PhantomTouch: Creating an Extended Reality by the Illusion of Touch using a Shape-Memory Alloy Matrix

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ABSTRACT

With the rise of VR applications, the ability to experience physical touches becomes progressively important to increase immersion. In this paper, we propose PhantomTouch, a wearable forearm augmentation, that enables recreation of natural touch sensation by applying shear forces onto the skin. In contrast to commonly used vibration-based haptics, our approach consists of arranging light-weight and stretchable 3×3cm plasters in a matrix onto the skin. Individual plasters were embedded with lines of shape-memory alloy (SMA) wires to control shear forces. The matrix arrangement of the plasters enables the illusion of a phantom touch, for instance, feeling a wrist grab or an arm stroke.

CCS CONCEPTS

• **Hardware → Haptic devices**; • **Human-centered computing → Virtual reality**.

KEYWORDS

Haptics, Pinching, Wearable, Shape-Memory Alloys, Touch Illusion, On-skin, Virtual Reality, Phantom Touch

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1 INTRODUCTION

In HCI, tactile sensation has been widely extensively explored. Typical haptic feedback interfaces [El Saddik et al. 2011] deploy servomotors, solenoids, and vibration motors. Recently, more silent, light-weight, soft, and flexible haptic actuators penetrated the research field of wearable computing, in particular using shape memory alloys (SMA) [Chernyshov et al. 2018; huda Hamdan et al. 2019].

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Proposed designs include pressure feedback, such as to squeeze the wrist and fingers. Using SMA, researchers investigated the perception and two-point-discrimination threshold for squeezing interfaces [Chernyshov et al. 2018], as well as user experience evaluation [Suhonen et al. 2012].

Building upon previous work, we developed SMA-based plasters, which are light-weight and stretchable, creating shear forces similar to light pinches on the skin. The advantage of small plasters is that these can be individually distributed among different body parts, potentially covering a large area, such as the forearm. We derived the design of the plasters based on a series of studies. Particularly, we looked into the perceptibly of different sizes and distances of plasters on the forearm. We arranged 15 plasters with a size of 3×3cm in the form of a matrix on the forearm. This enables us to create the illusion of touches, such as feeling a wrist being grab or an arm being stroke. These physical experiences are currently lacking in virtual environments. Recreating this experience can be an important contribution in collaborative work, as it increases the feeling of immersion [Grau 2003]. The contribution of this research lies in the creation of various phantom touches on the forearm.

2 PHANTOMTOUCH

In our work, we aim to recreate phantom touches that appear to be initiated by another person, in order to enrich VR experiences. To possibly create these touch illusions, we browsed literature and determined SMA as the technology of choice, since it provides a

Figure 1: A user is experiencing the touch of another hand on his own arm in VR environment

variety of advantages. SMA is demonstrably lighter in weight, flexible/bendable, and offer large-amplitude actuation. When heating the SMA from martensite to austenite, such as by applying an electrical current, it goes back to its initial form, such as from a long to a short wire like in our case. These properties predestines SMA for use in wearable computing. Also, previous research already demonstrated how SMA can successfully create the illusion of an arm or finger being squeezed. However, it was unclear how SMA can be utilized to also create other touch sensations and how it can potentially scale to the entire body.

Based on the two-point-discrimination of haptic perception on the epidermis, we decided to design a small plaster. The plaster is able to apply a shear force on the skin, which creates a very subtle pinching. The key advantage of small plasters is that these can be individually distributed among different body parts, potentially covering a large area, such as the forearm. Informed by a series of studies, we arranged 15 plasters with a size of 3×3cm in form of a matrix on the forearm *(see Figure 2)*, which enabled us to create the illusion of different types of touches. We recreated 8 phantom touches (*see Figure 3*).

3 IMPLEMENTATION

For our prototype, we selected the SMA wire: BMF150 SMA. According to the data sheet, our wire contracts to a predefined length when heated up to 70°C . This contraction is 4% of the total length of the wire and can be used to apply a force equivalent to 144gf (1.44N), when the recommended current of 340mA is applied. For activation we maintained the current in each patch for 1 second. The ability of SMA wires to contract enables a variety of actuation possibilities. We stitched the wire into a sticky cloth patch (Kinesiology Muscle Tape). This generates shear forces along the skin as shown. This shear forces subtly deforms the skin and hence generates touch sensations.

Figure 2: The PhantomTouch prototype: A plasters matrix augmenting the forearm using 15 plasters.

4 EVALUATION

The aim of this study is to recreate different phantom touches. Based on the literature related to social interactions [Hertenstein et al. 2006], we decided to recreate 8 touches. We recruited 10 participants (6 males and 4 females) aged between 22 and 32 (M = 26.3, SD = 2.87). We evaluated PhantomTouch in two ways.

In a VR environment (using an Oculus Rift) displaying the user's left arm. The participant was presented with videos of a virtual arm being touched, we synchronously activated a predefined actuation pattern. Each touch gesture was presented three times in a random order. After each trial, we asked the participant to report on a 5-point Likert scale (1: unreal, 5: very real) how realistic the touch illusion felt. According to the users feedback, all *PhantomTouches* were perceived to be fairly real as the perceived realism of the recreated touches was rated *M = 4.07 (SD = 0.27)* across all users.

In the second part of the study, we randomly provided one of the 8 phantom touches 5 times, while the user was not presented with a visual stimulus. The participant was asked to identify the touch gesture felt.

IDENTIFIED PHANTOM TOUCHES

RECREATED PHANTOM TOUCHES	GA	GW	TTU	TTD	SU	SD	RW	RA
Grabbing the Arm (GA)	92	0	0	0	0	0	0	8
Grabbing the Wrist (GW)	0	98	0	0	0	0	2	0
Three Taps UP (TTU)	0	0	96	0	4	0	0	0
Three Taps Down (TTD)	0	0	0	88	0	12	0	0
Stroking Up (SU)	0	0	2	0	98	0	0	0
Stroking Down (SD)	0	0	0	4	0	96	0	0
Rolling on the Wrist (RW)	0	0	0	0	0	0	100	0
Rolling on the Arm (RA)	8	0	0	2	0	0	0	90

Figure 3: Accuracy of correctly identified Phantom Touches in a Confusion matrix

The results show (*see Figure 3*) that across all 8 phantom touch gestures, users were able to correctly identify them by an overall accuracy of 94.75%.

5 CONCLUSION

The results show that touch illusions generated by PhantomTouch are perceived to be reasonably close to a real touch. In particular, the illusion of three taps on the arm was perceived as the most realistic. Because of the SMA's unique properties, we believe this technology to be predestined for wearable feedback technology in HCI. In future, the design of PhantomTouch should be improved by integrating the plasters into an entire sleeve, reducing the time of the costly setup. Moreover, moving away from sticky plasters could further benefit comfort and user acceptance.

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