Toward a

CORPOREAL ARCHITECTURE

Building about the Body

by

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Toward a Corporal Architecture: Building About the Body

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Master of Architecture

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Abstract

Throughout history the human body has formed the subject, defined the scale and proportion, and inspired the tectonic and symbolic language of architecture. While modern methods sought to codify the body for the purposes of standardized measurement, ergonomics, and the development of building codes, the implications derived from this approach have resulted in limited and standardized procedures for designing space in relation to the body. Recent advances in materials science, portable computing, and sensing technologies have opened up several possibilities for a deeper level of engagement and interaction between the body and its environment. As wireless communications continue to blur the boundaries between personal and global space, new dialogues are emerging that implicate both intimate material interfaces and wider organizational frameworks. Introducing the notion of 'wearable space', parallels between fashion and architecture are drawn as a means of re-examining the relationship between the body, clothing and architecture; the first, second and third skin of the body respectively.

Keywords: *Architecture, Fashion, Body, Network, Anthropometrics, Human Factors*

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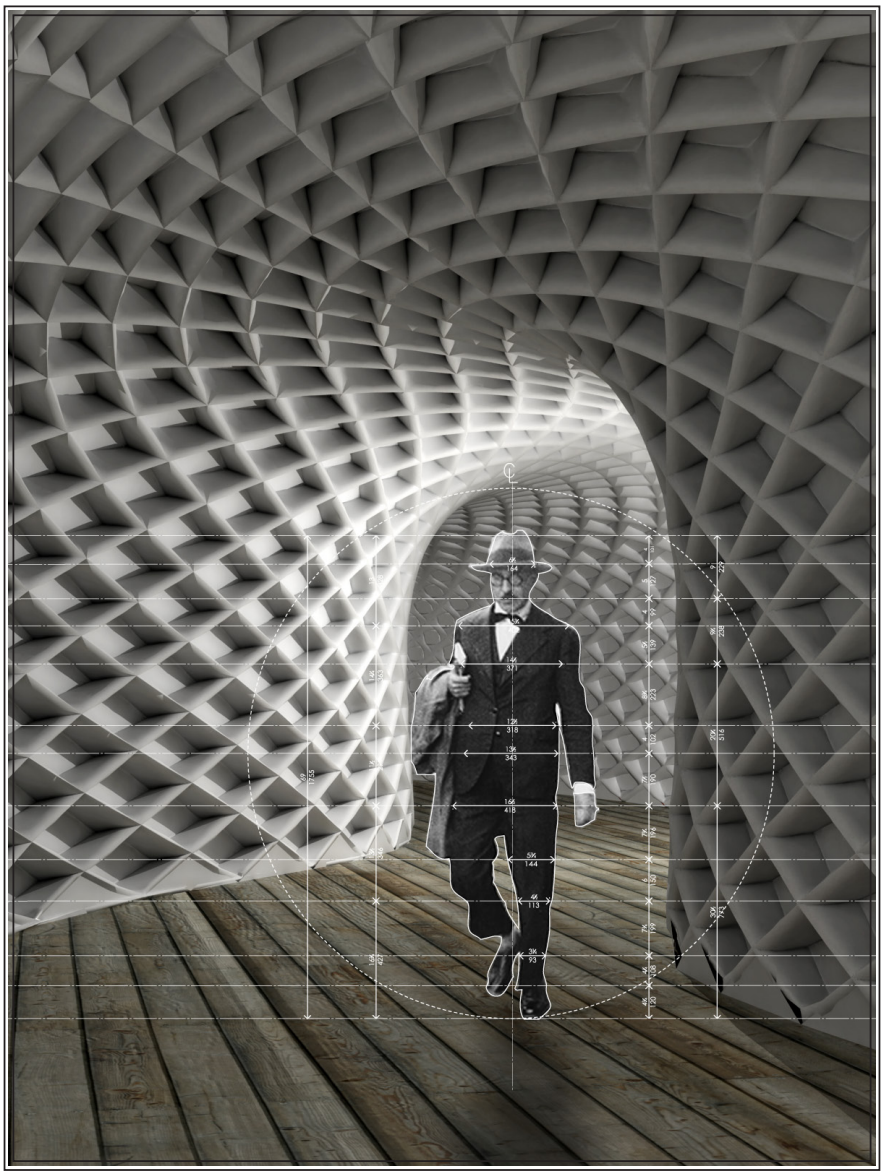


All around him he could feel its presence, reacting to his every movement, anticipating his every action and desire

1 Introduction

The relationship between the body and architecture has been a topic that has manifested in countless propositions over the millennia. The body has been used as an icon and symbol, has defined scale and proportion, and has inspired metaphoric and tectonic language of architecture. Fundamentally, architecture defines itself as a mediator between the body and its environment, acting as shelter and protection; as the body's second skin. It could therefore be seen as an extension of the human body; as a prosthetic device by which the body's capacities are augmented. (Wigley 1991)(Teysott 2004) (Hale 2012)

The imposition of modernist ideologies onto the body have resulted in a growing disconnection between the body and its environment. The development of standardized body measurements and their dissemination through design manuals such as Architectural Graphics Standards, have served to limit the possibilities for designed space by emphasizing a normative or ideal conception of the body. With this, all possibilities of addressing or engaging with the individual body have been lost. However in seeking to reestablish a meaningful relationship between architecture and the body, we can not return to historical conceptions of the body. Instead we must consider the body in the context of contemporary networked society. For that reason, anthropomorphic, and symbolic references to the body as well as idealized conceptions of "normative" bodies are avoided. Instead the "networked" body becomes the designated element for which new kinds of instrumental and theoretical representations can be established.

In accepting the body's primacy as a design subject, this project acknowledging the fundamental intention of architecture. By presenting the body as the 'site' for design production, this work seeks to establish a *corporeal* dimension: a tactile, adaptable and intimate space for the body: One which at once encloses and protects the body (as a skin), which extends and projects the body (as a prosthetic device), and which responds and adapts to the body (as an anthropometric system). As a result, fixed or static relationships are abandoned in favour of design methodologies which can register change in a dynamic environment. This thesis looks towards developing architecture which is capable of directly sensing and responding to the body. Not of a static body; but a moving, breathing, metabolizing, and social, human being.

Recent technological developments have increased our capacities to understand the body's inner and outer

workings, providing new opportunities to interface with it and build upon (or about) it. Emerging tools such as motion sensing, body scanning and mobile computing devices have expanded the repertoire of tools and techniques available for the architect to engage with the body. However any conceptualization of new design practices based on the body will require a fundamental reassessment of our current design standards, building codes, techniques, methods of fabrication and representation, disciplinary boundaries, attitudes, assumptions, and social and political norms, to name a few. In order to overcome such a wide range of issues, we require a combined understanding of all design disciplines (such as architecture, interior, industrial and fashion design) as an interdisciplinary entity which is grounded in a related focus on the body.

This project's title "building about the body" has a double-meaning. The first definition emphasizes the body as the origin of all design activity (as a subject, metaphor, generator of proportional theory and anthropometric study). The second meaning alludes to notions of building around the body (to enclose, protect, and project), in other words, on subject and site.

The theoretical position of this paper is based on three main hypotheses:

1. Architecture, as with all tools and technologies, could be thought of as an extension of the body because it expands our capacities to operate within our environment. In this regard, it could be conceptualized that architecture acts as a type of prosthesis for the body. By thinking in terms of this prosthetic relationship we might conclude that the body is the fundamental building block for design from which associations between materials, space, process, and assemblages emerge.

2. The most immediate mediators between the body and the environment are clothing and shelter. These are physical layers or interfaces which could be interpreted as extensions of the human skin; that which enclose and protect. We could therefore imagine several 'skins' acting outward from the body and having varying characteristics which support and protect the body; clothing being the 2nd skin, building the 3rd skin and so on. By treating these layers not as discrete but as part of a combined system that makes space habitable for the body, we can imagine new possible hybrids, connections, and spatial possibilities dormant between and among these layers or 'skins'

3. Current models practiced within the architectural profession are insufficient for accommodating different body types because they are based (as with building codes) on the presumption of a "normative body". On the other hand, heterogeneous approaches to designing for the body, afforded by methods of customization, adaptability, and responsiveness allow for the accommodation of a multitude of body types and abilities: This supplants the idealized or normative body in favour of the individual, the differentiated and the unique body. Therefore I argue against Universal Design approaches in favour of a

User-Centric methodology.

The congruence of tools and techniques employed in the wider design disciplines is critical in establishing a comprehensive and combined understanding of design for the body. Looking to fashion design is an obvious place to begin discussions on the concept of building on the body because clothing is the primary mediating element between the body and its environment, and because the tailoring of garments has always been focussed on fitting the individual body.

Throughout history, clothing and architecture have been closely related products of human craft and industry. Beyond the practical requirement for bodily comfort and protection from the elements, both are implicated in wider discussions related to aesthetics, expression, symbolism, politics, and identity. As technical artifacts, clothing and shelter are constructions which mediate between human bodies and the environment. They negotiate between internal and external forces (heat, moisture and movement), and between the individual and their society (cultural, gender, political aspects). With common concerns for form, function and materiality, both disciplines share a vocabulary of techniques and forms of representation.

This thesis will demonstrate the close relationship of these two disciplines and argue for a related understanding of these two approaches as based fundamentally on the body and as manifestations of their cultural contexts. The objective is to not only to draw parallels and make comparisons, but to find useful linkages and overlaps that may inform future practices. By linking attributes that have been normally relegated to one discipline or another, new opportunities for collaborative approaches emerge to address design problems that defy categorization.

A deeper examination of the structural relationships, material assemblies, and processes inherent in these industries is essential. Since textile and construction material industries share so many overlapping features within their production chains, a closer understanding of these overlaps may give rise to new perspectives on how we design and make. Recent technological developments across both disciplines such as now ubiquitous CAD/CAM tools, high performance and "smart" textiles, 3d scanning technology, the growing use of parametric design, scripting, and automation, coupled with the possibilities of digital fabrication and mass-customization, have opened up new areas of study which warrant further investigation and discussion.

The growing use of CAD/CAM over the past few decades has substantially affected the way design products are conceived, modelled, represented, simulated, resolved, and fabricated. Design software and scripting have introduced a number of paradigms which affect the way architecture is conceived and realized. At the other end, rapid prototyping is beginning to allow the production of customized building materials which are intrinsically linked to design software, allowing a greater engagement of the designer with methods of manufacturing and production, heralding an era of "mass customization" and "digital craft".

On the periphery of architectural concern is the ongoing development of electronic sensing devices which provide new means for charting the body and its motions. Body scanning technologies have been employed for mapping human figures to build anthropometric databases which are currently of use in industrial design, security, and fashion industries. Motion capture technology used for digitally recording body movement is currently used in film and video-games, sport sciences, manufacturing, and medical disciplines. Smart materials such as breathable fabrics and flexible electronic displays are finding increasing use architectural, engineering, fashion, and medical applications. Combined, these peripheral technologies could become useful in the realization of body-sensing architectural applications. For example, the possibility of determining where individuals are located in a building might lead to the design of buildings that can be more responsive and accomodating to users. In this manner, architecture may be employed as a means of augmenting the body (as a supplementary prosthetic), by creating an environment which is more aware of and therefore more supportive to the body.

The contemporary body as enabled by networked technology, introduces a new paradigm as it relates to architectural space. Rather than static or fixed relationships between users, buildings, program and space, the networked reality is dynamic, ever-changing, mobile, and instrumental. This shift in understanding requires a fundamental reassessment of the ways that buildings engage with their occupants. Rather than the building being seen as an entity which contains human activity, it must be seen in terms of its capacity to augment human abilities by facilitating a greater linkage between the body and its surrounding environment; In a sense, becoming a physical extension of those bodies. However, architecture must do much more than simply to support this changed condition it must represent it as a totality. In order to conceptualize how architecture might represent this new reality, we need to first reconsider how the contemporary body relates to the network. No discussion of adaptive or "networked" architecture can exist without first acknowledging the manner in which the body itself is "networked".

The ambition of this project is the promotion and development of a corporeal architecture and toward this goal, the design and development of architecture capable of engaging with the body through responsiveness and adaptability. These responses implicate a number of design factors related to the body such as ergonomics, environmental control systems, even health and body function. Harnessing the potential of emerging sensing technologies, new possibilities for architecture to engage with the human body might guide new tectonic and spatial possibilities where the body and building are mutually considered and engaged. These tools and technologies, understood as prosthetic devices for the body may be of enormous value in the realization of a corporeal architecture.

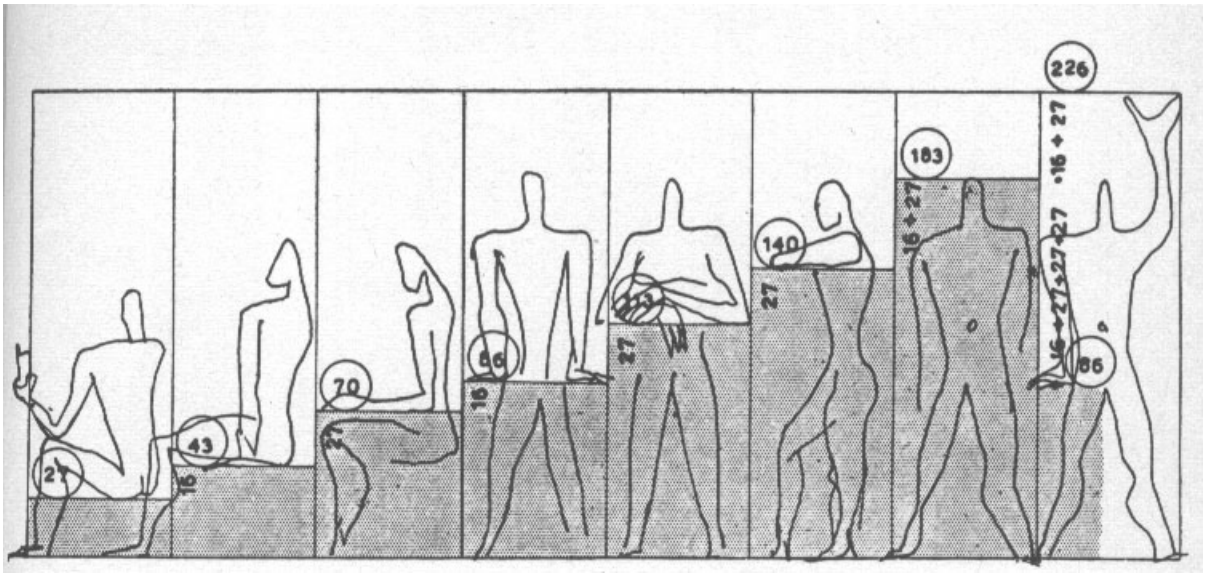


Fig 2. "Le Modulor" Le Corbusier, 1946.

2 Body Building

Architectural concerns are shaped by the prevailing paradigm and value system of the societal and cultural contexts from which they emerge. This chapter will give a chronological overview of the way in which the body became influential in the development of architectural theories throughout history, illustrating the means in which the governing cultural and technological paradigm of each time period would frame the dominant image of the body, thereby influencing or reinforcing architectural practices. Each historical era would characterize a significant shift in the way the body was seen, understood and thus represented as a generative model for architecture. The intent of this retrospective is not to simply provide a linear narrative, but to identify recurrent themes, theories, and attempt to trace out future trajectories.

2.1 Pre-History (The Physical Body)

To trace the lineage of ideas related to the body and architecture we must go all the way back to the point when humans developed their first tools. The development of tools in human culture marks the beginning of man's intention to shape his environment for his own purposes. In this we observe the first expansion of the body's capacity to extend its ability to survive and operate in ever more hostile environments. Of the development of technologies suited for survival, the invention of clothing and dwelling are perhaps the most significant. Therefore clothing, man-made shelter, and the hand that made them, should be considered important proto-technologies.

The first man-made shelters appeared approximately half a million years ago. These shelters were composed of readily available materials found within the local context, comprised of composite structures using natural materials; wood, clay, tendon, bone, hair animal hides, and using simple construction methods. Many of the earliest structures were portable because humans had to travel over vast territories to acquire food. As a result such shelters needed to be lightweight, portable and easily deployable, so a close relationship between body and building was essential. Not until the development of agriculture, did permanent man-made dwellings appear in any significant way. As agriculture spread, permanent dwellings began to replace portable

Fig. 3. Venus of Willendorf Figurine. 24,000-22,000 BCE. Austria.

Fig.4. Caryatid Porch of the Erechtheion, Athens, 421–407 BC

shelters. However, nomadic cultures continued to use portable shelters for their light weight and transportability, a tradition which continues today in some Bedouin and Mongolian cultures.

The early Neolithic period witnessed an explosion of tools and techniques related to the fashioning of garments. Clothing was an enormous step in the expansion of human inhabitation and the appearance of culture. The key activity to early humans was food production, but the production of clothing became the second most important activity (Barber 1992). Once people began creating clothing it expanded the environments which they could inhabit. It also meant the rise of fashion, affording people to convey information about tribal identity, social status, fertility, and other cultural matters.

The first garments provided similar functions as shelter, often using the same materials and construction techniques. People started wearing animal furs, presumably initially for warmth. This was a major development because until man could make clothing, he could not survive in the colder climate found north of Africa: in Europe and Asia. Anthropologists speculate that man first used animal skins about 100,000 years ago, although it is unknown precisely when people first took the step from just draping animal skins over themselves to actually fashioning crude garments. Some anthropologists believe that needles and other artifacts suggest that people were sewing clothes at least 25,000 years ago and possibly as much as 40,000 years ago. (Barber 1992) The fact that the development of clothing is pre-dated by the first shelters by 400,000 years would challenge many assumptions that garments represent a form of proto-architecture. In fact the

reverse is true; that garments are instead derived as a form of portable shelter.

2.2 Antiquity (The Objective Body)

"Man is the measure of all things. of things that are that they are, and of things that are not that they are not."
- Protagoras

By the beginning of the first civilizations, technologies related to textiles and construction begin to get increasingly sophisticated. The continuation and refinement of use of fur and hides, and the beginning of woven cloth, the use of wool, decoration of cloth and development of complex weaving began to appear. In addition, more complex social and political systems, development a labour segmentation led to specialized craft. The development of complex trade routes increased the number of available materials and the cultural exchange of techniques. It is also at this time the beginnings of architectural theory emerge. Architectural theories developed at this time placed a great importance on body's proportion in the realization of an idealized architecture.

Proportion became the main preoccupation of sculptors and architects in ancient Greece, shifting thus the focus away from metaphysical preoccupations towards expressing the human figure in a more naturalistic manner. While prehistorically the human figure had been used by many cultures as a symbol which signified mystical qualities. In classical Greece on the other hand, sculpture the figures often depict deities but clearly the human body becomes the subject of study. The Greeks invented their own selves and became the creator of god and man alike in a universe of perfect proportions, idealized aesthetics and a newly found sense of freedom. The human body is seen as the center of all measurements of the world; a sentiment best expressed by Protagoras: "man is the measure of all things"

Anthromorphic qualities in architecture began to be more expressive. Representing a supportive body, the Greek Column, Rykwert (1996) shows how the Classical orders (Doric, Ionic, Corinthian) are based on body proportions; the Doric column the male, the Ionic column female. The Greek classical orders were all based on proportional rather than dimensioned or measured modules. This relationship would allow ideal architectural archetypes to be scaled larger or smaller without losing their underlying proportional rules. Additionally, the earliest systems of measurements were based on body parts and their spans (fingers, palms, hands, feet, rumen, cubits, ells, yards, paces and fathoms) which became standardized for bricks and boards even before the time of the Greeks.

2.21 Vitruvius

The most significant treatise on the body and architecture is found in Vitruvius's writings. Vituvius's most famous work, entitled "Ten Books on Architecture" was written in approximately 20-30 BC. It is the only text on the subject of architecture to survive antiquity. It was also one of the first texts in history to draw the connection between the architecture of the body and that of the building. In his treatise, Vitruvius discussed proper symmetry and proportion as related to the building of temples. He believed that the proportions and measurements of the human body, which was divinely created, were perfect and correct. He therefore proposed that a properly constructed temple should reflect and relate to the parts of the human body. He noted that a human body can be symmetrically inscribed within both a circle and a square, and he thus illustrated the link that he believed existed between perfect geometric forms and the perfect body.

In this way, the body was seen as a living rule-book, containing the fixed and faultless laws set down by nature. According to Vitruvius, an architect's designs must refer to the unquestionable perfection of the body's symmetry and proportions. If a building is to create a sense of eurythmia - a graceful and agreeable atmosphere - it is essential that it mirrors these natural laws of harmony and beauty.

2.3 Middle-Ages (The Spiritual Body)

In the Middle-ages, the rise of the Roman Catholic Church would result in a pronounced shift of in the way the body analogy is represented in architecture. The overall tendency to move away from Classical and Humanist principles towards the Supernatural was made explicit the removal of the natural human figure in both art and architecture. Representations of the body became abstracted and iconographic, mostly representing religious figures that were most certainly clothed. Other representations depicted a grotesque figure of the body where inner organs and outer cosmic (zodiac) symbols are superimposed on the human figure. (Fig 5) The real body is seen a sinful and therefore denied, neglected, shamed, and repressed.

The definition of the 'corporeal' body emerges at this time to distinguish between the real 'earthly' body, and the Heavenly spiritual body. It is also at this time that the definition of 'body' became extended to mean a collection of people. The word "corporation" derives from corpus, the Latin word for body, or a "body of people". The body politic also emerges at this time in which a nation is considered to be a corporate entity, being likened to a human body which comprises all the people in a particular country considered as a single group.

The body reference in medieval architecture is largely evident in the cross-plan of Western church, referring to the body of Christ. As Gothic architecture placed such importance on the connection between the body

Fig 5 Zodiac Man. 1475.

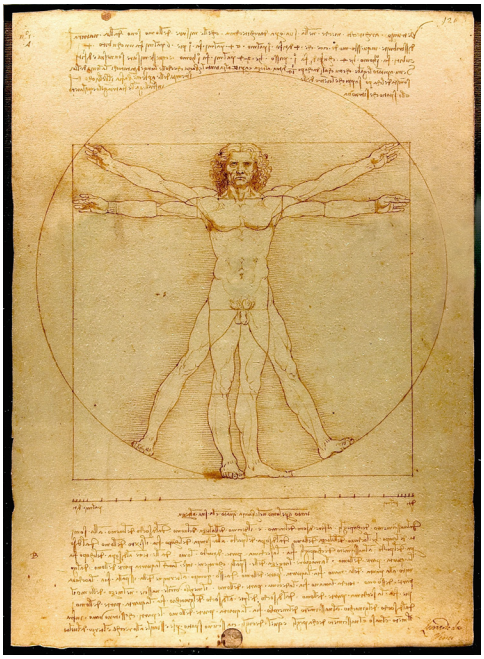


Fig 6. Leonardo Da Vinci's Viruvian Man. 1487.

and the Heavens, the emphasis on verticality and light and the necessary structure to support the buildings gradually began to take precedence over or at least have an influence on aesthetic proportions inherited from antiquity. "The Gothic preference for exaggerated forms and over ornamentation led to showy distortions of body and building (Horn, 80)." The human proportion is still intact in the cathedral plan, but reference in elevation is temporarily lost.

2.4 Renaissance (The Geometric Body)

The Renaissance period would mark a return to classical Humanist principles and to proportional systems based on the body inherited from antiquity. Early Renaissance thinkers such as Alberti, Filarete, and Francesco di Giorgio, would reinstate emphasis on the Vituvian model, however with more defined rules. Through to the Renaissance, "The body, its balance, standards of proportions, symmetry, and functioning, mingling elegance, and strength was the foundation myth of building." (Vidler, 71) Echoing Protagoras "Man is the measure of all things," according to Virilio, architecture is also the first measure of the Earth. Based on the same proportioning systems, it is thus the body and architecture that are the measures of the world.

