Sound Aesthetic: A Form of Narrative

Ardison Garcia
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School of Architecture
University of Hawai'i at Manoa

Doctorate Project Committee:
Hyoung-June Park, Chairperson
Karen Lee
William Paluch

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We certify that we have read this Doctorate Project and that, in our opinion, it is satisfactory in scope and quality in fulfillment as a Doctorate Project for the degree of Doctor of Architecture in the School of Architecture, University of Hawai'i at Manoa.

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I. ABSTRACT

This research presents an exploration into a novel design methodology that incorporates architecture, multimedia, and interactive digital technologies to create an immersive experience that encourages a spatial and sensorial discourse between user and their built environment. This immersive design method creates a continuous narrative that allows a multi-directional interaction between the two. This interaction creates a "sound" architectural aesthetic that changes the experience of space. The target of the interaction between user and space is the five human senses resulting in an immersive aesthetic.

In order to illustrate this immersive aesthetic, five architectural prototypes were created using an assorted design workflow of parametric programming environment and interactive prototyping platform. This workflow is employed for the creation of five prototypes used for the simulation that has user interaction as an input and formal geometries as an output. These five prototypes target various human senses in order to enhance the immersive aesthetic. Each protoype is evaluated according to individual prototype's ability to stimulate user's senses. Finally, future research based on the outcomes of this research is suggested.

II. INTRODUCTION

2.1 Background

Aesthetics is an aspect integral of design. The obsession of size, shape, and color is proliferated through popular culture and mass media. Digital technologies use new media to create innovative visions that are shaping the way we look at our environments. Architecture has begun to intersect with other design and multimedia disciplines, creating engaging immersive design environments that are challenging our interaction with space. "Today's dynamic signage, electronic facades, three-dimensional signage, and even robotic building features can be traced to the announcement of a new media paradigm in architecture..."[1]

Immersive design[2] - also known as experience design, is the synthesis between design, technology, and architecture. It is where architecture becomes a device for storytelling as narratives are woven in between structure, surface, and material. By incorporating architecture and digital media, immersive design is kinetic, cinematic, informative, and interactive[3], expressing unique and personalized experiences that change based on real-time changing parameters. Immersive design uses a hybrid design methodology that is catalyst for progressive and innovative design solutions.[4] New technologies like motion control/sensing and touch based user interfaces are broadening the mediums that can be used in experience design, releasing architecture from its current frozen state.

Immersive design looks to connect design, environment, and storytelling by dissolving the boundaries between mediums and methods of narrative media. It is difficult to pinpoint "immersive design" because of the broad range of media involved, but one can instead look at the term in a more qualitative way. If a design is immersive, then it should create a narrative between object and user, no matter the medium. Immersive is the state of consciousness where an immersant's awareness of physical

1 Greg Lynn. *Form* (New York: Rizzoli. 2008), 208.
2 *Alex McDowell*, http://en.wikipedia.org/wiki/Alex_McDowell (Nov 2009)
3 Krakowsky, Tali, *Building Fiction: The Architecture of Experience Design.* http://www.buildings.com/tabid/3413/ArticleID/6507/Default.aspx (Sept 2008)
4 ibid

self is diminished or lost by being surrounded in an engrossing total environment; often artificial. This state is frequently accompanied by spatial excess, intense focus, a distorted sense of time, and effortless action.[5] Immersive design seeks to unite digital multimedia and architecture in a seamless aesthetic. This convergence is possible because of the new digital workflow paradigm. From an architectural point of view, this workflow is a step forward from the linear design and construction process that architects are so used to. It is allowing for architects to commingle with other design disciplines.

The term 'immersive design' was first used by production designer Alex McDowell. It is a design philosophy that describes the framework for designers in the field of narrative media: film, television, animation, interactive and gaming and architecture[6]. This design process seeks to do two things:

-To design intact worlds that are coherent, have interior logic, contain history, geography, surface, metaphor, and story, and allow an audience to be fully immersed in both environment and story.

-To put in place a non-linear immersive process that provides a fully collaborative, often virtual production space for creators and the work that they are creating.[7]

Alex McDowell uses architecture to revolutionize movies using tools from the most forward-thinking firms and applying them to production design.[8] Fight Club was the first film which he used digital technology, but it was with Steven Spielberg's Minority Report that he used a fully integrated digital production design department

5 http://www.5dconference.com/forum/construction-designing-immersive-experiences/is-wikipedias-definition-of-immersive-design-correct/#p86
6 http://www.awn.com/articles/production/alex-mcdowell-talks-5d-conference-and-immersive-design
7 *Reviewing fmx/08 Which Happened In Stuttgart, Germany.* http://www.designtaxi.com/news.php?id=18721. (May 2008)
8 Kabat, Jennifer. "Behind the Scenes." Metropolis 09 Sep 2006: n. pag. Web. 5 May 2011. <http://www.metropolismag.com/story/20060911/behind-the-scenes >.

to create visuals. Previsualization, or "previs" uses computer programs such as Maya and SXI to simulate the film production space will look like. Not only does this process make it easier to plan every single physical aspect of the set, but it makes the post production occur before the film wraps up. Information from the digital model can be used to apply digital effects while the movie is still shooting. To create the film environment, McDowell worked with Greg Lynn and his expertise with Maya and digital fabrication. Greg Lynn says, "A lot of those things Alex cooked up for Minority Report, like the 3-D screens, have become real, so I try to bring him in on projects wherever there's a component of Vegas showmanship needed. He looks at technology, computers, and visualization in ways I find intelligent and creative.[9] It is the use of a common digital language that allows for architects to work with other disciplines.

9 Kabat, Jennifer. *Behind the Scenes*

2.2 Project Statement

What makes the spatial experience in great architectural works enriching? The building materials, how spaces are arranged, organized, and their symbiosis with the environment - these architectural characteristics work together to create an experience for the user. As time passes, designers engage in new methods of creating spatial experiences in order to push designed environments towards a new level, to satisfy the desire (for some) to see what is next. Technology – new materials, construction methods, computers – allow designers towards this new level.

Contemporary architecture has embraced technology. Designers use it to create and realize what once was only achievable through pen and paper. The potential that technology offers hasn't been fully reached. Technology has the ability to add a new layer to the experience of space. It is a tool to be used in order to discover (or rediscover) spatial experience. In an immersive design methodology, technology doesn't seek to replace existing conditions within the architectural dialogue; it adds another actor to it, to enhance the relationship between user and space.
In terms of architectural design, technology has allowed designers to push the boundaries of form and structure to new heights. However, the user's relationship within these structures has stayed mostly the same. Contemporary design focuses on form rather than the experience of the user. When interaction is the focus of the experience, the user becomes the focal point of the spatial environment. Environments are no longer just metaphors for dynamism; interaction creates personalization, variation, and continuous spatial reconfiguration.

Experiences of designed environments typically stay the same. One moves – walk, run, sit, stand - through spaces, feels textures with the hands and feet, and hears ambient sounds. This can describe most spatial experiences. In the current experience of designed spatial environments, user's interaction with space is discrete. He or she chooses where, when, and how to interact with the environment. The environment reacts according to this discrete interaction. What this project seeks to create is a continuous user interaction with the environment that engages all five senses in order to create a multi-level experience of a designed environment. Using Rhino 3D, prototypes are designed from the beginning to reinforce interaction. This interaction is made possible by the Grasshopper plug-in and Arduino microcontroller which creates a reaction between users with the Rhino model. The project will use sensor technology embedded within an architectural environment to connect the user with designed spatial environments by taking physical, real world data and translating it into digital information.

The interaction created between user and prototypes will create a unique experience of space which results in a unique aesthetic that occurs only at the specific time, in the specific position which the user occupies the space. The customization of a spatial experience is one that is highly sought in contemporary architecture due to the desire of visual impact.

2.3 Scope/Limits of Research

This project uses Rhinoceros 3D to create the architectural prototypes that are applied to the model spatial environment. The human senses – sight, sound, touch, taste, and smell – and the stimulation of specific senses are what drive the formal qualities of each prototype. After each prototype reaches an acceptable level according to the sensorial simulation, interaction is introduced to each prototype. Using Grasshopper, an algorithmic scripting plug-in for Rhino 3D, the interaction between user and prototype is simulated digitally. The simulation illustrates the possible movements and patterning that the prototype goes through as the user interfaces with each prototype. Once the limits to the interaction are set, the Arduino microcontroller is introduced to gather real world data that will power the digital Rhino/Grasshopper model to react according to this gathered information. The data is collected through multiple sensor types that measure physical information – light levels and distance – and then translated by the computer to react to the digital model. The digital model is then projected onto an architectural surface to simulate the prototype as a real object. The desire to create this hybrid physical/digital model this stems from the limitations in time and skill to create mechanical prototypes. Sample users are then introduced to the hybrid physical/digital model and are left to interact with it. This interaction is then captured and analyzed in order to gauge whether the prototypes achieve the goal of creating an immersive aesthetic.

The user interaction is targeted towards the human senses. Due to the limitations in the research, the senses of smell and taste aren't targeted in the digital simulation. Taste and smell require an actual physical model to test engagement. Due to limiting mechanical knowledge these senses weren't physically engaged. Instead, the stimulation of these senses are only implied in the investigation. The technologies used in simulation are limited to sight, touch, and sound. The lack of familiarity with the mechanical knowledge required in the construction of the prototypes limited to the physical models created.

2.4 Organization of Dissertation

This dissertation starts by introducing immersive design by explaining the existing definition of immersive design, and breaking down the different narrative media related to the field. Using the focus of creating narrative through design and multimedia, a new spatial experience through continuous interaction between user and designed environment is developed. Using an immersive aesthetic workflow of computer applications, prototypes are created and tested in a real world application. A summary is reached gauging if the architectural prototypes successfully applied an immersive aesthetic. The dissertation contains an introduction, four main chapters from Chapter 3 to Chapter 6, and a conclusion.

Chapter 3 introduces the project by introducing immersive design, narrative media, it's relation to the field of architecture, and the growing interest in the field. Chapter 3 goes into specific design technologies that are used to explore formal properties and experiential aspects of contemporary architecture. Chapter 3 discusses the role of technology in the field of future studies and how technology is at the focus of future scenarios. Chapter 3 concludes by explaining the role of digital technologies in humanity's future.

Chapter 4 starts by looking at three case studies of existing projects that span the fields of interactive media and architecture. From the summarization of these case studies, Chapter 4 then goes on to two small design charrettes. These design charrettes were used to create an immersive design methodology to be used in the later development of architectural prototypes.

Chapter 5 introduces the methodology in which the prototypes design and tested at every step of the process – Creation, Interaction, and User Interaction. The specific software used at each step is explained in terms of how it is applied.

Chapter 6 describes each of the four prototypes – Tear, Pixel, Bloom, Twist. Each prototype is broken down into how it was created, the intended stimulation of the five senses, its different states of interaction, and an investigation on how the user interacts with the prototype. After each of the prototypes is analyzed, they are then compared to each other in order to see if one is better than the other in creating an immersive aesthetic. The prototypes are then tested in a real world setting to determine if this is true as well.

The last chapter describes the conclusions drawn from the digital and physical simulations. Future applications are then described. A summarization of the project findings finishes the dissertation.

III. IMMERSIVE DESIGN

3.1. Narrative Media

Learning from Las Vegas opened architecture to popular media by analyzing its physical relationship with flat graphic content and signage. It was the first real analysis of architecture's relationship with popular culture, although it focused on two-dimensional graphics and signage. Today's graphics and signage have advanced since then and have become dynamic signage, electronic facades, and three-dimensional signage, and even robotic building features.[1] Architecture no longer limits itself to the design of buildings and the younger generations are recognizing this. "More young architects than ever are willing to accept that architecture is not uniquely about building,"[2] Architects are starting to look at this interaction between media, technology, and architecture and applying it to their work, creating new forms and styles that are changing the way people look at space.

3.1.1 Film/Video

Architecture and the built environment have an influential role in film. The two are not only backdrop but also are actors in the scene. In his film Rear Window, Hitchcock used commonly encountered architectural elements and used them to manipulate his audiences into acceptance of the tale he wished to tell in the space of a single room. Wong Kar-Wai's In The Mood For Love and Chungking Express uses the city of Hong Kong-cosmopolitan streets, old-city walls, cramped apartments-to convey a moody and atmospheric urban condition. Sophia Coppola's Lost In Translation does the same for the city of Tokyo. The control of the viewer's perspective in film is not only isolated to visual and spatial but extends to temporal as well. 2001: A Space Odyssey and Blade Runner transported viewers to times that didn't exist, but films offer the chance to glimpse at what might exist. As technology advances, so does the ability for films to portray realistic, perfectly visualized scenarios-past, present, or future.

1 Greg Lynn, *Medium,* Pg. 217
2 ibid Pg. 217

Immersive design uses film and video and combines it with and within the architecture to create a new narrative that enhances the user's experience. No longer is video just projected onto a surface or wall, it is a surface or object that moves and plays a part in the spatial event. The intersection of digital and physical design opens up new realities of form and experience. Film has always been an influence on architects and architecture. Charles and Ray Eames, Rem Koolhaas, Bernard Tschumi, and Diller & Scofidio have all used film as a medium to advance their ideas about architecture and urbanism.

In their short film Powers of Ten, Charles and Ray Eames uses film to take us from the atomic to cosmic in nine minutes. In his Glass Video Gallery, Tschumi challenges the feasibility of privacy in a culture where media turns viewer into subject, where the signified becomes the signifier. In his MoMA exhibition Exodus, or the Voluntary Prisoners of Architecture, Koolhaas created dense pictographic storyboards of London's urban fabric which reflects his screen writing background, posing factual and fictional events simultaneously. [3] OMA's Prada Transformer is a rotating structure that transforms to suit the interior function. With each rotation, the Prada Transformer assumes a new structural profile and a new spatial identity. For the cinema portion, the Prada Transformer rests on the rectangular face, while the hexagon, circle and cross act as walls. With its inclined seating auditorium, the rectangle is the ideal ground plan for the cinema. The smaller rectangle elevates the larger hexagon and generates a new object with different dimension and shape.[4]

3.2 Design Technology

Emerging technologies are rapidly progressing architecture and the expression of form and space. Designers are easily creating and constructing objects that few would've imagined possible only a few years ago. These technologies allow for new forms and experiences to be created, thereby expanding the horizons of architecture… The

3 *75 Years of Architecture at MoMA*. http://www.moma.org/collection/browse_results.php?criteria=O%3AAD%3AE%3A6956&page_number=5&template_id=1&sort_order=1
4 *Transformer Prada.* http://prada-transformer.com/assets/pdf/cinema.pdf

digital process allows for architecture, sculpture, and the experience to become one.[5] Technology has made design more efficient. Digital practices have the potential to narrow the gap between representation and building, affording a hypothetically seamless connection between design and making.[6] Designs can be executed in digital space and transition easily into physical form. Today, one does not ask if something is possible to make, instead it is a question of how and how much will it cost. Whether it it's a mobile phone, car, or building, people are willing to pay a premium for designer and new.

3.2.1 Technology: Generative (Algorithmic & Parametric) Design

Mathematics and architecture have always had a close relationship. Both seek to find order and rationale. Architecture is indebted to mathematics, as it is indispensable when it comes to numerical items such as structural calculations and dimensions, as well as aesthetics and proportional systems. From the ancient Greeks and the Golden Section, to Hindu and Renaissance symmetry, to the non-Euclidean geometries and surfaces that litter today's architectural landscape, mathematics has always been a driving force behind design. Mathematics, together with emerging digital technologies and programming language, is once again at the forefront of design.

Geometry, mathematics and art combine to realize the universal forces – regulated, measured and complete and thus shifted everything from the domain of 'sensory origin to that which excludes natural doubt'[7] – corresponding to Wells pronouncement of the imminent movement 'from dreams to ordered thinking[8] Parametric design focuses on the relationships between objects, where when one object in the system changes, the entire systems adjusts accordingly. In algorithmic design, scripting and computer programming language allows simple commands to deliver complex forms

5 http://www.architechweb.com/News/emATWeeklyem/ArticleDetails/tabid/171/ArticleID/6509/Default.aspx
6 Iwamoto, Lisa. *Digital Fabrications*
7 J. Derrida, 'Cogito and the History of Madness' in Writing and Difference trans. Alan Bass, 1978 p.47
8 McNamara, Between Flux and Certitude: The Grid in Avant Garde Utopian Thought' Art History vol.15 no.1 March 1992

while still having control over specific values and quantities. If holistic control and manipulation of objects at all scales defines parametric design, then algorithmic design is a simple rule based method of generating complex forms and structures.[9]

Parametric design, also known as associative geometry, views the digital model as a single database. Embedded within each object is histories and data that allow the model to be "smart," to react to the rest of the model. "The parameters are not just numbers relating to Cartesian geometry-they could be performance based criteria…"[10] Associations are created between individual components, which is useful in the design process. When a change is made with one component, the whole system adjusts to accommodate or reflect that change. However, with these linked relationships comes the issue of constraints.

Algorithmic design is the "repeating dynamic that compiles and reveals a series of embedded orders."[11] In the book *Tooling*, Benjamin Aranda and Chris Lasch break down their algorithmic design processes into seven basic techniques: spiraling, packing, weaving, blending, cracking, flocking, and tiling. Each technique was further broken down further using: 1. A recipe, 2. Shapes made by that recipe, 3. a project that uses that recipe within an architectural context, and 4. Programmatic computer code. These categorizations turn these computational rules into a guideline for construction, making it easier to understand and replicate. "The object of Tooling is to both articulate this resonant field and show that one of the biggest challenges of algorithmic architecture lies in establishing very coherent, pre-material rules that can be used with mathematics and geometry to control this field."[12]

9 Sakamoto, Tomoko. *From Control to Design.* Actar: New York. 2008 pg 3
10 Kolarevic, Branko. *Architecture in the Digital Age: Design and Manutfacturing*. Taylor & Francis: Oxford. 2005
11 Aranda, Benjamin & Lasch, Chris. *Tooling*. New York: Princeton Architectural Press, 2006. Tooling pg.7
12 *Tooling* pg.9

These design tools allows for the easier creation and manipulation of 3-D models. What took hours now takes a few minutes with these methodologies, which aids in an efficient workflow.

3.2.2 Digital Fabrication

The commercial availability of complex software and hardware technologies has created a fast, accurate, and globally transferable design culture and community.[13] Computer-Aided Design and manufacturing have been used by industrial design industries -especially in aerospace and automotive for over fifty years. Although digital drawings have replaced manual architectural drafting for twenty years, it has only been recently that architects have begun to implement these industrial fabrication technologies.

The work of Frank Gehry and Gehry Technologies revolutionized the way architects look at the process of construction. In 2002, Gehry Technologies was formed in order to further expand Digital Project, a specialized version of CATIA (Computer Aided Three Dimension Interactive Application)- design software used by aerospace industry- and reworked to suit the demands of complex architectural endeavors. Digital Project is not only able to handle design aspects of construction but also integrates building codes, mechanical, structural, and cost-criteria aspects. The project that required the intricacy of the software was the Walt Disney Concert Hall, where digital models were perfectly translated to physical mock ups through computer controlled milling machines. This building method revealed that the complexities and uniqueness of surface geometries did not significantly affect fabrication costs, and it is this realization, that one can make a series of unique pieces with nearly the same effort as it requires to mass-produce identical ones, that forms a significant aspect of the computer-aided manufacturing that has since been exploited for design effect.[14]

In the book Digital Fabrications: Architectural and Material Techniques, several

13 Spiller, Neil. Digital Architecture Now. New York: Thames & Hudson, 2008. Print.
14 Iwamoto, Lisa. Digital Fabrications. New York: Princeton Architectural Press, 2009. Print, Pg.6

methods of construction are presented: Sectioning, Tessellating, Folding, Contouring, and Forming. "Architecture continually informs and is informed by its modes of representation and construction, perhaps never more so than now, when digital media and emerging technologies are rapidly expanding what we conceive to be formally, spatially, and materially possible."[15]

The innovation and inventiveness generated by the necessity of trying to resolve the disparity between digital design models and physical construction has led to designers to develop skills that previous generations simply didn't need to know. "Making becomes knowledge or intelligence creation. In this way, thinking and doing, design and fabrication, and prototype and final design become blurred, interactive, and part of a non-linear means of innovation."[16] Designers are starting to use these fabrication technologies to create new tectonic systems and material effects. Surfaces and materials are being articulated using digital tooling, with methods such as punching, water-jet cutting, and laser cutting transforming the aesthetics of design. Whereas in the past the digital process was merely a means to represent a structure, today's digital tools now inform the architecture itself, allowing for innovation and experimentation in the built form.[17]

3.2.3 Interface Technologies

Many innovative technologies are incorporating new user interface techniques to create unique methods of interaction. A good interface focuses not on the technology itself but rather on the user's method of navigation. Natural user interfaces (NUI) are not only moving people away from key based interfaces, they are providing new experiences for users. Touch and motion based interfaces are nothing new to people thanks to the iPod and Nintendo Wii, while speech recognition technology have been available for years. New types of user interfaces are being developed, using the human

15 Iwamoto, Lisa. Digital Fabrications, pg.4
16 Speaks, Michael, "Design Intelligence and the New Economy," Architectural Record (Jan 2001)
17 http://www.architechweb.com/News/emATWeeklyem/ArticleDetails/tabid/171/ArticleID/6509/Default.aspx

body as the main controller, changing the way people live, work, and play.

Touch

The first touch based sensor was developed in 1971 by Dr. Sam Hurst, which he called the "Elograph."[18] Gaining popularity through point of sale systems, ATM machines, and PDAs, touch screens are recognized as a desired method of interface because of its intuitiveness. There are five main types of touch based technologies-resistive, surface capacitive, projected capacitive, surface acoustic wave, and infrared.

Resistive

Resistive touch screens are composed of two flexible sheets coated with a resistive material and separated by an air gap or microdots. When contact is made to the surface of the touch screen, the two sheets are pressed together, registering the precise location of the touch. Because the touch screen senses input from contact with nearly any object (finger, stylus/pen, palm) resistive touch screens are a type of "passive" technology.[19]

+ Works well with finger input
+Low costs
+Multi-touch support

Capacitive Touchscreens

A capacitive touch screen panel consists of an insulator such as glass, coated with a transparent conductor. As the human body is also a conductor, touching the surface of the screen results in a distortion of the local electrostatic field, measurable as a change

18 Bellis, Mary. Touch Screen. http://inventors.about.com/library/inventors/bltouch.htm
19 Resistive Touchscreen. 28 April 2001. http://en.wikipedia.org/wiki/Resistive_touchscreen

in capacitance. Different technologies may be used to determine the location of the touch. The location can be passed to a computer running a software application which will calculate how the user's touch relates to the computer software.

Surface Capacitance

Only one side of the insulator is coated with a conductive layer. A small voltage is applied to the layer, resulting in a uniform electrostatic field. When a conductor touches the uncoated surface, a capacitor is dynamically formed. The sensor's controller can determine the location of the touch indirectly from the change in the capacitance as measured from the four corners of the panel. As it has no moving parts, it is moderately durable but has limited resolution. It is therefore most often used in simple applications such as industrial controls and kiosks. [20]

Projected Capacitance

Projected Capacitive Touch (PCT) technology is a capacitive technology which permits more accurate and flexible operation. An XY array is formed either by etching a single layer to form a grid pattern of electrodes, or by etching two separate, perpendicular layers of conductive material with parallel lines or tracks to form the grid similar to LCD screens. Applying voltage to the array creates a grid of capacitors. Bringing a finger or conductive stylus close to the surface of the sensor changes the local electrostatic field. The capacitance change at every individual point on the grid can be measured to accurately determine the touch location. The use of a grid permits a higher resolution than resistive technology and also allows multi-touch operation. [21]

Motion

There are two types of motion sensors commercially available-active and passive

20 ibid
21 ibid

sensors.

Passive Infrared (PIR) Occupancy Sensors

Passive infrared sensors monitor the patterns of background heat energy in the space. When the sensor detects a significant change in the background heat energy, it responds by automatically turning the lights on or by allowing the lights to be turned on manually. When the background heat energy returns to a stable condition, the sensor turns the lights off. Passive infrared sensors must have a direct "line of sight" to occupants in order to detect human presence. In order to minimize false sensing, the sensors are designed to respond to the heat energy wavelengths that are emitted by humans.[22]

Active Ultrasonic Occupancy Sensors

These sensors broadcast sound waves at frequencies much higher than the human ear can detect. The sound waves bounce off of walls, objects and people. When the frequency of the sound waves returning to the sensor changes (the Doppler Effect), motion is detected and the sensor goes into the occupied mode. When the sound wave frequencies stabilize, the sensor turns the lights off. Unlike passive infrared sensors, ultrasonic sensors can "see" around objects and surfaces as long as there are hard surfaces in the space.[23]

Speech Recognition

Speech is the main method of communication between human beings. Many explorations have been done to use this tool to interact with digital technologies. Early studies used the theory of acoustic-phonetics, which looked at the basic sounds of language and broke them down acoustically. In 1952, Davis, Biddulph, and

22 Efficiency Maine. http://www.efficiencymaine.com/pdfs/OccupancySensors.pdf
23 ibid

Balashek of Bell Laboratories built a system for isolated digit recognition[24] using the formant frequencies measured during vowel regions of each digit. Format frequencies are the natural modes of resonance that occur during speech. Since that time, speech recognition technology has grown to accommodate the unlimited variations that occur in human language. The hidden Markov (HMM) model is the method that the majority of modern speech recognition technology uses. HMM is a doubly stochastic process which models the intrinsic variability of the speech signal as well as the structure of spoken language in an integrated and consistent statistical modeling framework.[25]

3.3 The Future

Future [fyoo-cher]
-Noun
1. *Time that is to be or come hereafter.*
2. *Something that will exist or happen in time to come*

The philosophy of predicting the possible, probable has been the topic of discourse for as long as history itself. These discussions seek to understand what is likely to continue, what is going change, and what is novel. From politics, economics, religion, philosophy to entertainment and the media, people want to know what tomorrow holds, whether it's through ritualistic practices or through more scientific means. Intellects have debated and discussed these forecasts, what the future will really be like, but we will never know until the day comes.

24 K. H. Davis, R. Biddulph, and S. Balashek, Automatic Recognition of Spoken Digits, J. Acoust. Soc. Am., Vol 24, No. 6, pp. 627-642, 1952.
25 L. R. Rabiner and B. H. Juang, Statistical Methods for the Recognition and Understanding of Speech, Encyclopedia of Language and Linguistics, 2004.

3.3.1 The Future: Futures Studies

The scientific study of the future breaks down "the future" into separate components, analyzing specific areas that will affect the future. Futures study is foremost an extrapolation, where trends and limits are set to create a framework for what is to happen. Throughout history there have been many oracles, prophets, and psychics, people who are looked to for answers about what is going to happen. From the Delphic Oracle, who delivered hysterical oracles induced by vapors, or to the prophet Muhammad, or to Nostradamus and his famous prophecies, these people are famous for their claims about what is to come. However, the world has changed since those days. Changes in the environment and society have become more and more complex which is requiring a proper, more educated claim to what our future will be like.

The first of the modern futurists, Marquis de Condorcet (1742-94), appeared in the French Enlightenment. Condorcet said that in order to forecast the future, we must understand the past in terms of society and the social trends that occur instead of individual events. "What happens at any particular moment is the result of what has happened at all previous moments, and itself has an influence on what will happen in the future"[26] His views on the future applied scientific rationale instead of religious or ceremonies based on history, views which still resonate with modern futurists. Condorcet believed that "the growth of knowledge, due to scientific discovery and education, was the chief cause of social progress in advanced countries."[27] There are several reasons why Condorcet is considered the pioneering futurist. His predictions aim for the long-run future instead of short-term trends without setting a time line. Most of his predictions have, over time, come true because of his methods. These methods are the basis of modern future studies.

Futurists are not interested in making predictions based on speculation but instead-

26 Condorcet, de Marquis. Outline of an Historical View of The Progress of the Human Mind. Charleston: Nabu Press, 2010. Print

27 Beckwith, P. Burnham. Ideas About the Future: A History of Futurism, 1794-1982. Burnham Putnam Beckwith, 1986. Print

using rational techniques and methods-want to seek a zone of potentiality, a more intelligent way to think about the future.[28] These methods are called futuristics, which starts with four basic assumptions:

- The future which actually occurs will be determined partly by history and physical reality, partly by chance, and partly by human choice. The relationships among these factors will vary according to the amount of time one is looking ahead and the nature of the choices made.
- At any given moment, therefore, there exists a range of alternative futures which might come about. History and physical reality determine which futures are in that range. Chance and human choice will determine which one of these possible futures will actually happen.

- True "freedom of choice" only exists when one understands the full range of options available and the possible consequences of each option.

- The purpose of futuristics, therefore, is not to predict the future, but rather to improve our understanding of the range of alternative futures which might come about and of the role that both chance and deliberate choice might play in either achieving or avoiding any particular future.[29]

However, because of free will, futurism will never be an exact science. It is based upon probability studies, past and present events, social and political behavior. Scientists have begun to adopt some of the methods pioneered in physics to understand and predict the behavior of large groups of people.[30] Scenario building, Systems thinking, Analogy and Evolutionary models are all tools used prediction. All of these methods are used together in "the alternative futures approach" to forecasting.[31]

28 Draper L. Kauffman Jr. Futurism and Future Studies. National Education Association, 1980. Print
29 Wofsy, McElroy, and Sze, Science [14 February 1975], pp.535-536
30 Ball, Philip. Futurology gets a little more exact. Guardian.co.uk. 2009 January 29. http://www.guardian.co.uk/education/2004/jan/29/research.highereducation4 (Dec 2010)
31 Wofsy, McElroy

Trends are an important aspect to the alternative futures approach. Trends are used to find consistent tendencies and patterns over a certain amount of time, to give clues on where things will or will not go. Analysis of trends does not require a lot of specialized knowledge. Identifying trends serves two purposes-one is to give a generalization of what's ahead and the second is to find the causes and alternatives to these trends, if they exist at all. Obtaining information from experts of specific backgrounds is another aspect of the alternative futures approach. Futurists use a variety of techniques for sampling expert opinion, most of which are variations on the commission and the poll.[32] A commission is useful as it gathers experts who share ideas with each other, placing anything discussed under examination by intellects. Polls are less specific than a commission, but hit a wider range of demographics. Combining the information gathered into "scenarios" and "alternative futures" is the next phase in the alternative futures approach.[33] This step is where similar alternatives are grouped together, which makes it possible to arrange similar alternatives into believable sequences. The last stage in the method is to convert each sequence into a scenario, a "fictionalized version of an alternative future."[34] These scenarios are usually written from the viewpoint of someone who has lived or is living in the scenario. Having alternative futures performs two functions. Although there are many possible futures, most of which are hard to imagine, people tend to rely on one image of the future and having alternatives "can be an indispensable aid to the imagination…"[35]

Futurism

"Beauty exists only in struggle..."

Futurism began in Italy by Filippo Tommaso Marinetti and his 1909 writing Futurist Manifesto. A celebration of speed, machinery, violence, youth, and industry, this manifesto exalted the new and looked down onto the past. For a generation raised

32 Philosophies and Aims for Education
33 Futurism and Future Studies Draper L. Kauffman Jr. pg.15
34 Toffler, Mead, and Shane, Phi Delta Kappan [Vol. 54, January 1973], pp. 326-339
35 Futurism and Future Studies Draper L. Kauffman Jr. pg.15

on the idea of Italy's once and future greatness, the prospect of Italy becoming a European power and a modern capitalist society was too great to be passed up. No other movement of the early twentieth century clearly attacked art for art's sake aestheticism, or so aggressively addressed mass audiences through a variety of popular cultural media.[36] Marinetti rejected traditional values as a guide for the future, he firmly believed Italy could only become reborn from a complete erasure of the past.

History and historic precedence had no part in the Futurist vision: "…daily visits to museums, libraries and academies (those cemeteries of wasted effort, calvaries of crucified dreams, registers of false starts!) is for artists what prolonged supervision by the parents is for intelligent young men, drunk with their own talent and ambition. For the dying, for invalids and for prisoners it may be all right. It is, perhaps, some sort of balm for their wounds, the admirable past, at a moment when the future is denied them. But we will have none of it, we, the young, strong and living Futurists!, …And so, faces smeared with good factory muck—plastered with metallic waste, with senseless sweat, with celestial soot—we, bruised, our arms in slings, but unafraid, declared our high intentions to all the living of the earth:[37] This disregard for the past was to help reinvigorate culture, to reinvent self. Utopia was the desire for the Futurists, and they envisioned a violent apocalypse or catastrophe before this utopia could be realized. Renato Poggioli, an Italian literary critic, says, "…the futurist manifestation represents, so to speak, a prophetic and utopian phase, the arena of agitation and preparation for the announced revolution, if not the revolution itself."[38]

MANIFESTO OF FUTURISM

1. We intend to sing the love of danger, the habit of energy and fearlessness.
2. Courage, audacity, and revolt will be essential elements of our poetry.
3. Up to now literature has exalted a pensive immobility, ecstasy, and sleep. We intend to exalt aggresive action, a feverish insomnia, the racer's stride, the mortal leap, the punch and the slap.

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36 Poggi, Christine. Inventing Futurism: The Art and Politics of Artificial Optimism. New Jersey: Princeton University Press, 2008.
37 Apollonio, Umbro, ed. Documents of 20th Century Art: Futurist Manifestos.
38 Renato Poggioli, The Theory of the Avant Garde, trans. Gerald Fitzergerald (New York: Harper and Row, Icon Editions, 1968)

4. We affirm that the world's magnificence has been enriched by a new beauty: the beauty of speed. A racing car whose hood is adorned with great pipes, like serpents of explosive breath—a roaring car that seems to ride on grapeshot is more beautiful than the Victory of Samothrace.
5. We want to hymn the man at the wheel, who hurls the lance of his spirit across the Earth, along the circle of its orbit.
6. The poet must spend himself with ardor, splendor, and generosity, to swell the enthusiastic fervor of the primordial elements.
7. Except in struggle, there is no more beauty. No work without an aggressive character can be a masterpiece. Poetry must be conceived as a violent attack on unknown forces, to reduce and prostrate them before man.
8. We stand on the last promontory of the centuries!… Why should we look back, when what we want is to break down the mysterious doors of the Impossible? Time and Space died yesterday. We already live in the absolute, because we have created eternal, omnipresent speed.
9. We will glorify war—the world's only hygiene—militarism, patriotism, the destructive gesture of freedom-bringers, beautiful ideas worth dying for, and scorn for woman.
10. We will destroy the museums, libraries, academies of every kind; will fight moralism, feminism, every opportunistic or utilitarian cowardice.
11. We will sing of great crowds excited by work, by pleasure, and by riot; we will sing of the multicolored, polyphonic tides of revolution in the modern capitals; we will sing of the vibrant nightly fervor of arsenals and shipyards blazing with violent electric moons; greedy railway stations that devour smoke-plumed serpents; factories hung on clouds by the crooked lines of their smoke; bridges that stride the rivers like giant gymnasts, flashing in the sun with a glitter of knives; adventurous steamers that sniff the horizon; deep-chested locomotives whose wheels paw the tracks like the hooves of enormous steel horses bridled by tubing; and the sleek flight of planes whose propellers chatter in the wind like banners and seem to cheer like an enthusiastic crowd.

Futurists expressed their ideologies through manifestos, from which art was extracted and interpreted through various mediums such as painting, sculpture, literature, theatre, and fashion. Painting was the first medium to express these ideas, followed by sculpture. Architecture was also used to articulate Futurist views on government and society.

In 1914, Italian architect Antonio Sant'Elia wrote Manifesto of Futurist Architecture. Out of all the examples of Futurist work, Sant'Elia's heroic drawings of future cities best exemplify the Futurist doctrine of speed and machinery. "We have to reinvent and rebuild the futurist city like an immense tumultuous construction site that is agile, mobile, and dynamic,"… Sant'elia's Manifesto takes up the theme, exalting "oblique and elliptical lines" because "they are dynamic;" "because of their innate qualities, they contain an emotional power that is a thousand times greater than that of perpendicular and horizontal lines."[39] Influenced by the work of Otto Wagner and Adolf Loos, his work expressed a utopian landscape "condemning the "perpendicular and horizontal lines, cubic and pyramidal shapes that are static, grave, and oppressive,"[40] Sant'Elia joined the military and fought in World War I, where he was killed in battle. His association with Marinetti and the Futurist movement were questioned after his death, but it is his work that still stands out today.

Sant'Elia created "a monumental representation of a glacial, timeless, country,"[41] with the Citta Nuova (New City), his most famous work. The metropolis is heavily emphasized in Futurist programmatic writing. The city "is the lyrical celebration, the plastic manifestation of an absolute novelty: speed; of a wonderful new spectacle: modern life; of a new fever: scientific discovery,"[42] Large open urban spaces were given absolute importance in Futurist writings, and the Citta Nuova exemplified this. Sant'Elia's drawings were of buildings not as single, isolated elements but as tenements, railway stations, bridges, roads, and power stations interconnected with a large web of walkways, stairs, and railway tracks. Although Sant'Elia never completed a holistic version of his vision, each of his works was fragments of a greater whole and it is necessary to look at his entire body of work to grasp his "unitary reality."

39 Ibid pg33
40 Ibid pg33
41 Ibid pg21
42 Ibid pg21

We must invent and rebuild the Futurist city like an immense and tumultuous shipyard, agile, mobile and dynamic in every detail; and the futurist house must be like a gigantic machine. The lifts must no longer be hidden away like tapeworms in the niches of the stairwells; the stairwells themselves, rendered useless, must be abolished, and the lifts must scale the lengths of the facades like serpents of steel and glass. The house of concrete, glass and steel, stripped of paintings, and sculpture, rich only in the innate beauty of its lines and relief, extraordinarily "ugly" in its mechanical simplicity, higher and wider according to need rather than the specifications of municipal laws. It must soar up on the brink of a tumultuous abyss: the street will no longer lie like a doormat at ground level, but will plunge many storeys down into the earth, embracing the metropolitan traffic, and will be linked up for necessary interconnections by metal gangways and swift-moving pavements.[43]

Ongoing movement is a prevalent theme throughout his work. "Sant'Elia's entire compositional method tends toward the representation of movement: transfer, slipping, and rotation processes recur and tend to suggest the movement of masses.." "…It is a brand new city, the cult of mechanical movement, a tendency to reduce even human presence to fluency.."[44] His drawings use oblique perspectives to heighten the sense of length and speed, creating unique scenes that express a sense of freedom, an escape from the rigor and heaviness of the time. The author feels he has to put the birth of a radically new architecture in its proper historical context. He feels that this cannot be done by messy "line manipulations", because the new architecture is anti-classical and anti-traditional and is not subject to and is not subject to "historical continuity", but is based on "the strength of materials,"… bringing about a "profound change in environmental conditions." This change provokes "the formation of a new ideal of beauty which abhors that which is "monumental, heavy, or static."[45] Energy was another theme in Futurism. Sant'Elia series of hydroelectric plants celebrate these structures, depicting them as "complex fantasies that simultaneously celebrate the colossal power of the electric plant while suggesting that in confrontation with this

43 Antonio Sant'Elia: "Manifesto of Futurist Architecture." Apollonio: Futurist Manifesto, pg.170
44 Ibid pg21
45 Ibid pg21

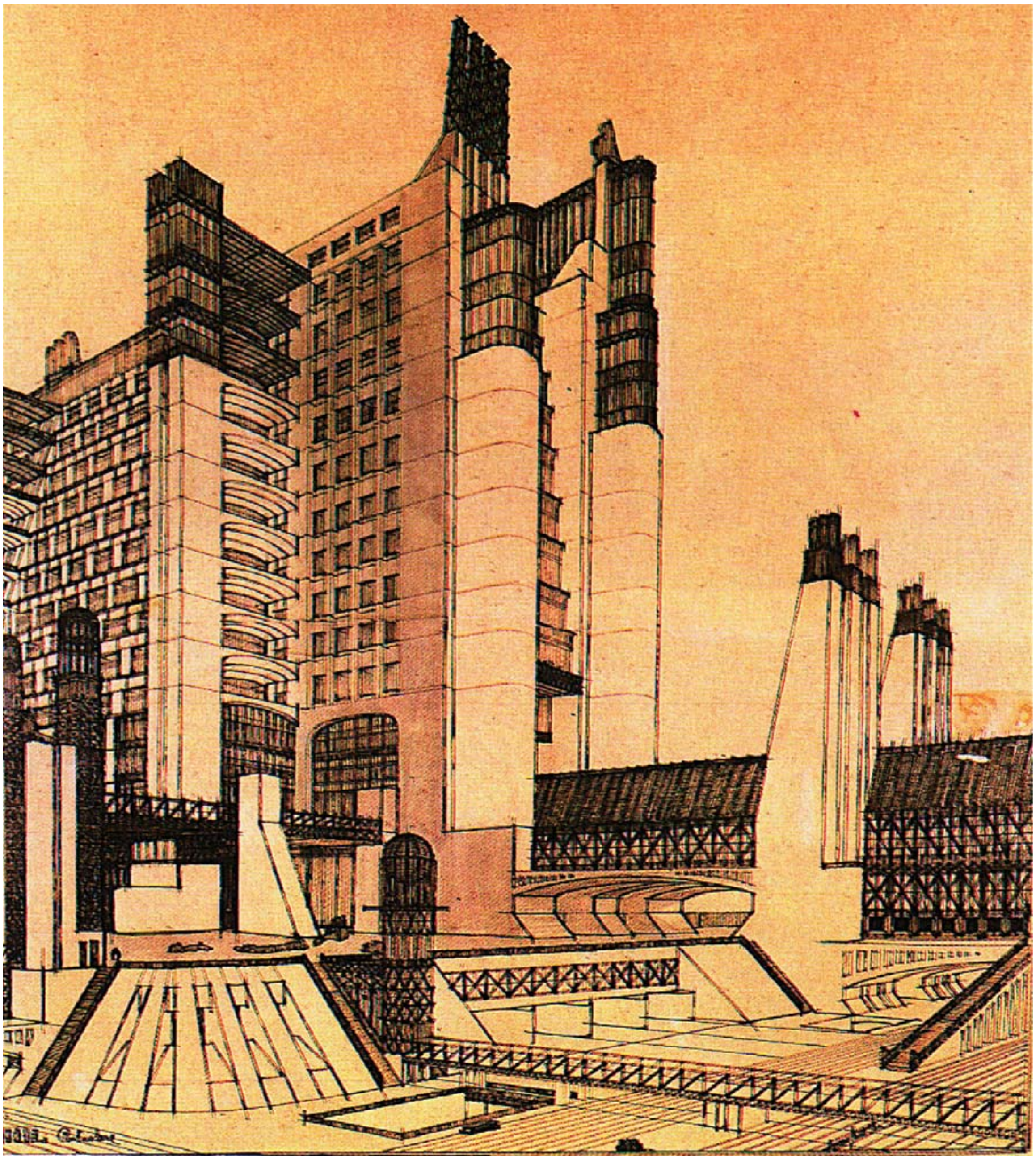


Fig. 3.1- Drawings of Antonio Sant'Elia - *La Citta Nuova*

technological world, the human subject is insignificant.[46] The futurists forecasted a future where the world was governed by electricity, where no one suffered from hunger, poverty, or disease.

The drawings of Sant'Elia have a fantastical quality to them, still futuristic by today's standards. He knew that his vision couldn't be realized at the time, which freed him from the constraints of gravity and reality. This allowed him to create new ideas in a time when people were only looking into the past, and never into the future. Sant'Elia's affiliation with Italian fascism helped to shape his visions of how the future is to be like. It is the departure from what has existed, an embracing of technology to create a mechanistic urban environment that people move through like a factory. Citta Nuova aimed for the future and gave us a vision that has influenced designers how the future could look like. Lebbeus Woods says of Sant'Elia's drawings, "…he evokes a world very much like our own: fast changing, obsolete even as it is created; a world in which architecture is neither reassuring symbol nor comforting shelter, but a swift-moving vehicle of change, an instrument whose very instability creates a need for inventing new ways to be. It is a vision that architects, still burdened by history, have been hesitant to give form to, because it challenges their most secure beliefs."[47] Although Sant'Elia's drawings do not necessarily portray his writings perfectly, they still gave a hope for the possibility of a new world. "From architecture conceived in this way no formal or linear habit can grow, since the fundamental characteristics of Futurist architecture will be its impermanence and transience. Things will endure less than us. Every generation must build its own city."[48]

The Future: Media/Pop Culture

The current state of the world isn't one people would have predicted to be. If it were possible to go back in time and show people what modern society looks like, they

46 Poggi pg 50
47 Woods, Lebbeus. Sant'Elia's Words. 2009 November 2. http://lebbeuswoods.wordpress.com/2009/11/02/santelias-words/ (Oct 2009)
48 Antonio Sant'Elia, Pg. 45

would be thoroughly disappointed. Media and pop culture are the causes for this general disenchantment of what the future is. "Utopian (and dystopian) ideas are usually presented in novels about imaginary perfect or vastly altered societies, remote in time or space."[49] The forecasts that have been presented in literature and film have given people extremely high expectations of what the future may hold for humanity.

The Future: Literature

Utopian thought is much older than futurist one. The word utopia is from Greek, ou, meaning not or no, and topos meaning place.[50] Utopia is used to describe a place of ideal perfection especially in laws, government, and social conditions, while dystopia is defined as "an imaginary place where people lead dehumanized and often fearful lives."[51] The first literary use of utopia appeared in Sir Thomas More's Utopia (1516).[52] In this book, Utopia is an island in the Atlantic Ocean home to a perfect society where everyone is concerned with public welfare. Utopian writers have hypothesized scenarios that futurists try to verify. The difference between futurism and science fiction literature is that futurism takes what exists and tries to explain how the world will realistically change over time, while these "stories ignore the long process of change and describe in detail an imagined, radically different, future society."[53]

In his book Profiles of the Future, Sir Arthur C. Clarke states his Laws of Prediction: "When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong. The only way of discovering the limits of the possible is to venture a little way past them into the impossible. Any sufficiently advanced technology is indistinguishable from magic. [54]

49 Beckwith, P. Burnham, Pg. 284
50 http://www.merriam-webster.com/dictionary/UTOPIA
51 ibid
52 Ibid pg.3
53 Ibid pg.3
54 Clarke, Arthur C. Profiles of the Future. New York: Henry Holt & Co. 1984. Print.

