Social Actuator: Interactive kinetic space that responds to variable activities

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Abstract

Public space is expected to address variable occupational cycles across a given space and time. The recent rise of individual public spaces presents an opportunity to analyze the needs and potential advantages of active and direct responsiveness to individual needs in collective spaces.

The Social Actuator is an interactive kinetic public space. The Social Actuator creates a personal and social public space while facilitating internal human activities based on occupants' potential desire for resting while accommodating their physical diversity. The selected public space test bed; Wurster Hall hallway provides the conceptual and physical scaffold of a dysfunctional public space where exchange, pause, and transience differences are required and unsatisfied. The interactive component is a responsive wall system that can transform locally for people to sit or lean on if needed, and globally to accommodate programmatic needs and mediate human interactions.

Keywords

Embodied Interaction, Interactive and kinetic architecture, Individual public space, Physical comfort, Psychological comfort, Personal space

Design Background

1. Individual public space and potential advantages of active responsiveness

1.1 Active inhabitants and Passive architecture

Architecture is often modulated by its inhabitants for their individual needs, however buildings are typically passive structures that do not respond physically to human inputs. For private spaces, adjusting space for personal needs is feasible so that occupants take an active role for optimizing and utilizing their own space. However, for public space shared with strangers and occupied temporarily, adjusting the space is difficult and occupants become passive to personalize the space. On top of that, often times there are frictions among people sharing the place. These frictions are more or less invisible, since occupants cannot claim the space as their own, however their presence in the place claims their own space physically and psychologically.

figure 1. Frictions among people sharing a public space

figure 2. Frictions among people sharing a public space

1.2 Individual use of un-programmed public space

While the development of mobile devices such as smart phones and laptops releases people from specific work places and make it possible for them to be where they want to, un-programmed public spaces are getting popular as a place to be for personal use. As un-programmed public spaces attract more people and become individual public spaces, the friction among people is increasing and creating more chances to make uncomfortable situations. For example, a set number of fixed seats is sometimes in the way when there are big flows of moving people, and sometimes they are not enough or not distributed properly for people who are staying relatively longer.

Public space is expected to address variable occupational cycles across a given space and time. The recent rise of individual public spaces presents an opportunity to analyze the needs and potential advantages of active and direct responsiveness to individual needs in collective spaces.

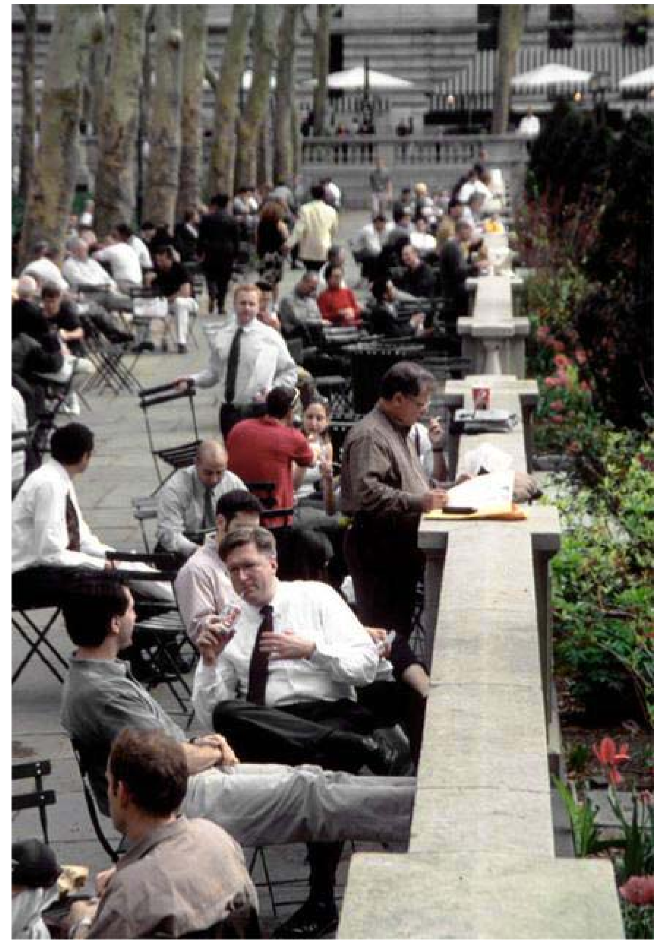


figure 3. Individuals or small groups of people occupying a wall in a public space

1.3 Architectural precedents of un-programmed public space and its engagement with people
: UN Studio, Burnham Pavilion, Chicago, USA, 2009

Pavilion is a type of architecture that does not have specific assigned program. Burnham Pavilion designed by UN Studio is an open space with thick undulating surfaces draping from the ceiling that function as columns. It is a three dimensional object from a distance since its form stands out from the surroundings and clearly exclaims its presence rather than creating a void. As you get into the space, however, it gives a new perspective of the pavilion, which is a gesture of embracing people.

What is most interesting is people's intuitive engagement of their body with the structure. They sat or lied down on the raised platform around the edge, or leaned on the tilted walls for a conversation. The pavilion facilitated longer stay by providing implicit physical support. Children engage their bodies more actively, playing with their shadows cast on the wall by touching them, or sliding down the wall and so forth.

The Burnham Pavilion not only accommodated people's activities but also encouraged social interactions by attracting people with its radical form and promoting staying with physical supports.

figure 4. UN Studio, Burnham Pavilion, Chicago, USA, 2009

figure 5. Children engage their bodies more actively.

1.4 Precedents of interactive architecture
:Rob Ley and Joshua G. Stein, Reactive Void, 2007

This research project was driven by asking "How can furniture scale objects move beyond the functional and instead operate as an interface between humans and their larger spatial environment? How can technology move beyond intelligent gadgetry and socialize space?" [1] These are questions that seem particularly relevant to me whenever I encounter interactive works.

The Reactive Void achieved two great potentials of interactive architecture. It relates mechanical movement to molecular scale of material movement for local and global morphological adaptation of the system. They used Nitinol wire which is a type of Smart Memory Alloys (SMAs) and considered as a reliable smart material. This technology makes the motion of the system "fluid and subtle" as opposed to the mechanical movement.

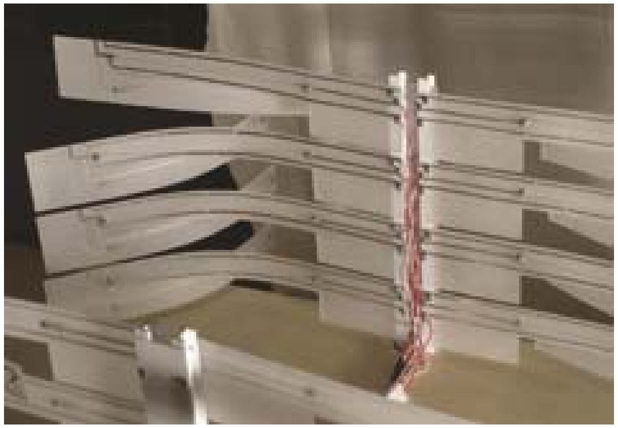


Figure 6. SMA embedded in the fins of physical scale model

The other achievement is that the system actively contributes to the human social interactions as well as dynamic circulation patterns in the given space. The fins create pocket spaces by bending themselves, offering an intimate place for a small group of people. The quality of transforming from linear two-dimensional surface to volumetric object, and from impermeable barrier to porous visual connection is a great advance for a flexible object, breaking the perception of space not by varying surface texture, but by participating in the space. In the space, "the human body becomes aware of its behavior in relation to its surroundings, creating a dialogue between body and space that is in

1 Rob Ley and Joshua G. Stein, "REACTIVE VOID: SOCIALIZING SPACE THROUGH REPONSIVE TECHNOLOGY", 2007 AIA RFP Program report, 2007, p 3

sharp contrast to our default understanding of space as static and impersonal context."[2]

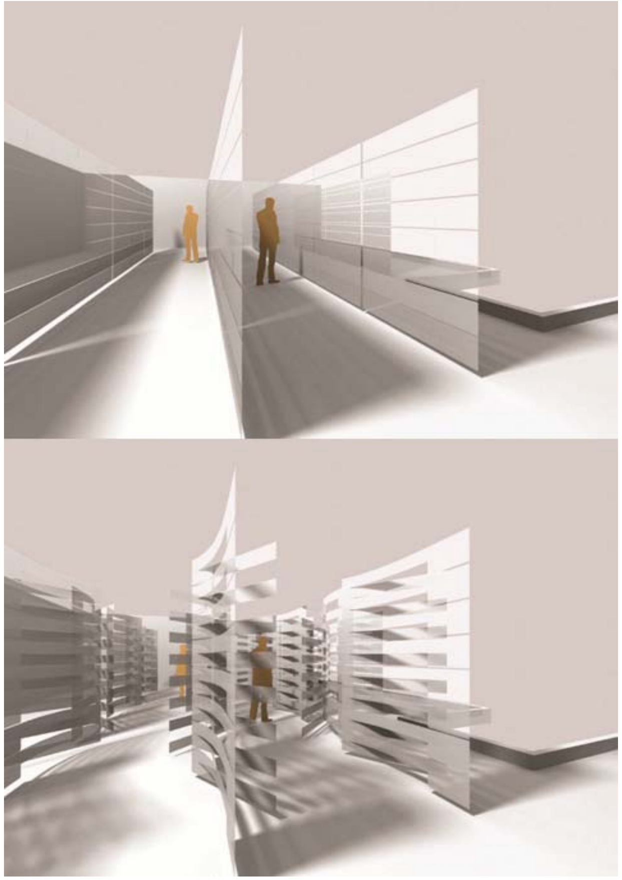


figure 7. Perspective rendering of spacial transformation, Rob Ley and Joshua G. Stein, Reactive Void, 2007

The Reactive Void is still in the stage of research, not tested as a full scale prototype. Rob Ley and Joshua Stein created a full scale installation work; Reef, which utilized the same technology as Reactive Void, however it does not do anything that they claimed as "an active socializing agent."[3] The main restriction is the thin and light fin, which is inevitable for the system since the Nitinol wire cannot carry heavy material with it. Lack of rigidity is a critical limitation of the system which prevents its use for primary elements of a building that is not temporary.

