LANGUAGE FOR TOUCH: AESTHETICS, EXPERIENCE AND TECHNOLOGIES FOR NEXT GENERATION TOUCH INTERFACES

by

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ABSTRACT

Explorations into the aesthetic, experiential, and emotional qualities of human-computer-interaction (HCI) has provided important and valuable insights for designing future interactive systems. However, one challenge that still persists is a method for designers to effectively communicate and contextualize their tacit knowledge and design process when exploring issues of experience and aesthetics. In response, this thesis a reflexive process that cycles through the *making* of an interface and then *reflecting* on the theory and concepts which affected its design. This process was used during design of three case-studies which explore different qualities of touch and tactile interactions. Analyzing the design process of each case-study reveals four recurring conceptual strands, that are stitched together to construct a cohesive framework for analyzing and understanding the aesthetic and embodied experience of tactile systems: *1.) InterSensory Mapping, 2.)Semantics, 3.)Technology,* and *4.) Materiality*.

Each theoretical strand is exemplified by analyzing the design process of the three-case studies. This analysis shows the practicality of the framework as being an effective tool for generating unique tactile input devices, which in a broader perspective, offers an example for designers on how to integrate theoretically insights and frameworks in their respective practice. Touch is important to explore as an aesthetic sense capable of transforming technologies and designs to better support experience.

For my nieces: Alisha, Tia, and Ariyanna

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CHAPTER 1: AESTHETICS, TOUCH & HUMAN COMPUTER-INTERACTION

1.0 Why Aesthetics?

Aesthetics in a technical field such as human-computer interaction (HCI) is growing in importance and value. As broader visions of ambient intelligence and pervasive computing are becoming a reality, HCI is colliding with older design traditions of industrial design, furniture, architecture, and fashion (plus many more). In these fields, aesthetics is a necessary and integral component in the design, execution, and evaluation of the artefact, its use and experience by people. As a result, principles of aesthetic interaction promises to be a hybrid and holistic research domain.

The rise of aesthetics in interaction design follows a classic trajectory in HCI research. The pattern is as follows: as computation becomes smaller and cheaper, it pervades deeper into human culture, mixing with pre-existing domains and established practices. For example, once computers became small enough to escape laboratories it spreads into office and work-spaces. The equation for interaction was no longer a sum of the user and the computer. Rather, context, ethnography, and the 'information ecology' (Nardi, 1999) became a necessary part of HCI research and practice. Another example is the rise of social computing and tangible-user interfaces, which shifted focus away from cognition to embodiment, bodily knowledge, and action (Dourish, 2001). The question of aesthetics arises from the same pattern: wearable computing is appropriating fashion, ambient intelligence is appropriating architecture, and embedded computing is appropriating industrial design. In short, computation is seeping into the domestic and normal ‘everyday’ aspects of human life (Weiser, 1991). With this appropriation, HCI inherits established practices of these fields and seeks reconciliation between the different domains. Since these domains of human culture include objects and spaces imbued with meaning, status, and emotion, HCI research is now tackling issues of aesthetics, experience, and ambiguity. The purpose of this thesis is to participate in this dialogue between aesthetics and interaction with a focus on touch and tactile based interactions. One important and guiding question emerges: when we speak of touch aesthetics in interaction, how do we define the ‘beauty’ of interaction? Historically, the dominant definition of aesthetics tends to refer to the visual beauty of an artwork or artefact. This perspective was adequate for analyzing and contemplating classical artwork. However, modernism brought complexity to the issue of aesthetics when artists began to present artwork that did not conform to classical definitions of beauty. Instead, art was concerned with other questions, and began to ask the viewer to contemplate the piece, think about its meaning, and reflect on its impact. Essentially, aesthetics is part of the experience (Dewey, 1934).

1.1 What is an Aesthetic Experience?

Contemporary philosophies of aesthetic experience have their roots in Dewey’s pragmatism, which strives to position lived experience and daily life worthy of aesthetic appreciation (Shusterman & Tomlin, 2008). Currently, instead of attempting to define 'aesthetic experience' in a reductionist way, the philosophical focus is now to articulate the effects of aesthetic experiences (Shusterman & Tomlin, 2008). Tracing the historical and philosophical theories shaping aesthetic experience reveals four key themes (Shusterman, 1992). Familiarity with these concepts is essential before applying aesthetic experience to HCI. The first theme is the evaluative dimension, which suggests that an aesthetic experience is inherently valuable or pleasurable to a person. This theme implies that in order for an experience to be aesthetic, and not mundane, it needs to be enjoyable or valuable so that the person remembers it and can recall and evaluate the experience at a later time. The next theme is the phenomenological dimension. An aesthetic experience is something that we distinctly feel and savour, and is thus, subjective. This argument implies that beauty does not only reside in an object but also in the way the object is perceived and felt by a person. The third dimension is the semantic dimension, which stresses than an aesthetic experience is meaningful in the way we perceive an object or action. Finally, the demarcational theme characterizes an aesthetic experience as a distinct experience different from the myriad of experiences and situations we encounter in a daily basis. When we have an aesthetic experience we can distinguish that experience from all others. This framework, while broad in scope, clarifies many questions and reservations that may impede applying aesthetic theory to interactivity. First, we learn that defining parameters or metrics of aesthetic experience does not provide a full picture of the issues involved. The guiding questions in aesthetic experience are not defining the experience itself, but how the experience affects a person, how is it felt, and what it means. Philosophers ask us to accept that an aesthetic experience, however indefinable, does exist. They ask us to direct our efforts to understanding how such an experience emerges and how an aesthetic experience feels. Aesthetics is not exclusively within the realm of empiricism and quantitative data. We can talk about and describe its qualities with striking resolution and clarity. This signals a shift in the methods and frameworks that human-computer interaction needs to construct in order to cope with aesthetic issues. The central question when developing frameworks for aesthetics in interaction design is "*when we shift from an interest in the expression of things to the expression of things in use, what is it that we refer to?*" (Redstrom, 2008)

1.2 Aesthetics in HCI

Several attempts have already been made to reconcile HCI with aesthetics. Djajadiningrat (Djajadiningrat et al, 2004) incorporates industrial design principles of form with interaction design principles of pattern, dialogue between user and product, and rich gesture and tangible action. Dunne (Dunne, 2006) stresses the need for aesthetics in design and suggests scenario development, speculative design, and critical design to expand the boundaries of electronic product. Heinreich (Heinreich, 2007) offers a framework that builds from Kant's classical definition of aesthetics as acts of judgments and uses this thesis as the foundation for a framework to understand aesthetics in interactive performances. Many other researchers pinpoint pragmatist aesthetics of Dewey and Shusterman as their inspiration for developing an aesthetic of interaction framework (Fiore et al, 2005) (Peterson et al, 2004) (Schiphorst & Motamedi, 2007). Here, beauty is not found in the visual appearance of the interface but in the action, somaesthetics~~,~~ and use of an interface. Finally, Hallnas and Redstrom are interested in the “inner logic” of design (Hallnas & Redstrom, 2002), computational composites (Vallgarda & Redstrom, 2007) (Redstrom, 2005), and how technology expresses it’s presence.

These frameworks each approach aesthetics from their own professional disciplines and highlight the reach that aesthetics has in interactive systems. This signifies an interesting trend for aesthetics research in HCI. Instead of one core and unified agenda, aesthetics in HCI will most likely consist of many well-articulated case-studies and frameworks from various disciplines and backgrounds. An outcome is that a single, well described theory of aesthetics of virtual reality may not be applicable to a theory of aesthetics for tangible interaction. Lastly, the rich diversity of existing theories parallels discussion in aesthetic philosophy where theorists have already abandoned the notion of an universal aesthetics in favour of theories that articulate the transformative and evaluative effects of aesthetic experience.

1.3 Emergence of Touch Aesthetics

This thesis emerges from this context of aesthetic experience and interaction, which proposes an aesthetic framework of interaction focusing on touch and tactile interfaces. The need for a conceptual framework for touch aesthetics became apparent after reflecting on the outcome of designing various touch interfaces. In each project, there were common themes and questions that were addressed throughout the design process. During this process of reflection there was a noticeable lack of a coherent model or framework for tactile interface design. This prompted a deeper investigation into the theories, science, and psychologies behind these design issues of touch, materiality, technology, and semantics. Eventually, these theories evolved and were braided together to form the framework.

The aim here is not to articulate a framework broad enough for every interaction design problem or scenario. Instead, the theories collected and the prototypes developed for this thesis contain practical knowledge on how next generation tactile and touch systems should be developed, designed, and engineered to better ensure an aesthetic user-experience. Further, the goal of this thesis is not to identify a set rules for designing tactile interfaces. The objective is to elucidate the theoretical factors involved in designing and engineering these systems that are seldom discussed and recognized. As a result, there is a clear focus towards the physical and material components of touch screens and their enclosures.

While the framework is rooted in practice, it grew from a recursive process involving creation and then reflection. This cyclical process gives the framework an inherent flexibility. Essentially, the more touch interfaces are designed, the better the framework is refined.

1.4 Framework Overview

The proposed touch aesthetic framework consists of four distinct and essential concepts for tactile interfaces. Moulded together they provide a comprehensive picture of the issues involved in designing aesthetic experience using touch or tactile technologies. The first section of this thesis explicates the principles and theories of each strand in the framework in a separate chapter:

1.) Touch and Intersensory Mappings

This chapter introduces the concept of sensory-mappings, which is the creation of appropriate cross-modal relationships between touch and our other senses, namely vision. This capability of mediated interfaces is a compelling strategy to evoke metaphorical haptic responses.

2.) Semantics

This chapter explores how meaningful and affective gestures can be encoded into computational models of gesture recognition. Semantics in touch is bi-directional: we encode meaning in the way we touch and caress, and at the same time, we decode meaning in what we feel and how are touched.

3.) Technology

The third chapter in the framework exposes technology as a design substance, not as a design tool. We introduce the concept of "designing technology" which ensures that the interaction better cultivates and nurtures an aesthetic experience.

4.) Materiality

The last chapter argues for the return of the primacy materials in interaction design. This section dispels the myths of “immateriality” or “dematerialization”, and highlights the role of physicality, texture, form, and materials in our experience with technology.

1.4.1 Structure of Framework

The framework should be understood as a composite of four key conceptual themes. Emphasizing specific aspects of the framework can be used to analyze touch interaction.

Figure 1: Aesthetic of Touch Framework with equal weighing of the four themes

Composites are engineered materials made from two or more materials each with different properties. When combined together, the composite material inherits the properties of its constituent materials. Adjusting the amount of each material in the mixture results in new and different material structures. Composites include brick (mixing mud and straw) or advanced hybrids such as carbon-fibre. By manipulating the ratio of the ingredients, different composite structures can be achieved. Similarly, the weight of the themes can enlarge or contract according to the specific design problem. This is clarified in the case-studies: each case-studies weighs one or two parts of the framework heavier than others.

1.5 Case-Studies

The second part of the thesis applies the principles of the framework to describe the design process of three case-studies. Each prototype emphasizes a different aspect of the framework, and together provide a comprehensive portrait of how the framework can be used to help guide the design process:

1.) Keep in Touch: A Tactile-Vision Intimate Interface

The first case-study investigates the aesthetics of mediated tactile communication by exploring how cross-sensory mappings, analogue visual designs, and material selection can create a unique tactile experience for remote couples. The resulting design is a networked fabric touch screen spread across two locations, which allows people to communicate via touch, gesture, and body language. This project's design process weighs more heavily on the *InterSensory* and *Materiality* strands (Figure 2) and these effects are discussed in the chapter. The results of this case-study inspired a closer exploration on material and technology which formed the basis of the second case study.

Figure 2: The first case-study emphasize *Materiality* and *InterSensory* strands

2.) Stay in Touch: a Vision-Volume Touch Interface

The second case-study began with an exploration into the affordances and capabilities of conductive fabrics. This lead to the technological development of a new type of tactile input-device that requires simultaneous touch input by two separate people. The interface consists of a dual-layer touch sensitive fabric that divides a room in half. People on either side of the fabric must touch each other through the fabric to view projected images. The second case-study weighs *Materiality* and *Technology* as these two strands influenced the design (Figure 3). After the completion of this case-study, it became feasible to consider designing new technologies for touch input. This realization formed the basis of the final case-study.

Figure 3 This case study emphasizes Materiality and Technology.

3.)   HD Touch: a High-Definition TableTop Interface

The objective of the final case-study was to design and develop a technological platform for next-generation ubiquitous multi-touch interfaces. The technological outcome is a new approach for engineering tactile tabletop surfaces using LCD screens. The tabletop can sense touch input, hands hovering the surface, and objects placed on top, and can be networked over the internet. This case study (Figure 4) emphasizes the *Semantic* and *Technology* strands of the framework.

Figure 4: The last case-study describes how Technology and Semantics influenced the design process of a new multi-touch table.

1.6 Framework Contributions

The results from the framework are encouraging. First, as an aggregate of crucial concepts in touch interactions it is useful as a resource for input device designers to consider when creating projects. Since conceptual resources for discussing or guiding input design is sparse, the framework is a healthy contribution in a field that is growing in importance. Secondly, the framework has the potential for evolving into an effective tool to inspire and guide future designs. The framework was influential in the three case-studies of this thesis, and led to the creation of a novel input device (Stay in Touch), demonstrated the power of haptic metaphors (Keep in Touch), and led to the development of a new method for creating multi-touch tabletop surfaces.

The case-studies discussed in this thesis each helped to define and adjust the proposed conceptual framework. The effects of this recursive relationship is that it gives the framework an innate flexibility with the ability to evolve. Future projects in touch interfaces can use the existing principles as points-of-departure for exploring aesthetics and experience. Afterwards, reflecting on the design process can refine the framework by strengthening the existing concepts or by creating new ones. In the end, actively designing and making can only strengthen the framework.

The successful application of the framework for inspiring new and innovative design solutions for touch interactions suggests that this process of reflecting on design process for developing theoretical frameworks is an effective and worthwhile exercise for other design practitioners.

CHAPTER 2: INTERSENSORY MAPPINGS

2.0 Overview

Figure 5: The first strand of the framework: *InterSensory Mappings*

In this chapter, the first strand in the framework, *InterSensory Mapping* is introduced. InterSensory Mapping is the unique capability of technology to create hybrid sense modalities by transforming the input stimulus from one sense to an actuated output of another. One unique inter-sensory mapping concept is 'haptic-metaphors'. Haptic metaphors are thoughtful and poetic cross-modal mappings, which evoke haptic response. It is an effective design strategy used in interactive arts and design for enriching user experience. This chapter first surveys important research in the science of touch and proceeds to describe intersensory mappings. Prominent examples from HCI research are discussed.

2.1 What is Unique about Touch?

The science of touch has not progressed as quickly or in as much depth as visual or auditory research. It has often been relegated as a 'lower sense' (Katz & Krueger, 1989) or dismissed as a purely 'subjective' sense unable to apprehend objective qualities from the world (Katz & Krueger, 1989). This perspective has biased vision as the dominant sense in attaining knowledge about the world. Visual terms such as ‘light’, ‘illumination’, and ‘enlightenment’ became synonymous with knowledge, nobility, and divinity. As a result of the diminished value of touch, the history of tactile research in computation is young and relatively sparse. This section will focus its analysis on the groundbreaking work of two influential touch researchers: David Katz and James J. Gibson. Katz’s voluminous book ‘*World of Touch’* (Katz & Krueger, 1989) is among the largest collection of touch research and experiments. One of the guiding goals for David Katz was to eliminate the hierarchy of the senses that placed vision as superior to touch. Instead of vision, he wanted to re-establish touch’s prominence in perception research (Katz & Krueger, 1989). Katz advocates the phenomenological importance of touch. He argues that touch is the only sense that reveals information on the ‘innards of objects’ and their true reality. Even vision is unable to reveal the true reality of world because we can only see the surfaces of objects and spaces.

The other pioneer of touch research is James J. Gibson. Gibson believed in the richness of stimulus instead of the human sensory system (Gibson, 1966). For Gibson, our senses, including touch, actively seek and explore the world for information (for more on affordances, see *Materiality* section). He was more interested in investigating the stimulus or substance instead of our tactile receptors. Since he was interested in active engagement with the world, he is well aligned with Katz on the importance of the hand and fingers in tactile perception. One key concept that was suggested to demonstrate the importance of the hand is regarding the hand as a ‘touch organ’. The literature review in the next section is greatly influenced by the original writings of Katz and Gibson, and also the editor's introduction written by Lester Krueger.