Clark states that H.G. Wells as the person who brought up the study of the future as an academic discussion. "Anticipations was the first comprehensive and widely read survey of future developments in the short history of predictive writing…represented a peak in human self-awareness," says Clarke of Well's writing Anticipations of the Reactions of Mechanical and Scientific Progress upon Human Life and Thought.[55] The subject matter ranged from futuristic transport to world order, but his most crucial thought was about the government. "By the close of the 20th century, he foresaw the collapse of capitalism and the nation state system in great technologically advanced total wars that the tycoons and the politicians could not, ultimately, understand or control. Power would slip through their fingers. They would be swiftly replaced by the technically competent, by scientists and engineers and managers, who would learn from their errors and build a world state of peace and plenty."[56] Well's body of work shows his fascination with the future as well as his ability to correctly forecast events. In The Shape of Things to Come, he wrote of a war started by Germany and Poland and six years later, World War II broke out. The World Set Free read of a "ruinous world war, which almost obliterated mankind. Out of its ashes mankind rose again and won salvation through world government."[57]

Aldous Huxley's Brave New World (1931) describes a utopian future where society operates in an eerie efficiency. Reproduction is an act of mass production in this novel. People's future is a predetermined process, instilled from the time they are artificially inseminated to their education as small children. Banned in many countries, including Ireland and parts of the United States,[58] A Brave New World spoke of sexual acts as a recreational activity that everyone can enjoy and taking soma, a drug that induces the characters in the novel to enter a stupor that renders the user idle. "By this time the soma had begun to work. Eyes shone, cheeks were flushed, the inner light of universal benevolence broke out on every face in happy, friendly

55 Wagar, Warrrn. H.G. Wells and the Genesis of Future Studies. 1983, Jan. 30. http://www.wnrf.org/cms/hgwells.shtml (Nov 2009)
56 ibid
57 ibid
58 Lombardi, Esther. Banned Books. http://classiclit.about.com/od/bannedliteratur1/tp/aa_bannedbooks.htm

smiles…"[59] Society has become a science, where people are experiments that can be controlled and emotions are no longer permitted. Love and family, husband and wife, mother and child are terms that Huxley's society views as obscenities.

Sir Arthur C. Clark's views of the future were mystical and cosmical. Technological innovation and scientific breakthrough are prevalent themes in his work, as is the idea of humans having contact with extra terrestrial life forms. In 2001: A Space Odyssey (1968), Clark teamed with Stanley Kubrick to create what Kubrick calls "the proverbial good science fiction movie."[60] Based on Clark's earlier story called The Sentinel, Clark and Kubrick co-wrote the book and screenplay simultaneously. The main theme of the book looks at human development over a long period of time, from ape-men to modern man, to ephemeral being. The story focuses on the future-1999 and 2001- and the space voyage of explorers. The novel presented forecasts of the future, how technology has both positive and negative ramifications as well as the advancement of space technology and space travel. 2001: A Space Odyssey described to the reader a familiarity with the physics involved with space travel and an optimistic view of astronautics. The most well known character is probably HAL 9000, the computer of the Discovery One, a robot who felt the emotions of a human. He was programmed to lie, conflicting with his internal rationale, and causing him to question, and ultimately kill, the humans that instruct him.

Philip K. Dick's Do Androids Dream of Electric Sheep? (1968) focuses on the relationship between human and artificial beings. The novel occurs in the year 1992, in a post-apocalyptic San Francisco. Similar to Well's global conflict scenarios, World War III and nuclear war have incapacitated the world, a world where most living creatures are extinct due to radiation poisoning. As a result, humans are forced to move to other planets, with the incentive of receiving androids as slaves. These androids lack the ability to feel empathy, a characteristic that allows for differentiation between android and human. However, some of the androids begin to fight back against their "masters," killing them, and returning to Earth. Dick explores the question of what

59 Huxley, Aldous. A Brave New World. New York: HarperCollins.
60 Clarke, Arthur C. (1972). The Lost Worlds of 2001. London: Sidgwick and Jackson. pp. 17.

reality is and the relationships between humans, the machines that we create, and how that relationship will be in the future. The question of, “What makes a human human?” is the theme of many Philip K. Dick’s books.

Neuromancer (1984) by William Gibson introduced a type of science fiction that was different from the novels before. Informed by the punk subculture and depicting the human-machine interface created by the use of computers and computer networks, it brought a different voice of a new generation. The book is set in the near future, where the city landscape has decayed. The book brought comparisons so Blade Runner, this book came out at a time where the idea of urban decay, crime, and corruption started to worry people’s mindset. Gibson also described a future where data ruled. Novelist Jack Womack suggests that Gibson’s novel helped shaped the Internet as it is today, influencing developers who grew up reading the book.61 The dystopian future of Neuromancer also forecasted a future where prosthetics and plastic surgery were the norm, where body parts were either grown or manufactured.

Literature has played an essential role in instilling the future into the mindset of the public. The ideas presented in these novels have resonated through society, influencing still to this day.

Films

Many of these film examples are adaptations of books mentioned in the earlier literature section. These adaptations brought these novels to life, providing visuals that have had a lasting impact on the media and pop culture.

61 Sullivan, Mark. Neuromancer turns 25: What it got right, what it got wrong. 2002 Jul 1. http://www.macworld.com/article/141500/2009/07/neuromancer_25.html mark sullivan pcworld.com Jul 1 2009 (Nov 2009)

2001: A Space Odyssey

Stanley Kubrick's cinematic vision for his collaborative work with Arthur C. Clark was a landmark sci-fi movie. It depicted artificial intelligence in a new light; similar to Blade Runner, where the servant questions the hierarchy it finds itself in. At first, HAL is cooperative with his masters, but eventually becomes "obsessive, even delusional, and kills all the crew.."[62]

Minority Report

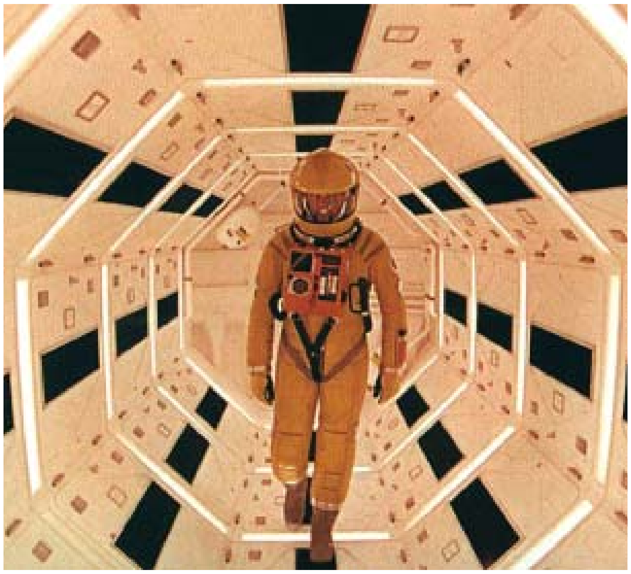
"We had to bring together a group of scientists and designers to invent a new world because Steven Spielberg wanted a more reality based future,"[63]

Set in a dystopian Washington, D.C. in the year 2054, this Steven Spielberg film is an adaptation on the Philip K. Dick short story "The Minority Report" (1956) revolving around Precrime officer John Anderton (Tom Cruise) and his quest to uncover the truth about the world he lives in. Precrime is the police force that uses mutants- "precogs"- to predict, and therefore preventing, crimes before they happen. This movie features a future with "sleek cars, the spider-like tracking devices used by the cops to find people, the use of eyeballs instead of fingerprints as the key identifying feature of a person."[64] The film shows a future that is a highly-possible scenario with its combination of old and futuristic architecture. The cinematography of the film, shot in a film noir style, helped to make this future distinct yet familiar.

Blade Runner

An adaptation of another Philip K. Dick novel, Do Androids Dream of Electric Sheep?, the Ridley Scott directed Blade Runner "virtually defined the 'tech-noir' mise-

62 Bell, David J. Cyberculture: The Key Concepts. New York: Routledge. 2003. Print
63 http://www.jawbone.tv/featured/2-featured/221-5d-building-new-worlds-and-stories-one-event-at-a-time.html
64 Ratskiwatski, Ignatz. Minority Report.http://www.iofilm.co.uk/fm/m/minority_report_2002_r2.shtml



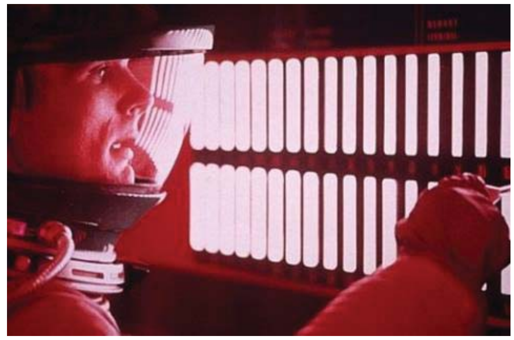
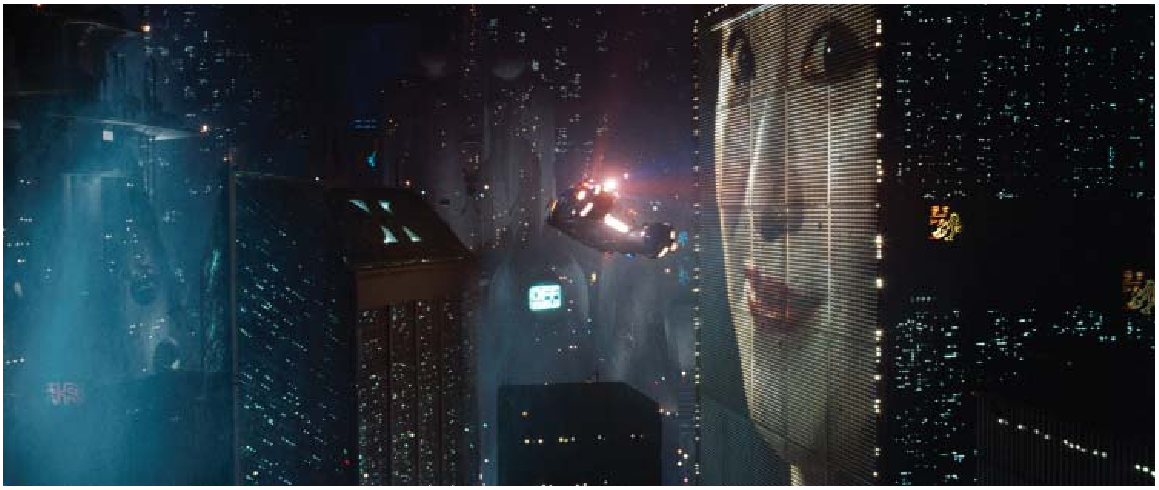


Fig. 3.2 - Video stills of *2001: A Space Odyssey*



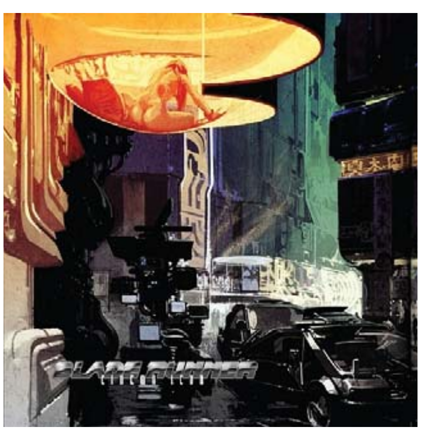


Fig. 3.3 - Video stills and Images of *Blade Runner*

Fig. 3.4 - Video stills of *Minority Report*

en-scene of the genre, with its description of post-holocaust Los Angeles in 2019."[65] The movie revolves around Rick Deckard (Harrison Ford), a blade runner whose job is to hunt down renegade androids, or replicants. The question of what separates humans from non-humans is the central theme of the movie, "a trope familiar to the sci-fi genre."[66] The dark visualizations of this movie show a future dominated by megastructures where the rich live at the top and the poor dwell along the street levels. . The special effects of this movie are benchmarks that have influenced many sci-fi films, with its flying cars and despite its initial commercial failure, Blade Runner has become a cult favorite and is an influential film, the first film in the cyberpunk genre.

Akira

Akira (1998) by Katsushiro Otomo and Ghost in the Shell (1995) by Momoro Oshii are two anime in the cyberpunk genre. Both take place in futuristic dystopian Japan. Akira is set in post-World War III Tokyo, where the city resembles Kenzo Tange's A Plan for Tokyo: Towards Structural Reorganization Proposal-Metabolist artificial islands floating in the middle Tokyo Bay. Their influence, like the live-action films mentioned above, still resonate today. Technology both play large parts in both, Akira with the military scientific testing on human subjects and Ghost in the Shell with bioengineering. The most influential role of these two anime is the stylization of the visuals they provided. The Wachowski Brothers, creators of The Matrix, stated that both of these films influenced the visuals of their movie, "One thing that they do that we tried to bring to our film was a juxtaposition of time and space in action beats."[67] Both presentations of the future, despite the dystopian future, exude style and attitude.

3.3.2 Humans & Their Future

65 Cyberculture: The Key Concepts , Pg. 9
66 Ibid pg.10
67 http://www.warnervideo.com/matrixevents/wachowski.html 6 nov. 1999 Matrix Virtual Theatre. DVD. Warner Home Video

What is the difference between human and other creatures? 99% of human DNA is shared with chimpanzees,[68] so why are we intellectually superior to them and other creatures? Humans are always looking at both past and future, to see where we've come from and where we are headed as a species. Technology plays a major influence in the development of humans. It is human's desire to better the world around them that separates us from animals. Humans have always sought ways to manipulate the environment. Using technology, humans create objects to make life easier. As time passes, humans become more intellectual, savvier in their methodologies.

Future Scenarios

There is a spectrum of postulated futures that have been hypothesized by futurists, scientists, authors, economists; everyone has an idea of what the future will be like. Literary scenarios can be categorized into two sets-utopia and dystopia. Forecasts provided by futurists and scientists are based on current societal trends. History plays an important role in predicting future scenarios, but individual historic events are insignificant in this task. Instead, attention is paid to long-term economic and social trends.

There are many different hypotheses as to what the future will be like. A holistic look at existing scenarios will show commonalities expounded upon in each scheme. One important topic is the type of government in operation and how the regime organizes the structure of society. Politics shape and affect everything, setting the standards of society. Whether the future population will agree or not with the regime is another matter of discussion, but it can be easily said that the government has an immense influence on these forecasts. Class systems, the organization of society, economics, and natural resources are other topics found in these speculations. The affect of technology on society is also an important future issue.

These future scenarios are all different from how current society are, most building upon what is wrong with the world today. Although one cannot cover all the issues,

68 Pollard, Katherine S. What Makes Us Human? Scientific American. 2009 April 20. http://www.scientificamerican.com/article.cfm?id=what-makes-us-human (Nov 2009)

there are certain topics that can be guaranteed which will have an affect on the future.

The Future

Politics

Government

Social

Education | Culture

Technology | Religion

Resources/Energy | Healthcare

Communication/Language

Economy

Utopia

An ideal place or state

Utopia is the word that describes a society where high technology and science has allowed high-standard living conditions that allows society to operate for the well-being of all citizens.

Techno-utopia

A techno-utopia is a society where technology has allowed a utopia to be created.

Four Principles of Modern Technological Utopians

We are presently undergoing a (postindustrial) revolution in technology.

In the postindustrial age, technological growth will be sustained (at least);

In the postindustrial age, technological growth lead to the end of economic scarcity;

The elimination of economic scarcity will lead to the elimination of every major social evil.[69]

Post-Capitalism

69 Gendron, Bernard (1977). Technology and the Human Condition. St.Martin's Press

In a post-capitalist society, the decisive factor of production is not capital, not land, not labor, but knowledge.[70] Peter Drucker's Post-Capitalist Society described how current capitalistic society may evolve into a society where information is the basis of wealth. Information will drive the economy, with productivity and innovation having utmost value. In this forecast, the leaders of society will be knowledge workers, "who know how to allocate knowledge to productive use,...practically all of these knowledge people will be employed in organizations."[71] Society can't change overnight, but we are in an age where changes can occur in a small amount of time. Knowledge wasn't always shared for the good of society, as it was once reserved for only the privileged of society. Up to the 1700's, abstract knowledge was distinguished from skill-which could only be learned through apprenticeship.[72] After that, knowledge suddenly became public good, when technology and organized knowledge led to the Industrial Revolution, where this information was applied to tools, manufacturing, and goods. Companies and organizations run and manage knowledge in the current capitalist society; however, the organization of the post-capitalist society of organizations is a destabilizer. Since its primary function is to put knowledge to work,it must be organized for constant change. It must be organized for innovation. It must be organized for systematic abandonment of the established, the customary, the familiar, the comfortable - whether products, services, and processes, human and social relationships, skills, or organizations themselves. It is the very nature of knowledge that it changes fast and that today's certainties will be tomorrow's uncertainties.[73]

The problem with innovation by large organizations is that despite putting a lot of resources into research and development, most of the time there isn't much to show for it.

Post-Scarcity

In a post-scarcity society goods, services, and information are free or practically free due to the abundance of resources-matter, energy, and intelligence. No labor is

70 Drucker, Peter F. Post-Capitalist Society. Harper Paperbacks: New York 1994 pg.6
71 Ibid pg.8
72 ibid Pg.27
73 Ibid pg.57

required as automated systems turn raw materials into finished goods. Many science fiction novels are set in post-scarcity society, and some experts are predicting that current society is heading towards this type of structure.

Author Jason Stoddard states that the current global financial is the catalyst for a change towards a post-scarcity society. The concept of value will change from, "materials, transport and refining, design and engineering, manufacturing, distribution . . . even our own sense of worth."[74] An example of this is the computer and communications. Stoddard uses modern technology to illustrate this point-

We're also already starting to see some examples of near post-scarcity. Consider computers and communications. If you're willing to use a computer that's a couple of years old, you can probably find a hand-me-down for free, and then happily talk to your friends around the world on Skype using free public wi-fi.

Stoddard also compares our current situation to the last big economic event-

Or consider that in the last Depression, the main worry was simply getting enough food. Today, the marketplace is more worried about maintaining the marketing budgets of 170 different kinds of toothpaste than about ensuring that everyone has toothpaste.

Our current system is inefficient, in that we are no longer focused on value but instead are concentrating on worth. This doesn't work well with the financial crisis we face, forcing us to rethink our concept of value. Stoddard poses three steps towards this- 1) Value Proliferation, 2)Unseen Golden Age, and 3) Magical Ideas. "Value Proliferation" states that we will no longer have a single monetary value system and things like social networks, corporate points, visibility, and reputation will become just as valuable as

74 Stoddard, Jason. First Steps Towards Post-Scarcity: or Why the Current Financial Crisis is the End of the World As We Know It (And Why You Should Feel Fine). HP Plus Magazine. 2009 March 19. http://www.hplusmagazine.com/articles/economy/first-steps-towards-post-scarcity-or-why-current-financial-crisis-end-world-we-know

tangible money. "Unseen Golden Age" is what Stoddard calls the "scariest," but only from today's viewpoint. This Golden Age sees manufacturing technologies become so efficient that people will no longer have to work and live by simply being themselves. Nanomachines will replace workers, allowing bioassembly to "slowly erode the value of raw materials refining, transportation, and manufacturing."[75] "Magical Ideas" states that the most wealthiest and high-powered people will be the innovators, those whose ideas create the things we can only dream of.

Transition Phases:

- Phase 1: Value Proliferation
  - Concept of value is expanding
    - Currency
      - Real, Virtual, Corporate Points, Visibility, and Repuation
- Phase 2: Unseen Golden-Age
  - Living simply by interaction
    - Nanomachines (molecular manufacturing) made production of materials free.
    - Machines find and refine raw materials also free
      - Turns value of production into zero
- Phase 3: Magical Ideas
  - Technologies advance beyond todays limits
    - Nanotechnology
    - Space Elevators
    - Artificial Intelligence

Paul Romer is one of the minds behind "New Growth Theory"- the idea that policies which embrace openness, competition, change, and innovation will promote growth. It also divides the world into "ideas" and "things" or physical objects. Objects are scarce and subject to the law of diminishing returns, alone which cannot drive growth.

75 ibid

Conclusion

This research focuses on immersive design and the future according to various multimedia outlets and popular culture. Immersive design combines architecture and multimedia to explain a story to people. The proliferation of technology is enabling people to communicate and interact digitally on a level unlike any in history. Immersive environments will shape the future of the built environment by creating engagement and interaction between people and their surroundings.

3.4 CASE STUDIES

This chapter explains the case studies done in order to explore the existing work along the lines of immersive architecture and multimedia design. Projects were chosen due to their varying typologies of user interaction.

3.4.1 NEW CITY

Location: MoMA-New York City
Designers: Greg Lynn
Peter Frankfurt-Imaginary Forces
Alex McDowell
Senses:
Sight
- Video/Animation
- Installation (Facetted Cave)

Sound
- Music Track

This project combines motion graphics, film production methods, and architectural design. If there was a digital/virtual version of the Earth, how would it look like? That was the premise of this installation done by Greg Lynn in collaboration with production designer Alex McDowell and Imaginary Forces. Initial research started with existing online virtual environments, but none had the quality of a film or contemporary architectural project that the designers were looking for. The existing models weren't up to date. Research was also done looking for existing conditions of looking at the globe. Construct a narrative of models that helped to visualize a new globe, a new encyclopedia, which also has a commercially viable aspect to it. World of Warcraft and Second Life were examples of online worlds looked at, but both were too familiar. Vignola's Mappamundo room in the Villa Farnese was the source of inspiration for Lynn, as it was a map but also provided visual and cultural information.

Fig. 3.5 - Images taken from the New City digital model

Construct
Digital

The digital model is a toroidal interpretation of the seven continents, intersecting and moving through each other. The major cities were mapped onto these toroids, as well as streets, and a hypothesized population of eight billion people. The model also provides statistics and data for each corresponding city. The toroids allow for the model to utilize two surfaces simultaneously, which is needed to visualize such a large amount of data. The model is intended to be the digital version of our planet. As changes occur in the real world, this model will adjust to match.

Physical

The physical installation is a faceted screen that simultaneously shows a video of the digital model and the concepts behind this digital city. It is cavern like, where the user must enter the space and stand or lie to view the video. The video-"sometimes as multiple, synchronized video narratives, and sometimes as a continuous canvas" -was

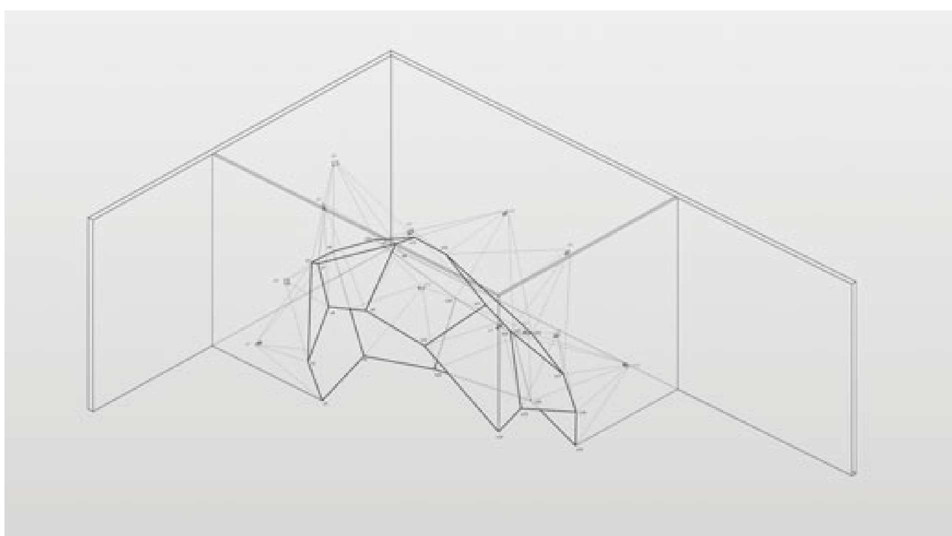


Fig. 3.6 - New City - Diagram of projection system

3.4.2 BLUR BUILDING

Swiss Expo 2001
Designers:
Diller+Scofidio
Yverdon-les-Bains, Switzerland

Senses:

Visual

Exposed structure + Mist

Aural

Haptic

Taste

Fig. 3.7 - Blur Building - Image from Entry Bridge

Concept

A proposal for the Association Expo 2001, Diller + Scofidio's Blur Building is a creative solution to a unique site. The Blur Building is artificial weather, a fog that limits vision and challenges the conventions of the spectacle. Instead of a space for congregation, it promotes dispersion; instead of individuality of user, the Blur Building gives the user anonymity.

Fog Building:

1. Visibility: it should scatter enough light to reduce considerably the visibility of the objects behind, and, at the same time, make visible the otherwise invisible dynamics of atmosphere;
2. Tangibility: it should feel soft and cool to the skin
3. Vulnerability: it should be subject to atmospheric conditions; it should disappear, not persist.

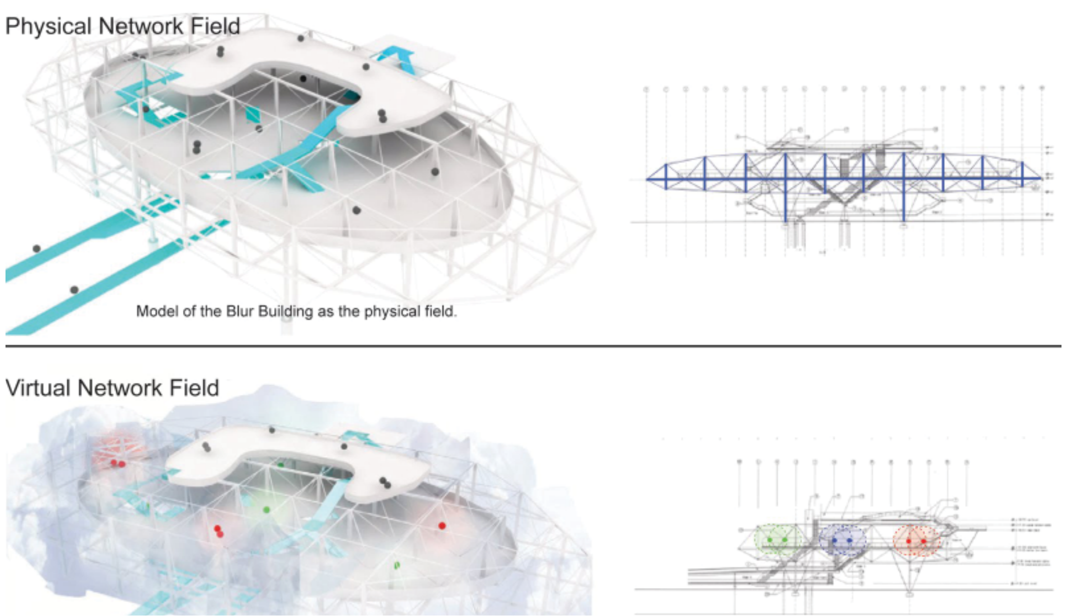


Fig. 3.8 - Blur Building - Interaction Diagrams

"Blur is a response to the visual noise around it. From the outside, the fog mass is undoubtedly a seductive visual icon, but from within the immersive environment, nearly all visual references are erased."

-Liz Diller

Media Concept

The media aspect of the Blur Building is equally important to the design concept as is fog. Diller+Scofidio wanted to create an experience opposite to the overstimulation of typical media exhibitions. Along with their five senses, the user is given a "sixth sense," a smart raincoat-or braincoat-embedded with information from a questionnaire filled out by the user. The coat reacts with four media installations within the cloud.

The first are LED gates that give the user a question, then the user chooses an answer by walking though the left or right gate. The braincoat records the user's answer, which is then collected into a multidimensional data matrix that governs the experience of the project, thus turning the questionnaire into part of the entertainment and experience of the project. The second data input device is a PDA. The user inputs their questionnaire answers into the device and then gives it to an attendant who would program these answers into the user's braincoat. The third input is device is a mobile phone, and the fourth would be the braincoat itself.

The braincoats play an essential role in the relationship between user and building, the heart of the media installation. They are raincoats that are embedded with LED lights, speakers, and heat sensitive switches. The coats have three methods of response. The first interaction is a visual response. As users pass one another, the braincoats compare user profiles and change color depending on the compatibility of the answers. LED lights glow a blue-green for antipathy or red for affinity, depending on the match level. This sensation is also done through an acoustic approach. As users approach one another, a pulse only audible to the user begins to sound. Depending on the match of

these answers, the pulse will begin to increase. Users can navigate through the space using this "sonar," moving through the space to find others with similar answers.
The internet plays a role in this media installation as well. On the LED columns, a webcam/fan is placed. A user on the internet can pick a column that is near a user whose responses are similar to their won, where the fan will blow the fog away temporarily so that the internet user can see that person of interest.

Construct
Structural System

Tensegrity system for roof structure
Space Frame for platforms
The mist system is made of 31,500 high pressure water jets using lake water. The system is computer controlled, monitoring the temperature, humidity, wind speed and direction in order to adjust the water pressure

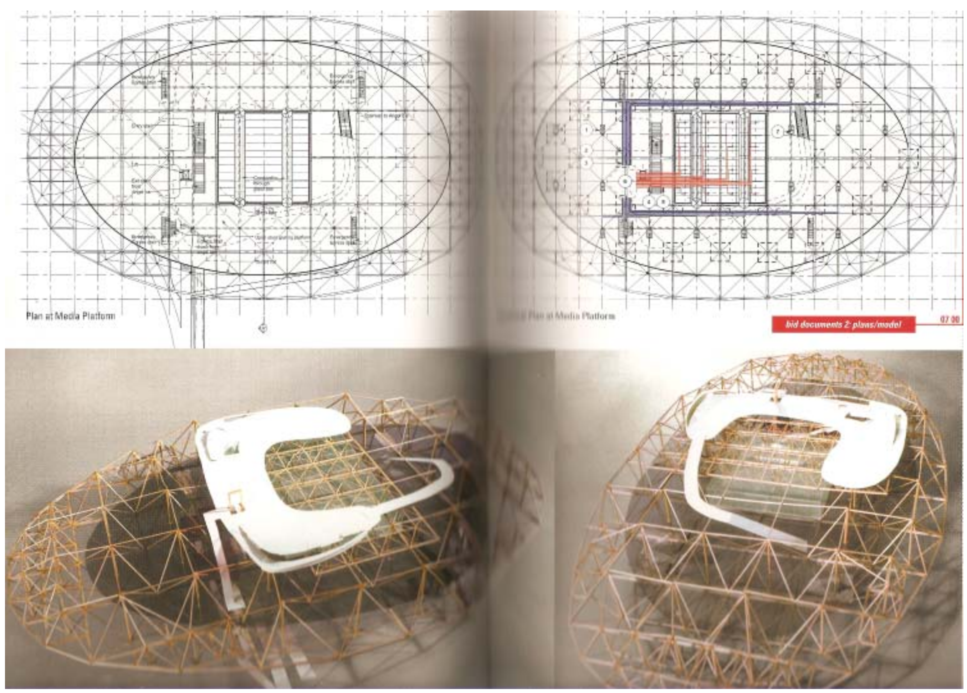


Fig. 3.9 - Blur Building - Floor Plan and Model Images

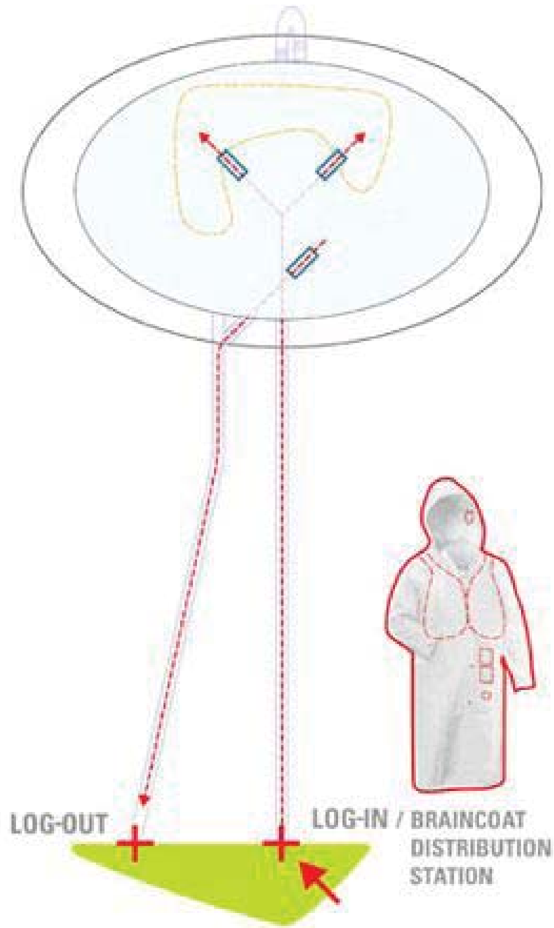


Fig. 3.10 - Brain Coat Concept Imagery

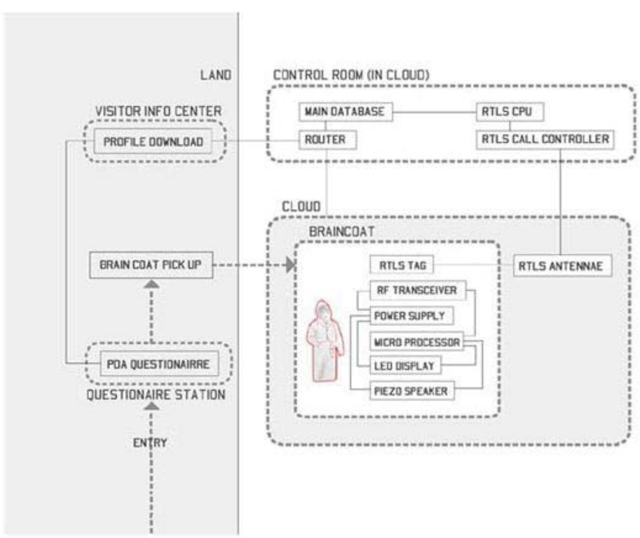


Fig. 3.11 - Brain Coat Concept Imagery

3.4.3 VOLUME/TRIPTYCH

Designers:
United Visual Artists
Volume-London, England
Triptych-Paris, France

Senses:

Sight
Sound
Touch

Concept

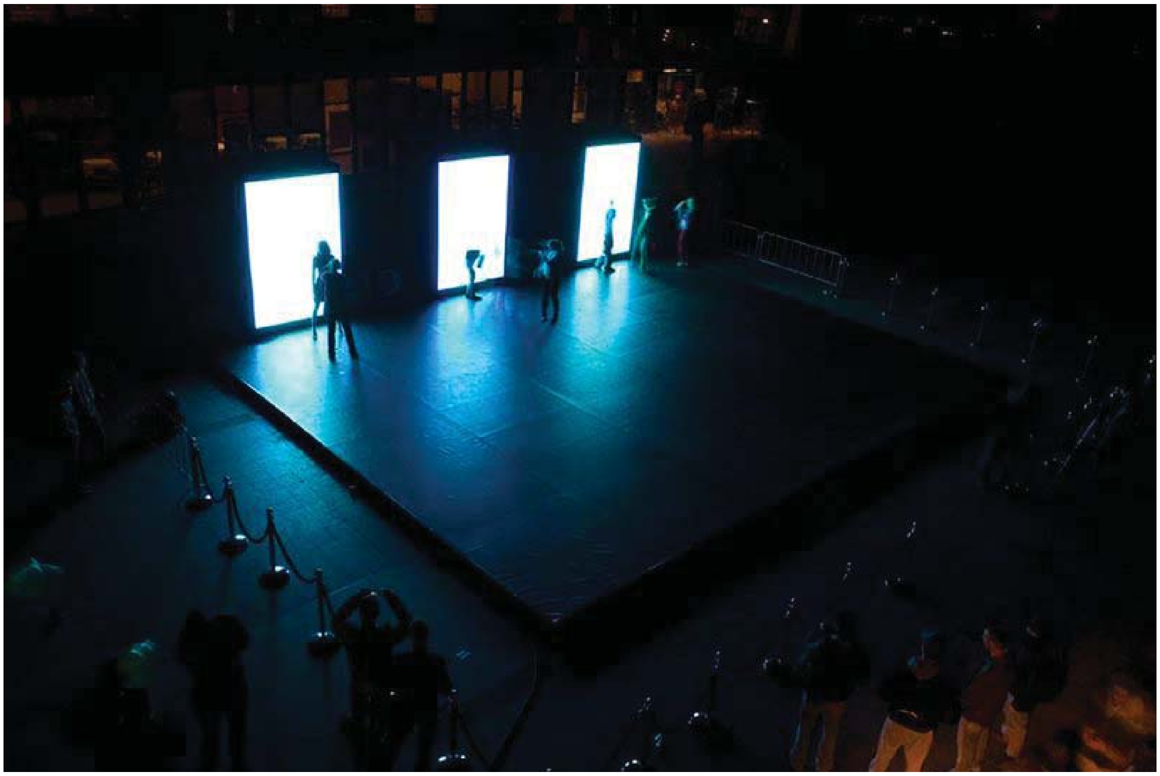
These two installations are two examples of public art installations that people interact with. Volume is an installation composed of a field of thin LED columns that change light and sound pattern according to the proximity of the user. Triptych takes the same concept of user proximity to affect three monolithic LED walls.

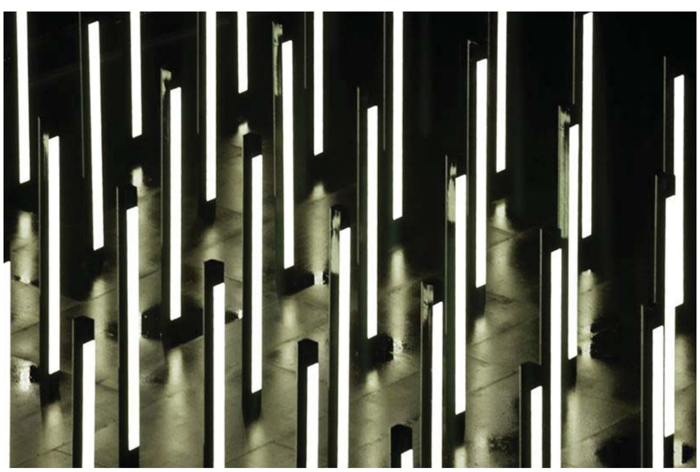
Construct

Volume
London, England

This installation features eight-foot tall vertical columns covered with LED lights on the front side, arranged in a field in the center of the garden. An infrared lamp senses the user's proximity to the column.

Fig. 3.12 - *Triptych* (Above) and *Volume* (Below)





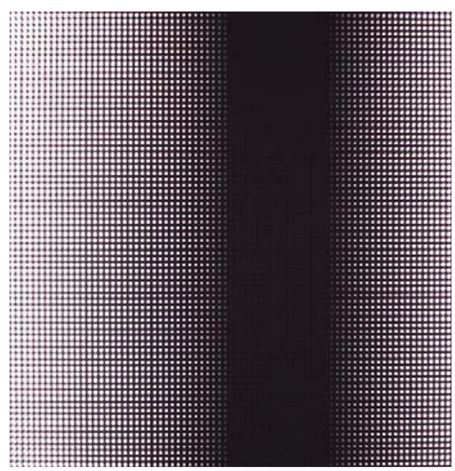


Fig. 3.13 - *Triptych* (Above) and *Volume* (Below)

Triptych
Paris, France

Similar to Volume, this installation features a monolithic LED wall that responds to user's proximity. Sounds and light patterns shift accordingly, allowing for the user to interact with the surface without any interference.

Conclusion

The common threads between these case studies is interaction - whether it be between the user and the design objects or between the each of the users. New City informs through multimedia and architecture. The Blur Building uses architecture as a medium to convey a message between you and other users. Volume and Triptych allow for an informal interaction between user and design object.

3.5 EXPERIMENTATIONS

Alarm Device

The exercise began with a few questions-
+How does an alarm clock work?
+Why can't people get up in the morning?
+What is the sensorial relationship between the alarm and the user?

Waking up the user from slumber is the simple answer, but what are the specifics of how the alarm clock accomplishes this? An alarm clock forcefully takes the user from one state of consciousness to another, stimulating the user's sense of hearing to wake them up. The alarm uses a slightly irritating tone, vibration, or music to wake a person, but sometimes this isn't enough. Sometimes a person is too tired, lazy, or simply too heavy a sleeper for the alarm to wake them. If one can't be awakened through their sense of hearing, which sense can be "attacked" next? Although eyes are closed during sleep, one can still see and feel light through the eyes and eyelids.

Program Analysis

Light can stimulate human senses using light and heat. This is the starting point of the design for this alarm device. How can light be used to wake a person up? The first step in design was to analyze the desired user experience when using this device. The goal is to create a device that uses light and sound to wake the user, light being the focal point with the sound there to reinforce. This also allows for multi-functionality, something which most people expect out of their electronic devices. The form of this device needed to also strengthen the light's ability to wake the user. From the beginning of the exercise, a generic room was created for the device to be placed in. The scenario where the user

would be assumed to be sleeping in bed is used in all design decisions.
Experimentation

+ Formal/Sensory Studies
+ Sight
+ Color
    The color of light is an important aspect to this device.
+ Pattern
    The patterning of the light is important to this device because of form

The first iteration was a ceiling mounted lamp with a form factor similar to the sound cones that isolate sounds so that the user standing directly under can

Fig. 3.14 - Alarm Device with Speaker - In pairs (Above) and as a standalone (Below)

only hear. Although this device fulfilled the desired sensorial "attacks", the form does not reinforce the concept of immersion.

The second iteration looked at the device in a floor lamp form factor. Trying to stray away a typical lighting device form, the first design was a dual light system that flanked the user on two sides. A single, linear emitter is the light source, with the supporting lamp covered in a shiny plastic material to aid in reflectivity. A speaker was added to the device to allow for multi functionality. The user could plug in a personal media player and program the device to play sounds or music like a typical alarm clock. White, orange, and red were the light colors chosen in this version. These colors were picked thinking that

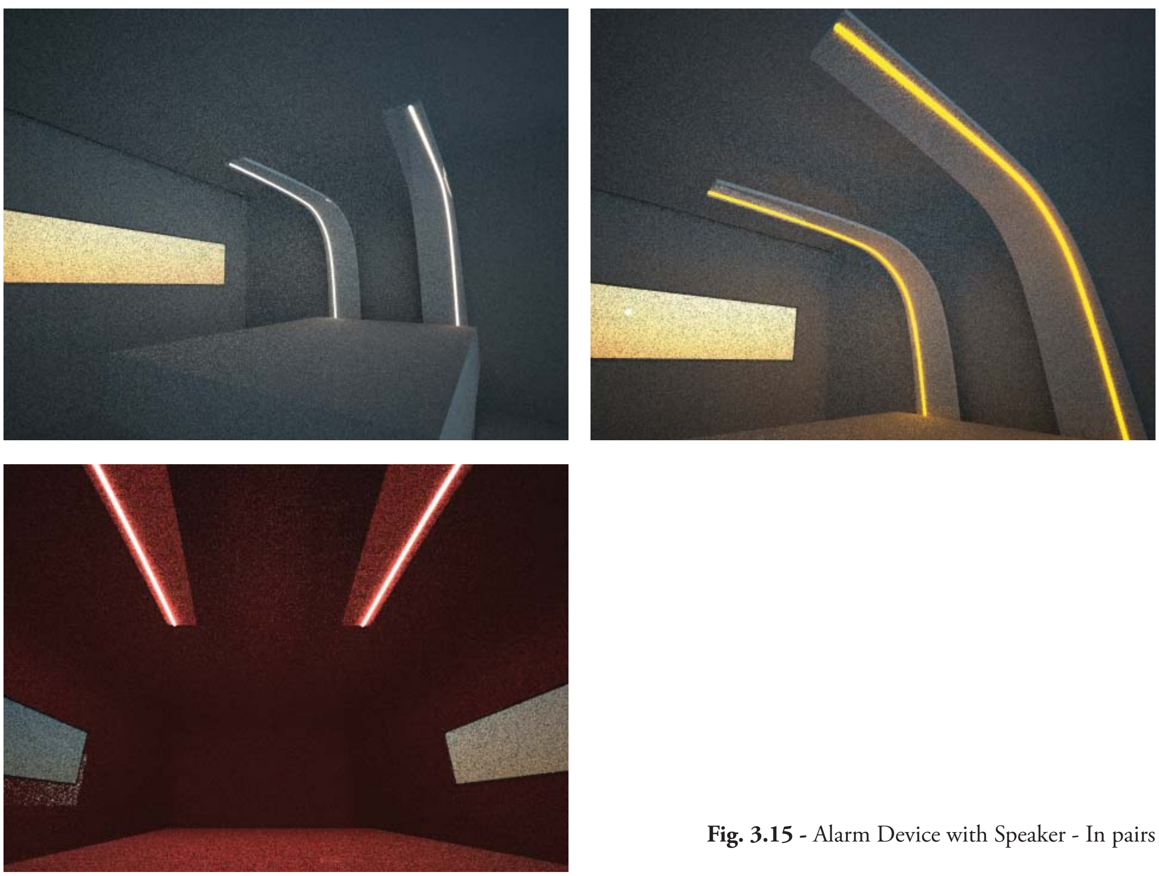


Fig. 3.15 - Alarm Device with Speaker - In pairs

they would be the most irritable to the user. However, during discussions, the question of would this artificial light be discernible with natural daylight? People will need an alarm device even during the day, so the device needed to address this issue.

