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Evaluation of a Tricycle-style Teleoperational Interface for Children: a Comparative Experiment with a Video Game Controller

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Abstract— **A tricycle-style teleoperational interface for children to remotely control a robot was developed. There were two crucial requirements in its design: (1) the interface had to be intuitively controllable so that children could use it without requiring detailed instructions and (2) the control of the teleoperational system needed to be fun so that children did not get bored. In this paper, we report an experiment in which 20 children (4—8 years old) performed a range of tasks by remotely controlling a robot using two types of teleoperational interfaces: the tricycle-style interface and a standard video game controller. The results show that the children could perform the tasks better with the tricycle-style interface.**

I. Introduction

There have been conducted a lot of researches related to telexistence and telepresence robots. Tachi pioneered the work on telexistence robots in the 1980s [1], [2]. Recently, there have also started the researches of teleoperated communication robots including androids [3], [4]. At the same time, companies have started developing telepresence robot products such as QB developed by Anybots [5] and Texai developed by Willow Garage [6]. The key feature of these robots is their mobility that allows an operator to move around remote locations through the robots, as opposed to the limitation of standard video conferencing systems in which users can communicate with remote partners only through audio and video channels. Another advantage of these robots is that people around the robot can experience the presence of a remote operator to a greater extent than existing video conferencing systems. One promising application domain for utilizing these features is education [7].

However, so far most of the telepresence robots have targeted adult users and few trials have been conducted on a telepresence robot that is designed to be operated by child users. In fact, there are many difficulties in targeting children as users. Unlike adults, we cannot assume providing detailed instructions as to how to operate a robot to children. In addition, the interface must be attractive and enjoyable to use because children are usually impatient. On the basis of these considerations, we developed a tricycle-style interface that satisfied two requirements: intuitive operability and a fun factor [8]. This tricycle-style interface had two rotary encoders on its rear wheels. Its operator could synchronously control the locomotion of the teleoperated robot by controlling the rotation of the tricycle wheels. Plus, the operator could use a data glove on the right hand, which had a bend sensor on the back of the hand along the middle finger, through which the operator could control the robot gripper for synchronously opening and closing the hand. A tablet PC was mounted on the tricycle's handlebar in which the operator could communicate with people in remote places through Skype software.

In this paper, we report a comparative experiment between the tricycle-style interface and a video game controller that is the most widely known operating interface. The purpose of the experiment was to investigate the differences between these two interfaces in terms of intuitive operability and a fun factor on child participants. We used both video recordings and interviews to measure the achievement ratio of various tasks to be performed. A total of 20 children aged 4—8 years participated in the experiments that were conducted at an English language school for Japanese children. The experimental tasks were as follows: grasp a pen, move backward, move diagonally forward, turn right/left, perform a combination of grasping and moving, and say "thank you" through the teleoperational interface. Each participant had to perform these tasks twice using either the two interfaces.

The structure of the paper is as follows. First, we provide an overview of our system and the interfaces in Section II. Then, the experiment that was conducted is explained in Section III and the results are provided in Section IV. After discussing the results in Section V, we conclude and summarize the paper in Section VI.

II. Overview of Our Teleoperational System

Our teleoperational system consisted of an operational interface, a server PC to relay data, and a teleoperated robot that could respond to instructions from a remote location (Fig. 1). The data input by the operator through an operational interface was first sent to the server PC that was located in the University of Tsukuba, and then transmitted to the robot located in a remote classroom. The encrypted operational data was transmitted through Secure Shell (SSH) tunneling.

A. Tricycle-style Interface

The tricycle-style interface had two rotary encoders on its rear wheels (Fig. 2) through which an operator could synchronously control the locomotion of the teleoperated robot by controlling the movement of the tricycle. The operator

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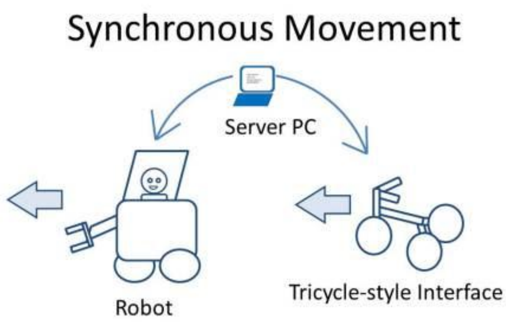

Fig. 1. System Overview

Fig. 2. Tricycle-style Interface

wore a data glove on the right hand, which had a bend sensor on the back of the hand along the middle finger (Fig. 3). The operator communicated with people in the remote location through a tablet PC that was mounted on the handlebar of the tricycle. We used a commercially available tricycle as the interface, which was familiar to children. We used rotary encoders (Baumer Electric, Southington, CT) whose pulse resolution was 5,000 per revolution. The direction of movement was determined by recording the rotation of each wheel of the tricycle. The rotation was calculated by measuring the difference in rotation of the two rear wheels on either side of the tricycle. The electric circuit used in this interface was mounted in a central location between the rear wheels. The circuit boards of the rotary encoders and the data glove communicated with the tablet PC by Bluetooth.

