Multi-Haptics: Remote Tactile Feedback on Multitouch Surfaces

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Abstract

Multi-touch input using multiple fingertips or hands has become the de-facto standard for the interaction with interactive surfaces such as tablets, tabletops or interactive walls. For single touch input, the addition of synchronous tactile feedback has shown to be beneficial in terms of reducing error-rates, increasing interaction speed and minimizing visual load. However, to this day, the non-visual communication of form, state and function of interactive elements has only been analyzed for single touch surfaces. We incorporate the notion of remote tactile feedback, i.e., the spatial separation of touch input and resulting tactile output on the user's body to provide several synchronous haptic stimuli for users of multi-touch surfaces. In the paper, we present the results of a preliminary study and an ongoing study in which we analyze the role of remote tactile feedback for quantitative and qualitative metrics of multi-touch interactions.

1 Introduction

Due to their ease of use and the flexibility in GUI-design, touch screens have become an essential element in HCI. Despite the technical progress of multi-touch displays concerning technology and visual resolution, they still present a flat and rigid surface to the interacting user's fingertips. No active tactile information on shape, state and function of the interactive elements is communicated. However, several user studies have evaluated the effects of active tactile stimuli resulting from interactions with touch surfaces on usability and subjective responses (Chang & O'Sullivan 2005). Presenting tactile stimuli on touch surfaces was found to increase typing speed and accuracy significantly (Hoggan et al. 2008). However, these effects haven't been evaluated for multi-touch surfaces, yet. With our work, we investigate the role of tactile feedback for *several contact points* with the interactive surface. Incorporating the notion of Remote Tactile Feedback, we argue that this multi-haptic approach influences interaction on multitouch surfaces in quantitative and qualitative metrics. Our contributions are new options for feedback on the body, observations on user behavior concerning bimanual interaction and first recommendations of multi-touch gesture properties.

2 Remote Tactile Feedback on Interactive Surfaces

On single-touch surfaces, the provision of tactile stimuli has been done using three methods: (i) moving or vibrating the device's screen or whole device (Fukumoto & Sugimura 2001) (ii) placing additional interfaces with tactile feedback atop the device (Marquardt et al. 2009) (iii) segmenting the interactive surface into individually movable tactile pixels (Poupyrev et al. 2004). However, these methods are not applicable for tactile feedback on multitouch surfaces, i.e. for individual tactile feedback for multiple points of contact with the screen area. (i) allows for only one tactile stimulus and it is the same for every point of contact. (ii) requires additional mechanical devices on the screen which could lead to occlusion; additionally this method is not applicable for non-horizontal touch surfaces such as interactive walls. (iii) lacks tactile resolution and is hardly scalable due to mechanical constraints of the numerous actuator devices which have to be integrated into the touch surface. Therefore, researchers try to incorporate the notion of "tactile sensory relocation" or remote tactile feedback (RTF) to communicate rich tactile feedback to the users of touch interfaces. This approach is based on spatially separating touch and feedback, for example using actuators located on the forearm. Recent publications by McAdam and Brewster indicate that remote tactile feedback can improve typing speed on portable tabletops while maintaining low error rates compared to physical keyboards (McAdam & Brewster 2009) when using a vibration on the wrist and upper arm. Additionally, applying RTF can simplify the design and implementation of tactile feedback devices (Richter et al. 2011-A) and to create novel tactile stimuli by combining different types of actuators (Richter et al 2011-B). At this point, multi-touch interaction has not been under much research concerning tactile feedback. Thus, we suggest RTF techniques to improve and enrich the interaction with multi-touch surfaces.

3 Preliminary User Study

We conducted a preliminary user study incorporating six participants: Firstly, we examined the effect of additional remote tactile feedback on total task time. Secondly, we observed how often people removed their fingers from the screen and how likely they use both hands in a steering task. We implemented a prototype application for the Apple iPad. As remote actuators, we chose voice coil actuators allowing us to quickly adjust frequency for different feedback signals. These speakers were small enough to be sewed into comfortable wristbands which are easily fastened and unfastened (see figure 1A). During the study, participants had to move a randomly rotated square atop a static square. In order to drag the square, two given points in opposite corners had to be touched at the same time using one or both hands (see figure 1B). One trial was complete when both squares matched and the fingers were removed from the screen. We measured task completion time and how often subjects lifted their fingers during a trial.

Figure 1- A: Wrist-worn actuator – B: Study setting "Moving Square" – C: More trials done bimanually

We implemented a within subjects design with two feedback conditions: visual feedback only and visual feedback combined with additional RTF were both tested with each participant. In the visual case, the square turned green while it was touched at the given points and it turned blue as soon as both squares overlapped correctly. For the combined feedback, additional tactile feedback was separately provided through a 160hz sine wave to the left wrist when the left point is under touch and vice versa. When the squares overlap correctly, a 20ms pulse signalizes a match. The order of conditions was fully counterbalanced over six participants, who were 25 years in average; five participants were male (all right-handed). Due to the limited number of participants, no statistically significant statement or result can be given. Preliminary results were near equal for visual and combined feedback, no indication for quantitative benefits of multi-haptic feedback is found in our setting. Participants uttered that the wrist-bands might have negatively influences their precision. However, we observed that 76% of overall tasks were completed bimanually, even though the object was small enough to be dragged and rotated with one hand (see figure 1C). In the questionnaire, individuals stated that they felt obligated to use both hands while wearing wristbands on both hands.

4 Ongoing User Study

With our second, ongoing study, we want to further investigate three aspects of RTF on multi-touch surfaces: Firstly, we want to assess the effects of RTF on larger multi-touch surfaces concerning interaction speed and the number of errors made. Secondly, we want to evaluate the influence of actuator placement on the decision to interact bimanually. Thirdly, we want to find out if it is more important to associate feedback position to the hand that caused an event or to simply give tactile feedback simultaneously to the touch, which we can evaluate by inverting the left and right actuator signals. For this ongoing project we deploy a larger multi-touch surface (Samsung SUR40 - Microsoft Surface 2) to have a higher degree of freedom when it comes to decide which hand to use for a certain action. The results from our preliminary study suggested that wearable tactile actuators are perceived as being cumbersome and bias the likeliness to use both hands. Therefore, we developed a "Tactile Chair" with built-in actuators for the left and right leg (see figure 2A). At the same time we can evaluate the applicability of RTF on the backside of the upper leg, which to our knowledge has not been done before. The dragging task will require the user to move two circles through an asymmetric tunnel that changes in size and orientation (see figure 2B & 2C). Also, we will have the participants move the squares simultaneously in one case and successively in the other. The latter tells us more about the decision to interact bimanually.

Figure 2 - A: Tactile Chair, actuators in sitting area – B: User Study on MS Surface – C: User Study GUI

5 Conclusion

In the paper, we presented our work in progress to analyze the role of RTF on interactions on multitouch surfaces. In a preliminary study, we recognized possible effects of actuator placement on the user's decision to use one or more hands for the interaction. To further analyze this correlation, we are currently designing a full user study incorporating a larger interactive surface. We will analyze the effects of remote tactile feedback on interaction speed and errors made as well as the influence of actuator placement on the decision to interact bimanually and the subjective evaluation of the given tactile signal. In conclusion, we think the remote application of tactile stimuli can help to enrich and extend the interaction with ubiquitous touch surfaces using one or more fingertips or hands. We believe that results of our ongoing study will help to further exploit the notion of RTF for multi-touch interactions in a ubiquitous computing scenario.

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