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In the attempt to create interactive architectural space, biomorphic design principles and theories have been applied to develop forms derived from nature. The experience of a space is developed through the use of patterns and surfaces, which have historical importance in architecture and design. Patterns have created unique identities for space throughout history, contributing to the perception and interactive nature of space. Therefore, this use of pattern develops a variety of different applications in the field of architecture; in this case it is the design and development of a wall used for the creation of boundaries within a space through the pattern's articulation of surfaces. These surfaces create a physical entity within a space, primarily forming the perception of limits that make up the wall system by defining two or more distinct spaces within the area.

The biomorphic design of the wall system integrates the uses of forms and patterns found in nature with the inherent human attraction to natural elements. Evidence supporting human affinity for nature uncovers features of natural forms that are both stimulating and beneficial to the user. The visually interactive qualities of the wall system will provide spatial cues that influence the perception and resulting behavior within the environment.

ART RESHAPING SPACE

by

Brooke Erin Elliott

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Approved by

____
Committee Chair

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Chair ________________________________

Committee Members ________________________________

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Date of Acceptance by Committee

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CHAPTER I

INTRODUCTION

This thesis is an inquiry into visually interactive environments through the development of natural pattern, utilizing biomorphic design. An important aspect of this study is to investigate the application of biomorphic design and applying it to the creation of visually interactive environments. Interaction, defined for this study, is an experience that involves the actions or input of a user, creating, as Bullivant (2006) states: "…spaces that interact with the people who use them, pass through them or by them" (pg. 7). Through this formal interpretation of the visually interactive there is an explanation of how an individual views the use of visually interactive elements, ultimately aiding in the development of stimulating environments.

In the development of visually interactive space, the use of Biomorphic design is the principle characteristic of this study. The initial uses of the term Biomorphism, originating in the arts, were being used to explain a new area of art that later became a foundation of the Surrealist movement. The artists of this movement, such as Miro and Dali, provided testament to the use of the biomorphic through their organic abstract cellular forms, later informing the basis of today's use of this concept in the fields of architecture and product design.   Therefore, the study of these various examples of biomorphic art and design can provide a foundation for the creation of visually interactive environmental elements that create dynamic perceptions from user to user.

Objectives

This research is an exploration of biomorphic forms to create a wall system inspired by naturally occurring organic shapes which are reflective of forms found in the field of biology. The term *biomorphism*, first used by Alfred H. Barr, the foremost director of the Museum of Modern Art in New York City, is more clearly defined in The Tate Collection's (n.d.) glossary stating: "In painting and sculpture biomorphic forms or images are ones that, while abstract, nevertheless refer to, or evoke, living forms such as plants and the human body" ("Tate Glossary: Biomorphic," n.d.). Through the identification of organic forms such as these, the aesthetic aspects of the biological structure can exhibit qualities that satisfy areas of elegance, harmony, form, and balance, which can then be introduced into environments through the creation of a wall system.

Limitations

The limitations facing this project include the development of a biomorphic pattern that will resonate with the user and the various aspects of the venue, the lobby of the Gatewood Arts Building on the University of North Carolina at Greensboro. The lobby of the Gatewood Building poses a significant number of the limitations this project will face including: lighting, the vastness of the space, and two distinct paths of traffic, implying there must be some suggested directionality to the installation.

Although most of the uses of biomorphic forms are based upon aesthetic qualities, humans have a relationship that runs more deeply than just its visual aspects; Joyce and Van Locke (2007) suggest that “humans are innately attracted to concrete types of natural environments..." (pg. 105) Therefore, for the installation, it is important to create forms that not only emulate the aesthetic elements of nature but also produce a direct example of nature, resulting in a recognizable form. Through this identification and creation of natural form, the patterns exhibited will result in a contrast between the typical smooth surfaces of the space and the three-dimensionality of biomorphic form.

Following the introduction of these biomorphic forms are the limitations of the space, beginning with the control of daylight and absence of directional lighting. The lighting of the Gatewood lobby is controlled entirely by the curtain wall windows covering the north side of the building, filling the space with natural light throughout the day. Consequently, this results in the inability to control the lighting aspects of the lobby space, ultimately affecting the role the dynamics of shadow play in visual interaction. This lack of light control also affects the importance of the placement of exhibit elements in relation to the natural lighting entering the front of the building. Secondly, the lobby also consists of a large amount of space, sufficient for the student and faculty traffic that utilize the area throughout the day. Although this area is sufficient for the amount of traffic, it's vastness does pose constraints, such as the directionality of the space. However, it is implied that the application or use of biomorphic elements can encourage a visual and tactile interaction by directing circulation, but having excess space causes the design to be limited to one area of the lobby, instead of the entire space. Lastly, there is the fact that there are two primary traffic patterns within the large scale space, suggesting that the installation must focus on one area. So, targeting the south side of the space, leading to the IARc departmental office will be the proposed visual directionality of the space.

Significance

The significance of this research is to determine if the design and fabrication of pattern, based on biomorphic design, can create visually interactive environments. With the introduction of pattern, as stated by Garcia (2009), a unique identity for a space can be created, acting as a fingerprint for different types of spatial patterns. Hence, the purpose of the introduction of biomorphic form is the human identification with the natural aspects of form as well as the directing the visual attention within space.

Knowing the creation and introduction of biomorphically patterned surfaces has the potential to direct visual attention due to the inherent human identification with natural imagery. Examples of the use of natural imagery can be seen throughout many disciplines, including science, mathematics, and geography, but viewed most prevalently in emerging and historical eras of art. The human inclination to identify natural characteristics within a visual scene, regardless of the discipline, can be attributed to pattern, such as a honeycomb or the amoeboid appearance of a cell. Through a variety of uses of natural characteristics a dynamic personal association with space is created that permits the visitor to draw comparisons and evoke a sense of remembrance from experience, engaging them to ask: What does this remind me of? Have I seen something like this before?

CHAPTER II

REVIEW OF LITERATURE

The understanding of spatial experiences and how they relate to visually interactive environments provide new ideas of how space can be defined. The use of pattern and its effects on the perception of space and creation of surface is also considered supporting the introduction of biomorphic forms into an environment. This discussion of pattern consequently demonstrates how biomorphic design and its use in the development of pattern affect the visitor through perception, experience, and sensory stimulation.

Spatial Experience

When relating a spatial experience to visually interactive design, it is important to understand how a person defines, perceives, and relates to space. Tuan (1977) finds that space can be defined in a variety of different ways, but identifies most with the fact that “place is whatever stable object catches our attention,” suggesting that perception can influence behavior. (pg. 161) This is evident in literary art’s creation of a sense of place, drawing attention to aspects of the experience that may go unnoticed, but in the case of the physical presence of three-dimensional form, such as architecture, it is the form that produces the experience. This personal identification with form is supported in Tuan's reference to Susanne Langer's *Feeling and Form*, giving an explanation to how an art object's form commands its world, saying it is "symbolic of human feeling" (as cited in Tuan, 1977). Further identifying with the experience of art, Dewey (1934) found that there is a continuous interaction between an organism and its environment, resulting in continuity in experience. The act of having an experience is the result of an event running its course and the moments found within the experience just punctuate its entirety. An example of this can be found in art where the movements in a piece are not clearly defined, they are fused together in a unifying experience found in the one quality that is prevalent.

Although all organisms have a symbolic orientation to space as seen in examples of art, Bloome (1990) found that an individual species' senses process information differently, creating a specific environmental niche upon which each organism depends on for survival. Therefore, spatial perception is an aspect of one's biological development which is found in how "visual cues" affect their behavior; the biological differences in these environmental niches create the inhabitation of different perceptions. (pg. 106) Perceptions, as defined through Bloome's seven methods of remembering: visual, kinesthetic, spatial, verbal, auditory, interpersonal, and intrapersonal, can contribute to the use of visual imagery in intellectual and physical problem-solving. The use of these ideas ultimately proves their greater use when a perception is used in an association with something familiar to the individual.

Tuan (1977) also suggests that culture is another factor affecting spatial experience, helping to determine spatial experiences by diverse audiences. When keeping this in mind, it can be implied that what one person may find as interactive, may not be to another. (pg. 164) Therefore, with culture having a strong impact on a personal relationship with space, a study of these various differences that cultures use in relation to each other was developed by anthropologist Edward T. Hall. Hall (1966) defined these relations as human proxemics in his study of distances in man, which explains how different distances and the means by which they are distinguished lead to the development of four zones, defining mans relationship with space. (pg. 107) These zones include intimate distance (six to eighteen inches), personal distance (one to four feet), social distance (four to twelve feet), and public distance (twelve to twenty-five feet or more), all of which classify a dynamic sense of space due in part to its relation to action within that space. The reasoning behind the creation of this classification system can be found in his hypothesis of territoriality where the senses are used to distinguish one space or distance from another. (pg. 120) Although, when identifying which proxemic distance classifies each situation is dependent upon each individual's interactions, feelings, and actions within a space. Subsequently, Hall used these terms to relate to architecture in order to determine how distance affects stress and sensitivity in relation to overcrowding, finding that “Proxemic patters point up in sharp contrast some of the basic differences between people…” (pg. 122)

In a study that addresses experiential factors in the art world, Lucy Bullivant (2007) examines how museums have begun playing a significant role in creating paradigms that focus on the field of public learning through the introduction of interactive elements. Through the testing of visitors’ use of interactive elements, museum curators have been able to expand on themes that are being addressed in society. This has in turn created a new relationship between the museum and the visitor by transforming “assumptions about art and design” (pg. 35). By creating spaces where visitors are able to use their senses and touch the pieces that are on display, these interactive spaces foster a free choice learning environment.

Visually Interactive Design

In the relatively new field of interactive design questions are being raised to understand how it fits into society. Mark Garcia addresses the questions in his article *Otherwise Engaged: New Projects in Interactive Design* (2007a). Some of these questions that are raised, which are only being addressed by a few architecture schools, include: “How interactive architecture should function in society, how interactive technologies should operate in more social and socially enabling ways, and how the general public, the public realm and public space should interface with these new design types” (pg.

44). In an attempt to answer some of these difficult questions in context Garcia identifies four of the most "socially engaged" (pg. 44) designs. One of which, The *Digital Pavilion Korea*, in Sampang-dong, Seoul, South Korea (Figure 1 and Figure 2), designed by Kas Oosterhuis and Ilona Lenard (ONL), is built on the idea that interaction is not just the response or adaptation to the changing conditions of the environment.

