Engaging the sense of touch in interactive architecture

Ingrid Maria Pohl  
Design Lab  
University of Sydney  
Ingrid.Pohl@sydney.edu.au

Lian Loke  
Design Lab  
University of Sydney  
Lian.Loke@sydney.edu.au

ABSTRACT

Touch-based interactions with computing technologies have become commonplace in the last few years, from mobile phones to tabletop surfaces. The sense of touch however is not limited to the hand; the entire skin surface of the body is available for tactile interaction. In architecture, researchers are now investigating the potential of interactive surfaces for future architectonic elements, such as walls, floors and ceilings. Apart from the traditional focus on the visual and spatial design considerations of such elements, tactile interaction with interactive surfaces is of growing interest. We present an interactive folded surface as a prototype of future interactive architectural surfaces. We explain how physiological understandings of touch and tactile interaction informed the design choices of the prototype. Our work contributes to understandings of how the material properties and interactive behaviours of these new surfaces will afford new kinds of human experience centred on the sense of touch.

Author Keywords

Architecture, haptic interaction, interactive surface, touch

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Touch-based interactions with computing technologies have become commonplace in the last few years, from mobile phones to tabletop surfaces. Touchscreens embedded in consumer products have brought about a new paradigm of interaction centred around the pointing, swiping and pinching gestures of the fingers of the hand. The touchscreen style of interaction frames touch as a gesture. Where and how the hand touches the screen is the point of interaction that is interpreted as input to the interface. The sense of touch however is not limited to the hand; the entire skin surface of the body is available for tactile interaction.

In architecture, researchers are now investigating the potential of interactive surfaces for future architectonic elements, such as walls, floors and ceilings. Apart from the traditional focus on the visual and spatial design

considerations of such elements, tactile interaction with interactive surfaces is of growing interest. The sensual and experiential aspect of tactile interaction with surfaces takes on a new context when surfaces are designed with interactive, programmed behaviours. This challenge forms the basis of our research. We are interested in exploring how the material properties and interactive behaviours of these new surfaces will afford new kinds of human experience centred on the sense of touch.

In this paper we present an interactive folded surface as a prototype of future interactive architectural surfaces. We explain how physiological understandings of touch and tactile interaction informed the design choices of the prototype. The technical implementation of the prototype is then described in detail. We conclude with a plan of our user testing strategy, where we will evaluate the prototype in terms of the user experience.

RELATED WORK

The Physiology of Touch

Touching and being touched are two simultaneous aspects of our experience. There is an active and receptive component to our touch-based interactions with the world. We derive information about our environment through the sense of touch (Kern, 2009). The skin contains a mosaic of different receptors distributed throughout, which enable us to detect and distinguish between an immense variety of different stimuli. We can perceive the nuances in the textures, temperatures and densities of materials.

The high sensitivity of the skin is formed by the different kinds of receptors. The main class of receptors are the mechanoreceptors, which can be divided in four types able to sense and process special stimuli. Merkel cells in our skin enable us to feel shapes, textures and soft touch. They can also be found in hair follicles to signal drafts and light touch when the hairs of our skin are moving. The Pacinian corpuscles in the skin are responsible for detecting fast changing stimuli, vibrations in a frequency range of 200-350 Hz, and pressure. The vibration also plays a role in detecting textures and surface roughness. Meissner corpuscles are highly sensitive to vibration lower than 50 Hz (light touch) and can adapt rapidly. They are highly concentrated in our lips and hands. Ruffini corpuscles are slowly adapting and are placed in the subcutaneous tissue near our joints and in our hairless skin. They inform us about the position of our joints and the stretching of our skin. Two other classes of receptors are the nocireceptors, responsible for feeling pain and the thermoreceptors, which enable us to feel temperature changes. These cutaneous receptors are distributed
throughout our skin in varying density and form a precise spatial resolution. Temporal resolution also plays a crucial role in the perception process. Receptors send signals at the beginning and the end of a stimulus change. Based on the adaption speed of the stimulated receptors, this altering signal transmission is responsible for our loss of awareness during a continuous and constant stimulus application. All these receptors constitute the multimodal nature of touch. The specific haptic characteristics of a touched object or material are a combination of these various receptor classes and types. Furthermore the geometry and built shape of an object is a trigger for haptic evaluation. Together with the aspects described above, this forms our personal touch aesthetic.

