Transformable Space Base on Human Body Movement

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Table of Contents

Abstract

Due to the increase in urban population and the rising cost of providing housing, the size and quality of dwelling space in the city has become an issue. Asian cities like Hong Kong and Tokyo have already shrunk the normal living space to accommodate more units in a development. Taipei, Singapore, and Shanghai are also evolving toward the same solution. This dissertation argues that there are alternative ways to design and reshape our dwelling space to create an efficient space based on human body movement and at the same time retain spatial quality[1]. Dance can be seen as creating extreme body movements compared to our daily movement, so the hypothesis of this dissertation is that if a space can accommodate dance movement, then most likely it will be a comfortable space for daily movement.

The study begins with a historical research of space, including the concept of space, human use of space, and body movement in the space. Rudolf Laban's theory of dance movement is one of the main ideas investigated and reinterpreted for the research and design dissertation. To understand the human daily movement, data gathering is key to the thesis. The subjects of study are from both dance body movement and daily body movement. A videotaping process is used to record these movements. During the data collecting process, both two dimensional and four dimensional methods[2] are used. The first phase records the body movements and translates these into two dimensional images. These images are simulated into three dimensional representations.

In the design phase, computer models are made with *Rhinoceros*, *Maya*, *3D Studio Max*, and *MotionBuilder* to simulate the new space prototype and body movements based on the analyzed information to create more efficient spaces that also provide a better quality living environment.

1 For the purpose of this study, spatial quality is defined as visual experience, lighting quality, and ventilation quality.

2 Four dimensional is a combination of three dimension and the time factor, can also be called 3D animation.

Introduction

What is architecture?

Throughout six years of academic education in architecture, many people have asked the question: what is architecture? My understanding of architecture is a combination of art and structure.

art + structure = architecture

There is a difference between "building" and "architecture". A building without an aesthetic design is still a building, but it is not considered architecture. There is always a discussion about form follows function or function follows form. Form is usually the shape or the visual appearance of the building and function is mostly associated with human activity or the program of the project. Function following form design corresponds to Frank Gehry's work with crazy forms. Form follows function design usually ends up being box-like which is how most buildings look in today's world. In this type only after the external shapes are designed will architects then start fitting users into the picture.

This dissertation argues that since architecture is design for human use, why not put the body into the picture first and design everything around the human. We do not move "box like" and we can only reach so far in a space, so why do we create spaces that do not fit our needs? One of the reasons that architects do not design this way is because there is not enough information on how people move and use the space. Simple human dimensions have been the primary data for architects. The study of human movement can become a new focus to design more completely for humans.

> *"Yet it is curious that most of the concern with functionalism has been focused upon form rather than function. It is as if the structure itself – harmony with the site, the integrity of the materials, the cohesiveness of the separate units, has become the function. Relatively little emphasis is placed on the activities taking place inside the structure...Architecture may be beautiful, but it should be more than that; it must enclose space in which certain activities can take place comfortably and efficiently."*[3]
>
> - *Robert Sommer*

Living space

Home is a concept, it is a psychological space. When

3 Robert Sommer, *Personal space; the behavioral basis of design*, A Spectrum book; (Englewood Cliffs: N.J., Prentice-Hall, 1969). 3,4.

we say *to go home* it means to a space that allows us to forget about the outside world, to relax and rest. Some people have added a layer of *family* to the concept of home. In general, physical space of home is called dwelling or living space. Depending on the size of the living space and the number of users, the ways of using the space of the home can be very different.

Due to the increase of population, size of living space has become an issue. Cities like Hong Kong and Tokyo have already shrunk the normal living spaces to accommodate more living units on increasingly expensive urban land. As the population increases, more and more cities will face the same issue. These small spaces are not usually pleasant to the users, so this dissertation argues that there are ways to design to give quality to small living spaces. Human body movement will be studied first and the results of this research will provide an approach to improve space design.

Our living style has been transformed from family-oriented to social-oriented, especially for single people. We have more choice of food, more entertainment services, so people are tending to spend more time outside of their homes. This type of life style can be clearly seen in big cities like New York, Tokyo, and Hong Kong where most of the people have a fast-paced life. These people are more stressed during the day compared to people in a small city with a slower pace. They do not have much time to spend on everyday essentials, so they have other people do services for them. Dining out is a way of having other people cook and do dishes. Also, because these people are so stressed during the day, entertainment becomes a big part of their night life. Home becomes a necessary relaxing space for these people and the users' experience in the home becomes essential.

Focus of the research

The purpose of this project is to create comfortable and quality space within a limited spatial area. Human movement, the use of space, and our perception of space are the main study of this research. By using this information, there is a way to create a new architectural prototype. During the process of forming this dissertation, there was constant discussion about using body movement to create space. From one perspective, if movement changes constantly, then space should change according to the movement. If we create a standard space, then it limits the possible movements that can be created within the space. Another perspective is having the space respond to body movement as an interactive space.

The research explores types of human body movement, this included normal daily movement and an extreme of body movement: dance. Dance can be seen as creating extreme body movements compared to our daily movement, so the hypothesis of this dissertation is that if a space can accommodate dance movement, then most likely it will be a comfortable space for daily movement. In order to achieve this goal, studying, recording and analyzing both types of movements are necessary.

The research will be mainly focused on the "public space" of an Asian household, that of the living room and the kitchen. There are two reasons to select this type of space. First, living spaces in Asia are generally smaller than in America and Europe, so there is more need to design small spaces that allow people to move about with comfort. Secondly, the "public space" can reduce the issue with privacy, so the research and design can focus on experience and functional aspect of the space.

Method

The study begins with a historical research of space, including the concept of space, human use of space, and body movement in the space. Rudolf Laban's theory of dance movement is one of the main ideas investigated and interpreted for the research and design dissertation. To understand the human daily movement, data gathering is the key to the thesis. As mentioned earlier, dance movements have been seen as an extreme of body movement. So the subject of study will be from both dance body movements and regular daily body movements. During the data collecting process, both two dimensional and four dimensional methods[4] are used. In the researching phase, a videotaping process is used to record these movements.

In the design phase, the recorded body movements are translated into two dimensional images, and a 3D computer model simulates the movements based on the two dimensional images. Computer programs including *Rhinoceros*, *Maya*, *3D Studio Max*, and *MotionBuilder* are used during the design process. They allow the digital model to simulate the new space prototype and body movements based on the analyzed information to create more efficient spaces that also provide a better quality living environment.

4 Four dimensional is a combination of three dimension and the time factor, can also be called 3D animation.

Part I: Research

Chapter 1 Space

01.1 **What is space?**

Space can be seen as physical or conceptual. The physical space appears in all dimensions, from the first dimension to the fourth. In geometry class we learned that one dimension is a line that lies on x, y, or z axis, there is no thickness to the line. Space in one dimension describes a segment of the line. Two dimensions is made by two axes, xy, xz, or yz. “Space in between the two words”, “a blank space on the wall”, “run out of space to write”, these are the some conditions that we see and use space in two dimensions. Three dimensional is made by the x, y, and z axes (see Figure 1). Space in this case is usually a volume defined by the boundary of it, and everything that we can see is a boundary of the space. The fourth dimension mostly describes the time factor, without the fourth dimension everything is static, (see Figure 2). For us being able to move within the space, we need to have all four dimensions. The first three dimensions create the moment for our movement.

Time is invisible, and it is made of consecutive moments. On a timeline, every point on that line is a moment. In nature, time is only able to go in one direction at a constant speed. It can be measured by its length which

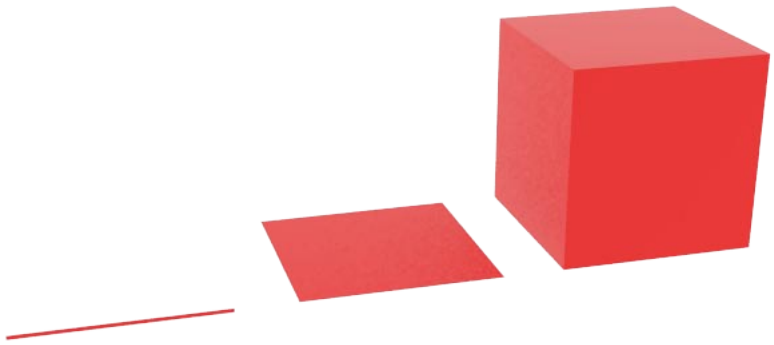

Figure 1.1 Three Dimensions

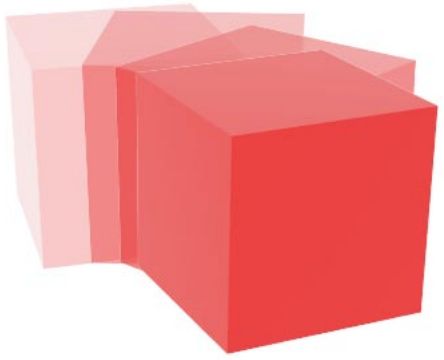

Figure 1.2 The Fourth Dimensions

can also be called duration. Moving fast or slow does not depend on the speed of the time but the duration. In current technology, we are able to capture the time and fast-forward, rewind, even capture the moment in time.

The study of the relationship between human and space is not new. In the ninety sixties Edward Hall wrote the book *The Hidden Dimension*. This is a book about the perception of space in general and also from different cultures. Hall created the term *Proxemic* which is used to describe "interrelated observations and theories of man's use of space as specialized elaboration of culture"[5]. He argues that "…we saw that man's sense of space and distance is not static, that it has very little to do with the single-viewpoint linear perspective developed by the Renaissance artists and still taught in most schools of art and architecture. Instead, man senses distance as other animals do. His perception of space is dynamic because it s related to action-what can be done in a given space rather than what is seen by passive viewing."[6]

5 Edward T. Hall, *The hidden dimension*, [1st] ed. (Garden City: N.Y., Doubleday, 1966). 1.

6 Ibid. 108.

01.2 **Type of Space**

This research argues that there are two types of space, the general space and individual space. Individual space is the space around us, the physical aspect of this space is only within the reachable distance for that person. The psychological aspect of the space also needs to be considered. Physical space combined psychological space might change the shape of individual space. However, in general, the idea of individual space reminds the same. General space in this case is the space outside of individual space and cannot be reached, but can be seen.

Research done by three Japanese university professors "The Reference Domains of the Three-Dimensional Space Based on the Demonstrative Pronouns"[7] analyzed the physical dimensions for "KORE", "SORE", and "ARE", which mean *this*, *that*, and *that over there*. Their research translated psychological space into a physical space with dimensions, it stated that:

> *"1. Height of the domain of demonstrative pronoun "KORE" was about 2400mm.*
>
> *2. Height of the domain of demonstrative*

7 Kazuhiko Nishide Kuniko Hashimoto, Takashi Takahashi, "The Reference Domains of the Three-Dimensional Space Based on the Demonstrative Pronouns," *Journal of architecture,planning and environmental engineering. Transactions of AIJ* no. 552 (2002).

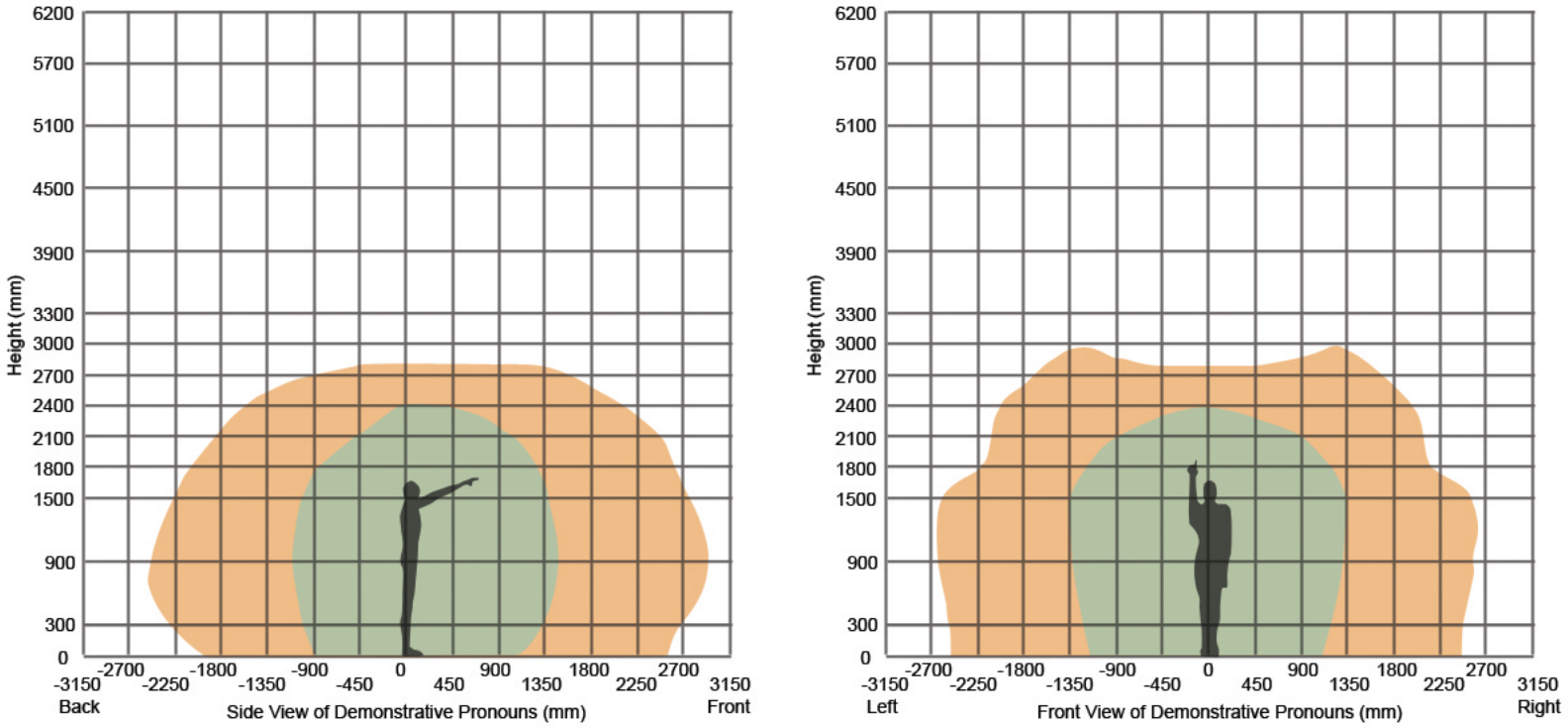

Figure 1.3 Reinterpretted Three-Dimensional Space of Demonstrative Pronouns

pronoun "SORE" was about 2800mm.

3. There was the domain of demonstrative pronoun "ARE" in the outside of "SORE".

4. The domain of demonstrative pronoun "KORE" was related to the movement of the body."[8]

Similar to the idea of individual space and general space, "KORE" describes the individual space. General space is a combination of "SORE" and "ARE", because both of these two spaces are untouchable.

01.2.1 **Individual Space**

The concept of space that one person can reach could be traced back to the Vitruvian Man well known through a drawing by Leonardo da Vinci. There is a difference between individual space and personal

8 Ibid.: 155.

space. Individual space refers to spaces that belong to the individual physically and psychologically. Distance or *reachable area* is the physical way of viewing the space. Personal space is one of the psychological perspectives of individual space. In the design stage, individual spaces are mainly designed to suit the users' physical experience.

> *"Rudolf Laban (1879-1958) was born in Austro-Hungary. Laban was a dancer, a choreographer and a dance / movement theoretician. One of the founders of European Modern Dance, his work was extended through his most celebrated collaborators, Mary Wigman, Kurt Jooss and Sigurd Leeder. Through his work, Laban raised the status of dance as an art form, and his explorations into the theory and practice of dance and movement transformed the nature of dance scholarship. He established choreology, the discipline of dance analysis, and invented a system of dance notation, now known as Labanotation or Kinetography Laban. Laban was the first person to develop community dance and he has set out to reform the role of dance education, emphasising his belief that dance should be made available to everyone.*
>
> *-- Laban Contemporary Dance*[9]

01.2.1.1 Kinesphere

"The Kinesphere is the sphere around the body whose periphery can be reached by easily extended limbs without stepping away from that place which is the point of support when standing on one foot, which we shall call the 'stance'."[10] Our body is capable of reaching all the points within the Kinesphere by bending, twisting and stretching.[11] Taking a step away from the stance means we are take our Kinesphere and move it with us to a new stance. Based on the Kinesphere, Laban defined orientation in space into three basic elements: three dimensions, four diagonals and six to form a sphere. The theory best applies when we move and stretch to our maximum, regular people like us do not move in this way. According to the human daily movement which will be discussed in Chapter 3, the shape of Kinesphere is more likely to be a half sphere.

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9 "Rudolf Laban," Laban Contemporary Dance http://www.trinitylaban.ac.uk/about-us/about-us/history/rudolf-laban.aspx. [October 23, 2009]

10 Rudolf von Laban, Ullman, Lisa., *The language of movement: a guidebook to choreutics*, trans. Lisa Ullman, 1st American ed. ed. (Boston: Plays, inc, 1974; repr., 1st American ed.). 10.

11 Ibid. 18.

Kinesphere is a tool for dancers and choreographers to analyze the dance movements. This research uses Kinesphere as the basic knowledge and starting point to understand the spatial relationship between our body and the space. Since technology is more advanced now than in Laban's time, we are able to analyze the movement in different media other than the Labanotation, such as 2D photoshop images and 3D computer modeling which will be discussed in Chapter 3. Data Collecting.

