Movement Support System of Telepresence Robot Based on Operating Skill

Yoshifumi Kokubo
Graduate School of System Design
Tokyo Metropolitan University
Tokyo, Japan
Email: kokubo-yoshifumi@ed.tmu.ac.jp

Eri Sato-Shimokawara
Graduate School of System Design
Tokyo Metropolitan University
Tokyo, Japan
Email: eri@tmu.ac.jp

Toru Yamaguchi
Graduate School of System Design
Tokyo Metropolitan University
Tokyo, Japan
Email: yamachan@tmu.ac.jp

***Abstract*—A robot called "Telepresence Robot" is on business in recent years. Existing telepresence robots has no assist in their moving. People have to control telepresence robots with just video information. To better develop the system of the robot, here we study a movement support system based on an operating skill. People are divided to beginner and advanced in a preliminary experiment. An experiment comparing beginner-level support system and an advanced-level support system was carried out to all of the beginners and advanced people. The beginners evaluated the beginner-level support system higher than the advanced-level support system. Considering user's operating skill, operators of a telepresence robot are free from a stress of operating the robot.**

I. Introduction

Studying that social robots move safely to people is a particular area of research within the wider field of Human - Robot Interaction (HRI) [1]. "Telepresence Robot", which enables people to have a pseudo face-to-face conversation with people in a remote place, is one of the social robots [2]-[4]. In America, this robot is being advanced for office work [5]. On the other hand, in Japan, it is anticipated that the robots will increasingly be used for aged people in domestic environments because of super-aged society. Therefore the robots will be required to work alongside with human residents.

Existing telepresence robots has no assist in their moving. People have to control telepresence robots with limited information, that is screen and voice information. It is possible for a conversation-partner to feel fear when a telepresence robot approach him or her too close. A person who does face-to-face conversation with a telepresence robot is called a conversation-partner in this study. Therefore operators need to be sensitive for driving because of poor information, just video information, acquired through a telepresence robot.

There are risks that telepresence robots give fear to people or invade their personal spaces. Personal space between robot and human is already researched in various ways [6]-[11].

As there are differences from individual to individual about operating skill of a telepresence robot, therefore, a support system for an operator has to be a system individual-oriented. To model people in 2 degrees, people divided to a beginner and an advanced people in a preliminary experiment. Subjects operates a telepresence robot in two ways. One is subjects drive the telepresence robot while directly seeing the robot in a room. The other one is subjects remotely drive the telepresence robot with video information. A standard that divides a beginner and advanced is determined by comparing operating errors of distance. A beginner-level support system and An advanced-level support system are proposed. An experiment comparing these systems were carried out.

The rest of this paper is organized as follows. The proposed telepresence robot in this study is described in section II. The preliminary experiment to divide all of subjects to two group is explained in section III. The experiment comparing beginner-level support system and advanced-level support system is described in section IV. The conclusion is explained in section V.

II. Proposed Telepresence robot

Figure 1 shows an image of a telepresence robot that is used in this study. The height of this robot is 120 [cm]. This robot developed by VECTOR Inc. mounts a tablet, a controller PC and a range sensor. As existing telepresence robots does not have a range sensor, robots can not keep specific distance from people or any obstacles. Using the range sensor, this proposed robot detects surrounding obstacles and measurement of a distance from this robot.

This robot is assumed to be used in hospitals or a patients house. People have communication or take care of the patient with patients remotely.

A. Hardware Configuration

This robot has a movement mechanism, a tablet, a controller PC, a range sensor. Explanations of each functions are described as follows.

1) Movement mechanism A movement mechanism is attached in the bottom of the robot for moving. Maximum speed of the robot is 0.8 [m/s]. This movement mechanism is connected through a USB connector and controlled by a PC.
2) Tablet
   Nexus 7, a 7-inch tablet, is mounted on the robot. While the robot is moving, the display shows a character's face. After the robot stopped in front of the user with keeping an appropriate distance from the user, the display turns