The third version of the alarm device took away one of the lamps. A single lamp provided enough light to stimulate, as long as the device was placed in the

Fig. 3.16 - Alarm Device with Speaker - Standalone

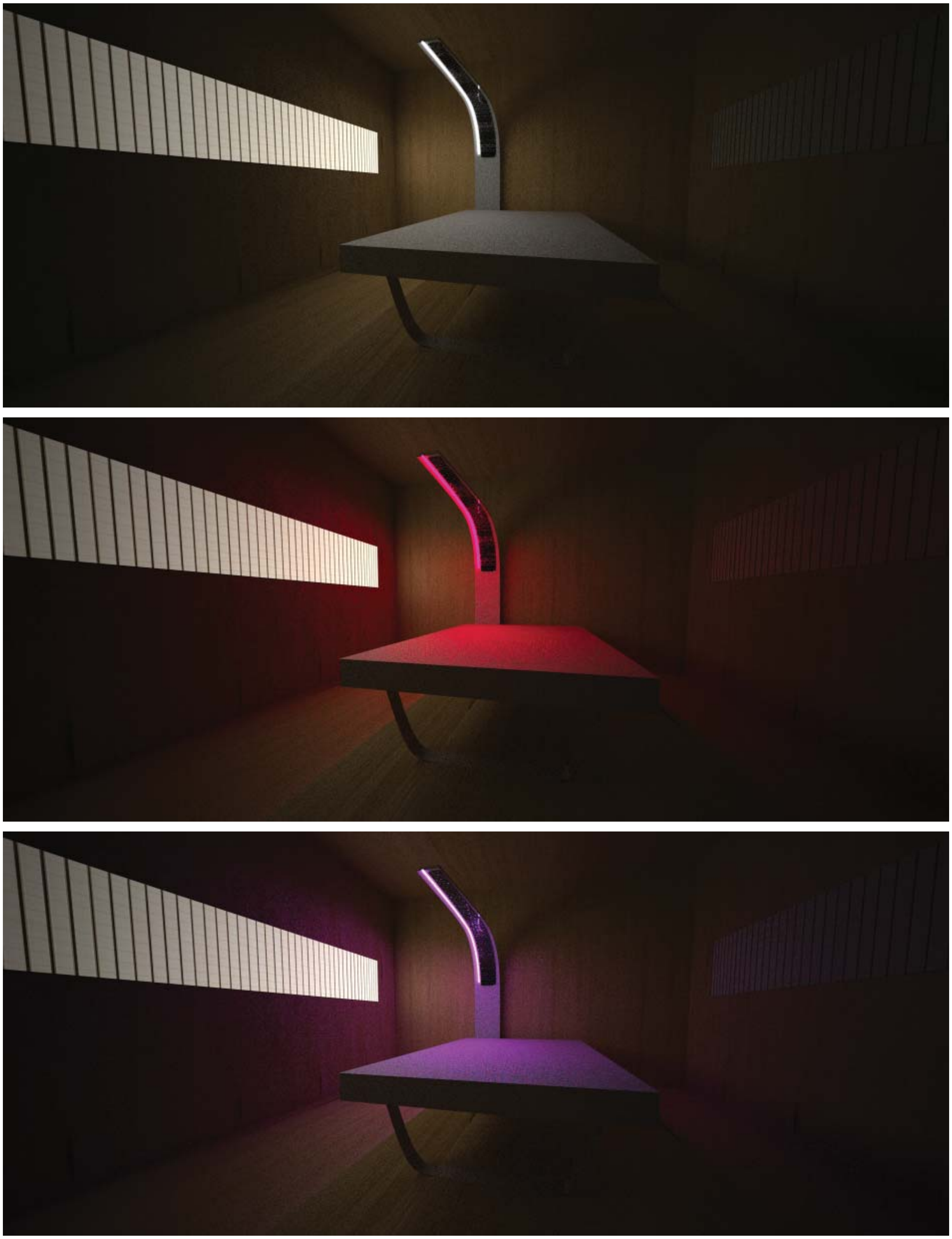


Fig. 3.17 - Alarm Device with Speaker - Light change variations

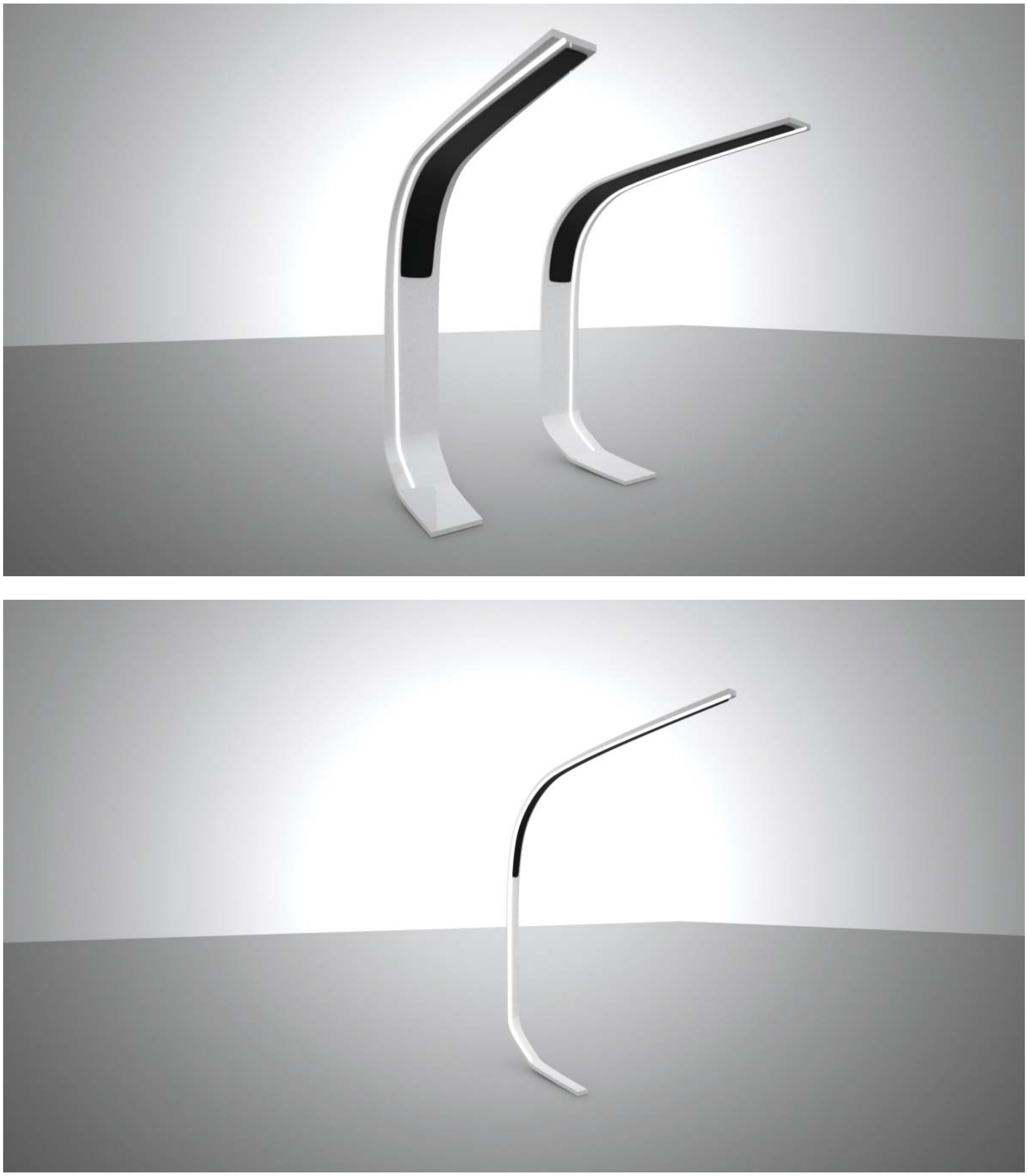


Fig. 3.18 - Alarm Device with Speaker - In pairs (Above) and as a standalone (Below)

right proximity to the user. To simplify the design even more, the device was made slimmer-minimizing the footprint and the space that the device takes up. The fourth iteration of the alarm device deviated from the form factor of the previous three versions. The previous devices kept the same width from base to the top, while the fourth version's form gave more emphasis on the light source than the base and stem. This was done with the idea that the light would be dynamic, programmable to move automatically by the user. The thinner stem allowed for this to happen a lot easier than the previous form factor. The adjustability of the device allowed for a slimmer profile when not in use. The fifth version of the device brought back the concept of keeping the device the same width from bottom to top. The difference between the fourth and fifth devices is that the fifth segments the device into three parts- light/speaker, stem, and base. This segmentation allowed for a hinge action which fulfilled the desired adjustability and slimming of the profile when not in use.

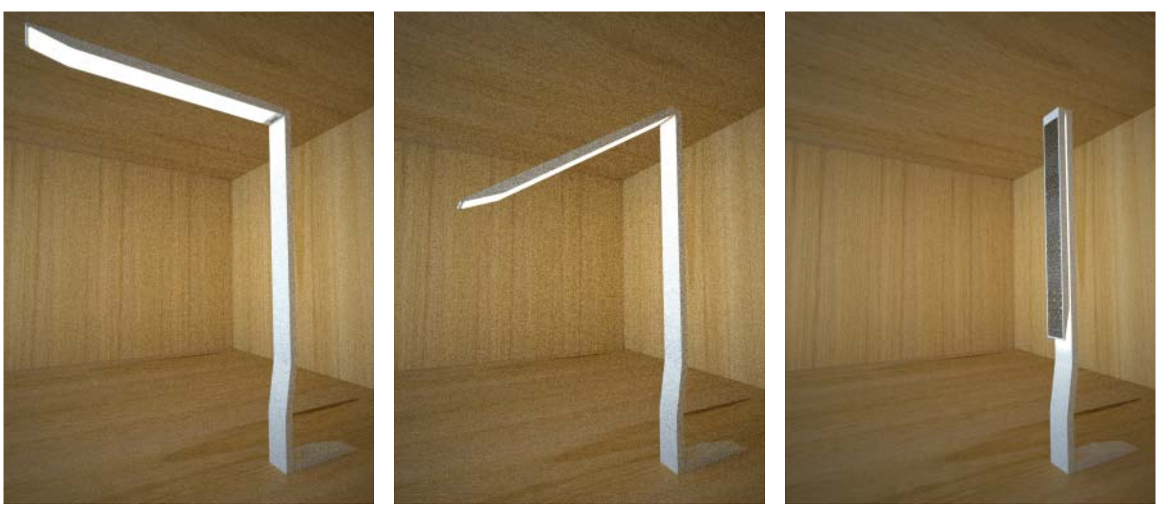


Fig. 3.19 - Alarm Device with Speaker - Open and Closing Sequence

The problem with these two forms was that the audio aspect of the device no longer had the seamless integration into the form. It was secondary to the light source. In both designs, the speaker placement is located on the opposite surface of the light source. The criticism that came with this is that it was "too modern," implying that the design didn't maintain the futuristic quality that the previous version provided. Another criticism was that this version was looked too much like a product, when the desired device needed to have some connection-a narrative-with the user. The relationship between device and user needed to be more personal, like a pet. A pet and owner relationship-although on more subservient than the other-goes both ways.

The final iteration was inspired by the *mecha* from Japanese *anime*. These humanoid robots transform, shift, and move; This version of the alarm device tries to attempt to create the same effect with light and form. The first form of the device starts off as something similar to a slender, floor standing speaker. When the time comes for the device to operate, it begins to shift and reveal the hidden speakers within the LED shell. Then the device begins to slowly bend downwards over the user, allowing for the light to be directly above in order to maximize the lighting effect.

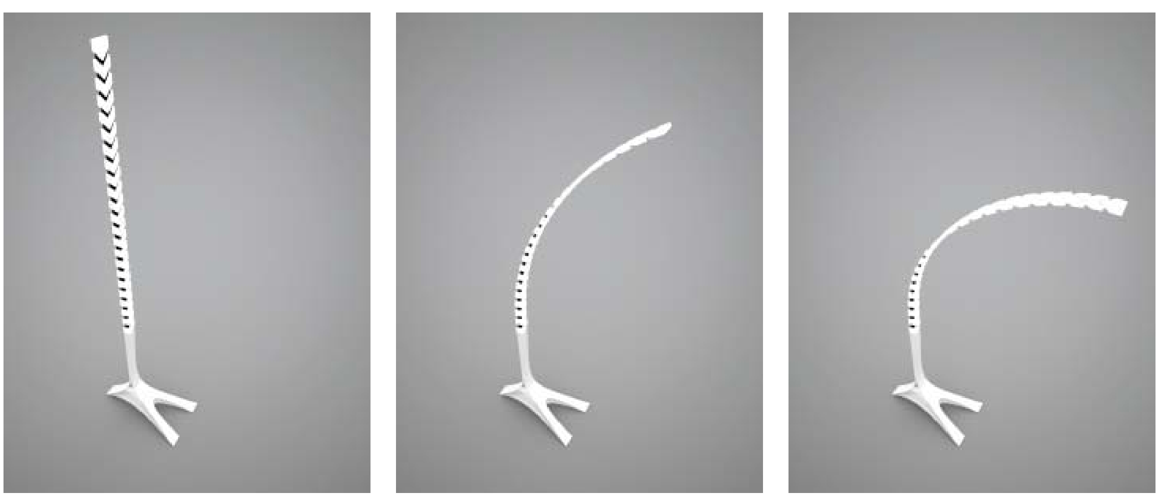


Fig. 3.20 - Alarm Device - Final Version: Movement Sequence

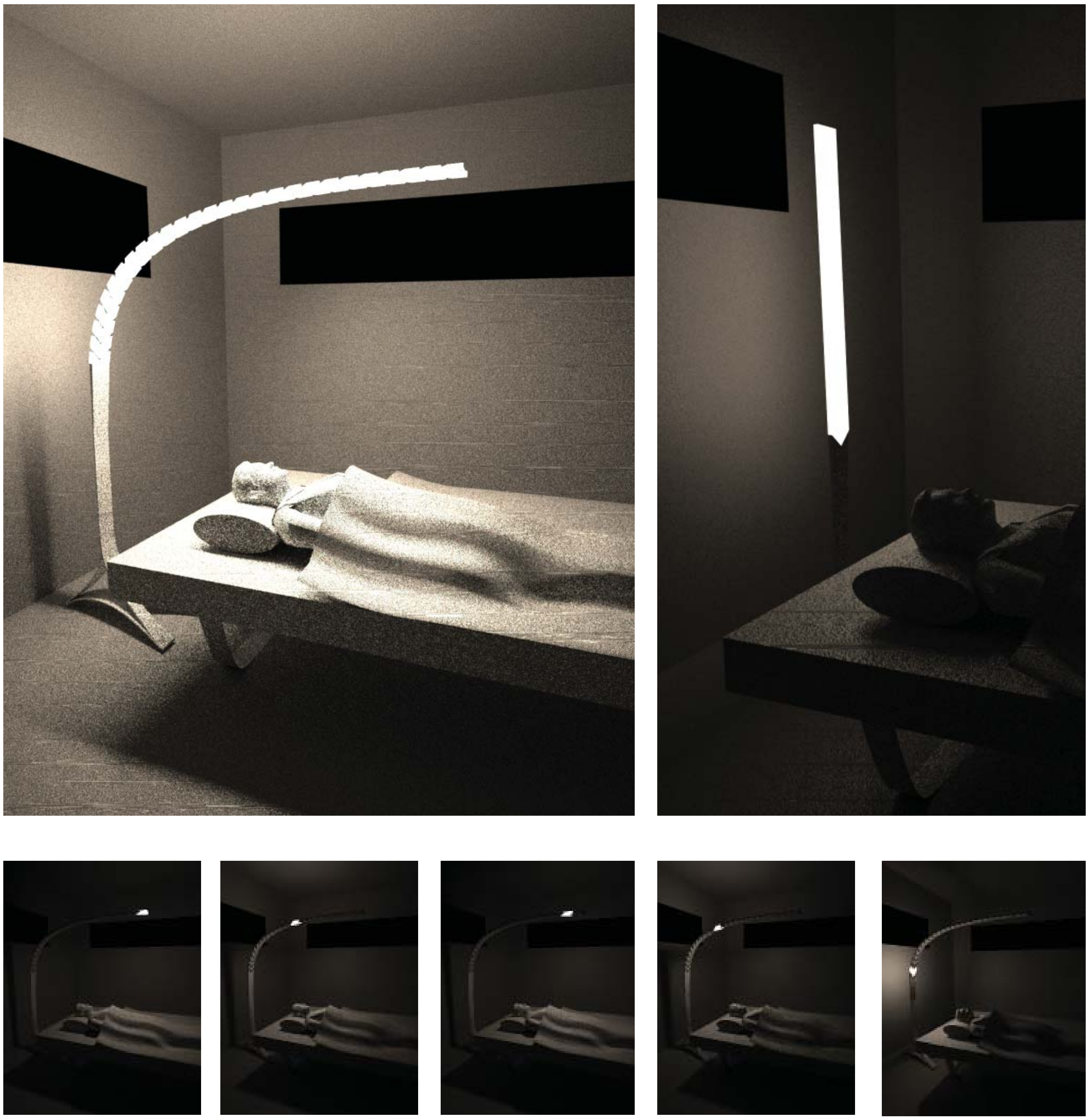


Fig. 3.21 - Final Version of Alarm Device - Light Sequence

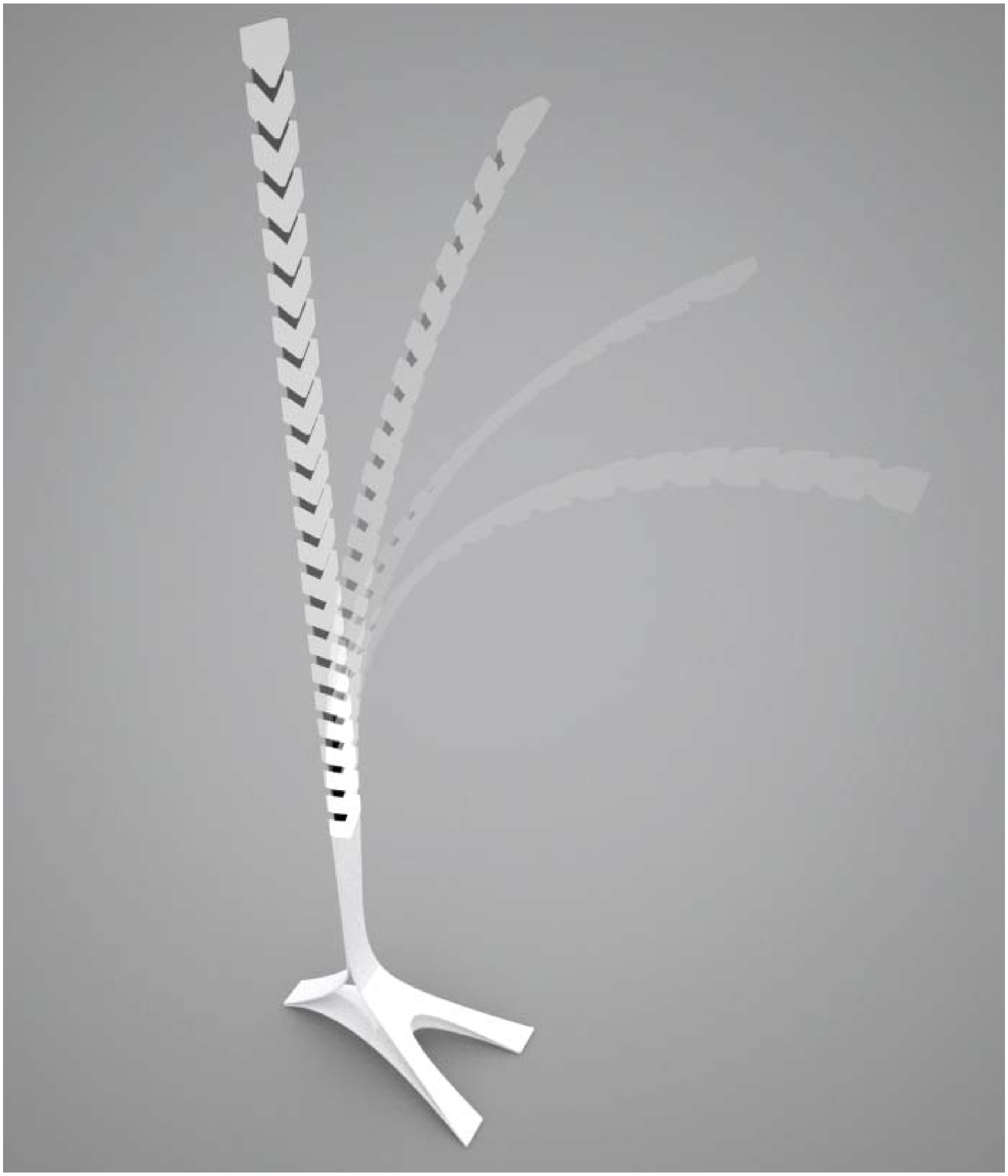


Fig. 3.22 - Final Alarm Device variation showing stages of changes in form

Conclusion

In this chapter, specific case studies were chosen in order to explore their ability to stimulate user's senses. From this analysis, a design methodology is created and implemented to a small design experiment for an alarm device. From the outcomes of this experiment, a design methodology is derived that is focused on the stimulation of user senses in order to create a multi-directional narrative between user and object.

IV. METHODOLOGY

4.1 INTRODUCTION

The previous chapter explained how the immersive design methodology was developed and created. Chapter 4 goes into how the methodology is applied in the design investigation of each prototype. The focus is placed on describing each of the computational design software used in each step of the investigation. Then the interaction between the digital model and physical data is described using digital design software and sensing hardware. Finally, the design process is described as a holistic process.

The immersive methodology created in Ch.4 aims to create an immersive aesthetic, an aesthetic that re-defines architecture experience based on a used focused narrative. The methodology's structure is shown in Figure 4.1:

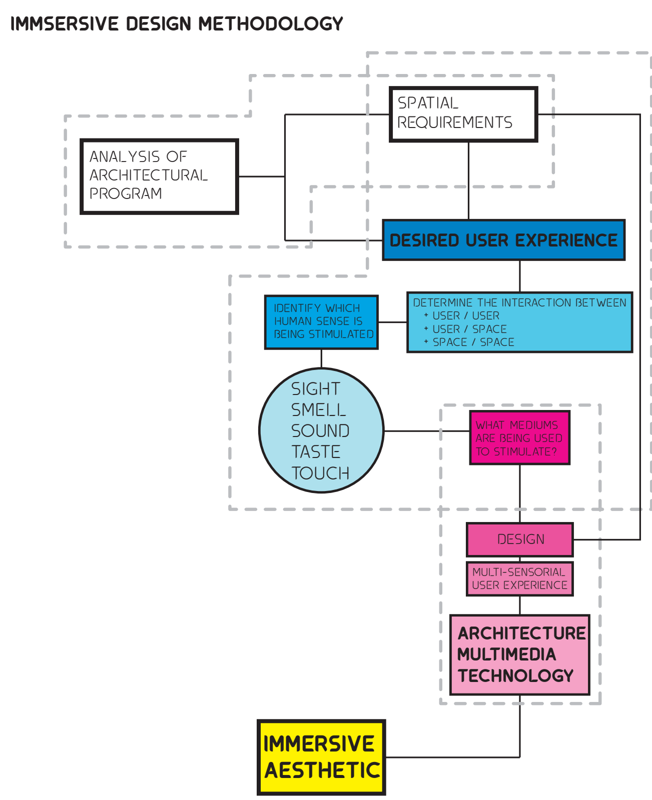


Fig. 4.1- Immersive Design Methodology

The first essential step, before any designing is done, is to determine the desired user interaction within the spatial environment using the five senses as the target of interaction. This interaction is the basis to which all design decisions will be informed by. Prototypes target specific user interactions; these targets vary from prototype to prototype. What the next sections describe is the process of the design portion of the Immersive Design Methodology.

4.2 Senses

Early in the design process, before any sketches or drawings are created, the stimulation of specific senses is determined. All design decisions are made – in addition to the spatial requirements - according to what sense is desired to be simulated. The five human senses, in this design methodology, is the focus of stimulation in order to create this interaction. By doing this, the design of the experience of the space is decisive and thought through at all levels of engagement. Sight, Sound, Touch, Taste, and Smell are the target senses. Typically, the visual aspect of design is held as the most importance in the experience of contemporary architectural design. There is always a desire to create interesting form. What informs form? What of the stimulus of senses other than sight? Sight is the strongest sense when dealing with architecture; it is often the first sense that is triggered. Sight is the trigger sense, interest stems from what we see. Sound, in the experience of spatial environments, is user dependent, as each user never hears the same phenomenon in the same way twice. Touch is a strong stimulant; Architectural environments heavily depend on materials to define the experience of that space. Texture can be experienced not only through the hands, but the feet, skin, and eyes as well. Taste and Smell are interrelated when it comes to spatial experience. The stimulation of Taste and Smell depend heavily on the relationships to other spatial conditions and or external environmental factors.

By determining the senses to stimulate at the beginning of the design process, the immersive methodology creates a holistic process

4.3 Prototype - Creation [Rhinoceros 3D]

The first step in the design process was the exploration of possible geometries for each prototype. Each prototype was developed within the NURBS (Non-Uniform Rational Basis Spline) modeling program Rhinoceros 3D. This program was chosen for its ability to easily create geometry as well as its' compatibility to work with other digital software. To start, prototypes were designed as single units/components. These components were then connected to form larger unit assemblies. Different pattern assemblies aimed to create specific narratives between user and spatial environment, with the narratives targeting specific senses. These sensorial narratives determined the formal geometry of each prototype.

IMMSERSIVE DESIGN WORKFLOW

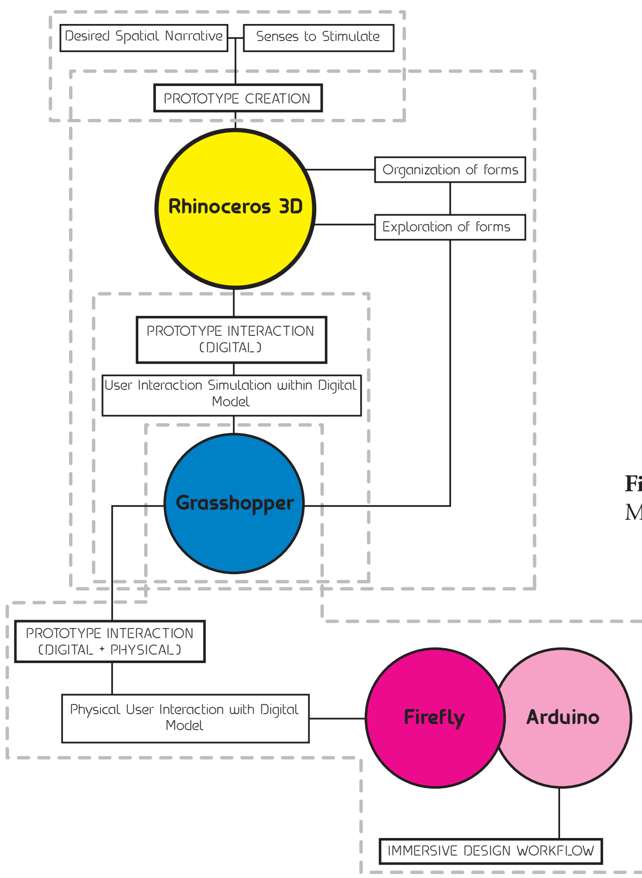


Fig. 4.2 - Prototype Investigation Methodology

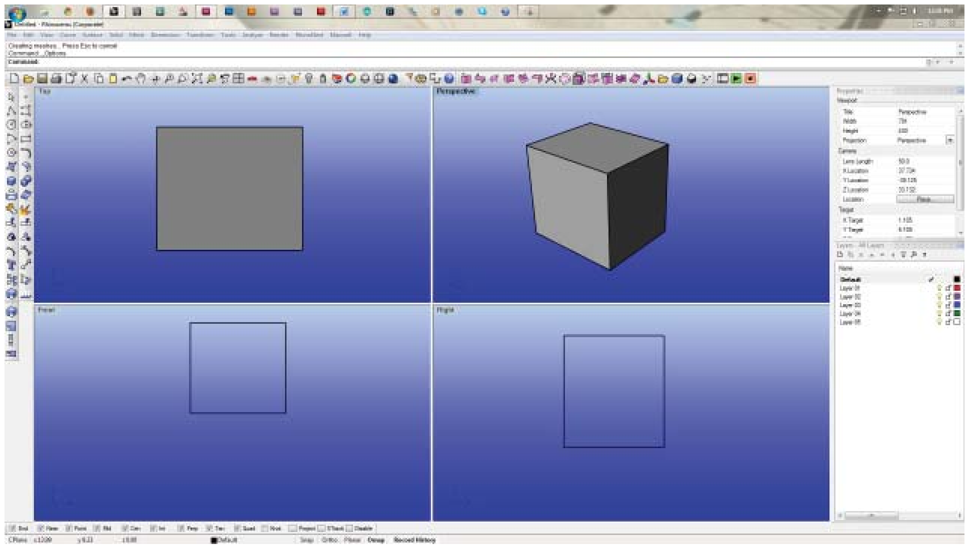


Fig. 4.3 - Rhinoceros 3D - Modeling environment and typical icon layout

4.3.1 Pattern Geometry

Each prototype begins as a single unit, and then arrayed to create a larger assembly made up of these individual units. The reason for creation both at micro and macro pattern scales is to investigate the prototype's potential for user sensorial stimulation. A single unit prototype has a different impact when arrayed as a larger assembly. In addition to micro and macro pattern investigations, initial explorations also began with two states – non-active and active. A "non-active" state describes the prototype without user interaction while an "active" represents the prototype's state during user interaction. Non-active and active can also be used to describe the limits of the prototype's range of deformations.

These deformations were explored in a variety of directions. Typically, deformations in the Z-direction create a more spatial and textural changes, while movements in X and Y-directions create more visual change. At a micro scale, movements were studied in order to gauge whether or not a unit would keep its overall integrity when deformed. At a macro scale, patterns investigations looked at the level of impact prototypes could create.

The prototypes created were applied to wall, ceiling, and floor applications to visualize how they were actualized within a spatial environment. The application within a generic spatial environment was also to show prototype's interaction with the natural environment, specifically with sunlight. Once the desired geometries were created,

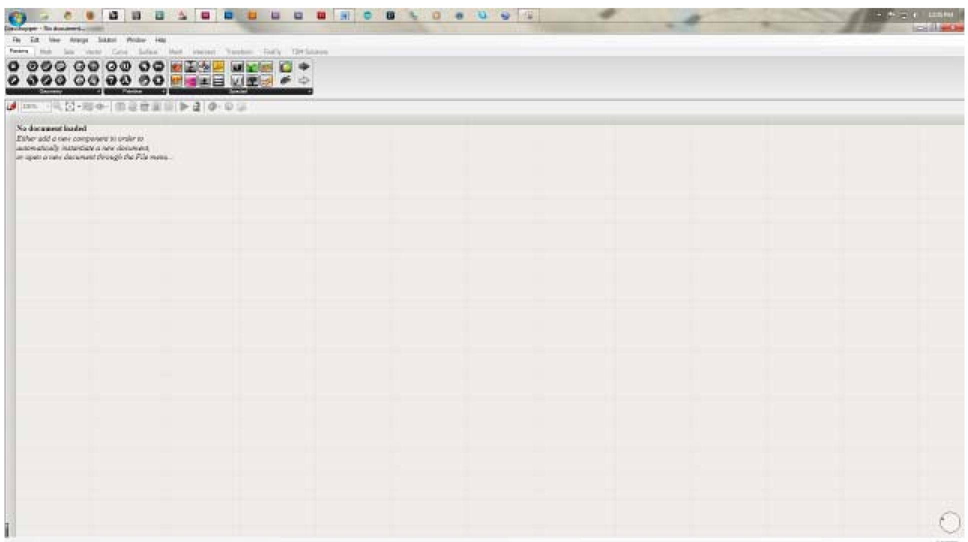


Fig. 4.4 - Grasshopper Plug-in graphic scripting environment

they were then rendered in Maxwell Render. Maxwell Render creates an accurate simulation of light, which aids in the formal exploration of prototype geometries.
The process of creating prototypes in non-active and active states was done in order to visualize possible spatial reactions to a user. However, what the immersive design methodology seeks to create is a continuous spatial narrative; the rendered images of the digital models do not capture the intermediate states between non-active and active. The interaction between user and spatial environment is difficult to visualize; the digital models up to this point were only illustrating captured moments and not the fluid interaction of a user.

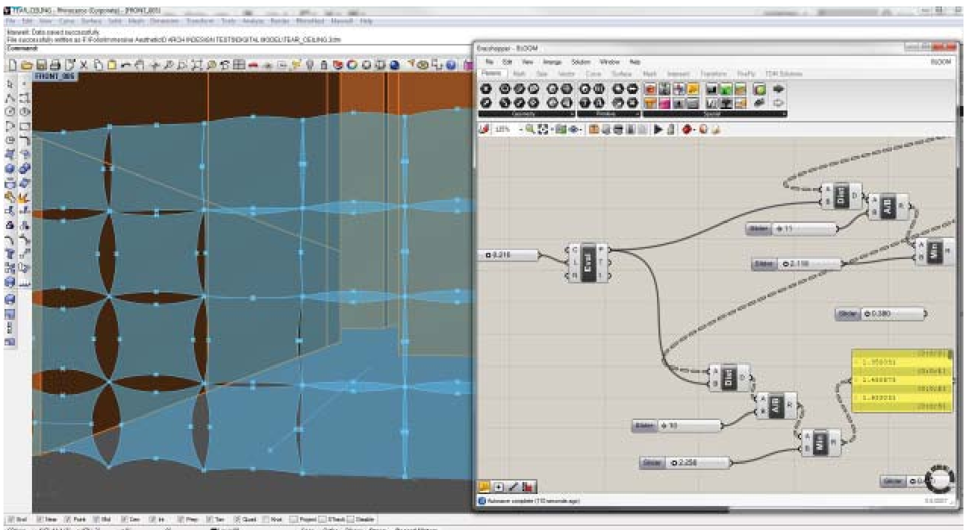
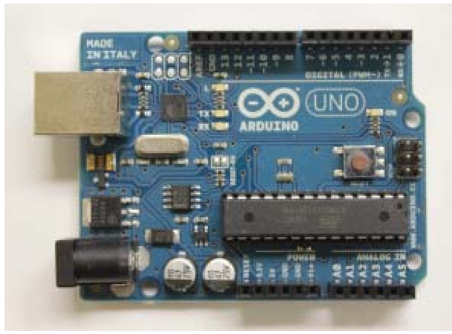


Fig. 4.5 -Grasshopper Plug-in graphic scripting environment within Rhinoceros 3D modeling envrionment

4.4 Prototype - Arrangement / Interaction [Rhinoceros 3D+Grasshopper]

4.4.1 Arrangement

In order to visualize a continuous narrative, the Grasshopper algorithmic design plug-in is used to create patterning and simulate user interaction within a spatial environment. Grasshopper is a visual programming language used as a plug-in for Rhinoceros 3D. It is connected to the Rhino software in order to make use of Rhino's NURBS modeling for algorithmic form generation. NURBS models are made up of points and curves, and it is from these points and curves where forms are further explored. The interface of the Grasshopper plugin uses a graphic layout to easily provide a palette for algorithmic design. Nodes are dragged onto an empty workspace, arranged, and connected to specific input and output grips using connecting wires.



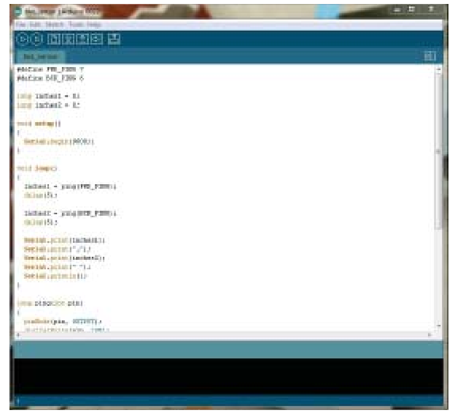


Fig. 4.6 - Arduino Hardware (Above) and Arduino coding editor (Right)

Where each wire connects is to be determined by the geometric form desired.

Grasshopper takes base geometries and uses generative algorithms to create formal variations. For this immersive aesthetic workflow, Grasshopper is used to break down the geometries created in Rhinoceros 3D into its' component mathematical parts – points, lines, and surfaces. Once these basic components are extracted, they are reconnected together to explore formal pattern variations. The beauty of the Grasshopper plug-in is that it instantaneously illustrates changes made to the Grasshopper script within the Rhinoceros 3D modeling environment. Variations can be recorded, saved, and compared quickly without having to change the original geometry.

The geometries and patterns explored in the Creation step of the design process are re-created using Grasshopper. The base geometries are first instantiated in the Grasshopper environment. Then, the basic geometric data – faces, edges, and vertices - is extracted. From that point, variations are created by adjusting the numerical information of the basic geometry data. These variations further explore pattern geometries and unit organizations. This allowed for the number of variations to grow exponentially, essentially endless. However, this process is not about a sought formal endpoint, but instead focuses on the interaction.

4.4.2 Interaction

To simulate the interaction that occurs between the user and the prototype in this immersive aesthetic, Grasshopper was used. In the Rhinoceros 3D modeling environment, a point was created. This point marked the location of the user in space. The point is instantiated in the Grasshopper environment. The main objective within the Grasshopper environment is to represent movement by moving the point. According to the specific script created, this point would affect how the patterned geometries would deform. As the point moves along the curve, the assembly deforms. The shape of this deformation depends on the unit's non-active and active states. The specific deformation/movement of each prototype will be described for each prototype in their individual section.

4.5 Prototype to User Interaction [Rhinoceros 3D+Grasshopper+Firefly+Arduino]

The experience of the user within the spatial environment is essential to the process. Although there is a digital simulation of user interaction, the end goal is to create a real world interaction. Therefore, this interaction between digital model and physical information was created using the Arduino microcontroller alongside various sensors. The bridge between Arduino and Grasshopper is the Firefly software, a plug-in within the Grasshopper environment. The connection between Arduino and Grasshopper through Firefly allows for real-time, real world data to influence the digital Rhinoceros 3D model.

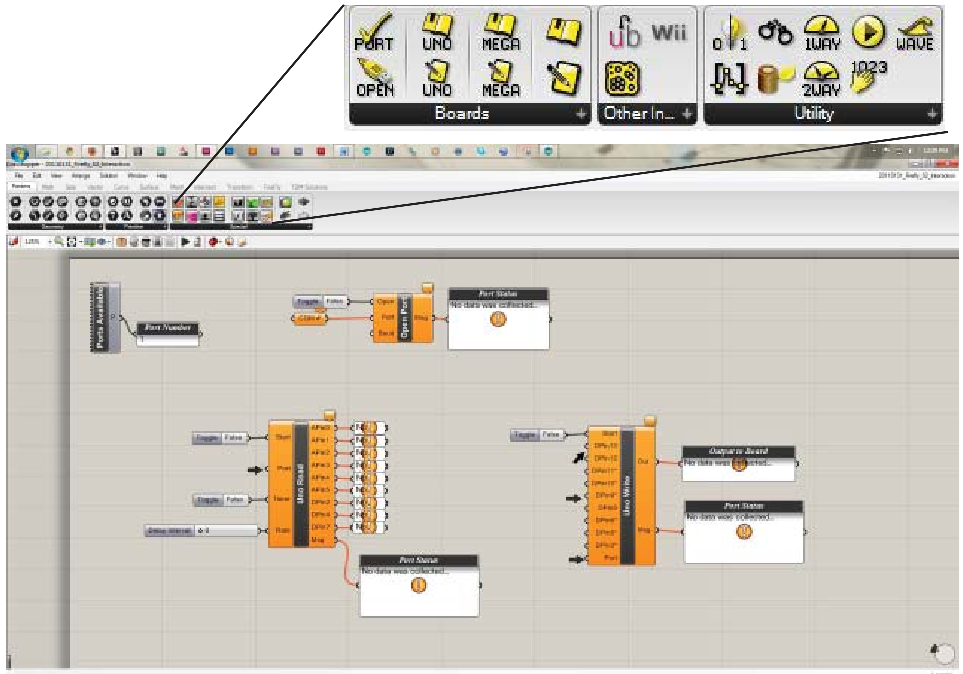


Fig. 4.7 - Firefly Environment with detailed view of Firefly toolbar within the Grasshopper toolbar

The Arduino microcontroller is an open-source electronics prototyping platform. The microcontroller is programmed using the Arduino programming language based on Wiring and the Arduino development environment, which is based on Processing. Wiring is an open source programming environment and electronics I/O board for exploring the electronic arts, tangible media, teaching and learning computer programming and prototyping with electronics. It illustrates the concept of programming with electronics and the physical realm of hardware control which are necessary to explore physical interaction design and tangible media aspects.[1]

Processing is an open source programming language and environment for people who want to create images, animations, and interactions. Initially developed to serve as a software sketchbook and to teach fundamentals of computer programming within a

1 http://wiring.org.co/

visual context, Processing also has evolved into a tool for generating finished professional work. Today, there are tens of thousands of students, artists, designers, researchers, and hobbyists who use Processing for learning, prototyping, and production[2]
The physical board, in this case the Arduino Uno, is a small board with 14 digital input/output pins, 6 analog inputs, a 16 MHZ crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The coding information is transmitted and downloaded onto the board via USB. Explorations were done to study and learn the necessary basic programming language in order to communicate with the Arduino hardware. The tutorials included with the hardware were read and basic experiments were done to familiarize the functions of each component for both software and hardware.

The coding within the Arduino environment is an essential step in the design process because it is how the digital simulation is informed. No prior knowledge of Arduino coding was known before the project, so further research of how to code was done.
Two sensors were used to initiate the data into the Arduino hardware. The first experiment used a light detecting resistor (LDR) to gauge the amount of light within a close proximity of the sensor. The second sensor used a Parallax Ping Sensor to measure the distance between the sensor and an object at a specified range. This range is predetermined according to the sensor chosen.

The Firefly software tool set is a plug-in for the Grasshopper plug-in in the Rhino 3D environment. Firefly is used to create a bridge between the Arduino hardware and digital Rhino + Grasshopper model. The interaction between Firefly and Arduino is real-time which allows for simulation of real world conditions using real world collected data. This data set is reorganized to communicate with the Rhino model in the Grasshopper environment. For this investigation, the information gathered from Arduino is used to move the point representing the user in the Rhino+Grasshopper model.

2 http://www.processing.org/

```
#define FWD_PING 7
#define BCK_PING 6

long inches1 = 0;
long inches2 = 0;

void setup()
{
  Serial.begin(9600);
}

void loop()
{
  inches1 = ping(FWD_PING);
  delay(5);

  inches2 = ping(BCK_PING);
  delay(5);

  Serial.print(inches1);
  Serial.print(“,”);
  Serial.print(inches2);
  Serial.print(“ “);
  Serial.println();
}

long ping(int pin)
{
  pinMode(pin, OUTPUT);
  digitalWrite(pin, LOW);
  delayMicroseconds(2);
  digitalWrite(pin, HIGH);
  delayMicroseconds(5);
  digitalWrite(pin, LOW);
  pinMode(pin, INPUT);

  long duration = pulseIn(pin, HIGH);

  return (microsecondsToInches(duration));
}

long microsecondsToInches(long microseconds)
{
  return microseconds / 74 / 2;
}
```

Fig. 4.8 -Processing code used in the Arduino experimentation.

Summary

The software chosen play a specific role and each is essential steps in the immersive design process. While also used in formal exploration, this process focuses on creating an interaction between digital and physical. This allows for the simulation of the user interaction desired in this immersive methodology. Using this workflow, prototypes will be created in order to visualize the desired sensorial outcomes described in the immersive methodology.

V. PROTOTYPE INVESTIGATION

5.1 Introduction

In the last chapter, the prototype design workflow is introduced. In Chapter 5, the wokflow - in addition to the immersive design methodology - is applied to the creation of five prototypes.

These protoypes are designed with user focused interaction as the basis of the design intent. Specific senses are targeted in order to explore various outcomes of the simulated interactions. Each protoype is applied in an architectural context - horizontal and vertical surfaces. User interaction is then simulated within the digital model in order to extract various formal variations. This application also allows for visualizations to be produced.

5.2 TEAR

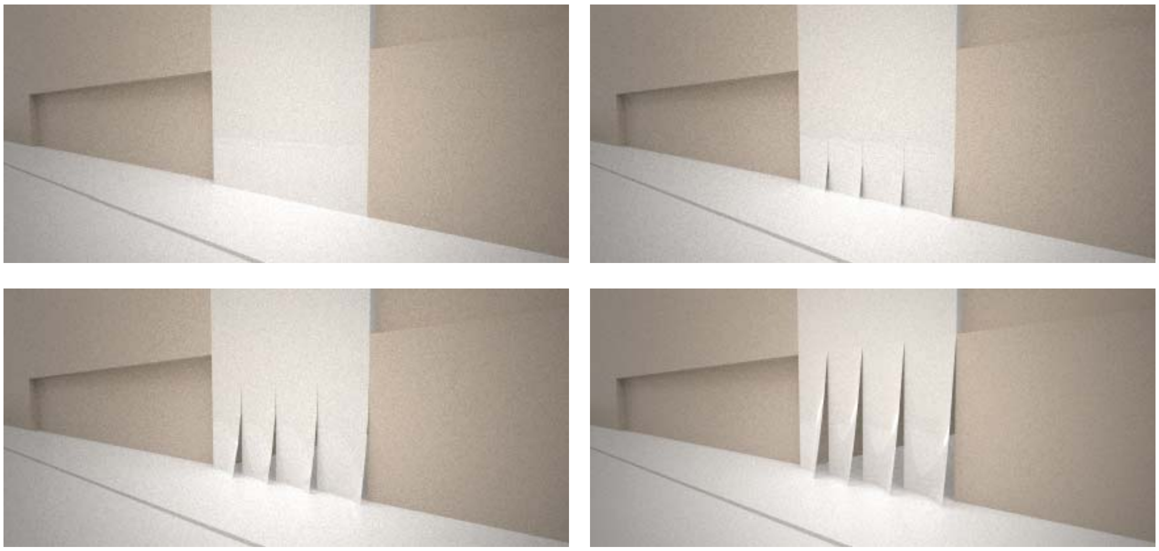


Fig. 5.1- Sequence Image of *Tear* prototype from Non-Active to Active State.

The concept behind this prototype is to create a vertical opening and closing of a surface, creating a "tear." The initial state appears to be a single, flat surface, and then when interaction occurs, the tear appears. The prototype's design intends to create varying opening sizes according to a user's physical attributes. The interaction between user and architectural prototype is what creates the aesthetics of the prototype. *Tear* was inspired by the design motif found on motor vehicles and airplanes, usually in areas that requires air intake to cool some mechanical assembly. Another aeronautic/ automobile inspiration is the adjustable spoiler that increases or decreases drag according to the driver preference. If users are treated as the environmental design variable and architecture is the adjustable mechanical assembly, what prototype can accommodate the constantly adjusting user information in an aesthetically and functionally pleasing manner? This is the question that *Tear* aims to answer.

5.2.1 Narrative Intent

As a user passes by the prototype in a parallel manner, the bottom of the surface begins to slowly open. The sight of the surface opening creates visual interest in the user. If the user chooses to continue on their initial path, the surface closes. If the user chooses to approach the tear, the opening becomes larger. The user - according to the user's physical characteristics – creates the length of the opening. The prototype is fully open once the user is directly within the range set by the designer, typically

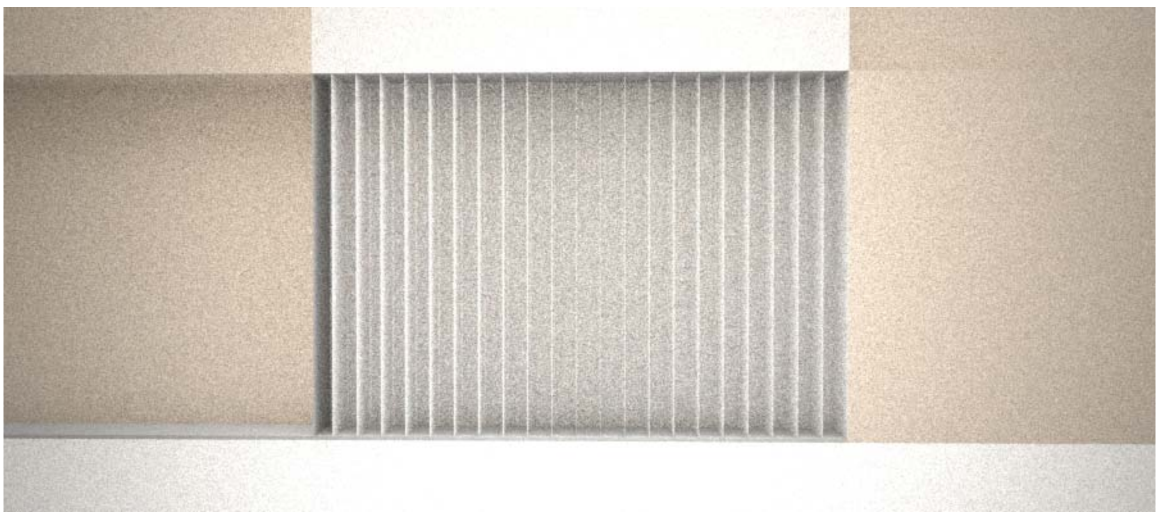


Fig. 5.2 - Elevation Image of *Tear* - Variation One

directly below the threshold between spatial zones. As the user begins entry into the new space and away from their initial location, the prototype begins to return to its non-active state.

