SPATIAL SONANCE

exploring spatiality, temporality, and user relations through kinetic design

Jennifer Dubowitz

Spatial Sonance: Exploring Spatiality, Temporality, and User Relations Through Kinetic Design

by

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Preface

Due to its expense and complexity, kinetic architecture is often reduced to artistic installations, partial facades, or otherwise limited visual displays. I believe that kinetic design has much more potential when applied spatially, rather than superficially. This research attempts to offer not only new ways to affect a physical spatial experience, but also tap into the phenomenology and user perception of that experience. By enhancing users' experiences and perceptions of dynamic spaces, we may be able to further explore how we can define and utilise kinetic design in contemporary architecture.

Abstract

This research utilises a speculative architectural design methodology to explore how liminality, inherent to kinetic architecture, can shift perception, and how it can create a new kinetic architecture that enhances users' relationship with time and built space. The research is through an intersection of design development, design-led research, and research on theory. The research pursues the question: How can kinetic architecture enhance the spatial and temporal nature of built space? This question is addressed through a speculative design research methodology in three discrete design stages that progressively increase in scale and complexity. This work endeavors to create architecture that adopts multi-sensory feedback responding to both active input and passive occupancy. The final proposition in the sequence of design explorations, a public scale concert hall, not only responds kinetically to auditory input to create a dynamic visual effect, but it also alters the quality and reverberance of audio as it moves. The occupancy of the auditorium space also affects how the sound was absorbed, making the user an integral and ongoing element of the spatial and temporal nature of the room. This research aims to contribute to potential future applications of kinetic design that alters an architectural space programmatically, volumetrically, and multisensorially. Through this, architectural design can move away from existing in a timeless stasis, and be more holistically integrated with the reality of time and presence.

Introduction

The goal of this thesis is to design space that utilises kinetic design in a way that enhances a user's understanding of their relationship with time and space. This will be done by exploring the multi-sensory, and sometimes ephemeral effects that dynamic architectural elements can have on a space, as well as emphasising how occupancy and temporality are just as important to space as its static, built elements.

The research is broken into 3 phases, each of which explores different concepts and precedents, at three different architectural scales: abstract installation, mid-scale building, and large-scale building. At the abstract scale, the design is expressed as a series of pavilion spaces that exist in a void, forcing users to focus on their spatial position within a dynamic architectural space that reacts to their presence. At the mid-scale, these concepts become more realistic and programmatic, using kinetic architecture and atmospheric lighting to alter a lofted apartment space with areas of dedicated purpose. At the large scale, the physics and atmospheric application of sound inform the design of a public music hall, where the internal space is configured by moving elements, lighting, sound, atmosphere, and user occupancy, which are considered just as integral to the space as the static elements. At each scale, I focus on theoretical ideas addressing spatiality outside the architecture discipline, such as theories of liminality, and look at ways to give them tangible presence in architecture. At each research phase, I create designs using digital software and parametric programming to integrate kinetic architecture into my spaces in different ways and at different intensities. Each research phase is reflected upon, and goes on to inspire and inform the next phase, with the research questioning gaining in architectural and critical complexity as the scale of the design experiments increases.

At the earliest design stages, the research focused on the most overarching theoretical concepts that I was looking to explore: the relationship between temporality and spatiality, and how each serves to influence and impact the other in an architectural context. This tied into ideas of liminality and presence, and how they are applied and observed in architecture; I expand on the literary context to these theories in the sections discussing the stages in which they are utilised. I also explored the contemporary use of kinetic design through modern precedents, in order to best understand how the latest technology and most ambitious dynamic designs have been implemented in the last decade. For the second phase, my research led to the more intangible aspects of architectural design that are often intentional, but can be hard to define from person to person. Lighting is obviously an integral part of designing and influencing the nature of a space, and is just as important in making the space visible as it is in giving the space an atmosphere. Like lighting, atmosphere is usually a deliberate part of design, but its reception and interpretation can often be lost in its own subjectivity. For the final phase, my research focused on sound, particularly the atmospheric qualities and temporal dimensions it offers to an environment. To do this I studied the physics of how sound interacts with a space. This technical background research, in combination with the two previous design research phases, guided and refined my final, large-scale design experiment. The resulting final project in this research is a design concept for a concert hall at the forefront of Wellington's Central Business District adjacent to the waterfront. This building speculates on how kinetic architecture can impact the volume of a space by using sound as a spatial intensifier within the concert hall; the concert space is designed with kinetic surfaces that responds to music, creating visual and spatial effects that simultaneously impact on and react to the movement of sound within the space.

Thesis Query

How can kinetic architecture enhance the spatial and temporal nature of built space?

Aims and Objectives

This thesis aims to test how to intensify temporal and spatial conditions in architecture, enhance passive self-awareness within the space's occupants, and explore new applications of kinetic architecture through parametric design. This will be attempted with digital modelling and heavy utilisation of parametric design tools, combining intangible spatial theory with the built environment, and designing a space that affects multiple sensory inputs for a holistic spatial experience.

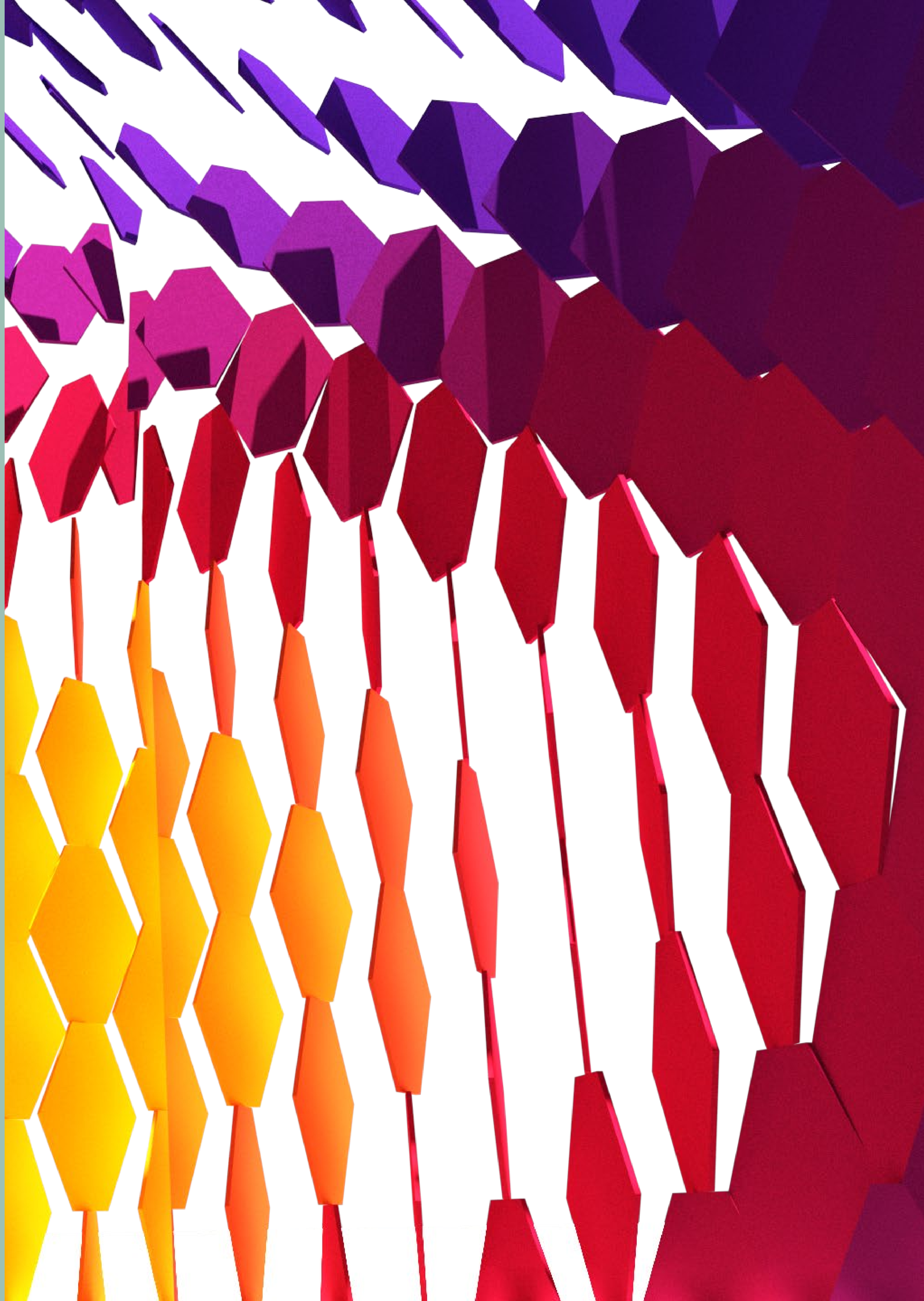
Methodology

The design research follows a research-through-design methodology, with theoretical concepts that have been well-established and articulated by key thinkers such as Juhani Pallasmaa, Gernot Böhme, and Martin Heidegger. Their ideas and writings on applications of architectural space and time influenced and inspired the designs of this thesis. Their works and others' have helped develop the groundwork for philosophical and architectural applications of more abstract experiential concepts, including spatiality, temporality, liminality, and atmosphere. Within this, the primary design method involved modelling digitally through Rhino and Grasshopper, and consequential qualitative research through that way of designing. The design iterations were developed with the purpose of visualising abstract concepts in a way that would be more tangible and observable to the user, with advancing immersive application over the course of the three phases. Each phase represents a growing scale, ranging from the speculative to the conceivable, with both architectural and mechanical detail becoming more complex at each phase. Each phase utilises a cycle of research of theory and case studies, research-through-design, analysis of the design, and continued development through these same methods at a progressively more complicated scale.

This research required learning of some basic parametric programs in Grasshopper, which were combined and adapted to create the different kinetic effects across the 3 phases. It also required ongoing development of design and research of contemporary case studies to find new ways for kinetic architecture to affect the user in a multisensory way, rather than just visually. This process resulted in the oversimplification of some applied concepts, while finding new ways to expand and extrapolate on others.

CHAPTER 1

EXPERIMENTAL SCALE



Experimental Concept + Program

This first phase of the research involved exploring key concepts in the thesis and trying to find ways to visualise them in a literal and tangible way. At this stage, I researched the broader, overarching themes that would ultimately apply to each subsequent stage; spatiality, temporality, liminality, and kinetic design. This stage was also designed to build up my confidence and understanding of parametric programming in Rhino Grasshopper, and how to apply simple Boolean mechanics and logic gates to achieve a desired effect.

For the first phase of research-through-design, and subsequently design-through-research, the concept for the space is entirely speculative. The goal is to create an immersive stage where the user can observe the theories of liminality, spatiality, and temporality in a tangible way. Ideally, the effect will be so obvious that if a random participant were to experience it, the only thing they would be able to comment on is a sense of self-awareness in correlation to the space, both within active kinetic areas and neutral/unaffected areas. If anything, the neutral static areas will make the user just as, if not more so, aware of the effect their presence has on the built space and passage of time around them.

This was executed by establishing an architectural space that reflected a program dedicated to observation and self-awareness, similar to an artistic installation, museum exhibit space, or a pavilion. In these cases, the user or users had the freedom to move around, but there still needed to be ways to isolate and differentiate the spaces in order to observe liminal threshold situations and void states.

The direct reactions between the user and space are designed to illustrate the relationship between temporality and spatiality in real-time. Without the user wandering the space, in turn causing the space to respond to that presence and movement, the space existed in a timeless vacuum, illustrating Heidegger's concept of 'vorhandenheit', a space that focuses on static snapshots of time. When the space had a presence to respond to, the change in the space was ongoing and spontaneous, illustrating Heidegger's concept of 'zuhandenheit', and how the consumption of the space over time is just as integral to the architectural space as the physical design. Between the two, there existed moments of stasis, where the user occupied a literal threshold between spaces, and can view what the space looks like in its state of vorhandenheit. By existing unobserved between these void states, the user occupies a liminal space, a literal threshold between spaces, as well as a literal threshold between the temporal influence of the user. By reducing the design to focus on these concepts, it allowed the user to focus on the pure space they inhabit and the pure temporality they provide to it.

Figure 1.01 A person occupying the threshold between spaces

Temporality + Spatiality

"The phenomenon of time consists of more than the explicit quantifiable measures of clock time , but includes as well the implicit temporalizing activity of human understanding which seeks to order entities within our world" (Stefanovic, 1994, p. 211).

Temporality in architecture is established and, in a sense, observed by the static permanence of the past in combination with the shifting, unestablished nature of ongoing presence. By regarding temporality without considering presence, one also rids spatiality of presence. As most architecture is designed with an intended program, a space without presence eliminates all intention and reduces design to shapes in a void. "Visual 'objects' subsist in both space and time, they have location relative to 'objects' and have duration relative to other 'objects' too." (Rodaway, 1994, p. 125) Time cannot be properly observed and defined without considering real-time occupancy, and the same applies for the space itself. Temporality in this context is measured by the self-awareness of the users, or those observing the users, and cannot exist in a theoretical, user-free vacuum.

In this sense, buildings serve as their own measure of time, which can be observed and described through phenomenology, taking into account individual experiences and biases when users encounter a built space, especially if they encounter the space regularly/ritually. In Stefanovic's words from her article on temporality and architecture, "…As explicit reflection and measurement of clearly delineated objects is not its goal, phenomenological intuition and description of the prethematic, taken-for-granted structure of experience will require a non-traditional, and non-empirical methodology." (Stefanovic, 1994, pp. 213-214). Phenomenology in this context refers to the relationship and response an individual has to an environment based on their own previous experiences and biases in conjunction with their present sensory attention. Although architects and designers can attempt to create a universal and consistent experience between their spaces and every occupant that encounters it, phenomenology is by nature individualistic and unique. It is that uniqueness in user interaction which further spurs the relationship between the static space and the shifting time.

Through this, architecture additionally serves to reflect the values and resources of the period in which it was built, offering an accurate depiction of its intended user presence in addition to its built space (Stefanovic, 1994, p. 214). For example, a Gothic cathedral emphasises devotion to God and the sublime through symbolism, ornamentation, and gratuitous extravagance at the cost of immense physical labour, craftsmanship, resources, money, and time. In contrast, a skyscraper in a city marks the value of evolving metropolitan lifestyles and values, including a shifted emphasis on spatial efficiency (vertical expansion), compartmentalisation, corporate space, and displays of wealth, power, and creativity in the private sector.

Heidegger proposed and elaborated on two concepts to help illustrate the relationship that users have with space in his 1927 book *Sein Und Zeit* (Being and Time), "zuhandenheit" (ready-at-hand) and "vorhandenheit" (present-at-hand). Production of space (present-at-hand) and consumption of space (ready-at-hand) are mutually exclusive, and do not intersect in an architectural setting. Stefanovic reflects on this application in architectural design and consumption, noting that an architect will be considering their design and construction in the present, which in turn makes the building all about "nows" and theoretical snapshots of how a space should be occupied and utilised. However, in the real, nontheoretical world, user interaction is ongoing, spontaneous, and relative to each individual user (Stefanovic, 1994, p. 218). These ideas are similarly reflected in Henri Lefebvre's 1974 book *La Production de L'espace* (The Production of Space), wherein he observes and describes spaces relative to their temporal/inhabited nature as perceived (le perçu), conceived (le conçu), and lived. (le vécu). Both Lefebvre and Heidegger explore these relationships relative to either the occupant or the space, and how the passage of time, or lack thereof, influences the nature of that space. Time within the built space can be considered both as static points of interest (production), although these cannot accurately depict and describe a real user's spatial experience (perceived), and ongoing/infinite flows that can be observed in retrospect, but are inconceivable to project for the future due to the spontaneity and variety of the human experience (consumption, lived). In my research, these ideas are made tangible when applied as physical positions within the space that are both observed and experienced by the user.

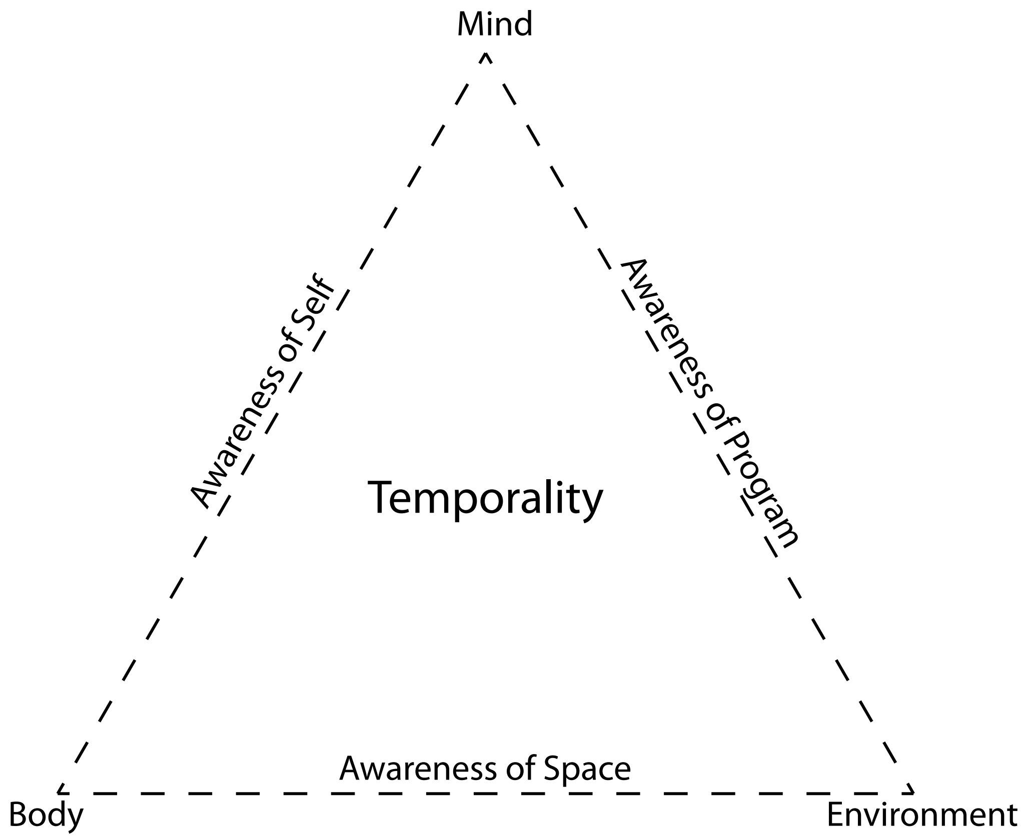


Figure 1.02 Spatiality and Temporality are defined by their respective relationships to objects and the users. The perceived concept of the passage of time introduces temporality to space, allowing the space to fullfil its intended programmatic purpose.

Liminality

Liminality as a concept was first developed and defined by Arnold van Gennep in his 1909 book *Rites de Passage* (Rites of Passage) and was later compounded upon by Victor Turner in his 1967 book *The Forest of Symbols*. Both explored liminality in an anthropological context, noting rites of passage that people took in certain cultures and religions that denoted a transition in life stage or status. Derived from the Latin word līmen, meaning threshold, doorway, or limit, liminality is also commonly referred to as a threshold state, literally denoting a transient position between spaces. In this anthropological context of liminality, an individual exists in a position that is more advanced than they were when they first started the rite, but have not yet completed, putting them in a ephemeral middle stage that often goes undefined or unobserved during the rite. In this state, one has moved past the perceptions and identities associated with oneself prior to the rite,

Figure 1.03 An empty shopping centre or mall is commonly thought to be a liminal space, as the building is designed and intended to be occupied by merchants and shoppers. By existing in the empty mall outside of this buyer/shopper paradigm that otherwise defines the space, an occupant would effectively exist in a in a functionless space of meaningless shapes. The occupant is faced with the disjunction of their presence in a space not currently meant for them to be present in.

but has not yet achieved or defined what they will be when they are finished. Liminality has since been explored and applied in other disciplines, and offers a range of possibilities and questions when applied to spatial theory in architecture.

Liminal spaces offer a similar experience of vagueness, displacement, and in-betweenness, but in addition to the literal and physical nature of threshold spaces-between-spaces, liminality in architecture can also apply to the juxtaposition of user and space, time, perception, intention, or occupation. As liminality in architecture is generally based around the user and their relationship to the space and other underlying context, it can be best observed by the self-awareness, unease, and ambiguity that marks the mid-point of a rite of passage, especially while in a transitory space with intended turnover and movement. We often find that more modern architecture is destination-based, and opts to neglect or rush through the movement and circulation between programs in order to avoid diverting focus from the bespoke destination.

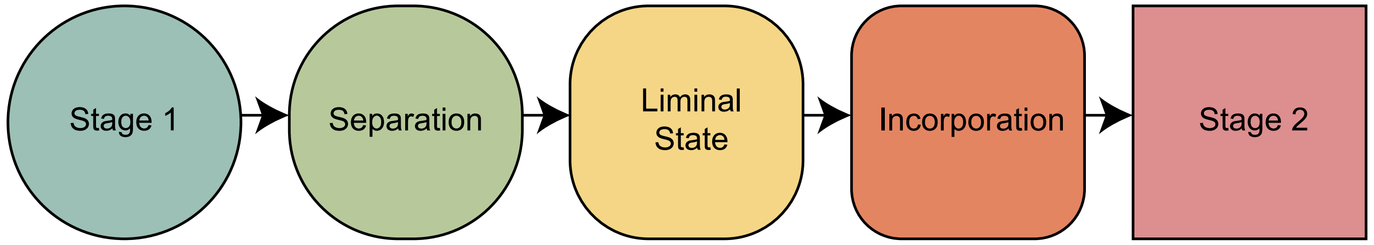


Figure 1.04 The substates of liminality can be extrapolated to be more or less specific, based on the spatial and/or temporal journey of the user. Ultimately, liminality marks the middle point of this journey. Based on Söderlund and Borg (2018)

As Stefanovic states, “Particularly in a crowd, one feels compelled to move quickly, to accomplish what is to be properly accomplished within this section of the journey, and to speedily move on to the next fresh image.” (Stefanovic, 1994, p. 215). This relationship between user and space, especially the evolution of that relationship, defines the temporality that a space both encompasses and provides to users.

As liminal spaces are tied to their purpose in relation to the existence and movement of their users, there is an overarching theme of temporality in how we perceive and define these spaces. As such, there is an inherent psychology and sociology associated with liminal spaces that encourages both perpetual occupation and movement, while the environment itself remains static. Because of this, there is a noted sense of unease when lingering too long in these spaces, especially when the aforementioned space is otherwise unoccupied. These sorts of spaces include airport gates, hallways and stairwells, empty schools, hotel rooms, supermarkets, and parking garages after hours. Because these spaces and their users exist in a space and time outside of the intended purpose, the space itself feels disorienting, and the user feels uncomfortably self-aware of their position.

The liminality of the space can most succinctly be broken down into a relationship between time, space, and the user. Temporality is just as inherent to a space as the physical spatial design, but it can be continually altered by its occupants in a way that space cannot be. When the user becomes self-aware of how their presence, and by extension their influence on the intended temporality of the space, they find themselves at a liminal crux; moving forward or retreating will allow the space to be as occupied or unoccupied as intended, whereas remaining in position will knowingly further disrupt the intended occupancy of the space and allow the user to view their surroundings in a way that was programmatically unintended by design.

Kinetic Design

“Is there an architecture that is materially liquid, that configures and is attentive not to stability but to change and is thus at one with the fluid and shifting nature of all reality? Is it possible to think an architecture that is more of time than of space? An architecture whose objective would be not the ordering of dimensional extension but movement and duration?” (Sola-Morales, 1977, p. 36)

Kinetic design and its implementation can be broken down into three general classifications; embedded kinetic structures, deployable kinetic structures, and dynamic kinetic structures. Embedded kinetic structures are systems that have a larger influence on volume, shape, and size of the architecture as a whole. These would include fully collapsible, twistable, or otherwise manipulable systems that could respond to environmental or user input, and would ultimately affect the architecture as a whole rather than just an isolated area or component of it. Deployable kinetic structures are systems that are independent of the architecture they are incorporated into, making them portable and ideal for temporary installations. Dynamic kinetic structures are what people are most accustomed to, with architectural components that function independently from the rest of the building’s systems and structure. These are commonly seen in partitions and louvres, which might have some impact on

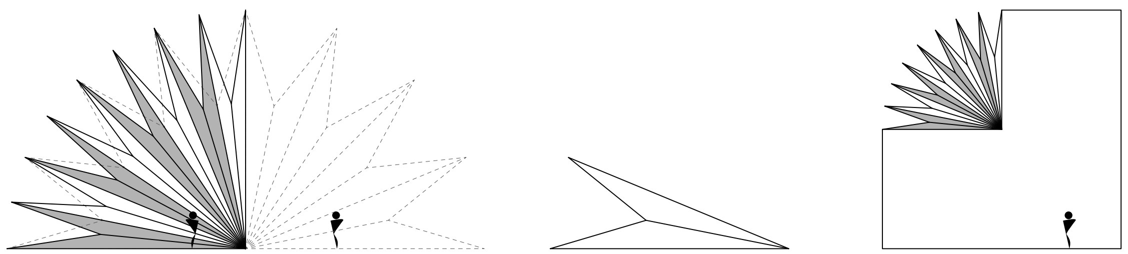


Figure 1.05 Kinetic System Typologies relative to architectural structures. These range from the kinetic system being the actual overal structural system of the architecture to being a detachable and unincorporated elemend, as well as the semi-incorporated dynamic systems in between. (Based on Fox and Yeh, 2000)

the lighting and atmosphere of a space, but would otherwise not impact the overall architecture (Fox and Yeh, 2000, pp. 94-95).

Two examples of the commonly employed dynamic kinetic system are the Al Bahar Towers in Abu Dhabi and the Harbour Kiosk in Hong Kong. Both utilise louvre systems that are attached to the fixed structure of the architecture, and have no effect on the building’s structure when deployed. The façade of the Al Bahar Towers uses an array of umbrella-like folding panels which collapse and contract in response to sunlight. This automatic change in the flux of natural light and heat allows for interior conditions to be better controlled and is overall more energy efficient for the entire building. The paneling does not encompass the entire building, but rather only on the opposing sides where the occupants will be most affected by sunlight, with the rest being exposed glazing. The Harbour Kiosk facade is comprised of wooden slats over glazing. At the front of the kiosk, those slats contract and pull upwards, forming an awning over the reception. At night, the slats collapse again, indicating that the kiosk is closed. In addition to controlling the amount of light that is let in through the day, the position of the facade indicates to the user the availability of the kiosk itself.

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Figure 1.06 REDACTED EXAMPLE - Al Bahar Towers, AHR, 2012. This system features an origami/umbrella -like facade system that controls light and heat.

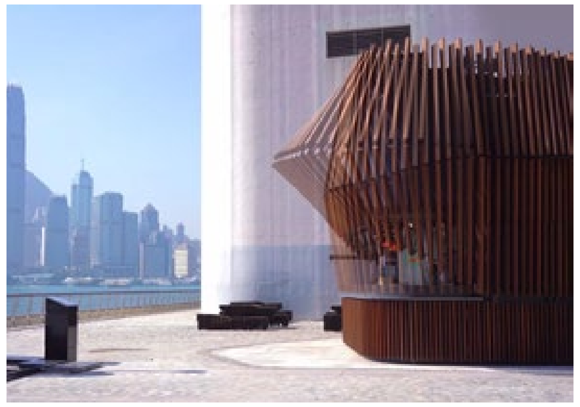


Figure 1.07 The Harbour Kiosk, LAAB Architects, 2019. This system features a contractable awning that indicates operating hours.