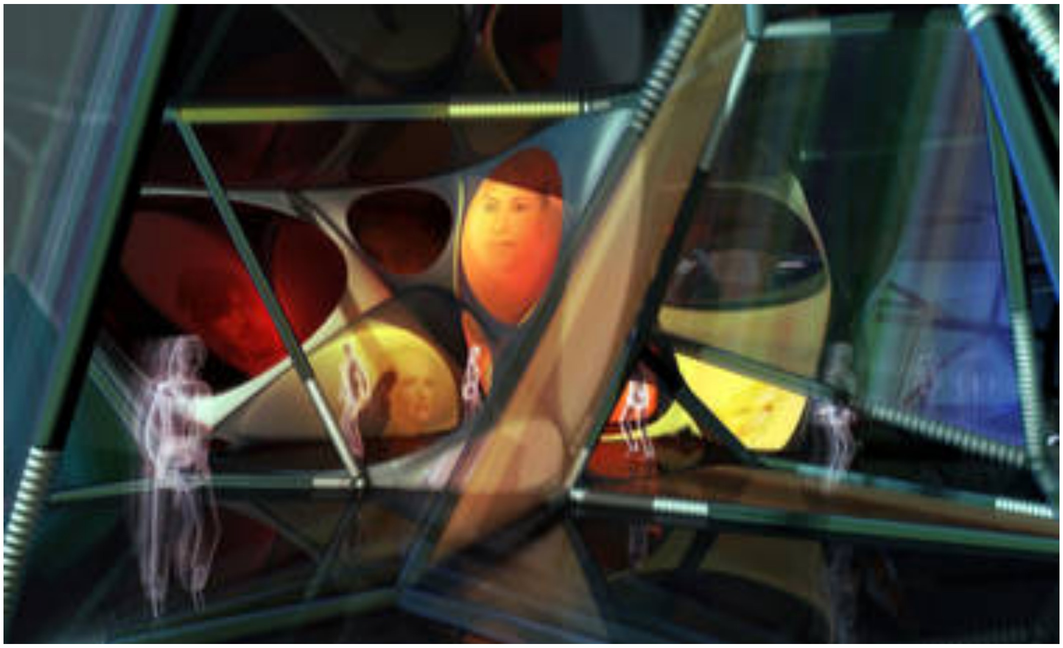

Figure 1. Interior of the Digital Pavilion Korea

Figure 2. Interior (2) of the Digital Pavilion Korea

Pattern

Garcia (2009) finds patter, deriving from the Latin word *pater,* meaning father, focuses on pattern as a mold in order to create a unique identity for space, acting as a fingerprint for various types of spatial patterns. Humans perceive patterns in spatial environments and subsequently interact with them to identify the character of the space. The recognition of repetitive figures is found in human sensory input; consequently, pattern can be attributed to the development of human survival skills. The recognition and perception of pattern has the ability to affect the psychological aspects of environmental perception and kinesthetic relationships of an individual with space.

The role pattern plays with interaction can be seen in both human evolution and spatial design. A significant amount of neural activity is based on the perception and recognition of pattern (Garcia, 2009). Garcia notes that in some cases pattern “can be perceived by the mind’s eye (as with forms of synaesthesia and Asperger’s or Savant syndromes), or directly hallucinated” (pg. 8), as seen in psychedelics. Pattern perception has the capability to affect the physiological aspects of environmental perception and the kinesthetic relationships of an individual with space.

Historically, Garcia (2009) finds the first references to Western tradition’s theoretical framework of spatial patterns are found in Plato’s *Timaeus* which “…described the world as filled with patterns of closely packed atom-like solids and geometric forms” (pg. 9). Pattern itself was seen as the foundation of style and pattern in Western tradition, having a deep influence originating from religion to the arts. The use of non representational patterns was not seen until geometrical and trompe l’oeil pattern were used by designers and architects to enhance or distort spaces in the time of ancient Greece to the present. The significance of pattern in the production of space did not gain momentum until the late 17th, 18th, and 19th centuries with the rise of global capitalism and the Enlightenment. The Industrial Revolution brought to the onset of the mass production of goods including paint, wall paper, and carpets and made them available to the middle class due to new middle class prosperity.

It was not until the 20th century that pattern was considered “art,” Garcia (2009) states. The development of pattern theorization includes the development of Gestalt psychology in 1912, the Bauhaus in 1919, and Christopher Alexander’s book *A Pattern Language* in 1977. There are a number of contemporary designers, books and organizations that are placing pattern in the forefront of pattern design revolution that include Zaha Hadid, MVRDV, and P-A-T-T-E-R-N-S. Garcia believes: “This rash of book, shows, designs and designers is evidence of spatial patterns as a whole reorienting towards greater, more high-tech and conceptual, dynamic, virtual, intangible, immaterial and invisible functions” (pg. 13). These new developing technologies have proved to be important to the expansion of the visualization of pattern in space.

Where most of the past’s application of pattern was used in styling and decoration, Garcia (2009) finds: “Today’s spatial design pattern morphologies are mainly digital/parametric or Postmodern reworking of ancient patterns (like waves) or new ones (like DNA)” (pg. 14). Through the emerging visualization of pattern with digital design technologies, pattern can be found in a variety of different areas, knots, networks, fractals, architextiles, micro-organisms and molecular structures. Now, through the unification of math and the arts, the visualization and creation of new digitally-generated patterns are being developed to create the next generation of spatial pattern design.

Pottman (2009) noted that in the vast array of patterns found in the variety of applications in architecture, the future of the recent research is "…motivated by the realization of complex architectural freeform shapes, where patterns arise naturally through the layout of panels and by supporting structures associated with freeform geometry" (p. 61). These new pattern making methodologies and technologies enable the creation of a spatial identity that is an inherent human identifier directly linked to the perception of space. These perceptual identifiers can also be linked to the creation of depth through gradient as discussed by Arnheim (1974), defining gradient as "the gradual increase or decrease of some perpetual quality in space and time." (pg. 275)

Arnheim (1974) believes gradient is most powerfully perceived through geometric and abstract compositions that produce complex gradients through their shape, color, or movement, ultimately resulting in an interesting visual articulation of depth. Depth itself can be created without order, where variations in size represent a movement through space, which can also be articulated through shadow. The two types of shadow, cast, a shadow thrown from one object onto another, and attached, relating to the shape, orientation, and distance from light, also define space in their differences between the vertical and horizontal through "contributing to the size gradients of convergent perspective." (pg. 318)

Surface Design

In the application of pattern to create an identity for space through the perception of surfaces of a wall system, it is important to explore surface design. Taylor (2003) begins his study into surface design by posing philosophical questions that Avrum Stroll discusses in his book *Surfaces*. Questions such as "…if a dice has six contiguous surfaces without gaps or openings, and it also has 12 edges, where are the edges?" and "If a solid glass marble has a chip, is the chip in or on the surface?" (as cited in Taylor, 2003) are posed as examples to philosophical questions of perception of how surfaces are defined and perceived.

According to Taylor (2003), Stroll's discussions describe surfaces as both "abstractions and physical entities" (as cited in Taylor, 2003) drawn from the examination of aspects of geometry, such as limits and boundaries. There are other new projects such as *Cluster* by Martin Böttger (Figure 3*)* and *Frieze* by Ron Arad (Figure 4) that are experimenting with materials and construction techniques that "realize form as surface as a new spatial condition" (pg. 31). These new projects address areas of abstraction and the physical which have a theoretical base rooted in the models suggested by Stroll.

Figure 3. *Cluster* by Martin Böttger

Figure 4. *Frieze* by Ron Arad

Surface itself can be described as the layers that can be pulled back to expose the inner surface of an architectural space, Taylor (2003) suggests (pg. 32). But in Taylor's interpretation of Stroll's text neither "…the outer cladding nor the inner substrate" (pg. 32) is important, the concern is primarily focused on the perception of a space through surfaces. Perception of surface can be seen in many different contexts; one of these areas is Leonardo da Vinci's abstract molecular model, where surface is seen as an interface or abstract entity which creates a distinction between things. Therefore, in terms of the design process used for the creation of a wall system, this scientific conception of surface, seen in da Vinci's model, is important to the treatment of the surface of this system as a boundary of a space.

Visual Perception and Gestalt Psychology

Nordby and Hall (1974) explain Gestalt psychology, developed by German psychologists Wetheimer, Kohler, and Koffka, as a study of perception. As a result of this research, Gestalt was set apart from the characteristic fundamentals of psychology in which the identification of environments is based upon the interpretation of sensory stimulation; instead, the focus is on "natural configurations and patterns that appear in direct experience" (pg. 57). Studies of perception within Gestalt psychology can therefore be directly linked to the examination of one's individual preference, or "ego," and how this effects the individual's specific "behavioral environments" (pg. 60). The ego can be characterized through it’s organization, maintaining an identity within an area that changes based on circumstance. Consequently, the effects of the ego can be seen in the behavioral environments that conflict with ones personal experience, dependent upon physical and geographical environments.

Founding psychologist Koffka (1935) explains that visual elements involve two main factors, what is included with the unit and how the unit is separated from it's surroundings. He states, "Gestalt Psychology claims that it is precisely the original segregation of circumscribed wholes which makes it possible for the sensory world to appear so utterly imbued with meaning..." (pg. 139). As children we are taught the behavior of segregating units, seeing that elements of approximately the same size and color within an environment stand apart as a unit. Although, this instance of visual grouping does not always apply, such as the case of units that consist of different parts; an example of this can be found in the arrangement of stars in the night sky, the Big Dipper and Orion, how some stars seem to belong together. It is when the components of a group are consistent of separate entities that it can be proven that a unit can not only stand alone, but also belong to a greater whole. To humankind, the greater whole is related to physical objects, due to their identification with objects made by man or a product of nature. It is in humans’ natural formation of these entities that the recognition of form and surface develop the ability for recognizable units to be seen.

Another aspect of Gestalt Psychology is the identification and use of a series of principles, grouping smaller units into a larger whole to enable the viewer to develop correlations between different visual cues. In a modern examination of how these laws are used in page formation and layouts, Wong (2010a) studies the basic principles of Gestalt's laws: similarity, proximity, connection and enclosure, visual completion and continuity to illustrate the effects of visual organization. Wong states that grouping is the basic concept behind every Gestalt principle; "we tend to perceive objects that look alike, are placed close together, connected by lines or enclosed in a common space as belonging together." (pg. 863) Therefore, to further exemplify the variances in Gestalt's grouping methods Wong defines each law, beginning with similarity (Figure 5), the organization of units by size, shape and color. Proximity (Figure 6), is a principle that can be closely related to similarity due to the emphasis placed upon spacing. The law of connection and enclosure (Figure 7) use the creation of a whole through their use of association, which Wong associates with the principles used in the layout of information in graphs and diagrams. Lastly, Wong (2010b) discusses the laws of visual completion and continuity, principles of Gestalt that, in terms of composition, can be exemplified through page layout and the formation of figures. Visual completion can be found in illusion created through the use of contours that are seen as non existent; an example of this can be seen in the Kanizsa Triangle (Figure 8). Continuity (Figure 9), the last of the principles of Gestalt, finds the use of shapes to fill voids, where the total of all elements influence the perception of others. The use of this law is found in graphics and text, when placed together, a composition is formed making a single unit of information.