2.2 Hand as Touch Organ

Since Katz wanted to prove the versatility of touch when compared to vision, his conceptual arguments are made to be analogous to vision. One of his analogies is the idea of the hand as being the touch organ in the same way the eye is the organ for vision, ears for sound, and nose for smell. Gibson, while not adamant on the hand as being the touch organ, emphasized the physical and manipulative capabilities of the hand and what it can perceive. We use our hands to grasp, prod, and caress objects in order to retrieve objective information. Gibson identifies three tangible properties: 1) geometric variables like shape, proportions, slopes, edges, curves, etc… 2) surface variables such as texture and 3) material or substantial variables like heaviness or mass (Gibson, 1966). More recently, researchers have categorized stereotypical hand manipulations into 'exploratory procedures' (Lederman & Klatzky, 1987), a set of physical hand gestures that are used to obtain different objective properties that are unavailable to the eye. These include lateral motion for texture, pressure for hardness, static touch for temperature, and dynamic touching for weight. Also, the hand performs certain manipulations to learn about an objects shape using grasp or contour following. However, since this information is perceived more quickly by the eye, it is not a unique capability of touch. Due to the overall complexity and breadth of touch, both Katz and Gibson regard touch as a system, rather than a unified sense.

2.2.1 Lateral motion >> Active touch >> Texture

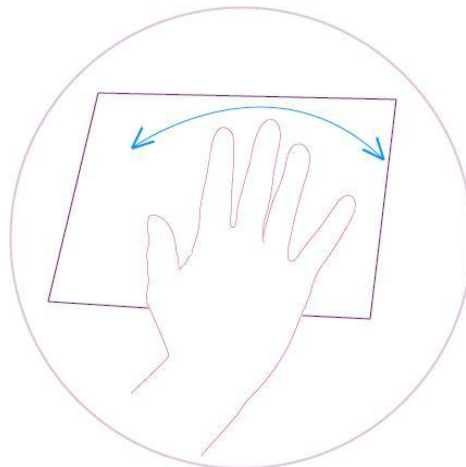

Figure 6: Moving hand lateral across a surface

The first exploratory procedure illustrates the most common and referenced attribute of touch called ‘active touch’. Active touch refers to the action of stroking one’s hand over a surface in order to feel its material texture and surface (Figure 5). Both Katz and Gibson were interested in active touch because it involved intention and motion on part of the person to actively and consciously explore their surroundings. Movement is a unique characteristic to touch. More information about a texture is perceived when the hand is in motion than in rest position. In other senses, primarily vision, motion impedes identification because it is harder to determine an objects properties when it is moving. Active touch is not only important because of its relationship with motion. It is an integral action for discerning the texture of a material and retrieve information about its roughness, smoothness, and hardness. Active touch can retrieve textural information that is unavailable to vision. As a result, touch is the only sense that can truly identify the textural properties of the world. Gibson attaches intentionality to active touch even further by claiming that our sense of touch actively seeks for surfaces and objects to caress and feel (Gibson, 1966). Both Katz and Gibson promote the value of texture in perception with Gibson suggesting that for animals, surface texture is probably more important than colour (Gibson, 1966). Similarly, Katz was keenly interested in microtexture and the microstructure of structures. Katz makes a clear distinction between a surface texture and the form of an object. As an example, the surface texture of a wood grain is consistent no matter in what shape it is carved. In his experiments on textural perception, Katz discovered that vibration sensors in the skin play an important role in perceiving texture alongside pressure sensors. For example, a person can feel a texture with their fingernail or by running a stick along a coarse surface. Katz discovery may explain why some surface undulations are better determined when felt with a piece of cloth than with fingers. Essentially, the vibration sense determines the properties of the surface while the pressure sense detects the presence of a surface (Katz & Krueger, 1989). Finally, Katz also wrote about tactual afterimage or sensory persistence of active touch. He describes the ability of the hand to retain some information of a texture even after than has stopped moving.

2.2.2 Pressure >> Hardness

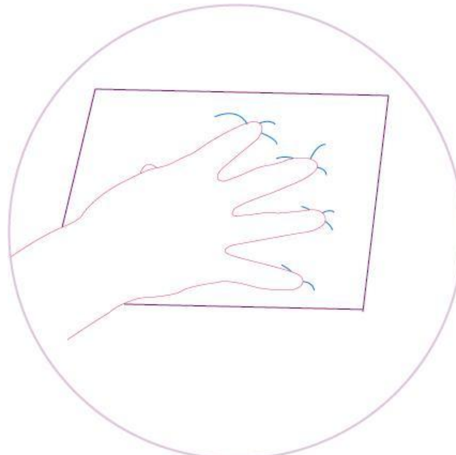

Figure 7: Pressing on a Surface

The secondary exploratory procedure illustrates a different sort of hand motion. Instead of the lateral movement of active touch, this exploration requires a person to perform a vertical motion on a surface, thus applying pressure. Through this procedure, a person is able to feel the elastic and hardness-softness properties of an object (Gibson, 1966). Katz developed a system for categorizing modes of touch analogous to vision modalities of surface, film, and volume. His touch modalities include surface touch (active touch), and immersed touch and volume touch, which involves the pressure exploratory procedure. Immersed touch occurs when we feel something that does not have form, such as water or air. When we touch these materials, our body penetrates the form and is wrapped by the substance. Consequently, this sort of material does not represent a quality of a body, rather, it characterizes a substance. According to Katz, what we feel is not a surface texture but the material substance. The resistance felt by the hand is usually experienced as elastic rather than stiff. We do not touch a surface, we penetrate the surface and the material closes up the void.

The second modality Katz describes is volume touch. Volume touch is the tactile equivalent to transparency and opacity in vision. It describes a person's ability to feel objects through a secondary material, such as a cloth or gloves. For example, when a piece of cloth is blanketed over a cup, a person can still feel the cup and its shape underneath the cloth. At the same time, they feel cloth and its texture. It is this ability and skill that allows trained persons to perform massage therapy or to diagnose a condition by feeling the muscle tension and organs of a person through their skin. Both immersed and volume touch are unexplored issues of tactile interface design. Exploring these under-theorized issues allows the designer to contemplate the phenomenological aspects of experiencing projection based displays and installations where the virtual image is emitted light that has no substantial form. This specific principle partially influenced the third case-study (see Chapter 8 *HD Touch)*.

2.2.3 Static Contact >> Passive Touch >> Temperature

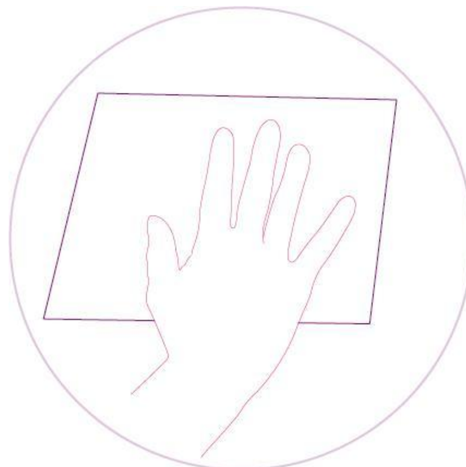

Figure 8: Feeling a surface with no movement

The next exploratory procedure is often placed in opposition to the different types of active touches. Passive touch, or static contact, describes the way we perceive external stimulus that is imposed on our skin. Neither Gibson or Katz were interested in passive touch, probably because they were more concerned with the phenomenological issues of intentionality and motion. However, Gibson notes that passive touch is induced by different stimuli than active touch. With passive touch, an external stimulus is pressed up to the skin causing the skin to depress or torsion (Gibson, 1966). This procedure is used to feel the sharpness of an object, like a needle, or to gauge the temperature of an object. Gibson’s interest in passive touch dealt with temperature detection because sensing temperature varied according to material being felt, and the temperature of the person’s finger. According to Gibson, the effective stimulus for detecting temperature is the direction of heat flow from the skin to the material by either radiation or conduction. Heat flows from one object to another, and depending on this direction it will be perceived as being either hot or cold. This is where the material's internal structure and electromechanical properties impact perception. Materials that conduct electricity very well, such as metal, will feel cooler to touch because heat flows and dissipates from the finger to the metal. Inversely, materials that resist heat will feel warmer to touch because the heat will travel less and slower.

2.2.4 Dynamic Touch >> Weight

Figure 9: Weighing an object

Dynamic touch is unique among the exploratory procedures because is the only method where information about an object is transmitted to a person through stimulation of the person's muscle and tendons instead of stimulation on the skin (Gibson, 1966). Dynamic touching involves synchronous inputs from the skin and joints. It also involves a non-spatial input from the muscle and tendons that seems to yield a further perception of the material substance of inertia of the object (Gibson, 1966). In dynamic touching, perception is blended with performance since information comes from muscular effort. At the same time, grasping an object during dynamic touching reveals other information to the person. This grasping and holding refers to the last two exploratory procedures: enclosure and contour following.

2.2.5 Enclosure & Contour Following: Shape and Volume

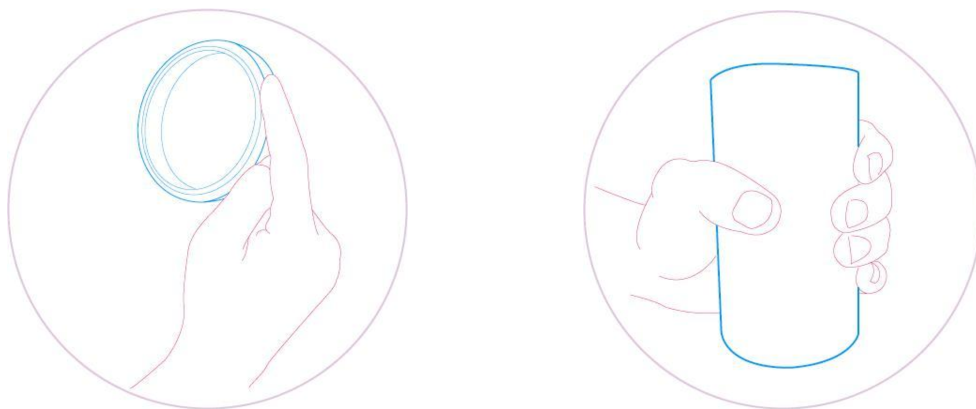

Figure 10 & Figure 11: Tracing an object with fingers and holding or grasping

The last two exploratory procedures are used when someone wants to determine the shape of an object. Grasping an object tells the person about the overall or global shape and volume. In the second procedure, the person traces their finger around the shape of an object to feel its exact shape. Since vision outperforms touch in determining global and exact shape, they are not unique properties of touch. They are included in this section for completeness.

2.3 Intersensory Relationships

This section introduces the concept of intersensory mappings. Intersensory mappings is a proposal for a derivative of research on sensory substitution and mappings that focuses on metaphorical and poetic mappings between two different sense modalities. Classical sensory substitution research usually aims to create novel sensory sensations for visually impaired individuals. For example, a video camera that transforms optical properties to an array of tactile simulators worn on the chest allows someone to feel the pixels of the video camera (Collins & Bach y Rita, 1973). These devices show the ability of the human body to map sensory input data from one modality into another. Participants using these devices show remarkable ability to navigate space and sense an objects form and shape. It is interesting to note that sensory substitution only works through active use from the user. A camera that translates light into tactile output is only powerful if the person can use the camera to pan, tilt, and zoom the view. By doing so, the user can recognize different forms and shapes. In these experiments, sensory substitution is achieved with literal and direct cross-modal sensations using haptic motor technology. But is there an analogous sensation that can be felt with interactivity, one that is metaphorical and evocative?

2.4 Haptic Metaphors

Gibson's view of the human perceptual system is the crux of the basic concept of intersensory mapping which states that a haptic sensation can be evoked. Intersensory mappings are metaphorical evocation of haptic responses. Instead of literal and direct haptic or tactile simulation, it is indirect, suggestive, and poetic. Virtual haptics has already been proven to be a phenomena in other interactive scenarios such as the "rubber-hand" illusion (IJsselsteijn, 2006) and with cursor displacements to evoke haptic feeling while using a mouse

(Mensvoort, 2002). For aesthetic experiences, the proposal is for thoughtful and poetic mappings from touch input into another output is a compelling strategy. Applying this concept to analyze key tactile interfaces in art and design reveals that each project uses this principle of intersensory mapping, but in their own respective way. The first example is *Bodymaps (*Schiphorst & Motamedi, 2007) where the Schiphorst mapped tactile contact, proximity, and gesture to audio output. Here, the gestures and proximity of the user is mapped according to layers. First, immersed touch (see section 2.2.2 Pressure) is mapped to water sounds. Sounds of water splashing is correlated to the users hand and gestures. Secondly, surface touch and active touch is mapped to body movements of a projected image. These two layers of intersensory mappings evokes the feeling of immersing hand in water, and then making contact and caressing a body. Another compelling project is the *Khronous Project* (Cassinelli & Ishikawa, 2005). In this interface, a video image is projected on a fabric screen. The user can then fast-forward the video clip by touching a region and applying pressure. The location of their hand and the amount of pressure is mapped to the location of the video clip that is affect, and how far in the future that area plays to. For example, one video clip shows a city landscape in the morning. By touching the sky and caressing it softly, the video of the sky will time-lapse to the afternoon. Applying more pressure will time-lapse it to the evening. In this intersensory interface, tactile input of surface touch and pressure is mapped to time which is represented visually. Affecting the video clip this way has a strong fluid, haptic feel.

Bodymaps and Khronous Projector are compelling examples of how thoughtful and poetic mappings between the tactile sense to another sense modality output can create an aesthetic experience. Their success is not only in due to the mapping but also the elements that are being mapped. Both interfaces are sensitive to the tactile sense and are able to respond to many exploratory procedures. Intersensory mapping has a common and intuitive strategy used by artists and designers to create aesthetic experiences. However, the concept has never been formally defined or contextualized. As a result, many of the emerging applications we see for touch interfaces are not as intuitive, poetic, and rich as the examples shown. At the same time, intersensory mapping is only one element in the aesthetic experience framework. It alone is inadequate for experience design and should be thought of with conjunction with the other concepts in the framework.

2.5 Science of Touch

This chapter began with a brief and condensed overview of the tactile sense and exploratory procedures. This sheer amount and complexity of the tactile sense indicates how crucial understanding the research is for interaction design. One key principle that emerged from this chapter is articulating the concept of ‘haptic metaphors’. This concept can result in unique and alternative tactile experiences.

Lastly, this chapter focused on the science of touch and the interplay between touch and vision with particular attention on how it can be useful for aesthetics in interaction design. Science does not provide a complete and cohesive picture on touch. Touch is a highly codified and symbolic sense, which presents many issues in interaction design and aesthetics. First, the meaning of touch changes in different contexts, cultures, and between people. This requires interactions to be flexible enough to accommodate the transformations in meaning. Secondly, there is the challenge of creating a gesture recognition that can sense and interpret the gestures of people as the use a tactile interface. Finally, not only does the system need to recognize the intent of the user, but also how to respond. All of these issues deal with the semantics of touch.

CHAPTER 3: SEMANTICS

3.0 Overview

Figure 12: The second strand of the framework: *Semantics*

This chapter looks at the social and communicative aspects of touch and how gestures are classified in HCI. This part of the framework proposes and describes a basic bidirectional view of tactile semantics: the meaning encoded in a gesture when we touch, and the meaning decoded from being touched. This concept forms the premise of a method for categorizing gesture libraries in HCI according to aesthetic dimensions of meaning, skill, and resolution. According to this charting, there is a trend from basic point and click gestures towards caressing and stroking gestures. An overview of the experiential and aesthetic dimension of computer-mediated communication reinforces the concept.

3.1 Socio-Haptics & Non-Verbal Communication

What happens when we touch something that touches us back? The science of Katz and Gibson does not include the social, cultural, and emotional ramifications of touching. Yet, this dimension of touch is perhaps the most important for our survival, reproduction, and development (Field, 2001). Touching between people is the most intimate and personal form of communication, and as a result, touch is the most socially and culturally regulated sense. Socially, the meaning of touch changes by gender, age, and context (Field, 2001). Context also changes touch meaning and dynamics. Obviously, touches are different whether in public or private settings, but also the parameters of a touch; such as the duration, type, and location changes the meaning (Floyd, 1999). In public settings, casual or accidental touches between strangers also have their own social rules and conduct. Casual touch between strangers is tolerated as long as the social setting is safe, and if the physical contact is brief or accidental, then touch is tolerated (Thayer, 1982). The crucial importance on the social dimension of touch indicates that the tactile sense is more than a perceptual system. It has a deeply encoded with symbolic, cultural, and social meaning. The challenge for HCI and experience design is to understand this meaning so it can be decoded by gesture recognition algorithms, and re-encoded to meaningful interactive commands and responses. Social touching has implications not only for haptic-feedback systems, but also for multi-point and gesture controlled interfaces.

3.2 From point and click to *stroke and caress*

Touching is part of the complex system of non-verbal communications that includes other tacit and bodily forms of expression such as gestures and body language (Kendon, 2004). As a system of communication, gestures are as natural and intuitive as speech. Gestures are used in co-presence, and now in telepresence, to inform another person about our feelings, intentions, and thoughts. Gestures are so natural that they are conceived as universal and embodied the goal of many touch-sensitive systems is to allow for a large repertoire of human gestures. Their universality means that people do not need to learn a new form of communication or method of expressing their intentions. Designing a touch system which is sensitive to the intentional nature of people's gestures has been a goal and challenge for experience design for many decades.

Charting the different approaches to gesture recognition is useful when considered in the following terms:

Decode*:* what are the tactile and gesture parameters the user inputs into the system?