A number of architectural projects explored dynamic responsivity to individuals. Most of them are either a facial / ambience change or a kinetic object separated from a building, which does not affect overall spatial configuration nor support internal human activities. However, the technology shows great promise and will open a new type of reciprocal relationship between human and space. This potential of an interactive system will become convincing as a design strategy when the objectives of the system are clearly defined for integrating performance, effect and emotion within an occupiable structure. Hence, the application of the technology needs to be explored more to reach the level of seamless integration with architecture and to play a vital role in spatial quality.

2 Rob Ley and Joshua G. Stein, "REACTIVE VOID: SOCIALIZING SPACE THROUGH REPONSIVE TECHNOLOGY", 2007 AIA RFP Program report, 2007, p 3

3 Rob Ley and Joshua G. Stein, "REACTIVE VOID: SOCIALIZING SPACE THROUGH REPONSIVE TECHNOLOGY", 2007 AIA RFP Program report, 2007, p 16

Design Strategy

2. Interactive kinetic public space that responds to diverse individuals and variable activities

How can a public space become personalized and provide individual comfort for a temporary stay while various occupants share the space? How can a public space promote duration of occupancy and create desirable atmosphere for social interaction?

The dynamic and spontaneous responsivity of physical computing has great potential for architects to address the issues of diversity of occupants and changing needs for a public space through automatically adaptable integrated building systems.

This project is to build a reciprocal relationship between humans and space by actively engaging the human body through an embodied interactive system. Presence of a human body and it's scale in a space establishes the relationship and the interaction with the space as well as between people sharing the space. The objective of the project is to create a personal and social public space while facilitating internal human activities based on occupants' potential desire for resting while accommodating their physical diversity.

2.1 Design references for individual comfort in a public space

There are a number of aspects that need to be considered for individual comfort in a public space. "Personal space" is one of the important factors which influence the way that people share a public space. It is the area around a person which they regard as psychologically their own. When it is invaded, the victim often feels discomfort, anger, or anxiety. This tension contributes to how people locate themselves in a public space unconsciously and leads them to disperse in a limited area. The size of personal space is highly variable and depends on the person and situation, but the Diagram of Edward T. Hall's personal reaction bubbles (Figure 8) shows an estimated dimension of the personal space.

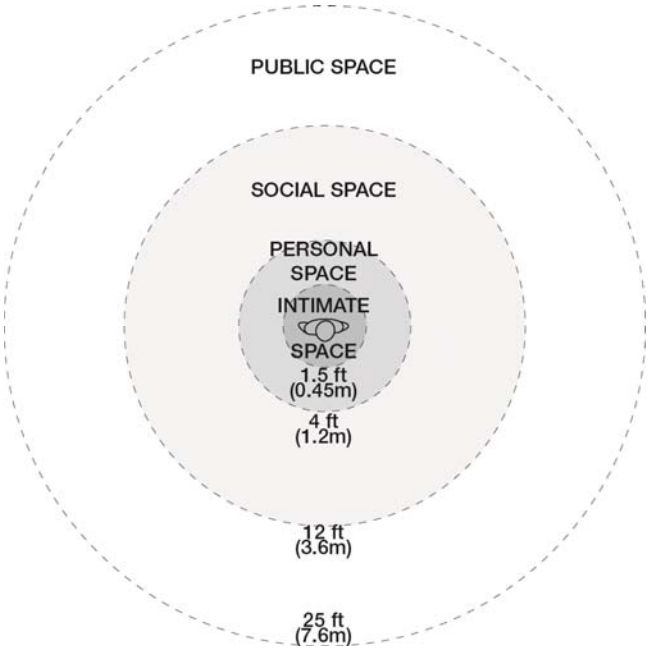


figure 8. Edward T.Hall, "Personal reaction bubbles"

Another critical factor for individual comfort is physical adaptability to the diverse human body. To design an adjustable system to various human bodies, I took Henry Dreyfuss Associates' book called 'The measure or man and woman' as a reference for a range of human factors. Henry Dreyfuss is one of the celebrity industrial designers of the 1930s and 1940s and a pioneer applying ergonomics, anthropometrics, and human factors to product development. An industrial design consultancy, Henry Dreyfuss Associates published this book based on the large quantity of data they accumulated over more than 40 years. The data in this book embraces 98% of the adult population which lies between the 99 percentile and the 1 percentile.

"It is not customary to design for everyone. The few at either end of the normal curve any be so extreme that an encompassing design could become too large or expensive to produce. The military chose to exclude 5 % at the small end and 5% of the large end, thus accommodating 90 % of the measured population in the Military Standards. The 5% value is called the 5 percentile, and the 95% value is called the 95 percentile."[4]

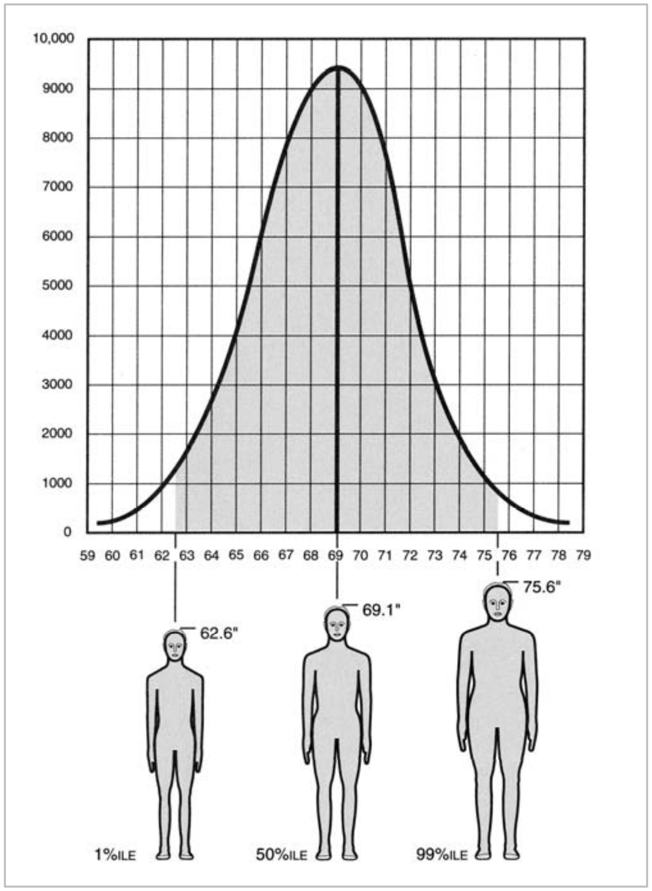


figure 9. Frequency Distribution Curve, Henry Dreyfuss Associates, The measure or man and woman, 1993

