Frictional Widgets: Enhancing Touch Interfaces with Programmable Friction

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Abstract
Touch interactions occur through flat surfaces that lack the tactile richness of physical interfaces. We explore the design possibilities offered by augmenting touchscreens with programmable surface friction. Four exemplar applications – an alarm clock, a file manager, a game, and a text editor – demonstrate tactile effects that improve touch interactions by enhancing physicality, performance, and subjective satisfaction.

Keywords
Haptics, tactile feedback, touch screen.

ACM Classification Keywords
H5.2. [User Interfaces]: Interaction Styles, Haptic I/O.

General Terms
Design, human factors, experimentation.

Introduction
Touch interfaces have advantages of flexibility, space efficiency and input-output collocation. Despite their name, however, they leverage only the motor aspect of touch and lack the tactile richness that is key to the enjoyment and expert use of keyboards, musical instruments and other conventional physical interfaces.

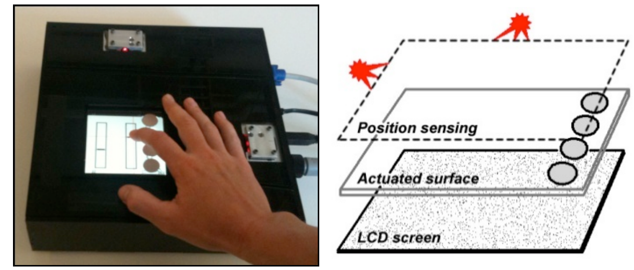
Constant visual attention, a scarce resource, is required for even the most basic touchscreen interactions.

In this paper, we investigate how the physicality of touch interactions can be enhanced when using a touchscreen with dynamically varied surface friction. We first briefly survey previous work on haptic feedback in touch interfaces and introduce the friction-reduction technique used in our work. We then present four exemplar applications that explore the range of tactile effects that can be produced with friction variations. We finally discuss the implications of this design space exploration and conclude.

Haptic Feedback in Touch Interfaces

Programmable haptic feedback is currently available in touch interfaces primarily through actuators that apply vibrations to the entire casing [3,8] or to touch sensitive surfaces [9,11]. The resulting vibrations are used to convey alarms, transient events such as the detent of a button press [3], and rich but abstract symbolic messages [11]. Effects such as sliding over the edges of a key, however, are difficult to render with vibration and are therefore often encoded, e.g. as pulses [3]. A variety of other haptic technologies have been proposed, including pin arrays [6], electrovibration surfaces [10,11] and actuated pen [4], but none has yet been deployed in consumer electronics products.

This paper focuses on a different type of haptic feedback that results from variations in the friction experienced by the fingertip at a touch surface. This concept is explored using the Large Area Tactile Pattern Display (LATPaD) [7,12], an experimental touchscreen that reduces its surface friction using imperceptible high-frequency vibrations produced with bonded piezoelectric actuators. Shown in Figure 1, the LATPaD combines an actuated glass surface with an LCD screen and a laser-based finger position measurement system to create a 57 by 76 mm touchscreen. Localized haptic effects are produced by varying the surface friction in response to finger movements. Moving beyond the current prototype, we expect programmable friction to be deployable in a form factor similar to current touchscreens with uniform feedback and no audible noise within 3 years.



(a) (b)

Figure 1. (a) Picture and (b) components of the LATPaD, an experimental touchscreen with programmable surface friction.

Exemplar Applications

Our exploration of the design possibilities offered by programmable friction has resulted in the development of four exemplar applications. This iterative exploration of the design space began with low fidelity prototyping on etched glass and matured through the development and refinement of software prototypes for programmable friction patterns and use cases. The *Alarm Clock*, *Game, File Manager* and *Text Editor* exemplar applications described below leverage the most promising tactile effects identified through this process, and anchor them in realistic contexts.

Alarm Clock

Users set the time and sound of an alarm with wheel and combo box widgets (Figure 2). The wheels are scrolled by sliding a finger against them. Friction increases abruptly as items near the center of a wheel (Figure 2d), creating detents along its length and resistance against departure from selections. The combo box is similarly scrolled by pressing against its arrow marker and sliding up against the listed items. Friction increases abruptly between items (Figure 2e) to create the sensation of ticks and resist slightly against selection changes. The widgets are strategically placed within the three columns of the LATPaD offering optimal friction reduction. The tactile feedback provided by the wheels and combo box is similar to that of physical rotary controllers and enhances awareness of the system state, particularly when visual attention is occupied elsewhere.

