Haptic Device that Presents Sensation Corresponding to Palm on Back of Hand for Teleoperation of Robot Hand
Report 5: Verification of development device specifications

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Abstract

In this research, we propose and develop a new tactile presentation device for tele-operation of a robot hand. The proposed device presents tactile sensation on the back of the operator's hand. The required specification for device development were determined by subject experiments in our previous studies. In this paper, we developed prototype device using suction stimulus with determined required specification and confirmed that the developed device can present tactile sensation correctly and discuss the results.

Keywords: *Rescue robot, Haptic Device, Teleoperation, Robot Hand*

1. Introduction

After the Great Hanshin-Awaji Earthquake in 1995, research and development of disaster response robots gained momentum [1]. In recent years, disaster response robots that can gather information and perform tasks are required [2]. Therefore, disaster response robots equipped with robot hands have been developed to work at disaster sites to achieve human-like characteristics, such as pulling out pipes and removing debris [3]. Disaster response robots are operated in unknown and extreme environments; therefore, they are controlled by teleoperation [4]. To make teleoperation more efficient with a robot hand, it is necessary to provide feedback to the operator on the contact state between the fingers and palms of the robot hand and the object to be grasped. In this study, the tactile sensation is substituted by the back of the hand instead of the palm, that is presented just behind the palm; therefore, we think that the operator can recognize the tactile state more accurately.

In the first report [5], the characteristics of tactile sensation on the back of the human hand were clarified to obtain the required specifications for creating a device. In the second report [6], we examined whether the tactile sensation can be presented as a surface instead of a point without changing the specifications. In the third report [7], we examined whether it was possible to present tactile sensations with suction stimulation instead of pressure stimulation. In the fourth report [8], we investigated relationship between the diameter of suction pad and the correct answer rate, and we found that the larger the diameter was, the higher the correct answer rate was. In this study, a prototype of the proposed device is fabricated based on the results obtained from previous experiments [8], and its performance is verified through subject experiments.

2. Substitute Tactile Presentation Device for Back of Hand

To correctly convey the state of contact between the robot hand and the grasping object to the operator ideally is to present the tactile sensation directly to the palm of the hand, as shown in Fig. 1. However, when the robot hand is directly tele-operated by the operator's hand, the haptic device may interfere with the work. In this study, we propose a method to present the tactile sensation on the back of the hand, as shown in Fig. 2.

2.1. *Parameter identification*

In designing such a back-of-the-hand substituting tactile presentation device, the following parameters are required:

- Interval between stimulus points (interval: *i*)
- Diameter of the stimulus point (diameter: *d*)
- Force of the stimulus point (force: *f*)

Human skin sensation has characteristics such as a two-point discrimination threshold. Too close stimulation points and very sparse stimulation points does not present an appropriate contact situation. Therefore, we conducted an experiment on subjects to confirm the characteristics of the tactile sensation on the back of the hand for our proposed device [5]. As a result, the combination (*i*, *d*, *f*) = (30 mm, 6 mm, 0.9 kg) had the highest rate of correct answers.

However to fabricate a tactile presentation device, suction stimulation is utilized instead of the pressure stimulation because the device will become very large with pressure stimulation. Therefore, we designed the device as shown in Fig. 3. In the third and fourth paper [7] [8], we checked how well the pressure stimulation position of the palm matched the suction stimulation position of the back of the hand. In addition, we found that the correct answer rate for suction stimulation was highest when (*i*, *d*, *f*) = (30mm, 15mm, 0.9kgf).

2.2. *Fabricated device*

The prototype device shown in Fig. 4 was fabricated based on the specification determined in our past studies. The device consists of a suction pad, a suction bracket, and a fixture created by a 3D printer. According to the determined parameters, the diameter of the suction pads is 15 mm and the interval between each pad is 30 mm.

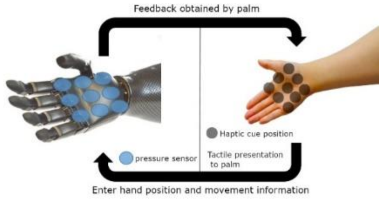

Fig. 1. Ideal method

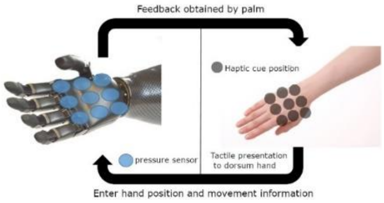

Fig. 2. Proposed method

Fig. 3. Designed device with parameters obtained by experiment

2.3. *Substitutional Tactile Presentation System*

Fig. 5 shows the system configuration of the whole tactile presentation device for the back of the hand explained in Section 2.2. The device provides suction stimulation to the user. A vacuum pump is GCD-051X (ULVAC), and 9 regulators for vacuum pressure control are ITV2090 (SMC). The vacuum pressure can be controlled by the input voltage of the regulator, and a micro-computer (Arduino) outputs the input voltage to each regulator. 9 surface pressure sensors are used to convert the contact strengths to voltages, which are read by the Arduino.

