

Transformable Physical Design Media

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Abstract

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Over the past decades, the WIMP based computer-aided design tools have been redefining the foundation of architectural design. As a materialization process, architectural designers are conceiving their mind through the help of computer-aided design tools. But the new emerging technologies are changing the people's cognition of design activity. The traditional 2D based design representation which operated by tools such as keyboard, mouse as well as monitors are less capable of fully representing physical 3D objects, thus the interaction between designer and design objects through these tools is expecting been enhanced. We are seeking a brand new design media which could provide a more direct and intuitive interaction to help designer inspire and improve their design intent.

In this paper, I provide a survey of intuitive and direct (tangible) media and their potential of being applied in design space, define an innovative concept of transformable physical design media which contains sets of user-friendly three dimensional input manipulating tools and physical augmented output representation to optimize the designers' interaction with design objects within the context of architectural design study as well as human-computer interaction, and describe the practical applications through three research prototypes : 3D pointer, InSpire, CuBe.

These research prototypes explore what kind of tools can be friendly enough for design-oriented user with less learning time consuming and what would be the best way for designers to represent design objects. These two elements form the concept of design media which can be combined in a 3D environment to improve design activity with a more intuitive and direct approach.

The document argues that the most intuitive tool should incorporate input manipulation through a natural language. The natural language in this context means not only an oral language, but also means the spontaneous behavior of human beings such as hand gestures. Meanwhile the paper also propose that there are several approaches to achieve the augmented representation as output display to enhance the design experience.

I conclude by discussing the observation from application themes for architectural design activity in the domain of HCI and the directions for future work that the transformable physical design media a desirable solution for enhancing design experience. Architects and designers could be benefit from the usage of transformable physical design media, especially the massing study during the early phase of architectural design which allows the designers can efficiently alter the topology properties and texture sitting of the building geometry.

Keyword

Architectural Design, Human-Computer Interaction, Design Media, Hand Gesture Input, Augment Representation.

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INTRODUCTION

The nature of architectural design is a materialization reflecting the designer's creative thinking. The design process is imagination interacting with the assistance of all kinds of tool. The development of designers' creative thinking is pushed by their perceptions about the physical world. Computer-aided design tools have made extraordinary contributions in architectural design practice. The progress of architectural design is heavily dependent on the assistance of computer-aided design tools. But current Computer-aided design Tools are fundamentally limited within WIMP (windows, icons, menus, and pointer) interface, which employs 2d based input manipulation and 2d based output display. Building geometry as physical 3d object being designed through 2d based workflow, is producing converting issues and slowing down the design process. Yet, designers are having less interaction with the design object.

My thesis introduces a sets of design tool prototypes: A simple 3d input manipulation study, integrated spatial gesture-based direct 3D modeling & display system, and tangible objects based massing study tool kits. All of these two design tool prototypes allow the designer to develop their design within a fully 3d environment with optical and haptic references, so that the interaction between designer and design object become much more intuitive and direct.

CHAPTER I

BACKGROUND AND MOTIVATION

In today's architectural industry, architects are using various kinds of tools pushing their project forward, forming their ideas, as well as communicating with their client and co-workers. The tools selected by architects will have significant impact on design objects. But the selection is also bringing negative limitation during design process while it is helping designers to conceive their concept. With the growth of computer hardware and software technology, computer-aided design systems have made a remarkable contribution to architectural design development.

But for the most of architects who didn't take professional computer training, are spending considerable time on learning to use softwares and solving software problem but not design problem. The manipulation of user interface, the interacting method of data, keeps confusing professional architects. It leads to the reduced efficiency and the misunderstanding of project. We have to realize that architects are facing an awkward dilemma: Architects, who used to work with descriptive drawings and physical models, now become the monotonous computer operators. Architectural design, which was suppose to be an interesting and creative process, now becomes a repetitive electronic task. Knowledge and professional skill which are accumulated through long term design education and practice are now replaced by the computers.

A brand new Computer-Aided Architectural Design system needs to be created which will inspire designer by deemphasizing computer manipulation.

1.1.1 A BRIEF HISTORY OF COMPUTER-AIDED DESIGN TOOLS

The concept of CAD appeared the 1960s, but the definition of CAD keeps changing. During the earlier phase of CAD development, when Ivan Sutherland invented his Sketchpad at 1963 which integrated evolving design and analysis programs, CAD stood for Computer-aided Drawing (Drafting) instead of Computer-aided Design which were usually known by us. At that time the goal of CAD is drawing 2D document which continued until 1970s. Aleksander (1999) and Kalay (2004) illustrated that three generations of CAD tools have been invented in the history. The first generation CAD systems were designed to be intuitive and architectural. But the shortcoming of 1st generation CAD is that the system contains excess elements of architectural design procedural and lack of graphic interface, so that the solution is quite hard to popularize. It is worth mentioning that the geometric modeling route CAD system which was another first generation CAD route based on 2D wireframe model led by an industry giant had already been applied in engineering practicing while the architectural specific route CAD was still in pilot phase.

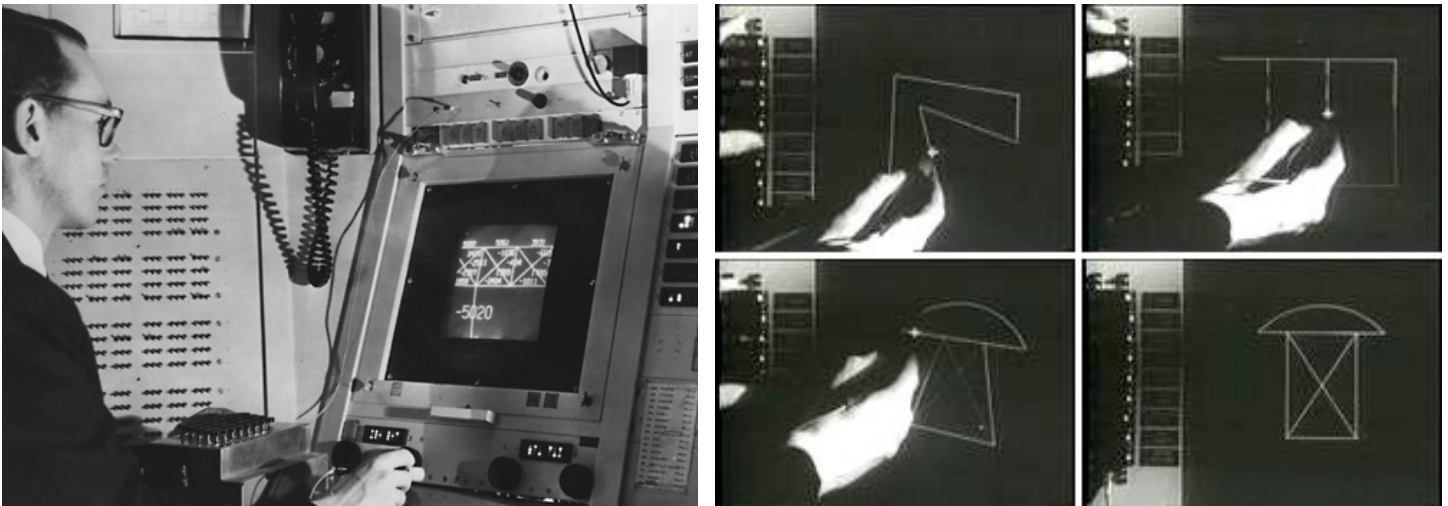


Figure1:Ivan Sutherland's Digital Sketchpad

With the growing demand of automotive and aerospace industry in 1970s, engineers desired to find new solution for defining complex geometry. The earlier CAD approach of geometric modeling system was a quite simple wireframe system. It can only present basic geometry information, yet cannot effectively represent the topological relationships between geometric data. In 1962, a French engineer Pierre Bezier formed new surface and curve designing method, which let the problem of computer drawing curve became operable. Meanwhile, French aircraft manufacturer found a way to build free form surface in computer based on CADAM system. It is first time to com-

pletely describe the main information of 3D product's element. Thus, CAD technology has been broken through from 2D wireframe modeling to surface 3D modeling expression.

In 1980s, the demand of architectural company had changed. Not only drafting, architects started to use computer communicate with different project participantes. The second generation of Architectural CAD system focused on drafting and modeling, rather than the first generation system which more focused on building design procedural. It was also defining different types of geometries rather than defining the building element properties. But comparing with previous context, we can summary that the second generation CAD of architectural design such as AutoCAD is quite similar with the CAD technology used in engineering industry in early 1970s. They all focused on 2D and 3D geometry such as line, polyline, surface and simple geometric relationships. Even though some companies started to develop rendering and modeling software for architects, it still just followed the action engineering industry. At the same time, engineering industry had already start their new experiment. Although the previous CAD technology of engineering has had the description for 2D and 3D geometry, but still hadn't find a way to present geometry's physical properties such as quality, the center of gravity, moment of inertia. Engineering researchers successfully achieved the solid modeling technology which can illustrate the topological relationships as well as the geometric properties. The first commercial solid modeling application was released at 1979, which was called I-DEAS. The solid modeling technology was based on unconstrained freeform model, users can directly modify geometry model, but the disadvantage is that cannot provide non-geometric information such as material, processing, etc.

But architectural design is a complex activity. The third generation of CAD system had become far more complex than the previous generations, architectural elements are interdependent, and the number of these elements is uncountable, if any of the data in the system goes wrong, it will have serious negative impact on entire project. Then, how should architects deal with the situation which has large number of associated data. Just like we've mentioned previously, engineering design tools are always adopted by architectural industry. In the current engineering industry, they've applied parametric and variable modeling techniques to solve these problems. Parametric technology is feature-based, full-size constraints; all data correlated each other, dimension-driven design, completely overcome modeling free form unconstrained state. Beyond the completing logical structure, parameters can be modified at all times. Variable modeling technique is developed based on parametric technique. Such as Grasshopper, Generative Component, Digital Project are the best examples to illustrate how architectural professionals apply the engineering technology into architectural industry.

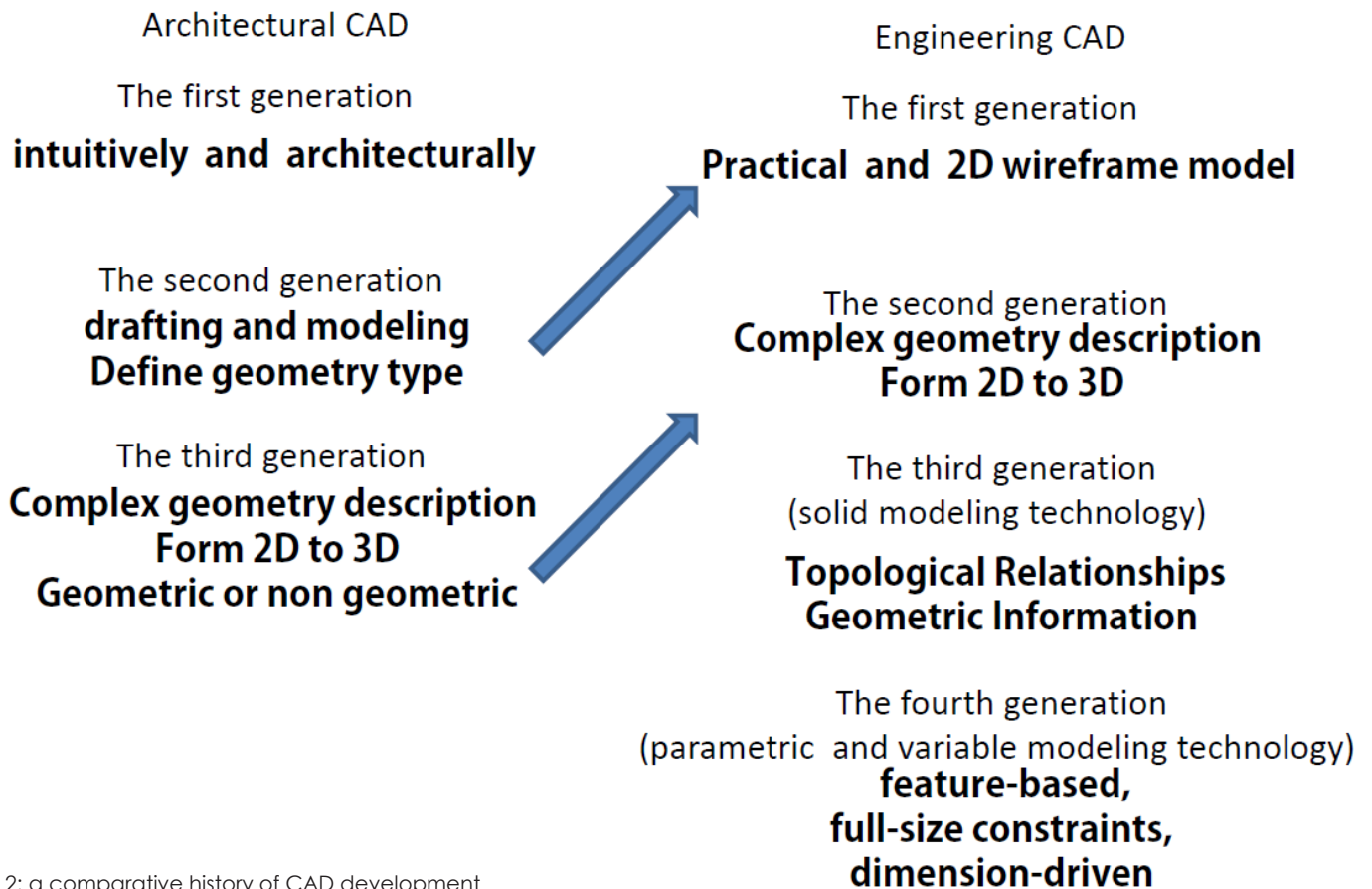


Figure 2: a comparative history of CAD development

1.1.2 CURRENT COMPUTER-AIDED DESIGN TOOLS AND ARCHITECTURAL DESIGNERS

Based on the history of CAD development, we can conclude that the technology used in Architectural industry was always behind the technology used in engineering industry. Because of the practicality, reliability and stability of architecture are emphasized, so that it is impossible for any form of experimental reforms to firstly happen in architectural industry. Just like the invention of the elevator leading to the emergence of high-rise building, the practical needs of architectural technology will not exceed the needs of social productive forces. Hence, adopting technology from other areas is understandable. When a new technology comes into the world, it wouldn't be mature until it has experienced long-term using and improved. But architects can introduce the mature technology from engineering directly, and make it be architectural. But the challenge is that, is the engineering design tools suitable for architects?

Widely adopting from engineering CAD technologies in to architectural industry has led to several consequences. The consequences are both positive and negative. The first consequence is changing

the working method of architectural designers. By introducing computational representation, architects “externalize the division between what we see and what we know.” (Josh Lobel, 2009) The CAD media provides us a new way and new means to explore the new idea, and introduces designer a new metaphor to see, to think and to make. But, if architectural designers didn't actively and critically consider that the changing of technology would impact on our ability to communicate and think, the CAD technology will be crippling.

Of course, there are certain ways to change the situation by changing architects. Robert Woodbury points to some solutions in his book “Elements of Parametric Design”. He cited six new skills and nine strategies for how architects could be fit into engineering method and how should designer to solve typical computational problems in the design process. Computer-aided design tools require people to play different role including designer, computer scientist and mathematician. The skills he offers is letting designers beware of what they must think about while they are using computational tools. Two of those impressive skills he mentioned are thinking mathematically and thinking algorithmically. All the computer-aided design tools are realized by mathematic and algorithm. Designers can hardly master those design tools without an appropriate adjustment. But he also claims that it is difficult to change the thinking pattern of those who have typical architectural backgrounds.

Architectural designers with typical background are trained and practiced in the means and methods of design, and design is an act of seeing, thinking, and making. (Josh Lobel, 2009) Based on Josh's research, design is a kind of creative activity combining eyes, brain and hands. Architectural designers are responsible for designing the aesthetics and spatial details of a building -- the building's size, shape, space utilization, and site requirements. That requires that no matter which tool designer selected, pencil, mouse or something, design aids should assistant the coordination of interacting among eyes, brain and hands while designer is observing, thinking and making. Through the association of brain, hands and eyes, architectural designers are aware of information; through the repetitive creation, architectural designers would have chance to re-define information and get feedback so that they can make the right decisions.

In short, the architect designs how the building looks; their typical thought pattern is based on graphics, intuitions and relations. In addition, architects are also responsible for making sure that the overall objectives of the client relating to the end-use of the building are met. Once the architect and client are in agreement, the architect then provides them with detailed architectural designs. It is under this framework that the architectural designer will design the buildings systems.

The tools which architects need should be designed to offer architects more freedom, blooming their design capabilities and enhance the communicating of design process. These tools should be able to support architects to effectively deal with more creative issues and complete their work without restrictions. The potential approaches of the new CAD system still need to be demonstrated in different ways. The efficient tools and revolutionary tools will be eventually integrated together into a new platform. But the urgent demand for the new CAD system has appeared in front of us. Consequently, these tools must become more “intelligent.”

1.2 NEWLY EMERGED TECHNOLOGY

As a graduate student majoring in design computing, I always pay my attention on new technology achievements which could potentially change our cognition of design activity. These achievement are mainly developed through information technology, electronic engineering, and human-computer interaction technology.

I evaluated three innovative digital technologies which can be potentially adopted into design space and help to optimized design tools.

1.2.1 Tangible User Interface.

A tangible user interface is one in which the user interacts with a digital system through the manipulation of physical objects linked to and directly representing a quality of said system.

In 1997, MIT media lab presented a new vision of “Tangible Bits” at the CHI '97 conference. The concept of Tangible User Interface (TUI) that is based on physical embodiment of digital information & computation, in order to go beyond the current dominant paradigm of “Painted Bits” or Graphical User Interface (GUI). Humans have evolved a heightened ability to sense and manipulate the physical world, yet the GUI based on intangible pixels takes little advantage of this capacity. The TUI builds upon our dexterity by embodying digital information in physical space. TUIs expand the affordances of physical objects, surfaces, and spaces so they can support direct engagement with the digital world.

The idea with Tangible User Interface is to have a direct link between the system and the way you control it through physical manipulations by having an underlying meaning or direct relationship which connects the physical manipulations to the behaviours which they trigger on the system.

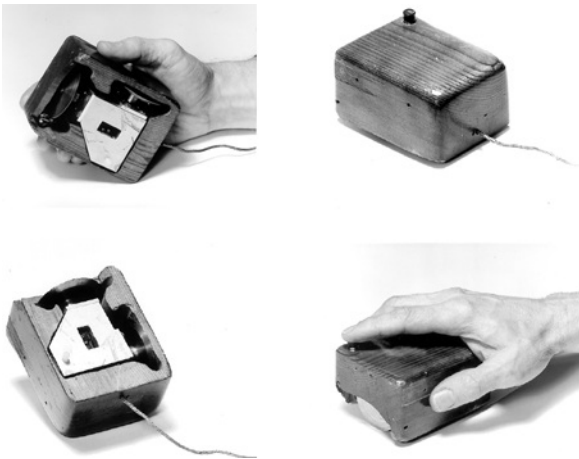


Figure 3 : Early prototype of mice

I think that in this last statement is where the secret lies. It's not just a question of having a physical controller for your digital system for the sake of having one, but making sure that by implementing one, it's use makes sense to the user and has added value for a more natural and intuitive control of your design. In a sense, the interface becomes virtually invisible, as the user has an inherent knowledge of manipulations such as grasping and moving objects (after all, we've been practicing since we were toddlers) so he is able to concentrate more on the system and the triggered behaviours than on how to trigger them.

It could be argued that one of the earliest examples of a tangible user interface is the all-too-well-known mouse.

Dragging a mouse through a flat surface and having a pointer move on a screen accordingly is a very straight forward way of interacting with a digital system through the manipulation of a physical object and the movements made with the device have a clear relationship with the behaviours which are triggered on the system (e.g. pointer moves up when you move the mouse forward), making it a very easy to master input device (with the help of a bit of hand-eye coordination). Its development was definitely one of the key factors which helped bring personal computing to the masses.



Figure 4 : Siffables @ MIT Media Lab

My favourite example of TUIs by far is the Siftables. These small devices, which started as a project at the MIT Media Lab and are soon to make the jump into commercially available products, are in essence tiny intelligent bricks with a display on them which are able to communicate and interact with each other depending on their position. The separate bricks know when another brick is near to them and depending on the game you are playing, they react accordingly.

Microsoft Surface is a table-like all-in-one computer, with a multi touch display which allows multiple users to interact with the built in system at the same time. But what really concerns us here is that it reacts not only to touch, but can also recognize objects placed on top of it and trigger it's own set of behaviours linked to these objects and how you manipulate them.



Figure 4 : Microsoft Surface

1.2.2 VIRTUAL REALITY

Virtual Reality (VR), a technology that began in military and university laboratories more than 20 years ago, may be called Artificial Reality, Cyberspace, or Synthetic Reality. VR is a computer-created sensory experience that allows a participant to believe and barely distinguish a "virtual" experience from a real one. VR uses computer graphics, sounds, and images to reproduce electronic versions of real-life situations.

Virtual Reality is not a computer, but a technology that uses computerized clothing to synthesize reality. Most current VR systems provide only visual experiences created by computer-assisted design (CAD) or other graphics/animation systems, but researchers are working on interface devices that add sound and touch. Eventually, VR may be delivered through direct computer-to-brain connections.

Applications for VR are many. Surgeons may soon use VR to “walk” through the brain or rehearse a surgical operation on a virtual patient. Just as flight simulators are now an integral part of pilot training, so surgical simulators will revolutionize medical training.

VR now makes possible telepresence, scientific exploration, and discovery. For example, the Jason Project for school children features both telepresence (the feeling of being in a location other than one’s actual location) and teleoperation (controlling a robot submarine) (McLellan, 1995). The Jason Project, now in its sixth year, was designed to generate excitement about studying science, mathematics, and technology. NASA has a telepresence educational program that uses the Telepresence-controlled Remotely Operated underwater Vehicle (TROV) deployed in Antarctica. By means of distributed computer control architecture developed at NASA, school children in classrooms across the United States can take turns driving the TROV in Antarctica.



Figure 5 : Oculus Rift

Oculus Rift’s headset is a next-generation gaming and entertainment media platform, designed to create a heightened sense of immersion at the average consumer price-point, elevating the industry beyond a screen-dominated experience.

Virtual reality as a design tool has experienced market chaos since its introduction years ago. but Oculus Rift as a mature technical product has digested the flaws and led to a good product qualification.

Designer could adapt the new technology to presenting their designer works in front of their clients. the photo realistic walking through experience will provide a brand new way to interact with the project and to feel the space. so both designers and clients will have more accurate environment to discuss the project.

1.2.3 Natural User Interface

A natural user interface (NUI) is a system for human-computer interaction that the user operates through intuitive actions related to natural, everyday human behavior.

A NUI may be operated in a number of different ways, depending on the purpose and user requirements. Some NUIs rely on intermediary devices for interaction but more advanced NUIs are either invisible to the user or so unobtrusive that they quickly seem invisible.

Touch screen interfaces, gesture recognition system, speech recognition is the partial application of NUI.

Touch screen interfaces let users interact with controls and applications more intuitively than a cursor-based interface because it is more direct – instead of moving a cursor to select a file and clicking to open it, for example, the user touches a graphic representation of the file to open it. Smartphones and tablets typically enable touch input. Touch is being adapted for non-screen applications as well. For example, Microsoft is working on a touch interface called “skinput” that allows users to interact by tapping their own skin.