Encode*:* what meaning does this gesture perform in the interface?

Analyzing this taxonomy according to experiential and aesthetic qualities reveals a spectrum of resolution, meaning, and skill.

Resolution: This dimension indicates how precise a gesture has to be performed by the user. The range goes from Precision to Expression. Expression means that the system is forgiving, while precision requires specific execution from the user.

Meaning: This dimension indicates how natural the mapping from the gesture is to expectations. This spectrum goes from arbitrary, where there is no clear or specific relation between gesture to output, and embodied which has a natural relationship.

Skill: This dimension charts how easy the gesture is to learn, memorize or perform. This spans from a task that has to be learned, to intuitive which requires no learning.

Gesture	Command	Resolution	Meaning	Skill
Sequential	Basic OS	Precise	Arbitrary	Task
Multi-Finger	Graphic	V	V	V
Co-Operative/Multi-User	CSCW	V V	V V	V V
Hand Shape	Bi-Manual	V	V	V
Flick	Scroll/Navigation	V	V	V
Pinch	Transformation	V V	V V	V V
Caress	Communication	V	V	V
Whole Body	Expression	Expressive	Embodied	Intuitive

Figure 13: The range and sort of gesture recognition libraries available

The first gesture recognition library to consider is the Fingerworks (Yuan et al, 2005) system. Fingerworks manufactured and sold a family of products that were multi-touch sensitive. Their i-gesture pad is one example. This product is the size of a mousepad, and the user can rest their hand and use a combination of finger movements to execute a range of basic computer commands. For example, moving all four fingers in unison downwards would scroll the display image down. From an experience and aesthetic perspective, the Fingerworks gesture library isn't very beautiful to use because the meaning of the gestures are arbitrary. Further, while the recognition library is extensive, the difference between the commands are small. This requires a degree of precision from the user to perform the gesture, and it takes while to commit all the gestures to memory.

The next step above Fingerworks are the common, multi-finger commands used for manipulating basic animation and graphic commands (Moscovich, 2006 & 2006) (Wu, 2003 & 2006). These gestures include multi-finger techniques to transform, scale, and rotate graphical objects and sprites. Since the researchers primary objectives were to identify multi-finger gestures that were efficient and optimal for a specific task, the meaning of the gestures are often also arbitrary. Also, they require a degree of precision and learned task to execute properly. While they may be useful for graphical applications, these gesture libraries are not aesthetic or experience based.

The next gesture-set are co-operative gestures (Morris et al, 2006) where users are required to perform synchronous gestures for specific commands. Here, users could collaborate or disapprove of certain collaborative tasks. This gesture approach is unique in that it is the only one where the gestures are collaborative.

The next series of gesture libraries approach more natural and embodied forms of interactions. Beginning with the gestures of VideoPlace (Krueger, 1984), natural and playful gestures of pinch, flick (Fitzmaurice, 2003), and stretch have become standardized in HCI and gesture applications in products like Surface and i-phone. These gestures work because there is a clear relationship between decoding the gesture and mapping it to a function, they allow for any fingers to be used, and they are intuitive. These gestures start to show the evolution from task-oriented and precise gestures to more embodied and expressive gestures.

The final category of gestures are from interactive art and installation research where whole body gestures and caressing and stroking gestures are used as input. Fabric based sensing systems (Berzowska, 2005) (Schiphorst et al, 2007) design their gesture recognition system to afford certain gestures such as petting or caressing. However, while these systems have lower input resolution they have higher degree of expression and are more intuitive. More extensive efforts on embodied gestures (Schiphorst et al, 2007) aim to differentiate between different affective forms of touching. Here, different forms of caress and strokes are interpreted by the system expanding the range of possible aesthetic input.

The final examples of gesture inputs show the future of multi-touch interface and gesture libraries. They include touch systems which attempt to recognize the affectionate and ambiguous forms of gestures which are more intuitive and natural for people to use. The future of touch interfaces is a shift away from pointing and dragging and towards stroking and caressing. Further, the next generation of displays will also afford more tactile input because of the materiality and physicality of the display surface.

3.3 Aesthetics of (tele)presence

The computer is not the only entity that needs to be able to recognize and respond to our gestures. More and more, all of our computing devices are becoming networked together allowing dialogue between devices and people who many not be co-located. Research in telepresence systems that transmit tactile-data with or without video-data has been investigating the experience and aesthetic issues of socially-mediated touch (Haans & IJsselsteijn, 2006). Since communicating with someone in a remote location is often a disembodied and detached experience, incorporating tactile, gesture, and body language has been a long design challenge. A taxonomy of telepresence systems reveals the span of technologies and interactions that encompass this domain, spanning every scenario from two users who communicate with an electronic device (i.e. cell phone) to hypervirtual tele-copresence where two people communicate as avatars in a digital site (Zhao, 2003). Further, haptic telepresence includes devices which transmit a signal to another location and actuate a motor. The feedback of the motor is meant to express or communicate with another person. This line of research has most of its applications in tele-robotics and surgery, to allow a tele-operator to use haptic feedback along with vision and hearing to perform a task.

Aesthetics for telepresence systems incorporate the issues of gesture encoding and decoding but with an added issue that the computer is not the only agent requiring to make sense of it. There have been important explanations to describe the aesthetics of telepresence. First, ‘Provocative Awareness’ makes a distinction between systems which communicate emotions versus those which evoke emotions. Interfaces which evoke emotions rely on the poetics of the physical form and material of the design, whereas systems that communicate emotions provide direct physical information between users (Gaver, 2002). Most efforts in HCI have focused on communicating emotions directly through haptics and touch sensors. However as Gaver argues, evoking emotions is more provocative and can result in designs that allow people to imbue their own meaning in the interface. Shifting focus to evoking emotions places more interest and responsibility on the physical and material aesthetic of interfaces. Secondly, Phatic communication (Gibbs et al, 2005) emphasis the importance of connectivity in telepresence interfaces instead of capturing and exchanging information. The aesthetics in phatic technologies is the manner and method of establishing a connection with another person, not what is communicated between them.

Finally, tactons (haptic icons) and actuated interfaces provide anther insight in telepresence aesthetics. First, tactons are haptic icons which rely on varying modulations in the intensity of vibrating motors to encode and transmit messages (Enriquez et al, 2006). By combining basic waveforms to modulate a vibrating motor (sawtooth, sine wave, square wave) different felt sensations can be achieved. This is the basic building block for creating a vocabulary of vibrations which can be felt and distinguished by a person. Using this principle of modulating vibrations can be used for communicating touch and also for other body data such as heartbeats (Lotan & Croft, 2007). Similar to haptics are actuated interfaces which use motors to transform and change the shape or structure of an interface. One compelling example of a tactile interface which use actuation is the E-Lumens interface from Sony CSL (Poupyrev, 2007). In this project, two tablets are installed in remote locations and are linked together via a network. The interface is built with an array of rods which raise and lower depending on where and how the other tablet is touched. For example, touching one tablet will cause rods in the other table to raise in the same location. The aesthetics of actuated tactile interfaces deals with structure, material, mechatronics, and architecture.

3.4 Semantics and Technology

The core principle in this chapter is charting of the trend in HCI from point and click gestures towards stroking and caressing gestures which are more embodied, intuitive, and aesthetic. This trend indicates the relevance and need for touch interfaces catered for intimate and expressive uses.

This also chapter explored the impact of social, cultural, and psychological factors on the meaning of touch and gestures. Specifically, it dealt with issues of mapping (encoding and decoding touch) as well as emerging issues in tactile telepresence interactions.

The meaning of touch is malleable, and there is a direct relationship between technology and the range of expressivity and aesthetics it affords. The impact of technology on aesthetics is the topic of the proceeding chapter.

CHAPTER 4: TECHNOLOGY

4.0 Overview

Figure 14: The third strand of the framework: *Technology*

This chapter in the framework deals with the technological dimension of tactile aesthetic and interactivity. Technology has a substantial influence on our experience with the world, and should be investigated as a design substance or material. To this end, this chapter proposes a co-constructive definition of technology, which characterizes technology as a product of both individual effort and society at large. A co-constructive perspective alters the relationship between design and technology from a deterministic one to an interdependent one, which mirrors and better explains the design process and engineering of tactile interfaces. A review of touch and tactile technologies is analyzed through the lens of co-construction, and how different technologies affect, nurture, or disrupt aesthetic experiences.

4.1 Defining Technology: Co-construction

Technology is an important concept and term in our lives, yet it is surprisingly very difficult to define or pinpoint. We speak of technology as being a physical entity such as microchips being researched and developed by scientists in laboratories. In this definition, technology is a ‘thing’ created by people for, mostly, economic motivations. At the same time however, we also think of technology in a broader sense as a deterministic force. For example, when we think that computer technology has changed the world, or that a certain technology will improve the health and welfare of people in poverty. From this perspective, we define technology has an external, yet concrete force that can alter society and culture. These two opposing definitions of technology; one that exists at the micro level of people, the other at the macro level of a paradigm makes defining technology a difficult problem.

Unfortunately, the literature from philosophy of technology and modernity theory is equally elusive. On one hand, modernity views technology as a force that affects the social and institutional structure of modern societies (Misa, 2003). These structures are conceptual such as industrialism, capitalism, rationalization, and reflexivity. As such, modernists look at the impact technology had on these structures from a macro and broad perspective. For example, Baudrillard (1995) describes how information technology, mass media communication, and cybernetics effected a transition from an industrial economy to an era of simulation (cited in Misa, 2003). Earlier, Marx describes the effects of industrial technology such as assembly lines and division of labour caused the shift from a feudal to capitalist society (cited in Misa, 2003). In both examples, technology is treated as an external pervasive force, which changes the structures of society such as economy. The underlining thesis is that technology is deterministic and changes society pervades industrial design discourse. Design studies, which also follows an historical lineage has a mysterious relationship with design. Often technology is framed as an external force that allows designers to explore new forms and styles (Dormer, 1993). Another common narrative is how technology dematerialized products and, thus altered the design profession altogether (Beurdeck. 2005). The relationship between design and technology from design history, again follows the pattern of an external force altering an institution of modernity or society.

Technology studies, or sociology or scientific knowledge studies, view technology in a diametrically opposite way. The opposing thesis is that technology is socially-constructed, as a product of people and organizations. Technology studies are concerned with the empirical study of the development of technical artefacts, systems, processes and their relation to society (Misa, 2003). For example, researchers would analyze the development of a certain product, from research and development, to prototype engineering, and finally to how the product is used and experienced by people.

The two perspectives on technology are interconnected. Technology made modernity possible, but at the same time, technology is a creation of modernity. The need for an integrated philosophical framework to reconcile the two schools of technology studies is quite apparent. The two schools are not polar opposites, rather they are entwined and entangled (Misa, 2003). In order to reconcile the two schools, a new theoretical framework has been proposed called co-construction (Misa, 2003). The aim of co-construction is to grasp both perspectives (modernity theory and social shaping) and to develop new intellectual frames by which to comprehend them (Misa, 2003). In order to achieve this, a new framework should accommodate the macro-level analysis of modernity, with the micro-level and empirical analysis from social-shaping perspectives. Co-constructionism is an attempt to engage the two philosophies and synthesize newer models to define and understand technology. Co-constructionist theory proposes three key ideas for consideration:

- The concepts of “technology” and “modernity” have a complex and tangled history.
- Technology may be the truly distinctive feature of modernity.
- Modernity theory missed what was modern about technology.
- Postmodernism is just as involved and entwined with technology as modernism.

A co-constructionist view of technology, by reconciling deterministic and social-shaping views of technology offers a compelling framework to apply to aesthetics and experience. The Co-constructionist argument explains the relationship between aesthetics and technology: aesthetics creates a certain technology, and new technologies creates newer aesthetic experiences.

4.2 Designing Technology: Review of Touch Technologies

The purpose of this section is to analyze the range of different touch sensing technologies according to a co-constructionist framework. This requires analyzing the technical components required to sense a touch signal and process the data, and how that specific technology impacts the experience and aesthetics of interaction. In order to do so, different touch sensing platforms are categorized according to the technology, and then key differences in the interaction techniques they allow and overall user experiences are identified. Only those technologies that have been personally experienced will be discussed.

4.2.1 Resistive

Resistive touch screens are the most common and ubiquitous of touch screen devices. They have been used in many applications such as information kiosks, point-of-sale systems, and with smaller screen devices including PDA's and smart phones. Resistive touch screens consist of a glass panel coated with a conductive layer, and a conductive coated plastic membrane which traps in small insulator dots. When someone touches the membrane and brings it in contact with the glass, an electric circuit is connected. Since the connectors between the glass and membrane begin at one corner and travel along the entire width and length of the glass, a gradient voltage outputs according to the distance away from the origin. Essentially, touching from left to right will give a voltage output from 1 … 100, and down to up will output 1 …100. Resistive touchscreens support the detection of only one point of contact, as multiple inputs will give an average value. Resistive touch screens are clear and are always placed over a monitor to enable direct touch interaction. Because they measure the resistance along the panel by physical contact, they also have the added advantage of being able to be used by a stylus, or by gloves and fingernails. Although they are not multi-point devices, they are ubiquitous and alongside a touchpad of a mouse, they are the most common touchpad people have encountered and experienced. As a result, next generation touch devices will need to be compared against, and discussed alongside resistive touchscreens.

4.2.2 Capacitive

Capacitive based touch technologies, unlike resistive-based screens, are able to detect multiple points of contact. The technology in the DiamondTouch (Dietz & Leigh, 2001) table from Mitsubishi Electronic Research Laboratories is an example of a multi-touch tablet that can sense the finger input of up to four people. Connected to the tablet are four chairs that are electronically connected to the sensing surface. When someone sits on the chair and touches the tablet, an electric connection is made and the users input and ID are sensed. This ability to differentiate between users is unique to this system and its technology, and allowed for the exploration of collaborative or co-operative gestures (Morris et al, 2007), and for applications that make use of different people collaborating on the same surface such as CSCW and games. Another example of a capacitance based system is the SmartSkin (Rekimoto, 2002) surface from Sony Computer Science Laboratory. In this device, the electrodes are embedded as a mesh in the surface material, as opposed to a coated layer underneath a glass or other substance. This integration of sensor with material allows for non-planar forms and surfaces, so that a cylindrical multi-point device is possible. Further, the system architecture can also be integrated into fabrics or cloths to enable multi-point fabric devices (however, neither of these two possibilities have been implemented so far). The final based multi-point device is the I-gesture pad from Fingerworks (Yuan et al, 2005. This device is not truly capacitive as it consists of an array of thermo-electrodes, which respond to body heat of the user's hand. What is unique about the iGesture pad is that he internal microchip of the device performs pre-gesture processing at the device level before inputting to the computer. Using a neural-net algorithm to differentiate between different gesture paths, the device responds only to certain gestures. Unlike other touchscreen devices, you are able to rest your hand on the device without triggering inadvertent signals to the computer.

Capacitance based devices are sensitive to contact and allow for zero force gestures. A person can gently touch the pad in order for a detection to be made, unlike resistive touch screens, which requires some pressure to be exerted. While gentle touches are detectable, pressure is not. Touch interactions using capacitance cannot use pressure as a parameter for gestures.

Another detriments of capacitance-based systems is that they are generally opaque, required front-projected displays. Front projected displays create shadows from the user, which from a user experience point of view, disrupts the experience and flow because it occludes the screen and also reminds the person of the projected image. Transparent capacitance systems have been developed and deployed for small screen devices.

4.2.3 Optical Sensing

The current state-of-the-art touch devices consist of optical sensors, most commonly a digital camera, which detects light reflected from the finger of the user they either touch a surface (Han, 2005) or come into close contact with it. The basic sensing principle is to use a camera to snap an image, and then use common computer-vision methods to identify fingertips or points of contact. Camera based sensing has the advantage of being inexpensive to produce, and scales really well allowing for large wall displays, table surfaces, or floor interfaces. Also, the camera can identify and track patterns attached underneath objects allowing for tangible interfaces (Kaltenbrunner & Bencina, 2007). Since most of these systems are coupled with a projected image, infrared light is used so that interference from the display is eliminated. There have been several notable prototypes to demonstrate the capabilities and near-future interaction techniques. One system, Play Anywhere (Wilson, 2005) uses this technique to convert any surface into a multi-point surface. This prototype was later refined and packaged as the Microsoft Surface table. The Surface table from Microsoft uses four cameras underneath the table surface to capture pictures on top of the table with a corresponding projector that shoots an image on the surface. The images are then processed by a computer to identify fingertips and objects which are then used for control data to manipulate virtual objects. A similar technology is used in the ReacTable (Kaltenbrunner & Bencina, 2007) to identify specially tagged objects as well as fingertips. While many of the camera-based touch systems use a projector to display an image, there have been efforts to integrate optical sensing inside LCD and other physical displays. One approach was to embed micro-optical sensors inside the active-matrix etching of the glass itself (Abileah & Green, 2007). The glass panel of LCD screens are etched with small squares where liquid crystals are inserted. The liquid crystals act as prisms that filter and polarize light according to an electric current, which is controlled by thin transistors. Alongside each pixel is a sensor, which reacts to light and shadow. This gives a very dense and high-resolution image of reflected light over the glass surface. Another prototype is ThinSight (Hodges et al, 2007) where they create an array of infrared transceivers behind the LCD panel of a laptop. Each sensor transmits an infrared light signal through the LCD and waits for the signal to reflect back to the receiver. Since there is an array of these transceivers behind the panel, they are able to obtain a medium quality image of activity occurring over the LCD surface. In both of these examples, optical sensing electronics are used to enable multi-point interactions. Different to these is the HD Table (Motamedi, 2008), which uses a digital camera to sense surface activity. Behind the LCD panel a camera is placed which is only sensitive to IR light. Accordingly, IR light is emitted from LED's that skim over the top of the LCD panel which reflect back down when there is a hand hovering or touching the surface. The latter examples of optical sensing indicates the emerging trend of integrating input sensing with physical displays, where the display itself is both an input and an output transducer. The advantage of physical displays (LCD's) over projectors is that they allow for thinner and great form factors, as well as higher resolution images.

