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The Effect of Tactual Feedback by the Vibration Device in Virtual Reality Environment

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Abstract: It has been reported that operating efficiency for teleoperations using stereoscopic video images is lower than that using the naked eye in real environments. Here, the authors tried to improve the human-machine interface of teleoperational system in order to achieve a higher operating efficiency for stereoscopic video images by adding other information. An experiment was carried out under the two following conditions: Condition 1 was only stereoscopic vision. Condition 2 was that tactual feedback was given through a vibration device put on the subject's hand, as one object touched another. The vibration device consisted of a small motor, and vibrated when objects touched each other. The subject's task was to insert a cylindrical object into a round hole. The completion time, when tactual feedback was provided (Condition 2), was shorter than when no additional information was provided (Condition 1). This result leads to the conclusion that the efficiency becomes higher by the vibration device.

Keywords: Haptic, Vibration, Feedback, Teleoperation, Stereoscopic

1. Introduction

Some of things that human being do at work expose the human body to danger. For example, rescue activities at disaster sites such as earthquakes, space exploration, and so on. In order to avoid injury in such situations, work could be done using teleoperated robots. In the operation of telerobots from a remote place, the operators require three-dimensional information about the space in which the robot works. They need to obtain depth cues to reconstruct the three-dimensional space. The depth cue of binocular disparity gives the strongest possibility of reconstructing the three-dimensional space within the range of around 20m in other depth cues [1]. It is known that operators with stereoscopic video systems can do this faster and more correct than with a monoscopic system [2),3)]. However it was reported that the task time of teleoperation in the conventional stereoscopic video system is longer than that of in the direct view, and subjects felt more fatigue in the use of stereo-scopic video images [4].

In order to obtain a higher performance and less fatigue, it has been proposed that a stereoscopic video system should have wide-angle and high-resolution images [4].

On the other hand, it was suggested to improve performance by tactual feedback. It was expected that when a tactile cue was available together with a visual cue, the efficiency of the teleoperation would become higher than that of using only visual information. In fact, some researchers reported that haptic devices made teleoperation more efficient [5),6)]. However there are some problems. First, the machines have delay. Second most of them are big and heavy. Therefore, those devices are not necessarily effective [7]. Thus, we would suggest to use a vibration device made of a small motor as a tactual feedback device. There are some researches using vibration device as tactual cue [8),9)]. However, there is no research that evaluates the efficiency of the teleoperation with the vibration device. The reason why we chose it is that it is easy to include existent input devices and response time is short. We thought that the advantage exceeds the disadvantage that subjects can only obtain one-dimensional information, such as one object contacted another object. And by using this vibration device, efficiency would become higher.

2. Experiment 1

2.1 Purpose

The purpose of this experiment was to evaluate the efficiency of the teleoperation using video images with additional tactual feedback information.

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2.2 Method

2.2.1 Subject

The subjects were 6 male students whose ages ranged from 22 to 25 years. All of the subjects had normal stereoscopic vision.

2.2.2 Experimental system

(Hardware): The experimental system was constructed using a workstation (Silicon Graphics: sgi540; Xeon; 500MHz) with a 17-inch CRT display, and a three-dimensional mouse with six degrees of freedom (Spacetec IMC: SPACE BALL) (**Fig. 1**). The virtual reality space of the experiment was displayed on the 17-inch CRT. A liquid crystal shutter glass system (StereoGraphics: CrystalEyes) was used to display the stereoscopic video pairs. The Sync-Doubling-Emitter sent synchronous signals to liquid crystal shutters.

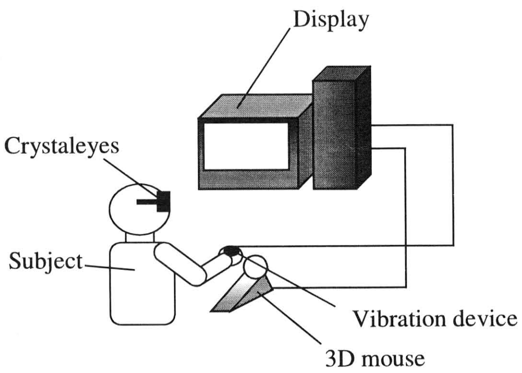

Fig.1 Experimental system.

