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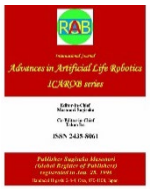

Research Article

Experimental Consideration on Requirements Specification of Haptic Device that Presents Sensation Corresponding to Palm on Back of Hand for Teleoperation of Robot Hand

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ABSTRACT

Teleoperated rescue robots have recently been on demand. However, it is known that the teleoperation of a robot hand mounted on a rescue robot is difficult. Therefore, we proposed a new haptic device that presents a haptic sensation for the teleoperation of a robot hand. The device stimulates the back of the hand instead of the palm of the operator. The determination of the required specifications by an experiment with subjects is presented in this paper. To design the device, the interval of the stimulation points (i), the diameter of the stimulation point (d), and the force of the stimulation (f) should be optimized. From the experimental results, we found that the accuracy rate was highest, when (i, d, f) = (30mm, 6mm, 0.9kgf). Moreover, we considered the decided specification in an additional experiment.

1. Introduction

Since the Great Hanshin-Awaji Earthquake in 1995, research and development of disaster response robots have been conducted [1]. In recent years, there has been a demand for disaster response robots that can gather information and perform tasks [2]. Therefore, disaster response robots equipped with robotic hands are being developed to work at disaster sites in the same manner as humans [3].

Because disaster response robots are operated in an unknown and extreme environment, they are often controlled by teleoperation [4]. To improve the efficiency of teleoperation, it is necessary to provide feedback to the operator on the state of contact between the fingers and palms of the robot hand. However, in the field of robot teleoperation, there are some systems that provide feedback on the contact state of the fingers [5][6], but we cannot find systems that provide feedback on the contact state of the palm.

In this study, we proposed a method of substituting the contact state obtained from the palm of a robot's hand to the back of an operator's hand. Okano et al. [7] proposed a method for substituting the tactile presentation with other parts of the hand. However, they substituted the sole of the foot for tactile presentation of the whole hand. In contrast, in this study, the back of the hand is substituted for its tactile presentation.

In a previous study [8], we clarified the characteristics of the tactile sensation of the back of the hand to formulate the specifications required for the device that substitutes the back of the hand, as the first step of the research.

We prepared three candidates for each of the three types of stimulus points, that is, the distance between the stimulus points, the diameter of the stimulus points, and the magnitude of the stimulus force.

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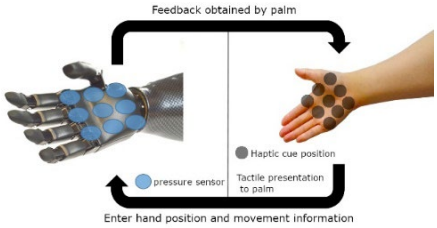

Fig. 1. Ideal method.

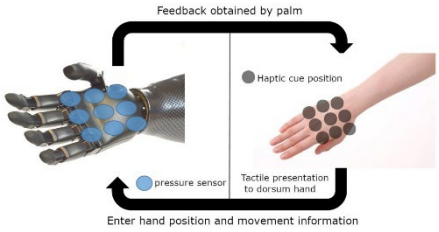

Fig. 2. Proposed method.

Fig. 3. Designed device with parameters which are obtained by experiment.

In this study, we report an overview of the previous study [8] and the results of an additional experiment in which the number of stimulus points is one or two and the subjects wear gloves to verify whether the tactile sensation can be presented as a surface instead of a point, without changing the specifications.

2. Proposed Device

2.1. *Overview*

As shown in Fig. 1, it is ideal to present the tactile sensation on the palm of the hand to correctly convey the state of contact between the robot hand and the object to the operator. However, this method would interfere with the teleoperation of the robot hand; therefore, we propose a method of presenting tactile sensations on the back of the hand, as shown in Fig. 2. The following parameters are necessary to design the device:
The interval between the stimulation points (interval: i)
The diameter of the stimulus point (diameter: d)
The force of the stimulus (force: f)

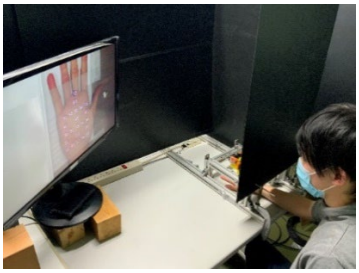

Fig. 4. Experimental setup.

