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Child-Operated Telepresence Robot: A Field Trial Connecting Classrooms between Australia and Japan

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***Abstract*— This paper reports the research outcome of a JST PRESTO project "Linking children across the world through telerobotics (2009–2013)." The project explored the use of child-operated telepresence robot systems for the purpose of facilitating international communication between distant classrooms. In particular, it was revealed that young children who could not communicate well with speakers of different languages over conventional video conference services could establish and maintain communication using the telepresence robot system developed by this project. Together with a control experiment to clarify its effectiveness, an international field trial that connected remote classrooms between Australia and Japan was conducted.**

I. INTRODUCTION

Telepresence robots have attracted increasing attention from both researchers and general public and are expected to enable more enriched forms of remote communication than those provided by conventional video conference services. In conventional video conference services, remote communication is interfaced only by a monitor screen. However, remotely controlling a telepresence robot, which functions as an avatar of its human operator, enables the operator to physically interact with persons in remote locations. For example, the robot can manipulate physical objects using its actuators and can navigate in remote locations. As a result, the operator's presence can be felt by the people around the robot, which is considered to be a key component of this technology. From the pioneering studies of telexistence in the 1980s [1] to the recent advancement of androids [2], [3], robotics researchers have been pursuing the development of highly advanced robotic devices that offer remote presence capabilities. On the contrary, companies have recently begun commercializing telepresence robot products [4], [5], [6], [7]. Compared with telexistence robots or androids described above, these products are designed at lower costs, thus limiting their performances. However, recently developed products have also been used to successfully offer remote presence at locations such as hospitals and offices.

A promising field for the application of telepresence robots is education. The introduction of telepresence robots into educational environments such as classrooms would provide significant value to both teachers and students. In fact, trials have already begun in elementary schools in South Korea to compensate for the shortage of English teachers by introducing robots designed to be remotely controlled by native English teachers [8]. On the contrary, few trials have been conducted so far involving telepresence robots that are operated (remotely controlled) by students. However, such robots would also provide immense educational value because they offer students opportunities to participate in remote classrooms and communicate with people in remote locations, such as those in foreign countries. For example, in countries such as Japan, there is a huge demand for foreign language education, particularly toward children. In reality, not many children have had the opportunity to communicate with speakers of different languages. Therefore, parents have always desired such experiences for their children. However, as discussed in previous studies [9], [10], the use of video conferencing alone provides children with very limited communication options. In practice, as will be discussed later, young children tend to get stuck and find it difficult to communicate with people speaking different languages over video conferences.

This study aims to facilitate communication between distant classrooms using different languages by introducing a child-operated telepresence robot system. Because most classroom activities for young children involve the use of physical objects such as educational toys, it is expected that even if a child is unfamiliar with the language used in classrooms, he/she could participate in the activities when offered physical access to objects. To test this fundamental hypothesis and demonstrate the system in the field of education, a research project "Linking children across the world through telerobotics," supported by a JST PRESTO program [11], was initiated in 2009. This project has been carried forward and has the following goals:

- (G1) Development of a child-operated telepresence robot system
- (G2) Demonstration of the system effectiveness in facilitating distant communication
- (G3) Use of the system to conduct a field trial involving the connection of remote classrooms

As explained in the previous paragraph, most telepresence robot systems developed so far have targeted adult users. In the case of (G1), which focuses on developing a child-operated telepresence robot system, the operation interface was re-designed to reflect specific characteristics and requirements of child users. Throughout the project, several prototypes of such operation interfaces were developed and

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tested in classrooms, the details of which are reported in [12], [13] and summarized in Section II of this paper.

(G2) and (G3) form the core of the project goal and the main topic of this paper. To evaluate the system and demonstrate its significance in distant education involving foreign languages, an experiment comparing the system with a video conference service was conducted (G2). In particular, we investigated how the introduction of the child-operated telepresence robot system addressed the issues faced when using conventional video conference services, which will be described in Section III.