4 Henry Dreyfuss Associates , The measure or man and woman, 1993

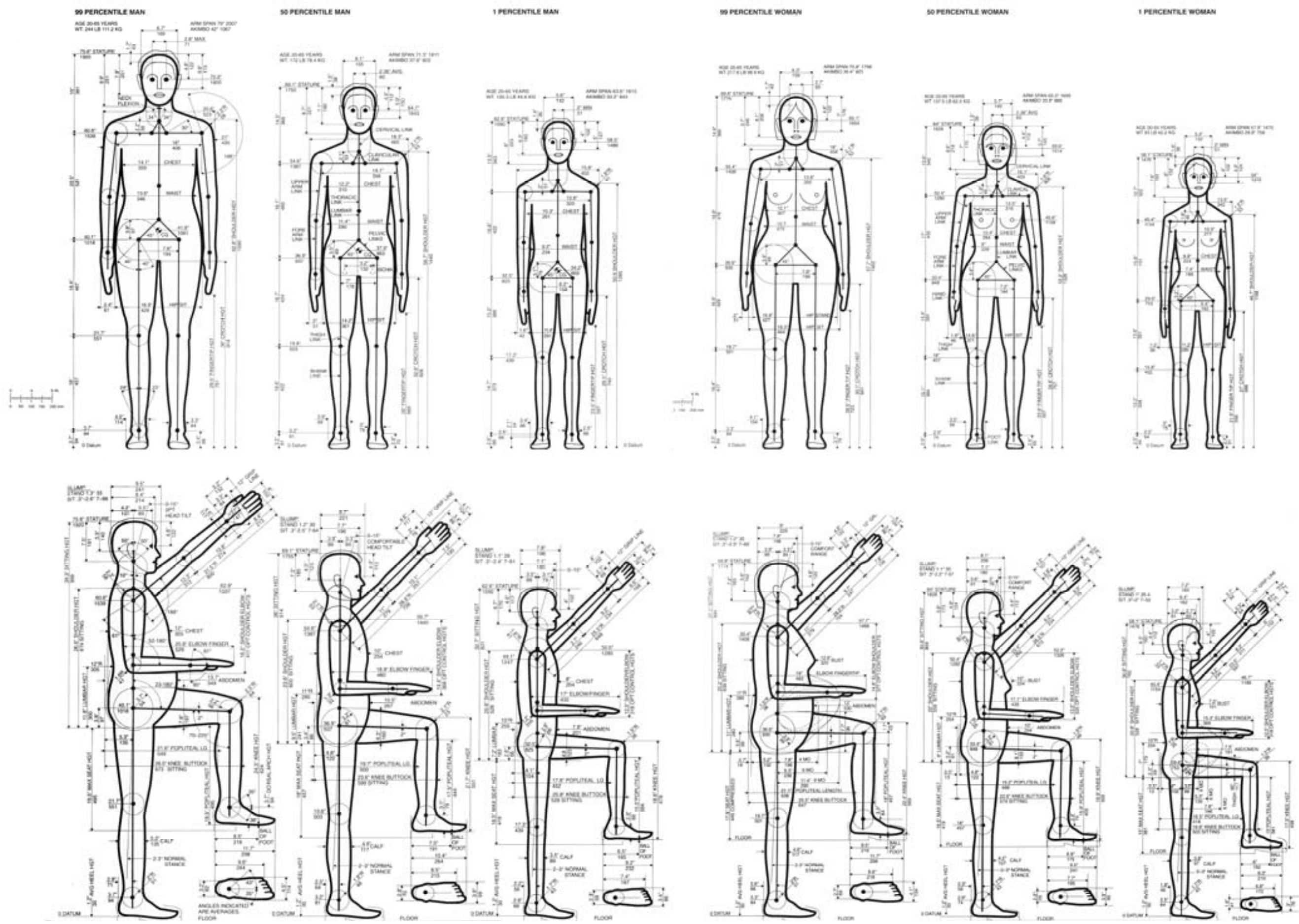


figure 10. Measurement of 1, 50 and 99 percentile man and woman, Henry Dreyfuss Associates, The measure or man and woman, 1993

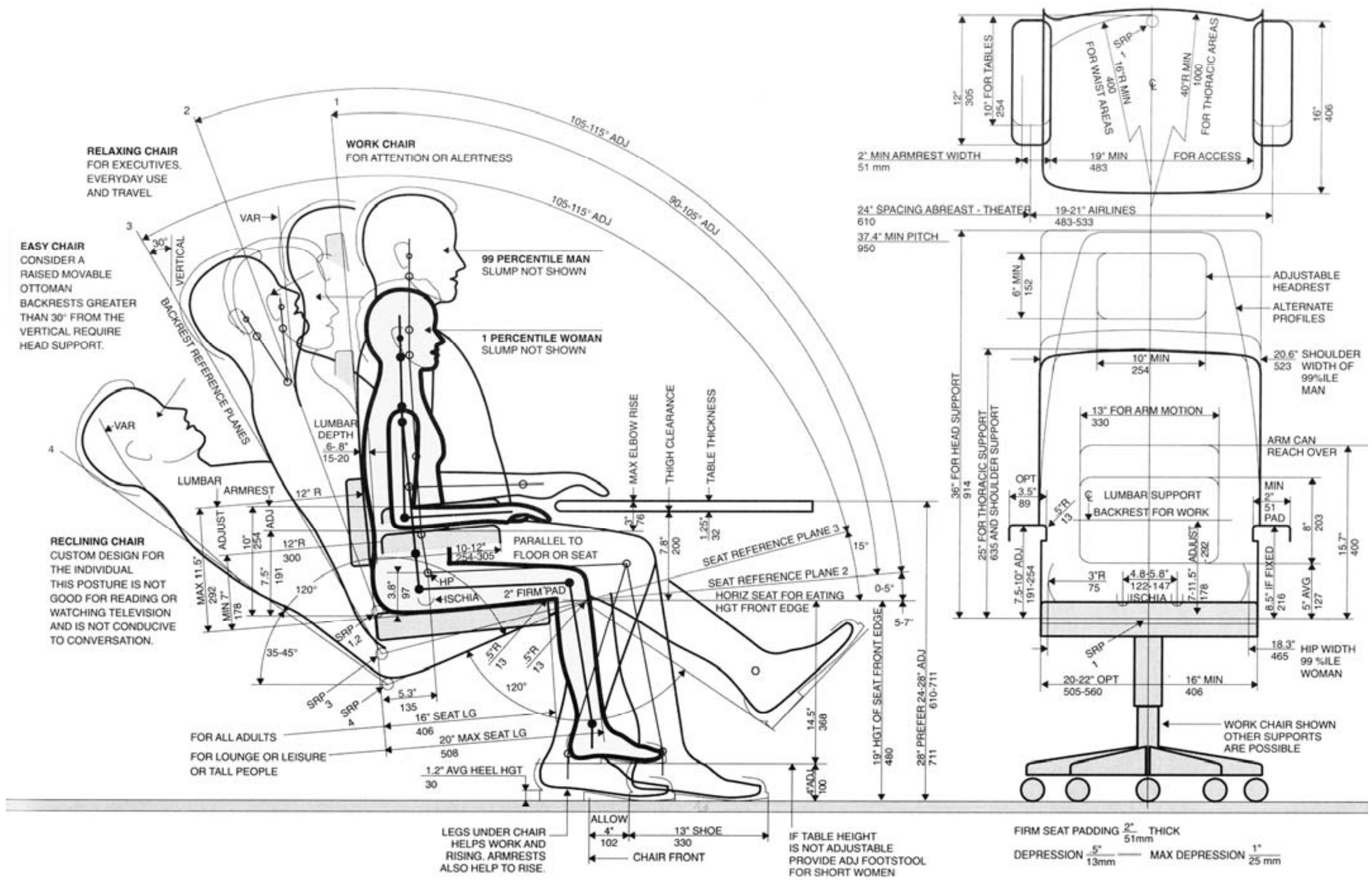


figure 11. Dimension of a chair accommodating from 1 percentile woman to 99 percentile man,, Henry Dreyfuss Associates, The measure or man and woman, 1993

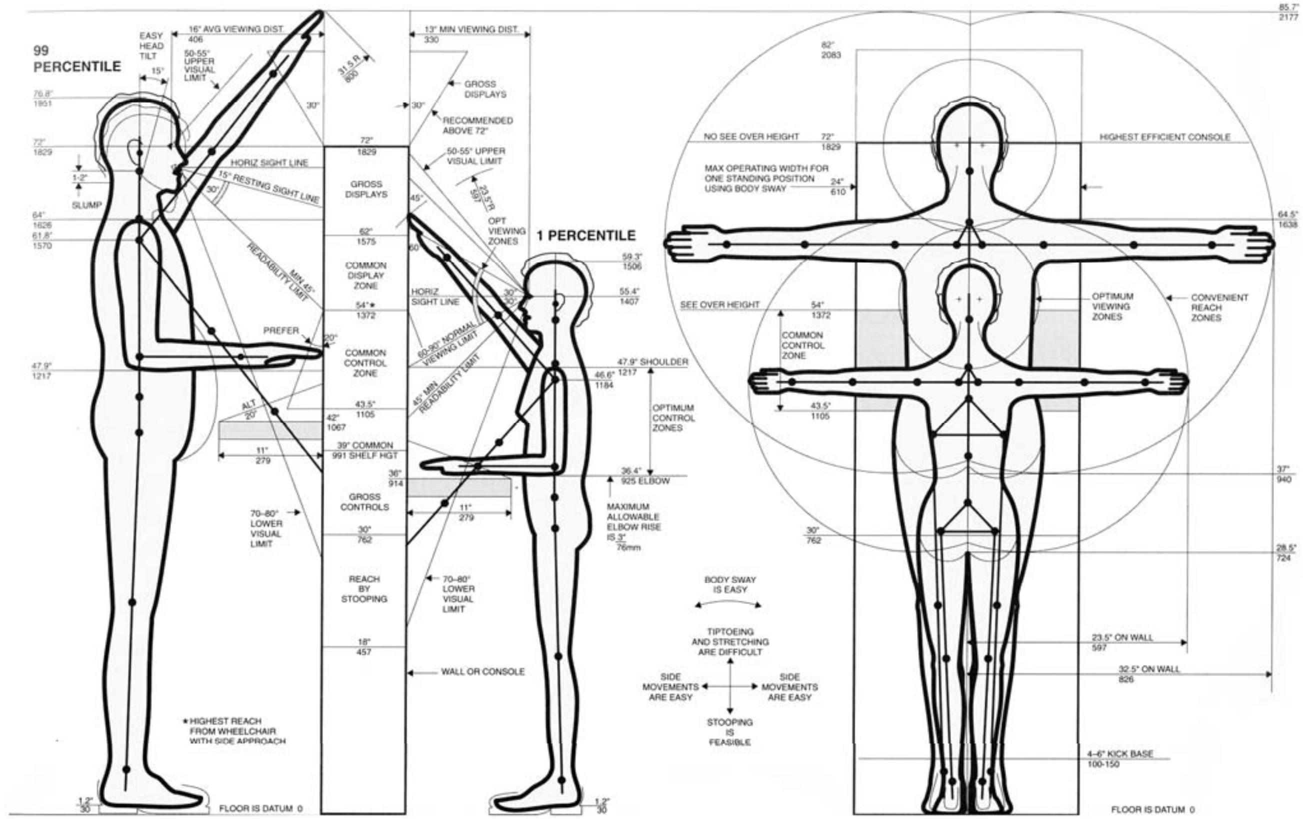


figure 12. Dimension of a kiosk accommodating from 1 percentile woman to 99 percentile man,, Henry Dreyfuss Associates, The measure or man and woman, 1993

