TPad Fire: Surface Haptic Tablet

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ABSTRACT
We introduce the TPad Fire, a handheld haptic device that incorporates a variable friction surface and a tablet computer. The device is designed to enable research and design in human-computer interaction by being affordable, easy to use, and easily available. An example application is given and advances over previous devices are listed as well. The full device design, as well as example programs, are posted online at http://nxr.northwestern.edu/tpad-tablet.

Author Keywords
Surface Haptics, Touchscreen, Variable Friction, Tablet

ACM Classification Keywords
H.5.2. Information interfaces and presentation (I.7): User Interfaces (D.2.2, H.1.2, I.3.6): Haptic I/O

INTRODUCTION

The TPad Fire is the first product of the TPad Tablet Project. It is a variable friction surface integrated with a Kindle Fire™ tablet computer. The intent of the TPad Tablet Project is to spur research and design with force-based surface haptic interactions by creating an affordable, easy to use, and easily available platform. The full device design and instructions for building and using the device are published on the website and free for non-commercial use [10]. Example software code is also available there, and it is our goal to start a community of developers who use the device and share code through the website.

BACKGROUND
Touchscreens have been a boon to computer interaction, offering flexibility to the designer and naturalness to the user. Surface haptics has the potential to enhance touchscreen interactions by increasing communication, improving performance, and making the interactions feel more real to the user. The vast majority of research on haptic surfaces has been done with vibrotactile devices. While vibration-based approaches have been successful to the point of being widely commercialized [4], force-based haptics allows additional interaction possibilities that may enhance realism and strengthen emotional engagement even further. These possibilities include the perception of weight, stiffness, resistance, and shape, and can aid in the performance of tasks such as target acquisition [5].

Variable friction technology is one method of producing force-based haptics. Our variable friction device (TPad) can control friction between the surface and the user's fingertip through low amplitude, high frequency (ultrasonic) vibration of the surface. The highest friction state occurs when the vibration amplitude is zero (i.e., native friction of finger on glass), and the friction level steadily decreases as the vibration amplitude grows. Variable friction technology has gone through many iterations of hardware advances [11, 12, 7, 3, 2]. However, the difficulty of building devices and their limited availability in the past has meant that researchers in the field of human-computer interaction have had few opportunities to develop novel applications.

DEVICE
As is shown in Figure 1, the TPad Fire is a self-contained, hand-held device roughly the size and weight of hard-cover book (200mm x 140mm x 43mm, 850g). Inside the device, also shown in Figure 1, is a first generation Kindle Fire™ tablet, a TPad surface, a printed circuit board, and a 6600 mAh lithium polymer battery. The device can operate for over 5 hours of continuous use.

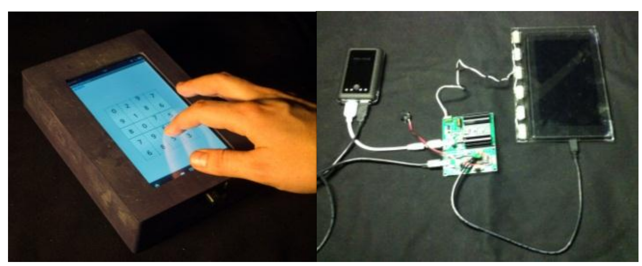

Figure 1. Assembled TPad Fire and component pieces.

System
The glass sheet of the TPad is mounted directly to the screen of the tablet. When a user touches the TPad surface, finger position is sensed by the tablet. Finger position is sampled at approximately 60 Hz. Once sampled, the finger position is used to calculate the output level of the TPad and immediately sent via USB to the microcontroller which sends a pulse-width-modulated signal through the amplifier to the TPad (Figure 2). For example applications the mean measured latency between a new finger touch and the TPad output is 27.5ms (SD 7.1ms). The mean measured latency between a new finger touch and an updated screen display is 103ms (SD 10.5ms).