4.3 Aesthetic Dimension of Technology and Experience

A common criticism of technology‘s definition within HCI is that it is too focused on efficiency, tasks, usability, and sequential and discrete steps. HCI inherited these metrics for developing technology from the work-centric applications that computing originally had a major impact in. However, the role of technology in our lives has expanded out of the office, and into the daily and felt experience of life. Today, we don't use technology we live with it (McCarthy & Wright, 2004). Technology that has been designed according to archaic metrics may not be adequate for everyday experience or aesthetic experience. As a result, the very notion of technology needs to be rethought and a new definition needs to be articulated. The proposal to view technology as a design material is not new, in fact it clarifies many of the alternative interaction models proposed by the HCI community. The various upcoming models for aesthetic experience technologies do not articulate a critical approach to technological studies. However, there is a common and latent argument for reconsidering technology and its role in aesthetics and experience design. The common argument in all the proposals is that in order to enable or provide a certain aesthetic experience, technology needs to be redefined and reconsidered.

4.3.1 Slow Technology

'Slow Technology' (Hallnas & Redstrom, 2001) is a design philosophy for envisioning a new purpose and role for technology and technological artefacts. It positions itself in binary opposition to *fast* technology that is concerned with making the use and task more efficient thus giving people *more* time. Instead, slow technology aims to create a more reflective environment, giving people more time to think about technology, it's purpose, how it works, and the consequences. Essentially, slow technology redesigns technology to allow for a reflective and contemplative aesthetic experience. Slow Technology is not about time perception, for instance, to make certain task take longer to complete. Rather it is about time presence, making people aware of time for contemplation and reflection.

Slow technology has an aesthetics of functionality, where the function of technology creates an aesthetic experience. This usually clusters in three design themes: reflective technology, time technology, and amplified environments. Reflective technology is designing technology that invites reflection and is simultaneously reflective in its expression, prompting people to think about technology. Time technology is technology designed to amplify the presence of time by slowing thing down or stretching time. Finally, amplified environments is technology that enlarges our perception of space or environment by extending the function through time as well as space.

'Slow Technology' has been formulated in response to the general definition of technology being concerned with efficiency and reducing workload or task time. Instead, slow technology extends the function of technology to make people aware of the presence of time, providing room for reflection and contemplation.

4.3.2 Ludic Engagement

Ludic Technology (Gaver et al, 2004) aims to design technology that appeals to the playful nature of humans, and the human need to do 'nothing'. In order for technology to achieve this, several underlying design assumptions have been proposed. First, ludic technology should promote curiosity, exploration and reflection. Essentially, the technological artefact should be engaging and allow a person to explore its use and function. Secondly, ludic technology should be a activity that is purpose-less to satisfy the human need for non-utilitarian tasks. Finally, the function of ludic technology should be ambiguous and open allowing people to create their own narratives about the meaning of technology. One example of ludic technology is the Drift Table. The Drift Table functions as a coffee table but with a peephole on the surface that looks onto a computer screen showing an aerial satellite view of the earth. This aerial view is navigated by placing objects on the surface and the object's weight and location are used as parameters to pan across the earth.

4.3.3 Ambiguity

Ambiguous Technology (Gaver et al, 2003) is a theory in reaction to the paradigm for technology to be rational and clear. Ambiguous technology is technology whose function and purpose is ambiguous, mysterious, and hazy. As a result, technology is open to interpretation allowing people to create or discover their own meaning in the use, function or purpose of technology. This process of discovery evokes a personal relationship between the user and the technical artefact. A key difference between ambiguity and fuzzy technology is that the property of ambiguity is not in the artefact, but in the interpretative relationship between a person and the artefact. For example, a prototype table with a corresponding picture frame is used to illustrate an ambiguous technology. Here, placing objects on the table will cause the picture frame hung on the wall to tilt and move. Other than this interactive element, the picture frame and table are normal; they both function as a regular table or picture frame is expected to. What has changed is the relationship between the table and the frame, and the relation between this system and the person. The mapping between objects and the actuated frame is not obvious, deliberate or informative. As a result, the person living with this furniture ends up creating their own narratives and meaning as to the mapping between the objects and their relationship to the furniture. While ambiguity is a property of the interaction, there are certain object attributes in ambiguous technology. The first is 'ambiguity of information' and refers to how information is presented. Instead of providing accurate and rich data, ambiguous interfaces presents data in formats that are fuzzy and open to interpretation. The goal is not give accurate and quick data, but to present or re-present information in a way that evokes the user to think about its meaning and content. The second attribute is 'ambiguity of context' which extends the notion that objects and actions change meaning according to context. Knowing that the function and meaning of an interaction changes according to context-of-use, ambiguous technology should be open enough to allow this transition. For example, people who use their mobile devices as flashlights, or mothers who use ring-tones as lullabies to sooth their babies shows how the meaning of function and use changes according to user and context. The final attribute is ‘ambiguity of relationship’ which is technology that compels us to project our subjective experience into a situation. An example is an electronic pillow (Dunne, 2001) which houses a radio that collects and broadcasts incoming radio and cell-phone signals. By hugging or using the pillow, the person is compelled to either eavesdrop on conversations or if they feel guilty, they discard it and can’t use the pillow any longer.

4.4 Designing Technology

This chapter asked for a redefinition of technology and a reconsideration of how it impacts design and aesthetics. Adopting a co-constructivist perspective of technology creates the possibilities for new ways of thinking about and designing technology. This idea of designing technology is not entirely new, the basic principles have been articulated by different researchers, but it’s application to design process is innovative and can empower designers. One of the insights that co-construction reveals is that technology is not abstract, that it is a physical and material construct. The last chapter of this section investigates the result of this return of materiality.

CHAPTER 5: MATERIALITY

5.0 Overview

Figure 15: The fourth strand of the framework: *Materiality*

This chapter argues for a renewed interest in the material effects, choices, and factors in interaction design. As part of the aesthetic experience framework, this section emphasizes the role that materiality has in our perceptual experience of the world, our knowledge of self, and how we associate and interact with the environment. This argument aligns interaction design with other, non-computational design where materiality has an important and large role in the design process. Specifically with the intimate relationship between the designer and the material that is common in crafts, art, and older design traditions.

This chapter first dispels a common misconception that interactivity is immaterial or dematerialized by revealing the impact of materials in the design of interactive products and interfaces. After, this chapter will introduce concepts of material agency, and how our interaction with materials mediates our perception of the world and knowledge of self. The final section deals with the uniqueness of digital artefacts because of the effect that computation has when layered on physical materials, and suggests viewing computation as a new hybrid (composite material). All together, this chapter is important for HCI because it offers a refreshing perspective on the value and importance of materials in interactivity.

5.1 Immateriality in Interaction Design

The emergence of interactivity in design theory has often led to assertions that digital artefacts are immaterial and virtual, and the eventual coming of an immaterial culture (Moles, 1998). The immaterial culture, a product of the post-industrialist society, is said to have dematerialized product design and ushered in newer fields of interface or interaction design (Beurdeck, 2005). This transition stressed the importance of software design and screen/display aesthetics (Beurdeck, 2005) over the form, structure, and material properties. Interaction design became a discipline and a field constrained to the visual events, states, and feedback that appear on a monitor or a screen. While computation has added an element that may appear to be immaterial, the idea that the physicality of design had disappeared is misleading and untrue. The obvious and superficial response to immateriality is the reality that every interaction requires a physical input and a physical device, such as a keyboard or mouse, all the way down to how memory and information is physically etched on a material substance (Hayles, 1999). Further, even virtual images that appear on displays are a result of the physical properties and optical manipulation of emitted light. The question of materiality becomes more complicated with the advent of wearable computing, pervasive and ubiquitous computing where interaction and computation occurs in objects that may not have a screen at all. These devices require interactions and feedback in the form of gestures, tactility, sound, and actuation. In addition, the development of smart materials and techno-materials has further conflated the myth of immateriality. Next generation touch interfaces can adopt a similar strategy to wearable computing to look at older design traditions for insight on the value of materials, and how materials affect the design process. Within a larger historical tradition, tactile and touch interfaces inherit older traditions from textiles, craft, and carpentry or industrial design.

5.2 Materials, Crafts, Design

Industrial design and material innovation have an intimate relationship in modernity. As a result of the mechanization of the post-world war II economy in the United States, many new materials and manufacturing processes expanded the possible range of designs and products that could be formed by new materials such as plastics and metals (Sparke, 2004). It was not uncommon for manufacturing firms to commission designers to “explore” the formal and structural limitations of these new materials. One famous example is Ray and Charles Eames exploration of fibreglass moulding and wire-bending to design one of their signature chair pieces. This work was made possible because of the industrial production complex which used to make airplane weaponry during the war, needed to identify new products and markets for their technology after the war ended. The rapid growth of the materials industry during this era, coupled with the booming consumer economy gave designers more resources and materials than ever before (Doordan, 2003). This explosion of capability, however, did not alleviate or provide solutions to issues. On the contrary, the introduction of new materials, have posed new problems for design and continues to do so today (Doordan, 2003). The root of the problem is the way designers traditionally viewed materials a priori to a design problem, rather than as part of the design problem (Doordan, 2003). This tendency to under appreciate materials, however, did not seep into crafts and textiles. One of the main differences between a designer and a craftsperson is that a craftsperson engages material in the process of formgiving (Risatti, 2007). Often, craftspersons are characterized as professionals who possess a deep and intimate knowledge of a material, its properties, and its characteristics. For example, typical materials used in crafts such as ceramics, wood, wool, and precious metals are often associated with a crafter with expert knowledge on how to manipulate and form the material into an aesthetic object (Risatti, 2007). With mechanization and the division of labour, the need for a new design profession emerged which tore away from the craft tradition. This pattern repeated during the rise of the computer with the rise of the interaction design profession. By the time interaction design matured as a discipline, the legacy of craft knowledge on materials has became abstract and foreign in interaction design, and the design of electronic products and devices, which are all some form of ABS plastic.

Recently however, tactile interfaces and electronic textile researchers are starting a renaissance in materiality. Textile displays is one research agenda to investigate the concept of computation *as a material* in it’s own right (Hallnas et al, 2002). A computational material proposes to view computation and technology not as an object or a process, but as a material. Since materials are manipulated to make forms and structures that are expressive and aesthetic, technology as material opens the design space for experiments to explore how artefacts function and work when designed in this view (Redstrom, 2005). This concept was extended further to view technology as computational composites (Vallgarda & Redstrom, 2007). In material science, composites are the product of two merging materials in order to create a material that reaps the benefits of both. A computational composite is a concept to describe the emerging class of materials that have computational elements such embedded in their function, expression, and aesthetic. One example of a computational composite are e-textiles used in wearable computing (Berzowska, 2005). Traditional fabrics are sewn together with conductive thread to add a computational layer over the cloth. The thread coated with heat-sensitive ink that changes its display colour whenever electronic data transmits through it. The final results are garments that respond to touch, gestures, caresses, through LED's and non-emissive displays. The concept of 'technology as material', textile displays, and e-clothing echoes the earlier days of crafts and shows an attempt to reconnect interaction design with it's lineage in industrial design, fashion, textiles, and crafts.

5.3 Materials and Touch Interfaces

Materiality and tactile interactions is perhaps the most promising and exciting domains for aesthetics and design. People relate to materials in a deep level which transfers over when materials become electronic and interactive. Fabric based sensing, or smart textiles, generally fall under two approaches: weaving conductive threads and fibres directly into the cloth textile itself. In these approaches, the material itself becomes a touch sensitive surface that could be used for a host of applications, including clothing and reactive tapestry (Bersowska, 2005). The second approach is to use conductive threads or wiring to sew electronic circuits onto a traditional fabric, most often used to create flexible and fabric connections between sensors and microchips (Schiphorst, 2005). Both methods are the roots of wearable computing, have also been used for touch and tactile input devices. What distinguishes fabric based touch sensing is that the textural richness of the surface affords more intimate, playful, and softer input compared to other sensing technologies. Since conductive fabrics have electronic capabilities integrated into the cloth structure, it diminishes traditional perspectives of computing and technology. This opens up the design space for new ways of thinking and building about interfaces. The fields of textile displays, textile touch screens, and wearable computing often demonstrate refreshingly new ideas about screens, input devices, networking, sensors, and feedback. In short, they redefine the essence of technology, interaction, and aesthetics.

SECTION II : CASE STUDIES

The first section of this thesis provided a theoretical framework for analyzing, understanding, and designing aesthetic experiences with touch interactions. Four key concepts were identified that need to be taken into consideration when designing for tactile interactions; they were intersensory mappings, semantics of touch, technology, and materiality.

The second section of this thesis evaluates the conceptual framework by showing how it has influenced or guided the design and development of three case-studies. Each prototype emphasizes a different aspect of the framework, and together provide a comprehensive portrait of how the framework can be used to help guide the design process.

CHAPTER 6: KEEP IN TOUCH

6.0 Design Objectives

The first case-study that illustrates the use of the framework is *Keep in Touch*. In this project, the goal was to investigate how an interface can be created to accommodate the sensual and intimate qualities of tactility for people in separate geographic locations. Being in separate locations presents many design challenges for tactile communication because people cannot directly interact through touch. A tactile interface allows direct communication and affords aesthetic interaction through intimacy and connection.

Interfaces for intimacy require technologies that bridge the separation of the users and provide a high degree of tactile interaction. There are major design repercussions resulting from this. First, existing communication devices (such as cell phones and web cams) are inadequate to facilitate intimacy through touch because they lack sufficient tactile technology, and because they have been designed for general and mass communication (Kaye & Goulding, 2004). Communicating intimacy is a very specific form of exchange because it is usually between only two people. Such qualities of sensuality require a fresh response in design. For instance, the physical material of the device needs to invite touch and reward it. Also, the scale of the device needs to be taken into consideration; should it be small and precious or should it be human-size? Another question is how is the device oriented; is it held in the hand, horizontal, or vertical? Instead of relying on off-the-shelf solutions, the goal of this project was to create an interface from the ‘bottom-up’ so that the physical design of the device will support the experience of intimacy.

The second major design issue is selecting *how* to communicate touch. Since touch will always be mediated in these applications, the choice of how to communicate tactility and how to feel touch is critical. The most common approach is to use vibrating motors to indicate that someone is touching a person. In one example, a vest with motors and electronics cramp to give the sensation of being hugged (Mueller et al, 2005). A person wearing this vest is intended to feel being hugged when activated by a remote user. These systems aim to both substitute and to simulate being touched with the use of technology. In *Keep in Touch*, instead of looking towards direct haptic interactions, alternative haptic modalities were explored that were more evocative and metaphorical. The objective was not to simulate a tactile response, rather to create an interface which affords a unique tactile experience as an alternative to directly touching someone. This strategy respects intimacy because it does not attempt to recreate touch with technology.

Another design objective was to build a system that allows people to express emotions through tactility, instead of communicating them through a cognitive form such as language. This difference is crucial because it affects the actual design outcome (Gaver, 2002). For instance, verbal and written linguistic communication devices allow people to communicate their feelings and emotions with each other (such as typing or talking) but they lack the capability of letting people express their feelings. People use gestures and body language to express themselves, especially in situations where non-verbal communication and experience is primal. Allowing for gesture and body-language alongside tactile communication is another design objective.

One risk of designing touch-interfaces for remote communication is limiting use to active and physical interaction, and neglecting ambient or “non-use” situations. One example is InTouch (Brave & Dahley, 1997) which consists of two pairs of cylindrical rods connected over a distance. Touching one rod will cause the corresponding remote rod to vibrate. This device is useful during active mode, but when users are not interacting with it, it has no ambient function. Having an interface with an active and ambient mode makes the design more relevant and rich because it has usefulness even when not in primary use (Ishii & Ulmer, 1997). A goal for Keep in Touch was to have an ambient mode which functions when not in primary or active use.