Moving beyond the building scale, Francesco di Giorgio Martini extended the relationship with the human

body to the urban organism; showing a gradual extension of the body image to greater and more complex domains. "The city having the reason, measurements, and shape of the human body...has all the same partitions and member in perfect dimensions" (Agrest 1993)

During the Renaissance, a revival of the Aristotelian writings on animal motion started contributing to a research trend which would give rise to a number of disciplines such as anatomy, physiology, and mechanics. Architects of the same period devoted themselves to understanding similar "body equilibria": the movement of body parts seen as levers; the conditions of equilibrium of animal bodies in terms of centre of mass theory; the resistance of bones and limbs. (Becchi 2009) In addition, newly developed techniques of perspective in painting allowed new means for representing the human body alongside architecture, a development which would come to characterize Renaissance art.

2.41 Vitruvian Man

The Renaissance's interest in the body is epitomized in Leonardo da Vinci's most famous illustration, The Viruvian Man. The Vitruvian ideas, presented by Leonardo, formed the basis of and would influence many Renaissance theories in art and architecture. In Leonardo's adaptation, Man is not static at all, but standing and in motion. Leonardo called this system a Canon of Proportions in which sixteen possible positions for the human body are systematized in the same drawing, generated by variations on two main positions overlapped and inscribed within the cosmological symbols of the circle and the set square. (Fig. 6)

This picture represents a foundation of Leonardo's attempts to relate man to nature. "Leonardo envisaged the great picture chart of the human body he had produced through his anatomical drawings and *Vitruvian Man as a cosmografia del minor mondo (cosmography of the microcosm)*. He believed the workings of the human body to be an analogy for the workings of the universe." *(Brittanica 2012)* Among other instances are Leonardo's manuscripts and his research on mechanics and on the equilibrium of bodies, where parallelisms between the body and architecture are made explicit.

2.5 Modern Age (The Mechanical Body)

The emergence of mass production and standardization in the Modern period would bring with it a fundamental change in the way architecture and the body-image were conceived. The rise of scientific management would lead to a mechanization of the body through various methods of control, ultimately leading to the development of ergonomics and cybernetics. Accordingly, the body became a territory of work, efficiency and normitization.

The theory of scientific management developed by Fredrick Winslow Taylor Between 1880 and 1890,

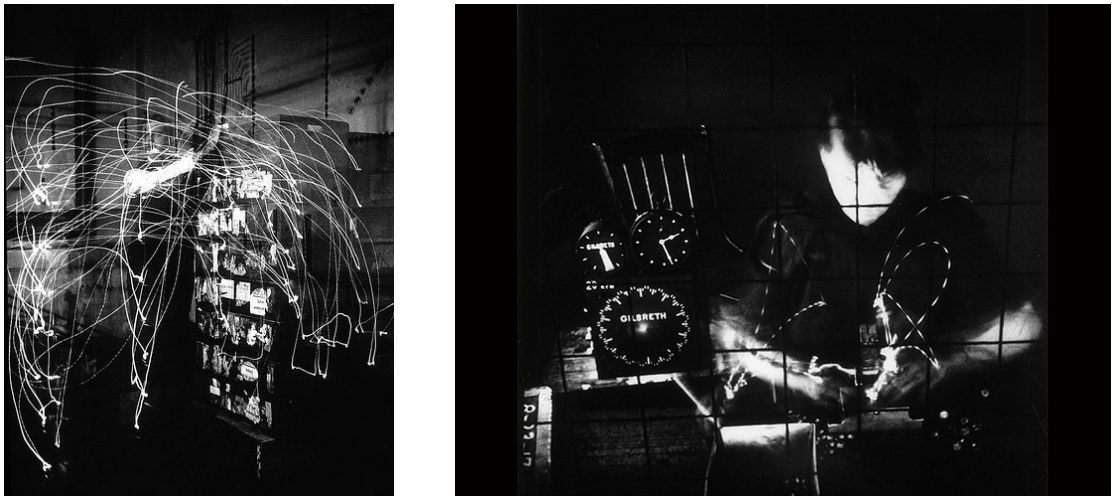


Fig 7. Time and Motion Studies. Frank and Lillian Gilbreth. Early 1900's

based the concept of workplace productivity solely by measuring time efficiency, "Taylor carried out time- and motion studies to determine the 'one best way' to organize labor, to link human to machine in the most efficient way possible so as to increase productivity," (Zabel 5). The Time and Motion studies conducted in the early 1900s by Taylor's contemporaries Frank and Lillian Gilbreth used cameras to record details of a worker's activities while recording the time required to complete tasks. They used this research as a means to both improve the efficiency of work methods and to train workers about the best way to perform a particular task. (Fig 7)

Scientific management attempted to transfigure man into a machine of productivity. The introduction of industrial scale machines and mass production drastically altered both the ecological landscape, biological processes of agriculture and human society which became treated as if they were cogs in a factory; mass produced, standardized and interchangeable. At this point, architecture became "viewed as a machine, produced by a machine, and arguably spaces suitable only for machines."(Biophilia + Technophila)

The modern period also marks a significant distancing from the body analogy in architecture, where for the most part, the body as an symbolic reference is absent. (Vidler 1992) Rejecting the decorative attributes of Semper's the Art of dressing, in favour of Adolf Loos' adage "ornament is crime", many turn-of-the-century architects sought simplicity and clarity of form and elimination of "unnecessary" detail. As a result, the body, at least as an anthropomorphic or decorative element for architecture is temporarily abandoned. Mark Wigley argues that traditional ornamentation appears to be removed from the building at the very moment when the building itself becomes a kind of ornament 'worn' by its occupant (Wigley 1991)

While the overall trend in early modernism would reject body analogies in architectural ornament, the pro-

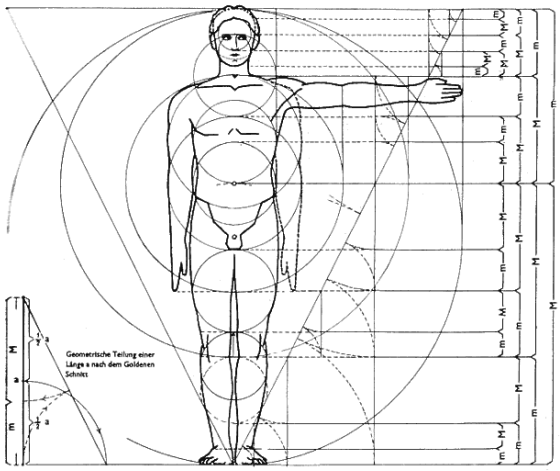


Fig. 8 *The Proportions of the human body*. Ernst Neufert 1943.

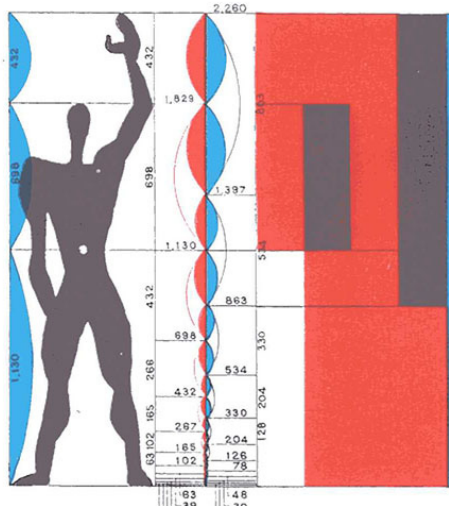


Fig 9 *Le Modulor*. Le Corbusier. 1950.

portional and kinetic characteristics of the human body would become a source of inspiration in a number of avant-garde circles. The geometrical proposition of the body had much focus in the German and the Russian avant-gardes of the twenties, especially at the Bauhaus. Bauhaus professor Johannes Itten concentrated his studies on the body's expressiveness, giving focus to the rhythmical coordination of the body limbs and the body structure as a whole, while Paul Klee was interested in the representation of the tectonics of the human body through linear drawings. (Ferreira 136) Oskar Schlemmer, based his work of art on the idea of merging the human body with the space it occupied and defined. He used costumes as a vehicle to re-characterize the body as a space making being. By using the distinct motion patterns of the body and the costume, he explored how architecture, space and the occupiers were all linked.

In 1936, Ernst Neufert, one of the first students from the Bauhaus and protégé of Walter Gropius, created the Architects' Data book which establishes a rationalization of the human (male) body and its direct built environment. (Fig. 8) His diagrams have been considered as a source of fundamental information in many projects since then and were fundamental to the development of later systems developed for Architectural Graphics Standards and other design manuals concerned with ergonomics. (Lambert 2012)

2.51 Le Modulor

In 1948, Swiss architect Le Corbusier published an anthropometric system based on human proportions he titled "Le Modulor". The purpose was to develop a "range of harmonious measurements to suit the human scale, universally applicable to architecture and to mechanical things." (Corbusier 2004) It was also an attempt to harmonize two virtually incompatible systems: the British Imperial system and the French

Metric system, the latter which he believed did not reflect human proportions. Le Corbusier developed the Modulor in the tradition of Vitruvius, and Da Vinci's Vitruvian Man, and other attempts to discover mathematical proportions in the human body as part of an effort to improve both the appearance and function of architecture. He based the system is based on human measurements, the double unit, the Fibonacci numbers, and the golden ratio. (Fig. 9) The system was used to set out a number of Le Corbusier's buildings such Church of Sainte Marie de La Tourette, and Carpenter Center for the Visual Arts, and Unité d'Habitation, in which Corbusier shows how the modular governs the plan, section and elevations; the brise-soleil, the roof; the supporting columns and the plan and section of the apartments. (Corbusier, 2004, 131)

That a revived and revised Vitruvian figure appears again in the midst of high modernism would suggest that the classical body is alive and well in the modern age, a tendency which Rowe asserts is the "persistence of humanism within the heart of modernism"(Hight, 2008, 82) This would also act to reinforce the thesis that modernism did not represent any clear break from the past with respect to the body. As Christopher Hight suggests it was part of a theoretical lineage in which intended to reconcile humanism within the modern context. This mid-century 'Renaissance' would include a divergent group of theorists and practitioners interested largely in establishing continuity from the Renaissance to the modern era. In Architectural Principles in the age of Humanism (1949), Rudolf Wittkower "constructed the Image of Renaissance architecture and its use of the Vitruvian figure that continues to inform contemporary architecture."(Hight, 2008, 73) Later, his protégé Colin Rowe sought to demonstrate proportion and ratio as an ordering system in Palladio's villas through a series of influential diagrams. Sigfied Giddeon would also be highly influential in spreading Architectural Principles, Le Modulor and other treatises related to proportion and human scale. It was also around this time that Neufert's Architect's Data and Architectural Graphic Standards began publishing expanded sections on human measurement and Anthropometry. Images of the Modulor would be revived later on to represent a normative figure upon which the post-modernists could project their own opposing theories and critiques.

2.6 Space Age (The Systematic Body)

The development of space travel promised by the Apollo Missions of the late 60s and early 70s would have a tremendous impact on architectural thought and inspire a whole new generation of architects to design high-tech, pneumatic, and soft architectures. The implications of the closed-system environments of space capsules and space suits would lead to new opportunities for cybernetics and environmental control systems to take their place in architecture. This shift in thinking is perhaps best expressed in the seminal work of Gordon Pask on interactive control mechanisms and by Reyner Banham's book A*rchitecture of the Well-Tempered Environment* (1969) in which he explored the impact that environmental engineering concepts had on architectural thinking up to that time. (Fig 10.)

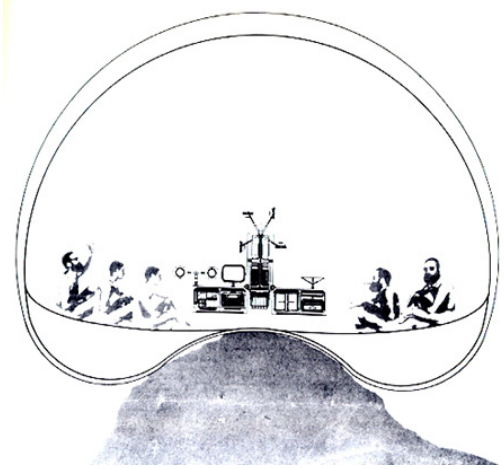


Fig. 10 *Environment Bubble*. Reyner Banham and Francois Dallegret. 1965

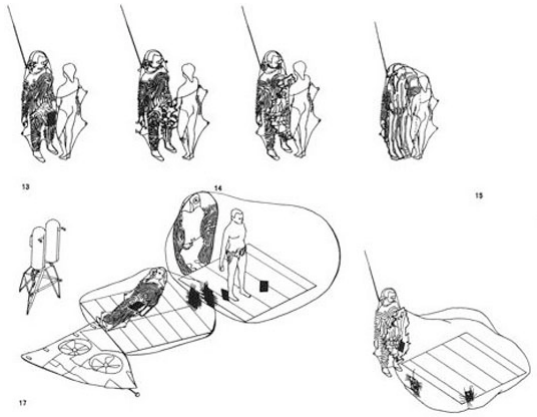


Fig 11. *Suitaloon,* Michael Webb, 1968

The advent of cybernetic thinking brought along with it a radical re-conceptualization of the body and its relationship with technology. The term Cyborg, short for cybernetic organism was originally coined by Clynes and Kline in 1960 to describe self-regulating human-machine systems required to enable human space exploration. Since then, this term has come to describe a broader range of human-machine couplings. An explicit architecture-oriented application of computers and AI was proposed by Nicholas Negroponte and the Architecture Machine Group in the 1960´s and 1970´s. Negroponte endorsed the integration of "intelligent minicomputers" in architectural spaces in order to intensify our relation with these environments.

Several architecture exposes and experiments would engage with the body's state of extreme defencelessness in space: from the plastic architecture of Peter and Alison Smithson and Ionel Schein, to the bubbles and balloons of Michael Webb's Cushicle and Suitaloon projects (Fig 11) and David Greene's lunar Pod (1966–67). These experiments with 'soft' architecture would begin to shift focus to the architectural envelope. Peter Cook discusses in his book *Experimental Architecture* (1970) the notion of the building skin to describe the outermost architectural envelope "The notion of an ultimate in skins: a membrane which is not there. The skin which can be seen through; the skin which can be parent to all within; the skin which can be regularized; the skin which can be treated as an environmental totality (Cook, 1970, 51)." In this supposition, the architectural surface becomes disengaged as a structural element and entirely utilized as a means of containing and controlling environment.

2.7 Post-Modernism (The Divided Body)

"Postmodern architecture is not designed to suit a conventional Renaissance body or the body of modern man; rather, it is a response to the breakdown of the body itself through the agency of technology, media, and time-altering techniques." (Vidler, 1992, 69)

Post-modernism has given rise to a number of divergent theories about the human body in architecture. Neo-Marxist critiques focus on the increasing repression of the body through capitalist structures. Feminist critiques focus on the continuation of masculine archetypes and gendered space. (Agrest 1988) Christopher Hight argues that contemporary architectural theories about the body could be divided into two camps: the post-structuralists (Eisenmann, Lynn), who maintain that the modern movement never broke away from classical humanism, and Phenomonologists (Rykwert, Perez-Gomez) who believe that modernity represents a rupture in the continuity of the body-building metaphor, and seek to recover a meaningful relationship. (Hight 2008, 62)

The difficulty of ascribing a meaningful relationship between architecture and the body continues in this period. The ambivalence of engaging with the body is evidenced in many works which ignore if not exclude the human subject altogether. In *Violence of Architecture*, Bernard Tschumi points out this dilemma:, "The human body has always been suspect in architecture," because it "sets limits to the most extreme architectural ambitions. The body disturbs the purity of architectural order." (Tschumi, 1994, 123)

It is telling that the use of skin emerges in architectural language at this time. The building skin is a visual device, an articulation of identity; skin in this definition has no corporeality. It is instead a semiotic device used in the formation of branded aesthetics. "The building skin - and especially the facade - is the calling card of the building and its designer. "(Schittich, 2006, 9) Venturi's notion of the "Decorated shed" has become one the dominant paradigms in postmodern architecture: a functional and anonymous box wrapped in a signifying skin. In the post-modern age, both the body and the building become "fashioned", and "branded".

2.8 Post-Humanism (The Obsolete Body)

Post-humanist theory hypothesizes that humans as a species have created a new technological environment in which we cannot operate effectively as living organisms. It suggests that the body is obsolete in the sense that it is no longer compatible with its technological surroundings, and that we have reached an evolutionary endpoint where the next logical stage of adaptation is for the organic to assimilate the mechanic. This would suggest a new body-image, one which is subsumed by technology, and along with it vulnerable to new measures of control, regulation, and surveillance, meaning that the body must adapt in order to accept

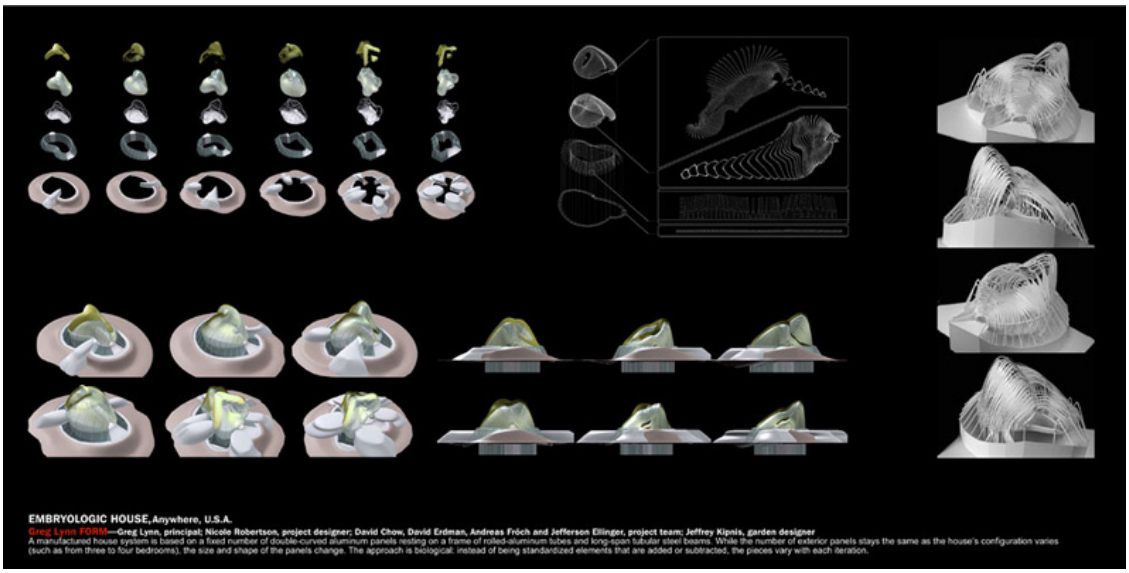


Fig. 12 *Embryological House*. Greg Lynn 2002.

mechanical logics of the technologies it now relies on for survival.

Post-humanist theory is evidenced in the work of many turn-of-the-millennium practitioners such as Greg Lynn and Lars Spuybroek. Drawing on biological paradigms, such as evolution, mutation, and hybridization, along with advanced computational techniques they have developed new forms which bear a resemblance to amorphous biological forms aka "bio-tecture". In Greg Lynn's Embryological House, he explores the house typology as an organic, flexible, genetic/generic prototype from which an infinite number of iterations can be generated. He extends the interplay of "generic" and "variation" to notions of individualization and mass-customization through consumer-specific, unique versions of the product. In this he addresses notions of tailored design within the context of globalized industry and consumer society.

In describing Son-o-House, NOX presents an architecture which is "swallowed up by technology so that it becomes completely capable of absorbing and enhancing the body's rhythm" This means that the body's rhythm will affect the form, and conversely that the form's rhythmicality in turn activates the body whereby architectural identity evaporates and the natural body moves into a bio-technical mutation. (Spuybroek 1996) According to NOX, architecture of the future will evolve in the same way. Building will soften by becoming capable of acting and reacting to human behaviors and activities and in doing so, there will be a radical change in the way we inhabit and experiment space.

2.9 Building on the Body

As we have seen, the predominant scientific paradigm of each historical period would impact both the development of architectural theory and the way the image of the body as a generative model for architecture was understood. In classical Greece, the body was seen as an object in perfect proportion, and so the predominant preoccupation of architects was to utilize the body's geometry in the formation of proportional theories. The Medieval period would place an emphasis on the body's spiritual connection to God, which would be evidenced both in body images which would position the body in relation to the celestial spheres, and the emphasis Gothic architecture placed on the connection between the body and the Heavens. In the Renaissance, the body once again becomes the focus of study. Renaissance thinkers would revive humanist principles and work toward building idealized models for the body, for architecture, and for the universe within unified geometrical frameworks. The advent of industrialisation would bring with it a number of new paradigms which would influence architectural theory and practice and impose new mechanized frameworks on the body. Bodies become machines for work, and buildings become "machines for living". The further sophistication of modernist mechanisms would lead to the development of cybernetics in the mid 20th century. In this conceptualization, bodies and building are seen less as objects, or machines, but rather as interdependent 'systems'. Post-modern theory would emerge in reaction to modernism's universal and absolute truths. As a result, a number of divergent theoretical models would develop as an attempt to better represent these varied conceptualizations of the body. Post-humanism would attempt to understand the body's relationship with technology, suggesting a bio-technical convergence where the body can no longer survive without the technologies we have developed for ourselves.

This historical record demonstrates a considerable shift in emphasis between corporeal and metaphysical dimensions, with a clear emphasis on humanist principles in the classic, Renaissance and modern periods, and the metaphysical in the pre-historical and Gothic periods. Post-modern theory however would reject both notions. The emergence of dialogues related to the human experience removed of these frameworks opens up new discussions related to both pragmatic and phenomenological aspects. This doesn't mean that we have abandoned previous models of the body but rather we have built upon them;. The contemporary body is at once physical, objective, spiritual, geometric, mechanical, systematic, divided, and networked.

Fig. 13. Augmented Reality as imagined in downtown Toronto

3 The Networked Body

"With every new artefact we create a new ideology – what are, then, the ideologies that we create and embody today? As we design and appropriate wearable technologies – we also start inhabiting a new set of ideologies. These new and emerging technologies are not mere accessories in the form of opportunistic embellishments to new lifestyles, but physical, psychic and social prostheses." -Despina Papadopoulos- ***Wearable Technologies, Portable Architectures and the Vicissitudes of the Space Between.***

With the advent of global communication networks and ubiquitous computing in the 21st century comes a radically transformed social landscape where the interrelationship between the human body and technology is becoming increasingly complex. Rather than a dislocation of the body from the real into the virtual as anticipated by Post-Humanists, wireless communication technology have in fact augmented our body's capacities to operate within wider spatial frameworks. Rather than the body becoming subsumed by the digital, the digital network instead becomes absorbed into the body, becoming both portable and ever-present. The networked body *is* global through communications technology; the body can be anywhere because it has the tools to sense anywhere. Social networks therefore become an extended set of eyes and ears to relay information back to us and thereby augmenting our body's sensory capabilities.

The possibilities of this networked body are only beginning to be realized. Virtual reality is becoming augmented reality as interfaces are becoming intuitive and invisible. The digital world is becoming real and and enmeshed with the physical world in more subtle and sophisticated ways. Information is becoming less fixed to place as cloud computing begins to replace traditional methods of data storage. We are at the beginning of a technological shift where the digital world is actually materializing in the real world through digital fabrication. As bits are becoming atoms and vice-versa there lies the potential to create more haptic, tactile and body-tailored material interfaces.

In the Information Age we arrive at a conceptualization of the body which is fully engaged in global information networks via mobile devices, surveillance systems, biometric data stored in government databases, and the increasing amount of information we share about ourselves on the Internet. We might say that this body has two selves: one of actual flesh and the other of a "meta-body"; a digital profile consisting of

biometric information, qualifications, preferences, habits, schedules, preferences, moods, etc. Enabled by portable computing, the *networked body* as proposed here suggests an reintegration of these two selves by a projecting the virtual back onto the physical body, enhancing and extending the body's capacities both into digital and physical realms.