(Software): The software was developed for this experiment using Visual C++ 6.0 and Graphic Library (Sense 8: World Tool Kit (WTK)). It was run on a workstation with Windows NT 4.0.

2.2.3 Experimental procedure

Subjects were asked to insert the cylindrical object (pole) into the round hole (target; see **Fig.2**) as quickly as possible, avoiding contact with the pole and the base of the holes to the best of their ability. There were four poles and four holes in the working environment. The order in which the poles were to be inserted into the holes was explained prior to the starting of the trials. One session of trials was to insert all of the four poles into the four holes. The completion time started from the starting signal of the trial to the time of success when all of the poles were inserted. The number of contacts when the pole touched the base of the holes was counted in each session. The conditions of the experiment were as follows: (Condition 1): No additional information was included (the condition with non-additional cue). This condition was only based on stereoscopic vision. The subjects could see the virtual environment as a stereoscopic image. (Condition 2): Tactual feedback was given through a small vibration device (the condition with the tactual feedback). When a pole touched a hole-base, the vibration that was put on the subject's hand vibrated. By this, the subject could feel the contact of the object in a virtual realty environment as contact information

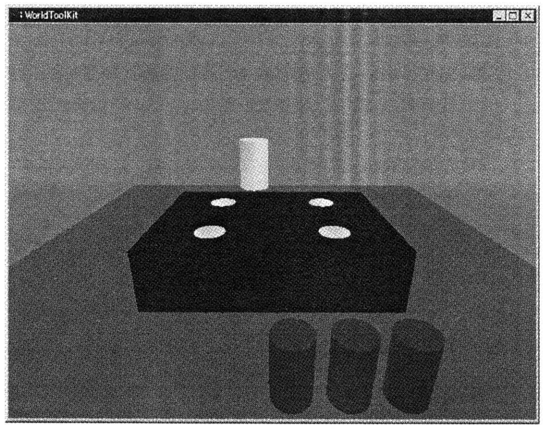

Fig.2 Experimental environment.

We simulated that the pole was 2.3cm in diameter and had a 5.0cm height (**Fig.3**), the size of the hole-base was 10.0cm in width, with a 7.5cm vertical width, and a 5.0cm height, and the diameter of the hole was 2.4cm and the depth was 5.0cm (**Fig.4**).

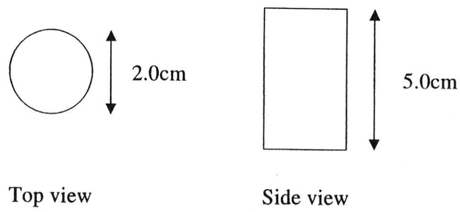

Fig.3 Figure of the pole.

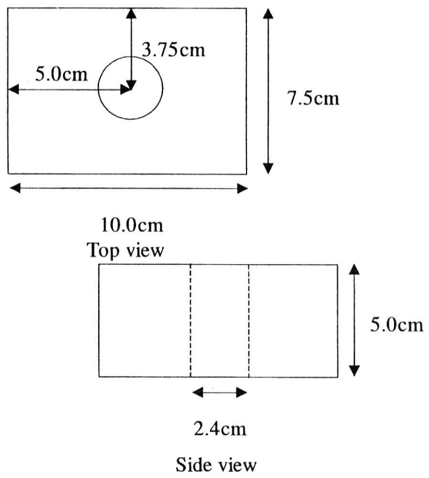

Fig.4 Figure of the hole-base.

2.3 Results

The mean completion times of the two conditions are shown in **Fig.5**. The mean numbers of contact by two conditions are shown in **Fig.6**.

By the analysis of valiance (ANOVA), there were no significant differences in the completion times, and the number of contacts, between the two conditions, as well as no additional information and tactual feedback.

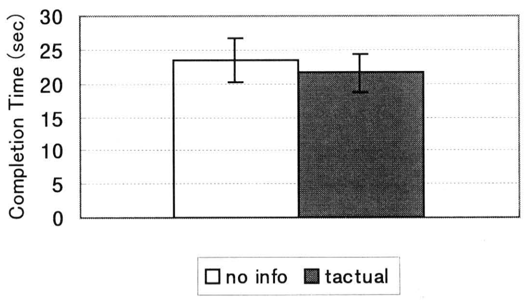

Fig.5 Mean completion times of two conditions. Abbreviations are as follows.