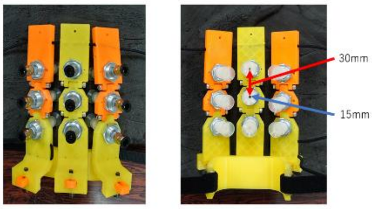

Fig. 4. Prototype device
(Left: Top view, Right: Bottom view)

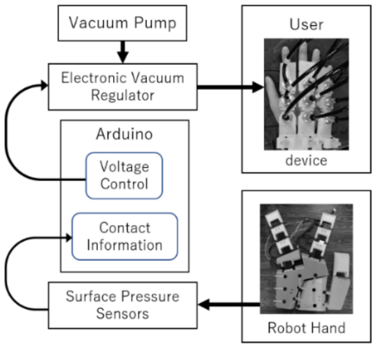

Fig. 5. Overview of the system for the experiment

3. Performance verification experiment of a tactile presentation device

3.1. *Experimental Methods*

In this study, we report the results (accuracy rates) of an experiment where two operators answer the position of a suction stimulation when it is applied to the back of the operator's hand using a prototype device. ten points on their backs of the hand are pressed one by one.

The scenes of the experiment are shown in Figs. 6 and 7. The stimulus presentation system for the experiment consisted of devices that provided stimuli to the back of the hand. Fig. 7 shows the devices of subject side. The prototype device, tubes, and a vacuum pump are used. The stimulation position is shown in Fig.8. There is a one-to-one relationship between the surface pressure sensor and the sucker. Suction stimulation was applied to the back of the hand in the pre-determined order, as shown in Table 1.

3.2. *Results and Discussion*

In this experiment, each subject was given 10 stimulation and the total number of collected data was 20. The graph of the results is shown in Fig. 9. Total accuracy rate was 80.0%. Accuracy rate of each subject was 80% and both subjects had 20% of wrong answers. However, we think that they recognized the position of the stimulus almost correctly, because the wrong answered position ware located to above or below position of the correct one. In addition, we measured response time from starting of stimulus to answering by subject. In most cases, the response was made within 5 seconds. Therefore, we think that the results are reliable because it was confirmed that the subjects answered without hesitation.

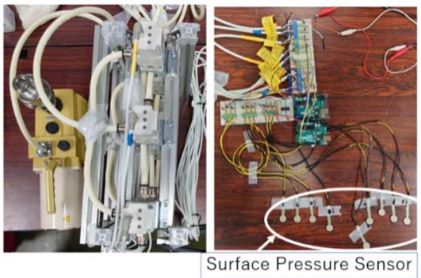

Fig. 6. Experimental scene
(Control side)

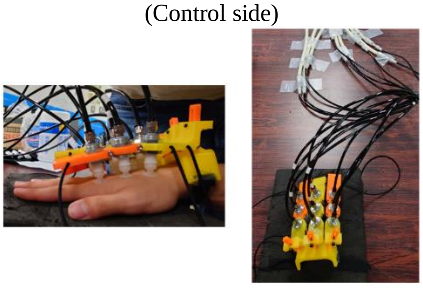

Fig. 7. Experimental scene
(Subject side)

Fig. 8. The number of stimulation point.

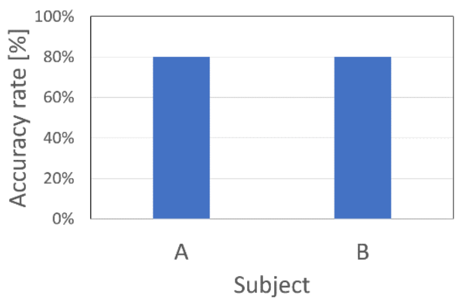

Fig. 9. Total accuracy rate.

Table 1. Order of Stimulus presentation.

Order of stimulation	Suction stimulation
1	5
2	7
3	8
4	3
5	6
6	4
7	5
8	2
9	1
10	9

4. Conclusion

In this study, we fabricated a device based on the required specification determined in our previous studies and performed subject experiments to verify the performance. As a result, we obtained 80% of the correct answers. Therefore, we think that this device has potential to be used in teleoperation of a robot hand.

In the future, at first, we will increase the number of subjects. After that, we will confirm if the users can recognize accurately when multiple stimulus points are given. Finally, the proposed device is verified in the teleoperation task.

Acknowledgements

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