As the digital realm continues to expand and wireless communication networks replace material networks, the air around our bodies is becoming charged with invisible fields of activity. In this space there are no longer any defined borders, but rather intersecting thresholds of intensity. With the replacement of tangible physical systems with increasingly digitized and wireless infrastructures, organizational structures and hierarchies are becoming increasingly illegible. This immateriality is perhaps why we have such difficulty in representing the networked body, building, or city for that matter. However, our bodies themselves may become participatory agents in the articulation of this networked space. The invisible is already made visible through the body language and behavior that we engage in while utilizing contemporary technology. Thus in attempting to understand the changed condition of culture, politics, and aesthetics that characterize the information age, the network can be seen as much more than a technology with social ramifications, but as a unifying medium from which new personal, social, and aesthetic ideologies might develop.

As information networks become a ubiquitous reality of contemporary life, material and tactile experience of space is becoming largely supplanted by visual interfaces, supplanting all other means of engaging with our body's senses. Ergonomics, insofar as it relates to our physical body is becoming less important than user-friendliness from the standpoint of cognitive legibility, and navigability in software environments. Any further development of networked reality must consider not only how our physical bodies might participate and interact across the network but also how to engage a wider range of our body's senses. Developments in *tele-haptic* interfaces have explored the possibility of engaging haptic, or touch sensations across networks. This opens up new possibilities for interpersonal communication and bio-feedback mechanisms involving much more than vocal and visual means of communication. (Fig 14b) Sensors and actuators ranging from pressure, temperature and kinesthetic sensing devices might be employed in such environments to invite a greater participation of the body across communication networks.

3.1 The Social Body

Humans are fundamentally social beings. In fact many of our technological aims have been in the pursuit of creating better linkages between us and our friends and families, to our community and our wider society. Certainly language may be seen as one of the most fundamental technologies around which society has developed. In the past century, the emergence of communication technologies has radically changed the relationship between our selves and our communities. In today's world, as wireless communication and

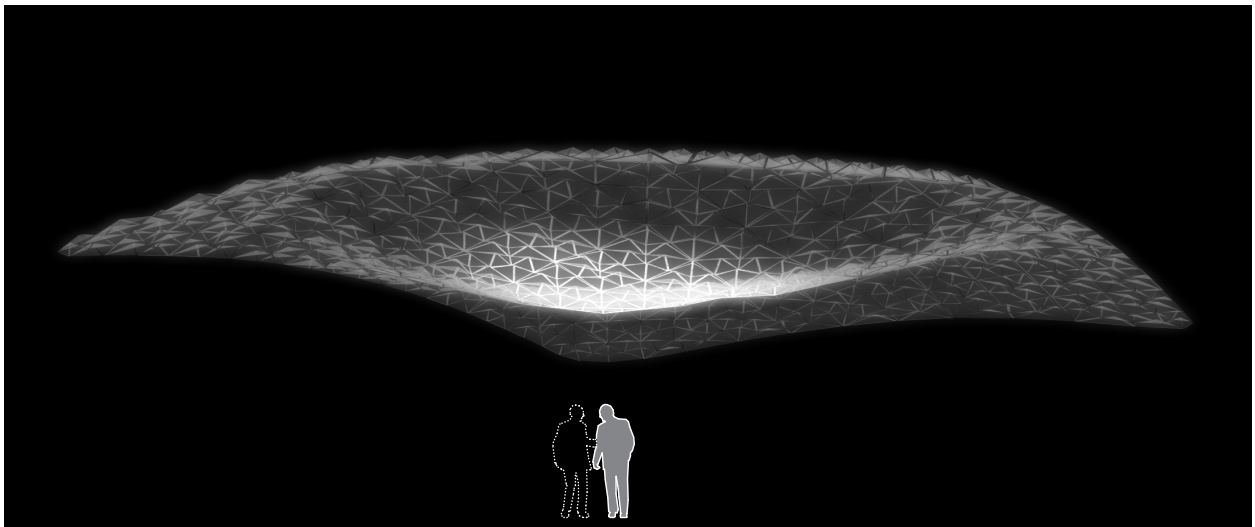


Figure 14a. Networked adaptive behaviour

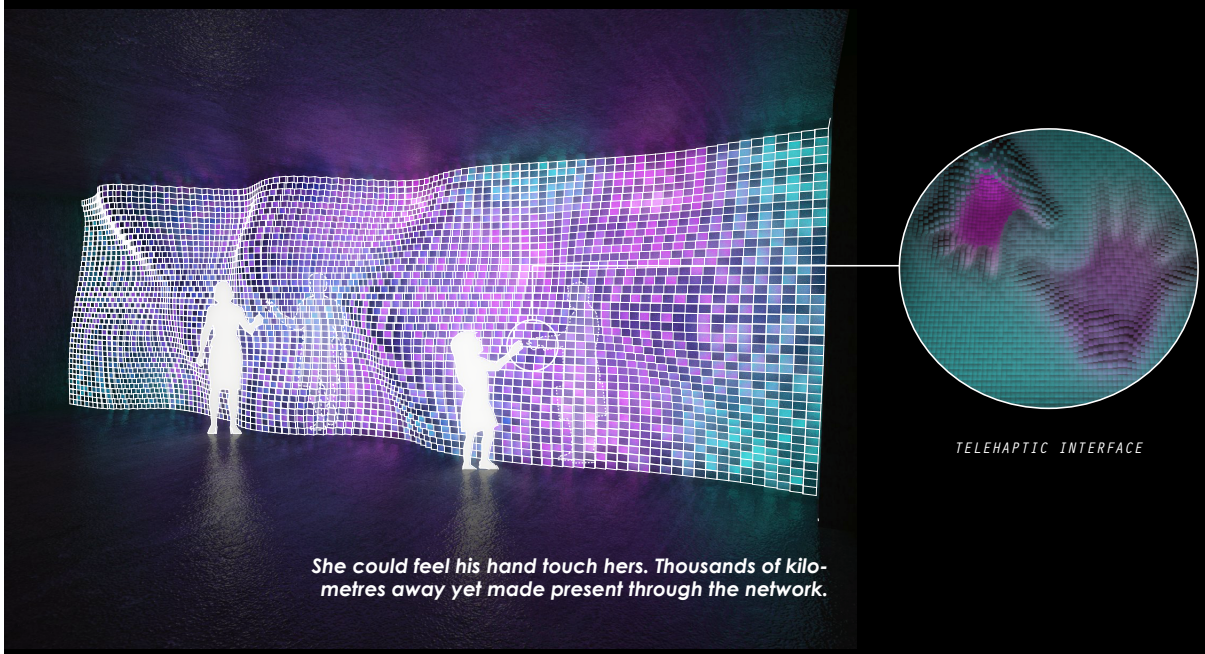


Figure 14b. Telehaptic Interfaces in the Networked Environment

social networking persist in mediating every aspect of our daily lives, our bodies' psychological boundaries are becoming increasingly vague. With such overwhelming influence over our daily lives, networked society brings with it the ability to impose more and more frameworks and control methods onto our bodies. In order to understand the degree to which network exerts influence over our lives one must only attempt to turn off devices, however difficult that may be. And while social media has become ever-present, the types of environment fostered by these applications are so far limited, allowing us only a narrow ability to control what type of identity we project into the world and what types of information we share about ourselves. These technologies work in an *orthotic* sense; they force us to conform to simplistic logic of the interface. The effects of these limitations are becoming increasingly evident on social networking platforms, which are creating a number of new social challenges such as miscommunication, misrepresentation, fragmented identities, cyber-bullying, privacy issues, to name a few.

In understanding how information technology might support the creation of individualized or 'bespoke' environments, we need to also consider how multiple occupants might interact in both in shared space and across network space. Beyond articulating the frictions between the needs and desires of multiple users, adaptive architecture can provide the means of catalyzing social interaction by moderating and seeking best-fit solutions to a number of various supportive or conflicting inputs. As the organization of human activity is becoming more dependent on connections between people than the environments in which they take place, program in this sense has less to do with organizing space for expected activities, but rather a set of responses to these activities wherever they present themselves.

By acknowledging the way in which communication technology affects us at the level of the individual body, within social circles, and at a global level, architecture can be seen as a means of articulating the changing condition that information technology brings to contemporary society. Thus interactive architectural systems might address aspects of individualization as well as those afforded by social networking.

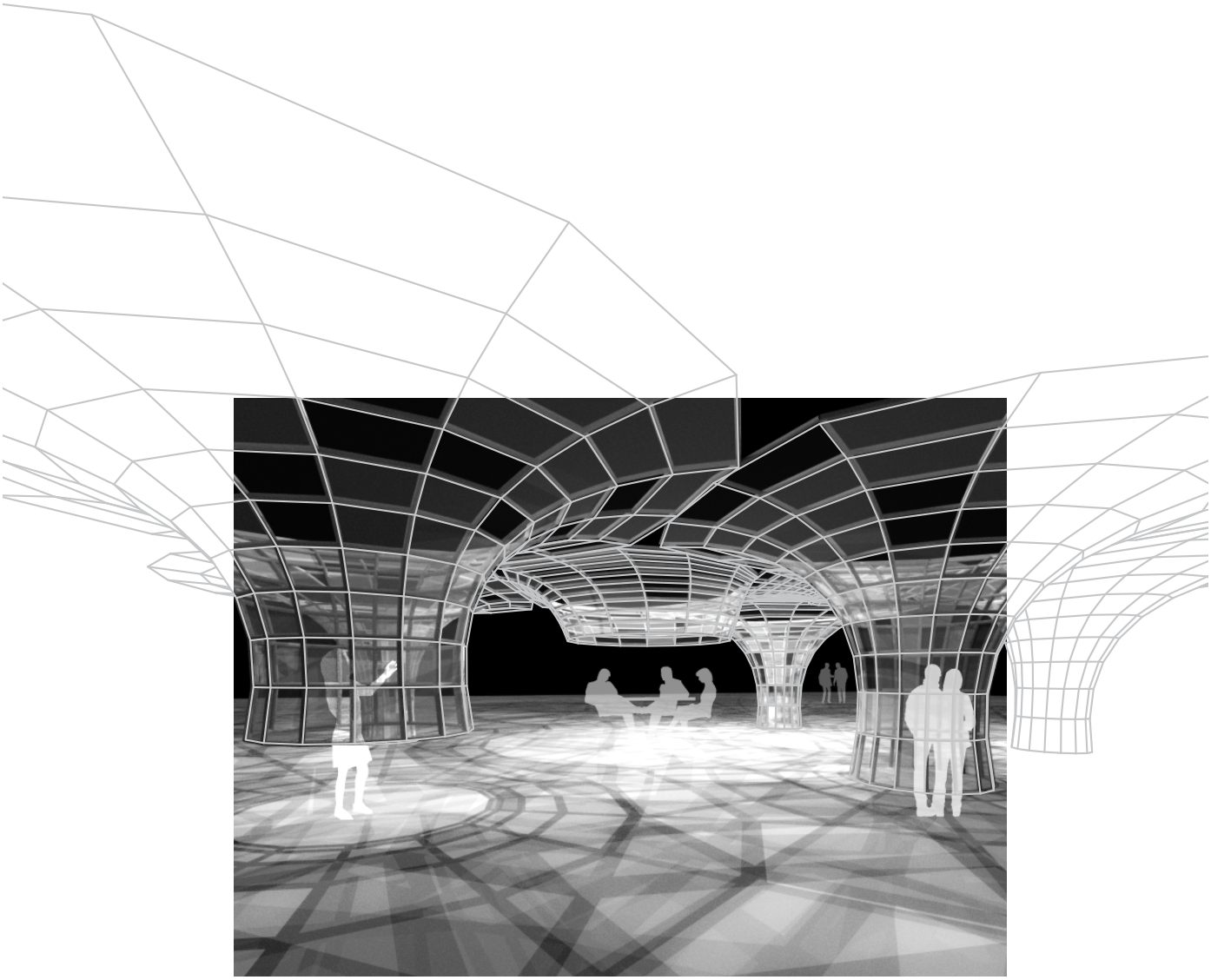


Fig 15. Adaptive architecture as a social catalyst

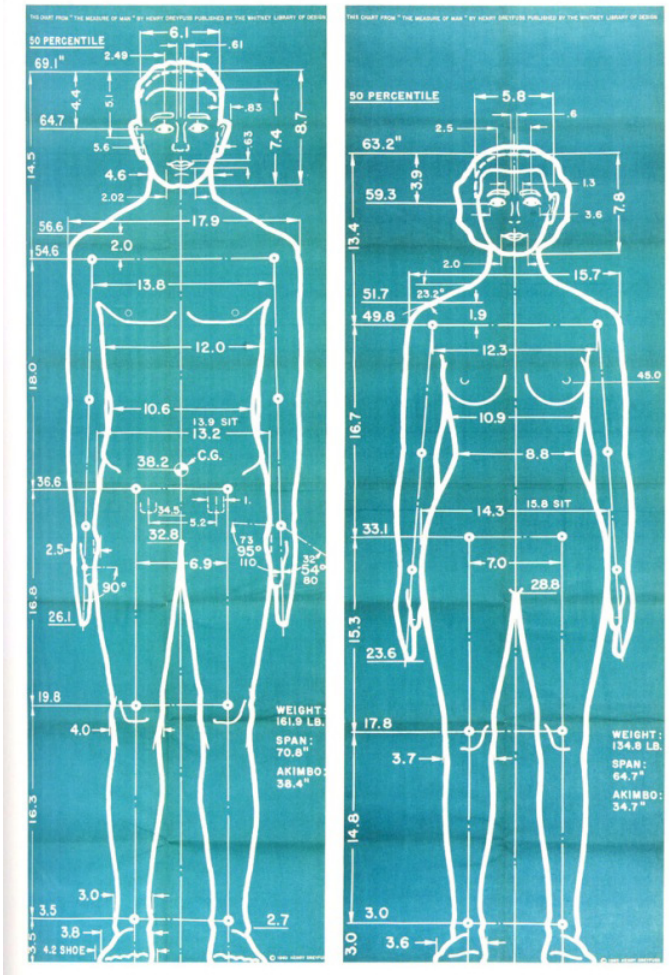


Figure 16. *Joe and Josephine*. Henry Dreyfuss Associates. 1974.

4 Anthropometrics and the Normative Body

"For most of its history, the anthropometric diagrams of Graphic Standards have presented an image of the human body that is sex and race-specific. These illustrations reveal at once the selection of certain demographic segments as representative of the population as a whole, as well as the restrictive conception of a preferred or model inhabitant of buildings." Lance Hosey - Hidden Lines. Gender, Race and the Body in Graphic Standards.

All bodies are different. While this statement may seem obvious, its implications are rarely evident in the way we design and construct our built environment. In fact the prevalence of design approaches based on standardized body measurements would suggest the opposite, that all bodies are the same. While Universal Design is fundamentally conceived as an inclusive strategy to account for a wide range of users, these regulations ultimately act to limit our ability to account for the differentiated needs of the specific user, and in doing so limit our bodies' potential engagement with our surroundings. If we are unwilling to accept a one-size-fits-all approach to the way we dress ourselves, then we should have the same feelings about the way we design buildings. Of course, most buildings are designed for more than one user, and so the development of design standards and building codes is a useful attempt to accommodate the dimensions of wide range of users. Unfortunately these standards fall short. The implications derived from building codes have in fact limited and constricted our approaches for designed space with relation to the body. Moreover, these standards are often discriminatory toward users that fall outside the normative conception of the body.

According to architect and theorist Leopold Lambert: "The precision and illusory exhaustiveness of dimensioned combination of the body and architecture, however useful, elaborates an imaginary limited field of possibilities both for the body and its environment.", he continues: "The elaboration of an architecture based on the consideration of an ideal normalized body is dangerous as this architecture will not only be discriminatory but will also force any body to physically tend towards this normatized body."(Lambert 2012)

Not surprisingly, the study of anthropometrics originates in discriminatory practices. Anthropometry has its roots in 19th century criminology, physical anthropology, and eugenics, where it was used to determine whether certain races were biologically inferior to others. (Hamraie 2012) Later these studies would be employed by the U.S. Army. "The United States military took up anthropometry for human factors design,

or design for the human body for designing cockpits and weapons which were better suited to soldier's bodies, thus maximizing their ability to engage in warfare. They produced one of the largest repositories of anthropometric data to date, and designed for average-sized bodies as determined by this data."(Hamraie 2012) Because of this, most anthropometric data which is still used today is based on a very narrow segment of population; mainly young, Caucasian, able-bodied, males.

In the mid 20th century, the industrial designer Henry Dreyfus, adopted human factors design from the military. Dreyfus used these approaches in the development of ergonomics, or the practice of making designs better fit the body. He published books beginning in 1960 that used the military anthropometry data and images. These handbooks were crucial to the development of ergonomic standards which would soon appear in Architectural Graphic Standards and many other later design textbooks. (Fig 18)However "In their early iterations, these figures displayed no data about disabled bodies, women, children, elderly people, or any other body not compliant with the normate template" (Hamraie 2012)

If the body is a consideration in the design process of today, it is predominantly referential. Measurements, compiled and analyzed to best approximate a user, are the extent of the bodily presence. The continued publication and use of books like Architectural Graphic Standards aides in the disassociation of the bodily experience in the built environment as it replaces the spatial requirements of a user with universally representative numbers.(Fig 18) In the introduction to the 1997 edition of Architectural Graphic Standards, the editor Sherri Scribner expresses this reality: "Even though these measurements are meant to give attention to the bodies functional needs, they act to standardize the body into a universally repetitive machine." Not surprisingly, these diagrams are noticeably absent from the latest edition of Graphic Standards Vol. 11 (2008)

Modern approaches have been accustomed to the practice of encapsulating volume and program, rather than indexing or informing the individual body in any useful manner. Not only does this impose limitations on the way we design architecture in relation to the body, but it also limits the way we might experience architecture. With the exception of relatively few encounters such as door openings, the rise and run of stairs and handrails, the human dimension is largely absent in modern architecture. With such emphasis on architecture being an object designed for cultural consumption, any means of creatively engaging with the body with any sense of intimacy has been lost.

However, by emphasizing a *user-centric* rather than a Universal design approaches we may begin to employ the differentiated body as an active subject in the formation of truly individualized, body-centric (corporeal) experience.

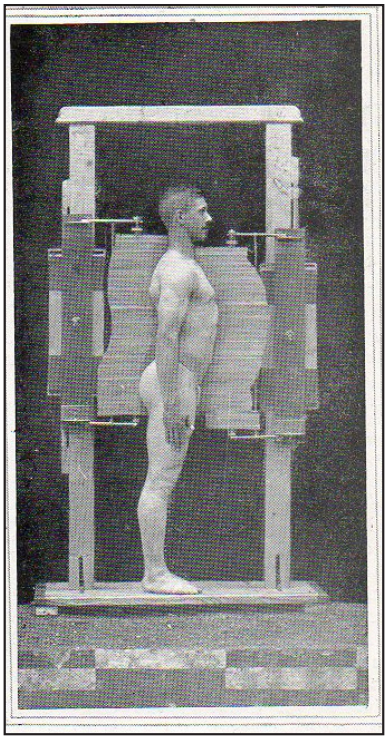


Fig 17. Anthropometric Study. Early 1900s.

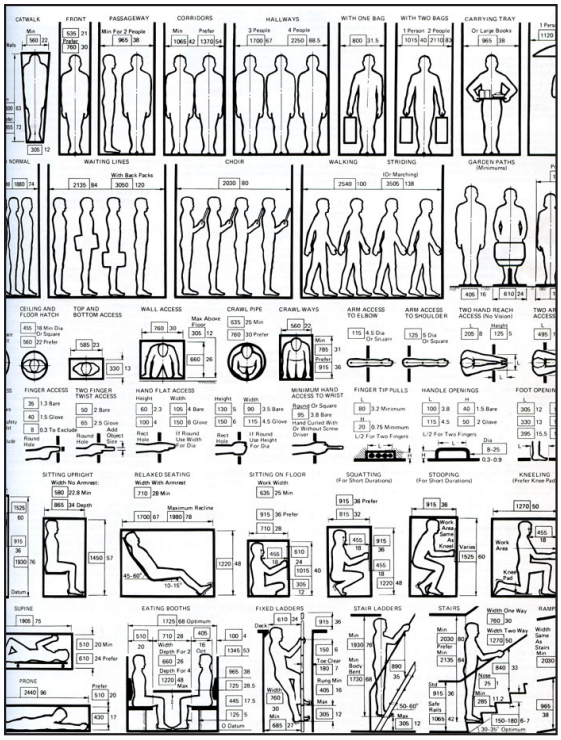


Fig 18 From Architectural Graphics Standards. 1998.

4.1 The Programmed Body

"Our lifestyle as much as our economic and social model, have brought us to build environments that are completely disconnected from the space we live in. We now live in a territory that is ubiquitously paralleled by a digital realm, and increasingly fragmented in the physical realm. Our environment has become a complex, unstable and multi-layered phenomenon, that is no longer structured according to independent entities – metropolises, cities, towns, villages – but into networks of interconnected nodes and individuals" -Domenico Di Siena. ***The Sentient City***

This critique of the normative body extends beyond the continued use of anthropometrics in design fields but rather questions the degree to which these machine-body diagrams represent our current condition in contemporary society. Networked society implicates much more than the physical dimensions of an individual body but the extended corporeal schema both afforded and imposed by communications networks. As communication networks exert influence over our daily lives, our programmatic developments will subsequently evolve along with our technological capacities. Human bodies moving through networked space introduce information, program, and human-to-human contact at varying levels of intensity and duration.

Buildings must therefore respond and interact with these programs by means of their most basic assemblages, human users. Rather than taking a passive or static role, as with traditional architectural approaches, networked architecture might actively respond to the various activities taking place within it and around buildings and seek to adjust to these programmatic events accordingly, thereby enriching the experience through interaction.

In trying to hypothesize how architectural programmes might be organized under this system we should consider that modernist methods are incapable of representing the networked body because they do not account for the complexities of globalized information. Rather than the highly demarcated modern program, networked programmatic space is created by bottom-up processes through the various agents/actors and their activities through time. Instead of fixed and static organizations, these spaces are dynamic, temporary, fuzzy and overlapping. Hard lines delineating program are replaced by intersecting zones of programmatic space creating participatory and anticipatory human-centric interaction landscapes. Therefore the design of future architecture needs to take into account the network, which facilitates interaction and flow, rather than stability of form, where program can seen less as a spatial construct than as a pattern of human activities and interactions.

4.2 Bespoke Architecture

The idea of the extended body as it relates to architectural space, programmatic organization, and material assemblages challenges the notion of architecture as being a fixed and static element in the environment, but instead as a dynamic, flexible, deployable, and mobile interface which reacts and responds to its occupants. A different understanding of architectural space may be produced via design methodologies which amplify the potentials of the individual body. Similar to with clothing, the concept of a 'bespoke', that is, tailored to the particular characteristics and requirements of any user at any time may be extended to account for buildings and urban environments. These bespoke environments seek to 'fit' the user not only on a physical level but also though learned preferences and behaviour as part of a smart system. Over time, such systems might even be able to recognize habitual patterns and anticipate human behaviour and activities.

By utilizing user-adaptive strategies instead of universal design solutions, buildings have the potential to become more responsive and accommodating to different users at any particular time. In order to create customized experience for each individual user, the body may become its own means of engaging the built environment: providing identification, activating tools, and physically affecting its surroundings. This engagement may be accomplished through a number of tools such as gestural interfaces, biometric scanning, and motion capture, where responsive feedback is achieved by adaptive architectural components such as movable partitions, adjustable fixtures, and environmental control systems, among others.