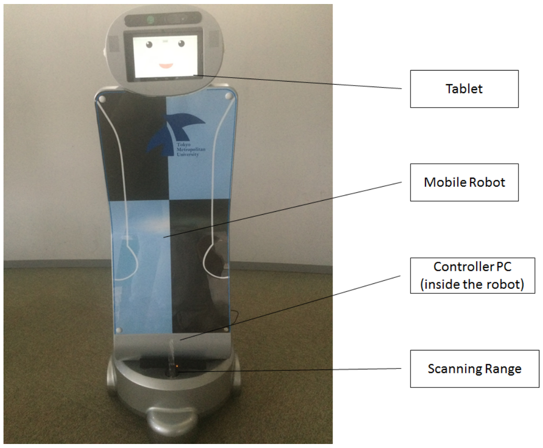

Fig. 1. This robot developed by VECTOR Inc. mounts a tablet, a controller PC and a range sensor.

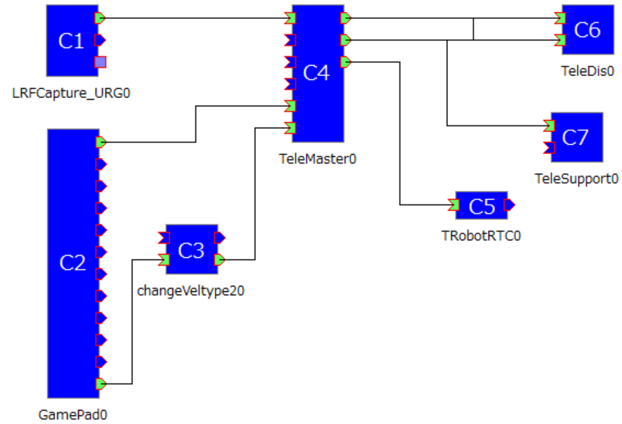

Fig. 2. Software configuration. C1)LRFCapture_URG gets data obtained from the range sensor and converts from polar coordinates to X-Y coordinate. C2)GamePad gets command value from a game pad. C3)changeVeltype converts velocity data type to suitable type for C4. C4)TeleMaster controls movement of the telepresence robot. C5)TRobotRTC gives command value to the motor of the robot by serial communication. C6)TeleDis shows distance between the telepresence robot and a subject on a display. C7)TeleSupport lets the controller PC emit an alert sound.

from a character's face to a face of an user who remotely controls the robot.

3) Controller PC
   A laptop PC is mounted inside the mobile robot. In this study, RT-Middleware [13] is used for building a robot-control system. RT-Middleware is the technology of constructing systems to operate modules of robot components, such as sensors and actuators. This system allows us to easily implement the robot by diverting some components to the new one.
4) Range Sensor
   A range sensor is positioned in front of the robot. This sensor is used for detection of surrounding obstacles and its distance from the robot. The sensor is URG-04LX-UG01 of HOKUYO AUTOMATIC Co. Ltd.

B. Software Configuration

A system to move the robot is developed by RT-Middleware. Figure 2 shows software constructions. Each components are explained as follows.

1) C1: LRFCaptureURG
   This program gets values obtained from the range sensor and converts from polar coordinates to X-Y coordinate. This component is basically developed by Nara Institute of Science and Technology [14] and a little modified for this system.
2) C2: GamePad
   This program gets command value from a game pad. This component was developed by Segway Japan Inc. [15].
3) C3: changeVeltype2
   This program converts velocity data type to suitable type for C4.
4) C4: TeleMaster
   This program controls movement of the telepresence robot. Input data for this program are sent from C1 and C3, that are distance information between the robot and a subject and command value information from a game pad. Drive levels, beginner-level support and advanced-level support, are selected as a configuration. A personal space of a subject is manually input before starts the system.
5) C5: TRobotRTC
   This program gives command value to the movement mechanism of the robot by serial communication. Considering distance between the robot and a person by using data obtained from the range sensor, command value is changed.
6) C6: TeleDis
   This program shows distance between the telepresence robot and a subject on a display. The distance information is sent as numeric value from C4.
7) C7: TeleSupport
   Based on a command which comes from C6, this program let the controller PC emit an alert sound.

III. PRELIMINARY EXPERIMENT

An objective of this section is to divide subjects into two groups (beginner and advanced). An operator of a telepresence robot generally controls the robot through video-information. It is difficult for an operator to control a telepresence robot by using just video-information acquired from the robot. There is a time lag between time when operator input command to move a robot and the robot starts to move. The time lag is one of the big factors for operators to take an improper operation. A major cause of the time lag is a delay of communication. Some operators are able to control a telepresence robot with considering the delay. However, others cannot do that. We focused on two situations that time-lag exists or not and held an comparing experiment.

