Touchscreen Overlay Augmented with the Stick-Slip Phenomenon to Generate Kinetic Energy

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ABSTRACT

Kinesthetic feedback requires linkage-based high-powered multi-dimensional manipulators, which are currently not possible to integrate with mobile devices. To overcome this challenge, we developed a novel system that can utilize a wide range of actuation components and apply various techniques to optimize stick-slip motion of a tangible object on a display surface. The current setup demonstrates how it may be possible to generate directional forces on an interactive display in order to move a linkage-free stylus over a touchscreen in a fully controlled and efficient manner. The technology described in this research opens up new possibilities for interacting with displays and tangible surfaces such as continuously supervised learning; active feed-forward systems as well as dynamic gaming environments that predict user behavior and are able modify and physically react to human input at real-time.

Author Keywords

User Interfaces; Tangible Interfaces; Multimodal Interaction.

ACM Classification Keywords

H.5.2 User Interfaces; Graphical user interfaces (GUI); Haptic I/O; Input devices and strategies; Prototyping.

INTRODUCTION

Kinesthetic information is the main component of haptic feedback that integrates diverse afferent signals into the entire percept. By generating a combination of directional forces and torques, it is possible to simulate some physical properties of virtual objects at real time. Different systems and transducers can be used to deliver these forces [1] in augmented haptic space. Based on these transducers, a number of devices [3, 4] have been developed which use kinetic energy to provide kinesthetic sense and convey information regarding different qualities and properties of virtual objects. However, most of these devices use linkages and stiff chains to generate the strong directional forces needed to simulate the properties of virtual objects. Large standalone devices like the *Geomagic's* Phantom and *Novint* Falcon may provide meaningful interactions in a controlled haptic space, but they are unsuitable for common touchscreen interaction in mobile and hand-held devices. Therefore, this research focuses on a physical phenomenon (stick-slip) by which it is possible to transmit in a linkage-free manner, kinetic energy as directional forces, to a stylus tip to generate tactile-kinesthetic afferentation with the help of a screen overlay.

RELATED WORK

Generating lateral forces on top of a touchscreen using a screen overlay has been addressed earlier [1, 7]. Many studies have been carried out to characterize user sensitivity to varying micro-displacements. However, most of these studies are intended for the purposes of providing tactile stimulation, and do not target tangible object manipulation, on the touchscreen itself. Furthermore, recent friction modulation research [2] illustrates how it may be possible by modulating the friction coefficient between the onscreen tangible objects and the display itself to create directional forces on interactive surfaces [5]. Friction modulation can be achieved in multiple ways [2, 5, 6], but in this research, our focus was to construct a mechanism to employ the stick-slip effect, which uses the variation in static and dynamic friction coefficients to transfer energy [8].

Stick-slip Kinesthetic Display Surface

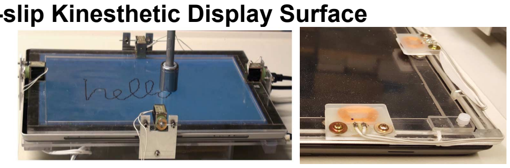

Figure 1. Various embodiments of the SKDS prototype.

The core system for delivering kinesthetic signals was designed as an overlay for the MS Surface Pro 3 tablet (Fig. 1). Four actuators were affixed to the plexiglas plate to in the center of each side using U-shaped aluminum brackets Unlike Reznik [8] and Perlin [7], we employed saw-tooth waves by forcing the objects stick and slip [9]. Thus the directional forces applied were used to manipulate stylus tip displacements on a flat surface covering the touchscreen. The position and pressure of the object was continuously monitored and, based on this information, an algorithm was computed to dynamically adjust the actuation pattern applied to the assembly of the 4 actuators.