Gesture recognition systems track user motions and translate those movements to instructions. Nintendo Wii and PlayStation Move motion gaming systems work through controller-based accelerometers and gyroscopes to sense tilting, rotation and acceleration. A more intuitive type of NUI is outfitted with a camera and software in the device that recognizes specific gestures and translates them to actions. Microsoft's Kinect, for example, is a motion sensor for the Xbox 360 gaming console that allows users to interact through body motions, gestures and spoken commands. Kinect recognizes individual players' bodies and voices. Gesture recognition can also be used to interact with computers.



Figure 6 : John Underkoffler
@TED Talk- Pointing to the future of UI

Prof. John Underkoffler, a leading scientist from MIT presented the innovative project which realized the UI technology showed in the movie of Majority Report. It allows user manipulating digital information through spatial gesture.

Speech recognition allows users to interact with a system through spoken commands. The system identifies spoken words and phrases and converts them to a machine-readable format for interaction. Speech recognition applications include call routing, speech-to-text and hands-free computer and mobile phone operation. Speech recognition is also sometimes used to interact with embedded systems.

One of the most famous applications of NUI is the SixthSense prototype

The SixthSense prototype is comprised of a pocket projector, a mirror and a camera. The hardware components are coupled in a pendant like mobile wearable device. Both the projector and the camera are connected to the mobile computing device in the user's pocket. The projector projects visual information enabling surfaces, walls and physical objects around us to be used as interfaces; while the camera recognizes and tracks user's hand gestures and physical objects using computer-vision based techniques. The software program processes the video stream data captured by the camera and tracks the locations of the colored markers (visual tracking fiducials) at the tip of the user's fingers using simple computer-vision techniques. The movements and arrangements of these fiducials are interpreted into gestures that act as interaction instructions for the projected application interfaces. The maximum number of tracked fingers is only constrained by the number of unique fiducials, thus SixthSense also supports multi-touch and multi-user interaction.

The SixthSense prototype implements several applications that demonstrate the usefulness, viability and flexibility of the system. The map application lets the user navigate a map displayed on a nearby surface using hand gestures, similar to gestures supported by Multi-Touch based systems, letting the user zoom in, zoom out or pan using intuitive hand movements. The drawing application lets the user draw on any surface by tracking the fingertip movements of the user's index finger. SixthSense also recognizes user's freehand gestures (postures). For example, the SixthSense system implements a gestural camera that takes photos of the scene the user is looking at by detecting the 'framing' gesture. The user can stop by any surface or wall and flick through the photos he/she has taken. SixthSense also lets the user draw icons or symbols in the air using the movement

of the index finger and recognizes those symbols as interaction instructions. For example, drawing a magnifying glass symbol takes the user to the map application or drawing an '@' symbol lets the user check his mail. The SixthSense system also augments physical objects the user is interacting with by projecting more information about these objects on them. For example, a newspaper can show live video news or dynamic information can be provided on a regular piece of paper. The gesture of drawing a circle on the user's wrist projects an analog watch.



Figure 7: The SixthSense

CHAPTER II

MECHANISMS OF TRANSFORMABLE PHYSICAL DESIGN MEDIA

2.1 RADICAL ATOMS: BEYOND TANGIBLE BITS, TOWARD TRANSFORMABLE MATERIALS.

Prof. Hiroshi Ishii, as pioneer of tangible user interface development, founded the Tangible Media Group and started their ongoing Tangible Bits project in 1995, when he joined the MIT Media Laboratory as a professor of Media Arts and Sciences. Ishii's research focuses upon the design of seamless interfaces between humans, digital information, and the physical environment. His team seeks to change the "painted bits" of GUIs to "tangible bits" by giving physical form to digital information.

In 2012, he presented the new vision "Radical Atoms" to take a leap beyond "Tangible Bits" by assuming a hypothetical generation of materials that can change form and appearance dynamically, becoming as reconfigurable as pixels on a screen. In his paper of "Radical Atoms: Beyond Tangible Bits, Toward Transformable Materials" He

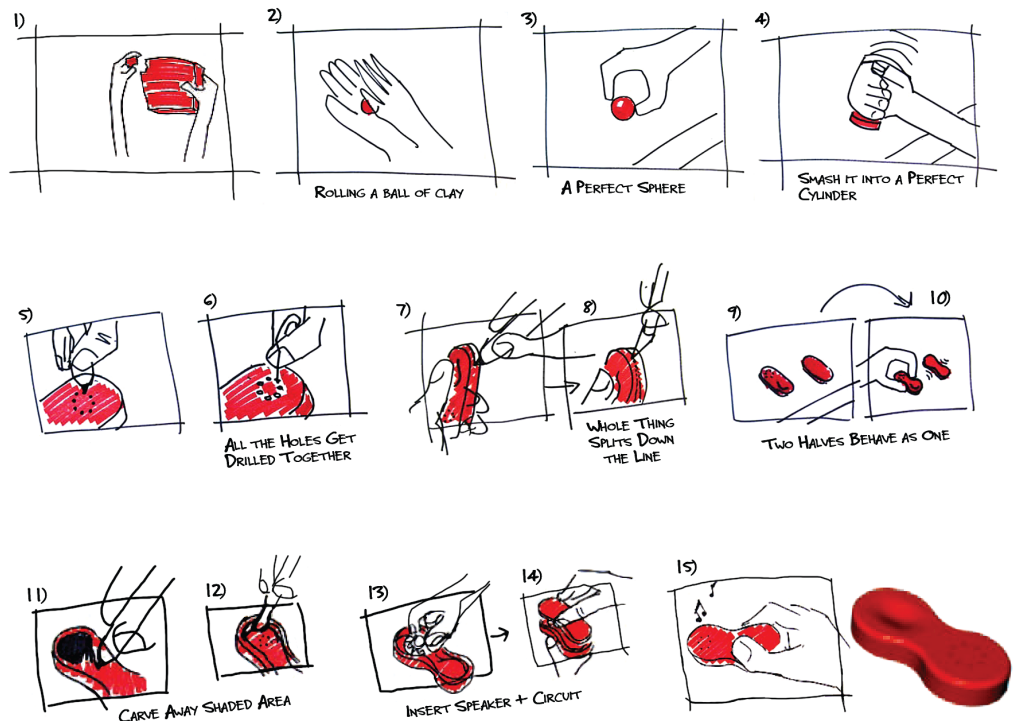


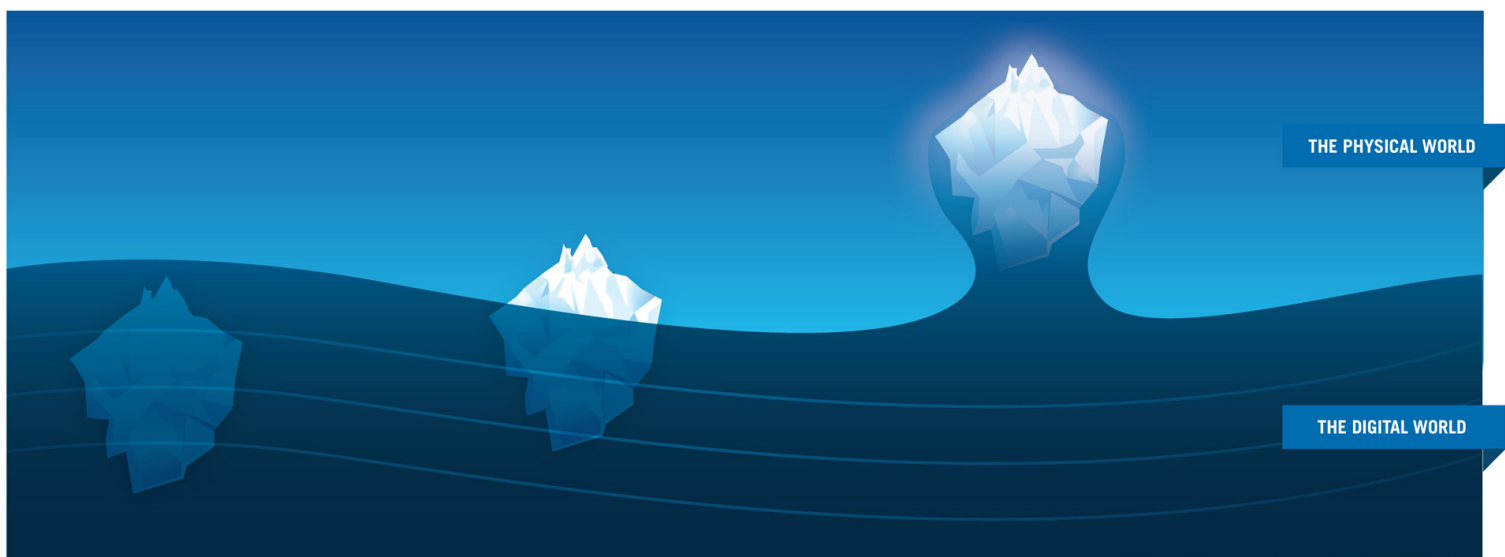
Figure 8: Radical Atoms, Making an enclosure with Perfect Red @ MIT Media Lab

mentioned that GUIs are inconsistent with our interactions with the rest of the physical world. He noticed the limitation brought by 2d input devices such as mice, touchscreens, and keyboards. The traditional graphical representations and “see, point, and click” interaction is not intuitive enough. The tangible interface and manipulation will provide user haptic sense and make the information directly manipulable and intuitively perceived through human’s gesture. But even the tangible interface is still limited, it has limited ability to change the form or properties of physical objects in real time. This constraint can make the physical state of TUIs inconsistent with the underlying digital models. Prof. Hiroshi Ishii claims that there is possibility to extend the interaction with frozen physical object by introducing the kinetic tangible object.

GUI PAINTED BITS

TUI TANGIBLE BITS

RADICAL ATOMS



A Graphical User Interfaces only let users see digital information through a screen, as if looking through a surface of the water. We interact with the forms below through remote controls such as a mouse, a keyboard or a touch screen.

A Tangible User Interface is like an iceberg: there is a portion of the digital that emerges beyond the surface of the water - into the physical realm - that acts as physical manifestations of computation, allowing us to directly interact with the ‘tip of the iceberg.’

Radical Atoms is our vision for the future of interaction with hypothetical dynamic materials, in which all digital information has physical manifestation so that we can interact directly with it - as if the iceberg had risen from the depths to reveal its sunken mass.

“Radical Atoms” is our vision of human interactions with the future dynamic physical materials that are transformable, conformable, and informable.

**Tangible Media Group
MIT Media Lab**

Figure 9: a brief introduction of Radical Atoms @ MIT Media Lab

The concept of Transformable Materials takes a leap beyond Tangible Bits by assuming a hypothetical generation of materials that can change form and appearance dynamically, becoming as reconfigurable as pixels on a screen. It is computationally transformable and reconfigurable material that is bidirectionally coupled with an underlying digital model (bits) so that dynamic changes of physical form can be reflected in digital states in real time, and vice versa. Prof. Hiroshi Ishii believes that the Transformable Materials is the future material that can transform their shape, conform to constraints, and inform the users of their affordances. Radical Atoms is a vision for the future of human-material interaction, in which all digital information has a physical manifestation so that we can interact directly with it. We no longer think of designing the interface, but rather of the interface itself as material. We may call it "Material User Interface (MUI)."

As a graduate student with architectural background. I started with my research question which is: can we extend the concept of the Transformable Materials into design space, providing designer an intuitive interface to enhance design experience. Because apparently it will deemphasize the manipulation of data or 2d graphic and somehow emphasize the intuitive representation.

2.2 THE DEMAND OF NEW DESIGN TOOLS

Nowadays Architectural design is heavily dependent on the traditional computer-aided design system with WIMP interface which has been invented for over 50 years since Ivan Sutherland released his SketchPad. Architects are using various kinds of CAD tools to push their project forward and materialize their intent. The workflow which current CAD produced has been considered as the main method of design activity. The tool that architect selected will have significant impact on their works while it could also lead to some negative limitations.

Yet, it is not deniable that with the growth of computer hardware and software technology, Computer-aided design systems have made a remarkable contribution to the evolution of architectural design, as well as generate no negligible negative effects. But with the development of current computer-aided design systems, most of architects who didn't accept professional computer training, spend considerable time on solving software problem but not design problem. The manipulation of user interface, the abstracted meaning of design symbol keeps confusing professional architects. It leads to reduced efficiency and the misunderstanding of project. We have to

realize that architects are facing a dilemma: Architects, who used to work with descriptive drawings and physical models, now become the monotonous operators of computers. Architectural design, which is previously an interested and creative process, now becomes a repetitive electronic task. Knowledge and professional skill which are accumulated through long terms design process are now replaced by the computers.

A brand new Computer-Aided Architectural Design system which I will explore in my thesis needs to be created to inspire designer by desalinating computer manipulation and enhancing the physical interacting between designers and design object.

But based on the development history of CAD, we can conclude that the technology used in Architectural industry was always behind the technology used for engineering. Because of the practicality, reliability and stability within the domain of architecture are emphasized, so that it is impossible for any form of experimental progress will firstly happen in architectural industry. Just like the invention of the elevator leading to the emergence of high-rise building, the practical needs of architectural technology will not exceed the needs of social productive forces. Hence, adopting technology from other areas is understandable. But CAD technology was invented for supporting engineer to define design description and create, modify analysis and optimize products. (Narayan, K. Lalit, 2008) However, an engineer's working method and thinking pattern is entirely different from architects.

Architectural designers are trained and practiced in the means of design, design is an act of seeing, thinking, as well as making. (Josh Lobel, 2009) Based on Josh's research, design is a creative activity combining eyes, brain and hands. Architectural designers are responsible for designing the aesthetics and spatial details of a building -- the building's size, shape, space utilization, and site requirements. That requires that no matter which tool designer selected, pencil, mouse or something, design aids should assistant the coordination of interacting amount eyes, brain and hands while designer is seeing, thinking and making. Through the association of brain, hands and eyes, architectural designers are aware of information; through the repetitive creation, architectural designers would have chance to re-define information and get feedback so that they can make the right decisions. In short, the architect designs how the building looks; their typical think pattern is more based on spatial, graphics, intuitions and relations.

Timothy Binkley (1997) pointed out that our ability to communicate with digital technology is far more behind the ability of using the digital technology creatively. Until “our language catches up with our creativity” we would be left “speaking about computers in paradoxes” (Binkley, 1997) Binkley claims that, it will be both positive and negative that we are still not skilled to master technical language. But the most important thing is design interaction. The interaction is not only between architects and other team members, but also between designers and computers, which Kalay(2004) defined the interaction as an “intra-process”. Current Computer Aided Design tools built the method to capture, store and process information by abandoning the dependence of physical material, so that users can represent the actual relationship by applying the abstract design symbol. But architectural designers need to understand that the final design products and design symbol (lines, polylines, 2d drawings, 3d models, etc.) is totally different and separated. Those design symbols appeared on the screen weren't the final design products but the physical buildings are. The symbols represent design concept or proposal through pixel, mathematics, computer graphic and algorithm.

2.2.1 THE FUTURE DIRECTION OF NEW DESIGN TOOLS

For those architectural designers who didn't take professional computational training, the translation between design symbols and design concept means communication blindness. Although computational design technology advocates such blindness by providing a standard and ambiguous information model, but if designer's idea involved the knowledge and information which is new to the standard model, the communication between design symbol and design concept will be likely to fail.

Furthermore, strict and fixed vocabulary (symbol) will lead to the information missing in the communication between design and construction. That the reason could explain why in today's architects are having huge number of inefficient and repetitive manipulating.

Once the uniqueness of a new design tool comes into the world, its intention in design and communication should be determined by its users. If the media cannot represent the design purpose, then the design project shouldn't be limited under the media. Some CAD systems which were developed for others industry, for instance, CATIA, indeed, can help architectural designers to achieve the complex project.

In an ideal situation, besides the reliable computing and flexible representations, architects' knowledge background will be also embodied by other industry, by working under their process, principles and knowledge structure. The embodied culture of digital technology is significant for understanding and using Computer-aided design tools to design and construct. Meanwhile, through enhancing the relationship between seeing, thinking and making, architectural designers will re-join the team of creator, but not stay with the role of computer operator. The progress of digital design method is pushed by architectural designer's attempting to understand the translation between design concept and design symbols.

In the above case, the enhancing of communication between design concept and design symbol were benefit by architects' initiative. But from a view of long term, the communication between designer and computer should happen more spontaneously and openly so that design symbols could more directly incarnate design intent.

Vladimir Bazjanac(1975) claimed that architects are still having faith on CAD because they believe CAD can help architects to avoid interference and inefficient work, so that they can put more time on design. The inefficient work was defined as "noncreative tasks that are considered wasteful of time (like drafting, manipulation of information, and maintenance of an extensive information system.)" but 10 years later, after he participated in CAD technologies, he started to doubt on his pervious statement. In his another article, he pointed out that the fixed and strict data structure (symbol) is pretty hard to capture and inspire designer's flexible and emotional design intent. At the meantime, design intent will not be well reflected by the designer who is using digital tool to create design symbols until he or she could skillfully grasp professional computer knowledge and skills meanwhile exactly know what designer's expecting.

The context above has illustrated the fundamental challenges of current CAD system. In the after content, I will talk about the ideal feature of the new CAD systems, in order to provide a potential research direction for my later study.

2.2.2 DESIGN MEDIA

My vision for future design activity relies on developing a brand new design media integrated with intuitive tools and augmented representations to enhance the design experience. Media is more than just a "tool", as articulated by McCullough (1996), media is also an environment where in our minds and bodies fully take on the issues of design. The tools incorporating an intuitive input via physical manipulation, would facilitate designers to master it quickly and smoothly. The augmented representation referring to display would enhance the physical interaction with designer to establish a more compre-

hensive cognition with the design object. So that designers would have an opportunity to ensure that the physical experience of final product will match with the design intent.

From both my personal experience and architects common sense, the complexity of design tools, the incomprehensive representations, are creating their own challenges while assisting to solve design problems. In the context of architectural design practice, designers are heavily dependent on classic graphic user interface, producing huge amount of design drawings. But the user experience given by physical presence of architecture is significantly different from the designers' experience given by design drawings. However, finding a solution is the main challenge for a designer, if the designer could not maximally predict the result of their design, it would be hard to claim that the project is successful. Even though we have various kinds of quantitative analysis tools to evaluate the building performance, it is still not intuitive enough for designers.

Compare this with artistic creation, where physical tools such as brush pen and graver used for artistic creation offer direct manipulation. Materials such as canvas and clay which are equivalent to the representation of design selected by artist, not only provide real-time optical and haptic feedback but what is more meaningful is its physical presence. I need to declare that I am not proposing that the designer, especially architectural designers, should directly work on final product without intermediary representations, but an augmented representation would improve designers' experience by delivering the same information across the design process and the final product.

The design tool refers to input manipulation while the design representation refers to output display. But the present tools and representations are built upon two-dimensional graphic user interface. Since the final works of design such as architecture, furniture, and product are all physically three-dimensional geometry, it would be reasonable that the design process should happen in a fully 3d environment.

For general labor, technologies are used to satisfied production needs and promote the efficiency. But for design technology, not only should it promote the efficiency but also it should meet the demand of innovative concept of design. Thence, an ideal design system should be defined as two different parts, which are efficient tools and revolutionary representations.

Efficient tools improve design efficiency to meet the existing needs of

design problems which requires a friendly access, in the meantime stabilize its influence in the design process. Revolutionary representations inspired the significant ideas happened of design, and enhance its position in the design process.

2.2.2.1 INPUT MANIPULATION TOOLS

Efficient Tools are designed to promote efficiency in design process, in the context of Computer-Aided Design systems, according to the previous research, efficiency means reducing the interference and inefficient work. What causes the interference and inefficient work is the unequal relationship between design concept and design symbol. In the current situation, design symbol is fixed and strict, while design concept is opened and creative.

Architectural design is a reflection of a form conceived in the designer's mind (Shouhen Chen, 2009) that means the process of design is the process of materialization. Architectural products are intuitive, but the method used to realize the products is abstracted. So the unequal status of design symbol and design concept is understandable. Design process is the transition from abstraction to materialization. Current transition (communication) relies on engineering technology, which is realized by sets of algorithms, mathematics, parameters and database. But most of professional trained architects are not familiar with them. So the realization of efficient tools depends on finding a readable method to interact between design symbol and design concept. That requires the method should be simple enough to be accepted by most of architects. At the meantime, the design symbol should be upgradeable so that designer can define new symbol base on his own design concept.

There are several achievement seems like could meet the requirements.

Python

Python's design philosophy is "elegant", "clear", and "simple." Programs written in Python are far more concise than many other languages, which have been recognized by most of programmers. Python is young, it has a strong versatility so that it can be applied in various platforms, but also it has the feature of object-oriented languages, and suitable for beginners structured programming.

Python has been selected by McNeel to replace Rhinoscript in the future. It has been fully integrated into the Rhino parametric design

platform, which has rich modeling libraries and is also fully integrated with Grasshopper, so that it can apply all Grasshopper SDK library, that means each of Grasshopper components can be implemented in Python. It is an excellent aid to parameterize our designs on Rhino platform. In addition, MAYA, 3D MAX, Houdini, Blender, and many other mainstream 3D modeling software, such as Catia, Arcgis, Revit, FreeCAD other commonly used design assistance and BIM software supports Python scripting extensions.

Processing

Processing is an open source programming language and integrated development environment (IDE) built for the electronic arts, new media art, and visual design communities with the purpose of teaching the fundamentals of computer programming in a visual context, and to serve as the foundation for electronic sketchbooks. The project was initiated in 2001 by Casey Reas and Benjamin Fry, both formerly of the Aesthetics and Computation Group at the MIT Media Lab. One of the stated aims of Processing is to act as a tool to get non-programmers started with programming, through the instant gratification of visual feedback. The language builds on the Java language, but uses a simplified syntax and graphics programming model.

Grasshopper

Grasshopper™ is a visual programming language developed by David Rutten at Robert McNeel & Associates. Grasshopper runs within the Rhinoceros 3D CAD application. Programs are created by dragging components onto a canvas. The outputs to these components are then connected to the inputs of subsequent components.

Grasshopper is used mainly to build generative algorithms. Many of Grasshoppers components create 3D geometry. Programs may also contain other types of algorithms including numeric, textual, audio-visual and haptic applications. Grasshopper features a fairly advanced GUI with a lot of features that are only rarely found in production software. It is not known however whether these elements improve or impede effective usage. The main window consist mainly of the component 'palettes' and the 'canvas', apart from standard Windows GUI elements such as the title bar, the menu and the status bar. Since Grasshopper is a plug-in to another windowed application, the layout of the main window is kept minimal.

All these tools I mentioned above have been far easier to access than other software, but are still based on programming even if it is visual programming. Mastering these new programming language is not a quick learning process for designers.

HUMAN BEHAVIOR INPUT

As far as I understand, the most intuitive tool should incorporate input manipulation through a natural language but not a programming language. The natural language in this context means not only an oral language like English, but also means the spontaneous behavior of human beings such as hand gestures. If the manipulation setting could be based on spontaneous behaviors, it will be easy enough to be picked up. The nature of design activity contains association of designer's thinking, observing, and making. The circular flow among thinking, observing, and making gives designers the opportunity to dynamically re-define the objects they sense. Body manipulation motivate designers evaluating object from multiple aspects so that inspire appropriate design intent.

Multi-Touch User Interface

Current CAD programs and other drafting software, whether operating in two- or three-dimensions, require users to manipulate non-intuitive tools (mouse) across a virtual workspace.

Apple Inc. has released a "Virtual drafting tools" details an intuitive computer-aided design and drafting user interface, with on-screen tools that can be manipulated via a multi-touch display, when the tool is active, the user can resize, scale, or make other adjustments with full gesture support. Multi-Touch interface will give designer a much more free and intuitive stage to perform their design.