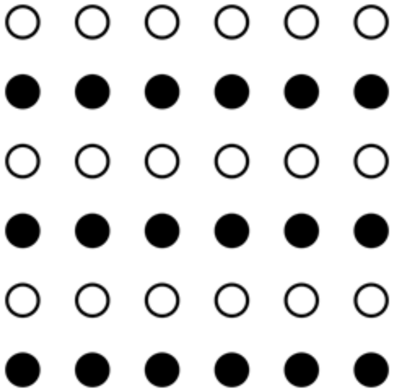

Figure 5. Law of Similarity

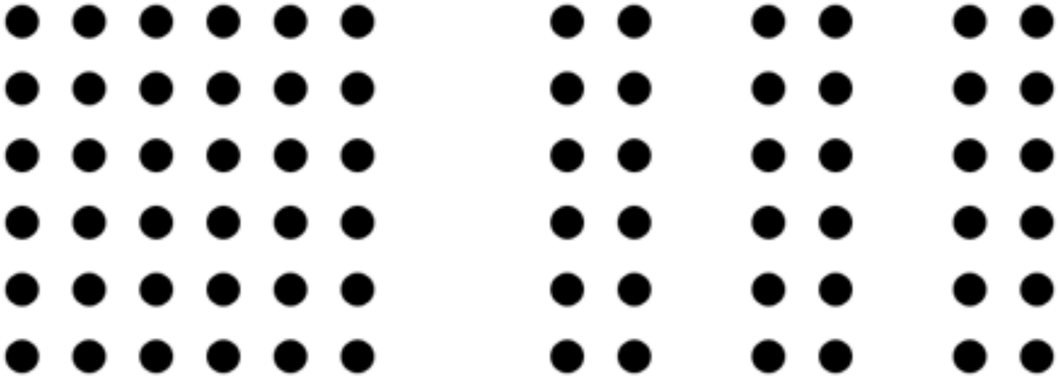

Figure 6. Law of Proximity

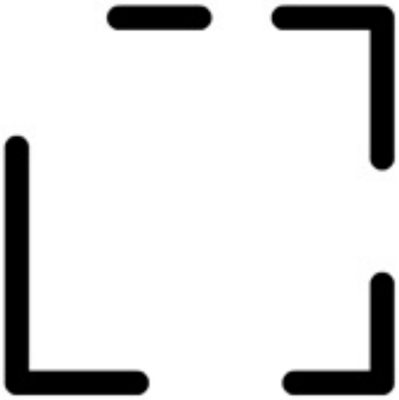

Figure 7. Law of Enclosure

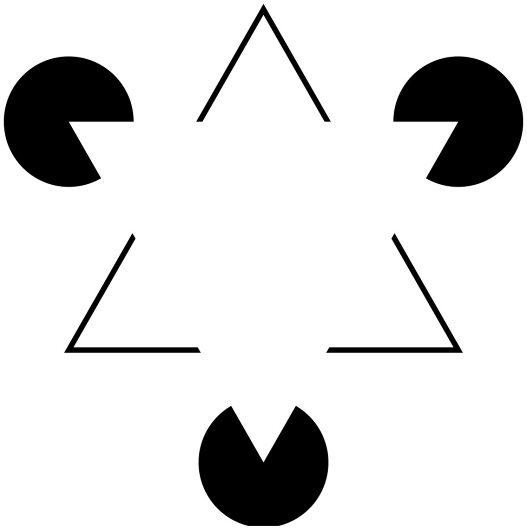

Figure 8. Kanizsa Triangle

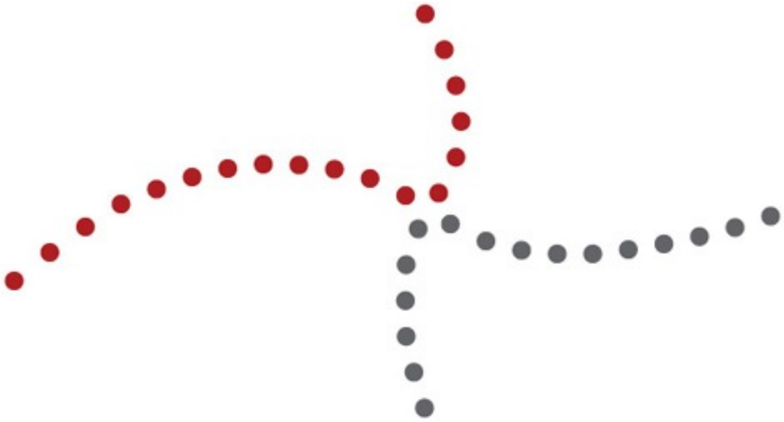

Figure 9. Law of Continuity

Katz (1950) finds that although applications of the traditional Gestalt principles are still in use, as seen in Wong's explanation, there is a problem with the established interpretation of grouping the visual field into units. Katz believes that more emphasis should be placed on another contributing characteristic that shapes visual elements into objects comparable to those seen in ones everyday environment. Humans, whose defining characteristics of the visual are more rigid, can consequently look to nature to provide the commonality to stand out in contour, color, structure, and density. He states: "The characteristics of environmental objects have either been given by nature or have been given by human agency" (pg.23), contradicting the basis of the Gestalt hypothesis that the original appearance of an object will be seen as a unit without the consideration of experience. It is this experiential factor, according to Katz, that is rejected as playing an imperative role where experience influences perception, i.e.

visualizing a group of objects as a unit before having knowledge of what they were like. Although, there is a some acknowledgement of it's role in correlation the laws of Gestalt. As the laws are applied to develop an understanding of the visual composition, it is inherent that interpretations differ from one person to another; one's training can impact how units are perceptually solidified.

In addition to the Gestalt scientific reasoning of perception, Hochberg (1981) added that individual perceptual organization occurs though another method, perceptual constraints, and these consist of three classes of organization: space, shape/form, and movement. Hochberg begins by defining space as the shape, size, and velocity in which change occurs at a distance. Velocity can be attributed as the most significant to the mental structure of an organism, resulting in a single variant of the perception of size and distance. Shape and form can be identified though their classifications of spatial configuration, creating constraints that create perceptual patterns for organization. Lastly, movement, which is constrained by stationary elements, can create perceived pattern in various ways due to movements of the head or eyes.

When applying the perceptual constraints of Hochberg, as well as the organizational laws of Gestalt, the different characteristics of perception become evident. An individual's ability to group units of objects can be based on a variety of different factors, most importantly, visual cues from experience and the surrounding environment. It is these cues that create an identity for spatial elements, providing a personal interaction with aspects of space.

Biomorphic Art and Design

Biomorphic design will be considered as a foundational element for the design of visually interactive wall space. The Tate Collection (n.d.) elaborates biomorphic design: "…biomorphic forms or images are ones that, while abstract, nevertheless refer to, or evoke, living forms such as plants and the human body" ("Tate Glossary: Biomorphic," n.d.). Originally defined for its uses in art by Alfred H. Barr, a curator for MoMa, biomorphisim also expanded into fields of industrial design, as seen in the works of Alvar Aalto. Today, research has expanded into areas of science and environmental psychology to explain how biomorphic forms have parallel uses in both art and science and the effects these forms have on humans.

Biomorphic: Artistic History

Flannery (1998) suggests that the cell, the basic unit of life, has been depicted countless times by biologists, and it's imagery has contributed to advancements in cell biology; but these representations can also be frequently seen in works of twentieth century art. In art of this nature, mostly found in realist, surrealist, and biomorphic forms of the abstract expressionists, the aesthetic aspects of biological form demonstrate traits of elegance, harmony, form, and balance (Figure 10).

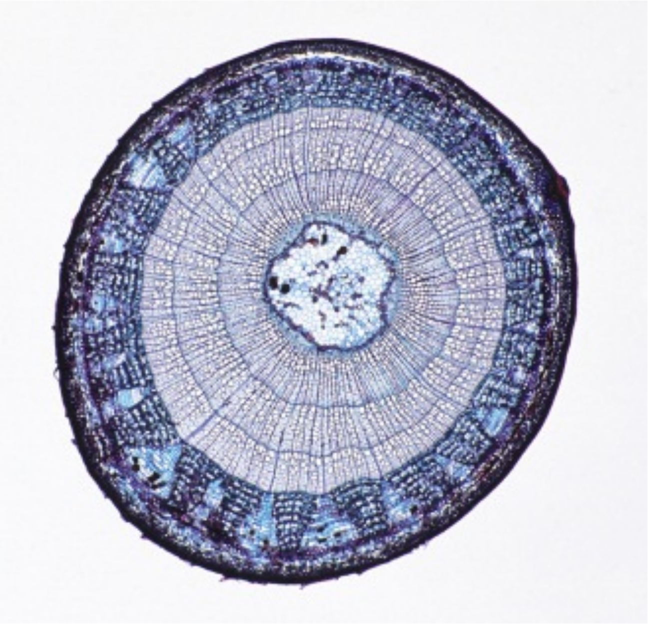

Figure 10. Ed Reschke, *Woody Dicot Stem*

The artistic use of forms found in nature, most recognizable in the post war art and design movements, was described by a language of the free form being applied to all fields of the practice. Surrealism attributed the use of the term *biomorphic* as a design expression, which can be found in Wood's (2007) assessment of its "associations with the subjective, the sensual, the psychological and the unconscious" (pg. 81). This unconscious rationale, helped rationalize for Surrealists a world that found the Modernist era irrelevant. Amid the growing influence of psychoanalysis in the twentieth century Sandler (2009) found that “the surrealists claimed that their exploration of the unconscious…” revealed more of the “truths about human nature than the practice of conscious reason” (pg. 69). Therefore, the surrealist’s use of automatism, the insights found through one’s inner conflicts to portray messages through emotion, became the source of biomorphic imagery providing insight into the human psyche. In turn, this could provide explanations of how the human organic perspective could be considered the antithesis of inhuman design, i.e. could biomorphism be defined as a subconscious impulse instead of an artistic representation derived from natural form?

The Modernist Surrealist movement of the 1930’s can attribute its use of biomorphic form to advent of the microscope; Flannery (1998) noted that the work of Kandinsky and Klee frequently included amoeboid shapes, the “quintessential cellular form” (pg. 200). Although the amoeboid was not the only biomorphic form used by artists of the time, other shapes that appeared included sinuous and spiral forms, which were found in the works of artists Dali, Miro, Arp, and Masson. The Surrealist’s attraction to these biomorphic forms was found through “the applicability of these shapes as symbols of life forces of nature” (pg. 200) and how representations of these forms mimicked technology. The era of abstract expressionism also found uses for the biomorphic form’s symbolism of life processes in various ways, from the representation of human psyche to evolutionary studies. Artists primarily focused on the form’s ability to convey energy and activity. Abstract expressionism also found uses for the biomorphic form symbolizing “the primordial and the universal process of life” (pg. 201). Artists of this style used these forms in a variety of different ways, from diving into the human psyche to studies of evolution. But many of these artists found these forms “as source of energy and used these forms to express dynamism and activity…” (pg. 201).