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SYSTEM EVALUATION & DISCUSSION

The SKDS core design employed 4 actuators affixed to each side of the screen overlay which created the directional forces to generate stick-slip motion. However, no actuator being utilized in these prototypes was primarily designed for this task. Therefore, we evaluated four different types of actuators to gauge the SKDS efficiency and ability to generate stable forces for stick-slip motion. These included pull-type solenoids (STC-05C-A05) two different types of piezoelectric actuators (APA120s, PPA40L) and custom electromagnetic actuators (eLA_X2).

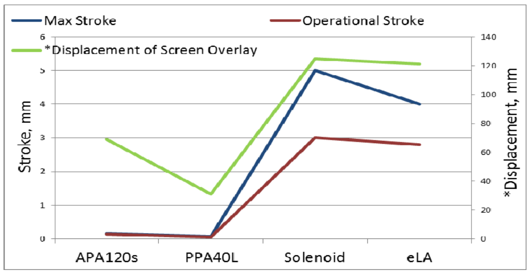

Figure 2. Operational, Max stroke vs. Screen Displacement.

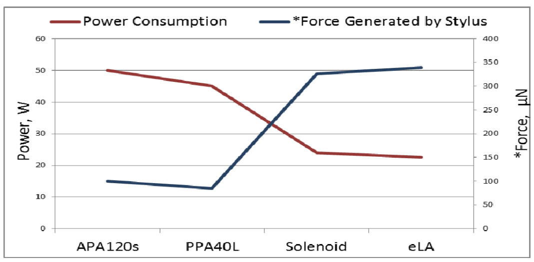

Figure 3. Force generated vs applied power to all 4 actuators.

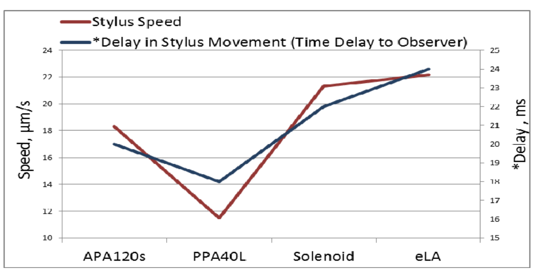

Figure 4. Stylus speed (Avg. over a 10cm) vs the delay

We measured the horizontal displacement (using a MicroSense 5810 sensor and a 5622-LR, 20 kHz probe), the force transfer to the stylus, as well as the speed of the stylus (averaged over 10cm), and compared it to each actuators' stroke and power consumption. The results showed that actuators which were able to generate larger displacements of the screen overlay with minimum power consumption were the most efficient as generating stick-slip movement of the stylus. To evaluate the usability of the SKDS we developed a graphical application where participants retraced different characters and shapes. The application matched the user input to the original shape / character and evaluated their discordances. If the deviation exceeded the acceptable error threshold, the SKDS forced the stylus to move in the correct direction, providing the participants with kinesthetic feedback. In a user test, 25 participants were asked to use the graphical Application with kinesthetic feedback and simple onboard vibrotactile feedback (of the Microsoft Surface Pro 3 tablet) on the SKDS and were then asked to rate the haptic feedbacks according to sensibility, pleasure-ability and usefulness. Results suggest that the sensibility of the onboard vibrotactile feedback was very poor; therefore users preferred the SKDS and found it to be much more useful for the particular task. However, we believe that further research would prove SKDS can be more useful in a wide range of application and devices.

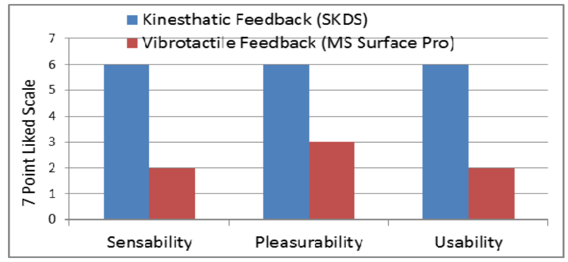

Figure 5. User Feedback on SKDS vs onboard haptic actuation.

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