B. Video Game Controller

We used a Microsoft Xbox 360 Wireless Controller (Fig. 4). An operator could control the locomotion of the teleoperated robot and the speed of the locomotion by tilting the joystick in a certain direction. The operator could control the gripper, i.e., open or close the gripper, of the robot by pushing the B button. All other buttons on the device were nonoperational. We used the same type of tablet PC as the one used in the tricycle-style interface. We placed the

Fig. 3. Data Glove

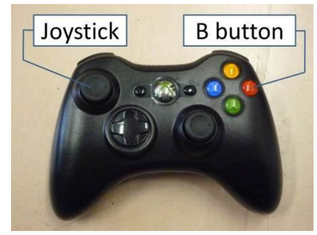

Fig. 4. Video Game Controller

Fig. 5. Teleoperated Robot

tablet PC on the floor to capture the face of the operator, irrespective of the body height of the operator.

C. Server PC

The server PC in the University of Tsukuba transferred operational data between the tablet PC of the operational interface and the laptop PC of the teleoperated robot through SSH tunneling. However, the video and audio data of the operator were directly transferred to the laptop PC on Skype software.

D. Robot

The teleoperated robot used a Pioneer P3-DX for locomotion (Fig. 5). This mobile robot could move forward and backward and turn right and left as a result of the difference in the rotational speed of the independent driving wheels on either side of the robot. The robot carried a laptop PC that received operational data and communicated with the tablet PC on the operational interface through Skype software. An external camera was used in addition to the built-in camera of the laptop PC. This allowed the operator to see the gripper of the robot as well as people in a remote location. The gripper was assembled using Dynamixel servomotors.

III. Experiments

A. Goals of the Experiment

The goals of the experiments were (1) to investigate whether any differences emerged between the two interfaces in terms of intuitive operability and a fun factor and (2) to investigate the type of differences present and the reason for their occurrence. This experiment targeted child users.

Fig. 6. Experimental Site in the University of Tsukuba

Fig. 7. Experimental Site in an English Language School

We hypothesized that children could more easily control the teleoperated robot with the tricycle-style interface than with the video game controller.

B. Method

We conducted experiments to connect a room in the University of Tsukuba (Fig. 6) with another classroom in an English language school for Japanese children (Fig. 7). With the kind cooperation of the Minerva Language Institute Co., Ltd., we were fortunate to be able to conduct experiments in a classroom in Tsukuba. After we received approval for this experiment from the Ethical Committee of the University of Tsukuba, we started recruiting participants by explaining our research to the parents of the children. The teleoperated robot was located in the university side and the participants used both interfaces (the tricycle-style interface and the video game controller) in the classroom of the English language school. Two experimenters participated in the experiment. One experimenter (Experimenter-A) was deployed in the classroom side and the other experimenter (Experimenter-B) was in the university side. Experimenter-A gave instructions on how to use each of the interfaces prior to performing the tasks and also ensured safety during the task period. Experimenter-B issued directions for the tasks and conducted the experiments.

A total of 20 children aged between 4—8 years old participated in the experiment. All participants performed the assigned tasks using both interfaces. We evaluated intuitive operability by means of video analyses to count the number of tasks that were completed within the time limit by using either the two interfaces. We asked two different participants to participate in each experimental session. Each participant performed six tasks twice using each of the two interfaces. We used the same type of the tablet PC for the tricycle-style interface and the video game controller. The six tasks to be performed were as follows:

Task 1: Hold a pen for 3 seconds within a period of 10 seconds.
Task 2: Move backward 0.3 meters within 10 seconds.
Task 3: Move forward diagonally by about 35 degrees and for 1 meter within 30 seconds.
Task 4: Turn right/left about 90 degrees within 30 seconds.
Task 5: Hold a pen and put the pen into a box within 30 seconds.
Task 6: Say “thank you” after receiving an object from Experimenter-B within 10 seconds.