The narrative sequence is triggered by the user; the tearing pattern doesn't exist if the user is not there. Sight is an important target sense that *Tear* aims to stimulate. The dynamic movement of the opening and closing sequence has visual interest for users near and viewers far. The interest created by users at close proximity is what creates

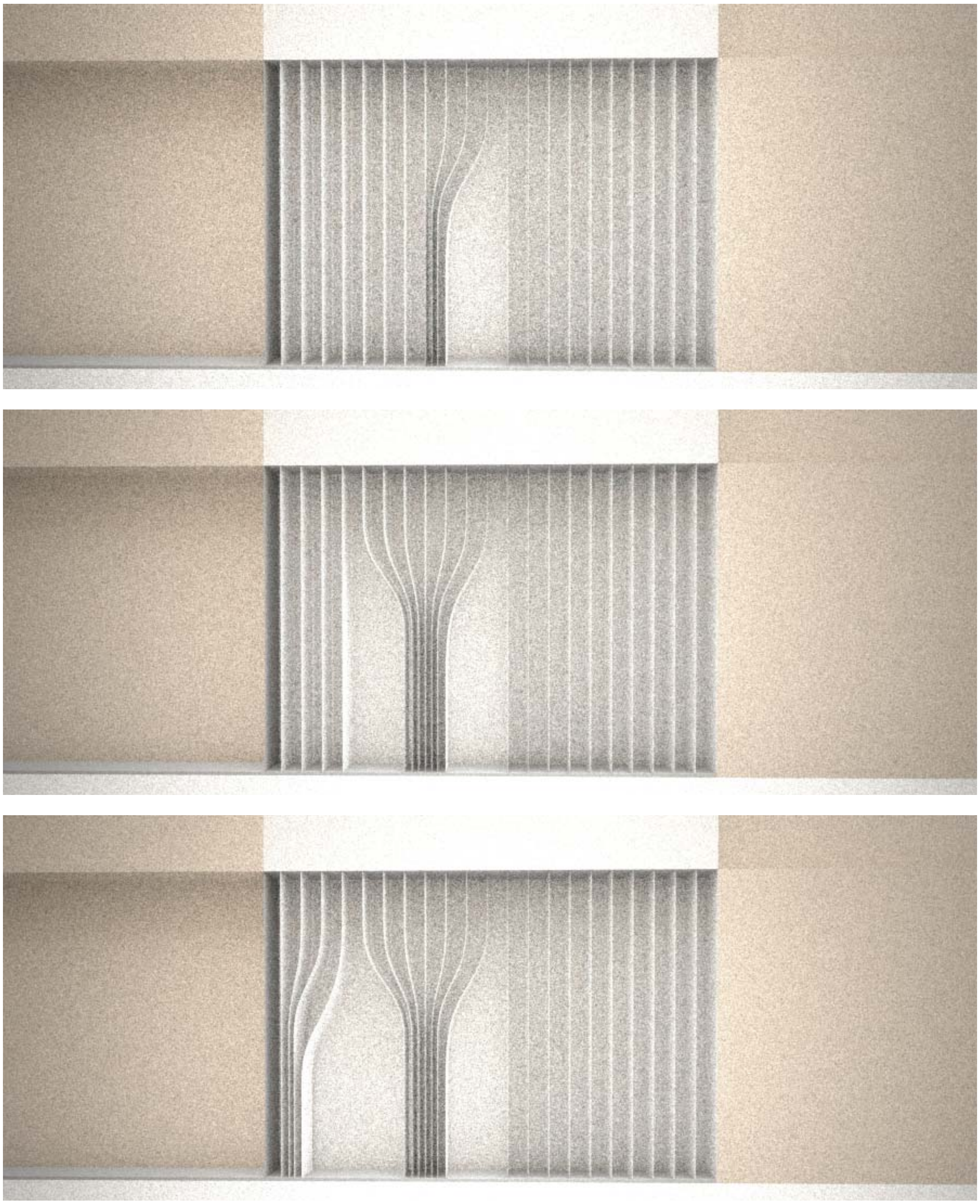


Fig. 5.3 - Sequence Image of *Tear* prototype - Variation One from Non-Active to Active State.

the interest from viewers at a distance from the surface. Like lifting a corner of a book page, Tear allows a person to seemingly disappear behind a torn surface creates a new entry/exit experience. The visual impact is enhanced if the surface is made of an opaque material because outside viewers will not know what is behind the surface.

The sound that this prototype creates is part of the interest that draws the user in. The sound of the moving surface creates a unique experience. This spatial experience is enhanced by the prototype's movement. Similar to most kinetic mechanism, the technology enabling this movement has an inherit sound that it already exudes when at work.

The Non-Active state of the *Tear* prototype is a smooth, undifferentiated surface. The Active state of *Tear* is the "torn" surface. The initiation from Non-Active to Active is done by the user, and depending on the application, the variations on the surface will be varying on different levels. *Tear* creates a unique experience of entrance. The opening size can be varied according to what type of data is being observed.

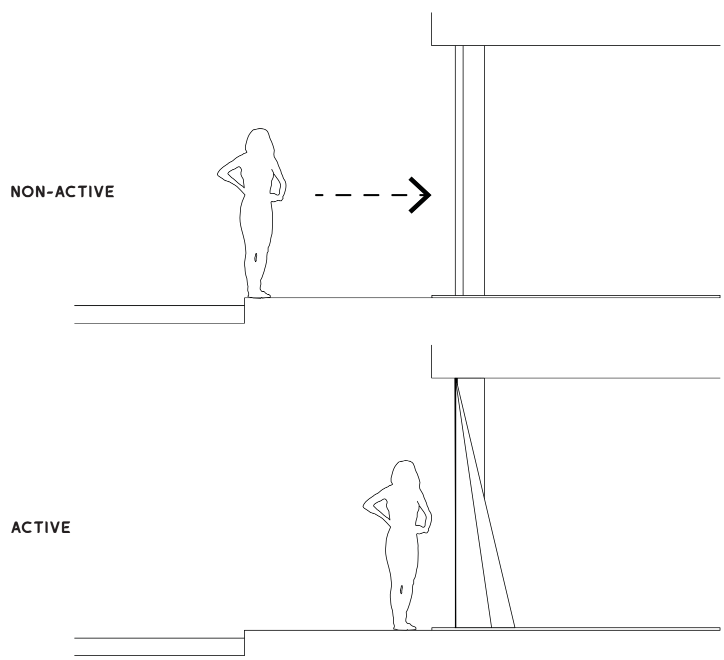
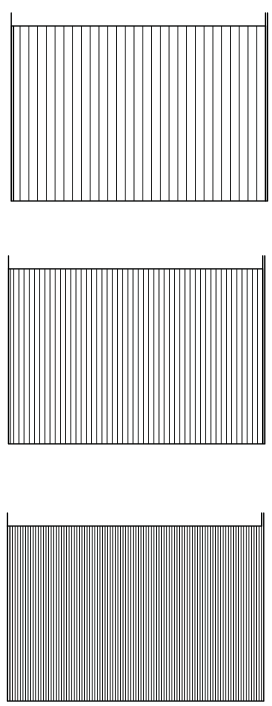


Fig. 5.4 - Elevation diagram of *Tear* prototype in Non-Active and Active states

5.2.2 Prototype Development

5.2.2.1 Variation One

The first digital model took a curtain like organization of seemingly rigid, vertical surfaces and applied it in a horizontal way to create a wall. This is its' non-active state. Then - according to the designer's narrative intent and programming - as the user(s) approach the surface, the surfaces begin to bend and deform to create openings. The size and the manner in which these openings bend and deform are determined by the designer. In these variations, the position of the user as well as the physical attributes of the user - height and width - determines the way the surfaces react.



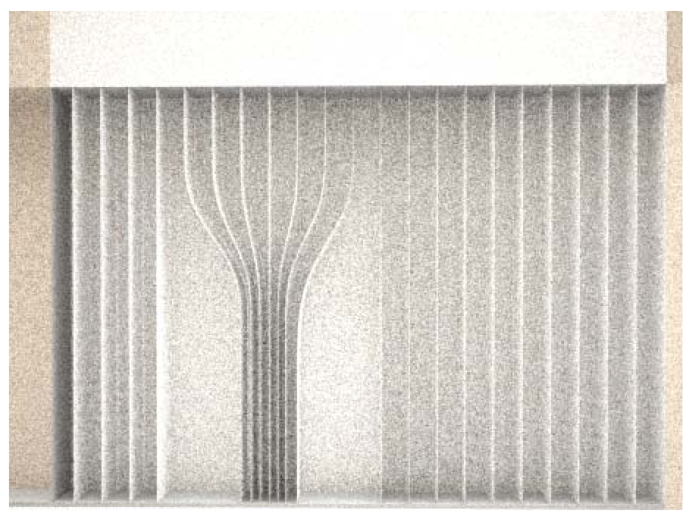


Fig. 5.5 - Patterning Variations of *Tear* - Variation One

This variation of this iteration serves two functions. First, it provides security, provided that the surfaces are densely placed together. The second is that the prototype provides a personalized entry sequence for every user. This creates visual interest, which is especially pertinent for storefront or facade applications. The surface tear prototype, in this case, is both functional and at the same time serves as an aesthetic advertisement for the spatial environment. The pattern of the surfaces also allows for a moiré-like effect, and depending on the direction of the user's approach, the effect will be magnified. The patterning is created by adjusting the bottom control points of the geometric model. As the user approaches the surface, the bottom most side of an individual surface slides in either X-direction to create an opening or revert back to its original position.

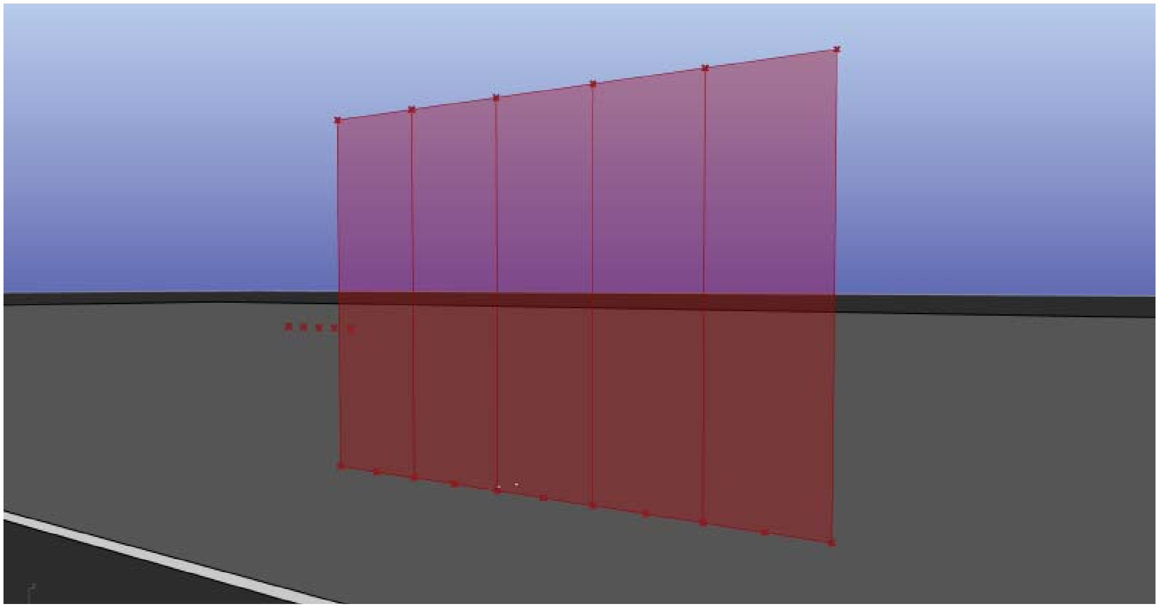
Of the two variations, *Tear*-Variation Two is chosen to create a simulation of user interaction within Grasshopper. First, a single surface is created and then linked into the Grasshopper model. This single, vertical surface represents a single division of a larger surface. Depending on the programmatic requirements, the divisions can vary in sizes. For this experiment, 5' divisions were used in order to simulate a typical storefront opening. That single surface was then broken into its' component parts - Faces, Edges, and Vertices – using the Explode Brep component in Grasshopper. From that step, the information from the Vertices output was broken down further into four separate points - which represent the corners of the initial surface. The bottom right corner was extracted and isolated from the rest of the points. This point is the first point of movement in the interactive model. A line is created, which simulates the movement of a user in the digital model. A point along this curve is then extracted, the point being the location of the user within the digital environment. As this point shifts from one end to another, it affects the movement of the corner point extracted.

Two user movements were simulated – 1) A movement perpendicular to the surface normals and 2) Movement parallel to the surface normals. The first movement simulates a user walking into the space behind the surface. The second movement simulates a passerby to the surface. This simulates user and viewer for the *Tear* prototype. Each simulation variation created a different patterning. The first simulation created larger openings as the user passes right through the surface. The second simulation created smaller openings, but created a larger pattern variation across the test surface.

5.2.2.2 Variation Two

The second iteration of the *Tear* prototype takes a single surface and creates a literal tear at the bottom of the surface to create the opening in which a user enters or exits a space. Instead of starting with a large surface, this iteration took a smaller sub-surface and explored the ways the points on the surface could be pulled. The outcomes were then rendered and stored for comparison. The version chosen is one where either bottom corner starts to pull outward or inward - depending on the desired reaction - as the user engages the surface. As the interaction between user and prototype continues, the other points along the same edge continue to follow in the direction of the initial corner pull. This creates a geometry that mimics a tear - a tear along a piece of paper, or a tear in a piece of fabric.

This movement creates a unique opening sequence that is both functional and aesthetically pleasing. Instead of allowing the user to view the contents of what is within the surface, this prototype creates a spatial interest from close proximity and a visual interest for viewers that are far from the proximity of the surface. The answer to the question of how one enters the space seemingly cut off from the outside is not



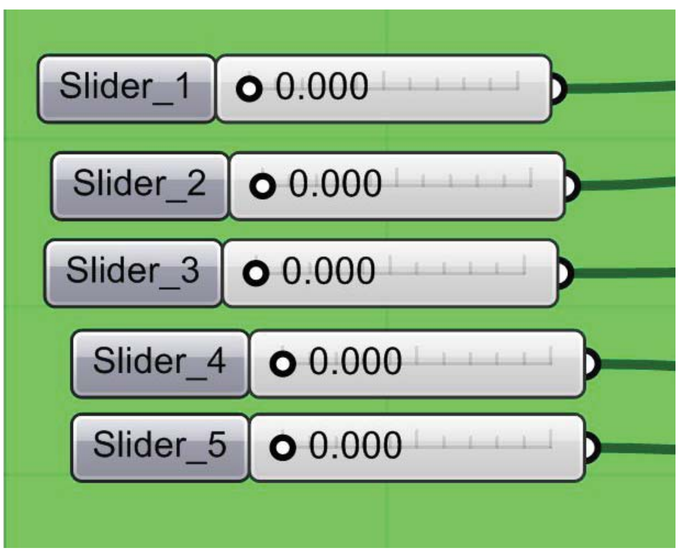
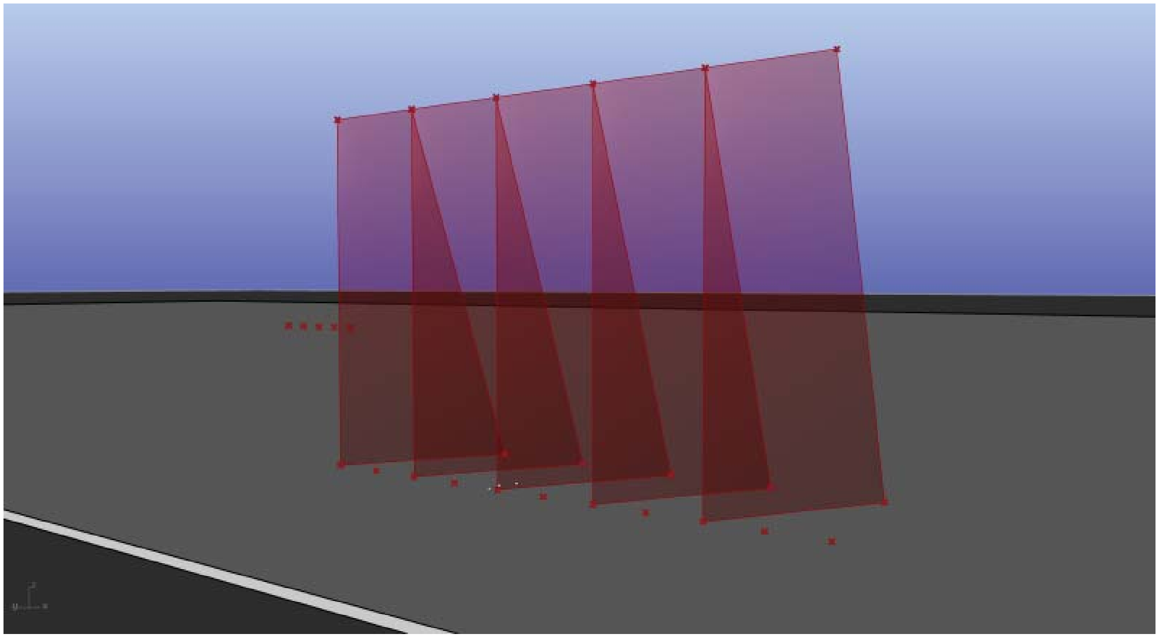


Fig. 5.6 - (Above) Initial *Tear* surface (Non-Active State) w/ corresponding Grasshopper definition (Lower Image) showing the Slider component that simulates the position of the User.



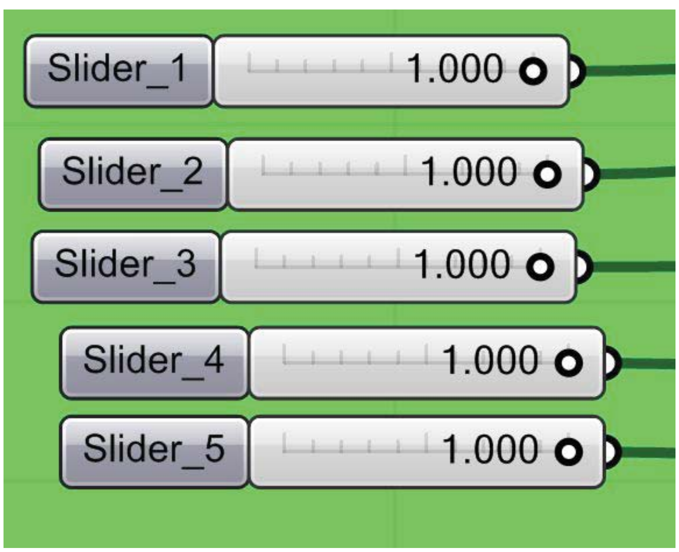


Fig. 5.7 -(Above) Initial *Tear* surface (Active State) w/ corresponding Grasshopper definition (Lower Image) showing the Slider component that simulates the position of the User.

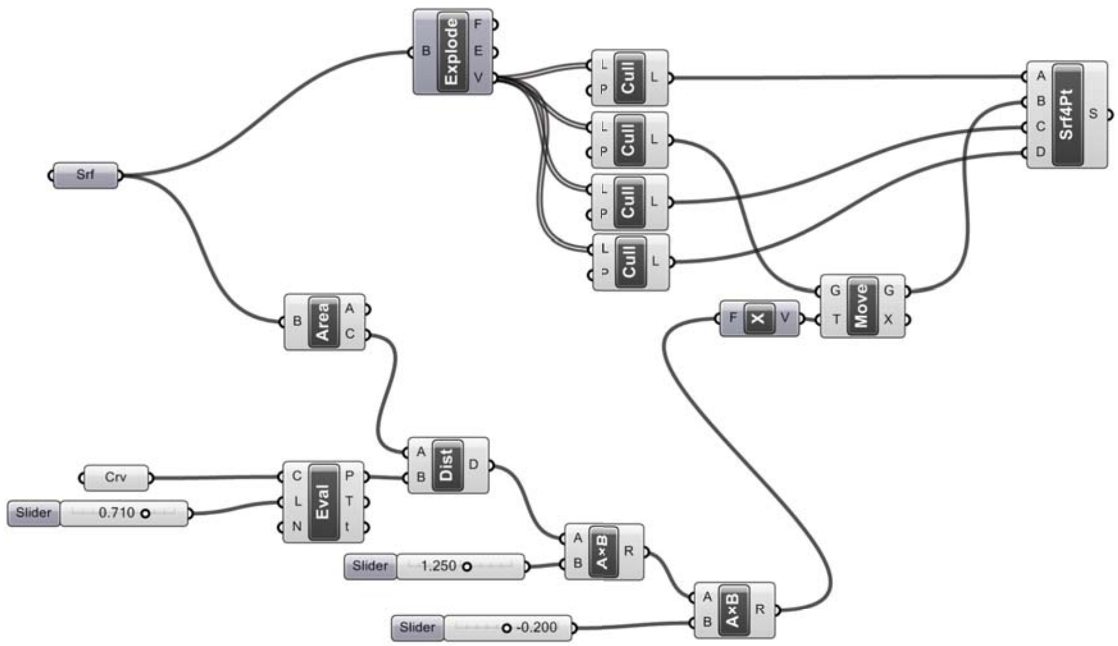


Fig. 5.8 - Grasshopper definition of *Tear* - Variation Two with a single surface.

known until a user approaches the surface. Then, as the prototype reacts, it becomes apparent that the prototype is reacting to their movement, more specifically the user's proximity to the surface. From a distance, a passerby notices the occurrence of the interaction between user and surface. That unique opening sequence creates a spark of interest for the viewer, who then turns from viewer to user and approaches the surface themselves.

5.2.3 Applications

During the design process, the main application of *Tear* was in entry/exit or spatial division applications because of *Tear*'s ability to allow users to go through the surface. After applying *Tear* to vertical surfaces, explorations were done to see *Tear*'s outcome

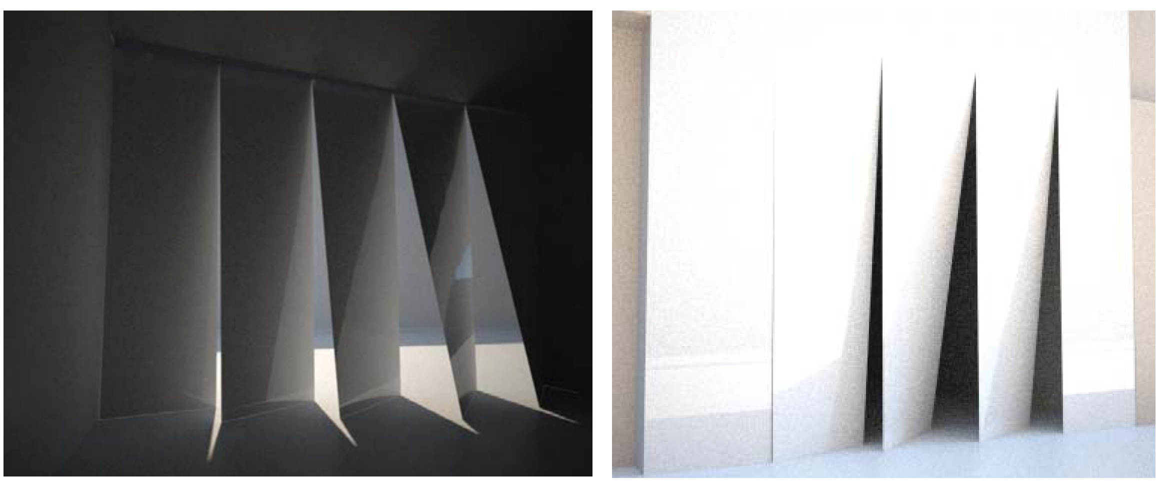


Fig. 5.9 - Elevation Image of *Tear* - Variation Two as a vertical surface

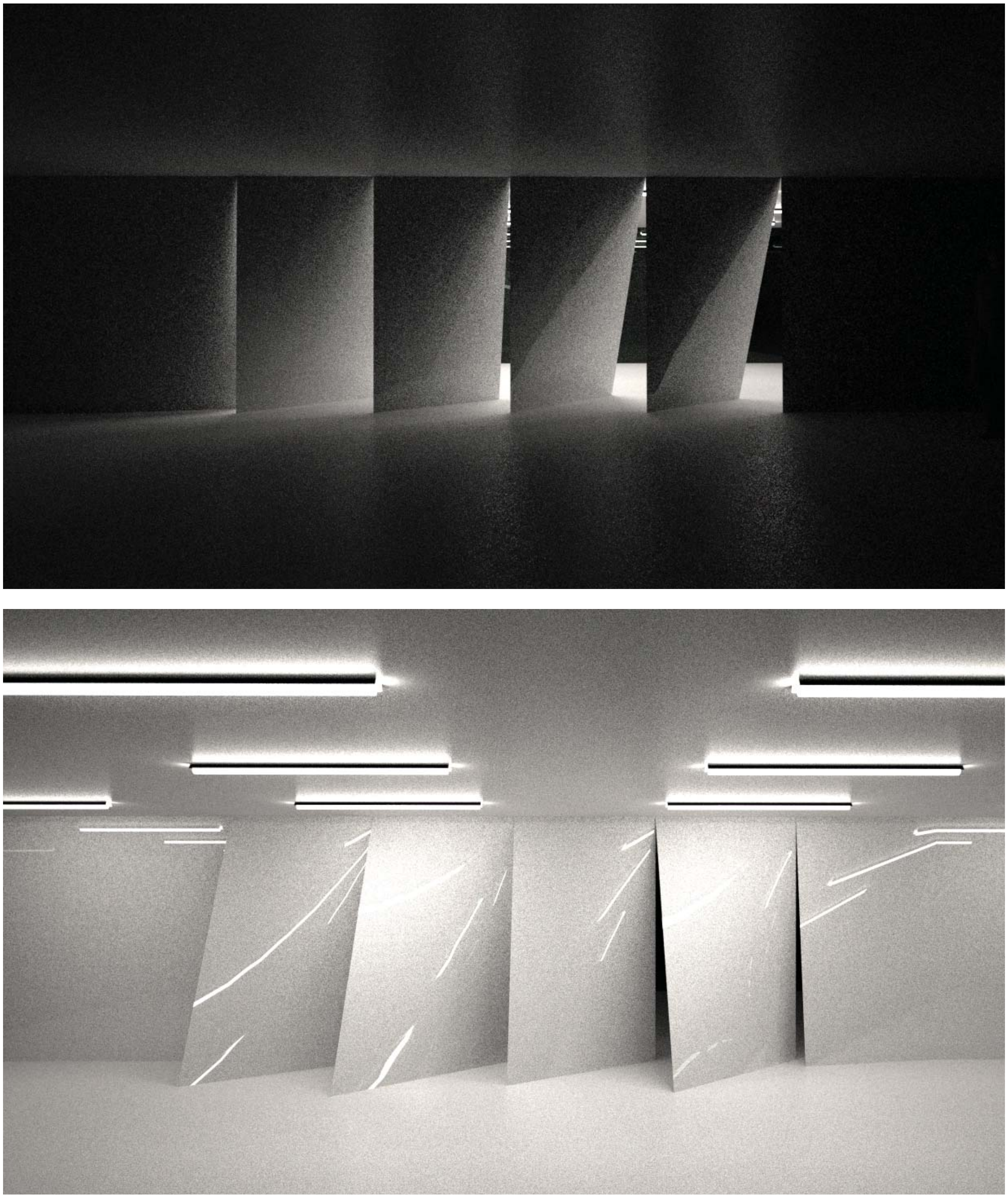


Fig. 5.10 - Elevation Image of *Tear* - Variation Two as a vertical surface

as a horizontal surface. The main difference between *Tear* as a vertical or horizontal surface is how the user engages with the surface. As stated, *Tear* originates as vertical surface allowing for users to use *Tear* as a door. However, as a horizontal surface – specifically a ceiling – the user no longer can easily pass through the prototype. Instead, when *Tear* is applied as a ceiling, it creates a narrative between user, prototype, and natural environment. Daylight entering the space can now be determined by user interaction with *Tear* as a ceiling.

Wall (Vertical Surface)

The application of *Tear* was intended for a vertical application, mainly for the use of entry, exit, or space divisions. The number of openings created is dependent on the spatial requirement of the space - smaller spaces would require less surface openings than larger spaces when used as an entry or exit. *Tear* as a non-entry prototype can have a larger amount of surface openings depending on the use and is limited only by the mechanization used to create the interaction between user and prototype.

Ceiling/Floor (Horizontal Surface)

Tear in a horizontal application is limited to a non-entry prototype - it cannot alter the spatial conditions. This would be useful in applications where light is needed in a space only sparingly in order to make use of the ability for the prototype to allow light in only when a user(s) is present.

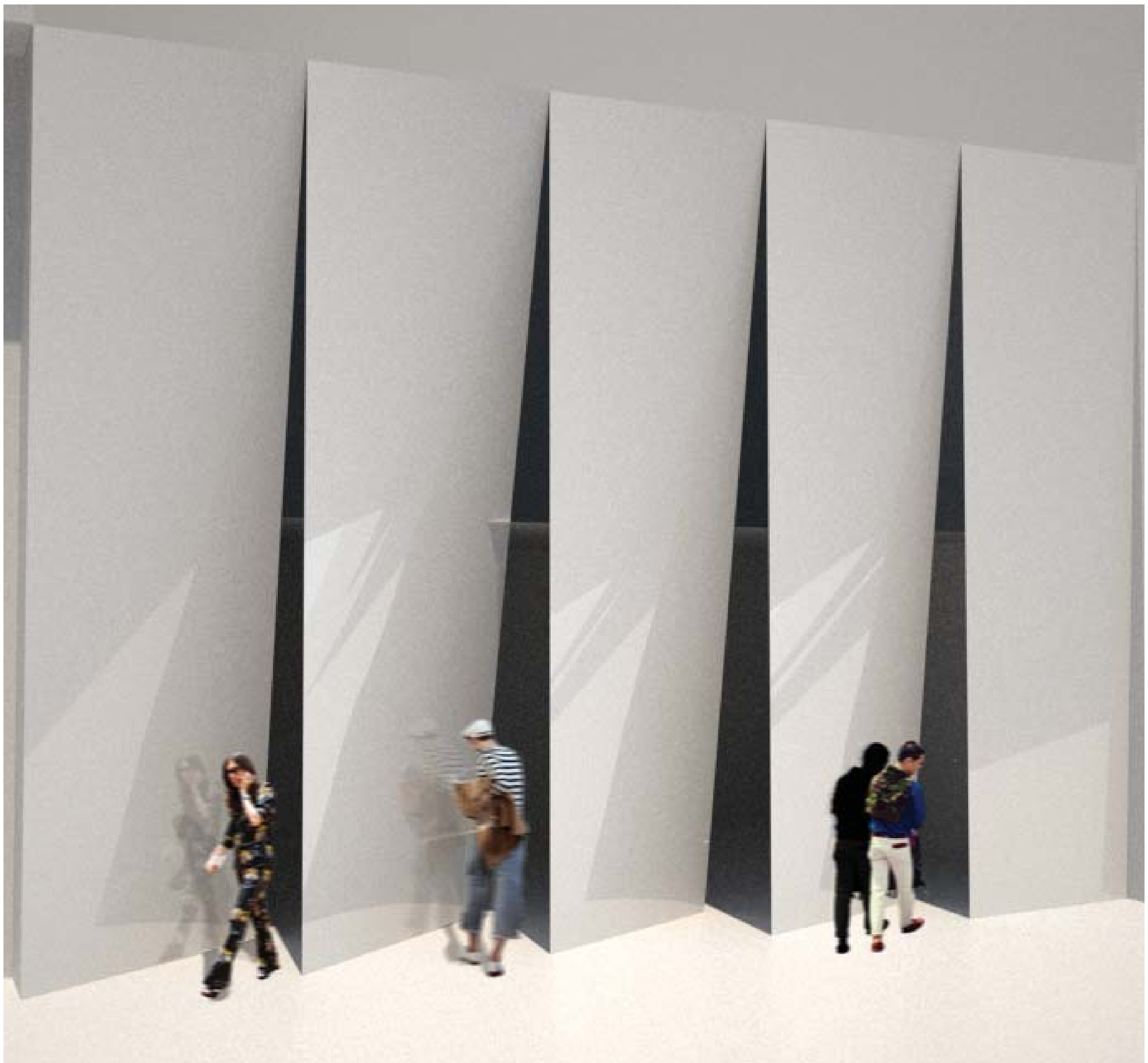
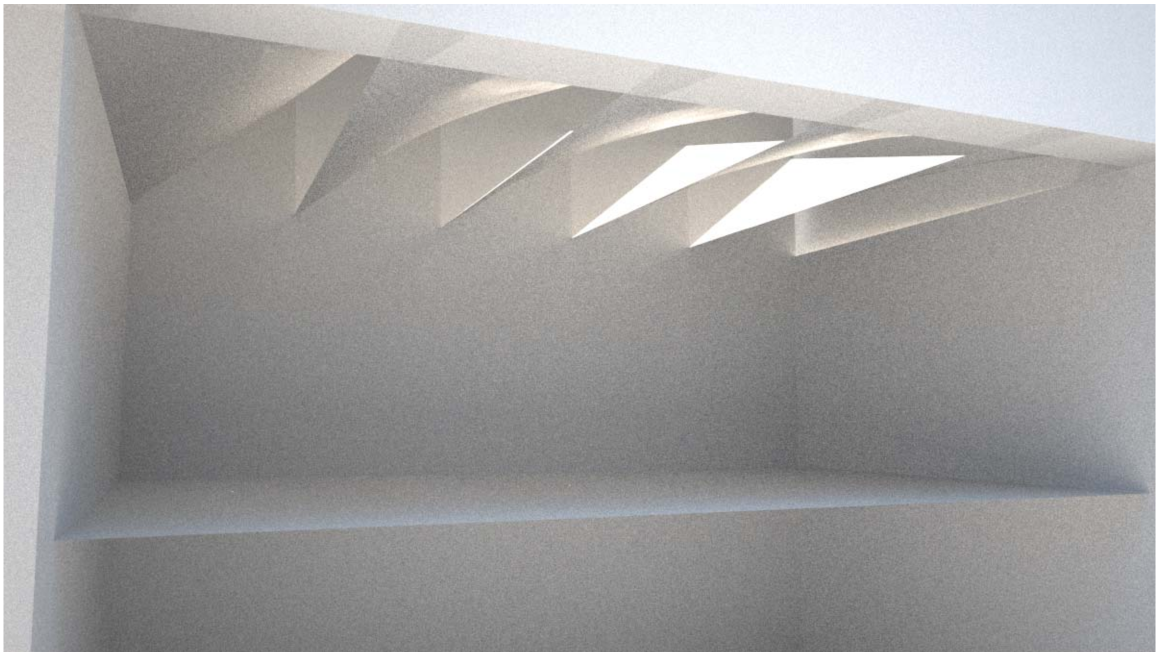


Fig. 5.11 - *Tear* as an Entry Sequence



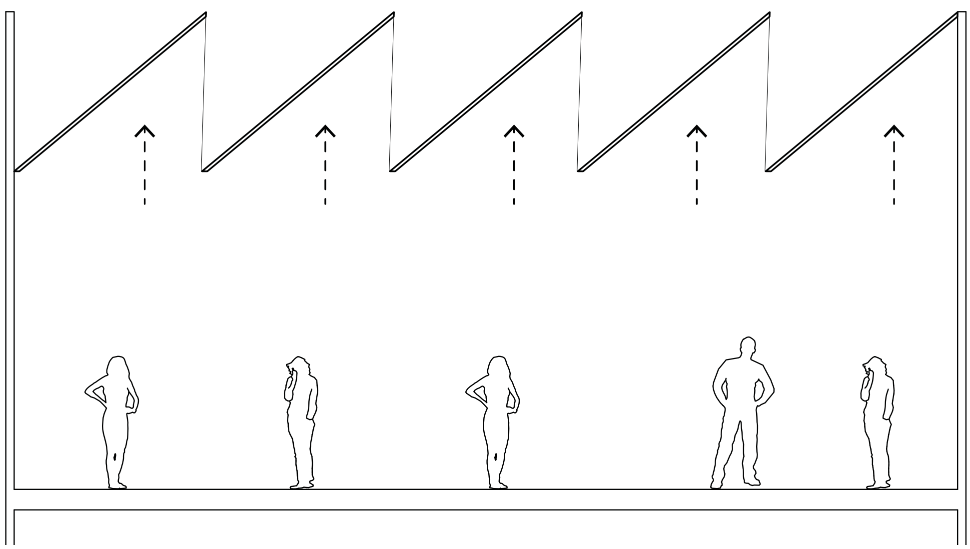


Fig. 5.12 - *Tear* as a vertical surface

TEAR

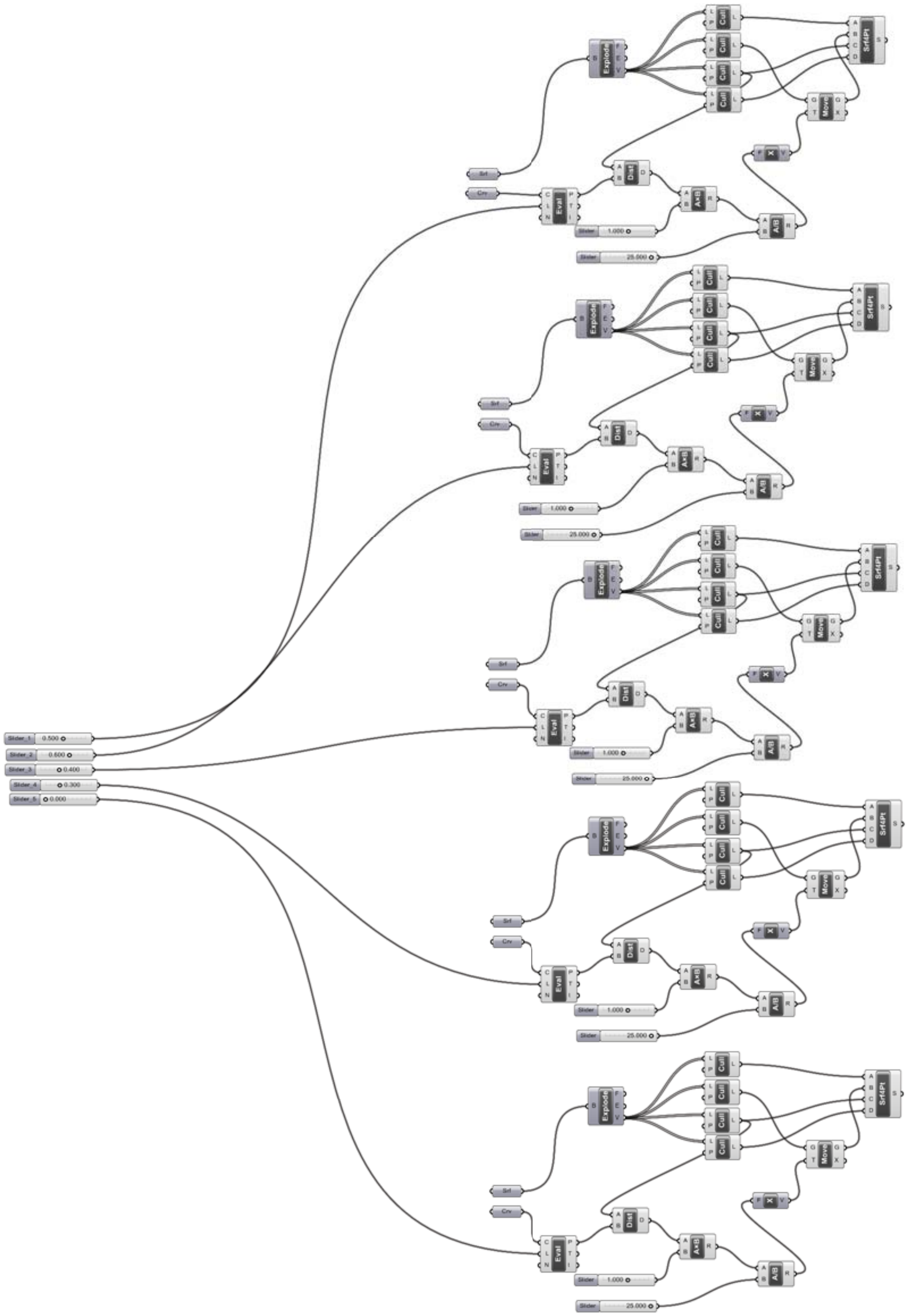


Fig. 5.13 - Grasshopper definition of Tear-Variation Two with five surfaces

5.3 TWIST

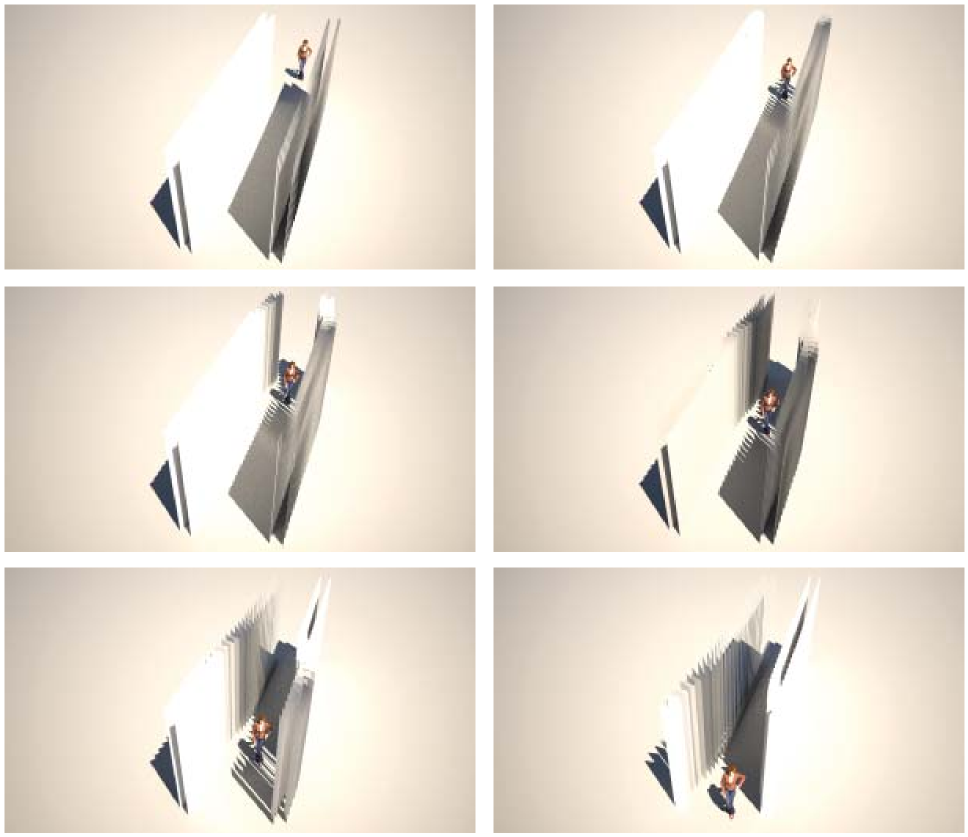


Fig. 5.14 - Spatial Sequence of User Walking through *Twist* prototype environment

Twist is a prototype that aims to create viewports along a surface that is unique to those users at a specific point. Its' main goal is to redefine the narrative between a user and window treatments. Instead of a user adjusting the treatments whenever they enter a space, *Twist* aims to create an instinctive narrative that allows the space to react to the user instead.

5.3.1 Narrative Intent

In a typical spatial narrative, a user enters a space and adjusts the levels of light according to their preference. What *Twist* aims to create is a dialogue that allows for space to adjust without direct user input. As a user passes by the prototype, panels begin to rotate. The degree rotation adjusts according to the user's proximity to individual panels; when the user is perpendicular to a surface panel, the rotation is 90 degrees. This creates an opening for the user to view through the surface and into the interior or towards exterior towards the natural environment.

Twist is a prototype that focuses on the view towards what is beyond. Instead of creating a viewing area that either open or closed, *Twist* creates a viewing pattern that works to create a distinct way of framing views. Only through interaction is this created.

The patterning of the panelization naturally lends itself to create an accompanying sound pattern. The proximity of the individual panels to one another creates a shuffling sound as the user moves through the space. Depending on the material of the panels, this effect can muffled or enhanced.

The non-active state of this prototype is a single, uninterrupted surface. As the prototype enters its' active state, individual panels begin to reveal themselves and rotate. This rotation is determined by the user position.