Overall, the Modernist era produced a new generation of designers that were not predisposed to the Surrealist movement with their use of biomorphism. Instead, Wood (2007) explains that this new type of organic modernism sought to “explore ideas of the emotional and psychological as a means of humanizing the technological” (pg. 82). As new artists began entering the field, biomprohism developed into a new style known as the American Modernism Movement, developing a new form of organic design language (Figure 11).

Figure 11. Dale Chihuly, cadmium Yellow Seaform Set with Red Lip Wraps

Biomorphic: The Human Appeal

Although some artists use biomorphic forms for the aesthetic qualities of their work, the relationship humans have with nature runs more deeply than visual aspects. Joye and Van Locke (2007) suggest that in the field of environmental psychology "humans are innately attracted to *concrete* types of natural environments" (pg. 105-106). They further state that most humans prefer landscapes, such as savannahs, or vegetative elements due to the evolutionary history spent in these settings striving for survival. Evidence that supports this idea of the human preference comes from many sources. Balling and Falk found that children had more of a preference for savannahs than adults possibly due to the innate preferences that diminish as adults (as cited in Joyce and Van Locke, 2007). Another hypothesis, of Heerwagen and Orians, suggests that artists who added savannah-like features to their art work improved over time (as cited in Joye and Van Locke, 2007). In terms of vegetative appeal, humans are able to identify with the differentiation of vegetation, as found in flowers, and protection, provided by trees, to explain the human attraction to these elements.

An investigation into the structural properties of nature reveals that the shape of many natural things is based upon fractal geometry. The presence of fractals, structures that have reoccurring details that reoccur at a variety of scales, in nature can suggest that their occurrence has some relation to the aesthetic responses that are induced. Experiments in the field of fractal aesthetics indicate that it is possible that human's evolutionary history provides an explanation for the appeal of complex environments. Joye and Van Locke (2007) find that visually complex environments stimulate to "…a degree that it keeps the observers interested, and awakes further explorative behaviour" (pg. 107). This explorative behavior is a desired result of the incorporation of biomorphic forms into an environment as described in this study.

There are numerous positive effects that natural elements have on humans, such as mental recall, positive social behavior, psychiatric health and stress reduction. One investigation into the area of stress reduction by Ulrich explains how views of natural scenes for hospital patients induced a better recovery than those who had views of brick walls (as cited in Joye and Van Locke, 2007). The restorative value of natural elements can also be related to fractal geometry. Research into the preferences for environments with a fractal dimension indicates that settings with these aspects have more restorative potential. Joye and Van Locke (2007) imply that “Patterns or environments with a corresponding fractal dimension are therefore likely to evoke more profound restorative responses than patterns with a lower or higher fractal dimension” (pg. 109).

The personal relationship humans share with nature is also discussed by Alexander (2002), where he defines "personal" as universal instead of individual. This universal personal is believed to be an "objective quality which adheres in something" (pg. 300), unlike the present view where the personal is specific to each individual. Therefore, to discuss how natural forms can evoke personal feeling when present in structural features the presences of life must be expressed. Lives, which Alexander states bring about personal feeling, can occur in any spatial system and are outlined through his fifteen examples of life. These examples include: levels of scale, strong centers, boundaries, alternating repetition, positive space, good shape, local symmetries, deep interlock and ambiguity, contrast, gradients, roughness, echoes, the void, simplicity and inner calm, and not-separateness, all of which, when expressed in structural form, can explain which compositions exhibit more life and which have less.

Consequently, the effects of introducing biomorphic aspects into environments can be both beneficial and stimulating to the user. The psychological cues that are introduced into the space through the use of biomorphic forms speak directly to the human user, identifying with ingrained evolutionary preferences. The structural features of biomorphic forms prove to be the most important to the introduction of forms of this nature to a wall system. The explorative behavior that is created will help stimulate interaction with the system that is created through the act of exploring the natural form in space.

Conclusion

In conclusion, the creation of a spatial experience can be defined in a number of ways, but for this study pattern generation is important to the creation of spatial identity. Patterns, used throughout history, provide a foundation for the perception of space through the application of pattern to surface, creating a physical entity that enhances visual interaction. Through exploration of patterned biomorphic forms, visual interaction can be enhanced to create connections between humans and spaces due to the inherent human attraction to elements in nature.

CHAPTER III

METHODOLOGY

The creation of a visually interactive biomorphic wall system consists of three phases: design, construction, and installation, all of which involve a reflection on each area of limitation. In the design phase all participants involved in the design and fabrication process will be identified along with guidelines for the documentation of the reflective process, defining possible outcomes and possible dates and venues for the final installation of the system. During construction and installation, final research outcomes will be outlined: these outcomes include software programs, possible construction materials, and equipment used to reach the final product. Finally, in the post-production phase a reflective evaluation of all of the phases, design, construction, and installation will be documented.

Design Precedents and Technique Informing the Design

Research revealed multiple representations of pattern created through the use of biomorphic design using a series of techniques which were used to inform this study. Iwamoto (2009) states that "Architecture continually informs and is informed by its modes of representation and construction, perhaps never more than ever now, when digital media and emerging technologies are rapidly expanding what we conceive to be formally, spatially, and materially possible" (pg. 4).

Technique: Folding

Folding methods give a flat surface the ability to become three dimensional; this is not only a good technique for the creation of form but also incorporating geometry into a structure. By applying folding techniques to a material rigidity is provided which can allow a material to span a distance or be self-supporting. Iwamoto (2009) believes: "In architecture, folding is theoretical concept, formal tactic, and most literally material operation" (pg. 62).

Figure 12. Chris Bosse: Interior view of Digital Origami installation

Folding: Digital Origami (2007) Case Study. Architect Chris Bosse (2007) found that most of his projects benefited from the wave of digital architecture during and after the mid nineties, with ninety percent of his projects being digital, where years earlier all of his projects were created from hand-drafting on balsa wood. Now, with the second wave of digital advancements, both architects and digital visionaries are able to "conceptualize and build in an entirely different fashion" (pg. 23), enabling them to build things. This and the creation of three dimensional experiences are what the digital master class at the University of Technology in Sydney is learning alongside guest lecturers such as Bosse.

The idea for this class was not to just create the typical rendering, but to actually realize concepts that were being researched including parametric modeling, digital fabrication and material science and their application to a space installation. Bosse (2007) states that:

> The aim was to test the fitness of a particular module, copied from nature, to generate architectural space, with the assumption that the intelligence of the smallest unit dictates the intelligence of the overall system. (pg. 23)

Reef ecosystems were used as a metaphor for how small components that interact with others benefit and grow to create larger environments. And through a reinterpretation of both natural and urban examples of symbiosis, students developed two different shapes that created 3500 cardboard molecules. The installation of the molecules then allowed the students to explore and interpret their own 3D drawing into physical space (Figure 12*)*.

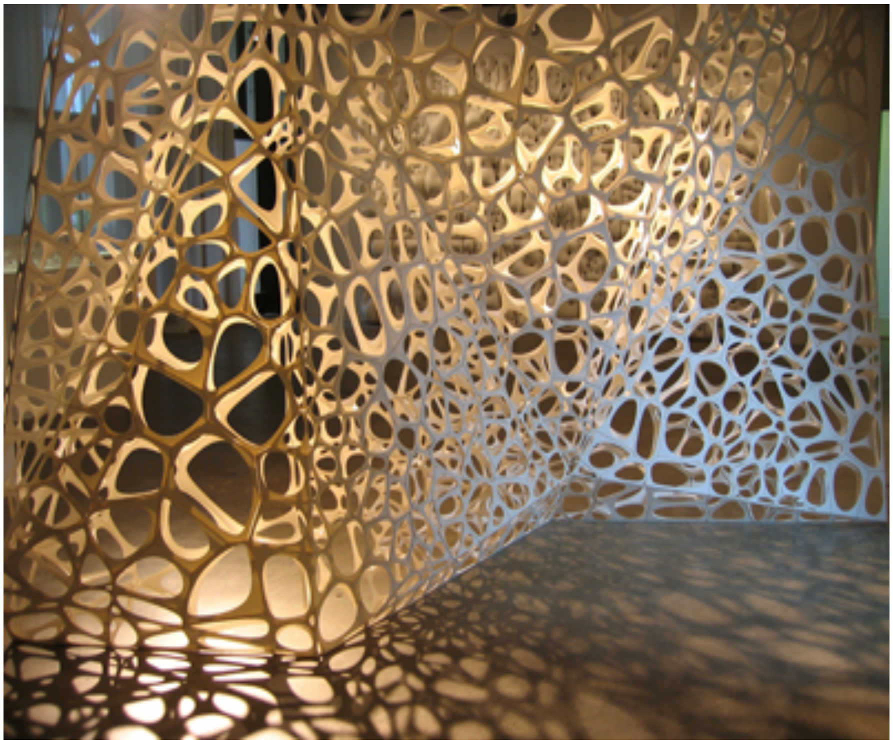

Figure 13. C-Wall side view

***Folding: C-Wall (2006) Case Study*.** Matsys (n.d), a design studio established by Andrew Kudless, architect and assistant professor at the California College of the Arts, that focuses its work around the areas of architecture, engineering, and biology. It's foundation was based on the notion that: "...architecture can be understood as a material body with its own intrinsic and extrinsic forces relating to form and growth..." (Profile section, para. 1). This idea is what fuels the studio's work, ranging from built concepts to the creation of new tools that take a new approach to design and fabrication.

According to Iwamoto (2009) the C-wall (Figure 13), installed in the Banvard Gallery on Ohio State University's School of Architecture in 2006, is a project that uses Kudless's ongoing studies of the voronoi algorithm. In this structure the use of the algorithm, utilized in a variety of fields, was researched for its creation of visually interesting structures. Therefore, the creation of this structure became a tool for the materialization of algorithmic data found through research. The result was the translation of points into cells that were "...unfolded, CNC cut, and reassembled into larger aggregates." (pg. 84)

Design

The initial design phase of the wall system involved research into biomorphic structures such as patterns that are based on abstract forms found in nature, specifically barnacle formations. This study of natural forms began with a visual investigation of images in Adobe Illustrator, where the exterior outline of a growth pattern of barnacles was traced in order to break the images down into their most basic geometric form (Figure 14). Once the graphic geometric breakdown of the images was created, a comparison was drawn between the vector image of the barnacle formation and the Voronoi diagram, seen in a previous study of natural forms. Vornoni diagrams, specific decomposition of space created through mathematical algorithms, have appeared throughout various areas of the natural and social sciences since the mid 1800's. Okabe, Boots, and Sugihara (1992), found that in two of the first studies of this concept, Dirichlet and Verona were mainly concerned with "the distribution of points with integer coordinates that give a minima of the values of a given quadric form." (pg. 6) Their studies resulted in the adaptation of two different labels: the Voronoi diagram and the Dirichlet tessellation. The first uses of the diagram concept were applied in the field of crystallography in the late 19th and early 20th centuries, while at the same time it was also being applied in the spatial interpolation and meteorology.

