mapping diagram; own work

My idea generation stems from three key factors: personal interests, popular social themes, and the skills and techniques I possess. Using concept mapping, I simplified these into three main topics within each area and the intersections between them.

- Interest Circle: This includes fractals, structure, soundscape, music, and 3D printing.
- Popular Theme Circle: This covers sustainability, digitalization, and transformation.

- Skills Circle: This comprises physical modeling, digital modeling, parametric design, and logical thinking. After brainstorming, things show up in the overlapping areas of these circles, possible topics emerged, such as soundscape visualization, fractals in music, and adjustable models. Ultimately, it leads to soundscapes visualization and installation. This concept mapping approach guided me in the early stage to generate my project theme.

## 6. Methods

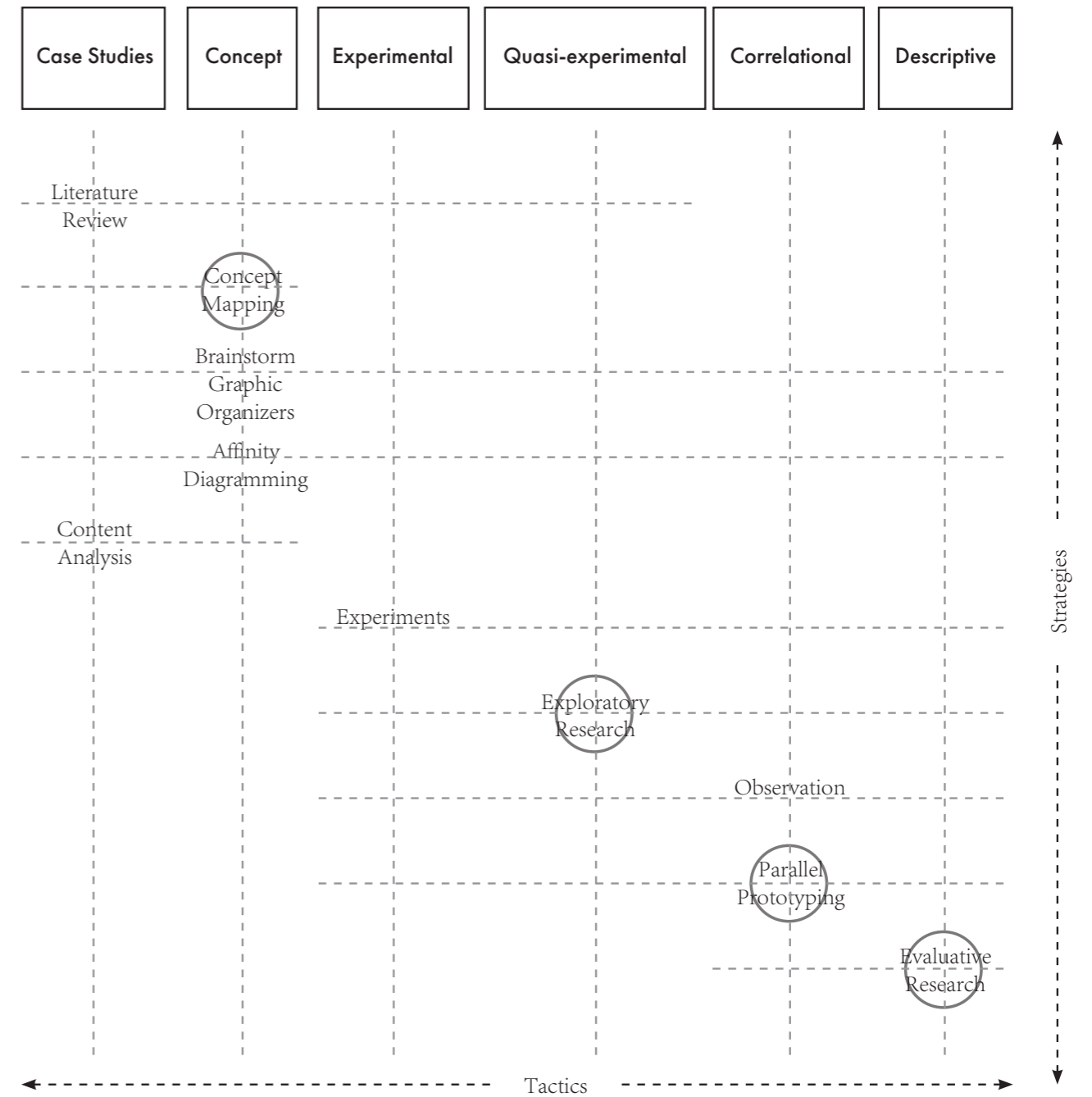


Fig 3. Method diagram; own work

The methodology combines literature review, concept mapping, exploratory experiments, parallel prototyping, observation, and evaluative research. Those methods are mainly used in the research stage and the experiment stage. The process is iterative, all of them contribute to the final design proposal.

The methods draw on [Diagramming Design Research] by David Wang and [Universal Methods of Design] by Bruce Hanington and Bella Martin. It offers basic frameworks and techniques for the thesis.

## 7. Thesis Structure

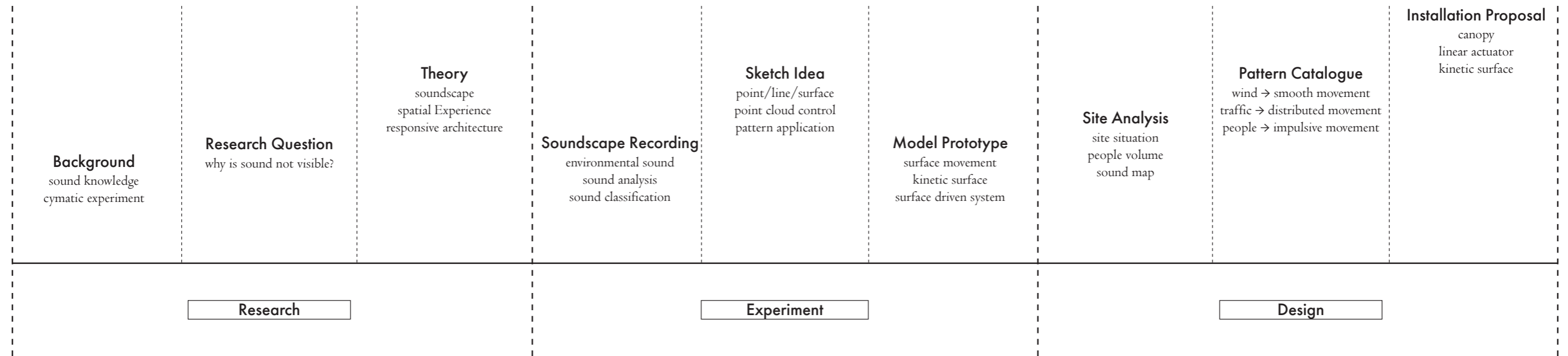


Fig 4. Thesis structure diagram; own work

This thesis is constructed with three main phases: research, experiment, and design. The project begins with a theoretical investigation of sound and sound visualization, continues through a series of exploratory studies and prototypes, and concludes with a responsive installation proposal at the architectural scale.

The research phase begins with a background of sound knowledge and cymatic experiments, followed by the main research question of why sound is not visible in everyday life. The theoretical framework is then developed through three related fields: soundscape,

spatial experience, and responsive architecture. This phase also conducts sound recording. Environmental sounds are collected, analyzed, and classified as the basis for later design translation.

The experiment phase centers on transforming sound into movable geometry. It starts with sketch ideas constructed by basic elements like point clouds, lines, and surfaces. The feasible mechanism is tested through physical model prototypes. Kinetic surfaces and surface-driven systems are introduced for the mechanism, which is the installation unit for the design stage.

The design phase applies the findings of the earlier stages to an architectural context. Site analysis introduces spatial conditions, pedestrian volume, and sound-related characteristics of the chosen environment. Based on this, a behavioral mapping is developed, in which different environmental sounds are interpreted as different movement tendencies, such as smooth, distributed, or impulsive motion. These behavioral principles

are then translated into the final installation proposal: a responsive canopy system based on linear actuation and kinetic surface logic.

Overall, the project structure describes a continuous process that moves from understanding sound, to testing its spatial translation, and finally to developing an architectural installation proposal.

# 8. Theory

## 8.1 Soundscape: Sound as Environmental Condition

Browsing through literature about sound, the concept 'soundscape' appears. It is a field of study within acoustics and urban planning. The concept of the 'soundscape' was systematically introduced by R. Murray Schafer in *The Soundscape: Our Sonic Environment and the Tuning of the World*, where he defined the soundscape as the acoustic environment as perceived and experienced by humans. He mentioned that these sounds are perceived as noise in our daily life, which is a negative approach.

'Which sounds do we want to preserve, encourage, multiply? When we know this, the boring or destructive sounds will be conspicuous enough, and we will know why we must eliminate them.' (Schafer, 1994)

Schafer emphasized that environmental sound should not be considered as background noise but selected to be meaningful in a place and culture. He proposed three main elements: keynote sounds, signals, and soundmarks, in the chapter 'Feature of soundscape'. Keynote sounds form the continuous acoustic background of an environment, such as wind, water, or distant traffic. Signals are foreground sounds that attract attention and convey information, such as alarms or bells. The thesis argued that distinctive sounds representing the identity of a place should be preserved.

Bryan C. Pijanowski defines soundscape from scientific aspect. Soundscapes include three main parts, which are biophony, geophony, and anthrophony. Biophony is the sounds produced by living animals such as birds or insects. Geophony includes natural non-biological sounds such as wind, rain, or flowing water. Anthrophony refers to sounds generated by human like traffic and human voice.

It also introduces scientific methods for analyzing acoustic environments, including long-term audio recordings, acoustic indices, and spatial mapping. The acoustic activity of birds in four spots throughout all seasons was recorded. They concluded the data in a soundscape map with a parameter called acoustic complexity index (ACI). (Krause, 2011)

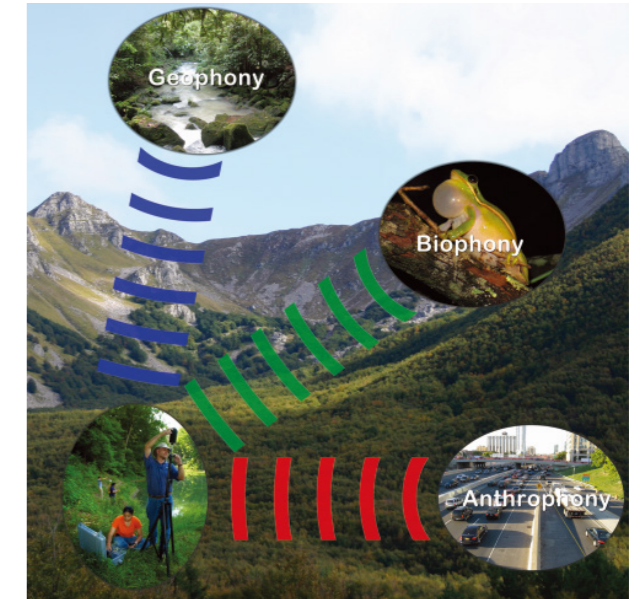
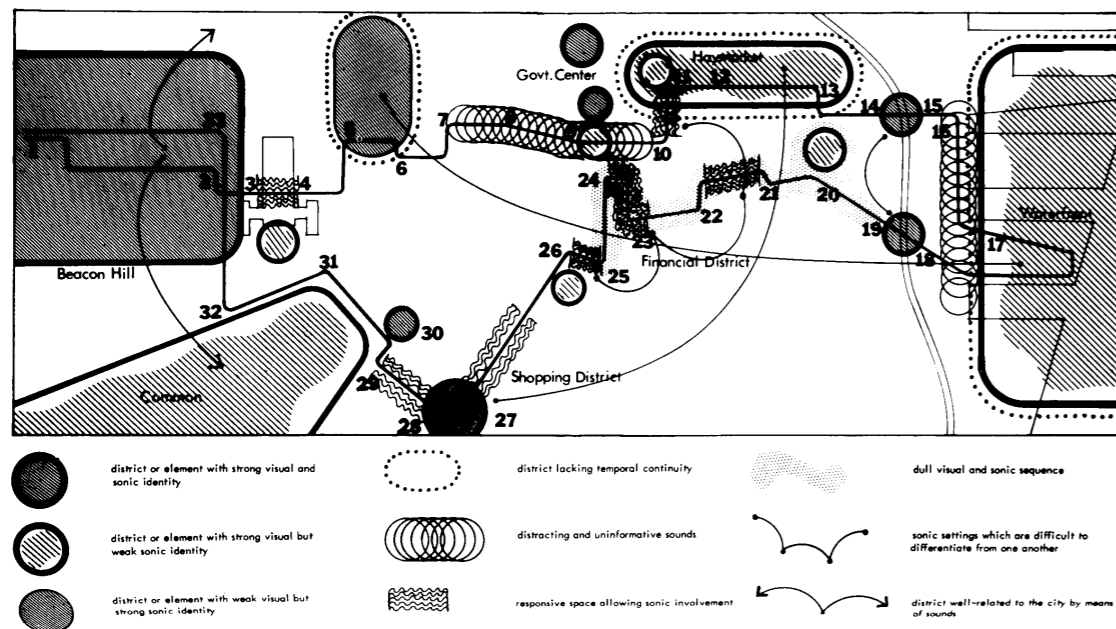


Fig 6. Pijanowski et al. (2011), *Soundscape Ecology*



Another sound event map, prepared by Michael Southworth in downtown Boston, that attempts to relate areas with similar and contrasting acoustic environments.

Fig 5. Schafer, *The Soundscape*

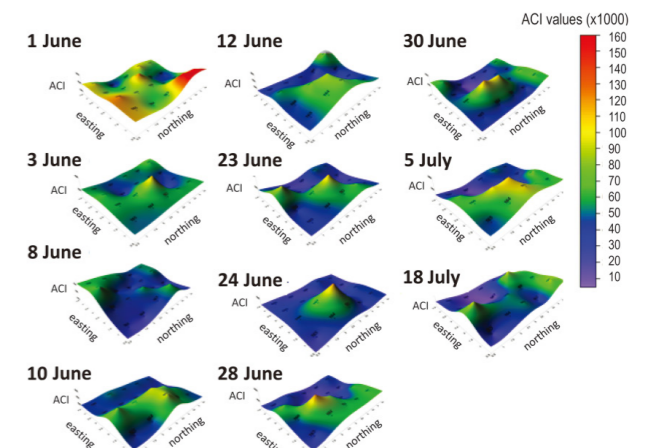


Fig 7. Pijanowski et al. (2011), *Soundscape Ecology*

These thesis mention the value of preserving both natural and urban soundscapes and understanding the relationships between human activity, ecological systems, and sonic environments.

## 8.2 Cymatics and Chladni Pattern: Sound as Visible Pattern

Cymatics demonstrates how sound vibrations can generate visible patterns through physical media like sand, water and fire. Ernst Chladni, a pioneer in acoustics, developed a technique to study the vibrations of metal plates, now known as "Chladni's Plates." By sprinkling sand on a metal plate and using a violin bow, he discovered distinct patterns related to the plate's dimensions. Chladni patterns act as both visual reference and organizational principle in this thesis.

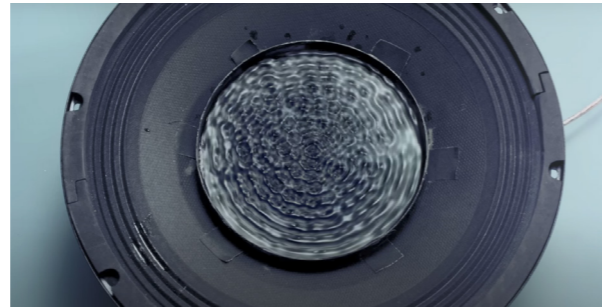


Fig 8. Water vibration-Cymatic



Fig 9. Water flow-Cymatic



Fig 10. Sand Vibration-Cymatic

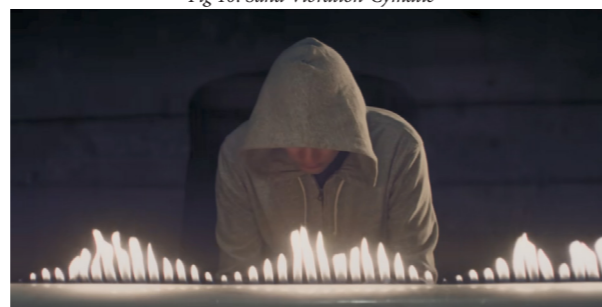


Fig 11. Fire Vibration-Cymatic

## 8.3 Spatial Experience: From Visual Pattern to Bodily Perception

Sound and spatial experience have been explored in theoretical research and artistic practice by Bernhard Leitner. The hypothesis 'Sound Cube' was first proposed as a concept explaining how people could understand space from a typology. Leitner worked with a series of sketches that proposed a hypothesis on how people understand movements of sound within a cube. By arranging loudspeakers in the space and programming sound to travel between them in different ways, Leitner came up with many space types inspired by the cube.