Kinetic architecture is being utilised in this research to create a tangible relationship between the user and their effect on a space. Kinetic architecture is generally considered when elements of a building can move through folding,collapsing, rotating, or shifting facades, or, in more advanced cases, affect the overall volume and program of the built space. Because kinetic architecture needs to be able to operate without sacrificing structural integrity, it can be difficult to effectively implement it on a programmatic scale. As such, most kinetic architecture that we see in the field is generally restricted to facade systems that react to consistent timers or environmental stimuli. However, although implemented dynamic facades would indisputably be considered a key feature of an architectural design, some kinetic elements toe the line between artistic installation/exhibition and actual architectural space.

For this phase, kinetic elements are restricted to predefined room volumes, and hover somewhere between an alteration in facade and an alteration in spatial conditions. In this sense, their change of state only alters the space by blurring the boundaries between the programmatic interior of the designed space and the boundless, undefined void that is the site for this design. However, the kinetic changes of state do not affect the occupiable volume. Ideally, future iterations will feature less complicated geometries, but more complicated responses, reactions, and animations centred around the occupant that would change the occupied volume of the space, and possibly go so far as changing the associated program.

For the sake of this research, I am exploring kinetic architecture in a theoretical spatial sense, and am worrying less about the physics and engineering associated with the moving parts, in order to instead focus on how moving, changing, interactive architecture causes noticeable change in space, in response to the user’s ready-at-hand experience with the spatial environment.

The first iteration of this design concept featured a generic, nondescript exhibition space. The space was separated by walls or partitions to properly isolate the conditions and reactions of each louvre to the environmental factors that influenced them, which would also ultimately allow for some sort of threshold between the conditions that could illustrate the user in a liminal position. The separation would also serve to create a stark and observable dichotomy in louvre parameters while also simplifying the theory behind the space as much as possible. The static space was modelled in Rhino, and both louvre systems were designed using Grasshopper scripting on a surface in Rhino, which would represent the area of the facade. A single attractor point that would move on an XY axis but remain on the Z axis at approximately eye-level served as the theoretical user, which the Grasshopper-based geometry would respond to. As long as the Grasshopper script was displayed in a preview mode and not baked, it would move and change as the parameters of its programming changed (the movement of the attractor point).

The aperture to the left featured a louvre system of rotating hexagonal panels that would spin in a radial pattern in response to the presence and position of any occupants. In Grasshopper, an attractor point in space served as the occupant that the facade would respond to, and as the point was moved around, the facade on the left would ripple to reflect the position of the point. From further away, the impact was broader, with more shallow ripples and a wider initial imprint. When closer, the ripples became a bit deeper, and the imprint would scale almost to the size of the reflected occupant. If the response to the attractor point were more refined and sensitive, the facade could theoretically act as a mirror to the user, moving in scale and proportion to the users that pass in front of it. Without input, which is to say without the existence of the attractor point at all, the facade would be static and flat, thus displaying the concept of human presence having effects on observable spatiality and temporality. Without the human presence, the facade, and by extension this part of the space, exists in a temporal vacuum.

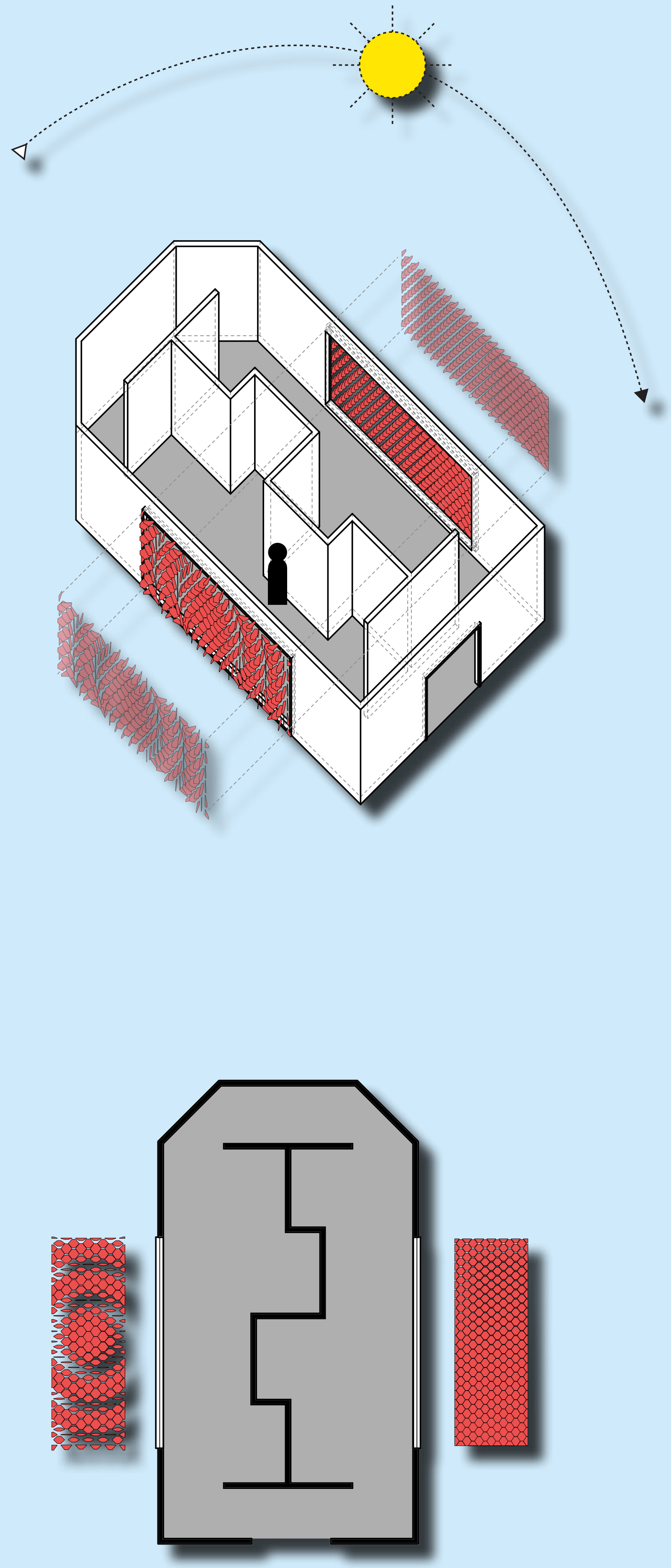


Figure 1.08 This first iteration featured a bullseye attractor point louvre system on the left side that responded to user position, and a gradiating louvre system that responded to the position of the sun to control the light and shading inside the space.

The right side of the space featured a facade system that would respond to the path of the sun throughout the day, and would ripple down the length of the louvres as the sun passed by. This louvre would animate regardless of human presence, and instead would only respond to environmental changes in natural light. In order to model and simulate this, the sun served as the attractor point in the Grasshopper script which moved across a fixed path. As the built-in sun light source in Rhino is not selectable beyond the designated panel controls, a directional light that was manually adjusted to the correct angle and intensity was substituted for the louvres to have a geometry to respond to. A more complex Grasshopper script would have been able to detect the changes in light source by measuring lumens rather than tracking an attractor point, but due to the lack of complexity at this scale in the design phase, the facade only responded to the movement of the point, and did not take into account more realistic factors such as cloud cover, brightness, or changes in the angle of the sun throughout the year.

Due to the oversimplification of the concept and the space, this model only served as a very preliminary base for subsequent theoretical spaces. The left louvre would respond to the attractor point based on its position and movement anywhere in the built space, even though visually there was a partition to divide the space between the louvres. That is to say, regardless of where the user was in the space, even if they existed outside of the confines of the space entirely, that louvre system would still respond to their position in space regardless of visual proximity to the system. This removed the user experiential element from the simulation, and rendered the louvre as omniscient of the entire model, rather than responding to local visuals. Most notably, this space reduced the kinetic design to something akin to an artistic installation that actually had a limited impact on the spatial conditions beyond altering the influx of natural light. The kinetic louvres did not make up enough of the overall design for me to consider it a spatial architectural element.

The second iteration at this scale moved from a static and relatively generic exhibition space to a series of domed pavilions in a closed loop. The spaces, compared to the window-mounted louvre systems of the first iteration, allowed for complete immersion of the kinetic effect in response to user occupancy. Additionally, the setup of the 6 different domed spaces and the subsequent thresholds in between them allowed for a better visual of liminality as a user would move from space to threshold to space.

In terms of modelling in Rhino and scripting in Grasshopper, the closed and double-curved surfaces presented a series of new complications that had to be overcome. In order for the script to read at all, the space had to be converted from a closed mesh or polysurface, in this case the union of a semi sphere and a cylinder, into an open surface to plug into the Grasshopper script. In this instance, the surface was created by putting a singular pavilion space inside a bounding box and generating precise contour lines that could then be lofted into one continuous but open surface that the script could understand. Because the loft would only read closed curves, it was not possible to completely cover over the top of the dome, creating an oculus window in every domed space that would always be open.

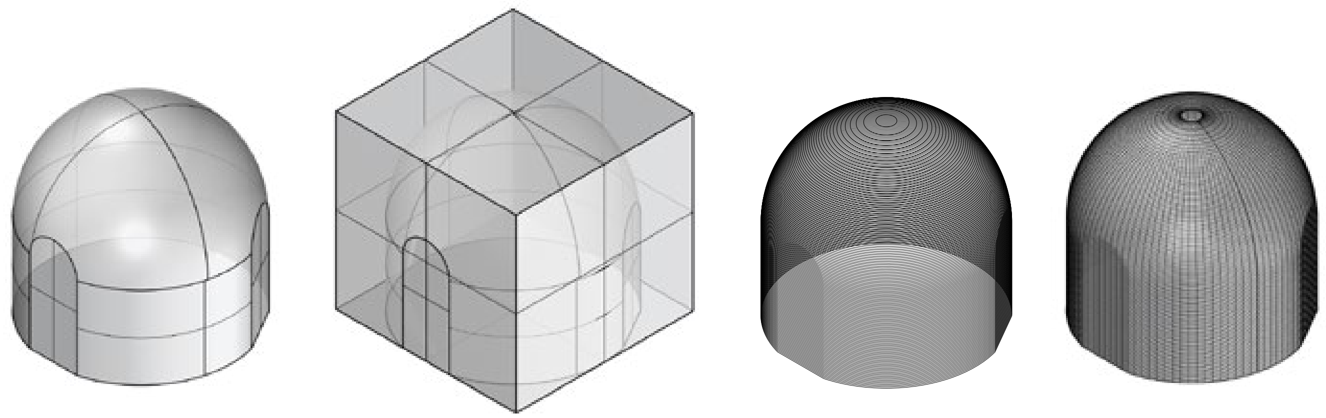


Figure 1.09 In order to generate a single surface that the Grasshopper script could read, a bounding box was constructed around the desired space. Using the perpendicular axes of the box as a reference, evenly spaced contour lines were generated . These lines could be lofted to create one continuous surface that Grasshopper could apply even paneling geometry to.

Having the otherwise closed polysurface of the space allowed the script to run Boolean analytics, such as whether the geometry of the space was interacting with the adjacent space and creating a threshold between them where they intersected, or knowing whether the attractor point/occupant was present in that space at all. Having the open surface allowed for the script to read the geometry accurately, although the script did read panels on the curved surface of the cylindrical base separately from the double-curved surface of the domed ceiling. This was overcome through flattening each panel relative to its respective plane of rotation, projecting, and rebuilding each of the panels onto the approximate surface so that they would all read as part of one system, rather than two distinct surface components.

Once the appropriate geometries were accurately modelled in Rhino, they were arranged in a closed loop and coloured with a labelling method that would carry into Grasshopper and keep the script organised. The red-hued geometries acted as the closed pavilion spaces that would react to user occupancy, while the blue-hued geometries represented the overlap in floor space extruded upwards. Here, user occupancy would be nulled and undetected by any of the red pavilions, including the adjacent ones. In this sense, the threshold spaces act as literal liminal zones, where the user exists between spaces and observe the null state of the pavilions without user presence in them. Without an effect on the active spatiality of the pavilions, the temporality of the space is also effectively nulled, allowing the user to witness the geometries in a timeless, userless vacuum.

The components in the Grasshopper script mirrored the colour scheme of the built geometries in Rhino, allowing for easy organization and comprehension of the overall script as more complex inputs were added. Although the overall visual user interface appeared tangled, it effectively operated as an organized switchboard to connect the geometry components to the desired Grasshopper transformation functions.

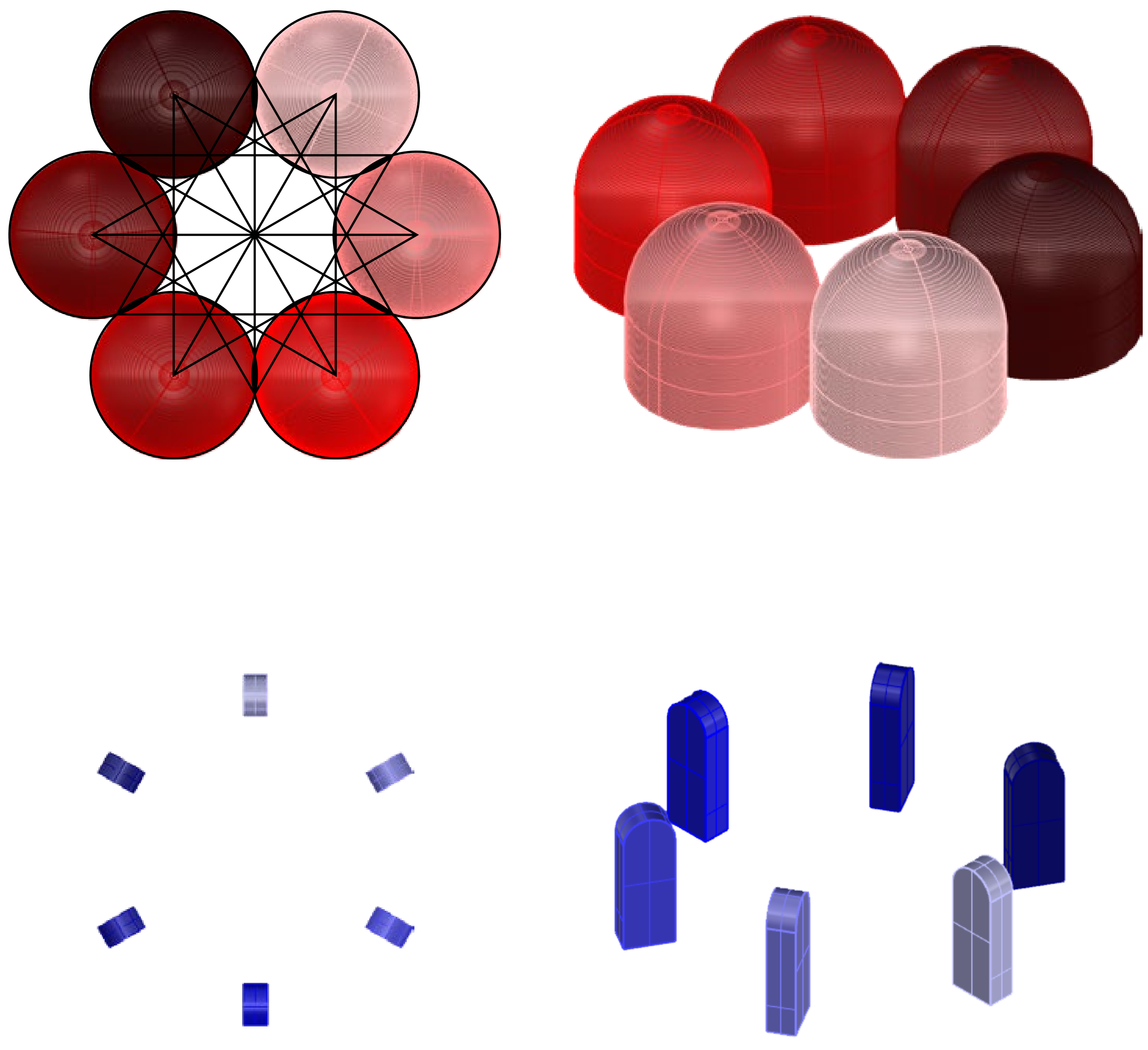
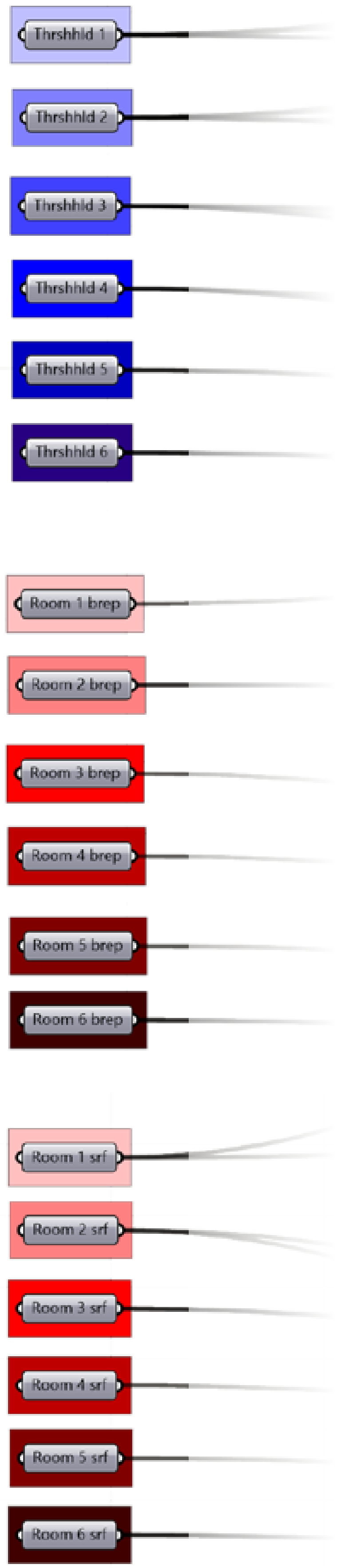


Figure 1.10 The red domed spaces represented the closed pavilion system that a user could wander through continuously, evenly measured out as regular angles to prevent geometrical analytical issues in the Grasshopper script. The blue arches represented the liminal spaces that existed where the circular footprints of the pavilion spaces over-lapped. The color of these spaces directly coresponded to their respective geometry input components in the final Grasshopper script.



The blue thresholds are all closed polysurfaces, defined as BREPs (Boundary REPresentation object) in Grasshopper. As they are closed geometries, it allows for easy analysis of whether the attractor point in space is within the confines of a threshold space or not. The threshold space was also used to carve out passageways in the geometry of the facade built on the surfaces of the pavilions, so that there would be no overhanging or clipping geometry in the defined threshold spaces as the kinetic elements changed.

The red components are separated into BREPs and surfaces. They occupy the same positions in space, but the base geometries are hidden in the final view to avoid visual clipping and overlap with the Grasshopper-generated geometries. Similar to the blue threshold geometries, these geometries act as surface guides for the facade panels to project onto, as well as solid BREPs to determine the presence and position of the attractor point(s).

Due to the circular and overlapping nature of the geometries, all of these components are plugged into the script multiple times to act as analytical and geometric guides in conjunction with each other. This way, if any of the original Rhino geometries are altered or manipulated, it will affect the Grasshopper script in real-time and keep the outcome accurate to the built space.

Figure 1.11 The Grasshopper geometry-linked inputs coresponded to the colors of the respective spaces to keep the script organized and traceable. The domed pavilion spaces were represented by two different types of geometry, a singular open surface for the pan-el system to be projected onto, and a solid closed BREP that could be used for geometry analysis.

These components were then plugged into up to two of three systems that would alter the surface state of the pavilion. Depending on the user's presence in the space, their movement and position relative to the edge of the surface would determine panel rotation, colour, and/or transparency. The rooms are arranged such that these effects transition into each other as the user moves in the loop.

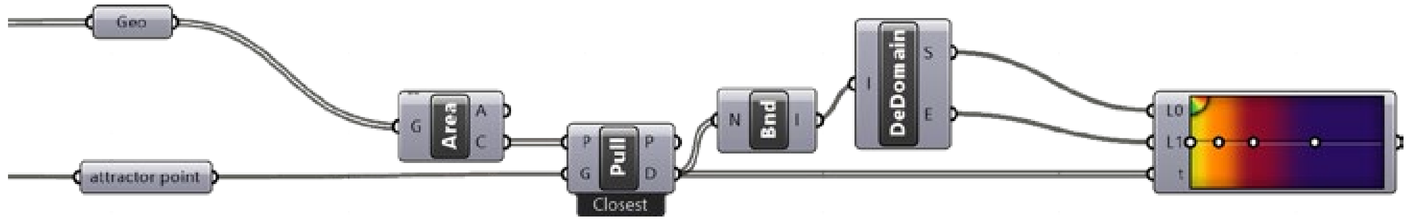


Figure 1.12 Grasshopper Panel Color Changing Function. The closer the user gets to the wall, the warmer the colors of the wall turn, with indigo being the furthest distance and yellow being the closest. Changing or adding control points to the color component would alter the gradient that responds to proximity, making it more subtle, sudden, or seemingly random.

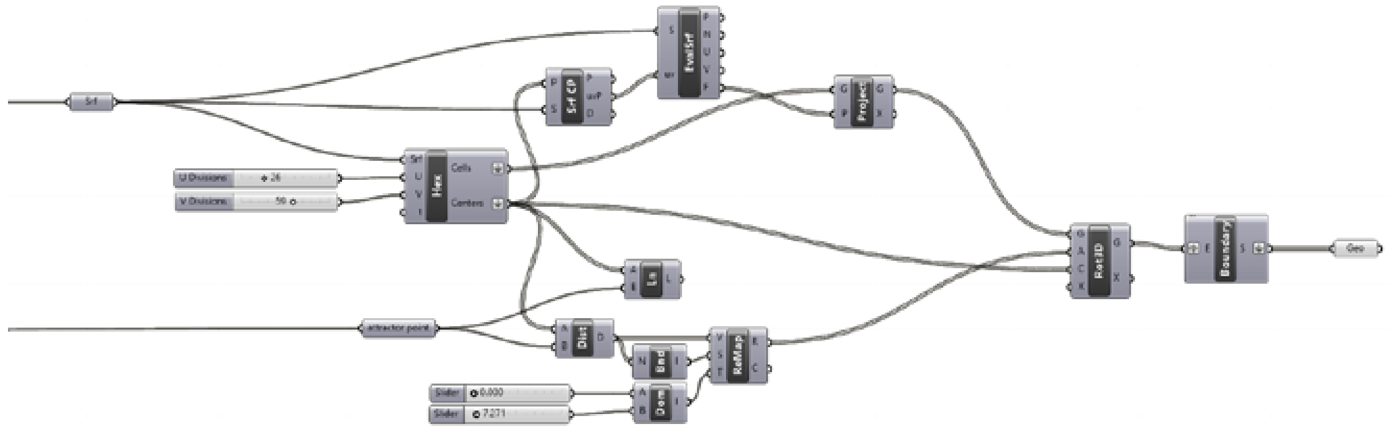


Figure 1.13 The Grasshopper Panel Rotating Function. The closer the user gets to the wall, the more focused the ripple of rotating panels is. Changing the domain would alter the extent to how much the panel could rotate (in radians or degrees), allowing for a more limited or more dramatic twisting effect.

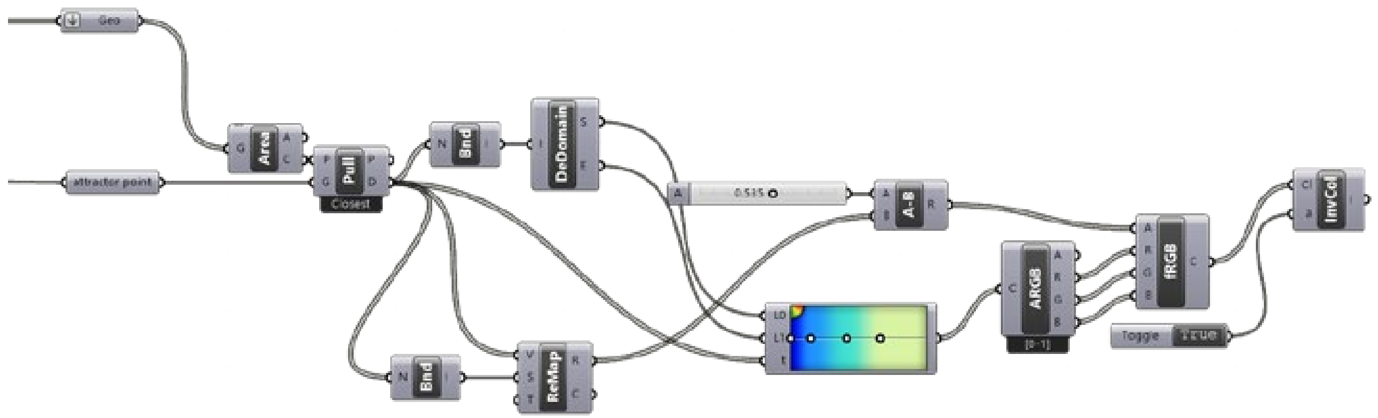


Figure 1.14 Grasshopper Panel Transparency Function. The transparency component worked in a similar way to the color changing, but the colors were instead plugged into the alpha channels that determined trasparency rather than material color.

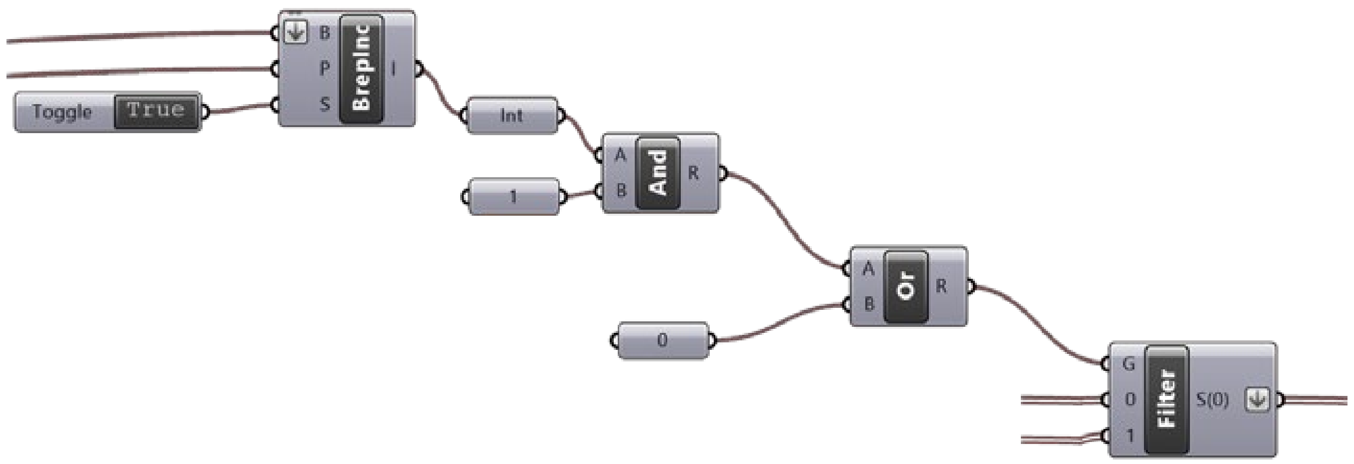


Figure 1.15 Grasshopper AND/OR Cull Function. In this case (when considering true, false, and an intermediate/overlapping state), a lesser than/larger than component would have worked just as well. Both systems use Boolean integer logic to divide and cull patterns from lists that the geometric analysis components produce.

