A Modified Tactile Brush Algorithm for Complex Touch Gestures

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Abstract

Several researchers have investigated phantom tactile sensation (i.e., the perception of a nonexistent actuator between two real actuators) and apparent tactile motion (i.e., the perception of a moving actuator due to time delays between onsets of multiple actuations). Prior work has focused primarily on determining appropriate Durations of Stimulation (DOS) and Stimulus Onset Asynchronies (SOA) for simple touch gestures, such as a single finger stroke. To expand upon this knowledge, we investigated complex touch gestures involving multiple, simultaneous points of contact, such as a whole hand touching the arm. To implement complex touch gestures, we modified the Tactile Brush algorithm to support rectangular areas of tactile stimulation.

Keywords: Touch gestures, tactile brush, apparent tactile motion.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O

1 Introduction

The sense of touch is an important perceptual function that provides vital information about the environment around us. Because of this, many researchers have investigated tactile technologies, control algorithms, and percepts to communicate complex information and symbolic meanings to users. These works are particularly relevant to virtual reality (VR) systems, which heavily rely on virtual objects that have no physical instantiations, and hence, provide no tactile feedback without additional technologies.

To that end, researchers have studied how perceptual illusions can provide realistic tactile sensations with haptic displays. For example, *phantom sensations* and *apparent motions* are two types of tactile illusions that take advantage of stimuli timing, intensity, and spatial configuration to provide a variety of different tactile sensations with a limited number of vibration points. A *phantom tactile sensation* is the perception of a nonexistent tactile stimulus between two real tactile stimuli [1]. This is created by placing two vibrotactile actuators in close proximity of one another. Another tactile illusion is *apparent tactile motion*, which is the perception of a nonexistent moving stimulus due to a time delay between onsets of multiple real tactile stimuli [2]. With the apparent motion illusion, the real stimuli are not perceived. Instead, only the nonexistent moving stimulus is sensed, provided that the real tactile actuators are close enough to one another and their actuation times overlap [3].

The effectiveness of tactile illusions depends on the properties of the real tactile stimuli. For instance, researchers have studied the appropriate *durations of stimulus* (DOS; how long the stimulus is displayed) and *stimulus onset asynchronies* (SOA; the time interval between onsets of subsequent actuations) [2]. In addition to DOS and SOA, researchers have investigated the effects of varying the frequencies, amplitudes, and spacing of vibrotactile actuators. However, most prior studies of phantom sensations and apparent motions have focused primarily on simple touch gestures.

A *simple touch gesture* is a touch involving a single point of contact on the skin at any one moment that can be static or dynamic. Static touch gestures involve touching a relatively restricted body location, such as tapping a person on the shoulder, while dynamic gestures involve continuous movement from one point to another, such as running a finger down someone's arm [4]. In contrast to simple touch gestures, a *complex touch gesture* involves multiple, simultaneous points of contact, such as a whole hand touching the arm or rubbing it up and down. While many researchers have studied simple gestures, there has been little research on complex touch gestures.

In our work, we are studying the perceived realism of different types of complex touch gestures on an upper arm. To display the complex touch gestures, we have modified the previously published Tactile Brush algorithm [5] to support rectangular areas of contact. This paper describes those modifications.

2 Related Work

Early on, researchers began investigating the effects of varying the parameters of apparent tactile motion. Two of the first parameters investigated were DOS and SOA. Shimizu [6] looked into the effects of DOS and SOA for a 7-by-9 pin display placed on users' palms. In his first experiment, he found that increasing SOA afforded faster responses for a character recognition task. In his second experiment, he found that increasing DOS improved recognition accuracy. In much more recent research, Niwa et al. [7] used a 2-tactor array on the upper arm to find similar results for recognizing single-axis directions. They found that increasing DOS and SOA improved direction recognition and that recognition accuracies were around 95% when a time interval greater than 400ms was used. Israr and Poupyrev [3] also investigated the effects of SOA on apparent tactile motion, but for the forearm and the back. They found that the range of acceptable SOA varied with DOS and body site. All of these results indicate that a longer DOS and larger SOA will yield more-accurate recognitions of touch gestures.