Later on, many experiments on site were conducted, and he proposed the concept 'Sound Architecture' that sound could function as an approach to generating physical space. One important discovery was that the direction and movement of the soundtrack can affect how people perceive spatial orientation and bodily sensation. Leitner created a 'sound gate' typology that sound build a boundary like gate. An experiment volunteer could feel the space with eyes closed.

He made a project proposal for Olympia Baugesellschaft's invitational. The project guided the audience through the one-kilometer-long walkway by using the theory 'Sound Slopes'. 'Ascending sound lines make walking on level ground more difficult. The physical effort of horizontal movement is counteracted, or facilitated – thus the idea – when sound lines slope downwards, parallel to the walking direction.' (Leitner,1998)

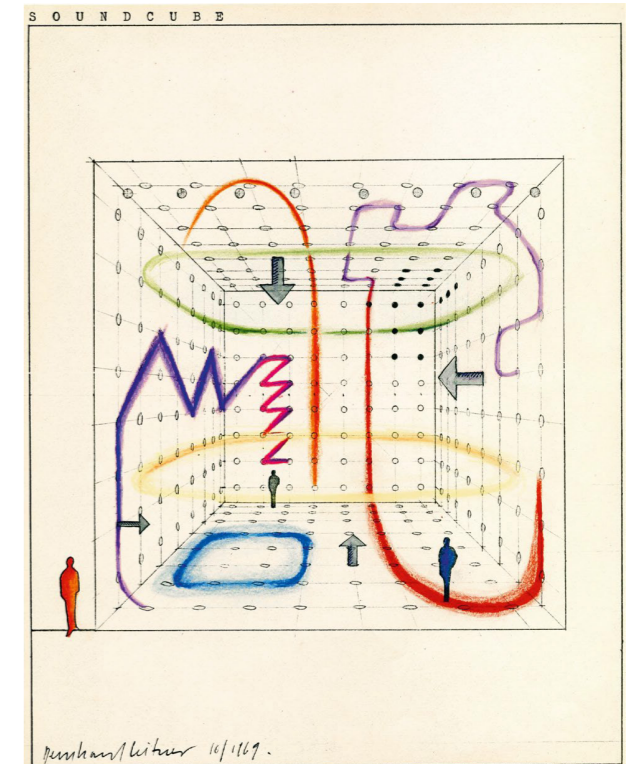


Fig 12. Bernhard Leitner's Soundcube, 1969

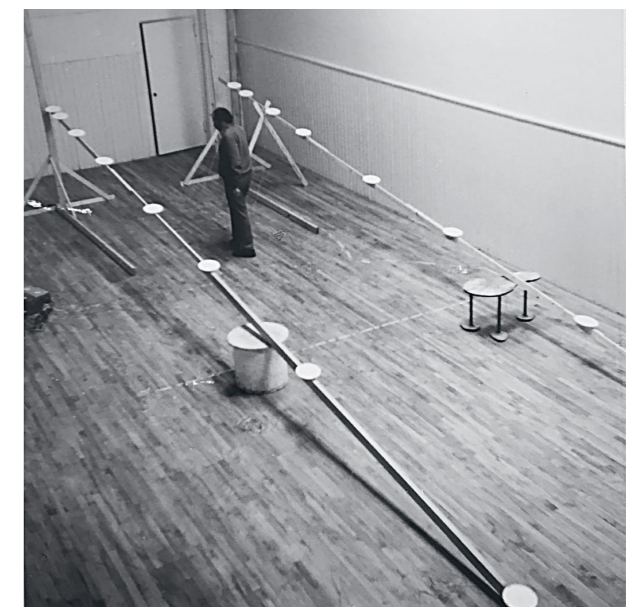


Fig 13. Bernhard Leitner's Soundlines descending, 1971

Except the sound gata, more sound sculptures were designed by him and put into application. There was the project 'Agoraphon' in 1993, which was a seven-column sound architecture made of steel pipes. Each pipe was equipped with a loudspeaker inside, creating a resonance effect by sound sonic pressure.

Another project, 'Blue Vaulting,' is translating sound into something visible with physical matter. It works with the sound and air pressure. The membrane vaults will be shaped into a barrel if sucking up the air. Otherwise, the ceiling can be transformed into a dripstone shape. Each column bears a sound source controlling the acoustic ceiling.

Blesser and Salter published an article, 'Space Speak, Are You Listening?' They argue that auditory spatial awareness includes the emotional and behavioral experience of space. It can influence people in four aspects: social behavior, participation in space, aesthetic sense, and experience of sound. Sounscape is defined as sonic events and aural architecture, in which sound and light play a critical role. (Blesser,2006)

These perspectives explain that sound can be understood as both a spatial generator and an influencer. Spatial experience becomes the bridge between sound pattern and architectural installation.



Fig 14. Bernhard Leitner's Agoraphon, 1993



Fig 15. Bernhard Leitner's Blue Vaulting, 1993

## 8.4 Responsive Kinetic Surface: Pattern as Architectural Movement

"Interactive Architecture is a process-oriented guide to creating dynamic spaces and objects capable of performing a range of pragmatic and humanistic functions. These complex physical interactions are made possible by the creative fusion of embedded computation (intelligence) with a physical, tangible counterpart (kinetics)." (Fox,2009)

Responsive architecture refers to architectural systems sensing environmental conditions and responding through physical or spatial transformation. Michael Fox and Miles Kemp describe this approach as a dynamic architecture that interacts with users and surrounding conditions. Architecture is no longer a giant container for human activity. Part of it becomes a responsive system that integrates sensors, computation, and kinetic mechanisms. These systems enable buildings to respond to a changed soundscape.

Several architectural projects illustrate how responsive systems translate environmental forces into spatial experience in the book 'Interactive Architecture. For example, the Tower of Winds by Toyo Ito in Yokohama uses sensors to detect wind speed and surrounding urban noise, which is translated into dynamic patterns of light across the facade. Similarly, Hylozoic Ground by Philip Beesley demonstrates how responsive architecture can create an interactive spatial experience. The installation consists of lightweight structures embedded with sensors and microprocessors. It can react to the sound and movement of visitors by lighting.



Fig 16. Tower of Winds-Toyo Ito



Fig 17. Hylozoic Ground-Philip Beesley

Other projects explore responsive effects through natural material behavior rather than computational systems. The Technorama Facade by Ned Kahn consists of thousands of freely moving aluminum panels that respond to wind, creating constantly changing patterns on the building surface. Likewise, the MAY/SEPTEMBER project adds color to the boring parking building. Thousands of angled metal panels hang on the facade and produce perceptual changes in double color with the wind.

These references shows how parts of buildings can be developed into adaptive interfaces and spatial experience. Sound acts as the input, while the adaptive system is the output. Therefore, a kinetic surface can make invisible forces visible by transforming them into movement, deformation or changing patterns.



Fig 18. TECHNORAMA FACADE-Ned Kahn



Fig 19. MAY/SEPTEMBER-Rob Ley Studio

## 8.5 Theoretical Position

Together, these theoretical references position the thesis. Soundscape provides the environmental input, Chladni patterns provide the visual and organizational principle, spatial experience defines the body awareness, and responsive architecture offers a practical method. Based on this framework, the thesis develops a frequency-driven system, translating environmental sound into a responsive canopy.

## 9. Research

This research chapter focuses on how environmental sound can become design input for a kinetic surface system. The purpose of the sound research is to identify relative frequency conditions that can be translated into different degrees of pattern complexity. The research is organized with three steps: sound recording, sound analysis and sound classification.

### 9.1 Sound Recording

This map shows the locations where the urban sounds are collected in Gothenburg. Walking along Kungsporsavenyen Avenue and the green space of Nya Allén in the central area, the sounds from the environment are rich.



Fig 20. Sound collecting positions in Urban Area; own work

The second map shows where the natural sounds are collected in Gothenburg. The author explored Brännö Island, recording the natural sounds of the environment and wildlife.



Fig 21. Sound collecting positions in Rural Area; own work

Environmental sound were recorded as the sample for the translation research. The recordings include different public sound conditions such as traffic, footsteps, voices, wind, and natural background sounds. These recordings are used to identify sound characteristic.

### 9.2 Sound Analysis

Recording: Voice Memos  
Analysis: Praat

Praat can analyze abundant data from sound and help me understand what characteristic can be quantified. Here are the four branched features.

- Spectrogram: This is like a picture of sound over time. It shows how different frequencies (like bass or treble) change as time goes on. The brighter the color, the louder that frequency is.
- Formants: These are special frequencies that help give a sound its unique "color" or timbre. For example, they're what make a violin sound different from a piano, even if they're playing the same note. Formants are like the "signature" of an instrument or voice that make it recognizable.
- Intensity: This is how loud or soft the sound is. For the violin note, it starts quietly, gets louder, and then fades away. You can think of it like how much energy the sound has at different moments.
- Pitch: This is the "highness" or "lowness" of a sound, like how you can tell the difference between a deep bass note and a high whistle. In the violin example, the pitch is A4, which is a specific musical note around 440 vibrations per second.

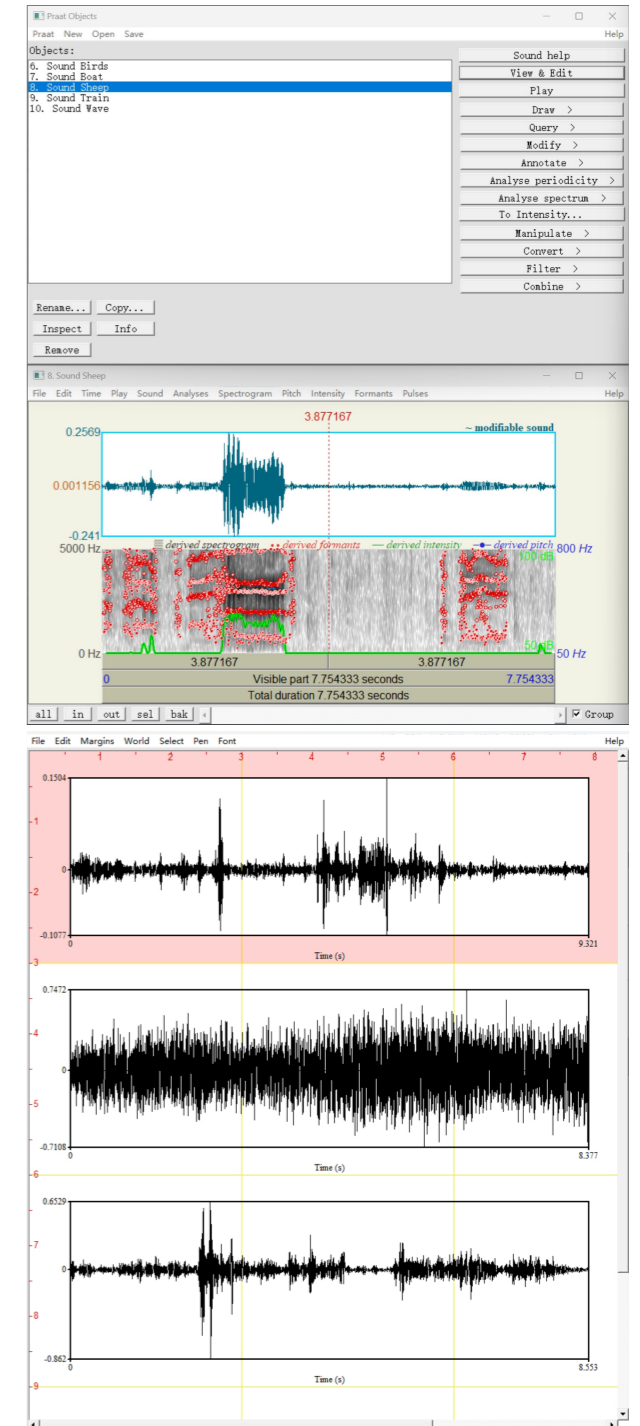
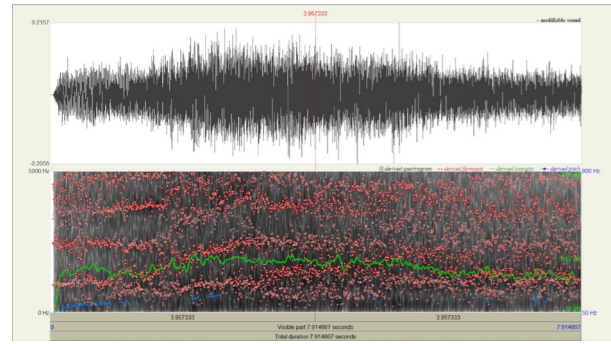
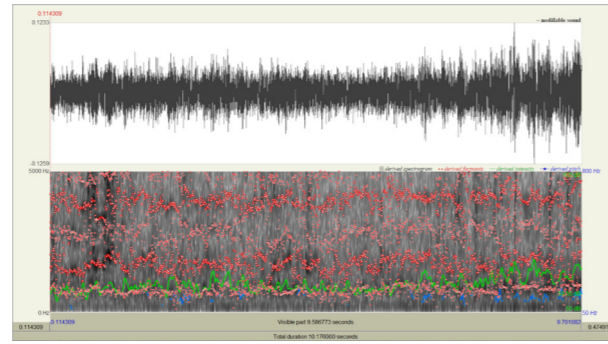


Fig 22. Screenshot of Praat; own work



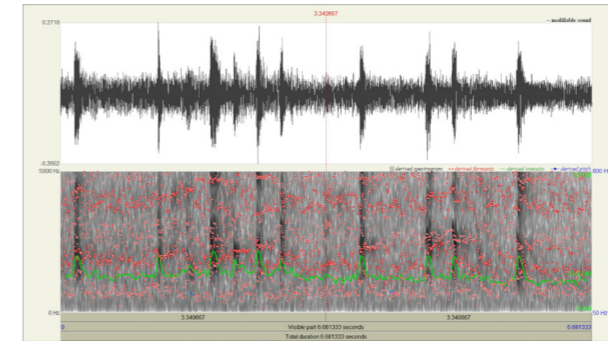
Cars

- Spectrogram: no clear stripes
- Formants: around 2500 Hz and 4000 Hz but fluctuated
- Intensity: average 68.7 dB
- Pitch: no noticeable changes



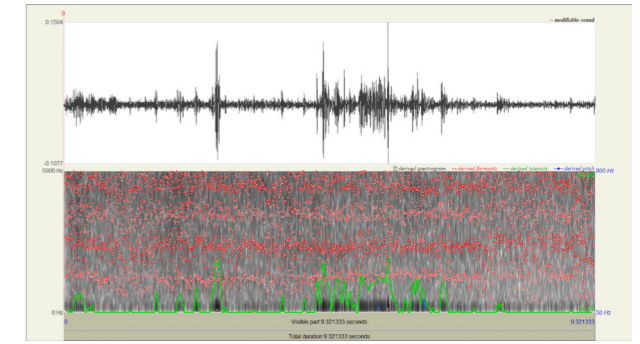
Parks

- Spectrogram: no clear stripes
- Formants: around 2000 Hz and 4000 Hz
- Intensity: average 56.56 dB
- Pitch: no noticeable changes



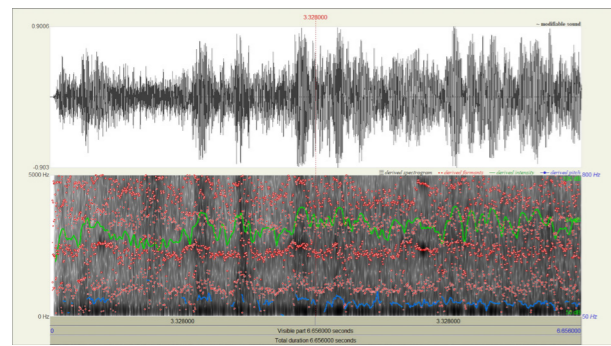
Urban Birds

- Spectrogram: no clear stripes
- Formants: no clear stripes, average
- Intensity: average 63.5 dB
- Pitch: no noticeable changes



