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Restoring Physicality to Touch Interaction with Programmable Friction

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***Abstract*— Rich tactile interaction with control surfaces has been compromised in the transition to touch interfaces. This paper discusses new haptic effects that restore physicality to touch interaction by dynamically altering a touchscreen's frictional properties.**

I. INTRODUCTION

Touchscreens have recently risen to prominence as the interface of choice in a range of consumer electronic products. Their flexibility makes them ideal in situations such as mobile computing where a large number of functions must be controlled within severe size constraints. The collocation of fingertip input with visual representations of interactive elements also often results in better usability and intuitiveness.

However, the tactile richness that is key to the enjoyment and expert use of keyboards, musical instruments and other physical interfaces is missing from touch interfaces which, despite their name, leverage only the motor aspect of the sense of touch. The resulting interfaces' many advantages require constant visual attention – in short supply in many contexts – for even the most basic of interactions.

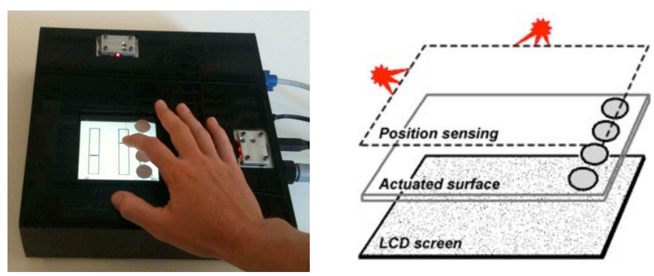
This paper briefly describes a mechanism by which we can dynamically vary the frictional properties of a touchscreen, then introduces interaction techniques which exploit this property.

II. HAPTIC TOUCHSCREENS

Programmable haptic feedback is currently available in consumer electronics primarily through actuators that apply vibrations either to the entire casing (e.g., [4,5]) or to touch-sensitive surfaces (e.g., [3,6]). The range and quality of the haptic sensations which can be produced vary with the latency, bandwidth and strength of the actuator used, from the ubiquitous but crude eccentric-mass vibrating motor to more expressive piezoelectric actuators [3,4,6]. Vibration actuators excel at attention-grabbing alarm signals, and have also been shown to convey more subtle symbolic messages through rhythm and other waveform variations [6]. Vibrations are also effective at producing transient events such as the detent of a button press [5], and are hence often used to confirm otherwise ambiguous actions. However, effects such as sliding over the edges of a key are more difficult to render and are therefore often encoded, e.g. through vibration pulses [5].

III. VARIABLE FRICTION TOUCHSCREENS

This paper focuses on a different type of haptic feedback which relies on variations in the friction experienced by the fingertip at the touch surface. This concept is explored using the Large Area Tactile Pattern Display (LATPaD), a variable friction surface developed at Northwestern University [1,2]. The LATPaD reduces the friction felt by the fingertip using imperceptible high-frequency vibrations produced with piezoelectric actuators bonded to its surface. Shown in Fig. 1, the latest prototype combines an actuated glass surface with an LCD screen and a laser-based finger position measurement system to create a 57 by 76 mm haptic touchscreen. A broad range of localized haptic effects are produced by varying the surface friction in response to finger movements. Moving beyond the limits of this early prototype, programmable friction is expected to be deployable in a form factor similar to current touchscreens with uniform feedback and no audible noise.



(a) (b)

Fig. 1. Prototype of a variable friction touchscreen: (a) picture and (b) illustration of components.

IV. HAPTIC EFFECTS

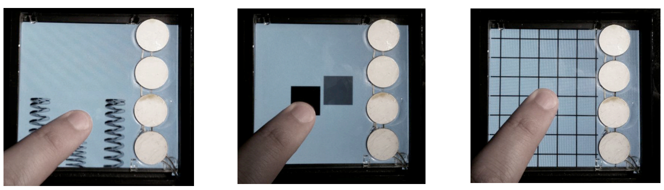
Friction is ubiquitous in interactions with everyday objects, and is responsible for a broad range of naturalistic sensations. Unlike vibrations, however, we experience friction only when sliding against surfaces, which constrains interaction design. This section describes a first exploration of the range of haptic effects which can be produced with variable friction. Many of these effects are based on similar friction patterns (namely, sustained, transient or patterned changes in friction) but result in distinct percepts when reinforced by different mental models, e.g. through visual feedback or a compelling metaphor.

Friction can perceptibly affect the velocity of a sliding finger, and hence encourage it to stop or dwell at some locations, or create barriers and constraints. A sustained increase in friction, when combined with appropriate visual feedback, also results in a realistic sensation of resistance, such as the compression of a spring (Fig. 2a).