Finally, to show a test case in which children participate in remote classroom activities and attempt to communicate with speakers of a different language, we conducted a field trial involving the connection of classrooms between Australia and Japan (G3). More than 200 children aged 6–8 years from both countries participated in the trial. Although the trial was conducted in a manner different from the experiment in (G2), the observations made throughout the trial were consistent with the findings obtained in (G2). Children in both countries were able to continue communicating with each other in spite of the fact that they spoke different languages. Section IV provides a detailed description of this field trial.

II. Child-Operated Telepresence Robot System

In 2009, when this project was initiated, the first challenge that we faced was the little knowledge about the design of an operation interface required for young children to remotely control a robot. Therefore, we first identified the requirements of the operation interface on the basis of the observations of daily classroom activities in an English learning school for Japanese children in Tsukuba City, Japan. For example, we found that the majority of classroom activities for young children involved the use of physical objects such as educational toys. Therefore, it was considered to be crucial to implement the function of remotely grasping an object and handing it to others. This is because even if a child found it difficult to understand a foreign language, he/she would be able to continue communicating with the speaker of the foreign language using the physical object. Other requirements that were identified during this observation period are summarized in [12].

By repeating exploratory observations, building prototypes, and testing them in the classroom, two main types of operation interfaces were developed. The first type was the tricycle-style operation interface (Fig.1), which was designed particularly for young children (3–5 years). Rider movements were detected by two rotary encoders on its rear wheels and were used to remotely control the robot. The movement direction was determined by calculating the difference between the rotations of both wheels. Skype - the video phone software, which was running on a tablet PC mounted on the handlebar of the tricycle enabled the operator to observe and hear a robot placed in a remote location. For details regarding the development of this interface, refer to [12].

In the case of children older than 5–6 years, finer manipulation becomes possible and operation interfaces should be redesigned accordingly. For this age group, another type of operation interface (left image in Fig.2) and robot (Fig.3) were developed. The operator was provided with a joystick and a data glove. Using the joystick in his/her left hand, the robot's movement was remotely controlled. At the same time, with the right hand, on which the data glove was worn, the operator could remotely open and close the robot's hand. The data glove was equipped with bending sensors extending along the fingers. As seen in the left image in Fig.2, the operator was given Skype monitor screens to remotely control the telepresence robot (right image in Fig.2) using the operation interface. In fact, the images in Fig.2 were taken from a pilot trial in which a Japanese child was participating in a remote English lesson given by a native English teacher. As will be described in Section III, this operation interface was improved by introducing an acceleration sensor on the data glove, which was used in the following experiment.

Fig. 1. Tricycle-style operation interface developed to allow young children to remotely control a robot [12], [13].

Fig. 2. Joystick and data glove (left image) to remotely control a robot (right image) placed in a remote location. The operator child is participating in a lesson given by an adult teacher (right image). Even if the operator cannot have a fluent conversation with a teacher speaking a different language, he/she can continue communicating with the teacher through the physical movement of the robot.

III. Effectiveness of the Telepresence Robot System in Remote Communication

As described in Section I, conventional video conferencing services are known to cause critical issues when applied to foreign language teaching. Young children easily get stuck or "freeze" when communicating with people speaking different languages over the monitor screen if they do not understand

Fig. 3. Telepresence robot used in the study. It was based on Robovie-R3, which is commercially available from Vstone Co., Ltd [14]. To convert the base platform into the telepresence robot, a tablet PC and a monitor camera were mounted on the neck. Using Skype, the operator's face was projected on the monitor screen of the tablet PC. The right hand was fixed in the forward position, and only its opening/closing movement could be remotely controlled. The robot base could move forward, backward, right, and left.

the conversation. This issue is particularly serious at the early stages of learning foreign languages.

However, telepresence robots can provide different perspectives. They offer children physical access to objects in remote locations, and the children can establish communication with people in those locations by manipulating the objects. As a result, it is expected that when using the telepresence robot system, children will not freeze when communicating with people speaking different languages.

