Weight Illusion by Tangential Deformation of Forearm Skin

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ABSTRACT
When we perform exercise or undergo rehabilitation, it is helpful to be supported by another person. To get this support, we normally take hold of a person's arm, and pull it. In this paper, we investigate the use of a special device to produce a "pulling arm" sensation on the forearm. Using a weight comparison task, we performed an experiment to confirm the sensation of illusory external force with our device. We concluded that our current device presented about 10g to 20g weight perception.

Categories and Subject Descriptors
H5.2. Information interfaces and presentation: User Interfaces – haptic I/O, prototyping.

General Terms
Performance, Experimentation, Human Factors

Keywords
Pulling hand, forearm skin, force sensation

1. INTRODUCTION
When we perform exercise or undergo rehabilitation, it is helpful to be supported by another person. Many power assisted devices have previously been proposed to replace the person in providing such support [1]. While the device can produce a large amount of force, safety is an issue. On the other hand, there are some passive type haptic devices that use brakes [2]. Although safety is less of a problem, such devices can only guide, but not help. In both cases, bulky structure hinders their practical use.

In the practicing rehabilitation field, it is often observed that tiny tactile sensations dramatically change patients' ability. For example, patients may subjectively feel that their legs were "supported", when the soles of their feet were merely being touched.

This observation suggests that skin sensation might be subjectively felt as an external force. If true, this notion would allow us to produce a "pseudo-power supporting device" that is simply a tactile display, but is interpreted by the user as real support. Such a device is safe, lightweight, and easy to wear.

In this paper, we focus on the forearm to produce "pulling arm" sensation. We make the device and perform an experiment that confirms the sensation of illusory external force, by means of a weight comparison task.

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1.1 Pulling Arm Sensation
We carefully observed the process of one person pulling the arm of another for purposes of support (Figure 1). First, the "puller" takes hold of the other person's forearm, and pulls it any direction. At this moment, skin deformation and pressure sensations are produced at the forearm in the direction of the pulling forearm (Figure 1: red arrows and green arrow).

We focused on the skin deformation and pressure sensation, predicting that if these phenomena were reproduced, one can feel the sensation of illusory external force in any direction. We made the device based on this principle.

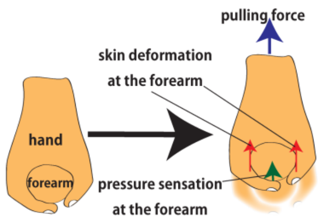

Figure 1. Process of "pulling arm" sensation

2. Related Works
A number of prior devices used internal force as a substitute for external force. Tsetserukou et al. [3] proposed a wearable device attached on the upper and lower arms to reproduce joint torque. However, the apparatus is large and cumbersome for practical use.

On the other hand, alternative devices provided the pseudo-force sensation by stimulating the skin. Minamizawa et al. [4] proposed to squeeze the skin of a finger to provide the pseudo external force. Barks et al. [5] produced tangential skin deformation on the arm. Their primary purpose was to provide the direction of arm joint rotation by tweaking the skin.

Our work can be considered as a derivation of these prior attempts to produce pseudo-force by skin deformation. We produced tangential skin deformation on the skin of the forearm as the pseudo external force. We believe that our approach meets the criteria for practical applications in a rehabilitation setting.

3. DEVICE DESIGN
Figure 2 provides an overview of our device. Briefly, it is composed of two servomotors (Grand Wing Servo-Tech Co., Ltd, GWSMICRO/2BBMG), a rubber band, wristband, strings and acrylic frames.

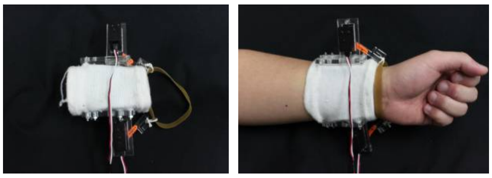

Figure 2. Overview of the device

3.1 Principle of Operation

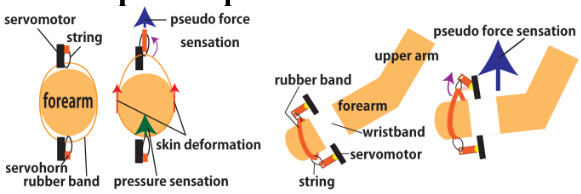

Figure 3. Principle of operation: Front view (left), Side view(right)

Figure 3 shows the principle of operation of our device. To generate an upward pulling sensation, the upper servomotor is actuated upward. Then, it pulls up the rubber band and produces lateral skin deformation because of the friction between the forearm (Figure 3 (left): red arrows) and the rubber band. At the same time, pressure sensation is produced in the lower forearm by the rubber band (Figure 3 (left): green arrow). In the same manner, the device can also produce the pseudo force sensation to the lower direction by actuating the lower servomotor.

