Tactile Display for the Visually Impaired Using TeslaTouch

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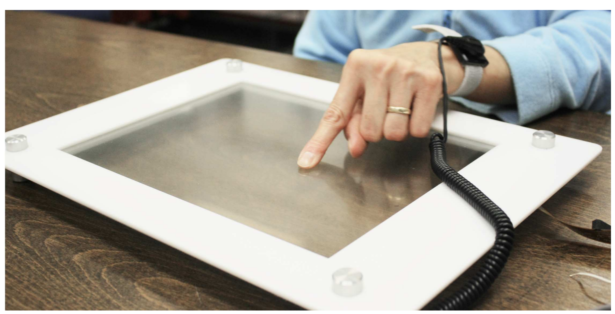

Figure 1. A blind user feels the TeslaTouch

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Abstract
TeslaTouch is a technology that provides tactile sensation to moving fingers on touch screens. Based on TeslaTouch, we have developed applications for the visually impaired to interpret and create 2D tactile information. In this paper, we demonstrate these applications, present observations from the interaction, and discuss TeslaTouch's potential in supporting communication among visually impaired individuals.

Keywords
Tactile display, assistive technology, visual impairment, TeslaTouch

ACM Classification Keywords
H5.2. Information interfaces and presentation: User Interfaces.

General Terms
Human Factors, Design

Introduction
To help visually impaired persons in a society predominantly developed around sighted population, many assistive technologies have been developed to provide them with access to visual text and graphics. These technologies generally employ auditory and/or tactile feedback as a substitute for vision. Auditory assistance such as a synthesized voice screen reader

can efficiently transfer text to speech. However, when it comes to information with a spatial dimension, such as mathematics expressions, illustrations, diagrams, and maps, visual layout and hierarchy are often lost, or would be tedious to articulate verbally. We demonstrate how to convey spatial information through tactile sensation using TeslaTouch, a touch sensitive screen with haptic feedback[3].

We start with a discussion of existing tactile displays for the visually impaired, and introduce a novel approach to show text and graphics using TeslaTouch. To study the feasibility of this approach, we implemented a prototype and conducted pilot studies with blind users. We conclude with future research for the benefit of the visually impaired users.

Related work

Current techniques for creating reading contents for the visually impaired, such as braille (raised dot patterns as characters, see Figure 2) and graphics, generally involve permanently shaping sheet material using a mold. However, producing illustrations in this way is costly and has severe limitations in quality and quantity[6].

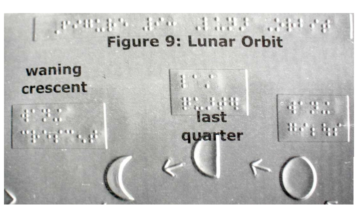

Figure 2. One page from a children's book. Braille, printed text, and tactile illustrations are all presented, so that blind readers and their sighted family and friends can read together.

Recent development in presenting visual material to visually impaired readers has focused on kinetic tactile displays. These displays can be categorized into passive and active ones[5]. When using passive displays, users keep their finger(s) at one place, whereas for active touch, feedback is physically coupled with location. Research has shown the superiority of active touch, as users can integrate the spatial and temporal information in exploration[12].

Most kinetic displays manipulate the shape of the surface with actuators, including electric motors[2, 14, 16], piezoelectric actuators[4, 11, 13], Nitinol wire[17], and pneumatic pressure[18]. Mechanical actuators pose several disadvantages. Firstly, current technologies have limited spatial resolution and dynamic range. Secondly, actuators are costly to produce and maintain, especially with large high-resolution displays. Moreover, when examined in a social context, the machine mediating the visual display and the hand draws attention to the user, violating the principle that assistive technology should be invisible and not "marking" users as disabled [15].

TeslaTouch involves no motors or moving parts. The touch panel has a conductive layer coated with an insulating layer, which the finger rests upon. When voltage difference is applied between the finger and the conductive layer, a normal attractive force are induced. By alternating the voltage, we modulate the friction force felt by the moving finger. Unlike electrocutaneous displays, which directly stimulate tactile receptors in

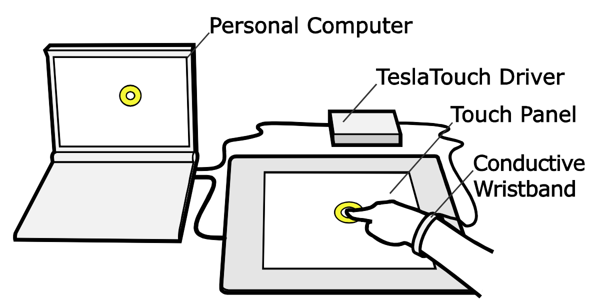

Figure 3. TeslaTouch presents digital content by programmatically modulating the friction between the figure and touch panel.