To test this hypothesis, an experiment investigating the effectiveness of the telepresence robot system is currently being conducted. Although we have neither completed the experiment nor analyzed the data from the experiment, here we report the latest results, which already show the expected usefulness of the system. Having received approval for this experiment from the Ethical Committee of the University of Tsukuba, the experiment has been ongoing at three kindergartens and an elementary school in Tsukuba City, Japan. In total, more than 50 children (4–8 year olds) have been participating in the experiment. Below, the latest results obtained from 26 children are presented.

The experiment aims to test whether the developed telepresence robot system can facilitate the children's distant communication with speakers of a foreign language. In particular, by comparing its performance with a baseline Skype condition, we analyze the changes in the behavior of children (such as the degree of their responses) when they remotely control the telepresence robot. To this end, the experiment uses the between-participants design, in which half the participants were allocated a Skype-only condition and the other half were allocated a Skype-Robot condition.

Each experimental session lasted for 10 minutes and involved one participant. If the participant belonged to the Skype-only condition group (C1 in Fig.4), he/she was told to join an English lesson given by a native English teacher in a remote location using a Skype monitor screen for 10 minutes. If the participant belonged to the Skype-Robot condition group (C2 in Fig.4), he/she was told to join the

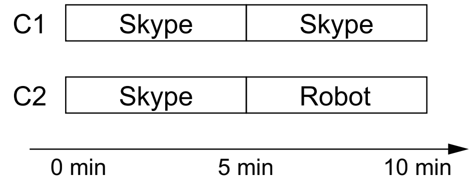

Fig. 4. Experimental design: participants were divided into two groups, the Skype-only condition (C1) and the Skype-Robot condition (C2).

same lesson for 5 minutes using only the Skype monitor screen, and then for another 5 minutes using the telepresence robot system. The telepresence robot system used in the experiment was almost identical to that shown in Fig.2, with only one modification made at the operation interface. In place of the joystick, an acceleration sensor was introduced in the data glove from which the hand movement of the operator was detected. This improved data glove enabled the operator to remotely control both the grip and movement of the robot.

The native English teacher conducted a story telling conversation lesson in English at a room located in the University of Tsukuba. The classrooms in the kindergarten and elementary school from which the children joined the experiment were connected via Internet to a room in the university. At the beginning of each session, the teacher was given three randomly chosen objects, e.g., stuffed animals. The teacher was instructed to improvise the lesson using the objects. Because most participants could not well understand English, they often got stuck and found it difficult to understand the teacher's speech; however, the teacher was instructed to use only English throughout the session.

Fig.5 shows a typical pattern of the interaction between the teacher and a child participant. Each dot plots the start point of an action made toward the partner. The action includes all types of behaviors (speeches, gestures, etc.) that can be interpreted as being directed toward the partner. As seen from the first 5 minutes period (Skype period), the teacher was trying to maintain interaction with the child; however, for most of the time, the child could not respond to the teacher. On the contrary, in the latter 5 minutes period (Robot period), where the child was using the telepresence robot system, the child could respond to the teacher more frequently. In fact, the average percentages of the participants' successful responses toward the teacher show that the participants could respond to the teacher more often in the Robot period than in the Skype period (Fig.6). Although we still need a detailed investigation on the behaviors of both the teacher and the participants, we now already observe the usefulness of introducing the telepresence robot system developed for children. As mentioned at the beginning of this section, young children easily get stuck or freeze when communicating with people speaking different languages over the monitor screen. In this experiment, the same tendency of the participants was observed; it was improved by introducing the telepresence robot system.

Currently, further analyses with data obtained from more

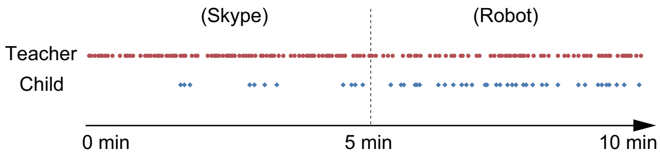

Fig. 5. Typical example of the interaction between the teacher and a participant child in the experiment. Each dot represents the start point of an action by the teacher/child directed toward the partner.