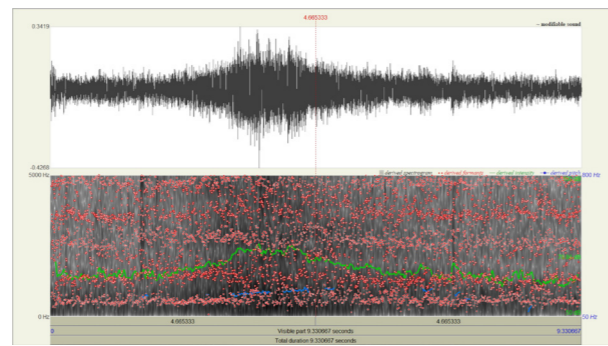
Rural Birds

- Spectrogram: no clear stripes
- Formants: around 2500 Hz and 4500 Hz
- Intensity: continuous and comparatively quiet
- Pitch: no noticeable changes



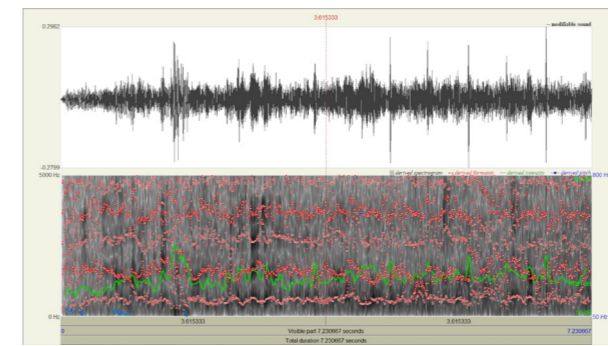
Train

- Spectrogram: lowest stripe around 100 Hz
- Formants: around 2500 Hz
- Intensity: continuous and comparatively loud
- Pitch: a steady pitch of 100 Hz



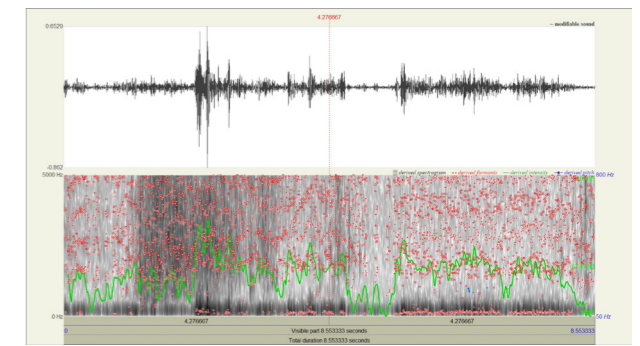
Street

- Spectrogram: lowest stripe around 100 Hz
- Formants: around 2000 Hz and 4000 Hz
- Intensity: average 70.86 dB
- Pitch: no noticeable changes



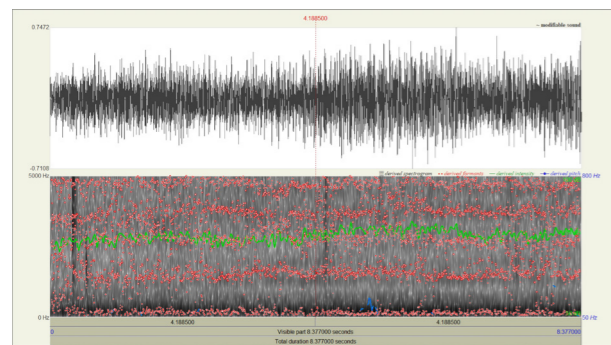
Human Voice

- Spectrogram: no clear stripes
- Formants: around 2000 Hz and 4000 Hz
- Intensity: average 61.5 dB
- Pitch: no noticeable changes



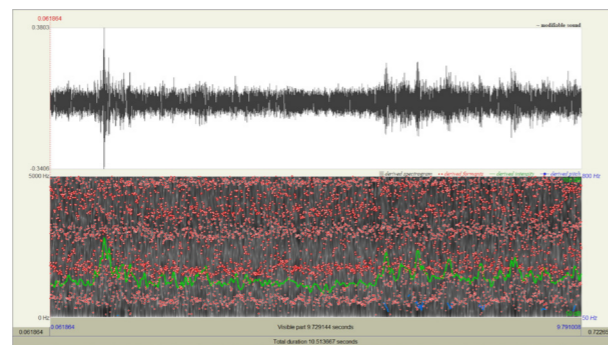
Wave

- Spectrogram: lowest stripe around 500 Hz
- Formants: no clear stripes, average
- Intensity: large fluctuations
- Pitch: no noticeable changes



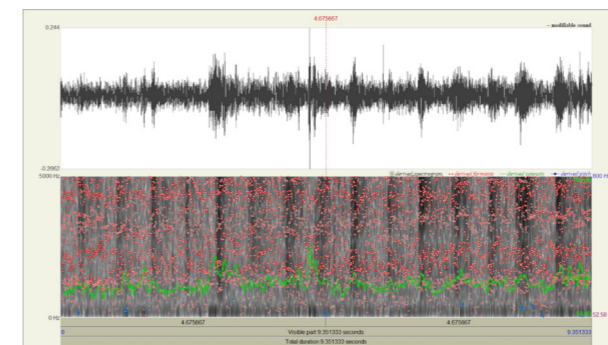
Boat

- Spectrogram: lowest stripe around 500 Hz
- Formants: around 1000 Hz and 4000 Hz
- Intensity: continuous and comparatively loud
- Pitch: no noticeable changes



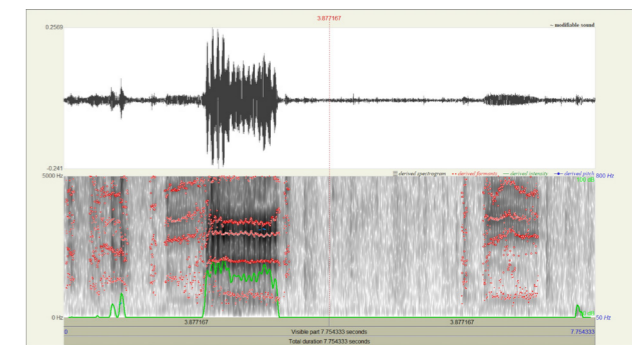
Square

- Spectrogram: no clear stripes
- Formants: around 2000 Hz
- Intensity: average 63.9 dB
- Pitch: no noticeable changes



Walking on leaves

- Spectrogram: no clear stripes
- Formants: no clear stripes, average
- Intensity: average 63.9 dB
- Pitch: no noticeable changes



Sheep

- Spectrogram: no clear stripes
- Formants: around 2500Hz, 3500Hz and 4500 Hz
- Intensity: occasional large fluctuations
- Pitch: no noticeable changes

Fig 23. Screenshot of Praat; own work

The spectrogram shows that urban sound is more complex, merging a variety of sounds along with noise. The formants indicate that animal sounds are more easily recognizable compared to geological

sounds and urban noise. What's more, the intensity levels demonstrate that city sounds tend to be louder and more continuous than those found in rural environments.

### 9.3 Sound Classification

The method is using Cymatics Simulator-Chladni. Different pattern levels are acquired by changing the value of m and n from 1-6 in this equation.

$$f(x) = a \sin(\pi nx) \sin(\pi ny) + b \sin(\pi mx) \sin(\pi ny)$$

I tried to match the sound and surface behavior. The scheme is that I generate the sound from frequency and each pattern matches each frequency.

However, there is limitation of the scheme. First, there is only three dominant frequency domain during these sounds, 0-50Hz, 50-100Hz, 3000-8000Hz. Most of the sound of level 2 is between 50-100Hz, which can not be separated. Second, the application of kinetic surface is not ideal. To show the pattern with the complexity, the triangle need to be very small size which is not possible and triangle panels of larger size cannot show the pattern.

Therefore, to show the Chladni plate pattern with the balance of aesthetic and feasibility, I chose 8 feasible patterns, following the same rule that higher frequency matches more complexity. The patterns selected are prepared for the kinetic surface prototyping.

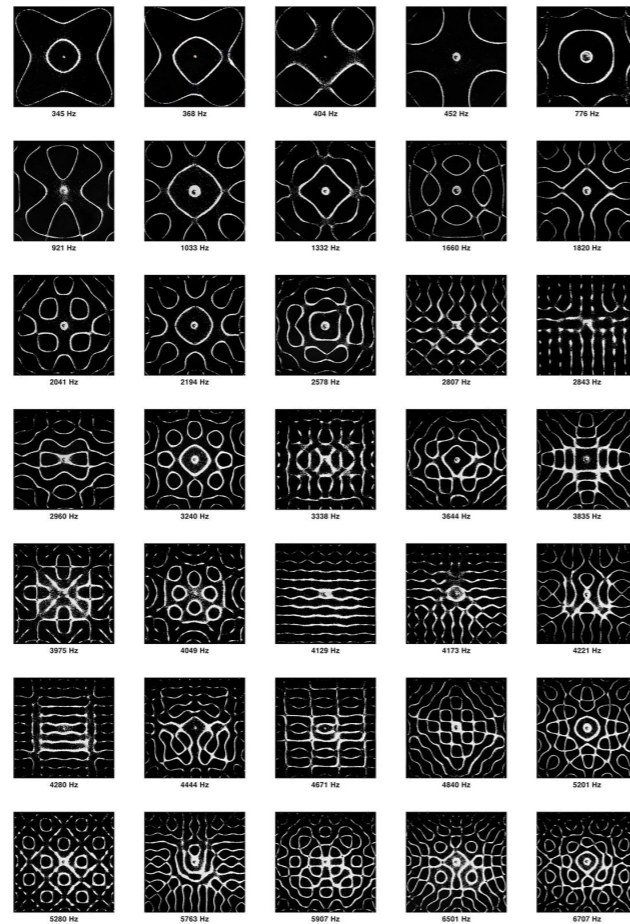
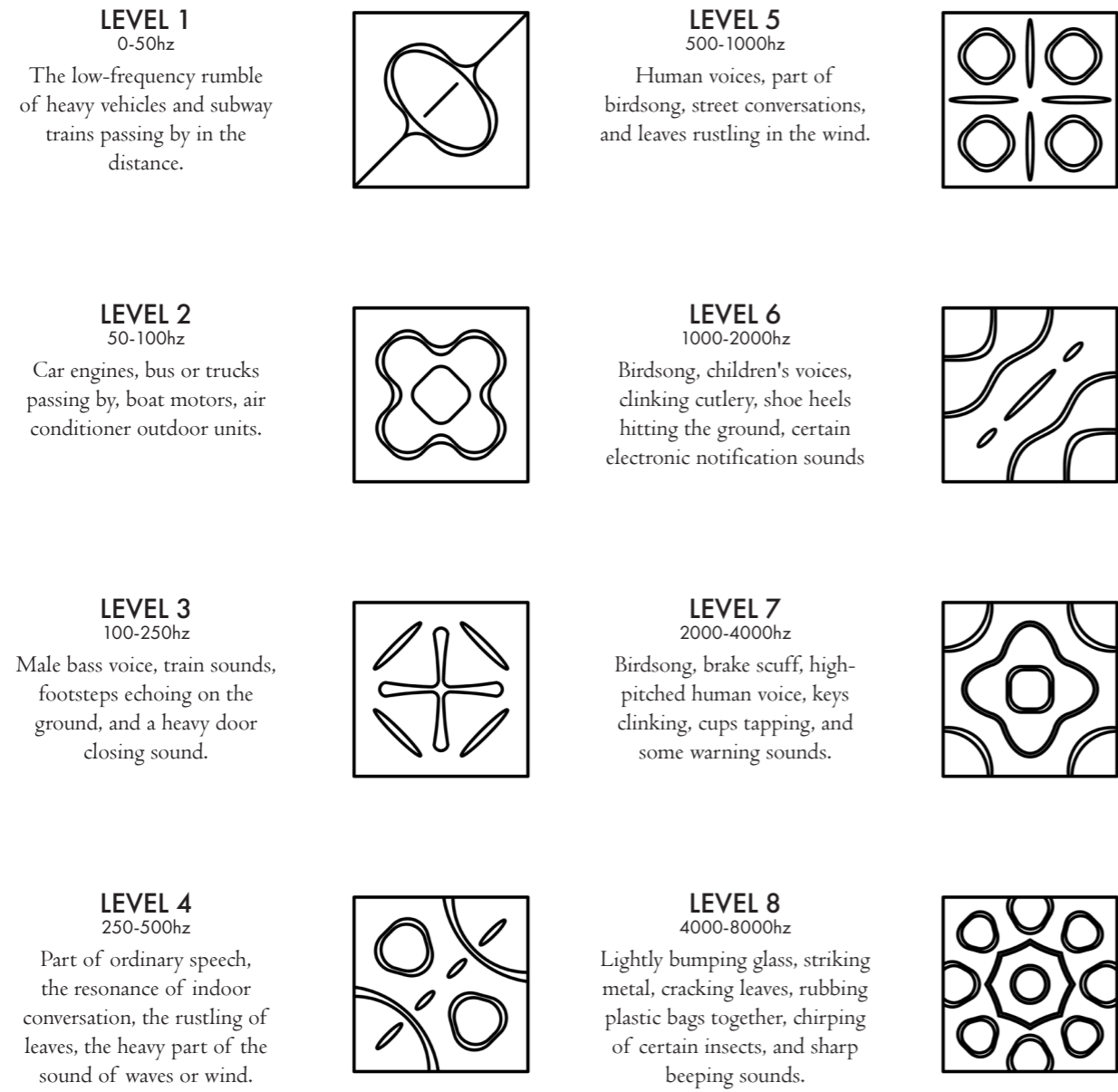


Fig 24. Chladni Plate Pattern

	🔍 Sound	☰ Dominant Hz	☰ Secondary Hz	☰ Band Hz	☰ Notes	☰ model level
1	Wave	30		0-200	stochastic, layered, immersive	Low
2	Boat	62	140	100-400	steady, harmonic, enclosing	Low-Mid
3	Adult voice	64	268	0-600		Mid-High
4	Park	68	224	0-400		Low-Mid
5	Train	70	363	0-400		Low-Mid
6	Square	78	200	0-300		Low-Mid
7	Street	85	275	0-400	dense, fluctuating, multi-source	Low-Mid
8	Cars	87	243	0-400		Low-Mid
9	Children voice	900	1800	0-1800	impulsive, chaotic, high-energy	High
10	Sheep	2923		250-4000		High
11	Walking	3974	8388	3000-9000		High
12	Birds	8159		1000-9000		High

Fig 25. Sound analysis data; own work



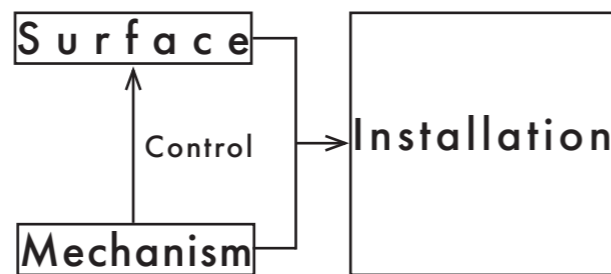
### 9.4 Research Outcome: Frequency-based Translation Rule

Based on the sound analysis and Chladni pattern study, the thesis establishes a translation rule: lower frequency conditions correspond to simpler and broader patterns, while higher frequency conditions correspond to denser and more complex patterns. This rule becomes the basis for organizing the kinetic pattern catalogue.

Fig 26. Sound pattern rule; own work

## 10. Kinetic Surface Prototype Development

The prototype phase explores how Chladni-inspired patterns can be transformed from two dimensional visual references into kinetic surface movements. To find practical ways, I made tests on both surface and mechanism, and finally combine them to be a complete system.



### 10.1 Surface Tests: Making Movement Visible

The first idea is a combination of surfaces, sticks, and balls, corresponding to the floor, columns, and lights in buildings. From architectural perspective, I extract these three abstract elements to sketch design, and set the view on a micro scale.

These are the questions from the sketch:  
 How to read the pattern?  
 How to read the movement?  
 How is the spatial effect?