Yet, our understanding of human's spontaneous behaviors is still in the early stage, especially natural gesture. The exploration of natural manipulation would find how it could affect design. Grandhi (2011) discusses the definition of natural and intuitive gestures. In his paper of Understanding Naturalness and Intuitiveness in Gesture, Production: Insights for Touchless Gestural Interfaces, the author mainly discussed the definition of intuitive and natural gesture by addressing two research questions.

1. What aspects of a gesture (such as motion, hand shape and form) are natural and intuitive when communicating a transitive action? In particular, are gestures using hand actions holding-imagined-objects more intuitive and natural than using body-part-as-object?

2. Is it easier to gesture a transitive action when the user communicates as how s/he habitually performs the action or when the user communicates it as an instruction? That is, should one gesture as "this is how I do it" or "this is how you should do it"?

The authors found that in the current industry, researchers are focusing on gesture recognition, but little attention has been paid to generating natural and intuitive touchless gesture. The authors try to define what makes a gesture natural and intuitive and whether a natural and intuitive gesture needs an imagined tool or a physical object/body part.

Grandhi explored people's intuitive preferences and natural tendencies under different conditions by showing participants different pairs of pictures which contained "before" and "after" scenarios. Participants were instructed to tell experimenters what needs to be done by performing a gesture. Responses were video-taped, then placed into one of several categories depending on the action done with or without external tool to distinguish between instructional and habitual.

The experiment suggested that user experience could be enhanced



Figure 10 : Grandhi's experiment of studying gestures representing objects

by developing the gesture vocabulary based on understanding that the actions are embodied. From the experiment, authors formed a guideline for design of a touchless gestural interface. The key points are:

A, a dynamic representation of motion will make interacting easier than static hand poses.

B, the interface shouldn't contain any of the body tools, which is not naturally and intuitively.

C, two-handed manipulation will be expected by users, it will provide a better sense of virtual space than one hand.

D, in the touchless gestural interface, the manipulation should be egocentric, it will help user to ignore the awkwardness between users and system.

There are a lot of projects which have been done within the field can achieve the gesture input. This research has focused more heavily on sensing devices, such as Wii Remote, Kinect, and Leap Motion, etc.

HoloDesk: Direct 3D Interactions with a Situated See Through Display

Otmar Hilliges, David Kim, Shahram Izadi, Malte Weiss, Andrew D. Wilson

Microsoft Research, Culture Lab

CHI 2012, May 5–10, 2012, Austin, Texas, USA

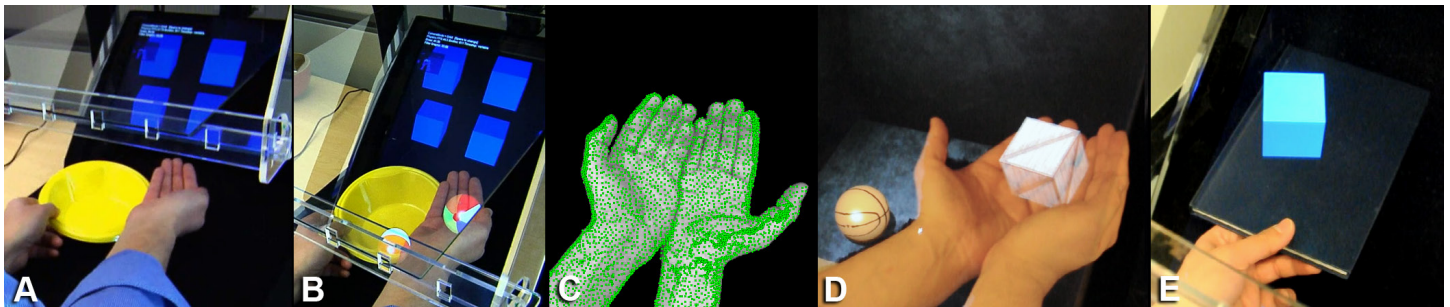


Figure 11 : HoloDesk @ Microsoft Research

Several members of the Sensors and Devices group at Microsoft Research have developed a new system called HoloDesk that allows users to pick up, move and even shoot virtual 3D objects, plus the system recognizes and responds to the presence of inanimate real-world objects like a piece of paper or an upturned cup.

Unfortunately, the research team hasn't talked too much about how its new natural user interface system works, but according to images showed in the paper, the device is under the size of a regular desk and is made up of an horizontal holographic screen which is projected a 2D image by a LCD screen. A Kinect camera keeps tracking user's hand position within the 3D virtual environment; a webcam captures the user's head location to help with viewport adjustment and perspective effect. User place hands inside the work area lets the Kinect sensor see what users are doing, and the display dynamically updates to let user virtually interact with objects that aren't really exist.

The user looks down through a transparent holographic screen into the viewing area which is under the screen. the holographic objects showing in the screen can be picked up and stacked on top of real-world ones, and real hands can juggle virtual balls or shoot them at targets, or play with a non-existent smartphone.

The researchers also seem to have applied the ability to remotely collaborate while multi-user are working together on the virtual projects. What is more interesting this is that objects shown in the virtual interface still obey real-world physics laws.

There are some graphic issues appeared in the project such as when real objects enter the digital interface, the graphics goes into jerkiness and fuzzy. but behave mostly as they would in real life, responding to gravity and force and other objects.

The big goal is support for walk-up-and-use mixed-reality tabletop interaction. The user study indicated that some of their ideas (physics, grasping, display) work OK, though the stereo-vision version was a little better. Question: Other than the “physics playground” what could this be used for? It seems well suited to disaster response or similar (where emerging data needs to interact with pre-existing information), but not so sure about design. Maybe Design Evaluation (by clients or future occupants)?

Other valuable attempts that explored the possibility that designers can get support from gesture input: Yi, et al. (2009) presented a novel method of gesture modeling supporting architectural design. They define various components of architecture based on a set of signs. However, their gesture recognition depends heavily on the application of colored marker to the user's hand and numerous motion capture devices. It is not a simple and inexpensive system.

Gesture Modelling-Using Video to Capture Freehand Modeling Commands

Mark D. Gross and Ariel J. Kemp
 Design Machine Group, Department of Architecture, University of Washington

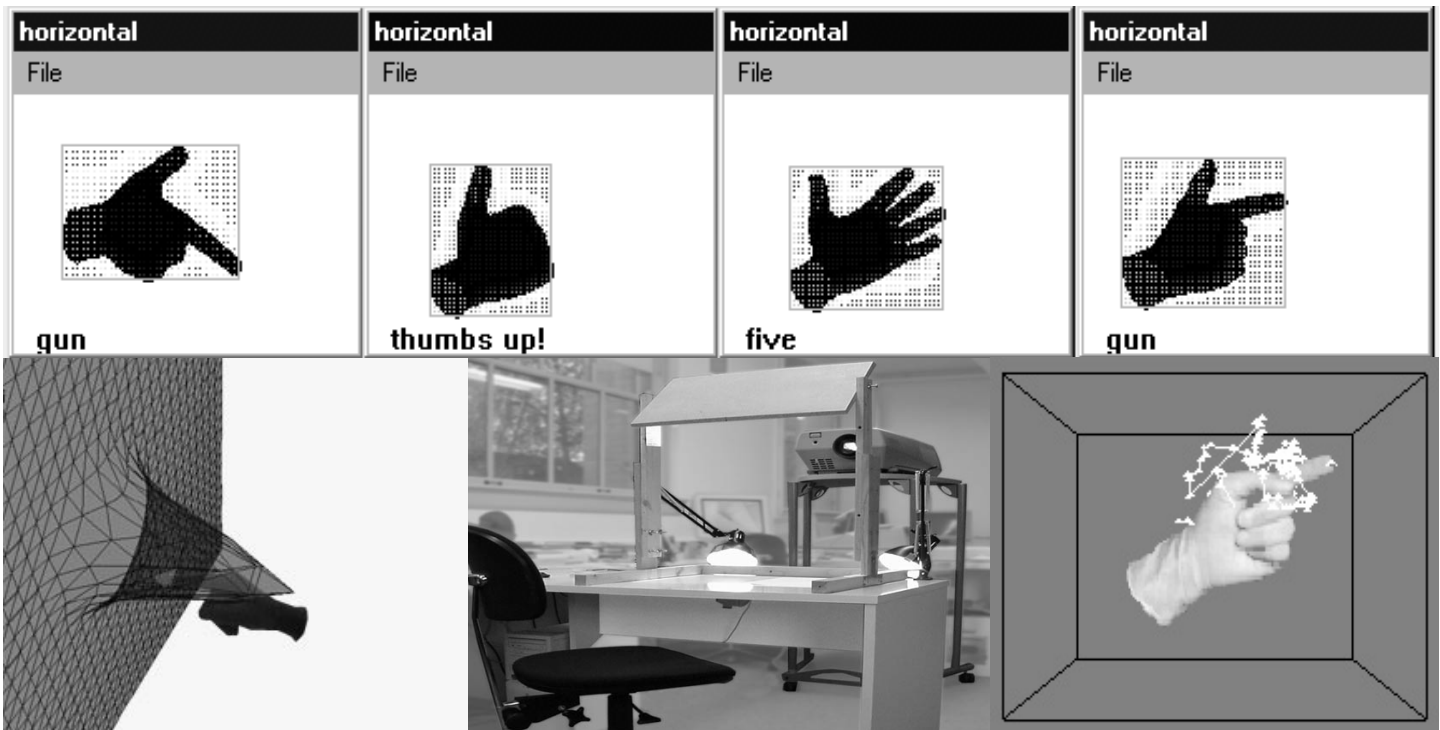


Figure 12 : Video Based Gesture Modeling Configuration by Groos and Kemp

Gross and Kemp demonstrated in their paper about how to construct a new gesture modeling system. The expected feature of the system is that designer could use free hand gesture to generate, edit, and view 3d digital graphics model. For the traditional CAD programs with WIMP interface has limited the workflow of 3d products which are approached by 2d based interface. In the paper, the authors address purpose by illustrating the physical arrangement (there is no Kinect at that year) of the system and the prototype written in C.

The gesture based CAD system appeared very early. Since 1980s, some related works have been showing up in some research projects. The early concepts of hand capture were depending on the sensing gloves. So Gross and Kemp are kind of borrowing the idea of using sensing gloves instead of actual hands.

The authors developed their prototype of desktop configuration which was a combination of desktop VR display and webcam input devices. The configuration was kind of like the holodesk which is designed by MS. A capturing webcam was attached at the bottom surface of the desktop (display). In order to calculating the depth of the image, the authors suggest to use a pair of webcams so that it can capture the depth of hand position from both z axis and xy plane. In order to improve the contrast, they also set a white background and black gloves so that the webcam could easier to capture the shape and position of gesture. For avoiding the impact of hands shadow, they use diffuse room light (a standard fluorescent light) to reduce shadow. The configuration can form the spatial information to serve the gesture modeling, and testing if the gesture would match with the known gesture series.

The shape of glove once captured by the camera will be simplified by computer into threshold image with bounding box. Then compare those simplified image with the pre-stored black and white image. Gross and Kemp introduced a new approach to recognize a configuration of a single known object that is guaranteed to reside within a given bounding box. The new approach can compare box-bounded camera image from the template images (pre-stored) pixel by pixel for fast per-frame performance. Each template images which is created by hand and photoshop are serving to different gestures. The pre-stored images are pre-designed as different command or purpose. Once the user's gesture is recognized and can be matched with the pre-stored images. It can be applied to editing the model.

There are several applications which were created in the research.

The first application was form generator, designer uses fingertip as brush and draw a 3d form in the digital interface. But it requires users to orient their hand so that the fingertip can be seen by the camera. Another application was called mesh distortion. Users can use their fingertip to point at a digital mesh. And reform the shape of mesh by pushing finger.

The final application was designed to be able to select and move objects. In the application, once the a terrain mesh was created ,it was possible for users to place digital object on the mesh.

A Multi-user Collaborative Space for Architectural Design Reviews

Viswanathan, Kumaragurubaran,
Design Machine Group, Department of Architecture, University of Washington

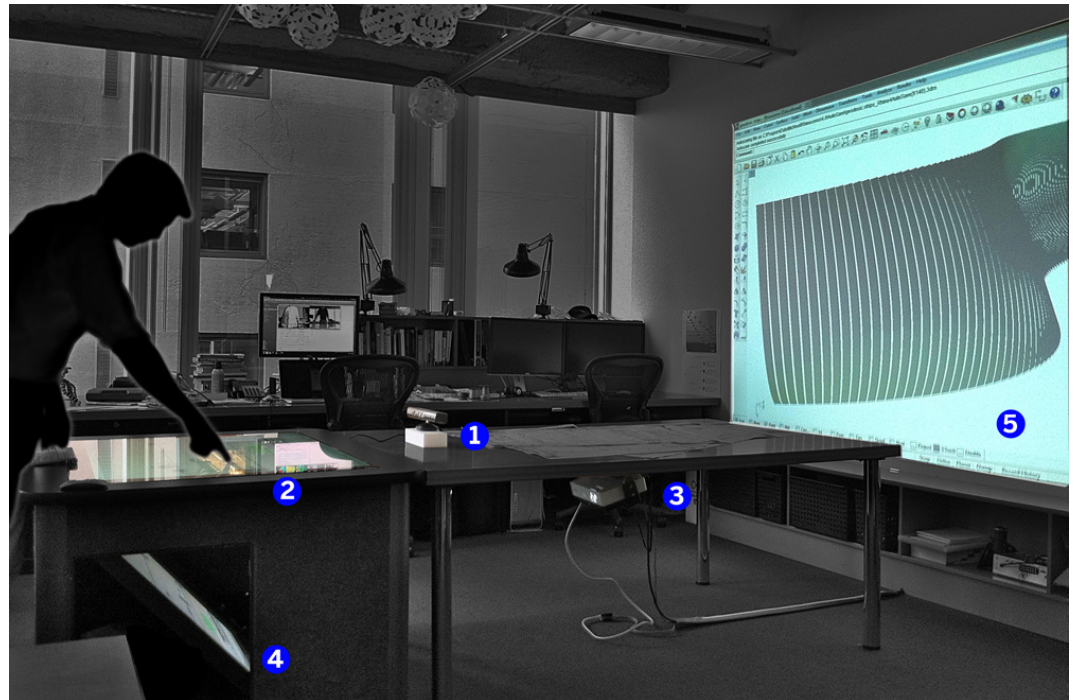


Figure 13 : Multi-user Collaborative Space Configuration by Kumaragurubaran

The gesture modeling system was one of the early achievement of interactive design added tools, which is simple and experimentation. Kumaragurubaran (2012) presented a hands-free prototype of gestural support for design using a Kinect to perform manipulation of a Grasshopper (a Rhinoceros plugin) interface and parametric model

Kumaragurubaran presented his multi touch interface system in his paper to figure out how designer can communicate with other professionals. This system aims to address this challenge through an implementation of a mixed-mode multi-user interface solution that involves a keyboard, a table top display, a wall display, and a Kinect sensor. It uses a tabletop display of the Grasshopper canvas and

touch-based input for navigation and manipulation of algorithmic components. A wall-projected display provides synchronized real-time visualization of the 3D model. The aim of the interface is to facilitate dynamic design decision-making, increase understanding among team and provide an integrated environment for collaborative interaction with parametrically driven designs.

Viswanathan selected Grasshopper as his working platform, because Grasshopper is a visual programming language and this makes it amenable to touch inputs. The system combines a wall display for visualization; a mirror under the table reflecting the projector light, a Kinect being placed above the table for sensing motion. There is also a digital model is displayed on the wall through a second projector. Once designer changed any parameter in Grasshopper, the digital model displayed on the wall will be changed as well. So those two displays both have different functions, the multi-touch surface is for manipulation, and the wall display is for displaying. Through Kinect, it captures depth information from multiple frames and calculating the average depth values. One user place hand above the surface, he must press and hold these points as seen on the table top display and each touch point is registered as a co-ordinate. The five co-ordinates obtained are used to define an affine transformation that maps the table collaboration space. Once the surface is activated; it will capture touch gestures and translates it to events on the Grasshopper canvas. So that makes user can directly manipulate above grasshopper interface.

One of the good things of the system is that it will not be limited to grasshopper; it can also extend into other visual programming platform. It will allow the system easily recognized some common gesture such as pan, zoom, add wires and connect components, etc. The system can create a more dynamic environment for team work and discussions face to multiple users, which is friendly for the design to evolve in real time.

Gesture input is also required appropriate sensing device such as a motion controller. Several Motion Controllers have been released in the past three years, such as Xbox 360 Kinect and Leap Motion. By integrating the Leap Motion Controller with their CAD platform, SpaceX-a private space experiment Company's engineers can manipulate virtual rocket parts with a high degree of nuance and control by motion. It allows them to dive into virtual models and see them in new ways.

I took a survey on several fundamental motion controllers including

Wii, Kinect, and Leap Motion as well as their applications.

Wii and Kinect with applications

Wii and Kinect

Rita Francese, Ignazio Passero, Genoveffa Tortora
University of Salerno, Fisciano (SA), Italy

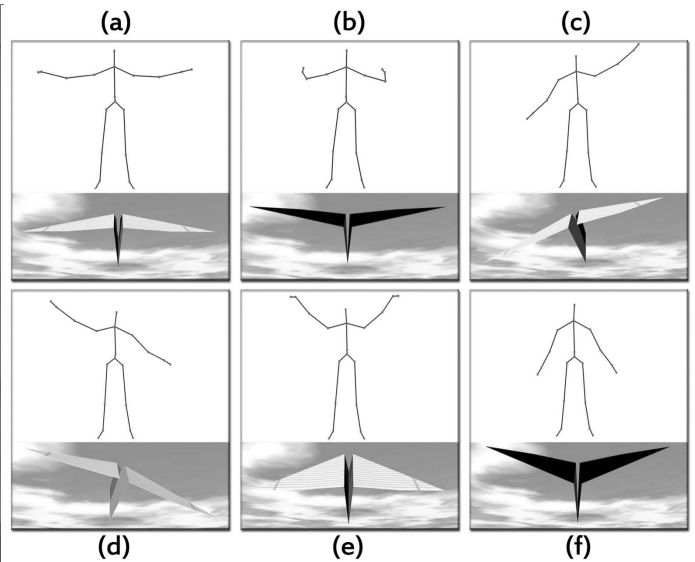


Figure 14 : A navigation system by using Kinect

The current gestural tracking technologies are most used in the game market. Using body language to control the game is pretty amazing. It makes the gaming experience more realistic and intuitive, But the paper <Wii and Kinect> mainly presents two different augmented applications based on gestural tracking devices— Wii (released by Nintendo) and Kinect (released by Microsoft). After evaluating these two different applications, the authors conclude that the potential of applying gestural tracking technology into augmented interfaces is considerable.

These two applications (wii and Kinect) are both used for controlling user navigation of Bing maps in the 3d environments. The result of these two experiments shows that users can quickly fit into the new body controlling system.

The difference between wii and Kinect is that: Wii is actually a controller which needs to be held in the user's hand, the information used in the system depends on the relative location relationship between the controller and the console. But Kinect is a single controller based on Infra-Red emitter and two cameras, users don't need to hold the controller. The infra-red emitter will capture the skeleton movement and send the skeleton information to the connected computer.

Before the authors discuss the experimental applications, they evaluated some of other motion controlled navigation applications. Comparing with the referenced applications, author's projects are more independent rather than system based, and more intuitively controlled by user's motion rather than multi-touch. Both of the Wing and King systems are easily mastered by the experimental users.

The Wing system is controlled by a wii and a nunchuk. Generally, the wing system needs both of two controllers coordinate with each other. The navigating movement is determined by the relative location relationship between two devices. Comparing with Wing system, the King system is much more intuitive. User can just control the flight by body movement without holding any other device (hands-free). The plane movements are determined by user's various arm gestures.

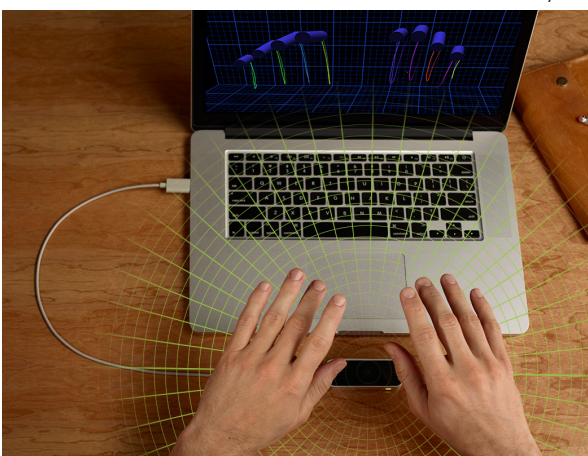
Both of these projects are evaluated by different participants with average age 24. Each participant is required to answer several questions after they play with two applications. All the questions and answers will evaluate two projects from Subjective Usability and Presence and Immersion. Participants are asked to complete the navigation of two digitalized cities with different tasks. Through experiment records, both of Wing system and King System have their special talents.

The authors also conclude that if the system could contain more body action, users will be more satisfied with the 3d gestural system. In the meantime, system should avoid some traditional computer element such as icon, windows, mouse.

Leap motion and applications

The Leap Motion controller: A view on sign language

Leigh Ellen Potter, Jake Araullo, Lewis Carter
Griffith University



Leap motion controller is a relatively small device with high sensitivity used for sensing hand and finger movement. It was released in July 2013. The authors wished to assess if it is able to recognize sign language for young deaf and mute children. (Seek and Sign)

For those normal parents who have hearing-impaired children, sign language is required but foreign. In order not to delay language development for the child, researchers seek inexpensive systems to teach (video) and interpret (Leap) sign language for hearing im-

Figure 15 : Interacting with computer via Leap Motion hand gesture sensor

paired children.

Using leap motion to help hearing impaired children has two steps the first step is evaluating the ability to recognize the AUSLAN, the second step is to look at the ability of recording AUSLAN and train system for later recognition and identification.

Regarding gesture recognition, the author identified several projects developed by other researchers, including wrist sensors, 2D and 3D cameras and Kinect platform. All these projects need specific additional technology to be useful. For example, a Kinect cannot recognize fingers movements which is a frequent requirement for sign language.

Leap motion technology is a highly sensitive device which can translate hand motion into computer command. It has already had over 200 app in its app site available by the end of 2013, all these apps consist of games, scientific and educational apps, and apps for art and music.

In this project, leap motion was used by a two member research team with leap motion SDK, to establish how the device worked and to understand its interaction. Researchers selected the AUSLAN alphabet for testing the functionality of leap motion.

Leap motion is found that have both of strengths and weakness:

Strengths:

1, leap motion is a pretty accurate device, all the motion which is recognized by hardware will be optimized by its API, it means that it could process the data faster and more accurate. But other devices such as Kinect are depending on its hardware.

2, the work range of leap motion is up to 1 meter, in the testing they found that the result will be much more accurate within 40 cm, which is the range that AUSLAN sign will need.

Weaknesses:

1, Leap motion was found to process the hand movement which is perpendicular to the device well, but when the hand movement involved some action such as flipping, it was hard to recognize. AUSLAN will need flipping hand (rotation) to demonstrate the alphabet.

2, when two fingers were touching with each other, leap motion recognizes these two fingers as one finger.or not at all? (touching thumb to finger, Pinching, a in Figure 4)

3, AUSLAN contains not only hand signals but also body and face movement; it is obvious that leap motion cannot capture those body

and face action.

Using leap motion to help with AUSLAN be accepted by deaf and mute children still need more work to develop.

