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Experiments with Cutaneous Haptic Feedback - A Preliminary Study

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Abstract - We demonstrate some preliminary results of the cutaneous haptic feedback device. The device is basically from the previous researches; however, our purpose is to achieve reality by exclusive usage of the cutaneous fingertip device. Thereby, we examine its feasibility and drawbacks, and improve the virtual reality.

Keywords - Haptic, Tactile, Cutaneous feedback, Virtual Reality, Haptic device.

1. Introduction

There have been a lot of attempts to realize more realistic haptic feedback. Most of them utilized common haptic devices, such as the Omega (Force Dimension), Spaceball (3D Connexion), and Phantom (Geomagic). Although they provide proper haptic sense, it is tough for those sizable devices to achieve cutaneous force feedback to users fingertip. The reason is that the way of grasping those devices is quite different from that of touching objects with fingers. The devices require the user to grasp some of the body parts (e.g., stylus, ball) while we need no additional such organ to contact objects in real world.

In order to solve this, various studies on simplified cutaneous haptic device have been in progress [1-6]. These devices apply haptic feedback to the fingertip directly. The size of devices is small and the user can move their hand freely relative to conventional haptic devices. Hence, cutaneous haptic device seems suitable for realistic fingertip tactile sense. Several researches including [1] tested the reality of tactile sensation. Afterward, using dual motors, the practical usage of independent finger device became feasible [2-4]. The device was applied to the augmented reality field by displaying virtual mass while holding real object [2]. The dual motors manage the cutaneous feedback to the fingertip, while holding real object refers to the kinesthetic feedback. The followed research [3] indicated that the integration of the kinesthetic and cutaneous feedback yields the best reality. Meanwhile, Prattichizzo et al. [5-6] demonstrated that the single cutaneous force feedback can replace the integration of whole haptic feedbacks effectively for some certain scenarios.

Accordingly, in this paper we represent some preliminary results of the implementation of cutaneous force feedback haptic device without kinesthetic part. The main purpose of this research is to allow multiple users to haptically interact with each other using these portable haptic devices via deformable objects. As a first step, in this paper, we present an implementation of cutaneous haptic device proposed in [2] and detail some issues related to its implementation.

2. Principle and Device Design

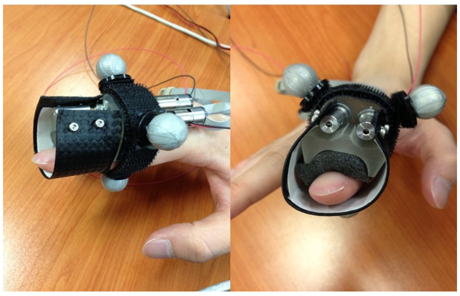

Fig. 1 Cutaneous Haptic Device

In order to confirm the previous researches, we basically adopted the wearable fingertip haptic device by Minamizawa et al. [2] at considerable portion. Dual motors with encoders (Maxon DCX motor, 10, 3W, 16:1 gear ratio) transmit normal tactile force to the fingertip via attached band.

The user can perceive the normal force by opposite direction rotation of two motors, while the same direction rotation induces shearing force.

3. Preliminary Experiment

A. Human-based calibration

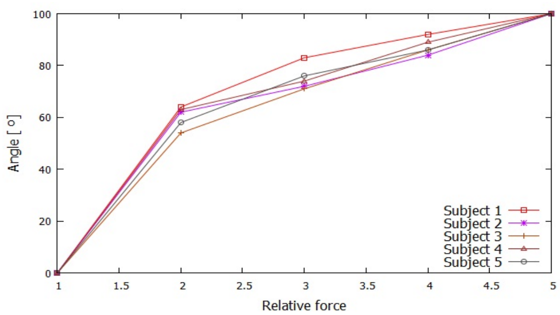

Fig. 2 Force-angle relation from human perception evaluation

In order to generate force of proper magnitude, relation between the rotating angle of dual motors and required force is necessary. Due to deformability of fingertip, it is difficult to obtain relation by using its geometric modeling or attaching force sensor. Accordingly, the following evaluation was carried out using human as sensor directly.

First, the maximum angle of each subject was measured which is also physically allowed maximum force. Then each subject was asked to report the points where he perceives 25, 50, and 75 percent level of maximum force. Five subjects took part in the experiment, and each of them made 5 repetitions. Surprisingly, the result shows that all subjects performed similar force perception which seems reliable after all maximum angles were calibrated to the same value, 100. This relation is used depending on the maximum angle which is measured in the beginning of every single experiment.

B. Experiment

As the first step, we demonstrated an implementation of simple rigid body. With cutaneous haptic devices on the index finger and thumb each (Fig. 1), user can freely move hand and fingers in the extent of hardware cables.

In the virtual environment, a fixed object such as sphere, plate, or cube and the position on the fingers are displayed. The object is rigid that the user can perceive its surface.

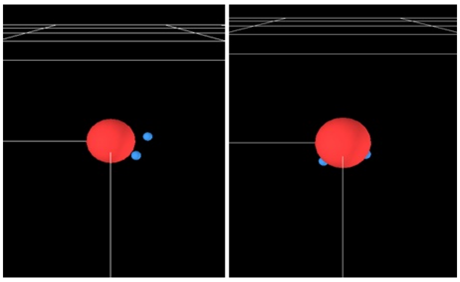

Fig. 3 Fixed object(Sphere) and position of two fingers. Contact off & on

When the finger touches the surface of the sphere, normal force is applied to the fingertip (Fig. 3). As the fingertip penetrates inside, the applied force continuously increases to the maximum value. Similar contact tasks are possible with various rigid objects mentioned above.

C. Results

Through our preliminary experiment of object contact, the implementation of haptic feedback with cutaneous device seemed realistic in some situations. Users can notice the existence of rigid object by pressing boundaries.

However, because of the absence of constraints that stop fingers penetrating the object, the fingers move freely inside the object, which decreases reality.

4. Conclusion and Future Work

The goal of this paper is to investigate the feasibility of the cutaneous haptic device. Hence, we began with the implementation of object contact. According to the result, it seems that single cutaneous feedback has possibility to partly substitute the complete haptic feedback. User can perceive rigid edges of the object without kinethetic feedback or real subsidiary object.

Nevertheless, as the previous research [6] explained, cutaneous haptic feedback alone is still somewhat different from actual sensation. The level of reality sharply decreases a few seconds after the contact, while the momentary perception is quite clear. It is mainly because the non-existence of limitation of fingers inside the object surface. To improve this, modification in computer vision is necessary if all other physical conditions are fixed.

As a future work, implementation of diverse cases among multiple users are expected. Also, in order to solve unrealistic penetration problem, concept of pseudo-haptics can be also applied. Finally, analyzing the reality of the device with experiments including several subjects can be carried out to check validity.

Acknowledgement

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