Submerged Haptics: A 3-DOF Fingertip Haptic Display using Miniature 3D Printed Airbags

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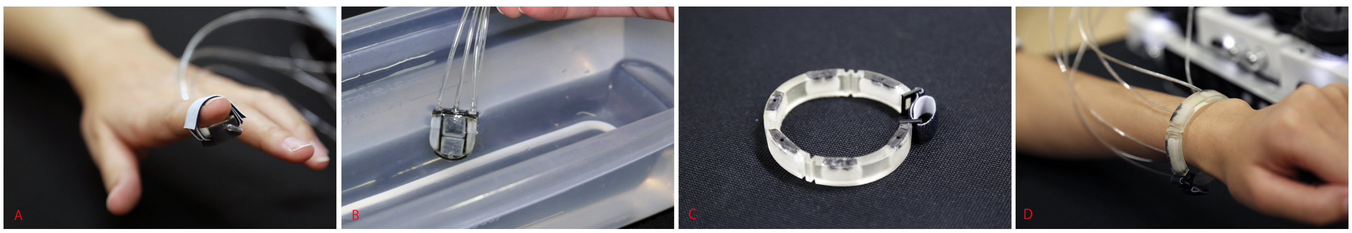

Figure 1: (a) 3 DoF Fingertip Haptic Display, (b, c) Haptic Wristband used in wearable applications

ABSTRACT

In this paper, we present a novel method of creating a waterproof wearable fingertip haptic display "AeroFinger" that is very light and small enough to fit on the fingertip and uses no electro-mechanical actuation. The display consists of 4 miniature airbags which are made out of 3D printed Rubber-Like material so that the display size, strength and shape can be customized by the user. A small sized full range speaker is mounted on a closed air chamber where the air is transferred back and forth through a tiny nozzle to the airbag. The Speaker movements creates a difference in air pressure and translated into airbag inflation and deflation. Therefore, AeroFinger can display the low frequency vibrations as force sensation and high frequency vibrations as tactile sensation. Unlike most ungrounded haptic devices which contains electrical components such as motors or vibration actuators, AeroFinger uses no electro-mechanical actuation and thus can be completely submerged on water or could be used in magnetic resonance environments.

CCS CONCEPTS

•**Human-centered computing → Haptic devices;**

KEYWORDS

Submerged Haptics, 3D printed Air Bags, Air Pressure, Force Sensation, Tactile Sensation

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1 INTRODUCTION

Ungrounded fingertip Haptic displays has been used in various applications such as virtual reality, telepresence, game controllers and consumer electronics. Researches have been able to create electro-mechanical haptic displays[Chinello et al. 2016; Perez et al. 2016; Scheggi et al. 2015] that consists of motors, fluids[TANAKA et al. 2002], or pseudo vibration based force displays[Yem et al. 2016] using high frequency motor movements. In order to render multiple force axises on a single fingertip, these systems require bulky hardware and thus only 1 or 2 fingers can be attached with such haptic displays. Furthermore, these systems does not follow water resistant standards and thus cannot be used on water which limits the haptic feedback applications underwater. Current pneumatic actuation technologies such as Huggy Pajama[Teh et al. 2008] and "AiraWear Haptic Jacket" has been used by haptic researches in order to provide force sensations around several body parts. However, these systems are not suitable for miniature wearable haptics such as fingertip due to low responsive airbag materials with heat press techniques and low frequency operation of bulky air pumps.

In this paper, we propose a novel method of creating a wearable fingertip haptic display "AeroFinger" by combining four 3D printed airbags and replacing the traditional low frequency air pump with a high frequency speaker. As shown in Figure 1(a) these airbags are very light to wear, small enough to fit in the fingertip and could render directional ungrounded force cues and tactile sensation. As a final fabrication step Thermoplastic polyurethane sealant (TPU) material was used to cover any fine air leaks so that it can be completely submerged on water or could be used in magnetic resonance environments.