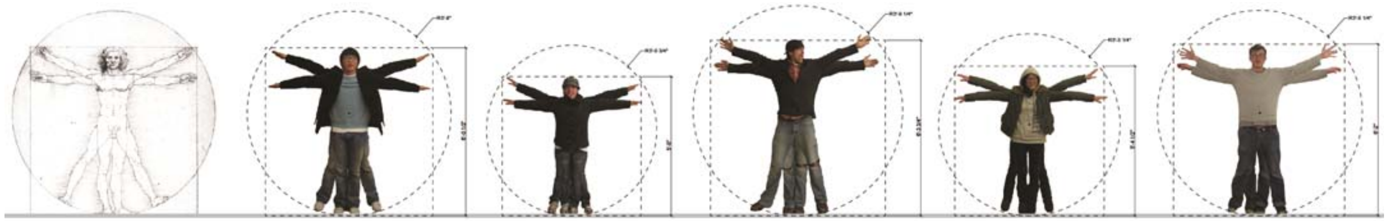


figure 13. Diagram of various types of human body

2.2 Scope of Design proposal

The project is to develop a spatial system that can be built through available technology and material which is affordable and reasonable to be realized for a public space. It is to design a practical application utilizing existing technology rather than an exploration of new possibilities. The final goal of the project is to investigate people's engagement with the proposed responsive space and various modes of actuation of the interactive system.

Fabrication efficiency is critical for the cost of production. In the process of the design development, a number of decisions were made to pursue effective use of resources.

2.3 Test Site

The test site had to meet several criteria. It had to a public space with more potential needs for the dynamic responsivity to enhance its function of limited space area, of fluctuating occupancy, and of diverse individual activities. Possible sites are listed below.

- Gathering place

- Transitional space (ex. hallway, lobby, movie theater waiting area, arcade)

- Service space (ex. waiting room, train platform, bus stops)

- Space for relaxation, refreshment (ex. courtyard, pavilion)

For test site selection, I investigated public areas of the Wurster Hall; College of Environmental Design building in University of California at Berkeley, since it is the place where I can analyze the activities over a period of time, and the spatial quality supporting them.

The bridge space on the 3rd floor of Wurster Hall is a space where the architecture department graduate office, faculty offices and graduate student instructor (GSI) offices are located. It also serves as a main pathway connecting the North and South wings of the building for students to walk through from the studio work spaces on higher floors in the North wing to facilities in the South wing. The majority of people who move through or occupy the space are regular occupants of the building.

The faculty offices are around the edge of the building, so that the offices have windows to let natural light in. The GSI offices are placed in the middle of the space and have deep ceiling openings which allow ambient light in. Consequently the hallways surrounding the GSI offices do not have any access to natural light, and are very dark all the time, even with artificial lights on. The space has two linear hallways.

figure 14. Light quality of the space

One of them is nine feet wide and serves as a main pathway to the offices on both sides as well as to the other wing of the building. The other hallway is only four feet wide at the back side of the GSI offices and serves only as a path to the faculty offices on one side. During the day, one may often find students waiting to speak with professors or GSIs outside of their offices in the main hallway. Also it is a place where professors run into each other every day and have casual or serious conversations. The hallway is busy with migrating students, even at night.

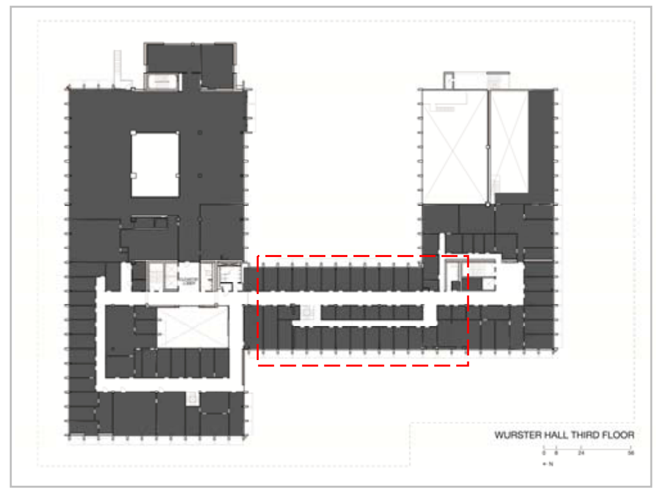


figure 15. Wurster Hall Third Floor Drawing and Selected Site

However the hallways are certainly not a pleasant space for a temporary stay because they do not provide any physical support. Students waiting for meetings mostly lean on the wall while staying, but when it gets longer they sit on a classroom chair if they find one around or just sit on the floor. Also, the hallways do not facilitate a small conversation well, since they are linear spaces where passers-by are not inclined to stop to chat, and interactions are often very awkward. Furthermore, they lack quality light as mentioned before. Even though the space is on the top floor in the bridge portion of the building, which could have access to a skylight, existing skylight openings are contained in the GSI offices in the middle, which are mostly underused.

figure 16. People sitting on the floor while waiting

2.4 Site analysis

To investigate the activities occurring in the space, I installed two surveillance video cameras, one for each hallway, for a week. Also, I collected data of weekly GSI office hours and other times that the offices are in use through contacting GSIs.

Most of the GSIs do not use their offices for times other than their office hours, and even some of them do not held their office hours in the offices because of their unpleasant spatial quality. The chart of regular weekly occupation of the GSI offices (Figure 17) shows that the offices are underutilized. The busiest one is in use officially only for seven hours per a week. Also there is no moment when all offices are occupied at the same time. The number of people in a meeting is relatively small, ranging from two to four, and the number of groups having meetings in the space does not exceed four at a time.

On the contrary, the main hallway is extremely busy. In the analysis of Tuesday afternoon from 12:00 to 18:00 from the surveillance video, 598 people entered the hallway for six hours. Figure 17 shows that there is huge number of people walking through the hallway spending less than one minute and they are mostly less than three people at a time. Meanwhile there are people staying more than ten minutes doing variable activities. Here is the list of activities mapped from the surveillance video categorized by physical status.

[Moving]
- Walking through

[Standing]
- Waiting
- Reading
- Looking at bulletin boards
- Making phone calls
- Having improvised conversation

[Sitting]
- Meeting
- Waiting
- Reading

figure 17. Occupancy analysis

Through the analysis, I found that there is an opportunity in the space to support occupants better by opening up the existing GSI offices and having responsive space to the variable activities. There is no need for the GSI offices to be enclosed completely for meetings because they should keep the office doors open during meetings due to the school policy. Having an open space with an adaptable wall system that creates half enclosed spaces and provides seats, would reduce residual spaces and utilize them to facilitate dynamic internal activities. By revealing the skylight openings for the open area, it would be naturally lit and provide a more pleasant space, allowing regular occupants to take a break, mingle, or have improvised conversation.

Design Proposal

3. Social Actuator

The Social Actuator is an interactive kinetic public space that responds to diverse individuals and variable activities. The interactive component is a responsive wall system that can transform from a primarily two-dimensional surface to a three-dimensional object that people can sit or lean on if needed and mediate human interactions.

3.1 Local scale of adaptability

The components of the wall need to be structural since the transformed portion cantilevers from the wall and supports human weight. Wood and non-stretchy fabric are used as primary materials because of their structural qualities: wood is stronger in compression, and the fabric in tension.