Since the logic of three elements is the same in digital modelling, I choose the balls (points) as the base. By graph mapper, I get the point cloud from the I,1 to I,6 image. The denser part has denser points. The points are moved by steps from the center point, in the vertical vector of the plane. There is only one control point in this model.

In conclusion, the model needs to have at least two variables to control it. Variable 1 is the density of the control points, and variable 2 is the amplitude (the vertical vector).

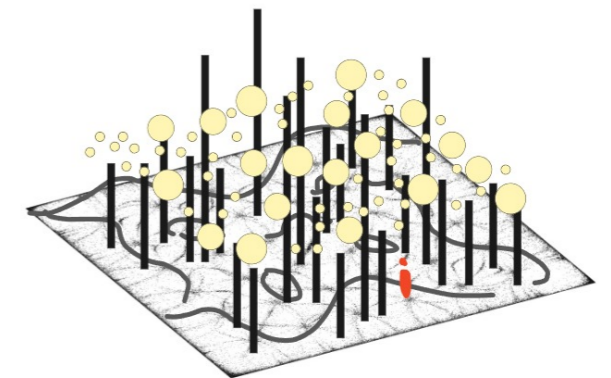


Fig 27. Surface, Sticks, Balls; own work

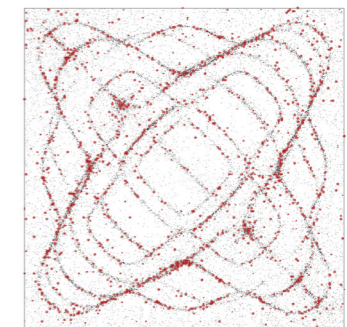


Fig 28. Variable 1 Density of control points; own work

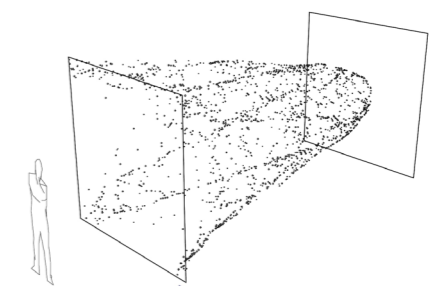


Fig 29. Variable 2 Amplitude; own work

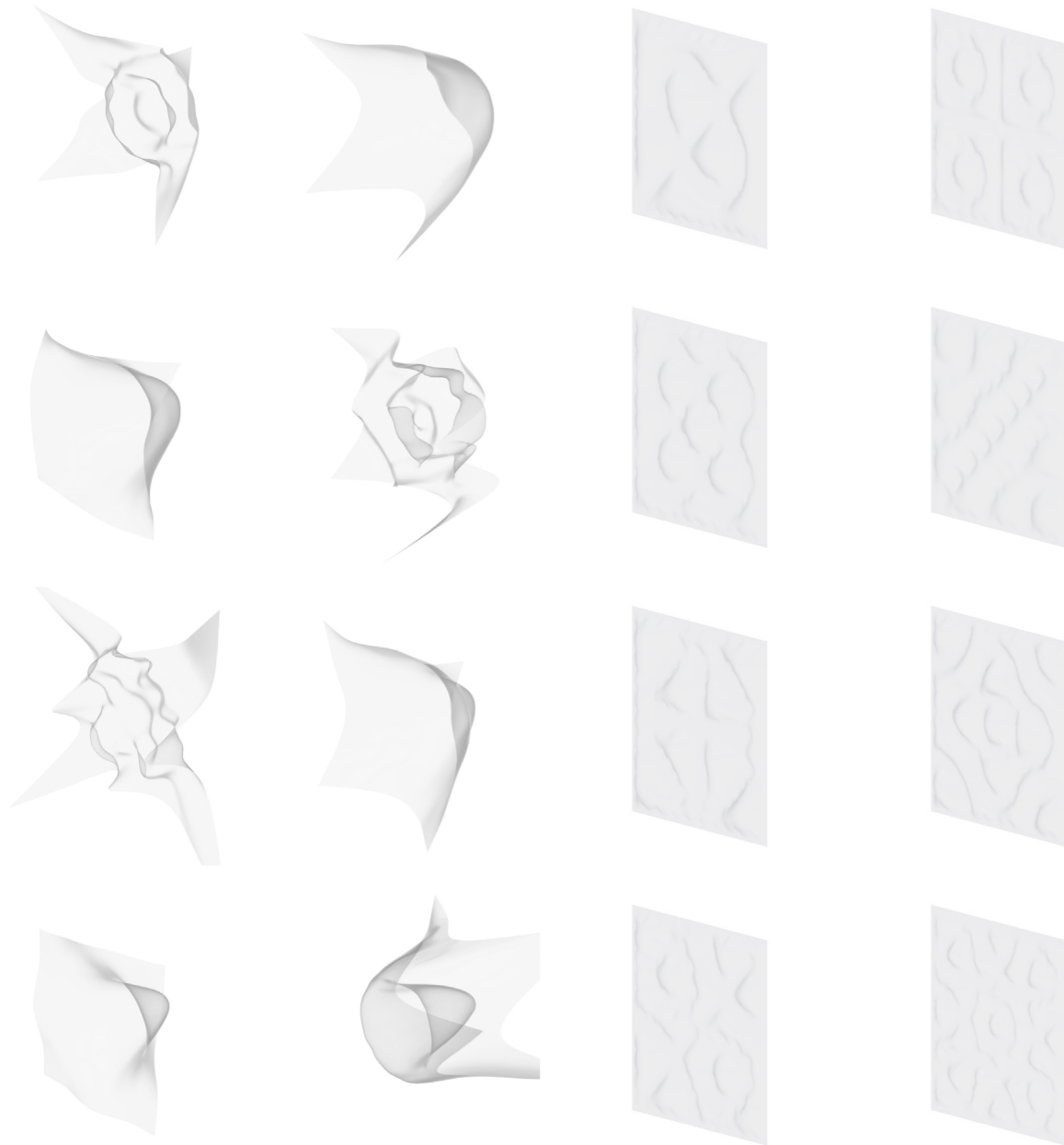


Fig 30. Surface by Graph mapper vs Kangaroo in grasshopper; own work

Different generation logics are tested in parametric design. One is using point clouds as input, and the graph mapper as shape reference. The other is making a surface directly in Kangaroo, with Chladni pattern as shape reference,

The conclusion is that the second method is chosen, as it aligns with the research in the last chapter and is more feasible for dynamic effects.

### Hybrid Surface Test

From the above surface, the problem is that the movement of the surface is not visible enough and lacks aesthetic. A new solution is proposed that the surface needs to be kinetic.

Kinetic is a mature approach used in architectural facade construction that is flexible and adaptable to parametric geometries, which provides better performance than hardcover elements.

The ideal kinetic surface in the thesis is a combination of fabric and a hard triangle surface (cardboard, plywood or acrylic). It is designed to be soft but with visible changes. The hard surface is for the audience to see the movement, and the soft layer is to keep the flowing effect. The gap is possible to change under force, so the amplitude is applicable here.

#### Variable: gap

The gap is changed between triangles with the same pattern to see which performs better.

Conclusion: The one with a 4mm gap has better touch feeling and visual effect.

#### Variable: glue

Two ways of gluing are tested to see which performs better with movement.

Conclusion: Gluing the whole surface has a better visual effect, while gluing only the middle makes the state chaotic.

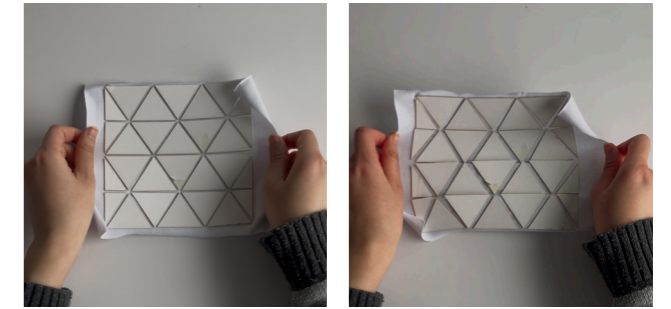


Fig 31. Physical prototype, kinetic surface; own work

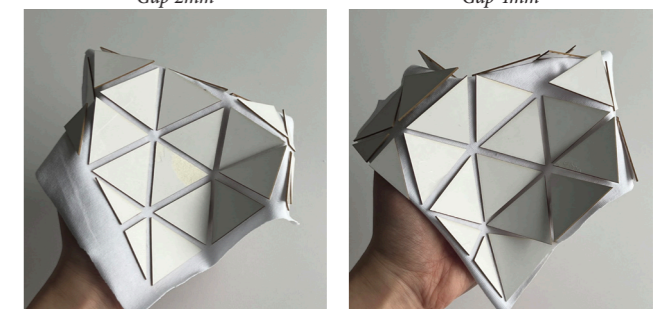
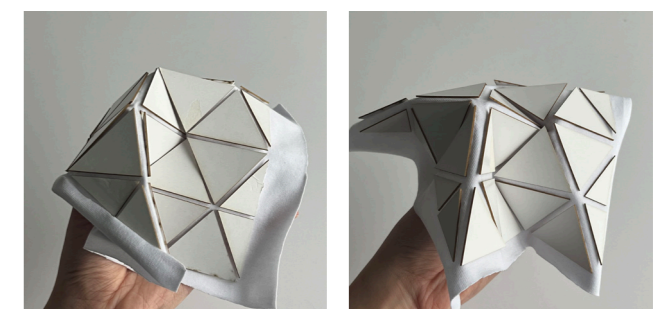


Fig 32. Physical prototype, kinetic surface; own work

Rather than understanding kinesis as a purely technological feature, Park et al. suggest that movement should be embedded within the tectonic logic of the architectural surface. This idea is reflected in the thesis through the development of a hybrid kinetic surface in which control, material, and geometry operate as one system.

**Typology A - Wall**

Both of the tests are based on my completed museum project. Typology A focuses on the wall near an atrium. The space and circulation are not interrupted after the kinetic surface comes in. It works more like a facade design approach applied to an inner boundary.

**Typology B - Ceiling**

Typology B tests the potential of ceiling in a comparatively enclosed space. Rather than treating the ceiling as a passive boundary, it creates a special space with the light coming in. The focus is directed upward to the ceiling more than to the space itself.

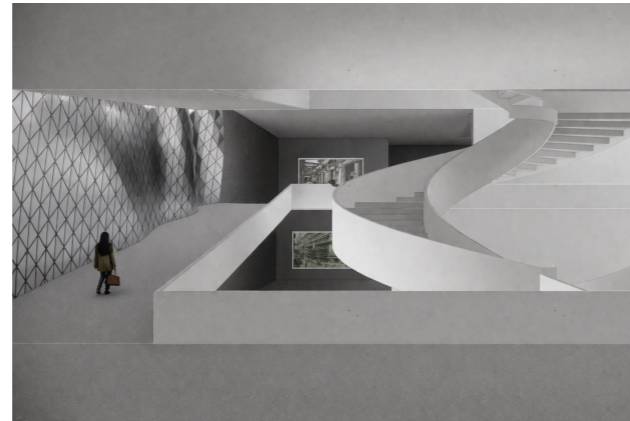


Fig 33. Kinetic surface render; own work



Fig 34. Kinetic surface render; own work

**Conclusion**

'Ceiling' is a good element for people to have the spatial experience even in an open space, together with the special effect of lighting.

**10.2 Mechanism Tests: Generating Movement**

**Test 1.0 - Rotational Mechanism**

**Aim**

It aimed to test if the rotated axle that has eccentric discs could work as the mechanism.

**Material**

16\*16\*16cm frame  
3d printed top and motor base

**Test**

The surface system is located at the top and consists of an irregular structure divided into several rings and approximately twenty individual segments. Each segment has a vertical column underneath printed as a whole. These columns transfer movement from the mechanical system to the surface.

The driving system is based on a horizontal rotating axle equipped with eccentric discs. As the axle rotates, the eccentric elements generate vertical displacement of the segmented surface above. The entire mechanism is supported by a base frame that stabilizes the axle and allows rotational flexibility.

However, after assembly, the system did not perform as expected. When the axle rotated, the columns did not remain vertically stable. They shifted together along the horizontal (Y) axis.

**Conclusion**

Although the system did not fully succeed, the experiment revealed the importance of movement guidance and constraint in kinetic surface systems.

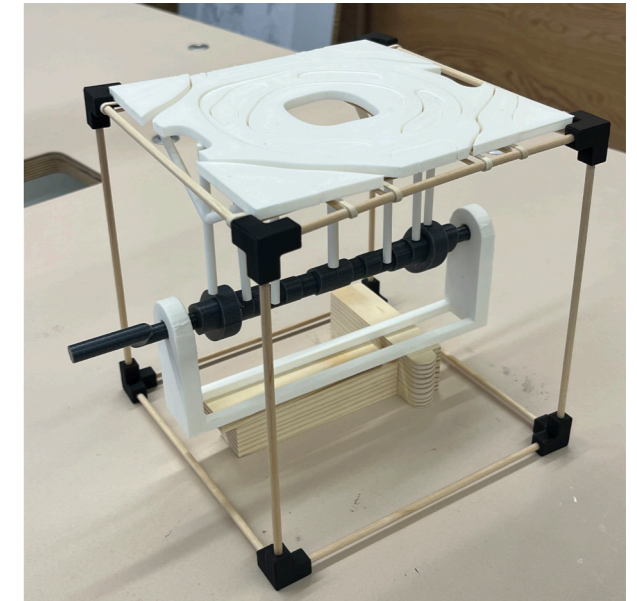


Fig 35. Physical test 1.0; own work

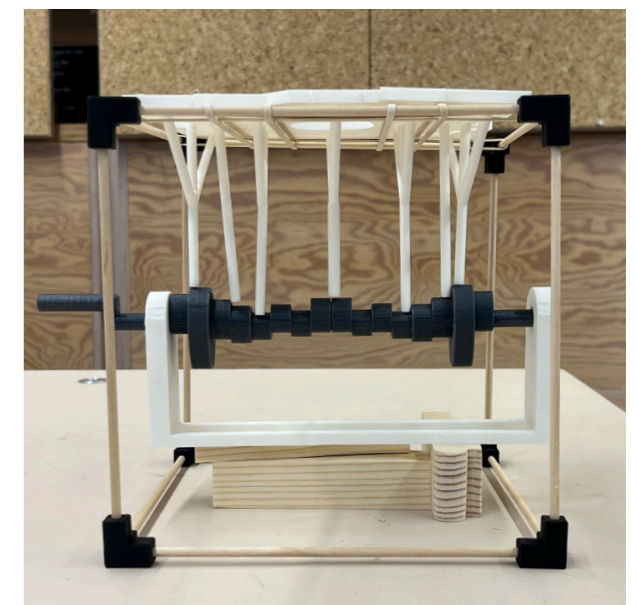


Fig 36. Physical test 1.0; own work

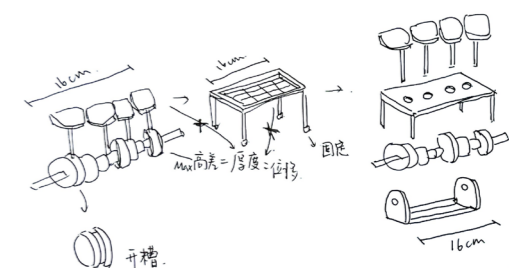


Fig 37. Physical test 1.0 draft; own work

### Test 2.0 - Single Control Point

#### Aim

It aimed to test if the rubber band material could work in both the surface system and mechanism.

#### Material

- 16\*16\*25cm frame
- Rubber band\*2
- 3D printed gearwheel kit

#### Test

The test is organized into three main components: the surface, the connection and the mechanism.

The surface is replaced by the elastic rubber band stretched across the upper frame. This band represents a simplified deformable surface. Its tension allows it to respond visibly when force is applied to a specific point.

The connection is a secondary rubber band that links the upper surface to the rotating mechanism below. This element transfers movement from the driving system to the surface element.

The driving element consists of a small gear system mounted on a 3D-printed base. The gears are manually rotated, producing circular motion. As the gear turns, it pulls the connected rubber band, which in turn introduces displacement to the upper elastic band.

