A Surface Texture Display for Flexible Virtual Objects

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Abstract. This paper presents a tactile device for displaying surface texture of flexible virtual objects. The texture is simulated using electrovibration effect produced by a flexible film. The deformation of the film is controlled by a DC motor to generate desired softness according to applied finger force. A prototype of the device is developed and integrated with a virtual environment. We show the application of the display using an online shopping scenario.

Keywords: Tactile Device, Electrovibration, Flexible Object, Texture Display, Softness Display.

1 Introduction

Tactile devices are utilized to provide user with tactile stimulus. Thus far, a wide range of tactile devices have been developed to simulate different tactile feedback. In recent years, tactile devices that can provide multimodal tactile feedback have gained increased interests [1-4]. A few devices presenting softness and texture have been developed. Bianchi used two motors to control the deformation and vibration of an elastic fabric for simulating softness and texture [5]. Nakamura combined a deformable pad with a rigid texture display based on electrovibration effect for simulating softness and texture [6].

In this paper, we present a new tactile device for displaying softness and texture. The texture is simulated using a flexible texture display and the deformation of the display is controlled by a DC motor to generate desired softness according to applied finger force. By controlling the deformation of the flexible electrostatic display, a large range of softness can be simulated as compared to the existing device using rigid texture display. We developed a prototype of the device and integrated it with a virtual environment to verify the function of the display.

2 System Design

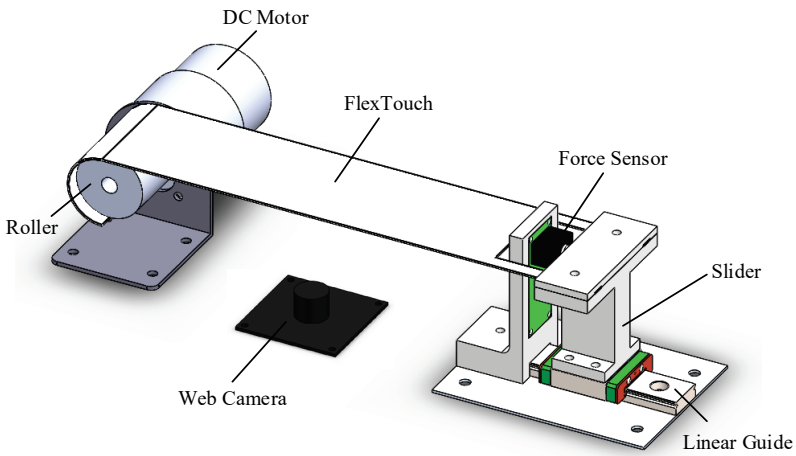

Fig. 1. Schematics of the tactile device

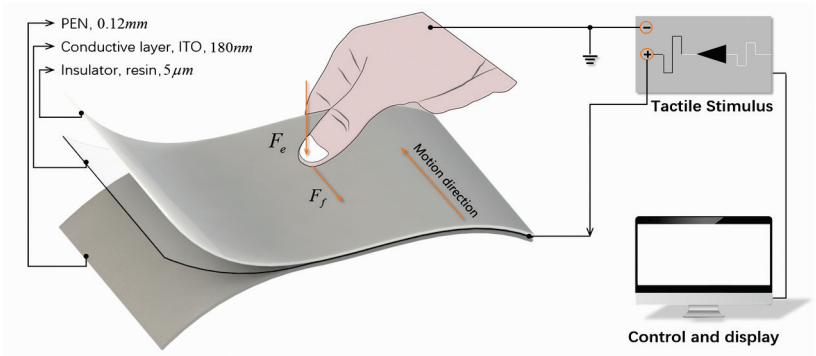

Fig. 2. Working principle of FlexTouch [7]

Fig. 1 shows the schematics of the tactile device. Texture sensation is simulated by FlexTouch, a flexible film described in [7] (Fig. 2). The flexible film is composed of three layers including a base layer, a conducting layer and an insulating layer. When the conducting layer is excited with a periodic voltage, an electrostatic force appears between the insulating layer and a sliding finger. The friction F_f increases with the electrostatic force F_e, which depends on the input voltage v, i.e.

$$F_f = \mu F_e(v) \tag{1}$$

where μ is the friction coefficient.

To simulate different textures, the input voltage is altered according to finger position which is detected using a web camera.

Softness sensation can be divided into kinesthetic softness and cutaneous softness [8]. The device presented in this paper generates only kinesthetic softness. The displayed stiffness is

$$k = \frac{F_n}{\Delta z} \tag{2}$$

where F_n is the normal force applied by the finger and Δz is the vertical displacement of the film. The desired stiffness is achieved by measuring the normal force and controlling the displacement accordingly.