2.2.2.2 OUTPUT REPRESENTATION DISPLAY

The revolutionary representations are designed to inspire the creative ideas happened of architectural design; according to my previous research, revolutionary means minimize restrictions and dynamic. The restrictions come from current CAD strategies. The strategies focus on building logical system to adjust parameters. But what designer needs is the subjective impression of the project, rather than accurate data.

So that means the revolutionary tool needs to be built on a more free level. It doesn't like the efficient tools; the revolutionary representation are on the hardware side. We need to find the right method that user can interacted with their design, not only through mouse and monitor, but also through a more intuitive and practical way to feel and control the project.

An augmented representation as output display has several approaches to enhance the experience of designers and achieve the desired results.

A. Emphasizing the visual experience

The first approach is to emphasize the visual experience during design process by using virtual reality technology. The virtual 3d representation would provide designers a co-located and coordinated mix of synthetic and real visual feedback to facilitate design generation. Current technologies such as virtual-reality headset devices and holographic technology can help achieve the idea smoothly. However, while operating these devices via manipulation through human behavior, the manipulating stability would be an issue because a purely optical representation would not enable a haptic feedback by the designer. While developing "InSpire", I found that unlike 2D mouse input, where the operating surface of the mouse provides extra support in the vertical dimension, the fully three dimensional gesture manipulation in a virtual-reality environment is lacking a stable reference plane which makes the deviation inevitable.

When designing in 3D, designers always welcome a 3D display. Still, multiple orthogonal 2D representations (plan & elevation) are commonly used to unambiguously represent 3D objects for editing.

A lot of research project has been done to achieve the first approach:

One notable feature of the HoloDesk project is its display (Hilliges et al. 2012). It uses a semi-reflective horizontal optical film onto which a 2D image is projected from above. Users put their hands under the semi-reflective surface, where they see a combination of reflected and transmitted imagery. An RGBD camera tracks the user's hand positions within the 3D design volume. By coordinating display and gesture recognition, a unified visual experience is presented to the user wherein models can be directly manipulated using hand gestures as well as other physical objects. Because the display occurs between the user's eyes and hands, the holographic objects shown on the screen can be picked up and stacked on top of real-world ones, and real hands can juggle virtual balls or play with a virtual smartphone.

SpaceTop: Integrating 2D and Spatial 3D Interactions in a See-through Desktop Environment

Jinha Lee, Alex Olwal, Hiroshi Ishii, Cati Boulanger
MIT Media Laboratory



Figure 16 : SpaceTop done by MIT Media Lab

An interesting project, SpaceTop, has been developed by Lee et al. (2013). Using a configuration similar to the HoloDesk's, the prototype device uses a modified OLED screen as a monitor, with the keyboard placed behind the screen. The user can type on the keyboard by placing their hand behind the screen, where they can also manipulate digital objects on the transparent monitor from behind. Depth sensitive cameras enable the manipulation to be in real 3D, and users can raise their hands to catch the displayed windows and arrange them in the 3D space. Like HoloDesk, SpaceTop is oriented to regular users rather than designers.

The prototype device used a Samsung transparent OLED screen as a monitor, and placed the keyboard behind the screen, it is kind of like an inverted desktop. It allows user to type on the keyboard,

while placing their hand behind the screen and manipulate digital objects on the transparent monitor from behind. Depth sensitive cameras make the manipulation be in real 3D and the monitor also tracks head movement so that the user always gets the appropriate perspective. This project brings us an amazing illusion that we can look into a sort of digital box.

Users can open up the see-through 3D desktop and type on the keyboard or use a trackpad just like manipulating in traditional 2D operating environment, Windows or files are allowed to be placed in a 3D digital space between a screen and the inside space.

The user can raise up his hands to catch the displayed windows and arrange them in this 3D space.

The device works through a combination of a transparent display (LED?) and 3D gesture detection algorithms that are placed in the input space. The authors demonstrated that 3D rendering can be achieved without users' 3D glasses.

As a result, SpaceTop liberates the user allowing them to type, select, draw in 2D and directly manipulate digital item within a 3D digital space above the keyboard.

Automatic Projector Calibration with Embedded Light Sensors

Johnny C. Lee, Paul H. Dietz, Dan Maynes-Aminzade, Ramesh Raskar, Scott E. Hudson
School of Computer Science, Carnegie Mellon University



Figure 17 : Automatic Projector done by Johnny Lee

Johnny Lee, etc. developed a motion-sensitive 3d display system (2008) by using the infrared camera in the Wii remote and a head mounted sensor bar. The system can accurately track the location of a user's head and render appropriate view-dependent (monocular) images to the screen.. The display reacts to head and body movement as if it were a real window, creating a realistic illusion of depth

and space and effectively transforming the user's display into a portal into a virtual world.

In his paper of "Automatic Projector Calibration with Embedded Light Sensors". Lee try to fit a projected image perfectly onto a target surface such as a white board. Typically that requires a screen to be directly in front of the projector, in a very specific orientation under-story image. But the in this project, Johnny lee is aiming to place a screen in a location which could be everywhere around the projector and calibrate the projector on to the target surface. The target surface is modified by adding some of the electronics at back side, which contains optical fibers at each corner and a USB sensor board. But at the front side, the fibers are invisible, the white screen acts to hide the fibers and also to provide light diffuser which improves calibration reliability.

To calibrate onto the target, user can simply place it in the projection area. After that projector projects a series of grid-coded binary pattern, which is horizontal and vertical. These patterns uniquely identify every pixel in the projection screen allowing system to locate the four fibers on the back corners. Users can use this information to project correct images.

The quality of projected image on the target surface is high enough to present graphics. It discovered the location of these fibers actually closest to the nearest pixel. The calibration takes about 1 second. Once the location of fibers been discovered, a homography matrix can be computed to warp the source image to fit onto the projection surface using a 3d programming environment such as OpenGL. To illustrate the robustness of this technique will gradually decrease the projection angle of calibration. Johnny lee found that calibration continues to work reliably even the projection angle is less than 2 degrees.

They also developed a wireless version for the optical sensors, which allows the projection screen to be completely untethered.

Johnny lee also add a total of six fibers on each corner at back of a large board. This allows users to calibrate two projectors side by side to creating a method of automatically stitching multiple projectors. User can calibrate each projector individually and then bring two images together.

Moveable Interactive Projected Displays Using Projector Based Tracking

Johnny C. Lee, Scott E. Hudson Jay W. Summet , Paul H. Dietz

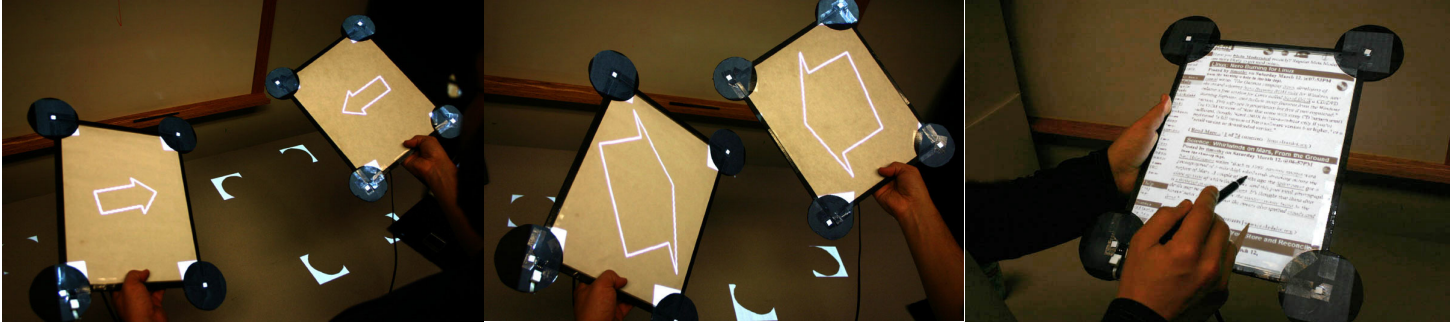


Figure 18 : Location sensitive multi-display interaction

In another paper Moveable Interactive Projected Displays Using Projector Based Tracking. Johnny Lee presents a system he developed for creating moveable project displays using a projector based tracking technic. A key device of the system is a handheld surface containing four optical sensors and a touch sensitive surface. When users placed the surface in the projection area, the system can discover the location of each corner using a sequence of pattern uniquely identify each pixel. Once the system discovers each sensors location, it can project small tracking pattern onto the target surface, to continuously track the surface at real time, it allows users to use a projector to simulate an active display on a passive surface.

The tracking pattern is appeared as solid gray squares. The way they accomplish this is by using a modified DLP projector to project two versions of grid that have the same apparent intensity. But Johnny rendered with two different frequencies of light modulation. The lighting may look uniform but there's a boundary between low frequency area and high frequency. The difference is it is invisible for humans observing but is easily detected by a light sensor. This allows users to high the location tracking patterns and what appeared to be solid grid squares .

One possible application of this technic is simulate the function of a tablet PC, users can use a touch- sensitive surface to attend input from the users, and create fully interactive surfaces, such as a drawing program and a interacting with web browser. When working with the interactive surfaces, probably detecting and handling occlusions for other loss a tracking signal is essential for such a system to be useful. Johnny generates several instances attracting lost, sometime due to a hand covering a sensor, or a surface corner exiting the projection area.

B. Tangible Representation

Another better approach would be tangible representation which can give designers a multi-somatosensory cognition. When operating devices via manipulation directly through gestures, designers can easily sense through physical objects by haptic or auditory sense rather than a purely visual experience. Besides, directly manipulating a physical object, designer can establish a three-dimensional control with more accuracy.

I did a detailed literature review within the field of tangible interface study, especially for the research project related to design.

Literature Review related to tangible interface study:

MxR: A Physical Model-Based Mixed Reality Interface for Design Collaboration, Simulation, Visualization and Form Generation

Daniel Belcher, Brian Johnson
Design Machine Group, Department of Architecture, University of Washington

MxR is an tangible and integrated working platform facing to solving early phase communication problem during the design process by combining digital information and physical objects. The name MxR stands for Mixed Reality, which is attempting to address the four issues of architectural design: communication, visualization, simulation, and form generation. Daniel and Brian found that although those four has be applied individually or collaboratively in other researches, but none of those project is able to combine these four aspect with a human conversations. There is one pre-condition for MxR, which is design team will need to have a digital model or/and a physical model before MxR providing supporting. MxR requires several video-based hardware including a head-mounted display (eMagin Z800)with a webcam (Logitech Quick cam). The existing models are placed above a foam core attached by black-and-white fiducial markers. The MagicLens, once be used in the ARchitecture project, plays the same role in this project, a magnifying glass. The Graphic approach is operated by multiple software such as ARToolKit 2.72(HIT LAB), osgART 1.0, and OpenSceneGraph. It also requires a visible indexed marker tag to be captured by webcam and associate with a specific 3D model counterpart in the database. The project allows Radiance and Ecotect, two simulation tools to participate into the computing, providing designers a lighting simulation data.

When users are using the MxR platform, the webcam will capture the physical environment and the fiducial marker. The heads-mounted display will mixed both the physical objects and digital represen-

tations together to achieve a Mixed Reality View. Users can freely move their hands to manipulate models by two ways; one of them is moving the foam core around attached with fiducial markers. Or, using MagicLens tool to view and manipulate the mixed objects. Currently, MxR has several features (functions):

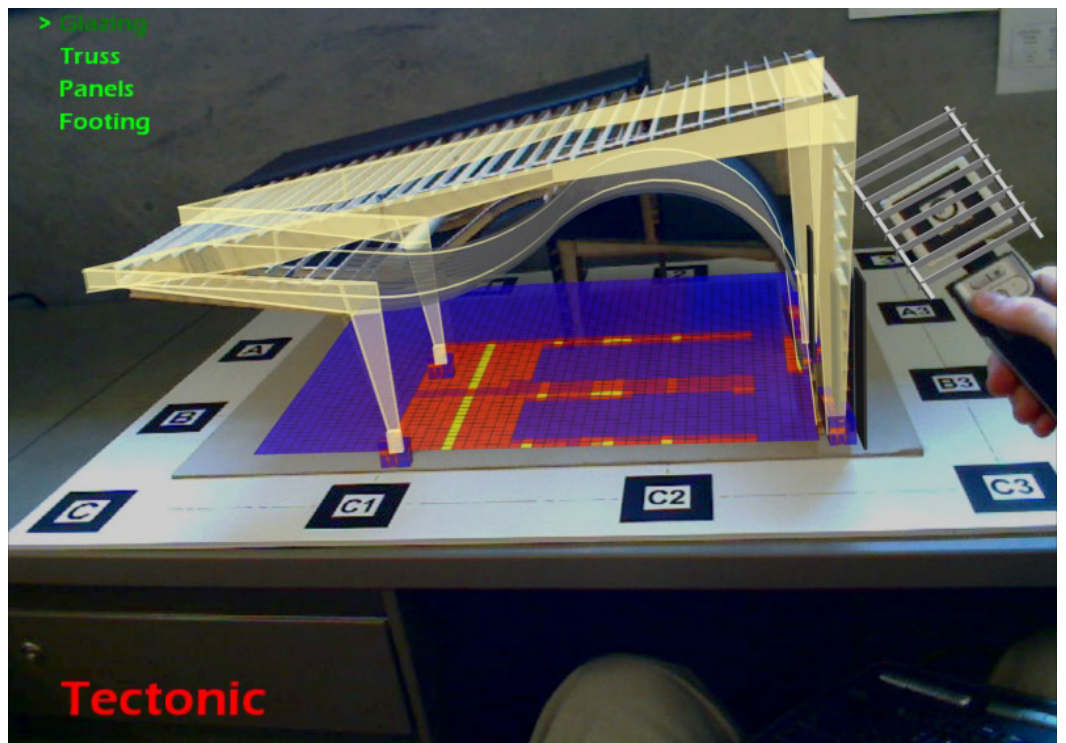
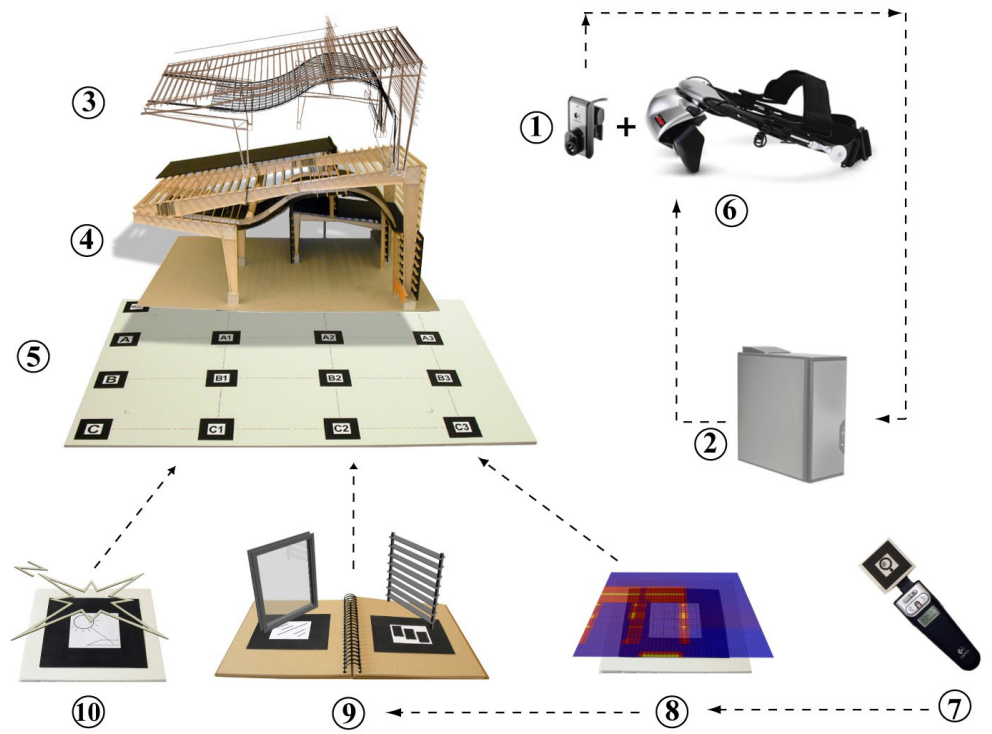


Figure 19 : Mixer configuration and the augmented representation

-Manipulation

Using the MagicLens, It can allow user to freely zoom, pan and highlight different architectural layers and elements. Users can simply select and move geometric elements within the platform range. When the lens is moved through the scene, potential “selectable” components are highlighted with a transparent bounding-box. To select and manipulate the highlighted object, the user simply presses a button on the lens handle. MagicLens can also allow users to change the opacity of the elements. User can set different degree of the transparency. It will give a good sense to illustrate the structure of building.

-Simulation

Connecting with Radiance and Ecotect, the system can apply the simulation diagram to the mixed reality interface depends on the relevant location of the fiducial markers. User can set different date and weather to simulate the environment. User can freely switch to different mode, from Mixed Reality mode, to Virtual Reality mode by simply pushing a button on the MagicLens. An analysis grid can be placed into a Virtual Reality interface and match with the data which is precompiled by simulation tools.

MxR is a good attempt for designers to understand the design ideas with a multi- somatosensory method. It is intuitive but data- oriented, and physically 3d Display. But I think MxR didn't perform as well as it described in the abstract. The form generating function didn't be mentioned as much as other features. It is a good tool for review existing conditions and help designer to judge the situation by providing simulation data. But it is not that powerful enough for designer's creative design activity to directly create new objects.

ExTouch: Spatially-Aware Embodied Manipulation of Actuated Objects Mediated by Augmented Reality

Shunichi Kasahara, Ryuma Niiyama, Valentin Heun, Hiroshi Ishii,
MIT Media Lab, 2012

ExTouch is an interactive product created by Tangible Media Group at the MIT collaborating with Sony Corporation; TMG try to invent an interface to enhance the spatial control with robotics and smart appliances with an intuitive and simple manipulation. ExTouch creates embodied Manipulation which could be spatially aware of actuated physical objects mediated by augmented reality (ipad).as a tangible interface, exTouch would let user manipulate actuated physical objects in space using augmented reality, it allows user to change the location and direction of target by using the fundamental interactive which is “touch and drag”, The “exTouch” system expands the users touchscreen interactions and transit it into real world by

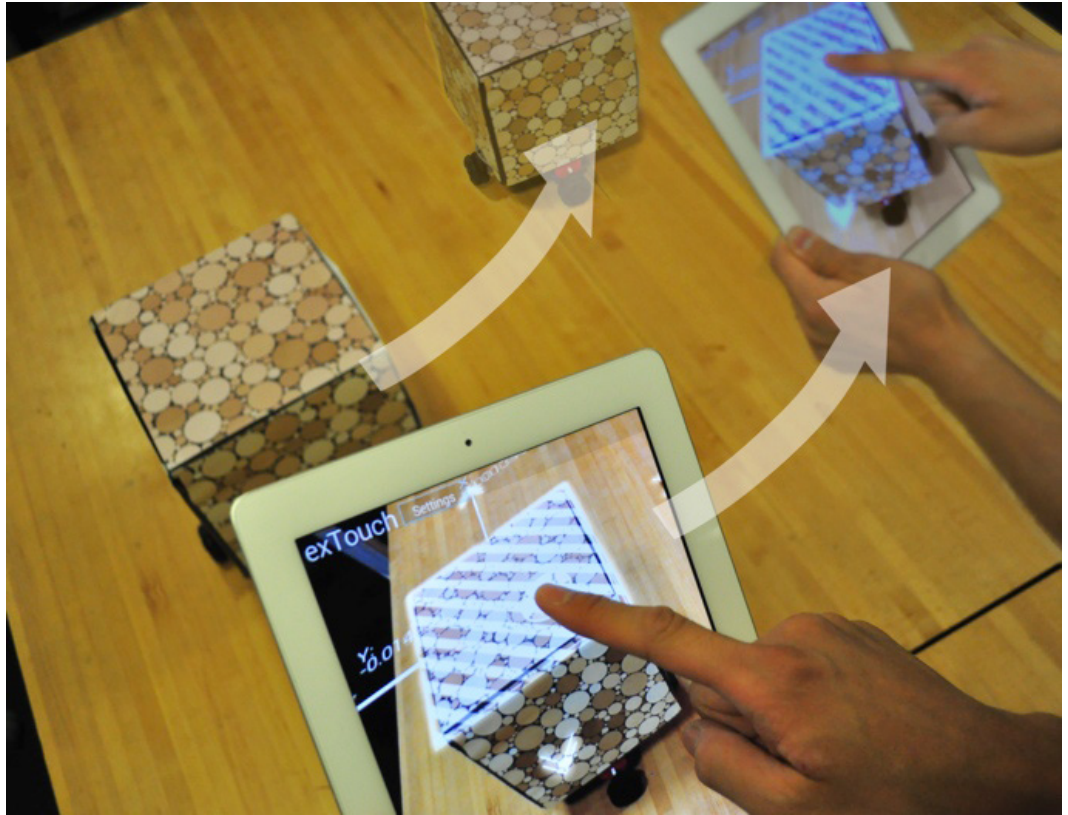


Figure 20 : exTouch, User can simply touch and drag the target device through live video on the screen, done by MIT , Media Lab

increasing spatial control over the physical object. When users touch a device shown in real time video on the screen, they can change its position and orientation through multi-touch gestures or by physically moving the screen in relation to the controlled object.

TMG apply the system with some electronic toys such as an omnidirectional moveable cube, a drone, and moving furniture for reconfigurable room. They claim that a proposed spatially-aware interaction would provide further enhancement of human physical ability through spatial extension of user interaction. Customized mobile app running on an iPad was built using OpenFrameworks. Omnidirectional moveable cube with Arduino and the system uses WiFi for communication between the objects and the device.

Second Surface: Multi-user Spatial Collaboration System based on Augmented Reality

Shunichi Kasahara, Valentin Heun, Austin S. Lee, Hiroshi Ishii
MIT Media Lab

The work on 3D drawing collaboration systems has been done from quite some years now but today it has been made even more possible and interesting to build an efficient system thanks to the rise of devices like tablets and smartphones. These devices are very much capable of delivering Augmented Reality content and take advantage of their cameras and motion sensors.

The project of MIT's Tangible Media Group called T(ether) has been

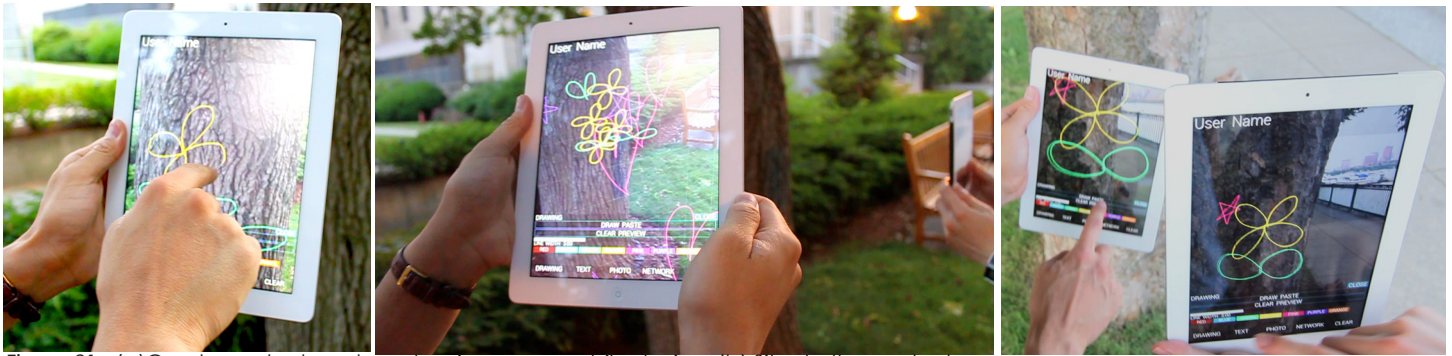


Figure 21 : (a) Create contents such as drawings on a mobile device. (b) Situate the content on the augmented reality spatial canvas. (c) Collaborative content creation in the shared spatial canvas with co-located users in real-time. Done by MIT, Media Lab

able to do that and took 3D drawing collaboration through augmented reality to a whole new level. (<http://vimeo.com/42173010>) the T(ether) is now developed into a brand new project called the Second Surface, which is a real-time interaction for user-generated contents on top of the physical environment. This system allows users to place three dimensional drawings, texts, and photos relative to such objects and share this expression with any other person.