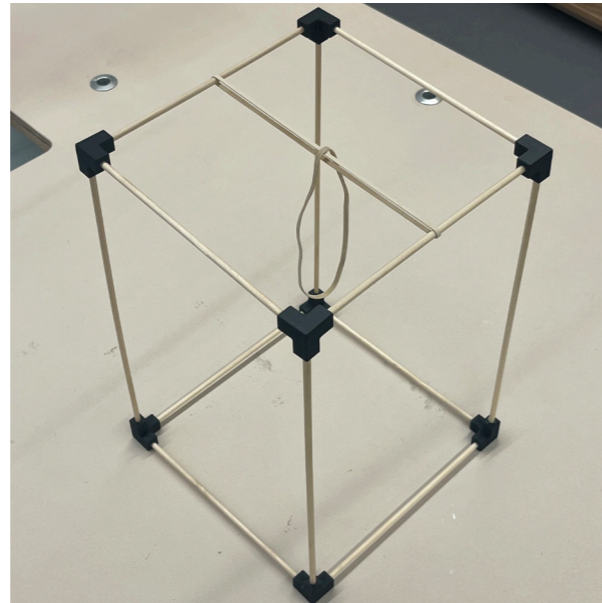


Fig 38. Physical test 2.0; own work

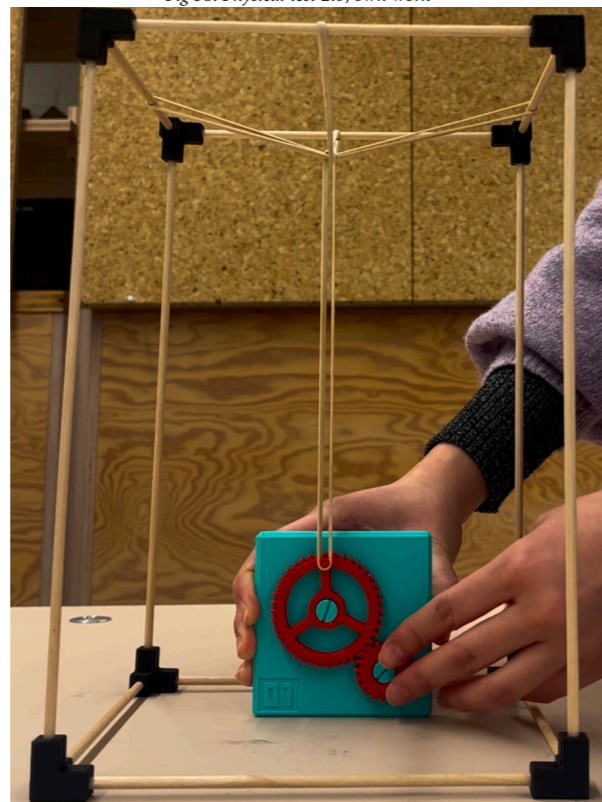


Fig 39. Physical test 2.0; own work

#### Conclusion

Through this configuration, rotational motion is transformed into vertical and directional deformation. The surface deformation appeared smooth and continuous due to the flexibility of the elastic material.

However, movement was concentrated around a single control point, resulting in limited spatial variation. The experiment indicates that although material elasticity improves visual clarity, distributed control points are necessary to achieve more complex and expressive surface behavior.

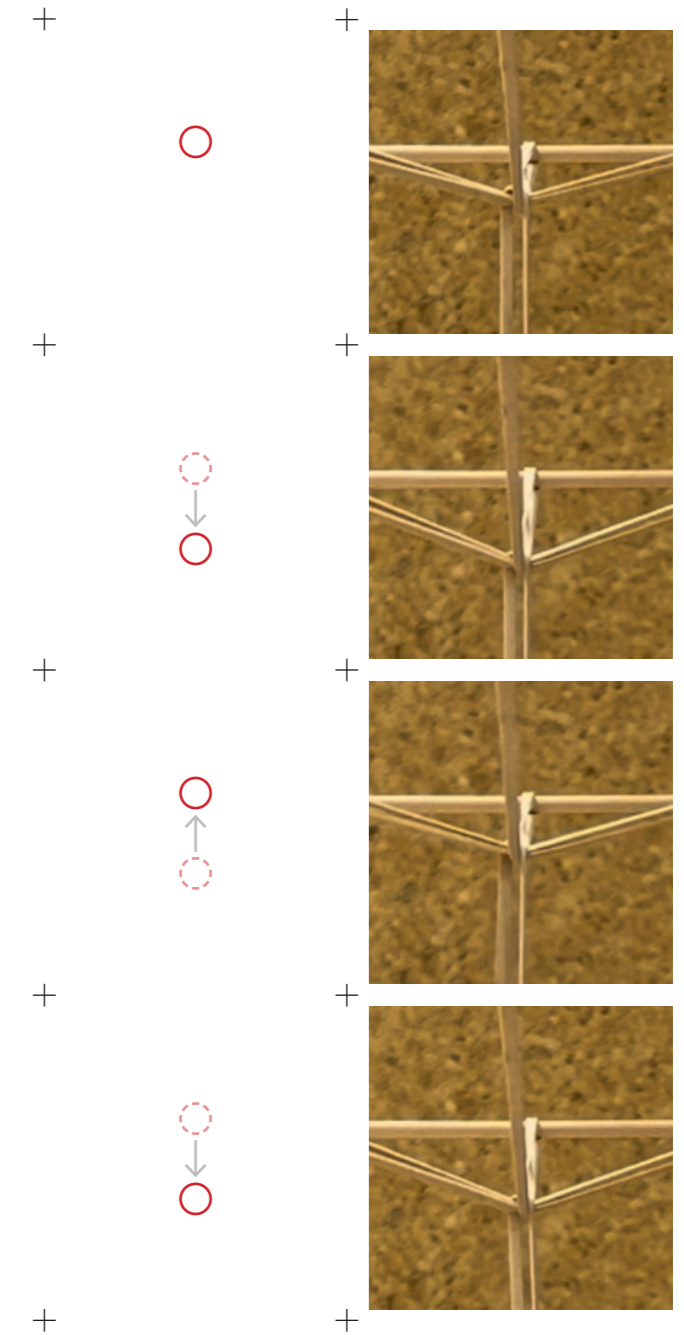


Fig 40. Physical test 2.0, Movement Diagram; own work

### Test 3.0 - Distributed Control Point

#### Aim

It aimed to test if the fabric material could work as the surface system and gearwheels as the mechanism.

#### Material

- I6\*I6\*I6cm frame
- An elastic fabric
- Screws and nuts
- Stainless steel wire
- 3D printed gearwheel kit

#### Test

The test is organized into three main components: the surface, the connection and the mechanism.

The surface consists of an elastic fabric and equipped with embedded metal eyelets. These eyelets define the controlled points where movement is introduced. When force is applied to these points, the fabric deforms, generating visible changes.

The connection is made of bent steel wires. These wires link the controlled points on the fabric to the rotating elements below. Their role is to transfer motion from the mechanism to the surface.

The mechanism is composed of a series of interlocking gearwheels. A single rotational input is distributed across multiple gears, each equipped with an eccentric pin. As the gears rotate, the eccentric pins move up and down, creating vertical displacement.



Fig 41. Physical test 3.0; own work

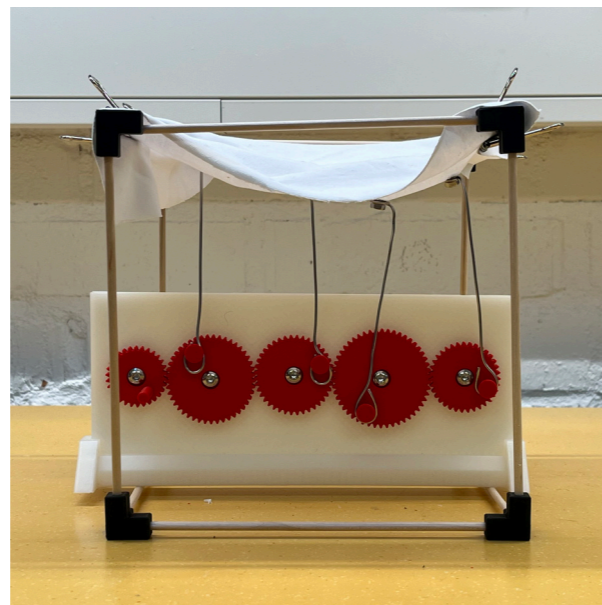


Fig 42. Physical test 3.0; own work

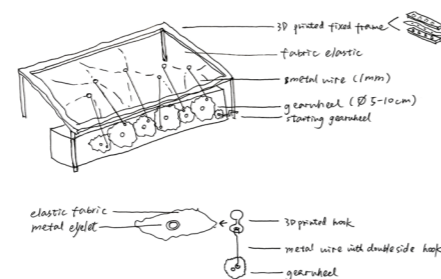


Fig 43. Physical test 3.0 draft; own work

### Conclusion

The introduction of multiple control points resulted in more differentiated and dynamic surface transformation. Movement became spatially distributed, enhancing visual complexity and clarity. The experiment confirms that distributed actuation increases expressive potential, while precise mechanical guidance is necessary to maintain stability.

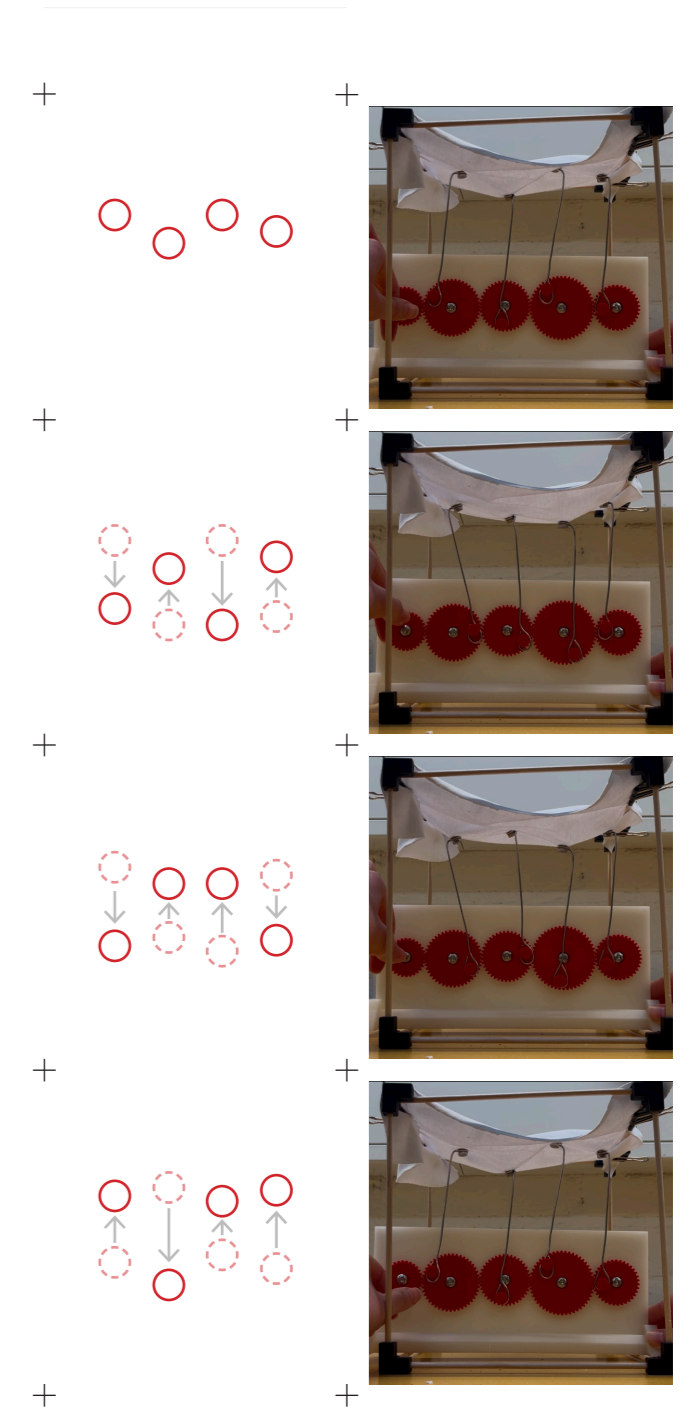
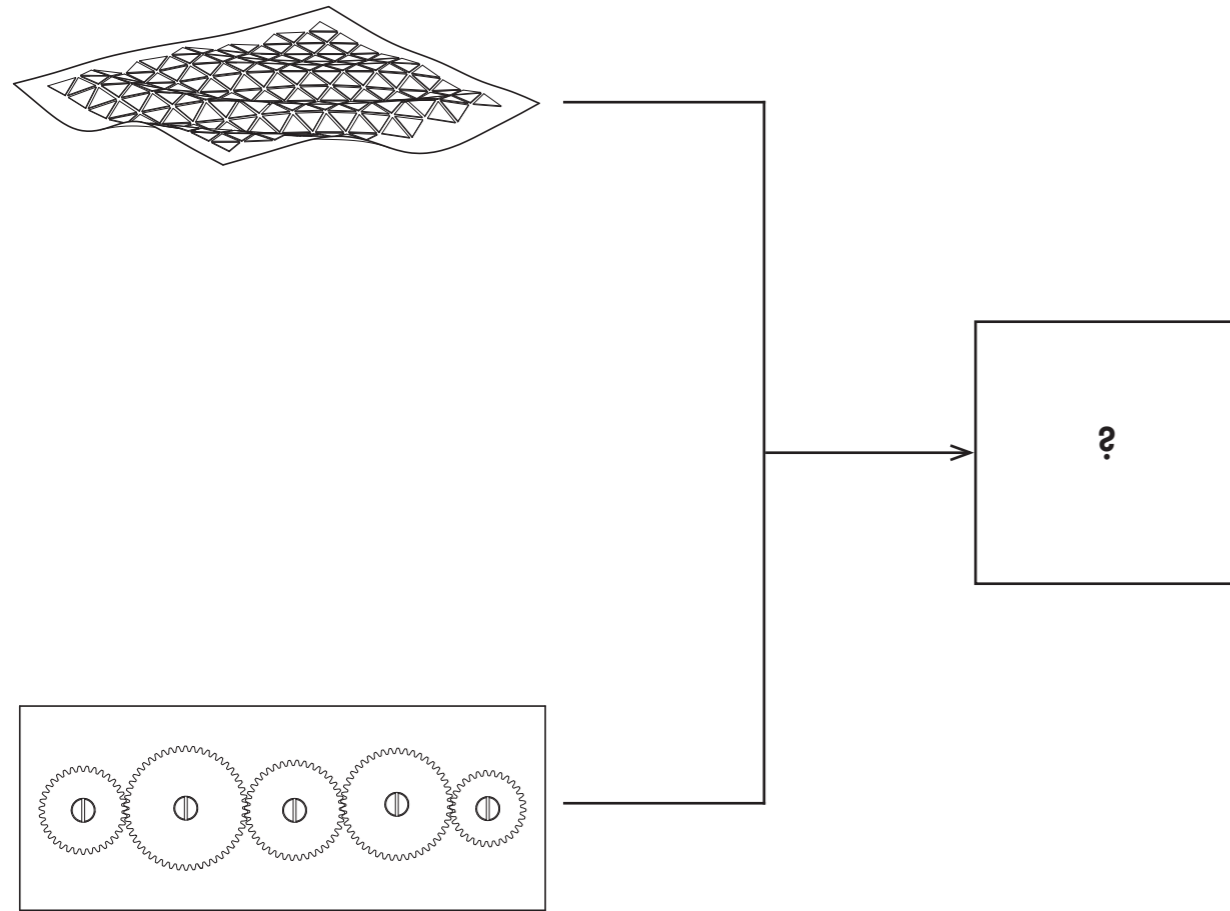


Fig 44. Physical test 3.0, Movement Diagram; own work



In conclusion, the tests of kinetic surface and mechanism contribute to the installation prototype. Kinetic surface includes the proper material and proper size of triangle panels. Mechanism will be developed more in the next chapter.