3 Prototyping

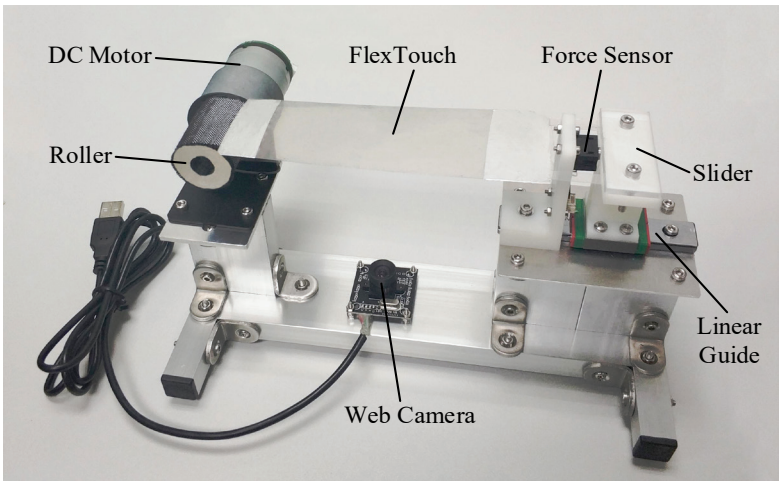

Fig. 3. Prototype of the tactile device

Fig. 3 shows a prototype of the tactile device. The right end of the film is connected to a 3D-printed slider, which is mounted on a linear guide (MGW7C, HIWIN Technologies Corp., Taiwan). A one-dimensional force sensor (FSG015WNPB, Honeywell International Inc., USA) is placed against the slider. To support the force sensor, a 3D-printed bracket is adopted. A piece of fabric is connected between the left end of the film and the roller driven by a DC motor (Minibalance, China). The DC motor is equipped with a relative magnetic encoder. A web camera (with a resolution of 1280×720) is mounted on the base of the device beneath the film to detect finger position.

OpenCV computer vision library is used to develop the algorithm of finger position detection. The input voltage for the film is generated by a DSP platform and a custom designed amplification circuit. A microcontroller board (Arduino Mega 2560, Italy) is used to process the input data of the force sensor and control the motor position accordingly.

4 Example Application

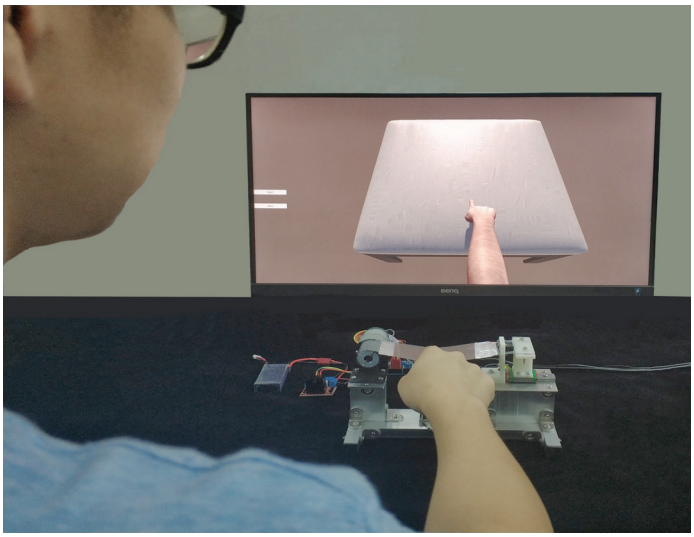

Fig. 4. Feel the texture and softness of an online product

An online shopping scenario shown in Fig. 4 is constructed utilizing Unity game engine. The user can control the virtual hand to explore surfaces of different flexible virtual objects in the scenario. Two kinds of gesture are supported in the exploring process, i.e., sliding finger horizontally to perceive texture and pressing finger vertically to perceive softness.

5 Conclusion

We have presented a tactile device for displaying surface texture of flexible virtual objects. The device was implemented and integrated with a virtual environment. An online shopping scenario was demonstrated. The preliminary result shows that the device is able to simulate texture and softness of flexible virtual objects. The estimated displayed stiffness ranges from 0.1 N/mm to 2 N/mm. We expect this device can enhance users' experience in broad applications of virtual reality.

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References

1. Nakamura, T., Yem, V., Kajimoto, H.: Hapbelt: haptic display for presenting vibrotactile and force sense using belt-winding mechanism. In: SIGGRAPH Asia 2017 Emerging Technologies, pp. 1-2. (2017)
2. Yem, V., Kajimoto, H.: A fingertip glove with motor rotational acceleration enables stiffness perception when grasping a virtual object. In: International Conference on Human Interface and the Management of Information, pp. 463-473. (2018)
3. Hashizume, S., Takazawa, K., Koike, A., Ochiai, Y.: Cross-field haptics: tactile device combined with magnetic and electrostatic fields for push-pull haptics. In: SIGGRAPH ASIA 2016 Emerging Technologies, pp. 13. (2016)
4. Murakami, T., Person, T., Fernando, C.L., Minamizawa, K.: Altered touch: miniature haptic display with force, thermal and tactile feedback for augmented haptics. In: ACM SIGGRAPH 2017 Emerging Technologies, pp. 2. (2017)
5. Bianchi, M., Poggiani, M., Serio, A., Bicchi, A.: A novel tactile display for softness and texture rendering in tele-operation tasks. In: World Haptics Conference, pp. 49-56. (2015)
6. Nakamura, T., Yamamoto, A.: Extension of an electrostatic visuo-haptic display to provide softness sensation. In: Haptic Symposium, pp. 78-83. (2016)
7. Guo, X., Zhang, Y., Wang, D., Jiao, J.: Absolute and discrimination thresholds of a flexible texture display. In: World Haptics Conference, pp. 269-274. (2017)
8. Tiest, W.M.B., Kappers, A.M.L.: Cues for haptic perception of compliance. IEEE Transactions on Haptics 2, 189-199 (2009)