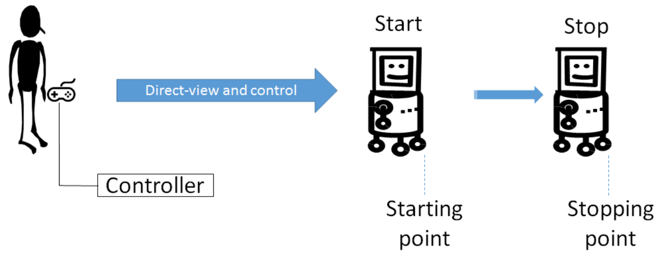

Fig. 3. The subjects drive the telepresence robot from a starting point (7 [m] point from a person) to a stopping point (0.7 [m] point from the person) with direct-viewing

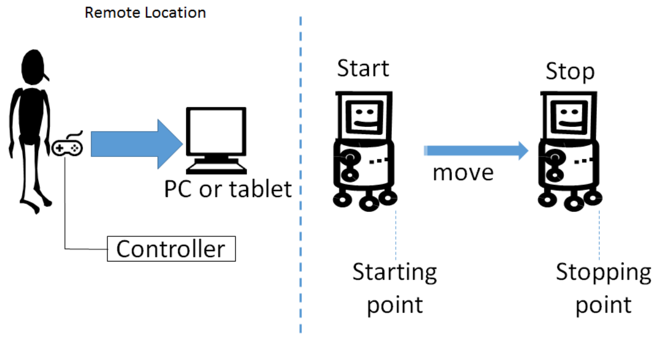

Fig. 4. The subjects remotely drive the telepresence robot to the stopping point with using video-information. The subjects get the information through a camera of a tablet attached on the telepresence robot.

A. Method

The subjects was males and females, a total of six people in their twenties. All of the subjects are accustomed to this robot. The subjects controlled the robot until the subjects judged that they are accustomed to the robot.The subjects let the robot to approach them and move front, back, left and right. Experimental images are shown in Figure 3 and Figure 4. As shown in Figure 3, the subjects move the telepresence robot from a starting point (7 [m] point from a person) to a stopping point (0.7 [m] point from the person) with direct-viewing at first. A way a subject looks and drives the robot directly is called direct-viewing. As shown in Figure 4, the subjects remotely move the telepresence robot to the stopping point with using video-information. The subjects get the information through a camera of a tablet attached on the telepresence robot. After the robot stops, in both of situation, a distance between the robot and a subject and an error distance from the stopping point are measured. A way a subject look and drive the robot through video-information is called remote-viewing. Figure 5 shows all of measured distances. The upper diagram is about direct-viewing. It is called that distance between the robot and subject is distance A and distance between the stopping point and a distance the robot stops is error A. The bottom diagram is about remote viewing. As well as distance A and error A, it is called that distance between the robot and subject is distance B and distance between the stopping point and a distance the robot stops is error B.

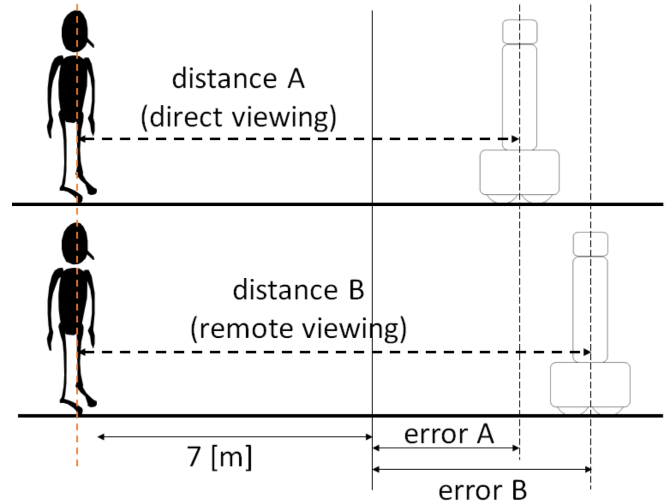

Fig. 5. The upper diagram is about direct viewing. It is called that distance between the robot and subject is distance A and distance between the stopping point and a distance the robot stops is error A. The bottom diagram is about remote viewing. As well as distance A and error A, it is called that distance between the robot and subject is distance B and distance from the the stopping point is error B.