1. Dimensions

The idea of dimensions is very similar to the 3 dimensions (3D) in the architecture field. It includes the x,y,z axes, in Laban's words they are called: height, breadth, and depth. Each dimension has two directions up and down for height, left and right for breadth, front and back for depth around the human body. He argues that if one moves within one location, the maximum space that can be used is within a reachable point on these three axes. Moreover, the reachable point on the three axes creates a frame for the space. The center of this space is the intersection of the three axes. The term Laban used in his theory for this framed space is called *Kinesphere*.

2. Diagonals

Laban pictures the frame of space as a cube. Diagonals connect opposite ends of the cube in all three dimensions. There are no terms for these diagonals other than naming their position. They can be described as:

1. Front lower left corner to back top right corner,
2. Front lower right corner to back top left corner,
3. Back lower left corner to front top right corner,
4. Back lower right corner to front top left corner.

3. Diameters

Diameters are very similar to diagonals but instead of connecting the end points, the diameters connect the midpoints of the 3D cube's edges two dimensions at a time.

1. Top left to lower right
2. Top right to lower left
3. Top front to lower back
4. Top back to lower front
5. Front left to back right
6. Front right to back left

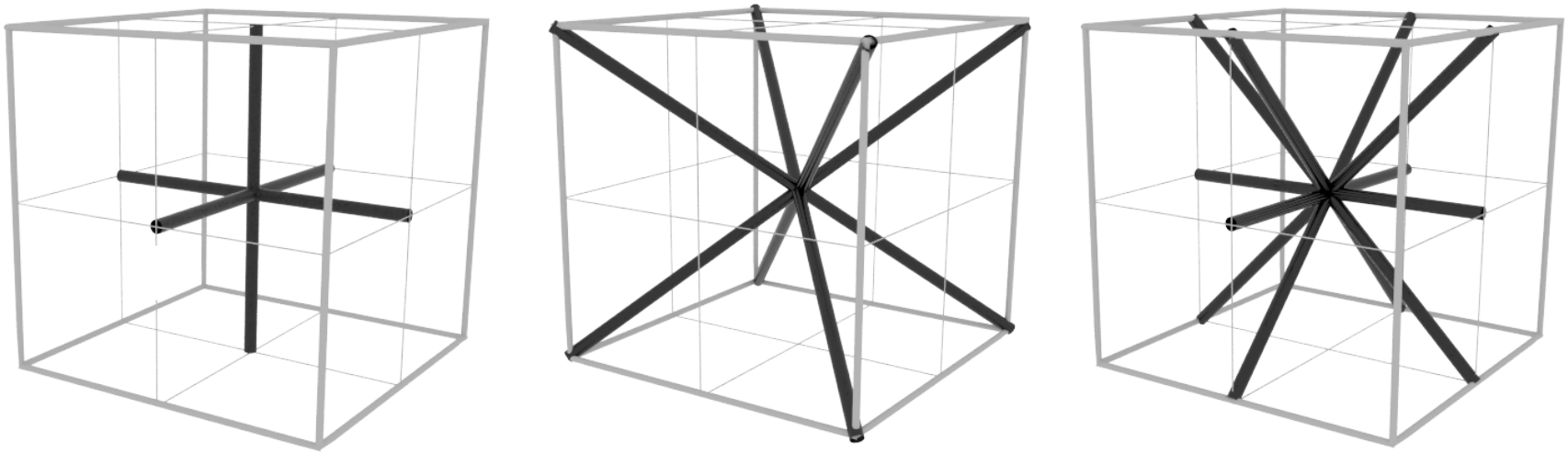


Figure 1.4 Dimensions, Diagonals, Diameters

01.2.1.2 Proxemtic and Personal Space

Edward Hall introduced the theory of Proxemetic, in his theory personal distance is understood by linear dimension, A few years later, Robert Sommer came up with the idea of personal space which describes space or territory around one's body. The difference between Hall's Proxemetic theory and Sommer's personal space is that Proxemetic comes from a social point of view. It is the relationship between the individual and the rest of the social group.

Intimate Distance[12]

Intimate distance ranges from 0 to 18 inches between people. This distance is not often used in regular communication; it is too close to one's comfort zone. The sight is often distorted in this distance. Edward Hall has divided intimate distance into two phases: close phase and far phase.

Close phase is "the distance of love-making and wrestling, comforting and protecting… In the maximum contact phase, the muscles and skin communicate. Pelvis, thighs, and head can be brought into play; arms can encircle. Except at the outer limits, sharp vision is blurred."[13] It usually describes distance between 0 to 6 inches. Far phase is the distance from 6 to 18 inches. At this distance, "head, thighs, and pelvis are not easily brought into contact, but hand can reach and grasp extremities. The head is seen as enlarged in size, and its features are distorted."[14] Also, one can still be able to smell and feel the heat from the other person.

Notes: Intimate distance only happens in a small part of our daily life. It considers the space between two or more bodies. This distance most likely happens in a crowded or private space. In this research, only semi-private space such as kitchen, living and dining areas is considered and designed due to the privacy issue. Intimate space will not be part of the design investigation.

Personal Distance

Similar to Intimate Distance, *Personal Distance* can also be divided into close phase and far phase. It is the distance between 1.5 feet to 4 feet. "It might be thought of as a small protective sphere or bubble that an organism maintains between itself and others."[15] The concept of

12 The idea of intimate distance came from Edward Hall's Proxemtic theory.

13 Edward T. Hall, *The hidden dimension*, [1st] ed. (Garden City: N.Y., Doubleday, 1966). 110.

14 Ibid. 111.

15 Ibid. 112.

personal distance is very similar to Laban's Kinesphere theory. They both describe space around one human body. Laban talks about the physical boundary of the space, and Hall talks about how people perceive and feel within this distance.

Within 1.5 feet to 2.5 feet from a person's body is considered close phase. "At this distance, one can hold or grasp the other person. Visual distortion of the other's features is no longer apparent…A visual angle of 15 degrees takes in another person's upper or lower face, which is seen with exceptional clarity."[16] The boundary of far phase is just outside of arm's length. It is between 2.5 feet to 4 feet from the person's body. "Subjects of personal interest and involvement can be discussed at this distance."[17] Within this distance, people feel they dominate the space; it gives a sense of security.

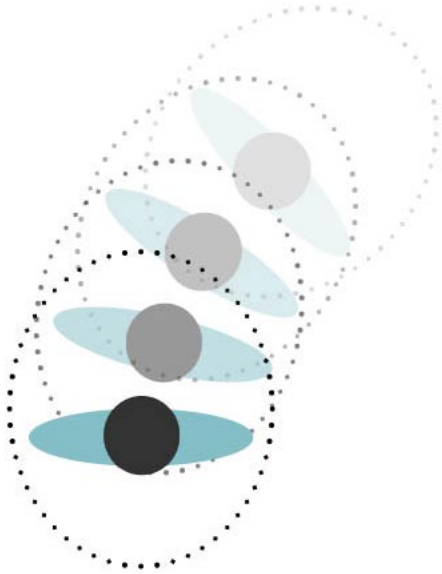


Figure 1.5 Personal Space

Personal Space

It assumes spatial distance around a person is all the same. Sommer argues that personal space has nothing to do with other people, it is simply the space needed for each individual. It requires less space on the side (left and right) than the front, so it is not shaped like a

16 Ibid. 113.
17 Ibid.

sphere. Personal space should not be confused with comfort zone. Usually comfort zone refers to a stable area, such as a bed room. Personal space constantly surrounds you. It is carried with body movement.

01.2.2 **General Space**

There is no physical boundary of general space in nature other than it is outside of the individual space. In architectural design, a boundary of general space can be a limit to the visibility of the space. Since general space is unreachable, visual experience becomes the most common way of experiencing and understanding space. In the design portion of this thesis, architectural space provides an opportunity to design the visual experience.

Social distance[18]

Social distance is used when there is an impersonal business conversation among a group of people. It is usually 4 feet to 12 feet. Within this distance, we are still able to see each other quite clearly, and hear each other in normal volume. Usually it is used to design gathering spaces, conference rooms, and small classrooms.

There are two parts of social distance, close phase which ranges from 4 feet to 7 feet, and far phase which is from 7 feet to 12 feet. In the close phase people tend to be involved more in conversation and activities. “It is also a very common distance for people who are attending a casual social gathering.”[19] Far phase is usually used in more formal settings, such as business meetings.

Public distance

Public distance describes distances that are 12 feet and more. Close phase in this case is 12 to 25 feet. Beginning at 16 feet the image of a person starts to be flat rather than round and three dimensional. “Thirty feet is the distance that is automatically set around important public figures.”[20] To communicate in this distance involves more hand gestures.

18 The idea of social distance came from Edward T. Hall’s *The Hidden Dimension.*

19 Edward T. Hall, *The hidden dimension*, [1st] ed. (Garden City: N.Y., Doubleday, 1966). 115.

20 Ibid. 117.

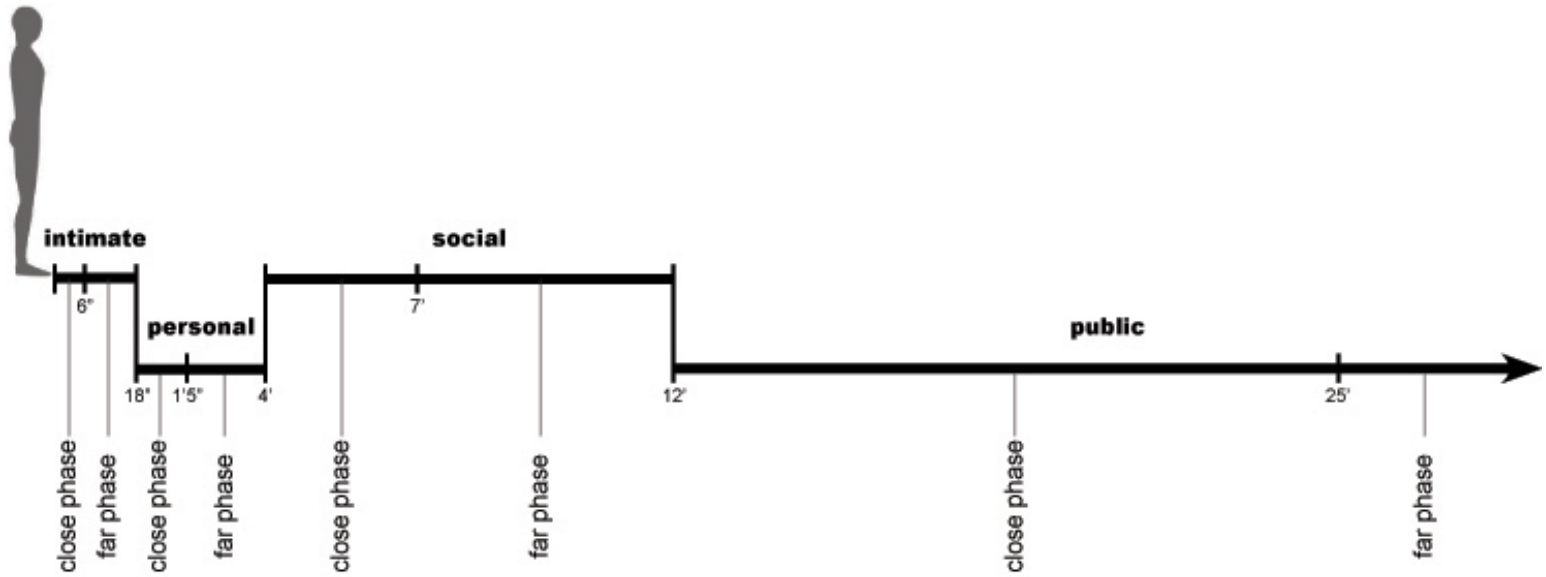


Figure 1.6 Proxemic (the diagram is a reinterpretation of Edward Hall's Formal distance classification)

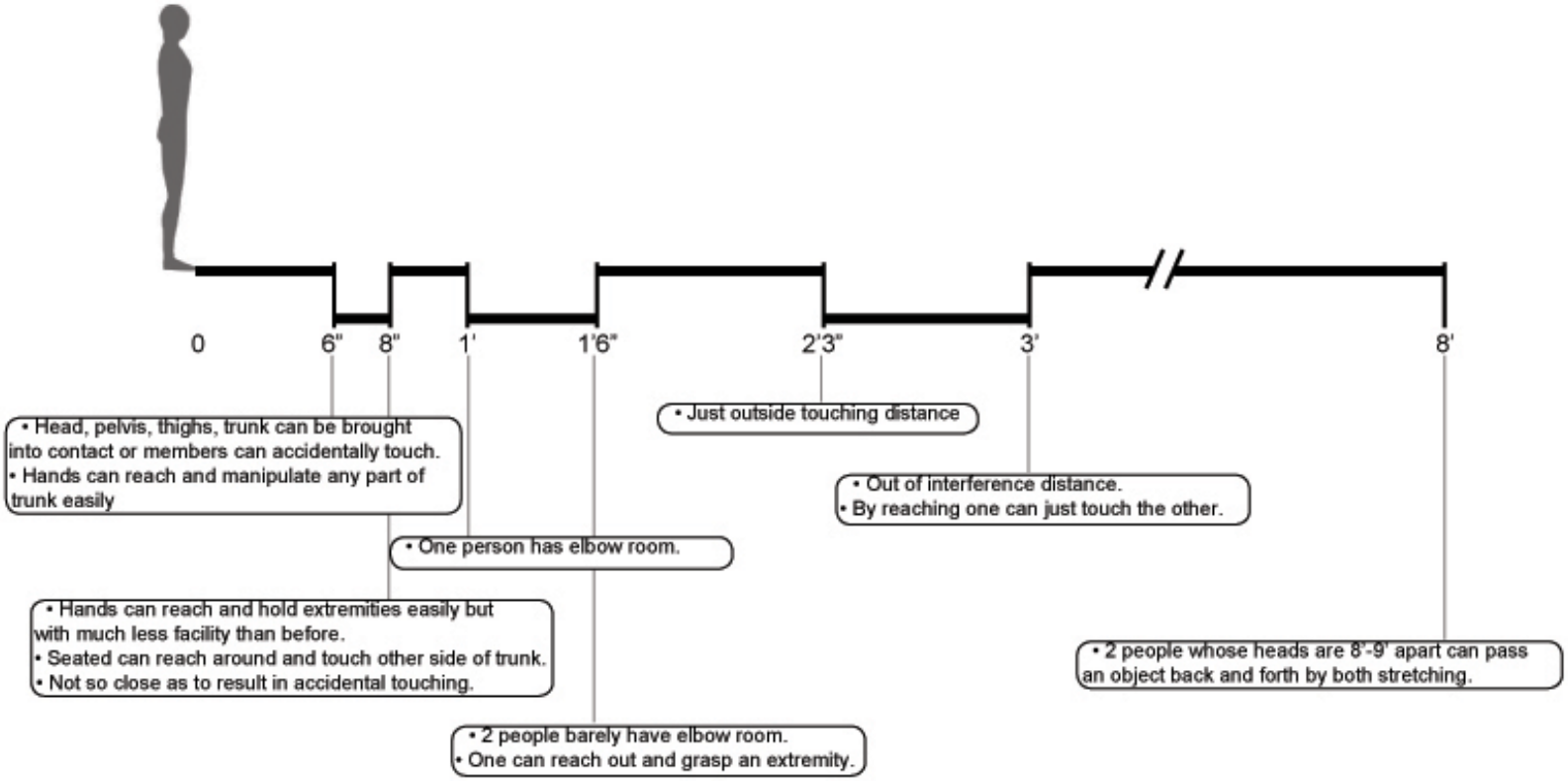


Figure1.7 Kinesthesia (the diagram is a reinterpretation of Edward Hall's Kinesthesia)

Chapter 2 Body Movement

02.1 **Types of movement**

We move for a reason, No matter how small or how big the reason, we move for it. These reasons can be categorized into four categories[21]:

- Functional
- Expressional
- Communicational
- Physical reaction

02.1.1 Functional Movement

Functional movement can be translated into everyday term as “doing something”. Turning on the TV, laying down on the bed to sleep, pushing a box against a wall, these are all functional movements. It is a type of movement that is needed for everyday living. Functional movement can be divided into two types: internal and external.

Internal can also be called instinctual and refers to movement that is triggered by internal motivation such as sitting down due to tiredness of standing and walking, scratching an itchy spot, stretching the arms and legs. From the design aspect, space can be designed according to some of the internal motivated functional movement such as lying and sitting down, but some movement is hard to predict and design for. External motivation usually comes from objects and environments. Grabbing a cup, fanning with a fan, taking off the jacket, these are all considered to be external motivated functional movement. In theory, these types of movement are shaped by the external space. The two perspectives of using body movement to create space which we have discussed in the introduction can be identified by using these two types of functional movement.

02.1.2 Expressional movement

Film contains multiple instances of expressive movements. Dancing is mainly made of expressional movement In different cultures, the space required for this type of movement can vary. In America, when someone is using hand motions while they talk, the arms usually span wider than the body. I n Asia, people tend to have hand motions within the width of their body.

21 The priority of this research is to study the functional movement follow by the expressional movement. Communicational, entertainment, and physical reaction will not be considered in this research.

02.1.3 Communicational Movement

Communicational movement is usually used when there are two or more people involved in the event. Tapping someone's shoulder to catch their attention is a way to communicate with others. Talking is also considered to be communicational movement, even though we cannot see movement made by major body parts, our lips are still moving up and down.

02.1.4 Physical Reaction

Sneezing, yawning, and coughing are all part of physical reactions. This is a type of movement that we usually have no control over. Our bodies have a system that allows us to reset our bodies from any irregular situation. This layer of system has more control than our brain, but all is processed in the brain.