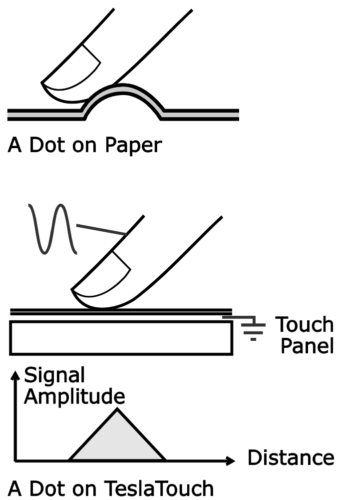

Figure 4. By mapping output signal amplitude to distance from a virtual dot, a similar sensation of raised dot on paper can be produced.

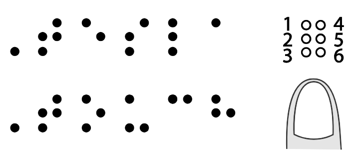

Figure 5. "TeslaTouch" in braille (left), empty braille cell (top right), in comparison to average finger tip size (bottom right).

human skin with electric charge[8], no current passes through the finger during operation.

This has several advantages over mechanically actuated displays. It is inexpensive to build, easy to maintain, consumes low power, and supports a wide range of tactile sensation. With minimal modification, TeslaTouch can be incorporated with various sizes of touch surfaces on tablet computer, interactive kiosks, cell phones, and handheld game consoles. It is limited, though, in that the finger has to slide on the surface to feel the sensation. With careful design, TeslaTouch can be universally accessible to both visually impaired and sighted users. This opens up exciting new interaction opportunities for visually impaired users.

Applications

We implemented a tactile interface on a 3M Microtouch capacitive touch panel. A computer receives finger location from the touch panel and calculates the corresponding frequency and amplitude of a sinusoidal electrical signal (Figure 3). By controlling the amplitude of output, the existence of dots, lines, and planes can be felt. Variation in frequency further adds texture. A control driver amplifies the signal and delivers it to the finger through the wristband. The driver amplifies the signal amplitude to a sensible level, while limiting the current supplied under a safe threshold. All data is processed in real-time. For details of hardware construction, please refer to [3].

To study the feasibility of displaying and producing tactile information on TeslaTouch for the visually impaired, we developed applications that allow users to sense and create 2D tactile images. We conducted interviews with three blind volunteers (one male and two females). Two of them were born blind, and one was blind before the age of five. Their average age is 59. During the hour-long interview, the users were asked to feel dots, read braille, identify simple images, and finally create images using the TeslaTouch display.

Dots

A dot is rendered as a linear change of signal amplitude, arriving at its maximum at the position of the dot (Figure 4). Participants started by feeling a row of dots. As the signal is directly coupled with figure location, users engage in an active touch, an intuitive and effective way of exploration. After two or three minutes adjusting to the sense, participants recognized the dots and described them as a “slight change of friction”, “sticky” spots, or “chalk board”.

Braille Letters

The six dots in a standard raised braille cell can be felt simultaneously under one fingertip (Figure 5). Since TeslaTouch renders the same sensation for the entire contact area, the dots are not distinguishable in the same way. We experimented with three strategies of mapping braille to tactile sensation.

FREQUENCY MODULATION

Each dot is mapped to a distinct frequency, and dots in the same column are played at the same time. Unlike ears, the human skin proved to be poor at identifying multiple simultaneous frequencies.

TEMPORAL MAPPING

Dots one through six are played in sequence as the finger moves along, with short pauses between dots, and longer pause between characters. Nokia Beta Labs took a similar approach using cellphone vibration [1].

When it was demonstrated to our participants, though, one commented that this requires “a lot of effort”, and may not be practical.

SPATIAL SEPARATION

We enlarged the distance between dots in a braille cell to be slightly bigger than a fingertip. Within the given 2 minutes, no participant could recognize a letter. In discussion we identified the following issues.

Locating the braille on touch panel was hard. This is partially due to the subtlety of the dots. More importantly, most visually impaired users locate information with the help of the non-dominant hand. As our current touch panel registers only one touch point, the other hand had to stay off the panel, eliminating the necessary location reference. It was also difficult to keep a finger moving horizontally or vertically, making it impossible to detect the relative position of the six dots.