6.1 Framework Spectrum

These design goals deal more with the conceptual issues of experience rather than specific issues of construction. However, they are important because they lay the groundwork to start exploring and constructing interfaces which support these goals. Since design goals are conceptual in nature, the framework can help to group and categorize these goals so that they can uncover constructive design choices. This project best exemplifies the *InterSensory* and *Materiality* strands of the framework (Figure 16). In chapter 1, it was stated that emphasizing different strands of the framework clarifies and explains different touch interactions and designs. In this case-study the *InterSensory* and *Materiality* strands are the most prominent in the design. This next section will revisit the key principles of the strands to describe the design process of *Keep in Touch.*

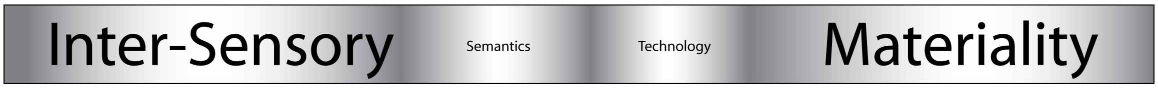

Figure 16: This case-study exemplifies the *InterSensory* and *Materiality* strands.

6.2 InterSensory Strand

The main design concept from the InterSensory strand is that poetic and thoughtful mappings between touch and other sense modalities can allude to and engage haptic and felt sensations. This concept inspired one of the main strengths in *Keep in Touch.* In the prototype, an interactive fabric is installed in two separate locations, each projecting a shadowy and blurry image of the other site. When a couple walks up to the fabric, they see a blurry silhouette of their partner. Once they touch their partner’s blurred body the image comes into focus revealing their partner’s features (Figure 17 & 18). This sensory mapping allows couples to touch each others digital bodies with their hands, and feel one another with their eyes.


Figure 17 & Figure 18: Touching the blurry body brings it into focus

6.2.1 Haptic Metaphor: Touch + Blur

The combination of different senses to produce a hybrid sensory mode is referred to as synesthesia. This project explored how touch and vision can be combined to produce a haptic synesthetic response that doesn't simulate or substitute touch, but can be used as a new method of creating intimacy with a loved one far away. Touch and vision have an intricate and mysterious evocative relationship. For example, during intense intimate moments such as kissing, people often close their eyes to dampen the visual sense and in order to heighten the tactile. This is because sharp and focused vision commands a lot of attention from our eyes and gazing at a body has the effect of objectifying and fixing the body (Pallasmaa, 2005). This intricate interplay between the two senses is the source of inspiration for the sensorial mapping design. The sensorial mapping is to connect the motion of active-touch with the blurry shadow of unfocused vision. The solution was to project a blurry and unfocused image of the other lover. When the image of the person is touched, the projection slowly comes into focus revealing a shadowy silhouette of the other person. By mapping the motion of touch with blurred vision we were able to evoke a rough haptic response and create a novel hybrid sensory mode for exploring alternative ways of expressing intimacy.

6.2.2 Ambiguity of Shadow and Blur

The first iteration of the prototype displayed a sharp projected image of the other person's body. The haptic metaphor requires dampening the visual design, but this was only applied to the blurry state. When the person's image came into focus, the visual sharpness overflowed the experience. In order to ensure sensual equilibrium in the second prototype, darkness filters were placed over the projector to convert the sharp image into a shadowy silhouette (Figure 19 & 20). This helped to improve the tactile and rough haptic response of the experience. Now, touching the blurry body of the remote person brings their body into a shadowy outline. Another advantage of this conversion from sharpness to shadow is that it made the experience more mysterious and sensual. The shadow of the other user is more interpretative and provocative because of the ambiguity of their form.


Figure 19 & Figure 20: The visual sense was dampened to heighten the tactile.

The other major visual design decision for *Keep in Touch* was how to blur the image projected on to the fabric. Essentially, the two choices are either to use a true-blur by putting the camera lens out of focus, or to use a computer to digitally simulate blur. The easier of the two options would have been to apply a blur filter to a video signal with a computer. This approach was not chosen for a few reasons. First, a digital blur will apply the same amount of blurriness over the entire frame which flattens the image. In contrast, a blur that results from an out-of-focus lens has greater depth since objects further away from the focal point are more obscured. An analogue blur has richness in depth. Secondly, a digital blur will pixelate the frame and has the connotation of being low quality and cheap. On the other hand, an analogue blur is not pixelated and still has a high-resolution image. The analogue method of blurring is visually rich producing a deeper range of sensual input. In the end, an analogue blur will be more effective for the experience of the design. In order to accommodate this into the prototype, a video-camera was modified to gain access and control of the auto-focus dial. This was achieved by attaching a servo-motor to the focus-dial which could now be controlled by a microcontroller. All together, the visual design strategies of reducing the visual impact of the bodies reinforces the intimate and tactile connection between the two people.

6.3 Materiality Strand

The second key conceptual strand that explains *Keep in Touch* is the Materiality strand. The main concept of the Materiality strand is the emerging importance of material selection and choices in interaction design, especially with tactile interactions. The question of materiality extends beyond recognizing the importance of materials and proposes an intimate relationship between design and material akin to those in crafts. In this case-study, the design of *Keep in Touch* was heavily influenced by carefully selecting the right material for achieving the experience. This section describes how the Materiality strand helped guide the process of identifying the right material.

6.3.1 Invitation to Touch

There are two design criteria that material needs to satisfy within *Keep in Touch:* a technical and experiential component. Technically, the material has to be opaque enough to capture the projected light, but it also has to be transparent in order for the camera to see-through to capture an image of the person. At the same time, the material has to afford caress and stroking in order to invite a sensual and intimate tactile experience. These two requirements drove the criteria for selecting the right material. The first step was to find materials that could satisfy the conflicting technical criteria required by the projector and the video camera. Several translucent materials were tested first as a projection screen, then for their transparency. This narrowed the field of samples down to knitted mesh fabrics since they outperformed other types of fabric. The second step was to stretch the fabric over the frame and feel for the fabric that felt the nicest to touch. The criteria for evaluating the feel of the fabric is based on the elasticity of the threads, the softness, smoothness and texture of the material, and the spacing of the knitting. In the end a mesh fabric with a matte white colour was chosen because it was the softest to touch. Although it’s optical properties were only moderately adequate compared to other materials, the sensual aspects were given more weight (Figure 21 & 22).

Figure 21 & Figure 22: The selected material was chosen not only for its technical and optical properties, but also for its sensual affordances.

6.3.2 Sensitive Fabric

Since the fabric was chosen for its experiential and optical properties, it had to be augmented with sensors for the interaction. Embedded along the wooden frame were magnetic and proximity sensors. The proximity sensors could detect the location of a person's hand as they touched fabric. The magnetic sensors detect pressure from magnets attached along the edges of the fabric. When the fabric is pressed, it pushes the edges closer to the magnetic sensor. The magnet moves closer to the sensor and gives a higher value the harder the fabric is pressed,. This range can be used to determine pressure since the value of the magnetic sensor is proportional to the pressure exerted on the fabric. The location and pressure sensor information spins a motor attached to the camera bringing the lens in and out of focus. Embedding the sensors in the frame of the device was useful for iterative design as multiple material samples were easily stretched over the frame for testing and evaluation. Also, by keep sensors and electronics off the material there was minimal modification to the fabric.

6.4 Implications for Design

This project connects two of the strands of the framework with a constructive outcome. While this section started with conceptual goals of the design, clustering them and comparing them to the framework started to reveal how the qualities of intimacy and experience could be constructed in an object. Revisiting the arguments of Materiality and the importance of materials, and thinking of materials as computational composites ensured that the final material form of both the structure and the surface met technical and experiential criteria.

Revisiting the arguments of InterSensory mapping was perhaps the most useful application of the Framework. Especially with the concept of poetic mappings between senses that can evoke haptic responses. This could be explored more explicitly in design with technology. This is an important thing to consider because touch can never be simulated or substituted in remote systems. Also, physical touching between people is a precious experience, and trying to simulate or substitute it doesn't respect that. Haptic metaphors such as touch-vision (blur-touch) allow a tactile experience that is an alternative to real physical touching. I think this respects touch because it let's people experience a new mode of touching and feeling, reminding them of the importance of real touching.

Another interesting outcome is the triumph of analogue over digital in this interface. The technology strand of the framework proposes to view technology as something that has to be constructed. Conceptually, this opens the design thinking space to look at all sorts of technologies and selecting those which best support the experience. This project showed how visually rich and engaging interfaces can be made without having to use a computer. The same experience would probably not have been possible by using regular computational devices, such as keyboards, LCD screens, or web-cams. When tactile or sensual experience is the main goal of the design, the most intriguing solutions blend the high-resolution experiential value of analogue materials with the interactivity of digital systems.

CHAPTER 7: STAY IN TOUCH

7.0 Design Objectives

The *Stay In Touch* case-study inverts the situation in *Keep in Touch* examined in the previous chapter by exploring situations where people are co-located in a space but are separated by a physical structure. The goal in the prototype *Stay in Touch* was to create an interface that compelled strangers to connect with one another through touch. There are numerous obstacles and challenges that this experience design overcomes. First and most importantly, it is not customary for strangers to have physical contact with one another. In many situations, people go to great lengths to avoid slight and accidental contact with another person. The interface needs to be designed to be reassuring and inviting. When participants trust the design they are able to release inhibitions allowing them to touch or make contact with another person. In order to achieve this, the design does not require individuals to touch or make physical contact with each other unexposed. Rather, they make contact with each other through two layers of fabric. Since our hands have the ability to feel and distinguish objects underneath another layer (see *Volume Touch* in chapter 2), people can still feel other through the fabric while a layering of materials provides a soft boundary providing a cover of anonymity and safety. Once people feel safe enough to interact with the piece by touching another person, then the interface needs to be engaging so that they can continuously explore their interaction through touch (Figure 23).

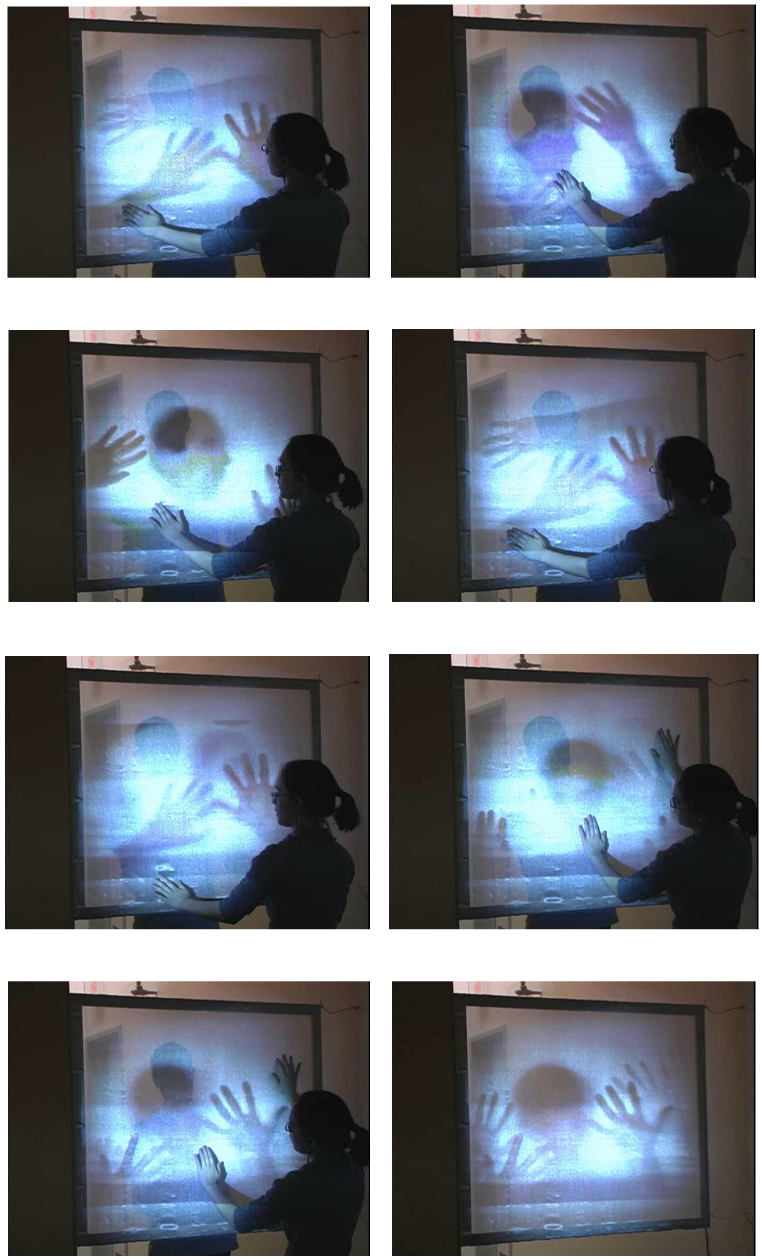

Figure 23: Screenshots of two people interacting

Another design challenge beyond the obstacle of overcoming cultural bias and the accompanying apprehension of touch is to provide the participants with feedback. Participants require cues to indicate: 1) that there is someone behind the fabric, 2) where their hands are located and 3) what their actions are. At the same time, if there is total visibility of the identity and actions of the other user, the experience will be less interesting and the cloak of anonymity will be compromised. The second goal of the interface then, is to provide appropriate visual cues of the position of the interaction partner while ensuring that not too much of transparency is revealed (Figure 24). The goals of ambiguity and legibility need to be balanced in order to provide an inviting, evocative and satisfying interaction where touch plays a central role in expression.

Figure 24: Two strangers on opposite sides of a fabric touch each other to interact with the piece. They can only see a partial shadow of one another.

A major technical goal is to create an input device that requires simultaneous multi-touch input on both sides of the fabric. This is unique since all other touch-activated input-devices require input on only one side of the surface. Since there is a person on both the front and back of the fabric screen, computer-vision approaches are not feasible because of occlusion. Much like *Keep in Touch*, this experience necessitates the creation of a new sensing and input device. The touch screen is actually a layer of two fabrics and can sense 48 distinct locations.

Finally, another goal was to create the visual design of the projected image to conceptually reinforce the act of touching. Once the participants' touch each other, an image of a body fades in. The body-part that is projected is selected in order to align with the location of the participant's touch. A body part is projected overlapping the location of the participants' hands no matter where they contact each other on the fabric surface.

This case-study exemplifies the *Technology* and *Materiality* strand of the framework. Since many of the design goals for the experience are solved through the creation and manipulation of conductive fabrics and multi-input sensing.

7.1 Design Framework Spectrum

The outcome of the first case-study *Keep in Touch* reviewed in the previous chapter, inspired a deeper investigation into the *Materiality* and *Technology* strands of the design framework in this second case-study *Stay In Touch* (Figure 25). The key design principles from the *Materiality* strand argued for interaction designers to have a closer relationship with the materials they create with. This led to a renewed investigation into the affordances and technical capabilities of conductive materials. Furthermore, the key argument of the *Technology* strand was that designers could *create* a new technology to support and nurture the experience of their artefacts. The design implications of these two strands are woven together in this chapter to describe the creation of a novel input device to support tactile interaction among strangers co-located within a space.

Figure 25: This case-study exemplifies the *Technology* and *Materiality* strand.

7.2 Materiality Strand

In the Materiality strand of the framework (see chapter 5), it was also argued that a close and intimate relationship with materials can inspire new design explorations similar to the process exemplified in crafts and traditional design. The *Stay In Touch* case-study exemplifies this principle because the main technical innovation of the input device was a direct result of investigating and taking advantage of the material structure and composition of conductive fabrics. The experience and design of this interface is specific to the material used. This section will describe how the material influenced and guided the design process.

7.2.1 Material Structure

The primary technical innovation in this design is the implementation of a simultaneous multi-user touch screen. This requires that the same location on the screen grid is touched simultaneously by two different people on either side of the screen. This capability is made possible by the specific conductive fabric used in the design. Other popular approaches to input, such as computer-vision, would not be technically feasible because people stand on both sides of the fabric blocking the frame for analysis. This project began by sourcing different conductive fabrics and yarns to explore their affordances and limitations. Exploration was necessary because manufacturers use different methods for creating conductive cloths. For this project, a type of silk organza was identified that used metallic threads as the warp of the cloth. The metallic thread was then interlaced with silk as the weft running in the other direction. The end result is a mesh cloth with conductivity travelling in only one direction. The other direction was woven using silk and therefore was not conductive at all. In order to create simultaneous input, two pieces of the fabric were criss-crossed and layered on top of each other with a 1” gap in between. Here, conductivity travels along the X axis of the first layer, and along the Y axis of the second layer (Figure26).

Figure 26: The fabric screen installed in a hallway. Each side of the screen is laced with conductive fabric.

These two axes can give location and positioning data when part of an electronic circuit is activated through touch. The resolution of the touch screen depends on the number of input ports the host microcontroller can support. Finally, the two pieces of the fabric were attached to a wooden frame and installed in a hallway. The layering of the fabric also helped to obscure vision through the screen.