In case a participant was not able to perform a task within the defined time limit, or the participant could perform a task ahead of the time limit, Experimenter-B instructed the participant to move on to the next task. Experimenter-B used a stopwatch to check the elapsed time for each task, which started at the command of Experimenter-B. If the participant dropped the pen in Task 1 or 5, the participant had to start the task from the beginning of the task. In Tasks 2, 3, and 4, Experimenter-B determined whether a task was completed successfully or not. The object used in Task 6 was a toy apple.

The procedure and time allocation of the experiment were as follows: first, Experimenter-A chose randomly one participant who would first perform the experiment. Then, the participant conducted the tasks according to the directions given by Experimenter-B. The order of using the two interfaces was expected to become an important factor. To counterbalance the effect, the participants performed the tasks in the order of either Pattern A or B shown in Fig. 8. Each pattern was conducted 5 times. Experimenter-A switched the participant after the first participant completed the tasks and started explaining the same procedure to the new participant. After two participants finished all tasks using respective interfaces, Experimenter-A swapped the interfaces and asked the participants to repeat the experiment using the other interface. When the experimental session was over, the participants and the parents were interviewed one by one. The interview items towards the participants were as follows:

- Q1-1: Which interface was more fun?
- Q1-2: Which interface was easier to use?

The interview items towards the parents were as follows:

- Q2-1: Does your child play video games?
- Q2-2: How long does he/she play video games per day?

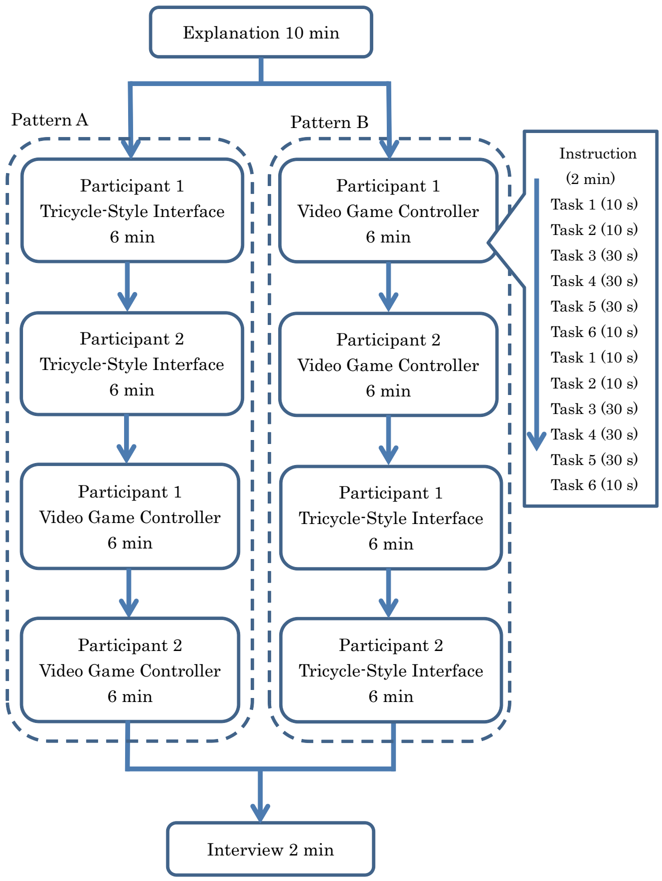

Fig. 8. Flowchart of the experiment. Pattern A was conducted with 10 participants. Pattern B was conducted with 10 other participants.

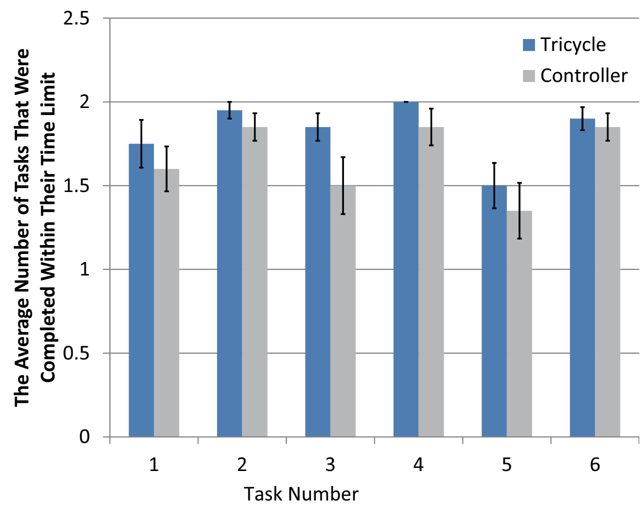

Fig. 9. The average number of tasks that were completed within their time limit on the six tasks respectively. Each of the tasks was repeated two times.