In order to determine whether the attractor point was within the geometry, a series of AND/OR gates were used. The point and BREP were both plugged into the BrepInc (BREP includes) to determine whether true (the point is inside) or false (the point is not inside). If the output is true, the filter will select the script that responds to user presence. If the output is false, the script will default to a null state, where the attractor point is at the bottom of the centre of the respective space. This is what the user would see if the attractor point were inside a blue threshold space. The parameters could also be toggled, so that the script tries to detect presence within the threshold space for truth, rather than inside the pavilion space.

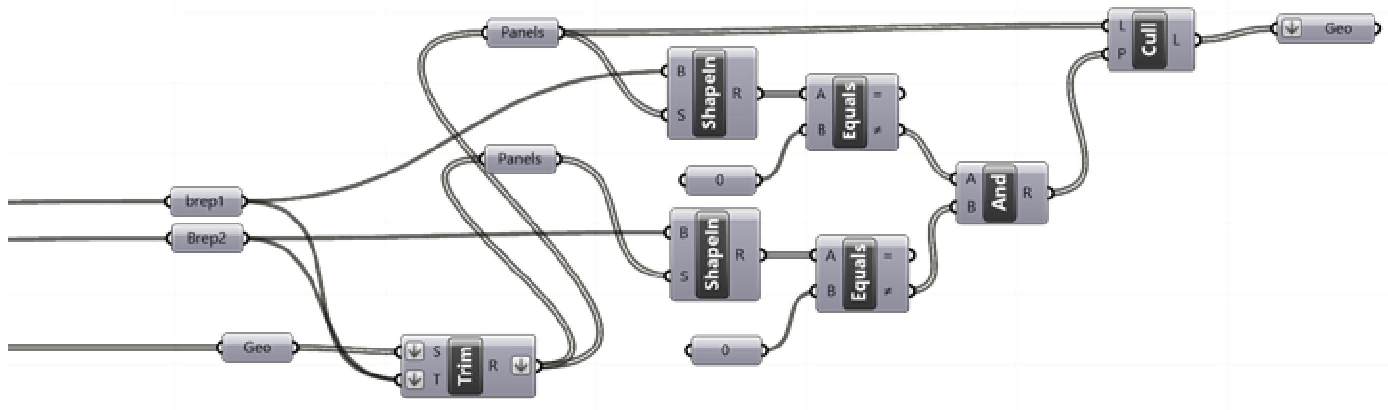


Figure 1.16 Grasshopper Geometry Trim and Cull Function. Once the desired list items are filtered out using Boolean logic, these patterns and the original list can be plugged into a cull components, which will delete items that match that pattern and only list the remaining items. In this case, the cull component was removing items that intersected the liminal threshold area to produce a clean, unintruded space.

A similar conditional system was used to detect whether the Grasshopped-generated facade geometry clipped into the threshold space and therefore needed to be cropped and culled. However, this script used ShapeIn (Shape Intersect) rather than bREP Includes (point). If the Grasshopper-generated facade panel geometry was entirely within a threshold space, it would be culled completely. If the facade panel geometry intersected with the threshold space, but was not entirely confined, then it would only be trimmed. If both intersecting and confined geometries had only been culled, it would create gaps around the passageways that would not accurately depict the border between pavilion and threshold space. If both intersecting and confined geometries were only trimmed, the script would not be able to read the completely confined geometries, and those would be left behind unculled, which would create floating geometry in the thresholds.

The outcome of this phase was initially intended to be displayed in a real-time VR simulation, where the user would replace the attractor point and be able to experience the space reacting around them. Originally, this was proposed to work by feeding the Grasshopper script and Rhino geometry into a C# coded pipelineto Unity, where the attractor points would act as a UI, and the entire simulation would function like an immersive video game. However, due to the geometric complexity and scale of the model, particularly the several thousand hexagonal panels generated by Grasshopper every time the script was run, the pipeline as I used it ended up working as an inefficient rendering program, and I was unable to get Unity to read the embedded point (or affiliated geometry) as game objects that could be altered in real-time.

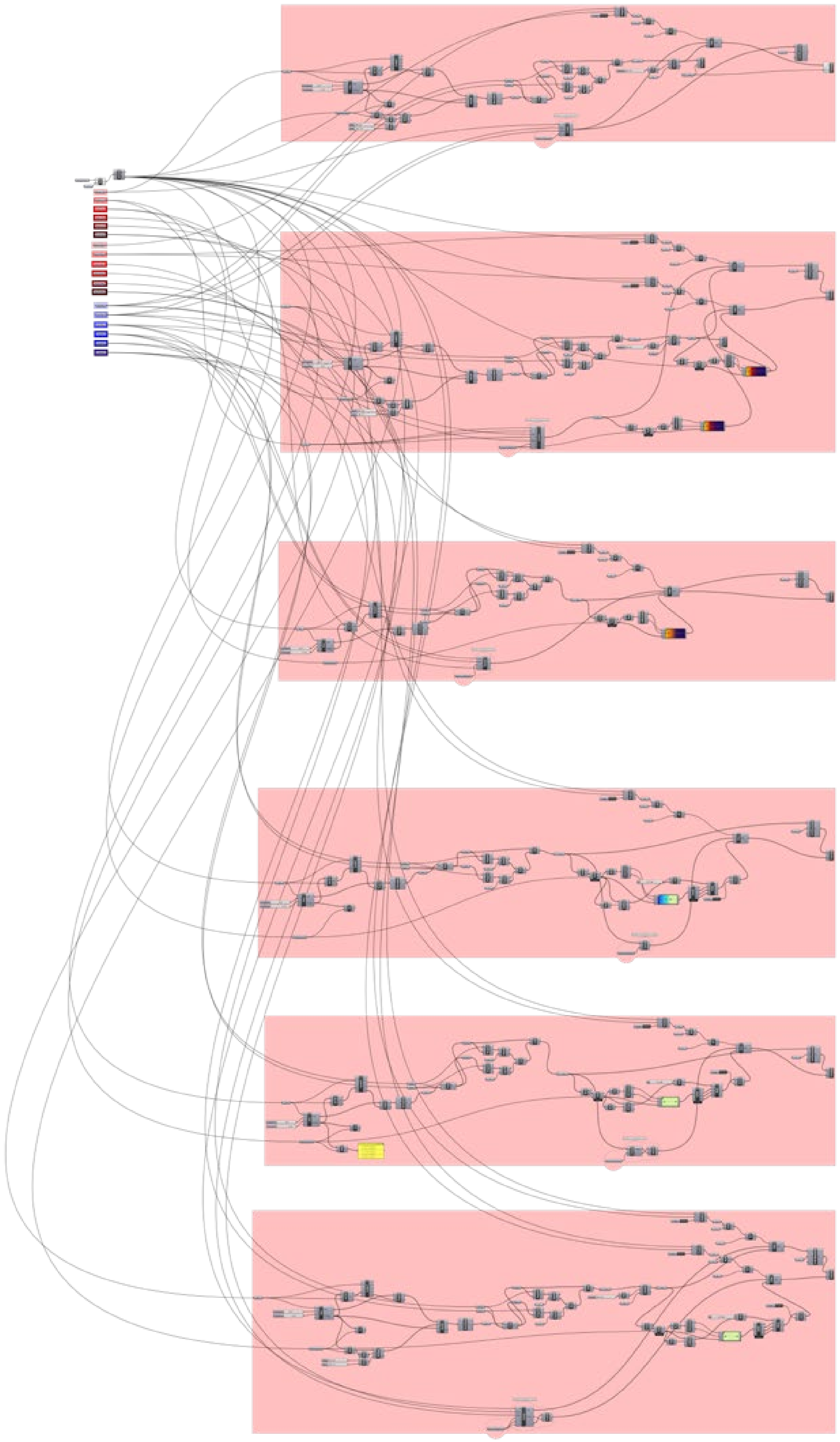


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Figure 1.17 The final Grasshopper script was broken into 6 separate groups, each representing a distinct domed kinetic space. The script functioned similarly to a switchboard, where the bespoke geometry components could be plugged in to create each colored, rotating, and/or transparent-paneled space as well as the liminal voids between them.

To compensate, I printed A1 sheets of the pavilions as though they were being walked through, and lined them up to create a promenade that would depict someone walking though the spaces in elevation, and how the panels would respond as users walked close to the edge. The A1 prints also featured information on the Rhino modelling, Grasshopper coding, and the theory behind it, so that it worked a bit like a museum exhibition. Although the goals of a VR exhibition fell short, they were not discarded, and were instead potentially tabled for a final, more immersive design.

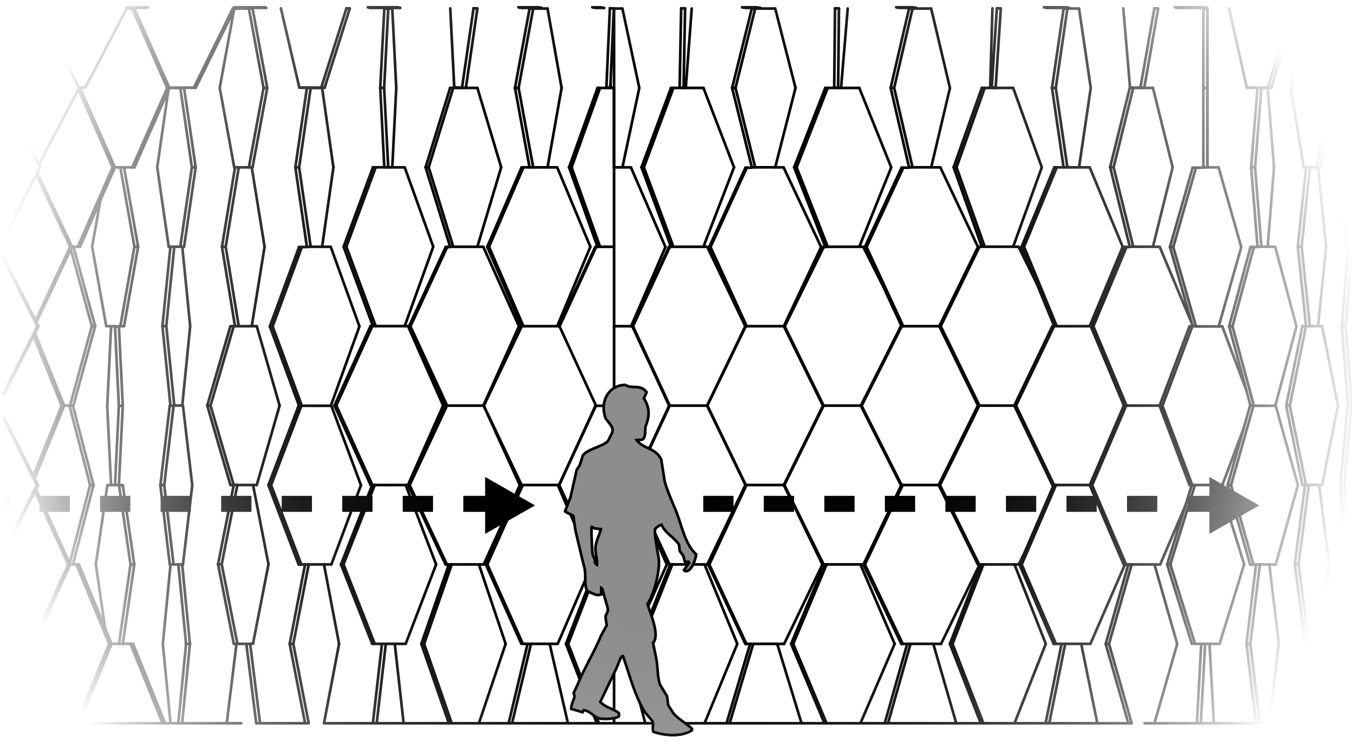


Figure 1.18 This simple section illustrates the panels rotating function relative to the proximity of the user. The closer the user is to the wall, the more the panel will stay flush with the base surface to face the user almost like a mirror. The surrounding panels continue to rotate out in a ripple effect, the intensity of which can be changed with the domain inputs.

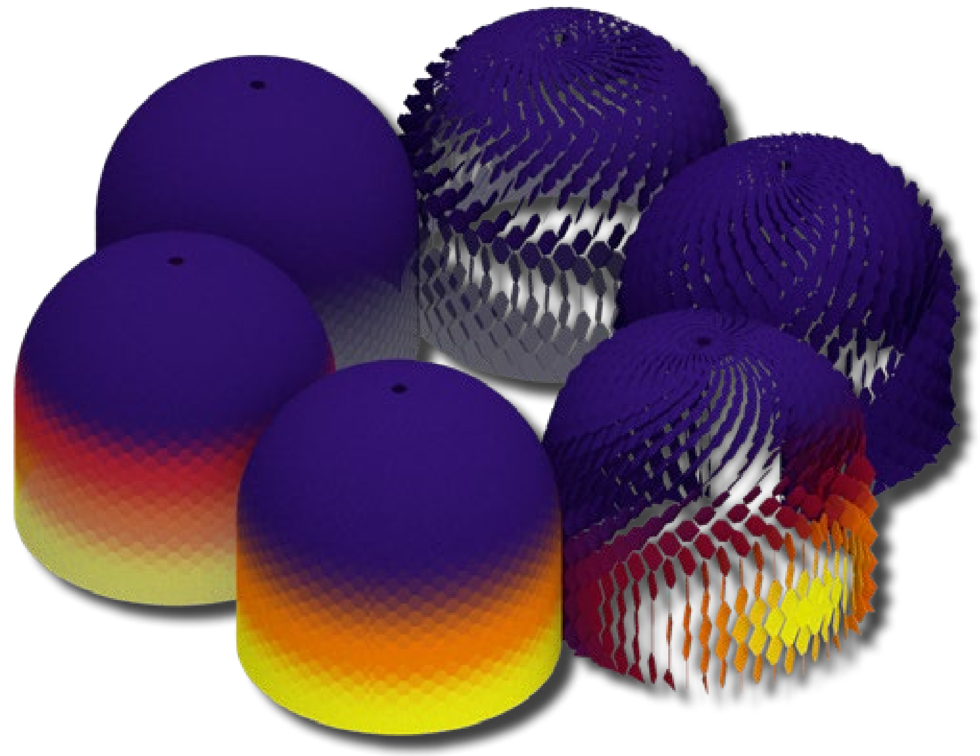


Figure 1.19 These rendered views of the pavilion system offer an omniscient view of the void states relative to an occupied space (TOP: far right, BOTTOM: lower right). When the pavilion space is in this void or null state, as it would be when the user is in a threshold area, the attractor point defaults to the center of the floor of each respective space.

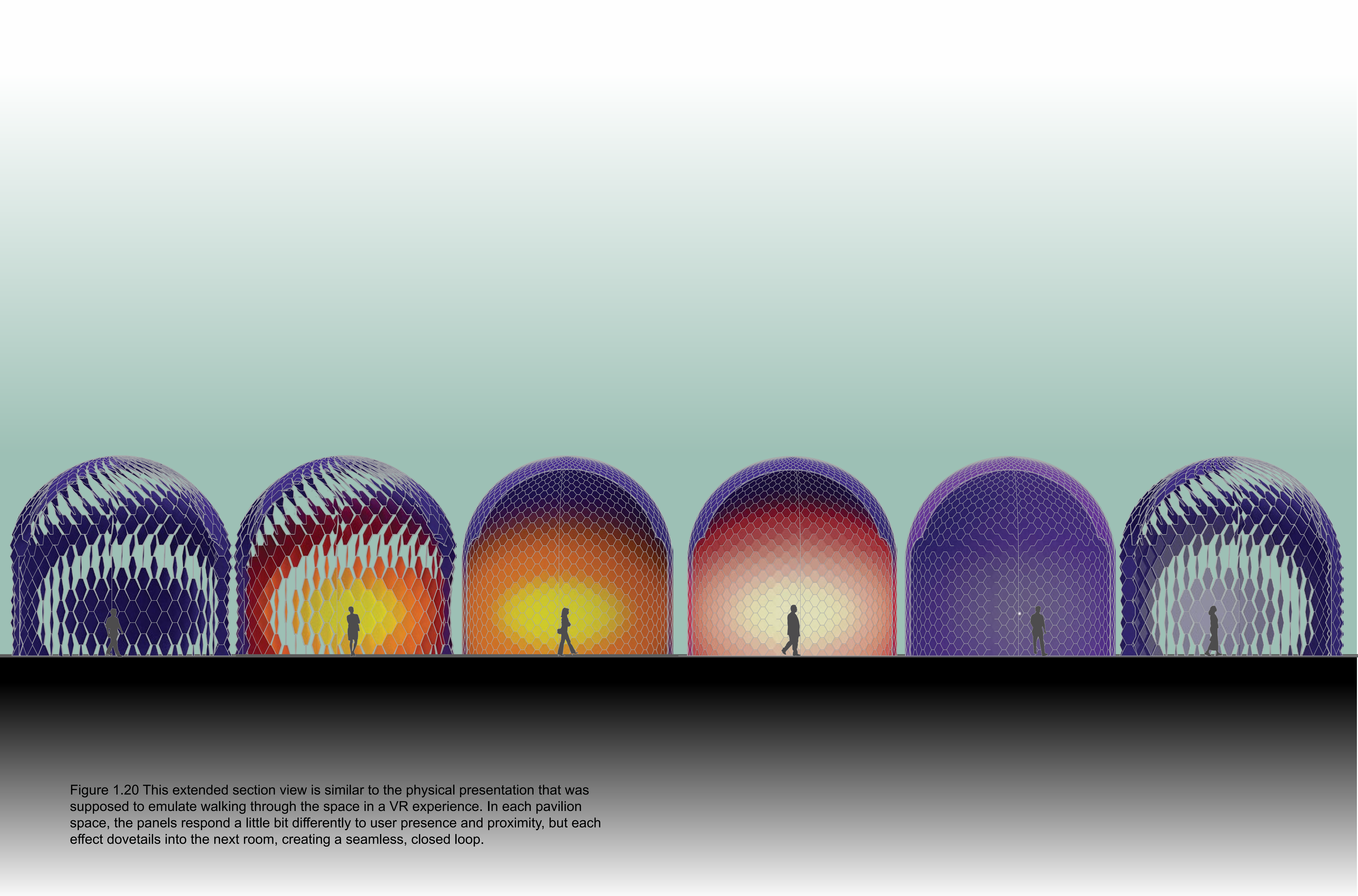


Figure 1.20 This extended section view is similar to the physical presentation that was supposed to emulate walking through the space in a VR experience. In each pavilion space, the panels respond a little bit differently to user presence and proximity, but each effect dovetails into the next room, creating a seamless, closed loop.

Figure 1.21 This render features a user exploring the rotating and color-changing pavilion space. Once the user reaches the threshold between this pavilion and the next, the space will default to a null state.

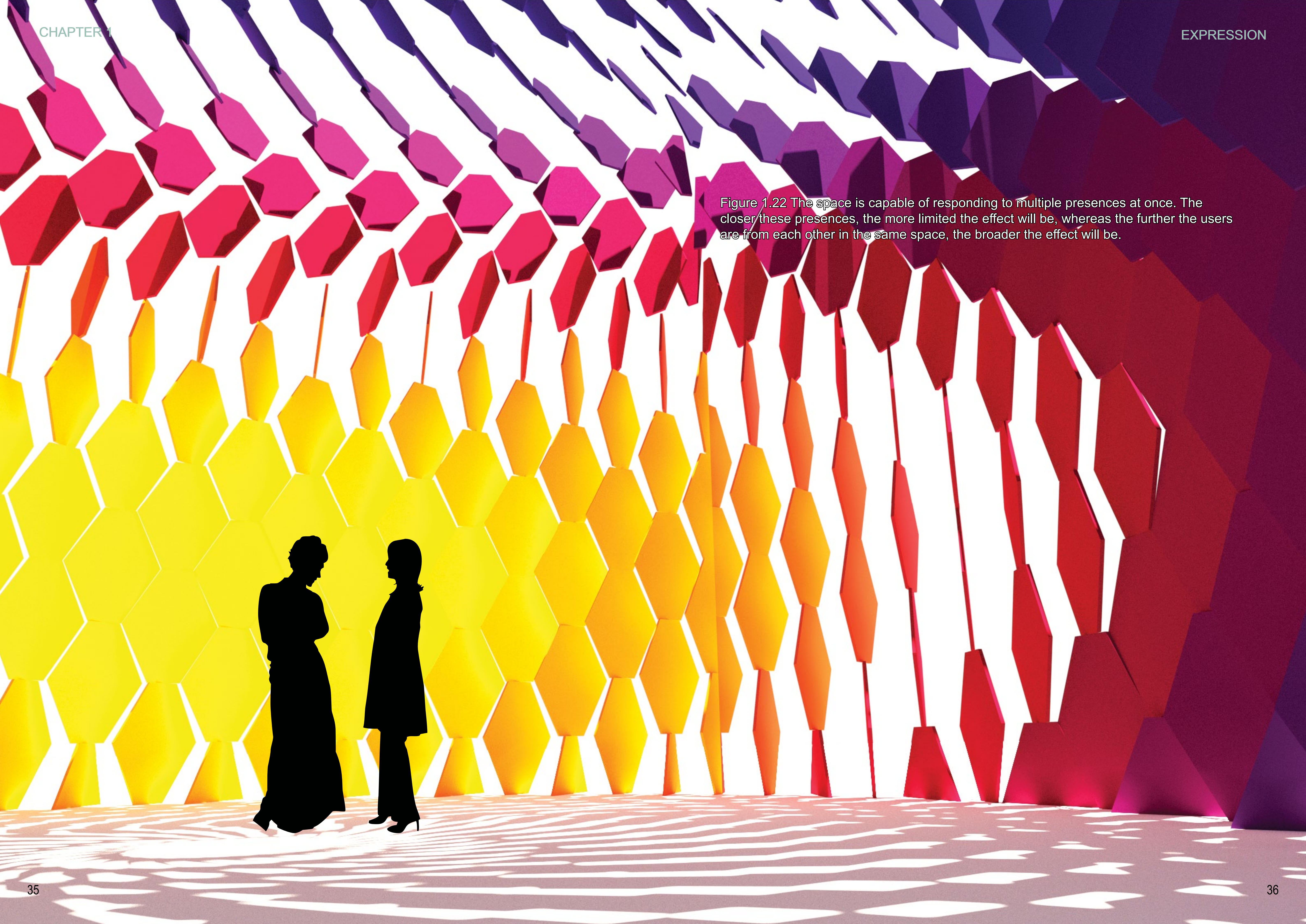


Figure 1.22 The space is capable of responding to multiple presences at once. The closer these presences, the more limited the effect will be, whereas the further the users are from each other in the same space, the broader the effect will be.

Figure 1.23 From the threshold space between pavilions, the user can view the spaces in their default position as though the person does not exist at all. As the user introduces temporality to the space, by removing the influence of the user but still having the user present, the space exists in a liminal, defunt state.

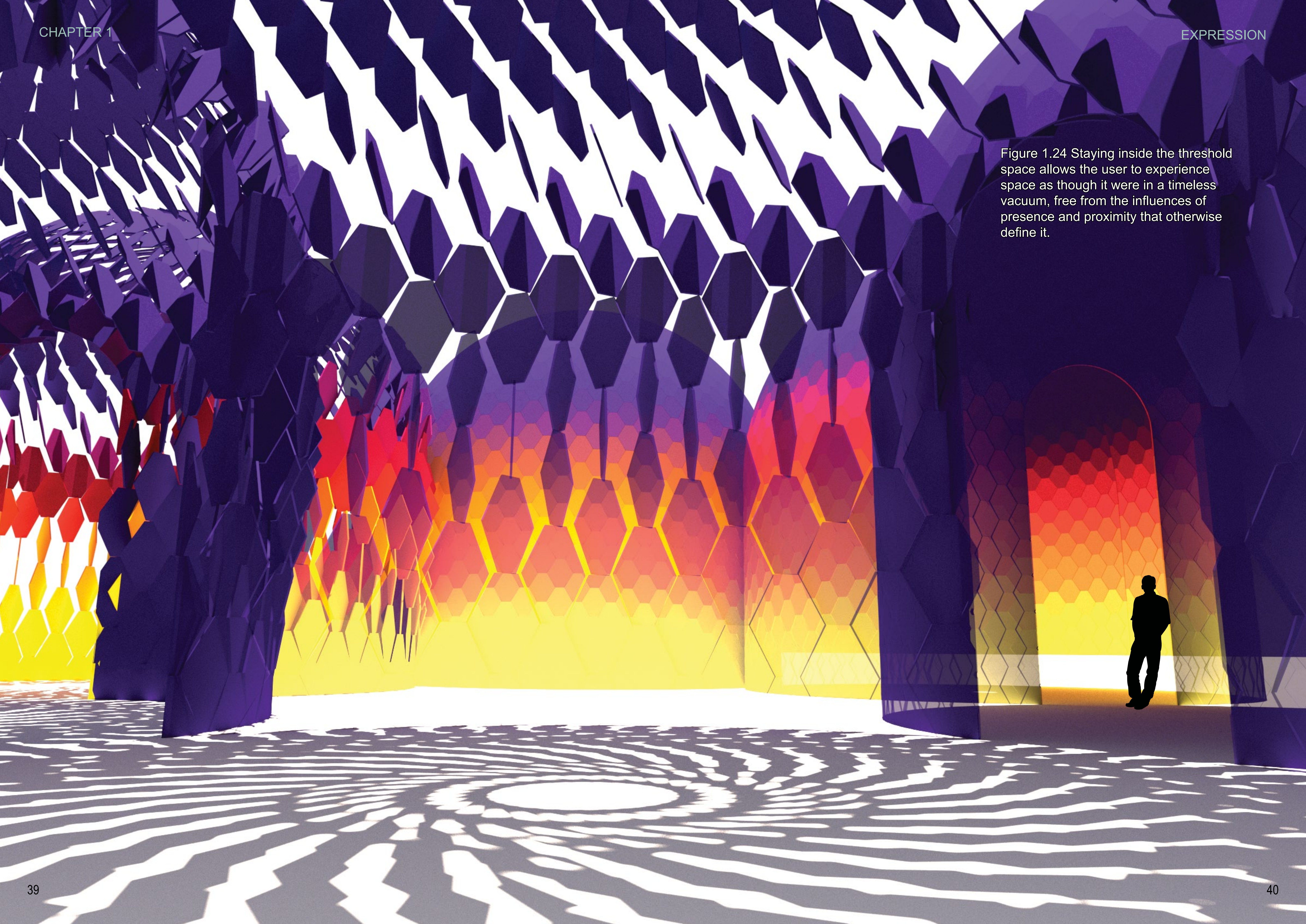


Figure 1.24 Staying inside the threshold space allows the user to experience space as though it were in a timeless vacuum, free from the influences of presence and proximity that otherwise define it.

Figure 1.25 The closer the user gets to the panels, the more transparent they become. At some point, the user might think they are free from closed loop of pavilions, but ultimately the effects are only visual, and the physical, geometric reality of the panels is constant.

Affirmation

Overall, the digital model and its interactive counterparts accomplished what I had set out to do; they successfully illustrated an occupant's temporal and spatial effect on a built space by means of kinetic elements incorporated into the architecture. The very obvious changes in the space made the user acutely aware of their own presence and movement, further illustrating Heidegger's definitions of "ready-at-hand" consumption of a space.