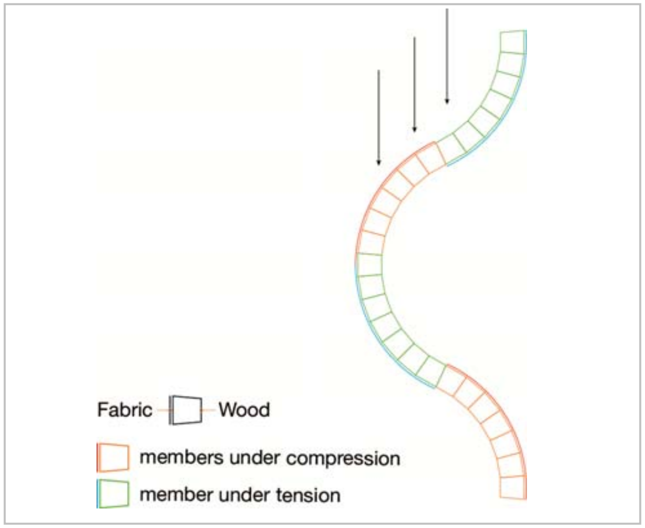


figure 18. Section Drawing of geometry and material that carry compression and tension

figure 19. A Series of study models

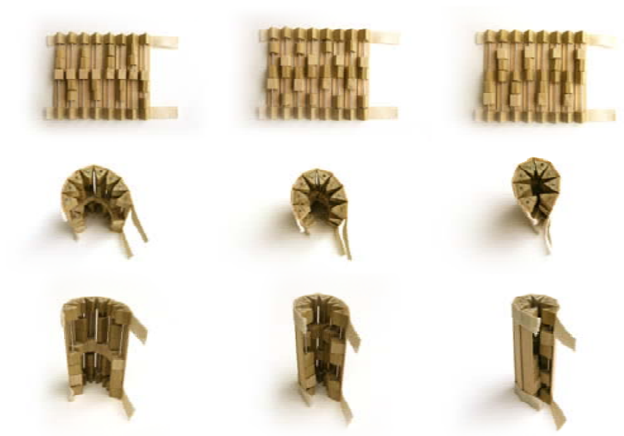


figure 20. Study model exploring micro level of adaptability; the different combinations of sliding wood parts of different profile makes various curvature of the deformed surface

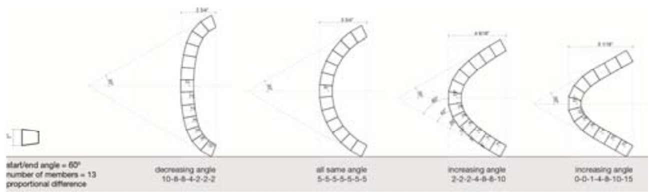
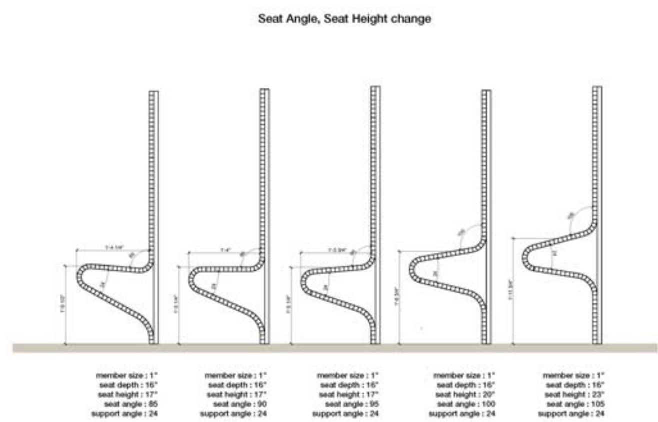
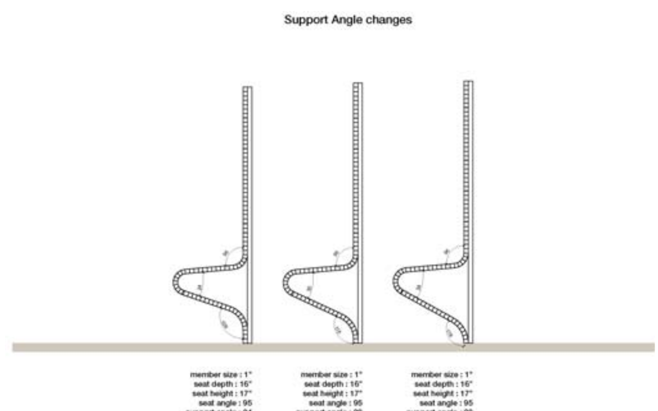


figure 21. Morphology study of member profile and surface curvature

To reach the level of adaptability that accommodates diverse body types and physical needs, the surface needs to be flexible enough to morph into various forms, but still remain rigid under human weight. Figure 21 is a surface curvature morphology study based on member profile. The angle of the top and bottom sides of the members changes to create various forms. The study model in Figure 20 is one way of accomplishing the level of adaptability by having different combinations of sliding wood parts of different profiles attached at the back of each member. This sliding “bracket” system demonstrates a possibility of having flexibility of a deformed rigid surface using conventional materials.





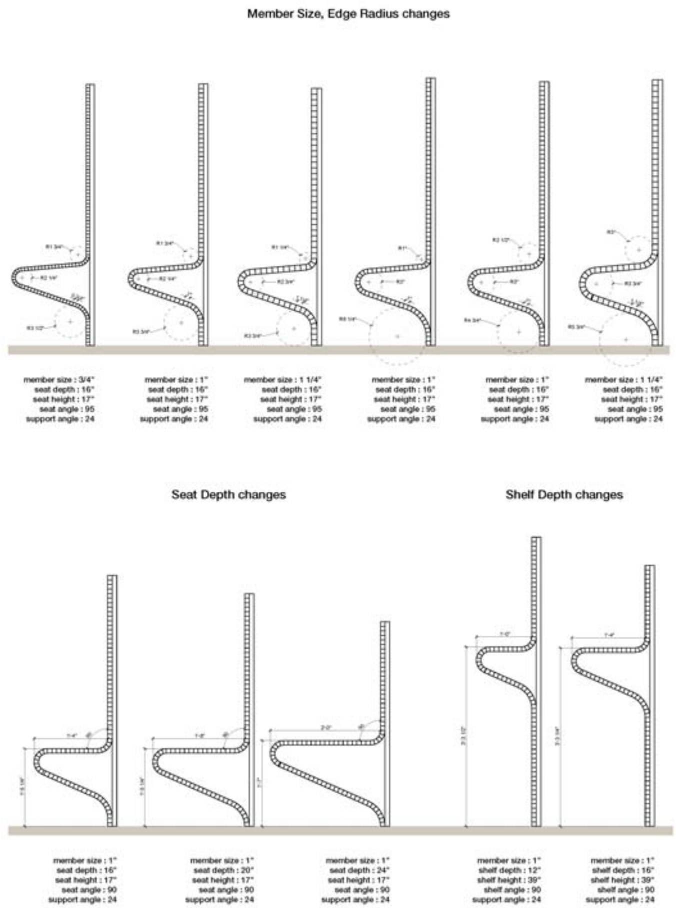


figure 22. Possible changes of the module for different needs

Figures 22 shows possible adaptabilities in the module through parametric modelling. In these studies, the member size and member profile angles in each curvature are consistent in a module for fabrication efficiency.

3.2 Global scale of adaptability

For programmatic spatial response to different phases of occupancy, the wall system subdivides the space into areas of various sizes. Figure 23 is a series of cases showing how the wall system responds to various occupancies by creating spaces from open to half-enclosed.

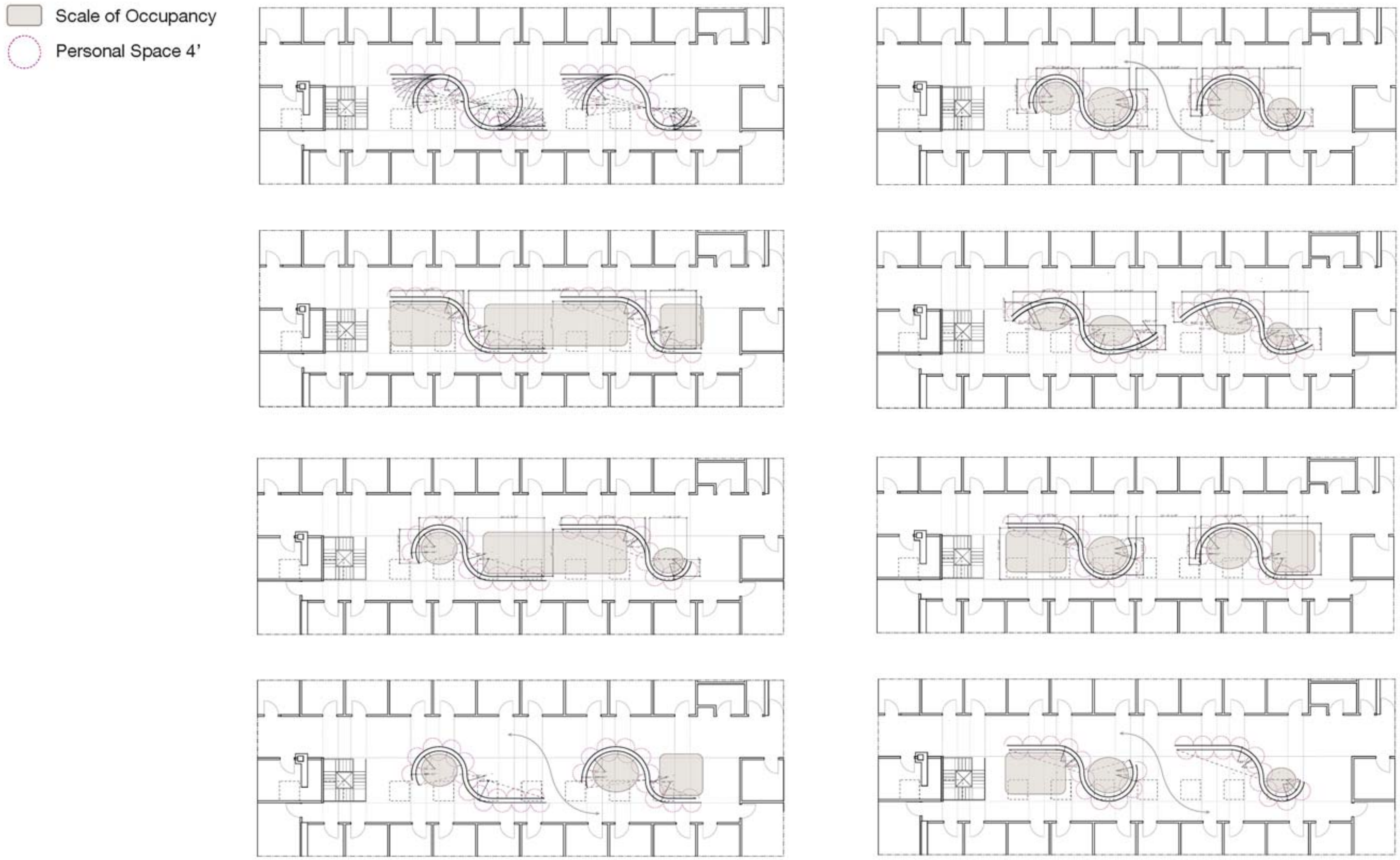


figure 23. Programmatic spatial response of the wall system to different phases of occupancy