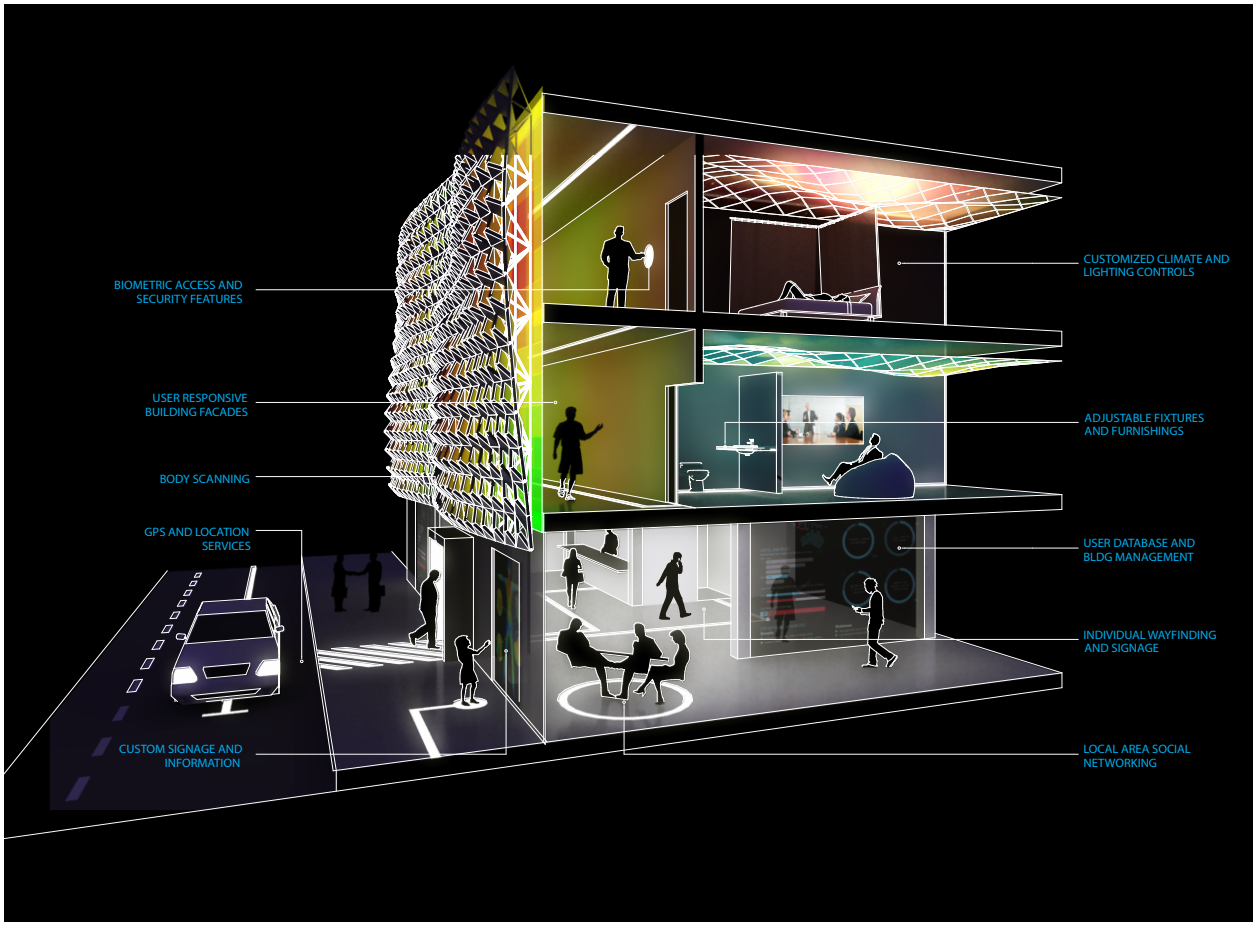


Fig. 19 Features of the Bespoke Environment

In order for 'smart' building to respond to and interact with individual users, a linkage between the body and the Local Area Network of the building must first be established. This is easily done through wifi protocols, which can determine the presence of user via their networked devices. In order to achieve a higher level of accuracy, the use of body scanning technology at building entrances provides the means in which to record and catalogue users into a smart building database. With this user database established, the building might 'know' who is present in the building, and what sort of activities they are engaged in. This data might be used to establish safety features such as security, user-capacities, fire-safety and disability requirements. By linking these biometric signatures to larger profiles, such as through social networking, customized space may be intrinsically linked to the body and called up wherever such systems are present.

4.3 On Limits

In seeking an architecture for the individual body, it is important that such an approach does not actually serve to limit the types of spatial engagements possible for the user. Catering only to a user's preferences may in fact limit the range of possible experiences by creating simplistic and predictable outcomes. In addition, such emphasis on the individualization of space runs counter to the belief that buildings serve as a medium for which social activity takes place. Environments that promote individualization may serve to limit the types of shared experiences that characterize social engagement in both public and private realms, and with that the potential for unexpected interaction, social frictions and emergent outcomes that come along with social space. Network space as it implicates wider social networking capabilities introduces a whole new set of considerations as it encompasses both present interaction between people but also with their wider social network.

In imagining how architecture might represent this new condition, we need to consider that networked reality is a relatively nascent cultural phenomenon. The technophilia that leads to the conceptualization of the virtual self as a fully formed and functional being ignores the material realities of the physical body that will always be present. The real body breathes, metabolizes, and senses its immediate surroundings. Until the network can engage with these wider sensory qualities, they will remain fixed to their immediate environments. The network must address the body on its own terms, in its own place.

Rather than forcing us to accept its logics, technology must be seen as an evolving entity which will only fully become integrated with the body once it is adequately designed for the body. While distinct terms, body and technology will always necessitate their interdependent consideration as a relationship. As technology develops, it becomes increasingly difficult to talk about bodies and technologies as separate entities, and similarly to separate theories of technology from theories of our embodiment. (Richardson 2001)

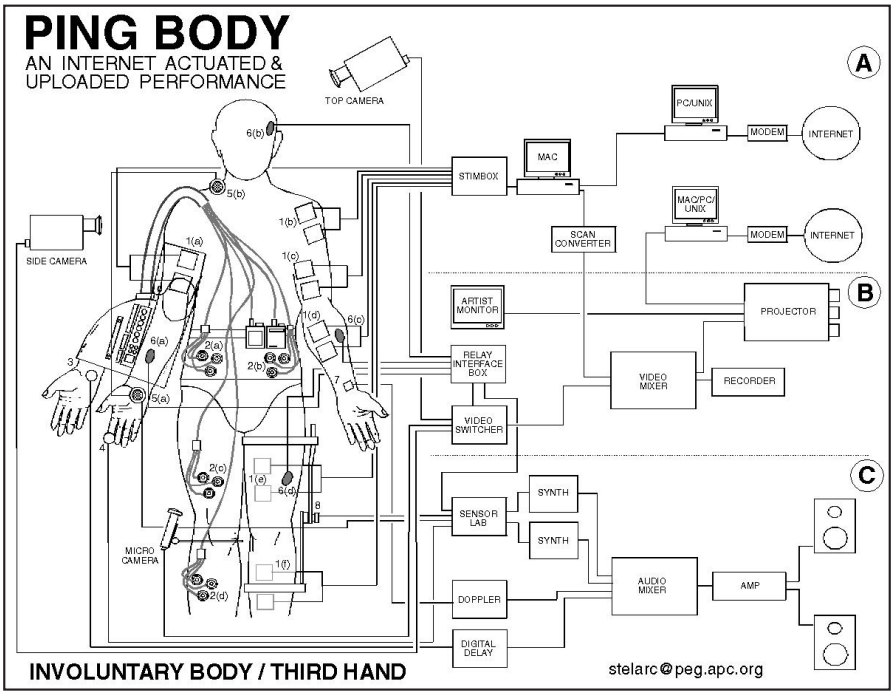


Figure 20. Stelarc. Ping Body. 1995.

5 Prosthetic Architecture

"Visible and mobile, my body is a thing among things; it is caught in the fabric of the world, and its cohesion is that of a thing. But because it moves itself and sees, it holds things in a circle around itself. Things are an annex or prolongation of itself; they are encrusted into its flesh, they are part of its full definition; the world is made of the same stuff as the body." Merleau-Ponty, 'Eye and Mind', 1964

The body has been design's primary point of reference across history, not only because people like to fashion things in their own image but because functional objects come in close contact with our bodies. (Lupton 2002, 29) Humans invented technologies to supplement the inadequacies of the natural body. These prosthetic devices: objects such as chairs and jackets, cups and spoons, buildings and cars, serve to extend and support the body, compensating for its failures and allowing it to survive in a world that is largely inhospitable to human life. (Lupton 2002) In this sense, prostheses, or technology in general, constitute an essential characteristic of humans: That humans are defined as prosthetic beings.

Architectural theorist Jonathan Hale proposes a wider redefinition of 'technology' as one which includes both tangible physical tools, and abstract cultural constructions:

"If we include within the category of technology the sum total of all the things that we produce in the pursuit of a better life: Our clothes, furniture, equipment, buildings, cities and even landscapes (to the extent that they are actively organized and productive) –in fact anything made, managed, configured, or transformed in the process of modifying the environment for human habitation. This broad definition should also include less tangible tools such as social structures, conventions, habits, forms of entertainment, styles of behaviour – and even language itself." (Hale 2012, 513)

All of these artefacts should be seen first and foremost as tools for reaching out and engaging with the world. As the anthropologist Tim Ingold has defined the term: "A tool, in the most general sense, is an object that extends the capacity of an agent to operate within a given environment'" (Ingold 1993, 433). Following this line of thinking, all technologies should be seen in terms of their prosthetic relationship with the body, and more fundamentally, that "The prosthesis is not a mere extension of the human body; it is

the constitution of this body qua human" (Stiegler 1998,152) The phenomenological idea of the corporeal schema or body image is significant in that it is not restricted to the physical body itself. As Merleau-Ponty points out, "The spatiality of the phenomenological body image is not limited by the boundary of the skin, it is extendible through artifacts." (Merleau-Ponty 1964).

Marshall McLuhan described technological devices as the external organs of the body and media as 'the extensions of man' He used several examples to illustrate this analogy including the wheel as an extension of the foot; clothing, of the skin; radio, of the ear; print of the eye, even electric circuitry as an extension of the central nervous system. (McLuhan 1964) In a later essay he focuses his discussion on the relationship between clothing and housing: "Clothing, as an extension of the skin, can be seen as a heat control mechanism and as a means of defining the self socially. In these respects, clothing and housing are near twins, though clothing is both nearer and elder; for housing extends the inner heat-control mechanisms of our organism, while clothing is a more direct extension of the outer surface of the body." (McLuhan 1967)

In his book, *Prosthetic Architecture: An Environment for The Techno-body*, Georges Teysott argues: "The urgent task (that) architecture ought to assume... is that of defining and imagining an environment not just for 'natural' bodies, but for bodies projected outside themselves by means of their technologically extended senses. Far from assimilating the tool with the body according to the mechanistic tradition of Cartesian dualism, we must conceive tools and instruments like a second sort of body, incorporated into and extending our corporal powers." (Teysott 28) The network, conceived as an extension of the body, becomes a type of auxiliary 'digital' skin. This shift in thinking from the virtual as a de-corporealized act of assimilation with technology is thus contested by notion of embodiment, through which our physical bodies extend themselves into virtual terrains.

5.1 On Orthotics

Orthotics are described as: "an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system" (Merriam-Webster 2013) This definition could be extended to include all apparatuses that impose restrictions on the body, including immaterial structures such as rules, laws, regulations, and cultural norms. Just as prosthetic tools aid the body in its capacities, we can imagine other technologies that impose restrictions upon it; causing the body to warp and disfigure due to repetitive and ongoing strain. One can think of the effect of computers or drafting boards as on posture and its effects to the spine, carpel-tunnel syndrome caused by overuse of drawing tools or mice, or damage to the ribs and internal organs caused by restrictive garments, as with corsets, or high heels. These technologies work in an orthotic or corrective sense rather than a prosthetic or enabling sense.

The process of alienation between the body and technology has been a recurrent theme which has roots in the nineteenth century with the writings of Marx and Engels. This implies that the technology serves to entrap the body in evermore complex web of technological tools necessary for participating in modern life. The growing use of digital platforms imposing restrictions, limiting access, presenting difficult and awkward interfaces, has served to extend the orthotic tool into the digital realm, a crisis anticipated by post-humanist theory.

5.2 A Body of Theory

Perhaps the most significant contributions to philosophical discussions of the body in the last century were martin Heidegger's discussions of existence and the "question of being", and Maurice Merleau-Ponty's discussions of perception. These ideas would have a significant impact on architectural theory, emphasizing the human experience, over the functional or aesthetic characteristics of architecture. The "essence of perception" as purposed by Merleau-Ponty has given rise to a number of phenomenological considerations which have influenced architectural theory.

Heidegger suggests we live in the space opened up and revealed by technology. And that: "The fact of our being fundamentally not at home in our so-called natural environment forces upon us the need to fashion a 'third space' in which we are firstly to survive, and secondly to thrive." (Hale 513) Merleau-Ponty builds on a number of Heidegger's concepts. At the core of Merleau-Ponty's philosophy is a sustained argument for the foundational role that perception plays in understanding the world as well as engaging with the world. Equally important was his emphasis on the body as the primary site of knowing the world, as a counterpoint the long philosophical tradition of placing consciousness as the source of knowledge, and his insight that the body and that which it perceived could not be disentangled from each other. Consciousness, the world, and the human body as a perceiving thing are intricately intertwined and mutually engaged. The articulation of the primacy of embodiment led him away from phenomenology towards what he was to call "indirect ontology" or the ontology of "the flesh of the world". (Merleau-Ponty 1968, 135). Merleau-Ponty's 'flesh' defines an outward manifestation of the body in which tools, property, and territory may become part of the living body through a thickening of the extended body image, or *corporeal schema*.

Juhani Pallasmaa has been a leading figure in disseminating ideas of phenomenology in architectural discourse. Pallasmaa argues that "all the senses, including vision can be regarded as extensions of the sense of touch – as specializations of the skin. They define the interface between the skin and the environment – between the opaque interiority of the body and the exteriority of the world" (Pallasmaa, 1996, 46) He draws a distinction between the eye and other organs, and critiques modern architecture's penchant for creating architectural 'objects' which privilege the eye as the primary organ through which we experience architec-

ture. He argues: "The eye is the organ of distance and separation, whereas touch is the sense of nearness, intimacy and affection. The eye surveys , controls and investigates, whereas touch approaches and caresses" (Pallasmaa, 1996, 46)

The present state of phenomenological thinking in architecture theory suggests an ongoing discourse relating to human experience as it incorporates architectural, spatial, environmental, and material dimensions. The emphasis of these approaches based on the body's perception of space clearly ground the body as the means in which architecture is experienced, and therefore understood.

5.3 Networked Prosthetics

Recent developments in medical prosthetics and neural devices have provided new means for technology to directly connect to the body. The release of Google Glass device in 2013 was the first product to bring augmented reality to the consumer market. The development of non-invasive neural devices such as the Emotiv Epoc allow direct brain-computer interfaces that can feed off brain signals to then translate them into commands that are sent throughout a building. Other possibilities use the skin itself as a surface to display information: several proposals project displays on the hand or other skin surfaces. The use of tattoos to contain biometric and health information is another example of embedding technology on the body. As these technologies become better integrated, there lies a potential for material interfaces to disappear altogether, creating an integrated and unmediated connection between the body and its smart environment. A number of these tools are listed in figure 21.

Given this, the body might drop all its baggage of 'stuff'. Stuff meaning the summation of all obsolete technological prosthetics (or orthotics) the body requires to be a functional modern body: Devices, keys, wallets, clothing, perhaps even buildings to the extent that they organize program. Without the need for such stuff, we might have new attitudes towards the 'objects' of everyday life. Functional objects will become replaced by symbolic artifacts linked to our memory: objects that somehow resist digitization.

5.4 Body as Site

By imagining technological tools such as clothing and buildings in terms of their prosthetic relationship with the body, new linkages between the body, clothing, and technology can be examined for their potential to drive new spatial and temporal possibilities. While most prostheses are devices (objects), this project examines the potential of prosthetic surfaces (environment) that register change conditions and react as a dynamic system. Here, prosthesis is an apparatus by which to locate and accommodate human presence and

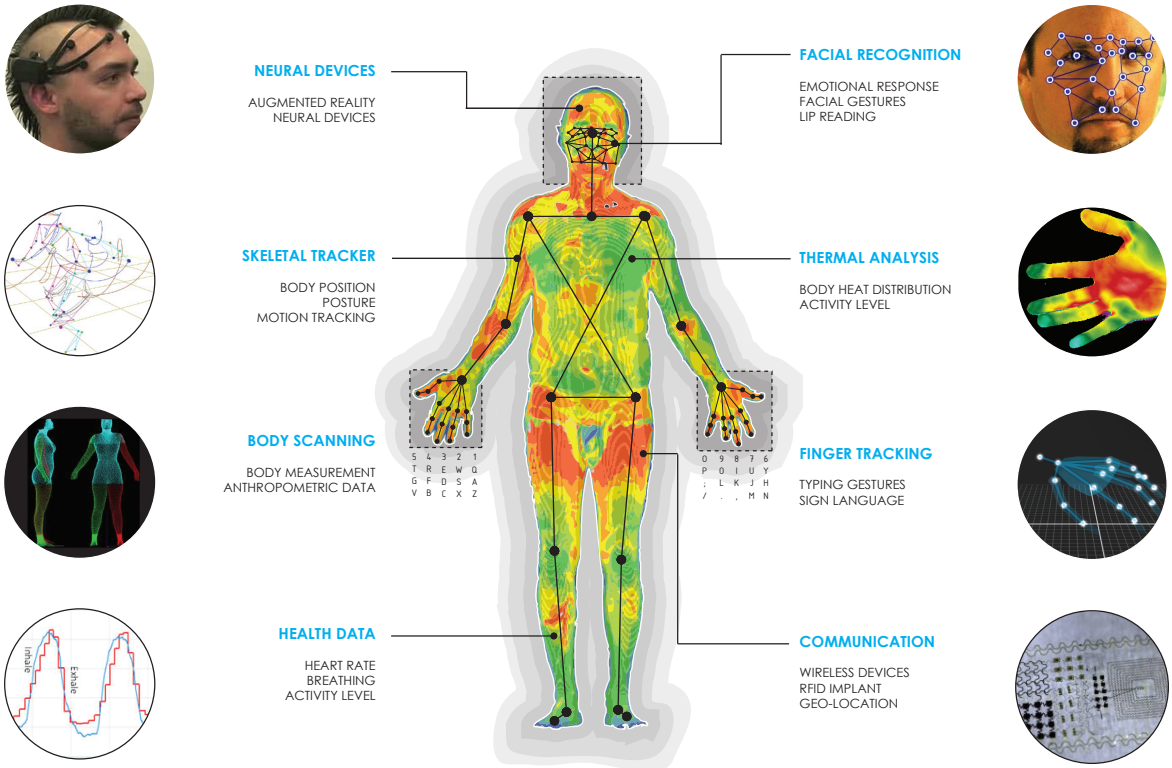


Figure 21. Netwoked Prosthetics

to respond to it through adaptive techniques. These dynamic approaches are employed in the creation of spatial, material, and environmental control mechanisms. Although 'dynamic' in this sense does not necessitate the use of kinetic devices, a feedback system between body and building is inevitably established.

Introducing the body as the primary site of exploration creates a foundation upon which further articulation of the body can be undertaken, beginning with the body and extending outward. This approach points to a number of architectural possibilities acting in and across varying scales. Employing the previously discussed concepts of the expanded 'skin', this project examines the potential of interfacial connections among and throughout these layers. In this manner, linkages between sensory elements working both at the body scale, the clothing scale, the room and building scale,and within their wider urban and digital contexts, are established. For example, smart clothing and environmental controls may work together to better regulate the direct surroundings for the user. At the room scale, interactive and kinetic surfaces may be capable of responding to the body's position, motion, or activities. At the building scale, the use of body scanning and

identification coupled with anthropometric data may support individualized spatial preferences within the building. Beyond the building scale, interaction between multiple human actors may create temporary programmatic spaces within their wider urban contexts.

5.5 Mind/Body/Space

In considering the implications of responsive environments, we must consider first how not only at how architecture may react to bodies, but more fundamentally how bodies themselves react to architecture. Buildings have the capacity to instill awe, fear, joy, pain and wonder in the people that experience them. Instrumental in the act of designing space is the capacity to influence or direct human experience.

Beyond the need for comfort and familiarity in our surroundings. It is important that we are sometimes challenged, discomforted, surprised, or amazed by unexpected situations. This notion of challenge is a central theme in the work of Arakawa and Gins, which they conceptualize under the name of Architectural Body (2002). They propose that the absolute non-dissociation of the human body and its environment develops a form of symbiosis which resists to death as a process. They believe that aging can be overcome through the resistance of bodies to accommodating learned habits, and by creating architecture that prevents the development of such habits. According to Gins: "Works of Procedural Architecture prompt the body to perform sequences of actions—procedures—that bring into play the full range of human capability." In two of their projects, Biocleave House (2008) (Fig. 22), the Reversible Destiny Lofts (2005), the intention was to create a scenario where residents must constantly negotiate their surroundings, and therefore constantly be aware of their own body. To achieve this, floors are purposely bumpy and sloped, windows are too high or too low to look out of, doors are missing, and electric sockets and switches are deceptively positioned. Because of this, occupants are constantly forced into performing mental tasks that challenge the body's proprioception at all times.

We can also image a space which might mitigate the effects of communication networks by presenting a space devoid of any such network connection. In this situation the user is presented with minimal diversion and simple surroundings, separating the body from all distractions: including other people, electronic devices, visual clutter and noise pollution causing the mind to reset to its reduced corporeal schema, (to the body alone.) Thereby acting to restore and rebalance the user's self-awareness (Fig 23, page 42)

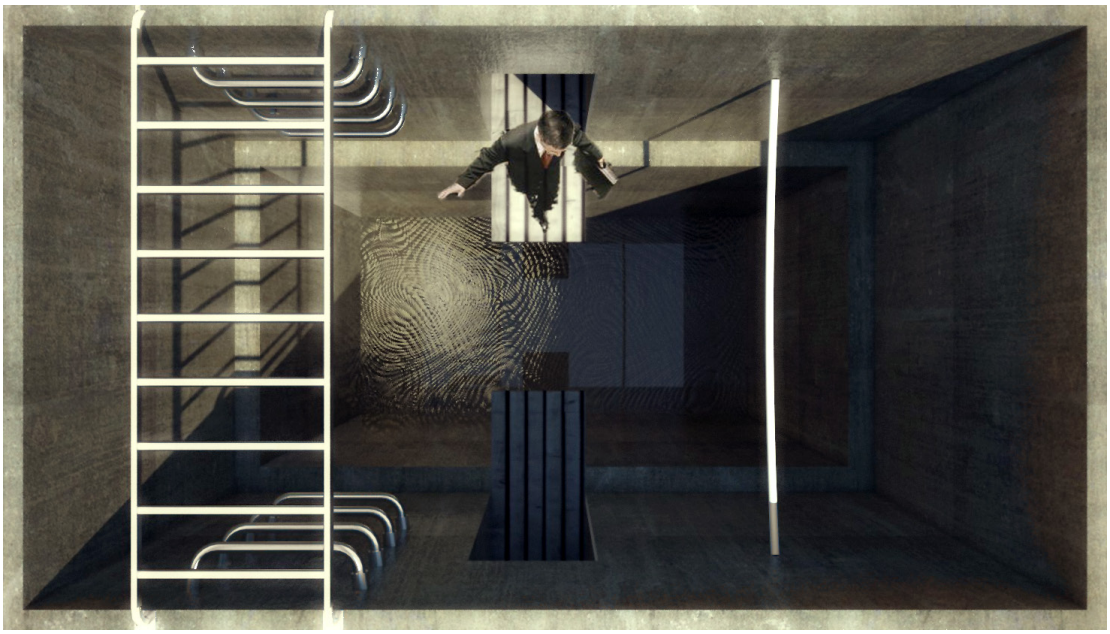
On the other hand, we can imagine a scenario where the body must heighten its awareness in order to negotiate its surroundings. By creating a challenging and somewhat dangerous scenario, the body is forced into a proprioceptive shift, enabling a greater mental lucidity and causing the release of adrenaline and endorphins

to excite and stimulate the body.(Fig 24, page 43)

In both these scenarios architectural situations create a neuro-chemical effect on the body which will affect how a user might react or behave to a space but to also create a longer-lasting effect in the body which will continue even after the user has left the space. Here, architecture seen as a prosthetic tool can become a means to both augment the body in its physical capacities but also its mental capacities through psychological stimuli.