Additionally, liminality as a theoretical concept was made tangible through creating literal threshold areas where the user's presence would not affect the architecture at all. Although their movement through this limited threshold did not change the space in the same way occupation did, the contrast allowed for the user to observe the space as "present-at-hand" in its theoretically void state. This allowed for that key liminal sense of self-awareness in a passage state between destinations. Since the space had no real program other than for continual movement in order to view its effect on the spinning, colour-changing, and fading panels, existing in this liminal space defied the intention of the space, putting the user in a position that existed physically out of time and programmatically out of place.

Finally, the research allowed me to reach for a better comprehension of new softwares, including Grasshopper and Unity. The logical application of geometrical analysis that Grasshopper provided pulled the theory of liminality, spatiality, and temporality out of abstraction, and instead read that theory as computer code that could be compiled and visualised.

Criticism

From the perspective of a case study in modelling theoretical concepts, the model served its purpose well. However, the kinetic elements of the model were still facade conditions that acted in an aesthetic capacity rather than in a programmatic capacity, and ultimately did not really impact the spatial conditions to the extent I had intended. This was largely due to the simplicity of the space, but I felt that a true change in spatial conditions would have had the ability to impact the program, volume, and accessibility for the user.

Although the theoretical application of the design research was largely successful in visualising the threshold space and the user's perception from that vantage, there were some software shortcomings. The original intention of the simulation stage was to have a user be able to move through modelled space with VR equipment, putting the user in the 'ready-at-hand' position, rather than viewing from an omnipotent 3rd person camera angle. Because the geometry produced by Grasshopper ultimately generated over 7200 individual objects that all responded to a singular point of attraction, the processing and rendering time in Rhino alone was much slower than desired and was made nearly unusable after being processed through Unity.

Trying to pipeline that geometry and the respective Grasshopper script to Unity only compounded on that problem. The file took upwards of 15 minutes to open in Unity, with Rhino and Grasshopper running inside the program rather than separately, and every smallest change in the Rhino/Grasshopper geometry would take at least another 10 minutes to update in Unity. Ultimately, the pipeline was intended as a sort of external renderer that could generate some user interfaced controls like sliders and toggles for simpler models, but was not intended for the scope of the project that I introduced. By the time I had

realised this, it was too late for me to try to import all of the static geometries into Unity and try to learn and write C# script for the animations to run solely inside of Unity, rather than through stacked embedded programs. As a result, my first exhibition illustrated my research through a series of comprehensive posters, rather than the VR suite experience I had originally intended.
In retrospect, there were definitely more efficient and practical options for generating a VR experience from a Rhino/Grasshopper model, but I was unfortunately not aware of these at the time of modelling and programming.

Projection

As a result of this first stage of design research, I have plenty of content to work with to continue to expand my understanding of liminal, spatial, and temporal theory and apply it to more complicated architectural works.

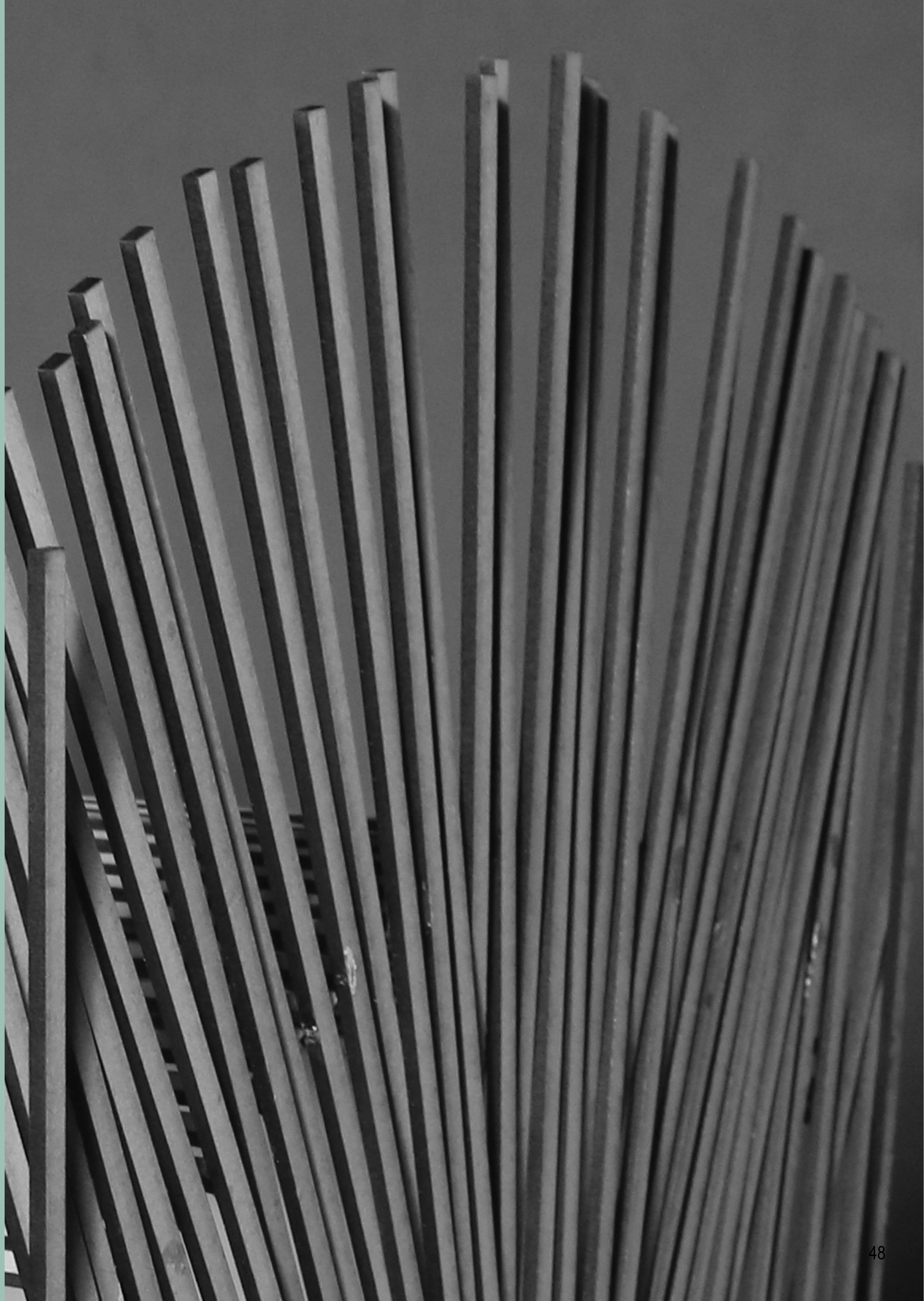
In terms of geometry, the space becomes less abstract and more complex, and I move on to some programmatic applications of architecture. The goal is to move towards a residence or established communal space with predetermined necessary program spaces that need to be both attended to in the design, and somehow altered through kinetic architecture.

In order to achieve this, the moving elements cannot simply be restricted to the facade and outer elements, but actually impact the usable space in reaction to the user's presence. My proposal for this stage is to explore changes in volume that both change the space atmospherically and affect its usability and accessibility.

I plan on achieving this through more Rhino modelling with Grasshopper scripting, with the design focusing on potentially buildable space that could be applied and constructed in real life. This intermediate stage of applying program and exploring changes in volume will serve as an intermediate step before working on a final, large scale architectural experiment.

CHAPTER 2

INTERMEDIATE SCALE



Intermediate Concept + Program

For each successive phase, an increase in architectural complexity has been added, both in terms of the functional program and technical components. In response, the program is moving away from the sole program of walking, hesitating, observing, and introspection, and towards a program that reflects habitation in a more intricate sense. Rather than having a blank expanse of space for the user to wander aimlessly, this program features designated spaces for food prep, public socialization, private needs, and a semi-private sleeping. Incorporating programmed spaces with associated privacy needs forces the atmospheric, lighting, and kinetic designs to be executed more thoughtfully and deliberately to reflect a comfortable living environment. The kinetic component of the design was developed to have more impact on the space beyond the influx of natural light. The goal of the use of kinetic design is to intensify the impact of temporality on liminal spaces in the built environment in order to explore how these shift our understandings of space, engaging more senses than merely sight/visibility.

The concept of this phase is a small loft, featuring space for an elevated sleeping area, spacious living, and split-level lowered bathroom, kitchen, and entrance area. However, the main focus is not on the simplistic floorplan and program, but rather the fully fluctuating ceiling overhead. The goal is that through elastic or telescoping connections, the panels of the roof can move in arcs and waves, creating high lofty ceilings with soft interior lighting, or low, claustrophobic spaces with sharp lighting and high-contrast shadows.

The goal of this fluctuating ceiling is again to force the user to be made aware of how their presence affects the space in conjunction with the kinetic elements of the design. Not only does the claustrophobic setting create a heightened sense of self-awareness, but the presence itself also has an impact on how the light illuminates the space and creates an open and welcoming or closed and foreboding atmosphere.

Additionally, the rolling ceiling has an overhang that can cover the side windows. When the ceiling is lowest in the main area, the windows are mostly covered, increasing the sharp unnatural interior lighting, and blocking out the exterior natural light. When the ceiling is high, more natural light can enter the space, further opening up the space visually and blurring the impact of shadows on the space.

Atmosphere

“Atmosphere is the common reality of the perceiver and the perceived. It is the reality of the perceived as the sphere of its presence and the reality of the perceiver, insofar as in sensing the atmosphere s/he is bodily present in a certain way.” (Böhme, 1993, p. 122) Atmosphere is used to describe the holistic and overarching experience of a space, setting, or social/cultural scenarios, combining perceivable and tangible qualities of the environment with a person’s own biases, intuition, and imagination. Although atmosphere can be superficially gleaned through visual elements and a person’s response to them, the best sense of atmosphere, especially in architecture, can only really be applied and understood in person. In person, not only are more of the five sensory systems being used to perceive the space and setting around them, but it forces the user to take in other vestibular inputs, such as orientation, gravity, balance, and duration. These added sensory and kinaesthetic inputs add a deeper understanding of the intended, or perhaps unintended, atmospheric design, well before the user can even add their own pre-existing experiences and biases to it.

However, atmosphere is not limited to just the tangible senses that enhance a visual experience, but it also relies on the reading and response of every individual user (Böhme, 1993, p. 118). Pallasmaa notes that “In addition to environmental atmospheres, there are interpersonal atmospheres – cultural, social, family, workplace, etc.” (Pallasmaa, 2014, p. 19). Atmosphere derives its complexity from that complexity inherent in human emotions and reactions to their environment, and as such this can make atmospheric design difficult to replicate and recreate consistently across a series of works or experiences. Humans have evolved to have an intuitive bias when they first encounter a new space or experience, much as less intelligent creatures are able to differentiate between predator, prey, and kin.

In the same way that humans can pick up on differences in human appearance despite the nigh identical genetic configurations that would be negligible or indeterminable to another species, as well as being able to pick up on minute changes in face and tone to determine and understand mood and intent, humans can pick up the same emotional and individual subtleties in an environment. This again relies on the unique experiences, biases, and intuition of every individual that encounters the space, but the capacity for that scope is what can make a spatial atmosphere especially impactful. Because of expanded human intellectual and emotional capacity, people are generally able to pick up on more atmospheric traits without experiencing every facet of the environment independently and at length, such as a new city, social group, etc. (Pallasmaa, 2014, p. 21). Because this perception and understanding is also largely based in bias and personal experience, it can range from person to person, and that initial judgement can have negative or positive associations.

Figure 2.01 Le Bar Italien at La Mamounia, Marrakech, Morocco. The warm-toned, red ambient lighting from the light fixtures and bulb selection creates a cozy and warm atmosphere.

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Figure 2.02 REDACTED EXMAPLE - OZONE at the Ritz-Carton, Hong Kong. The purple colors and use of fluorescent and LED accent lights creates a cool, futuristic atmosphere.

Light

Light determines how users perceive a space, both in terms of literal visibility as well as setting a specific atmospheric tone by eliciting mood, memories, and environment. In any space, lightness, and by extension darkness, is always integral to the established atmosphere, whether intentional or not, but it can be harnessed and manipulated in a multitude of ways to add depth and nuance.

"…Light itself is a form of architecture that may be utilised to provide three-dimensional forms" (Edensor, 2015, p. 335)

Much in the same way that cold is understood to be absence of heat, darkness is the consequential absence of light, and any space or environment that utilises natural light has to contend with this as time pass throughout the day by either embracing the eventual darkness, or finding ways to compensate for it artificially. That is to say, as night-time does not have the benefit of natural environmental illumination, a space needs to compensate with unnatural lights in ways that it likely did not have to (or were not as noticeable) during the day. Especially in public areas, people are drawn to light, and bright clusters of lights in an otherwise largely unilluminated environment can dictate a location intended for congregation and entertainment, such as a popular tourist spot or nightlife scene (Edensor, 2015, p. 332). This can be applied just as easily to the enclosed nature of an architectural space; light indicates habitation, and provides the visibility needed to perform tasks and be aware of one's surroundings.

However, environmental darkness can be used just as effectively in a built space by creating a sense of intimacy and immediate focus (Edensor, 2015, p. 332). The subject or user is forced to focus only on what they can see, and are forced to give up on perceiving everything else around them. As long as this type of lighting is deliberate, it can be assumed that the periphery is unnecessary and unimportant to the user experience, and that the user will have to trust that what they can see is what they should be focused on.

In this phase of design, the light source moves with the roof as it fluctuates in a wave pattern, creating instances where an area is either brightly illuminated or much dimmer, as well as playing with the influx of natural light in certain positions. This use of lighting forces new atmospheres on top of changing spatial conditions, forcing the user to consider the abstract architectural nature of light in conjunction with the tangible volumetric change in occupiable area.

Figure 2.03 Atmosphere by Pneuhaus. The use of narrow light access and added fog to cut through the space elevates the lighting effect to a more visual and almost tangible architectural element, rather than merely as a source of illumination.

The program of the tiny home was purposefully kept minimalistic, based on a plan for a lofted apartment and adapted accordingly. The entrance to the home would enter directly into the kitchen, with a bathroom built off to the side. Both of these spaces are on a lowered level from the main living space tucked under the loft, offering some privacy and quiet for the user. A short set of stairs leads to the more open living space, which offers more flexibility in use and has the most access to natural lighting. The stairs to the side lead to a loft-style bedroom, which again offers personal privacy for the user from prying eyes at street level and guests on the main floor. Similar to the first phase, all of the static elements were designed and modelled in Rhino, but the dimensions of the architectural elements, such as doors, stairs, and walls had to meet standard widths, heights, and thicknesses of New Zealand building codes.

The roof, which curves up and down in a waving motion, has overhanging beams that function as louvres. When the roof is in a position that is lower over the main living space, the louvres are lowered with the ceiling level, blocking out natural light from the windows at the side. When the ceiling of the main space is high, the louvres are lifted upwards, and natural light is allowed to enter the rooms. The ceiling lights fitted into the roof also add a change in illumination and mood as they move up and down with the ceiling. At a lower position, there is less natural light and a flood of unnatural light, creating brightness in every corner of the space and generating sharp shadows. At a higher position, the louvres are lifted and natural light can come into the space, and the unnatural lights are raised to create a softer, less harsh ambiance with more diffuse shadows. When the ceiling is raised, the unnatural and natural light sources switch in tandem, and these conditions have to be considered and compensated for over the course of the day. As the day gets darker, the use of the natural light becomes more apparent and integral to the space, with no natural environmental light to balance it out. The user is forced to become more aware of their presence in the space by perceiving how the space around them is illuminated, and how their presence

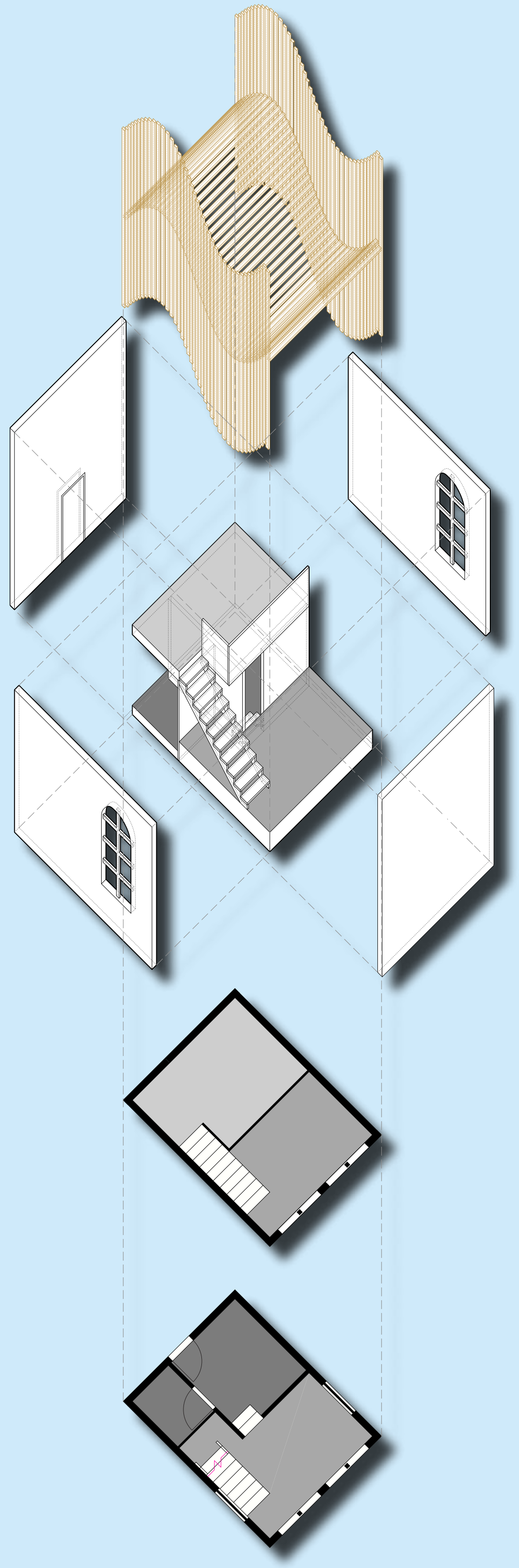

Figure 2.04 The exploded axon shows the plans at each level and illustrates the separation of private living spaces from public hosting spaces. These spaces are affected in different ways atmospherically when the ceiling moves.

generates shadows in different conditions. It also forces the user to consider psychological differences in smaller versus more open spaces, and will have to choose between how they want to illuminate and volumise their public or private space.

Kinetic design is integrated into this space with the waving roof, which rolls on a curve. At construction scale, this would be controlled remotely with mechanical controls and built with flexible materials that would be able to adapt to the changes in surface area as the material lifts up and down. At a 1/20 scale, this was done with beams and pre-tensile elastic, so that the roof had the ability to shorten at tighter angles, but would not droop or splay at wider angles because of the pre-stretched limits of the elastic. However, even at this scale, the elastic nature of the roof and the fragility of the beams were difficult to regulate, and would likely have required a larger model to accurately and effectively model the intended effect of the roof. Despite this, the effect of the changes in spatial conditions and lighting were still illustrated effectively, and were additionally reflected well in renderings.

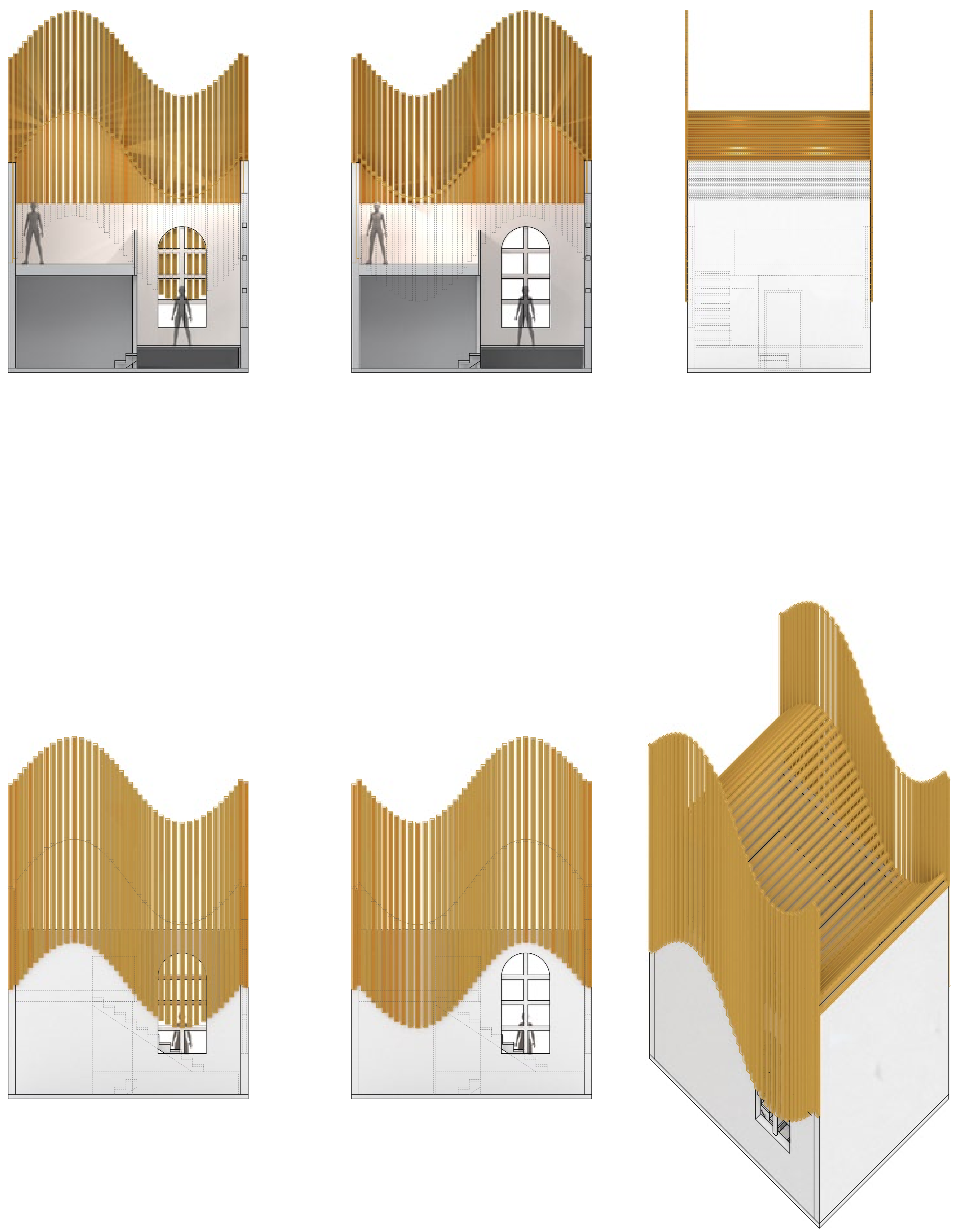

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Figure 2.05 These sections and elevations show how the rolling ceiling creates different volumes in the private sleeping area and the public hosting area. With the side windows as the primary source of natural light, the height of the ceiling and the attached louvres at the side produce an inverse relationship between natural and unnatural light.

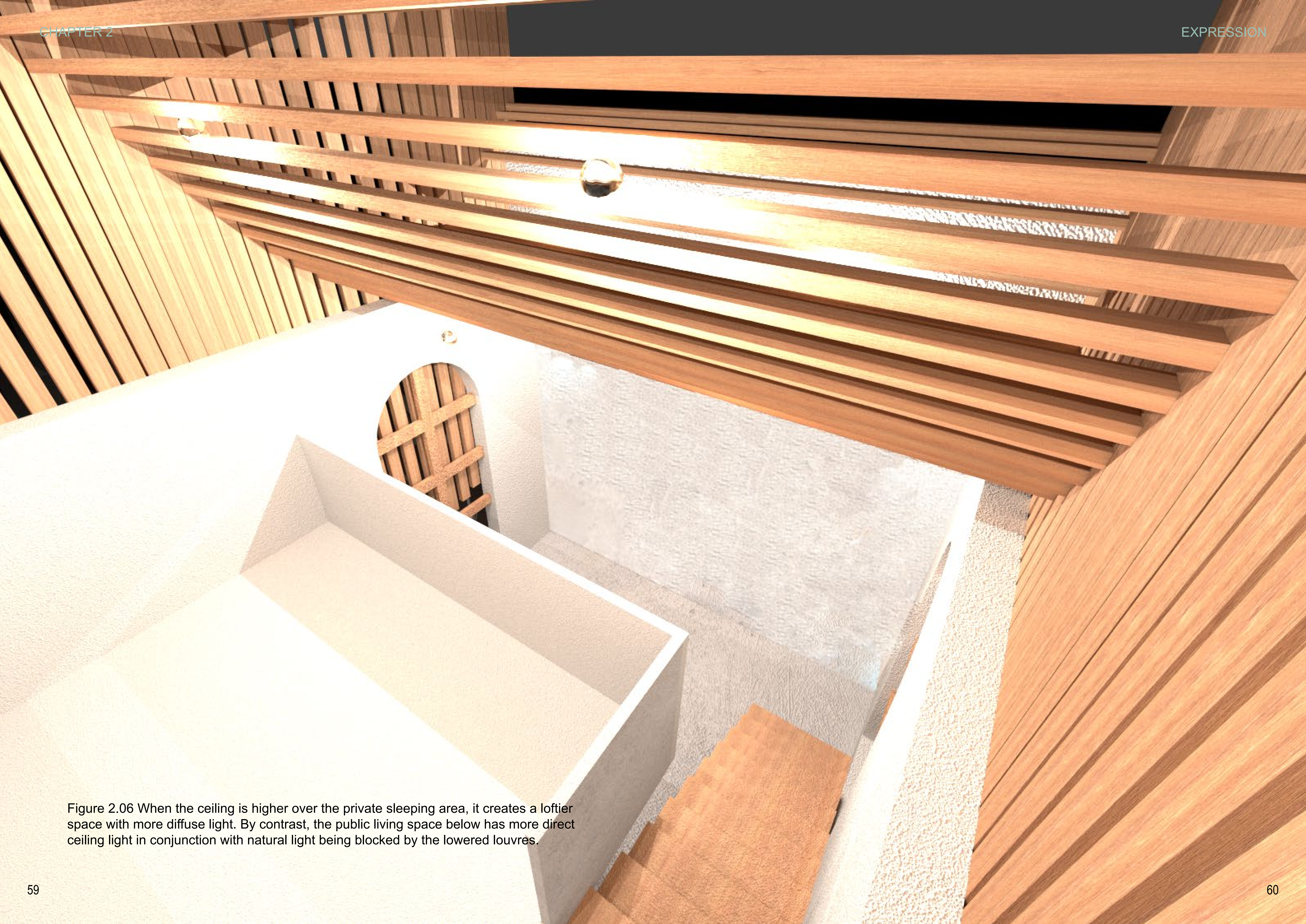


Figure 2.06 When the ceiling is higher over the private sleeping area, it creates a loftier space with more diffuse light. By contrast, the public living space below has more direct ceiling light in conjunction with natural light being blocked by the lowered louvres.

Figure 2.07 When the ceiling is higher over the public living space, there is less light coming from the ceiling, casting softer shadows in the area at night and introducing more natural light into the space during the day when the sleeping area is not in use.