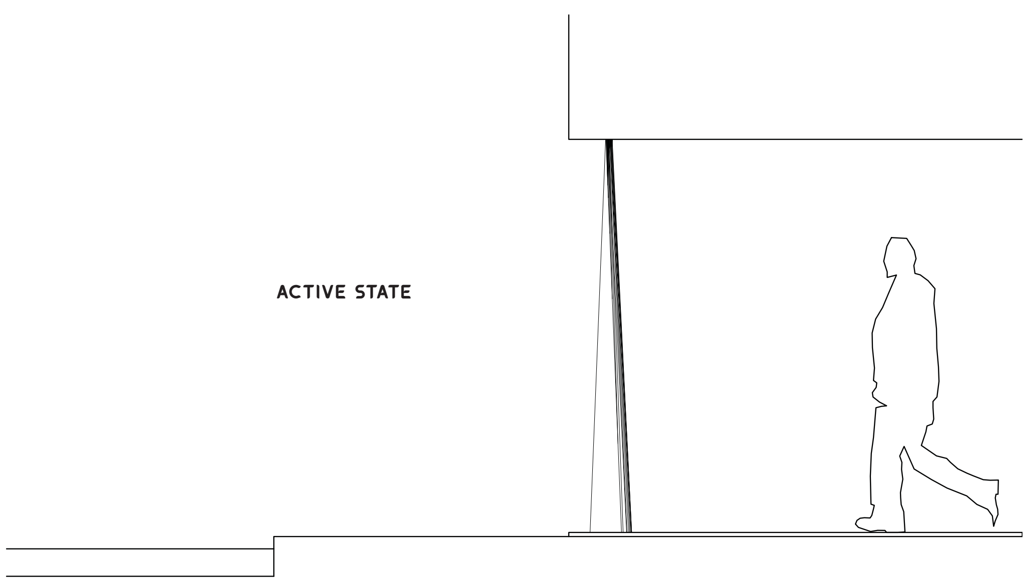


Fig. 5.15 - Section Diagram of *Twist* in an active state

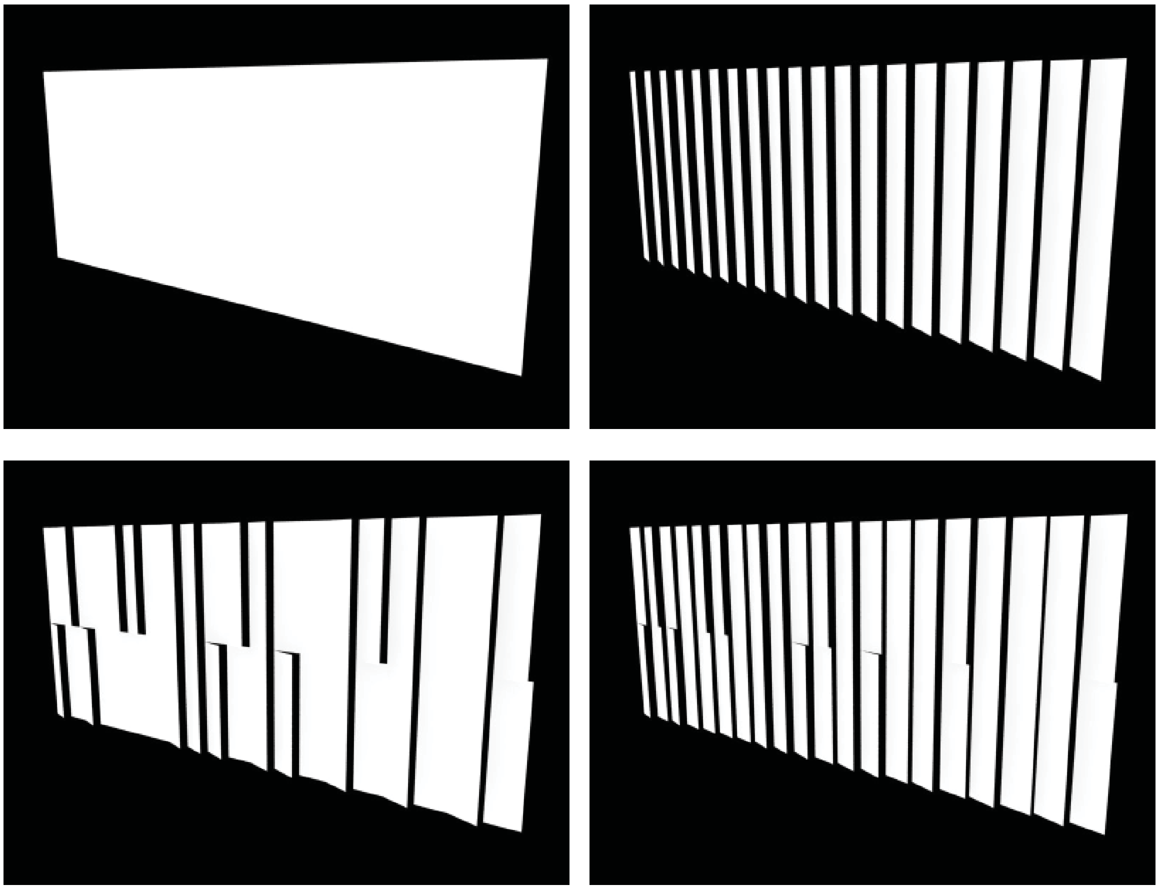


Fig. 5.16 - Elevation Image of *Twist* Variation Two as a vertical surface

5.3.2 Prototype Development

5.3.2.1 Variation One

This variation of *Twist* is simple in its geometric make-up. Comprised of vertical panels, the interaction between the prototype and user creates the complexity. Investigation explored the amount of panelization that would create the most useful spatial change. Since the original intention was as a shading device, divisions were only done along the surface normals, creating tall, narrow surfaces. These surfaces rotate according to the narrative intent.

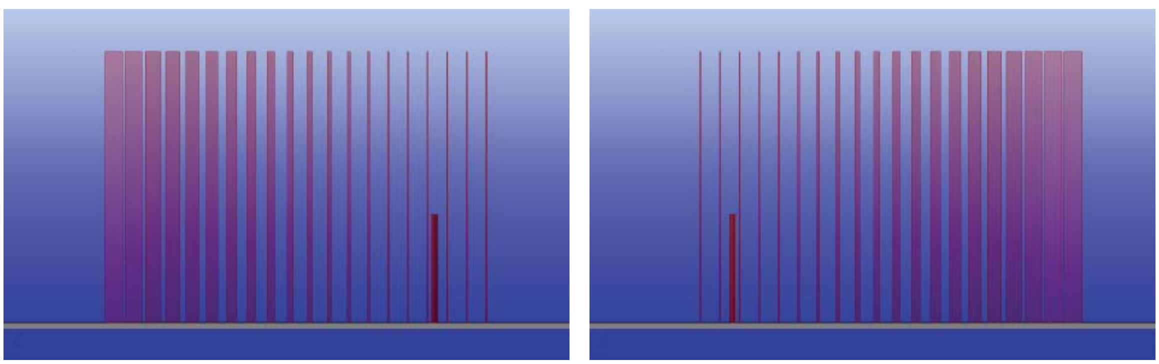


Fig. 5.17 - Grasshopper-simulated user interaction within digital model of *Twist* Variation One (Cylinder representing the user's position.)

This variation of *Twist* takes a surface and subdivides it along the U-direction, which determines the sizes of the panels. Then, each panel is exploded to extract the Faces, Edges, and Vertices information. This geometrical information is how the surfaces are separated, which allows for individual rotation. From the exploded geometrical information, the information from the Vertices is separated into four individual points, the four points representing the corners of the surfaces. Then, each corner is then reconnected to create the new individual surfaces needed for the panel rotation to occur. From this, the panels are rotated simultaneously along its central vertical axis. The angle of rotation can be adjusted in two ways for this variation – there can be 1) A simultaneous rotation of the same degree amongst all surfaces or 2) An individual rotation amongst panels determined by the user position to the prototype. If a simultaneous rotation is desired, then there is only one rotation input, which is limited to 90 degrees. However, if an individual rotation is desired, then a user path is defined in the Rhinoceros 3D modeled and instantiated in the Grasshopper definition. Along this user path, a point is extracted in Grasshopper. Then, the center points of each panelized surface are extracted. Using a measuring component in Grasshopper, the distance between the point and each center point is measured. Depending on this value, each panel rotates. If the user is further from the panel, the more acute the angle of rotation. As the user approaches the panel, the rotation increases until the user is perpendicular to the surface, at which point the surfaces stops rotation.

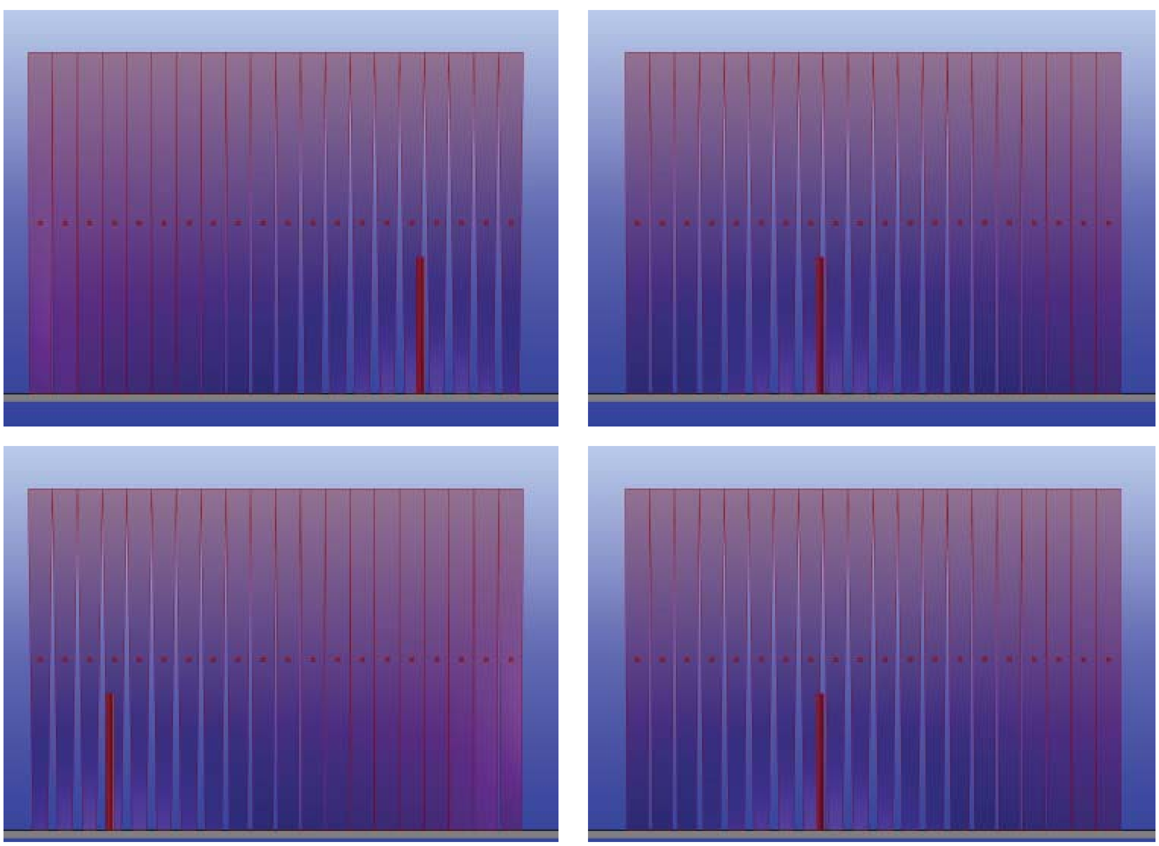


Fig. 5.18 - Grasshopper-simulated user interaction within digital model of *Twist* Variation Two (Cylinder representing the user's position.)

5.3.2.2 Variation Two

The second iteration of *Twist* takes the original intent of the first iteration. However, instead of rotating the entire panel, only the bottom edge of the panels rotates, creating a stronger visual pattern within the prototype itself. Again, a single surface is divided along the surface normal and panels rotate according to the intent of the user.

The second iteration takes a single surface and divides it in the U-direction. This determines the sizes of the panels. Then each panel surface is exploded in order to extract the basic geometrical information – Faces, Edges, and Vertices. After geometrical separation, the vertices are separated into individual points. From this, the top and bottom pairs of points are extracted and separated. In this variation, the bottom two points create the rotation while the top points are stationary. The

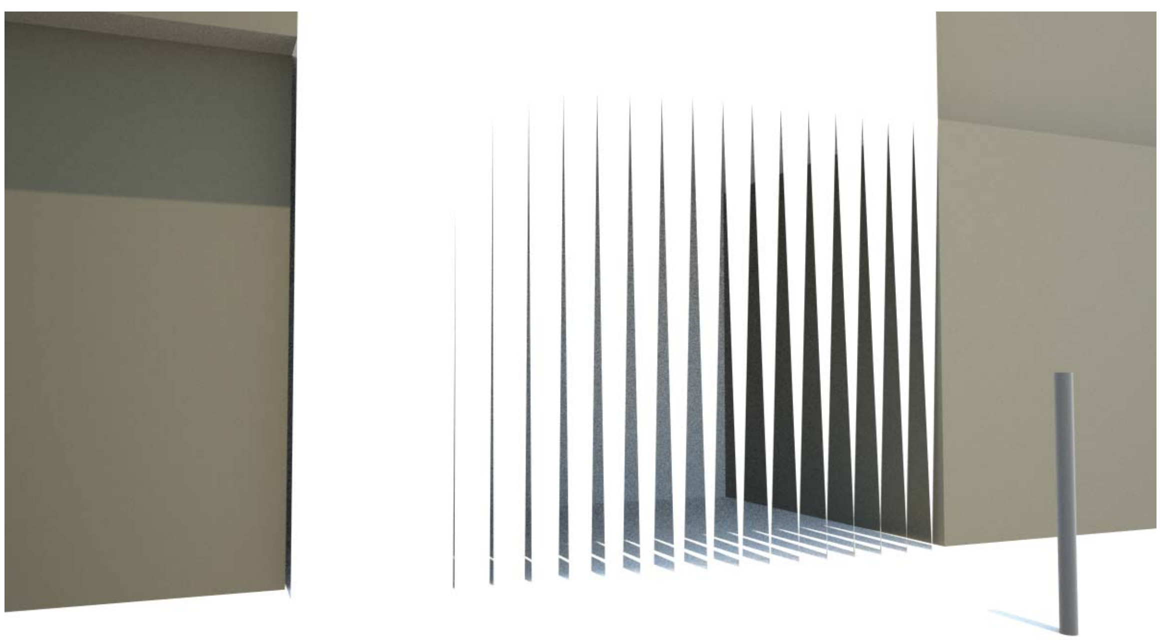


Fig. 5.19 - Digital model of *Twist* Variation One (Cylinder representing the user's position.)

stationery top edge and the rotating bottom edge of the surface create a twisted geometry. The angle of rotation can be determined using the same two methods that determine the rotation in *Twist* Variation One.

5.3.3 Applications

Twist's intended application is that of a window treatment. As the user moves through a space, the prototype rotates the individual panels that compromise the surface according to the user's proximity to each panel. However, through further design investigations, more applications were found.

As a vertical surface, *Twist* can function as a window treatment. The rotating panels provide the ability to let the user view through the surface. This interaction is not limited between user and space; naturally, daylight factors come into play with this opening and closing of surfaces. This creates a further interaction between prototype and natural environment.

In the same manner, when *Twist* is applied as a horizontal surface, it creates apertures that allow for the user to view through the surface. If applied to a ceiling condition, *Twist* is a very useful tool in controlling amounts of light needed within a space.

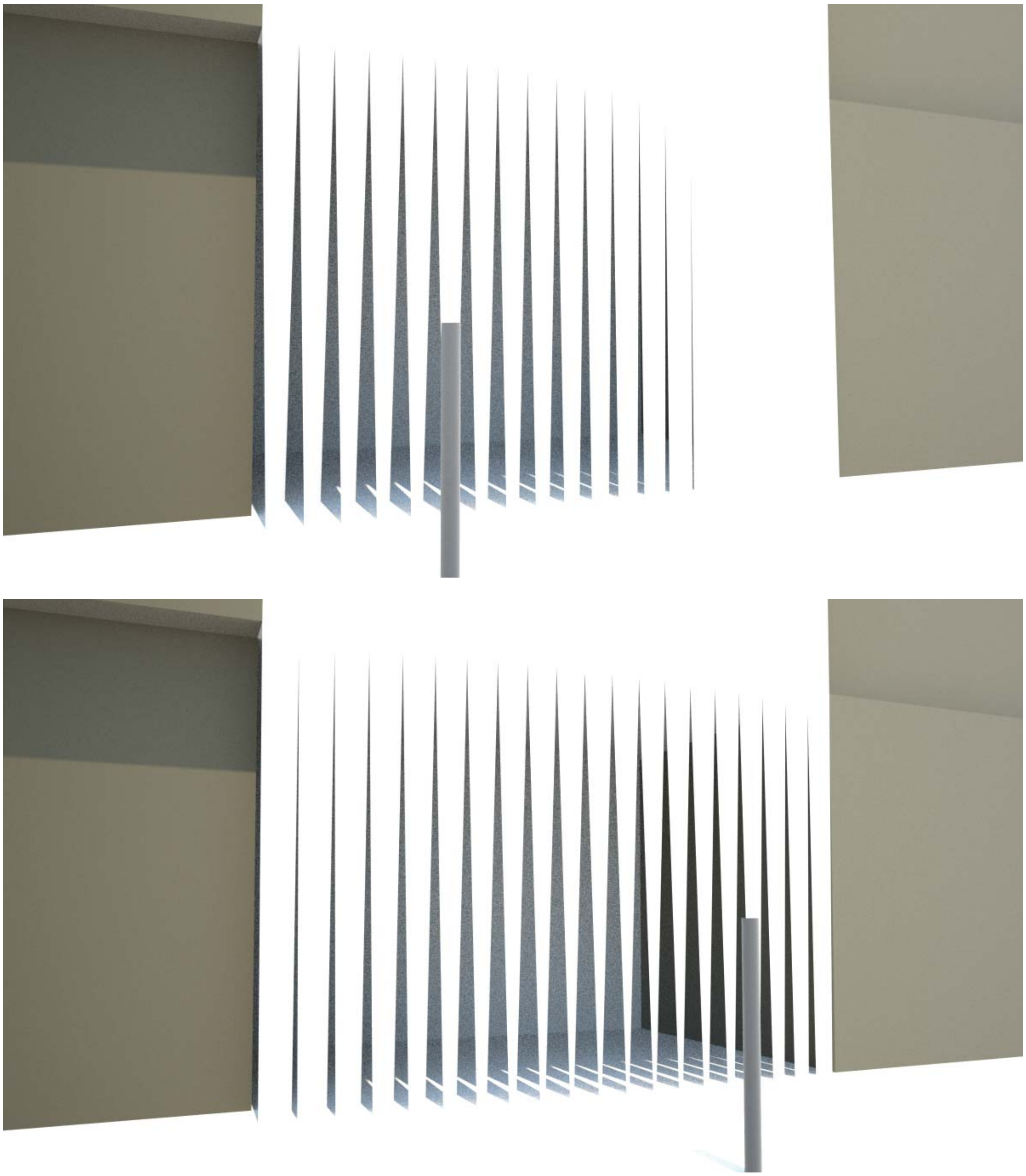


Fig. 5.20 - *Twist* Variation Two as a vertical surface with User interaction captured (User is Cylinder)

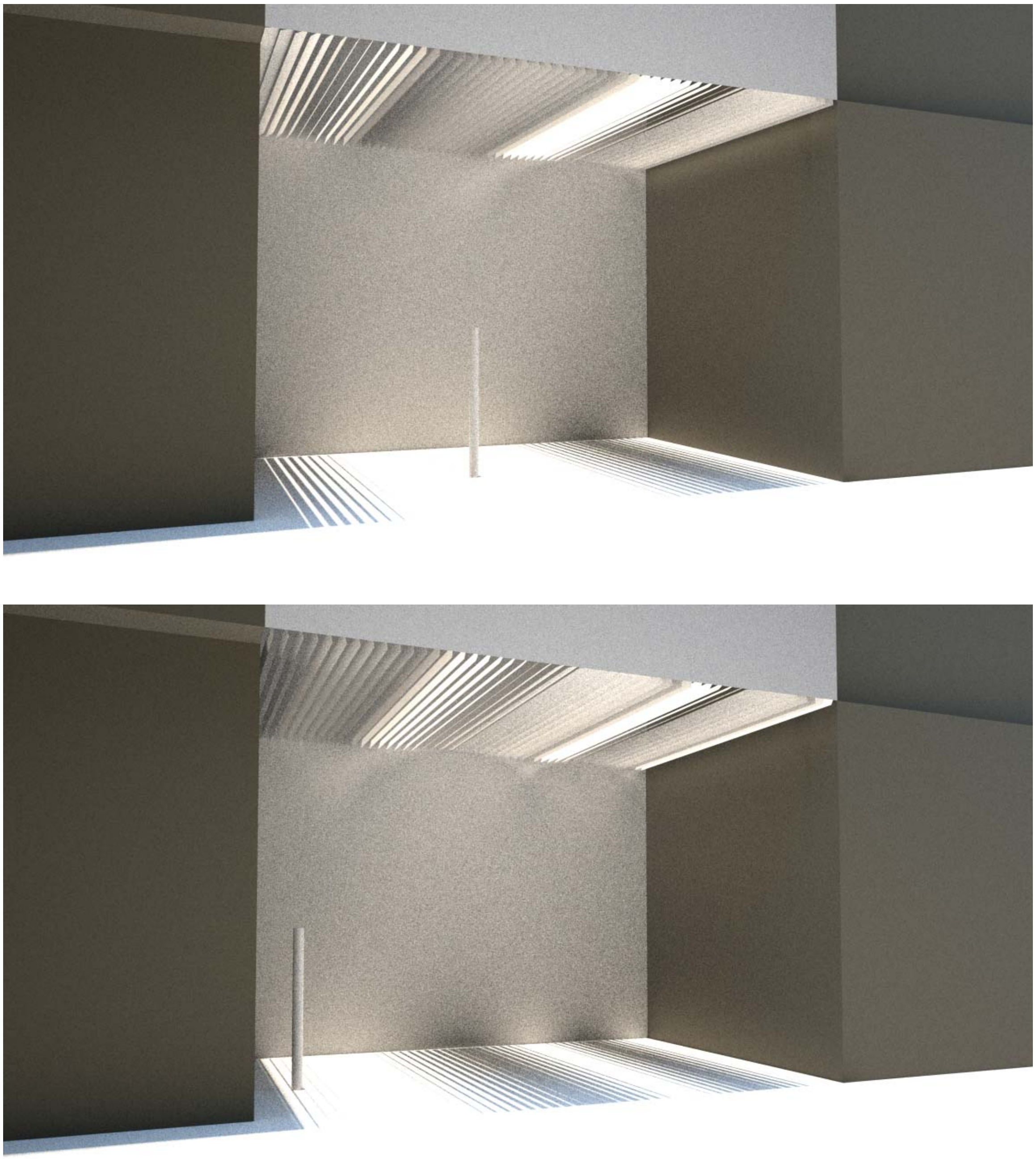


Fig. 5.21 - *Twist* Variation Two as a horizontal surface with User interaction captured (User is Cylinder)

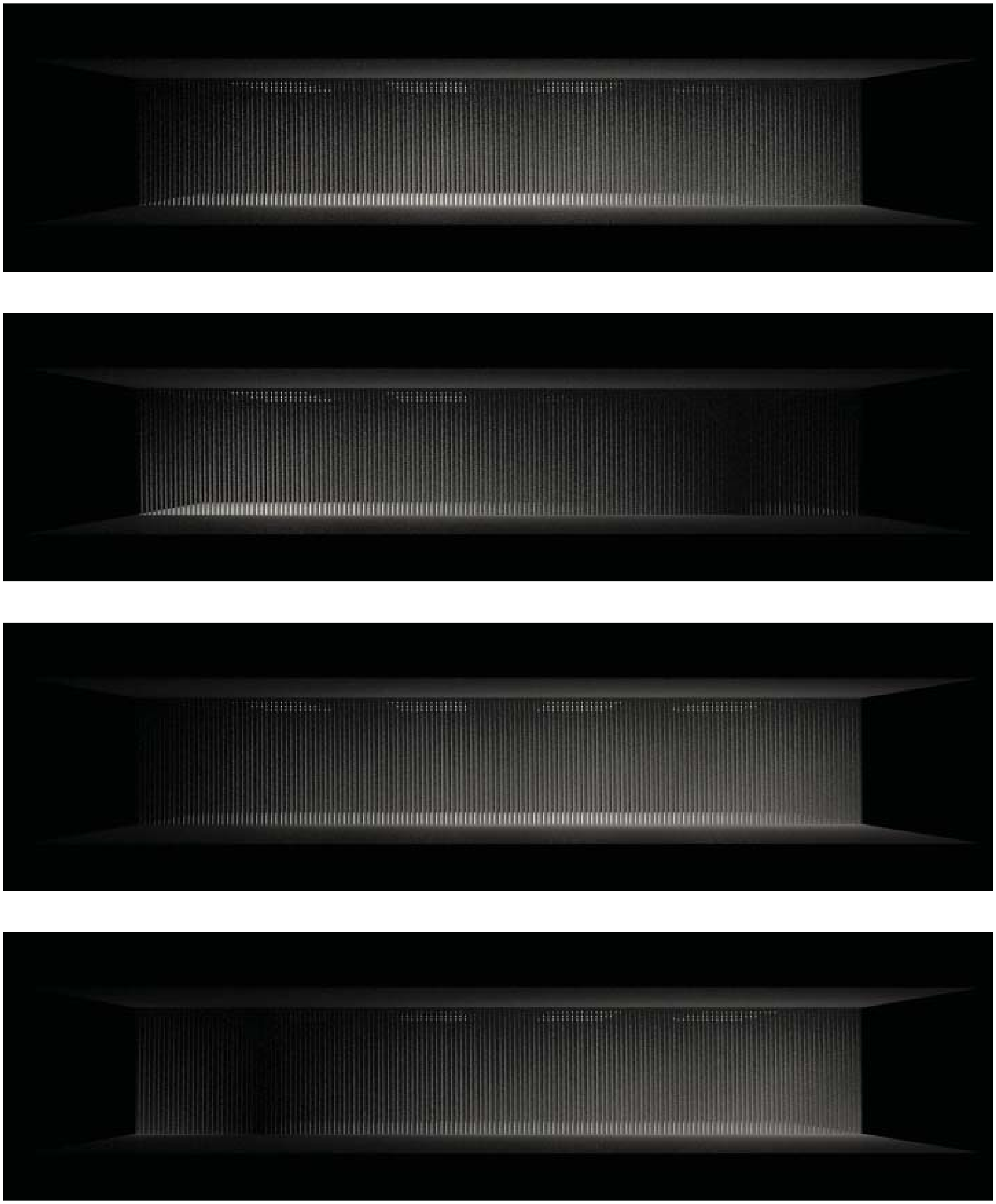


Fig. 5.22 - Sequence showing effect of *Twist*'s lighting effect

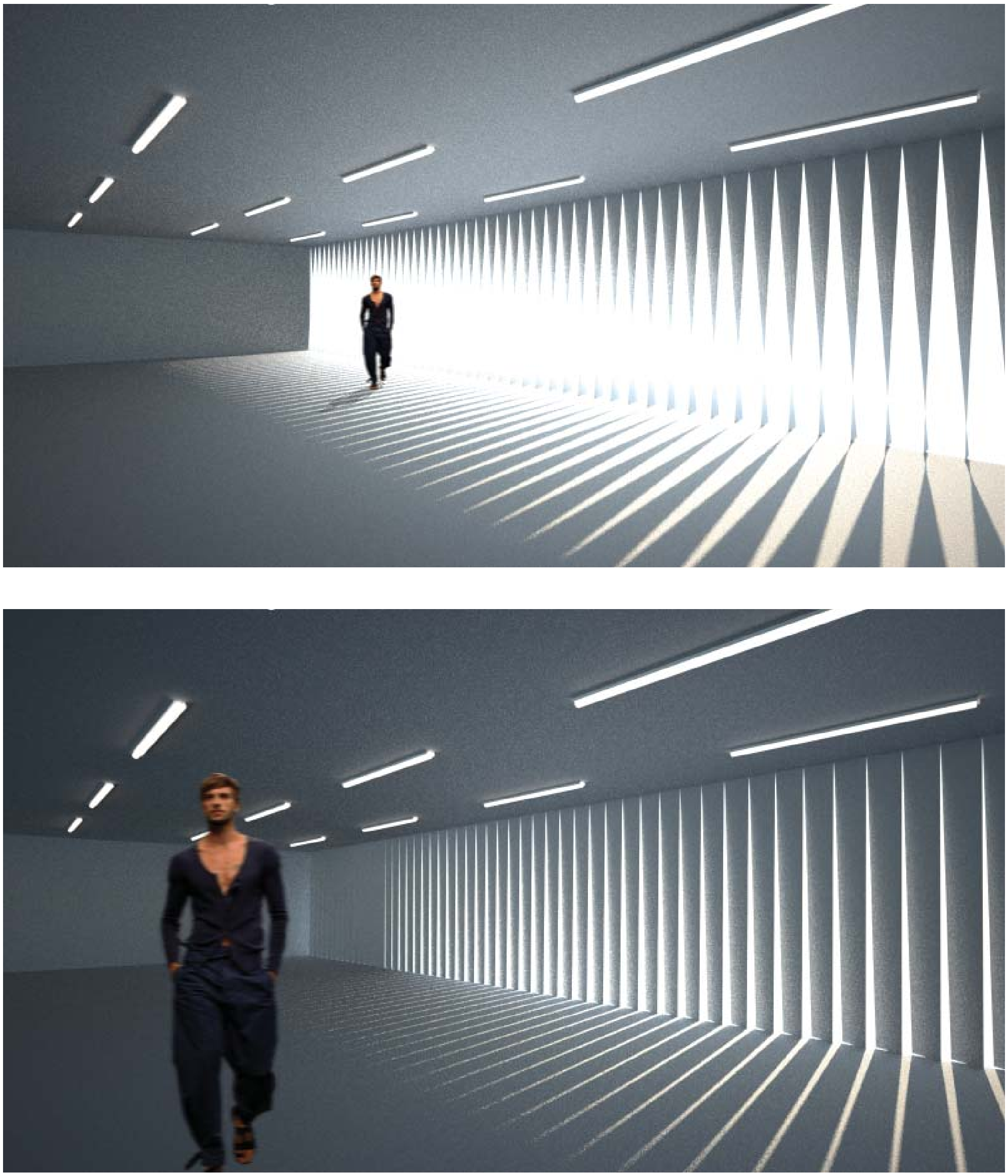


Fig. 5.23 - Elevation Image of *Twist* - Variation Two as a vertical surface

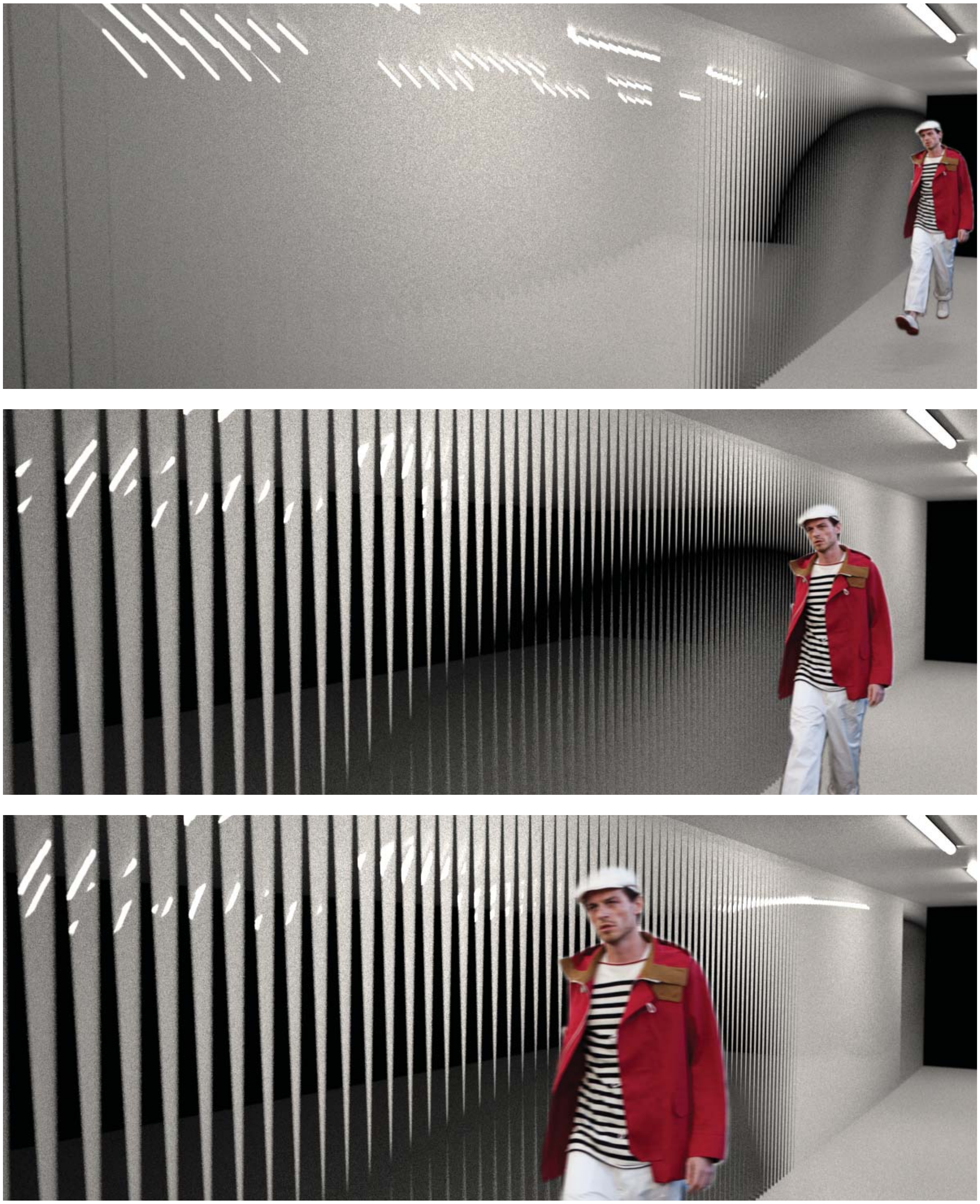


Fig. 5.24 - Elevation Image of *Twist* - Variation Two as a vertical surface

TWIST

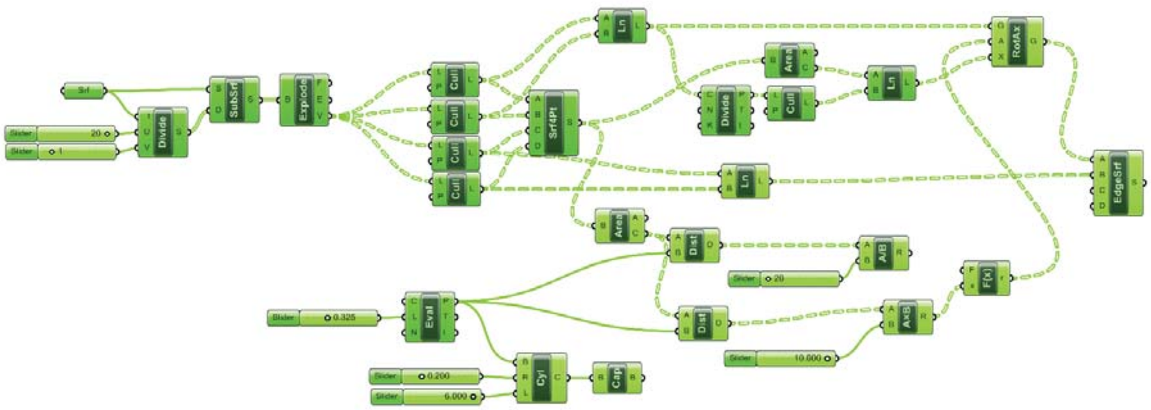


Fig. 5.25 - *Twist* Variation One - Grasshopper definition

5.4 PIXEL

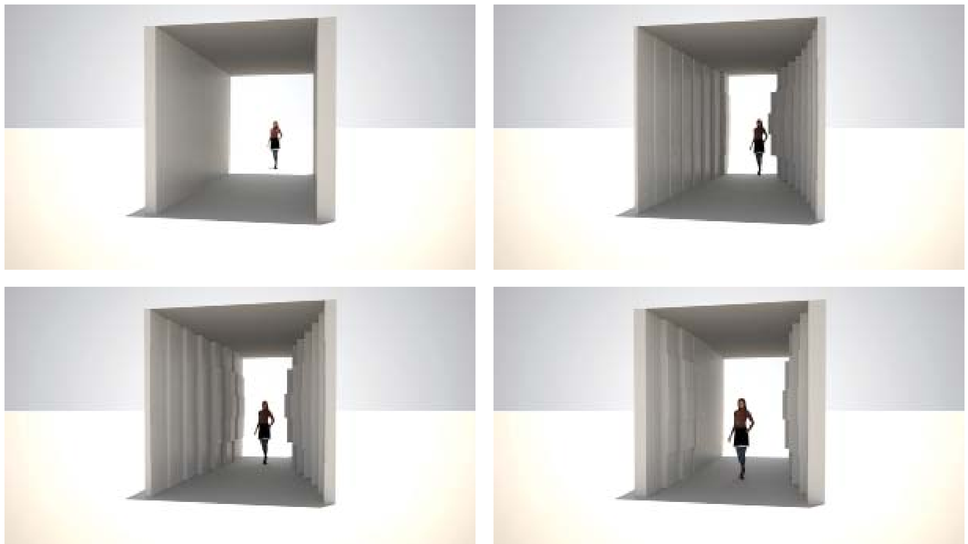



Fig. 5.26 - Image showing user interaction through *Pixel* environment

This prototype set out to create a prototype that changes the experience of a spatial environment by redefining the area boundaries of a wall, ceiling, or floor. The initial state of *Pixel* is a single, continuous surface. As the user(s) enters the environment, the surface deforms and "pixelates" according to the position of the user. The inspiration behind *Pixel* is a simple tiled wall or floor. The intention of this prototype was to explore the possibility of creating architectural patterning that created a spatial change instead of the current paradigm of patterns being static, predefined, and limited to surface applications. Some works of art use the technique of using small tiles or modules to create a large image. Instead of being just a visual applique, can tiles create space?

5.4.1 Narrative Intent

As the user approaches the space, the interior surfaces that make up the room appear to be smooth. As soon as the user enters the space, the prototype begins to react by either protruding or depressing of its surface according to the amount of tile divisions. The amount of tiling is determined by the designer according to the programmatic requirements. The user notices this change in his/her surrounding, creating a visual interest. As the user continues to move through the space, the prototype continues to react by changing the level of pixilation on the surface. This changing pixilation, in addition to creating spatial change, creates a textural quality. This quality is enhanced the greater the amount of tile divisions there are. The narrative between user and space continues until the user exits the space, returning the surface back to its original state.

This prototype is based on a grid pattern. Pattern variation only occurs with user interaction. A user enters the spatial environment and the surface reacts by creating the extrusion or depression pattern. Immediately, the user is engaged whether or not he/she chooses to. *Pixel* engages a passerby - a random viewer - and will immediately notify the user/viewer that their presence is engaging the prototype. Depending on the surface divisions, this prototype can have a different effect on the spatial conditions. A smaller surface division will create less of a spatial effect as a larger square takes up more of a spatial impact and is less subtle.

The sound that this prototype creates is part of the interest that draws the user in. The sound of the moving surface creates another level of engagement. The sound pattern, like the visual pattern, only occurs when a user is recognized with the spatial environment. This spatial experience is enhanced by the prototype's movement. Similar to most kinetic mechanisms, the technology enabling this movement has an inherit sound that it already exudes when at work.

A user's engagement with a spatial environment with *Pixel* applied creates multiple levels of spatial deformation; this deformation can be interacted through touch. This prototype can create a pattern that is both visual and textural. The smaller the subdivisions, the smoother the texture will be. Touch can also be experienced by the feet in *Pixel* when installed as a floor surface. If the extrusions/depressions are small, the interactions with the user's feet are almost organic in the way the variations are created.

The Non-Active state of this prototype is a smooth, undifferentiated surface. The Active state is a surface of extrusions and depressions of varied distances. The initiation from Non-Active to Active is done by the user, and depending on the application and

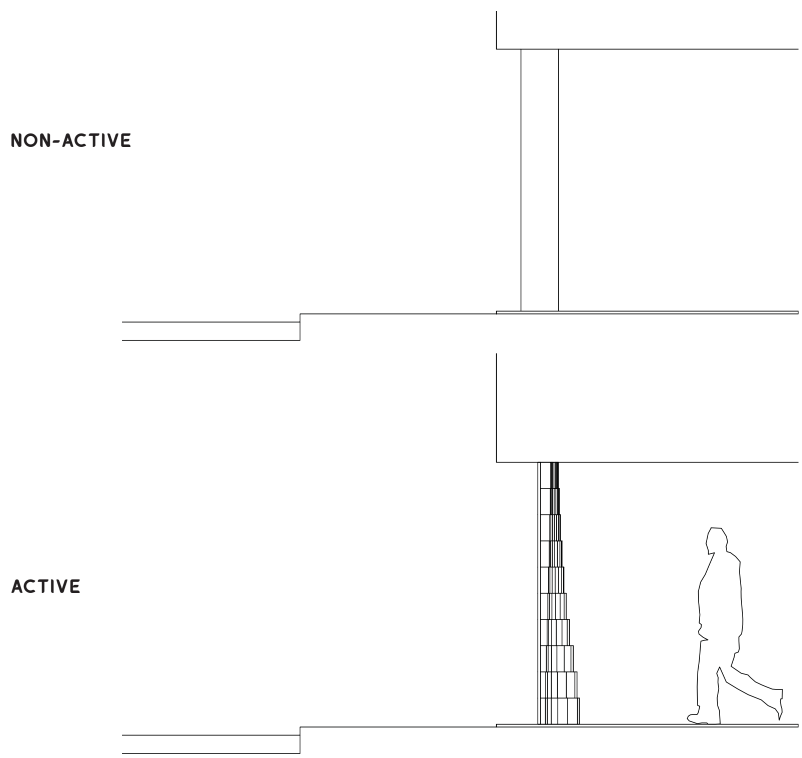


Fig. 5.27 - Section diagram showing Pixel prototype from non-active to active state.

the design intent, the variations on the surface will be varying on different levels.

5.4.2 Prototype Development

5.4.2.1 Variation One

Pixel started with a single surface. Then, this surface was subdivided into smaller, square subdivided surfaces. The pattern that this creates is a simple grid along the surface, which when viewing the surface from the front, stays the same always. This prototype is a good example of the intention of this immersive aesthetic. The pattern is simple - a grid - but the variation and complexity are created only when the user engages the spatial environment. Instead of the designing the patterning, the interaction is designed. The biggest design factors for this prototype are the thickness of the original surface and the number of surface divisions. The first factor - wall thickness - limits the distance the surface can extrude/depress. Depending on the mechanisms used to power the movement, extrusions can be farther than depressions. The second factor

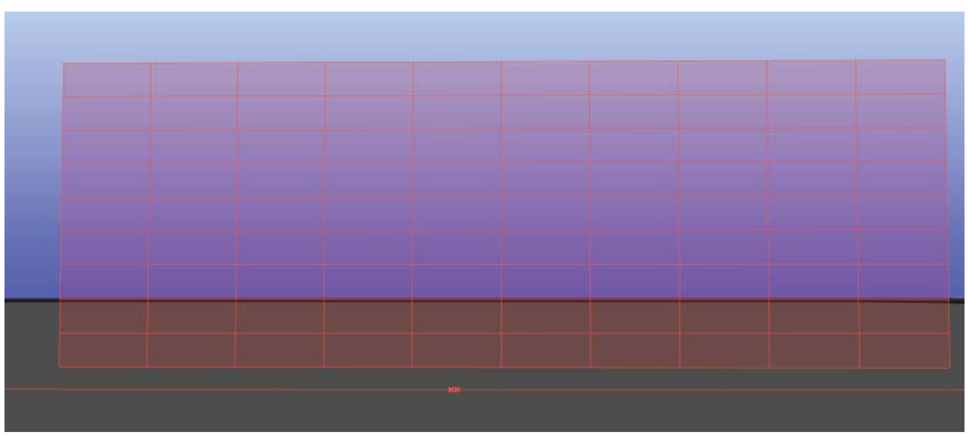


Fig. 5.28 - Image of digital user interaction simulation of Pixel within Rhinoceros 3D environment

- the amount of surface divisions - determines whether the prototype functions more spatially or more as a texture along a surface.

The digital user simulation of *Pixel* starts with a single surface. This surface is then linked into the Grasshopper model. This single surface is then subdivided into a desired number of U and V divisions. This is completely dependent on the desired engagement between user and surface; if the desired interaction is more of a spatial engagement then the lesser amount of divisions are needed; if there is a desire to create more of a textural application, then an increased amount of divisions should be used. Once the desired divisions are created within the surface, they are broken down into their individual components - Faces, Edges, and Vertices. This is needed in order to extract the edge curves that make up each subdivision, which will be the base geometry for extrusion. After extracting the component edge curves, they are then rebuilt and joined together to create individual square sub-surfaces. The area of each individual surface is then analyzed to extract the center point of each surface. It

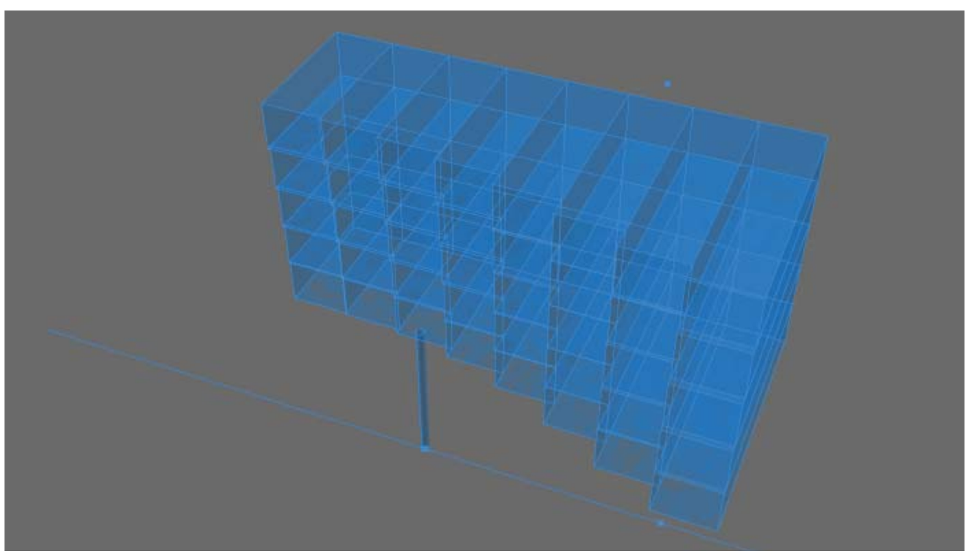


Fig. 5.29 -Image of digital user interaction simulation of Pixel within Rhinoceros 3D environment

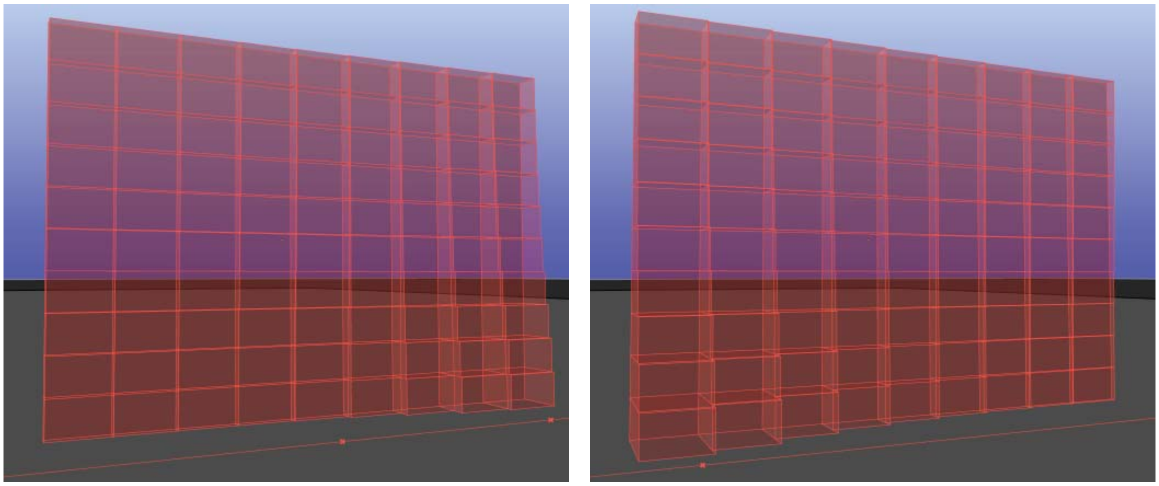


Fig. 5.30 - Grasshopper simulation of Pixel digital model (Above)

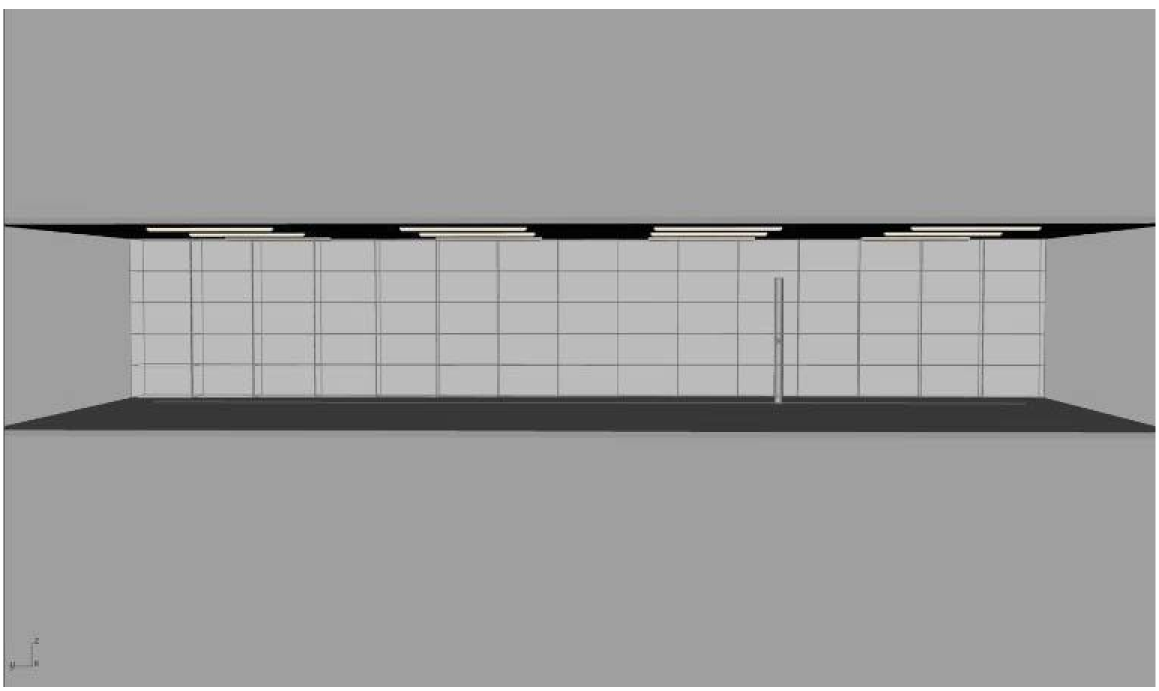


Fig. 5.31- Screenshot of digital user interaction simulation rendered using Rhino render.

is from these center points that the interaction between user and prototype starts to take shape within the digital model.
The interaction between user and prototype was simulated in *Pixel* by analyzing a point along a line. This point represented the user's position within the digital modeling environment. The line used for the interaction experimentation was a straight line, but it can be replaced with any type of path shape. The distance between the line and the surface also determines how the surface reacts in the digital model.