02.1.5 Locomotive and Non-Locomotive Movements

Body movement in general can also be divided into two types, locomotive and non-locomotive. Locomotive movements refer to movement that is made in multiple locations or can be understood as multiple x,y coordinates from the three dimensional point of view. As we stand up from the sitting position, our body still remains in the same location in space, on the same coordinate, this is called non-locomotive movement. In most cases, locomotive movement requires the use of legs, and non-locomotive movement is done by the use of arms and hands. Only significant non-locomotive movement such as sitting down and standing up requires the use of the whole body.

To record and analyze these two movements is important to this research. By analyzing the recorded data, we can understand space. Examples of this analysis include a small kitchen that is dominated by non-locomotive movement, and a hallway where most of the activity is locomotive movement. In this latter example space changes from individual space to general space rather quickly, and general space dominates the hall way. Creating visual experience is more important in this case than creating quality personal space.

02.2 **Quality of Movement**

In order to understand human body movement, we need to study the quality of movement. There are many different fields of study in human movement, such as kinesiology, human performance, and dance therapy. This research studies dance movement because unlike other fields that focus solely on the body, dance movement considers both body and space. For

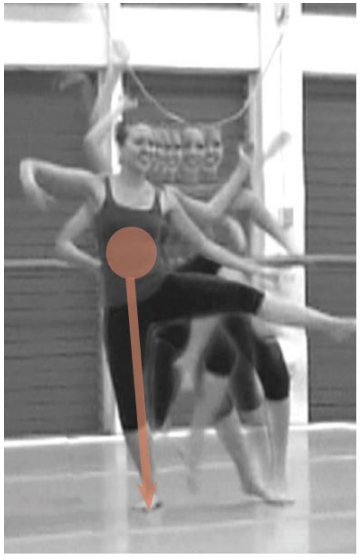


Figure 2.1 (Left) Non-Locomotive Movement
Figure 2.2 (Right) Locomotive Movement

example, when a person stretches his or her body, from the kinesiology point of view, the focus is on the joints and muscles used in that movement. From a dancer's perspective the same movement has several factors to be considered. One is how big of stretching you can do, which is how surroundings affect movement.. Second is the dynamic of the movement, not just slow or fast but also light or strong. Third is the type or shape of space the movement creates. And fourth is the physical location and indicated direction of the movement. From this study with a primary focus on dance movement one can understand the relationship between body and space.

02.2.1 *Effort*

Laban and his colleague, F.C. Lawrence created the Effort Theory of body movement to understand the quality of each motion by measuring flow, weight, time and space factor.[22] The concept behind this theory is that humans do not move in a monotone. We change acceleration of our movement all the time. The tension of our movement changes as well. For example, moving a glass vase from one table to another, the tension of

22 Cecily Dell, *A primer for movement description using effort-shape and supplementary concepts*, Rev. ed. (New York: Dance Notation Bureau, Center for Movement Research and Analysis, Bureau Press, 1977). 6.

this movement is on both hands. One tends to move slowly and with care. When a plastic cup is moved from one table to another, the tension of the movement is only on one hand, and one moves more quickly and with less attention. This research uses Laban's idea as a foundation to generate a new way of understanding body movements.

Flow

Flow can be divided into two states, free and bound. Free flow describes movements that are fluent and loose. Muscles required for the movement are in a relaxed mood which allows the movement to be smoother. Most of the time free flow is hard to stop instantly due to the relaxation of the muscles. For example, when a baseball player swings the bat, it is hard for him to stop right in the middle of the swing.

On the other side, bound flow is movement that is controlled and careful, such as moving in a glass shop. In this kind of movement, the muscles are usually stressed because we pay more attention to the relationship between the surroundings and our body. Because the muscles are in a caution mood, most of the time we are able to stop our movement instantly.

Weight

The quality of weight can be described as strong or light. Strong weight is when you apply more force to the movement, it does not necessarily make the movement faster, but it is more powerful. For example, pushing a heavy box against the wall, one applies a lot of force to this movement, but the box still moves in a slow speed. Light weight is applying small force to the movement, like holding an egg or moving a piece of art work. It appears to be light and gentle.

Strong weight should not be confused with heaviness. Weight is the amount of force applied to a movement, and heaviness describes motions that deal with gravity. For example, if someone is slouching on a couch, the person does not apply force to the movement, gravity pulls down the weight of body.

Time

Getting ready to work on a Monday morning, rushing to change clothes and eat breakfast, every movement the person does is fast in speed. Time in this event is very limited, so we try to squeeze all the movement into this limited time. On a Sunday morning, we tend to move slower, because we have more time in hand. Laban sees time not just as the fourth dimension, but as a factor

of movement. There are qualities to time. Sustained and sudden are descriptions for the quality of time, it is not measured by the clock time but by speed. Speed can be determined by the acceleration or deceleration of the movement.

Space

Space in Laban's Effort theory identifies the focus of a person. There are two types of space as an effort factor, direct and indirect. Direct space describes the relationship between a person with another opponent. For example, talking to another person one on one, we usually focus on that person. On the other hand, indirect space describes a person with multiple opponents. When teaching a class with many students, eye contact and movement do not focus on just one person, but on all of them. Direct and indirect can be translated as the number of focus points, single is direct and multiple is indirect. How humans associate with space is not only visual, it can also be imaginary. In a dark room, we are not able to see anything, but we can feel our surroundings by using all senses and imagine the space in our mind.

02.2.2 *Shape*[23]

Shape was an idea originally created by Warren Lamb in parallel to the Effort concept. While Effort Theory deals with mainly the inner intention, Shape deals with mostly outer intention. These two qualities of movement can be used together or separately. Shape contains three types of movement: *Folding and Unfolding*, *Orientation*, and *Space Shaping*.[24] It involves physical relationships between the body and space. Every movement that we make contains a change in shape. Similar to the Effort research, Lamb's Shape idea is the foundation of this research. In addition, three types of movement have been manipulated for the needs of this project.

Folding and Unfolding

The idea of folding and unfolding came from *Shape Flow*[25]. It is understood as a type of movement that mostly considers the open and close of a person's body. It can be viewed from two perspectives: grow or shrink and folding or unfolding. Grow or shrink describes the

23 Ibid.

24 Based on the Shape theory, these terms were created for the need of this research.

25 Cecily Dell, *A primer for movement description using effort-shape and supplementary concepts*, Rev. ed. (New York: Dance Notation Bureau, Center for Movement Research and Analysis, Bureau Press, 1977).

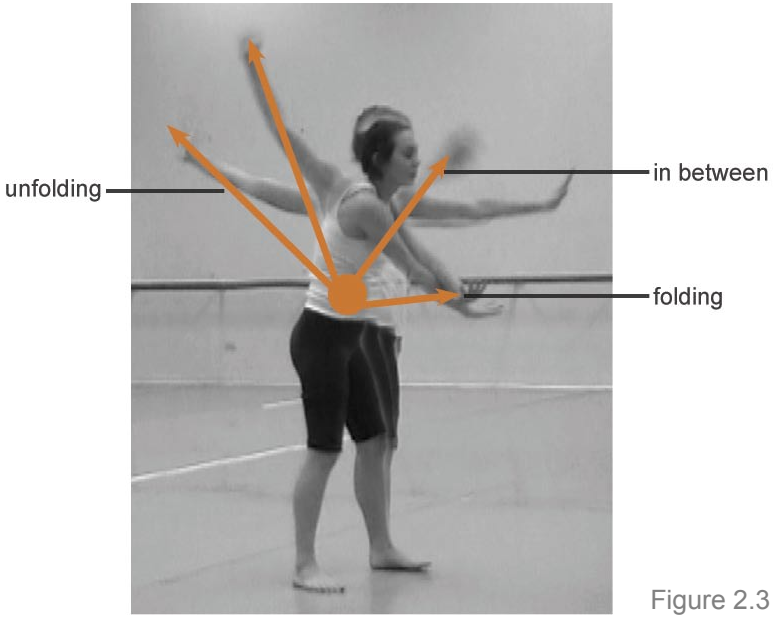


Figure 2.3 Folding & Unfolding

change of the body in size, such as when someone takes a deep breath, the body grows at this stage; as the air is released out, the body shrinks. On the other perspective, it is used to describe the limbs in relationship to a center. In the folding stage, limbs are closer to the center, and unfolding is the opposite of it.

Center point changes depend on the intentions of the movement or the scale of the movement. Scale in this case describes the reach space of the movement. Near, intermediate, and far are the three areas in the scale. Usually the center point of far reach is in the middle of the body. When someone is lying down, center is around the abdominal region and limbs are moving toward the opposite side of it. It is an unfolding movement. Squeezing a toy ball in the hand is considered folding in a near reach, where the center is in the middle of the hand.

Notes: For the purpose of this research, movements that deal with far areas will be the main focus of the data collecting process. In small spaces, one can do near and intermediate movement quite comfortably. It is usually the far movement that is limited by space and thus forms a greater challenge for the thesis.

Orientation

In the process of reaching an object, from the front of the person to the object, it indicates the orientation of the movement. Orientation should not be confused with direction. It is describing the movement, and direction is the relationship between the object location and its changing place. Body orientation is not restricted to the relationship of body and object. It can also be purely movement in space.

There are two ways of expressing body orientation. One is by creating directional spoke-like movement which is straight linear movement. It is not often used in daily movement except when there is a need of applying direct force, such as pushing an object. The second type is called directional arc-like movement, by creating an arc path in the space to reach a stopping point, it usually only requires use of one joint. This type is often used in daily movement, because it allows us to reach more territory in the space. Also, Orientation can be divided into locomotive and non-locomotive types. Orientating body in one location is considered a non-locomotive movement. Locomotive movement, similar to a walking path, is not just a line, but indicates a direction in space.

Figure 2.4 Orientation

Note: the hypothesis of Orientation, unlike dance can create movement 360degrees around the body. Movement is typically in front of us, at the side will be the second common area, and back is the uncommon area in everyday movement. This hypothesis can be proved in the data collecting and analysis. For design application, this can be translated to provide quality space 180degrees in front of the body.

Space Shaping

Imaging space is a piece of clay and body is a tool to shape the clay. Space Shaping can be understood as carving space. While our body is moving, we created a trail. This can easily be seen from movement created by our limbs. These trails are the outlines of the shape of space. Every movement we do involves shaping, we create form in space. Sometime this form can be an actual object, such as holding a big box in front of your chest and the volume of the box becomes the form. There are two ways of describing Space Shaping: gathering moves toward the body and scattering moves away from the body. Unlike Folding and Unfolding that deal with the body itself, Space Shaping is used to understand the space in relation to the body. Both of them describe the same quality of movement, but they are two ends of the spectrum.

Figure 2.5 Space Shaping

Note: in the architecture field, there are similar ideas of forming space. In the *Handbook of Environmental Design* written by the Japanese Architecture Institute, it illustrates the shape of space created by everyday movement. These shapes of space are just physical illustrations. They illustrate when the movement is complete and do not involve any quality aspect. The Space Shaping is used to see the relationship between body and the space, it is a quality.

02.2.3 ***Rhythm***

For this research, rhythm is made up of repetitive elements of movement or combinations of the elements. Elements of movement refer to Laban's and Lamb's Effort and Shape theory. They included Flow, Weight, Time, Space, Folding and Unfolding, Orientation, Space Shaping and *Trail*. Typically these are lines created by our movement,they can be physically identified. On the other hand, movement with only repetitive weight and space is the hardest to be observed. One needs to understand the movement and its environmental context in order to see other elements.

Rhythm can be understood from three scales: instant, event, and daily. The scale is determined by the

Figure 2.6 Trace-Form

relationship between movement, event[26] and time, every movement or event can have multiple scales. Chopping vegetables in the kitchen can be seen as an instant rhythm, the trace-form of movement is repeating during the process of chopping. In this scale, rhythm happens within the event. The relationship between the movement and the event is the measurement of this scale. To view rhythm at the event scale, you would need to combine multiple events in order to see it. For example, within the time of cooking in the kitchen, it probably requires one to open the refrigerator door a few times and this can be seen as rhythm over multiple events. Daily rhythm takes a long period of time to be recognized. If someone has a repetitive life, such as using the bathroom the first thing every morning, than walking to the kitchen to prepare breakfast and reading a newspaper while eating the breakfast, this is considered daily rhythm, and takes many cycles to be recognized.

26 For the purpose of this research, event in here is referring to a complete functional movement.

Chapter 4 Data Collecting

03.1 **Recording Movements**

The data collecting process has been done in two stages. First, daily movement was recorded in a private home. Second, dance movement was recorded during a dance rehearsal.

03.1.1 Recording Daily Movement

A series of daily movements was recorded in a 60 square meter apartment in China. There are 3 occupants living within a two bedroom and one bathroom apartment. All the recordings were done within a 20 square meter space of the living room and the kitchen, the public space of the unit. The recording went on continuously for one week during dinner time from 5pm to 9pm, which was the period of most active use of the space. The camera was set in three different locations: the main entrance viewing the living room space, lanai entrance viewing the living room space, and kitchen entrance viewing the kitchen space.

03.1.2 Recording Dance Movement

The dance movements were recorded during the rehearsal of *Signal*, there is no particular reason why

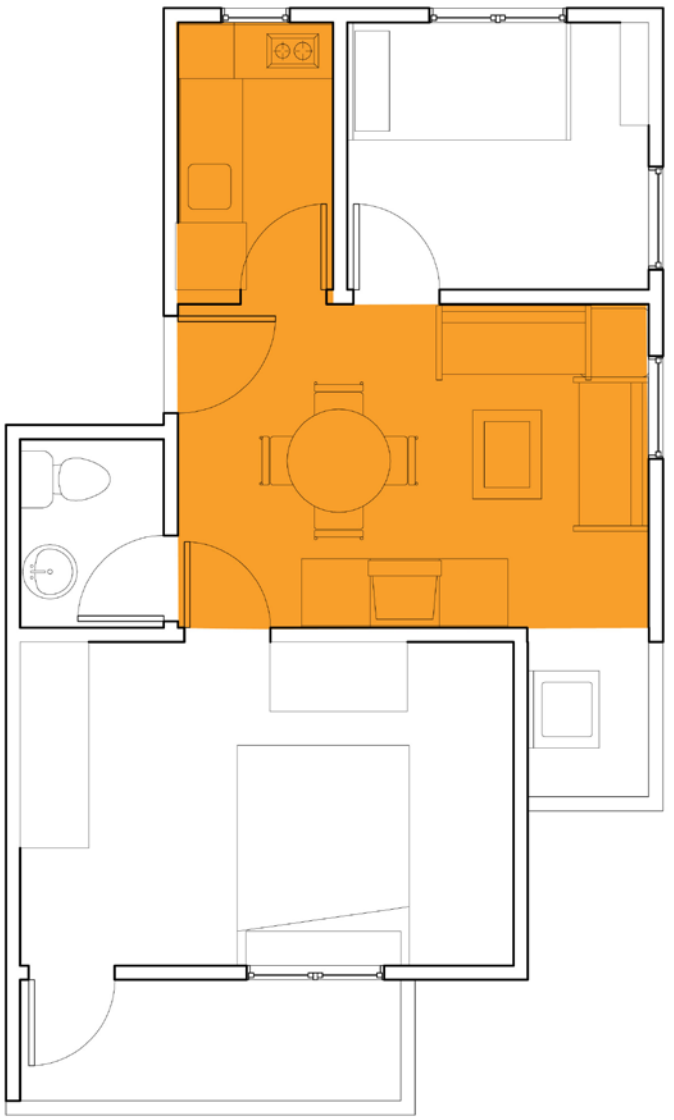


Figure 3.1 Floor plan of recording apartment

this performance was chosen other than it was easily accessible. Three rehearsals were recorded, two of them were of similar choreography and one was entirely different.

In every movement that we make, one can see a trail behind it. By connecting the trails together, we are able to see the required amount of space for that movement. Putting each individual movement trail (including legs, arms, head, and movement within one spot) side by side, or overlapping them in the 3d program, we can analyze the space that we never touch or reach. This study can help to define the Kinesphere of human daily life.

Body movement was discussed in Chapter 2. Two types of movement were identified: locomotive and non-locomotive. They can be found in all kinds of movement, including dance and daily movement. After recording daily movement in the studio apartment, we were able to identify which type of movement is created in a particular space. If we divide the recorded dance and daily movement by these two types, we are able to place them into groups.

03.2 **Method**

03.2.1 Two Dimensional Data

Space and movement happen in a four dimensional world. Two steps are used to translate four dimensions into two dimensions. The first step is to divide the movements into moments, by recording the movement and taking snapshots of it. From this, we are able to capture the first three dimensions. The fourth dimension is presented by putting a number of moments into one image and following the timelines of the movement or event. For the purpose of this research, these combined moments will be called *segment of movement*. Typically an event will be divided into a few segments of movements. Each moment is taken at every 0.2 seconds of that movement, so the faster the movement is, the fewer images there are. Also the duration of the segment varies from case to case.

During the process of translating four dimensions into two dimensions, there is a loss of information. The weight of the movement and the space factor in the Effort theory are some of the factors that cannot be captured in two dimensions. To solve this issue, a chart was created to record the un-imaged information.

03.2.2 Four Dimensional Data

Four dimensional data puts all the movement information into computer modeling form. Its representation is the same as video recording, but it allows more information to be adapted in the model, which is useful in the design process. *Autodesk MotionBuilder* was selected to be the motion modeling software because it allows the user to create movement in every joint of the body to produce animation. Creating the four dimensional model will be done in the second part of this project, which is the design phase.