File Manager

A 3 x 4 arrangement of icons represent files, folders and a recycle bin. Users file or delete files by dragging and releasing them over a folder or the recycle bin (Figure 3). Folder and recycle bin icons enlarge when a file hover above them and the friction felt is altered to communicate the impending action. Friction increases abruptly above folders, both indicating the presence of a target and facilitating its selection by creating a sticky

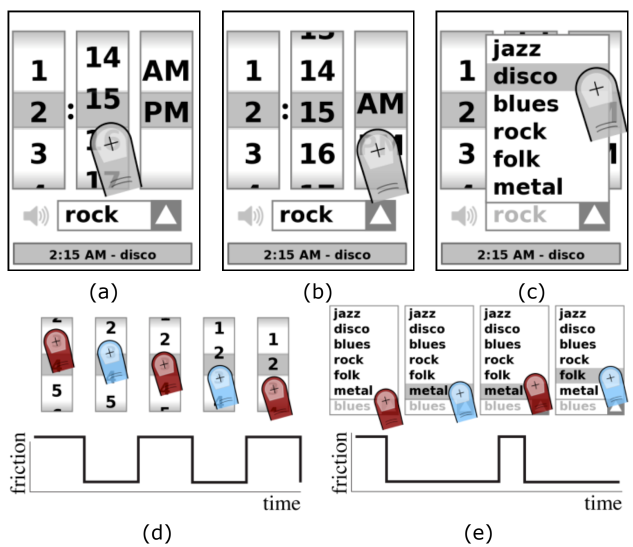


Figure 2. Alarm Clock: (a) hour and minute wheels, (b) AM/PM wheel, (c) sound combo box and friction patterns while selecting (d) hour and (e) sound. The finger color changes from light blue to dark red as friction increases.

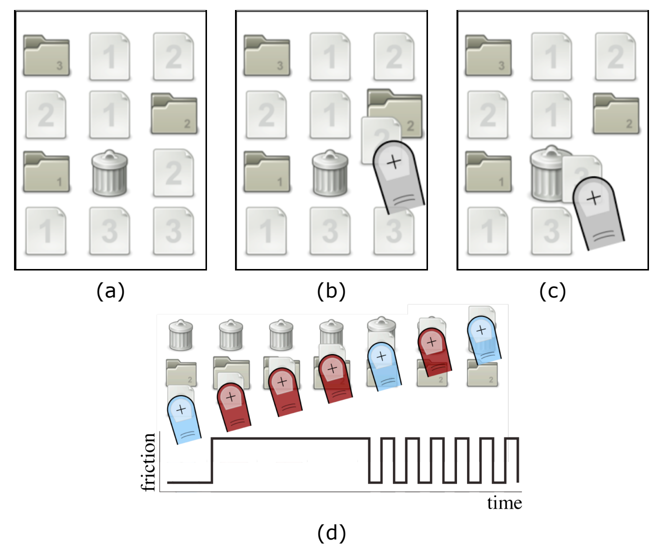


Figure 3. File Manager: (a) initial screen, moving a file into (b) a folder or (c) recycle bin, and (d) friction patterns while over a folder or bin. The finger color changes from light blue to dark red as friction increases.

region (Figure 3d). Friction, on the other hand, oscillates at 37.5 Hz over recycle bins, creating a strong and somewhat unpleasant sensation similar to vibration (but contingent on sliding) and communicating the severeness of the action (Figure 3d). The tactile feedback is intended to facilitate filing while reducing the occurance of erroneous deletions.

Game

In an arcade-like game, players throw a ball against breakable blocks by making it bounce against a circular cursor surrounding the fingertip, as illustrated in Figure 4. A sensation of impact is produced as the ball bounces against the cursor by briefly and abruptly increasing friction as the ball nears it (Figure 4e). Since this sensation is perceptible only when sliding, flicking against the ball is encouraged by making the speed of the ball dependent on that of the cursor at impact and by requiring a minimal ball velocity for blocks to be broken. Some blocks require more than one hit to be broken while others produce special effects – releasing a second ball or making the cursor flicker and the ball bounce erratically against it for a few seconds. The latter is accompanied by the same oscillating friction pattern as the *File Manager*'s recycle bin, coupling a negative event with an uncomfortable sensation. The ball is also initially released using a spring-like launcher. A corresponding resistance is produced by gradually increasing and then maintaining the friction at its maximum, with multimodal reinforcement through a visual representation of a spring (Figure 4d). Similar to sound effects, this tactile feedback is intended to augment the game interactions and make them more engaging and enjoyable.