Figure 2.08 The photos from the 1/20 very similarly reflect the lighting and spatial conditions of the simulated renderings

Figure 2.09 The photos from the 1/20 very similarly reflect the lighting and spatial conditions of the simulated renderings

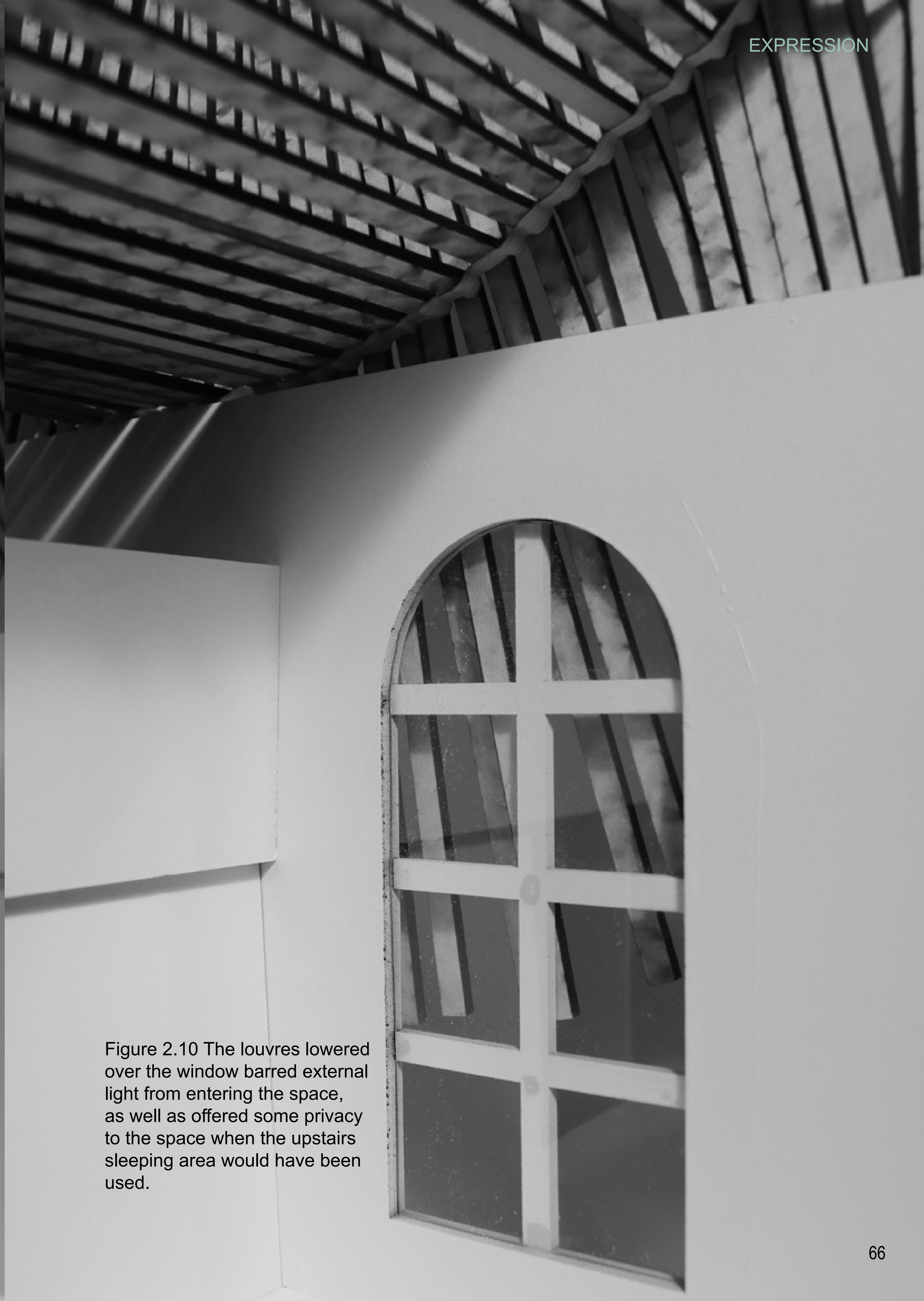


Figure 2.10 The louvres lowered over the window barred external light from entering the space, as well as offered some privacy to the space when the upstairs sleeping area would have been used.

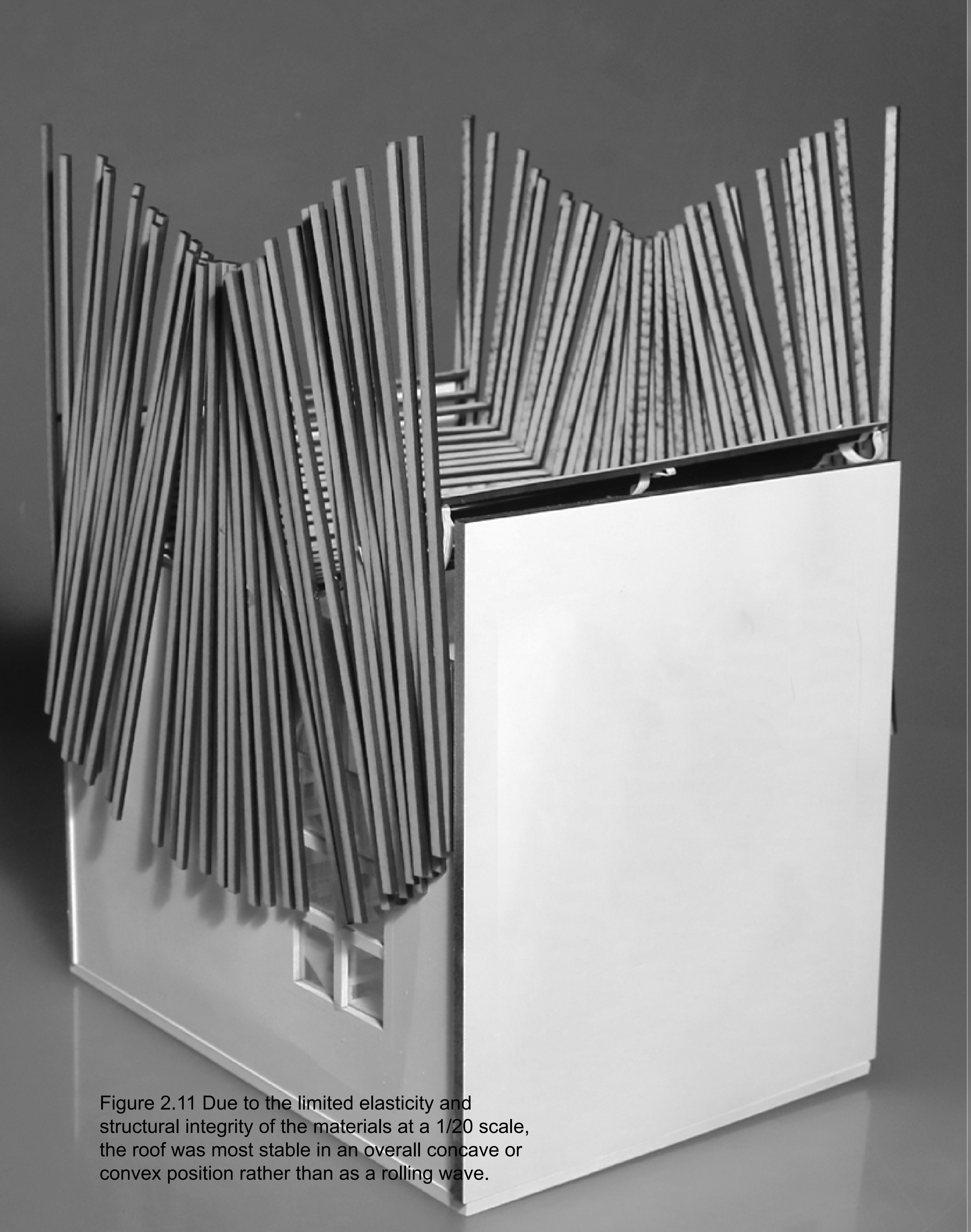


Figure 2.11 Due to the limited elasticity and structural integrity of the materials at a 1/20 scale, the roof was most stable in an overall concave or convex position rather than as a rolling wave.

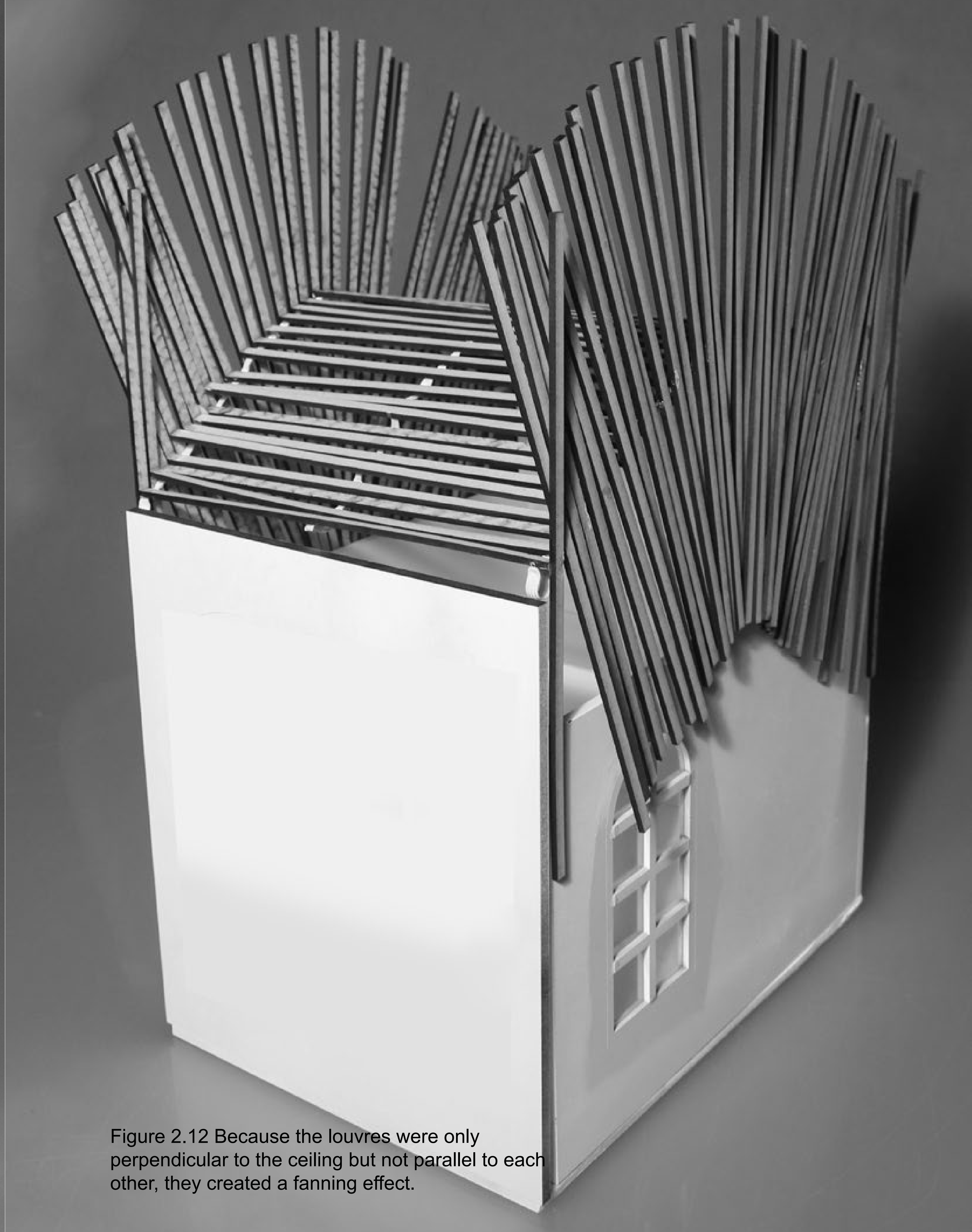


Figure 2.12 Because the louvres were only perpendicular to the ceiling but not parallel to each other, they created a fanning effect.

Affirmation

Designing the roof in this program and modelling the space to scale allowed for a more accurate and authentic understanding of the potential that kinetic design can have on a space through changes in volume and atmosphere. Although design was overall simplistic, it offered insight and inspiration for how kinetic architecture can best be utilised at the final architectural scale. It provided a good push away from the standard use of kinetic architecture solely as facade elements that control influx of natural light, and instead incorporated it directly into the size and atmosphere of the space.

Building the model itself posed a mixture of success and failure. At its scale, the roof, attached with pre-tensile elastic band, was able to flex and fluctuate to recreate the scenarios of higher and lower ceilings in the space. It showed that with the correct materiality, a similar, more developed concept could conceivably achieve the desired effect as designed in Rhino, with evenly rolling waves and parallel beams. At a smaller scale, it is unlikely that the beams would have been strong enough to support themselves at all, let alone fluctuate in the way they were able to do.

Criticism

Despite the relative simplicity of the design scope, the digital and built model both presented challenges that were difficult to overcome and realise in a physical context. At the scale the model was built at, the ceiling was too heavy and too fragile to properly support itself the way it was illustrated in the drawings and originally intended to. The fragility of the roofing material actually prompted me to build a static roof that would more resemble the perfect rolling curve of the illustrations, but the pieces were difficult to handle and assemble without better adhesives. Although the model served its purpose in understanding the built space through photography and physical observation, it is unfortunate that the roof was not brought to its full potential. A better design may have been interlocking 3D printed beams that would offer more sturdiness and consistency across the structure.

Additionally, the design itself was somewhat underdeveloped, with no established site and the bare minimum of habitable space to allow for appliances, plumbing, and living and sleeping rooms. A more complicated floorplan in conjunction with a more complicated roofing system, possibly one that incorporated double curvature, could have created some really interesting and diverse spatial conditions across the entire building.

Finally, despite the push for a more complicated use of kinetic design, the sensory experience was ultimately limited to sight, which is something I want to break away from with kinetic design. Ideally kinetic design will be able to engage with and respond to more than one stimulus to create a more immersive spatial and temporal experience for the user.

Projection

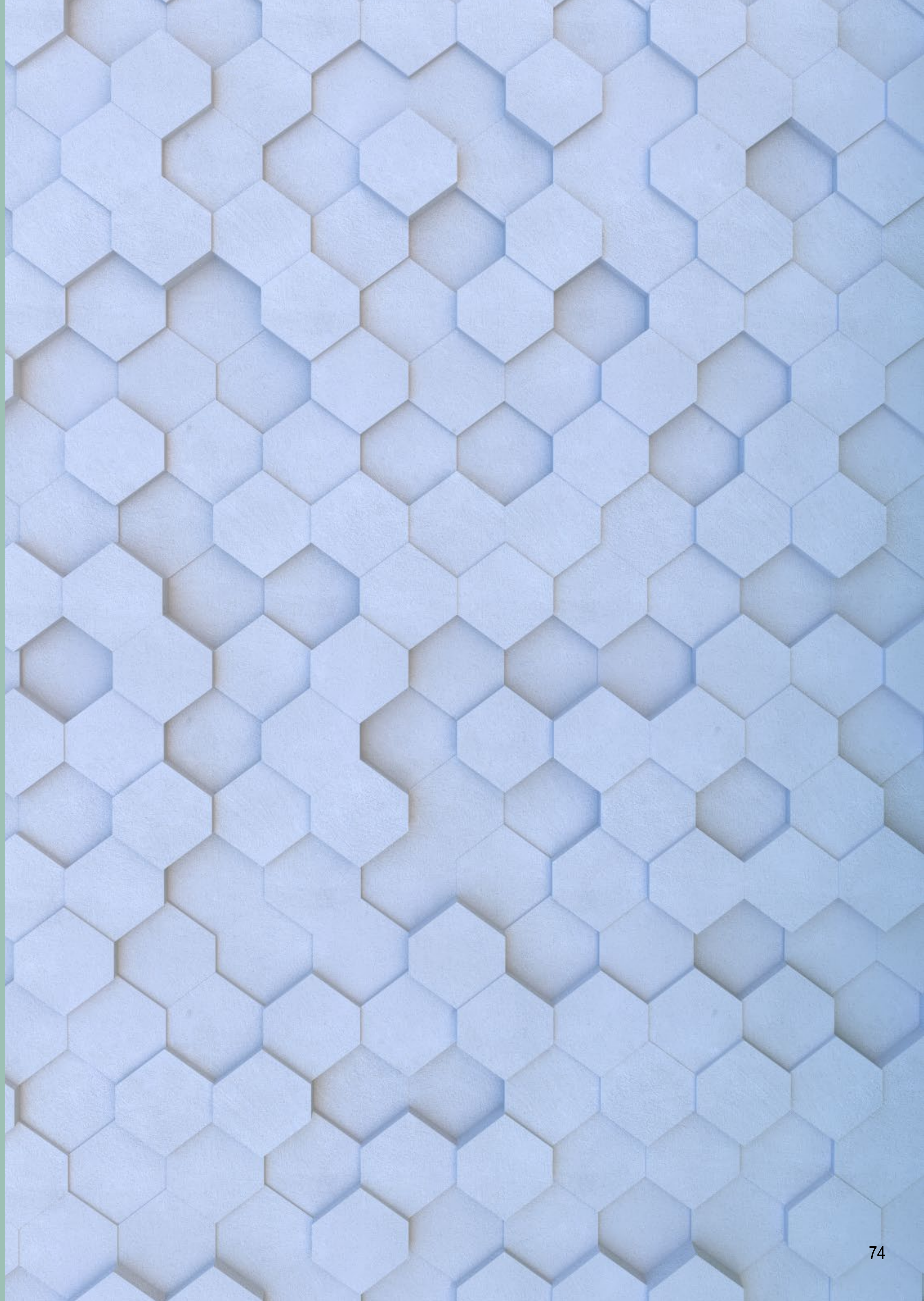
Moving forward, the goal is for all attributes of the design process thus far to be advanced as much as possible. The program should reach a larger public scale and be able to accommodate several people at once, all while affecting them through the imposed atmosphere of the kinetic design. With the more complicated architectural program comes a more defined architectural context; the final phase should fully incorporate site analysis and consideration into the program of the building.

The kinetics should be able to be experienced not just through sight, but possibly through other senses, such as touch, kinaesthesis, vestibular, or sound. This will call for a level of engineering and technical analysis in order to design moving mechanics that in themselves do not interrupt the user's experience more than necessary, such as through unwanted jilted movement or loud noises. This will also call into account a higher scrutiny of material, rather than the vague speculative material that has been used in the digital modelling process.

Finally, the modelling and expression of the final phase should also reach new heights of complexity compared to previous phases, drawing on all previous learned and applied skills to generate a manipulatable UI to set parameters for the built space, as well as a software system for users to experience the built space in an immersive VR environment. This will likely require more advanced use of Grasshopper and Unity in order to create an experiential system that has a multi-sensory effect on users.

CHAPTER 3

ARCHITECTURAL SCALE



Architectural Concept + Program

In this final stage, the goal was to create a cumulative design that addressed all of the theoretical concepts, methodologies, and design choices that preceded it, all while answering my original thesis query: how can kinetic architecture be utilised to enhance a user's relationship with the spatial and temporal nature of a built environment? The program that I felt best addressed both temporal and spatial relations with the user, as well as multisensory atmospheric design, was a music hall.

The concept would be that the space of the hall reflected the auditory input generated within the space, taking into account all forms of user presence in the room. When the room is completely unoccupied, the room exists in a stasis, making it otherwise indiscernible from any other public performing hall. However, once users are added in different capacities, the room will change in a multitude of ways, and will further change based on its own feedback. A series of kinetic interior walls and suspended reflectors will twist, fluctuate, and move based on the frequency, volume, and pressure of sound emanating from the stage. In an otherwise empty hall, the sound would reverberate and feed back into the system, and the space would constantly change in response to the existing sound bouncing around in addition to new sound being produced. The kinetic elements, which will serve as both acoustic dampeners and reflectors, will be altering how the sound reverberates as they move, so that the audio quality is never consistent within the space. However, human occupants in a music hall are an important consideration to the acoustic quality of the space, and as the room is filled with bodies, they serve as sound absorbers. By absorbing the sound, the reverberation will regulate, and there will be less bouncing feedback playing off of the kinetic elements, creating a better acoustic experience. Having people in the audience will actually improve the overall acoustics of the space, all while offering a dynamic experience that alters the space visually, volumetrically, and acoustically.

Music + Temporality

Although visual components are usually the primary factor for determining the atmosphere of a space, sounds, especially music, are just as important for an emotive response from the occupant. Music in a setting adds a dynamic 4th dimension that many of the other senses cannot provide in the same way; auditory input is an ongoing experience that cannot be captured accurately in an instant. In the same way atmosphere cannot be contained or understood by a cursory consumption of the space, music cannot be completely understood or appreciated by one note alone. This is why music is often used in the background to encourage circulation or in spaces with intended occupancy turnover, such as shopping centres, elevators, and waiting rooms. The music helps keep the space from feeling as though it is trapped in a stasis, and works to help the occupant feel as though time is moving forward and ultimately carrying them towards their next setting (Pallasmaa, 2014, p. 20).

There are different types of intelligence beyond efficient and rational problem solving, including linguistic intelligence, intrapersonal intelligence, interpersonal intelligence , logical/mathematical intelligence, musical intelligence, bodily/kinaesthetic intelligence, and spatial intelligence. All of these are measured in each individual in very different ways, and they all have an effect on how a user might interpret, understand, and appreciate the atmosphere of a space, setting, or situation. However, an occupant does not necessarily need to have an intelligent or academic understand of music theory or appreciation in order to have an emotional response to it. By introducing music to a space, one could drastically alter the emotional atmosphere simply by changing the music style, and further with musical quality and volume (Pallasmaa, 2014, p. 20). Ideally, if a space had a means to alter these conditions in real time, the atmosphere would be in constant flux, and would be extremely difficult to identify and capture holistically, especially from an external viewpoint. This is ultimately where my research will take me.

Acoustic Physics

Sound travels in waves from source to destination, and the measurements of those waves provide information on the objective perceivable qualities of the sound. The width of the wavelength, and subsequentially how often a wave cycles over time, is measured as a frequency in hertz (frequency = 1/(time)). A higher frequency, or more wavelengths cycling over a period of time, is perceived as a high or shrill sound, like a flute or a whistle. A lower frequency, with fewer wavelengths over a period of time, would be perceived as low and deep, like a cello or bass. Different pitches and notes are assigned to different notes. For example, a frequency of 440hz is the A above the middle C on a standard piano or keyboard, and is generally used as a starting note to tune an instrument. Some pitches are either too low or too high for the human ear to pick up, but can be heard by animals with more sensitive hearing such as dogs or bats, or can be felt by animals that move through a material that allows them to feel the pressure of the wavelengths impact them physically, such as fish through water (Barron, 1993, p. 12).

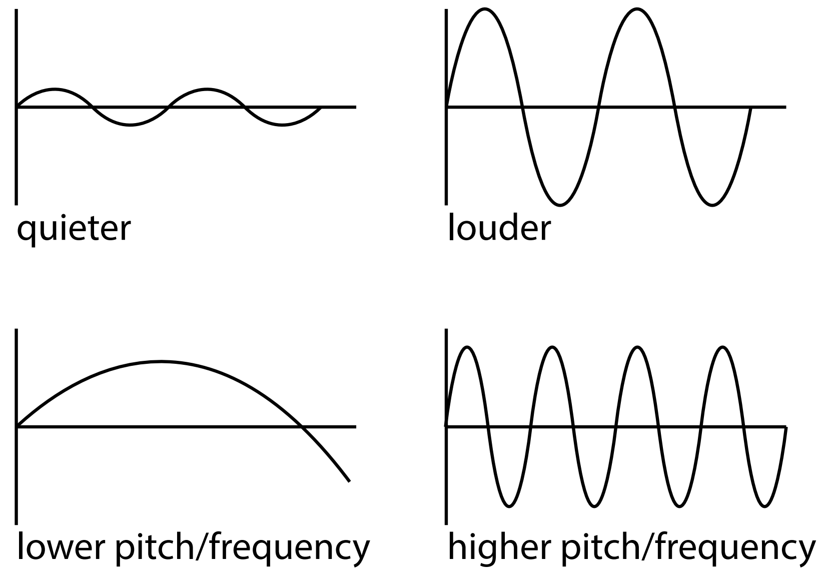


Figure 3.01 Sound travels and can be measured in waves by its distance over time. Different notes have different pitches as denoted by their wavelength over time.

Amplitude denotes the energy that a sound produces, and is visualised by the height or magnitude of the sound wave. The shallower the wave is, the quieter it will be be, and the higher the wave is, the louder the sound will be. The medium through which the sound travels will affect the amplitude, as a denser medium will be more difficult for sound to pass through in the same amount of time as a less dense medium, so the sound coming from the same source will sound much quieter. (Barron, 1993, p.12).

In the context of a concert hall or area with acoustic programming, reflectors and absorbers are used to change how the sound bounces around the space and sounds to the audience. A rigid, nonporous surface can be used to bounce sound from its source in a different direction without completely absorbing and stopping the energy of the wave. A concave reflector will focus the sound inwards, and is useful for amplifying and directing sound within a space when it would otherwise be more scattered. A convex reflector does the opposite, and spreads soundwaves outwards to reach a wider area. Although reflected sound travels more throughout a space, when sound is reflected but not controlled, it can create unwanted dissonance and echoes. Absorption does the opposite, and takes in the sound energy through a porous, denser medium that the sound cannot pass through and bounce back from. This effectively reduces the sounds amplitude, and quiets or stifles the sound altogether. These are used in concert halls to counteract the effects of reflectors and reduce unwanted sound bouncing. As people wearing clothes are effectively dense, porous mediums, the presence of an audience in a concert hall serves as a variable absorber, and must be taken into consideration when designing and placing the architectural reflecting and absorbing elements (Barron, 1993, pp. 23-24). However, as 100% audience capacity is not always guaranteed, any unoccupied or under-occupied space is likely to encounter extra echoing and reverberation without the expected mass to cancel it out. A stationary balance of these two elements ideally results in a space that sounds good from nearly anywhere in the room, with minimal distortion or reduction of quality between the sound origin and the audience.

When parametric design is applied to acoustic physics, the angles and surfaces that affect reverberation and absorption can be mathematically calculated and modeled with precision and deliberation. In a currently ongoing project, the acoustic elements of the Sydney Opera House are being redeveloped by a team of architects, engineers, and acoustic professionals, using parametric design to focus on the more even reflection of sound to improve audibility and quality. A series of intricate folds will be replacing the original acrylic doughnuts that used to hang over the performing area (and the current flat, angled wooden panels that have been serving as a temporary solution). The geometry will ideally bounce more sound outwards, as previously it was estimated the audience was only able to hear about 60% of the sound being produced from the stage. It will also work to optimise the proper absorption of amplified sound to reduce echoes and sound distortion in the space.