Figure 22 Arakawa and Gins. Biocleave House. 2008

With all connection to the outside world absent. She truly felt naked. It wasn't that she wanted to talk to anyone at the time, but just to know that she could. Eventually she came to forget everything else. It was simply her, alone, content in her own body in this time.



Adrenaline rushed through his body. His heart pounded in his chest and his stomach clenched. Yet his mind was lucid and focussed on the task at hand, giving him a heightened level of awareness that would last for hours.

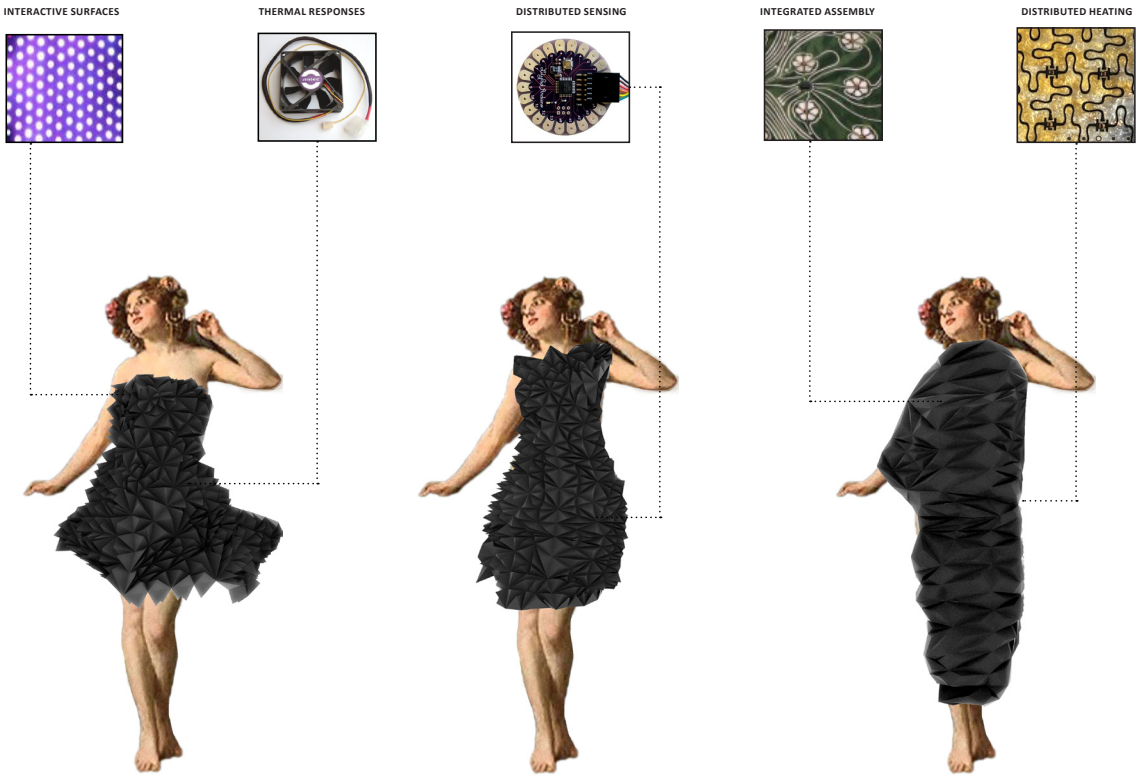


Fig. 25. Adaptable Smart Clothing

6 Fashion and Architecture

(The Second and Third Skin)

"We inhabit space tactilely by way of habit, and tangibly so. A haptic bond links sheltering to clothing the body. To occupy a space is to wear it. A building, like a dress is worn and wears out." - Giuliana Bruno. " Public Intimacy"

As previously established, the development of clothing and shelter are rooted in the very same technological origins. The primary function of both clothing and buildings has always been to provide the body with shelter and protection. Both operate within the same spatial frameworks to manage energy and material, and map the boundaries of the body by creating climatic environmental systems around it. Fashion and architecture revolve around the scale of the human form, and therefore rely heavily upon human proportions, mathematics, and geometry to create the protective layers in which we inhabit.

Both fashion and architecture express ideas of personal, social and cultural identity, reflecting the concerns of the user and the ambition of the age. Within this system, garments can be seen as more than mere clothing – "they form a part of a structure that negotiates the relationship between private space and public arenas, both defining our identity and place in society." (Quinn 5) Being fundamentally rooted as design professions, both architecture and fashion have a shared vocabulary of technique, fabrication and methods of representation. Both professions also share methods of communication, coding and signage, form, information, program, pattern charts, volume outlines, texture fields, surface operations, and implement electronic or digital extensions. (Reinhardt 2005)

Since the modern era, architects have become increasingly interested in ideas of mobility, soft materials, and techniques of tailored garments such as draping, folding, and seaming. Projects such as Shigeru Ban's Curtain Wall House. (Fig 26) and its usage of a large-scale fabric curtain on the building exterior show an interest in possibilities which lie at the margins of architecture and fashion. High-end fashion boutiques by Zaha Hadid, OMA and Toyo Ito demonstrate attempts to translate fashion branding into architectural form. At the same time, fashion has often looked to architecture for inspiration. The works of Issey Miyake, Alexander McQueen, Victor & Rolf frequently reference architectural forms and materials in their collections. At the margin, artist and designer Lucy Orta, has explored portable clothing/architecture, through lightweight and autonomous structures representing issues of survival.(Fig. 27)

In recent years, the connections between fashion and architecture have become interesting. Several recent publications have explored this area and attempted to draw parallels between these disciplines. (Wigley 1995) (Hartman 2000) (Quinn 2003)(Reinhardt 2005). In the introduction to the "Skin and Bones" exhibition, this cross-disciplinary exchange is made clear:

"As advances in materials technology and computer software have pushed the frontiers of each discipline, buildings have become more fluid and garments more architectonic. Architects are adopting strategies more usually used in dressmaking, such as printing, pleating, folding, draping and weaving, using new materials and techniques to create more versatile, adaptable and ecological structures that can respond to human need. While fashion designers are looking to architecture for ways to build or engineer garments which present new and provocative ideas about volume and structure, and in many cases also draw on the intellectual principles and concepts inherent in architecture." (Hodge 2005)

While both fashion and architecture address the human scale, their proportions, sizes and shapes differ enormously. And while fashion is, by its very nature, ephemeral or 'of the moment', both design realms deal with movement and matter through different times and spaces. As with all technologies, their respective life-span depends on their ability to reflect a change in context and value systems. They are adapted or updated, if not, they vanish. (Reinhardt 2007) While architecture traditionally has a more solid, monumental and permanent presence, fashion is rapid, ephemeral, experimental, thus a predestined medium of cultural phenomena. As Claire Wilcox notes, "fashion is composed of change" (Wilcox, 2001). In this context, designs have emerged that show an alteration, variation or transformation in form and material.

6.1 Textiles

Perhaps the most fundamental link between fashion and architecture is the mutual employment of textiles. Textiles have always been integral to architecture, whether from woven partitions, metal lath, or geo-textiles. In today's built environment, textiles offer a wide range of attributes such as water-proofness, breathability; elasticity; softness; tactility; to name a few. They also employ differing construction methods (weave, knit, felt) and operate on scales of construction from the microscopic to the engineering of entire landscapes. In "Der Stijl" Gottried Semper argued that "the beginning of building coincides with the beginning of textiles" and that textiles are "the origin of many ornamental types and symbols in architecture and design." (Semper, 34), as the use of mats and floor coverings are observable in the earliest cultures, even those that had not developed sophisticated clothing. Semper defined the origins of architecture through his concept of Bekleidung - translated Dress Principle. He cites the primitive use of woven mats that were used interchangeably on the ground, stood upright as wall, and draped over frames as the beginning of architecture. Most importantly Semper identified a 'universal nomadic textile culture as the original form of art, and he

Fig 26. Curtain Wall House. Shigeru Ban. 1995

Fig 27. Refuge Wear. Lucy Orta. 1992.

considered adornment "the first and most significant step towards art" (Semper, 251). The use of decoration had suggested a similar textile origin for the repetitive, regular motifs he discovered. According to Semper, the "knot" is actually the fundamental building-block of human production, predating the masonry structures which eventually came to supplant the screen enclosure. And so subsequent architectural materials bear the marks and motifs of their textile predecessors.

6.2 Techniques

In recent years practitioners in both architecture and fashions incorporated many techniques from one another. Much of this interdisciplinary sharing of technique has been made possible as a direct result of developments in material science and design software, which has allowed for significant advances in both disciplines. CAD/CAM technologies have become prevalent in both industries as a means to better manage construction and manufacturing documentation, as well as providing more sophisticated means of engaging in their respective subject matter.

The transmutation of techniques in fashion and architecture can formulate new concepts for organization,

structure and detailing of form in a responsive and interactive system. In the case of architecture and fashion, the prosthesis addressing change is external to the body; a surface that is a highly profiled supplementary skin. "A surface as prosthesis, attached to the body, becomes part of the body, evidences this congruence and operates according to principles of body technology: restoring, normalizing, reconfiguring and enhancing it." (Reinhart 51)

6.3 Smart Clothing

"As garments evolve to create self-controlled environments that provide the wearer with heat, music, privacy and communication, they amplify fashion's primary function as shelter, and signal fashion's capacity to assume the functions of modern dwelling" - Bradley Quinn – Techno Fashion, 2002.

The development of smart clothing has paralleled similar in advancements in the built environment. Recently, both disciplines are beginning to incorporate technologies such as portable electronics, adaptive environmental controls and smart materials which are transforming both disciplines and their relationship to one another. In light of these changes, a new dialogue is emerging: one that further questions the boundary between what is "lived in" and what is "worn".

Increasingly, electronic devices, optical fibres, touch-sensitive surfaces, and RFID chips have been integrated into clothing and textiles to create soft, flexible and portable sensing technologies. Smart clothing may be used as a means to communicate information about the user's state to the surrounding Smart environment. Both clothing and building may then form a combined system which responds to the body. In this way, the garment acts both as a semiotic device to convey personal values (style), but also to create a micro-climate for the body by means of embedded environmental sensors and actuators (heating, cooling ex.). As a communicative tool, both levels may be linked to both their immediate sensing environment as well as global information networks. Real-time relaying of information between the garment and its extended environment allow the Smart environment to become intrinsically linked to the garment, and therefore to the body.

Figure 25 Shows a garment which is capable of both physical adaptability by allowing an alteration of silhouette and through the employment of sensors and actuators embedded in the garment to sense the state of the wearer. Alterations of form allows the garment to change from more formal dress configuration (a cocktail dress) to a practical thermal envelope for the body (a sleeping bag). Through adaptability, the garment provides the possibility to express changes in style, mood, behaviour, and internal and external environmental conditions. Embedded technologies in the garment both add to the wearability and comfort of the garment, but also provide new provocative ways to convey style. Lights and electronic displays integrated into the garment can reflect dynamic changes adding another layer of communication to the garment.

6.4 On Surface – Facade, Envelope, Skin, Interface

Most contemporary writings relating fashion and architecture have focused their discussion around the significance of the building surface or "skin": (Wigley 1995)(Leatherbarrow & Mostafavi 2002) Referring to a seamless architectural envelope, the building skin has become common terminology among architects, designers, and the general public. As an exterior layer mediating between the building and its environment, the notion of skin replaces previous conceptions of the building "facade"; maintaining the concept of a communicative surface but also imbuing it with action, information, graphics, motifs, projections, engravings and other types of communicative techniques.

Notions of the architectural skin originate in discussions around the architectural surface. The origins of this discussion begins according to (Middleton 1984) in the 19th century, with the discovery of polychromy (surface painting) in Ancient Greece, the writings of Gottfried Semper on architecture, weaving, and clothing, and John Ruskin's discussion of surface ornament and his theory of the adorned "wall veil". By the turn of the century, modernist critiques ornament from Adolph Loos to Le Corbusier, turn away from surface towards the articulation of architectural volume and structure. The surface reappears half a century later with the writings of Venturi and Scott-Brown and their notion of the "Decorated Shed", and evidenced in their use of polychromy, ornamental motif, and their application of semiotics. By the 1990s, surface appears once again with the development of computer aided design and manufacturing, as seen in practices of Gehry, FOA, and NOX. At the same time, discussions on the intersection between fashion and architecture appear with the writings of Wigley, and the emergence of high fashion retail works by Hadid, OMA. Most recently, aspects of sustainability and energy efficiency have become focussed around the performance of building envelopes. Applications include double-skin and dynamic facade systems which are responsive to environmental conditions.

Examination of the changing attitudes towards the role of the architectural surface demonstrates that the architectural skin it is not merely a by-product of programmatic and structural concerns, but can in fact provide a means for informing program, communicating information, and expressing values, styles and motifs. Aspects of depth reflected in contemporary works which employ double-skinned or programmed facades open up new spatial possibilities and challenge conventional notions of interiority and exteriority. Recent advances in mobile computing, kinetic and responsive building systems have embedded another level of interaction between users and building skin. This new building skin could be considered an interface, which provides new possible connections between the body, the building, and their wider contexts.

6.5 On style

Architectural discourse tends to reject notions of 'fashion' in favour of notions of 'permanence' or 'timelessness' . In doing so it ignores the reality that buildings are constantly affected by economic forces, changing building codes, public opinion, overuse, etc., and hence that buildings may wear out, fall out of fashion, or become obsolete. Loos' rejection of ornament in architecture was based on his belief that ornamentation can have the effect of causing buildings to go out of style and thus become obsolete. The accelerated pace of global consumer culture's endless quest for novelty has created a situation where buildings might become obsolete for no other reason than that they don't represent current tastes or cultural values. However, by imbuing buildings with a greater capacity to change, adapt, be reused, disassembled and disposed, we may extend a building's lifespan by allowing it to "change clothes". The use of the building envelope as a means for expressing pattern, texture, light, and information, opens up new possibilities for dynamic activities to take place on or through this skin. Therefore the skin can be readily 'updated' to reflect current tastes, values, and purposes, allowing the underlying building structure to remain unaffected, and thereby extending the lifespan of buildings

6.6 Responsive Envelopes

While most reactive building facade systems are primarily concerned with controlling environmental factors such as sunlight and ventilation. Such systems might be driven in response by the presence of building occupants and their activities; seeking to regulate or enhance conditions in the building interior. By linking response factors to the occupants, the building facade can dynamically reflect the presence and activities of the building occupants. Both exterior factors (environmental) and interior factors (user-based) might become generative elements for an adaptive and kinetic shading device. In this way it is less about the body or the environment interacting with the building facade independently, but rather the building skin becomes the interface where human and environmental dialogues are made present.(Fig 28)

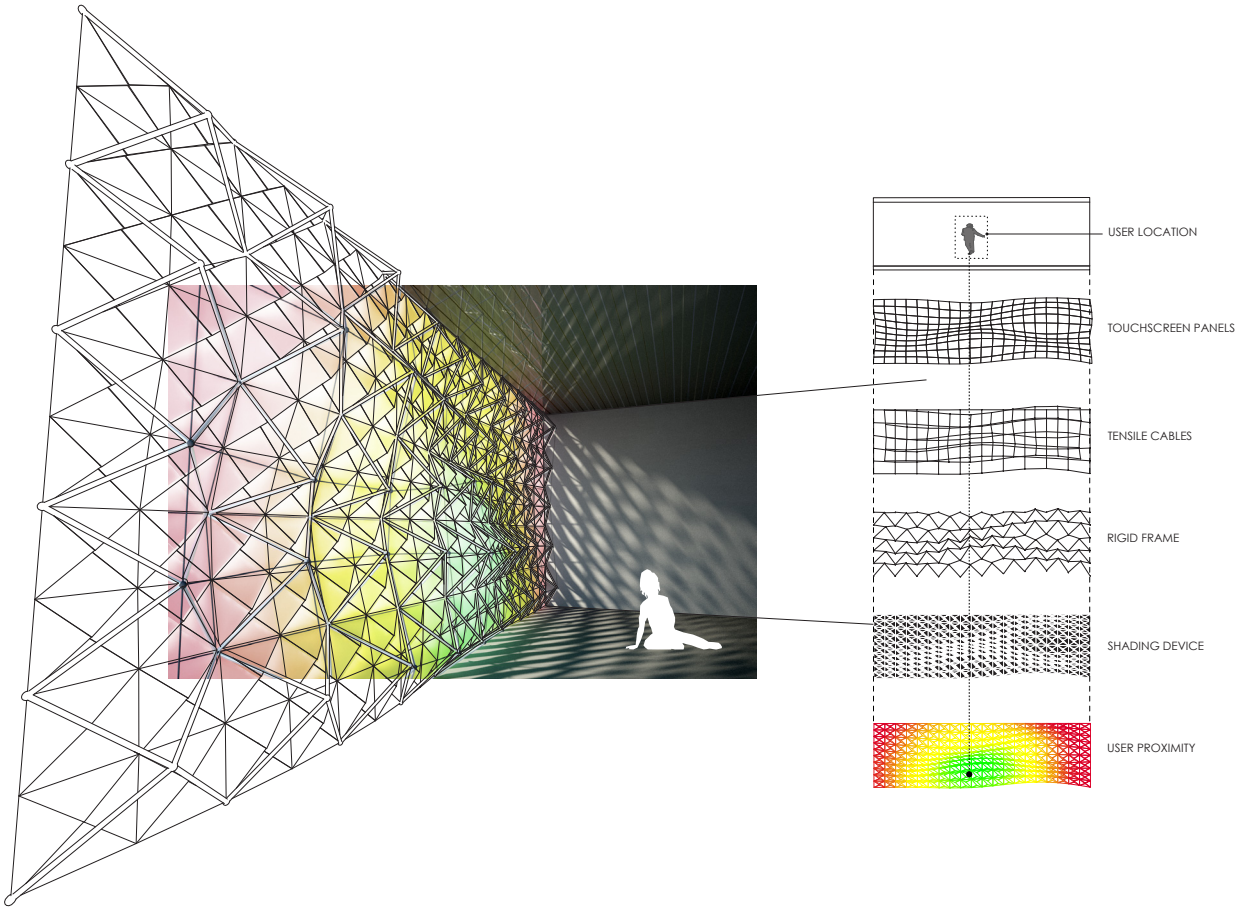


Figure 28. User Responsive Building Envelope

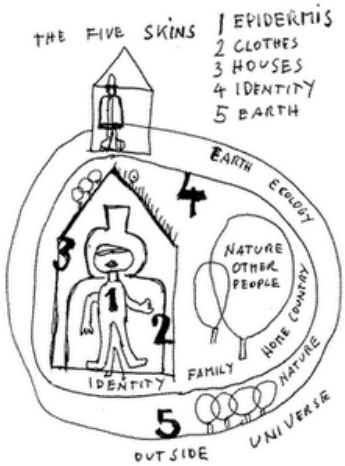


Figure 29. Hundrtwasser. 5 Skins. 1982

6.7 Five skins: Hundertwasser

Throughout his career, Austrian artist and Architect Friedensreich Hundertwasser (1928-2000) developed an existential theory that he called the 'Five Skins'. (Fig. 29) He believed that every human being has five skins that make up their personality and relationship with social and global environments. These were:

1. 'Epidermis' - the biological skin,
2. 'Clothes' - the man-made skin,
3. 'Houses' - the protective skin,
4. 'Identity' - the social skin and
5. 'Environment' - the global skin.

Hundertwasser believed that man could not achieve wholeness until he understood each of these skins and engaged with them. The ultimate aim of this engagement was for mankind to establish a closer relationship with his inner self and the ecology of his planet and thus develop a deeper awareness of the body in relation to its material, social, and natural contexts. (Hundertwasser 1982)

By envisaging Hundertwasser's skins not as discrete layers but part of a combined system, new relationships between these so-called 'skins' emerge. For example: the surface seen as a cultural indicator (as with skin, clothing, building), or the skin as a thermal envelope. Interestingly, Hundertwasser positions the social skin external to clothing and shelter implying an externalization of these aspects as a means of communicating

personal identity. Understanding an outer skin which operates at the global level is now possible in a way that might not have been envisioned in his time. The global skin could be seen as a digital skin, which connects the body through technology to both its farthest reaching and its most intimate levels.

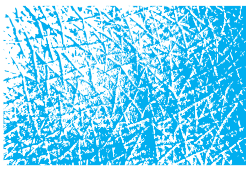
6.8 Skin as Interface

"The epidermis is only in the most superficial way an indication of where an organism ends and its environment begins. There are things inside the body that are foreign to it, and there are things outside of it that belong to it." – John Dewey, Art as Expression.

The body's skin itself is far from a hermetically sealed envelope. The skin is a permeable membrane which controls the body's temperature through sweat, expels cellular wastes and fluids, and tactilely senses its direct surroundings. If we extend this conceptualization to the 'skins' of clothing and buildings we might define them not as enclosures, but mediators between the body and the environment. As Merleau-Ponty's concept of 'flesh' implies in its intertwining of body and world, its 'thickness' is not an obstacle between them, it is their means of communication. Enabled by wireless communication, these interfaces become transparent in new ways, allowing a deep layering of information as well as material structures. Rather than simply enclosures, they become animated surfaces of activity; as interfaces for matter and information both on their surface and passing through them.

6.9 On Layering

By extending and projecting space and form outward from the body and its movements, a new paradigm can be applied to the structure of place as it relates to the human self. The table shown in figure 30 list a number of these extended 'skin's and outlines several possibilities for the implementation of adaptable technologies across these varying scales. It lists a number of possibilities body-architecture interaction, ranging in scale from the microscopic; where materials come into contact with the skin, to the building scale; how our bodies participate within wider communications networks. In many cases, the focus is on the architectural surface, both as a means of communication (as a semiotic device), but more importantly as an interface which acts as a mediator, or in some cases a connector between the body and its networked environment. Although perhaps of greater interest are the possibilities dormant between and among these 'skins' with their potential for creating new types of hybrid typologies with unique spatial and tectonic characteristics.