3.3 Scenarios for actuating the system

I propose two scenarios for automated response to occupants. The first scenario (Figure 24) is an implicit implementation of actuation, where in the system gets triggered by physical contacts with the human body. The system measures the time of continuous physical contact to estimate needs for physical support before actuating the transformation. It has embedded Force Sensing Resistors (FSR) that detect the pressure of a person leaning on the wall and CMOS cameras that measure the frame of the person and approximates the body weight. By calculating the percentage of pressure that gets transferred to the system from the body as well as the time of contact, a micro-controller triggers the actuator for the movement mechanism.

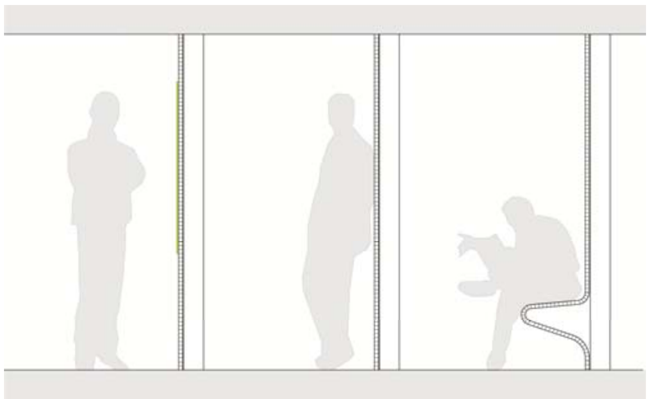


figure 24. An implicit implementation of actuation where in the system gets triggered by physical contacts with the human body.

The second scenario (Figure 25) is a more active response to people's movement by sensing with imbedded infrared proximity sensors. This is more explicit and spontaneous, and challenges conventional perception of architecture as a static structure. People would be aware of their movement through a new medium, allowing a new type of activities to evolve.

The interesting effect of actuating the system is that people affect the topography of the system because the modules move up and down according to the location of occupants. This can be a new form of implicit communication which tells people's existence in the space even to places where the occupants are invisible, such as the other side of the wall. Also, the response of the wall towards a person in front of it is a gradual transformation of multiple modules rather than just one module, so that the person also influences the vertical terrain of the space. The dynamic vertical transformation based on people's presence or movement would attract people and create more opportunities for social interaction.