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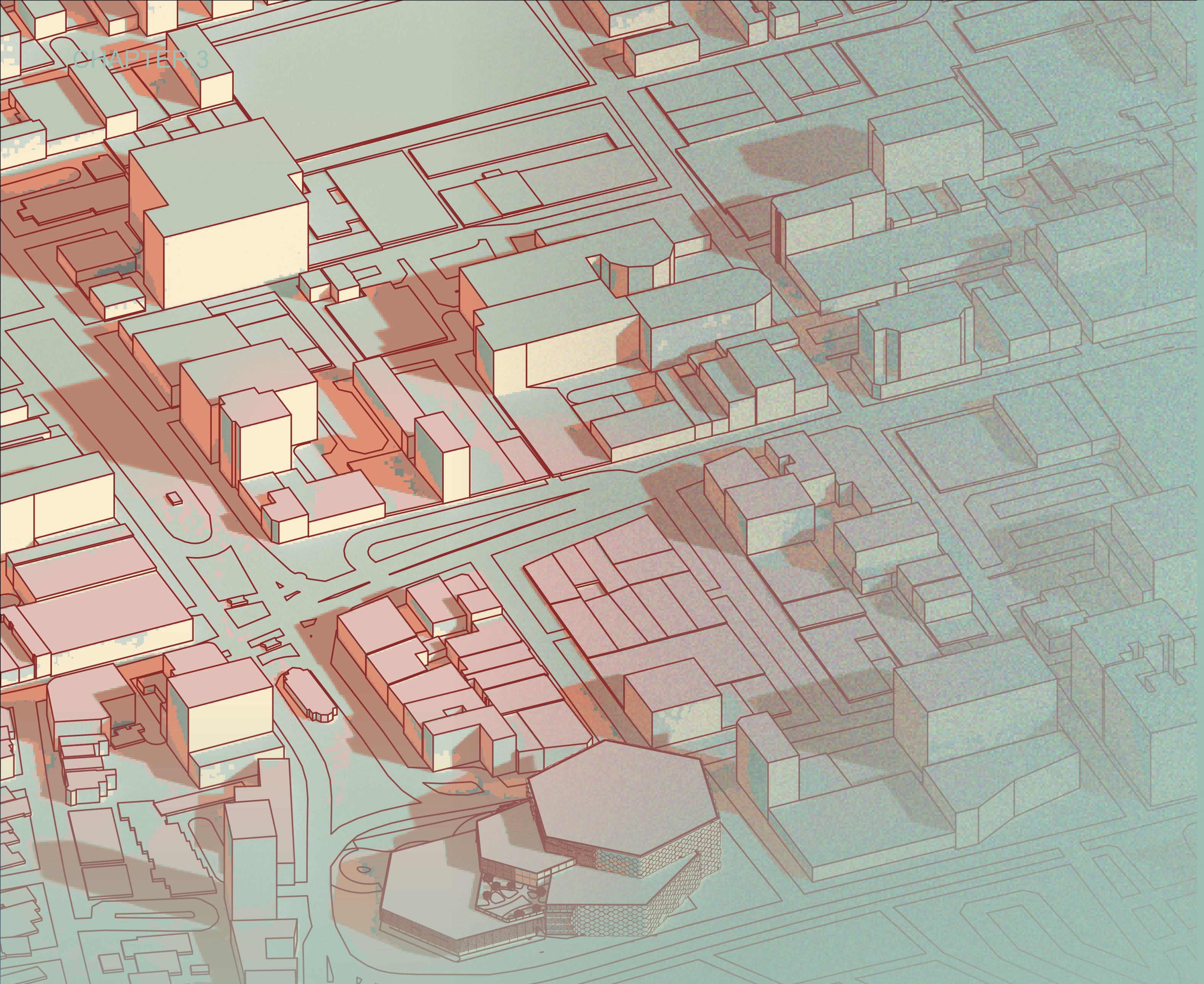
Figure 3.02 REDACTED CONTENT - The folded fan-like panels behind and above the performance space ensure a more even reflection of sound throughout the hall.

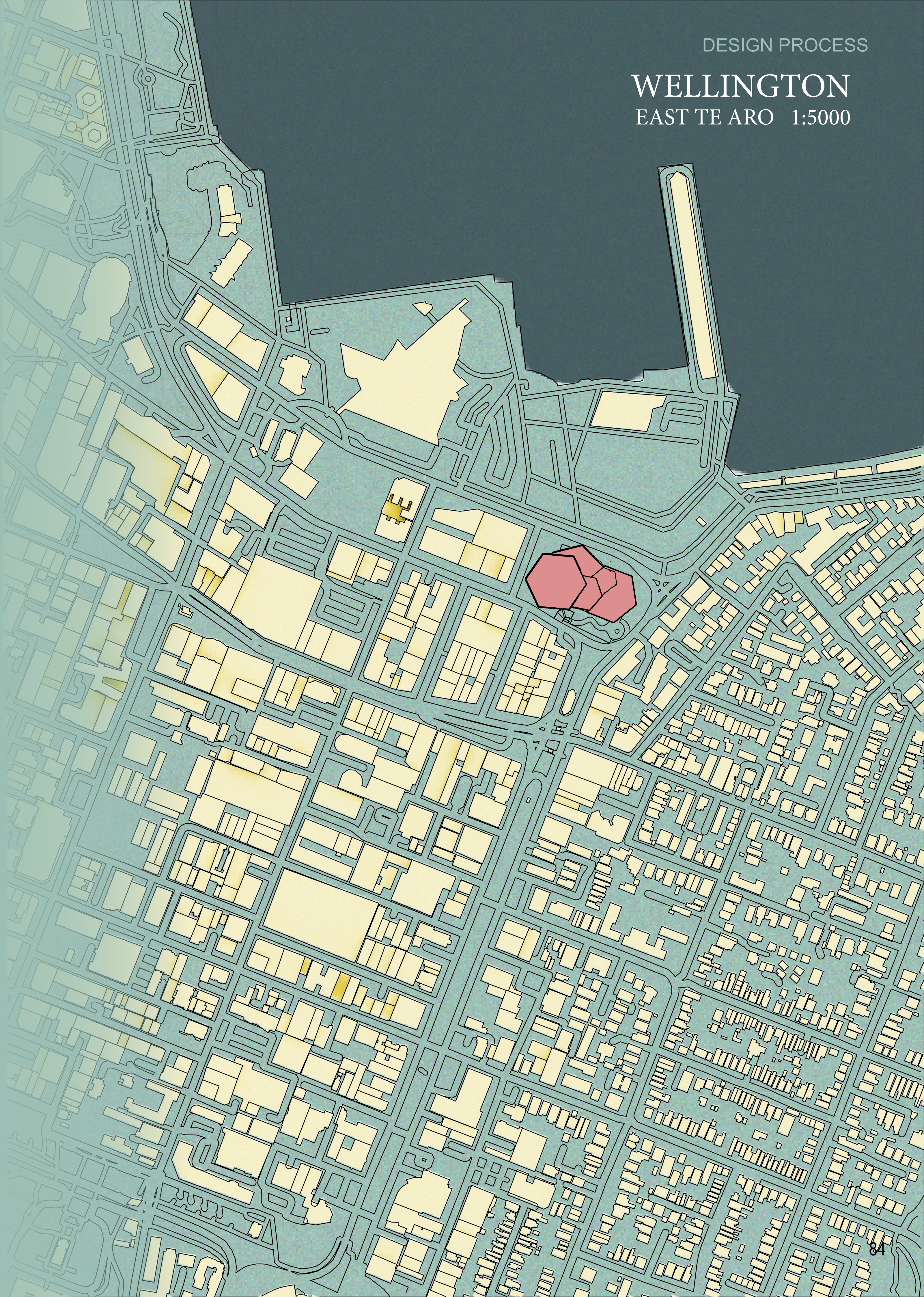
In contrast, the suspended reflectors for the University of Iowa Voxman Music Building's Theatroacoustic ceiling system were designed parametrically to create organic curves and geometric surface cutours to optimise the audio quality of the space. The reflector panel serves as one surface over the span of the performing hall, but has strategically placed geometrical perforations that serve to bounce and absorb sound as needed. It is most 'opaque' over the performers area and the back and edges of the hall so that the sound can reach as much as the audience as possible, with gaps in between to prevent too much echoing or unwanted reverberation. The angle of every panel ensures that the sound is being directed accurately, and that it is neither too scattered or too focused in any area of the room. The gaps in the suspended reflector also have lighting fixtures to allow for aesthetically seamless illumination of the space that blends in with the acoustic architectural elements.

Figure 3.03 The Voxman Music Building's Theatroacoustic Ceiling System uses a carefully designed curved surface to make sure that sound is reflected evenly after bouncing from the stage to the ceiling and back onto the audience. The cut-outs are similar designed and positioned to absorb sound to prevent echoes and dissonance.



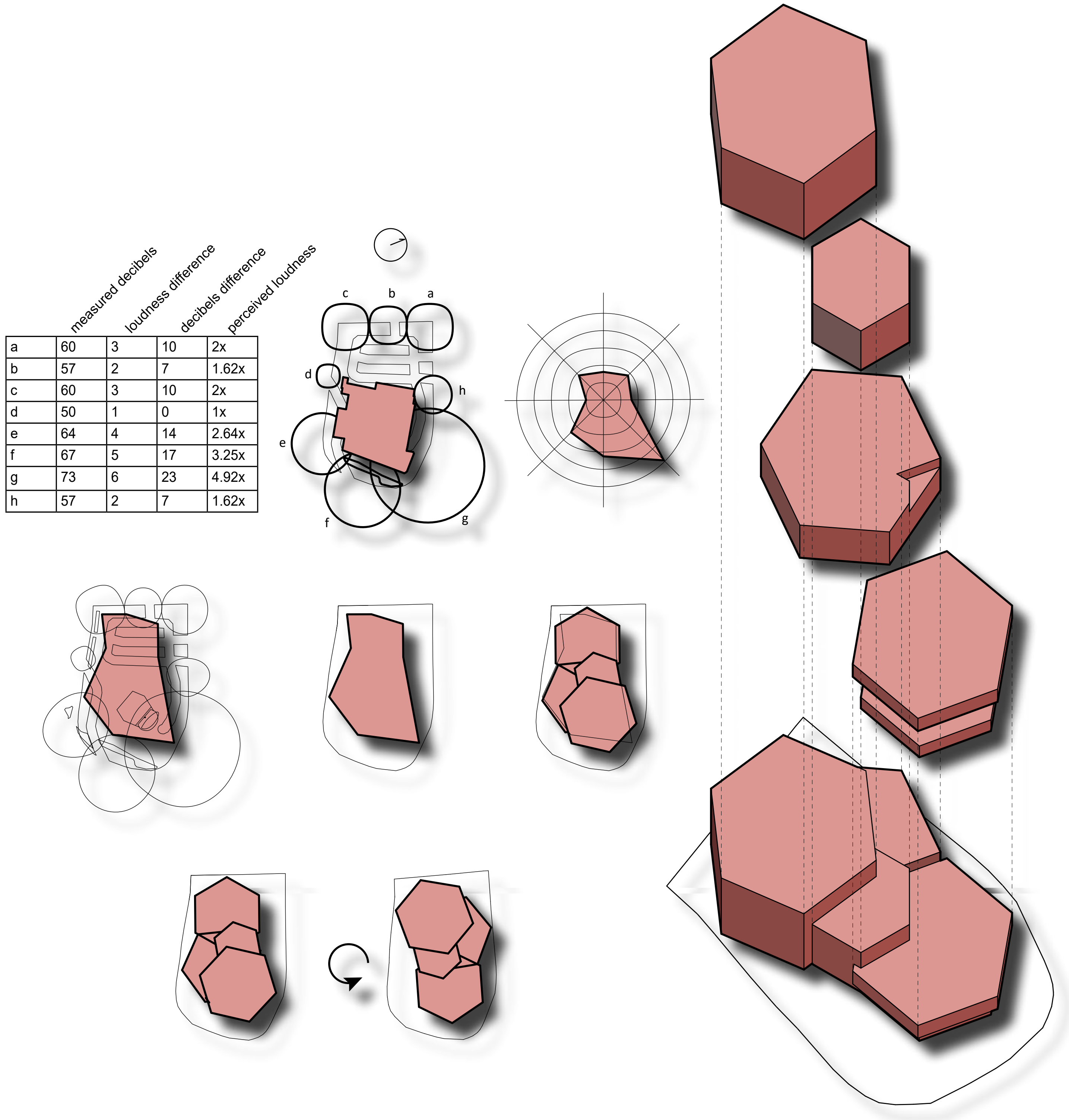
Based on the program and environmental factors, I elected to design my final phase at the seafront of Wellington Central, a block away from the active waterfront and surrounded on all sides by the ever-moving infrastructure of the city. Just a stone's throw away from some of Wellington's most notable cultural venues, I decided that the best location for my music hall would be tucked at the end of Cable Street and Wakefield Street in place of an existing New World supermarket. This location offered the public infrastructural access that would befit a performing arts building, and that infrastructure itself would offer some environmental input to consider in the acoustic analysis of the site. In the same way the program and design has successively evolved and advanced throughout this thesis, I wanted the site to reflect the architectural complexity that this final phase represented in my design research.

Figure 3.04 An isometric and plan view of the building's placement near the downtown Wellington waterfront



My first step in analysing the site was to go out and take measurements of the decibel levels at different points around the site. Although the equipment was not as sensitive as desired, the results were purely for design purposes, and were intensified to generate some visual concepts. This way, my built space that was designed to house sound was just as much defined by the interior acoustics as it was the environmental acoustics. The correlation between sound intensity and geometry was explored through several iterations to determine the best building footprint on the site that still illustrated and reflected the invisible elements of the environment. This resulted in a larger focus towards the waterfront-facing areas of the site, where heavier and constantly-moving traffic made up the bulk of the noise pollution on site. The quieter areas of the site were facing inwards towards the city, where a series of apartment and retail buildings faced the site. With fewer, slower cars in this area, most of the sound was from pedestrians, and was negligible compared to the automotive sounds on the opposite side of the lot. As such, the building was oriented so that the main program, the performance auditorium of the concert hall, was angled towards the quietest part of the site. The entrance and footpaths were oriented to be facing the movement of the city and the access to the waterfront.

Once a general outline was developed from my data, I overlaid a series of hexagonal masses to represent different areas of program on my site, as well as to offer visual and spatial depth to the overall building. The tallest and largest space was intended to house the stage itself, as well as the mechanics surrounding the space to accommodate the kinetic elements. The spaces around and underneath the stage were programmed to be storage and practice areas for the performers. The intermediary spaces were intended to serve as a mix of publicly accessible amenities and program, as well as private offices and functional spaces.

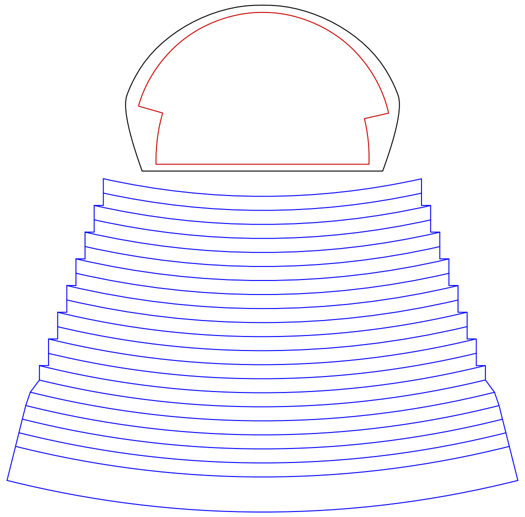


	measured decibels	loudness difference	decibels difference	perceived loudness
a	60	3	10	2x
b	57	2	7	1.62x
c	60	3	10	2x
d	50	1	0	1x
e	64	4	14	2.64x
f	67	5	17	3.25x
g	73	6	23	4.92x
h	57	2	7	1.62x

Figure 3.05 The decibel measurements at the site helped to inform the allocation of program and massing when designing

After the footprint was established, I went on to focus on the concert hall performance space, drawing on multiple precedents to design an interior that was functionally viable but would be maximally impacted by the audio-visual experience of the kinetic elements. The seating facing the stage is placed specifically to prevent any visual obstruction while still offering direct access to the source of sound. Most notably, the walls adjacent to the main hall seats were left unoccupied by balconies so as to introduce the first kinetic elements to the space.

RIGHT >
Figure 3.06 The stage design was based on research and precedents to determine best audio range while still allowing for universal views of the kinetic walls and ceiling and their auditory effects.



A series of louvre-esque panels were placed along the sides of the space where absorption panels would usually be to prevent excessive reverberation and distortion. These panels, as designed in Grasshopper, were affected by the sound volume/acoustic pressure generated from the stage, which was fed into a multiplier component that alters the intensity of the panel's movement.
Due to the fabric and rotating skeleton of the panels, they were able to twist entirely around, drastically reducing and impacting the surface area that would usually absorb the sound coming towards the audience. Because of this and the delay in sound input to allow for adjustments in movement, the moving absorbers actively changed the sound pressure and volume within the space, creating a feedback loop that they were directly incorporated into. The more these panels twist and respond to sound, the more they affected the sound in the space, and thus continually responded to the changes they influenced in the acoustic quality as long as sound was being produced.

Because the louvres were based on two separate starting surfaces but were impacted by the multiplier value, the script was effectively twin processes with a conjoined value slider in the middle so that they would always be adjusted in sync with each other. The panels were created by dividing the surface into a series of vertical panels, which could be adjusted to allow for fewer, wider panels, or more, narrower panels. The more panels or subdivisions, the smoother the gradient of rotation would look along the overall surface. These panels were then further subdivided horizontally, creating the skeletal system that would allow for internal rotation. Each horizontal subdivision was then rotated evenly according to the intensity number slider, and the 'vertebrae' of these panels were lofted vertically to create each individual twisted panel.

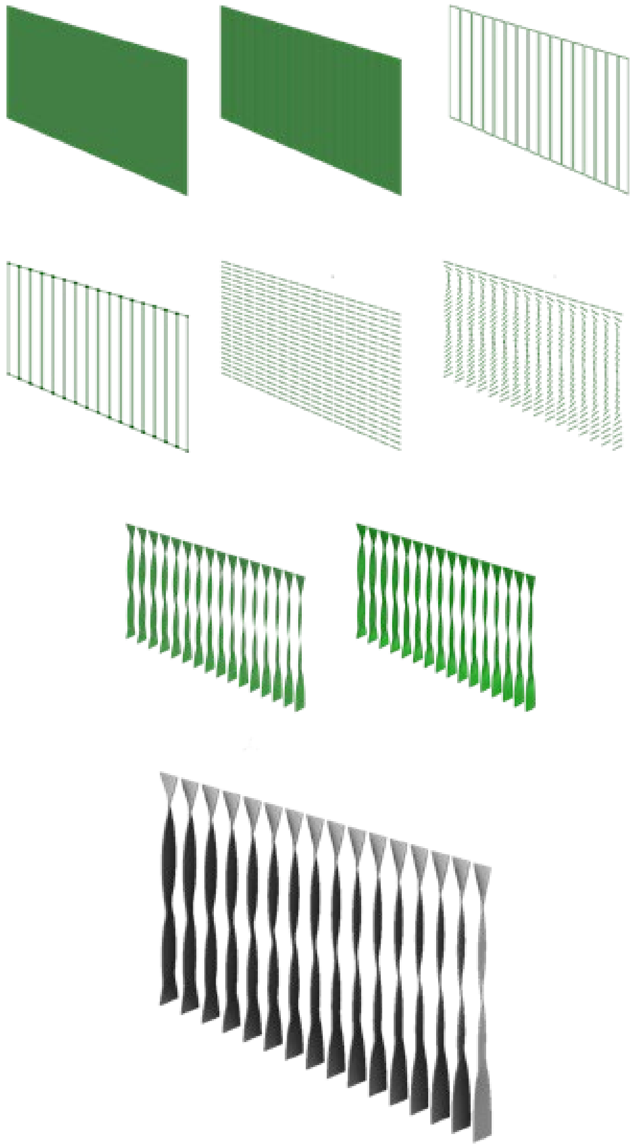


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Figure 3.07 The Grasshopper script subdivided the starting surface into a series of parallel lines that would then twist according to an attractor point, similarly to the paneling systems in the experimental phase. Several geometric transformation scripts were recycled and adapted to suit the needs of the architectural phase.

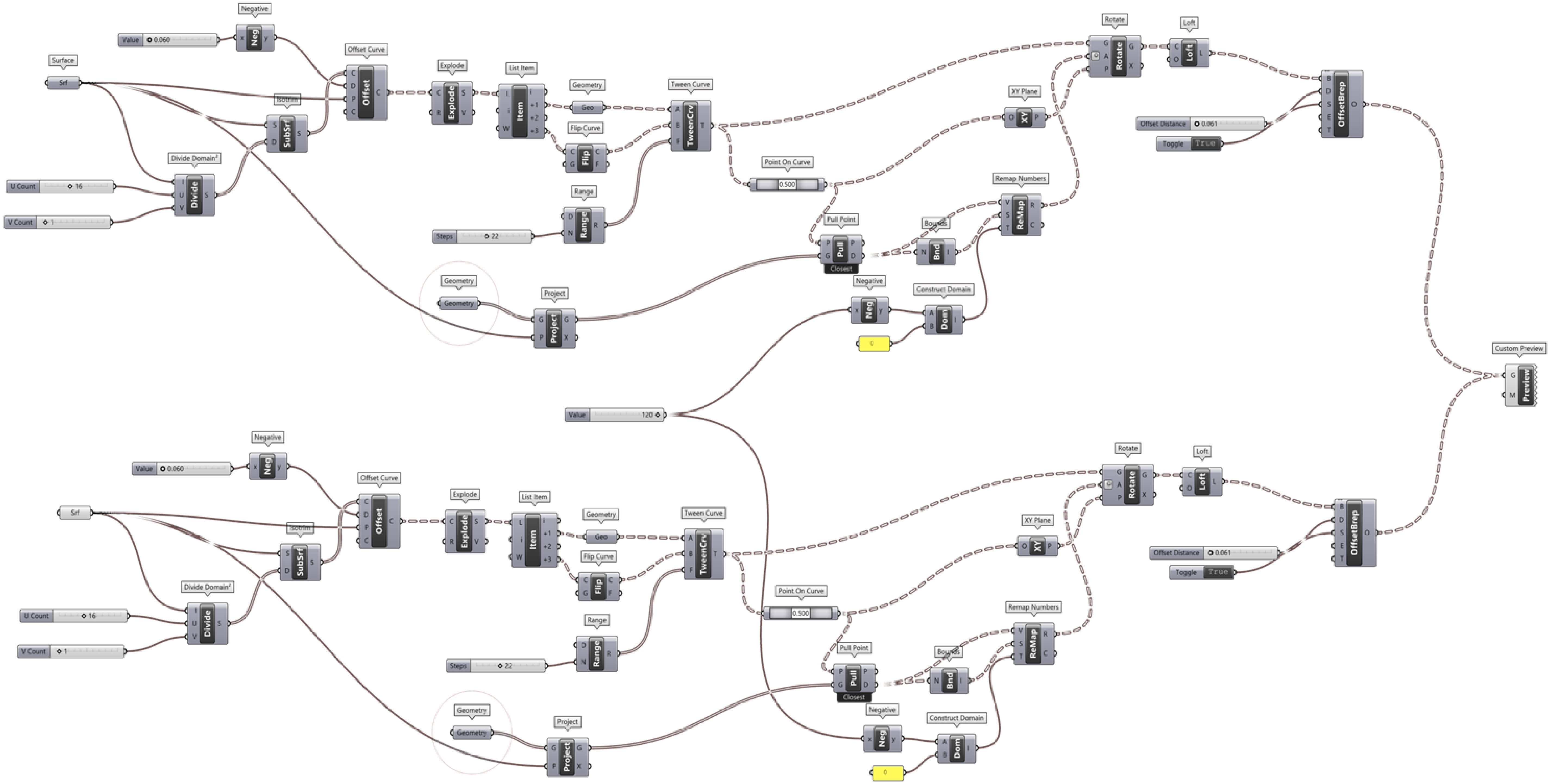


Figure 3.08 The kinetic louvres at the sides of the concert hall that absorb sound were designed using twisting subdivded surfaces which would feasibly be constructed using a skeletal system and a stretchy fabric. The intensity of the twisting is determined by a multiplier, which would be informed by the volume and pitch of the sound coming from the stage.

In contrast to the sound absorption at the sides, the ceiling elements serve as reflectors, so that sound can reach the highest and furthest extents of the room. Rather than designing this with standard static elements that are optimally angled and placed for the best sound quality between the stage and the audience, the reflectors were designed to visually reflect the acoustics of the space. This was accomplished by mapping out the area of the ceiling into a hexagonal grid not unlike the pavilions from the initial abstract phase of my design research. These grid cells were extruded to create masses that would move up and down with hydraulic presses installed in the mechanical space above the stage, and when the masses move together, the ceiling fluctuates and waves like a continuous surface. The more dynamic the sounds coming from the stage are, the more intense and livelier the movements in the ceiling will be to reflect it. The hexagonal cells were created on a surface based on a coplanar angled curve that was positioned over the concert hall space. Because the base surface was not level or coplanar with the world origin/axis, the data tree had to be flattened in order to be read by the components, resulting in the cells being generated on a rectangular surface that was oriented to the world's XY plane. In order to refit the cells to the desired surface, the cells were run through a ShapeIn analysis, similar to the culling and trimming system of the phase 1 geometries. A bREP was created by extruding the base surface upwards, creating a large closed polysurface that would enclose the desired hexagonal cells. From this, the hexagon cells were analysed relative to their containment or intersection with the bREP. A value of 0 meant the cell was inside the bREP, 1 meant intersecting, and 2 was outside. The resulting data was then fed to a culling component that eliminated all cells with a value greater than 0, so that only the cells inside the bREP were kept. From these remaining cells, I generated corresponding surfaces from the boundaries and evaluated the centerpoints of each face. These center points were then moved up or down in a sin(x) function relative to an imaginary attractor point whose coordinates are determined by the detected volume and pitch of the sounds in the room. This created a continuous wave effect across the hexagonal grid, although the bases of each surface stayed level with the ground plane. Each surface was then extruded the same value upwards, producing masses that would move up and down independently, but as a group would appear to move as a singular surface. This was intended to be a continuation of the roofing system from phase two, where the movement of the ceiling impacted both the lighting and the volume of the occupied space relative to the user. This fluctuating ceiling ideally has the similar capacity to drastically change the atmosphere in the same way, generating potential reactions of awe, claustrophobia, and self-awareness in the space.

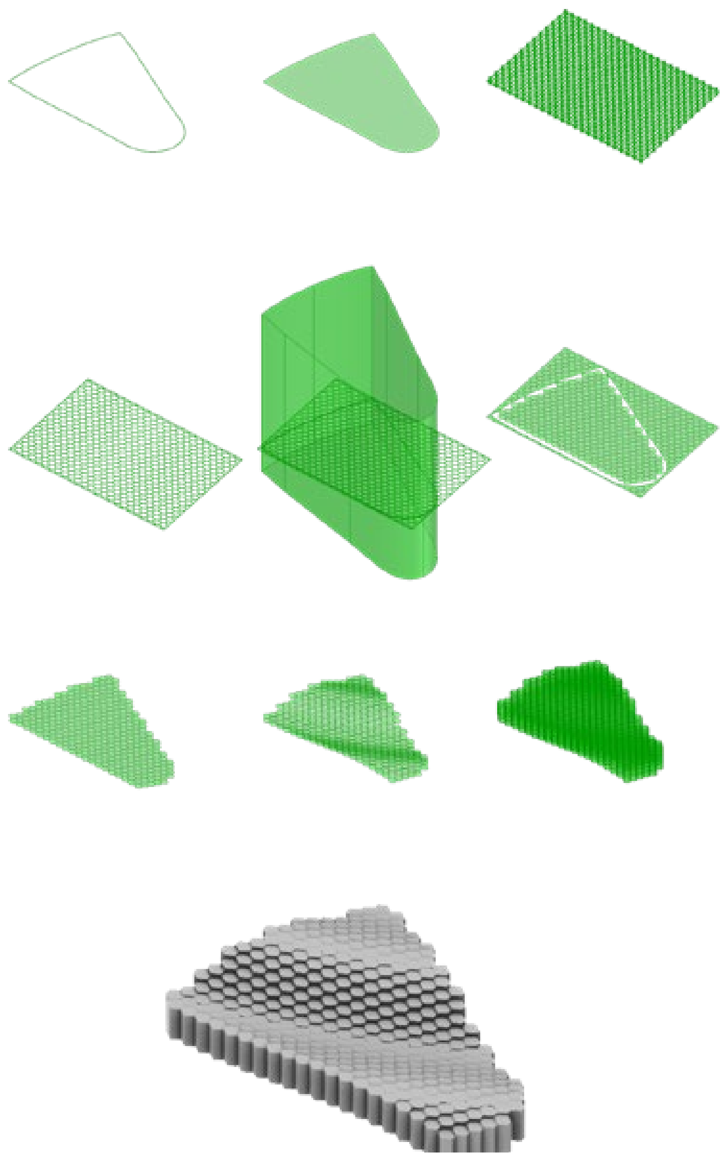


Figure 3.09 Due to the angle of the base surface, the panels had to be projected and reapplied to the surface.The wave of the ceiling is determined by a sine function.