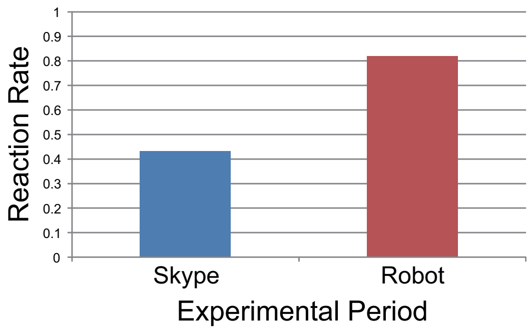

Fig. 6. Average reaction rates of the 26 participants during the last 5 minutes of each session for the two conditions. Each bar represents the average percentage of the participants' successful responses to the teacher's action in the Skype/Robot period.

than 50 participants are ongoing. We observed that there might be multiple factors that made the telepresence robot system effective in facilitating the communication between the teacher and the participants. For example, from interviewing the teacher, it was found that the system had facilitated both the participants and the teacher. The teacher expressed that compared with the Skype period, it had been much easier to teach the participants in the Robot period. Because of the physical embodiment and movement of the robot, it became easier for the person to recognize the state or the intention of the participants. After this finding, we started new experiments and behavioral analyses focusing on the teacher side by recruiting several teachers.

IV. Field Trial Connecting Classrooms between Australia and Japan

An original goal of this project was to present a test case involving the connection of classrooms in different countries and to share the experience with the academia and others in related fields. To this end, a field trial connecting classrooms between Australia and Japan was conducted in November 2012. In this section, we report the results from our trial and describe our experience.

When connecting actual classrooms, the first issue that was faced was the time difference between the locations of classrooms. This difference was not negligible. Usually, there are more scheduling constraints when conducting a field trial in an actual classroom as opposed to a laboratory experiment. Moreover, in the case involving the connection of multiple classrooms, multiple time zones were to be considered. Therefore, we first decided to connect the two

Fig. 7. Location of Jindabyne, NSW, Australia, from where children remotely controlled the telepresence robot (Fig.3) located in Tsukuba City, Japan (Fig.8).

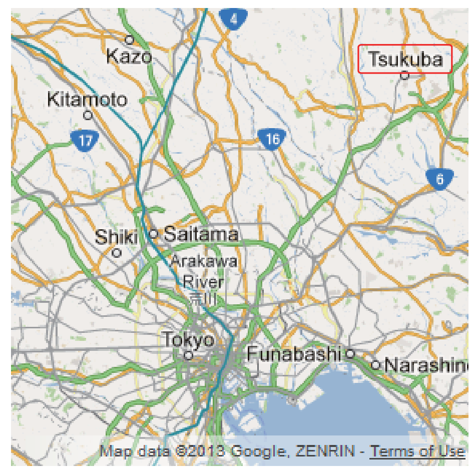

Fig. 8. Location of Tsukuba City, Japan. Australian children participated in classroom activities of Kasuga Elementary School located in Tsukuba City by remotely controlling the telepresence robot.

locations whose time difference was relatively small, making the scheduling easier. We therefore chose Australia and Japan; the time difference between these locations is 2 hours.

We were fortunate to have received cooperation from the following two schools in both countries.

Snowy Mountains Grammar School [15] is located in Jindabyne, Australia. Jindabyne (Fig.7) is a mountain resort located about 170 km south of Canberra, Australian Capital Territory. In this trial, the children in Jindabyne were the operators. About 20 children (6–8 year olds) came to the operator room set up in the school, one at a time, and remotely controlled a robot located in Japan. At times, other children and teachers also entered the room and observed the trial. The school already had the opportunity to use video conferencing services to facilitate communication between schools, including some in Japan.