In general the sensing modality of touch can be categorised into three main channels: kinaesthetic, tactile and haptic. Firstly the term kinaesthetic describes our bodily perception when we are moving; it senses the orientation and rotation of our muscles, joints and tendons. Secondly the tactile stimuli are applied on our skin, when we are passive. Thirdly haptic sensations are produced during the active exploration of an object (Loomis and Lederman, 1984). In addition to this intrinsic variety of different qualities, the sense of touch has also a strong correlation with the sense of sight. We tend to touch a seen object to confirm the expected material quality and shape.

**Interactive Architecture**

Architecture has traditionally dealt with the design and construction of static structures in the built environment. The notion of interactive architecture introduces temporal and dynamic concerns through embedding kinetic and interactive behaviours into materials and surfaces. Researchers are exploring how to include the body and the sense of touch in the design of novel interactive surfaces (Pallasmaa, 2005). The following examples of architectural interactive surfaces provide an outlook on how this interaction with architecture could look, or rather feel like. These prototypes provide a more holistic engagement of the user’s body and its haptic zones, since they have a much larger scale, than mostly hand sized, interactive devices in human-computer interaction (HCI).

'Dynamic Terrain' by Janis Pönisch is an interactive floor-like structure (see Figure 1).

The horizontal surface is responding in real-time to user preferences and can be controlled via a graphical interface. This digital manipulation of the physical space gives users the possibility to design the geometrical shape of their surroundings in a direct way. The user is lying on the kinetic surface with the entire body. The body is shifted into different positions on the surface, by its dynamically morphing form. Although it provides an innovative haptic output, this user-controlled manipulation does not allow the surface to autonomously re-shape itself. It is a predefined, predictable interaction.

The project ‘Slow Furl’ positions itself outside the tradition of static representations of architecture (Ramsgard Thomsen, 2009). The dimension of time in relation to action was a key concept in the design of this interactive wall. A membrane, loosely attached on a wooden, kinetic framework, is forming the wrinkled surface (see Figure 2). In the membrane, sensors are embedded, detecting the touching user. While the user can touch or sit between the folds, the wall also detects and interacts with itself. Therefore a continuous cycle of slow pulse and movement is created, involving the user in its tangible and delicate interaction process.

**Figure 1. Dynamic Terrain prototype**

**Figure 2. Slow Furl wall detail**

Such large-scale prototypes give us the opportunity to investigate bodily and haptic interactions, which are not solely focused on the hands. But so far haptic, interactive prototypes with an architectural approach are only using a fragment of the sensory bandwidth. The detailed resolution of such architectural surfaces is not comparable to our skin and is still in early development compared to achievements in touch-based HCI devices.

In HCI and engineering, haptic interaction has been concerned with the problem of how to simulate the real-world forces that provide us with information on our actions in the world (Kern, 2009). Simulated force-feedback on operations that occur in virtual space need to provide a sense of the simulated material and mechanical properties of the virtual objects encountered. For example, the Phantom Haptic Device tracks the motion of the user’s finger tip and can actively exert an external force on the finger, creating compelling illusions of interaction with solid physical objects (Massie & Salisbury, 1994).

In architectural design however, the main focus does not lie on simulating a physical phenomenon but rather on experimenting with different haptic stimuli, their perceptual and aesthetic effects, to create a haptic atmosphere.
The design of an interactive folded surface with haptic qualities was informed by physiological understandings of touch and the potential to embrace the wide spectrum of the sense of touch in an interactive, architectural environment. During the design process we experimented with different actuators, surface materials and geometric forms to compose an appealing haptic experience (see Figure 4). Our current prototype is a folded geometric structure, with a kinetic framework for dynamic movement and ergonomic aspects, thermoelectric elements for adjustable temperature and LEDs for visually augmenting the haptic atmosphere.