An abrupt increase in friction produces the sensation of a contact or impact (Fig. 2b), whereas a decrease produces a sensation of release. Variations in friction can also indicate the weight of a dragged object. These effects are particularly strong when combined with visual feedback.

Transient increases or decreases in friction produce sharp ticks, clicks or detents, which can be used in controllers such as sliders, wheels and latches, and more generally to create gratings or grid patterns (Fig. 2c). Purely temporal variations in friction, on the other hand, result in paradoxical sensations due to their non-linear relation with finger motion, but can nevertheless be used to create distinct tactile textures.

This preliminary set of haptic effects forms the building blocks for more complex interaction techniques. Other desirable haptic effects, such as the perception of the edges and shape of virtual objects, are under investigation.



(a) (b) (c)

Fig. 2. Haptic effects: (a) compression of a spring, (b) impact with a virtual object, and (c) grid pattern.

V. Interaction Design

A range of interaction techniques that leverage these haptic effects have been prototyped and will briefly be discussed.

An important potential advantage of physically reactive over "passive" touch interfaces is use without vision. The volume knob of a digital music player can for example easily be adjusted without taking the device out of a pocket. A similar feat may be possible with haptically-augmented touch interfaces, allowing for example a phone number to be dialed using the tactile feel of a numeric keypad. While currently achievable friction variations may be insufficient to support purely non-visual operation, they may reduce visual attention requirements enough to support interaction with occasional glances, which is critical in contexts such as driving.

The force necessary to overcome increased friction can also be perceived as an obstacle, and hence makes variable friction interfaces suitable for "conviction widgets" [7]. A conviction widget uses resistance as an indication of the commitment necessary on the part of the user to perform an action. A button that performs an irreversible action may for example be harder to press, indicating the risk involved in the operation. In the context of variable friction interfaces, higher friction could for example surround a recycle bin so that a file dragged to a nearby folder would have less risk of being accidentally deleted. Adjusting the volume on an audio player past a certain safe limit could similarly require additional force.

Variable friction could introduce a variety of other benefits to interaction with touchscreens. Friction variations may improve the accuracy of target acquisition by slowing the finger over targets, or by facilitating both the ballistic and landing phases of sliding gestures. The immediacy of haptic feedback may also be used to quickly inform users of manipulation failures, such as the drop of a dragged object, the release of a controller's handle, or the non-recognition of a gesture. Friction variations may also provide better awareness of information flow by producing tactile feedback similar to that found in many physical knobs.

The greatest contribution of haptic feedback in touch interfaces may however simply reside in its aesthetic value. Even without measurable performance improvements, the addition of variable friction to a touchscreen may well result in a greater appreciation of the interface, in more confident interaction, and in an overall more pleasant user experience.

VI. Conclusion

In this paper, we have discussed applications of haptic touchscreens with programmable friction. We have produced a range of naturalistic haptic sensations using friction variations, then explored interaction techniques building on these haptic effects. With improvements to the underlying technology, we expect programmable friction to make its way into a broad range of consumer electronic products. Our initial evaluation suggests that programmable friction could bring significant benefits to interaction with touch interfaces by restoring the physicality lost with the elimination of physical interfaces.

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References

[1] L. Winfield, J. Glassmire, J.E. Colgate, and M.A. Peshkin, "TPaD: Tactile pattern display through variable friction reduction," Proc. World Haptics Conference 2007, Tsukuba, Japan, 2007.

[2] N.D. Marchuk, J.E. Colgate, M.A. Peshkin, "Friction measurements on a Large Area TPaD," Proc. Haptics Symposium 2010, Waltham, MA, 2010.

[3] I. Poupyrev and S. Maruyama, "Tactile interfaces for small touch screens," Proc. UIST '03, Vancouver, Canada, 2003.

[4] I. Poupyrev, S. Maruyama and J. Rekimoto, "Ambient touch: designing tactile interfaces for handheld devices," Proc. UIST '02, Paris, France, 2002.

[5] E. Hoggan, S.A. Brewster and J. Johnston, "Investigating the effectiveness of tactile feedback for mobile touchscreens," Proc. CHI '08, Florence, Italy, 2008.

[6] B. Swerdfeger, J. Fernquist, T. Hazelton, K.E. MacLean, "Exploring Melodic Variance in Rhythmic Haptic Stimulus Design," Proc. Graphics Interface '09, Kelowna, Canada, 2009.

[7] G. Chu, T. Moscovich, R. Balakrishnan, "Haptic conviction widgets," Proc. Graphics interface '09, Kelowna, Canada, 2009.