The Kasuga Elementary School is located in Tsukuba City, Japan. Tsukuba City (Fig.8) is located about 60 km north of Tokyo and is actively promoting the use of ICT (Information

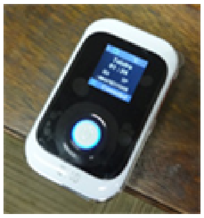

Fig. 9. Telstra Wi-Fi modem ZTE MF91. Two modems were used during the trial to connect with a public 3G network in Jindabyne.

Fig. 10. Field trial connecting classrooms between Australia and Japan. The operator child (left image) in Australia was remotely controlling the robot (right image), which was placed in a classroom in Japan.

and Communication Technology) in education. This school was newly opened in 2012 and had begun introducing video conference services to some classes at the time of this trial. The telepresence robot (Fig.3) was introduced in nine classes; more than 200 children (6–8 year olds) participated in its introduction. The activities performed during the trial using the robot will be described in the following paragraphs.

A practical issue that we faced while preparing the trial was the speed of the Internet connection. At the time of the trial, the latest 4G LTE network was available in Tsukuba; however, the best Internet connection available in Jindabyne was a public 3G network accessible from a mobile Wi-Fi device (Fig.9). For the trial, two independent Skype connections and a control signal connection was required. The first Skype connection was used for providing a bird's-eye view with both sides projected on a large monitor screen. The second Skype connection was used for the operator's local view, connecting two laptop screens (one on the robot and the other in front of the operator) with each other. The control signal connection was used for sending control signals from the operation interface to the robot. Because the expected communication traffic was higher than the capacity of a single Wi-Fi line on the 3G network, two independent lines were set up using two modems. As a result, the condition of the network communication between the two locations during the trial was feasible or even better, which was unexpected. The delay in data transmission observed during the trial was approximately 0.5–1.5 seconds.

Fig.10 shows snapshot pictures that were taken during the trial. The operator child in the left image was at the Snowy Mountains Grammar School, Jindabyne, and was remotely controlling the robot shown in the right image. The robot was placed in a classroom at the Kasuga Elementary School in Tsukuba City.

The most remarkable observation made throughout the trial was that in spite of the language difference that existed between both sides, the children were capable of communicating through the robot. In particular, many interactions were either triggered or invoked on some physical objects that could be manipulated by the robot (Fig.11). Japanese children surrounding the robot were actively trying to convey their intentions while speaking some known English words to the operator via the robot. As explained in previous sections, this type of interaction is not usually easy to induce with conventional video conference services. Although there were different factors, this observation appears to be consistent with the experimental results described in Section III.

Fig. 11. Interaction via a physical object. This type of an interaction was frequently observed. Even if there existed a language difference between children on both sides, they could still communicate through such physical interaction. Sometimes, it also facilitated their spontaneous utterances using the language of their partners, which is significant in terms of language education.

Fig. 12. Participating in physical exercises. This rope activity was performed on site at the request of a teacher in this classroom. By incorporating more advanced humanoid motion generation technologies, it is expected that the telepresence robot system can be applied to experience learning of the operator-side students.

The trial was conducted for two days in nine classes. In another interesting case, the robot participated in some physical exercises in the classroom (Fig.12). Australian children had the opportunity to participate (help) in rope-jumping and other related activities and enjoyed local Japanese playing exercises. This may easily be applied to other use cases such as experience learning. For example, Japanese traditional dances are very popular in many countries; in fact, they are often included in classes such as social studies or cultural studies in schools. Recent advancement in humanoid robotics studies have already enabled robots to imitate and generate traditional dance movements [16]. While applying these technologies, remote operators can participate in such traditional dances by remotely controlling the robot. The ability to participate in the dances is expected to motivate students and facilitate their learning.

V. DISCUSSIONS AND SUMMARY

As explained in Section I, companies have already begun to commercialize telepresence robot products. Although most current products were designed as a simple combination of Skype and mobility, our experience suggests that for child users, the ability to remotely manipulate the robot is essential; thus, the telepresence robot should be equipped with arms/hands. As discussed, this is particularly significant in facilitating communication between speakers of different languages.