From these two point sets - the center points along each subdivided surface and the point along the path curve - the interaction starts to take shape. Using the measurement between the points as a basis for the amount of extrusion and depression, each surface is then extruded. The values of the distances between the points needs refinement, so

additional division components were added. The division component adjusted the distance values until the desired extrusion/depression distances were created.

5.4.3 Applications

Pixel is a versatile prototype as it can be applied along all surfaces and still keeps the original narrative intent intact. The application of *Pixel* was first investigated as a vertical surface. When interacted with, the pixilation creates spatial and texture changes. Depending on the surface division along the surface, the amount of spatial change can be tremendous. Users can redefine space with their movements or just create simple textural changes to the prototype surface.

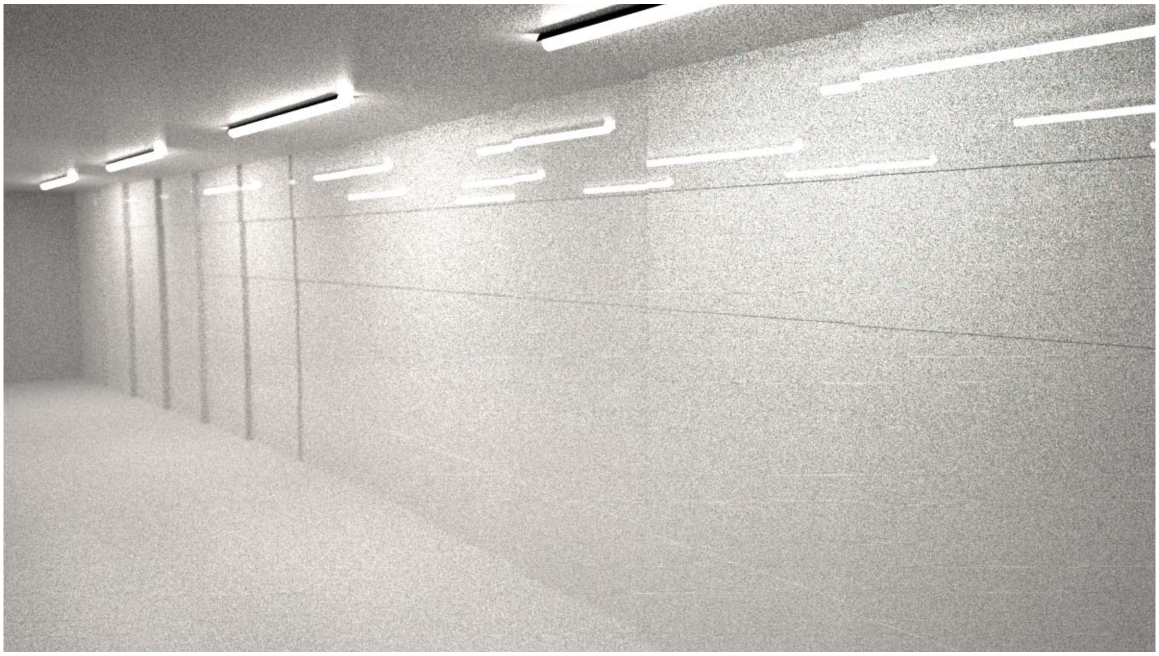


Fig. 5.32 - Rendered image of *Pixel* as a vertical prototype (Above)

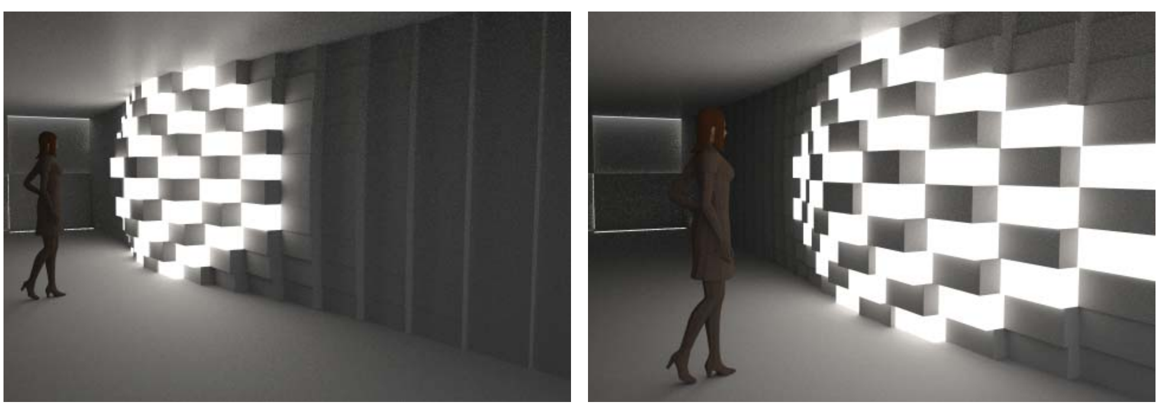


Fig. 5.33 - *Pixel* prototype with light application installed with each surface division (Below)

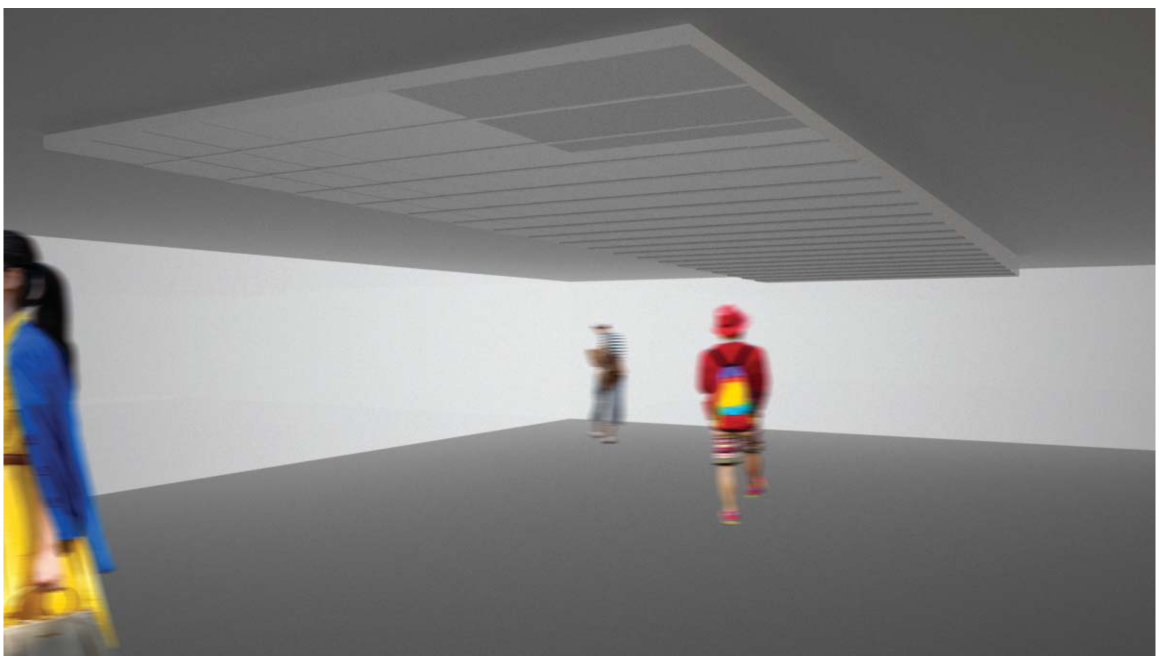


Fig. 5.34 - *Pixel* prototype as a horizontal application showing the sequencing of user interaction. (Below)

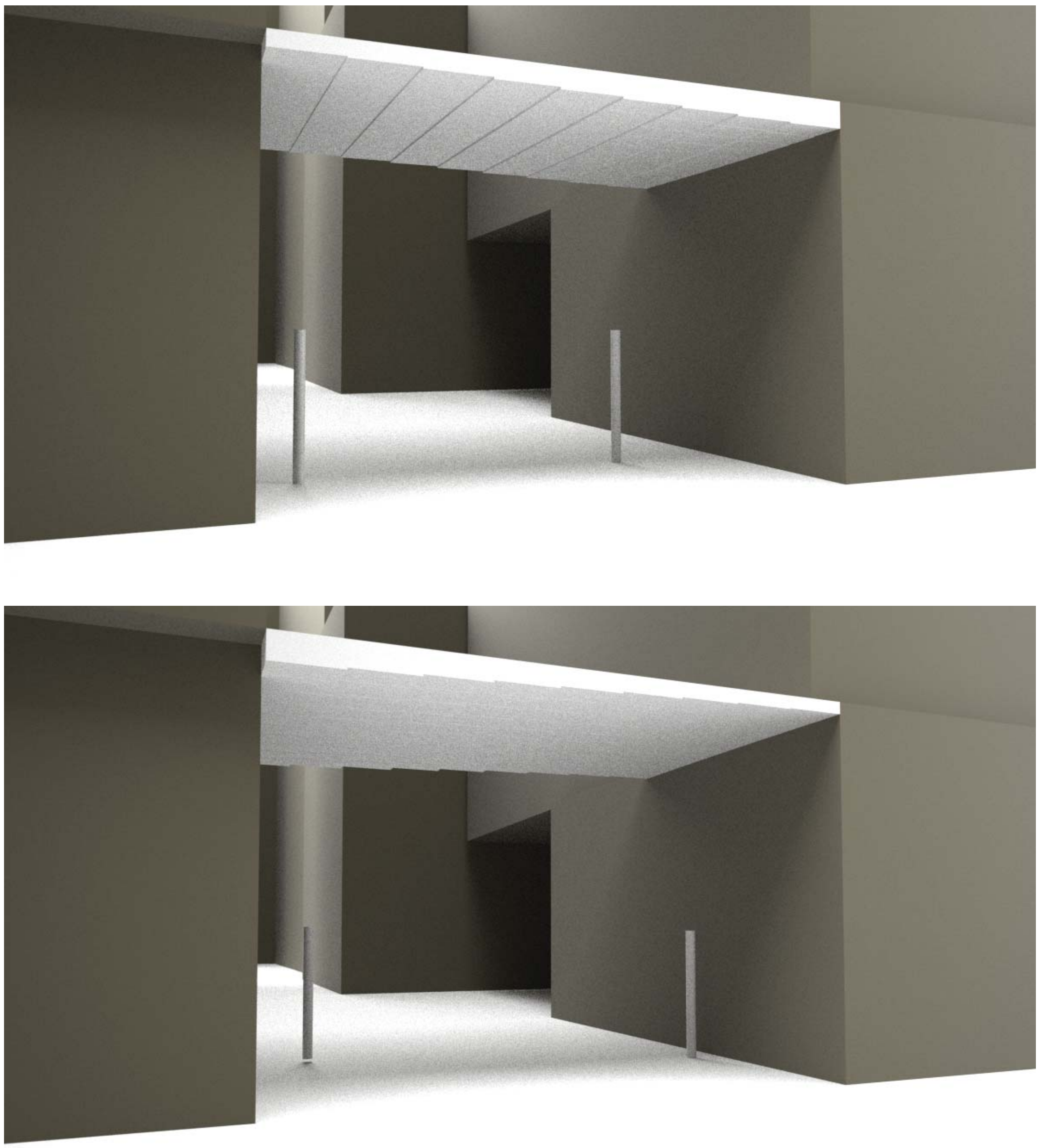


Fig. 5.35 - *Pixel* prototype as a horizontal application showing the sequencing of user interaction. (Below)

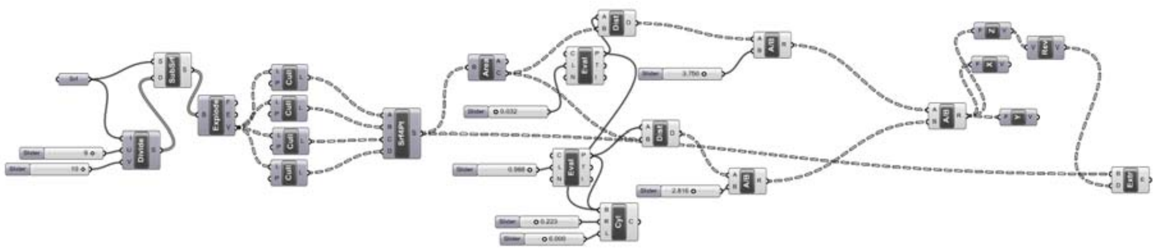


Fig. 5.36 - *Pixel* - Grasshopper definition

5.5 BLOOM

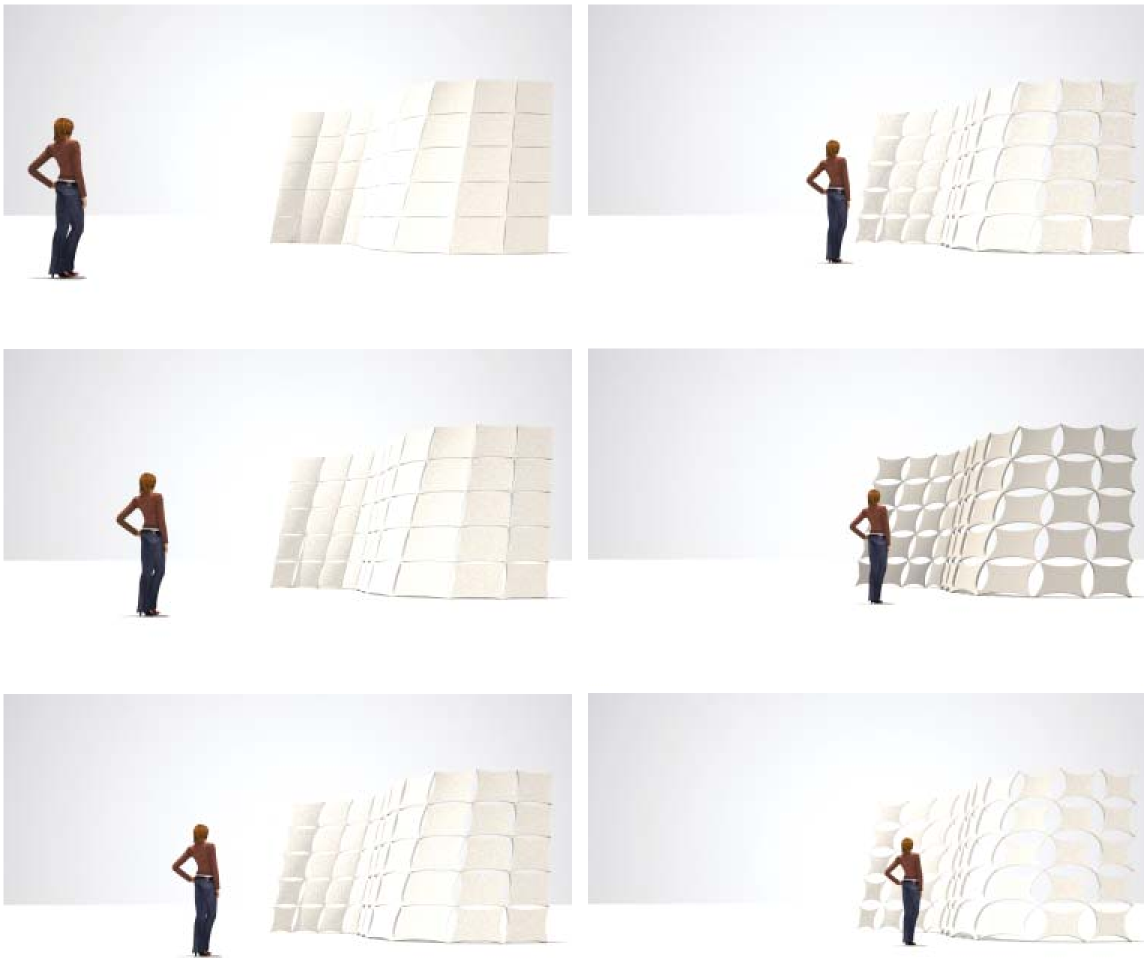


Fig. 5.37 - Image showing interaction sequence of *Bloom* prototype

The *Bloom* prototype seeks to create a highly visual, dynamic surface interaction between the user and spatial environment. The variation between open and closed surface allows for a large range of interactions, as well as a wide range of applications.

The prototype *Bloom* is an aperture type of prototype. It takes a large surface and divides it into smaller surfaces. These smaller subdivisions are then populated with an adjustable surface that opens and closes according to the designed user interaction.

5.5.1 Narrative Intent

At a glance, *Bloom* is seemingly a static pattern. As one approaches the surface, the pattern begins to react. Depending what iteration of *Bloom* is chosen, this reaction will vary. One variation creates a spatial change; another creates a textural quality, while another creates a strong visual pattern. All variations of *Bloom* create a surface of high geometrical pattern variation.

Bloom stimulates the sense of sight with patterning with its opening and closing motion. This patterning continuously adjusts during user interaction and creates a dynamic visual point of interest. Initially, the *Bloom* prototype adjusted as a single surface. However, to create a more striking visual pattern, latter variations supply a variation of the degrees of opened and closed apertures across the surface. This variation creates a more customized interaction for each user. This variation is enhanced when working with daylight factors.

The sound that this prototype creates is part of the interest that draws the user in. The sound of the moving surface creates a unique experience. This spatial experience is enhanced by the prototype's movement. Similar to most kinetic mechanisms, the technology enabling this movement has an inherit sound that it already exudes when at work.

The texture created in *Bloom* is one that is designed to create visual texture and less about texture for human touch. Variations of the Bloom prototype react in multiple dimensions, creating changes in depth which lead to an interest in the user to interact using their hands. This texture also is created depending on the material chosen to create the prototype.

The Non-Active state of this prototype is a single uniformly patterned surface. In its' Active state, the uniformity of the pattern is broken and variation is introduced. Depending on the version of the prototype selected the patterning moves in two and sometimes three dimensions. Another variation creates changes in the pattern, creating seemingly different units across the surface.

5.5.2 Prototype Development

5.5.2.1 - Variation One

Bloom set out to create a prototype that initiated a patterning that would make the experience of a spatial environment to be unique every time it is entered. Architectural

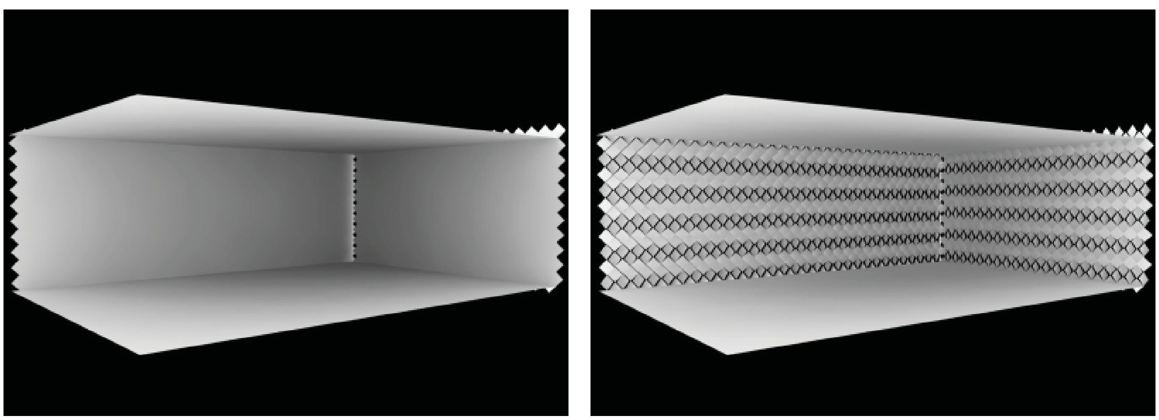


Fig. 5.38 - Early *Bloom* investigation models

programming that required sound dampening or enhancement was an initial application that was in mind during the investigation.

The first iteration for this prototype looked at creating more complex geometry instead of the straight extrusions/depressions. The square is used as the basis of the component's design; this is because the target surface in which the prototype will populate is based on a square grid. The first geometry that was experimented with is the pyramid, as its' base shape is square. The first step was to populate the target surface with the static pyramid geometry in order to explore its aesthetics. After that was done, experimentation was done in order to explore how to create an interactive pyramidal geometry that is adjustable. Instead of having the four corner points - a la Pixel Wall - extrude/retract, a center point is extracted from the base square surface and then moved up and down in the Z-direction. When this center point is connected to two points along the square base, a triangle is created. This step is repeated with the remaining three corners. The end product is a pyramidal shape that has an adjustable point. The pyramidal shape is similar to the product material used in soundproofing various musical program functions, which led to the thought of this prototype in that application. As the environmental factor - whether user or outside environmental

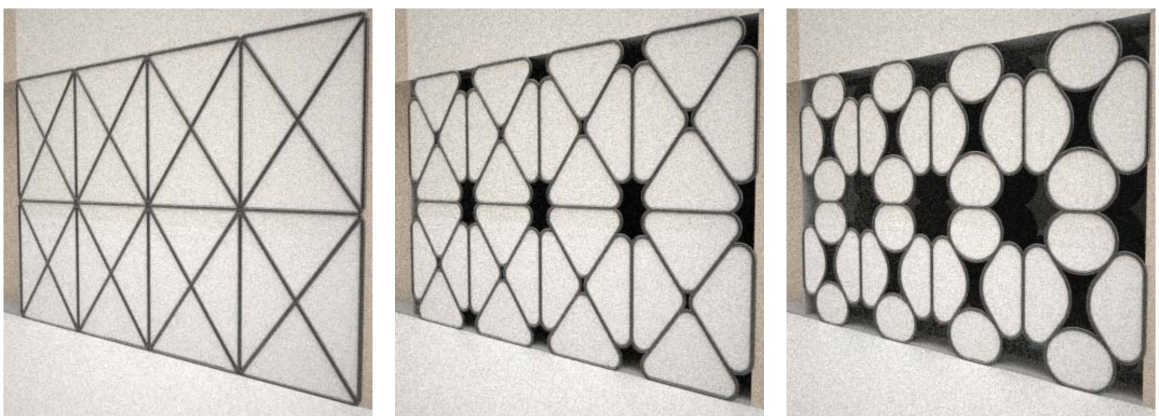


Fig. 5.39 - Early *Bloom* investigation models

conditions - begins to react to the prototype, the point of the geometry begins to move back and forth. This movement is determined by the designer and their intention of the space. Some limits of the prototype are the surface material for each subdivision, size of the mechanisms used, and the complexity of the target surface.

There are three geometries needed in order to start the interactive portion of the model - 1) A target surface, 2) Geometry to be populated the surface, and 3) a bounding box for the geometry. The target surface of the definition starts with a wall-like surface in

Rhinoceros 3D - 16' x 8'. This surface simulates a wall as a generic spatial environment. Then, this surface is divided into U and V subdivisions - 10 in the U-direction and 5 in the V-direction. The second component is the pyramid geometry. The pyramid geometry is then contained within a box. This box defines the boundary of the geometry is to be populated along the target surface. The last step is to combine the

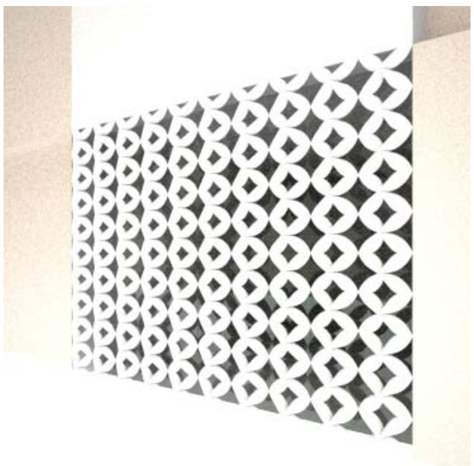
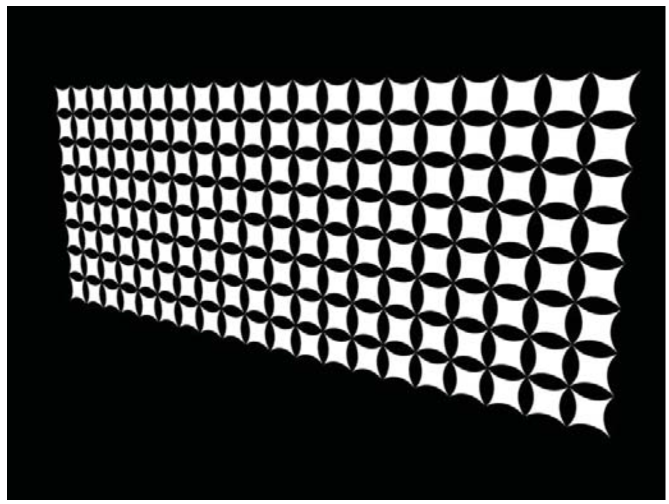



Fig. 5.40 - Early *Bloom* Variation Two investigation models

three components, which takes the pyramid geometry and populates each U and V division with that geometry. This results in 50 pyramid geometries populated along the target surface.

5.5.2.2 - Variation Two

This iteration creates an aperture in between grid subdivisions, exploring the visual pattern that the interaction between user and prototype can provide. The aperture is created by the points of the subdivided surface moving towards its' own center. The three points - start, middle, and end - of each side are connected by an arc. Then, each of the four arcs are joined together to create a surface. The result is as the interaction occurs, the arc increases or decreases according to the environmental factors creating

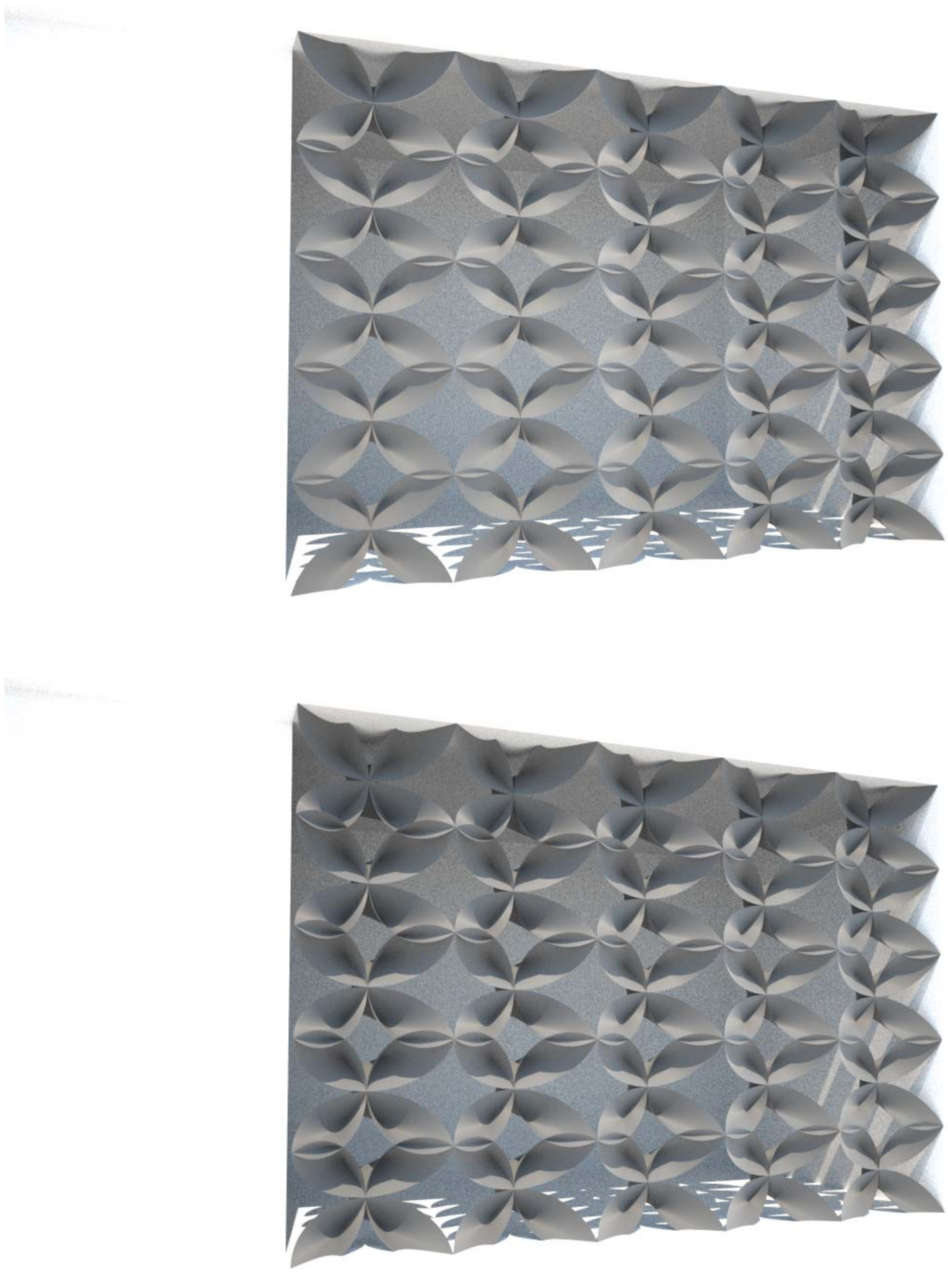


Fig. 5.41- Rendered interaction sequence of *Bloom*

an opening or a closure. The second iteration of the *Bloom* prototype then takes the pyramidal methodology from the first iteration and combines the two, creating another level of complexity and interaction.

Instead of creating the pyramid geometry using the method of creation used for *Bloom* One, *Bloom* Two creates the pyramid form using points along a base surface. The Grasshopper definition of *Bloom* Two takes this surface and divides it into U and V subdivisions – 10 in the U-direction and 5 in the V-direction. These subdivisions are then used to extract the basic geometrical information of each – Faces, Edges, and Vertices. From that data set, the center point of each subdivision is extracted. The vertices were then separated into individual points. Pairs of vertices points and the center point are then used to create a triangular face on each of the squares side in order to form pyramid geometry. The reason for creating the pyramid geometry from points is to allow for the top point of the geometry to be adjustable. This will create a non-uniform deformation across the surface which will define the narrative between the user and space.

To create the source of the deformation, a line parallel to the base surface is created. This line represents the linear movement of a user walking through space. A point is then extracted from this line. Using the Grasshopper component that measures the distance between two points, the distance between the point along the path and the center points of the surface subdivisions in the previous step is measured. The extrusions of the individual panels are based on this numerical information. Adjustments are then made through additional Grasshopper components until the desired extrusion length was reached.

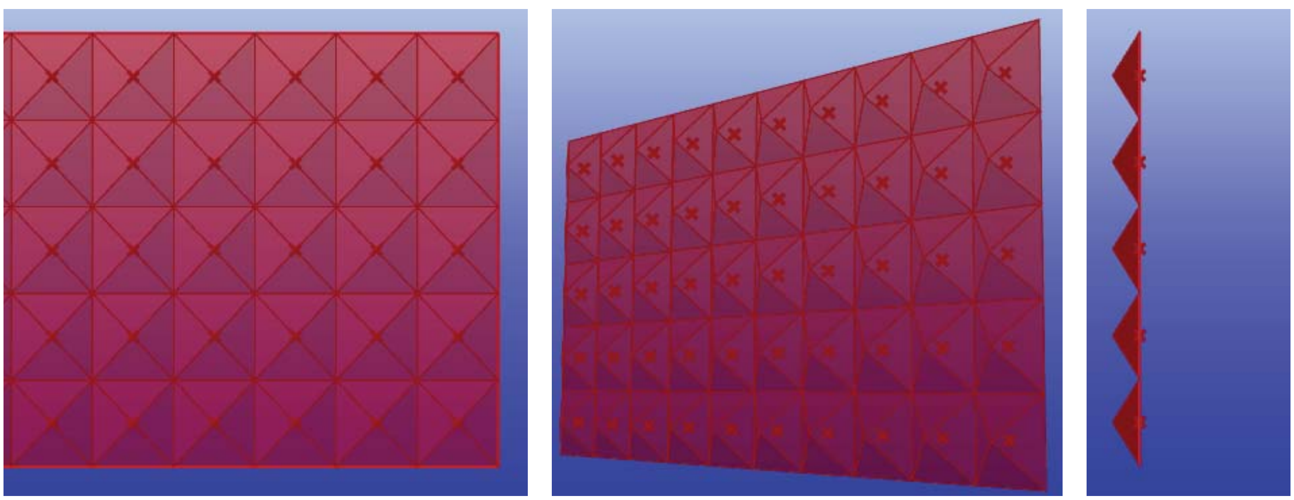


Fig. 5.42 - Image showing digital interaction model of *Bloom* Variation One

5.5.2.3 - Variation Three

The third iteration of *Bloom* looked at creating apertures within the subdivided surface. The idea for this version stemmed from the idea of the corner points of the subdivisions moving simultaneously towards and away from each other. When combined with the pyramidal geometry in the first iteration, a complex three dimensional patterning is created, one that reacts in the X, Y, and Z directions. This results in a highly interactive prototype; its dynamic movement in all directions is easily discernible from all distances. This prototype also allows for a multitude of applications, which is further explored in the latter part of the section.

Bloom is a highly visual prototype as the patterning it creates is more complicated than any other prototype. The differences between each version of the *Bloom* prototype are subtle; changes iterations provide are noticed only when interaction is introduced. The first version takes a simple geometry and creates a simple extrusion; the second and third versions further this geometry by creating movement along the edges of the

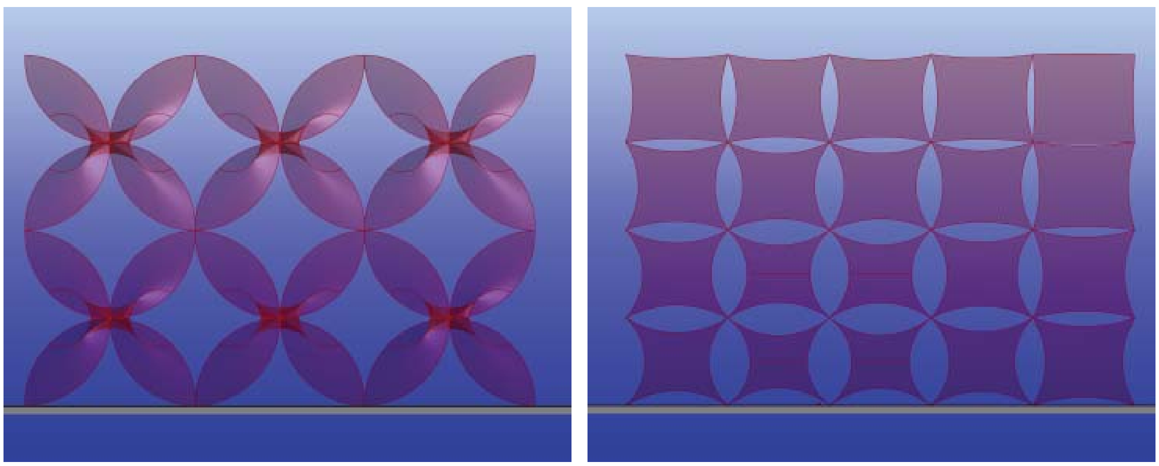


Fig. 5.43 - Image showing *Bloom* Variation Three (Right) and *Bloom* Variation Two (Left)

grid.

The Grasshopper definition of *Bloom* Three takes a base surface and divides it into U and V subdivisions – 5 in the U-direction and 5 in the V-direction. These subdivisions are then used to extract the basic geometrical information of each – Faces, Edges, and Vertices. From that data set, the center point of the faces of each subdivision is extracted. From this step, the Grasshopper definition splits into two paths that are later rejoined in the advanced stage of the definition. One path of the definition creates openings along the surface and the second path controls the degree of these openings.

To create the degree of openings along the surface, a line parallel to the base surface is created. This line represents the movement of a user passing by the surface. A point is then extracted from this line. Using the Grasshopper component that measures the distance between two points, the distance between the point along the path and the center points of the surface subdivisions in the previous step is measured. This data is used to determine the degree of openings. Adjustments are then made through additional Grasshopper components until the desired opening degree was reached.

5.5.3 Applications

The application of *Bloom* was originally intended to create a pattern across a vertical surface that is created only through interaction. As a ceiling application, *Bloom* can create the same effect.

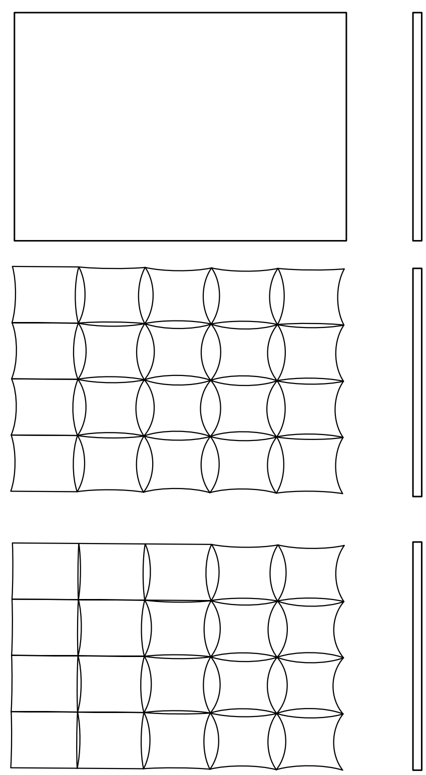
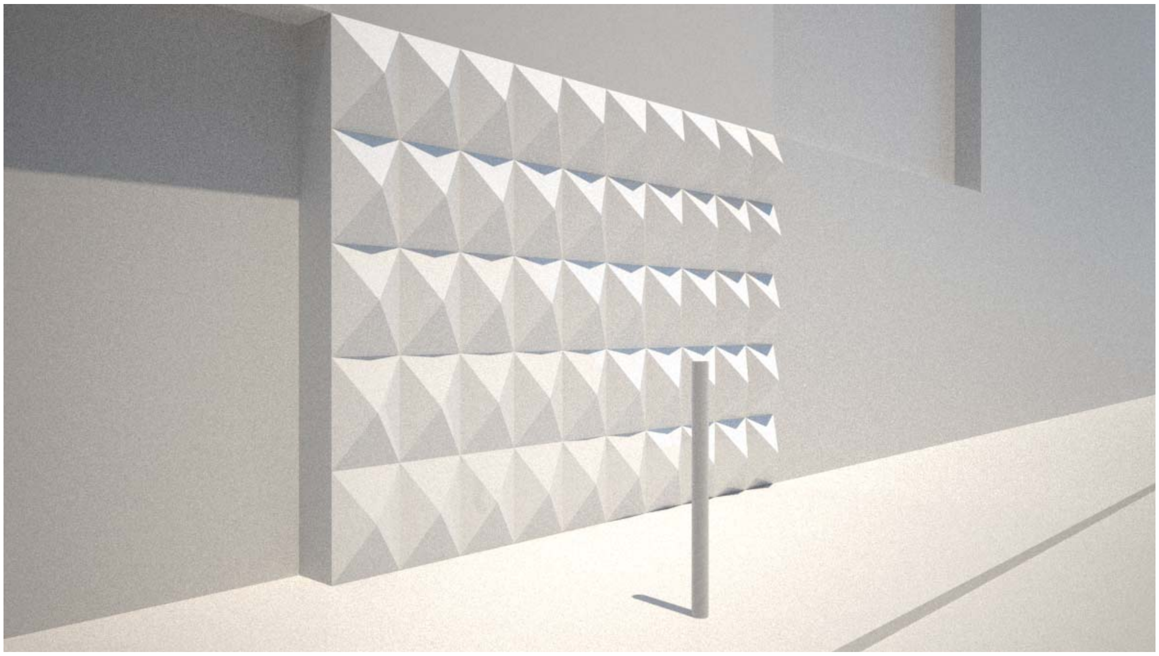


Fig. 5.44 - *Bloom* Variation Two from Non-Active to Active State



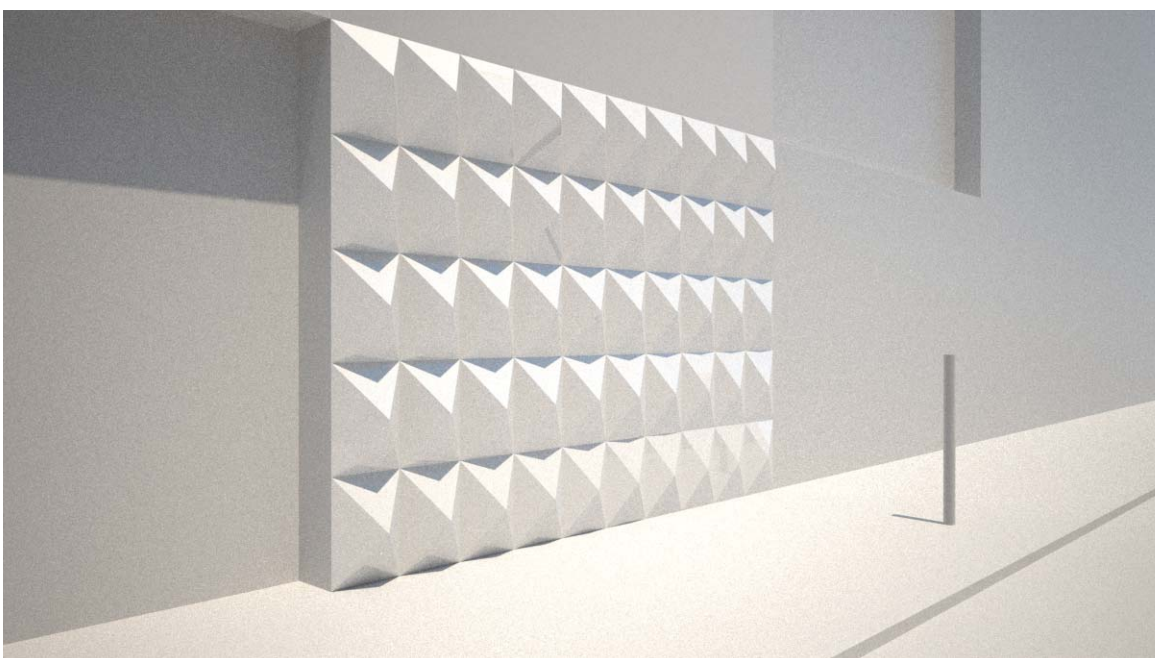
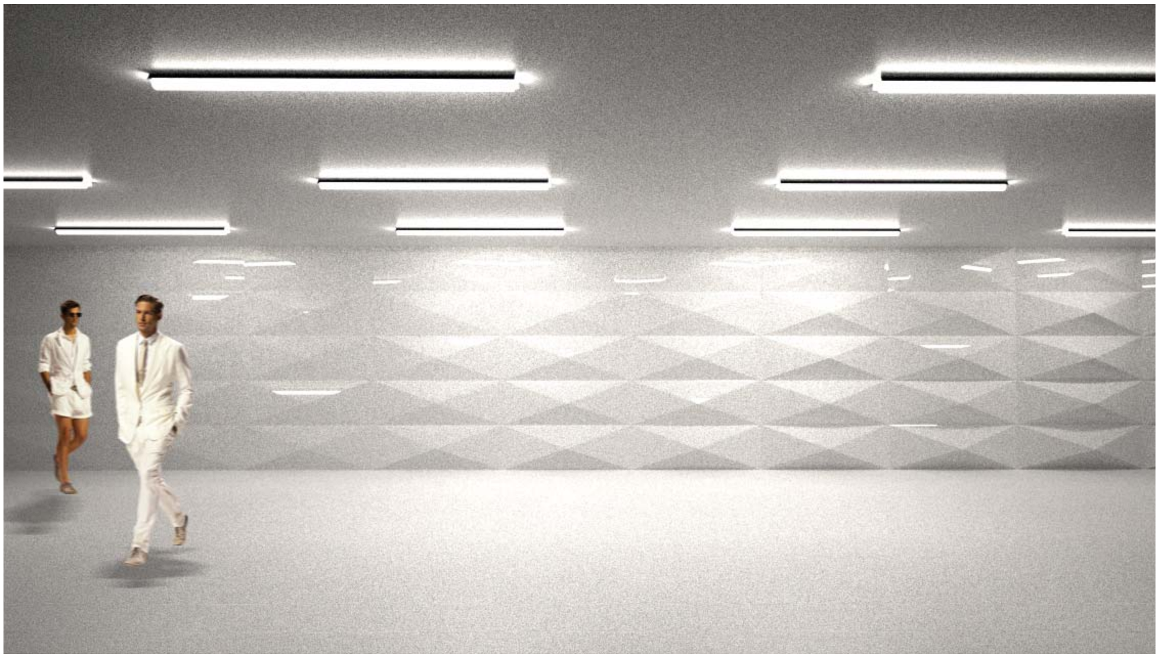