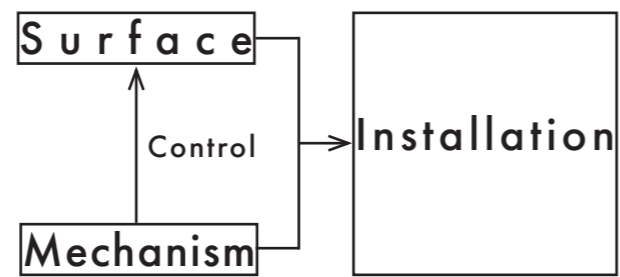


Fig 45. Physical prototype 1.0; own work

### 10.3 Installation Prototype

#### Prototpe 1.0

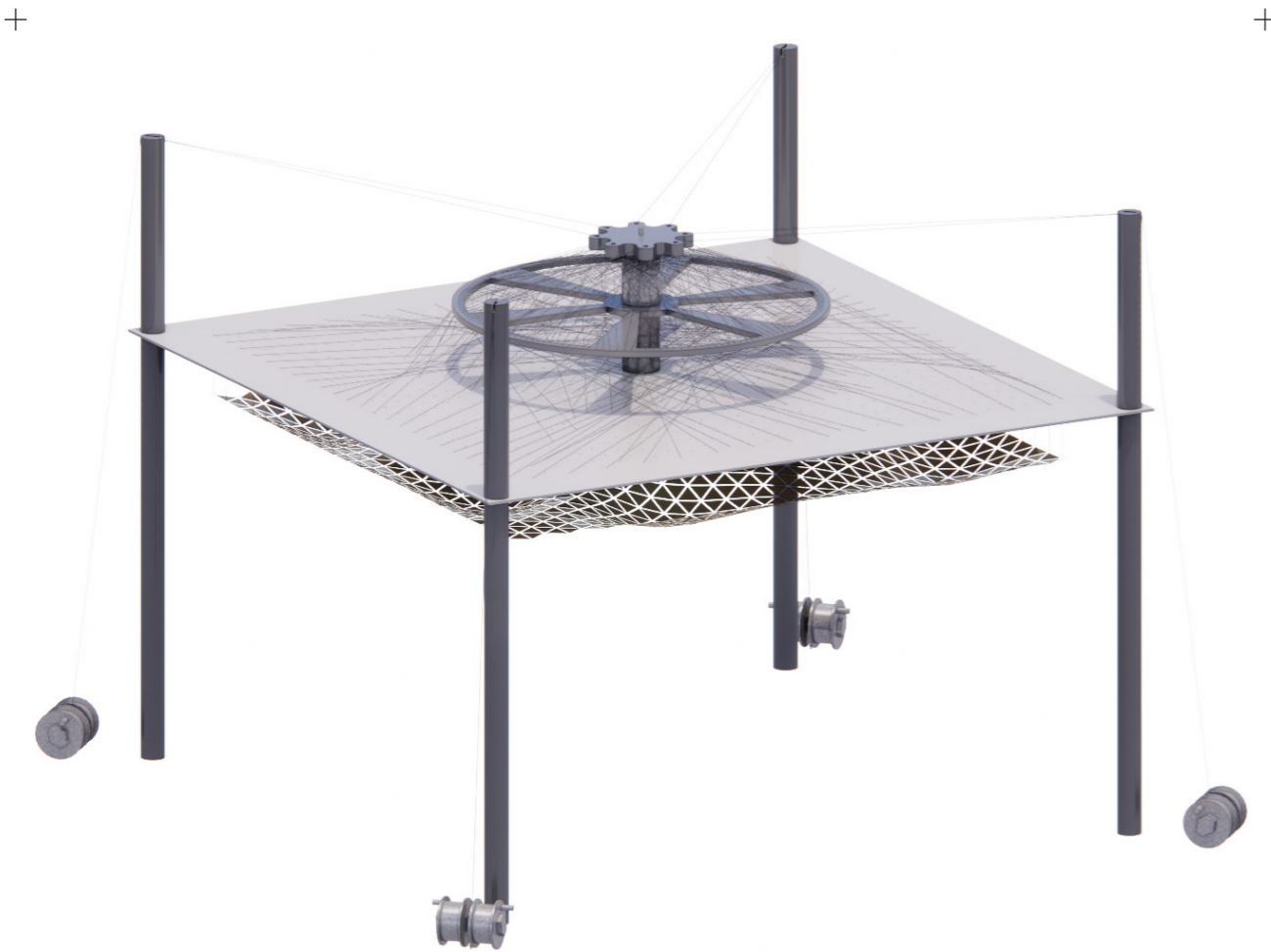


Fig 46. Physical prototype 1.0, Axon; own work



Fig 48. Physical prototype 1.0, Explosion diagram; own work

The mechanism is inspired by the test 3.0. To achieve the same goal as the physical model, the number of motors is controlled to be only 1. The control part includes one motor and 160 strings. The strings going through the holes on the board control the surface. The dynamic of the surface is the ideal result of the mechanism.

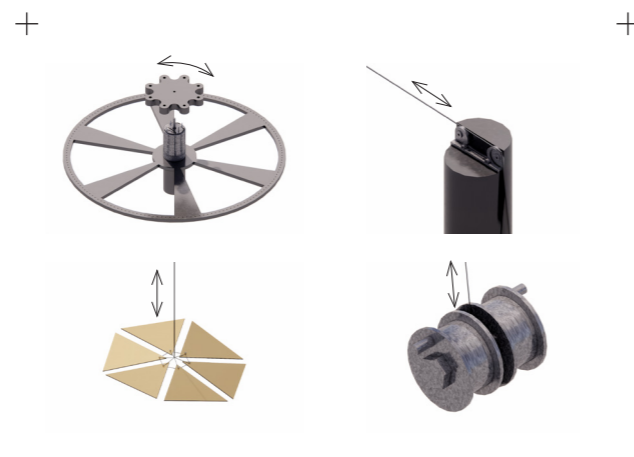


Fig 47. Physical prototype 1.0, Detail; own work

In this canopy prototype, the benefit is that it relies on only one motor and shows interesting mechanical motion. The limitation is that it can only make one pattern, which means it lacks flexibility.



Fig 49. Physical prototype 1.0, Axon; own work

Prototpe 2.0 (final version)

+

+

+

+



Fig 50. Physical prototype 2.0, Axon; own work



Fig 52. Physical prototype 2.0, Explosion diagram; own work

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Updated from the prototype 1.0, everything is simplified. To achieve the possibility of showing different patterns in one mechanism, the control part is changed to 622 linear actuators. Each actuator is connected to one control point.

Within this system, programming by code controls the movement of the kinetic surface, which would achieve a better effect than the one-motor version.

+

+

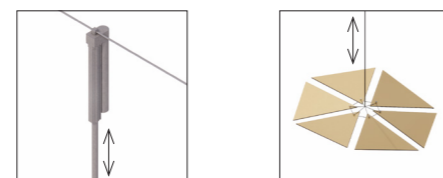


Fig 51. Physical prototype 2.0, Detail; own work

This installation prototype considers the proper material and mechanism. The kinetic surface is detailed to be light and flexible like a soft fabric. The mechanism is simplified to be less volume and covered under the transparent acrylic from rain or wind. The aesthetic effect is showing people the kinetic surface and mechanism behind it.

+

+



Fig 53. Physical prototype 2.0, Axon; own work

## 11. Design Proposal



The design proposal applies the frequency-based pattern catalogue to a responsive canopy installation in public space. The proposal is developed in five steps: site selection, sound-pattern strategy, installation introduction, spatial experience section, and final atmosphere. The sound is translated into data and transformed into a kinetic surface in the canopy installation through this process.

*Fig 54. Site Axon, AI-assisted composition of project rendering and site photograph; edited by author*

# 11.1 Site Analysis

## Current Situation



Fig 55. Site analysis, Current situation; own work



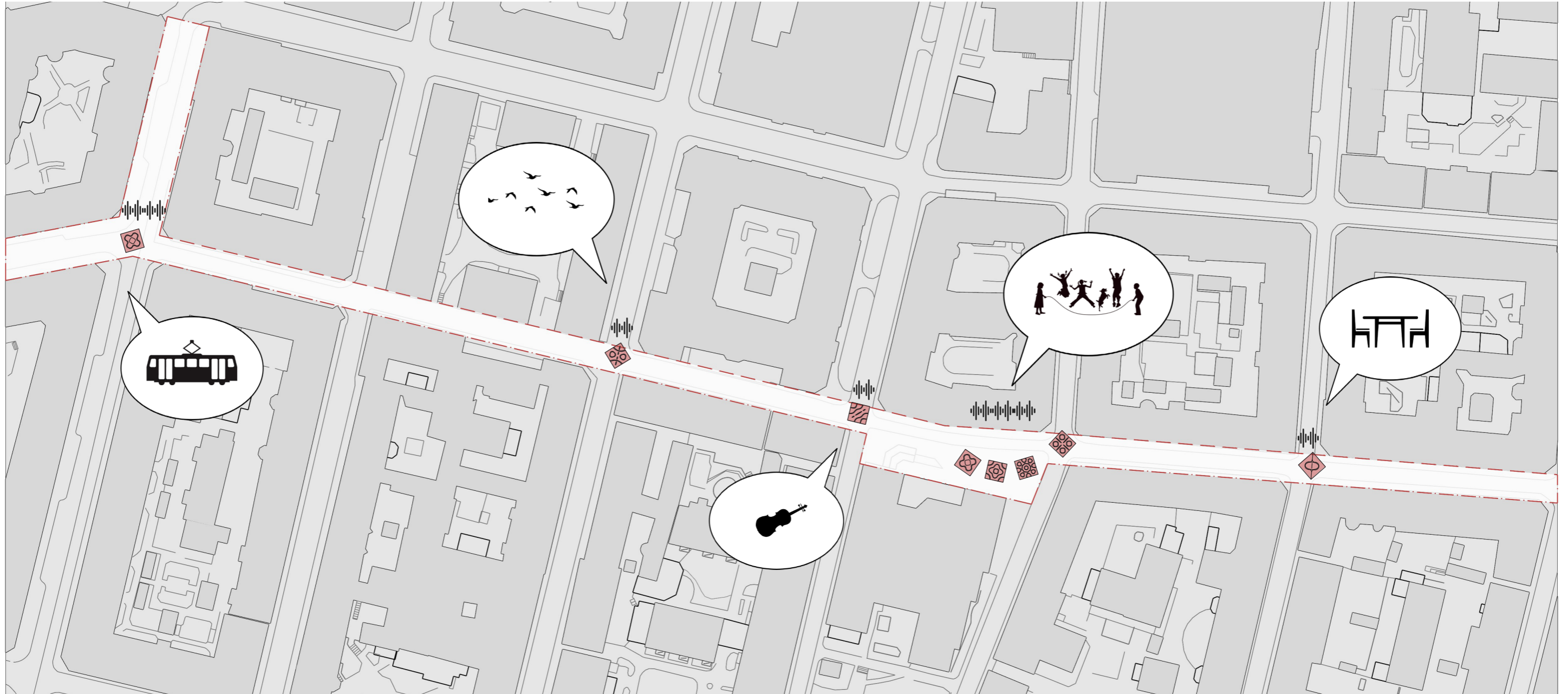
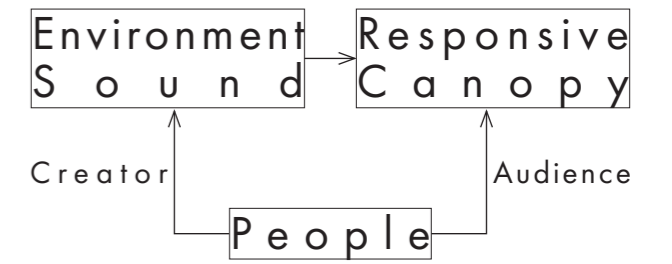
After the observation, the site boundary is set within the Haga street since it has characteristics of both noisy and quiet. There are two main gathering areas on the street, which are A and D. They are rich in both space and people. D, as a pocket square, is chosen as the main site in the project.



In the natural state, sound on the street varies according to the number of people, the weather, animals, and activities. When there are more people, sound has a higher volume and often a higher frequency; otherwise, it has a lower volume. The frequency is the most random fact, and high frequency can be created by people and animals.

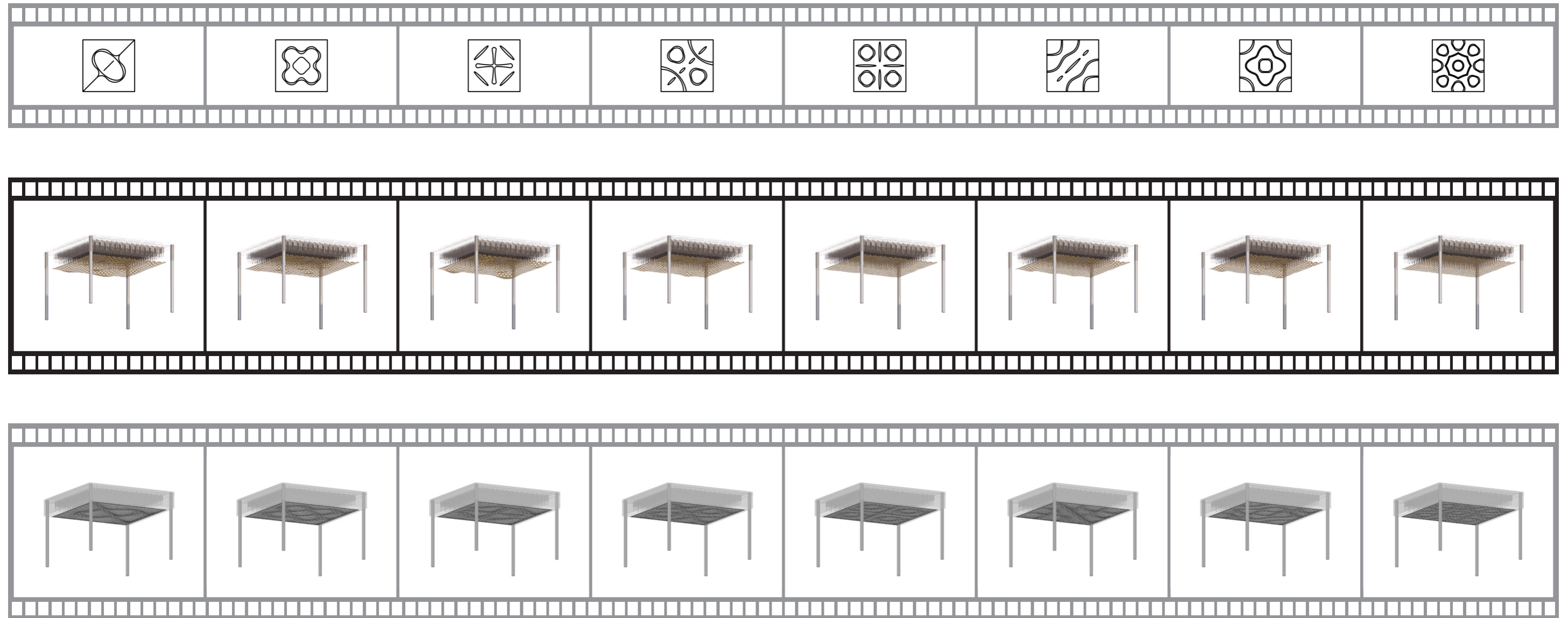
Fig 57. Site analysis, Gathering point; own work

11.2 Strategy

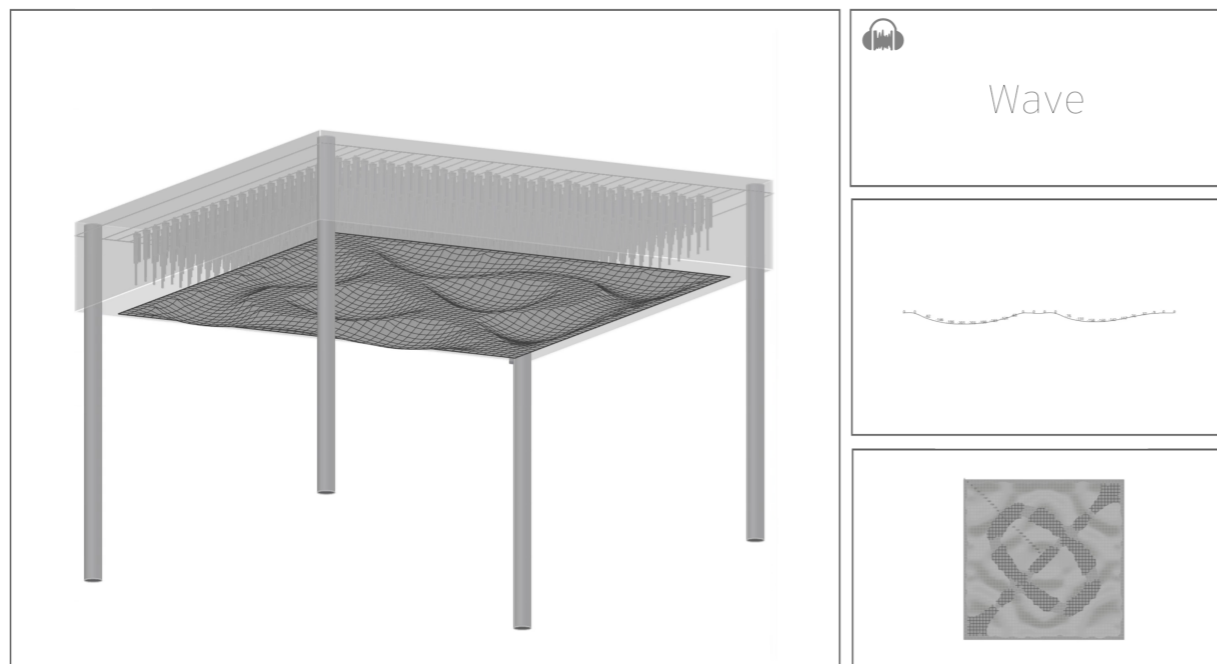


The design strategy is that sound triggers a pattern on the kinetic surface according to frequency. Each canopy works by itself. Imagine: a train passing by, violin music from a street performance, children playing on the square, and people dining outside under the sunshine. When these scenarios happen, the canopy will present a different pattern in these areas.