Second Surface explores a vision that integrates collaborative virtual spaces into the physical space. Our system can provide an alternate reality that generates a playful and natural interaction in an everyday setup.

The Second Surface project is about creating an environment of creative collaboration between several users and to develop a system that can adapt to different environments. It can create a real-time interaction space and allow users with iPads to draw in that space. When first user draws anything through his or her iPad, the second one is able to see that in a 3D view and can take his iPad near to the text written by the first user and vice versa.

Second Surface recognizes a natural image as a target and allows users to draw on it. The drawings which include texts, photos, and other 3D objects are placed on relative objects. The system shares the location of the objects drawn by one user with others so they can see the drawing on their iPads as well while running the same app. This interaction of 3D drawing happens in real places such as on walls, trees, or anywhere in the air.

Second Surface is an augmented reality project that I personally would like to use, even if it's for entertainment purposes only. However it has got a huge potential and can be utilized for a number of applications if evolved a little more.

Beyond - Collapsible Tools and Gestures for Computational Design
 Jinha Lee and Hiroshi Ishii
 MIT Media Laboratory

Beyond is a brand new 3D interface based on a collapsible input

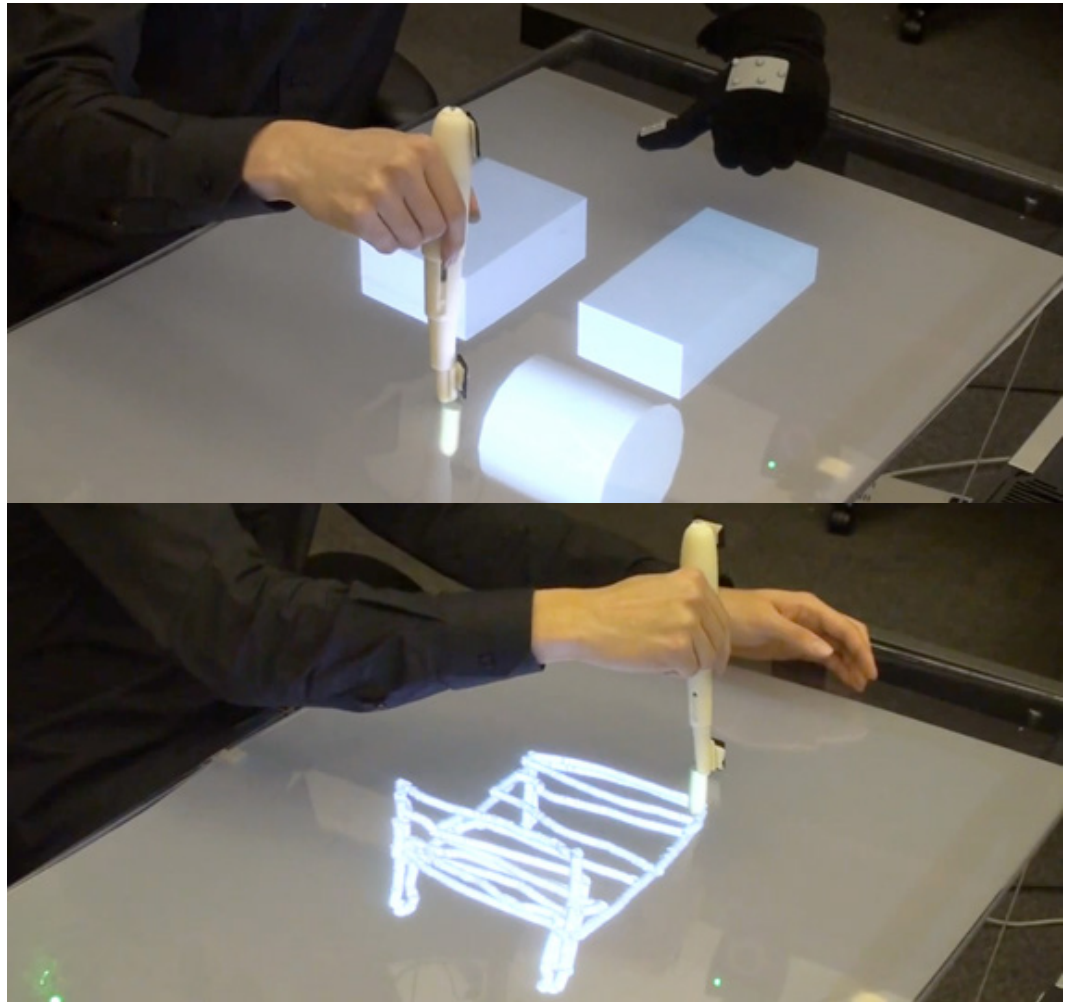


Figure 22 : Beyond, using tangible device manipulate 3d digital geometry. by Jinha Lee, MIT

device that users can press into the screen to directly manipulate 3D objects through the digital interface. The device can retract and project itself onto the screen, letting users perceive that they are inserting the device into the graphical display. Users can directly select, draw and sculpt, in 3D virtual space without having to wear special goggles or HMD, since the scene is being rendered based on the user's head position tracked by a camera.

The Beyond device consists of a telescoping plastic body with push button housing, a Bluetooth communication module, and a vibrating motor controlled by an Arduino Board. Two passive infrared reflective markers are attached to the ends of the device. Tracking of both sides of the device is accomplished using a vicon system, which illuminates and captures infrared light reflected by the attached retro-reflective tags . The position of the user's head is tracked by two additional cameras with a face-tracking algorithm. The perspective of 3D scenes is corrected based on the users' head position such that they can look at the virtual objects from different angles by simply moving their head.

By supporting straightforward 3D selection and manipulation, Beyond serves as an intuitive 3D sketching and modeling environment, minimizing unnecessary abstractions in the interface. Beyond allows

the user to draw, sculpt and define shapes directly in 3D space without having to map the 3D geometry into multiple 2D constructional planes. Such an interaction allows users to rapidly externalize their ideas and share with others.

Through short experiments, the authors found it intuitive to use gestures of non-dominant hands to communicate abstract functions or shapes, combined with dominant hands' direct manipulation with the Beyond device. In our 3D sketching application, users can define lines, curves, squares, and ellipses and extrude or rotate surfaces with predefined gestures developed by oblong industries.

The current Beyond platform cannot fully support multi-user interactions because of the view-dependent perspective correction, this can be largely resolved by using volumetric or lenticular lens-based light-field displays. The authors further plan to implement this interface with a tablet and a device that can sense tilt and retraction, which will greatly improve portability of the system.

The unique idea of Beyond helped me established general framework of how to create a 3D input manipulation within a 2D interface.

2.3 Transformable Physical Design Media

If we are talking about the tangible media in design space, one of the fundamental challenges is that design process are always dynamic; design objects keep changing. Finding transformable materials would be the foundation of physical design media. Generally, when people interact with a physical object, there are two ways to sense it (Coelho 2009) which are theoretical abstractions and physical entities. The surfaces of the object are considered as boundaries through which we interact with things. Surface will eventually define physical forms and the form can be sensed by human. A transformable surface will impact the designer's cognition. In mathematics, surface changes are usually realized by topology transformation. But in the physical world, transformations are limited to additive or subtractive processes. Based on the shape-changing study, currently available transformation of object potentially could be realized through topological transformations and textural transformations.

2.3.1 the shape-changing study

Coelho and Jamie (2007) provide a holistic approach about how to design a shape changeable human computer interface. In this paper, one of the main ideas is finding the suitable material for building

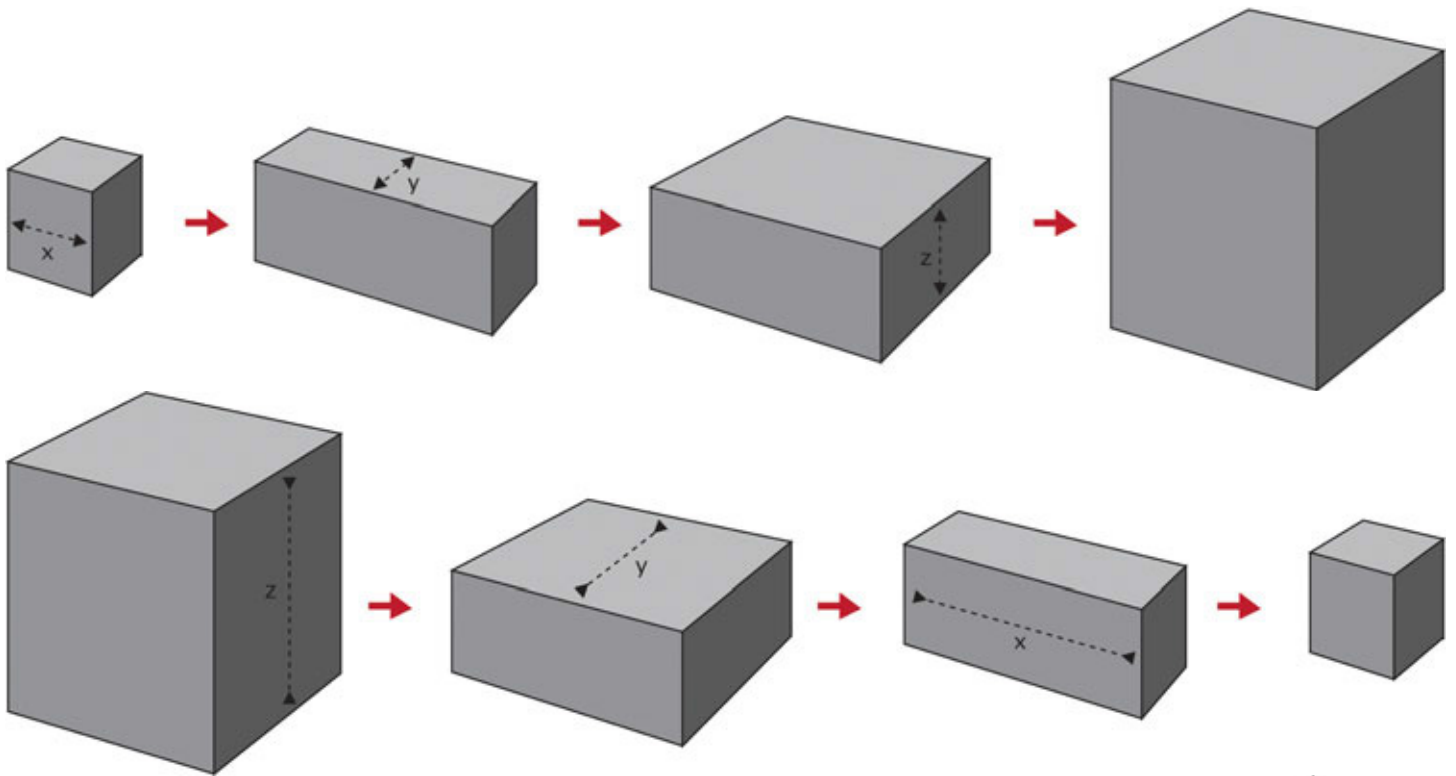
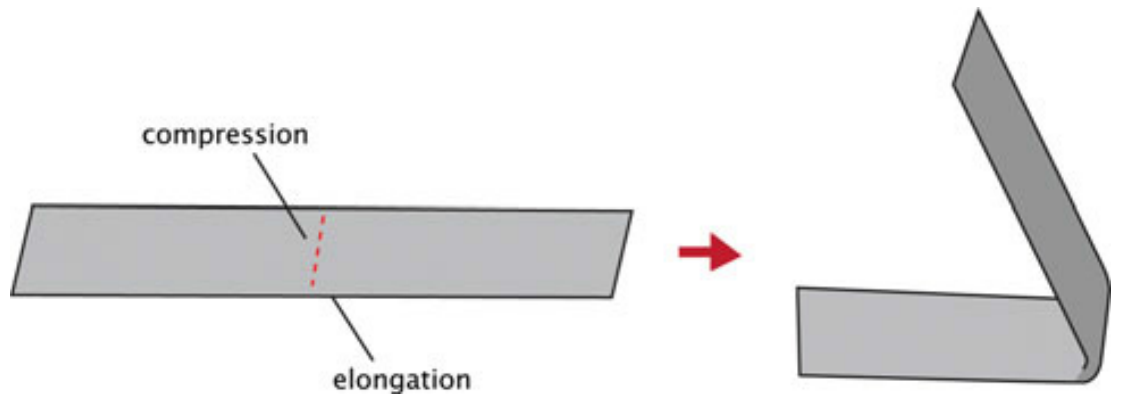


Figure 23 : The shape-changing study: A transformation process occurs through consecutively elongated or compressions in one, two, and three dimensions. A single orthogonal line of a paired elongation and compression makes the surface bend.



a shape changing interface. Since there are already several types of material are changeable, the authors explore the properties and limitation of the available materials. One of the main challenges of shape changing was its mechanical properties. But currently, the material can respond with a more adequate behavior to its changing environment.

The authors point out that some alloy or dielectric will become dynamic under the influence of direct or indirect electrical stimuli. They provided several currently available materials which can change shape. Most of them are alloy and dielectric. The properties of these materials are different than regular material, such as deformation strength or power requirement.

The authors cite shape memory alloys as a main material to describe in the paper. Once heated, shape memory alloys will form a specific shape and it will be able to indefinitely recover from large strains. After the temperature changing, the shape will return to the original form. But shape memory alloys is not suitable for all the applications, it needs to consider forces, displacements, and temperature.

Generally, when people interact with a physical surface, there are two way to sense it which is theoretical abstractions and physical entities. But surface is considered as boundaries through which we interact with things. Surface will eventually define physical forms and the form can be sensed by human. A shape changed surface will change the people cognitive of object. In mathematics, surface changing are usually realized by topology transformation. But in the physical world, the shape changing surface is limited by constructive or destructive progresses. In the aspect of digital graphic, a surface is regarded as a 2d programmatic field. Things like gravity, construction is not necessary to consider when building a surface.

Based on the properties of surface, the authors defined the shape changing surface as 3 different types:

- Topological transformations.
- Textural transformations.
- Permeable.

Although these types are different, it is still related to each other. It applies that how different transformations can support new interaction possibilities.

Since shape changing is a subject for the authors, they already developed several project in the aspect, Such as Surfex, SpeakCup, and Sprout I/O. these three projects based on the 3 different types which have been listed above.

The authors summaries that users can perceived shape changes from 4 different way.

- * the overall shape changes
- * the external surface quality changes
- * homeomorphic changes

The changeable shape can improve interaction with users through 4 ways, gaining a new physical shape, responding to with force-feed-back, recording user's action and applying to different surface, constraining and deformation.

There are several problem laying in the shape changing area. 1, most of current shape changing interface are limited with in design points, it should contains the design space for shape changing interfaces study. 2, most of current studies are focusing on the technical, but it should pay more attentions on the psychological and artistic aspects. 3, shape changing interface are study should pay more at-

tention on forming interaction. This paper reviewed several existing projects of shape changing interface and try to form an overview of design possibilities in shape changing. The project this paper reviewed includes Actuated Interfaces, Kinetic Interaction, Organic User Interface, Kinetic Organic Interfaces, Pro-active Architecture, and Computational Composites, the authors are comparing them together under the phrase shape-changing interface.

Based on the projects and researches I reviewed, there are several types of shape changing, such as orientation, form, volume, texture, viscosity, spatiality, adding/subtracting, and permeability.

Topologically: Shapes can pass from one form to another through continuous deformation.

Orientation: Changing the original shape through rotations or changes in direction;

Form: preserve the approximate volume of the shape while changing its overall form;

Volume: maintain the approximate form and are used in some shape-changing interfaces;

Texture: small changes on the surface of the shape that that leads to the visual effect changed;

Viscosity: result in both physical shape changes and in the illusion of shape change, but the original form is maintained. (haptic feedback)

Spatiality: the spatially changing of elements leads to an illusion of shape change

Un-topologically: Shapes are being split, united, or perforated.

Adding or subtracting: through unite or divide elements, and it can return to the initial shape.

Permeability: shape is perforated, but able to return to its initial shape

Majken, etc. (2012) defined the endpoint of shape changing, and the mid-point which is called transformation (means?) Transformation is defined into several aspects, such as Kinetic Parameters and Expressive Parameters. Kinetic parameters contain the some physical value like speed, frequency and description of spatially and geometrically values.

Another key context in the paper is talking about the interaction, the authors found that in the aspect of shape changing area, there are three kinds of interaction, which is No interaction, indirect interaction, and direct interaction. Direct interaction takes advantage of this bi-directional relationship, and in some cases indirect interaction also uses digital input to change the physical form.

No interaction: shape change solely as output and disregards user input.

Indirect interaction: use shape change as output, but base the change in shape on implicit input, when users don't realize that their actions are being used as input.

Direct Interaction: The user interacts intentionally with the system through deforming the shape, while changes in shape are simultaneously used as output. Or the shape changes performed on one interface are transferred to an identical interface, where they are reproduced.

2.3.2 the shape-changing case study

SpeakCup

SpeakCup is a voice recorder in a soft silicone disk with embedded sensors and actuators, which can acquire different functionalities when physically deformed by a user. Advances in sensor technology and material science have provided new ways for users to interact with computational devices.



Figure 24: SpeakCup and its interaction design, MIT

SpeakCup's body is made from a six-inch disk of platinum cure silicone rubber. A ring of aluminum is embedded inside the outer rim of the disk so that it stays round when deformed. A combination microphone/speaker is embedded in the center of the disk. Red and green LEDs are wired around the perimeter of the microphone/speaker. Two flex sensors that change resistance when bent span the diameter of the disk embedded in the silicone and facing in opposite directions to sense deformations on either side.

SpeakCup is wired to a protoboard where the electronics and batteries that power it are located. The project is a simple interface for sound recording and playback but similar interface techniques could be used for a number of other applications.

Sprout I/O:

Sprout I/O is a textural interface for tactile and visual communication composed of an array of soft and kinetic textile strands, which can sense touch and move to display images and animations. It combines textiles and shape-memory alloys to create a soft and kinetic membrane with truly co-located input and output. While the SMA is responsible for sensing touch and giving two directional movements to the fur strands, the felt provides structure, as well as visual and textural quality.

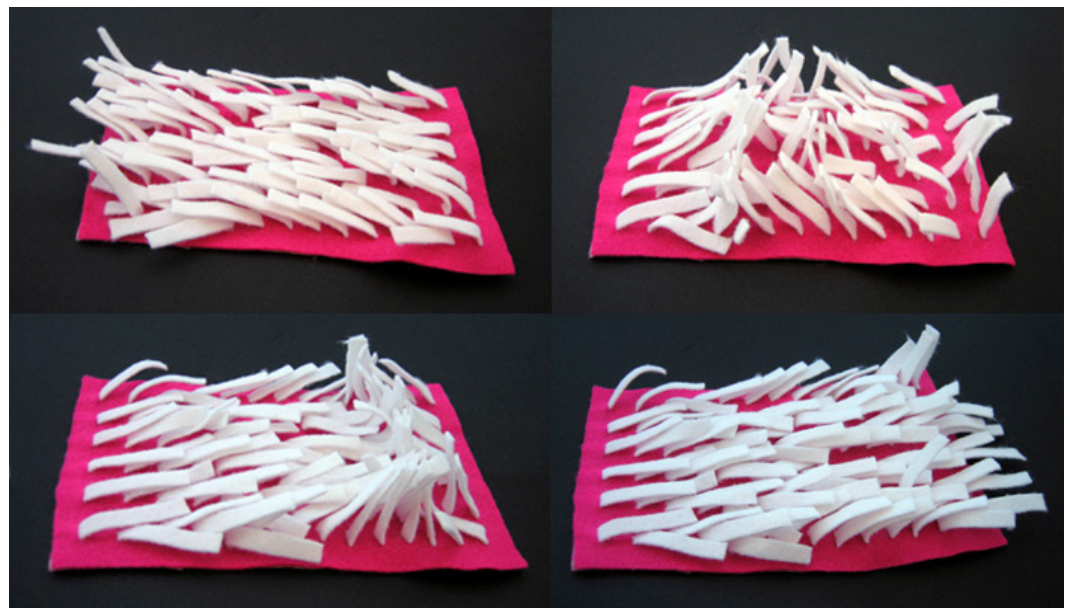


Figure 25: Sprout I/O conceptual design

Surflex:

Surflex is a transformable and programmable physical surface for the design and visualization of digital forms. Surflex combines the physical properties of shape-memory alloy and foam to create a surface that can be electronically controlled to deform and gain new shapes.

Surflex is constructed from 1" foam which can return to its original shape after being compressed. This substrate is pierced by 4 assemblies of 2 printed circuit boards (PCB) each, which are connected to each other through 8 shape-memory alloy coils arranged on an x,y grid. A shape-memory alloy (SMA) is an alloy made of nickel and ti-



Figure 26: Surfex's surface deformation in three steps

tanium that, once treated to acquire a specific shape, has the ability to indefinitely remember its geometry.

Surflex works by counteracting the contraction force of the SMA strands with the ability of the foam to return to its original shape. Through resistive heating, it is possible to electronically control the temperature of the SMA coils to make them contract.

Surflex could be used as a tool for displaying computational models in real time. Designers could make their models in a CAD program and have that design instantly sent to a tabletop Surfex

I did a detailed literature review within the field of transformable material study, especially for the research project related to design.

PneUI: Pneumatically Actuated Soft Composite Materials for Shape Changing Interfaces

Lining Yao, Ryuma Niiyama, Jifei Ou, Sean Follmer, Clark Della Silva, Hiroshi Ishii
 UIST '13 Proceedings of the 26th annual ACM symposium on User interface software and technology

PneUI is novel project developed by MIT Tangible Media Group. The reason I select this paper to summary is it provides me a brand new cognition of human-material interaction. In the aspect of architecture, I found that people will always pay attention on the objects which could enhance humans some of the sense, but architecture is lacking of ability in this aspect. if the research purpose is combining traditional architecture and human's daily object to fully interact with users, the Soft Composite Materials could be a great solution. Like it mentioned in the paper: "Hard bodies with construction of rigid structural and electronic elements have limited the form, function and interaction of shape changing interfaces in HCI." (Vertegaal,2008) Soft bodies could change its shape in terms of users need.

PneUI is an enabling technology to build shape-changing interfaces through pneumatically-actuated soft composite materials. The composite materials integrate the capabilities of both input sensing and active shape output. This is enabled by the composites' multi-layer structures with different mechanical or electrical properties. The shape changing states are computationally controllable through pneumatics and pre-defined structure.