1)no info: the condition without tactual feedback.
2)tactual: the condition with tactual feedback.

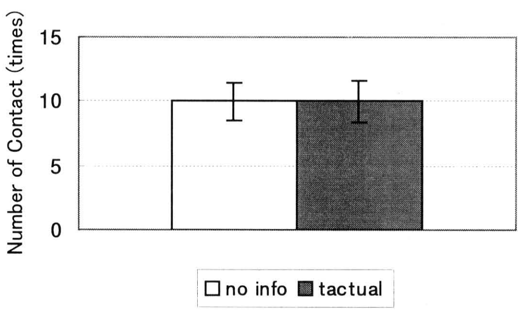

Fig.6 Mean numbers of contact of two conditions. Abbreviations are the same as in Fig.5.

2.4 Discussion

There were no significant differences between the completion times, and between the number of contact in the two conditions. The vibration device vibrated whenever the pole contacted the hole-base. It is considered that this way did not effective in raising working efficiency. If we contrive how to give the subjects the vibration, efficiency would become higher. Concerning the number of contact, it was not a good idea to compare both conditions concerning efficiency, because the tactual feedback worked after contact, and subjects could not avoid contact by tactual feedback.

3. Experiment 2

3.1 Purpose

Experiment 1 indicated that we needed to contrive how to give the subjects the vibration. Thus, we modified an algorithm of controlling the vibration device, because in Experiment 1, it vibrated when the pole touched to the hole-base, even though the pole was on the hole and able to be inserted. We decided to measure the times in which the pole had contact with the hole-base (contact times) in addition to completion times and number of contacts. This is because the tactual feedback would help to recognize pole contact with the hole-base, and contact times could be reduced.

3.2 Method

3.2.1 Subject

The subjects were 6 male students whose ages ranged from 22 to 25 years. All of subjects had normal stereoscopic vision.

3.2.2 Experimental system

The experimental system was the same as in Experiment 1.

3.2.3 Experimental procedure

The experimental procedure was the same as the one in the Experiment 1 except that the contact times were counted in each session, the vibration algorithm was modified, and the color of the holes was changed from yellow to blue, the color of the hole-base.

The conditions of the experiment were as follows:

(Condition 1): No additional information was included (the condition with non-additional cue). This condition was the same as Condition1 in Experiment1.

(Condition 2): Tactual feedback was given through the vibration device (the condition with the tactual feedback). In the same way as Experiment 1, when a pole touched a hole-base, the vibration motor that was put on the subject's hand vibrated. But if a pole was on a hole, the device did not vibrate.

3.3 Results

The mean completion times of all sessions are shown in **Fig.7**, as well as the mean completion times of two conditions in **Fig.8**. The mean numbers of contact in all sessions are shown in **Fig.9**, and the mean number of contacts of two conditions in **Fig.10**. The mean contact time of all sessions are shown in **Fig.11**, and the mean contact time of two conditions in **Fig.12**.

By the analysis of valiance (ANOVA), the mean completion times were shorter in the tactual feedback condition than in the no additional information condition. (F (1,5)=10.073,p < .05))

There were no significant differences in the number of contact, and the contact time between the two conditions had no additional information and tactual feedback.

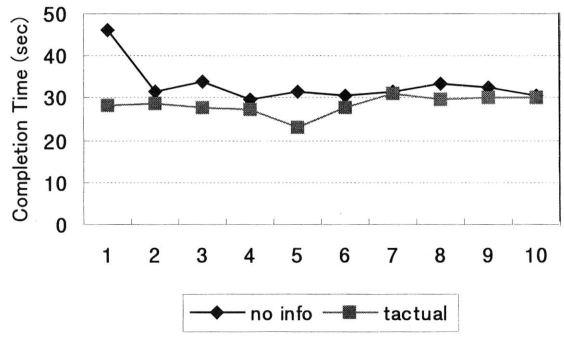

Fig.7 Mean completion time of all sessions. Abbreviations are the same as in Fig.5.