7.2.2 Division of Touch Areas

One of the main objectives of the design was to encourage strangers on opposite sides of the fabric to continually explore connection with one another in a continuous manner through touch. While using fabric does have this affordance of stroking, the interactivity also needs to have repertoire of tactile input to reward and encourage active-touch. In this design, the frame was divided into 48 unique touch-points using an 8 x 6 matrix (Figure 27). Each of these 48 locations gives a unique command to the host-microcontroller, and up to 3 simultaneous locations can be sent at once.

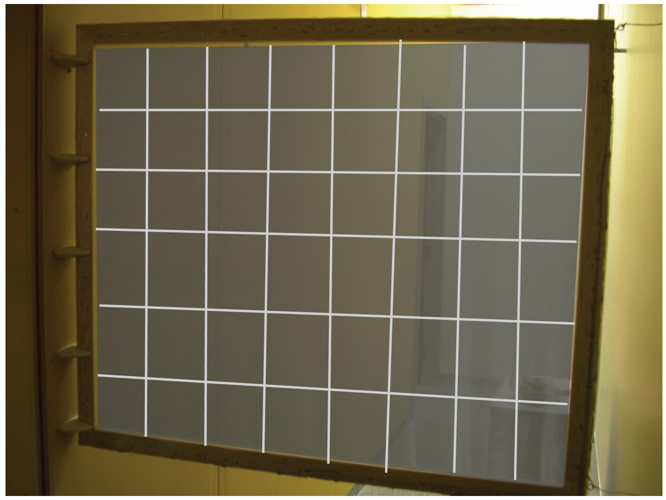

Figure 27: Division of the touch input areas is an 8 x 6 matrix shown here digitally superimposed on the fabric.

Figure 28: The location of their touch prompts an image to fade in underneath their hands

The location of each touch quadrant was mapped to a database of images which faded in and out when people touch the same location simultaneously and then release contact (Figure 28). The images were cropped and framed photographs of various poses of the human body. The mapping criteria is selected to ensure that a body-part of the image fades in underneath the user's hands. Everywhere that the touched each other, a different image of a body would fade in. This interaction design heightens the awareness of touch and presence of the other person. Since the fabric can support 3 simultaneous inputs, the participants can use both hands to explore the fabric, which enables two different images to fade in simultaneously.

7.3 Technology Strand

This case-study also exemplifies one of the principles from the *Technology* strand. In Chapter 4, it was argued that technology can be applied beyond its use as a design tool. Technology can be explicitly *designed* as a direct contribution to experience. By adopting this co-constructive perspective technology is expanded beyond a deterministic force into one that is explorative and malleable. Designers should have the ability to explicitly design technology in order better create the experience of the interaction. In this case-study, the experience of touching a stranger through a fabric led to the development of a novel input technique and device. The materiality portion of this chapter described how this was achieved because of the compositional structure of conductive materials. This next section describes the process of creating a sensor-based technology system that allows multiple tactile input.

7.3.1 Multi-Input Sensing

The main technical challenge for this design is developing a sensing-based system that could detect and respond to the multiple contact points of the fabric screen. To accommodate the technical requirements, a regular computer keyboard was repackaged to accept the touch commands from the fabric. In the first iteration, individual strands of wires were soldered directly on the fabric and connected to the computer via the keyboard interface (Figure 29 & 30).

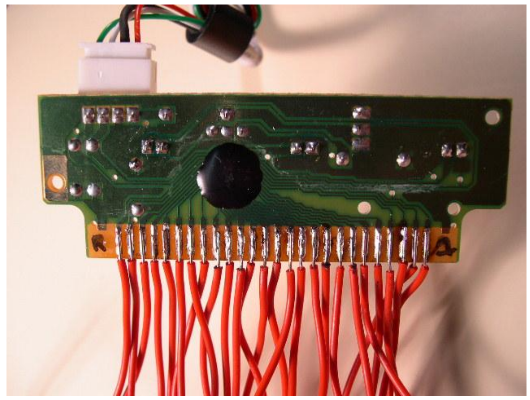

Figure 29: Matrix encoder of a keyboard that was repurposed for the design.

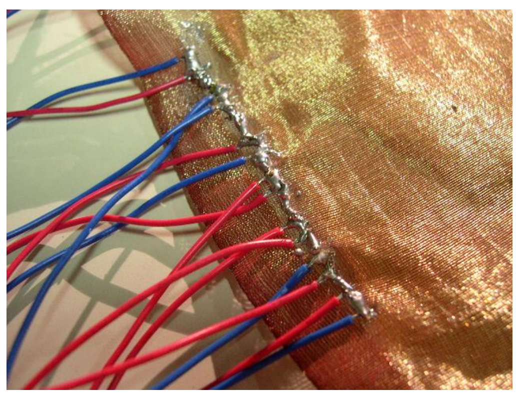

Figure 30: Wires soldered to the fabric are then sent to the encoder chip.

This proof-of-concept prototype demonstrated the viability of this approach because the sensing was robust, fast, and allowed multi-input. In the current prototype, metallic button-snaps replace the wires since they result in a much cleaner look (Figure 31). Wires are then soldered to the button snaps which transmit data through the keyboard encoder-chip back to the computer. Once connected to the computer, the fabric screen sends different letters or numbers which can then be used to develop software or visual applications because every development programming language has built-in capabilities to respond to keyboard events. In other words, the end result is a large fabric keyboard that requires simultaneous tactile input. The main advantage of this approach was that the device is portable because it can connect and immediately work with any computer. Also, this approach can be generalized to develop a wide variety of new and unique input devices.

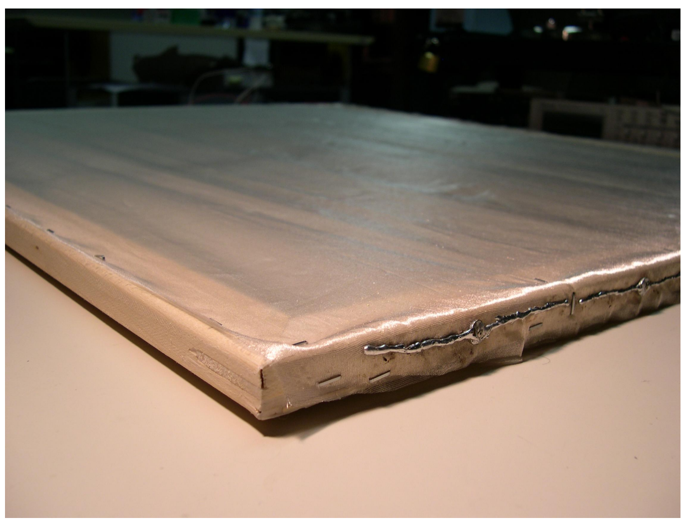

Figure 31: The final prototype with a neater wiring and electronic design

7.4 Implications for Design

This case-study shows how understanding low-level structures of materials and technologies allows the designer to manipulate and craft new interaction designs and create new input devices to support them. The design principles of the *Materiality* strand had an important influence in the design. For example, this design would not have been possible without a deep knowledge about the material composition and how the threads of the fabric are woven together. This is a direct result from a careful and intimate relationship with discovering the affordances and capabilities of conductive fabric.

The fabric gave enough cover and obscurity so people would be invited to touch each other. This would not have been possible if the design used a clear acrylic screen for example because the hardness and coldness of plastic does not afford warmth and intimacy. It would have been a harder experience to nurture because there is no anonymity and safety. However, the material in this design invited people to explore the fabric with their hands, and provided a veil to allow them to feel each other through the screen. Also, the selection of images and how the strategy for how they are presented further nurture tactile exploration and awareness. This prototype is another example of the effectiveness of dampening visual cues in order to increase the sensitivity of tactile interaction, and the ability to use materials to increase the awareness of touch and presence.

Also, this case-study reinforces the main arguments in the *Technology* strand since this project led to a new type of touch interaction and thinking about tactile input devices. Normally, a touch screen will only have one surface for input. However, in this case-study, the input device has two input surfaces that need to be activated simultaneously by two different users. This novel type of interacted directly resulted from studying and understanding the composition and threading of the conductive fabric. The structure of the weave was also crucial in this interface. The fabric's warp consists of strands of metallic thread while the weft was silk. This composition allowed signal data to flow in only one direction. By crisscrossing two layers, it creates a grid that allows for location sensing when touched. This interaction is only possible with this material structure, and was crucial for the development of the interface. The materiality strand of the framework calls for a return to study the material properties of digital systems. By studying the physical weave of this conductive material, the structure itself was used as part of the design. Replacing this material with another conductive fabric will quite possible destroy the sensing technique, as the actual stranding of the cloth may be different. This shows how important it is to understand the material of design right down to the composition of the threading, because by doing so, it can be used to create new possibilities for design.

The crisscrossing of the layers allowed for essentially, a large keypad input, albeit built with fabric. Since the electronic circuit is no different than a regular keyboard, repurposing a keyboard-matrix chip to encode the data from the touch-screen into keyboard events to the computer was the optimal solution. The advantage of this approach, other than simplifying low-level commands, was that keyboards are actually multi-touch devices. A keyboard can send up to 3 distinct commands to the host computer, this allows for commands such as SHIFT + letter for capitalizing, and other commands like CTRL A, etc… In this interface, people can touch two different areas with their hands, and two images will fade at the same time. This approach for developing input devices is advantageous because the fabric screen can plug into any computer and start working immediately. Also since the keyboard method is a robust, fast, and multiple-input interface, this approach allows designers to develop a wide variety of tactile input devices by focusing on the interaction and the experience without worrying about technical or electronic issues. This is another example of how by understanding the low-level properties of technology, allows the designer to manipulate and craft the technology to enable new interaction designs.

This case study illustrates how the *Materiality* and *Technology* strands of the framework can lead to new tactile input device designs. This is revealed through the design process of studying the structure of conductive fabrics, and experimenting with how to repurpose existing input device (keyboards) in order to make the interaction more robust and quicker to build. These two strands often seem to blur in this project because of the close dependency the material has on the technology. Lastly, one of the startling outcomes was the potential of reusing the keyboard-sensor as a platform to explore more tactile and touch based interfaces and experiences. This led to the inspiration for the final case-study which explores creating the technological infrastructure for designing enrich and engaging tactile interfaces.

CHAPTER 8: HD TOUCH

8.0 Design Objectives

The primary objective of the final case-study emerges from the outcome of the *Stay in Touch* project. Specifically, the concept of designing a *platform* for tactile interactions rather than designing for a specific experience. In this case-study *HD Touch*, the overall objective is to *design the technology* for next generation touch and tactile interfaces. The technological platform should provide designers with a rich repertoire of tactile input for developing applications, while being flexible enough to anticipate future needs or scenarios. Specific objectives and observations need to be determined in order to limit the scope of the platform design. These objectives articulate the *Semantics* and *Technology* strands of the design framework.

The first goal is to reconsider the display technology used in touch sensing for tactile interfaces by turning attention away from projected displays to physical displays. This objective is influenced by the *Materiality* strand and is a more generalized goal based on the results from the previous case studies. The first two case-studies created specific experiences that were directly influenced by the material affordances of the touch screen. As with most interfaces, projection displays are the most common component in tactile-interfaces. The first two case-studies use projectors with fabric materials to increase the sensual nature of the tactile experience. This project twists the *Materiality* strand slightly by focusing on the actual material of the ‘pixel’. However sensual fabrics may be, when interacting with these computational systems, the user touches and feels a material that is not the screen itself. The user does not physically touch a pixel or a computational artefact. The closest experience people have with touching computation is feeling the heat emitted from the projector’s light source. However with LCD screens, since the pixel is embedded inside the glass panel, when someone touches the glass, they are actually touching the liquid crystal pixel. In essence, touching a LCD panel feels more responsive, fluid, and direct compared to projected surfaces. Furthermore, the liquid crystal pixels are etched inside glass. The top of the glass is then sprayed with a polarizing coating and an anti-glare coating of paint, which gives the screen a soft, rubbery, and matte finish. Anyone who touches their laptop monitor can attest to the softness, warmness, and fluid feel of LCD screens. This basic difference between projectors and LCD monitors motivated the attention towards physical displays.

Another objective of this case-study was to design a tactile input device that expands the repertoire of tactile interaction so that the platform could be used for a wide host of cutting-edge applications. This requirement derives from the *Semantics* strand which looked at the meaning and mechanics of gestures and touch input. As a direct result of the technology, this led to the inclusion of unique gesture-sets including the ability to detect hover gestures where a person’s hand floats above the surface and does not make direct contact. Also, this case-study reflects a shift in orientation from vertical to horizontal surfaces bringing about recently identified issues in touch interfaces. Tables afford objects being placed on them changing the dynamics of the surface. Tactile interactions no longer involve the person and the surface but include interactions with objects and artefacts placed on the table. One technical goal then is to provide object tracking capabilities so that interactions which include the surface, the person, and objects can be possible. Lastly, since the platform should anticipate future interactive scenarios and applications, one particularly possibility, that of networking and connectivity applications, is developed and described

Altogether, this set of objectives requires a cohesion between the *Semantic* and *Technology* strands in order to design the appropriate technology for the platform, and to categorize the large set of desired gestures and inputs.

8.1 Design Framework Spectrum

This case-study, *HD Touch*, completes the design framework by emphasizing the *Technology* and *Semantic* strands (Figure 32). The primary purpose of this project is to develop a platform for designing next-generation ~~of~~ touch interfaces. The *Technology* strand provides the context for questioning conventional approaches to touch interfaces, while the *Semantics* strand provides the context for describing and selecting the range of tactile and gesture input.

Figure 32: This case-study exemplifies the *Semantics* and *Technology* strand.

8.2 Technology Strand

The *Technology* strand of the framework provides the context for questioning conventional approaches to tactile interfaces that use projectors for the display surface. Surprisingly, very little inquiry and effort has been invested into investigating the potential of LCD and other physical displays for tactile surfaces. This is the case despite the better visual performance, cost, and resolution that LCD monitors afford over projectors. The first phase of this project began by investigating the literature and the field by learning about the manufacture and assembly of LCD displays. The first prototype dismantled and repackaged a 19" LCD monitor into a tabletop interface, and then a larger 37" LCD TV was also dismantled and repackaged into a table. This exploration of the technology led to discoveries described below and resulted in the multi-touch LCD platform.

8.2.1 19" Prototype

The basic concept of the platform is to combine the robustness of IR web cam tracking (Han, 2005) with the high-resolution of an LCD monitor. First, a 19" wide-screen monitor was purchased and dismantled into its constituent electronic parts (Figure 33). This step involves unfolding the electronic components from behind the glass panel so that there is a clear view from behind the LCD. This folding of the electronic components is a manufacturing technique to make the profile of the monitor as thin as possible. Once unfolded, a small table structure (Figure 34) was built to house the LCD panel and the electronics (Figure 35). This re-arrangement of the components is a crucial and necessary step.

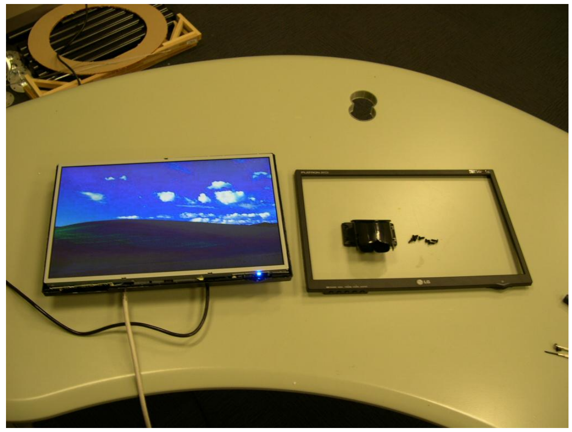

Figure 33: Dismantling 19” LCD monitor.

Figure 34: LCD repackaged into a small table.

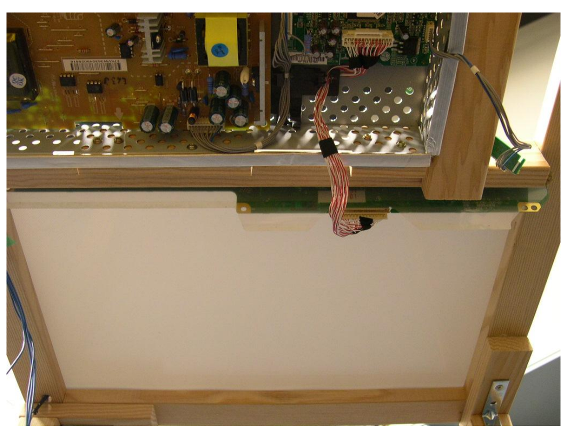

Figure 35: Underneath the table showing the unfolding of the components

The next step is to inspect the filter chain the manufacturer uses to manipulate the brightness and light-levels of the monitor. An LCD pixel is made from three sub-pixels of red, green, and blue filters. Behind these filters are liquid crystals, which twist according to an electronic current. This modulation allows more or less light to pass through the filters. Since the pixels consist of filters with liquid-crystals, they do not emit light. Instead, manufacturers create a sophisticated backlight to illuminate the LCD panel. To increase the brightness, diffusion, and contrast-ratio of the screen, various filters are used between the backlight and the LCD panel. This filter-chain varies according to the manufacturer but the basic standard includes a diffusion filter, a fresnel lens filter, and opaque-white reflective filter. It is this final opaque-white layer that needs to be removed so that there is a transparent optical path for IR light to shine through. Once the visual pathway has been cleared, an IR illumination and web-cam system can be installed.