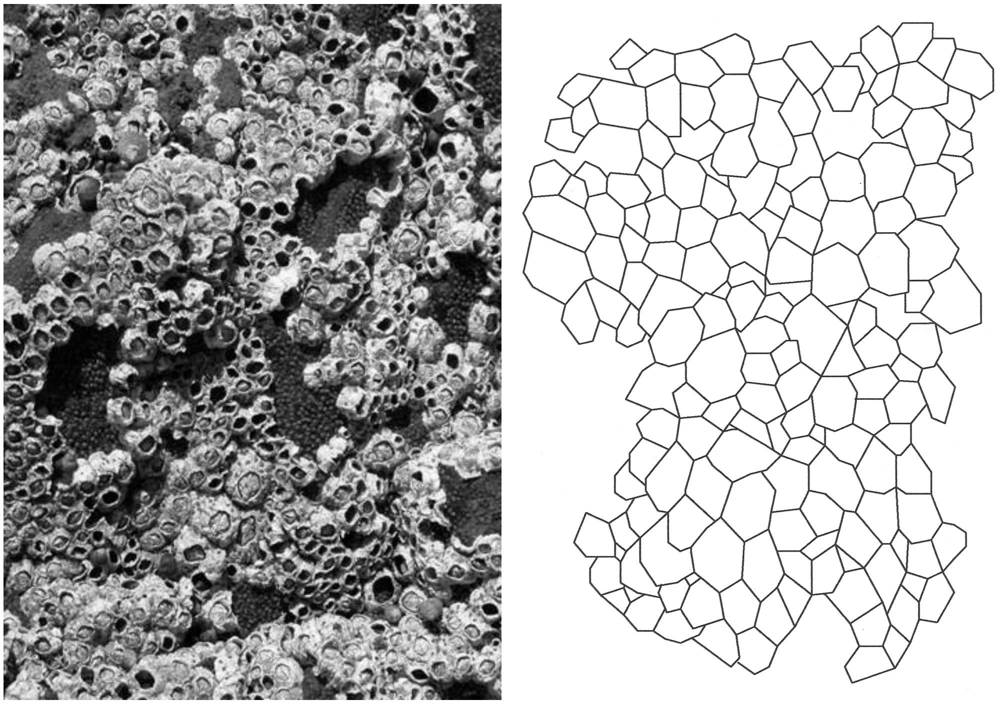

Figure 14. Barnacle Formation and Geometric Trace

Through its identification and exploration, the Voronoi diagram was determined as the best way to approach the basis of this design, and with the use of the website "JavaScript Implementation of Steven J. Fortune's Algorithm to Compute Vornoni Diagrams" a personalized diagram for the design was created. This website uses a blank canvas where *sites*, simple points upon which a mathematical formula is attached to create its corresponding *pod*, can be placed to generate a different diagram after each *site* is added. Once the prototypical diagram was formed through the individual placement of each *site*, an animation of the sweep line was created (Figure 15). This animation was then filmed to show the process of the generation of each pod used in the make up of the diagram. The diagram was then copied as a jpeg image and uploaded into Rhino for the 3D modeling phase of the design.

Figure 15. Animation of Voronoi generation with sweep line

3D Modeling

Finding a location for the design was the first determinate in the 3D modeling of the design. Initally an 8’ x 24’ wall in 401 Gatewood was selected as the site for the installation. So, using Rhino 3D Modeling software, the digitally created jpeg image of the Vornoni diagram was imported and the lines were traced to create a 2D vector drawing of the diagram, at the scale of the specified wall, including a point representing each generator, or *seed.* Each *seed,* provides a specific point in each *pod* and was used to draw a line of height eight inches tall where all edges of each *pod* could converge. At these central points, triangular surfaces were created forming a series of pyramid structures covering the Voronoi diagram.

To create the depth of each *pod* the height of five and a half inches was chosen so that they would be deep enough to store items within them, but not to obstruct walking space around the wall. The outcome of this modeling resulted in a flat 8’ x 24’ wall covered in Voronoi barnacles, where the original base diagram formed a rectangular surface. However, two issues with this formation were posed after consulting with my committee: the fact that the natural formations of barnacles do not form straight lines, and how I would address the *pod* development once it reached a corner. Consequently, these issues called for a change in location for the installation and also a redesign of the original flat Voronoi diagram.

A freestanding partition wall, donated to the Interior Architecture Department at UNCG, measuring 48” x 18” x 96“, was suggested as an alternative for the installation. This wall allowed for viewers to walk around the installation and also gave me the opportunity to address how a *pod* would look when it reached a corner, resulting in the refitting of the original Voronoi diagram. Even though the diagram had to be changed to wrap around the wall, it worked well with the new dimensions of the partition wall considering that the height of the wall and the height of the original diagram were the same. Therefore, when the 3D model of the partition was created in Rhino, the top corner of the Voronoi vector diagram was matched up with the top corner of the digital partition wall and this matchup enabled the wrap of the flat vector image around the entire wall.

With the vector image of the diagram wrapped around the wall partition, the *seed* locations were once again used to create eight inch tall height lines to where all of the edges could converge, creating again a series of pyramids covering the wall. Although, the pods that wrapped around corners had to be addressed differently, in some cases the *seed* point was at a point on the wall where the points could not converge to form a surface without being obstructed by the wall. In this case, I measured from the farthest corner to the wall edge, where the *seed* was not located on the same plane, and moved the location of the *seed* towards the section that wrapped around that distance. This movement, along with a slight degree of rotation of the eight inch height line, allowed a surface to be created without obstruction of the wall corner converging into a pyramid shape.

Again, a five inch line of height was drawn, but this time lines were drawn around the base, angled at the corners, and the lines extruded as a surface the height of the wall. These surfaces enabled the openings in the pods to be created by trimming the points that extended beyond the surface, leaving the pod behind once the trimming surface was removed.

Model Fabrication

To test the appearance of the barnacle forms a box was chosen and its pieces printed on printer paper from my home computer. Since this paper was not sturdy enough to hold its form, the cut-outs were used as templates to trace the forms onto Bristol board and 2ply chipboard to test each material’s sturdiness (Figure 16). With basic Elmer’s Glue, each piece was glued together to create a small version of a barnacle box, but in order to be more efficient in the fabrication process, a faster and more precise way to create each box was needed, and this is where the use of the laser cutter became useful.

Figure 16. 2ply chipboard printer models

Using the laser cutter and 2ply chipboard I was able to construct three different sizes of one specific *pod* from the diagram for modeling, and it was during these beginning stages is where I ran into some early limitations of fabrication. I decided that individually cutting each box piece could be averted by digitally *unfolding* each box and having the laser cut each exterior piece attached to its base.   This method did not allow the edges of each corner to meet, since folding the chipboard would not provide a sharp edge at the base as to give the exterior edges enough material to connect at each side. Therefore, each individual piece needed to be cut out, both base and side pieces, which also created the need for all of the pieces to be numbered so that each piece could be collected and assembled with the corresponding numbers (Figure 17). This numbering process also proved helpful in the placement of the boxes, since each *pod* has a specific placement in the wall installation.

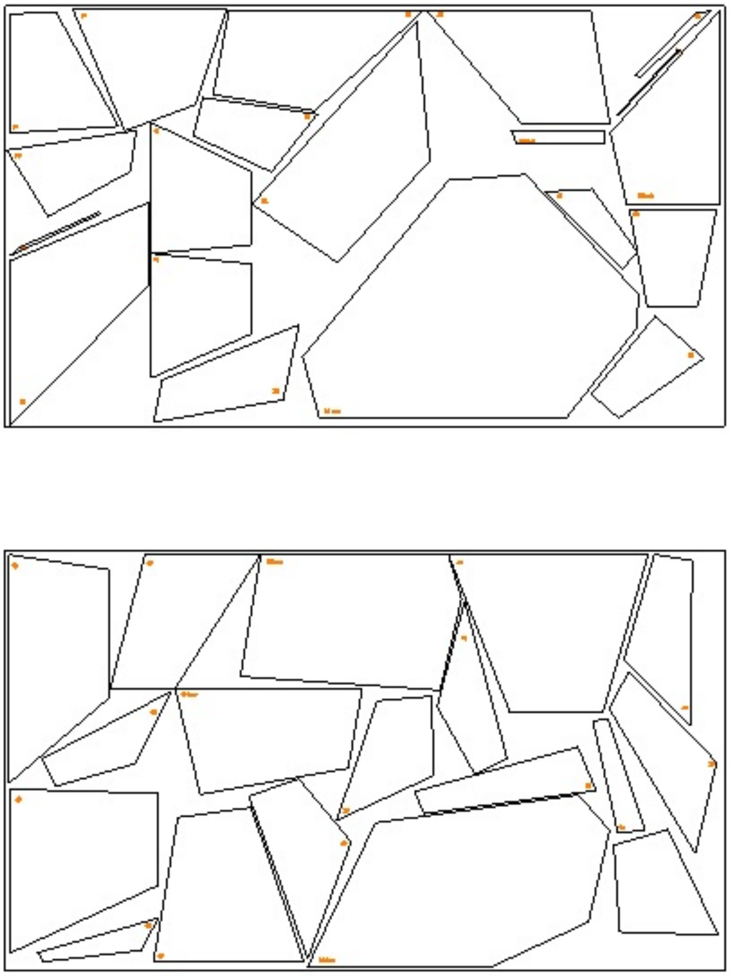

Figure 17. Individual *pod* piece cutouts

Attaching each of the pieces to the base also became a challenge using my first attachment method, glue. The issue of the sharpness of the edges, as well as how the edges fit onto the base, was resolved through taping all of the exterior pieces of each *pod* to its matching base while all the pieces were laying flat using paper box tape, whose color closely resembled and complemented the chipboard. This technique created a type of "live hinge" where the exterior pieces of the *pod* were able to fold inward, from the edges of the base, allowing each of the exterior pieces to touch so they could also be taped together, forming each barnacle box. Additionally, the interior base-to-exterior taping provided a reinforced edge, allowing the edges and base to be taped together both internally and externally.

Model Material Covering Testing

Later, with the use of my models I was able to test a few ideas for external coating and strengthening. With some research I decided on four different techniques to test in order to get a smooth exterior surface. These four methods included a resin and fiberglass cloth application, Bondo, vinyl contact paper, and resin gelkote, all of which were tested on actual, full-scale models constructed with 2ply chipboard.