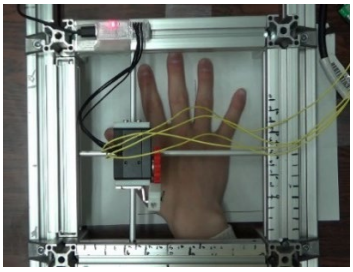

Fig. 5. Device used in experiment. (Top view)

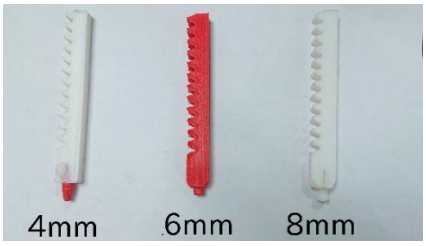

Fig. 6. Rod of experiment device.

It is known that human skin sensation has characteristics, such as a two-point discrimination threshold.
Therefore, in a previous study [8], we clarified the characteristics of the tactile sensation on the back of the human hand by subject experiments described in the next section and determined these specifications. Fig. 3 shows a conceptual view of the device designed using the specifications determined by the experiments.

2.2. *Subject Experiment for Specification*

In this section, we report the optimal combination of the above parameters determined through a subject experiment. The procedure of the experiment was as follows: 10 subjects are prepared and 10 points on the back of their hands were pressed one by one. The subjects were requested to report where the pressed point corresponded to the back of the hand on the palm. The interval of the stimulation points (i), the diameter of the stimulation point (d), and the force of the stimulation (f) were the parameters of the combination. The combination with the highest ratio of correct responses was adopted as the required specification for the device. The objective of the experiment was to find the combination with the highest correct ratio among 27

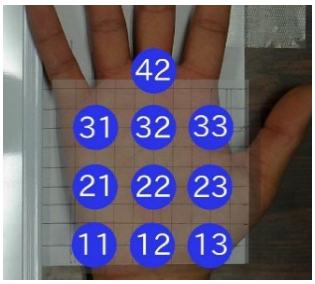

Fig. 7. Reference image for subject.

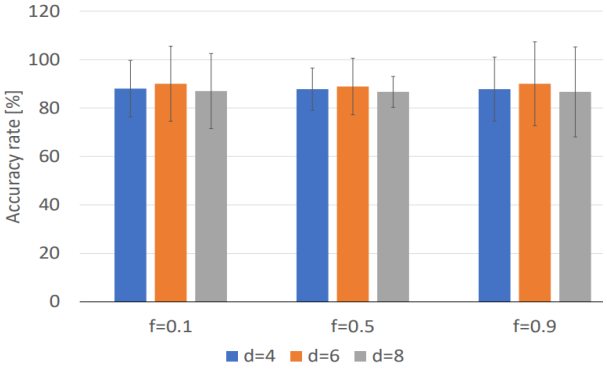

Fig. 8. Experimental result.

combinations, where the candidate values of i are 10, 20, and 30 mm; d are 4, 6, and 8 mm; f are 0.1, 0.5, and 0.9 kgf. Fig. 4 shows the experimental setup. Figs. 5 and 6 show the devices used in the experiment. Fig. 7 shows the image of the subject who was to report on the pressed place, which is displayed on the monitor.

2.3. *Experimental Results*

We collected 2,700 data points from 10 subjects, each of whom pressed 10 points. A graph of the results for i = 30 mm is shown in Fig. 8. other results are presented in our previous study. The vertical axis shows the average ratio of correct responses for each combination, and the error bars show the standard deviation of the ratio of correct responses. In the graph, the three bars are grouped together when d is the same. The blue, orange, and gray bars represent the cases where f is 0.1, 0.5, and 0.9 kgf, respectively.

The experimental results show that the correct response rate is the highest, and the standard deviation is the smallest when (i, d, f) is (30 mm, 6 mm, and 0.9 kgf). In this case, the ratio of correct answers was 93 % and the standard deviation was 7 %. Therefore, we decided to design the device using this combination because the mean value was the highest and the variation was the smallest.

