Multi-mode Simultaneous Tactile Feedback Using Soft Pneumatic Fingertip Actuator with Dual Air Chamber

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Abstract The paper suggests a new fingertip actuator made of silicone that can simultaneously produce pressure and vibrotactile feedback in order to offer a more realistic and immersive haptic experience in virtual environments. The actuator has a dual-layer air chamber design, with the top layer providing vibration feedback and the bottom layer providing pressure feedback. Pneumatic valves with pressurized air tanks can regulate the actuator. The actuator was tested in a simulated environment to render three different kinds of haptic textures. It is made to be worn conveniently at the fingertips. To compare the effectiveness of the suggested actuator to an actuator with a single vibrotactile feedback, performance assessments and user studies were done.

1 Introduction

Virtual reality (VR) utilizes hardware and software to replicate the physical signals produced by real-world interactions for our five senses [1]. While haptic feedback is still inadequate and requires technological advancement, new developments have enhanced the accuracy of visual feedback in VR. High-fidelity virtual interaction requires tactile feedback, which simulates the sense of touch [2], yet most tactile actuators today can only produce one sort of feedback [3, 4]. The article suggests a dual-layer fingertip actuator made of silicone that can deliver pressure and vibrotactile feedback at the same time, offering a variety of haptic sensations for a very realistic

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and engaging VR experience. The actuator is made up of two air chambers that are stacked on top of one another, with the bottom chamber creating pressure feedback and the top chamber producing vibration feedback.

2 Actuator Design and Fabrication

Ecoflex 00-30 (Macungie, Pennsylvania, PA, USA) was chosen as the material to mold the proposed actuator. A specific mold was employed, which was manufactured using acrylonitrile butadiene styrene (ABS) material on a 3D printer. In the mold, there was a hollow chamber into which the liquid material was poured. It had to wait until the liquid material solidified after being poured. A model of the final object served as the basis for creating the mold. The final actuator, depicted in Fig. 1, was a fingertip-shaped item made of two movable molds that were intended to be worn on the index finger. The size of the mold must be changed in order to adjust the actuator to various finger sizes. Our complete proposed framework for texture rendering using the proposed actuator is shown in Fig. 2. Users can visually and physically explore virtual textured surfaces that develop in the VR environment.

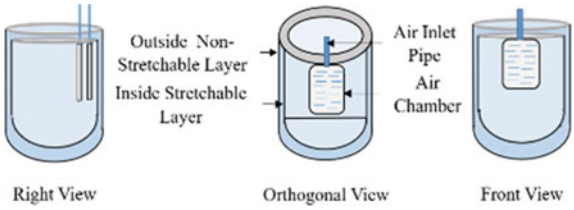

Fig. 1 Design and structure of the actuator

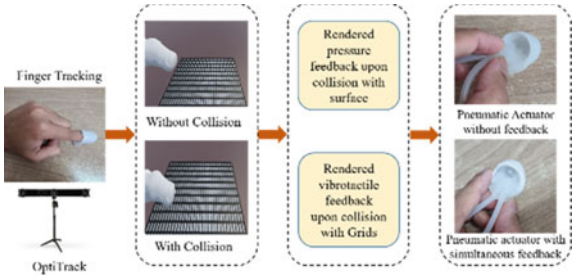

Fig. 2 Proposed framework for haptic texture rendering

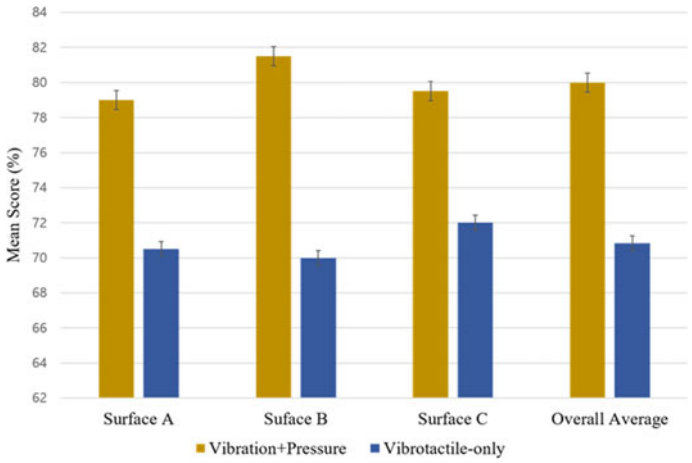

Fig. 3 Mean scores for the realism. The error bars show the standard error

3 User Study: Overall Realism

In this experiment, we directly evaluated the simultaneous feedback's subjective realism. The realism of the "vibration + pressure" method is contrasted to that of the "vibration-only" method here. For the experiment, we invited fifteen participants—eight men and seven women. Their ages ranged from 22 to 30 and were on average 26. Participants twice used the "vibration-only" and "vibration + pressure" methods to examine each sample. The participants were asked to report the overall fidelity ratings to the operator by answering how realistic the feedback was (realism) on a scale from 0 to 100. The mean scores for the questionnaire are plotted in Fig. 3. The Type B surface that utilized simultaneous feedback received the highest score, 81.5, followed by the Type C and Type A surfaces. Again, for all three types of surfaces, the actuator with a single vibrotactile feedback displayed worse fidelity.

4 Conclusions

The paper details a novel method for enhancing virtual reality systems' haptic feedback using a fingertip actuator constructed of two layers of silicone that can simultaneously produce pressure and vibration input. The actuator is made up of two air chambers that can change in size to provide the desired level of haptic stimulation. The suggested actuator may be simply made into several sizes depending on the user's finger size and is wearable. The study demonstrates that the novel method can be a substitute for wearable haptic devices, which often are incapable of delivering kinesthetic feedback. The actuator might be used in the fields of medical education and rehabilitation. We did not consider the change of pressure according to

the depth of force applied on the surfaces. The study ends by recommending that further research take into account changing pressure feedback and conduct in-depth numerical analysis.

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