03.2.3 Factors

There are a total of ten factors in the data analysis, based on Chapter 2. Body Movements:

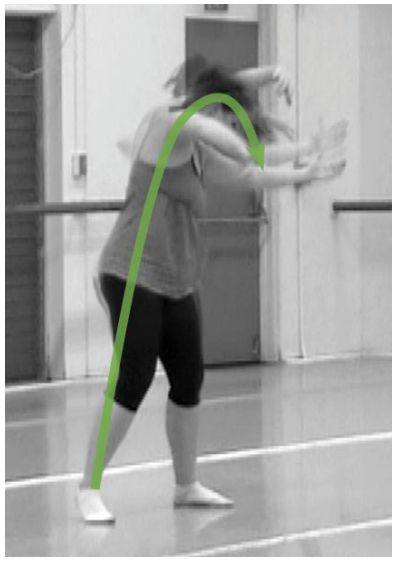
- Trace-form
- Location
- Flow
- Weight
- Time
- Space
- Folding and Unfolding
- Orientation
- Space Shaping
- Rhythm

Some of these factors some can be described graphically by lines and arrows, such as *Trace-form, Location, Shape, Orientation*, and *Space Shaping*. Factors that cannot be described graphically are put into a grading system, ranging from one (1) to five (5). One (1) and five (5) represent the two extremes such as, for example, strong and light are the extremes for the weight factor. Two (2) and four (4) are used to describe movements leaning towards one extreme but not completely, and three (3) is used for movements that are right in the middle.

Case 1

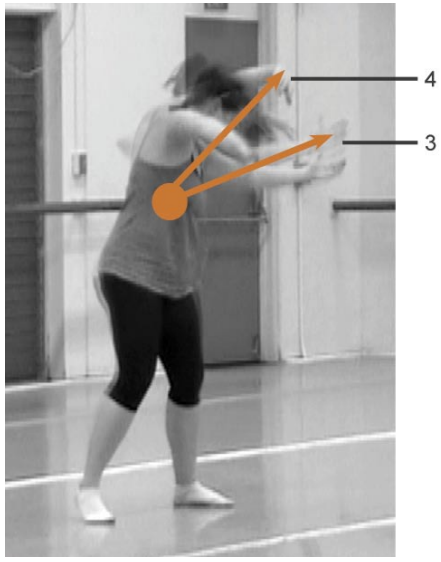
Non-Locomotive

Trace-Form



Orientation

Space Shaping



Folding

Case 1					6 frames
	Free(5)	4	3	2	Bound(1)
Flow					
	Strong(5)	4	3	2	Light(1)
Weight					
	Sustained(5)	4	3	2	Sudden(1)
Time					
	Direct(5)	4	3	2	Indirect(1)
Space					
	Unfold(5)	4	3	2	Fold(1)
Fold & Unfold					
	Instant	Event	Daily		
Rhythm					

Case 2

Non-Locomotive

Trace-Form

Orientation

Space Shaping

Folding

Case 2					17 frames
	Free(5)	4	3	2	Bound(1)
Flow					
	Strong(5)	4	3	2	Light(1)
Weight					
	Sustained(5)	4	3	2	Sudden(1)
Time					
	Direct(5)	4	3	2	Indirect(1)
Space					
	Unfold(5)	4	3	2	Fold(1)
Fold & Unfold					
	Instant	Event	Daily		
Rhythm					

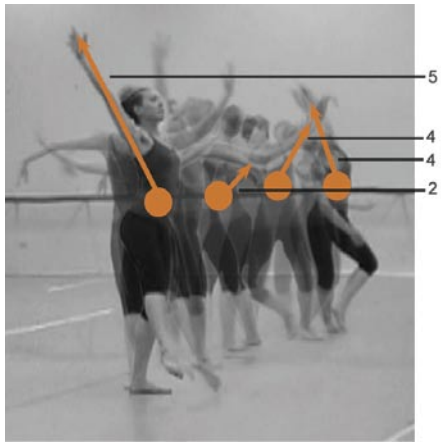
Case 3

Locomotive

Trace-Form

Orientation

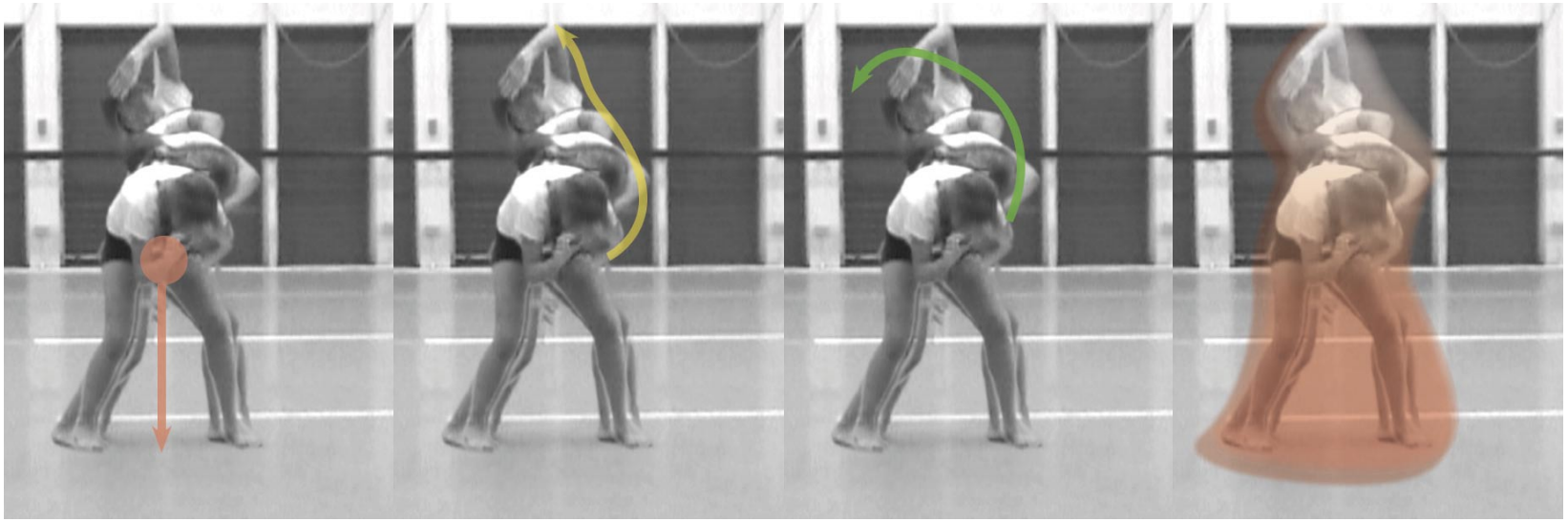
Space Shaping



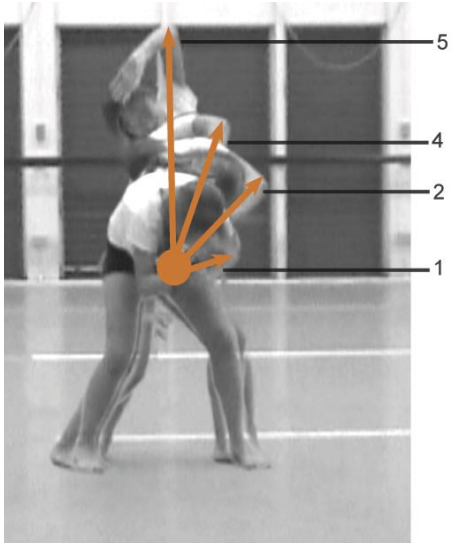
Unfolding

Case 3					14 frames
	Free(5)	4	3	2	Bound(1)
Flow					
	Strong(5)	4	3	2	Light(1)
Weight					
	Sustained(5)	4	3	2	Sudden(1)
Time					
	Direct(5)	4	3	2	Indirect(1)
Space					
	Unfold(5)	4	3	2	Fold(1)
Fold & Unfold					
	Instant	Event	Daily		
Rhythm					

Case 4



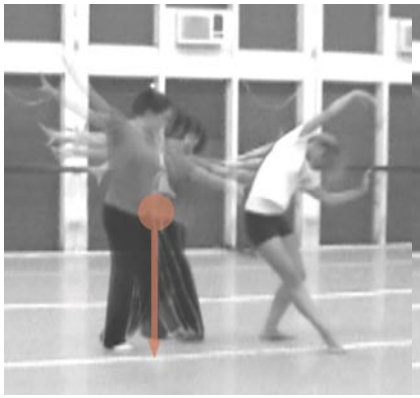
Non-Locomotive | Trace-Form | Orientation | Space Shaping



Unfolding

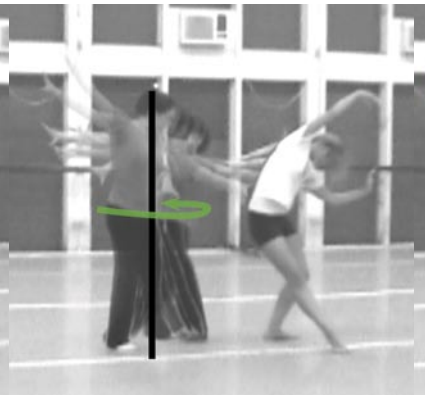
Case 4					5 frames
	Free(5)	4	3	2	Bound(1)
Flow					
	Strong(5)	4	3	2	Light(1)
Weight					
	Sustained(5)	4	3	2	Sudden(1)
Time					
	Direct(5)	4	3	2	Indirect(1)
Space					
	Unfold(5)	4	3	2	Fold(1)
Fold & Unfold					
	Instant	Event	Daily		
Rhythm					

Case 5

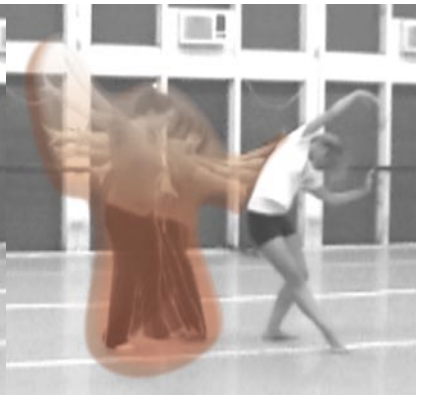


Non-Locomotive

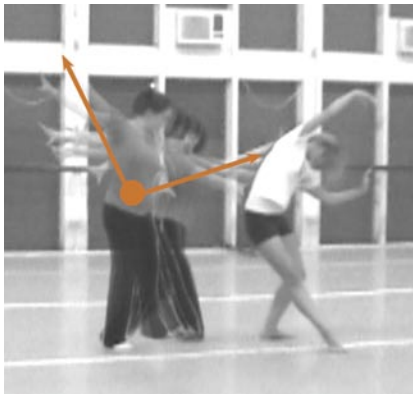
Trace-Form



Orientation



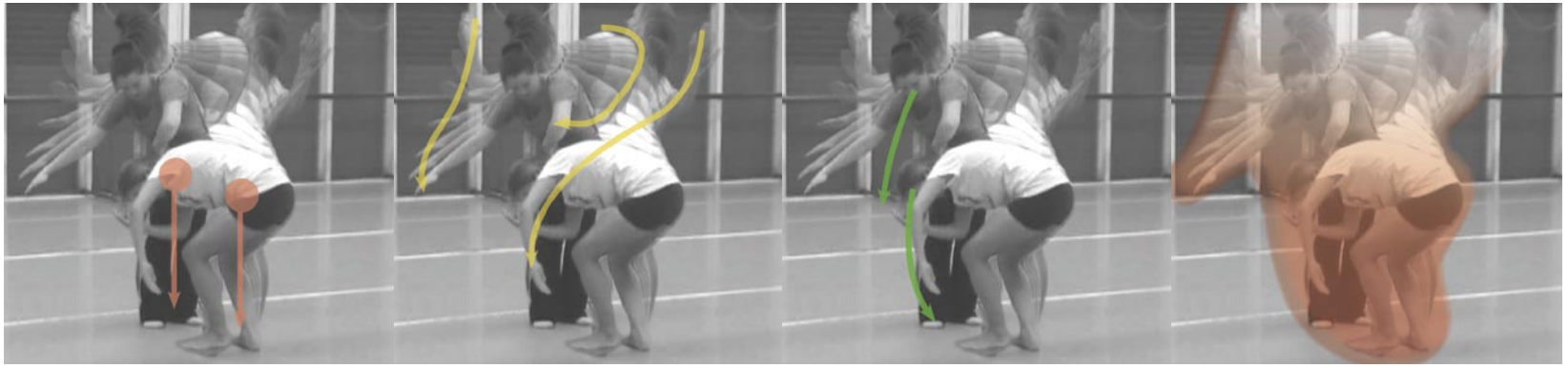
Space Shaping



Unfolding

Case 5					9 frames
	Free(5)	4	3	2	Bound(1)
Flow					
	Strong(5)	4	3	2	Light(1)
Weight					
	Sustained(5)	4	3	2	Sudden(1)
Time					
	Direct(5)	4	3	2	Indirect(1)
Space					
	Unfold(5)	4	3	2	Fold(1)
Fold & Unfold					
	Instant	Event	Daily		
Rhythm					

Case 6



Non-Locomotive | Trace-Form | Orientation | Space Shaping

Unfolding

Case 6					12 frames
	Free(5)	4	3	2	Bound(1)
Flow					
	Strong(5)	4	3	2	Light(1)
Weight					
	Sustained(5)	4	3	2	Sudden(1)
Time					
	Direct(5)	4	3	2	Indirect(1)
Space					
	Unfold(5)	4	3	2	Fold(1)
Fold & Unfold					
	Instant	Event	Daily		
Rhythm					

03.3 **Technical Issues**

The purpose of this thesis is to redefine small residential space to be more ergonomic, efficient, and of higher quality. Due to the limitation of space, capturing the whole body becomes very challenging. This problem arises when positioning the camcorder at human eye level. Shooting the top or bottom of the room is one option for recording, but this method does not allow the recording of body movement as accurately as from the eye level.

Layering more than five snapshots sometimes creates a challenge for analyzing the images two-dimensionally. The more snapshots there are, the harder it is to see the full body movement, such as in Case 3, where most of the right hand movement are blocked by the dancer's body. One way to avoid this issue is to divide the movement into smaller segments, approximately five snapshots per image, which is about one-second in time. If needed, the analyzed information can be overlapped according to the timeline. Also, analyzing movement and space two dimensionally is sometimes not so accurate. Many of the spatial qualities have been lost in the image. One solution is to record the movement from multiple directions, at least two directions from the eye level, and possibly one from the top.

Part II: Design

Chapter 4 Before Modeling

04.1 **Design Concept**

At this stage of the project, basic understanding of space and body movement has been researched. Both daily and dance movement have been recorded. The design then merges the research knowledge and data into a form of physical space.

04.1.1 Option 1

This design option creates a maximum space shell by combining dance space and daily used space together into one, then dividing the shell into uniform modules. The idea is that each movement will have an individual shell and each shell can be collapsed or opened, depending on the movements that the user creates. The advantage of this design is that multiple movements can be created within one space and space can be efficiently used. The disadvantage is that it requires multiple controls of collapse and expand actions. This design is similar to creating an interactive space.

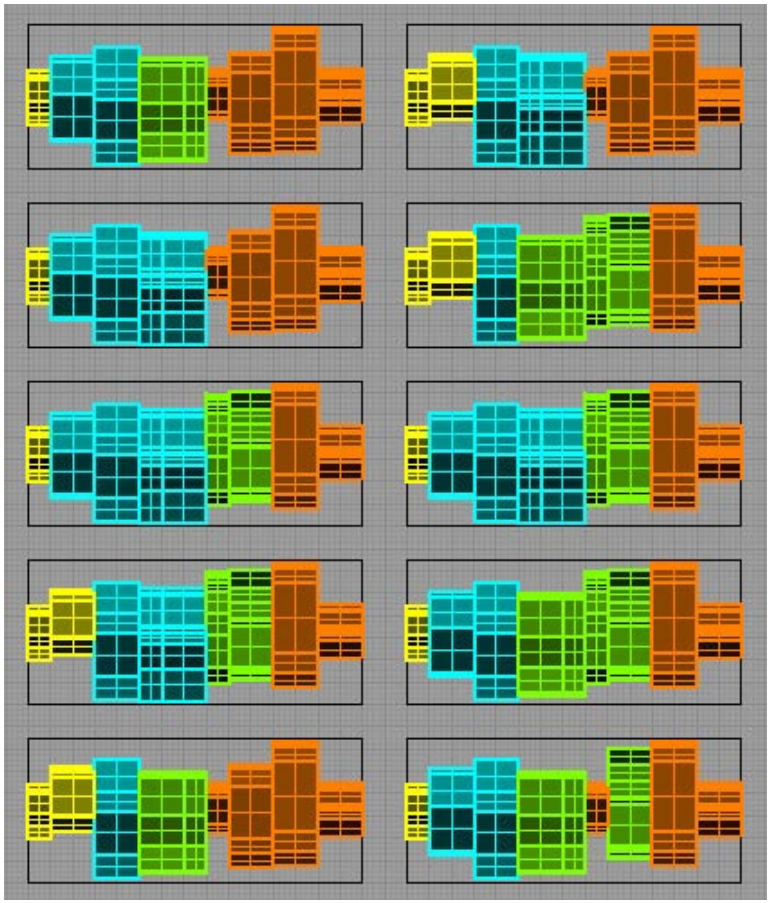


Figure 4.1 Option 1, Different Configuration of Shells (Plan View)

04.1.2 Option 2

Another direction the design could take is to create a spatial experience between daily movement space

and the dance movement space. Users have the opportunity to transform the quality of the space based on the number of users within a space. As the number of users increase, the shell will transform from dance movement space into daily movement space. On the opposite side, when the number of users decreases, it will transform back to dance movement space.

04.1.3 Option 3

This is a combination of Option 1 and 2. In Option 2, the shell can be transformed into functional furniture. When a shell is not in use, it can collapse into a furniture piece, and another shell will open in the same place. This is also based on a modular system.

Since the project has been mainly focused on daily body movement and dance movement, exploring spaces for these two types of movements became the design focus. There are various ways to design with the given information, this project has chosen Option 2 to be the design focus, it is based on personal interest and it has the possibility to be expanded into Option 3.