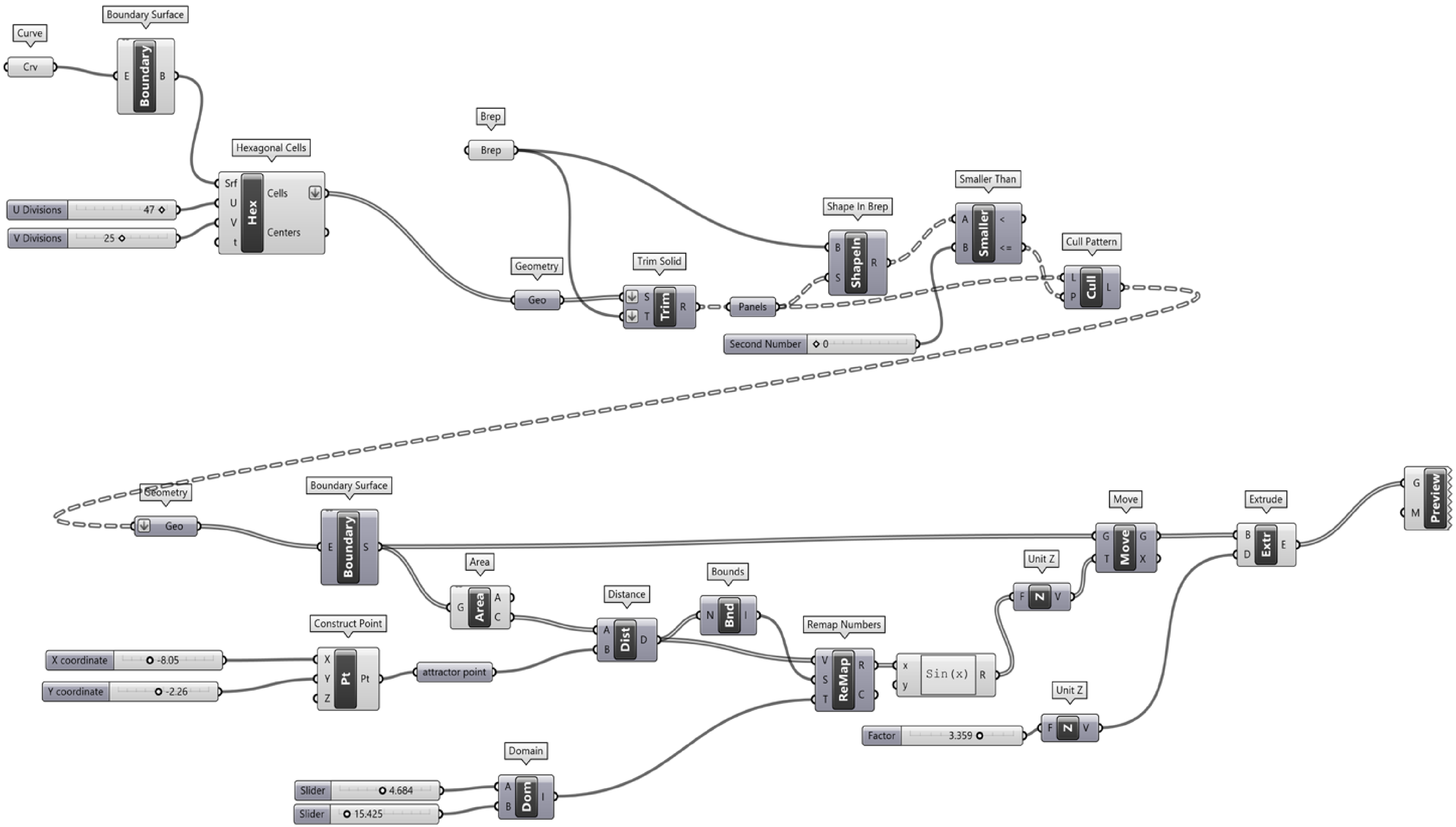


Figure 3.10 The movement of the ceiling panels is determined by an attractor point similar to those from the experimental phase of design. The location of the point is determined by the input of volume and frequency from the stage, and then fed back through a feedback loop of the sound that the ceiling itself altered.

In addition to the kinetic elements of the space that would influence and be influenced by the acoustics, the absorption of the seats and their occupants were also considered when measuring the sound pressure and volume of the space. In a room occupied only by the performer, there would be much less passive absorption, and the sound would bounce around the space much more, creating more dramatic movements in the twisting panels and overhead reflector hexagons. In a completely filled room, the sound would bounce around much less, incorporating the occupants as passive but calculated components for the moving elements to respond to. In an empty room with no performer and no audience, there is nothing at all for the kinetics to respond to. However, an audience without a performer collectively exists in a liminal state of its own; the audience exists to experience and passively influence the space around them while music is playing, but without the performer to provide that music and a sense of temporal passing, the audience is sitting in a space that is not at present meant for them. The space is timeless, but the users continue to experience the passage of time in a way that the room was not intended for. The concept of an occupant exists both as an active and as a passive participant in the spatiality of the concert hall, influencing the start, end, and continuation of the sound, and how the space responds to and influences the ongoing sound. As researched through the relationship between sound and temporality, the music produced in the space created a stopwatch for the visual aspects, triggering the start and finish of their movement, and was a part of the feedback loop that continued that movement. Without human presence to perform, there is no sound, and therefore no movement, rendering the kinetic-intended elements in the room as nothing more than meaningless shapes in a timeless vacuum

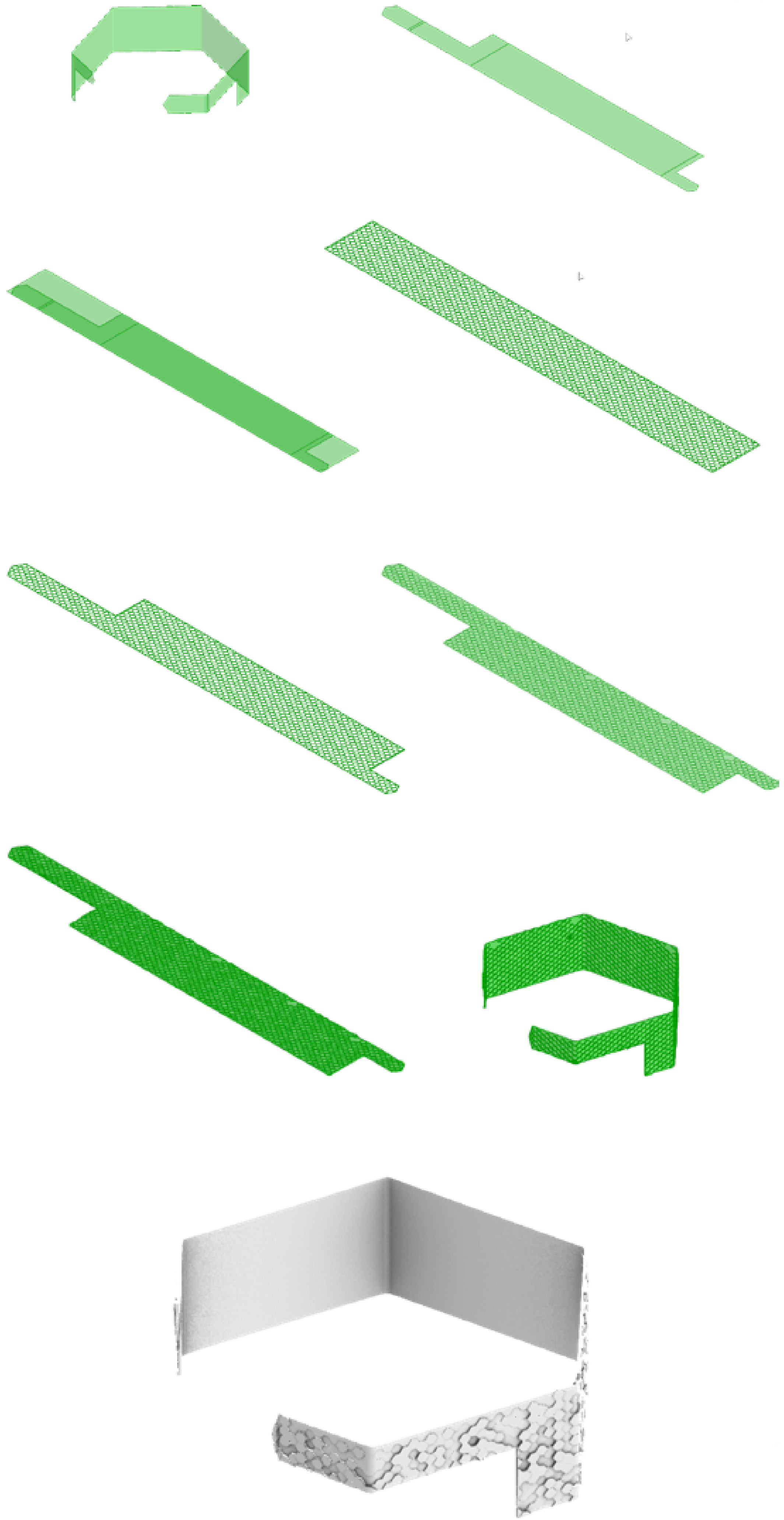
Once the performance area was fully designed, the surrounding program was built around it at the basement level, allowing for enough space and facilities to accommodate the public, the performers, and the employees. This included restrooms, practice spaces, offices, and delivery areas that would all have appropriate access to the concert hall and backstage areas. The upper levels focused more on employee spaces and public amenities, such as eating and drinking spaces, reception, offices, restrooms, and storage. The highest floor additionally offers rooftop access to a terrace garden, where patrons can lounge and dine with a full view of the Wellington waterfront.

The façade of the building was intended to create a gradient from opacity to transparency, with the most natural light penetrating the most public circulatory areas, and no natural light penetrating the performing space or the secure areas around it. The opaque façade was designed in a similar vein to the concert hall's ceiling, with a hexagonal grid overlaid evenly across the intended surfaces, and its pattern is again reflected inside the concert hall in the kinetic ceiling component.

Due to the complexity and sheer number of baked components in the hexagonal façade, the script was broken up into sections to reduce the processing load from beginning to end. Because the base shape was a bREP that could not be easily converted into a workable surface, the bREP was first unrolled and flattened to create a workable surface that the geometry could then later be projected back on to. From the flattened bREP, a bounding rectangle was generated to evenly distribute the UV values of the hexagonal cells on the surface. From there, the hexagon cells of the bounding box were trimmed by the outline of the unrolled bREP, turned into surface faces from the boundary curves, and randomly extruded upwards between 0.25 and 0.75 meters. The resulting geometry was then flowed along the surface of the original upright bREP, producing an evenly spaced hexagonal panel system. However, due to the diverging directions of the original bREP geometry 'walls', the script had to applied twice to two different geometries in order to cover the entire surface evenly. Rather than trim the geometries in Grasshopper, the same script was applied to a secondary bREP that occupied the same position as the first, but affected different surfaces, and the overlapping baked geometry was trimmed manually in Rhino.

RIGHT >

Figure 3.11 The hexagonal facade system had to be done in two parts, as the surface would not unroll properly when the split into multiple directions and stopping and starting at variable heights (rather than a straight up extruded footprint).



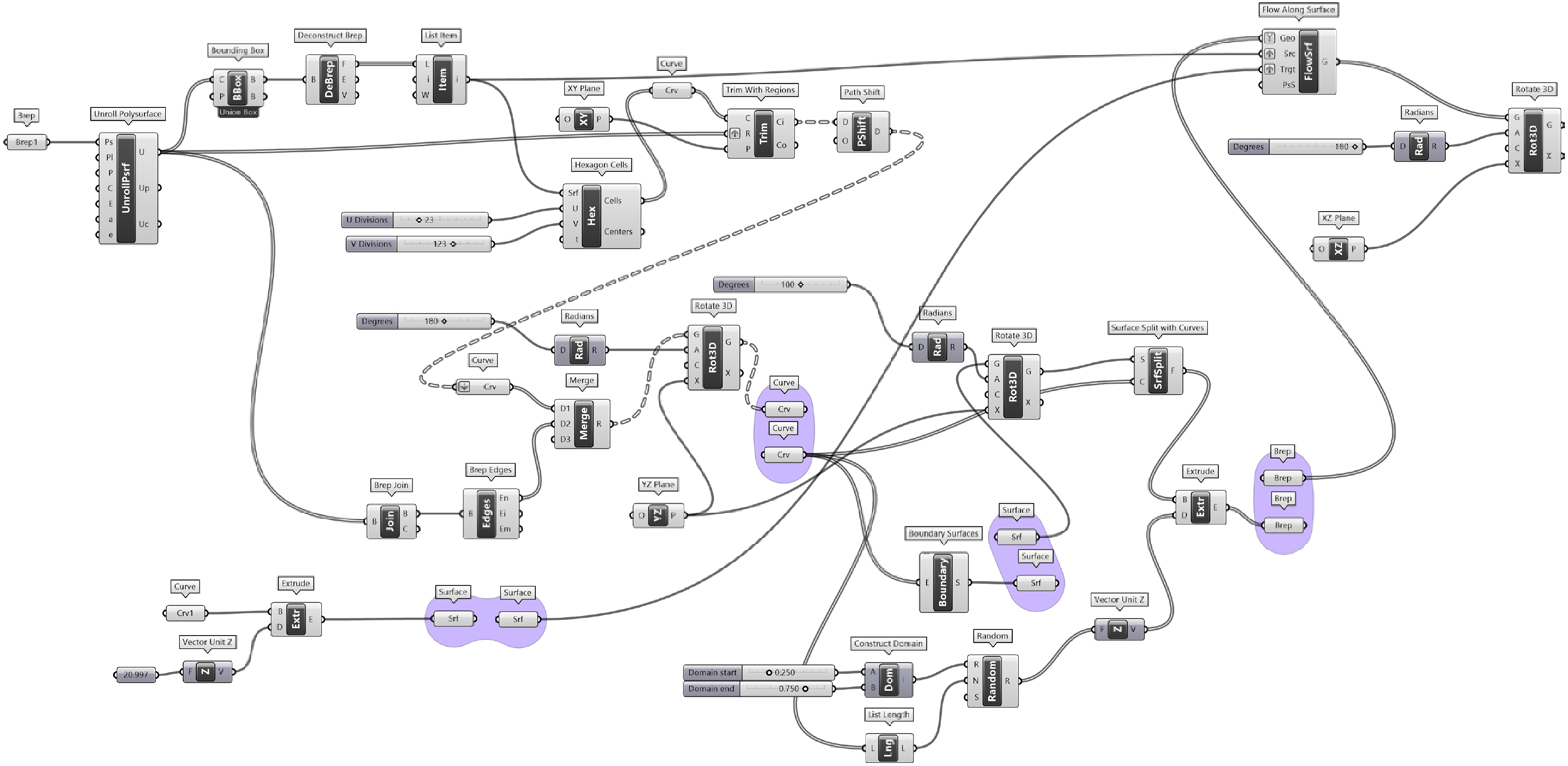


Figure 3.12 Due to the geometric complexity of the facade and its several component stages, the script was broken up to allow for stage-by-stage baking and overall faster processing time. The resulting facades were then manually combined to create the appearance of one continuous surface system.

The panelised façade was applied in a manner that was initially attempted with the hexagonal façade, but would have required far more manual intervention in order to evenly work across the surface of the building. Whereas the UV values of hexagonal cells would have been more difficult to regulate over several different surfaces at different heights and orientations, the panelised façade system had a consistent V (vertical) value of 1 (subdivision), and while the U values did vary, it was much easier to calculate to keep the panel heights approximately similar but otherwise visually indifferentiable. Once the needed surfaces were selected, they were offset from the glazing of the building by 0.35 meters in order to account for the structural geometry that would be fastening this curtain system to the building. After the offset surfaces were horizontally subdivided to be 0.45 meters tall and undivided across the length of the surface, they were then randomly subdivided vertically to create the appearance of panels. These panels were then randomly culled to create gaps in the system, and could be adjusted by the number of panels removed and the random seed that determined the culling. When the panels were complete, the edges of the panels were extruded to create structural geometry that would hold them in place and mount them on the structure of the glazing components of the building. In order to avoid manually trimming the unwanted geometry, a bREP of the buildings general geometrical mass was created and used to trim any geometry that intersected inside of it, using a similar ShapeIn analysis culling system that was utilised for the kinetic ceiling. The material of the panels is a perforated metal, so as to only limit some natural light into the building, but otherwise offer some superficial privacy.

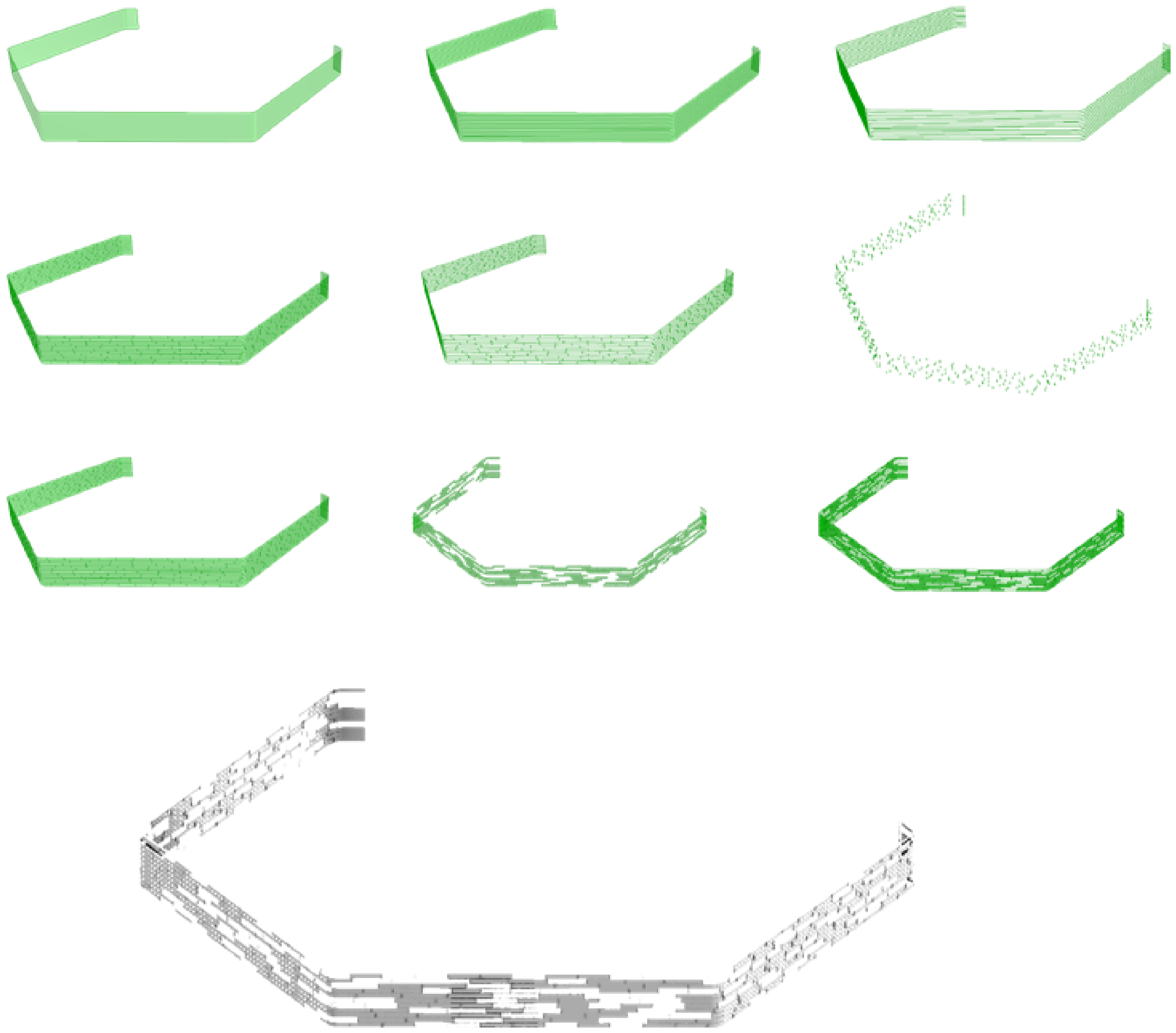


Figure 3.13 The strip panel facade system was executed in a similar way to the louvres on the walls inside the concert hall, by subdividing the surface into parallel structural lines. However, this system instead employed random distances and culling to create a mathematically unique facade. The panels were textured with a perforated material to avoid having to perforate the geometry beforehand, which would have created hundreds of thousands of extra faces and edges.

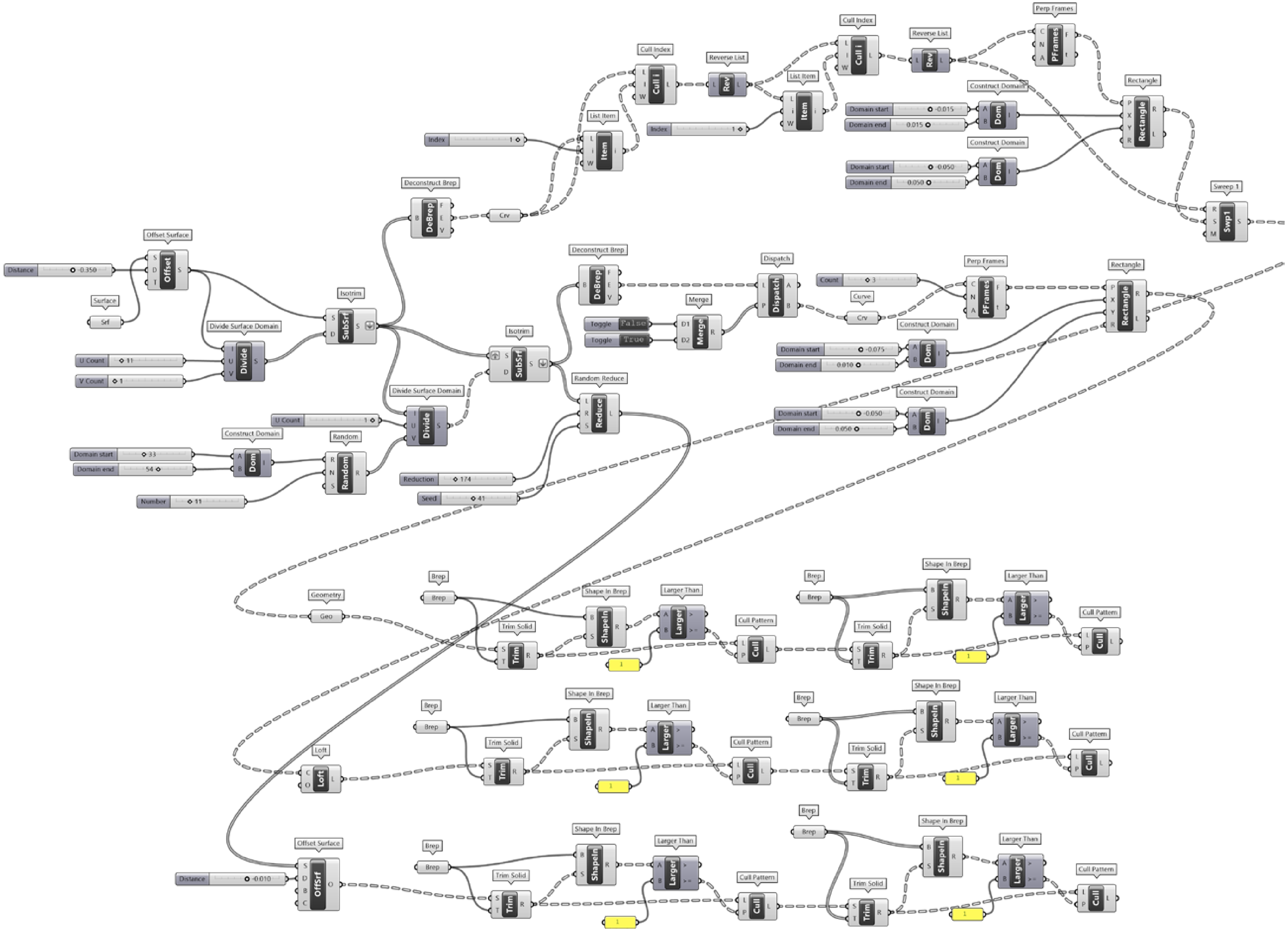


Figure 3.14 The script for the strip panel facade system had three different outputs to bake; The horizontal structural beams, the vertical structural mullions, and the panels themselves.

Figure 3.15 This section features the open atrium conditions as well as the moving ceiling components caught in stasis.