Researchers have also investigated the effects of varying frequency and amplitude for vibrotactile stimuli on various perceptions. For example, Cholewiak and Collins [8] investigated the effects of frequency on a localization task, in which users identify where the tactile stimulus is perceived. In four different experiments, they repetitively found no significant effect of varying frequency on their localization tasks. In other work, Seo and Choi [9] investigated the effects of amplitude on perceived intensity and location using two vibrotactile actuators in a mobile device. They found that the perceived intensity of a phantom actuator was much more consistent when the amplitudes of two neighboring LRA motors were logarithmically scaled. However, in a similar study, Israr and Poupyrev [3] found no significant effects of amplitude on the range of SOA. They later exploited this fact to develop their Tactile Brush algorithm [5].

The Tactile Brush is an algorithm for producing smooth, two-dimensional apparent motions. The Tactile Brush adheres to an

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energy summation model to allow the moving phantom actuator to maintain a constant intensity to produce a smooth motion. While this algorithm is effective for displaying simple touch gestures, it does not support the rendering of complex touches.

3 Modified Tactile Brush Algorithm

While the Tactile Brush produces smooth, two-dimensional apparent motions, it only displays one point of contact at a time. Hence, it only supports simple touch gestures. However, we were interested in investigating complex touch gestures, such as a whole-hand rub. To support these gestures involving multiple, simultaneous points of contact, we wanted to modify the Tactile Brush algorithm to support rectangular areas of contact.

Initially, we assumed creating a rectangular area of contact with the Tactile Brush algorithm would be simple. We planned to display the area by activating the four phantom actuators that would define the four corners of the rectangle. However, we quickly realized that a phantom actuator within a grid square would require conflicting levels of amplitude from its contributing physical actuators. The same issue occurs when trying to activate phantom actuators at the intersections of the rectangle's boundaries and the grid lines, as an interior motor will have conflicting amplitude requirements in both of the grid axes.

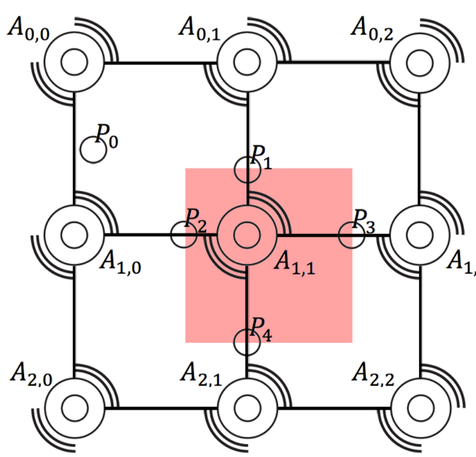

Figure 1: Amplitude conflicts arise when attempting to place phantom actuators within grid squares (P_0) and placing multiple phantom actuators around the same physical actuator ($A_{1,1}$). For P_0, the four surrounding physical actuators should be activated. Horizontally, both $A_{0,0}$ and $A_{1,0}$ should use an amplitude near 100% of P_0. But vertically, these actuators should use an amplitude near 75% of P_0. Hence, P_0 creates conflicting requirements. Similarly, P_2 and P_3 create a conflict for $A_{1,1}$, as do P_1 and P_4.

To minimize these conflicting requirements, we applied one constraint to our rectangular areas—the boundaries of the width perpendicular to the motion must coincide with the display's grid lines. This constraint automatically eliminated one of the two conflicts for real actuators. To address the remaining conflicts parallel to the motion, we used the higher amplitude requirement to avoid losing intensity within the contact area. For any perpendicular actuators, we applied the same amplitude. Figure 2 demonstrates our modified version of the Tactile Brush algorithm.