Resin and Fiberglass Cloth

One fabrication method used was suggested by my thesis chair after discussing the forming and reinforcement of surfboards, fiberglass cloth coated in resin. In the surfboard process the foam form of the board is covered in fiberglass cloth and resin is then applied and smoothed over the cloth, reinforcing the board underneath. Reproducing this process for the reinforcement of my models, I enlisted the use of *YouTube* videos for tutorials showing how to resin and fiberglass surfboards. With multiple visual references, I was better equipped on how to approach applying the fiberglass and resin to the model.

Fiberglass cloth first needed to be cut to form around the chipboard *pod*, so laying the cloth flat on the floor and placing the *pod* on top of it, the cloth was cut so it would create a single sheet that wrapped flat on the bottom and around each side (Figure 18). Once the fiberglass was cut and formed around the model, the resin and hardener were mixed together creating a honey textured liquid (Figure 19). I began with applying the resin mixture to the bottom of the box, since the resin application smoothed out the fiberglass to create more room for the sides, brushing the resin onto the cloth with a small paintbrush. Moving to the bottom and around the sides, the resin was brushed on until the entire model was covered in resin (Figure 20), and with this amount of resin being used the model needed over two hours of dry time before it could be sanded for painting.

This resin coating method encountered a few limitations throughout the process, most of them found in the resin application. First, when applying the resin to the bottom of the model, the fiberglass cloth would slide on the chipboard, keeping the cloth cutout from aligning with the sides. This alignment issue also contributed to getting the corners of the cloth to lay down smoothly when the resin was brushed onto the outside edge, producing air pockets around corners and interior edge. These issues, along with the overall complexity and skill needed to work with resin and fiberglass, raised the questions: How else the *pods* could be reinforced? Do they need to be reinforced or could they be made from another material?

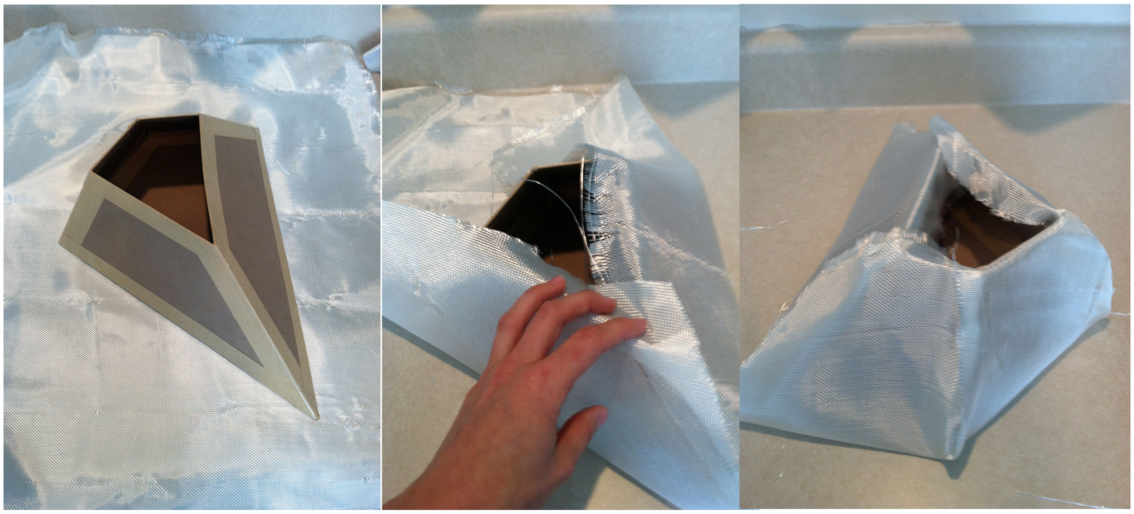

Figure 18. Fiberglass cloth wrapping

Figure 19. Resin Mixture

Figure 20. Fiberglass and Resin Application

Bondo

Bondo was another method chosen for the covering and reinforcement of the *pods*. Preparing for the use of Bondo, found at a local auto parts store, was similar to resin preparation. Deciphering this accurate mixture of paste and catalyst became my first challenge using this method, but through many attempts I discovered that the Bondo developed a pinkish tint once the correct amount was mixed together.

Figure 21. Bondo Mixing

To apply the Bondo paste mixture to the chipboard, a small plastic handheld spreading applicator was provided although this only allowed for small amounts to be applied at a time. This small applicator also did not permit you to smooth large areas once the Bondo was applied to the entire surface. As a result, a larger putty knife was needed to smooth the surfaces of the model when the Bondo was applied (Figure 22). Subsequently, the larger knife could smooth the entire surface in one sweep over the surface instead of smaller areas like with the plastic applicator. Using this smoothing process also kept the edges of the applicator from creating ridges on the putty surface, which aided in the sanding of the dried surface.

After the Bondo was completely dried, all of the surfaces needed to be sanded to smooth down any imperfections. To begin sanding I needed to make sure that I was in a ventilated room and also had a respiratory mask on to prevent the inhalation of any of the dust created from the sanding process. During the sanding process I used two different methods of sanding, hand sanding and a handheld power sander, using medium grit sandpaper (Figure 23). However, using both of these sanding processes made it difficult to get the surfaces of the Bondo completely smooth; divots and lines could still be seen on the surface. Consequently, the application and sanding process needed to be repeated to get the surfaces of the model completed.

Figure 22. Bondo Application

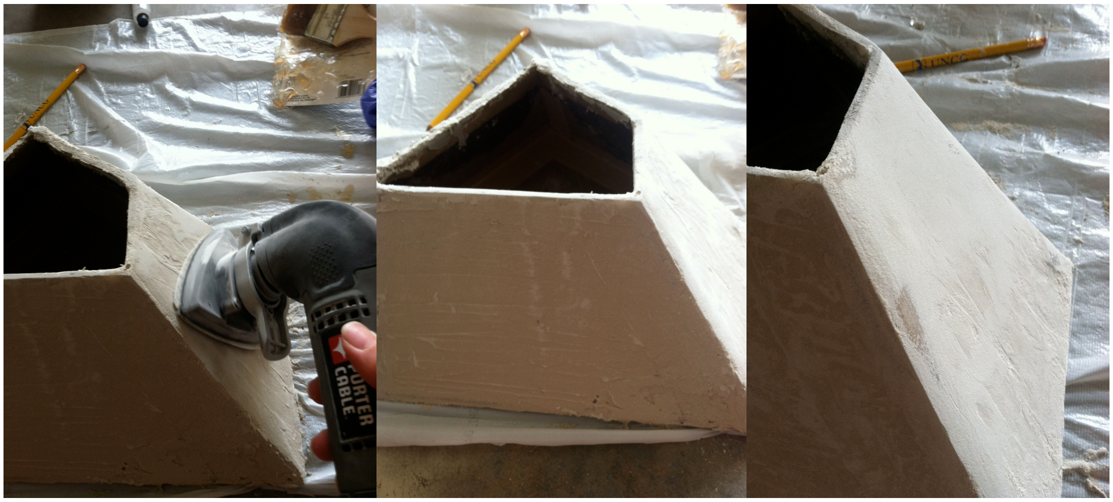

Figure 23. Bondo Sanding Results

Vinyl Contact Paper

Vinyl contact paper was an applied method used to smooth the interior and exterior surface while also giving a uniform color to the boxes surfaces. Contact paper is typically used for shelf covering, so it easily cut and removed from surfaces, providing a washable and replaceable surface.

To begin, all of the pieces of one box, used for modeling, were matched to the base and laid flat with the interior of the box facing up (Figure 24). A square piece of the contact paper was cut to the size of the box and the adhesive covering exposed (Figure 25 and Figure 25). Once the contact paper was adhered to the flat box it was smoothed over to remove any air pockets, leaving a flat surface for the interior. With the shape of the unfolded box exposed from underneath the contact paper (Figure 26), it could then be trimmed around the exterior edge of the shape creating a cutout that was already adhered to the interior of the box (Figure 27). After trimming the exterior edge of the shape, the connection between the sides and the base create a hinge between the base and its corresponding side. This hinge allowed for the edges to be folded inward producing a three-dimensional box form with a white coated interior.