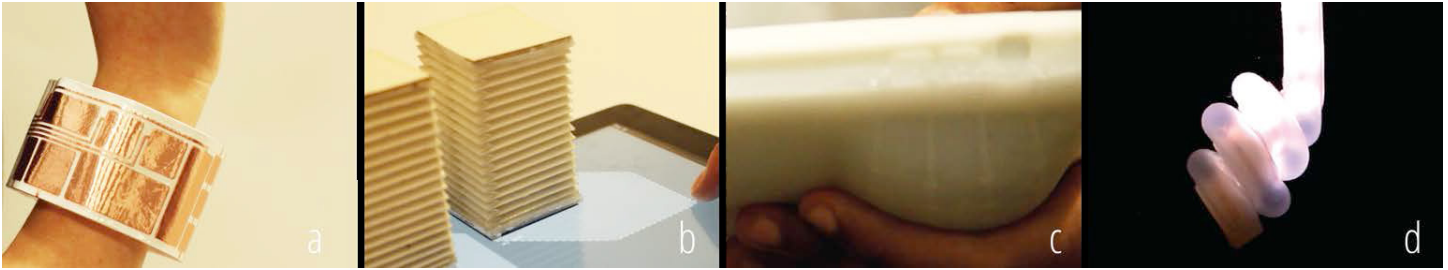


Figure 27 :
 PEN UI Application demonstrations.
 (a) A shape changing mobile.
 (b) Height changing tangible phicons.
 (c) A transformable tablet case.
 (d) A shape-shifting lamp.

The paper cites several achievements, which are using PneuUI concept. The most interesting application is the shape changing mobile. It is a smartphone activated by pneumatically actuated soft composite materials, the default shape is bracelet. When user is not using it, it can bent around the wrist, which provides great convenience for users storage and carrying. But when user needs to make a phone call or sending a text, it would be very simple to grab it from wrist and make it flat. When a phone call comes in, the mobile will be automatically and slightly bended into a more ergonomic shape.

PneuUI is consist of multiple layers composite material including liquid, silicon electronics, air passage and an origami structure similar to graphite composites. The combination of these composite materials leads the device be extreme soft and flexible.

While this advanced technology is still stay in lab, but I think it will have a great vision in the future. Soft objects can be used in the aspect of architecture element to provide users some of daily functions. It might change the concept of architecture. It can also adated into design space bringing designer more possibilities.

Direct and Gestural Interaction with Relief: A 2.5D Shape Display

Daniel Leithinger, David Lakatos, Anthony DeVincenzi, Matthew Blackshaw, Hiroshi Ishii
 MIT Media Lab

Actuated shape output provides novel opportunities for experiencing, creating and manipulating 3D content in the physical world. While various shape displays have been proposed, a common approach utilizes an array of linear actuators to form 2.5D surfaces. In the project, the authors used two prototype systems to demonstrate how to create and manipulate a 2.5D surface.

Currently, Tangible User Interface (TUI) successfully generates a relief shape in a space and allow users to simultaneously view, feel and manipulate the physical shape. However, it hasn't been applied to CAD software. Prior research work is generally limited by 2D arrays of linear actuators. The term 2.5D is defined by the authors as a shape without overhangs. So the purpose of this research is try to find a way



Figure 28: 2.5D shape display, MIT, Media Lab

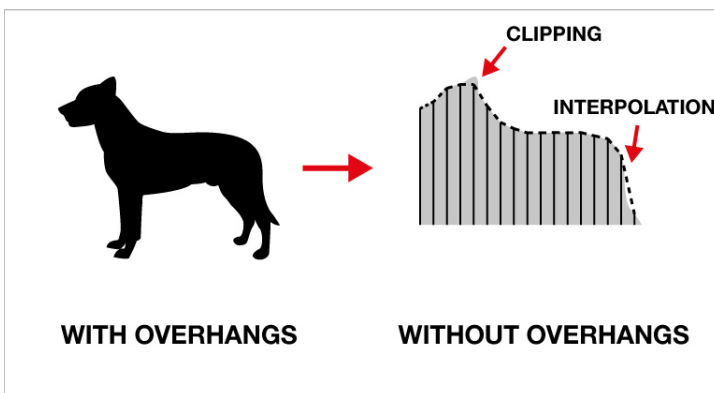
that 2.5D shape can be manipulated by users directly touching and pressing. Two projects used in this research, one of them is focused on rendering a physical surface with graphics. Another is focused on touch and hand-free gesture manipulation.

The authors evaluated related work, such as Sutherland's ultimate display system. They found that there are several limitations are contained in 2.5D shapes:

The first limitation of 2.5D shape is it cannot allow overhangs.

The second is about resolution of the actuated point.

The third limitation is about the linear range, if the shape formed exceeds the range, it will fail.



Authors found that in the related works, touch is the only way of input in 2.5D shape display, so they suggest that to extend the input method with freehand gesture, which is inspired by Wilson's project using pinching to interact with data.

Authors defined three types of interaction:

- *Transformation of scene view
- *Selection of model vertices
- *Transformation of selected vertices

Figure 29: the limitation of 2.5D shape display is it cannot overhang, MIT, Media Lab

To support these interactions, they firstly demonstrate the limitation of direct touch, touching is more like a traditional graphical manipulation by using finger instead of mouse. They found that pushing surface is easy while pulling pins to a desired height is quite hard. So using an external controller or freehand gestures as an input means will be helpful.

After the input test, they identify gestural input as the best additional

interaction modality with a 2.5D shape display. The authors identified four basic functions used for interacting with 2.5D shape display: Selection, Translation, Rotation and Scaling.

In the phase of applying, two applications are used to show how gestural input and direct manipulation can be used to navigate and to manipulate a 2.5D shape display.

Unlike in the related work, 2.5D shape display cannot create arbitrary shapes. But authors found that shape without overhangs, such as terrain data can be formed. The application allow user to load a 3ds file to represent a reasonable terrain. The terrain can be manipulated by users gesture to select, translate, rotate and scale.

inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation

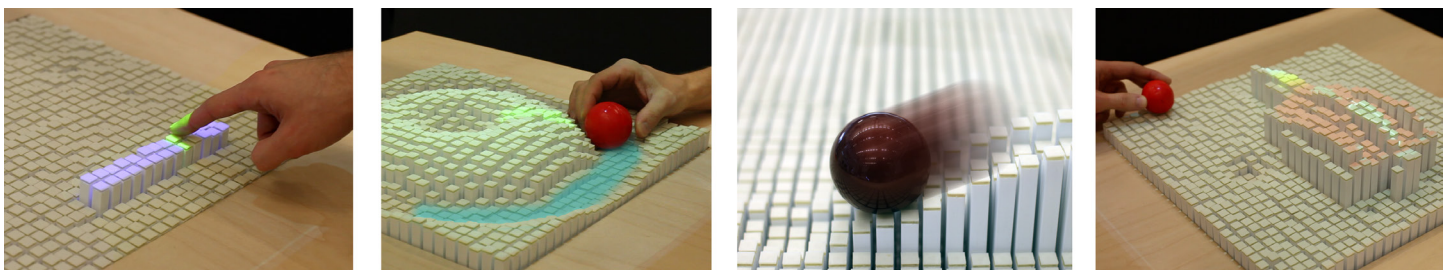
Sean Follmer Daniel Leithinger Alex Olwal Akimitsu Hogge Hiroshi Ishii
MIT Media Lab

Two MIT PhD students, Daniel Leithinger and Sean Follmer, introduced an eye-catching project from the MIT Media Lab: A table built with motors, linkages and pins, that can render a person physically in real time via a digital source. Some articles hailed the technology with potential to change the world and others were captivated by its strange, almost science fiction-type quality. The consensus was that this thing was really, really cool. But for a concept so complex, the initial idea came from a simple beginning.

The idea is inspired by those pinscreen toys where you press your hand on one end, and it shows on the other side. However, the 15-by-15-inch table, known as inFORM, is much more complicated than a toy.

The choice for the motors came down to function and how Leithinger and Follmer wanted the table to work. They knew they wanted inFORM to be an interactive and perceptive process, meaning they wanted users to physically shape the table as well. The duo decided on the kind of motors that power faders, which are commonly used on audio mixing boards and cost \$20 to \$30 each. These motors

Figure 30: inFORM enables new interaction techniques for shape-changing UIs. MIT, Media Lab



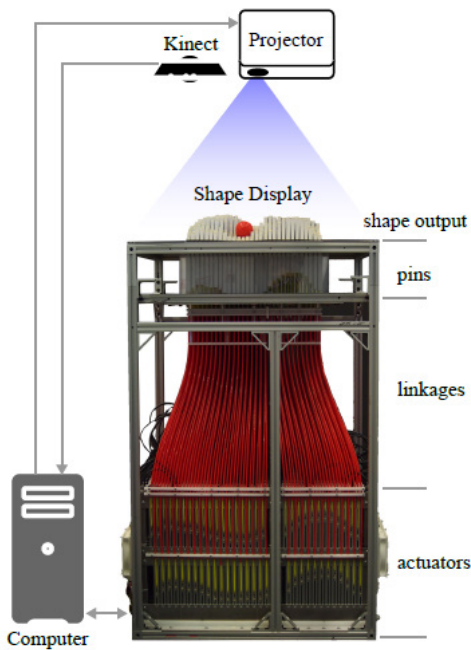


Figure 31: The inFORM system configuration

are pretty weak, though, so Leithinger and Follmer used linkages—long cables that reduce friction. Each motor is then controlled by a custom circuit board with a microcontroller, which is then connected to a computer.

By moving these pins up and down with computer control, user can form a shape, the shape can be a three-dimensional model you load from a computer, it can be a user interface, or it can be a shape of a remote person.

The most complex feat the inFORM can accomplish is the last one—rendering a person or object remotely. For this, the tangible media team decided to use a standard Xbox Kinect, a sensor typically used for motion-intensive gaming, to capture a person's movement. A mounted projector also displays color.

When setting out to create the inFORM display, Leithinger and Follmer—along with Hiroshi Ishii, professor and associate director of the MIT Media Laboratory—had a clear goal. “We really see this as a research platform where we can just quickly prototype things,” Instead of waiting a few minutes or hours for a 3D printer to create a design or using even slower traditional methods of prototyping, testing out different scenarios can happen instantaneously. Leithinger and Follmer also envisioned practical application in urban planning and CAD modeling, though currently in a lower resolution, where designers could physically manipulate their creations and changes would be reflected on their digital compositions.

But the prototype device could also be a boon for other industries and areas that the creators never intended.

The ZeroN : Levitated Interaction Element

Jinha Lee, Rehmi Post
MIT Media Lab

the limitation of 2.5 D shape display is the geometry can not be overhang, but another group of researchers at MIT have developed a prototype environment, named ZeroN, which can suspend a ball in mid-air and use it to navigate both a virtual and physical environment in a three dimensional space. Using active electromagnets, the environment can be programmed to manipulate the path of the ball or allow it be guided by hand. An intriguing feature is that ZeroN can “remember” and play back the movement of the ball, whether programmed or hand-guided, within the three-dimensional space.

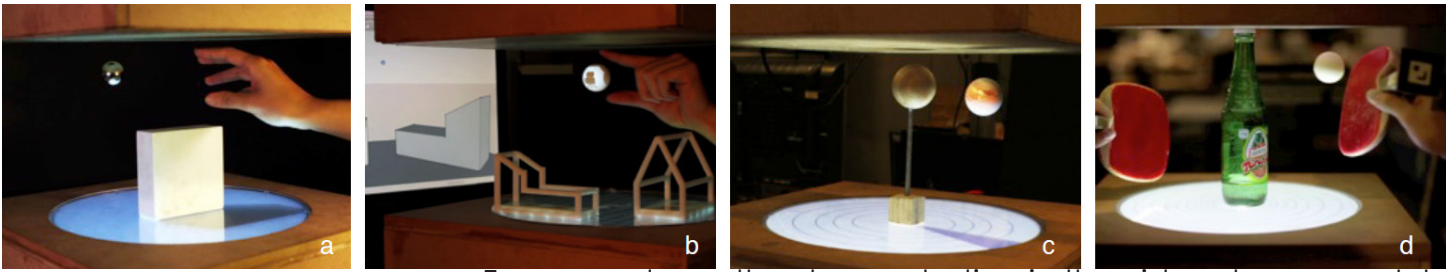


Figure 32: ZeroN enables such mid-air tangible interaction with computer controlled magnetic levitation. currently it can achieve architectural simulation, physics simulation, entertainment: tangible 3D pong-game.

For example, as the demonstration in the video shows, models of “planets” within the environment with programmed orbital rings, guide the ball as it revolves around the model. Adding a second model immediately changes the orbit of the ball, as it begins to revolve around two “planets.”

The simulator uses infrared stereo cameras, taken from conventional webcams. The cameras sense the position of the ball and objects within the three dimensional space and plots three dimensional models of the newly introduced objects in the environment. A second instrument for measurement called the Hall Effect Sensor.

The cameras can build a virtual model of physical objects position in the ZeroN, which can then allow users to navigate the virtual environment with respect to the ball. If you get creative, the ZeroN’s applicability can range from architectural, gaming or even medical purposes, like virtually navigating the chest cavity of a patient.

ZeroN however was built with the purpose of redefining what it means to interact with physical objects. “Our body and minds have developed great capacities for understand and manipulating physical environments. The long-term vision is to embed computation and physical materials that can directly interact with us. In this way, we seek to redefine the relationships humans have with materials, space and digital information,” Lee said.

The prototype is still a proof of concept and has its minor kinks to work out. When you watch the video, you’ll notice that the ball’s movement is undoubtedly unstable. The electromagnet, in conjunction with the Hall sensor, which constantly calculates how much repulsion or attraction is necessary to maintain the ball’s approximate position in the three dimensional space, may need to be programmed to for a gentler touch. But the video is evidence enough that Lee’s concept works. In fact Lee has begun to build the ZeroN’s second iteration. According to Fast Company, Lee is scaling the prototype to be capable of manipulating multiple objects within the ZeroN environment.

CHAPTER III

RESEARCH PROTOTYPE

My vision for future design activity relies on developing a brand new design media integrated with intuitive tools and augmented representations to enhance the design experience.

The study space of designer oriented transformable physical media remains partially unexplored. My goal is to establish an understanding of the space as well as develop a system prototype which could embody the vision I seek to explore. The invention of physical design media will potentially completely change the traditional workflow of designers and bring them brand new working experience.

Most of the final works of design such as architecture, furniture, and product are all physically three-dimensional geometry, it would be reasonable that the design process should happen in a fully 3d environment.

My early experimental project "3DPointer" was trying to design a low cost 3 three-dimensional input device to break away the limitation of 2D mouse input.

My second experimental research projects, "InSpire," which is an interactive 3D modeling system combining an optical see-through "holo-display" and natural user gestures which could be applied into design process, has been published by the Association for Computer Aided Design in Architecture 2014 International Conference.

With my limited experience of shape changing study, I have started my third thesis project "CUBE" . "CUBE" is a designer oriented physical media device combining natural gesture manipulation and tangible representation together to achieve my vision of Physical Design Media. It allows a designer operating with a transformable object to explore design. The transformable cube communicates in real-time with a digital interface so that additional, related information and data can be displayed on it. The project is expected to be applied in the massing study of early design phase.

3.1 3D Point

Computer Aided Design tools are fundamentally realized through WIMP interface which currently are mainly depending on 2D input and out devices. The design workflow as a paper based process has been limited within 2D space, yet all of the final products of design is physically 3D objects. During the Renaissance, in order to abstract the material world, artist Albrecht Durer invented the perspective machine which could help to convert 3D physical object into 2D shape. After that, the 2D representation drawings became a main approach of communicating within designer teams. In the meantime, people started utilizing scale drawings which were produced by pens and rulers and models as instruments for describing design project and for enhancing the communication within design teams. The utilizing of these traditional design tools provided more conveniences and allowed more design individuals participate in the design process. Thus, designers could accomplish more intricate design. The design method combining prospective drawings, scale drawings and models has been existed for few hundred years. Even for now a days, there are still quite a number of architects are still relying solely on these practices.

The paper based 2d input approach has been converted into digital after WWII, MIT's Lincoln Laboratory developed SAGE (Semi-Automatic Ground Environment) system in 1950s, which is a nation-wide complex of digital computer linked to radar and anti-aircraft weapons. The project led to the development of some other technologies including wireframe graphics and related computer aided design research prototypes. Sketchpad, developed by Ivan Sutherland, as one of those technologies which was running at TX-2, a computer of Lincoln Laboratory, had been considered as a most important pioneer of modern computer aided design system. It is a revolutionary approach of the interaction between human and computer graphics. Sketchpad is utilizing a set of buttons, switches, knobs, and a light pen to directly draw some simple symbols on a display. Sketchpad is the first program allow user to create and copy primitive shapes as well as stretch or reposition shapes while operating the objects.

The tradition of 2d input has been firmly tagged in designer's mind. But most of them hasn't realized that the 2d input manipulation is not direct enough. Designers are using all kinds of 2d graphic buttons, sliders, commands and clicking to operate digital information, but based on my previous research, the thinking pattern of architectural designer is more rely on the graphics, intuitions and relations. For designers, the current WIMP interface and manipulation is apparent-

ly lacking of direct relation with the operating intent. The mouse clicking, dragging and keyboard typing is quite hard to blooming designers imagination and inspire their idea. The 2d based manipulation is obviously not suit for designers.

I am seeking a design-oriented manipulation concept which can avoid indirect input manipulation and provide more direct relations to user so that user wouldn't be confused by the complex interface and different commands. The direct manipulation concepts can be illustrated by driving a car by manipulating the steering wheel and pedals. The car responds immediately to drivers actions, and these responses are immediately evident. If the driver is making a mistake such as turning too sharply, the driver can quickly recognize this and perform a corrective measure. Turning steering wheel to change the direction and stepping on gas to speed up has obvious direct relation. But when a passenger sit in the backseat of the car giving a stranger directions. The indirect manipulation will lost the feel for the road and the passenger doesn't have a direct view of where he is going.

The same situation has been happening with designers for decades. People are always using the indirect manipulation input to approach the design intent. The limitation is from both hardware and software. For the hardware side, the keyboard is utilizing typing to input command, but what's architectural designers doing is communicating with object to develop the design idea but not giving command to control the object. What's designer need is a spatial platform to operate object wherein designers could have a multiple dimension reference. The mouse is seems to be a spatial platform due to its x and y operating space, but it just have two dimension. Using two dimension manipulation to operating 3d space is still missing the depth. For the software side, the WIMP interface is a combination of windows, icon, menus, and pointing. Each of these items is representing a command or a purpose. Sometimes calling one of the icons user will have to find another one. To use the WIMP interface, designers have to pay extra attention on software learning. Especially, as I said in the previous context, some of the interface is not friendly enough for designer to learn and use.

In this case, I try to develop a set of input manipulation which contains spatial hands gesture manipulation and clear commands. The manipulation will not take too much time on learning process, desinger could master it real quick.

3.1.1 Engineering 3D Pointer.



Figure 33: the system implement of 3D Pointer

The current 3d pointer physical configuration is a combination of a pair of customized glove with IR LED, 2 hacked IR webcams and a CPU. The customized glove is refitted from the regular glove. I mounted 3 IR LEDs on the three fingertips. A pair of touch switch is installed on ring finger and palm, so that when user close palm and make a fist, the touch switch will touch with each other and activate three IR LEDs. The IR webcam were hacked from two regular cameras by removing the IR-blocking filter and covering a new Optolite IR-filter sheet. Mounting two IR webcams at to up corners of laptop will improve the accuracy of IR LED capturing.



Figure 34: customized glove with fingertip IR LED

The IR webcam only capture the IR LEDs mounted on glove. It is actually accounting the number of IR fingertips and calculate the spatial position of the IR led, at least two IR LEDs will need to be visible at the same time. So the system can calculate the depth of hand position based on the distance of each two visible IR LEDs. The different number of fingertips represent different design-orient commands. User will only need to put down fingers to make it invisible to the IR camera and switch to another command.

The webcams I am using is Logitech HD Webcam C310 which can film video calling in 16:9 with 84 degree lens angle. It means the visible area for the camera is spatially a horizontal pyramid. When users hand is getting

close to the webcam, the visible area is getting smaller. In order to maximize area and get rid of distortion, I utilized two webcams. And apply the average value from both two cameras into spatial position calculation.



Figure 35: Logitech HD Webcam C310

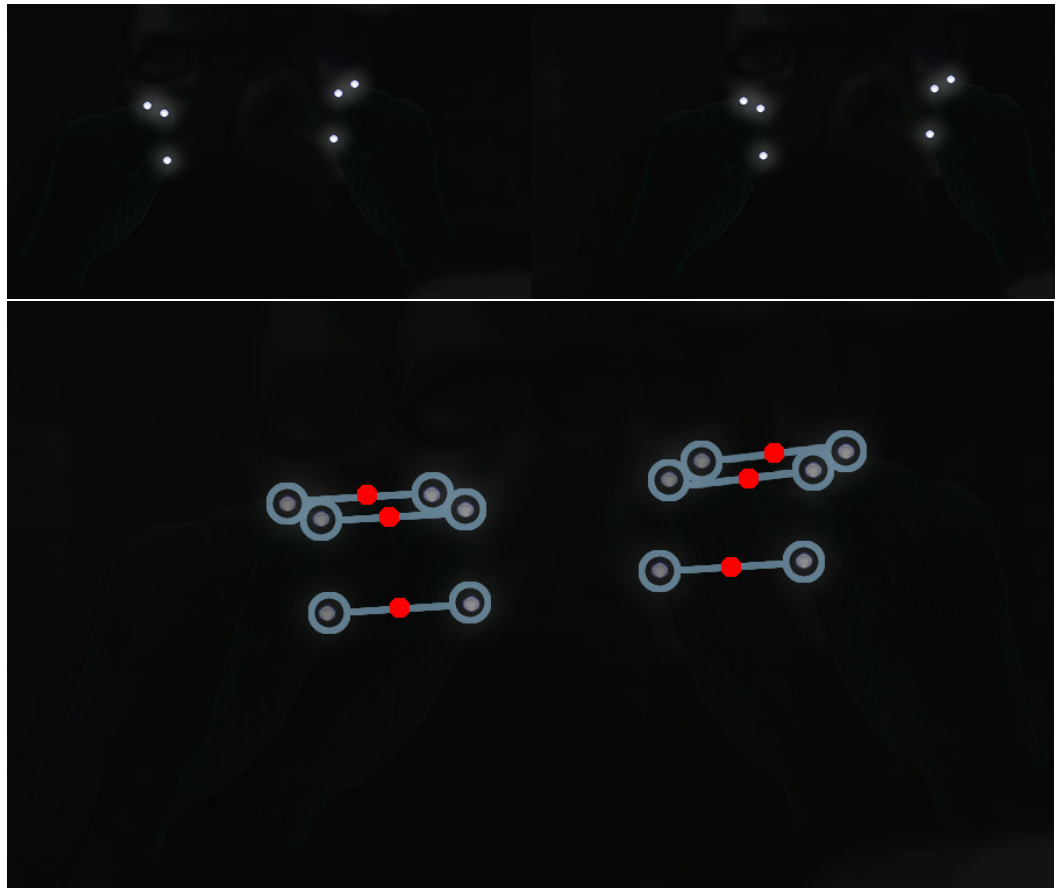


Figure 36: merging camera view angle

Gesture Recognition and Application

The IR webcams are mainly capturing 2 elements, the number of visible fingertips LEDs, and the spatial position of users' hands. Different number of visible fingertips represents different manipulation com-

mands. For instance, if IR webcam can't capture any fingertip LEDs, no command will be executed. When IR webcam sense two visible fingertip LEDs, the system will executed drawing command. The distance between two visible LEDs will provide system as a reference to calculate the depth.

Figure 37: two fingertip LEDs recognition



If the IR webcam sensed three visible fingertip LEDs, and the three LEDs can form a circumscribed circle besides its area is smaller than a specific value (means the three visible fingertips LEDs are belong to the same hand), the system will consider the gesture as spatial axis orient tools. So user could use a hand to adjust the digital camera of modeling environment.