Figure 3.16 A series of sections showing the ceiling in different positions

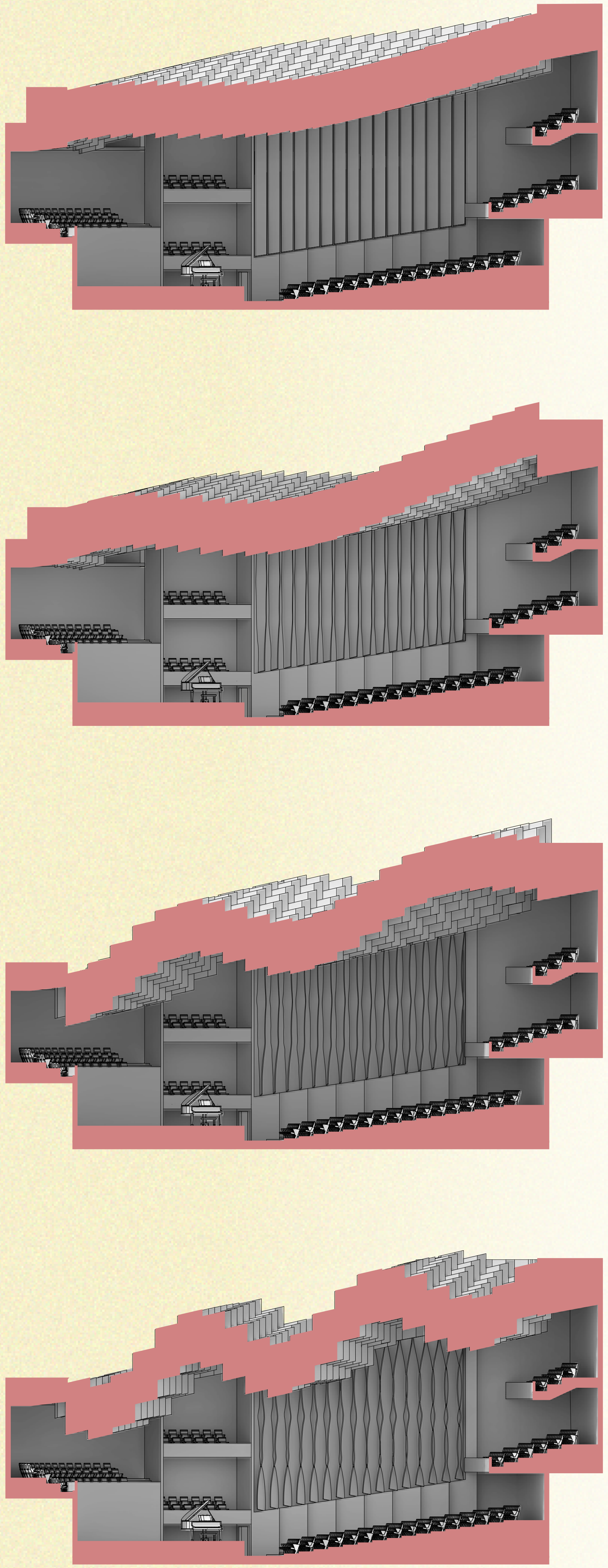
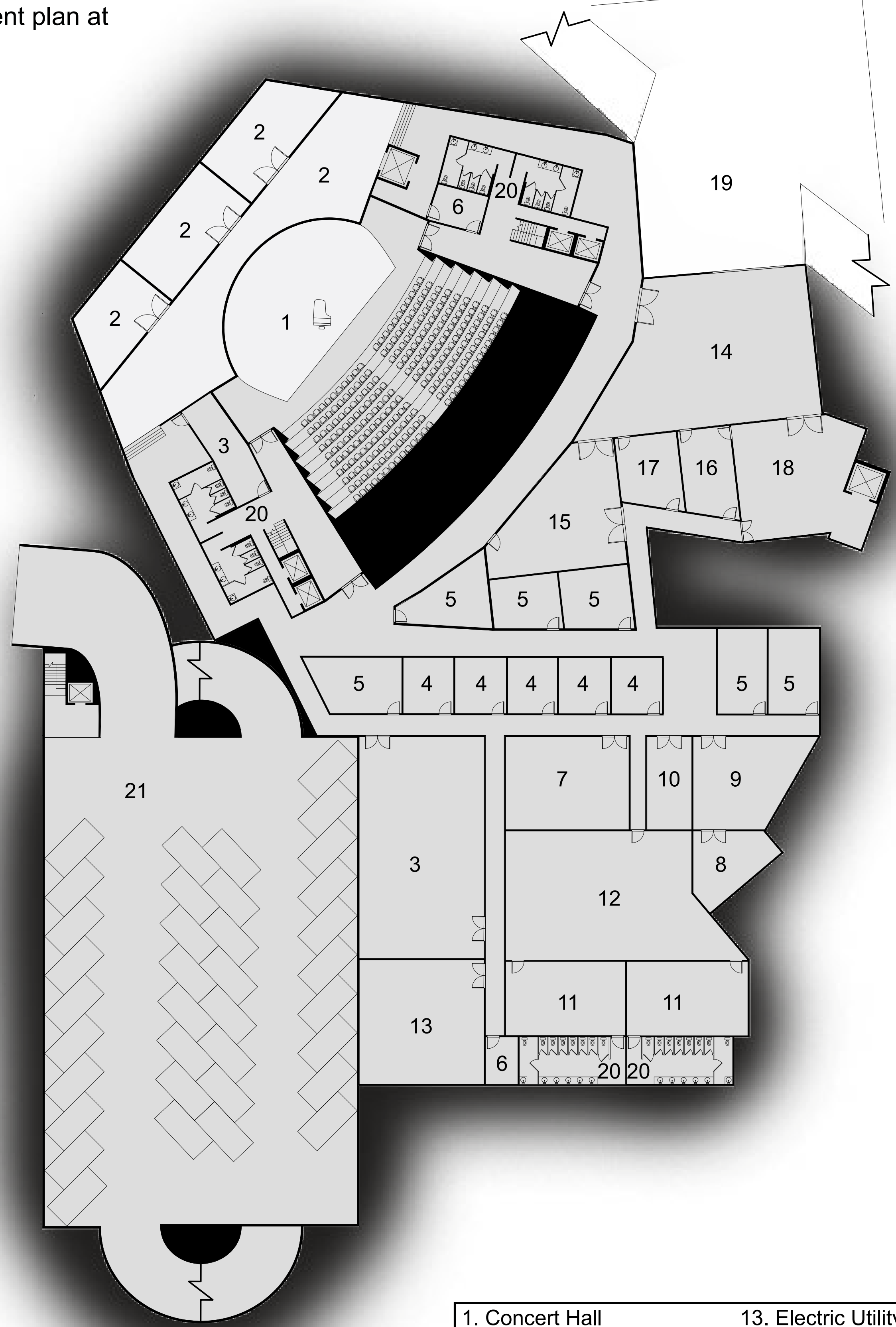
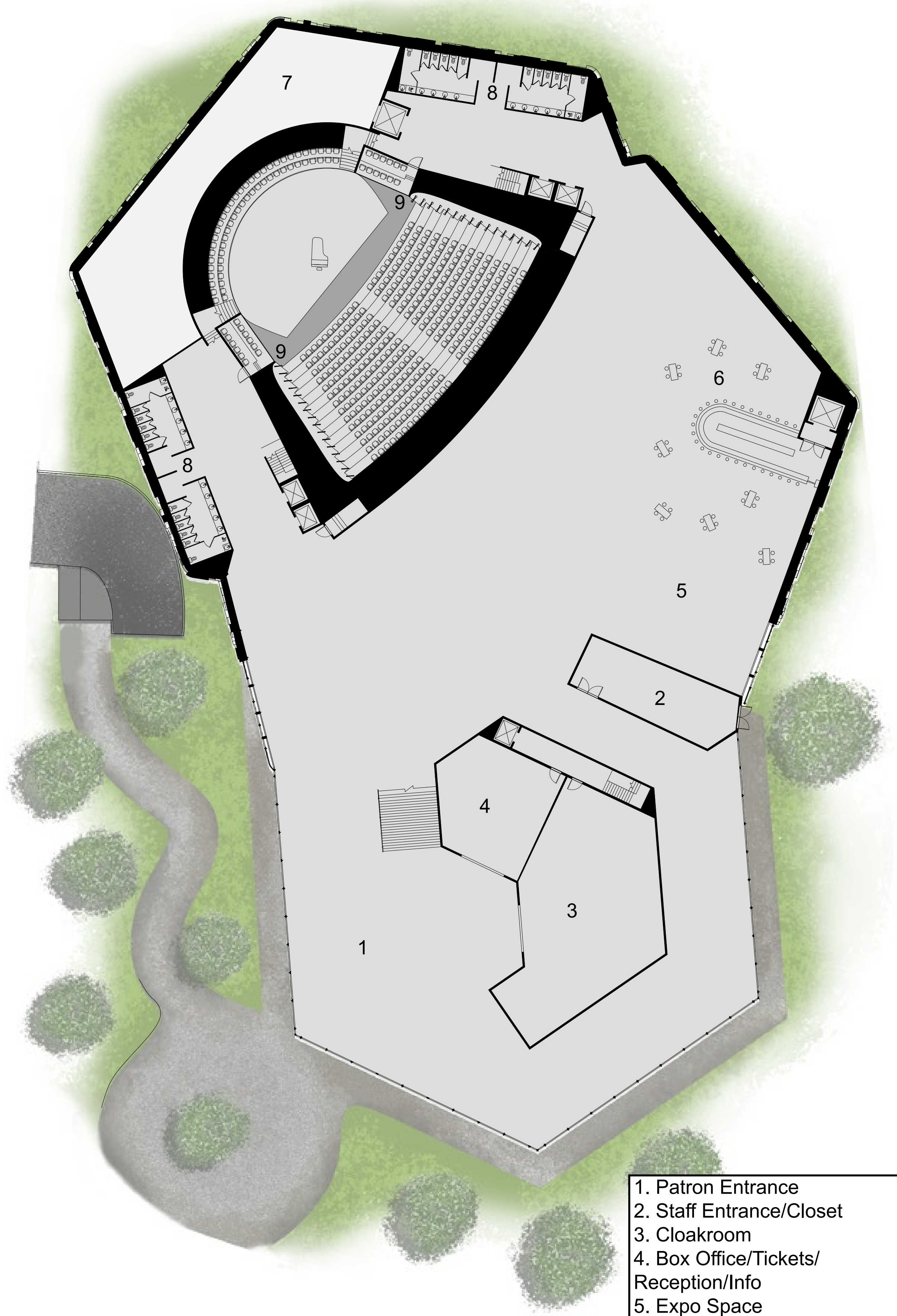


Figure 3.17 The basement plan at 1:6000



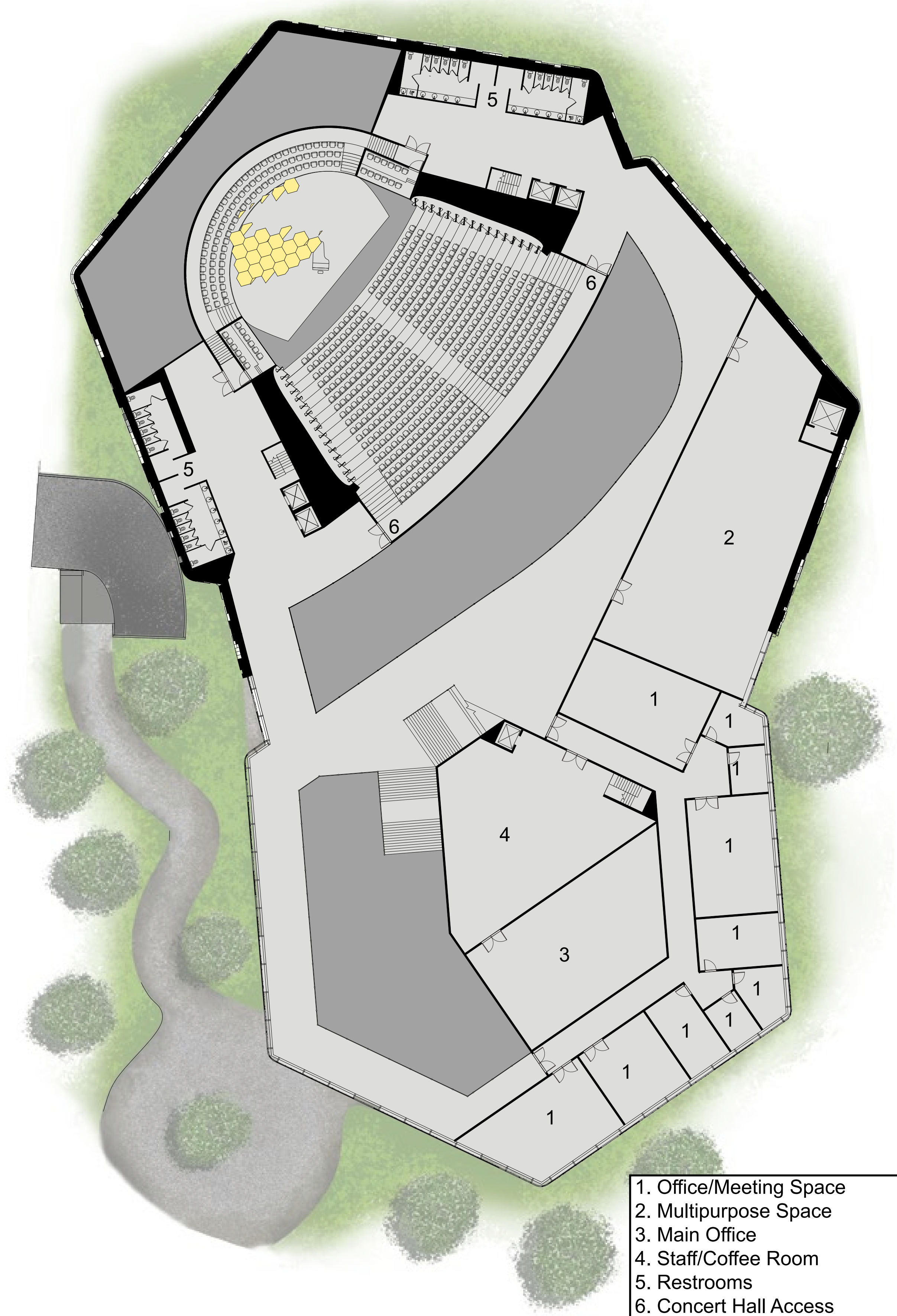
1. Concert Hall
2. Instrument Storage
3. Equipment Storage
4. Practice Room
5. Conductor/Soloist Room
6. Janitor
7. IT Room
8. Tech Room
9. Crew Room
10. Recording Studio
11. Changing Room
12. Performer's Lounge
13. Electric Utility
14. Prep/Warehouse
15. Waste Storage
16. Docking Mgmt/Crew
17. Security
18. Food Storage
19. Delivery/Packaging
20. Restroom
21. Parking

Figure 3.18 The 1st floor plan at 1:6000



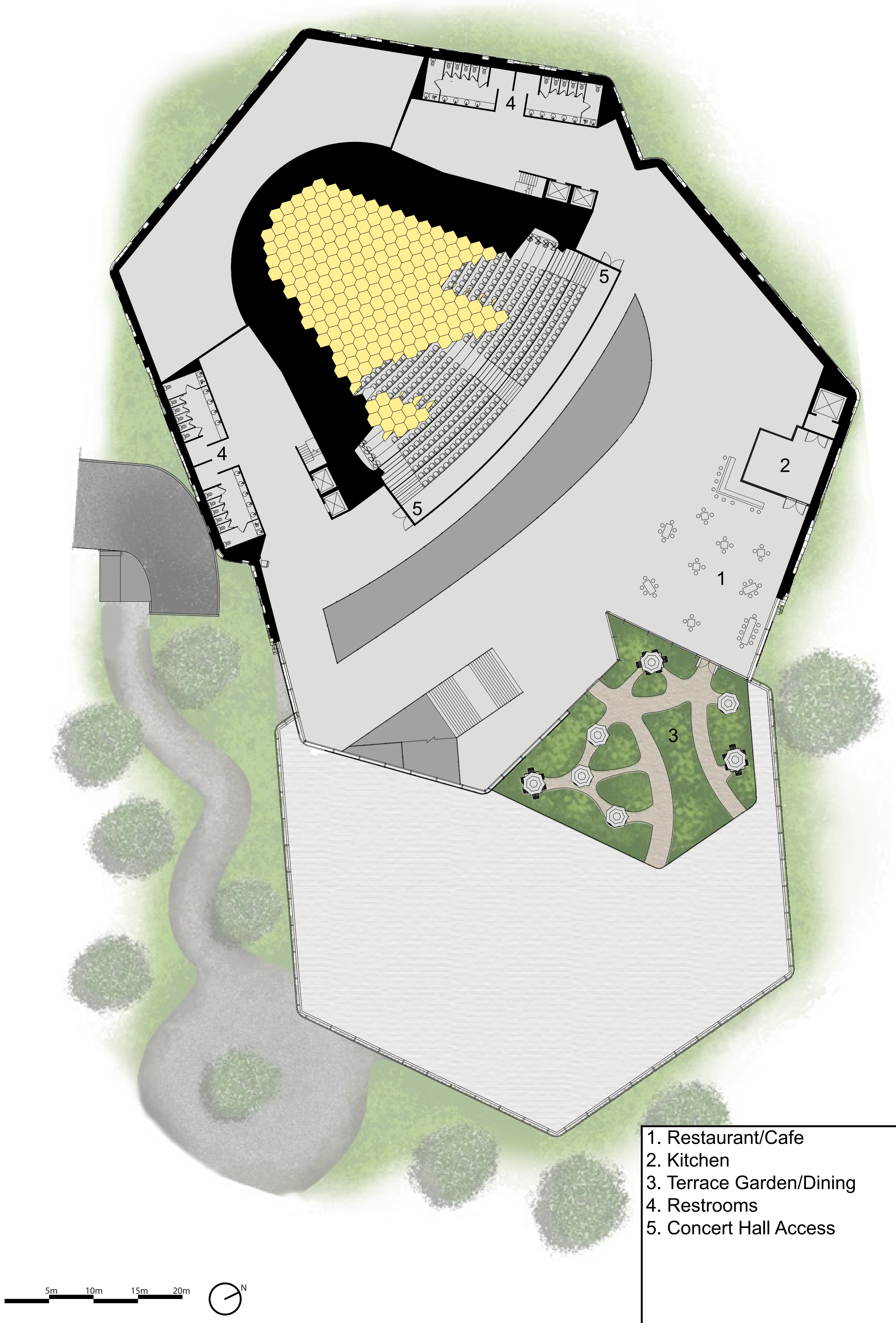
1. Patron Entrance
2. Staff Entrance/Closet
3. Cloakroom
4. Box Office/Tickets/ Reception/Info
5. Expo Space
6. Bar
7. Performer Storage
8. Restrooms
9. Concert Hall Access

Figure 3.19 The 2nd floor plan at 1:6000



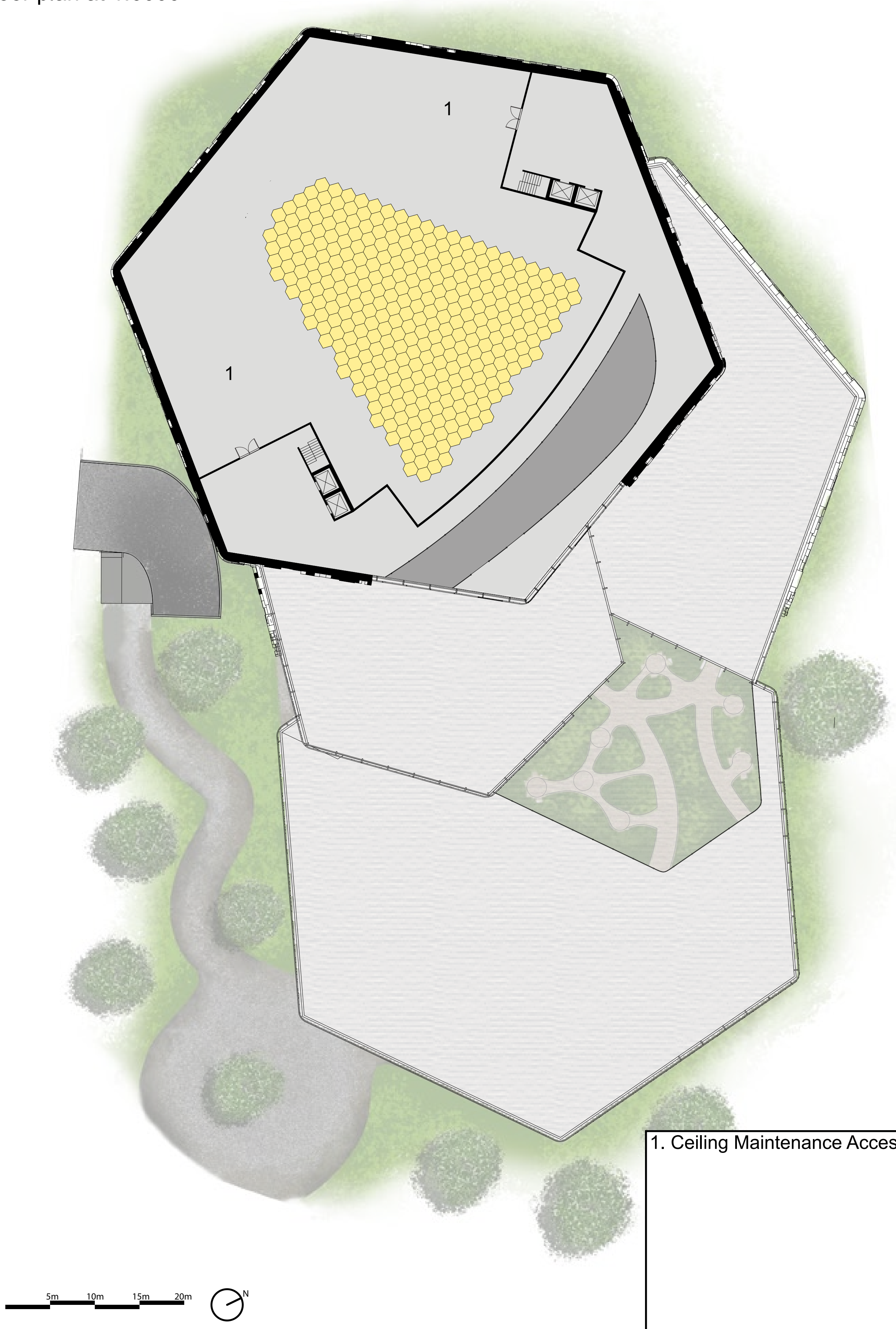
1. Office/Meeting Space
2. Multipurpose Space
3. Main Office
4. Staff/Coffee Room
5. Restrooms
6. Concert Hall Access

Figure 3.20 The 3rd floor plan at 1:6000



1. Restaurant/Cafe
2. Kitchen
3. Terrace Garden/Dining
4. Restrooms
5. Concert Hall Access

Figure 3.21 The 4th floor plan at 1:6000



1. Ceiling Maintenance Access

Figure 3.22 Although the lobby does not feature any kinetic architectural elements, it is programmatically defunct without movement.

Figure 3.23 The bar in the atrium offers a convenient meeting and waiting area for events and performances. However, without waiters and watchers, the area is more shapes than architecture.

Figure 3.24 The more full the audience is, the more environmental sound absorption there is in the space, and the less dramatic and more stabilized the kinetic components will be.

Figure 3.25 An empty auditorium with no sunlight, presence, or sound effectively has no means of keeping time, save for the eventuality of decay.

Affirmation

The performance space of this phase did effectively provide a multisensory experience for users, combining the quantitative changes in environmental sight and sound as well as the psychological responses to atmosphere and user connection to the built space. It was additionally a successful culmination of several Grasshopper techniques that were utilised early on in the research and developed to reflect the architectural complexity of the successive research phases.

However, the real goal of the design was to culminate the theoretical ideologies explored throughout the thesis into an architectural space that addressed all of these concepts. By using sound and music as a marker for time that dictated changes in spatiality, the design reflected the spatial explorations of ready-at-hand/lived space. The space only existed in its intended state when it was occupied and actively in its intended use. When the building is void of users, there is no sound, creating a timeless void where the architecture sits still in a present-at-hand state that does not accurately reflect the architecture as it was intended to be perceived. The changes in volume and space additionally reflected the experimental roofing system from the second phase, but expanded the movement to respond as points on a grid, rather than beams in a row. This allowed for a more architecturally and mechanically complicated kinetic system than had previously been explored, but also expanded on the projected theories that more complicated kinetic architecture would result in more complicated and nuanced reactions to the space. The design research in this phase showed that not only could all of these concepts be applied to a space, but that the space could be continually improved upon for a better and deeper understanding of those concepts.

Criticism

Despite the successes of the third phase design research, there were some limitations and shortcomings that could have overall improved the user experience and expanded on the theories behind the design.

In order to truly build on the concepts explored in phase 2, a more sophisticated lighting system integrated into the kinetic ceiling and wall panels would have further emphasised and visualised the dynamic nature of atmosphere in a closed environment. As it was, the lighting system was static so as to illuminate the theatre safely and the stage effectively, but adding ornamental, nonprogrammatic lights to the kinetic components would have made their movements more visually impactful, both in terms of atmosphere and the visibility of the components. Furthermore, a more sophisticated engineering system for the kinetic elements beyond speculation would have added a further sense of plausibility and depth to the design. As it stands, the current system for the ceiling system is a series of hydraulic pumps arranged on a mechanical floor above the theatre that would be accessible for maintenance, but otherwise largely undeveloped. Likewise, the system for the twisting panels was simply a twisting base and top, and the connective vertebrae in between would gradually deform to meet at a static point in the middle. Neither systems were more complicated than a baseline plausible explanation, but were otherwise not explored or designed in depth. A more complicated and better researched mechanical system would have likely allowed for opportunities for even more complicated kinetic architectural elements to be employed, both as improvements on the existing designed elements and potentially new components throughout the building.

Although the focus was on the auditorium of the concert hall, there was ultimately too much peripheral program that I felt detracted attention away from the kinetic architecture. Although this program was necessary to establish a plausibly buildable design, an even more focused program that isolated the sensory experience without a need for the static built space surrounding it would have potentially been a better setting for the design.

By contrast, the kinetic design felt somewhat limited by ways of it being once again linked to a form of performance art, rather than existing in its own right. Although a concert hall did offer the perfect opportunity to combine an audio and visual experience with the relations of audience and performer, the actual use of the kinetic design was ultimately a bit reductive in potential.

Finally, all shortcomings aside, the best development for this design would have been more in-depth acoustic modelling in order to create a space that didn’t simply alter and distort the sounds in the space, but actually optimised the reflection and absorption to create a universally perfect sonic experience from every seat in the theatre. As a concept, this development would still allow for the subtle environmental changes to come through visually, but would also serve as a practical, applicable use for this speculative design.

CHAPTER 4

CONCLUSION

Conclusion + Projection

This thesis has used a combination of architectural theory and applications of kinetic design to explore and emphasise the relationship between spatiality, temporality, and the user. By exploring these concepts at gradually advancing architectural phases with practical applications of parametric design, I was ultimately able to produce a space that offered a multi-sensory using environmentally-influenced kinetic architectural elements. It proved that kinetic architecture can enhance the temporal and spatial nature of a space by utilising multisensory design, volumetrically and/or programmatically altering the architecture, and incorporating the occupant into the feedback of the kinetic system to combine the spatiality of the kinetic architecture with the temporal reality that the user provides.

Phase 1 took the basic ideas of architectural temporality, spatiality, and its applications and definitions in liminality, and applied it to an abstract pavilion system to try to illustrate these concepts in a more tangible manner. Although it achieved this in a visual sense, the kinetic elements were very limited and offered only superficial visual changes in environment. The movement of the geometries in the space were ultimately little more than shifting façade panels not unlike any kinetic architecture that has been accomplished before. They provided no real change in architectural space, only a change in the appearance of the architectural boundaries. The lack of a real environment additionally prohibited any input beyond user movement throughout the space, which somewhat restricted the suspense of disbelief with the design. It did however develop a lot of the groundwork for later Grasshopper geometries and parametric applications.

Phase 2 built on the ideas of phase 1, and incorporated program to establish user interaction with space, and how changes in lighting and spatial volume impacted those respective programs. The waving roof did actually alter the spatial volume of the architecture in a way that affected the public and private living spaces. It also addressed lighting as an extension of space, serving both as a means of literal illumination and an agent of atmosphere. However, it was again limited to only visual perception, but inspired and informed later volume-altering kinetic design.

Phase 3 combined visual and audio effects of kinetic design, as well as created a feedback loop to reinforce the spatial influence of temporality and the temporal influence that occupancy has. It utilised several of the Grasshopper scripts developed earlier in the thesis to create more complicated architectural facades and kinetic components, and brought through several visual motifs. In addition to the visual changes in environment that the kinetic elements offered, they also actively changed the acoustic properties and quality that they were reacting to in the first place, creating an ongoing and everchanging display that ran as long as the music played. Despite its largely speculative engineering, it could very possibly be developed into something more visually, architecturally, and mechanically complex.

In future research, I believe that more interpersonal utilisations of kinetic architecture can be achieved by incorporating more sensory experiences, and potentially integrating physical kinesthetics. The more combined with the architecture the user can be, the less the architecture exists in a timeless, programless stasis.

Presentation of this future research could additionally be optimised with utilisation of more advanced immersive experiential equipment, such as VR. This way, a user is not simply experiencing the design research through static imagery or pre-recorded animations, but rather can engage, influence, and experience first-hand the feedback loop and optimization of the design.

Figure 4.01 One person acting as both the performer and the audience is all the room needs to come alive.

CHAPTER 5

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