For illumination, IR LED's are lined along the length of the bezel of the LCD surface. The LED rail creates a cloud of IR light over the surface of the screen. When a hand hovers or touches the screen the light reflects downwards through the screen where it is then capture by an IR sensitive camera.

While this method is suitable for finger and hand tracking, another IR system is used to accommodate object tracking. The typical approach for object tracking is to print a fiducial (fiducial pattern is a 2D pattern for object recognition) pattern on a piece of paper and attach it underneath an object. IR light then reflects off this pattern back to the camera. However, since this platform uses a side-illumination technique, the common approach for object tracking will not work. Instead of this approach another strategy is employed. Each tangible object has an embedded IR LED, which shines light down to the camera. The object then has a plastic stencil in the shape of a fiducial which shines light in that specific pattern. The camera then captures this pattern, which is the processed by the computer using pattern-recognition software to discriminate different objects. For multiple objects, different stencils need to be created.

In the end, the first prototype of the new platform consists of a 19” LCD monitor with an IR camera that can detect both fingers and objects placed on the surface (Figure 36 and Figure 37). The success of first prototype demonstrated the feasibility and viability of the LCD approach and encouraged further investigation into larger LCD monitors.

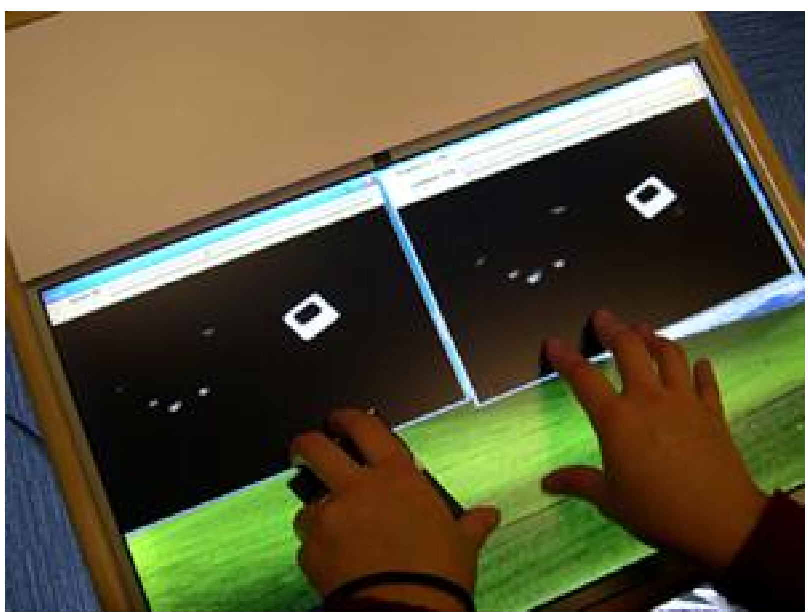

Figure 36: Fingers and objects are recognized by the camera

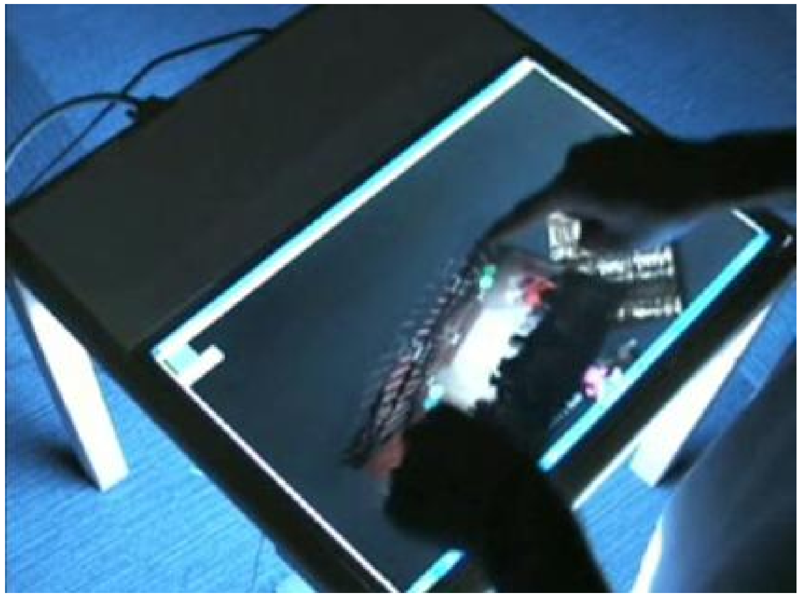

Figure 37: Snapshot of the first prototype in action

8.2.2 37" Prototype

The successful results of the first prototype encouraged developing a larger tabletop interface. This second prototype consists of a 37" LCD TV with full HD (1080p) resolution (Figure 38) and is large enough for multiple users to interact with. The process for building this prototype is similar to the first prototype only on a larger and more involved scale. Again, the first step requires dismantling the LCD TV rearrange the components in order to clear the visual pathway for the IR light. This process revealed that larger monitors are manufactured and assembled quite differently than smaller computer monitors.

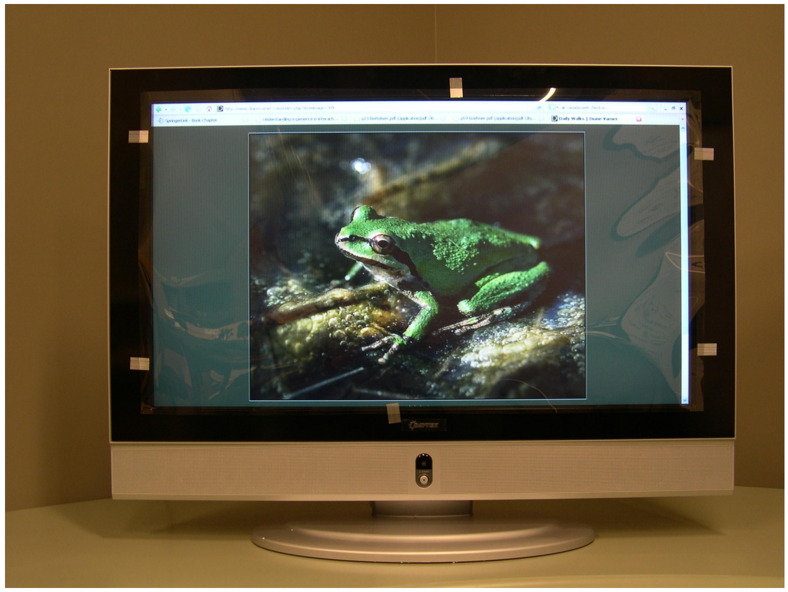

Figure 38: a 37” LCD TV before dismantling

The main difference is with the backlighting system used to illuminate the screen. Large monitors use an array of cold-cathode fluorescent lights (CCFL), which are installed directly behind the LCD panel (Figure 39). This backlighting system requires a different approach to the structure of the table design. The table structure now needs to enclose the lighting-rail as a separate entity in the assembly (Figure 40).

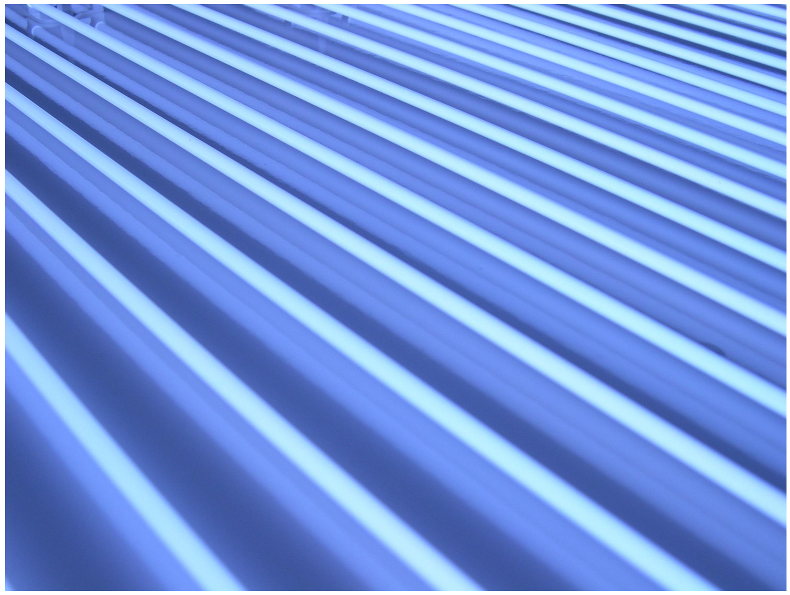

Figure 39: An array of CCFL used to illuminate large LCD screens.

Figure 40: The backlight separated and reintegrated into the table structure.

Once the components of the screen have been rearranged and attached to the table structure, the same IR lighting scheme is used for the object and finger sensing. Once again, a rail of IR LED's are lined up along the two lengths of the panel, which illuminate the surface above the screen. When a finger touches the screen, a portion of this light reflects downwards through the screen to the camera (Figure 41).

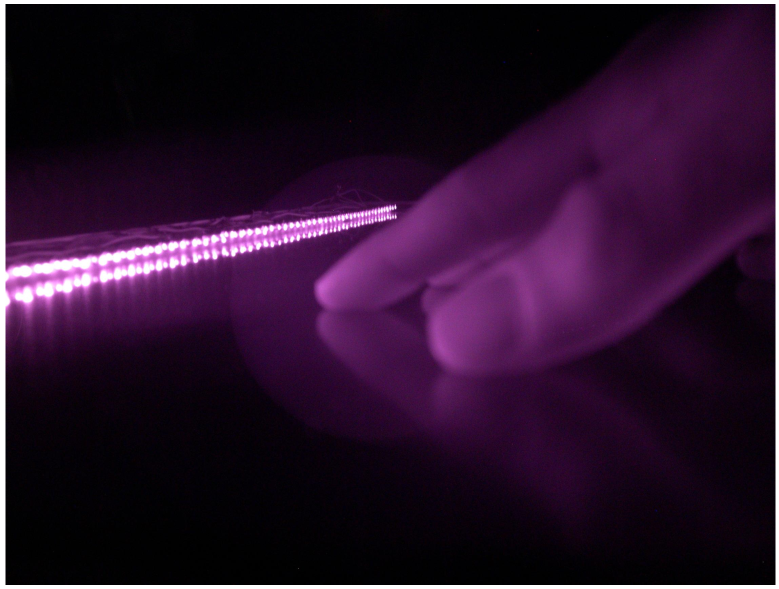

Figure 41: IR light reflects off the hand downwards through the screen.

The success of the large tabletop prototype affords a new technological platform for tactile interfaces, which utilize LCD physical displays as the interactive surface. LCD technology has inherit qualities which improves the user experience over projector based systems, including a soft and warm glass surface that feels inviting to touch, and a hi-definition pixel resolution. In the next section, the affordances of the technology and the sensing data is processed using basic computer-vision algorithms to generate a rich tactile input library consisting of finger gestures, hovering, object recognition, and networking capabilities.

8.3 Semantics Strand

The *Technology* strand motivated the creation of a new sensing surface for tactile input. The large tabletop prototype can detect fingers and objects that are placed on the surface. This next section on *Semantics* begins where *Technology* strand ended. Now that the table has the technology for detecting contact and objects, the principles from the *Semantics* strand can be applied to determine what set of gestures, events, and actions the table should detect and provide. This section begins by describing how the camera signal is processed to provide various tactile input, and outlines the overall input-library.

8.3.1 Sensor Data Chart

The first step in creating the input-library is processing the camera signal. The raw image signal from the camera undergoes a basic background subtraction and a threshold filter in order to output data appropriate for multi-touch and tangible interactions (Figure 42). This data creates three unique sets of interaction techniques. The first data-set allows for tracking of fingers and objects as they make contact and are moved on top of the surface. The second data-set enables the system to detect if a hand or an object is hovering over the surface. The final data-set allows us to determine which object is being grasped or held by the user. While the first data-set is standard for multi-touch and tangible interfaces, the second two are unique to this system and can enable novel interactive techniques. All together, the library of input techniques affords the platform a powerful and rich repertoire of tactile input that is outlined below:

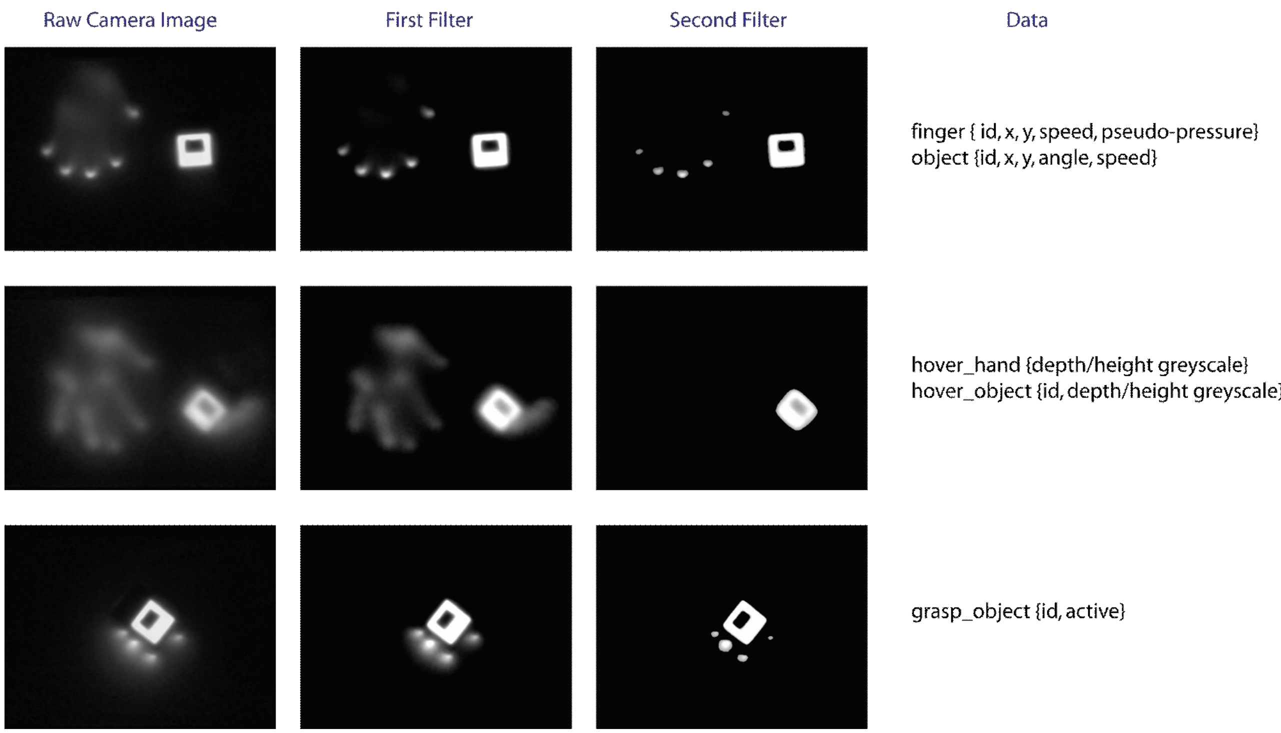

Figure 42: This chart shows how the camera signal is process to allow for the wide range of input techniques: this include finger and object tracking, hover tracking, and grasping.

8.3.2 Tracking on Surface

Finger Tracking {id, x, y, acceleration, area}

The system can track the user's finger, its location, and calculate the speed and area of each blob. This is standard multi-input data.

Object Tracking {id, x, y, angle, acceleration}

The system can track rectangular geometric objects when they are on the surface. The fiducials need to be rectilinear so the system can distinguish a finger blob from an object. This allows the system to track multiple objects with different patterns, their location on the screen, angle, and acceleration.

8.3.3 Hovering over Surface

Hover Hand { range of grayscale to white, x, y }

The system can distinguish how far away the user's hand is from the screen by analyzing the grayscale map of an image, as well as location.

Hover Object { grayscale, id, x, y, angle, accel.}

One unique capability of the system is to accurately identify different objects as they are being placed or hover across the surface. This information can allow future applications to anticipate which tangible is being added to the surface, or to allow tracking of tangibles even if the user does slightly lifts the object from the surface.

8.3.4 Object Grasping

Object Grasping {object_id }

Another unique capability of this system is its ability to identify which object the user is currently grasping or holding. This lets the system know which object is active.