Figure 38: multiple hands gesture recognition

If the IR webcam sensed four visible fingertip LEDs, once the distant between each two LEDs is less than 5 inches (usually the maximum distance between thumb tip and forefinger tip is less than 5 inches), system will consider those visible fingertip LEDs belong to both of users hands. So that the move

and rotate command. If system senses one single fingertip LED plus a group of three visible fingertip LEDs, the system will remain at camera orient control command.

If the IR webcam sensed five visible fingertip LEDs, the system will automatically consider the two of fingertip LEDs which are close to each other as one hand, and other three fingertip LEDs as another hand. So that user can use two hands gesture to navigate the digital camera at the meantime to draw some 3d geometry directly.

If the IR webcam sensed six visible fingertip LEDs, the system will consider user is using both hand, a “grab” command will be activated. User could freely use both hand to pick up digital object and move it to different location.



Figure 39: multiple hands gesture recognition

3.2 InSpire

Increasingly, during schematic architectural design, digital modeling plays an important role in the design process. With the rapid improvement in computer graphic technology, 3D systems have multiplied, but most of them depend heavily on Window-Icon-Menu-Pointer (WIMP) interfaces, using 2D design symbols to represent 3D design objects and operations. The content of the design, as well as the interaction between the designer and their design tools (mouse and monitor)—all the fundamental elements of design activity—are based on two-dimensional representations. Some designers find these workflows, which derive from paper-based practice, to be awkward, fundamentally contrary to the 3D nature of architectural design.

Design requires the designer to create objects through integration of the mind, the hand and the eye (Lobel 2009). Architectural designing includes the activities observing, thinking, and making. An unexpected mistake of hand may create a new opportunity for the eye to observe things differently, and cause the mind to find a new design possibility. A useful design aid should improve the association between the designer's hand, eye, and mind, so that the intra-process communication would be enhanced (Kalay 2004). In contrast, within most digital modeling methods, the function of hands has been weakened, replaced by the more indirect actions of mouse and keyboard use. We believe that the limited use of the hands reduces the excitation of eyes, and may inhibit an architects' spatial cognition. Research comparing textual fluency and keyboard vs. manual writing indirectly supports this (Richards et al. 2009). Therefore, while many great designs have been accomplished using 2D input, we seek to support a modeling process using direct gestural manipulation.

InSpire combines an optical see-through display and gesture input, enabling users to directly interact with the system using spatial gestures in the same visual volume as the displayed geometry. The actions of input are three dimensional and output display is virtually three-dimensional.

3.2.1 Engineering InSpire

The current physical configuration for InSpire is shown in Figure 40. It is a single user installation consisting of a CPU (not shown), a mini projector (A), a rear projection surface (B), an RGB webcam (C), an adjustable semi-reflective plastic surface (D), a Leap Motion sensor (E) and a tablet (F). The virtual geometry is displayed on the semi-re-

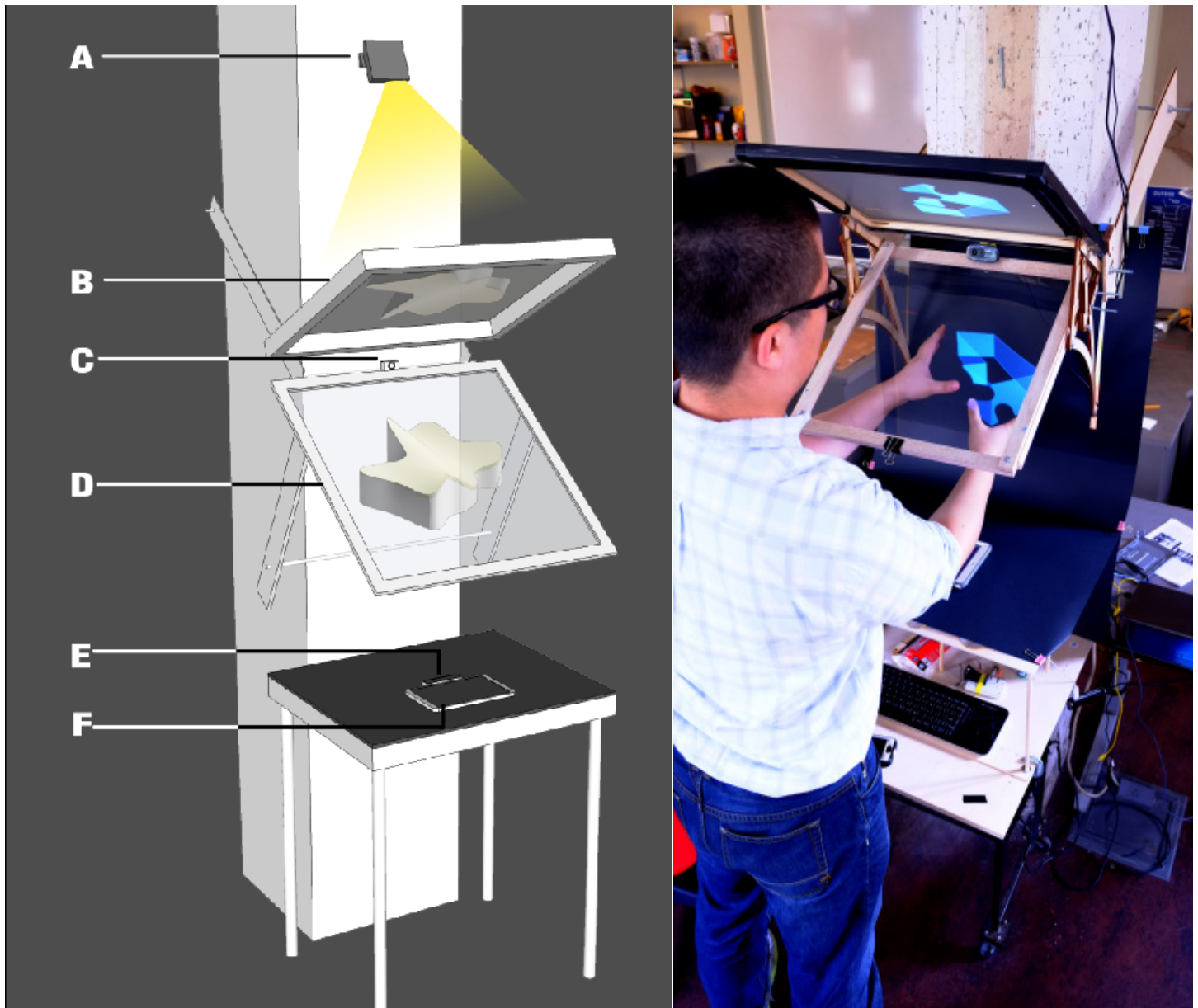


Figure 40: The physical configuration of InSpiRe

surface, which acts as a see-through holographic screen. The size of the display screen and the volume below it roughly match the sensing range of the Leap Motion sensor. This configuration allows a single user to put their hands below the display screen without obscuring content, allowing their hands to directly (if virtually) “touch” the 3D model. The Leap Motion sensor placed on the bottom surface tracks the hand. The tablet placed next to the Leap Motion provides a control panel to switch between different functions. The semi-reflective surface reflects only the light parts of the projected 2D image; dark areas allow the user to see through to the space below the surface.

During project development we found that although the mirrored image on the display provided users some sense of depth, the absence of motion-parallax was a problem. In the physical world, when a viewer is observing an object, what they see changes with head

position. In order to achieve this effect, we added an RGB webcam and head-mounted LEDs to provide head-tracking. Visually, the user interacts with the mirrored shape in the display. The RGB webcam tracks the user's head position and automatically updates the view-point used to produce the model display. Since the RGB webcam is a 2D input device, head tracking requires a tracking target with extent, which we provided using two LEDs mounted at the hinges of a pair of glasses (Figure 41). Based on the angular separation between the two LEDs, the system calculates the distance to the head and



Figure 41: reviewing the same geometry from different angle via head mounted IR LED on my glasses.

generates 3D position data.

The tablet (Figure 42) in the system has two purposes. The Leap Motion is based on structured light in the IR spectrum, captured by two built in monochrome infra-red cameras. During testing, we found that sometimes it did not seem sensitive enough to capture hands in

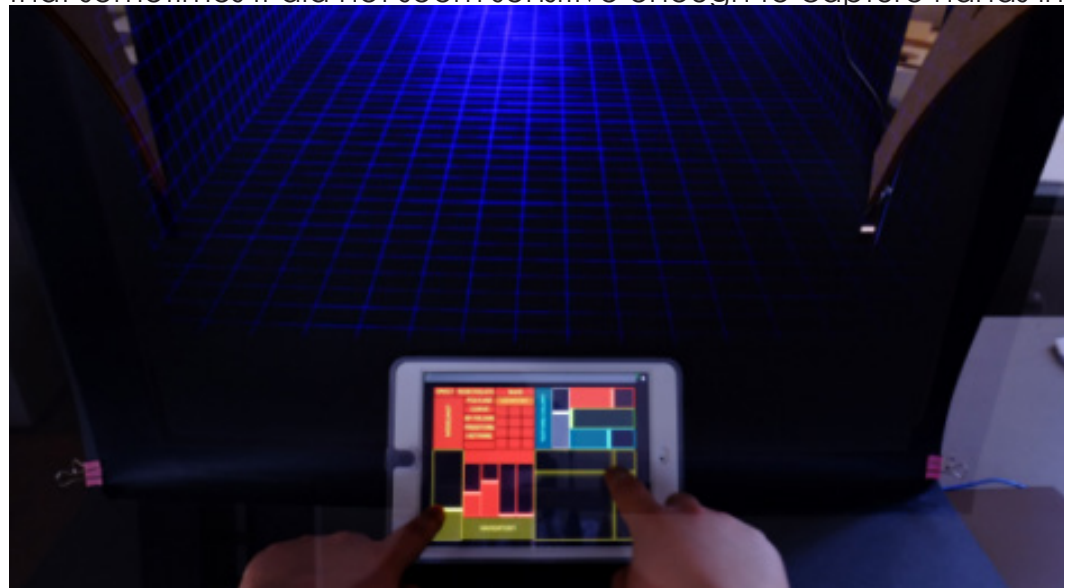


Figure 42: A tablet for switching between command and providing extra light.

dark conditions, but the extra light provided by the tablet has proven helpful. In addition, the tablet acts as a control panel for the system. Hand gestures are used to perform geometry manipulation—creating, scaling and rotating geometric elements—while more abstract operations with the object, such as file save, object delete and setting textures, which lack natural gesture mappings, are conveniently carried out on the embedded tablet. The tablet sends Open Sound Control (OSC) messages to the CPU via a Wi-Fi connection.

The InSpire system prototype is mainly built on top of Rhinoceros 3D and its parametric plug-in, Grasshopper. In order to support all the application and tentative ideas mentioned above, some other platforms and software are also used.

Input

As described above, the Leap Motion sensor captures the position, trajectory, and speed of fingertips and palm, producing a compact “hand” data structure. We transfer Leap Motion data into Grasshopper by using user datagram protocol (UDP) and then use a python script component in Grasshopper to extract the coordinates of the hand. Within Grasshopper, manipulation command gestures were defined based on the number of fingers and palm, the speed of fingertips, and the vectors. For the head tracking feature, images are acquired from the RGB camera. After lowering the gamma value of the video frames, the LEDs are easily seen. Based on the 2D positions (as XY values) and the distance between the LEDs (as Z value) we compute a 3D head position, which is used to control Rhino's scene rendering. Grasshopper also receives commands from the tablet via Open Sound Control (OSC) messages, filtering the information through different definitions to activate modeling commands.

Gesture Recognition

The inSpire system uses two types of gesture, as mentioned above: modeling mode gestures and trigger mode gestures. The modeling



Figure 43: Modeling mode gesture:(From left to right) push, click, drag, select and move & rotate

mode gestures are mainly used to support direct manipulation of geometry in the modeling applications – including continuous drawing, scaling, rotating, and selecting. Compared with the trigger mode gestures, the modeling mode gestures are more natural; users just need to open or close thumbs and palms. Trigger mode gestures are used in the navigation application. Swiping two fingers defines a vector which the system applies as an adjustment to the camera view-vector.

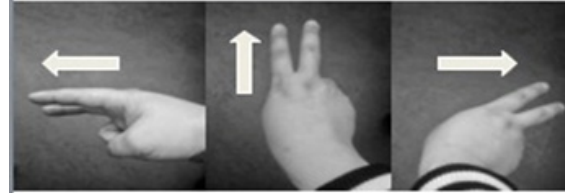


Figure 44: Trigger mode gesture

All the gestures are pre-set in the Grasshopper definition, based on features such as the number of fingers & palms and the movement of fingertips. Once a gesture's feature gets confirmed, a command is activated to manipulate the geometry. Using Grasshopper definition is possible to create NURBS surfaces and 3d volumes. When a model is complete, the user can use the tablet for saving files, setting layers or deleting objects.

Display Occlusion Adjustments

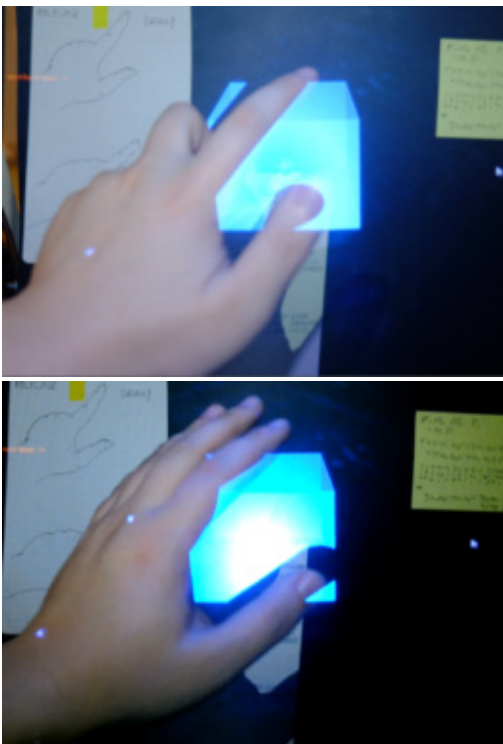


Figure 45: Occlusion display

Although the shape seen on the screen is a 3D projection, when the user places their hand below the screen their sense of space may still be confused if they see the geometry displayed on top of their hand even when the geometry is located farther from the user's eye than the hand. In the real world parts of user's hand should block, or occlude, the geometry of the model, depending on the distance of hand and geometry from user's eyes. We address this issue in the way we render the hands. The Leap Motion performs onboard image analysis and joint detection, so the data stream does not include a point cloud or depth mesh, but does report fingertip positions and the palm's center. Using the hand data, InSpire generates a 3D hand shape in the model and applies a flat black texture to it. When any part of the hand is in front of the holo-geometry, the rendered geometry will be partly or completely blocked by the hand's black shape. However, because the user sees through this part of the display (black is the background color and not reflected) they see their own hand in correct relation to the 3D model, enhancing their sense of immersion (Figure 45).

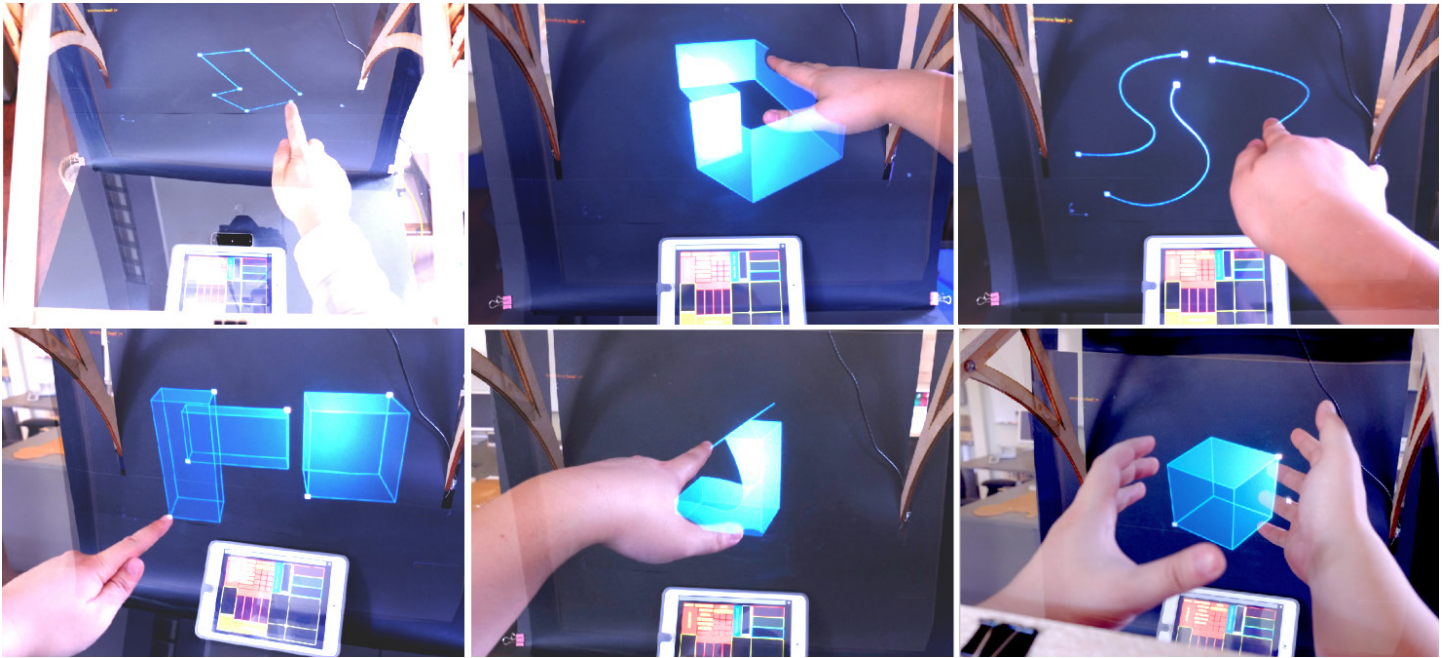


Figure 46: Gesture modeling applications

3.2.2 Application

We have used the InSpire system to develop support for two designer-oriented applications and several interaction possibilities. The most mature and important application so far is the modeling function. The function leads to interesting natural modeling possibilities. A designer could build a 3D model with hand gestures just like sculptor and observe it from many different angles. Currently InSpire recognizes modeling mode gestures for drawing lines, polylines, and curves, as well as creating single or multiple simple and complex surfaces and 3D volumes. After the geometry is created, users can edit an existing object via “hot wire” cutting gestures and control-point “tweaks” to further develop the freeform geometry, as well as moving, scaling and rotating objects. As an architectural design tool, InSpire also allows users to set the geometry of different architectural elements on different layers.

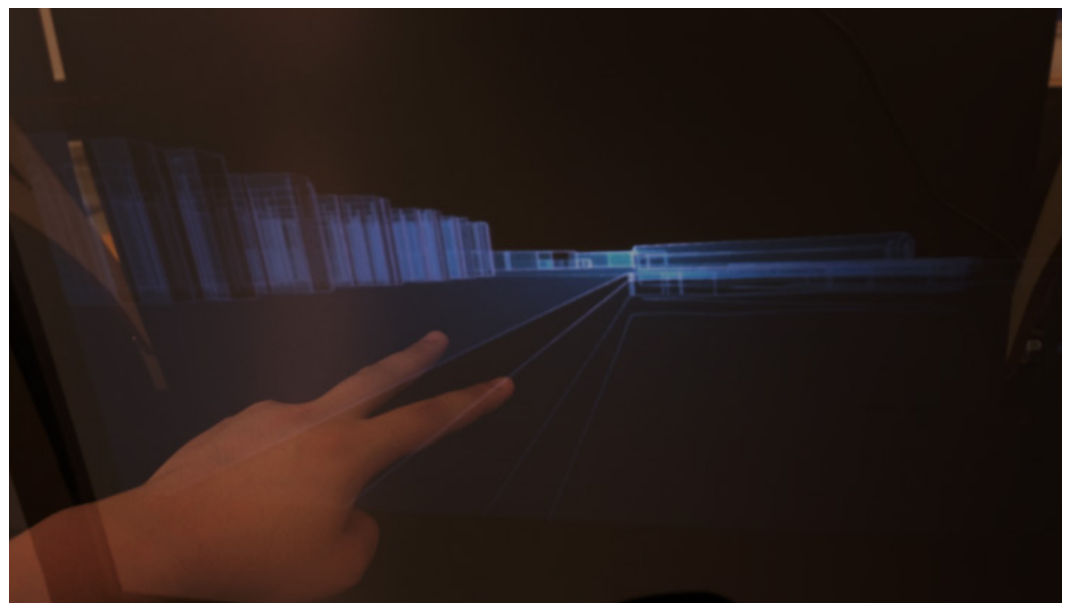


Figure 47: Navigation Function

The InSpire system can also be utilized to navigate a model. Users can control the camera, flying or walking through the entire project. For displaying an architecture project, the model view, which is generated by InSpire, could be shared on a large display, giving a larger audience access to the project. The navigation mode utilizes a different set of gestures from the modeling mode, and is called trigger mode. It can be used to view both the outside and the inside of a model, an improvement over the traditional physical model. The Figure below shows a user manipulating a camera flying through an urban model and focusing on a specific object.

3.2.3 Discussions

The InSpire system is an initial prototype, with a number of issues and limitations. Some of these arise out of the hardware configuration we have chosen, while others are more fundamental.

The fundamental difficulty is that architects must provide small-scale size and position control of large objects. Although the 3D “holo-interface” enables manipulations with one more dimension than available with a mouse, vision-based positioning is approximate. In the traditional CAD system, object snap features are available to make the modeling job more accurate. Without object snaps InSpire remains useful in massing studies which occur at a very early phase in the entire design process, but is less helpful when working with complex models or detailed geometry. Related to this issue, the interface enables one to directly manipulate the model geometry, but under the current scenarios it is difficult to measure the depth dimension accurately. Features such as head tracking and hand-model occlusion partially solve the problem, but another strategy, such as adding a projected outline of hands to both of side and bottom in the display, or voice-activated positioning constraints, might further enhance the experience.

Another fundamental problem is the lack of tactile feedback. In the physical world, when people are manipulating an object, there are at least two senses that help them to feel in control of the object—visual and haptic. The InSpire system is now focusing on the visual interaction. With further development, the holo-geometry could be perceived not only visually but also tactilely. A touch sense could help to enhance the participation of hands. A potential strategy could be wearing tactile feedback gloves.

Finally, we note that while architectural design is frequently collabo-

rative in nature, the current system is built for a single user. Duplicate workstations might share a model (see Hilliges 2012) allowing multiple modeling participants, but true collaboration requires a shared space of discussion as well as a shared model (Belcher and Johnson 2008), which will be difficult to achieve with the current approach.

3.3 CUBE

So far I've achieved the 3D manipulation and augmented representation through previous research prototypes. Combining input and output in the same 3d volume seems to be a solution of producing direct and intuitive design media. But during my research development, I found that the gesture input of 3D pointer and InSpire is artificially pre-set. Once an individual has some different culture background or hobbies. The pre-set gesture command will not be functionally direct and intuitive any more. It makes me start thinking that what if the gesture commands could be purely human's natural behaviors, what if the gestures could be customized by users.

In the physical world when people are manipulating a physical geometry, nobody will think about which gesture I should use to interact with the television. All the gesture come out spontaneously based on current condition. In the physical world, a physical object will provide people haptic reference but not only visual experience. For instance, when you need to open a bottle of wine, observing is obviously not a wise choice to do so, but you will have to touch the cork and hold to pull it up. Haptic feedback can allow user to judge how much force to be used to open the bottle.