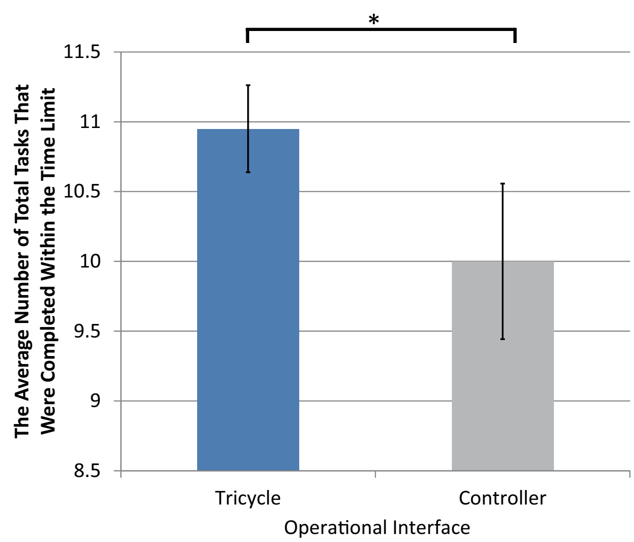

Fig. 10. The average number of total tasks (summed up over all six tasks) that were completed within the time limit.

IV. Results

Fig. 9 shows the average number of tasks that were completed within the time limit for each task. Because the tasks were appeared to be relatively easy for the participants, most of them were accomplished within their time limits. Wilcoxon signed rank test was conducted and it was found that the differences between the two conditions here were not statistically significant, although overall the results show that the tricycle-style interface had better scores than the video game controller.

Fig. 10 shows a comparison about the average number of total tasks (summed up over all six tasks) that were completed within the time limit. The difference between the two condition here was significant ($Z(20) = -2.09, p < 0.05$).

From the analysis of videos taken during the experiment, it was found that participants had dropped a pen significantly more often when using the video game controller (27 times) than when using the tricycle interface (12 times) (Chi-square test, $\chi^2 = 5.77, p < 0.05$).

From the results from the interviews, we could not observe notable differences between the two interfaces. 11 participants chose the tricycle interface and 9 participants chose the video game controller in answer to Q1-1. 10 participants chose the tricycle interface and 10 other participants chose the video game controller in answer to Q1-2.

V. Discussion

The results showed that the tricycle-style interface performed better in the total number of tasks that were completed within the time limit over the six tasks. It was also observed that some participants were reaching out their hand toward the display to grasp objects when they were using both interfaces, and thus, they seemed to want to grasp the objects directly by their hand. It seemed that the data glove interface was accepted as being more intuitive than pushing a button. In fact, there had observed cases in which participants closed their hand when they performed with the video game controller even though they had not used the data glove. This also shows that closing of hands is an intuitive action while grasping something.

However, from interviewing the participants, no significant difference was found in their subjective evaluations on the two interfaces. One reason for this could be due to the easiness of the tasks used in the experiment. Also, the robot hand had only one degree of freedom and the participants could have become bored with it. Regarding the tricycle-style interface, there had observed mainly two issues: first, participants became incapable of moving anymore when they were near a wall when using the tricycle-style interface and they did not know how to deal with such a case. Second, the other participant who did not take a role of the operator needed to keep following the tricycle to see the display or to know what people in a remote place were doing.

We need to improve the mounting position of the camera and the audio equipment on the robot when we deploy our system in an actual classroom. Participants were observed dropping the pen before reaching the box when using both interfaces in Task 5 because there was inadequate visual and audio information to operate the robot located in a remote place using Skype. Although the Experimenter-B continued to issue instructions during Task 5, the operator sometimes seemed not to be able to listen to the voice because of the noise from the next classroom. As a further problem, the display did not have a sense of depth because the operator watched the pen in a same straight line on the robot's gripper and the camera on the robot.

VI. Conclusions

We conducted an experiment to investigate differences between a tricycle-style interface and a video game controller interface for remote-controlling a robot for children. The results showed that the tricycle-style interface had an advantage in terms of intuitive operability as shown by the number of tasks that were completed within the time limit. However, no difference was observed between the two interfaces at the results of interviewing the participants.

VII. Acknowledgments

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