4. EXPERIMENT

We performed an experiment using a weight comparison task to confirm the sensation of illusory external force with our device.

A participant compared the weight grasped by the left hand (standard stimulus) and the weight grasped by right hand (comparison stimulus) while wearing our device in both hands. In addition, the right hand's device was actuated. We adjusted the participant's right hand's weight until he/she reported that both weights were equal. We performed the experiment under three conditions of the device on the right hand: pulling-up sensation, pulling-down sensation, or no operation with three standard weights (100g, 200g, or 400g). Four trials per each combination produced a total of 36 trials (3×3×4). The participant grasped and lifted the weights for five seconds. After that, he/she placed both weights and chose from three possible answers (heavy, same, or light).

Five right-handed participants (three males and two females) whose ages ranged from 22 to 25 years participated in this experiment. All participants had their eyes closed during the experiment.

5. RESULT

Figure 4 shows the difference between the standard weight and comparison weight when participants perceived them as equal. Results of three standard weights are averaged.

We performed an ANOVA [$F(2, 12)=12.89$, $P<0.01$], which supported the effect of our device on weight perception. Specifically, participants perceived that the both weights are equal when the right hand's weight was heavier than left hand's weight in all cases. We speculated that this tendency is due to the dominant hand effect, since all subjects were right handed.

When we produced the pulling-down sensation, participants perceived both weights to be approximately equal, but when we produced the pulling-up sensation, they perceived that a 33g heavier weight in their right hand was equal. Combining these results, we concluded that our current device provided about 10g to 20g weight perception. In this experiment, we did not eliminate skin sensation of the fingertips. Therefore participants could perceive weight by using not only movement of the arm but also skin sensation of the fingertips. We suppose that if we eliminate skin sensation of the fingertips, the result may become more obvious

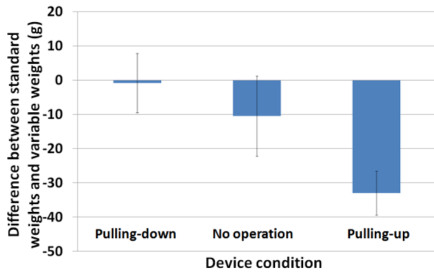

Figure 4. Difference between standard weight and comparison weight for the device condition

6. FUTURE WORKS

In this paper, we illustrated the use of a novel haptic device to produce tangential skin deformation to the forearm, and thus, an external force sensation. The experiment showed that the device could produce a force sensation of around 10g to 20 g.

Although the current experiments were conducted in quasi-static situation with a five-second duration, we speculate that our skin stretch method may be more effective in a dynamic situation. Our future efforts will aim to test this speculation, and develop a more effective device.

7. REFERENCES

[1] H.Kazerooni, Human power extender: an example of human-machine interaction via the transfer of power and information signals, Advanced Motion Control Conference,1998

[2] M.Sakaguchi et al., Passive Force Display Using ER Brakes and its Control Experiments, IEEE Virtual Reality2001,pp.2-7,2001

[3] D.Tsetserukou et al., FlexTorque: Exoskeleton Interface for Haptic Interaction with the Digital World, Euro Haptics 2010,Part II ,LNCS 6192,pp.166-171,2010

[4] K.Minamizawa et al., Simplified Design of Haptic Display by Extending One-point Kinesthtic Feedback to Multipoint Tactile Feedback, IEEE Haptics Symposium 2010,pp257-260,2010

[5] K.Bark et al., Rotational Skin Stretch Feedback: A Wearable Haptic Display for Motion, IEEE TRANSUCTIONS ON HAPTICS 2010 (vol.3 no.3),pp166-176,2010