04.2 **Selecting Movements**

Before building the model, movements and structures needed to be selected. By analyzing the recorded data

Figure 4.2 Option 3, Furniture

from both daily movements and dance movements, general movements were selected for the foundation of space making. According to the recorded data, four movements have been analyzed as the common movements within the recording space, including bending, reaching, walking, and sitting/standing. Reasons to select these movements are:

- Most commonly used
- Functional movements
- Movements requiring folding and unfolding
- Movements that are reaching the edge of a person's Kinesphere

The corresponding dance movements were selected based on the relation to the daily movements:

- Folding and unfolding of the body
- Locomotive and non-locomotive of the body

Bending

Figure 4.3 (Left)
Daily Bending

Figure 4.4 (Right)
Dance Bending

Reaching

Figure 4.5 (Left)
Daily Reaching

Figure 4.6 (Right)
Dance Reaching

Walking

Figure 4.7 (Left)
Daily Walking

Figure 4.8 (Right)
Dance Walking

Walking & Sitting

Figure 4.9 (Left)
Daily Walking & Sitting

Figure 4.10 (Right)
Dance Walking & Sitting

04.3 **Exploring Digital Modeling Method**

After the movements were selected, videos of each particular movement were cut into frames. Depending on the speed of each movement, frames are taken at a range from 0.2 sec/ frame to 2 sec/frame. In MotionBuilder, every joint of the body is then moved manually from frame to frame. The program then automatically simulates the movement by moving every joint from point A to point B. Simulated body is then brought into *Maya* to trace the trail of each movement. After the trail of movement has been physically identified as a curved line, it is transferred into *Rhinoceros* to create the physical shape. *3D Studio Max* is used in the last stage of modeling process to animate the transformation process.

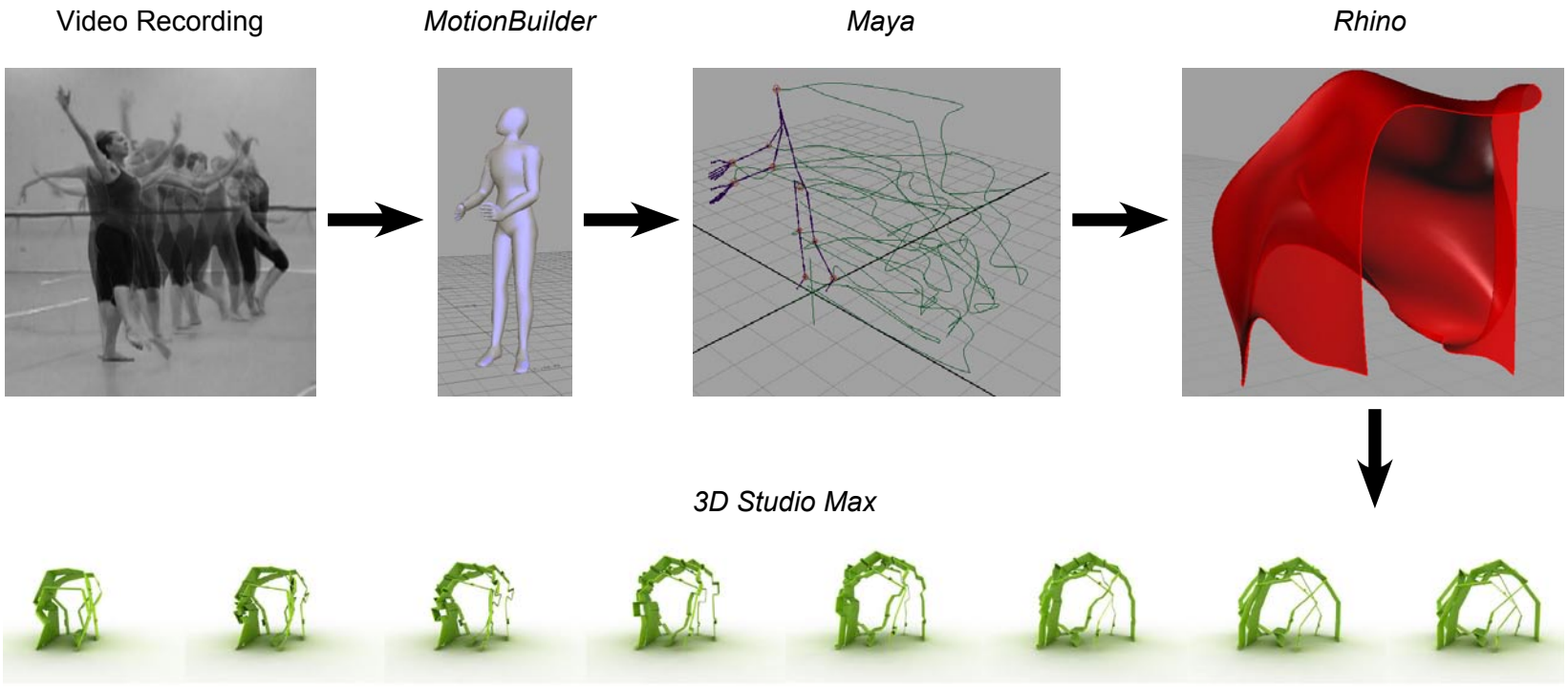


Figure 4.11 Digital Modeling Process

04.4 **Exploring Structure Systems**

04.4.1 Origami Tessellation (uniformed)

The first exploration of potential structure systems was the use of origami tessellation. With uniform folding patterns, it allows one to create symmetrical three dimensional shapes. However, since the main idea of this dissertation is to design shapes/ spaces based on the human body movement, the opposite of ordinary symmetrical shapes. In order to create the asymmetrical with symmetrical patterns, we need to control every individual point of the surface. This method involves a too complicated system for it to be built, so it was off the table.

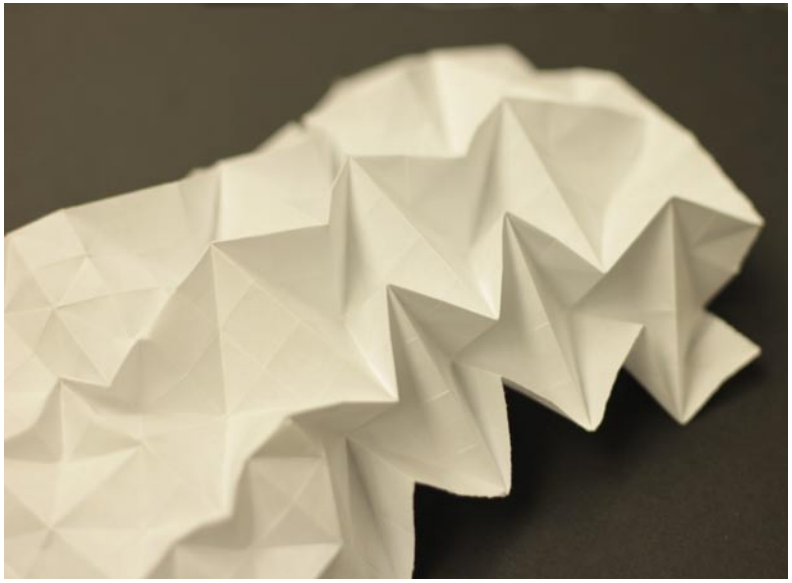


Figure 4.12 Study Model, Origami Tessellation (uniformed)

04.4.2 Origami Tessellation (customized)

The second approach was to customize each unit of the tessellation. The design concept of the project is to be able to transform the shape/space between daily use space and dance space. Due to this idea, the structure needs to be able to transform from one to the other, so each structure contains two shapes in it. To embed a shape into the structure, both shapes were uniformly divided into 50 panels, 10 rolls in the yz direction, and 5 columns in the x direction. By over lapping Shape B's

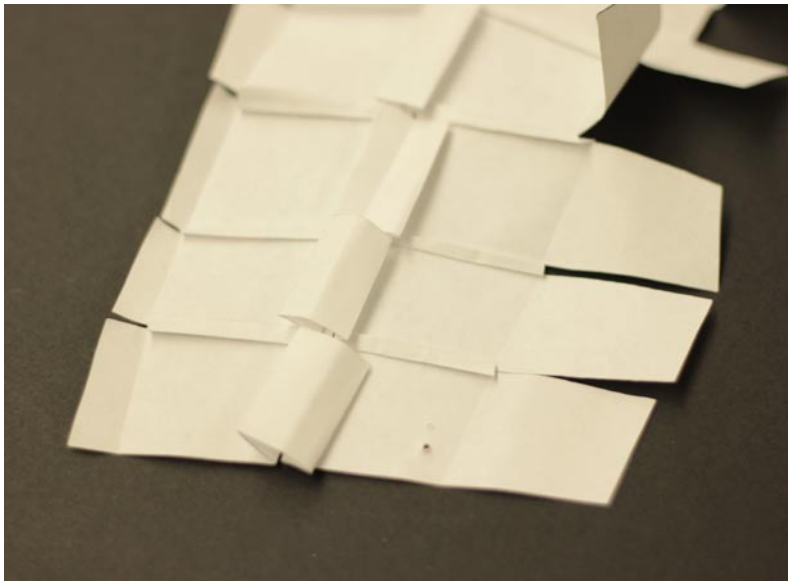


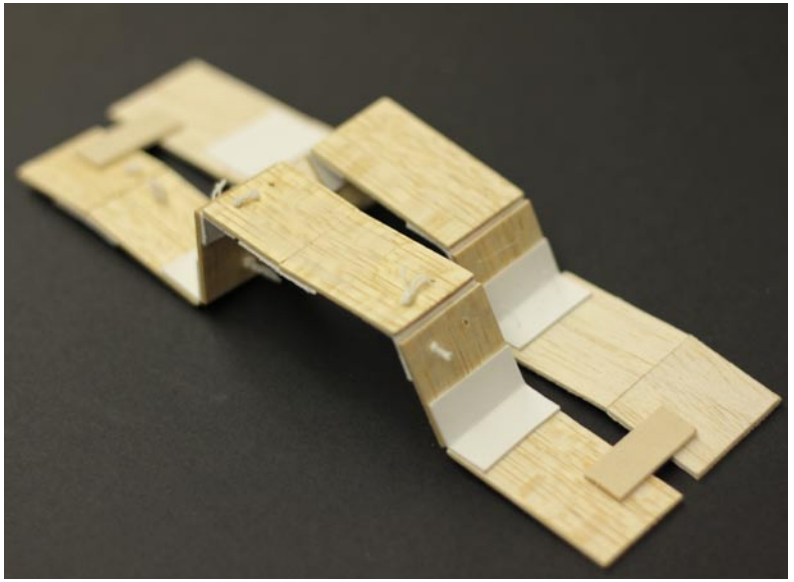
Figure 4.13 Study Model, Origami Tessellation (customized)

panels on top of Shape A's, we are able to create a dual shape surface. To open Shape A, the extra surface from Shape B will be folded away in both directions of the panel. To form Shape B, all the panels will open to the maximum allowance. This method was based on the theory that Shape B is bigger than Shape A in all directions, or the idea that dance space is always bigger than daily used space. Considering the irregular shape of each panel, it is difficult to fit one panel inside another and to be able to fold the extra surface.

04.4.3 Extruded Section Modules

The third approach was to simplify the previous customized origami tessellation by splitting each module column into individual strips. In this way, each panel only has to be controlled in one direction instead of two. The idea of column in this case is similar to a section of the shape, so the model was modified again by cutting a few sections through the shape and then extruding each section profile for a certain distance. Creating a 1 foot modular system gives the possibility for the shell to transform into functional furniture that is related to the human body dimensions. Each section profile is extruded 1, 2, 3, or 4 foot depending on the functionality of the furniture.

Figure 4.14 Study Model, Extruded Section Modules



Since there are two shapes of transformtion, the connecting corner of two panels needs to have flexibility to change the angles and constrain it to a fixed degree. A middle piece was added to the corner, this allows the corner to have two fixed degrees. By tying the two panels to this middle piece with a measured amount of wire, two angles are created. Threading the wires into the panels and the middle piece, allow the middle piece to be pulled back from one side or the other, which gives the corner flexibility.

- Pulling wires on the left hand side,
    - Middle piece will go towards the same side,
    - Fixed wire between the middle piece and right panel will create the angle
    - Angle between left panel and middle piece becomes 0
- Pulling wires on the right hand side
    - Middle piece will go toward the same side
    - Fixed wire between the middle piece and left panel will create another angle
    - Angle between right panel and middle piece becomes 0

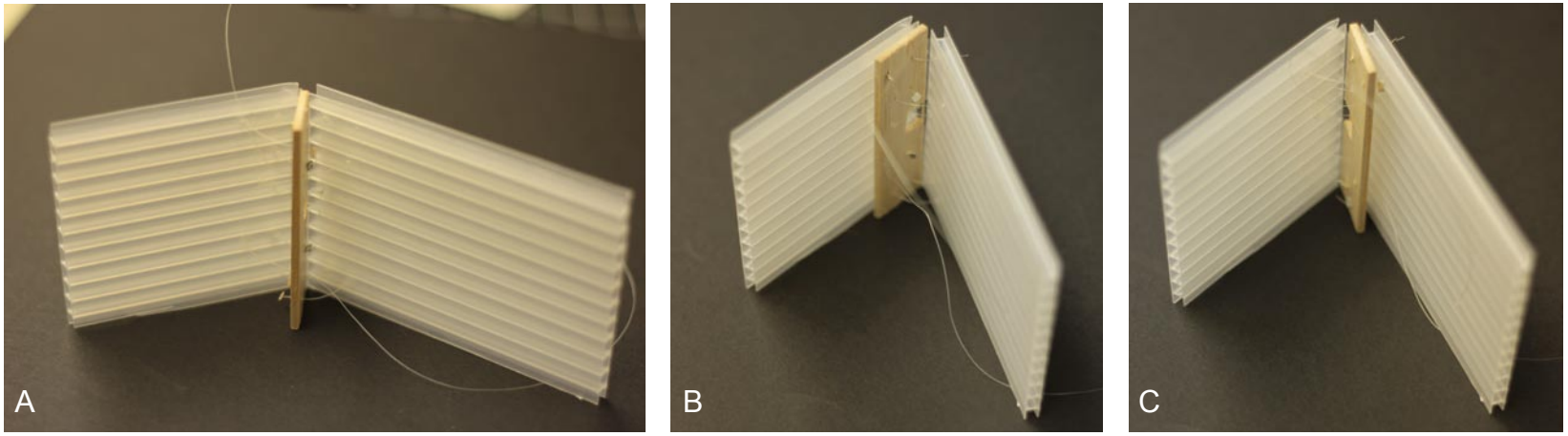


Figure 4.15 Study Models of Connections

Chapter 5 Forming the Space

Based on the MotionBuilder simulation, the trails of the motion were traced in Maya. During this process, motions have been converted into curved lines. This is the first step to translate movement into a physical form. Then the physical form got further developed into a shell. As mentioned in Chapter 1, space is defined by objects, so the shell then defines the needed space for the body movements.

05.1 **Creating Shells**

After the lines were extracted from the motions, they are then exported into Rhino to form the shell. Each line was traced with another line to create a smoother outline. By using the Loft command, surfaces were generated by these lines.

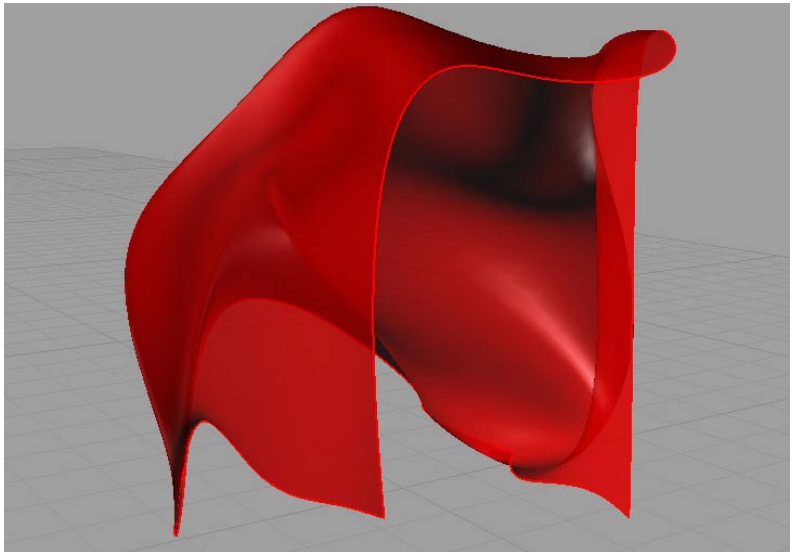


Figure 5.1 Shell Lofted from Lines

05.2 **Applying Maximum Space**

In theory, space created by dance movement can be seen as an extreme compared to the daily movement, but extreme space that dance creates does not mean maximum space. There are two steps to apply maximum space to the extreme space.

First, under the theory that dance movement created

the extensive folding and unfolding of the body, space created by extensive unfolding movement can be seen as the maximum space for that specific movement. On the other hand, the extensive folding movement creates the minimum space. By applying daily movement space to the minimum space, we can at least ensure it is comfortable to be used for the daily movement. In order to do so, we take the section profiles of the dance space and overlap it with the daily space, then modify the dance profile points from within the daily profile to the edge of it.