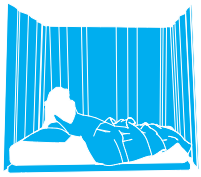


Epidermis

- Health Monitoring
- Location and Position
- Tactile Interfaces

Furniture and Soft Partitions

- Body-conforming Materials
- Interractive Surfaces
- Adaptive Configurations

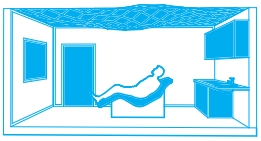


Textile

- Flexible Configuarations
- Nano-Climate Control
- Tactile Interfaces

Rooms and Hard Partitions

- Biometric Health and Security
- Adjustible Fixtures
- Heating and Lighting



Garment

- Adaptive Silhouettes
- Micro-Climate Control
- Wireless Communication

Building

- User/Occupant Databases
- Responsive Building Envelope
- Local Area Network

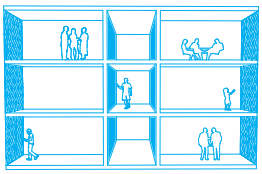


Figure 30. Extended body as a multi-layered interface

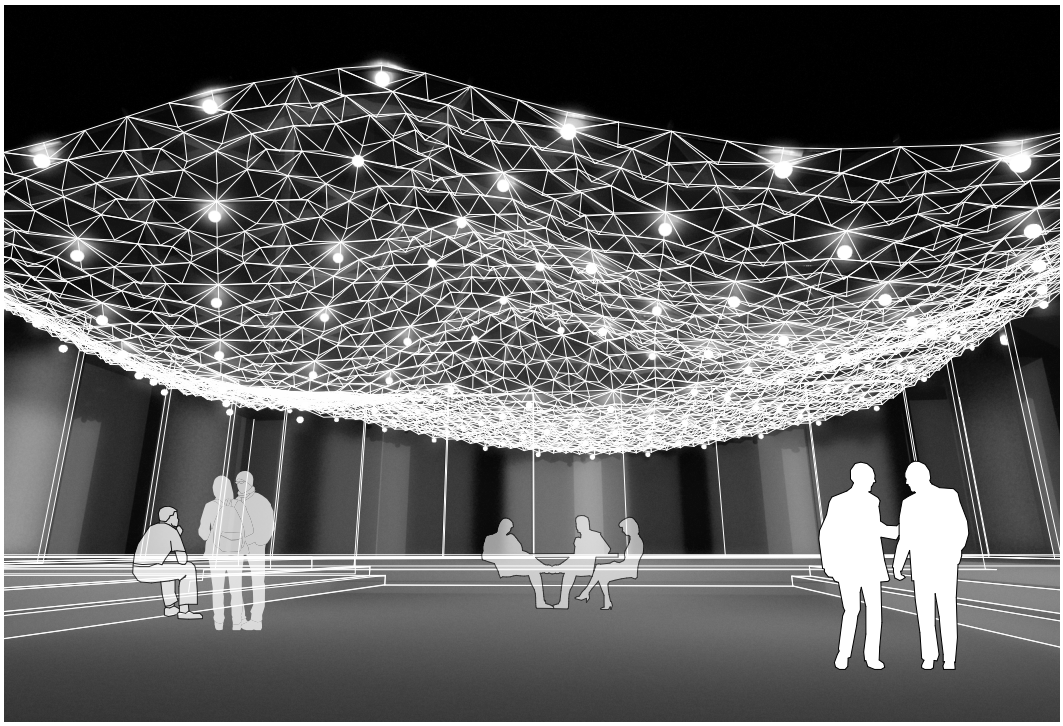
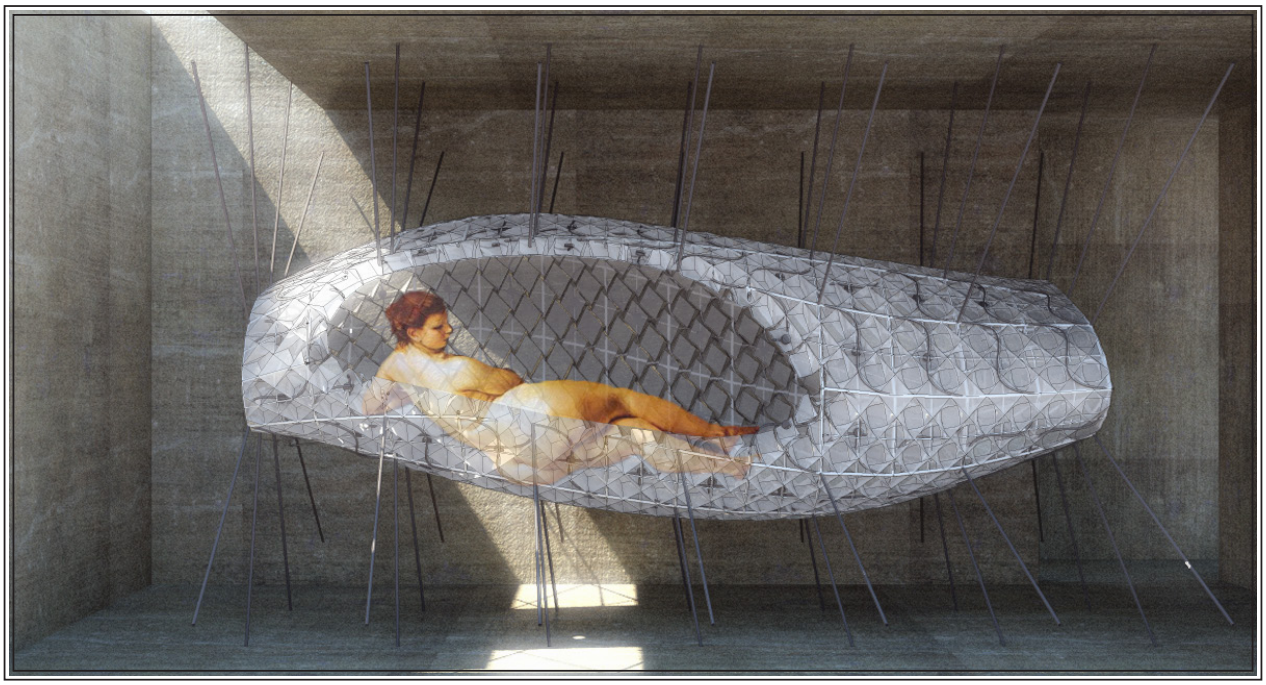


Figure 31 Adaptive Ceiling System responding to social activity.



She felt it close in around her. Slowly at first as it matched her every movement, harmonized with her every breath until it felt indistinguishable from her own body.

7 The Sentient Environment

Recent developments in wireless communication and sensing technologies have provided a number of possibilities for engaging the body in new spatial and material realities. Body imaging technology has given us the means to see inside the human body ability to map the body at various scales. Medicine has allowed us to live longer and adapt our bodies with increasingly sophisticated drugs and medical prosthetics. Electronic sensing allows us to capture the body and its movements, and to respond to it through various feedback mechanisms. Communication devices allow us to extend our bodies to global scales, and digital media allows us to represent the body in a number of new ways. These technologies can be seen as prosthetic tools, which expand our capacities to engage in both the micro and macroscopic workings of our own bodies.

Ubiquitous computing and sensing enabled by wireless communication has created a technological revolution which affects many areas of modern-day living. The proliferation of devices linked through networks is creating an "internet of things" wherein a growing number of everyday objects are becoming integrated and interactive. In the near future, sensing devices will be embedded within our built fabric in more subtle and sophisticated ways. As computing technologies are becoming an integral component of buildings, architects will need to familiarize themselves with these technologies, not only by accepting their presence but by understanding how they affect our interaction with buildings and how this interaction may lead to the design of richer environments.

In order to understand how this condition implicates design, we should consider that the definition of the term 'architecture' has been expanded to accommodate this wider organizational domain. In software development, a software architect is similarly responsible for high-level design choices and dictates technical standards, coding standards, methodologies, tools, and platforms. Spatial design in the future will implicate a wider domain of disciplines engaged both in material organization (fashion, interior, architecture, landscape, and planning) and in interface design (programmers, engineers, cognitive scientists)

7.1 Smart Environments

The smart environment is comprised of numerous computing devices, which each function to sense and activate according to a given occupant's interaction. Within the smart environment there may exist a multitude of sensor types such as cameras, microphones, smartphones, and pressure sensing floors for example. As technology evolves, a growing number of tools and devices may become networked, creating an 'internet of things' in which a greater level of interaction between people and the objects around them can occur within a given context. (Fig 33)

The potential of this smart environment is that a given space may be able to sense and determine the activities of an occupant over time, and then be able to assist them in reaching certain objectives. Features employed by smart environments may include identification of individuals, their location and activities, and emotional state as a means of determining an occupant's needs. As these technologies develop, humans will be able to communicate with their environment in more and more way. In this manner, the advent of smart architecture brings with it greater potential for a more comprehensive creation of architectural space which includes an engagement with more and more of an occupant's senses.

Given the implementation of body-sensing technologies into buildings, such systems might become smarter through a constant state of feedback and interaction with their occupants. These feedback mechanisms might be established through communicative inputs by the user such as active behaviors (voice commands, touch, motion, gestures), or passive inputs such as the body's position, respiration, and core temperature.

Buildings will be able to measure and identify individuals, and know exactly where occupants are and what type of activities they are engaged in. They will be able to acquire information on the user's body dimensions, age, gender, and physical abilities and respond accordingly. For example fixtures counters and furniture could position themselves according to a user's height. By sensing activity patterns, habits, and preferences over time, buildings may be able to anticipate and better accommodate user activity. The emotional state of the individual may be determined through facial recognition software and responses, such as the change of light quality, temperature, or aromas may be used as a response. These technologies may be also employed as a means of monitoring and regulating the health of the individual body. For example, the body's heart rate, breathing, temperature, and blood-sugar, might be used though a number of feedback mechanisms to restore and enhance the health of the individual. With the advent of smart clothing and medical prosthetics, these systems may work in a combined system which connects the body to its direct environment as well as to wider health-care networks.

Smart environments also implicate a number of sustainable factors. For example, using a greater number of sensors distributed thoughout a building and collecting more data about environmental conditions, HVAC systems can better self-regulate, mitigating energy losses while encouraging energy gains. By knowing the

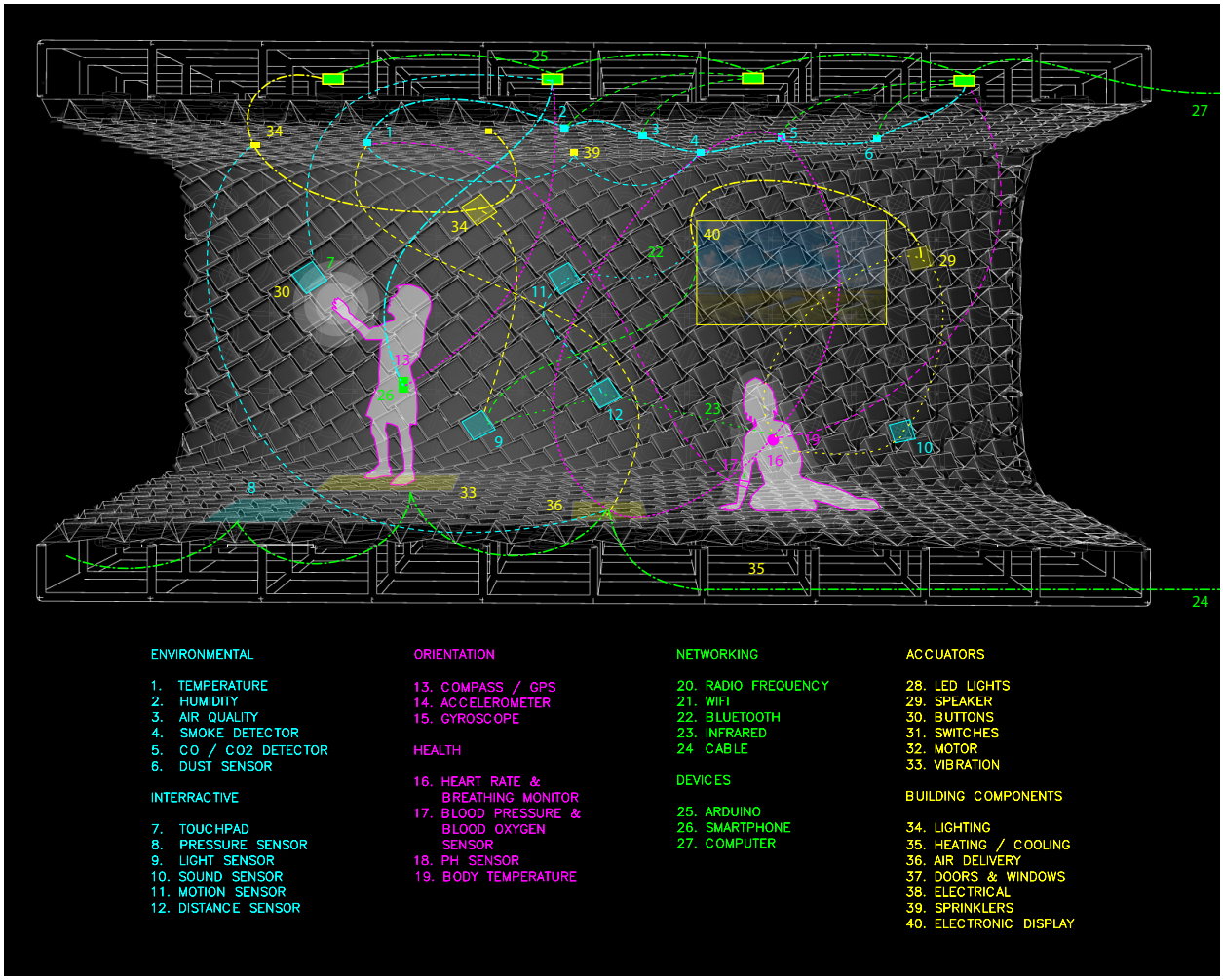


Fig. 33 Sensors in the Smart Environment

location of building occupants, light, heat, and oxygen, may be delivered only where needed, thereby reducing the energy required to supply services to areas that are unoccupied.

This two-way communication platform encourages adaptive responses via real-time feedback. Building components which may participate in this network might include: HVAC systems, elevators and escalators, fire and safety systems, lighting, security, appliances, doors and access. A number of possible building components may be wirelessly networked to the internet allowing not a collection of sensing information from these devices, but also allowing remote control of these devices.

Fig. 34. Hyposurface project by dECOi

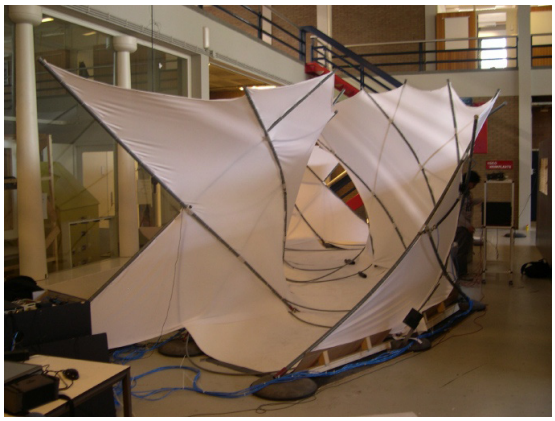


Fig. 35 Muscle Pavilion by Kas Oosterhuis

7.2 Responsive Architecture

Responsive Architecture is one of various terms that have been used to describe the ability of space, structures or buildings to respond to stimuli from users or the environment through changes in shape, organization, content or appearance. Some of these responses are more complex than others, they can include feedback, and become adaptive. Examples of responsive architecture include the Hyposurface project by dECOi, which is an interactive wall comprised facetted metallic surfaces that can physically deform in response to electronic stimuli from the environment such as movement, sound, and light. (Fig 34) Another project, the Muscle Pavilion by Kas Oosterhuis (Fig 35) is a concept for a data-driven pavilion that changes shape and content in real-time. The WallBots project developed by Otto Ng is a user responsive robotic partition that will can move, resize, attach, and detach to create different sized spaces and accommodate different functions. In each of these examples, physical changes occur in real-time and are driven by physical events, physical variations in the environment, or physical interaction between the architecture and the users. Used for the purposes of adapting to human presence through interaction, responsive architecture may enable a deeper interrelationship between the body and its environment.

7.3 Body Scanning

Body scanning technologies can been employed as a means of quickly scanning a live model in order to extract surface geometry and automatically derive body measurements. Full body scan booths have been implemented in the past decade to streamline and augment the process of deriving body measurement and other anthropometric data. Body scanning software works by automatically locating body landmarks and generating measurements which can then be fed to other application such as apparel CAD creating a streamlined framework for made-to-measure clothing development. One such booth, located in Ryerson's

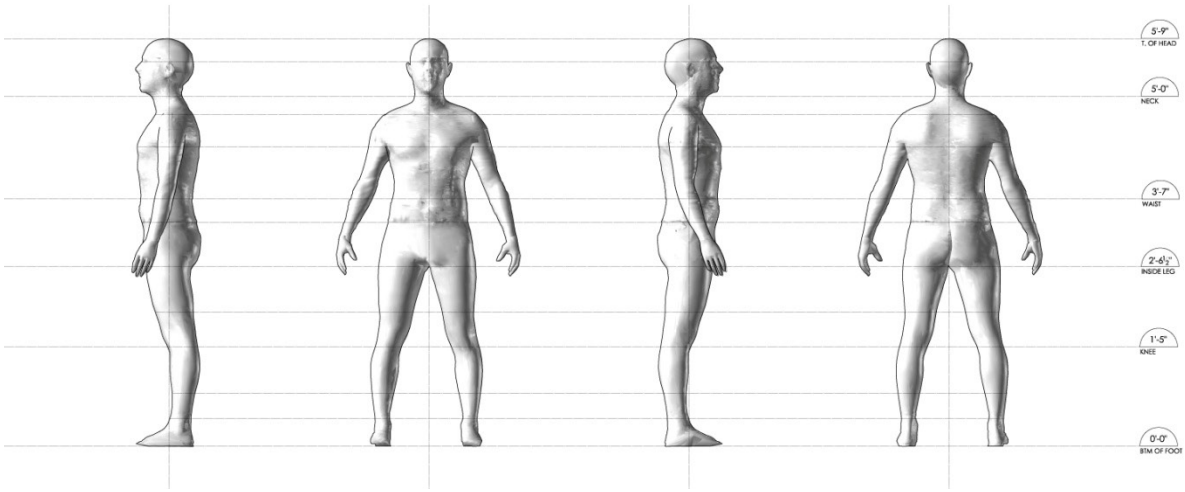


Figure 36 Body Surface Geometry from Body Scan

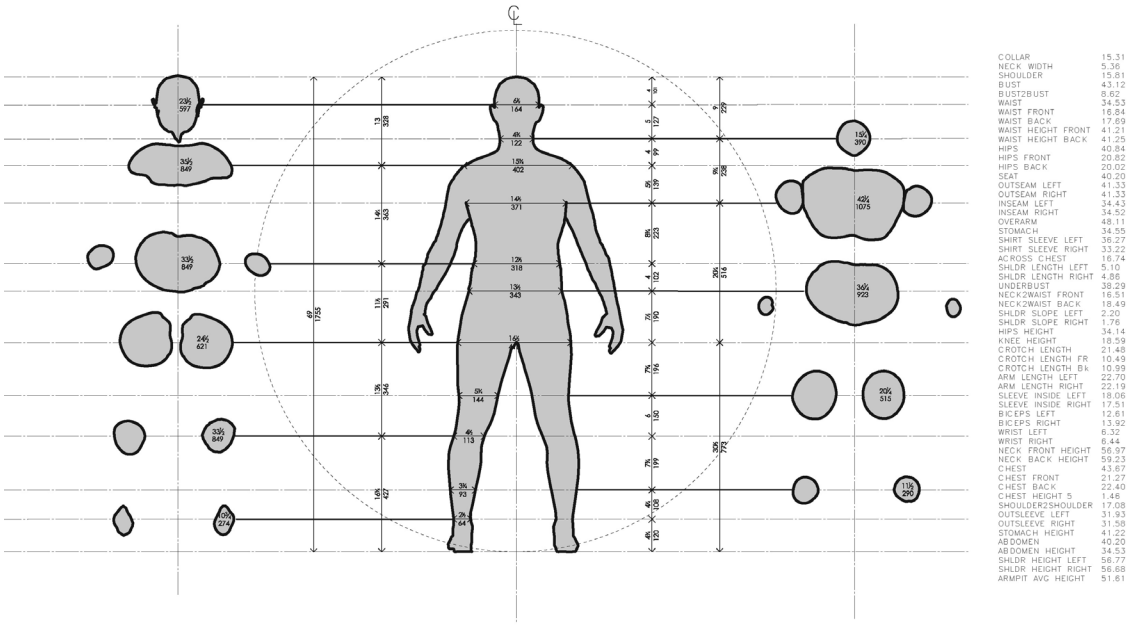


Figure 37. Body Measurement data derived from body scanner.

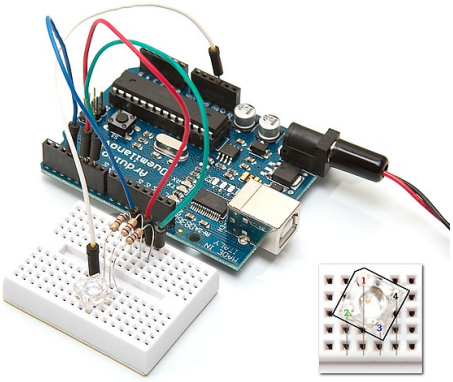


Fig. 38 Arduino Microcontroller

Fig 39. TouchOSC App. for Mobile Devices

fashion department was used to extract a full-body scan of my body which generated both accurate body measurement and an high quality surface geometry (Fig. 36, 37) Body scan data can then be imported into a number of 3d modelling softwares, where further transformations and refinement to the mesh geometry can take place. This surface can then be used as a reference for further geometric transformations on the body scan data, creating a type of digital 'scaffolding' upon which further formal articulations may remain intrinsically referenced to the body figure.

7.4 Body Sensing

Sensors and motion tracking devices have recently been added to the collection of advanced building components which have the ability to sense alterations in light levels, temperature, and human presence, and in turn inform building systems that can seek to adapt or normalize the changing condition. Simple motion tracking devices, such as Microsoft's Kinect sensor have the ability to track a body's location in space and determine the position of its limbs via a skeletal tracker. Employed in a distributed network throughout a building it is possible to determine where any given person is located in a building and what activities they are engaged in at any time. These systems may be able to determine the identity of an individual based on biometric signatures which may be based on physical traits such as height, build, posture etc, and then apply preferences via a number of adaptive mechanisms, such as lighting, temperature, height of certain fixtures and working surfaces, furniture etc... With this system in place, it is possible to build a database of user behaviour over time in order to determine and predict user habits, which might then contribute to a wider

personalized anthropometric database hosted via the internet and therefore accessible from any location.

Skeletal tracking via the Kinect, allows a real-time extraction of body position data. The Kinect platform is able to determine the location and posture of up to 6 persons standing in front of the sensor. This data can be imported into parametric design software such as Grasshopper for Rhinoceros through a newly developed plug-in: Firefly, which allows basic body geometry to be collected and used in a real-time parametric design interface. The Firefly plug-in also enables read and write commands to Arduino controllers. Arduino is a type of microcontroller used for creating interactive objects and environments. (Fig. 38) Arduino components may drive a number of sensors and movable components which allow for the possibility of real-time feedback and interaction.

This framework is used towards building an adaptive architectural surface capable of responding to human presence through real-time feedback. By using the Kinect to track the body's position in space, this information is then used to determine a number of potential responses such as lighting, heating and cooling, ventilation, and kinetic motion of the surface. All of these responses are possible by utilizing a distributed grid of sensors and actuators managed by an Arduino device. Responses may be determined by any number of potential "programs" uploaded to the boards. In this investigation, an exploration of potential applications for a direct and immediate haptic feedback between body and surface are examined where the distance between user's limbs and the surface determines a kinetic transformation of the surface. (Fig 40)

7.5 Controllers

In the previously described setup, a real-time interaction between a user and the responsive surface model is established. To demonstrate the viability of this concept, three differentcontrol methods are used: the Kinect Skeletal tracker, TouchOSC controller, and light dependent sensors.