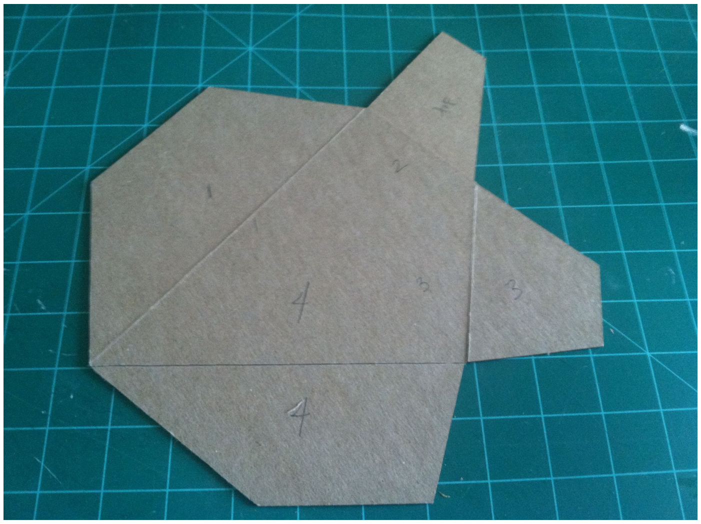

Figure 24. Unfolded flat box

Figure 25. Contact Paper Cutting and Application

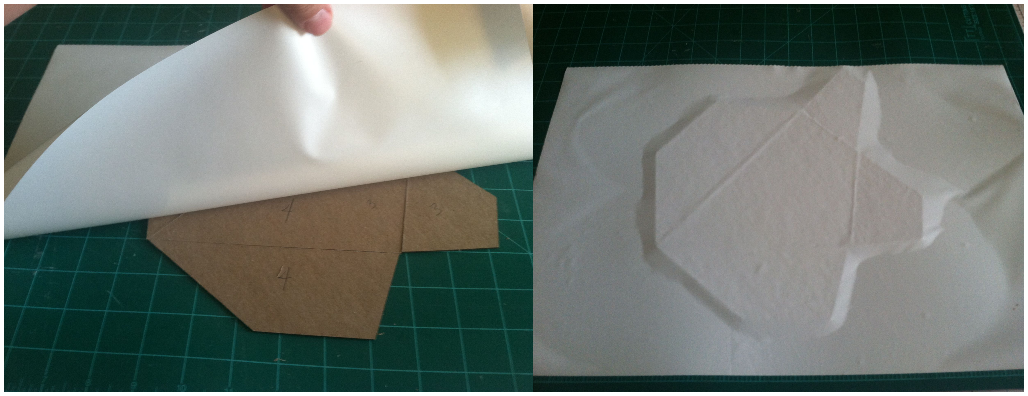

Figure 26. Contact Paper Adhering

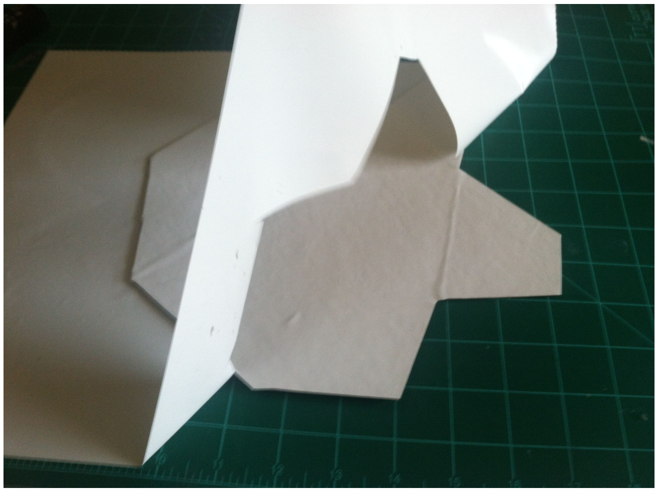

Figure 27. Trimming of Excess Contact Paper

To cover the exterior of the box a slightly different approach was needed; another piece of contact paper was applied to the base of the folded box, and each side was laid flat on the adhesive surface. When the pieces were unfolded, an angled line was cut from the center of two edges (Figure 28), making a flap that adhered one exterior piece to another keeping the box formed three-dimensionally. These flaps were hidden when the box was folded back together by being placed underneath the contact paper covering another exterior side (Figure 29). Therefore, when the process was competed and the box is folded together, a smooth white vinyl coated barnacle was created.

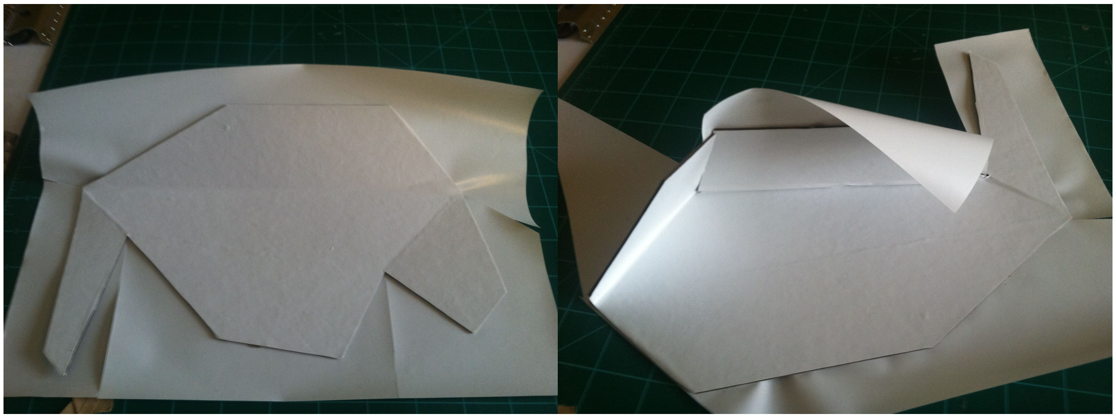

Figure 28. Exterior Application of Contact Paper

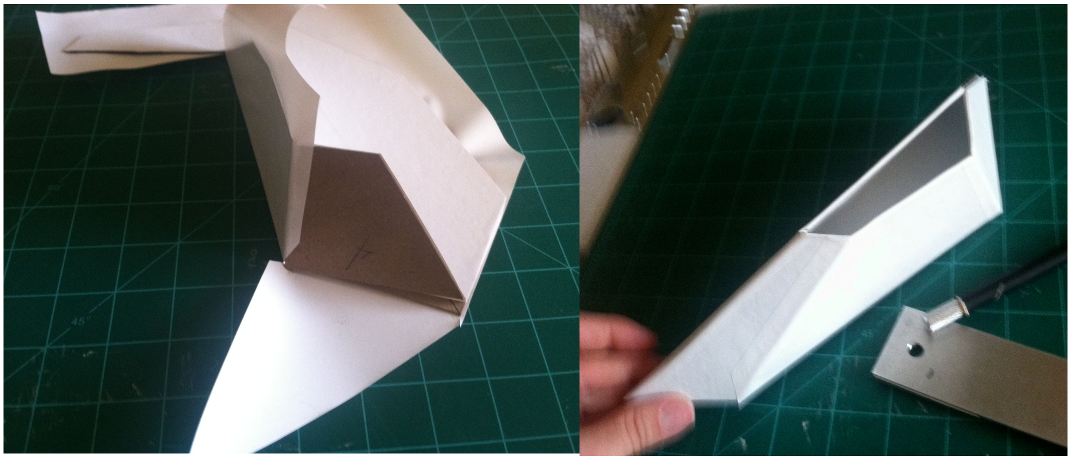

Figure 29. Exterior Flaps and Completed Covering

Resin Gelkote

Gelkote, a polyester resin, is a coating material that is typically used for the repair of scratches and scrapes in fiberglass surfaces. Unlike the use of standard resin, which cannot be used as a coating due to its ingredients and stand alone strength, gelkote does not need to be used along with a reinforcement material like a fiberglass cloth. The gelkote resin can be applied solely to any material using two different methods, spray or brush, to create a gloss finish that can be polished to a shine with wax.

Gelkote preparation is similar to resin; the correct amount of hardener needs to be mixed with the base for the gelkote application to dry. Unlike resin, the mixture can be applied by brush or spray gun, but for a sprayer application the gelkote mixture needs an additional mixture, acetone. The acetone additive thins the consistency of the gelkote so that it could be pushed through the spray gun.

For this testing process both methods, painting and spraying, were used to distinguish what application technique provided the best final appearance. First, the gelkote was applied through a compressor powered sprayer, and the mixture of acetone, hardener, and gelkote were added to the paint reservoir to be applied to the chipboard surface. To apply the mixture, the sprayer was held from six to ten inches away from the surface to prevent excess buildup from creating drips on the surface (Figure 30). An even application was sprayed over the interior and exterior of the pod giving the chipboard a consistent white glossy finish (Figure 31). Secondly, I used another mixture of only hardener and gelkote to be brushed onto the surface of another chipboard model. Brushing the gelkote onto the surfaces did not produce the same smooth appearance as the spray application; the brush bristles disrupted the surface making faint ridges. The use of the brush also was difficult since the gelkote would set up in the brush, making the bristles stiff and rigid, contributing to producing the surface ridges. This experimentation with application techniques led to the conclusion that the spray application was the best approach to get an easily applied, consistent look on all of the surfaces.

The main limitation encountered using the gelkote was the viscosity of the base, resulting in the clogging of the sprayer. Since the gelkote is generally sticky and sets up quickly, even with the thinner, it is difficult to remove from contact surfaces, skin, and even the sprayer without the use of acetone. After one coating of gelkote with the spray gun, the gun began to clog due to set up within the gun. To resolve the problem, the paint reservoir was removed and parts of the gun taken apart so the components could be soaked in acetone. A small coiled brush was also soaked in acetone and brushed through the internal pieces to attempt to break down any gelkote that had adhered. Many attempts and countless hours were spent brushing and soaking the gun in acetone to try and remove the gelkote with no result. Once the gelkote had set up inside the sprayer it could not be removed making the spray gun inoperable.

Figure 30. Gelkote Application

Figure 31. Completed Gelkote Model

Final Assembly

For the final assembly of the pods for installation, the unfolded pods were laser cut at the TechShop in Raleigh, North Carolina. The shop is a membership based workshop that provides access to equipment after a training class is taken on the specific equipment of interest. For the use of the laser, a class on laser safety and basic use was required before I was able to schedule daily two hour time intervals for the laser printer. Each piece had to be arranged on a piece of 2ply chipboard measuring 24"x18", the size of the TechShop's laser bed.

Once all the pieces were cut and collected, which required over ten trips to the shop, they needed to be separated by their numbers to be placed together accurately. Each coordinating number was separated into its own stack (Figure 32), creating over ninety pod groups that needed to be kept from being mixed together so they could be moved to a flat workstation for assembly. Every group was stacked together with paper separating each group, this allowed for over ten groups to be stacked together at one time without mixing.

Figure 32. Separating *Pod* Pieces

Assembly began with the base piece lying flat with the interior of the box facing upward, exposing the pod number. All of the exterior pieces were then placed at their correct spot around the base, also with their numbers facing upward, and box tape was used to tape around all the edges, connecting the base to the exterior side pieces

(Figure 33). This taping method created a hinge between the base and sides, so when then pod was turned over the exterior pieces fell to the middle, creating the 3D pod form.

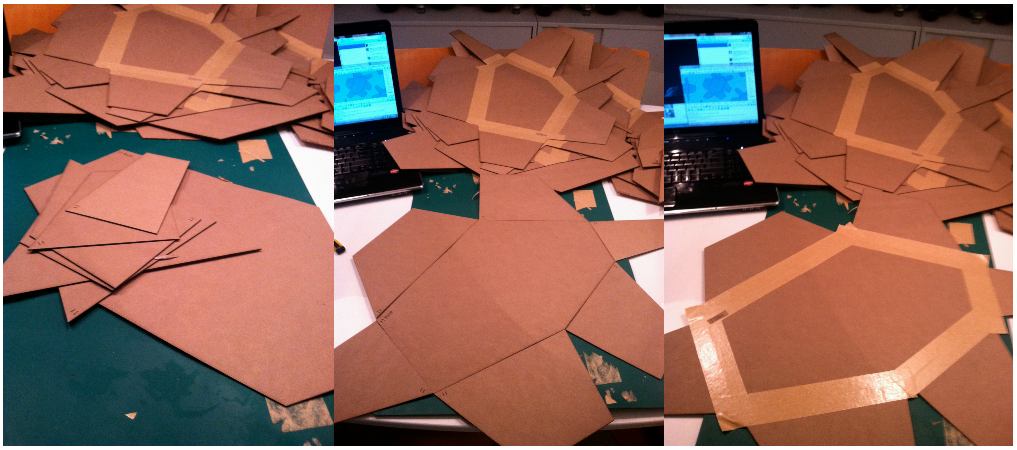

Figure 33. *Pod* Base Assembly

The three dimensional form then needed to be taped externally to close the pieces of the pod and reinforce the base edges. The box tape was applied to each edge by placing the center of the tape where the two pieces of every exterior edge met at a point. This, for the most part, kept the tape equal on both sides of each exterior edge. The reinforcement of the base also used this same method, placing the center of the tape where the base and sides met and wrapping the tape around the base and exterior side.

