Wearable Soft Pneumatic Ring with Multi-Mode Controlling for Rich Haptic Effects

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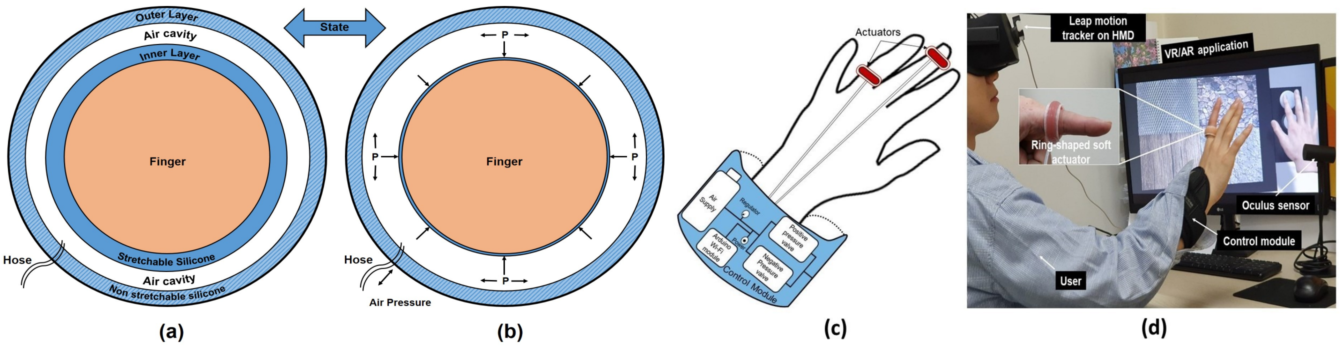

Figure 1: Illustrated concept and use-case of our soft haptic ring: (a) a cut section view of the multi-layer membranes of the ring in a normal state, (b) pressurized state, (c) pressure control module and examples of actuator's positions of finger mounting, (d) illustrative scenario of VR/AR application: exploring the virtual textures and perceiving its haptic feedback.

KEYWORDS

Haptic, Actuator, Pneumatic, Vibrotactile, Multi-mode, Soft-haptics, Augmented reality, Haptic interface.

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1 INTRODUCTION

Common mechanical actuators for haptic feedback are generally dedicated to creating single kind of feedback, e.g., vibrotactile only, the pressure only, or shear force only, [Choi and Kuchenbecker 2013; Girard et al. 2016; Pacchierotti et al. 2017]. This is against the fact that highly realistic fully immersive VR/AR sometimes requires rather complete and rich multi-mode haptic feedback. For instance, when rubbing your finger on a wooden desk, the fingertip simultaneously senses both the high-frequency vibration due to the roughness of the surface texture and the quasi-static pressure due to pushing force, and your brain combines them to feel it as a wooden desk. The lack of any of the involved physical signal may seriously deteriorate the realism. This may be one of the reasons why current haptic interface technology for VR/AR environments is not at the same level as visual interfaces.

Using multiple actuators having different covering bandwidth can be one of the solutions. However, making different mechanical end-effectors from multiple actuators share the same contact area on a finger skin is not a trivial task. Besides, multiple hardware inherently makes the system bulky, decreasing the usability, especially when wearability is one of the important requirements.

This paper presents our new haptic interface that partially overcomes the issues. The interface is a soft silicone bladder and wearable, i.e., small and light enough to wear, to the finger as a ring. It is capable of providing various haptic feedback including high pressure, high-frequency vibration (up to 250 Hz), and an impact to the finger simultaneously through a single end-effector. Through our empirically formulated controlling algorithm, the rendered pressure, the frequency of the vibration, and the amplitude of the vibration can be precisely controlled.

2 OUR APPROACH

We choose to use pneumatic actuation to a soft bladder due to the following reasons. First, pneumatic actuation is small and lightweight (if combined with miniaturized valves and compressed air tanks) but powerful, so is optimum when considering portability. Our device, for instance, can generate up to 2.2 g acceleration and up to 7.6 N force with the hardware weight only 250 gram. Secondly, the membrane of the ring-shaped bladder used as an end-effector is very thin and flexible, so it can be not only used as a static pressure contactor but also moves rapidly to convey vibration. More importantly, combined with a high-pressure air source, the bladder can generate very fast changing pressure, which can be perceived as an impact. As a result, the design of this bladder is one of the essential

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