The Kinect skeletal tracker is read via the Firefly plug-in for Grasshopper. In this particular definition, the position of a body part (in this case the left hand) is read by it proximity to a virtual point representing the location of a servo motor on the model. The relative distance between the points determine the rotation on the servo motor (from 0-180 degrees) which then actuates the surface via Arduino. Assuming these positions are calibrated, the surface will deform at a real time, 1:1 scale. This interaction may be considered both passive and active based on the level of awareness or intention the user has on controlling the surface. (Fig 41a)

The TouchOSC application provides a framework for wireless communication between a Smartphone devices and Arduino. (Fig 39) Open Sound Control (OSC) is a content format for messaging among

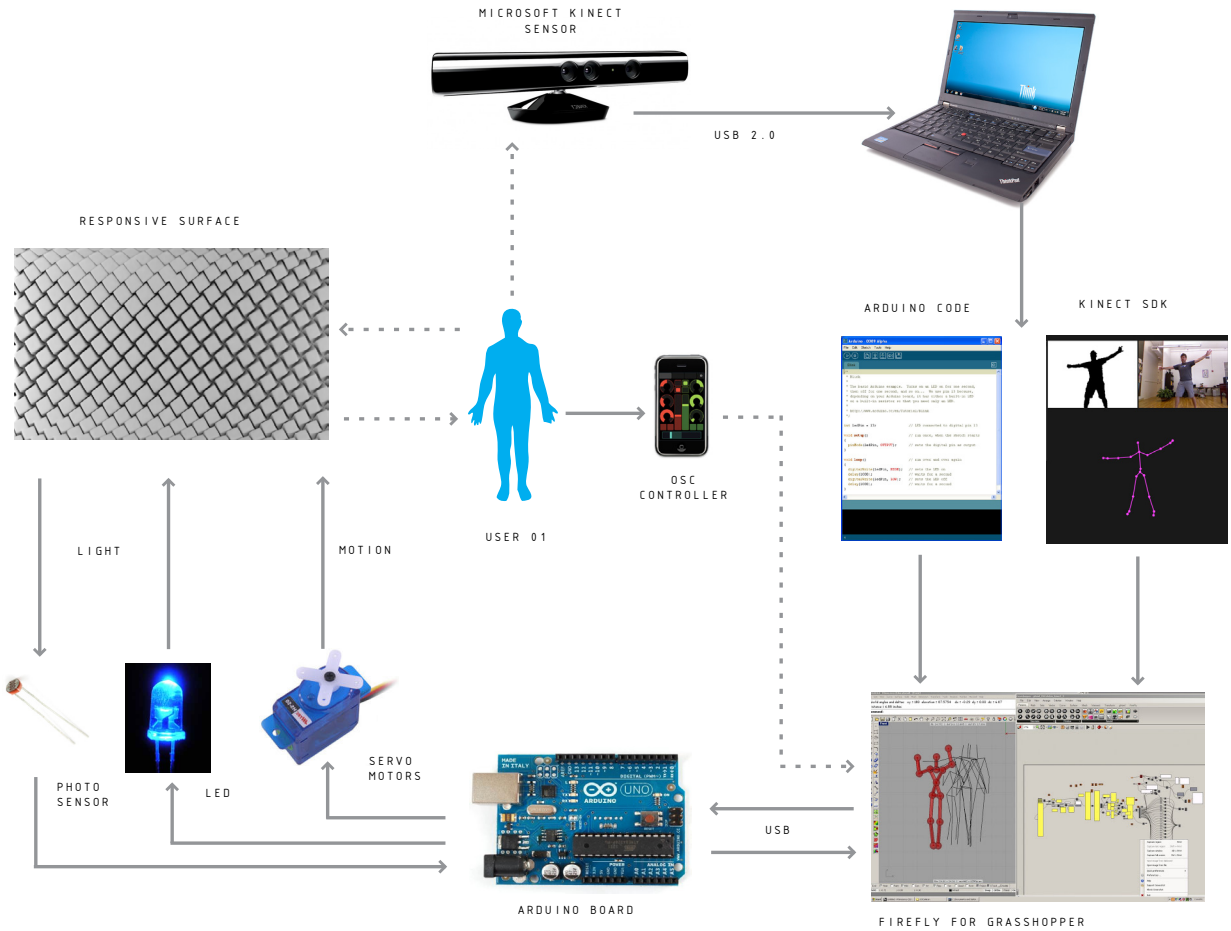


Fig. 40 System Diagram for Responsive Surface using Kinect and Arduino.

computers, sound synthesizers, and other multimedia devices that are optimized for modern networking technology The GHowl plugin for Grasshopper is able to capture OSC protocols which can be linked to parametric software as well as Arduino controllers. The Touch OSC app available on many Smartphones allows custom-built touch control interfaces. In this example, an XY Graph in the TouchOSC app is used to create a real-time link between the surface configuration and the finger position. Allowing a deliberate or 'active' control interface.(Fig 41b)

Light-dependent sensors are one of the simplest and most inexpensive sensors which can be read by Arduino. Three light sensors mounted onto the model surface read the amount of light falling on the sensor and relay this information back to the board. The relative light levels determine the position of the servo motors which then determine the configuration of the surface. Upper and lower light threshold levels may

Fig. 41a Responsive surface controlled by light sensors

Fig. 41b Responsive surface Controlled by OSC controller

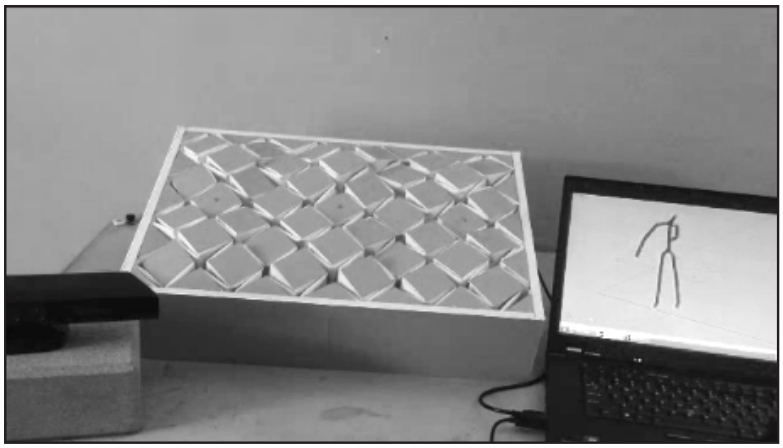


Fig. 41c Responsive surface Controlled by Kinect sensor

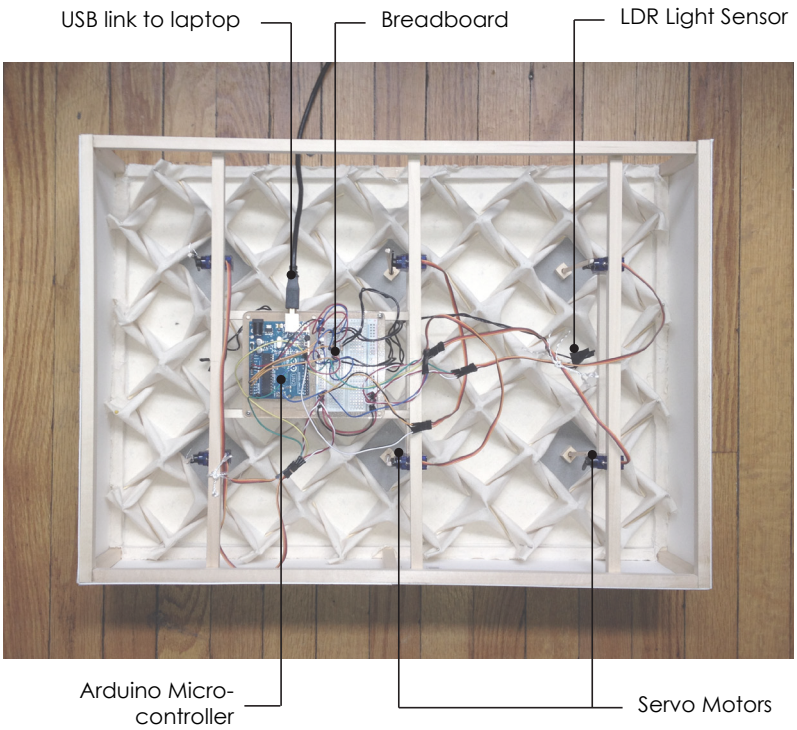


Fig. 42 Reverse side of responsive surface showing sensors and actuators

be readily adjusted to suit ambient light levels in the room. (Fig 41a)

In these three cases, the surface model is dynamically engaged with a human user through both active and passive interaction In this model, a physical deformation of the surface is created in an attempt to spatially transform and envelop the active area. The surface is self adjusting and self-regualting in order to engage or normalize conditions within the activated area. (Fig 43)

Reactions to sensor data may be responded to in a number of ways based on the instructions of the Arduino code. For example, movement of the surface away from the user, to provide more space for the body (a bio-phobic reaction), or a movement toward the body, to provide a plane for activity(a bio-philic reaction) These reactions could also be variable over time or interchangeable based on changing environmental conditions or through gestural or voice commands by the user.

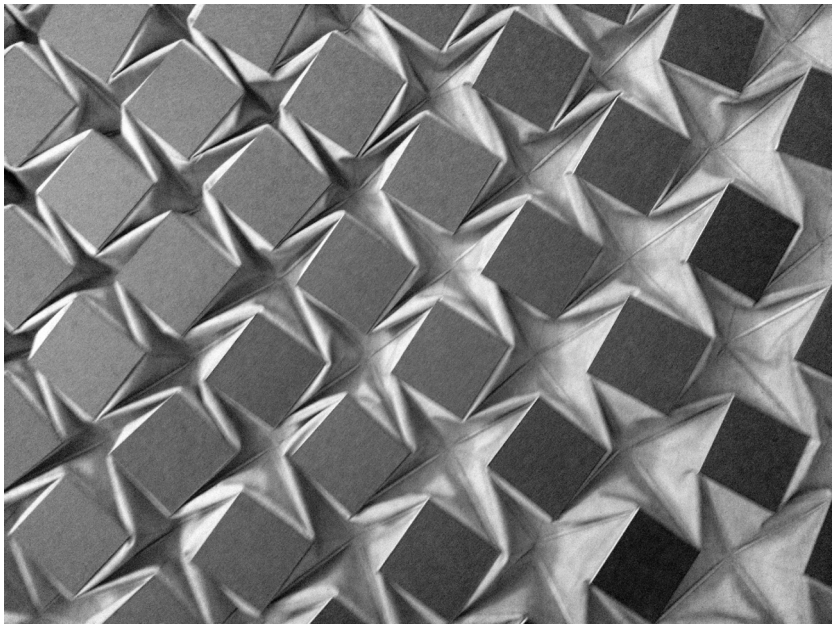


Fig. 43a Exterior Surface

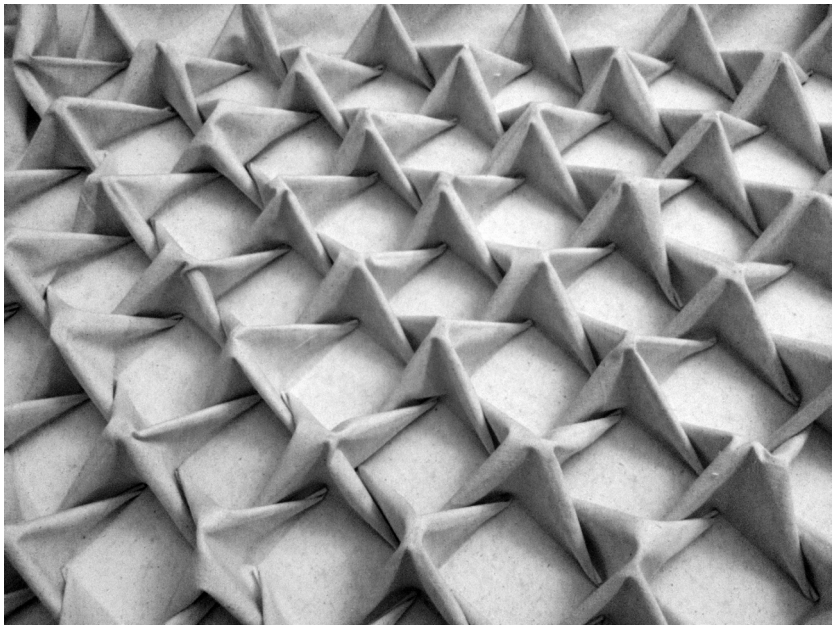


Fig. 43b Interior Surface

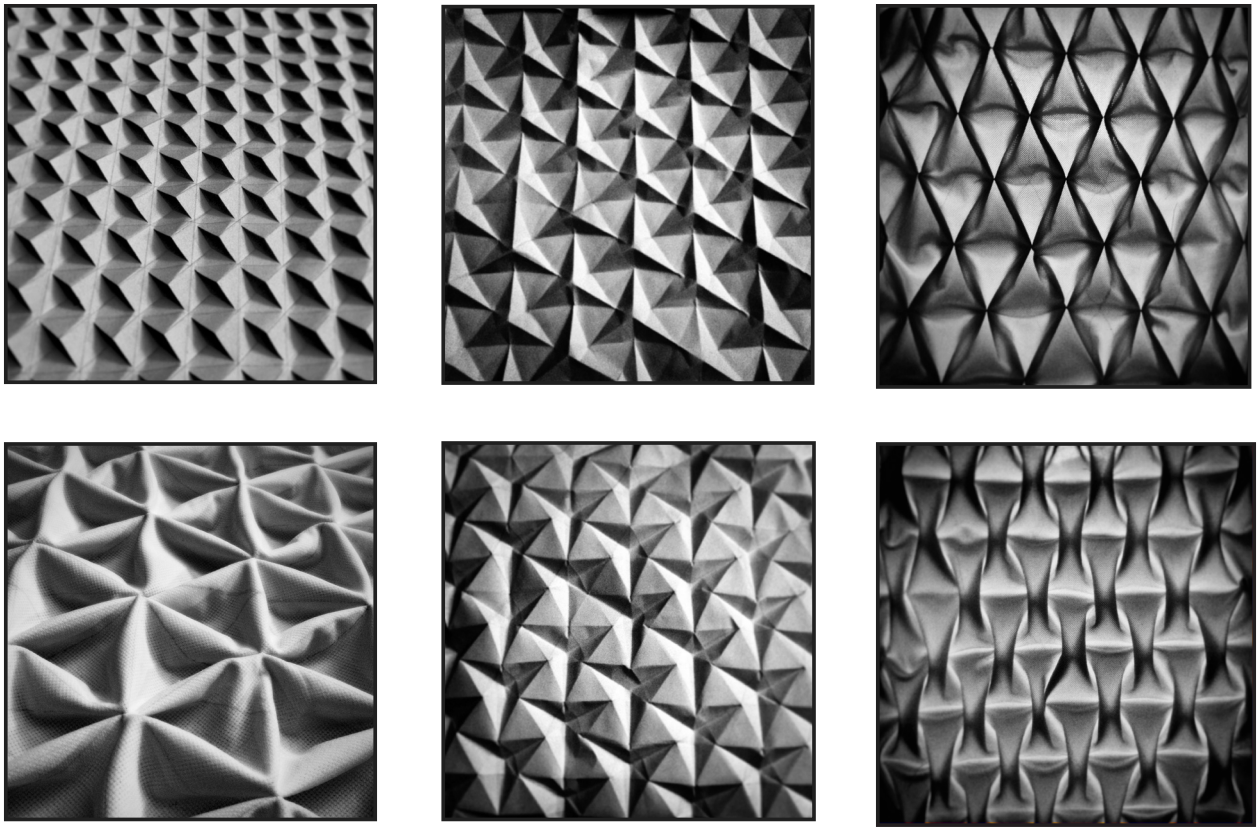


Fig. 44 Pattern Studies

7.6 Biophilic Surface

This model might be scaled up and extended to encapsulate space as part of a wider architectural system integrating both building servicing systems such as lighting and HVAC, and adaptable spatial configurations. A growing number of sensors and actuators available for Arduino may be integrated into such a system in order to engage with a wider variety of environmental and user phenomena therefore creating a richer level of engagement with more of the body's senses. This adaptive surface, in a sense, becomes a type of architectural "computer" capable of running a number of potential "programs" Such programs might determine a configuration best suited to a variety of human activities such as sleeping, sitting, eating, using devices etc.. However these programs do not have fixed outcomes but rather become presently engaged with the user in constant feedback cycle which enables potentially unexpected outcomes.

Architectural systems capable of such a high degree of adaptability of form demand a an equal amount

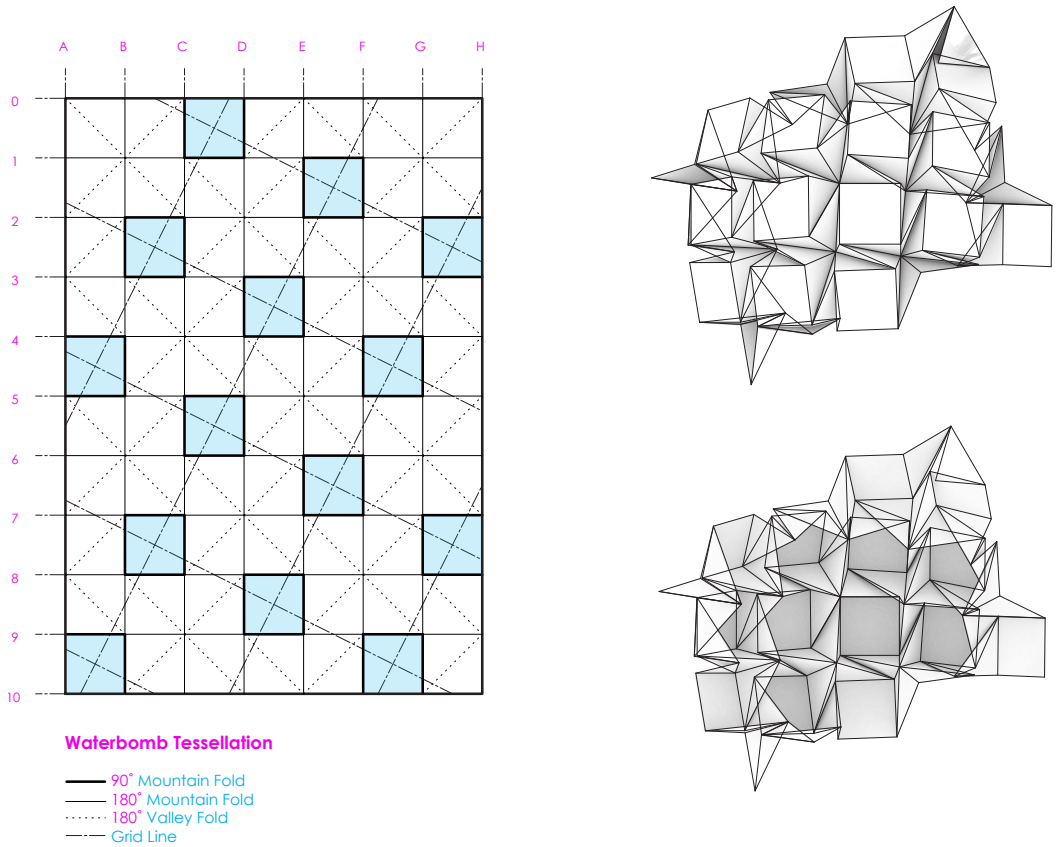


Fig. 45 Folding Plan for "Waterbomb" Tessellation

versatility in terms of material reconfiguration, thus implicating a number of considerations such as movability, stretch, and foldability. Such considerations draw parallels within the fashion discipline which deal with organization of soft materials as they concern the movement of bodies. In this sense, 'wearable space' as proposed here is a type of auxiliary 'clothing' for the body, independent of the body, but linked through wireless communication and sensing technologies.

To accommodate this high degree of adaptability of form, aspects of material folding are employed as a means of supporting transformation of surface topology and encapsulated volume. Rigid origami has been utilized for architectural purposes such as foldable partitions and deployable structures. An origami tessellation pattern comprises of a number of regular folding patterns which are distributed on a planar grid. Localized transformations of the pattern, such as folding and twisting, produce a global behavior of the system, demonstrating a high level of material self-organization. Experimentation with a variety of folded structures is shown in figure 44. In these studies, both rigid materials (cardstock, paper) and flexible materials (woven

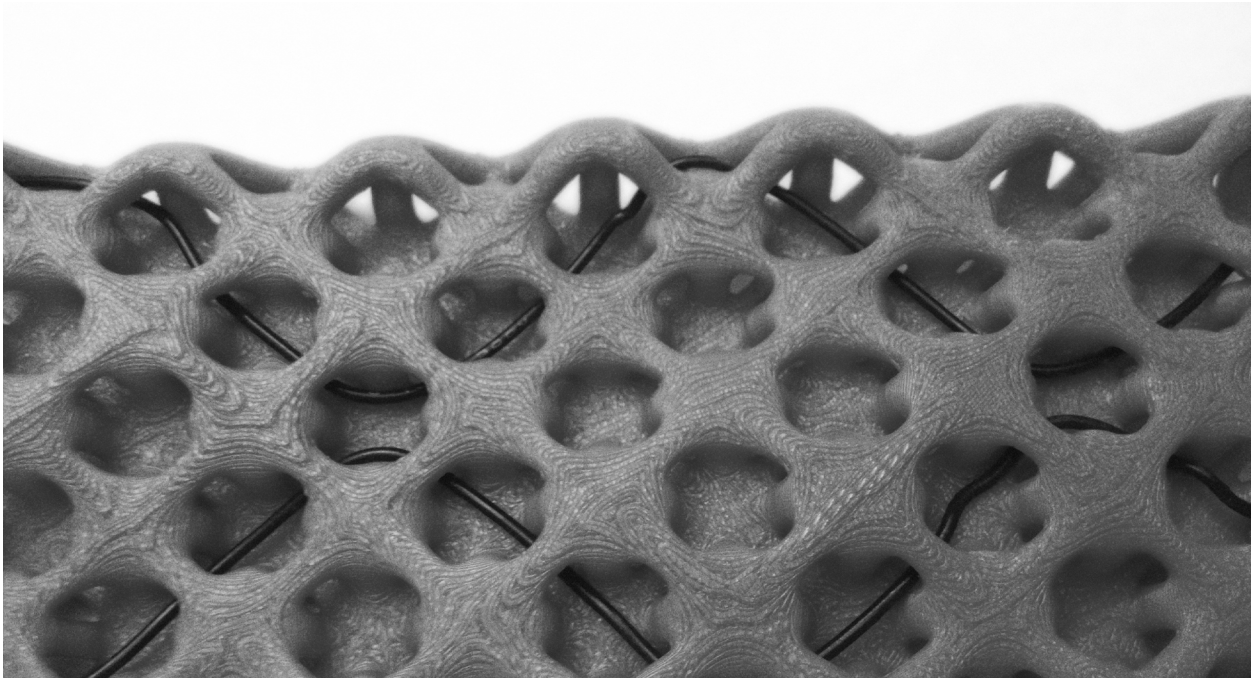
and knit textiles with a range of stretch) were conducted in order to discover patterns which supported high amounts of material adaptability.

A substantial transformation between unfolded and folded configurations is observable in the 'Waterbomb 'tesselation where the folded surface encompasses only 1/5 of the total surface area while still maintaining a flat surface to one side. This configuration able to accommodate a wide range of transformation in scale as well as curvature (Fig. 45)

To support this transformation, the surface comprises of a deep assembly which encompasses the interior surface, the flexible membrane, rigid structure, sensor network and supportive tensile grid. In order to support adaptive configurations, a structural systems of cables acting through tension, both support the structure of the surface but also control the degree to which it is folded and bent. The folding of the structure is made possible by an array of rigid members integrated within the foldable membrane which act as folding lines to maintain the structural organization of the system. The tensile grid and the rigid frame work together as a type of tensegrity framework which is held in place by the flexible membrane. (Fig 47)

Rather than managed through via centralized control systems, micro-sensors are dispersed in an evenly distributed array throughout the surface allowing a location-specific responses to various sensory inputs.