When asked whether bigger braille helps, one participant suggested that tracing print letters might be more effective, as some visually impaired people are accustomed to feeling raised letters on doors and in elevators.

Images

The visually impaired could potentially use TeslaTouch to share photos in a family setting, or view whiteboard in a classroom setting. To understand how to best represent images on TeslaTouch, we started with three simple geometric shapes- circle, square, and triangle- and asked participants to feel and identify them. Each shape was 5 cm in width and height, and was rendered in three styles: outline, solid, and solid with outline (Figure 6), totaling nine. One image was displayed each time. The names of shapes are described to participants before experiment (“we will show you circles, squares, and triangles”). Participants were allowed as much time as needed to explore the shapes, “thinking aloud” as they examine it. An average of less than two minutes was spent on each image. One user recognized 7 images out of 9, the other two recognized 4, averaging to a success rate of 56% (Figure 7). This is considerably high among shape recognition studies for blind users, especially given that TeslaTouch offers an unfamiliar sensation.

Solid shapes proved easiest for participants to recognize. Figure 7 shows the finger movement from the same participant for three renderings. For the solid rendering, the participant followed the edge of the shape by moving in and out of the filled area. Edge finding seemed harder for the other two renderings. In a few instances, participants described outlined shapes as “broken pieces”, or geometry that was “open” on one side, as they missed part of the contour when scanning the figure quickly. Similarly, as solid with

Figure 6. Three rendering styles of tactile images. From top down: outline, solid, and solid with outline. The darkness of the shape indicates output signal intensity. Red traces are records of the finger exploring three renderings of same shape.

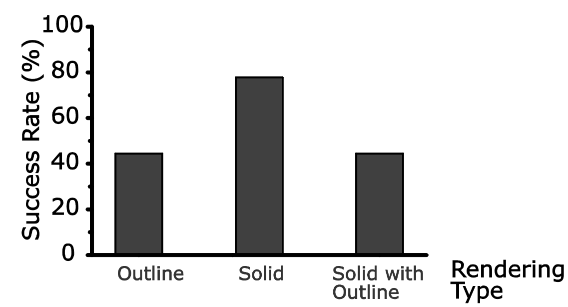

Figure 7. Success rate for three rendering types.

outline renderings have a weaker sensation inside the shape than solid ones, edge following also seemed difficult.

Although this finding is based on simple geometry, it sheds light on displaying more complex tactile images. Unlike the human eye, which excels at isolating objects of interest out of the background, grouping objects identified with the sense of touch seems harder. We hypothesize that rendering parts that belong to same entity with the same solid tactile sensation would help the visually impaired to understand 2-D graphics. We intend to investigate this in future research.

Tactile Drawing

Several studies have shown that blind persons can interpret 3D objects and create the outlines of 3D objects on 2D media [7, 9, 10]. Two participants tried a paint program implemented on TeslaTouch, which allows users to draw, feel, and modify tactile images. Both participants chose to write their names. One also placed a physical object on the touch panel and traced it. They told us that when learning to sign their names, one challenge is the lack of feedback on their hand writing. They suggested that the touch panel could help the learning process by having a model on half of the screen and a practice area with tactile feedback on the other.

Discussions

Our initial tests with blind volunteers revealed great interest in using TeslaTouch to create and display visual information, and identified several future research areas.

Tactile Rendering Palettes

A distinguishable palette of textures would allow multiple shapes to be displayed on the same canvas. They may hit at physical properties such as hardness, mass, or even color.

Tactile Icons

Our participants indicated great interest in reading maps on TeslaTouch, and discussed what legend might be used for elevator, intersection, and other details that are important for indoor navigation. One participant also suggested providing tactile cues on electronic devices such as ATMs and the iPod. For these devices it would be helpful to design tactile icons with minimal size, yet distinguishable after a quick touch. This would benefit both visually impaired and sighted people.

Navigation on TeslaTouch

Difficulties participants encountered in navigation require further work on both hardware (such as row indicator on the frame) and software (such as compensation for unstable hand).

Dynamic Information Display

Complex images could be shown in multiple layers, starting with the overall shape, and increasing details with exploration.

Other complementary sensations

Two participants noticed the subtle sound between figure and touch panel as finger moves across dots. The sound helped reassure the tactile sense without being intrusive. This suggests that concurrence of simulation in multiple channels might help tactile display.

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