Fig. 5.45 - Image showing *Bloom* Variation One as a vertical surface with User represented as a cylinder



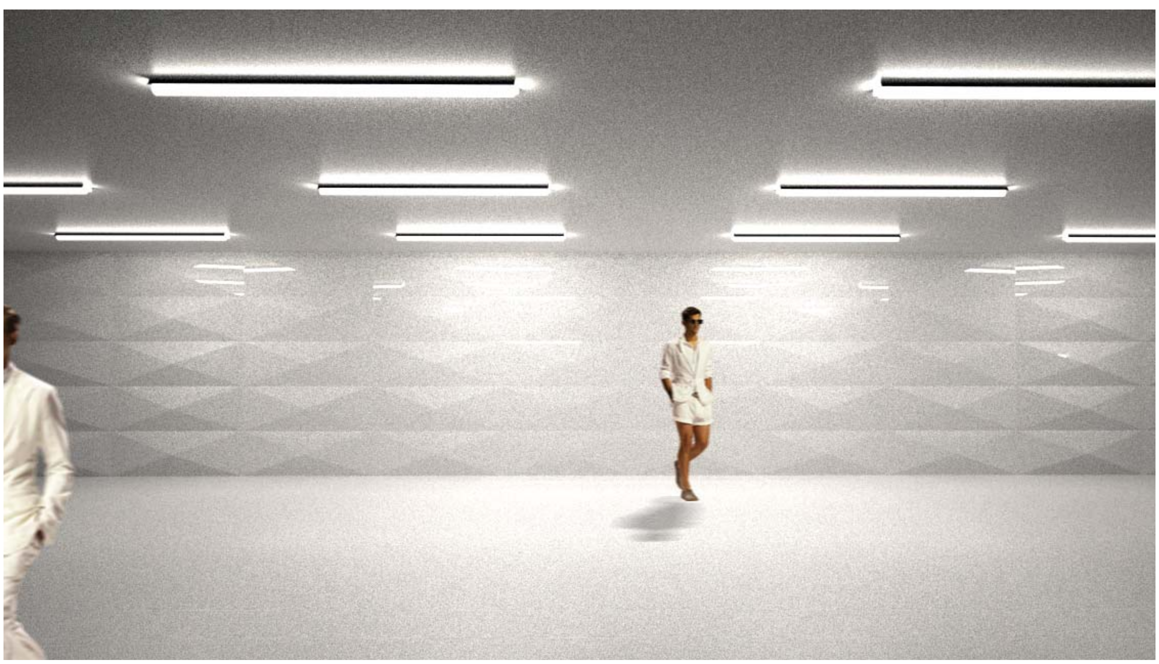


Fig. 5.46 - Image showing *Bloom* Variation One as a vertical surface

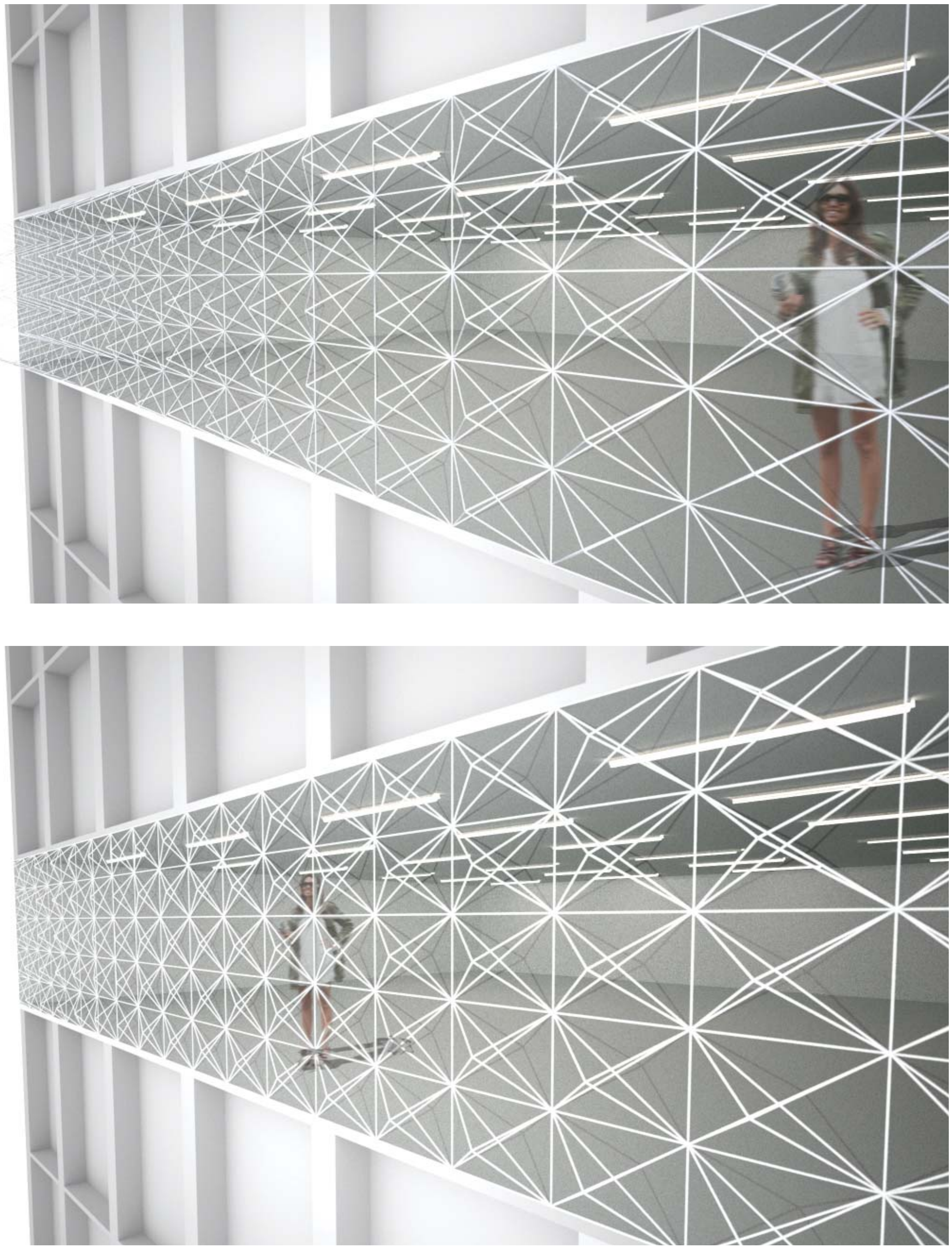
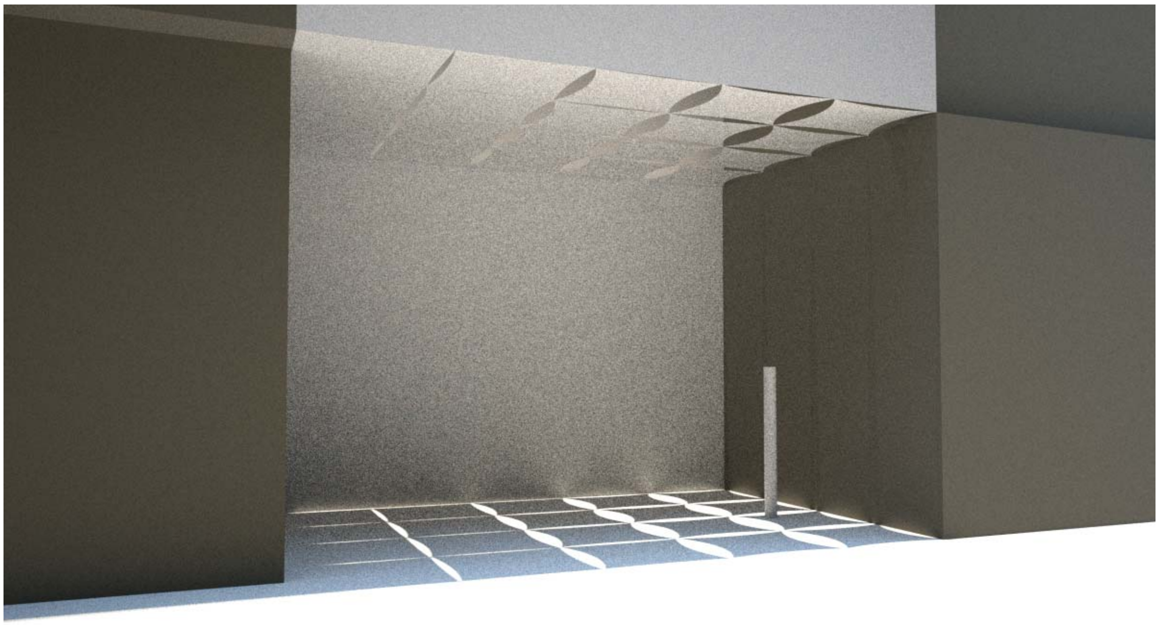


Fig. 5.47 - Image showing *Bloom* Variation One as a vertical exterior structural surface



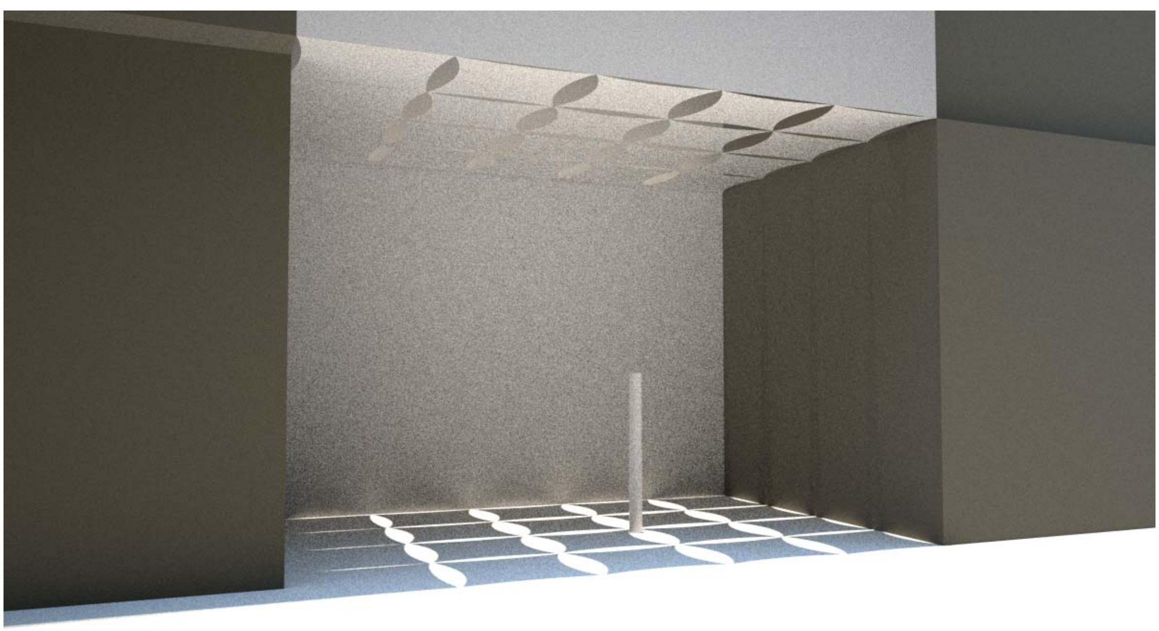


Fig. 5.48 - Image showing *Bloom* Variation Two as a ceiling surface with User represented as a cylinder

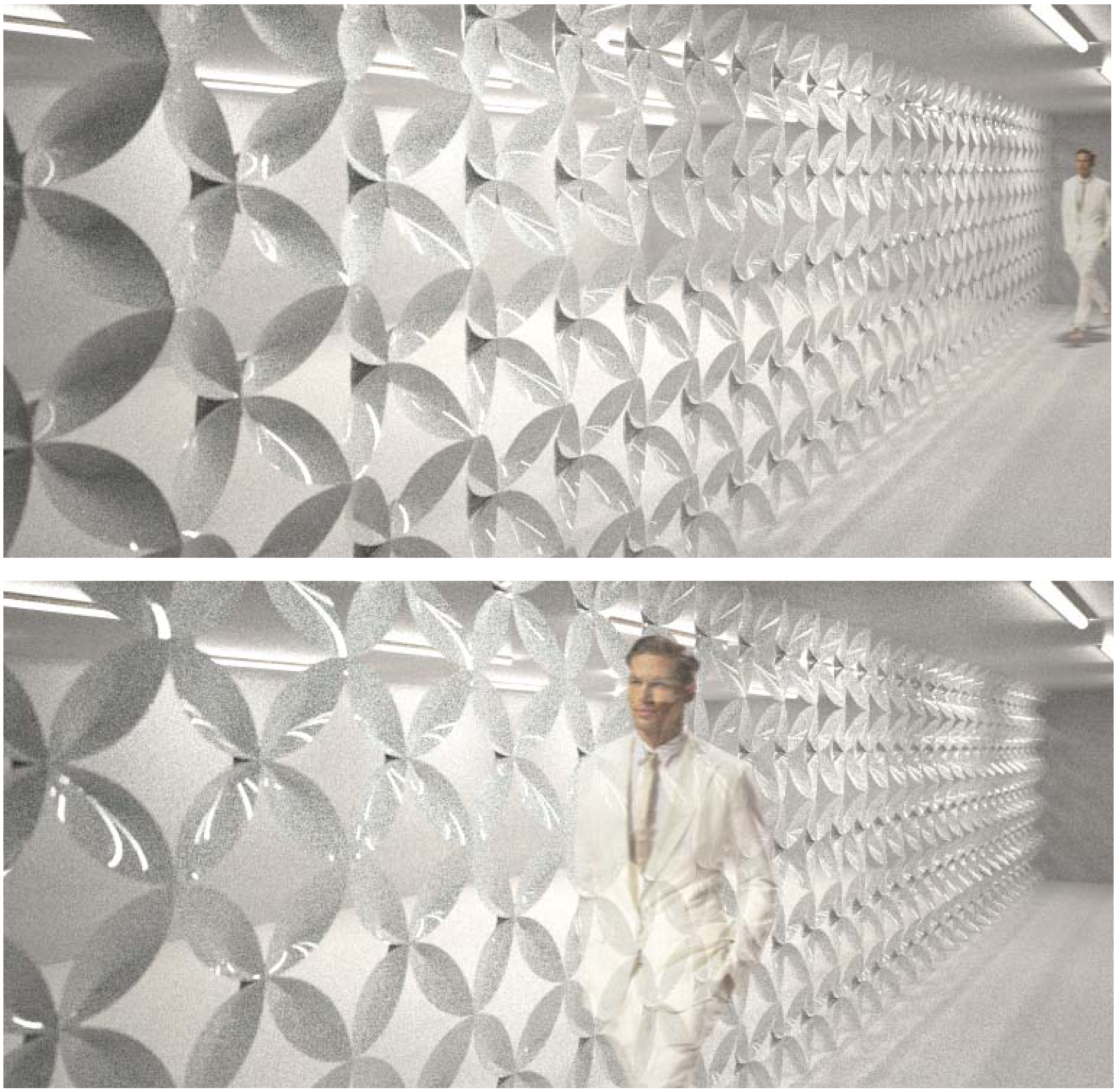


Fig. 5.49 - Image showing *Bloom* Variation Three

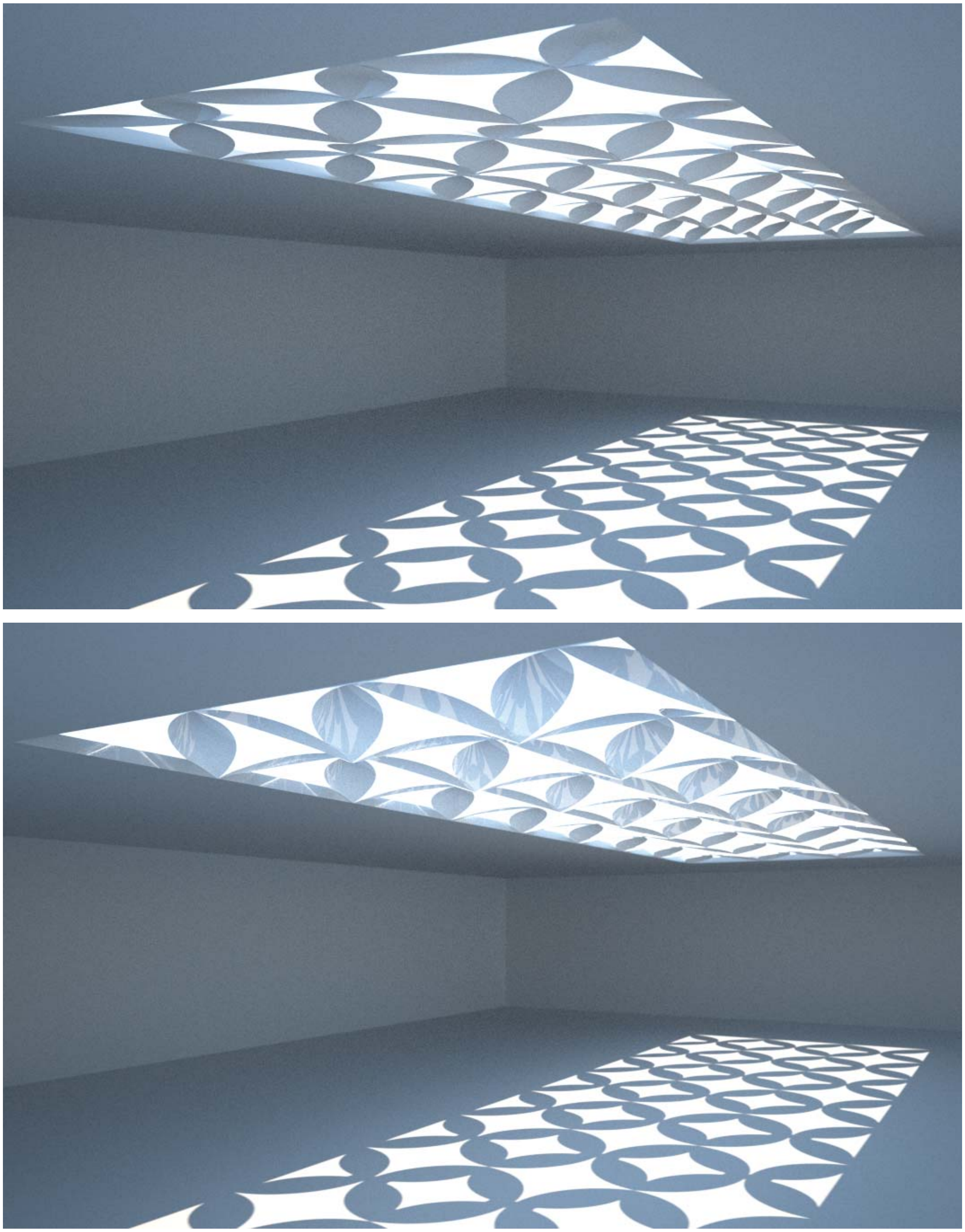


Fig. 5.50 - Image showing *Bloom* Variation Three as a ceiling surface

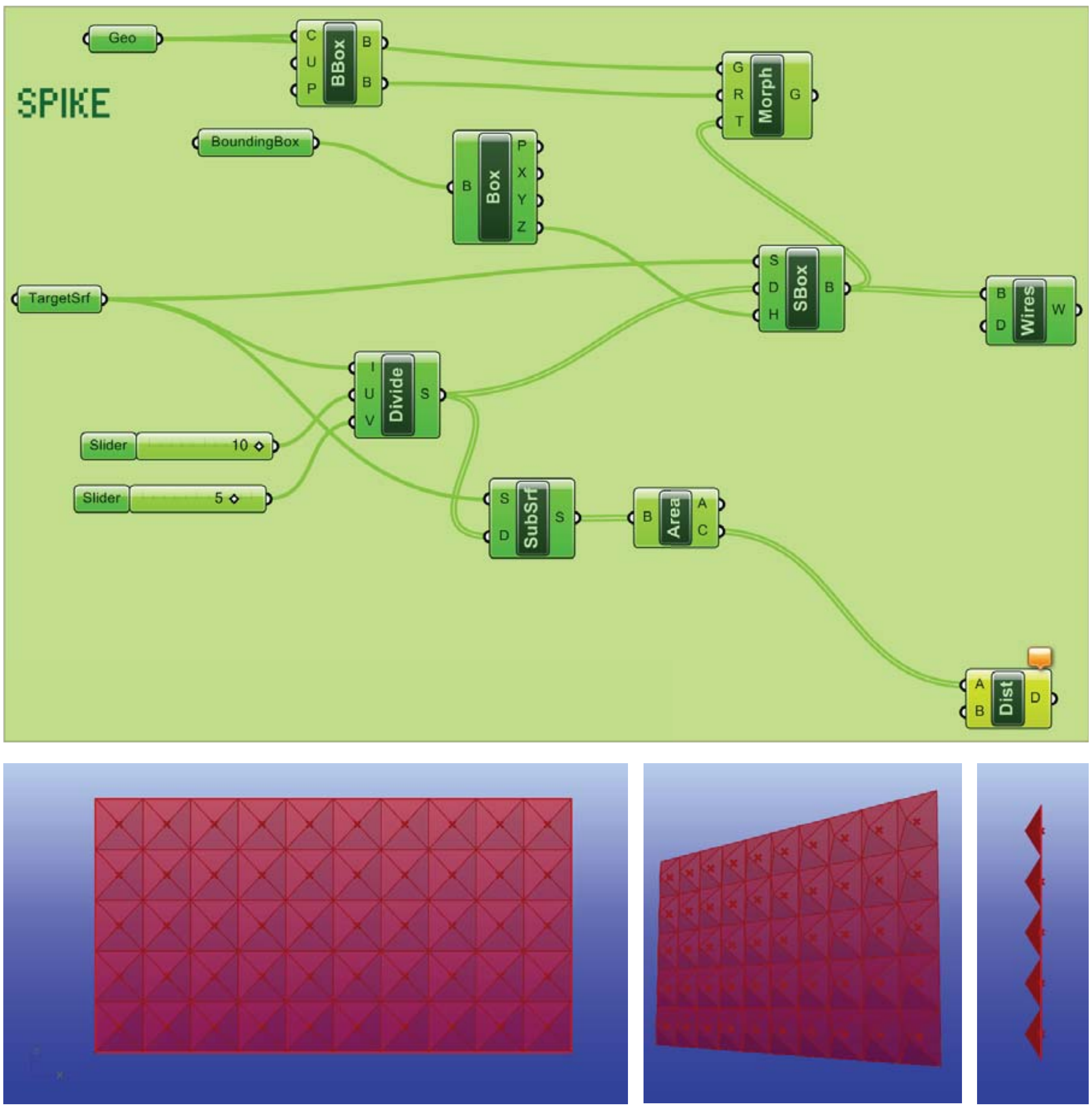


Fig. 5.51 - The Grasshopper definition (Top) of *Bloom* Variation One and the corresponding Rhinoceros 3D model images (Bottom)

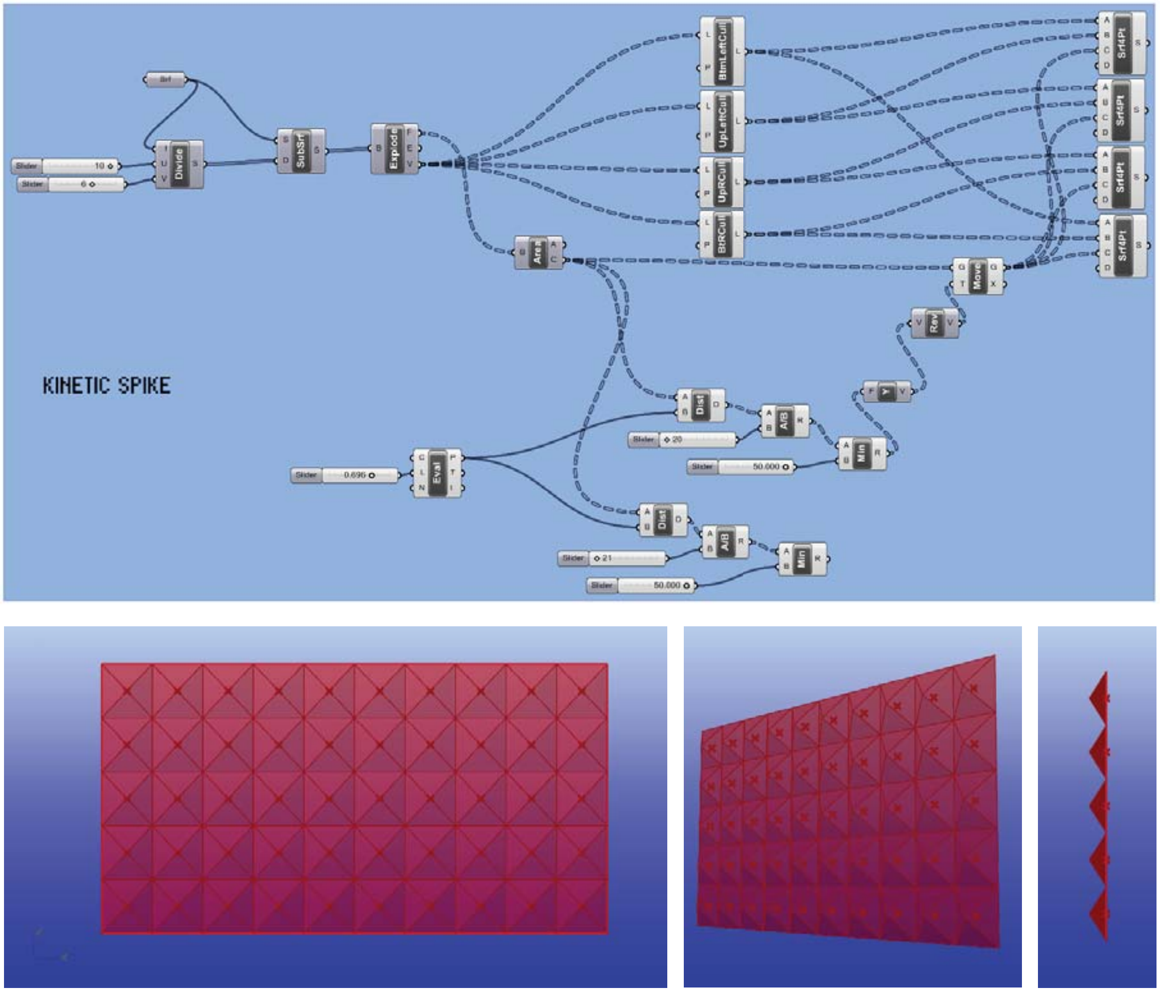


Fig. 5.52 - The Grasshopper definition (Top) of *Bloom* Variation One definition and the corresponding Rhinoceros 3D model images (Bottom)

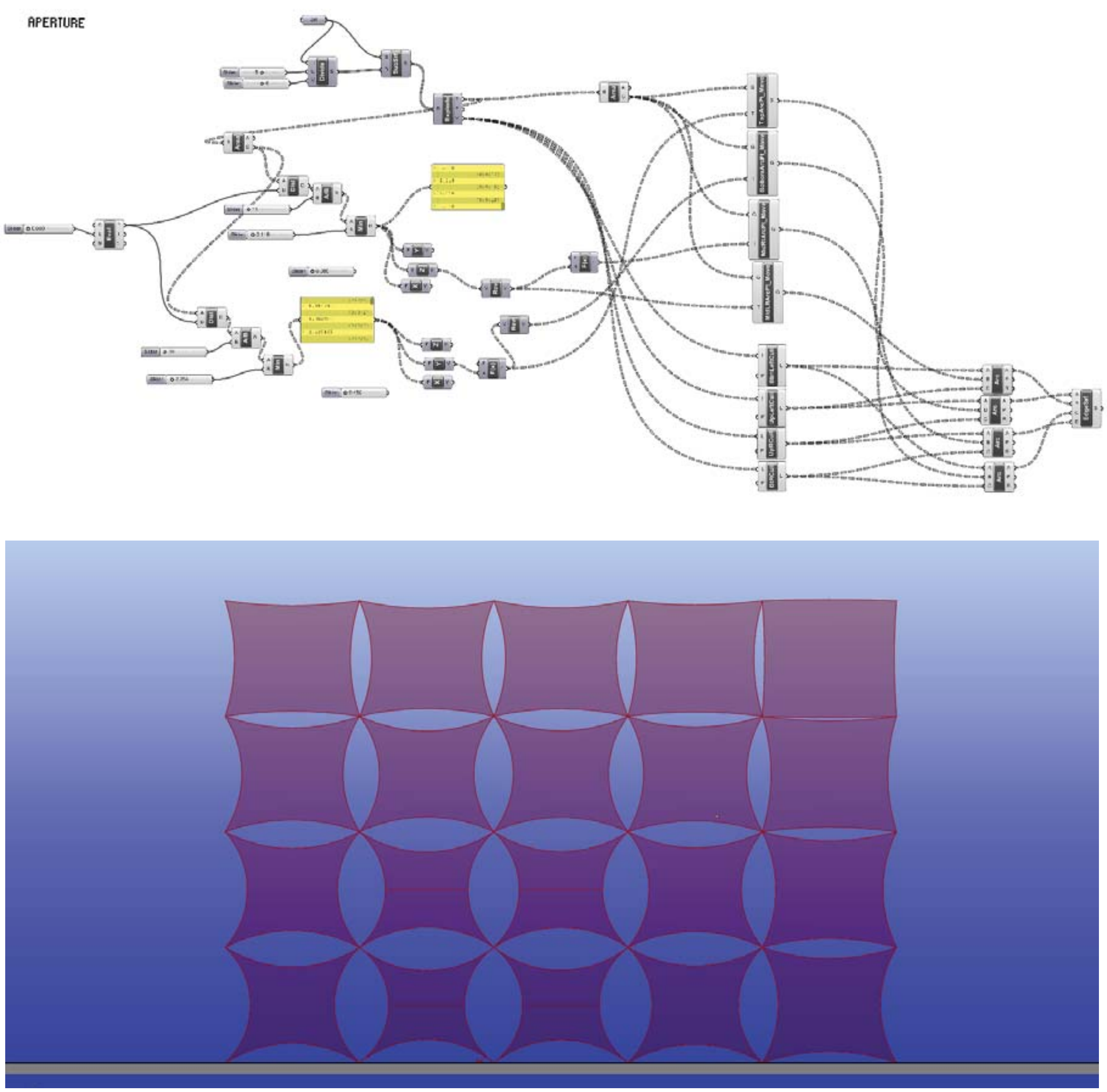
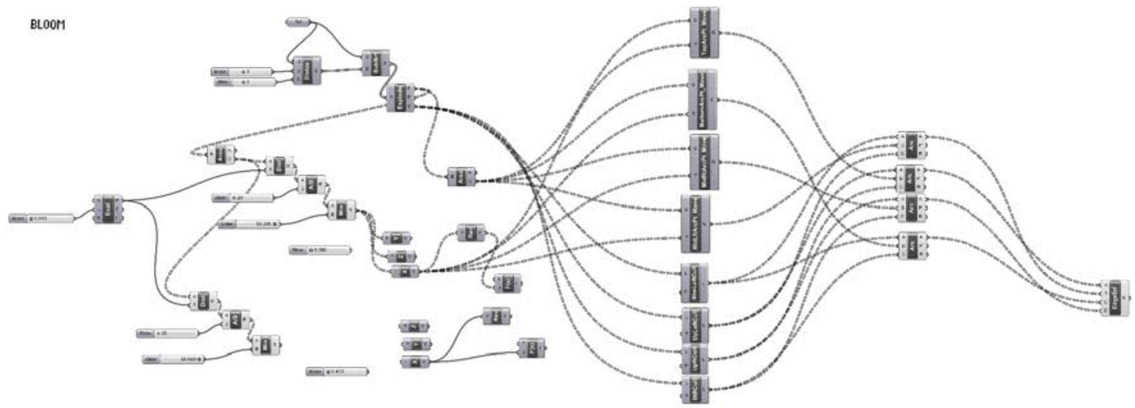


Fig. 5.53 - The Grasshopper definition (Top) of *Bloom* Variation Two and the corresponding Rhinoceros 3D model images (Bottom)



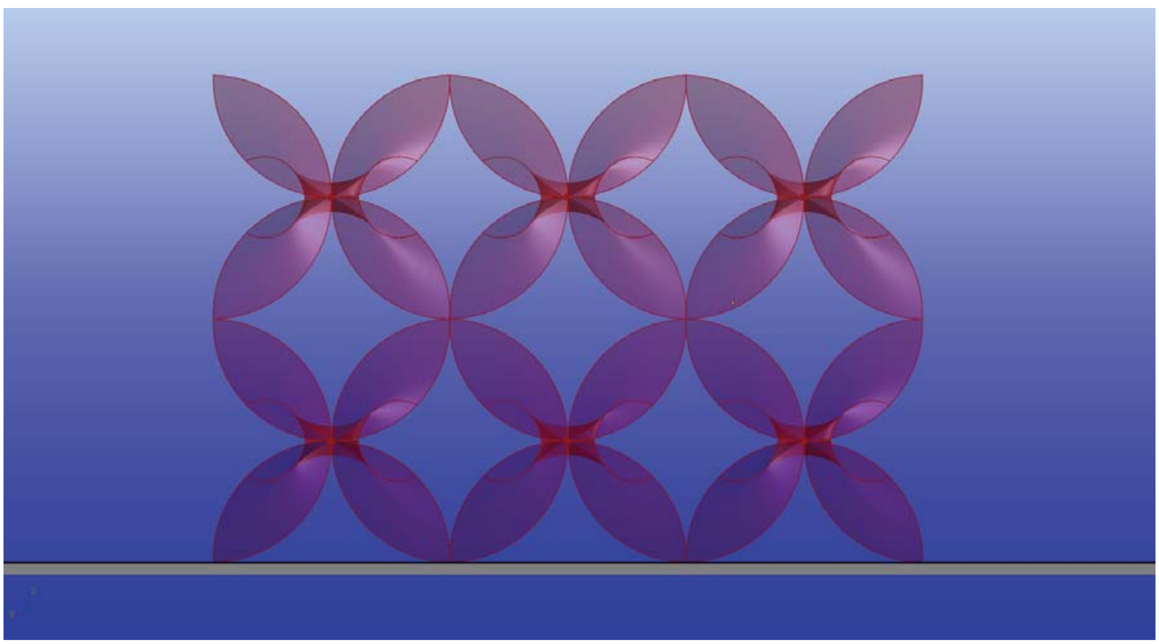


Fig. 5.54 - The Grasshopper definition (Top) of *Bloom* Variation Three and the corresponding Rhinoceros 3D model images (Bottom)

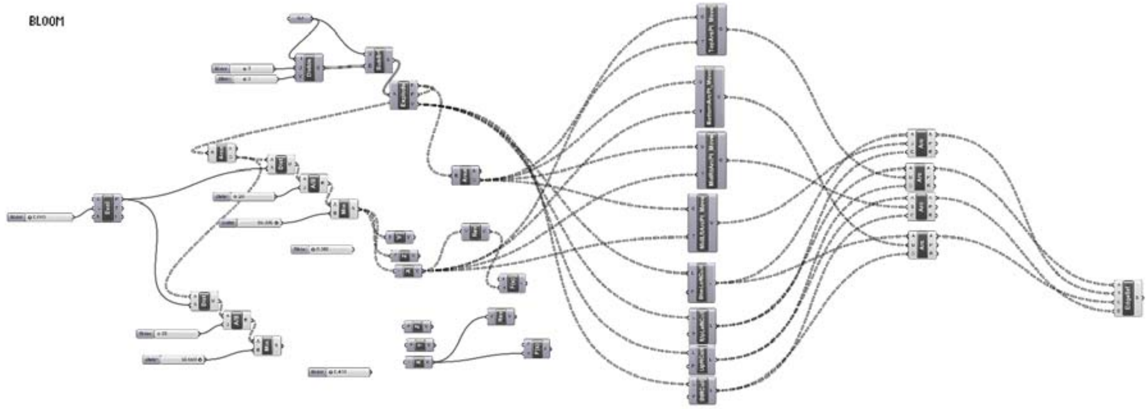


Fig. 5.55 - The Grasshopper definition (Top) of *Bloom* Variation Three detailed.

5.6 HYBRID

5.6.1 Narrative Intent

The intent of *Hybrid* is to create a prototype that is simultaneously physical and digital. This is possible due to the bridging of the Grasshopper and the Arduino hardware through the Firefly plug-in. Based on the previous versions, a physical model was developed.

5.6.1 Narrative Intent

The intent of this narrative is to create a prototype that translates the interaction of the digital model into a working physical model.

5.6.2 Prototype Development

5.6.2.1 Variation One

The investigation for *Hybrid* began with creating patterns with paper folding techniques. This was done in order to simulate the transition between non-active and active states. The first investigation uses the simple form a of piece of paper folded in even divisions along its' width, similar to that of an accordion pattern. The movement of pulling this up and down was analyzed to see if more stimulating or interesting forms could be created. This movement was done manually by simply holding the two ends of the sheet of paper and compressing and extending. The desired geometry was one that created a pattern that was varied throughout the form. The form of variation one takes the accordion type geometry and creates a repeating pattern of extrusion and depression. This was done in order to break up the monotony of the crease pattern. To create a continuous interaction, the geometry needed to be mechanized someone.

To initiate this interaction, the digital model was connected to the Arduino hardware. The Arduino hardware takes physical data and inputs this data into the digital model. The physical data is captured using various sensors; for this investigation, a light-detecting resistor (LDR) was used. The LDR measures the amount of light near the sensor area. As the sensor is covered by an opaque object, the values read on the LDR decrease. Then, as the object is removed from over the sensor, the values from the sensor increase. First, the LDR was connected to a breadboard in order to connect it to the Arduino board. This layout is shown in Fig.X-X. This was then connected to the computer via USB (Universal Serial Bus) in order to load the proper coding into the Arduino board. The coding used for this investigation used

Fig. 5.56 - Arduino Hardware - Board

one that allows for the Arduino data to transfer to the Grasshopper model via Firefly plug-in. Once that coding is loaded, the data was instantiated in the Grasshopper environment. Within Grasshopper, the data being streamed from the Arduino board is simply numerical information. This numerical information is translated using the Firefly plug-in, which allows for simultaeneous interaction with both digital Rhino model and physical model.

The physical model's interaction is powered by a servo motor. The servo motor rotates

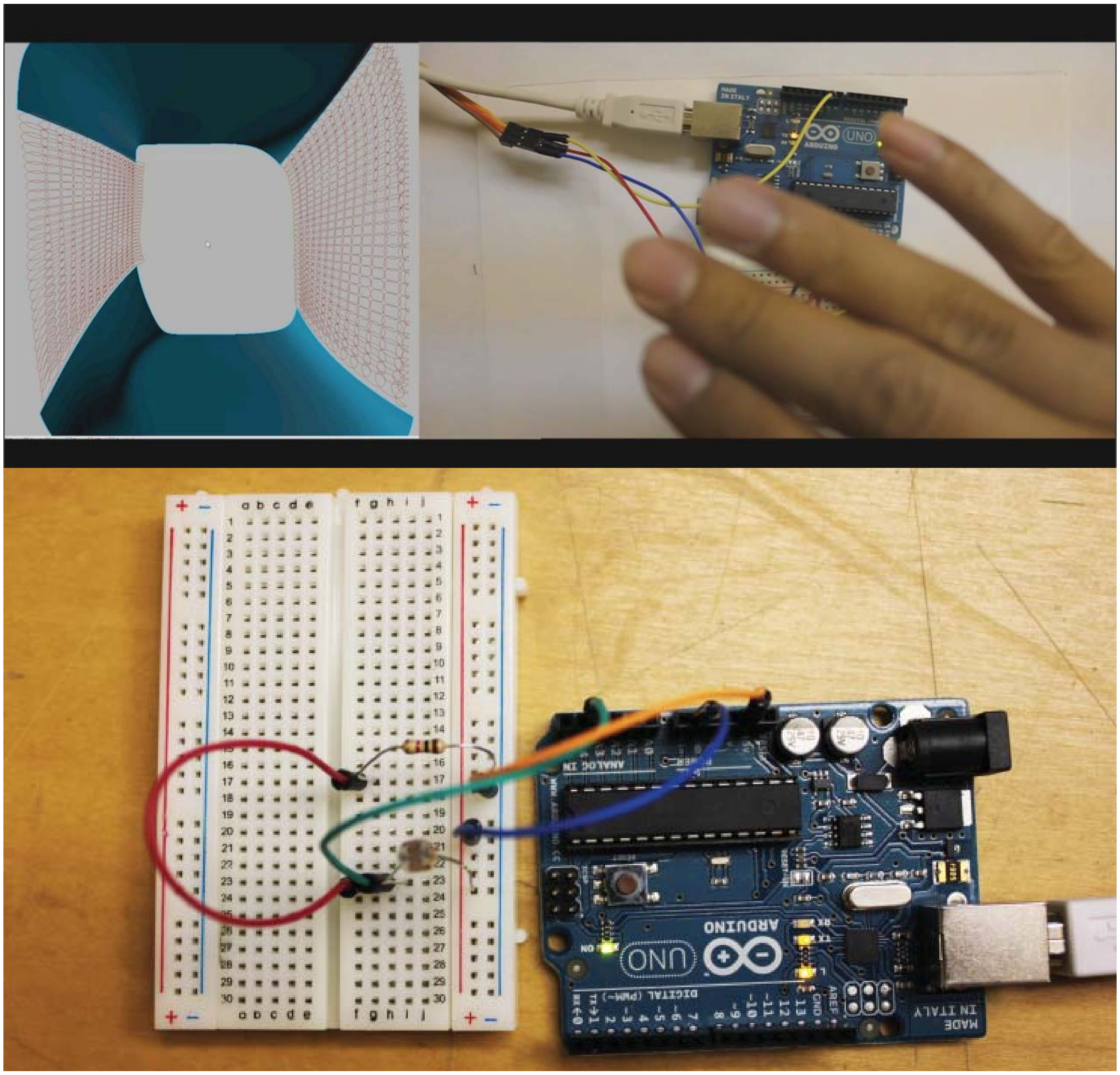
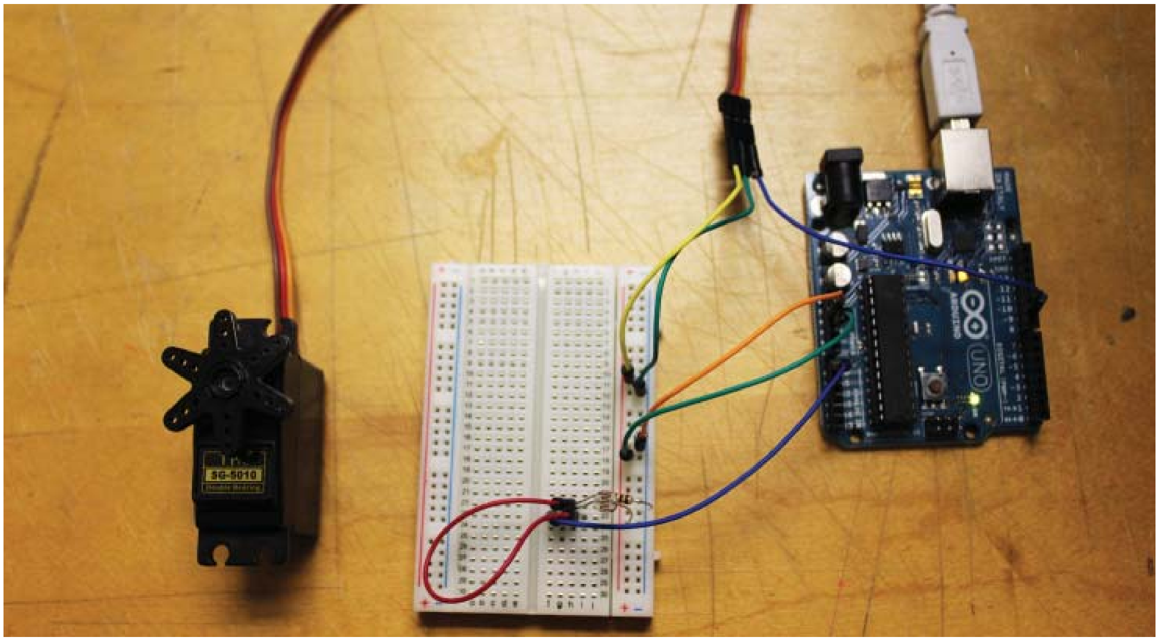


Fig. 5.57 - Image showing interaction between digital model (Above), light detecting resistor, and Arduino hardware (Below).



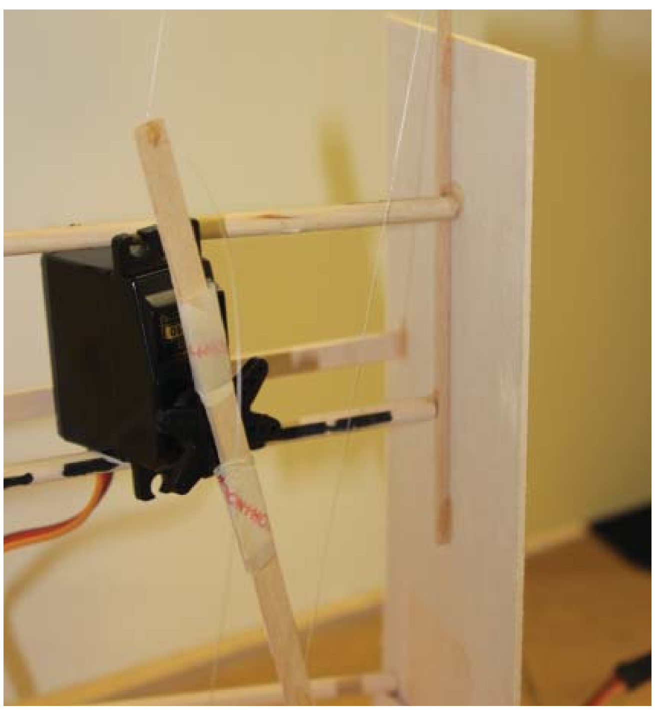


Fig. 5.58 - Image showing interaction between light detecting resistor, Arduino hardware, and servo motor.

from 0 to 180 degrees, then back again. This motor is connected to the Arduino hardware along with the LDR. The servo motor is then connected to the prototype using a designed mechanism. As the motor rotates according to the light readings from the LDR, it pulls the prototype upwards or downwards. This results in a continuous user interaction between user, physical, and digital model.