05.2.1 Individual Rotation Point

The second step is to apply maximum space according to the individual rotation point of each movement. Similar to the Kinesphere idea created by Laban Rudolf, individual rotation point also outlines the maximum space for each movement. It divides the body into three parts: arms, legs, and body. In each frame of the movement, a sphere around the point forms a maximum space for that part of the body. The individual rotation points located at the joints of shoulder, pelvis, and hip of the body. Based on an average human dimension, radius of each sphere is:

- Leg 2’10”

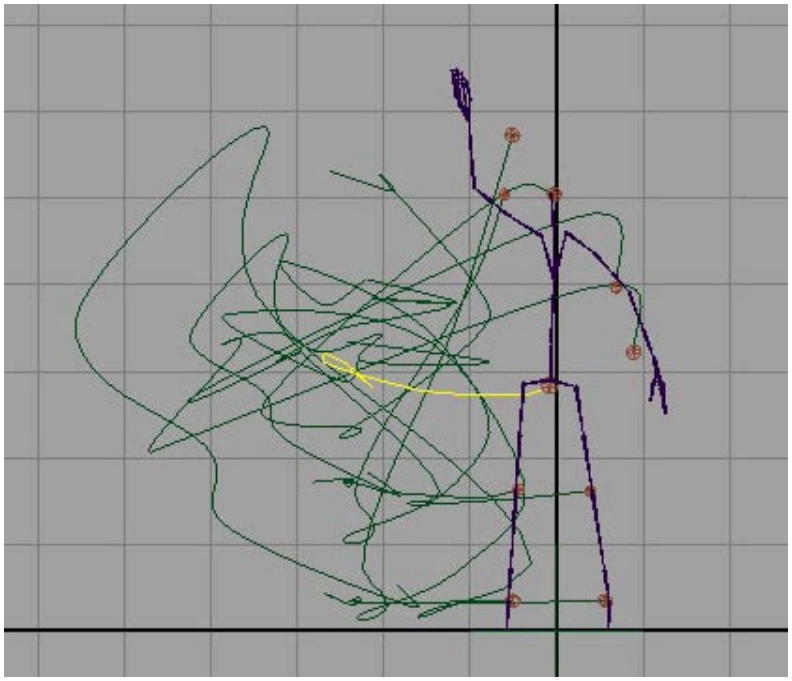


Figure 5.2 Trail of Individual Rotation Point

- Body 2’10”
- Arm 2’

Connecting the frames together with time, a trail made by the points can be traced. The sphere then becomes a tube along the line.

Not every individual rotation point is in use all the time. Depending on the movement, the focus of the movement is used to identify the rotation point. For every movement that we make, there is always at least one individual rotation point to be found in the movement. For example, if we are walking, the rotation point will be on the legs; if we are reaching for something, the rotation point will be on our arms and hands trying to grab an object. Each movement can have one or multiple rotation points. When we create a series of movements, rotation points sometimes change from one to the other.

05.3 **Sectioning Shells**

According to the design concept, the final product of this project is a structure that is transformable between a daily movement space and dance movement space. Daily movement space is created by daily movements have, and the combination of three shells (see Figure 16) creates the dance movement space. Both types

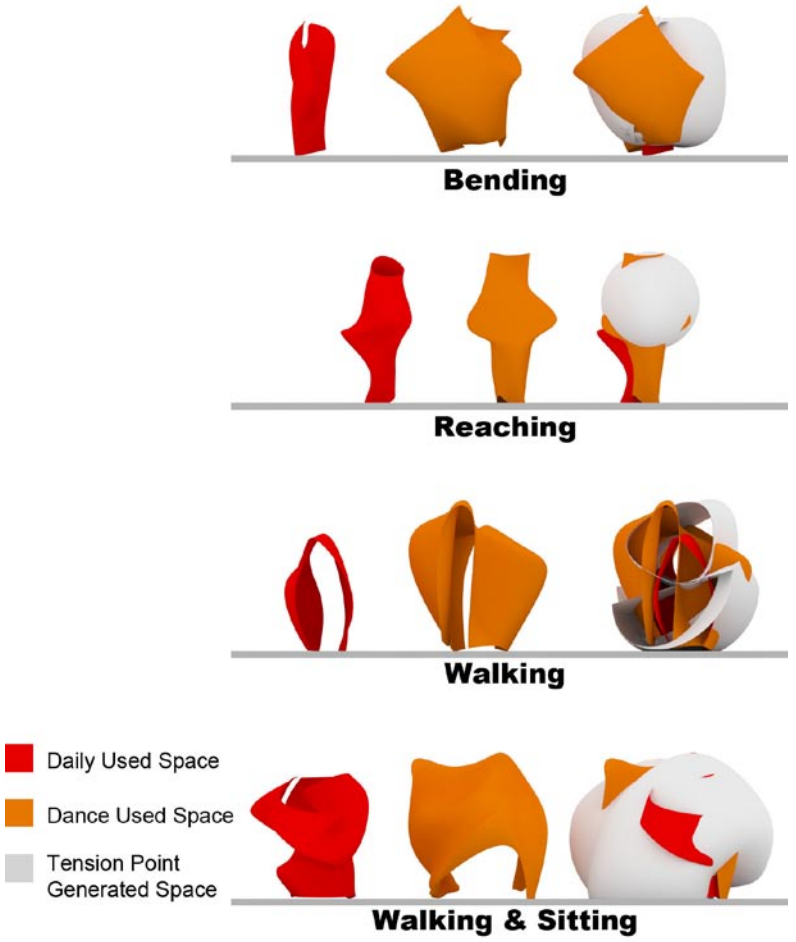


Figure 5.3 Differences Between Daily Movement Space, Dance Movement Space and Maximum Space

of shell were contoured into one foot apart sections. Each section was then traced with a 10 segments line to create a standard. This standard later allows the two different shaped shells to merge into one.

The 10 segments line was then extruded with a depth. It translated the two dimentional lines into a three dimentional object. Each segment now becomes a panel.

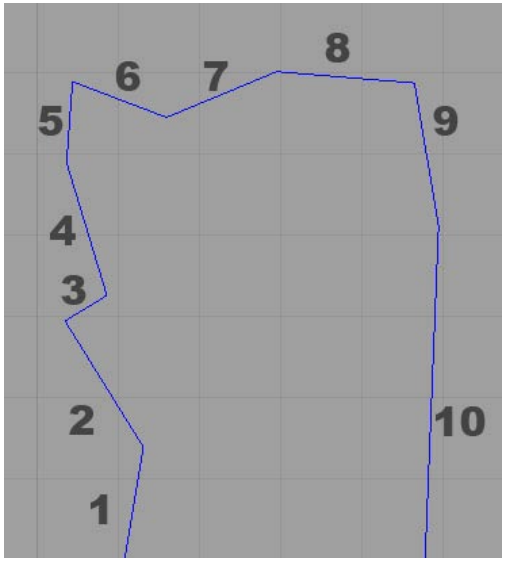
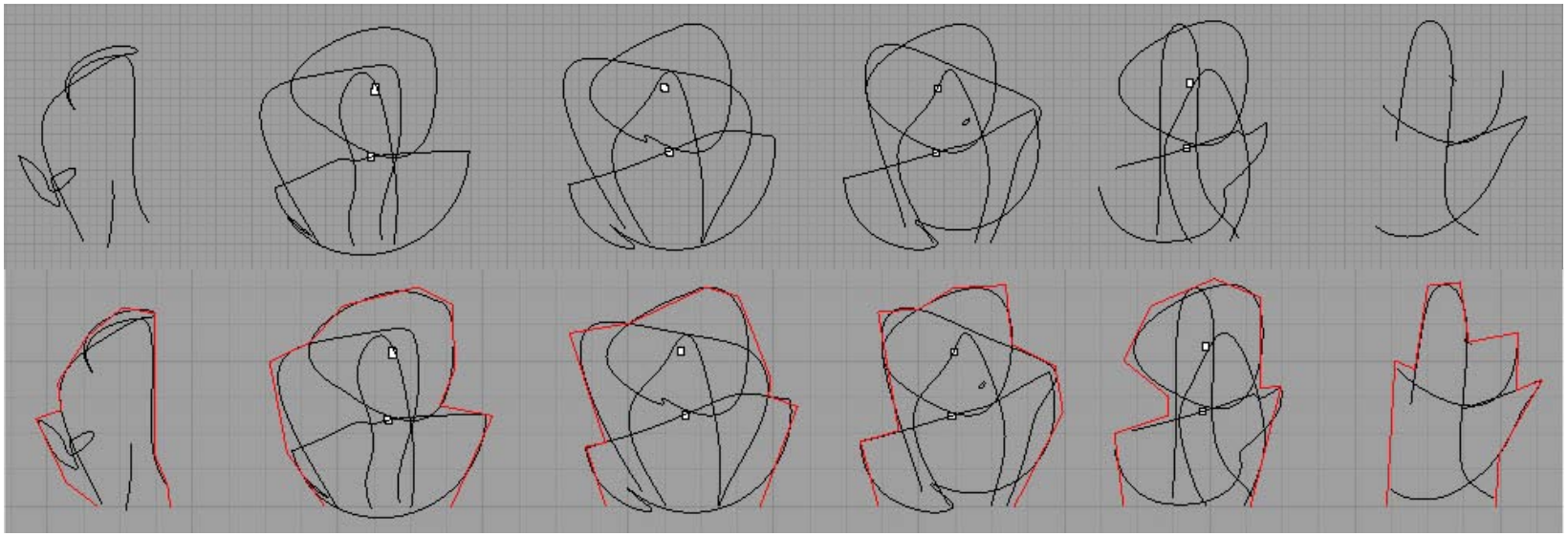


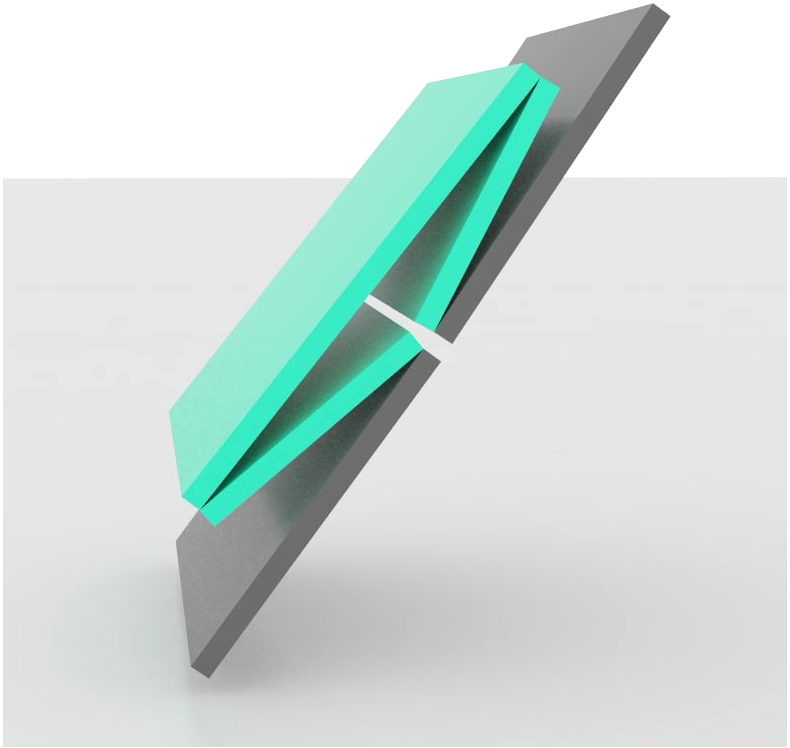
Figure 5.4 (Right) Section with 10 Segment Lines
Figure 5.5 (Below) Apply 10 Segment Lines to Sections



05.4 **Merging Two Spaces into One**

By using the folding method that was explored earlier in Chapter 5, two shapes have been combined into one. Based on the standard 10 segments rule, each panel has a corresponding panel to it. Depending on the length of the panel, the merged one shrinks into a shorter length or expands to a longer length.

Figure 5.6 (Left) Folding System
Figure 5.7 (Right) Segment
Fully Collapes and Fully Opens



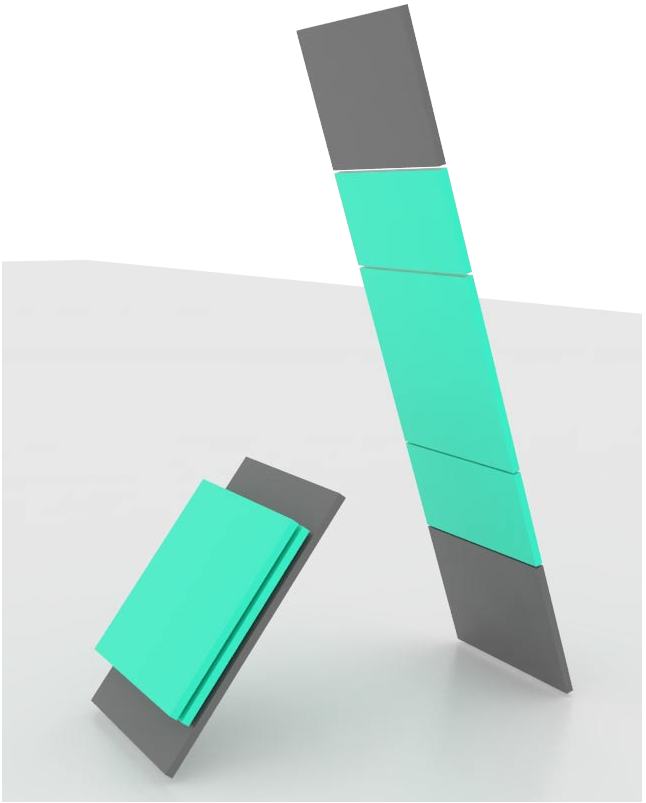
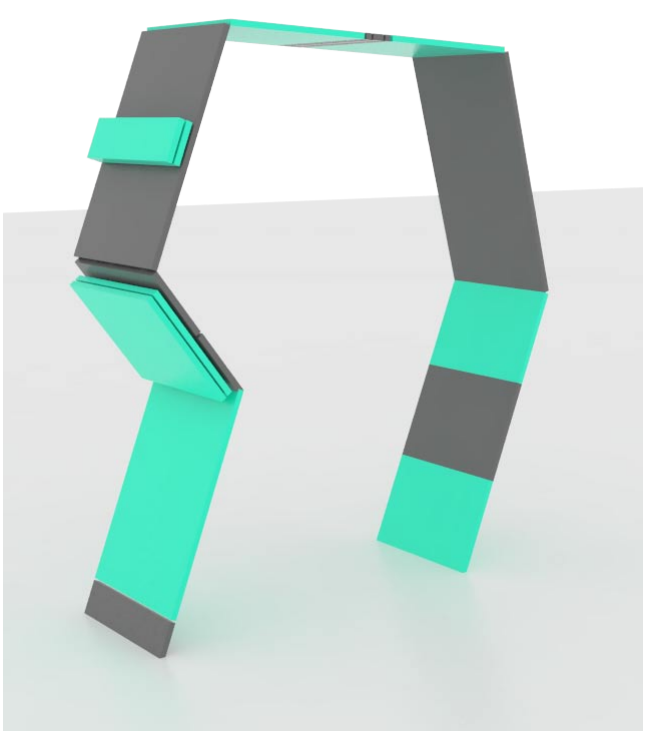
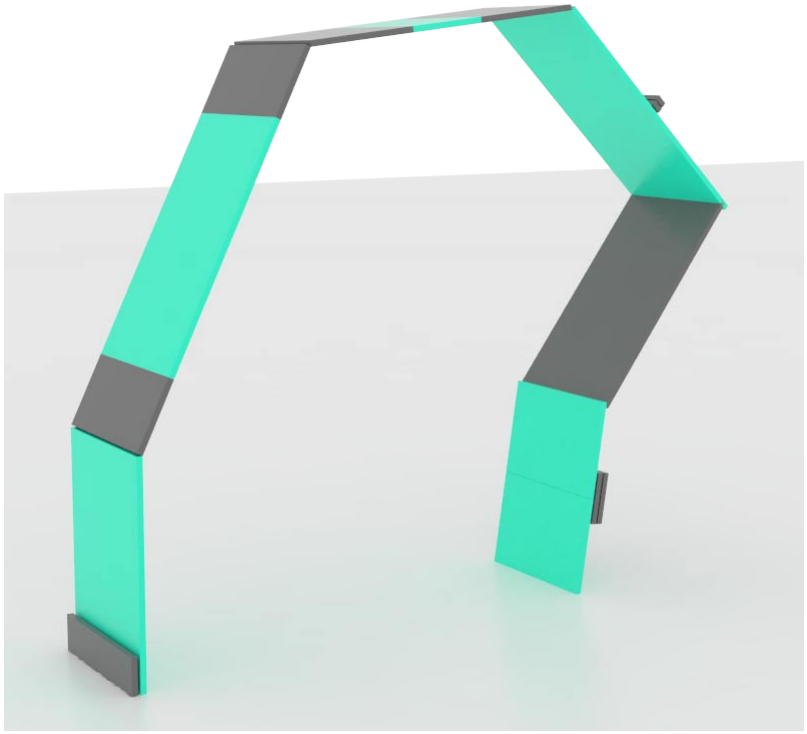


Figure 5.8 (Left) Section Collapes
Figure 5.9 (Right) Section Opens



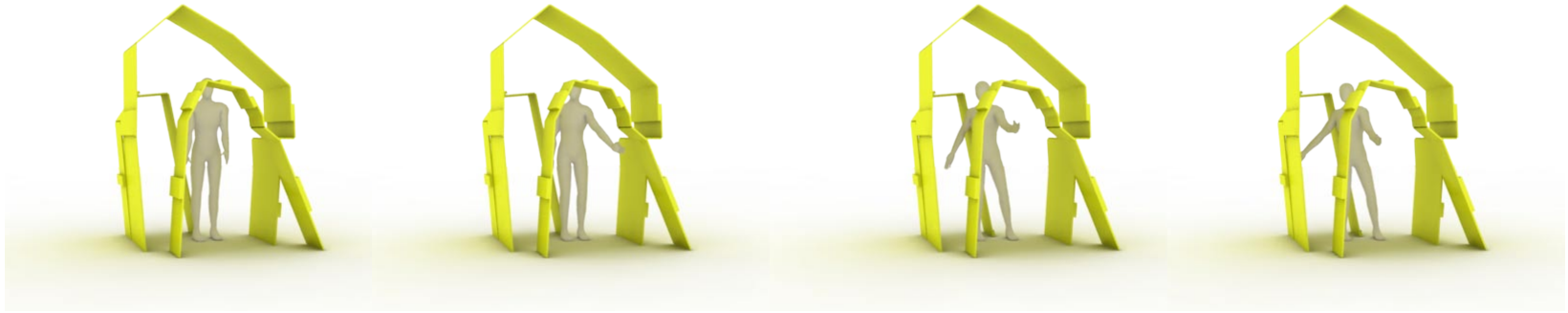


05.5 **Movement and Transformation**

Depending on the capacity of the whole space, every user added to the space shrinks each individual shell by a percentage. A full dance movement space is measured as 100% expansion, and daily movement space is measured as 0% expansion. For example, a space with a capacity of 5 people, user A is making a movement in a 100% dance movement shell, as user B enters into the space, both user's shell will transform into 75% expansion. When the third person comes in, all three shells will transform to 50% expansion.