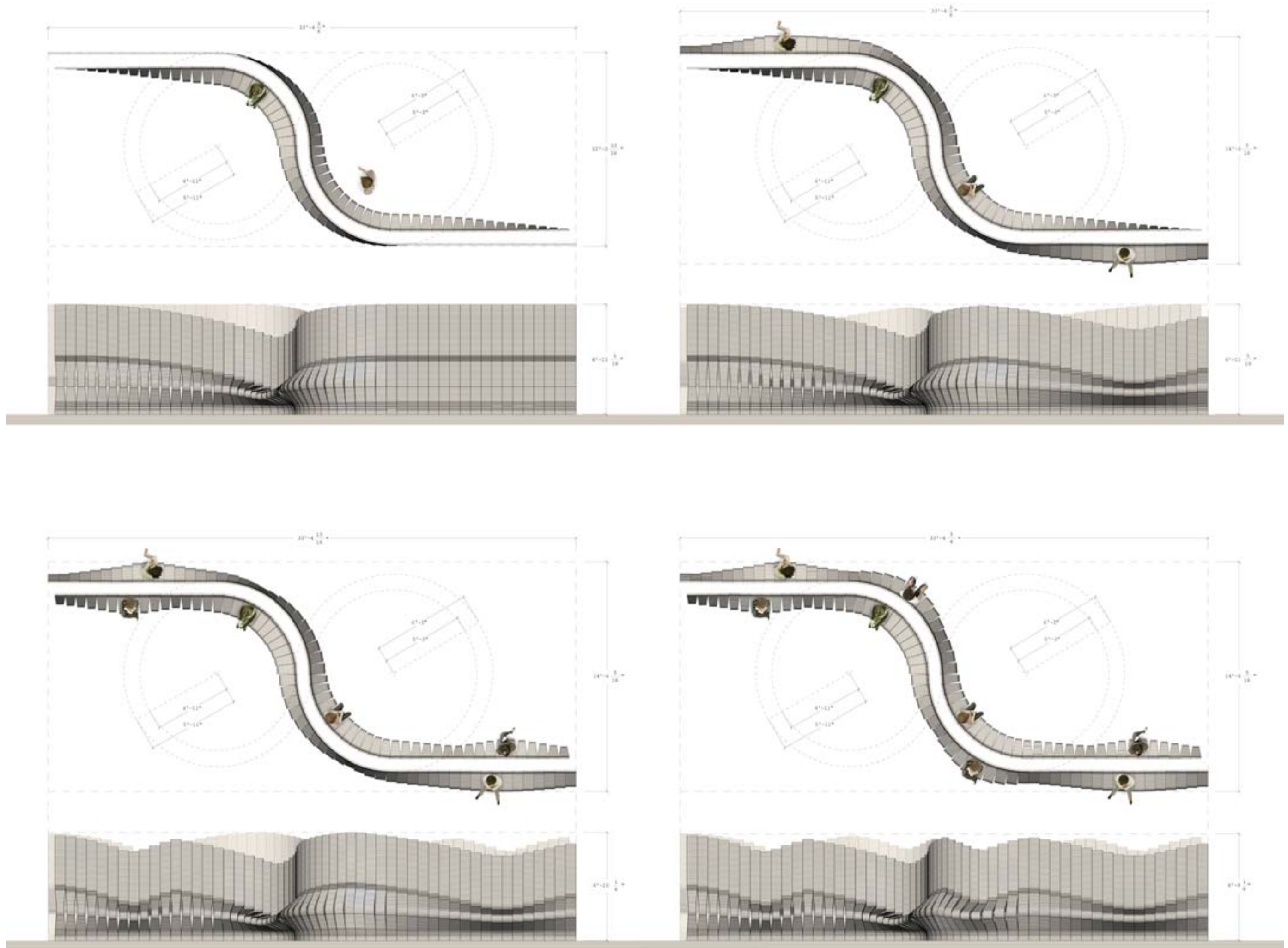


figure 25. Scenario of active actuation for individual occupation

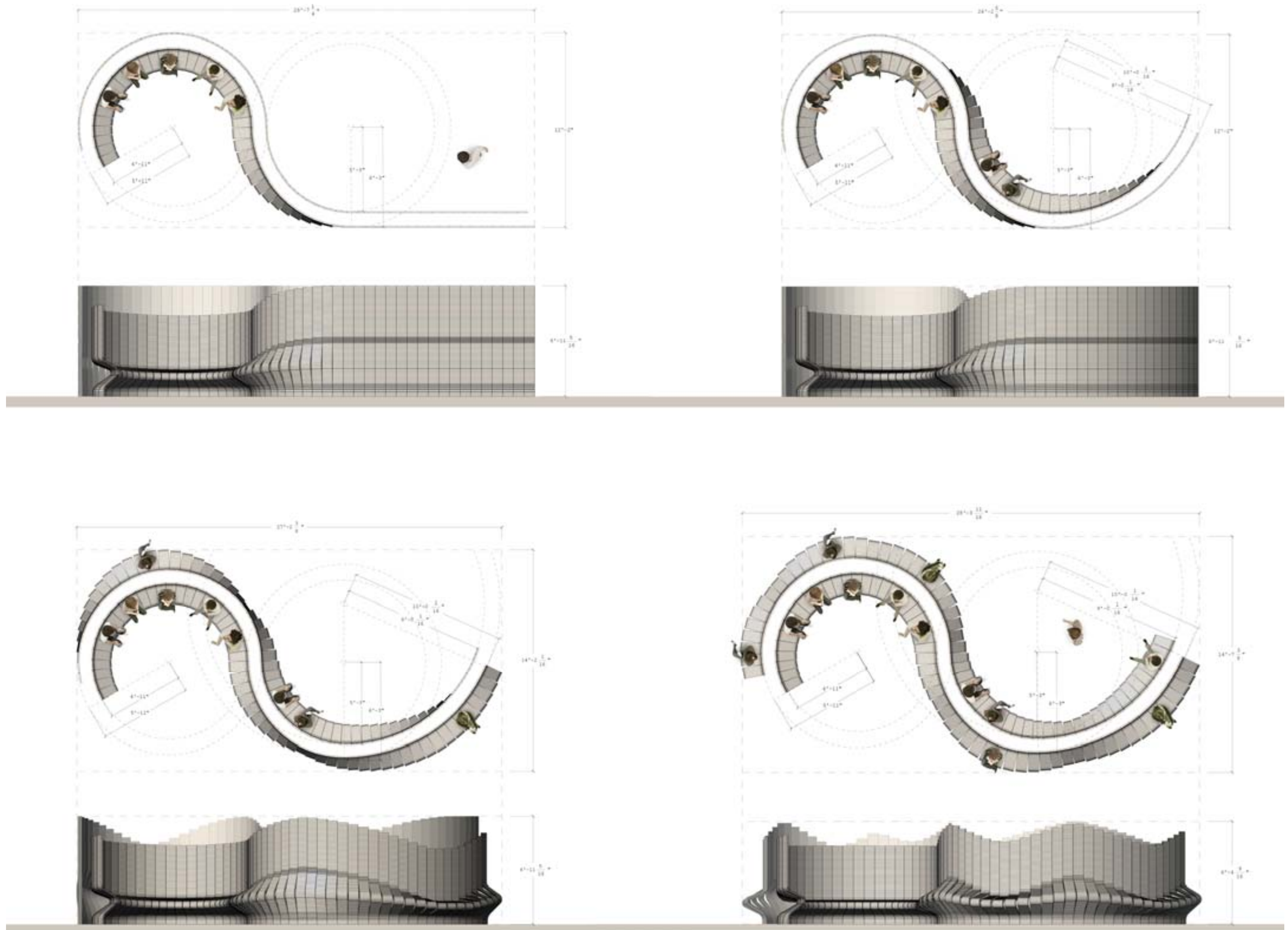


figure 26. Scenario of active actuation for a small group, big group and individual occupation

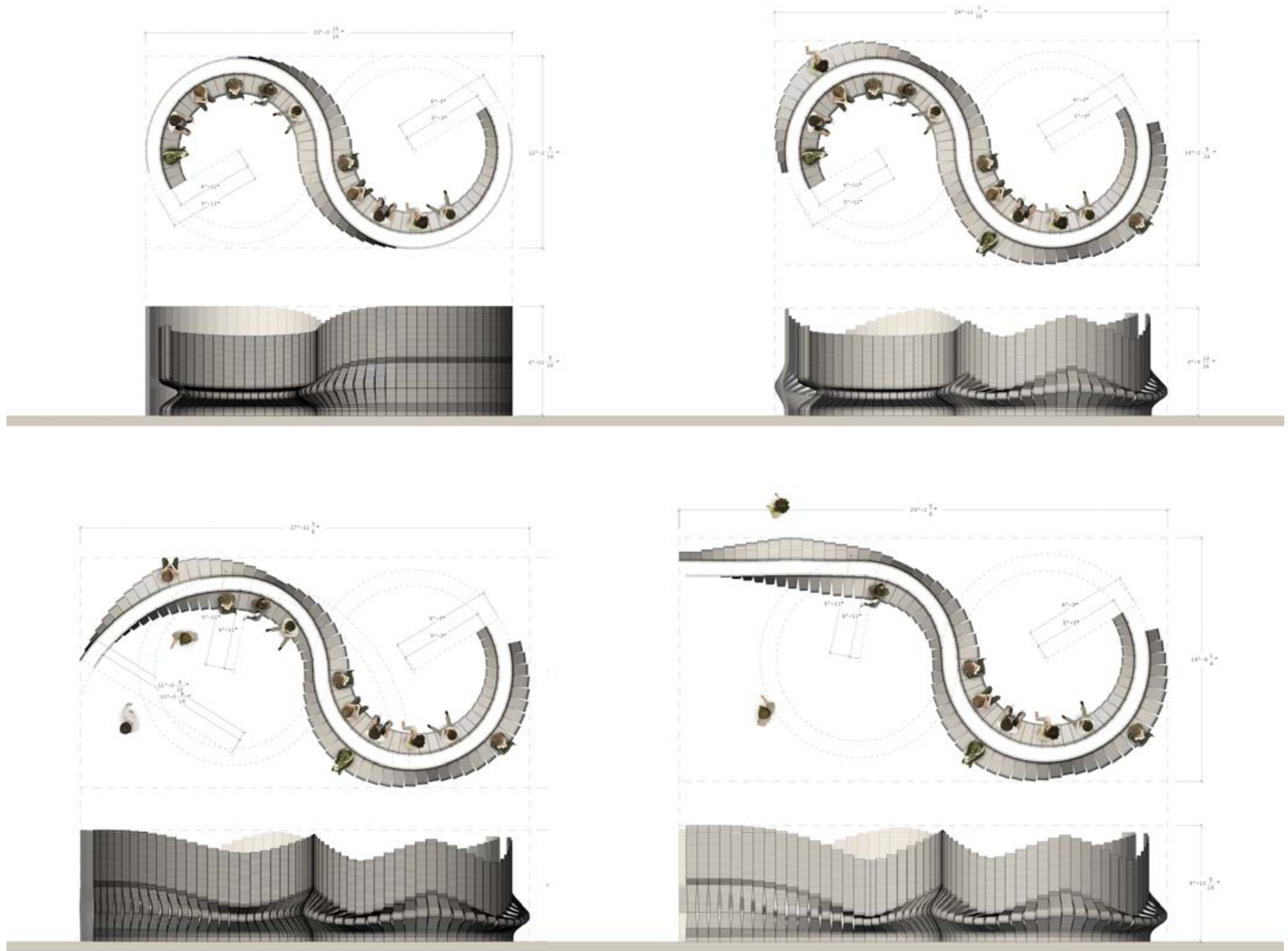


figure 27. Scenario of active actuation for two-group occupation

figure 28. Interior renderings

figure 29. Site model in half-inch scale

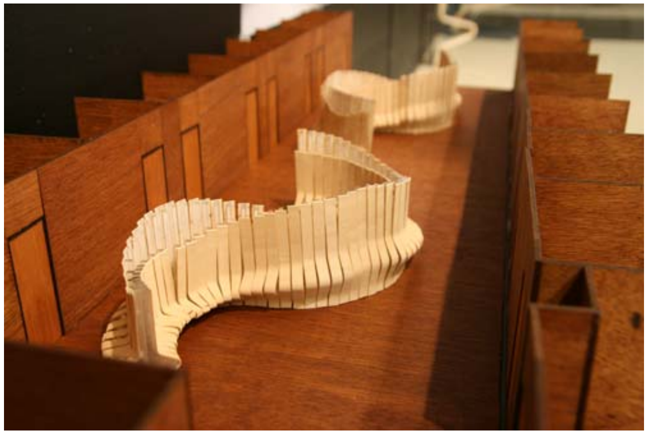


Figure 30. Site model in half-inch scale

4. Prototype fabrication

The first full-scale prototype is made of wood and canvas fabric, the fabric is laminated to the wood members and holds them together. It successfully supported human weight, however, it was too heavy to motorize the system with the available servo motors.

To resolve this issue, the wood was replaced with dense foam insulation sheeting material. It was selected for its strong compression force and extremely low weight. One module is motorized by one servo motor, which costs about ten US dollars and laser cut spur gears, which I experimented with various material. Material for the system needs more study to be reliable.

The structure that encases the mechanics of the wall system also has flexibility to create straight or curvy forms in plan so that the system adapts itself to programmatic needs of the space.