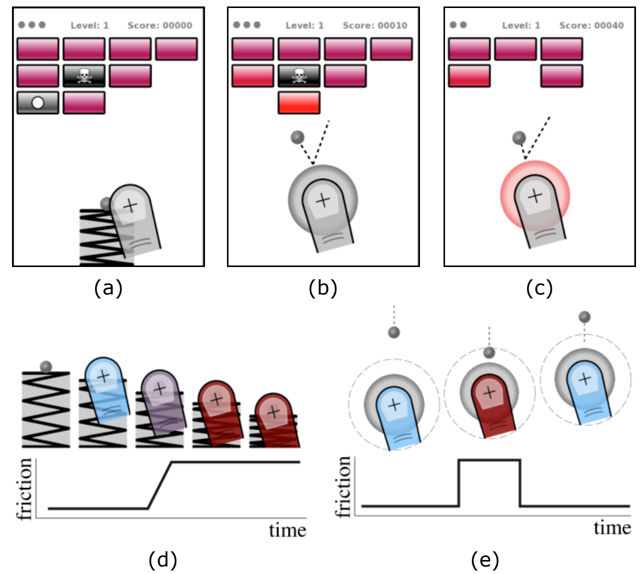


Figure 4. Game: (a) launch, (b) normal and (c) erratic bounce, and friction patterns during (d) launch and (e) bounce. The finger color changes from blue to red as friction increases.

Text Editor

Users navigate through pages of text and displace words in each page (Figure 5). Pages are swapped by rapidly dragging towards the left or right by a minimal distance, accompanied by a sudden increase in friction as the swap occurs, with a sensation similar to a click. A word is selected by briefly dwelling on it. As a selected word is pushed against its neighbor, both words are visually compressed and friction is gradually increased to produce a sensation of resistance. Friction remains at the maximum and the words stop moving as maximum compression is reached, followed by a sudden drop in friction as words are swapped (Figure 5c). The result is a popping sensation as words

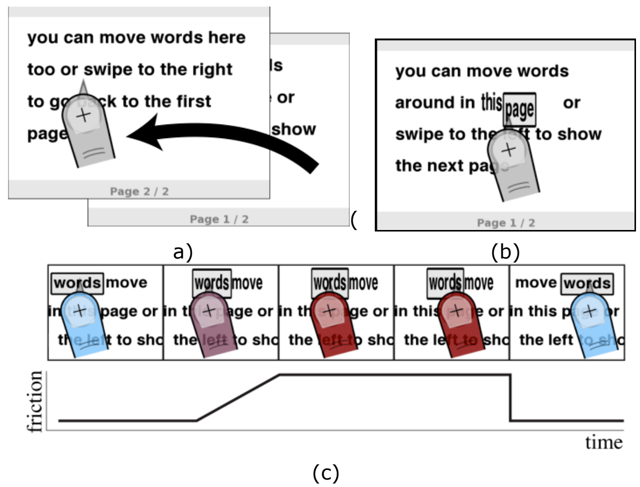


Figure 5. Text Editor: (a) page swap, (b) word movement and (c) friction patterns while moving a word. The finger color changes from light blue to dark red as friction increases.

travel through a line in discrete jumps. Moving a word between lines produces a similar sensation by fading in and out line-based friction patterns and by introducing a peak in friction half-way between adjacent lines. This tactile feedback provides strong confirmation cues as actions are performed and increases realism.

Discussion

We used the exemplar applications described above in [5] to evaluate the emotional and subjective response of users to programmable friction. Participant reactions were collected through questionnaires and interviews, with results demonstrating that programmable friction can instill a sense of realism, increase awareness of the system state, and improve the appreciation of an interface. Reactions varied inconsistently across applications, however, suggesting a need for customization of the tactile patterns based on personal preferences and tactile sensitivity. Most participants nevertheless showed a preference for programmable friction in at least some contexts, suggesting a great potential for this type of feedback as our understanding of its design space matures.

These exemplar applications cover a range of tactile sensations and uses of tactile feedback that were identified through our iterative exploration of this design space. Distinct effects were obtained not only by varying the width, attack, decay, and repetition of friction patterns, but also by reinforcing these patterns with supporting visual and contextual cues. The resistance of a word to swapping was for example represented by visual compression of the word matched with an increase in friction. These effects were used to inform of past or impending actions, to communicate the system state, and to enhance the realism, physicality and enjoyment of the interactions.

Taken together, these examples demonstrate that programmable friction can enhance touch interfaces provided that interactions are designed to encourage sliding gestures where friction can be felt. Importantly, the tactile effects demonstrated here could be deployed in support of a wide variety of interactions and contexts. The discrete tick marks felt as the *Alarm Clock*'s wheels are turned could, for example, naturally be remapped to other scrolling contexts such as contact list navigation or web browsing. The *Game*'s impact with the ball could similarly be used in other physics-based interactions such as virtual environments or physical desktop metaphors [1]. The exemplar applications are only a first foray into the design space and affordances of programmable friction.

Conclusion

This paper discussed the design of touch interactions that leverage programmable friction on the surface of a touchscreen. We described four exemplar applications that demonstrate a range of tactile effects and their uses for interaction. While programmable friction has yet to be fully exploited, our results suggest that this tactile feedback could greatly enhance the physicality of touch interfaces and lead to greater user appreciation.

Acknowledgements

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