folded, geometric structure
The ergonomic aspects, shape and form became an important design element - in traditional architecture, the geometrical exploration process affects our haptic aesthetic experience in a crucial way. We introduced the folded structure in our design, which led to the possibility of including geometrical forms for our affinity to feel and explore the shape of objects and surfaces. From a construction perspective, the folded structure provides an opportunity to create three-dimensional cells in a simple way, without the need to add or subtract any part from the initially plane surface. Due to the folding grammar (Resch, 1968), the cells are joined together by flexible folding creases and have a high degree of freedom of movement. This provides manifold structural configurations, forming altering geometrical, spatial boundaries. The 40 by 40 millimeter cells have a degree of granularity, which aligns well with the spatial resolution of the skin. This grid of cells spans a homogeneous, folded surface, made of identical cells, which are carrying the actuators.

The actual materiality of the folded surface is a central aspect for the sense of touch and our perception. Therefore the surface material had to meet certain standards, regarding its haptic quality and technical performance. After several material tests, we decided to use an awning textile, because its stiffness makes it stable enough to keep the folded form. It transmits the actuator stimuli instantly and almost without diminishing the intensity. The coating of the surface makes it appear very smooth when touched and is responsible for the neutral appearance of the material, which means it does not dominate the tactile quality of the surface and the actuators.

Kinetic framework
The surface is connected to a kinetic framework, to produce dynamic movement (see Figure 5). The kinetic structure consists of plywood bars, which are attached by gears to servomotors with a continuous rotation. Every motor has a radius of influence of 20 centimetres.

This activation radius and the folding pattern allow the bending of the cell structure in different curvatures, forming a constantly evolving topography.

Establishing an adequate interaction between user and surface requires a sensor system to identify the user activity. An array of proximity sensors was embedded in the cells, to measure the user’s bodily position and proximity. According to the proximity of the user the surface will be programmed to behave in different choreographies to motivate the user to establish a bodily contact with it. All the electronic parts are controlled via
several Arduino boards and allow the surface to interact with the user.

**Adjustable temperature**
Temperature is a significant and dominating characteristic of materials. We associate the surface temperature with certain materials, for example wood has a warm touch, whereas metal is cold. In keeping with our current environment and corporeal constitution, the personal preference for temperature varies significantly and hence also its qualitative evaluation.

The thermoelectric elements are placed in the grid cells, directly underneath the surface for an optimal temperature transmission. By switching the polarity of the current and adapting the activation time, we can produce different temperature variations, ranging from cold to hot, when the user is directly getting in contact with the surface.

**Visual augmentation**
Architects are specialised in designing visually appealing spaces by using geometry, colours and light. To create a certain atmosphere and to influence the mood of inhabitants, architects are using the psychological effects of colour theory in combination with lighting technologies. In our prototype we are using the concept of the sensual correlation between the sense of touch and the sense of sight, by adding RGB LEDs in order to generate different colour temperatures, which are linked to the surface temperature. The lighting should motivate users to get in direct contact with the surface and reinforce the haptic perception of the temperature output.

Starting with a closed surface configuration (see Figure 6), we are constantly adding degrees of stimuli by activating the electronic elements, which are also overlaying and interplaying with each other and creating a sort of digitally informed material (Vallgårda & Redström, 2007).

**CONCLUSIONS AND FUTURE WORK**
In this paper we presented a prototype of an interactive, folded surface, the design of which was informed by various aspects of the sense of touch. The 1.3 by 1 meter large surface panel is now developed to a point where we can start to conduct user tests. Currently, the surface is able to produce three main outputs for the sense of touch: temperature, dynamic movement and shape transformation. It does not yet cover the entire spectrum of possible haptic qualities, but it already demonstrates the potential of this intermix of interactive stimuli. The user tests will provide us with information about the user's perceptual experience during the interaction process with the surface. In later prototypes we will be adding other elements such as vibration motors to further explore the relationship between the material and interactive properties of the surface and the user’s haptic experience. With our investigation, we seek to obtain guidelines for the design of future interactive haptic architecture and to enrich our surrounding environment by engaging the sense of touch in novel ways.

**REFERENCES**