Originally, when the pods were taped together a wallpaper cut was used, making each taped edge appear to gap at the corners and leaving the connection point weak. To solve these problems and give the tape a more polished look, on each edge one side of the tape was cut to mirror the corner, and the other was wrapped around the edge. When repeating this process around the base, it created an edge where the side folded over, reinforcing the edge, hidden by the polished the appearance of the straight edge of the other side.

After taping all the pods together, my committee suggested that the interior edge needed to be thickened to create the illusion of thickness throughout the entire box. One way to approach this, without having to reprint all of the pods on thicker paper, was to cut three strips of chipboard, stack them together, and tape them to the interior edge. This method of thickening the edges had a few limitations: cutting the pieces was very time consuming, trimming the pieces to the accurate size was difficult and once taped to the interior edge it did not create a flat edge. Therefore, to fix this problem I chose to use another material that would be the same thickness as three pieces of 2ply chipboard while also making a flat surface edge, foam board.

From a sheet of three sixteenths thick foam board, half inch strips were cut to thicken the edges of the interior (Figure 34). One strip was taken and measured to be cut by placing one end of the strip against an interior corner and making a mark where the other end touched the opposite corner. After the foam was cut to size for each interior edge, it was taped to the edge by placing the strip on the interior edge and taping it to the exterior box (Figure 35). The taping technique did not tape the base of the strip to the interior of the box, leaving the strip unsecured with an unpolished interior tape edge. So, to secure the foam strip after it was attached to the exterior edge, another piece of tape was applied to the interior of the *pod* by aligning the top edge of the tape with the interior edge of the foam. When applied, it secured the foam to the *pod* and also improved the appearance of the taped interior edges of the *pod*.

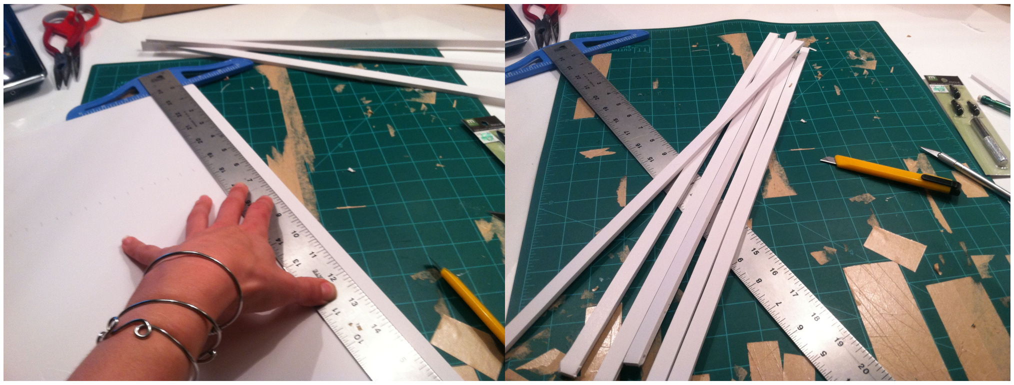

Figure 34. Foam Board Strips for Thickening

Figure 35. Foam Board Thickening

Installation

Preparation for the installation began with cutting of one inch strips of mounting tape, 3M 4658F double-sided removable foam tape, and the separation of all of the individual pods into groups based on their corresponding numbers. The numbered grouping of the pods allowed for numbers to be found quickly while reading their location from a numbered 3D generated map (Figure 36) created during the modeling process. The installation started with the placement of each pod on the front plane of the wall in a sporadic fashion to simulate a growth pattern when a photograph was then taken of each individual pod's placement. This method proved to be problematic due to the need to have the pods aligned with the edge; the sporadic placement developed a slight shift, creating an offset of the overall grouping. To address this problem, the pods taped to the wall had to be removed and reinstalled along the front edge first.

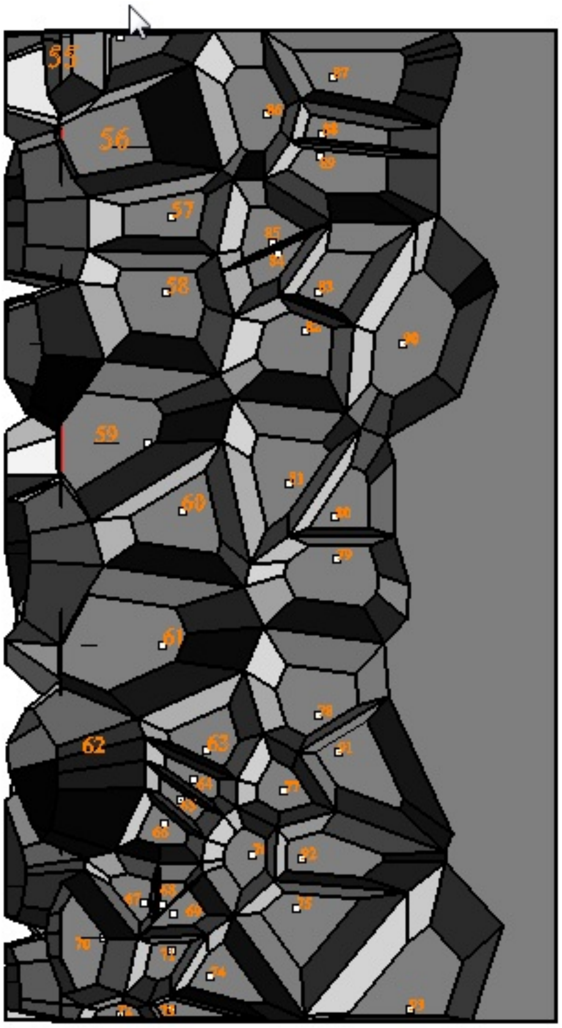

Figure 36. *Pod* placement map with numbers

The installation of the pods filled the front side of the partition wall, but once the first corner was reached another problem was encountered. It became apparent that the measurements of the wall were incorrect when a gap was detected between the wall and the back of each corner pod, prohibiting them from sitting flush with the wall. This incorrect measurement also created an issue with the pods to be attached to the side of the partition; the edges of the side and corner pieces did not touch, and a one inch gap separated the edges. Therefore, new measurements of the partition wall were needed to remodel for laser cutting new corner and side pieces to correct the gaps.

In Rhino, the wall measurements were adjusted so that the existing pods placed on the front and back of the wall partition were not affected. The length of the wall was scaled up to the correct measurement to address the gaps at the corners, resulting in the adjustment of the spacing created between the side and corner pieces. Once the pods were digitally formed, they were unfolded to a flat surface to be laser cut, numbered, and taped; following the original method the pods were produced. These corrected pods could then replace the existing corner and side pieces and were therefore separated along with the other pods based on their corresponding numbers.

Beginning the installation process again, the partition wall, with the front pods attached, needed to be moved for exhibition purposes, uncovering the need to address the pods attachment to the wall. During the move, the larger pods appeared to be attached securely to the wall due to the amount of tape used but the smaller pods became detached easily, falling off even when there was no movement in the wall. Consequently, all of the attached pods and the tape remaining on the wall was removed to consider other attachment methods.

Securing the pods to the wall with drywall screws became the method chosen, providing quick and permanent attachment of all the pods and the ability to easily remove them for readjustment. For the rest of the installation this attachment method was followed along all the sides of the wall, using two screws for larger boxes and screwing through the back of the wall into the pod for the smaller, since the extended drill bit would not fit in the front opening. The completion of the installation of all the pods created the *Varnacle Wall* (Figure 37), a biomorphic inspired design created through the use of the Voronoi Diagram.

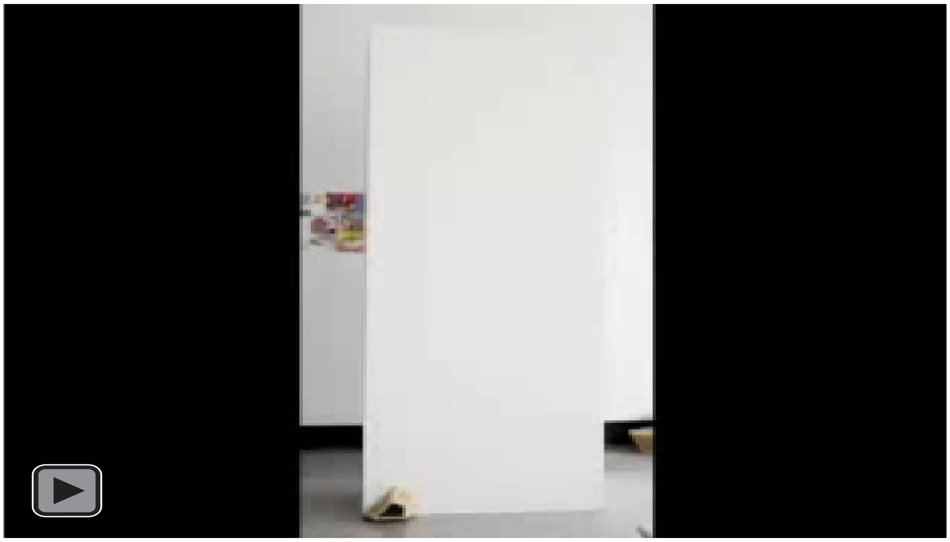

Figure 37. Video of individual *pod* placement

CHAPTER IV

CONCLUSION

In conclusion, I have uncovered aspects of this project that raise additional questions in order to further the development of the installation, beginning with the utilization of other fabrication methods. The availability of molding processes, primarily injection and blow molding, used for the development of a range of products, from bottles to musical instruments, provides an alternative method for the pod creation. Although individual molds of each pod are required, a time consuming process, the entire pod could be cast from one solid mold, instead of separate pieces to be fused together. The use of injection and blow molding methods can also address the edges and strength of the pods. Since molding enables the pod to be made entirely of one material, the edges would be sealed. Sealing each edge would add strength while also providing the ability for the pods to contain liquid or weighty objects without collapsing. While molding results in a whole pod piece with sealed edges, it also can create crisp or smoothed edges that could not be achieved though the use of taped edges.

Determining scale and location is also an important aspect of this installation; different spaces require the consideration of viewing distance for the effectiveness of the design. The vast space chosen for this installation required large scale development of pods to create the composition in order to have an overall effect on visual spatial perception. Smaller scale productions would have not had the same impact.

Lastly, other expressions of this installation can be explored, like those seen in the fabric tufting and acrylic progression displayed in my exhibition. Large scale implementations of these methods can be executed in other installations. The inherent geometry in all natural elements leads me to believe that there are countless other applications of biomorphic form to be explored. Further development, of fabrication techniques, scale variations, and strategies of location-provide~~s~~ endless inspiration for other ways the Varnacle installation can implemented (Figure 38 and Figure 39).

Figure 38. *Varnacle Wall*, Installation 2013

Figure 39. *Varnacle Wall*, Exhibition Video

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IMAGE RESOURCES

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Figure 2. Interior (2) of the Digital Pavilion Korea
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