Figure 5.10 Daily Movement Space (0% Expansion)

Figure 5.11 Dance Movement Space (100% Expansion)



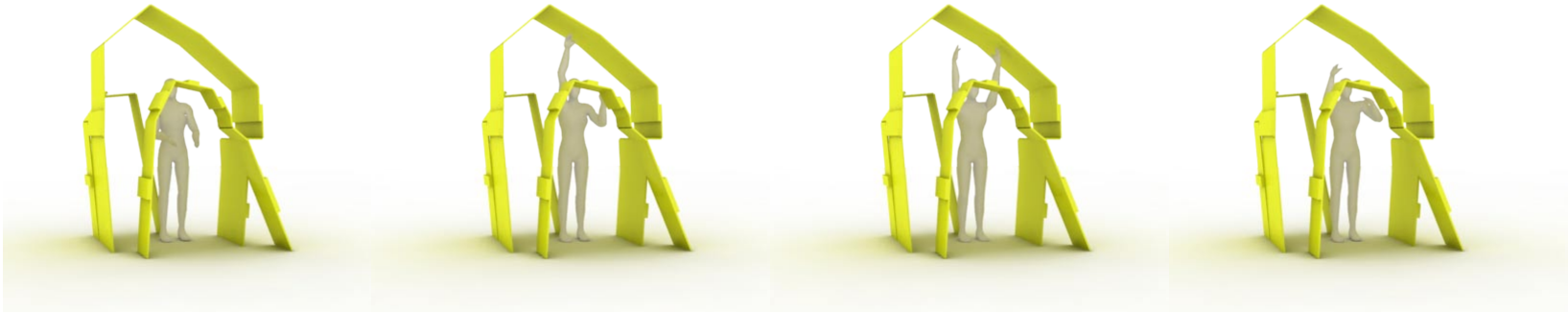
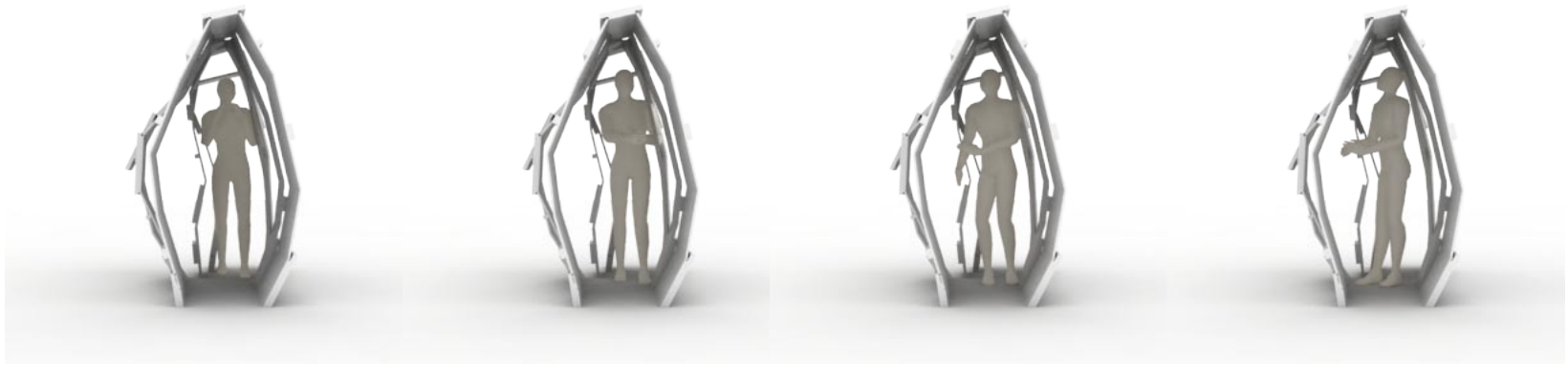
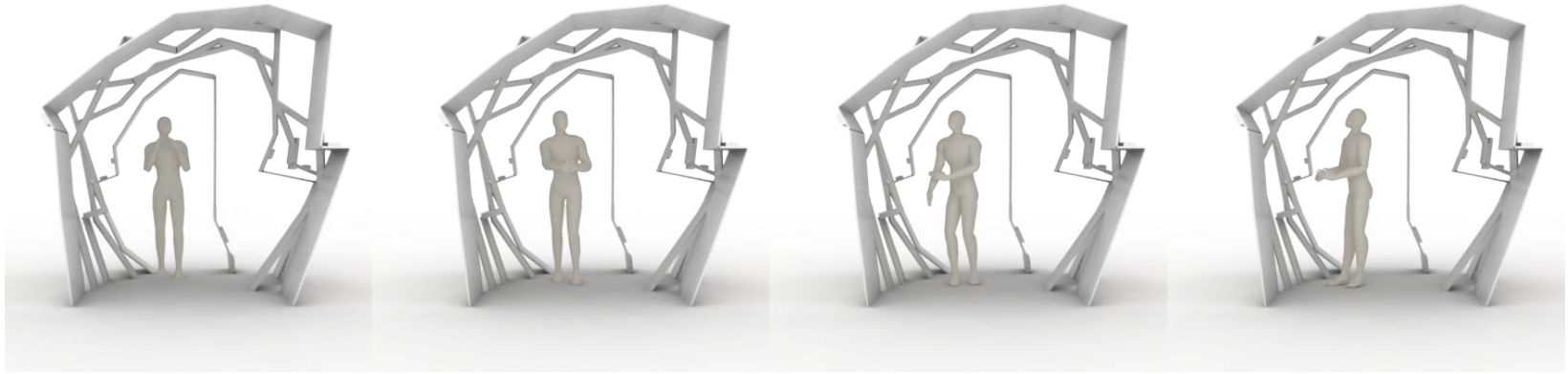


Figure 5.12 Daily Movement Space (0% Expansion)

Figure 5.13 Dance Movement Space (100% Expansion)





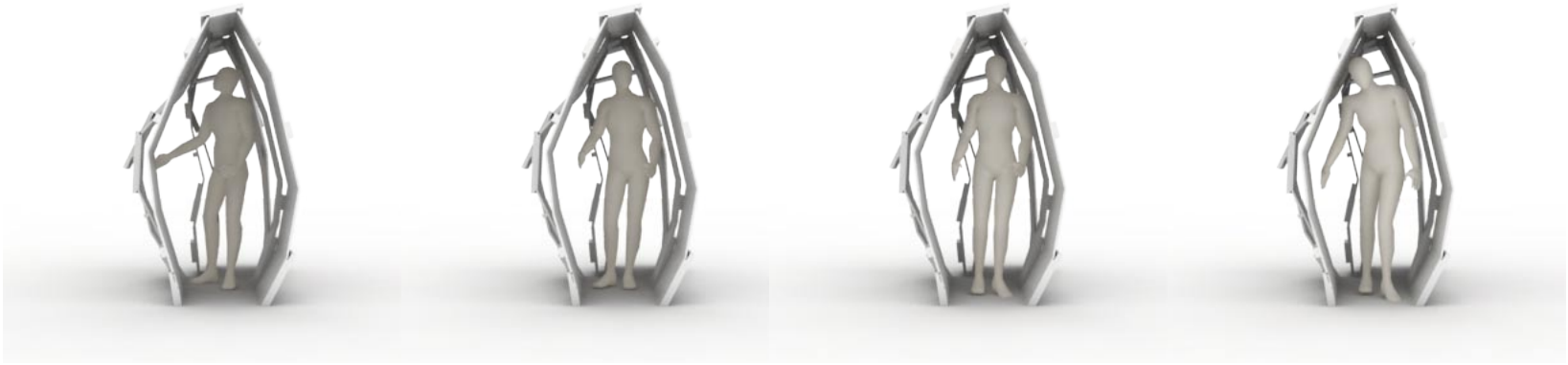


Figure 5.14 Daily Movement Space (0% Expansion)

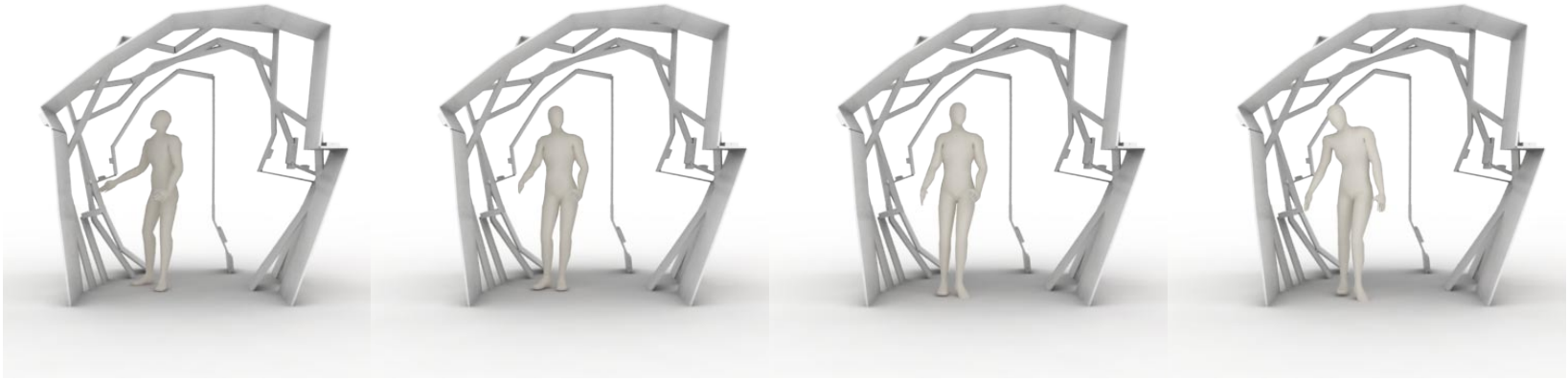
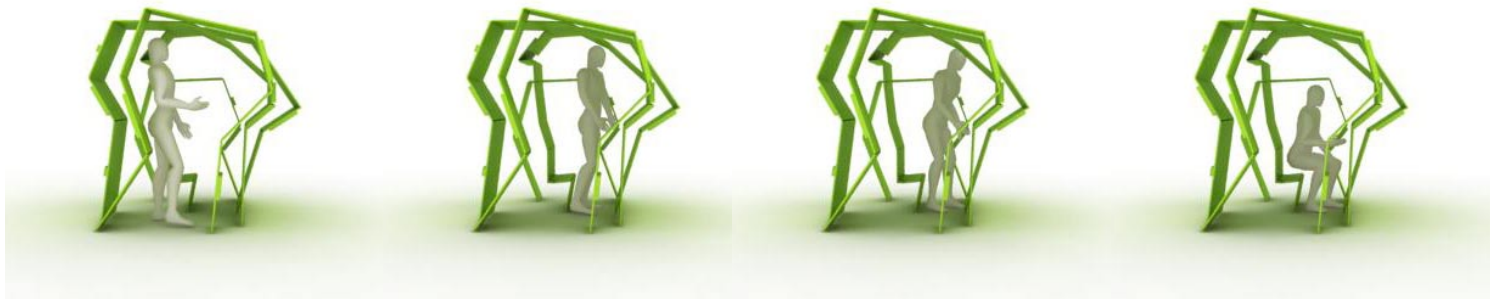


Figure 5.15 Dance Movement Space (100% Expansion)



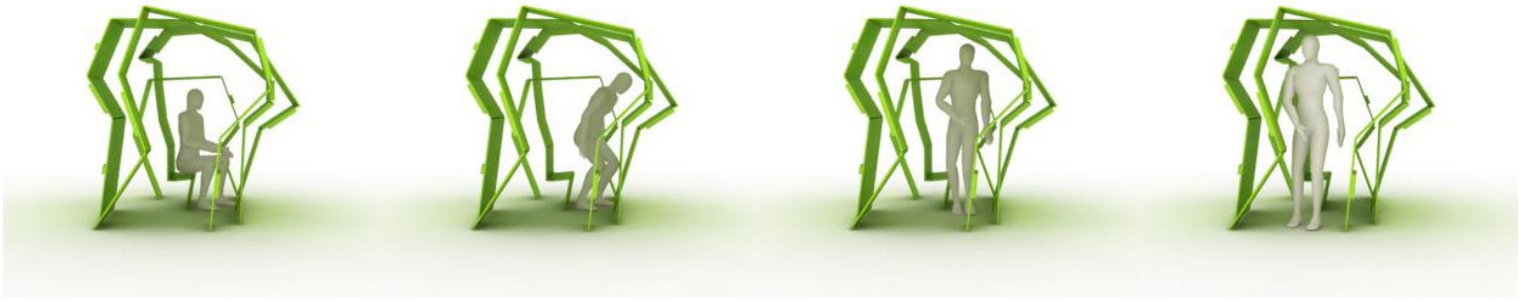


Figure 5.16 Daily Movement Space (0% Expansion)

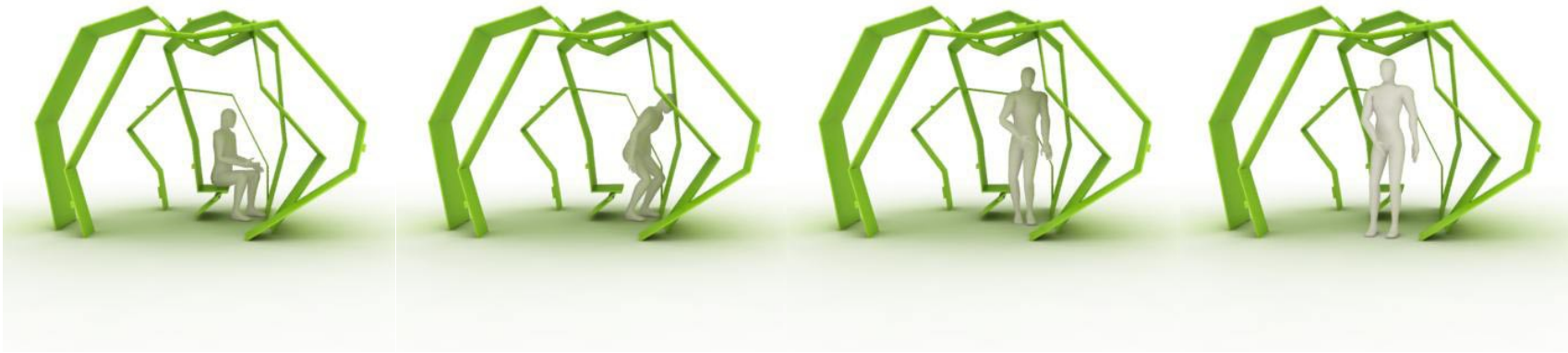


Figure 5.17 Dance Movement Space (100% Expansion)