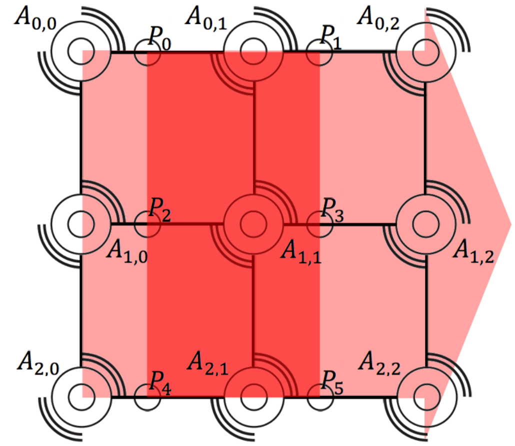

Figure 2: Our modified Tactile Brush algorithm that supports apparent motion for rectangular areas of contact. To avoid amplitude conflicts perpendicular to the apparent motion, we require that the boundaries of the area's width must coincide with the display's grid lines. For the remaining conflicts parallel to the motion, we use the higher of the two amplitudes. For instance, the amplitude of $A_{0,1}$ would agree with the intensity for P_1, not P_0. We use the same amplitude for any perpendicular actuators, such as $A_{1,1}$. For non-conflicted actuators exterior to the contact area, their amplitudes adhere to the normal energy model (e.g., $A_{0,0}$ concurs with P_0). We use the intended amplitude of the contact area for any non-conflicted actuators interior to the contact area.

4 Conclusions

As originally designed, the Tactile Brush algorithm is only capable of producing simple touch gestures involving a single point of contact while displaying smooth apparent motions. We have modified the Tactile Brush algorithm to now support the smooth motion of rectangular areas of contact, which can be used to convey complex touch gestures involving several simultaneous points of contact. Preliminary results from a user study (not covered here) indicate that these complex touch gestures are considered accurate and acceptable. We plan to utilize these gestures in VR-based treatment programs for persons with hypo- and hypersensitivities to touch, such as some autism patients.

References

[1] G. von Békésy, "Sensations on the skin similar to directional hearing, beats, and harmonics of the ear," *Journal of the Acoustical Society of America,* vol. 29, pp. 489-501, 1957.

[2] C. E. Sherrick and R. Rogers, "Apparent Haptic Movement," *Perception and Psychophysics,* vol. 1, pp. 175-180, 1966.

[3] A. Israr and I. Poupyrev, "Control space of apparent haptic motion," in Proceedings of *World Haptics Conference (WHC)*, 2011, pp. 457-462.

[4] I. Morrison, L. Löken, and H. Olausson, "The skin is a social organ," *Experimental Brain Research,* vol. 204, pp. 305-314, 2010.

[5] A. Israr and I. Poupyrev, "Tactile Brush: Drawing on Skin with a Tactile Grid Display," in Proceedings of *ACM Conference on Human Factors in Computing Systems (CHI)*, 2011, pp. 2019-2028.

[6] Y. Shimizu, "Temporal Effect on Tactile Letter Recognition by a Tracing Mode," *Perceptual and Motor Skills,* vol. 55, pp. 343-349, 1982.

[7] M. Niwa, R. W. Lindeman, Y. Itoh, and F. Kishino, "Determining appropriate parameters to elicit linear and circular apparent motion using vibrotactile cues," in Proceedings of *World Haptics Conference (WHC)*, 2009, pp. 75-78.

[8] R. W. Cholewiak and A. A. Collins, "Vibrotactile localization on the arm: Effects of place, space, and age," *Perception and Psychophysics,* vol. 65, pp. 1058-1077, 2003.

[9] J. Seo and S. Choi, "Initial Study for Creating Linearly Moving Vibrotactile Sensation on Mobile Device," in Proceedings of *IEEE Haptics Symposium*, 2010, pp. 67-70.