Fig 58. Site analysis, Sound Map; own work



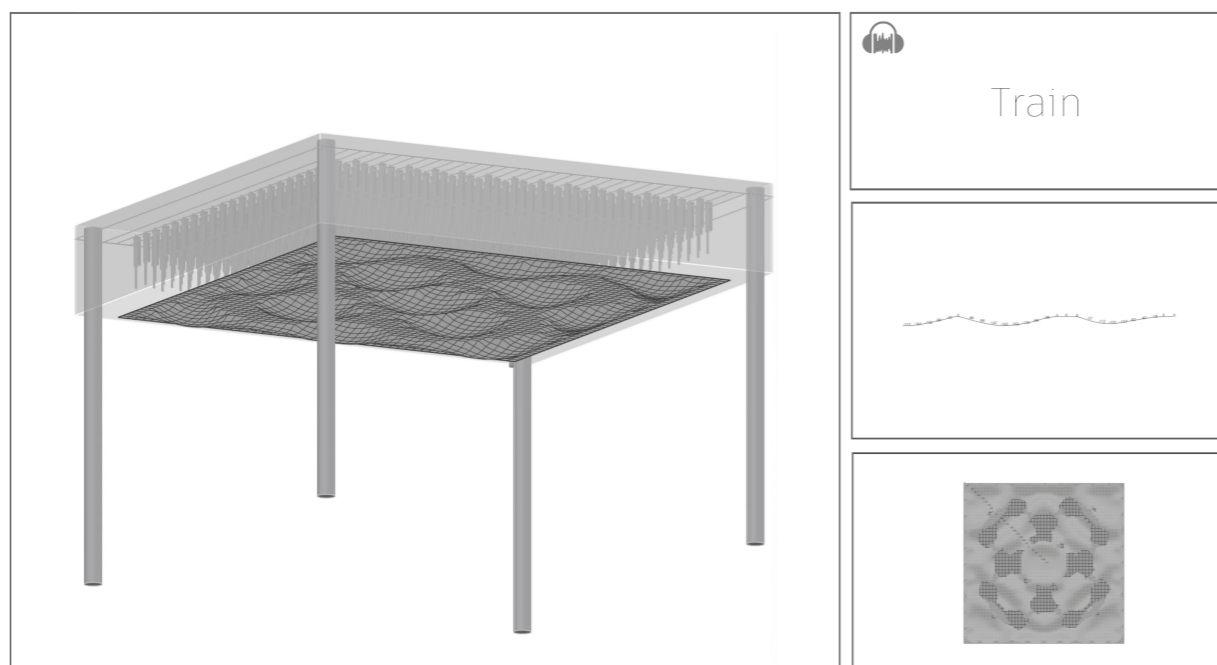
The dynamic film shows how one canopy unit shifts between the eight Chladni patterns. As the sound frequency condition changes, the installation will gradually shift to another pattern. The film presents the pattern icon, the real render with material and the original surface.



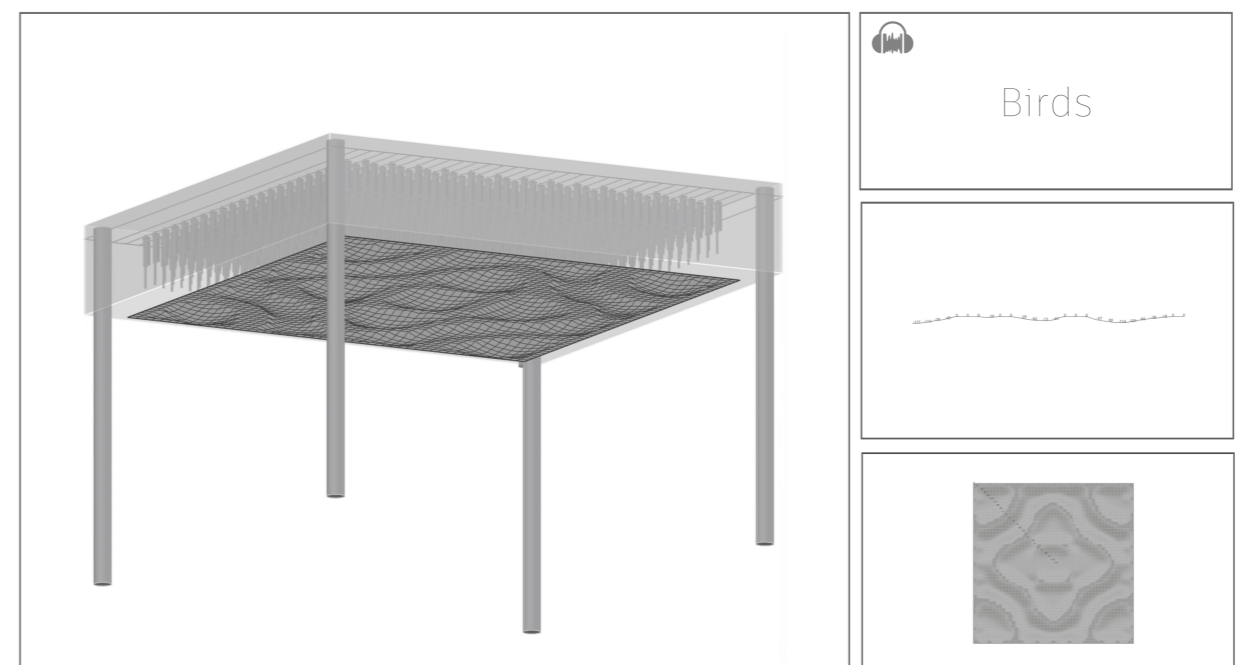
20-50hz



250-1000hz



50-250hz



1000-8000hz

The screenshots from the short video show the sound source, kinetic surface with canopy, surface plan, and surface section on one page. They explain how the specific sounds influence the movement patterns, and show more quantitative data.