8.3.5 Network Tables

The tabletop platform now has an impressive range of tactile and object input available for interface development. However, another objective of this case-study is to anticipate future needs or scenarios for interface development. This next section anticipates the scenario when two, or more, tabletop surfaces are connected via the internet. In this scenario, objects and gestures performed locally on one surface can interact with gestures and objects on a tabletop in another location (see Figure 43 as a sketch). Distributing these physical events among different locations causes unique and challenging issues to emerge. Among the plethora of issues these scenario reveals, the *Semantics* strand of the framework helped to focus this project on two: 'Embodied Presence' and 'Virtual-Object Collision'. Embodied presence is the problem of not knowing or not having enough cues to determine the location and orientation of the remote user. This issue was explored in the first two case-studies where the other person's shadow was used to provide a poetic sense of presence. However, this issue becomes problematic with generalized input-devices such as *HD Touch*. The second issue is the lack of haptic feedback when remote objects collide with each other. Since, the remote object is visually represented, there is no embodied response when a physical object collides with a virtual one. Before providing some initial responses to these issues, a proof-of-concept prototype has to first be demonstrated to verify the feasibility of this exploration.

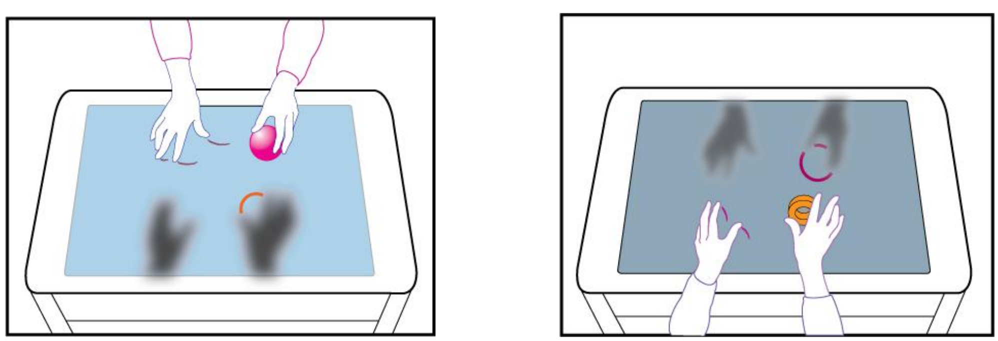

Figure 43: A sketch of two tabletop surfaces connected over the internet.

8.3.6 TableTop Over a Distance

The objective of this first experiment is to resolve some of the technical issues of remote tabletop interaction. In this set-up, two identical tabletops connect with through a custom server-client protocol to transmit data between the surfaces. As a proof-of-concept, two objects are placed on each table and the outline of each object is shown on each table (Figure 44). Moving around an object on one table will cause its corresponding shadow to move in a 1:1 direct relationship on the other.

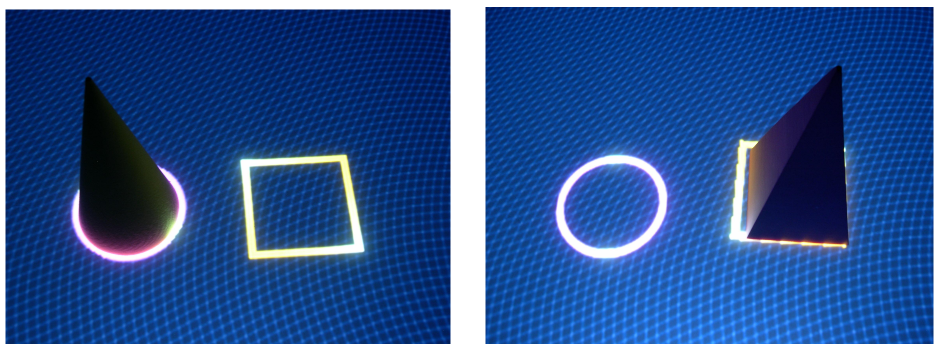

Figure 44: Two separate tables connected over a network. The outline of each object is shown on both tables.

This experiment demonstrates the feasibility of expanding the range of interactive techniques to include networking and remote interactions. Now it is possible to explore some of the interface issues that emerge from networked tabletop surfaces. The next section of the *Semantic* strand will focus on two issues: Embodied Presence and Virtual-Haptic Collision.

8.3.7 Motion Shadow

The concept of motion-shadow is proposed to resolve the issue of embodied presence. It became clear after the first network prototype that there is an issue with being aware of the presence of the remote user. In the first experiment, the only visual feedback given to the user is the movement of their object or cursor: specifically, with an outline of the remote object or finger. In order to increase awareness of the other user, another experiment implemented the concept of ‘Motion Shadow’. The concept of ‘motion shadow’ is to show the shadow of the remote user’s arms and hands only when it is moving (Figure 45 is a sketch). When a gesture is performed or an object is grasped and moved, the person’s shadow is shown on the remote surface. Once the motion stops, the shadow disappears. This concept has two key advantages. First, it reduces latency because instead of constantly being transmitted, video-data is only sent during movement. Secondly, it creates a compelling foreground-background relationship between the interface and the intention of the remote user. Against the backdrop of stillness, the gestures and actions of the remote user become sharp and easier to see.

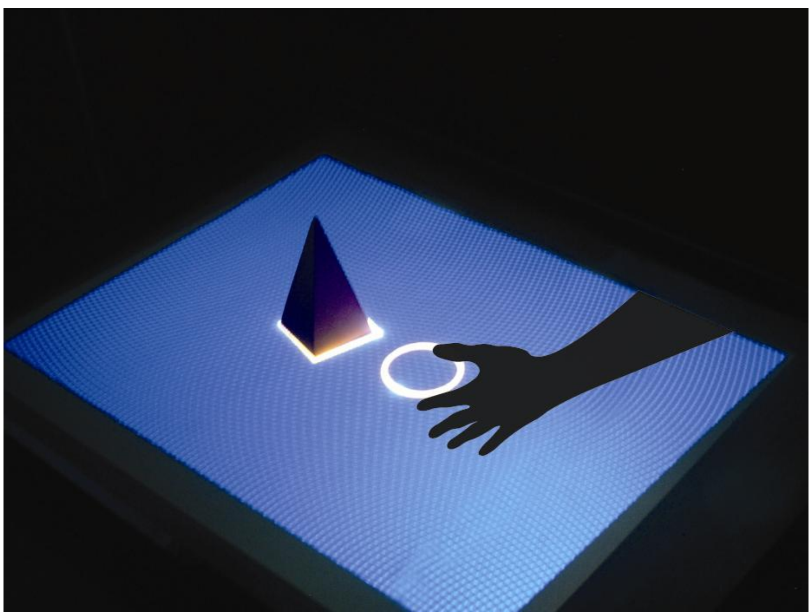

Figure 45: Motion Shadow Sketch: the shadow of the other user is only shown in it is moving.

8.3.8 Virtual-Physical Collision

The second design issue with network tabletops is the issue of collision detection between objects and people. In the physical world, when two objects collide they bump with other creating physical and audio feedback. However in this system, there is no physical or tactile cue when a physical object collides with a virtual object. The concept proposed to solve this issue is to embed small vibrating motors inside each object so that it provides a small haptic response when a physical piece hits a virtual shadow (Figure 46 is a sketch). In this implementation, two objects were made with an embedded microcontroller, Bluetooth antenna, and a vibrating motor. In this scenario, when a physical object collides with the virtual representation of the other tangible, both physical objects will vibrate. The person who initiated the bump will feel a nudge, whereas as the remote user will see their object vibrate and hear it buzz.

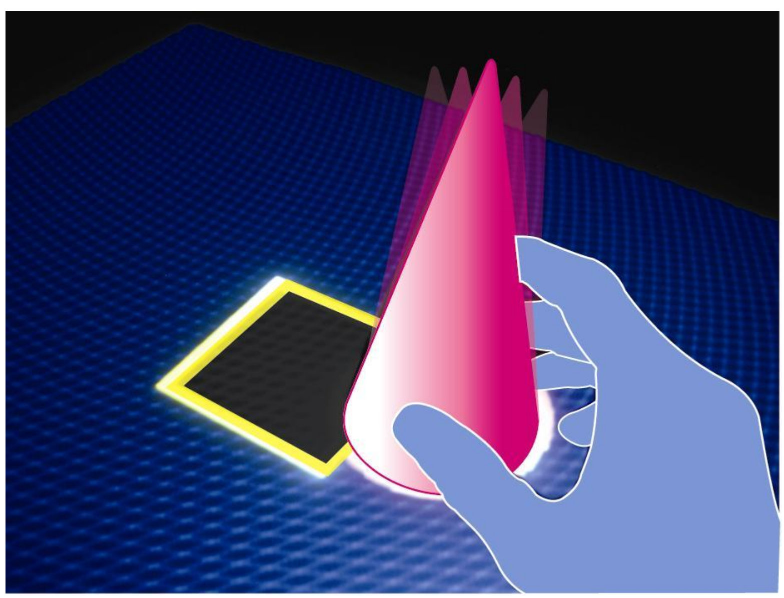

Figure 46: Virtual-Haptic collision: embedded vibrating motors in objects nudge when a physical object collides with a virtual one.

The ‘motion shadow’ and ‘haptic collision’ are implementations of two solutions to the large number of design issues that arise with networked tabletop interactions. As part of the larger context of *Semantics* they indicate a trend away from local gestures and touch input, and towards multi-modal gestures that need to pan across space and time.

8.4 Design Implications

The issues raised in the first two case-studies regarding the importance of understanding the material affordances for enriching aesthetics and user experience inspired the exploratory research into the assembly and manufacturing technology of LCD glass panels. This process of disassembly and reviewing technology led to the discovery of being able to use LCD’s as a sensing surface. This shows the practicality of applying the *Technology* strand of the design framework by questioning assumptions and exploring new avenues. In this case-study, the common use of projectors for tactile-vision based displays is questioned and challenged. The result of this is an innovative new technique for tabletop interactions, which promises to advance the field of tabletop and multi-touch interfaces by making the technology more mainstream and economical.

The successful implementation of LCD as a sensing surface is the technological basis for a platform for designing rich touch based interactions. The *HD Touch* platform builds on the standard gesture-set of multi-touch input discussed in the *Semantics* strand by adding *hover* and *grasp* input. Also, since objects are placed on tables, the platform can also track specially created objects that emit a specific fiducial pattern. All these capabilities afford the *HD Touch* platform with a rich repertoire of tactile and tangible input combined with a large and high-resolution visual screen with strong tactile properties. The *HD Touch* platform is a powerful input device for generating next-generation tactile and tangible tabletop interactions. *HD Touch* is a milestone in this class of input device because of the wide range of input it supports, and because of the many technological design issues it resolves.

Lastly, another promising avenue for future research is the capability of networking interactive tables over the internet. This portion of the project only scratched the surface of the design issues involved in tabletop telepresence. However, the two identified issues of ‘embodied presence’ and ‘virtual-physical collision’ indicates a burgeoning opportunity to apply other stands of the framework to explore and resolve new questions of tactile presence, communication, and intersensory mapping that network tabletop scenarios create. Also, because the design scenario and issues are drastically different than the first two-case studies, further work in network tabletops may also refine or expand the framework as new conceptual themes begin to emerge and evolve. This case-study ends with a series of newer questions and design points-of-departures for future research and development.

CHAPTER 9: CONCLUSIONS

9.0 Summary

This thesis began with the observation that the value and respect for the experiential, aesthetic, and emotional qualities of human-computer interaction has increased, creating a space for research methods that support designerly knowledge. One such method is the reflexive process of creating an object, reflecting on the process, constructing a theoretical framework, and then applying the insights back into practice. This method formed the basis for the theoretical framework outlined in chapters 2 through 5. Throughout the process, different touch prototypes were made and their design process was analyzed. Emerging from this analysis was a theoretical framework for touch interfaces. This design framework for tactile interactions consisted of four interconnected yet unique conceptual strands:

The first section of the thesis begins in Chapter 2. This chapter introduces the *Intersensory* strand which proposed the concept of 'haptic metaphors' as poetic and thoughtful cross-sensory mappings emerging through technology. This design concept is effective for creating unique tactile experiences which are evocative, metaphorical, and sensual.

In Chapter 3, the *Semantics* strand provided an overview of the issues of encoding meaning from touch input, and then outlined the trend in HCI from basic finger gestures towards the use of more embodied and intimate gestures, such as caresses for communicating and expressing emotions and feelings.

Chapter 4 is the *Technology* strand which proposes a new perspective on viewing technology in design. Instead of regarding technology as an a priori component in the design process or as a tool for designing, this chapter suggested that technology is an entity that can be created through the practice of design itself. When applied to a design problem, this idea of *designing technology* means that the technical outcome better supports and nurtures the desired user experience.

The last strand of the framework, *Materiality*, is outlined in Chapter 5. This strand dispelled the myth of immateriality that pervaded some interaction design processes and methods. As an alternative, this strand asks for a return to the importance of materials in design. The return of materiality is crucial when considering the aesthetic and experiential qualities of touch interactions.

Woven together, these four conceptual strands outlined in Chapters 2 through 5 create a cohesive framework for touch interaction, which is then contextualized through three case-studies. Chapters 6 through 8 describe the design process and outcomes of three individual projects that each explore a different and unique set of questions emerging from the framework. Each project exemplifies a different pair of strands of the framework, and results in a different core contribution to the framework specifically and to HCI broadly. These contributions are presented in the next section.

9.1 Contributions

9.1.1 Prototypes as contribution

Each case-study from Chapters 6 through 8 has its own set of results and contributions which were presented in their respective chapters. In this section, the core contribution provided by each case-study is presented, providing a context for touch interaction that can be applied to the broader HCI design community.

9.1.2 Keep in Touch:

The main contribution of this project is the demonstration of the haptic-metaphor concept first described in the *Intersensory* strand. This concept is manifested in the interface through a poetic mapping of touch and blurred vision. The concept of haptic-metaphors is useful in interaction design considering the industry trend towards replacing manual buttons or tactile switches with touch screens. With these smooth touch-screens, many of the mechanical tactile feedback of buttons and keypads are lost. Instead of trying to recreate these affordances the haptic-metaphor concept allows for alternative tactile experiences. The strength of this concept is the fact that it is not dependent on a specific technology or hardware. Haptic metaphors require designerly approaches illustrating poetry and thoughtfulness from both the designer and the design process.

9.1.3 Stay in Touch:

The core contribution of this case-study is illustrating the value of materiality in interactive design. This principle requires that the designer have an intimate relationship with the material of their craft. Interaction designers can bring knowledge of their material, it's capabilities, structure, limitations, affordances and the affect and impact of material properties upon the final form. This principle is manifested in the design process and outcome of this case-study. The tacit knowledge gained from this process of investigating conductive fabrics was core to developing a new input-device which enabled the unique tactile experience in this case-study. The relationship between the designer and their material is common in crafts, arts, and older design traditions but is not emphasized in interaction design. This intimate relationship between the designer and materials can directly inspire and generate innovative solutions.

9.1.4 HD Touch:

The final case-study brings the value of technical innovation presented by the *HD Touch* prototype to the larger HCI community. While the technical innovation gives the project an immediate impact and relevance to the HCI community, its core and long-term contribution is the empowerment of design process and designerly knowledge. The primary source of inspiration for developing this technology was not economical or technical. On the contrary, the source was the quest to improve the user experience, and evolved out of questions of technology and materiality that emerged from the practice of design itself. The outcome of this project illustrates a pragmatic approach for designers to *design technology* focussing on its direct impact on experience, a goal which can only be reached through values set within the design process. Also, common in all the case-studies, is the repurposing of everyday and inexpensive technologies to create new and rich technical prototypes that are on par with industry leading corporations.

9.1.2 Framework Contribution

The results of this work also makes contributions to design practice through the development of its framework. The framework of emerged from a reflexive relationship with practice. The strands that make up the framework originally emerged from practice, but then also helped to inspire or guide further designs, which in return, helped to refine the framework. The process from which this framework is constructed is a useful example for other designers who are deeply rooted in the act of *making* but are also committed to understanding and communicating the theories and concepts underlying their work and creative process. Other designers can regard this thesis as a resource for building their own conceptual frameworks to better understand their own practice. The process of thinking and writing about practical work in this way is useful for practitioners who need both pragmatic principles to improve their craft, and also structures for describing their work.

9.2 Final Thoughts

As designers, we possess unique forms of knowledge. We communicate these ideas and concepts visually or tangibly in the form of sketches, images, models, and prototypes. Increasingly, there is a growing interest in other professions to understand this design process in order to apply it to their respective fields. However, there are certain attributes of design thinking that still evades non-designers. This attribute is the ‘designer’s intuition’. Throughout the design process, we develop and continually refine our ‘design intuition’. This intuition is a valuable skill to hone and nourish because it helps us to quickly select the best decision. Instead of rationalizing this intuition by attributing it to other factors, as a profession we have the responsibility to communicate, validate, and advocate our design thinking and intuition. Assembling theoretical insights and constructing a framework is one method that has been shown to be effective especially when designing interfaces that deal with questions of aesthetics and experience. Different requirements and different designers will have their own theoretical influences and need to develop their own frameworks. This ability to blend theory in the design process strengthens our profession, and empowers us as designers.

This thesis is as an exploration into the aesthetic qualities of touch interactions through a reflexive process of design and reflection. This process resulted in a conceptual framework for tactile interfaces that is articulated and exemplified by the design of three-case studies. The entire process led to a body of work and an expertise into the design and theory of touch and tactile interactions.

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