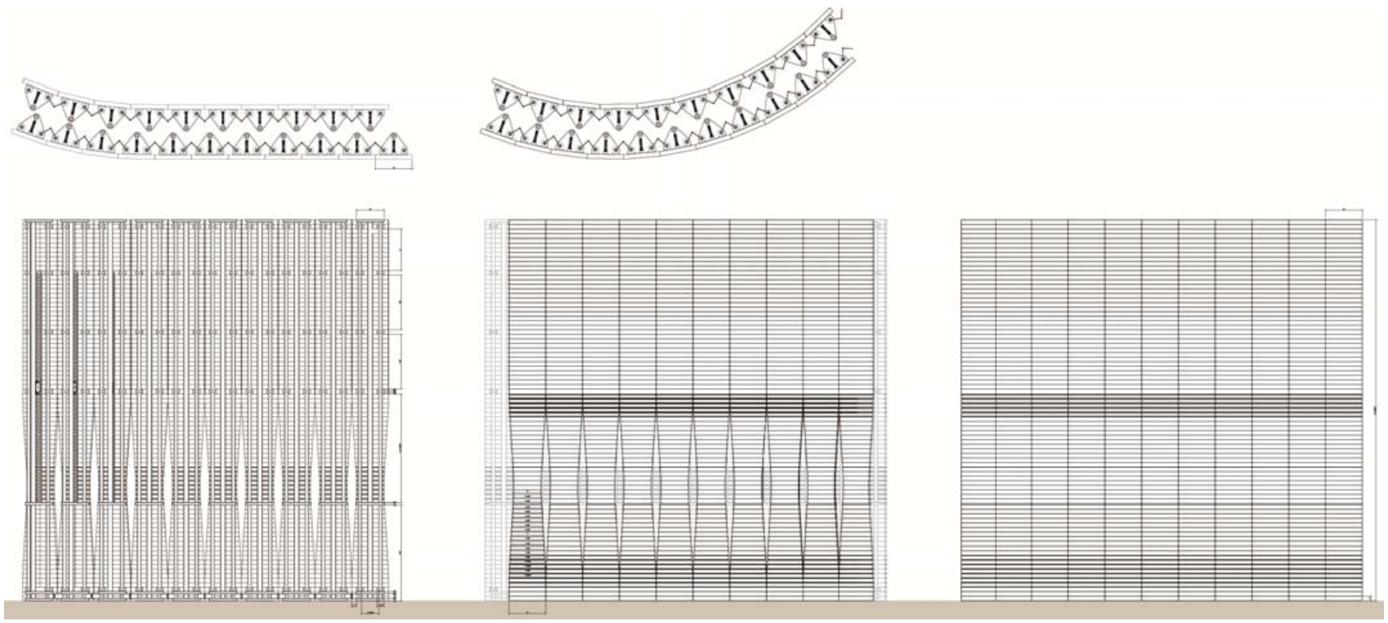


figure 31. Detail drawing of the wall system

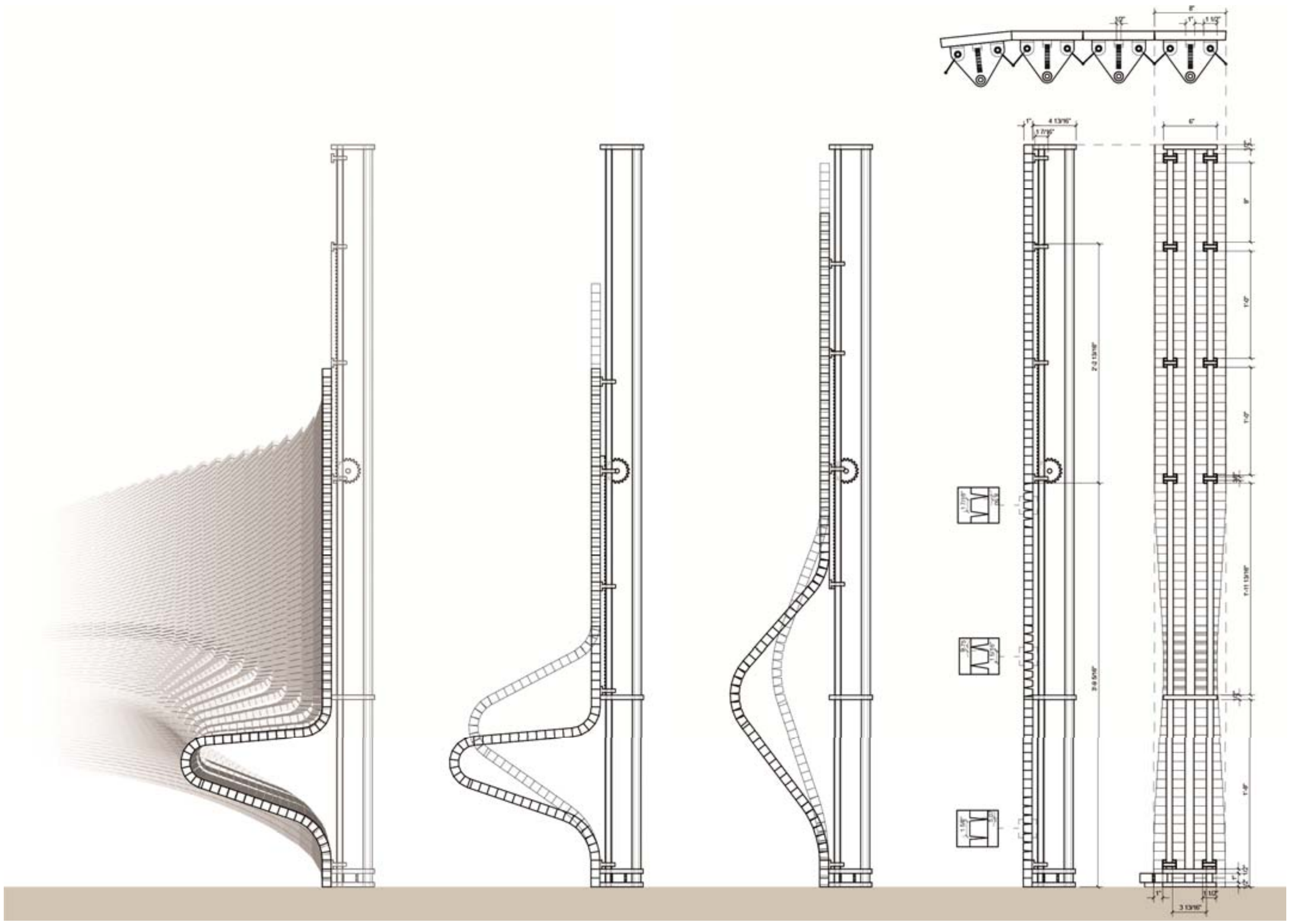


figure 32. Detail drawing of the one module

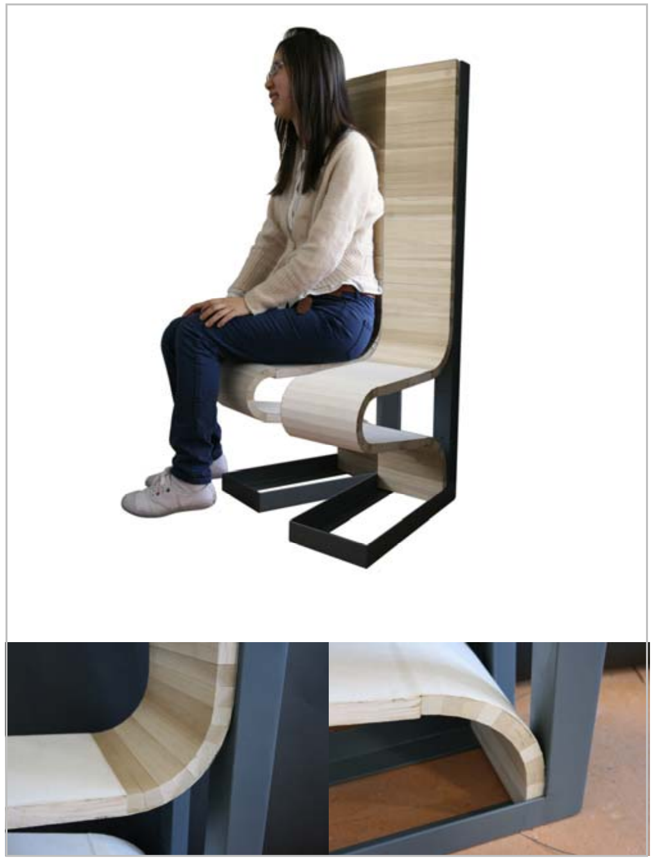


figure 33. The first full-scale prototype

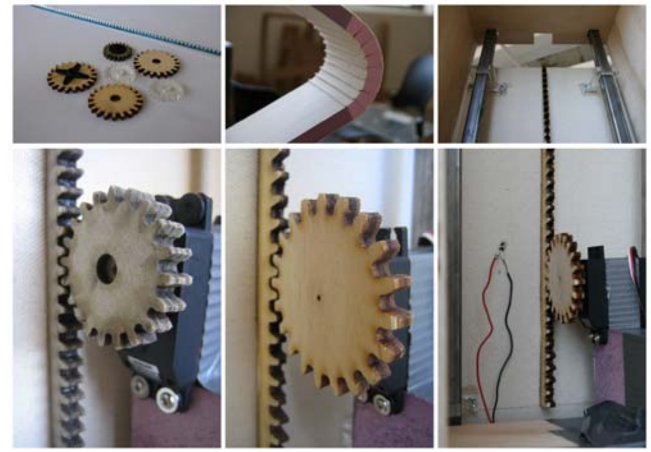


figure 34. The working prototype with servo motors, spur gears, photocells and Arduino boards

figure 35. Actuation of the working prototype

Bibliography

Books
Fox, Michael, and Kemp, Miles. Interactive Architecture. New York: Priceton Architectural Press, 2009.
Kronenburg, Robert. Flexible; Architecture that Responds to Change. London: Laurence King Publishing Ltd, 2007.
Hall, Edward T. The Hidden Dimension. Garden City, N.Y.: Doubleday, 1966.
Henry Dreyfuss Associates. The measure of man and woman. New York: Whitney Library of Design, 1993
McCullough, Malcolm. Digital ground: architecture, pervasive computing, and environmental knowing. MIT Press, 2005

Journals
Freese, Ernest Irving. “The Geometry of the Human Figure”, American Architect, July 1934, 57-60
Ley, Rob and Stein, Joshua G. “REACTIVE VOID: SOCIALIZING SPACE THROUGH REPONSIVE TECHNOLOGY”, AIA RFP Program report, 2007
Sterk, Tristan. “Using Actuated Tensegrity Structure to Produce a Responsive Architecture”, ACADIA 2003.