### 11.3 Installation System

### Sound map

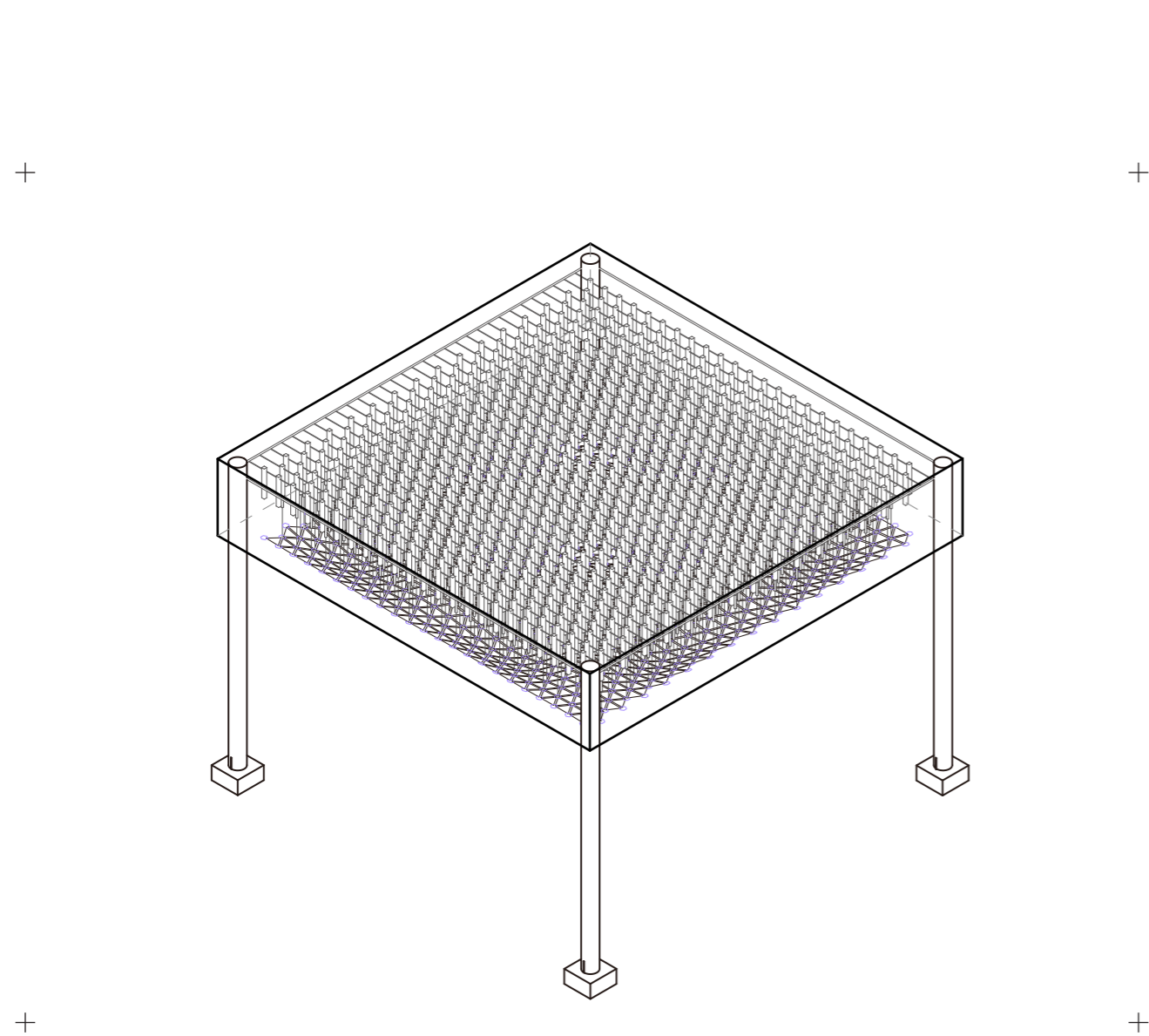


Fig 61. Canopy, Axon; own work

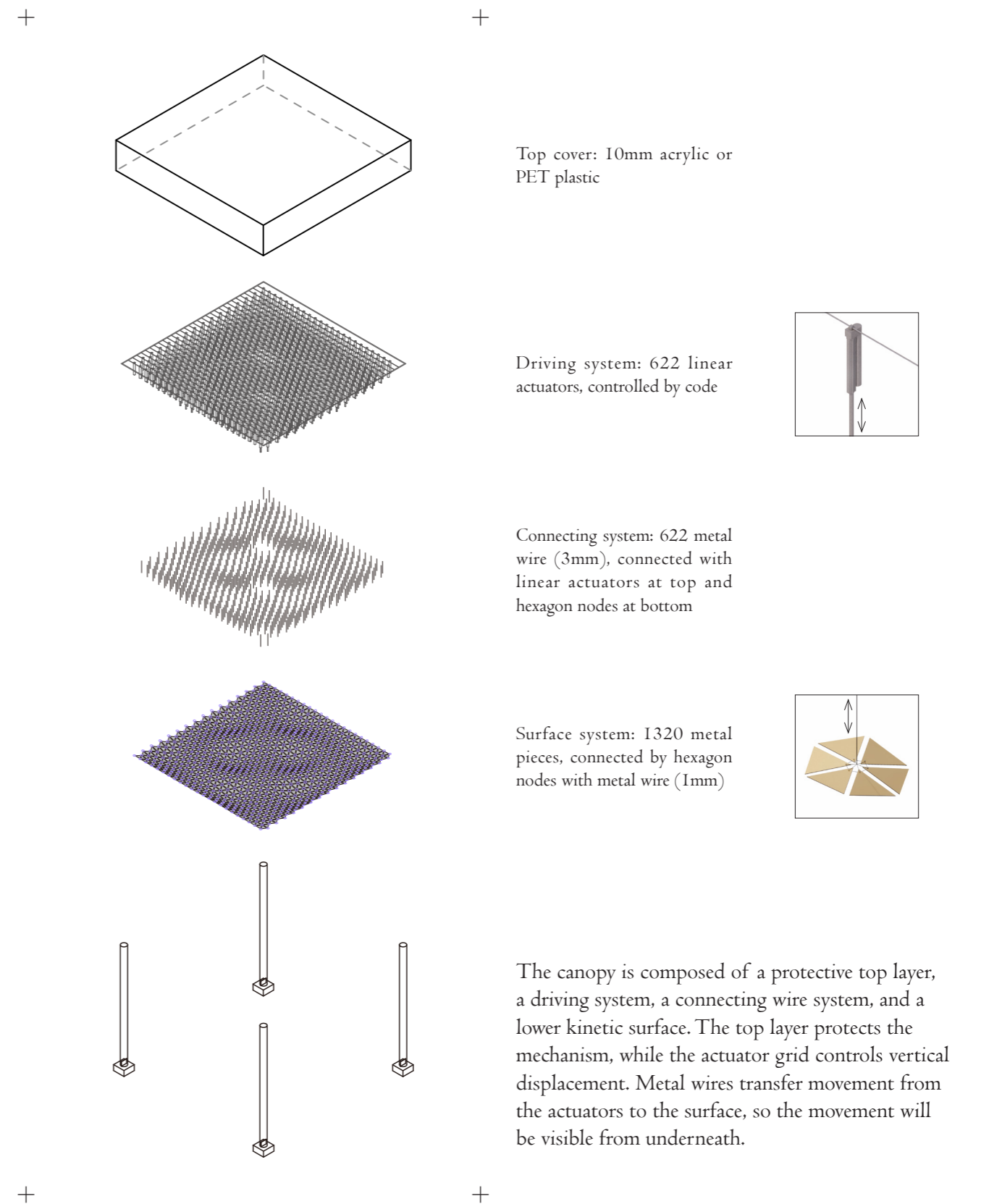


Fig 62. Canopy, Explosion diagram; own work

Fig 63. Canopy, Detail; own work

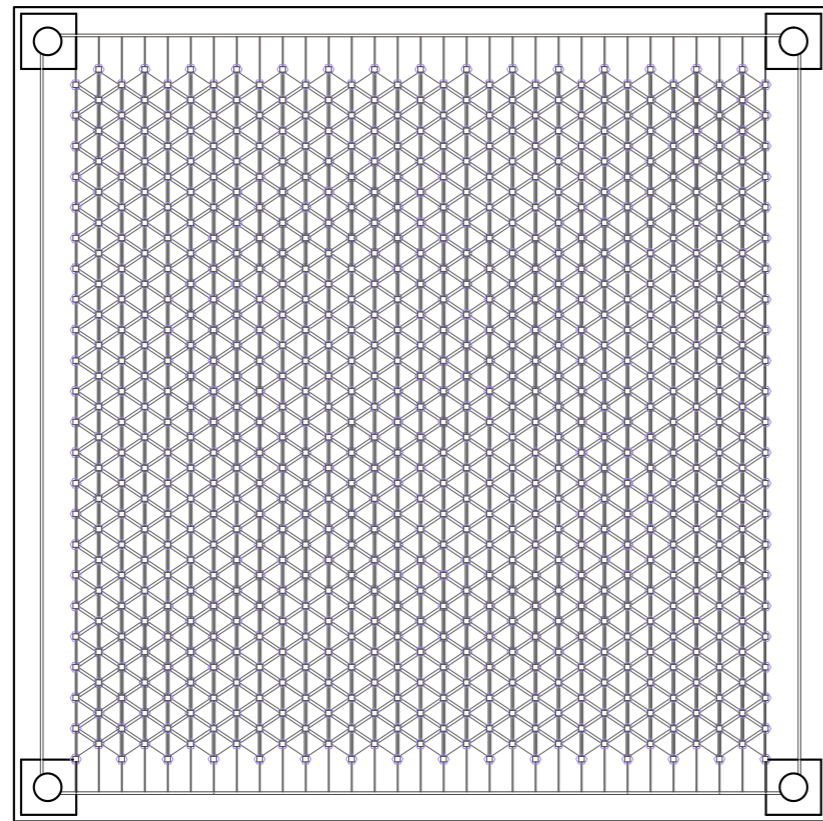


Fig 64. Canopy, Plan; own work

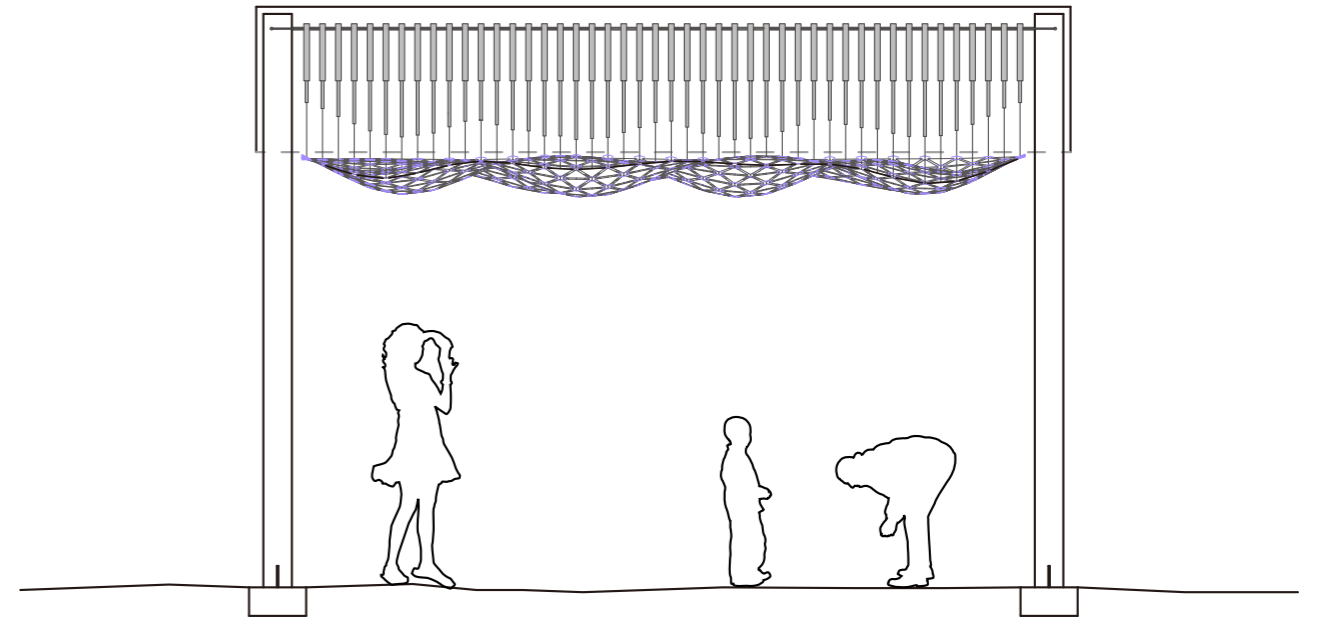


Fig 65. Canopy, Section; own work

11.4 Final Atmosphere



Fig 66. Design proposal, Axon, AI-assisted composition of project rendering and site photograph; edited by author



Fig 67. Design proposal, Render, AI-assisted composition of project rendering and site photograph; edited by author



Fig 68. Design proposal, Plan, AI-assisted composition of project rendering and site photograph; edited by author.



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Fig 70. Design proposal, Render, AI-assisted composition of project rendering and site photograph; edited by author



Fig 71. Design proposal, Render, AI-assisted composition of project rendering and site photograph; edited by author



Fig 72. Design proposal, Render, AI-assisted composition of project rendering and site photograph; edited by author

Ideal Effect



Fig 73. Design proposal, Render, AI-assisted composition of project rendering and site photograph; edited by author

## 12. Discussion

### Contribution

This thesis explores a design method of sound visualization in architectural field. Through Chladni patterns, the thesis finds a relationship between frequency, pattern complexity and spatial movement. The final proposal applies the relationship to a responsive canopy installation in public space.

The main contribution of the thesis is the development of a frequency-based pattern catalogue. The catalogue connects environmental sound conditions with different Chladni-inspired surface. Lower frequency sounds correspond to simpler and broader patterns, while higher frequency sounds trigger denser and more complex patterns. Sound is represented as a changing sculpture and changing space.

### Limitation

This is a thesis that researches deeply into the micro view compared with architectural perspective.

The thesis does not develop a complete real-time prototype due to equipment limitations as well as structural or mechanical. The final proposal should be understood as a speculative prototype.

The frequency-based pattern catalogue is a mapping system created with art instead of a precise and scientific acoustic system.

### Future development

The future development could focus on real-time sensing, programming and larger-scale prototyping. What's more, user experience studies would be necessary to understand how people perceive the moving canopy triggered by sound. Despite the limitations, the thesis demonstrates a possible way to transform invisible environmental sound into a responsive spatial experience.

### AI Appendix

AI tools were used as supporting tools during the thesis process. ChatGPT assisted with thesis framework organization, English writing, abstract revision, terminology clarification.

AI tools were also used for visual representation. Some atmosphere images were created through AI-assisted compositing, combining project renderings with real photographic site environments. These images were used to represent atmosphere, scale, lighting, and contextual relationship.

All design decisions, research direction, sound analysis, Chladni pattern selection, prototype development, and final proposal were produced and evaluated by the author. AI-assisted outputs were reviewed, edited, and adapted before being included. The author takes full responsibility for the final thesis content and representations.

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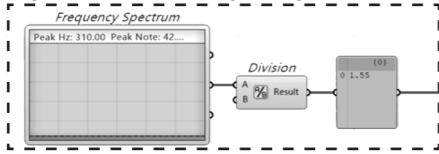
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# 15. Appendix

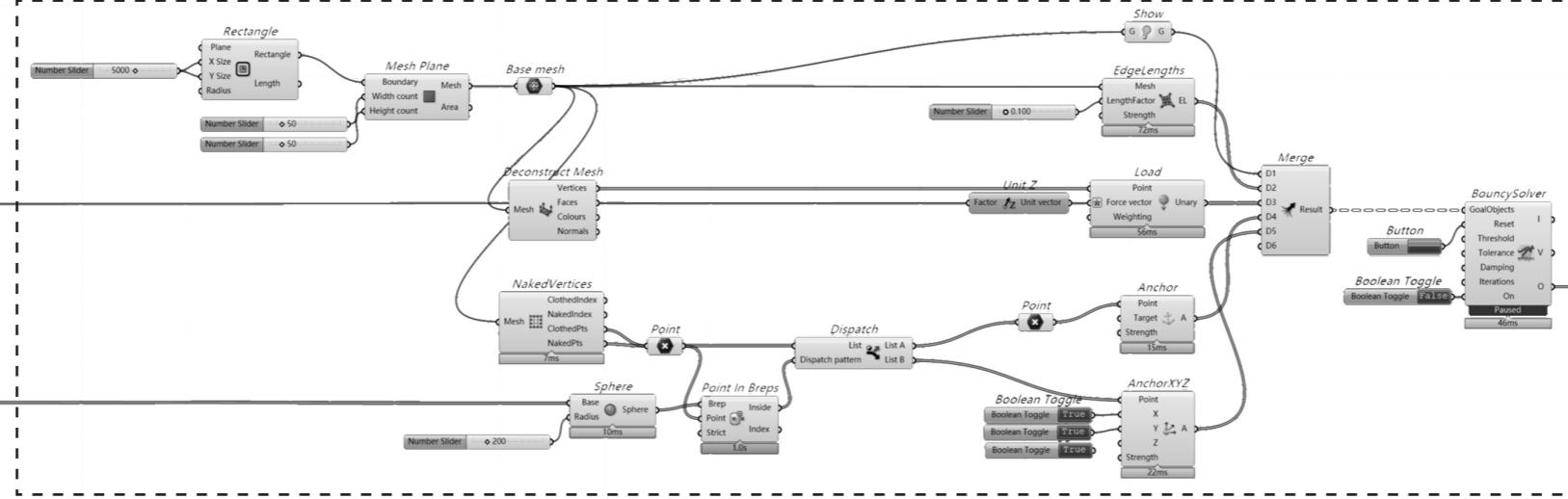
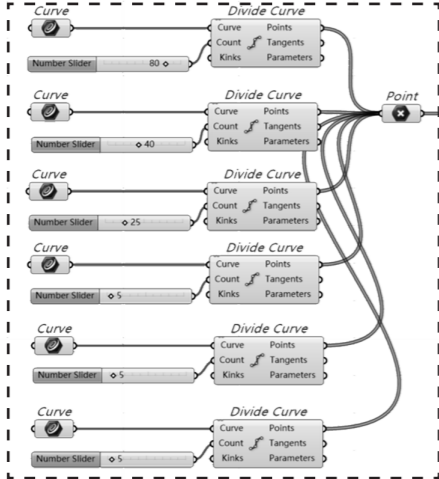
## Appendix - Grasshopper

### Simulation - Bouncysolver

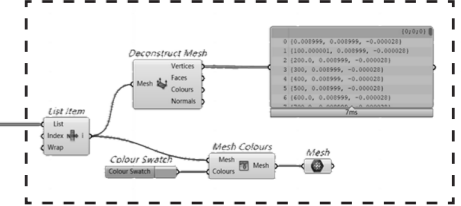
#### Input - Sound frequency



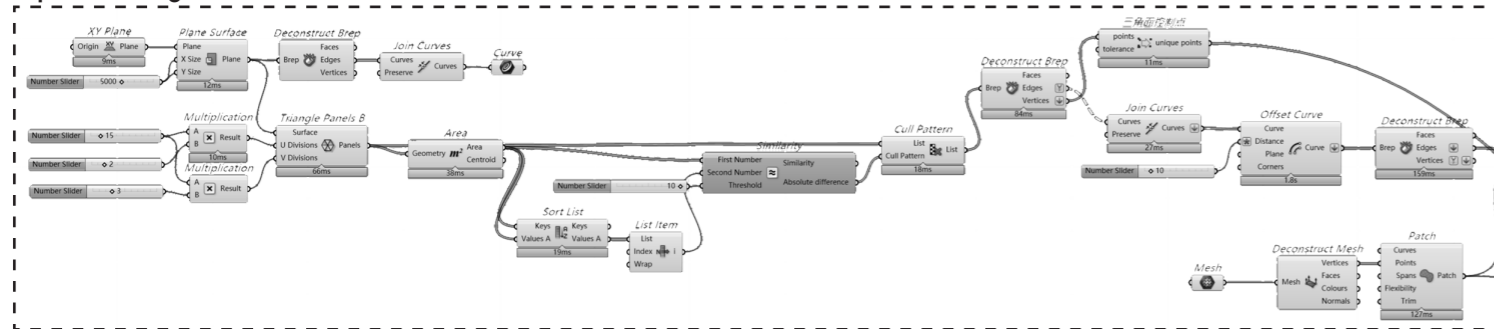
#### Input - Curve



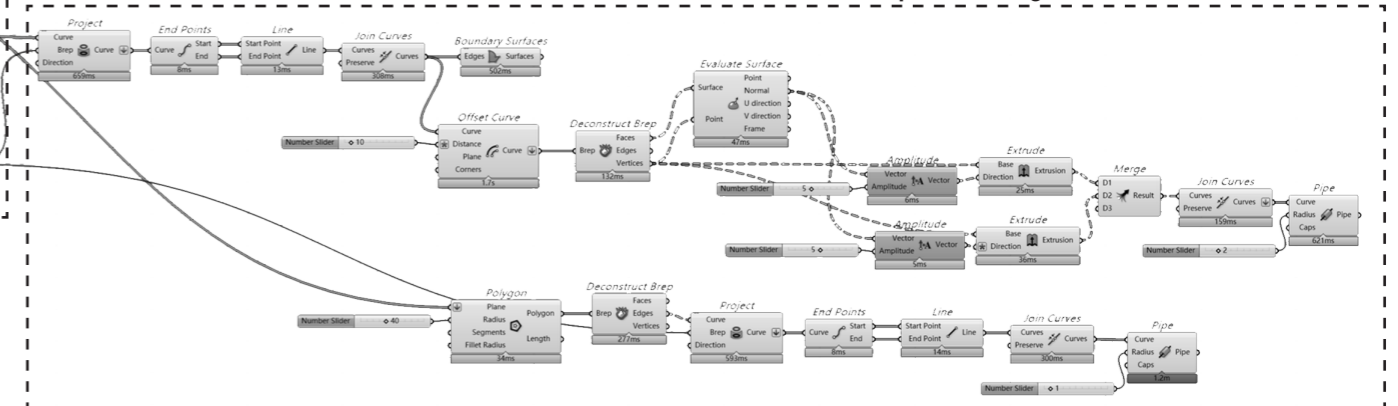
#### Output - Mesh



#### Input - Triangle Panel



#### Output - Triangular Surface + Node Detail





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**Education**

**Chalmers University of Technology**

Master

**Shanghai University**

Bachelor

Gothenburg, Sweden

09/2023-06/2026

Shanghai, China

09/2018-06/2023

**Course&Projects**

**ACE400 Architecture in the Anthropocene 2023**

09/2023-06/2026

**ACE475 Material & Technique 2023**

**ACE355 Colour and light in spatial contexts**

**ACE415 Media & Representations 2024**

**ACE530 Prototypes & Assemblages 2024**

**ACE510 Mediated material interfaces**

**ACE475 Parametric Pavilion**

11/2023-12/2023

Developed a lightweight shell structure in Rhino, informed by AI-generated references, and designed biophilic, buildable 3D textures using Grasshopper. Explored digital fabrication through 3D printing and robotic arm node prototyping, while producing structural detail drawings, analytical diagrams, and renderings to support the project development.

**ACE530 Central Bath Center**

03/2024-05/2024

Used Grasshopper to develop both the form and structural logic of the project, designing a large-span roof that combines a shell structure with a cross-laminated timber system. Developed a tree-like structural prototype as the main support system, created two distinct spatial worlds above and below the shell connected by a central core, and produced physical models using 3D printing and laser cutting.

**ACE510 Microworld in Crack**

11/2024-12/2024

Conducted a design research project on the adaptive reuse of an abandoned building in Gothenburg, combining site analysis, photogrammetry, and material experimentation to explore a repair strategy using yeast-based hydrogel. Developed and tested robotic 3D-printed patterns and toolpaths to respond to cracks and broken facade edges, proposing an intervention that transforms structural decay into a light- and shadow-based architectural interface.

**Work Experience**

**BIG-Bjarke Ingels Group**

Copenhagen, Denmark

**Design Assistant**

02/2025-01/2026

Qiantang Bay Headquarters Art Museum (Hangzhou): Responsible for generative design workflows using AI-assisted form generation; participated in concept development, 3D modeling, and surrounding urban landscape integration.

Czech Philharmonic Concert Hall: Collaborated on parametric logic for complex geometries; optimized roof facade modularization to reduce digital fabrication complexity while balancing acoustic and geometric requirements; coordinated facade modules with plaza landscape design.

Supreme Court of Tirana: Contributed to conceptual-stage floor plan optimization; improved spatial efficiency and circulation through modular planning strategies.

**PES-Architects**

Shanghai, China

**Architectural Intern**

06/2024-08/2024

Wuxi Cultural Center: Conducted spatial circulation analysis for large public spaces and developed high-precision Rhino models; participated in plan drawings for theater halls and foyer spaces.

2026 MASTER THESIS

Author: Hui Chen

Supervisor: Kengo Skorick

Examiner: Jonas Lundberg

Chalmers University of Technology  
Department of Architecture & Civil Engineering