0%

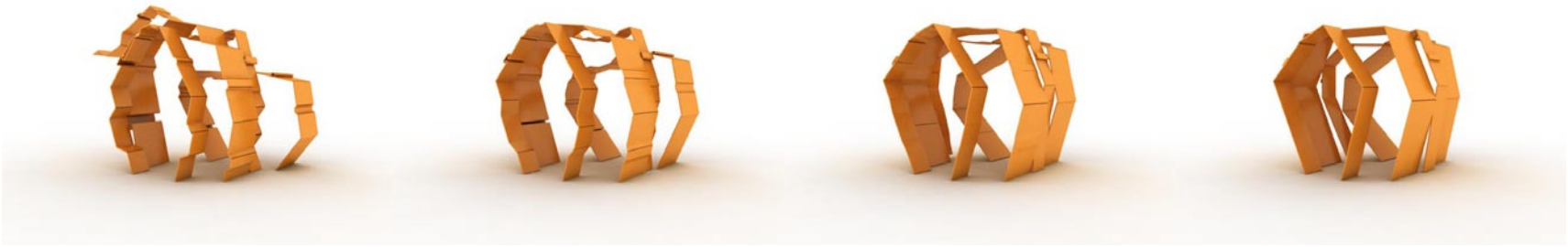


Figure 5.18 Bending Movement Space

100%

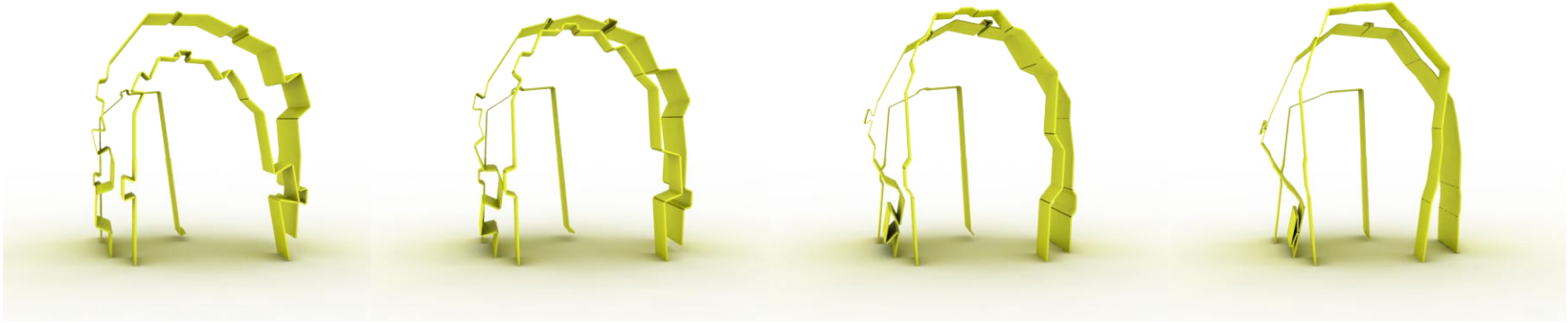


Figure 5.19 Reaching Movement Space

0%

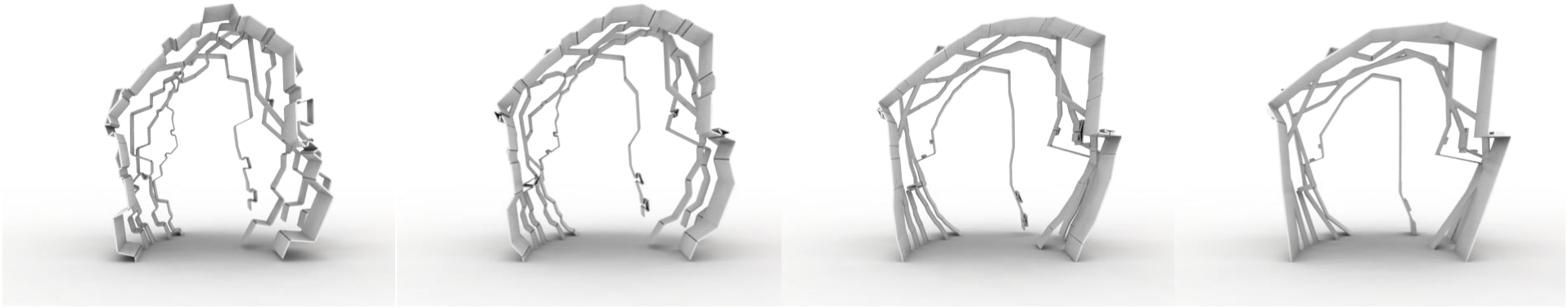


Figure 5.20 Walking Movement Space

100%

Figure 5.21 Walking, Sitting, and Standing Movement Space

1 User → 2 Users

0% → 50%

100% → 50%

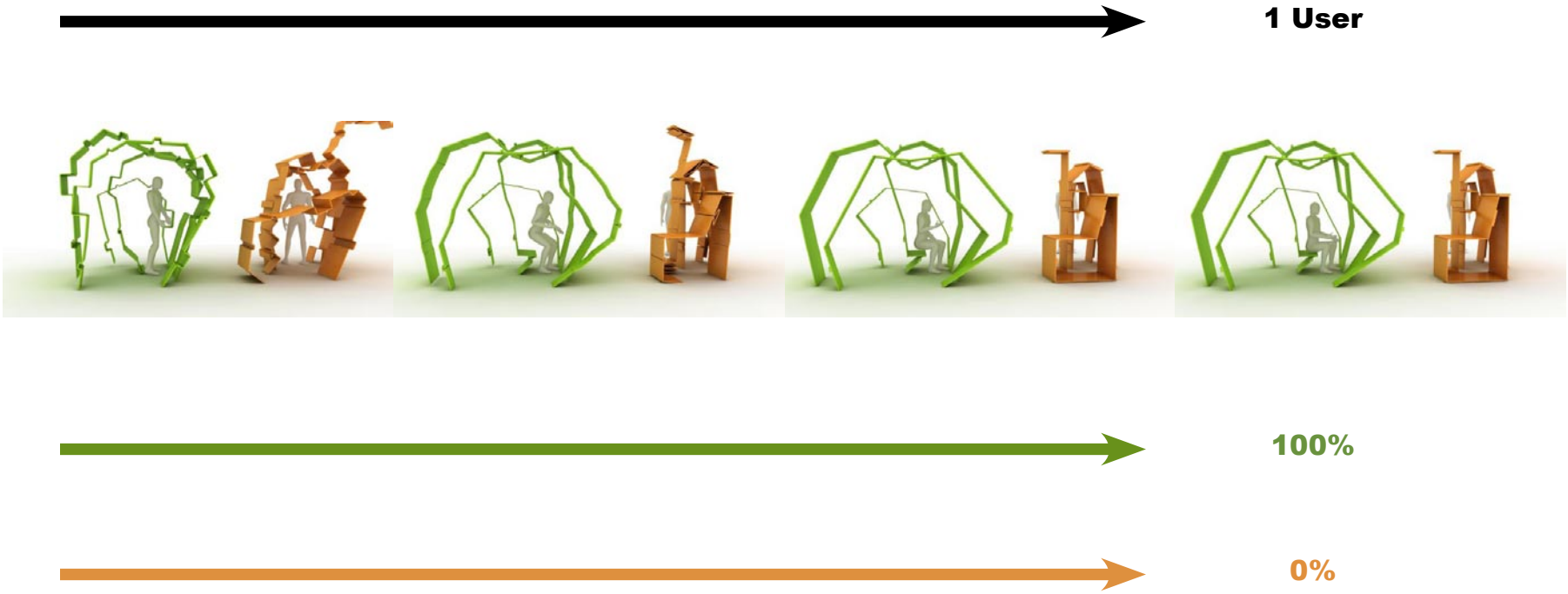


Figure 5.22 Transformation Based on Number of Users

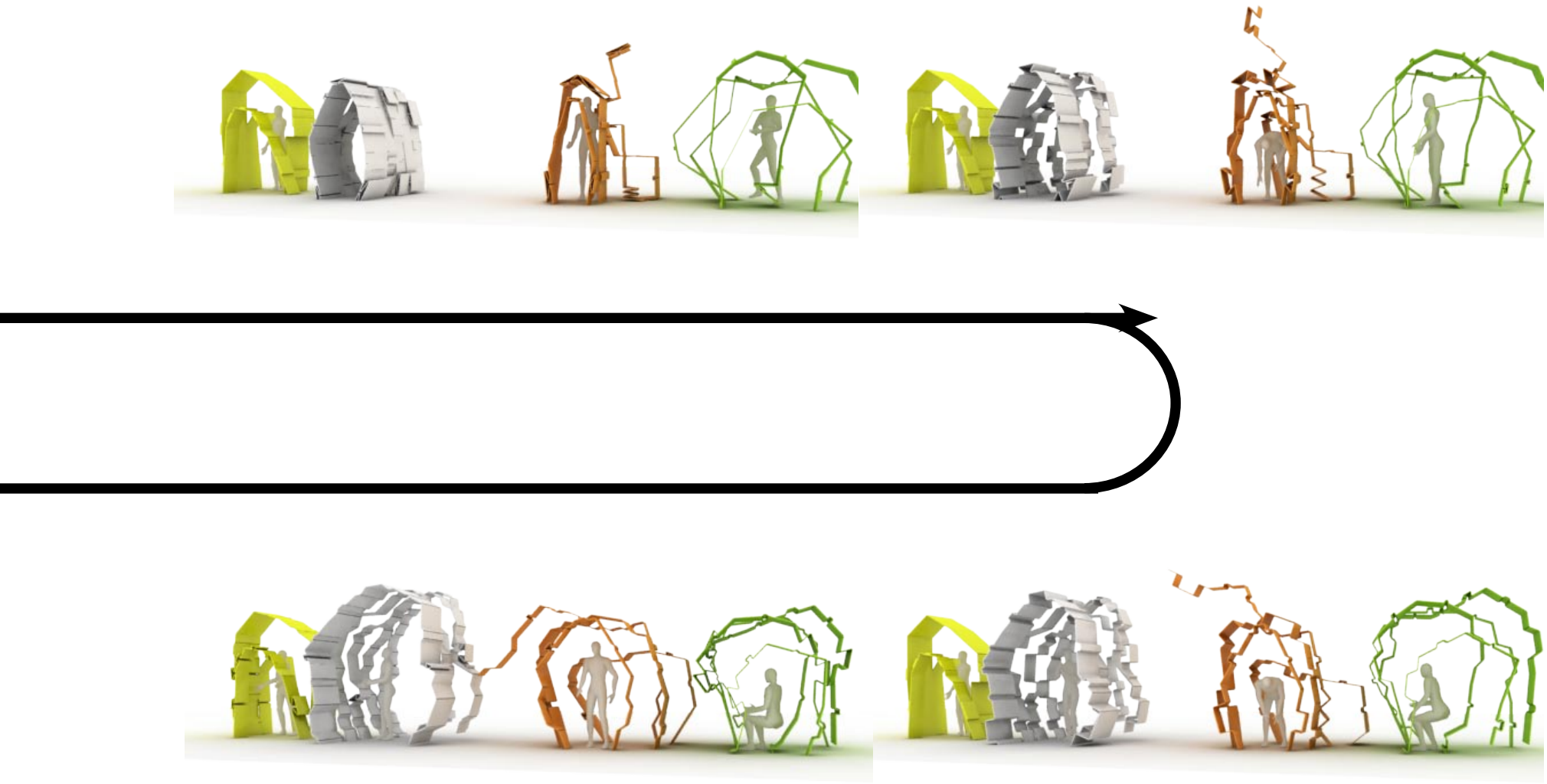


Figure 5.23 Transformation With 4 Users

Figure 5.24 (Top Left) Section 1
Figure 5.25 (Top Right) Full Section
Figure 5.26 (Bottom Left) Metal Hooks
Figure 5.27 (Bottom Middle) Eye Hook
Figure 5.28 (Bottom Right) Wiring System

Conclusion

Due to the increase in population, designing small spaces and increasing the heights of buildings seem to be the trends of future urban architecture. However, this should not lower the quality of the architecture and the spaces within it. In this fast paced world, home is the only place for a person to relax physically and psychologically, so maintaining the quality of human experience within a small space becomes the key to future architectural design. To achieve this goal, many fields of design need to be studied, such as environmental design, human body movement, interior design and sustainable design. This thesis researchs and explores design based on human body movement.

To design space, we first need to understand what space is. In Chapter 2, we understand that space is made of the three-dimensions plus time, so designing space cannot only consider three dimensions, time needs to be involved. How people use space over time is very important. In addition, we need to understand how we move in our daily lives, and what the extremes are of our movements. To do so in this thesis, recording both daily movement in a small space and dance movement was undertaken. As mentioned in the introduction, the hypothesis of this thesis is that dance movements can be seen as an extreme of body movement. As part of the hypothesis, if a space can accommodate dance movement, it can then accommodate all types of daily movement. Finding the balance between the extreme body movement and the limited space becomes a major factor of the design.

The design chooses to shape each body movement space into two extreme, daily and dance. Daily space is seen as the minimum space needed for the movement. On the other hand, dance space had been incorporated with central rotation point to form the maximum needed space. By combining daily used space, dance space, and individual rotation point together, the design found the maximum space for daily movement. However, due to limited data, space is designed for the exact movement. This leads to the design to be not as accurate as expected. To improve this weakness, more movements need to be recorded in order to create the ultimate space for movement. Transformation between two space forms depends on the number of users within a room. This allowed space to be efficiently used and also to maintain the space.

Future exploration

There are two templates this thesis has provided.

One is the digital modeling process as a template for transforming body movement into a physical space. Digitalizing body movement, tracing movement, and translating into physical space allows future designers to create spaces that are user-movement oriented. Second is the idea of individual rotation point. This is a further development of Laban's Kinesphere idea. It is broken down into parts based on the main rotation joints on the body. This allows designers to apply a more detailed space around the human body, especially in dealing with small spaces, every inch counts.

By using these two templates, a few directions can be explored in the future. First, as described in design Option 1, two or more shells can be located in one location. Based on the movement made in that location, different shells can be opened to accommodate the user's movement. Designed as a modular system, one unit can be easily replaced by another. This allows creating maximum efficiency of the space.

The second direction is mentioned in design Option 3. The shell can be transformed into a third shape: furniture. By using the same structural folding system, temporary furniture shapes can be embedded into the folding panels. When both daily and dancing shell is not in use, it can be transformed into furniture. This allows more possibility to happen in one space.

Third, by using the same idea of shell transformation, one shell can be designed based on movement made with multiple users. Similar to recording and applying maximum space to a single body, this option deals with multiple bodies in one shell. The shell shrinks and expands according to the number of users in the space. It expands with more users, and shrinks with less users. This moves the design from personal to community.

Fourth, building interior can also be designed using the two templates. Even without transformation, space can still be designed based on body movement. By recording the same type of movement a number of times, the space can be accurately analyzed. For example, recording bending movement 10 times, each time the movement is different from the others. Combining all ten into one, the space can accommodate 10 different types of bending. The more data there is, the more accurate the space will be. Then one can create the maximum space for daily use by applying individual rotation point into the analysis. Later, personal distances and individual space can be brought into the analysis. Last, all the analyzed space can be collected into one to form the ultimate living space.

What I learned from the thesis?

The first thing I learned during the research were ways to understand space. Physical space is different from psychological space. When we are dealing with one person, physical space is usually the priority of design. The person's experience through space is the key to design. On the other hand, in design with multiple users, psychological space becomes the key. By looking at research that has been done in the past relating to personal space, it is easy to see that we tend to care more about the distance between us and others. One of the main focuses during the research phase was to understand body movement and to be able to identify factors within a movement. I have learned to see both physical body movement and qualities within the movement.

All the explored structural systems were constructed with one piece of paper. Exploring these systems allowed me to see the possibility of constructing structure from a single plane. Even though most of the systems were not able to be used in the final design, they can still be options for future exploration.

As mentioned during the introduction, there is always a constant discussion about architecture design to be form follows function or function follows form. This thesis gave me an alternative way to think about architecture, form follows movement. In addition to that, by using the two templates, I am able to design alternatively.

Figures / Case Studies Sources

Figures

Figure 1.1	Yishan Fu - Author
Figure 1.2	Yishan Fu - Author
Figure 1.3	Reinterpreted image of Three-Dimensional Space of Demonstrative Pronouns. Kuniko Hashimoto, Kazuhiko Nishide, Takashi Takahashi. “The Reference Domains of the Three-Dimensional Space Based on the Demonstrative Pronouns.” Journal of architecture,planning and environmental engineering. Transactions of AIJ no. 552 (2002): 155-159, page 157. Yishan Fu – Author
Figure 1.4	Yishan Fu - Author
Figure 1.5	Yishan Fu - Author
Figure 1.6	Reinterpreted image of Proxemic. Hall, Edward T. The Hidden Dimension. [1st] ed. Garden City: N.Y., Doubleday, 1966, page 117-118. Yishan Fu - Author
Figure 1.7	Reinterpreted image of Kinesthesia. Hall, Edward T. The Hidden Dimension. [1st] ed. Garden City: N.Y., Doubleday, 1966, page 117-118. Yishan Fu - Author
Figure 2.1	Video recording of Signal rehearsal, (Dancer: Carolyn Wilt). Yishan Fu - Author
Figure 2.2	Video recording of Signal rehearsal, (Dancer: Carolyn Wilt). Yishan Fu - Author
Figure 2.3	Video recording of Signal rehearsal, (Dancer: Spencer Garrod). Yishan Fu - Author
Figure 2.4	Video recording of Signal rehearsal, (Dancer: Carolyn Wilt). Yishan Fu - Author
Figure 2.5	Video recording of Signal rehearsal, (Dancer: Carolyn Wilt). Yishan Fu - Author
Figure 2.6	Video recording of Signal rehearsal, (Dancer: Carolyn Wilt). Yishan Fu - Author
Figure 3.1	Yishan Fu - Author
Figure 4.1	Yishan Fu - Author

Figure 5.11 Yishan Fu - Author
Figure 5.12 Yishan Fu - Author
Figure 5.13 Yishan Fu - Author
Figure 5.14 Yishan Fu - Author
Figure 5.15 Yishan Fu - Author
Figure 5.16 Yishan Fu - Author
Figure 5.17 Yishan Fu - Author
Figure 5.18 Yishan Fu - Author
Figure 5.19 Yishan Fu - Author
Figure 5.20 Yishan Fu - Author
Figure 5.21 Yishan Fu - Author
Figure 5.22 Yishan Fu - Author
Figure 5.23 Yishan Fu - Author
Figure 5.24 Yishan Fu - Author
Figure 5.25 Yishan Fu - Author
Figure 5.26 Yishan Fu - Author
Figure 5.27 Yishan Fu - Author
Figure 5.28 Yishan Fu - Author

Case Studies

Case 1	Video recording of Signal rehearsal, (Dancer: Sarah Carlton). Yishan Fu - Author
Case 2	Video recording of Signal rehearsal, (Dancer: Sarah Carlton). Yishan Fu - Author
Case 3	Video recording of Signal rehearsal, (Dancer: Carolyn Wilt). Yishan Fu - Author
Case 4	Video recording of Signal rehearsal, (Dancer: Madeline Lammers). Yishan Fu - Author
Case 5	Video recording of Signal rehearsal, (Dancer: Sarah Carlton, Madeline Lammers). Yishan Fu - Author
Case 6	Video recording of Signal rehearsal, (Dancer: Sarah Carlton, Madeline Lammers). Yishan Fu - Author

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