As I discussed in the previous content, tangible user interface could be a possibility. Designers could directly work on a physical object to improve their design with more direct and intuitive interaction. Using a physical object to represent building geometry let designers better experience their design object and feel the proportion of the building shapes. For achieving the concept, I developed CUBE, which is tangible objects based massing study tool kits.

3.3.1 Engineering CUBE

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background or hobbies. The pre-set gesture command will not be functionally direct and intuitive any more. It makes me start thinking that what if the gesture commands could be purely human's natural behaviors, what if the gestures could be customized by users. In the physical world when people are manipulating a physical geometry, nobody will think about which gesture I should use to interact with the television. All the gesture come out spontaneously based on current condition. In the physical world, a physical object will provide people haptic reference but not only visual experience. For instance, when you need to open a bottle of wine, observing is obviously not a wise choice to do so, but you will have to touch the cork and hold to pull it up. Haptic feedback can allow user to judge how much force to be used to open the bottle.

As I discussed in the previous content, tangible user interface could be a possibility. Designers could directly work on a physical object to improve their design with more direct and intuitive interaction. Using a physical object to represent building geometry let designers better experience their design object and feel the proportion of the building shapes. For achieving the concept, I developed CUBE, which is tangible objects based massing study tool kits.

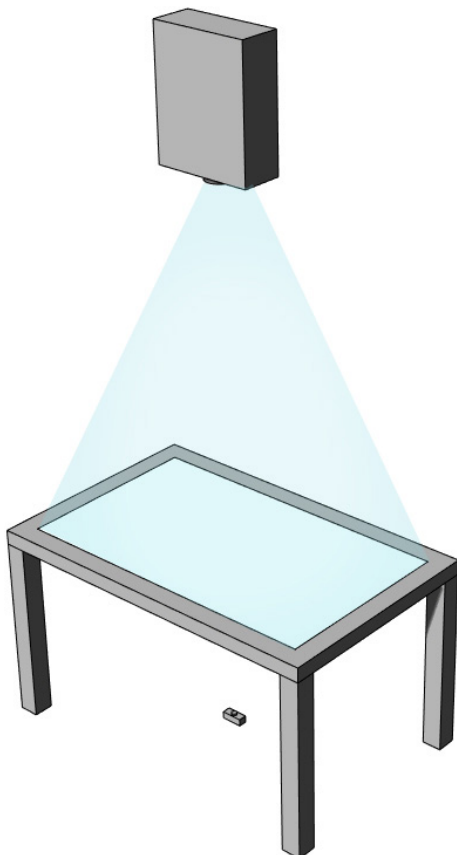


Figure 48: CUBE system configuration

3.3.1 Engineering CUBE

The general environment of CUBE contains a projector, an interactive desktop, and several sets of tangible objects based massing study tool kits. The interactive desktop is an ordinary desk covered by rare projection film. It needs to be associated with the projector on the top, and a regular web-cam from button. For the software, it mainly depends on Processing UDP, reactIVision and grasshopper. ReactIVision senses the QR marker and transfer to processing then send the data though UDP to grasshopper.

Currently, I've developed three sets of tangible objects based massing study tool kits.

The first set is static geometry containing a cube, a key-stone, and a tapered. Each of the geometry represent a single building object. At the button of each geometry has a QR marker which can be captured by regular webcam, system also tracks the location and orient. I did several experiments and found that the regular lighting condition is not suite for the webcam to capture the QR marker. So I insert a 4 RGB LEDs at four corners behind the marker, when the 4 RGB LEDs are activated, webcam will

Figure 49: QR marker used in CUBE



clearly capture the QR marker. For the cube, keystone, and, tapered, each of these geometry has a specific QR marker matching with. When user places any of these geometry above the desktop, the system will be activated. User could move or rotate the static geometries to do the massing study and evaluate what would be the best location and orientation of building.

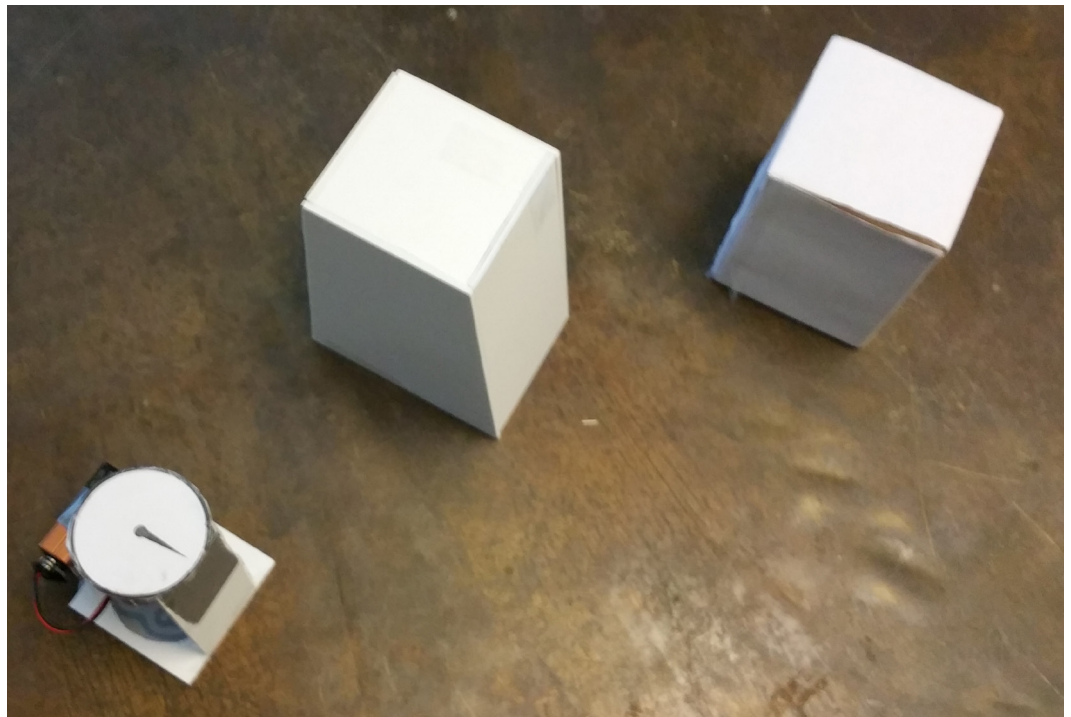


Figure 50: static geometry, cube, keystone, and, tapered

Using static geometry representing building geometry might be sufficient for simply changing the location and orientation. But when massing study start getting involved form finding, the static geometry is not a satisfied option. Beyond the static geometry, I develop the second set which is the transformable twisting block. For each transformable twisting block there is one potentiometer and one slide potentiometer inside the object. The regular potentiometer is mainly recording the rotating angle and the slide potentiometer is mainly recording the vertical height changing. Both of these potentiometers send real-time data into computer, thus the system could apply the data to generate a matched digital model automatically. The button of transformable twisting block is also covered by the QR



Figure 51: transformable twisting block

marker, so the location and orientation information is also trackable.

The transformable twisting block is capable of affording more design tasks, such as evaluating the high raise building shadow situation or curtain wall reflection simulation. But the twisting block just have two dimension to be transformed, the rotating angle and the height. What designers need is more flexibility and less limitation. and all these transformation data need to be send to computer and generate the matched digital model. based on my vision of transformable design

media, I developed the third version of the tangible objects based massing study tool kits.

The third version of CUBE is made up of 10 transformable edges (two of them is diagonal) and 4 fixed edges. Each of the transformable edge is installed a slide potentiometer which connect to a central micro controller. A QR marker is also necessary for the tracking the location and orientation. Designer consider the CUBE as representation of a single room or a building geometry. He or she will just need to lengthen or shorten the transformable edges to change the shape, proportion, and scale of the cube. Once the central micro controller receive these resistance data, computer will convert them into length, and utilizing trigonometric function to reconstruct the shape of CUBE, all these transformation are remapping into a matched digital model with same geometric properties. The 3-dimensional physical CUBE provide direct manipulation and tangible representation of architecture geometry.

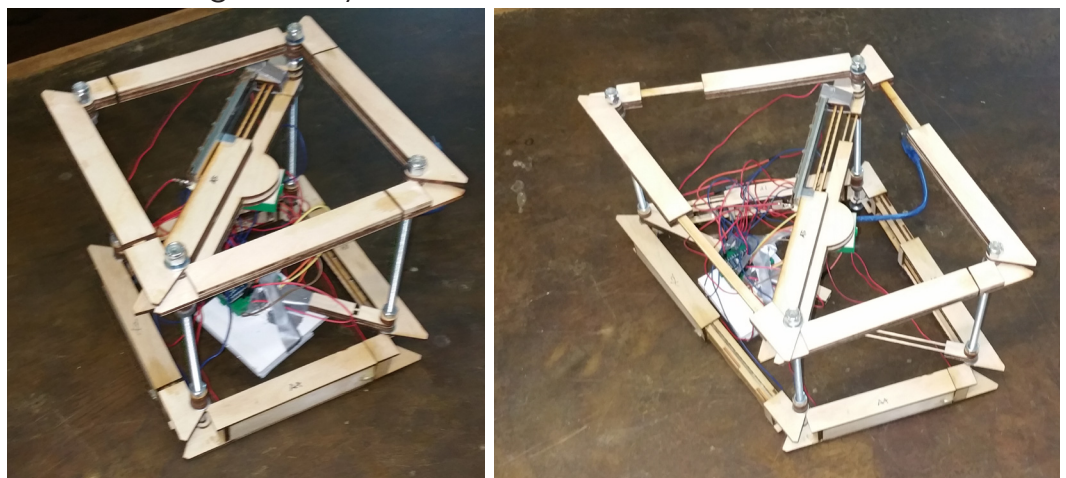


Figure 51: CUBE,

3.3.2 Applications

Currently, CUBE can achieve 4 main functions:

Building Information Storage

Since CUBE is an abstract physical representation, when doing massing study, designers need to pay attention on architectural properties of the 3d volume such as area, height, number of stories. The feather allows designer to pre-storage those data and information into the static geometry. When designer is manipulating the geometry, these architectural properties will be automatically projected on the interactive desktop. So designer would have an intuitive impression about the building. Even designer moved the geometry, the property information will stick with the static geometry.

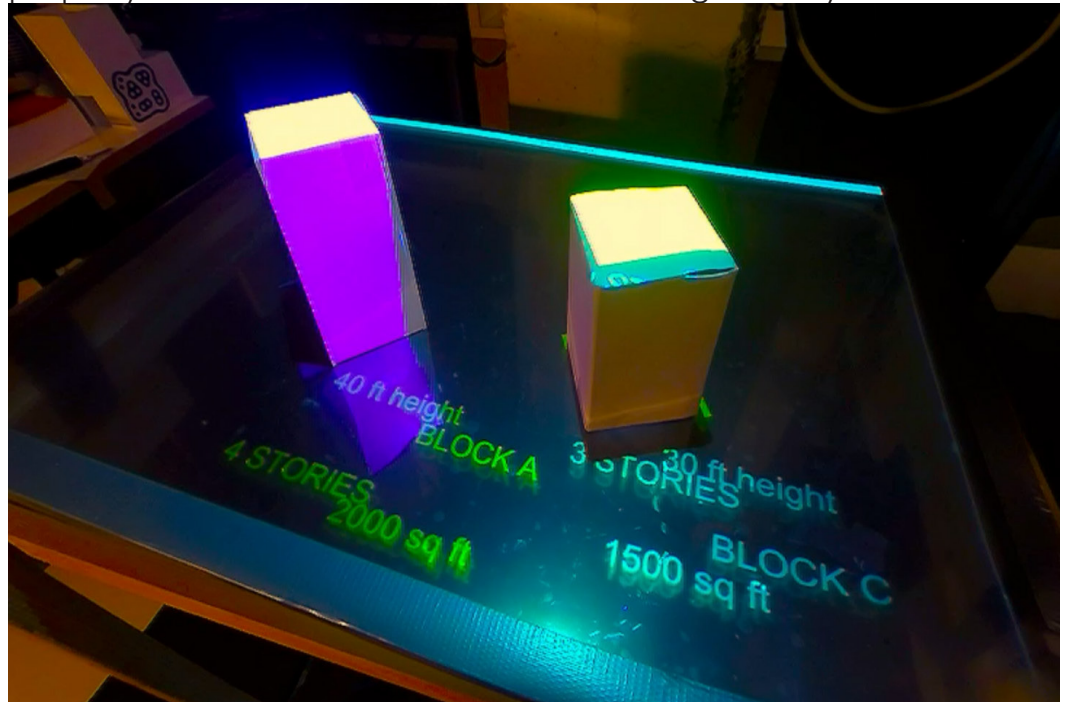


Figure 52: Building Information Storage

*Shadow Analysis.

Shadow analysis is another achievement. The system will generate digital shadow based on the location of the building and the position of sun. The simulated shadow is also dynamic. User can set one of the static geometries as shadow input parameter. Manipulation the input geometry could dynamically simulate the whole day shadow situation.

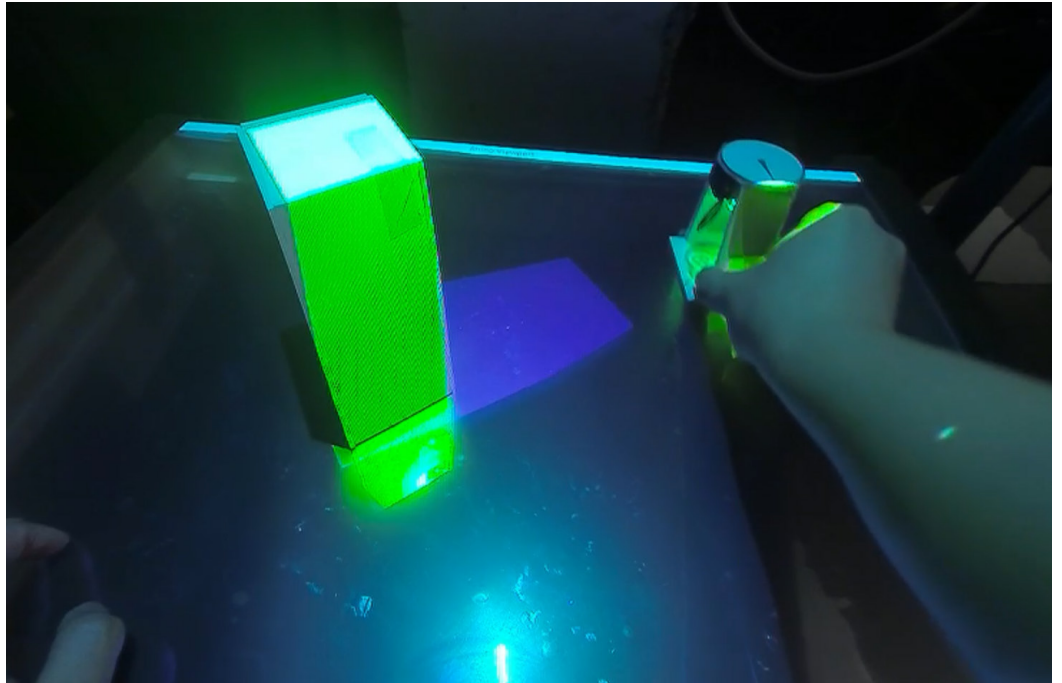


Figure 53: static geometry shadow analysis

Using transformable twisting block, designer could evaluate the shadow impact from the shape changing. The system would sense the motion of twisting block and automatically updated the shadow in the real time.

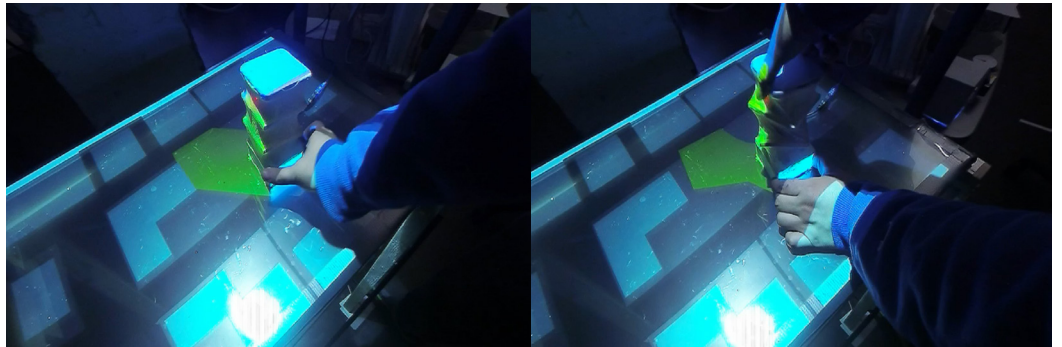


Figure 54: transformable twisting block shadow analysis

Wind Analysis,

The function allow user to evaluate the impact of wind to the building surrounding area. Once designer move or rotate the geometry within the interactive desktop. The wind vector will be automatically updated, and generate visual pattern for designer's judgement.

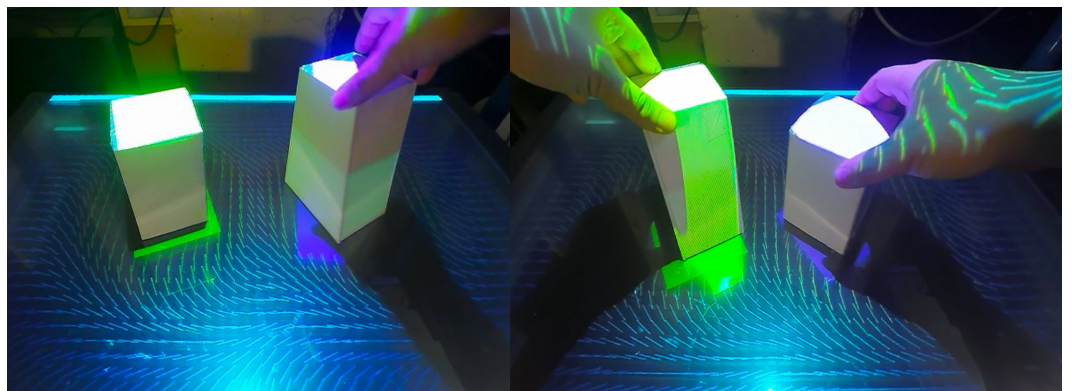


Figure 55: Wind Analysis of CUBE

$$c^2 = a^2 + b^2 - 2ab \cos C$$

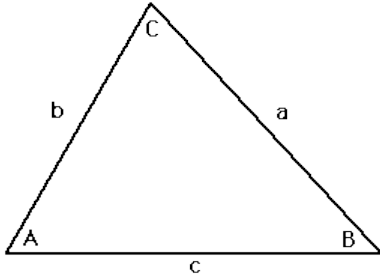


Figure 56: cosine theorem

***Digital Model Reconstruction**

The value provided by potentiometers can be remapped into length. When users are manipulating CUBE, motions will be recorded by computer. By utilizing trigonometric function, a digital model is capable of being reconstructed in computer. It is not necessary for user to accomplish the modeling task through manipulating mouse and keyboard.

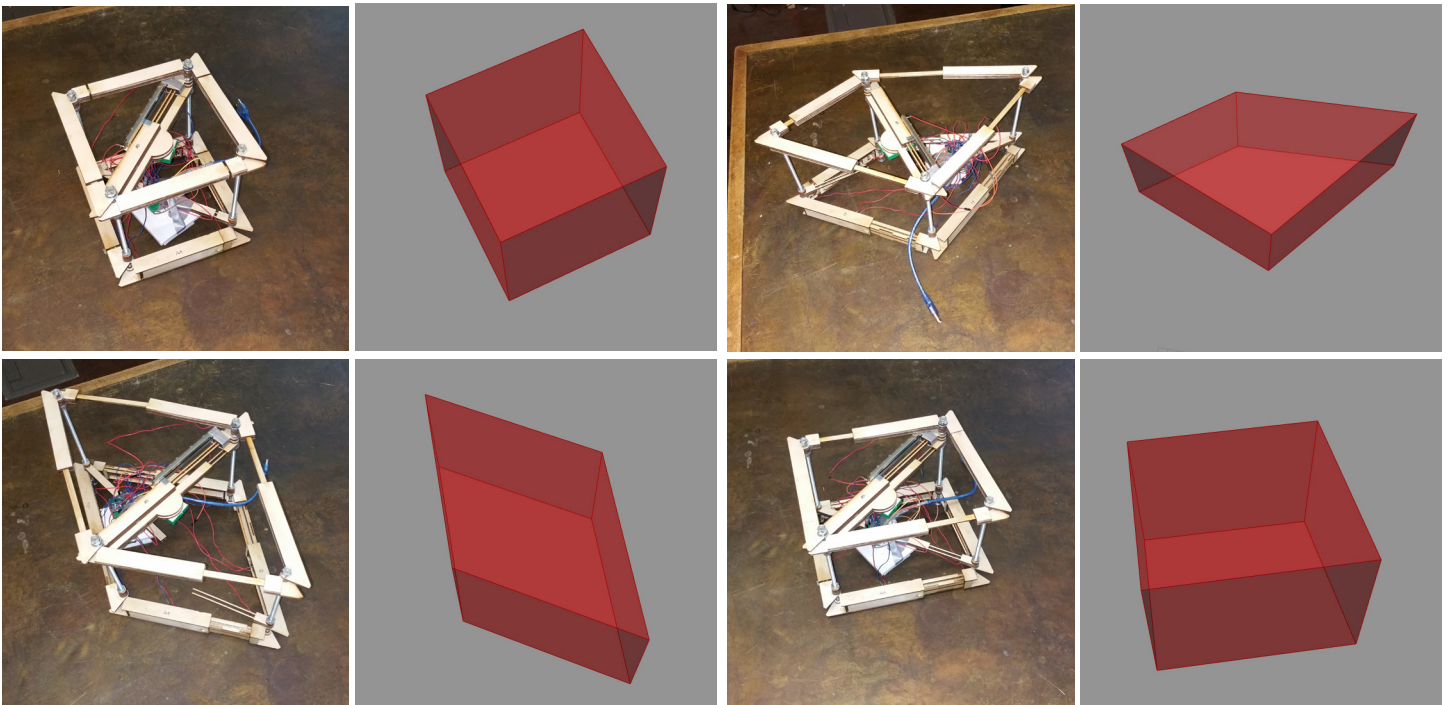


Figure 57: comparison of transformable physical model and reconstructed digital model

SUMMARY AND FUTURE WORK

In my thesis document I have introduced 3 interactive 3D architectural design system prototypes called 3d pointer, InSpire, and Cube. These prototypes allow users to directly interact with virtual or physical 3D objects using nature or pre-set hands gestures. I described the system implementations, focusing on the workflow for developing gesture interactions (visualization and gesture recognition). We illustrated several interactions that these three prototype support, and described application scenarios and possibility.

I summarize my thesis's contribution as follows: Developing several system allowing for 3D geometry being created and manipulated through interactions based on user gestures, while leveraging the affordances of enhancing the visual experience or providing haptic reference and good hand gesture to approach appropriate fully 3d working environment. This research highlights that it is possible and helpful for designers working in a total 3d environment.

The study space of designer oriented physical media remains partially unexplored. My thesis is attempting to establish an understanding of the space as well as develop several system prototypes which could embody the vision I seek to explore.

The invention of physical design media will potentially completely change the traditional workflow of designers and bring them brand new working experience.

The research I've conducted thus far makes me realize that the study of physical design media will not be wholly accomplished, understood, and delivered within the domain of design study, or the domain of Human-Computer interaction research. Instead, the work I propose resides in the connection between multiple areas - an interdisciplinary environment which is necessary condition to support.

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