Fig 46 Membrane Structure



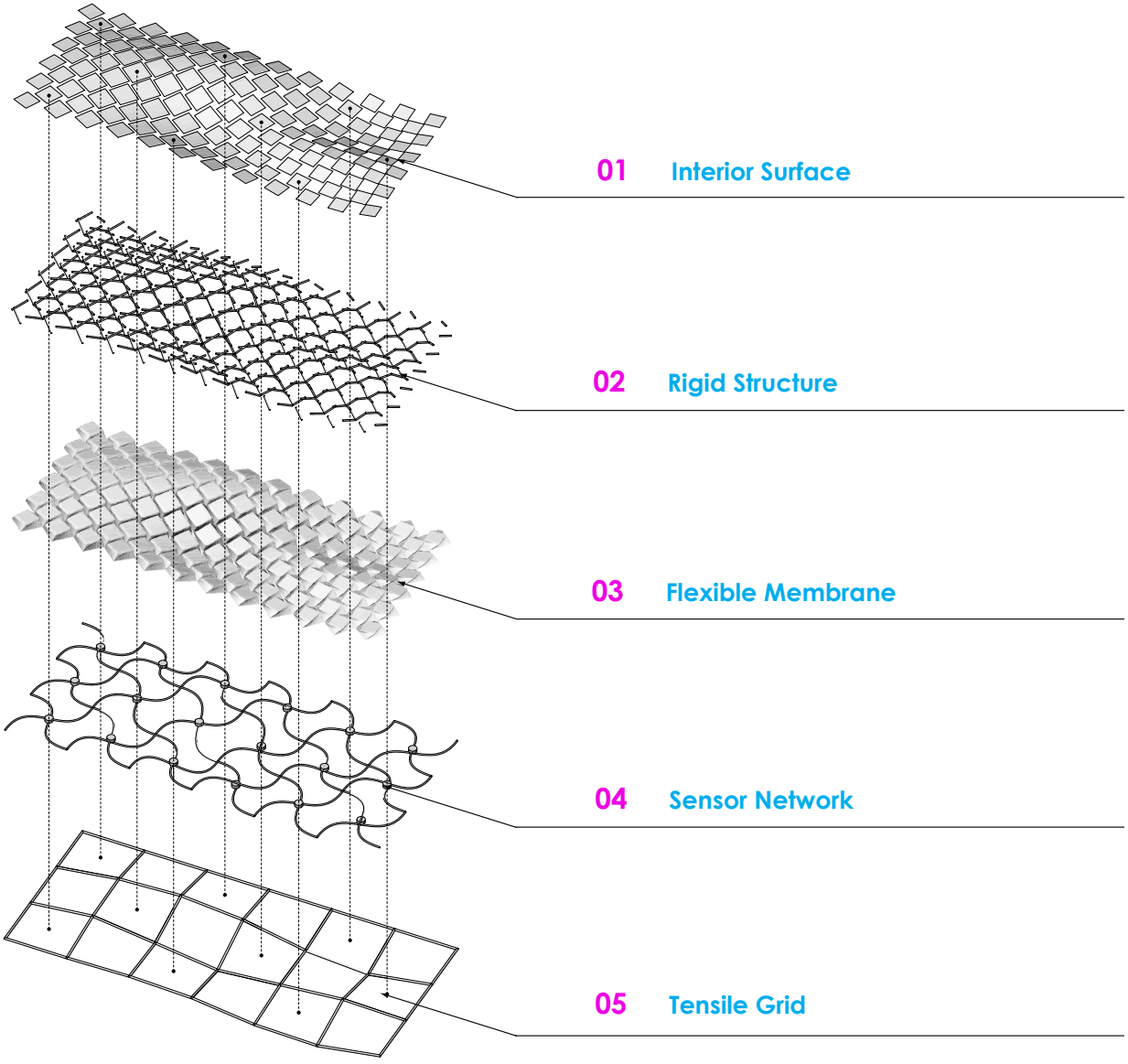


Fig. 47 Layered Assembly

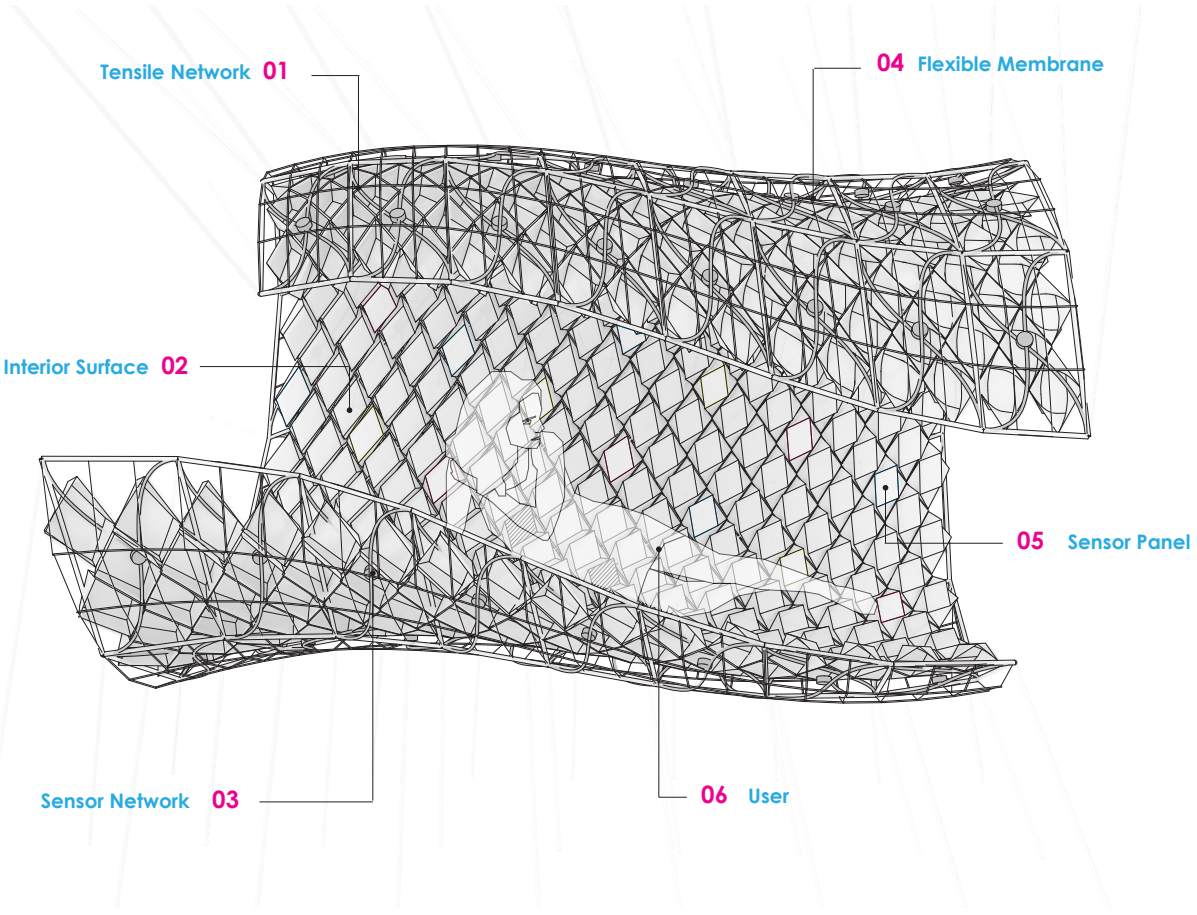


Fig. 48 Biophilic Surface

This network of sensors and actuators is embedded within the membrane providing a continuous field of data collection. The membrane itself is comprised of a double layered, porous textile system. As a flexible and material, this textile is made of a neoprene lattice which provides an unobstructed network of channels within it to allow the networking of sensors without interfering with the movement of the surface. The material is capable of a wide range of physical alterations such as bending, stretch and variable porosity. These changes allow the structure to 'breathe' and control thickness in response to physical changes in the environment. (Fig 46)

The adaptive surface is imagined as a continuous architectural component, comprising ceilings, walls, and floor systems, and possibly a combination of these functions. The form of the interior space is determined by a network of cables linked to the building structure. Through differential tension of these cables, aided by the folding action of the membrane the surface may assume a wide range of spatial configurations (or programs) Services such as heat and fresh air may be delivered anywhere within the plenum space that surrounds the surface and through the porosity of the membrane. The embedded sensor network is directly linked to a local area network which enables communication throughout the building as well as wider area networks.

In a constant state of feedback with the user, the surface seeks to adjust and normalize conditions in response to changes of user behaviour such as body position or preferred environmental factors such as temperature and lighting conditions. As illustrated in figure 48, the surface is deployed close to the user's body providing a body-conforming furnishing. Figure 49 shows the system adapting to a number of configurations based on an occupants activities or desired uses; changing from an open room configuration, to a semi-closed environment to a closed 'cocoon' configuration where it comes to envelop the body. The enclosed volume around the body operates as a hybrid space, existing somewhere between clothing and room: as the body's 2nd and 3rd skin.

It is important to clarify that the goal of such a system is not simply to undergo a kinetic transformation in response to human interaction but rather that it seeks to become part of the extended body, as a type of architectural clothing. As McLuhan describes man's prosthetic relationship with technology, it is seen as an architectural prosthesis which may become so enmeshed with the human experience that it becomes un-noticeable; it becomes part of the body.

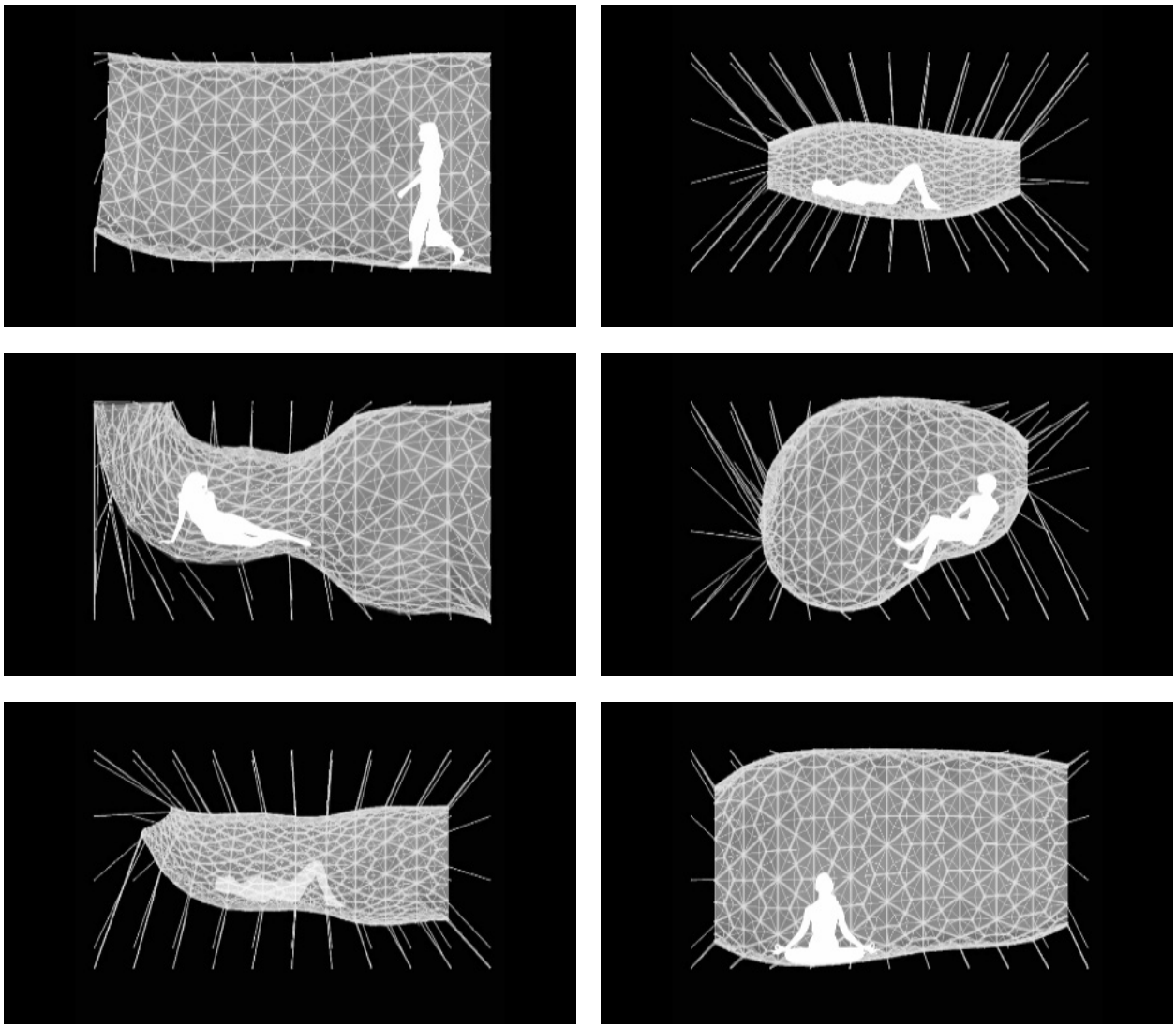
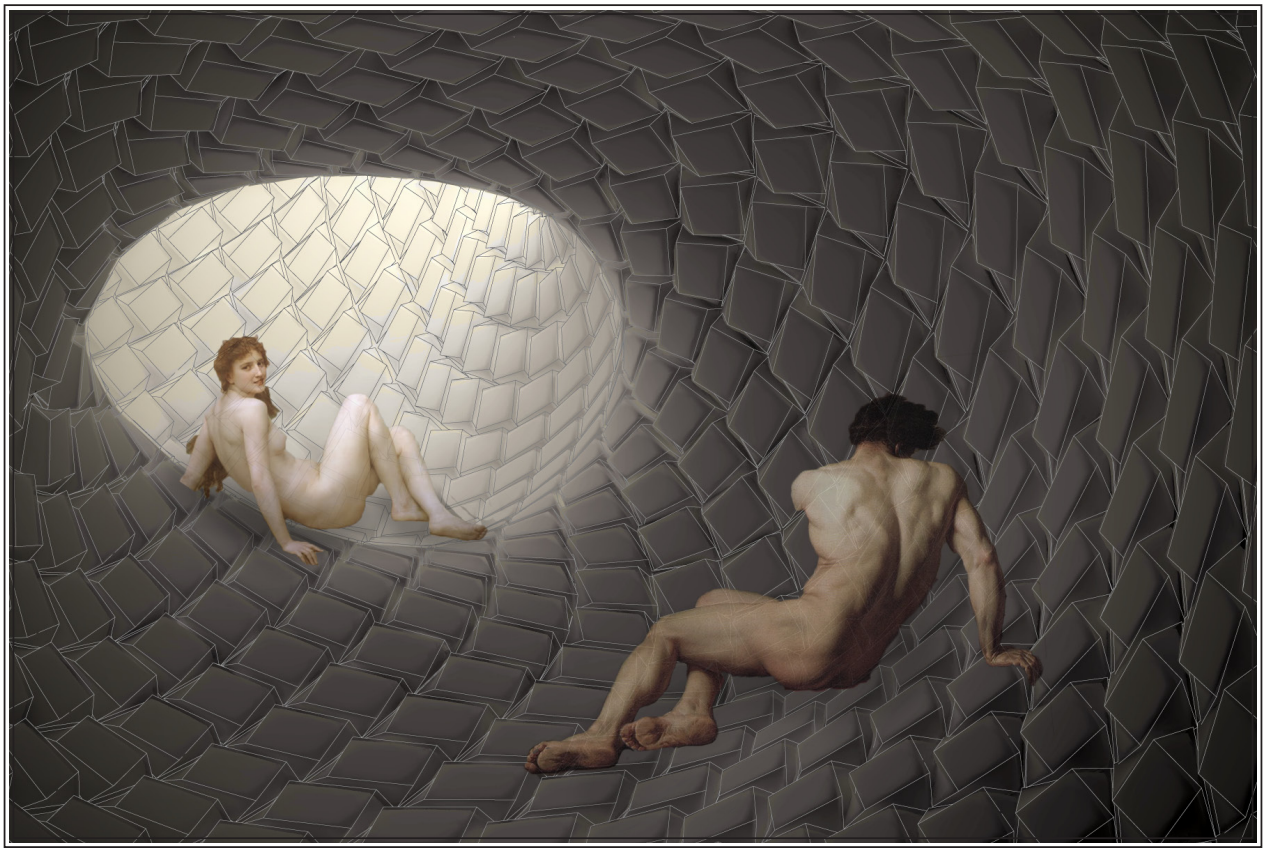


Fig. 49 Adaptive Configurations



8 Conclusion

Contemporary society brings with it a radically changed conception of the body and its relation to the built environment. In this technological age, both the body and building are *networked*. How does this new reality affect the way we make architecture? Certainly to engage them in new dialogues. Perhaps buildings can be more like the body. Perhaps buildings might become part of our 'bodies'.

By looking to the past we can see how the body has served as a foundation for the development of architectural ideas and theories. Throughout history, the body image was developed within the predominant sociocultural paradigm of the age, which would in turn influence the architectural theories upon which they were based. Although this lineage of ideas seems to have apbruptly ended in modernism with the development of anthropometric size charts which position the body in a neutral and idealized state. Modernist ambitions would suggest the the project has finished: we have codified the body and therefore it can exist within predicable mechanized or systematic frameworks. Not only has this thinking served to limit the possibility of architectural space as it might engage the individual experience, but fails to address the body in the context of 21st century society. Architecture must represent the condition and ambition of its age. In the information age, this means the body and its environment are 'networked' and interconnected in more complex and comprehensive ways.

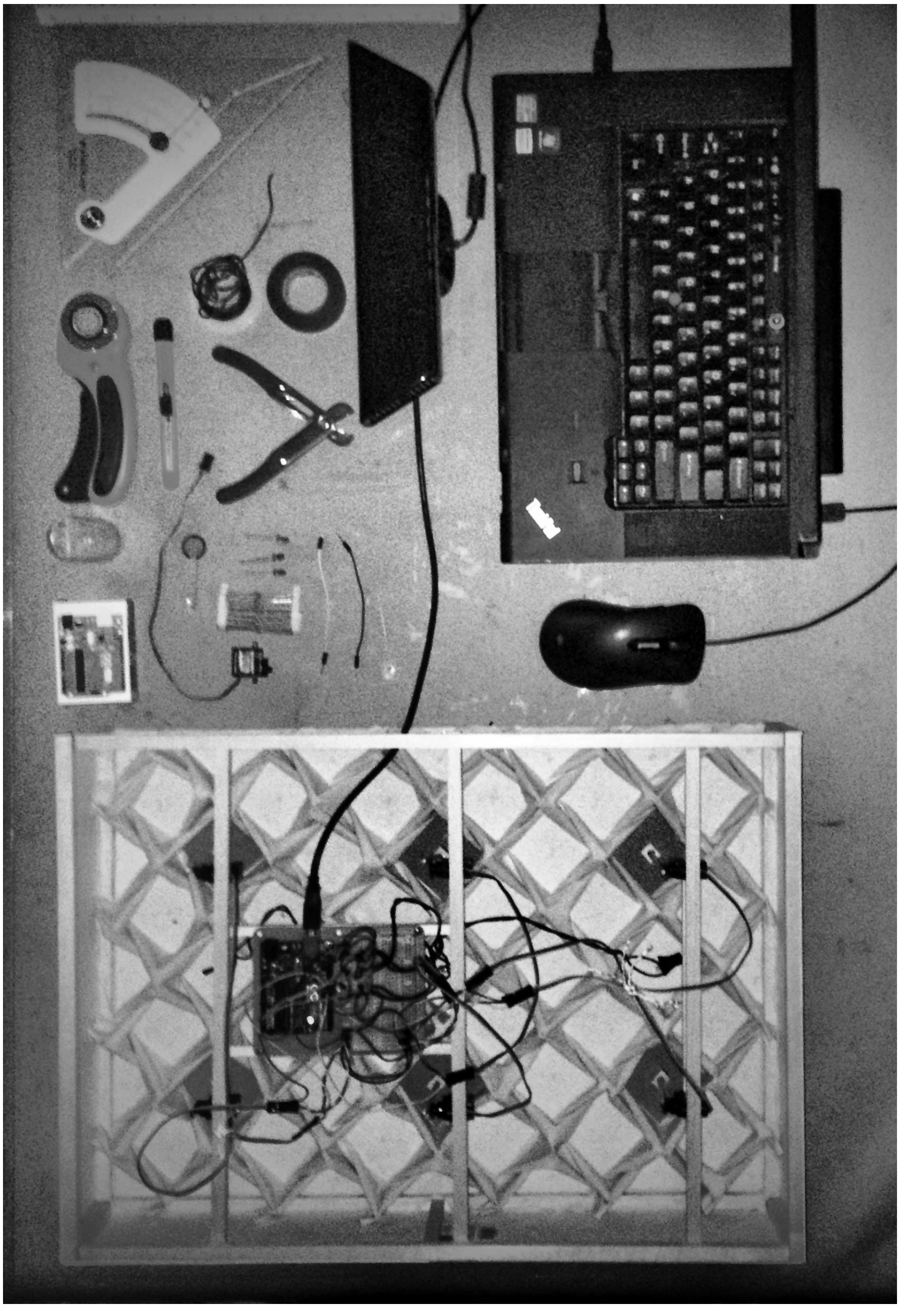
As with all tools and technologies, architecture can be seen in terms of its prosthetic relationship with the body; as a means in which to augment our bodies' capacities. Recent developments in wireless communication and sensing technologies have opened new possibilities for connecting the body to its networked environment so to extend our bodies reach into both physical and virtual terrains. The inclusion of sensing and mobile technologies in architecture can lead to the creation of spaces which are able to register and respond to users through real-time feedback mechanisms. With this comes the possibility to account for a greater degree of individualization and interaction between the body and building in the creation of 'bespoke' environments. In this way, the body senses the building and in turn the building senses the body, augmenting and enhancing it as a type of prosthetic technology.

Given the possibility of bespoke architecture, Universal Design standards are superseded in favour of a user-

centric methodology, where the individual body rather than abstract notions of "standard" bodies becomes instrumental for generating new architectural practices. In understanding how the concept of 'bespoke' or made-to-measure might be applicable to architecture, a interdisciplinary transfer of concepts and techniques from fashion design is critical. The fundamental basis for fashion design and architecture has always been the human body. Both of these practices have shared origins and have influenced each other over the years, most recently emerging in discussions of the architectural 'skin'. In fashion design, where the body is the primary focus for design, concepts of fit, style, mobility, and wearability are critical factors as they relate to the body. In the creation of 'wearable' space enabled by wireless communication, a transfer of these concepts to architecture implicates both the material structures that surround the body and the invisible networks that might materialize though such interfaces.

As we seek to find our body's limits in ever-expanding technological realms, the distance between our global and physical bodies and the boundaries between physical and digital realms are becoming increasingly vague and complex. As virtual and augmented reality are becoming realized, and as digital fabrication is allowing digital objects to materialize in the real world, new areas are emerging for architectural practices to take hold. We are currently at the beginning of a technological era where concepts of individualization and mass customization are becoming central tenets for new design practices. But what we need to consider, above all things, is how these technological paradigms will affect us at our most fundamental level, our physical bodies. Technology at once shows the promise of assisting us in our daily lives, on the other hand it has the potential to impose violence on the body. It is the task of architecture, and all design disciplines for that matter, to seek a greater integration of technology to better suit the body, working with its rhythms, movements, habits, preferences, rather than against them.

The ambition of this thesis is the recognition and promotion of the corporeal dimension in architecture. Towards this goal, a fundamental reassessment of priorities within the discipline, and a critique of discourses which exclude the body are necessary. We must work toward re-establishing the primary intention of architecture, and seek a purpose which is both comprehensible and pertinent to everyone. This is the pursuit of what are perhaps our most basic existential desires: to reconcile one's place in the world and to feel one's body resonate in space.



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