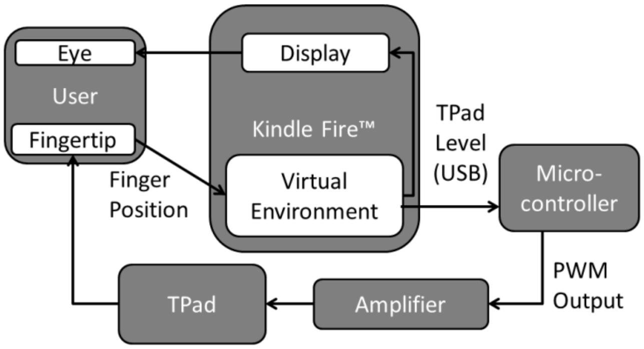

Figure 2. System diagram of TPad Fire

Tablet Advantages

Direct integration with the tablet offers many advantages and simplifications in a low-cost package. The virtual environment, including all computation, is hosted on the tablet. The Java-based Android™ programming environment provides a wide user base and is open for developers, allowing apps to be easily and quickly installed and shared. The architecture allows easy integration with finger sensing, 2D and 3D graphics, audio outputs, accelerometer, as well as Wi-Fi communication.

Advances over previous devices

The TPad Fire has many added capabilities beyond those of previous devices, the most important of which is integration into a single portable form factor that can be held with one hand. This opens up new interaction postures and mobile user experiences. The TPad Fire also has a large screen area (88mm x 152mm), increasing the range of potential applications.

Certain past devices have had noticeable nodal lines where the friction reduction effect is diminished [7, 9]. In the TPad Fire, the nodal line spacing is reduced to 8mm. Since there is an averaging effect of perceived friction over the fingertip, reducing nodal spacing results in reduced detectability of nodal lines and a near-uniform feeling.

Past devices have also suffered from emission of a high-pitched noise [5]. Through a combination of increased driving frequency and careful construction, high-pitched noise is greatly diminished in the TPad Fire. It is audible to only a small fraction of users. A "clicking" noise due to abrupt changes in friction level is audible.

Availability

In order to maximize the availability of the device, open-source, free to use, and commonly available technologies were used wherever possible. All electronic components including the piezoelectric actuators for the TPad can be purchased from major online electronics suppliers. The communication protocol between the tablet and the micro-controller is supported by the Android operating system. The full building instructions and example code to get started are available online at http://nxr.northwestern.edu/tpad-tablet.

EXAMPLE APPLICATION

A typical touchscreen interaction for setting a sequence of values (e.g., a time of day) is based on the dial metaphor. Adjusting a dial requires a certain degree of hand-eye coordination, which can be enhanced with variable friction as illustrated in Figure 3.

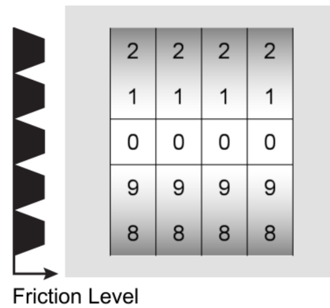

Figure 3. Example application- number dials

In this application, if the user were to place his/her finger on the zero and then slide up or down along the length of the dial, he or she would feel the friction profile shown in Figure 3. There is high friction when a number is selected in the center, low friction when transitioning between numbers, and then high friction again as the dial "sticks" when the next number is reached. In this way, the user is both informed of their current state and physically guided toward making a correct selection. A video of the number dials app is available online [10]. Beyond this example, a wide variety of detents may be explored [6]. Additionally, a haptic designer may choose the friction levels to change for any number of reasons such as finger direction, finger speed, time, or system state.

CONCLUSION

The TPad Fire is a new variable friction surface haptic device available for use by interaction researchers and designers. It is low-cost and accessible, opening up the potential for new research and unique applications. It offers numerous technical advantages as well as improvements in ease of use over previous variable friction surfaces.

ACKNOWLEDGMENTS

This project has benefited from contributions of many individuals. Special thanks to Motoki Mizoguchi, Olivia Gann, Sheng Wu, and Adam Birnbaum. Communication firmware was adapted from code shared by the IOIO and Microbridge projects [1, 8]. This research is supported by NSF (0964075), NSF REU, and the Segal Design Institute.

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