From the perspective of intercommunication using different languages, it would be further useful to incorporate more methods that assist in understanding the partner's intentions. For example, the ability to interpret operator behavior can be feasible and useful. During the trial, two members of our research group accompanied the operators at the Australian school. From their observations, when remotely controlling the robot, most of the operator intentions could be predicted by the movement sequence of their hands. By combining a gesture recognition technique using a motion sensor and a language translation service on the Web, the robot could more comprehensively express the operator intention by its gestures and/or speech in the local language.

With the increasing availability and inexpensiveness of telepresence robot products, a bidirectional connection of both sides and classrooms may be possible. In such situations, telepresence robots will become the gateways of physically distant classrooms, and multiple operators will be able to remotely control multiple robots asynchronously.

This paper presented the results of a project whose goal was to develop a child-operated telepresence robot system and to show its effectiveness in distant communication including for the facilitation of foreign language education. Throughout the project, we had many opportunities to demonstrate the system and explain its potential applications to various people, including teachers, parents, education boards, managers of educational businesses, and of course, children. From our observations to date, everybody appreciates this technology. To fulfill further expectations, the next research step should include topics such as prototyping a curriculum that uses the telepresence robot system in daily education.

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REFERENCES

[1] Susumu Tachi. *Telecommunication, Teleimmersion and Telexistence*. IOS Press, Amsterdam, The Netherlands, 2003.
[2] Hiroshi Ishiguro. Android science: Conscious and subconscious recognition. *Connection Science*, 18(4):319–332, 2006.
[3] Kohei Ogawa, Shuichi Nishio, Kensuke Koda, Giuseppe Balistreri, Tetsuya Watanabe, and Hiroshi Ishiguro. Exploring the natural reaction of young and aged person with telenoid in a real world. *Journal of Advanced Computational Intelligence and Intelligent Informatics*, 15(5):592–597, 2011.
[4] Anybots, Inc. https://www.anybots.com/.
[5] InTouch Health. http://www.intouchhealth.com/.
[6] VGo Communications, Inc. http://www.vgocom.com/.
[7] Suitable Technologies. https://www.suitabletech.com/.
[8] Sangseok Yun, Jongju Shin, Daijin Kim, Chang Gu Kim, Munsang Kim, and Mun-Taek Choi. Engkey: Tele-education robot. In *Proceedings of the 3rd International Conference on Social Robotics*, pages 142–152, Berlin, Heidelberg, 2011. Springer-Verlag.
[9] Svetlana Yarosh, Kori Inkpen, and A.J. Bernheim Brush. Video playdate: toward free play across distance. In *Proceedings of the 28th International Conference on Human factors in Computing Systems*, pages 1251–1260, New York, NY, 2010. ACM.
[10] Sasa Junuzovic, Kori Inkpen, Tom Blank, and Anoop Gupta. Illumishare: sharing any surface. In *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems*, pages 1919–1928, New York, NY, 2012. ACM.
[11] JST PRESTO. http://www.jst.go.jp/kisoken/presto/en/index.html.
[12] Fumihide Tanaka, Toshimitsu Takahashi, and Masahiko Morita. Tricycle-style operation interface for children to control a telepresence robot. *Advanced Robotics*, 2013. in press.
[13] Toshimitsu Takahashi, Masahiko Morita, and Fumihide Tanaka. Evaluation of a tricycle-style teleoperational interface for children: a comparative experiment with a video game controller. In *Proceedings of the 21st IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN 2012)*, pages 334–338, Paris, France, 2012. IEEE.
[14] Vstone Co., Ltd. http://www.vstone.co.jp/english/index.html.
[15] Snowy Mountains Grammar School. http://www.smgs.nsw.edu.au/.
[16] Shin'ichiro Nakaoka, Atsushi Nakazawa, Fumio Kanehiro, Kenji Kaneko, Mitsuharu Morisawa, Hirohisa Hirukawa, and Katsushi Ikeuchi. Learning from observation paradigm: Leg task models for enabling a biped humanoid robot to imitate human dances. *International Journal of Robotics Research*, 26(8):829–844, 2007.