Internet of touch: analysis and synthesis of touch across wearable and mobile devices

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DOI
10.1145/2968219.2971382

Publication date
2016

Document Version
Final published version

Published in
UbiComp'16 Adjunct

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Ubicomp/ISWC'16 Adjunct , September 12-16, 2016, Heidelberg, Germany
ACM 978-1-4503-4462-3/16/09.
http://dx.doi.org/10.1145/2968219.2971382

Abstract
We demonstrate a method that allows two users to communicate remotely using their sense of touch by dynamically applying vibrotactile feedback to one user's forearm using two different input methods. User input on a standard mobile touch-screen device or a purpose-built touch-sensitive wearable is analyzed in real time, and used to control intensity, location, and motion parameters of the vibrotactile output to synthesize the stroke on a second users arm. Our method demonstrates that different input methods can be used for generating similar vibrotactile sensations.

Author Keywords
Affective touch; Vibrotactile stimuli; Mediated social touch
H.5.2 [User Interfaces]: Haptic I/O

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: Haptic I/O, Prototyping.

Introduction
We have a plethora of remote communication technologies at our disposal, mostly limited to visual and auditory senses. These spatial senses are according to Boernstein important for dealing with the concept of structure in physical objects, this also includes the sense of touch [2]. Thus, like the visual and auditory senses, the sense of touch is

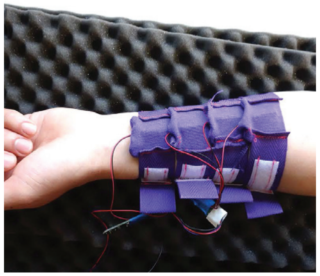

Figure 1: Vibrotactile array with actuators spaced 3cm apart from each other

Figure 2: Wearable touch sensor array with one sensor exposed

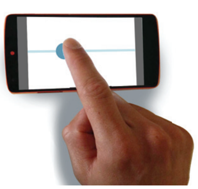

Figure 3: The mobile device interface for stroke input

important for Human Computer Interaction when dealing with the physical environment. Examples of applications are spatial navigation, such as for drivers, helicopter pilots, and astronauts [6, 19], not to mention the incorporation of haptic feedback into virtual environments, where users have the ability to push, pull, feel, and manipulate objects in virtual space [16].

Human-human communication also includes this physical element. Research has shown that the sense of touch is highly important in social interactions [15]. Gentle stroking touches applied with a velocity of between 1-10 cm/s have been suggested to be especially relevant in social-affective touch interactions [4, 5, 14]. Researchers have now begun to investigate how such social-affective aspects of touch can be used in HCI, for example for remote communication between partners [9, 21], or in interactions with social robots [20].

Considering the importance of touch in physical HCI on the one hand, and interpersonal communication on the other, there is a challenge for wearable interfaces to address both these aspects in the design of wearables that can detect touch and stimulate the sense of touch. Here we demonstrate a method that allows for touches to be detected in real time, on multiple devices, using different input technologies, and rendered on the same vibrotactile array.

Demo Outline

In this demo we introduce a method for the detection and generation of touches, including stroking touches. An optimized method for rendering vibrotactile stroking touches based on the work of [1, 12, 11, 13] is used as output. A linear array of four Precision Microdrives PicoVibe 306-117 vibration motors is worn on the forearm to apply vibrotactile stimulation (see Figure 1).

For input, we introduce a method of detecting dynamic touches across different devices including a touch-screen based mobile device (Google Nexus 5. See Figure 3), and a novel type of wearable touch sensor based on the work of [10] (see Figure 2).

Touch input from both the mobile device and the wearable touch sensor is synthesized on the vibrotactile array, and can be used for both static (i.e. localized vibrotactile sensations) as well as dynamic (i.e. vibrotacitle stroking sensations) touches. The wearable touch sensor has four textile touch sensors in the same configuration as the vibrotactile array. The sensors combine capacitive and resistive sensing and are thus capable of detecting very gentle contact, as well as different levels of pressure applied to the sensor. Conversely, the mobile device does not detect touch pressure, but has a higher resolution for detecting touch location. On the screen of the mobile device a line can be seen that users can touch and stroke in any way they like (see Figure 3). The precise location of the finger is directly coupled to the vibrotactile array. When a user's finger is in a location on the touch screen that does not correspond with the exact location of an actuator in the array, a vibrotactile sensation will be generated using an algorithm for phantom haptic sensations [1, 12].

We demonstrate how, despite the differences between input methods, both methods can be used to synthesize dynamic vibrotactile feedback on the linear array.

Conclusions

We demonstrate the use of tactile interactions across different devices, by detecting static and dynamic touches on a touch-screen based mobile device and a novel wearable touch-sensor. These touches are synthesized on a linear array of vibration motors using phantom haptic sensations

[1, 12, 11]. Our method demonstrates that different input methods can be used for generating similar vibrotactile sensations. Touch sensors and actuators may be used in remote social interactions for affective communication [9, 21], but may also be useful in more specialized settings. One such setting is communication with visually impaired, or deaf-blind users [7, 18, 8, 3], who may strongly benefit from tactile communication. In such a situation it is plausible that caregivers have access to ergonomically designed wearable touch sensors that do not interfere with their daily routine for the purpose of communicating with their clients, while family members can use standard touchscreen-based mobile devices to communicate with loved ones through tactile feedback. Another example is to extend communication to more task-oriented interactions, like covert touch communication for military applications [17]. Here, soldiers in the field may have sensors and actuators integrated into their garments, while personnel at a command post may use touchscreen-based input methods for tactile communication with soldiers in the field.

To conclude, the setup discussed in this paper opens up opportunities for touch-based wearables that can use different input methods, and are applicable in diverse situations.

Acknowledgements

This publication was supported by the Dutch national program COMMIT/.

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