Fig. 5.58 - Image of *Hybrid* Variation One

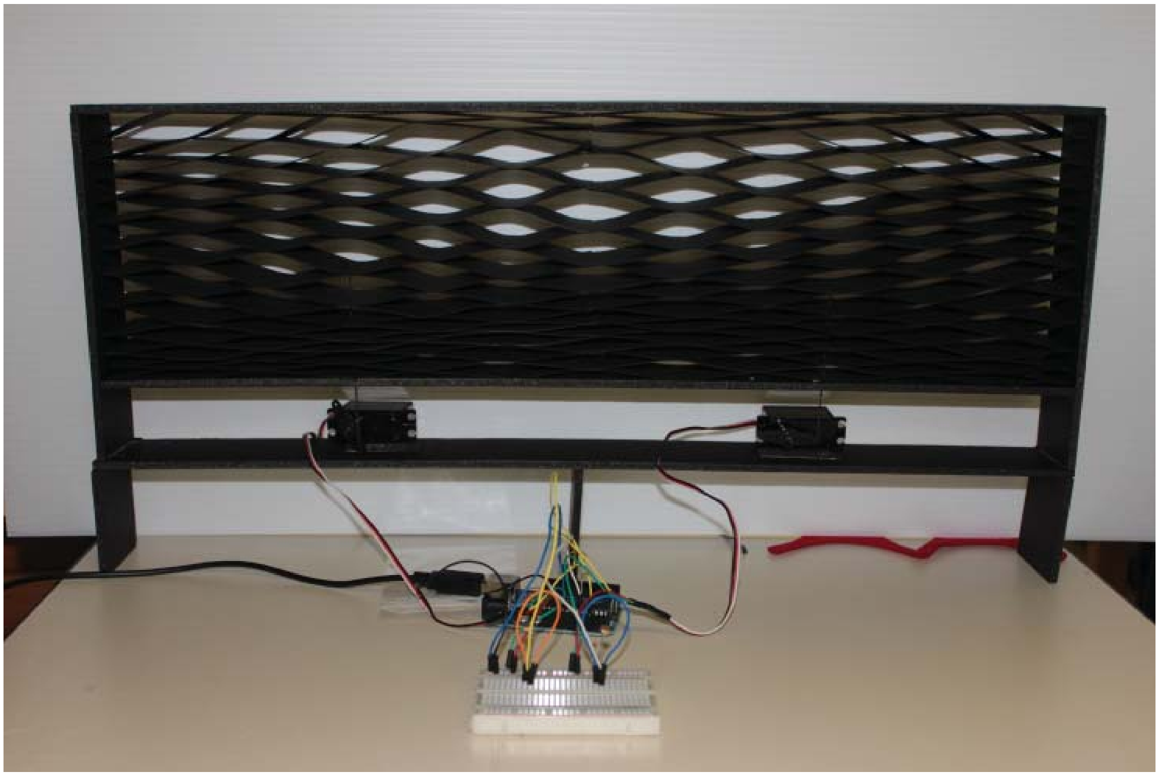
5.6.2.2 Variation Two

Variation two of the *Hybrid* model tried to create a geometry that has a non-active state that can be read as a simple geometric pattern. To begin, the same accordion type of fold was applied to a sheet of paper. Then, cuts along the creases were made, resulting in even strips. Then, pairs of strips were glued at 3-inch intervals. These pairs of strips were then glued to each other. This process made a geometry similar to that of a diagrid. This geometry, coupled with the flexibility that paper provides, created a highly deformable geometry that could be compressed and extended. This compression and extension created a lot of change. When forces are applied at opposing directions at different end points, the result is that of highly varied geometrical pattern.

5.5.2 Applications

Hybrid's ability to interface digital and physical allows this prototype to be useful in real-world settings. This prototype is highly dependent on the mechanics of the physical construct, without the proper mechanical tools, *Hybrid* isn't functional.

Fig. 5.59 - Image showing interaction of *Hybrid* Variation Two



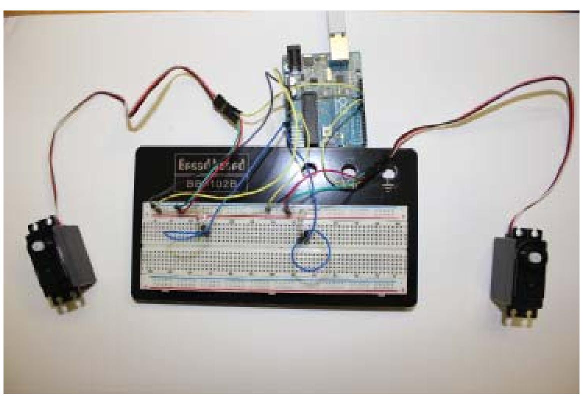


Fig. 5.60 - Hybrid Variation Two with two-servo motors connected

Fig. 5.61 - This image sequence is taken from a video showing the prototype being deformed to user interaction using the light-detecting sensor set-up.

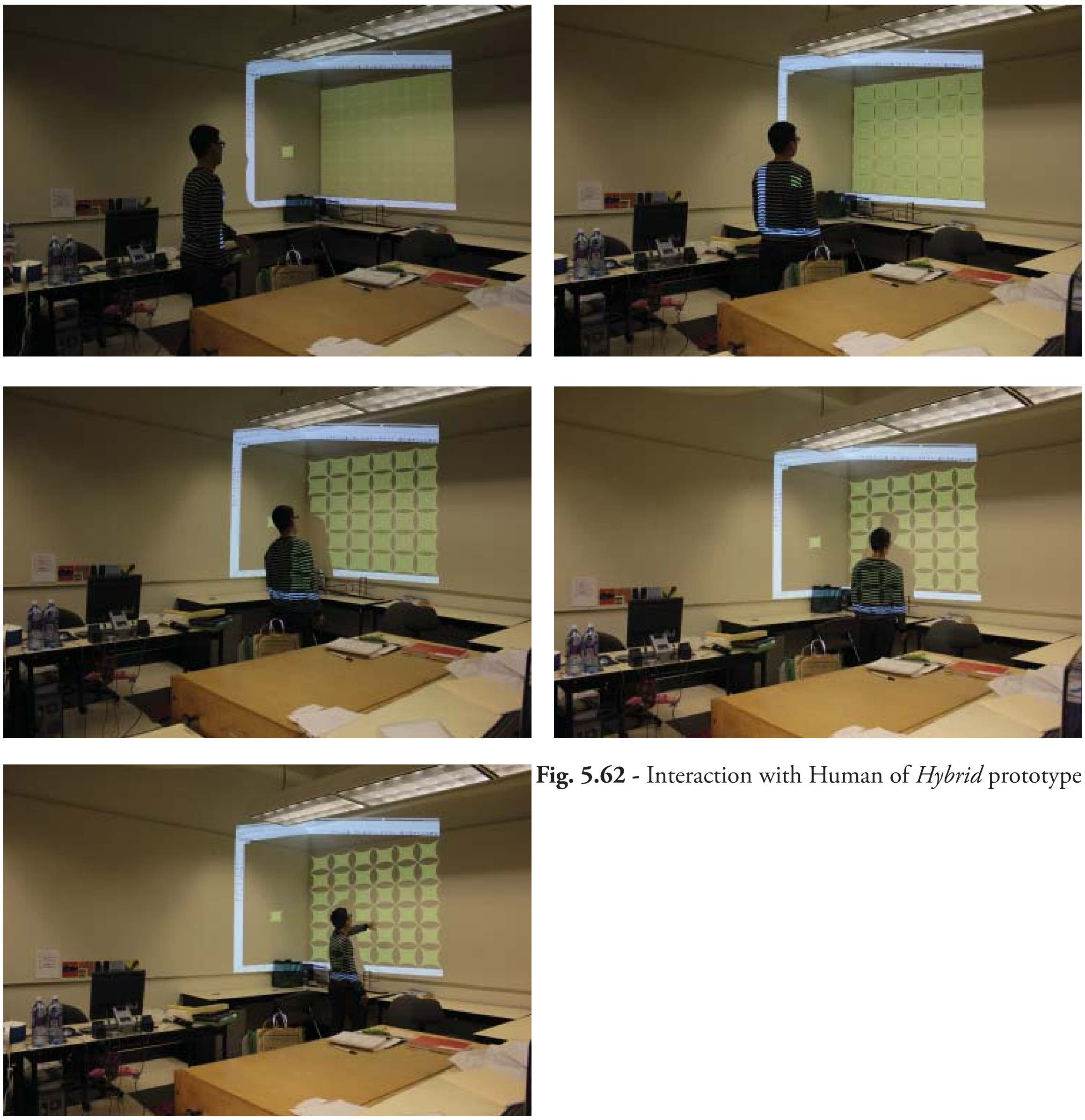
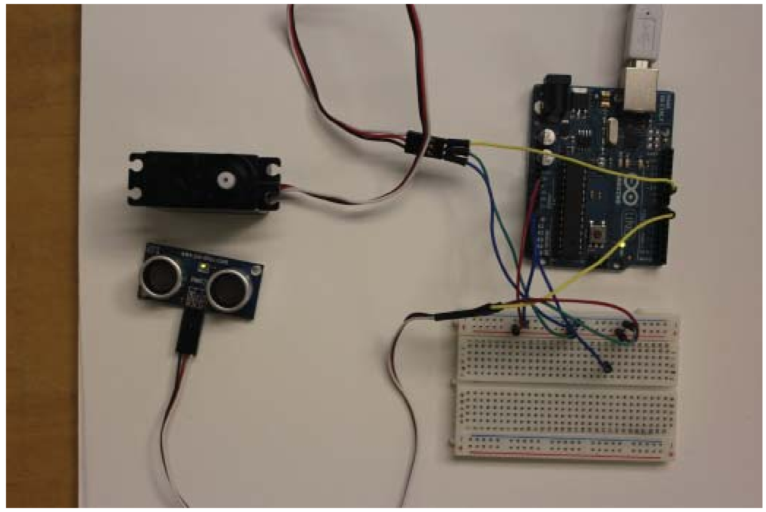
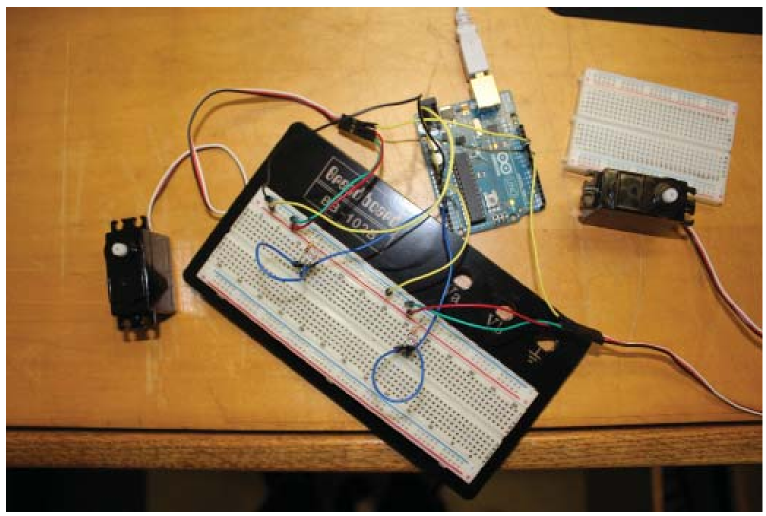


Fig. 5.62 - Interaction with Human of *Hybrid* prototype





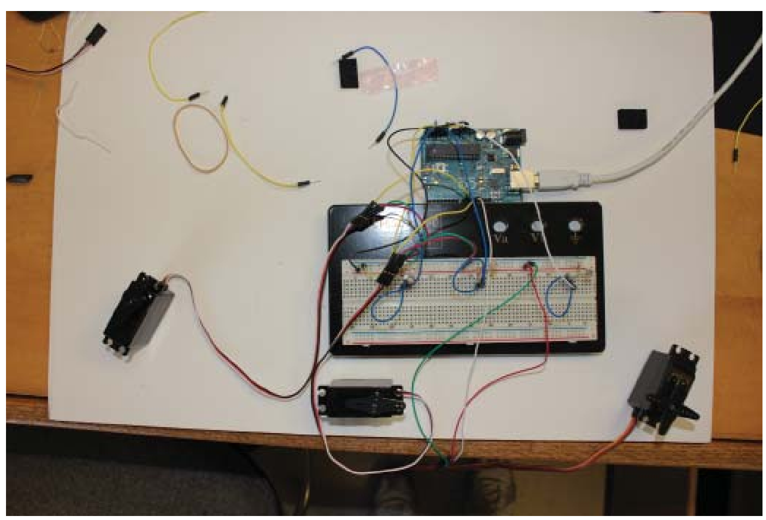
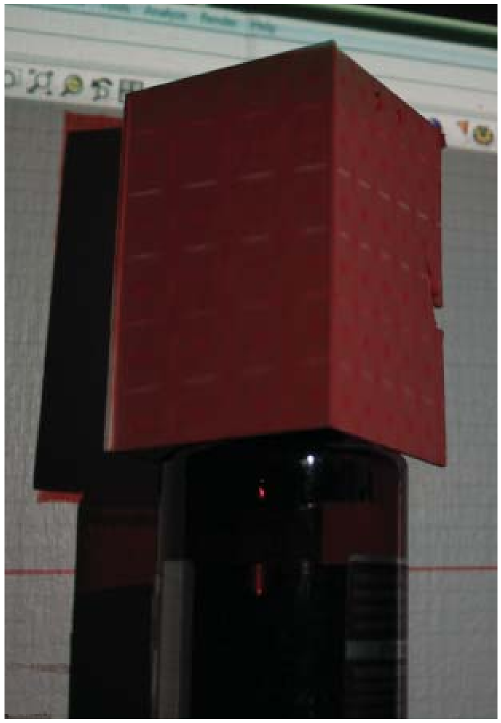


Fig. 5.63 - Images showing servos connected to Parallax Ping sensor.



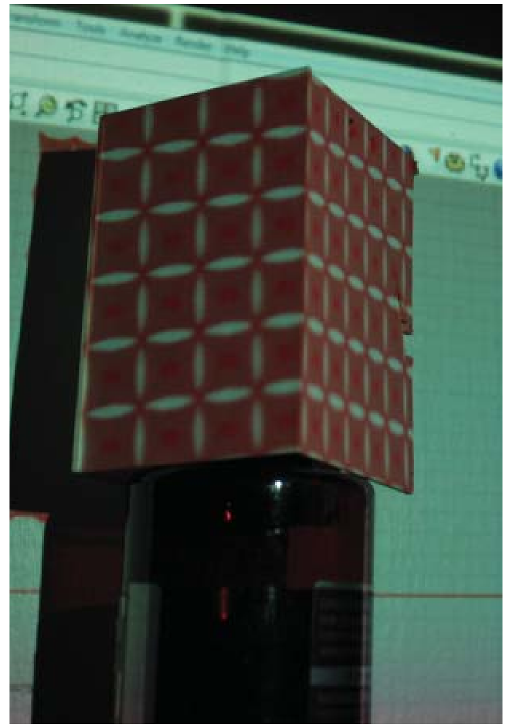


Fig 5.64 - Images showing projection mapping experiments using Rhinoceros 3D. The object is a small chipboard box using a portable projector. The series shows the patterning through different stages of user interaction.

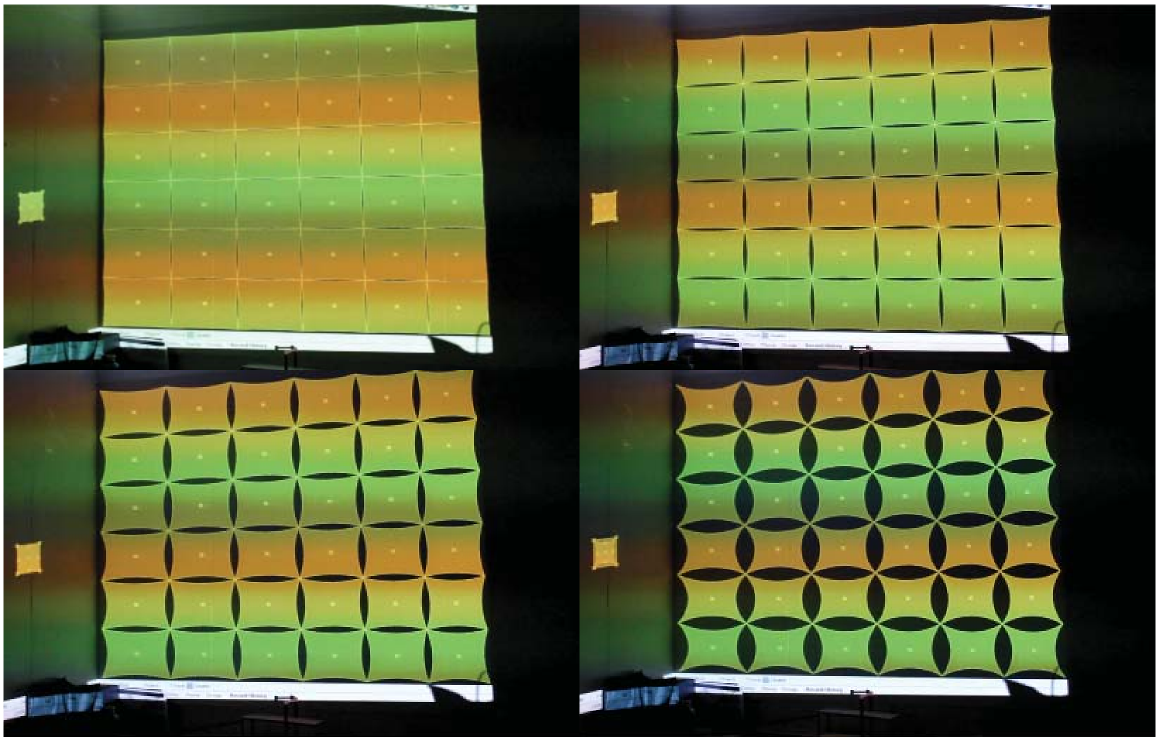


Fig. 5.65 - This image sequence shows the transformation from non-active to active on a human scale.

5.7 COMPARISON OF PROTOTYPES

5.7.1 Introduction

The five prototypes created – *Tear*, *Twist*, *Pixel*, *Bloom*, and *Hybrid* – seek user interaction through the stimulation of the five senses – sight, sound, touch, taste, and smell. This chapter analyzes the prototypes by comparing the level of stimulation each prototype has on the individual senses. According to this stimulation, the prototypes are compared in their ability to create interaction. This chapter classifies the stimulation of the five senses for each of the five prototypes, and which prototype stimulates the user most efficiently overall.

Based upon the criterion for this analysis focusing on individual prototype's ability to stimulate user's senses, the intensity of the stimulation caused by the prototype is evaluated. Intensity in this comparison is defined as the amount of the interaction in which a user's targeted sense is engaged.

5.7.2 Senses

The sense of sight is often times the strongest human sense to be stimulated when it comes to the experience of architecture and design. High visual impact automatically creates viewer interest. Creating visual stimulation is a goal for all of the prototypes.

Each of the prototypes tries to start with an undifferentiated surface, which creates no sense of expectation within the user. As a user engages with the space, the reaction to this ostensibly seamless surface transforming into a visual configuration heightens the user interaction. *Tear* is the most subtle in visual impact. The surface's opening increases according to the user's proximity to the prototype; the extent of this opening is dependent on the user's physical dimensions. The opening and closing of the surface creates an entry space for the user. Viewers of this opening sequence, a user stepping into the surface, and disappearing into an unknown space will be intrigued by both the prototype and the curiosity of what lies beyond, a sensation only *Tear*

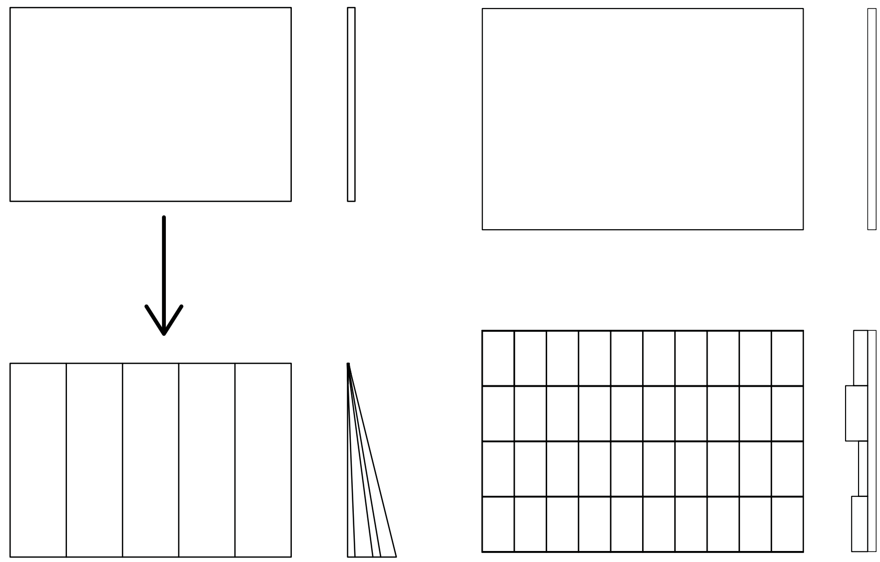


Fig. 5.66 - Diagram showing transition of *Tear* prototype (Left) and *Pixel* prototype (right) from non-active to active states.

provides. *Twist* provides a similar interaction sequence of an initial undivided surface turning into openings, however, the vertical panelization of the surface creates a visual connection to an already existing architectural prototype –window blinds. Even though *Twist* creates a surface opening, the way this opening is exposed – the rotation of the paneled surface – is less visually intriguing than *Tear*.

Pixel takes the notion of an existing architectural prototype – surface tiles – and redefines the way it functions. *Pixel* is initially just a surface pattern, which leads the user to believe that it serves no other function than that of a visual appliqué. Then, as interaction occurs, the tiles begin to extrude from the surface. This extrusion creates visual interest because the user is not expecting the tiles to deform in that manner. Tiles don't physically extrude– or depress – into space, but that is the illusion *Pixel* creates.

Bloom generates the highest visual impact within the typical definition of patterning. Its' initial state is already a pattern, which in itself, creates interest within a user or viewer. In one variation of *Bloom*, the surface – like the other prototypes – is smooth and only patterned with user interaction. Another variation of *Bloom* starts with a patterned, brise soleil-like geometry as its' non-active state. What *Bloom* does differently is its' pattern is highly varied in geometrical deformation. This variation creates a strong visual impact, especially when compounded with environmental factors (can explain further into how environmental factors make it strong). Unlike any of the other

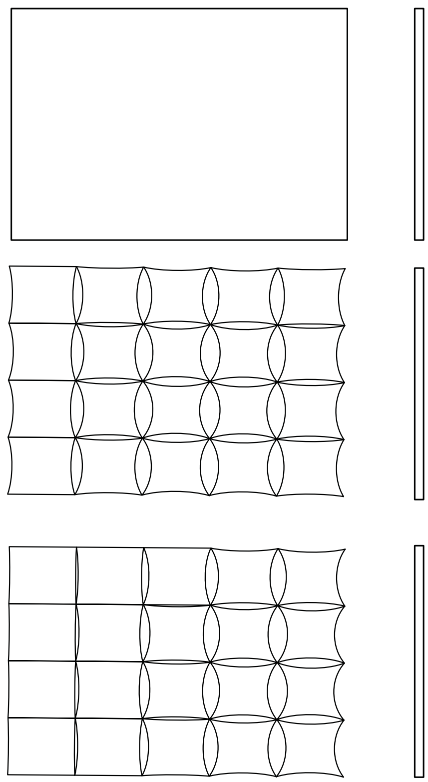


Fig. 5.67 - Diagram showing transition of *Bloom* prototype (Left) from non-active to active states.

prototypes, the active state of *Bloom* creates a geometry that is distorted from the base unit. It is this deformation that makes the visual impact of *Bloom*.

Sound within the architectural experience is the result of spatial formation, material, and environmental conditions existing within the same timeframe. The sound heard within a spatial environment at a specific moment in time is unique only to that timeframe. The prototypes create sound only in their active states. *Pixel* and *Twist* create the most aural stimulation due to the panelization and pixilation of the

Fig. 5.68 - *Bloom*

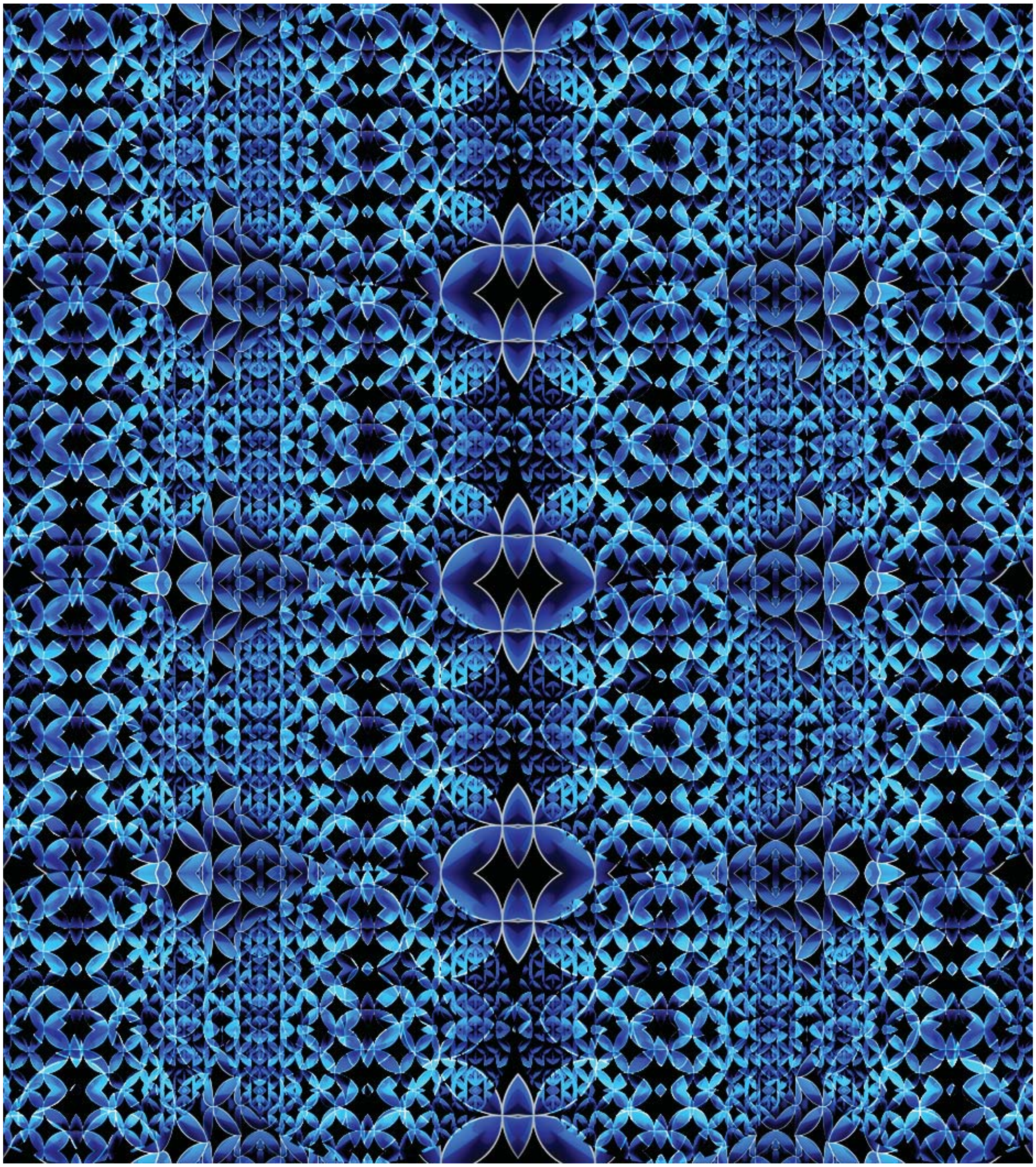


Fig. 5.69 - *Bloom*

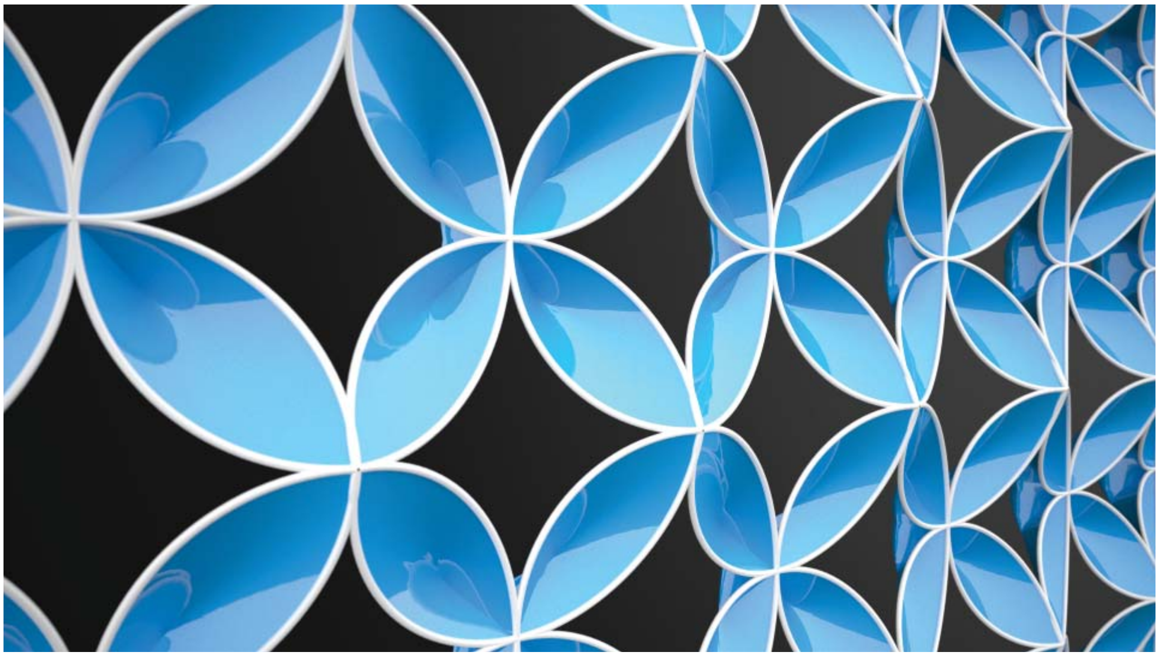


Fig. 5.70 - *Bloom*

prototype surface. *Pixel* extrudes and depresses surface tiles; this movement causes friction within itself and creates sound. The sound created is a signifier of user presence and also of user coordinates within a spatial environment. Sound is created when a user is present; when there are multiple users within the same spatial environment, *Pixel* allows for these users to know of one another's presence. *Twist* possesses the same ability of creating sound. The main difference between *Twist* and *Pixel* is that *Twist* uses contact to create sound. The panels that make up *Twist*'s surface rotate from non-active to active according to user. The rotation of its' panels create a noises as the hit each other in the process of interaction, similar to shutters opening and closing. This noise is enhanced depending on the material of the panels. Another factor in the creation of sound is the speed of at which the panels rotate. The quicker the rotation, the greater the impact *Twist* has on the sense of hearing. *Tear* and *Bloom* stimulate sound through the mechanisms that make up the prototype. Unlike *Twist* and *Pixel*, *Tear* and *Bloom*'s patterning do not create sound directly. Their strengths lie in visual patterning.

Touch is the most universal user sensation as the whole body can experience the sensation of touch. Some of the prototypes create texture through patterning. The sensation of touch through the user's hand is limited to the texture of the prototypes; however, touch can include other sensations experienced through the skin. *Tear* creates stimulation through touch by the opening and closing of the surface. This movement creates a movement of air that interfaces with the user through his/her body. *Twist*, similarly, uses its rotation motion to create air movement that interacts with the user's sense of touch. *Pixel* creates the most texture amongst all of the prototypes. Depending on the surface subdivisions set by the designer; this texture can be finer and create a smoother, more touchable surface.

5.7.3 Summary

The prototypes stimulate user's senses through a variety of fashions; some prototypes function better than others in terms of specific sense stimulation. From this analysis, *Bloom* creates highest level of intensity of stimulation out of all of the prototypes. *Bloom* targets multiple senses simultaneously at the highest level of all prototypes. *Hybrid*, however, is the only protoype that physically interacts with the user. Although the interaction is a hybrid physical-digital one, it creates an environment where the user is real.

VI. CONCLUSION

6.1 Contributions of Thesis

This chapter re-introduces the topics discussed throughout this thesis and discusses the implications and applications of thesis outcomes. In addition, future applications and further areas of research are discussed.

+ Invention of an immersive design methodology that focuses on user interaction by creating a continuous narrative between user and spatial environment.
+ Formation of immersive design workflow that places design emphasis on the stimulation of target senses.
+ Creation of five prototypes using immersive design methodology that illustrate interaction with a variety of spatial conditions.
+ Demonstration of a sound aesthetic where user interaction creates form

6.2 A Design Methodology

The immersive design methodology developed in this thesis focuses on the interaction between user and space. The intent of this method is to create a way for the experience of architecture to go beyond the typical spatial experience paradigm. Instead of discrete moments of user interaction with the spatial environment, an immersive design creates an experience where a user and spatial environment are in a flowing and continuous narrative. The narrative creates an elongation of space - where the user's occupation within the space is extended due to the interaction between user and his/her surroundings.

The formulation of the immersive design methodology began in Chapter 3 "Immersive Design", through a starting design investigation. Through the re-definition and re-design of an existing prototype – an alarm device - the design methodology is created. The methodology is then refined to the point where the focus of the methodology is established - targeting the stimulation of user senses. The determination of which senses are stimulated at the beginning of the design process – before any formal exploration – enables this methodology to create a more intimate spatial experience.

Within the framework of the immersive design methodology, an immersive design workflow is determined. This workflow first creates a digital prototype model, secondly digitally simulates user and spatial interaction, and lastly, creates an interaction between physical user and digital model.

In Chapter 5 - “Prototype Investigation” - this workflow - in addition to the immersive design methodology - was used to create five prototypes – Tear, Pixel, Twist, Bloom, and Hybrid. These five prototypes depict the immersive design method at work by creating spatial environments and simulating user interaction both digitally and physically. This simulation is done both digitally and physically to illustrate the intended user interaction.

In Chapter 5.7, “Prototype Comparison”, the developed immersive prototypes are evaluated according to their ability to stimulate targeted user sense(s). Bloom and Hybrid – when combined - is determined to be the two most effective of the five prototypes in the stimulation of user senses. Bloom achieves a highly varied visual pattern while still creating textural and spatial changes; Hybrid is the only prototype to achieve a physical user interaction; the other prototypes are strictly digital simulation models. A combination of the two prototypes would be useful as a starting point to implement the immersive design method in a small scale project.

6.4 Future Research

The typical design methodology satisfies programmatic requirements through only space; user consideration is limited to only the user's movements through the designed environment. What the user sees and feels is a by-product of architecture and natural environment. The immersive design methodology provides a way for designers to create a specific level of intimacy non-existent in contemporary architectural design. This intimacy is beyond what is first perceived when engaged in the spatial environment. The immersive design method creates spaces that are continuously reacting to user engagement, a sound aesthetic that is informed by the user movements.

During the prototype investigation, the usage of digital modeling limited the ability to simulate the senses of taste and smell. The computer technology used in the investigation was constrained to visual and textural. The outcome of the stimulation of taste and smell can only be inferred. Contemporary architecture does not address taste and smell directly. Taste and smell in the architectural spatial experience is usually a result either various architectural material evoking their natural aroma or the effect of time on the physical architecture. This thesis deals mainly with aesthetics; in order to enhance the outcomes of the investigation, taste and smell need to be furthered explored as part of the design methodology. The only way to engage the senses of taste and smell is to construct a physical prototype in order to physically engage the user.

The immersive prototypes visualize a kinetic interaction between user and space; non-active states describe a static prototype and an active state describes a dynamic prototype. In Chapter 5 - "Prototype Investigation" – Hybrid begins to explore the construction of a physical prototype and the mechanization required to create the interaction desired. However, the model was at a small scale. A physical, full scale model would allow for a true user interaction to occur.

CONCLUSION

The elongation of space that the immersive design methodology creates is useful in spatial programs that benefit from users occupying a space longer. Entertainment, retail, and dinning settings are programmatic examples that would benefit from this methodology because of their dependence on constant user occupation.

What the immersive design methodology provides is a user focused approach to design; where space is seemingly customized to each user. Customization is highly desired aspect in today's global market; the creation of customizable spatial environments is an elusive concept but this methodology creates it. The beauty presented by this methodology is that outcome of the user and spatial narrative is unique to only that moment of occupation. The designer sets the boundaries of the space; the user is left to fashion the interaction and the aesthetic of the moment.

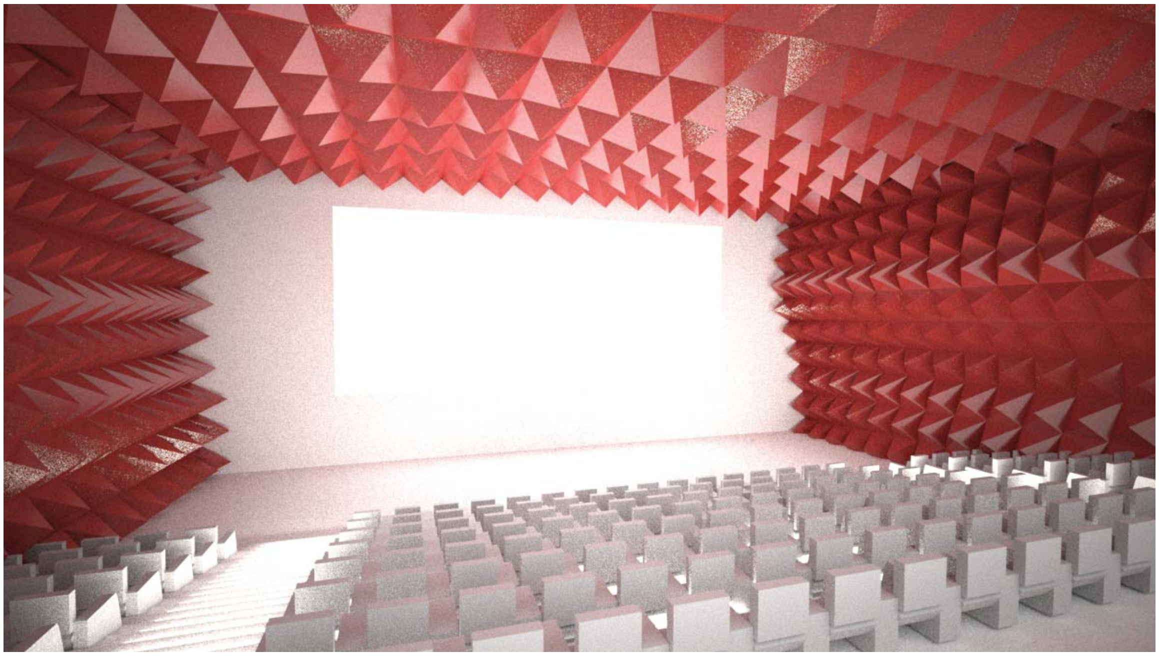


Fig. 5.71 - Future Movie Theatre with *Bloom* acoustical panels

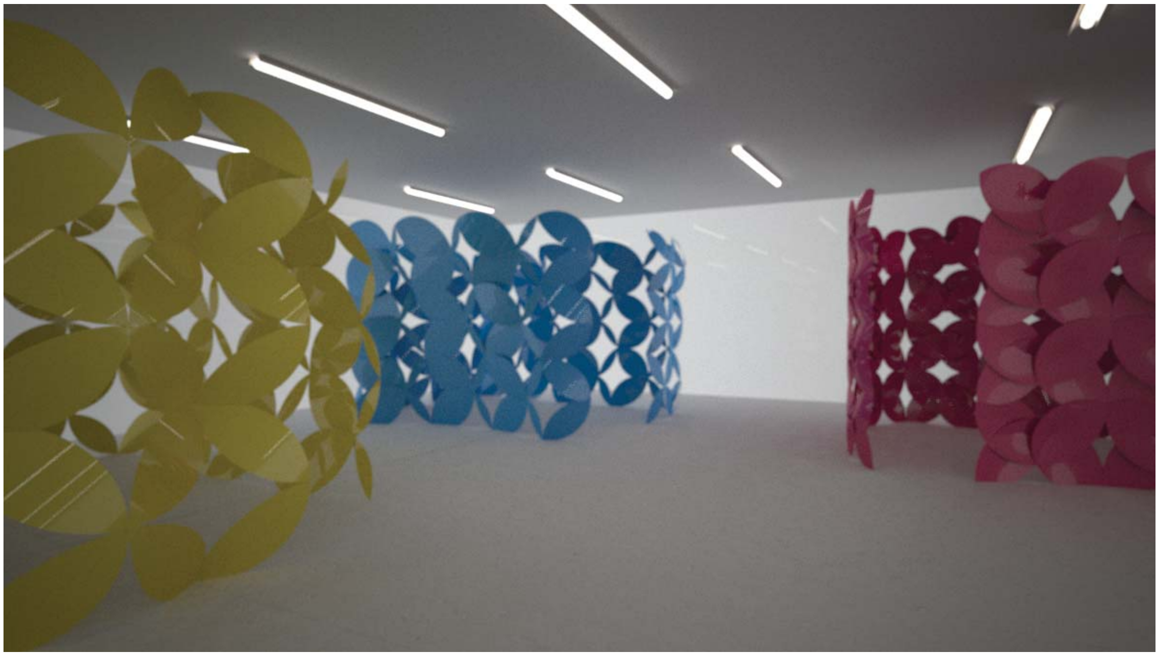


Fig. 5.72 - Future Office Environment with *Bloom* workspaces

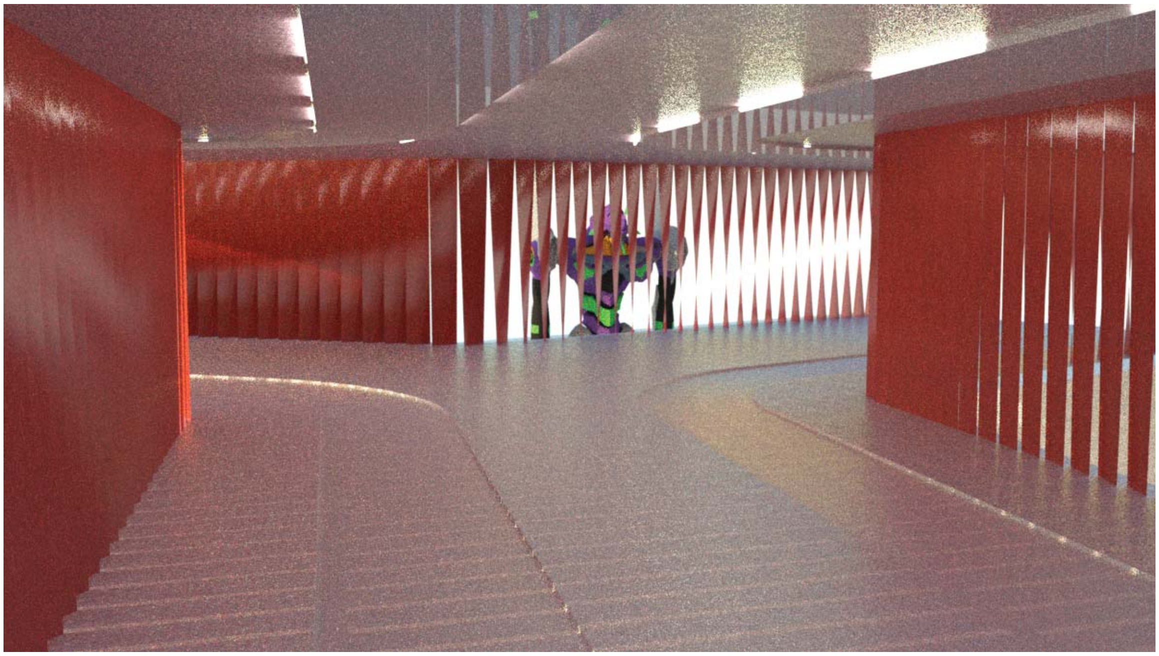


Fig. 5.73 - Future Spaceport with *Twist* corridors

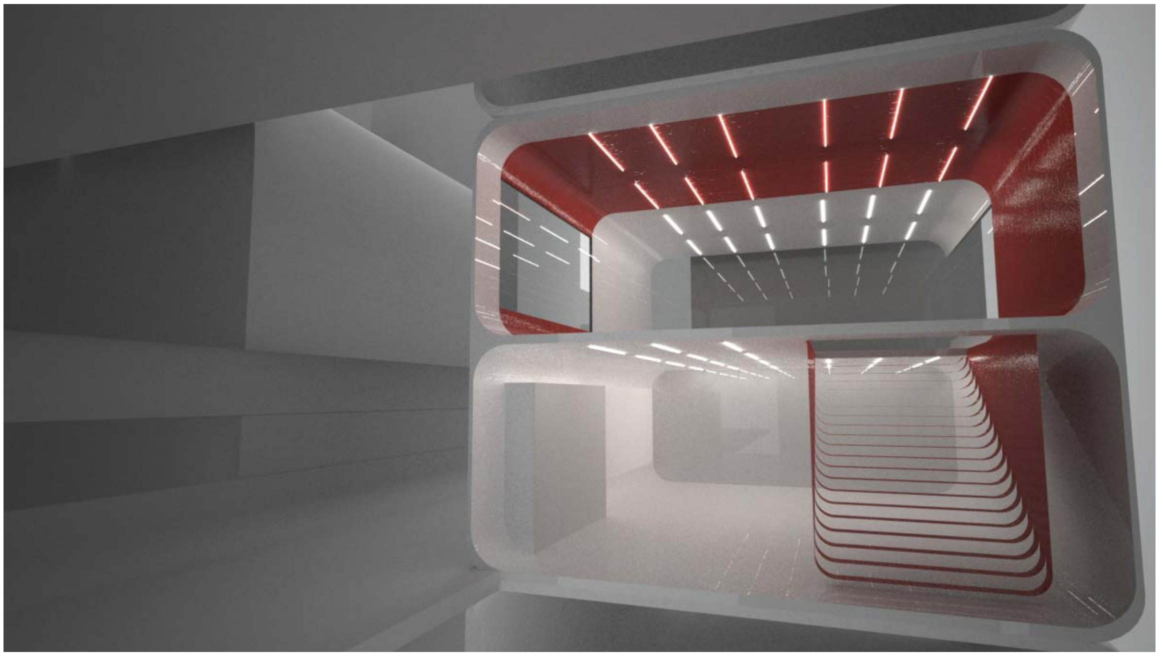


Fig. 5.74 - Future Retail Space with *Twist, Tear,* and *Pixel*

6.5 Epilogue

A sound aesthetic is created through the continous narrative between user and spatial environment. Through the immersive design methodology, a new experience of space is proposed, where the target is the stimulation of user senses. By putting the focus of space not on formal qualities but one of experience, immersive environments allow for user a more intimate experience of space.

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