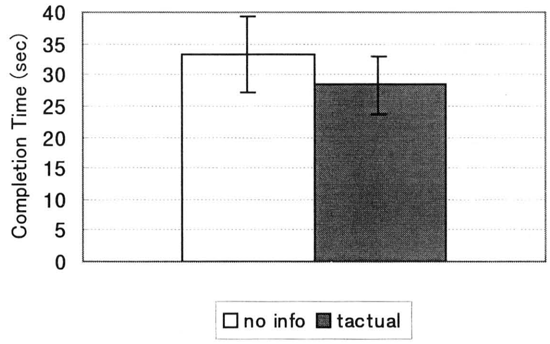

Fig.8 Mean completion time of two conditions. Abbreviations are the same as in Fig.5.

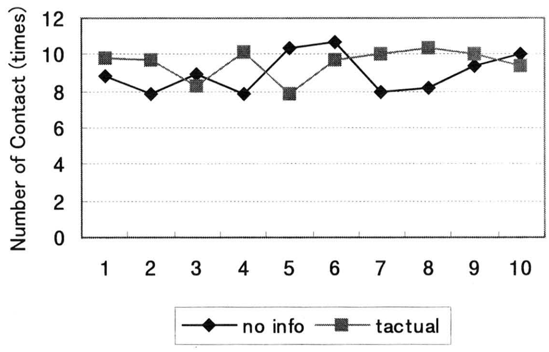

Fig.9 Mean number of contact of all sessions. Abbreviations are the same as in Fig.5.

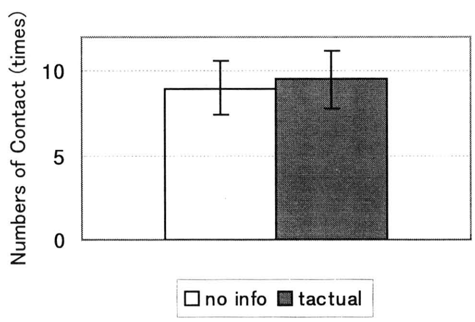

Fig.10 Mean number of contact of two conditions. Abbreviations are the same as in Fig.5.

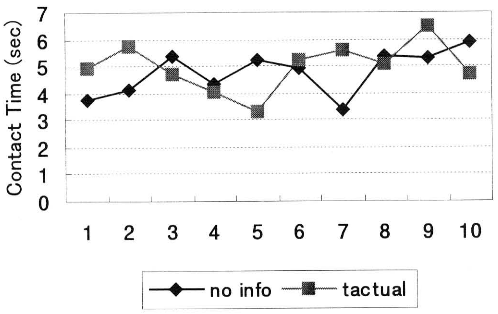

Fig.11 Mean contact time of all sessions. Abbreviations are the same as in Fig.5.

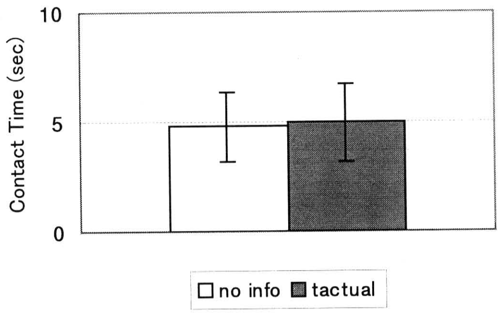

Fig.12 Mean contact time of two conditions. Abbreviations are the same as in Fig.5.

3.4 Discussion

We concluded that tactual feedback was effective in reducing completion time if the vibration was pertinently given the subjects. In Experiment 1, the vibration device vibrated whenever the pole contacted the hole-base. However, in Experiment 2, it did not vibrate when the pole was on the hole and able to be inserted.

The difference in the completion time and the similarity in the contact time meant that the time during the pole movement was reduced by tactual feedback. This indicated that the subject could quickly move the pole closer to the hole.

There were no significant differences in the number of contact. It was thought that human subjects could feel the contact, but they could not avoid the contact.

4. Summary

When we operate machines, we would use tactile sense together with vision. Thus, these experiments evaluated the efficiency of the teleoperation using the video images with tactual feedback information. The result was that the mean completion times were shorter at tactual feedback than no additional information. Therefore, it is consider that tactual feedback is effective in raising working efficiency, when the vibration was pertinently given the subjects.

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