2 SYSTEM DESCRIPTION

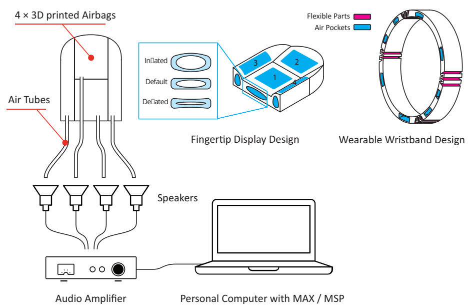

Figure 2: AeroFinger: System Overview

As shown in Figure 2, the AeroFinger haptic display consists of four 3D printed airbags, speaker based actuation mechanism and Max MSP patch for generating the necessary low and high frequency waveforms to inflate/deflate the airbags. 4 speakers has been attached to a multi-channel USB audio playback device (Roland - OCTA-CAPTURE) and 4 audio amplifiers were used to interface the pre-amplified signal to the speakers. The speakers were mounted on closed air chamber where the air is transferred through a tiny nozzle (1.8mm) where the audio signal is converted to a difference of air pressure.

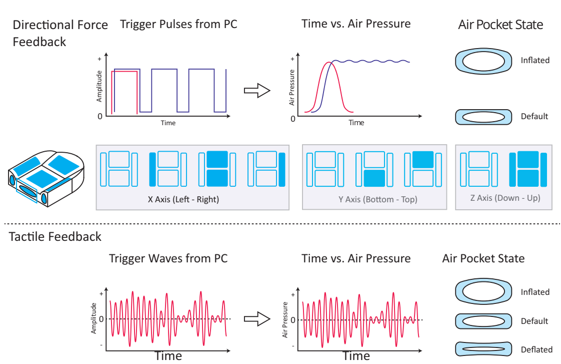

Figure 3: Directional Force Rendering and Tactile Sensation

As shown in Figure 3, the 4 airbags (front, back, left, right) was used to provide x, y, z axis force rendering into the fingertip. The 4 airbags are connected independently to the PC using separate audio channels. Based on the airbag inflation/deflation time and the inter-time delay between two airbags, directional force rendering cues can be generated. For example, up directional force was rendered by continuously switching down and up airbags where a down directional force was rendered by continuously switching up and down airbags. Similarly, 4 directional forces such as up, down, left, and right can be rendered. An impulse force can be generated with inflating all 4 airbags at once. When the deflation time and inflation time is further decreased the airbag surface creates a high frequency vibration which can be felt as a cutaneous tactile sensation. We have experimented with sinusoidal waves ranging from 0.1Hz 50Hz with the current airbag design for texture rendering. Furthermore, when the sinusoidal signal was replaced with a real textural .wav file, airbag acts as a non-mechanical vibrator and feel the tiny vibrations as it would felt on conventional tactile rendering systems such as TECHTILE-TOOLKIT[Minamizawa et al. 2012].

3 USER EXPERIENCE

As shown in Figure 1(d), 3D printed airbags allow the users to effectively reduce the complexity of manufacturing custom shapes of airbags so that these airbags could be embedded with any wearable device or object at the design manufacturing process. At Siggraph 2017, we plan to demonstrate a full haptic glove with 5 aeroFinger configuration to interact with virtual/real world with directional force and tactile force rendering.

4 CONCLUSION

In this paper, we present a novel method of creating a wearable fingertip haptic display "AeroFinger" that is very light to wear, small enough to fit in the fingertip and uses no electro-mechanical actuation to render the 3DOF force feedback and tactile sensation. Since it does not contain any electro-mechanical actuation it can be completely submerged on water or could be used in magnetic resonance environments. As a conclusion, 3D printed airbags allow the users to effectively reduce the complexity of manufacturing custom shapes of airbags so that not only can be used as a haptic display for fingertip, but also be extended to the entire hand as a haptic glove, embedded with any wearable devices objects at the design manufacturing process to give a sense of haptic touch.

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