3. Experiment with Multiple Stimulation

3.1. *Experimental Method*

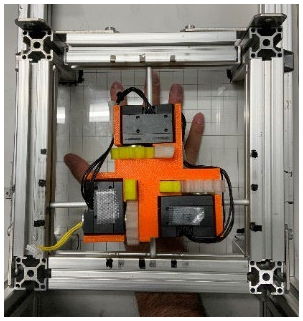

Fig. 9 Device used in experiment. (Top view)

Fig.10 Groves for experiment.

In this section, we report the new results of an experiment to check whether subjects misidentify the number of points by pressing the back of their hands simultaneously. In the experiment, we prepared three subjects, and requested them to press one or two points on the back of their hands and to report where the pressed points corresponded to in their palms. We use the combination (i, d, f) = (30 mm, 6 mm, 0.9 kg), which is the required specification for the device.

The subjects were three males (in their twenties), and in each condition, stimuli were applied to ten patterns of the points on the back of the hand in a random order. The scene of the subject experiment was similar to the situation shown in Fig. 4. We set up an experimental device that can press at two points simultaneously, as shown in Fig. 9. The intervals of the points were fixed at 30 mm. In this experiment, the subjects wore gloves to imagine their practical use, as shown in Fig. 10. Fig. 11 shows an image of the subject who was to report the pressed places.

3.2. *Results and Discussion*

We collected data for a total of 135 points, as 15 points were pressed by three subjects in three conditions. We calculated the average ratio of correct responses if the number and position of the points pressed corresponded to the points reported by the subjects. A graph of the results is presented in Fig. 12.

From the experimental results, the subjects collectively recognized the positions of the pressed points, similar to

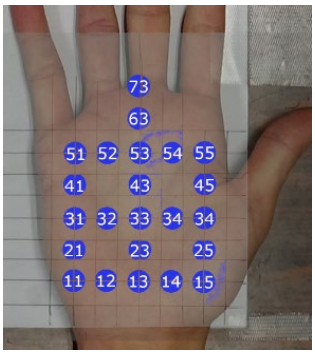

Fig.11 Reference image for subject.

the previous experiment, as shown in Fig. 8. Therefore, we believe that the device developed with the specifications obtained in the previous experiment may be effective in the case of multiple stimulations. Conversely, we believe that it is necessary to consider how to stimulate when a large object touches the robot hand. If we need the operator to recognize the tactile sensation as a surface, we may need to set the distance between the stimulus points to less than 30mm, which is the discrimination threshold of the back of the hand.

Moreover, the accuracy rate decreased when the subjects wore thin gloves. Therefore, it is necessary to focus on the selection of the thickness and material of the gloves. It is interesting to note that the accuracy rates of two subjects (Subject 1 and 3) increased when the subjects wore thick gloves. We will verify this phenomenon in more subjects in the future.

4. Conclusion

In this study, we propose a method to present the contact state of the robot hand to the back of the operator's hand as a substitute for the palm in the teleoperation of a disaster response robot. We conducted an additional experiment with multiple stimulations.

In the future, we will conduct further verification of the experimental results. Subsequently, the device will be developed, and the efficiency of teleoperation of the robot hand using the fabricated device will be verified.

Acknowledgement

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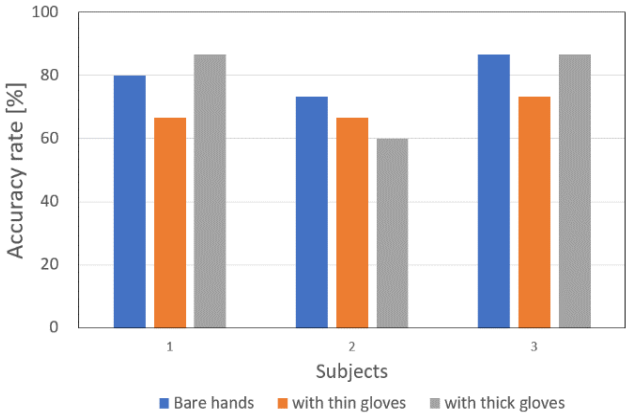

Fig.12 Experiment result.

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