TABLE I
DISTANCE A AND B, ERROR A AND B AND STANDARD DEVIATION OF SIX SUBJECTS IN THIS EXPERIMENT

subject	distance A [mm]	$\|errorA\|$ [mm]	distance B [mm]	$\|errorB\|$ [mm]	SD [mm]
subject 1	815	115	673	27	71
subject 2	797	97	627	73	85
subject 3	821	121	714	14	53
subject 4	793	93	652	48	71
subject 5	808	108	523	177	142
subject 6	996	296	580	120	208

B. Result

The data of six subjects, distance A and B, error A and B and standard deviation, was obtained in this experiment and shown in TABLE I.

Focusing on standard deviation, subject 3 has the lowest score. Comparing standard deviations of subject 1, 3 and 4, subject 3 is about 20 [mm] lower than subject 1 and 4. Subject 3 are set as advanced and the rest of subjects are set as beginner in this paper.

IV. EXPERIMENT COMPARING BEGINNER-ASSIST SYSTEM AND ADVANCED-ASSIST SYSTEM

The two kinds of systems, a beginner-level support system and an advanced-level support system, were prepared.

All of subjects, a beginner and advanced subjects, are warned by the controller PC that they use when robot approaches a person in both of systems. The difference between the beginner-level support and the advanced-level support is where the controller PC emits a warning. The beginner-level

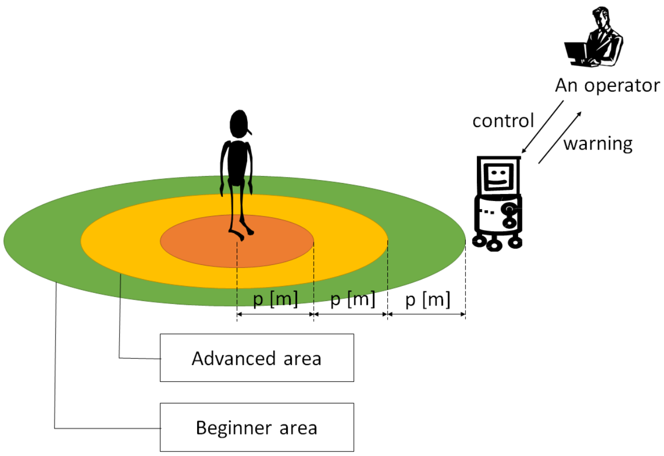

Fig. 6. The experimental image of the experiment comparing beginner-assist system and advanced-assist system. p [m] in the figure is each personal spaces of each subjects. Beginner-assist system warns an operator since where the robot is in three times as far as their own personal spaces. Advanced-assist system warns an operator since where the robot is two times as far as their own personal spaces.

support system warns subjects nearer than the advanced-level support system. Personal spaces of each subjects were obtained in our previous study [16].

A. Experimental Method

Two kinds of robot-assist systems are prepared about this experiment. An experimental image is shown in Figure 6. One is beginner-assist system that warns since where the robot is in three times as far as their own personal spaces. The other one is advanced-assist system that warns since where the robot is two times as far as their own personal spaces. The subjects who participate this experiments is the same as the subjects who participated the preliminary experiment. In the both of systems, the distance between a subject and the robot were shown. After the experiment, Each systems were evaluated in 5 stages.

B. Hardware Configuration

Hardware is the same as the robot used in the preliminary experiment.

C. Experimental Result

The distance data and evaluation data of six subject's personal space were obtained in this experiment. Graphs of Figure 7 and 8 shows distance error from the stopping point and evaluation in 5 stages of each subjects. A vertical axis is rating and a horizontal axis is operating error. A red dot is an advanced subject. Blue dots are beginner subjects. TABLE II is rating data of the advanced subjects and average rating of the beginner subjects. The advanced subject rated both systems high. The beginner subjects rated beginner-level support system higher than advanced-level support system.

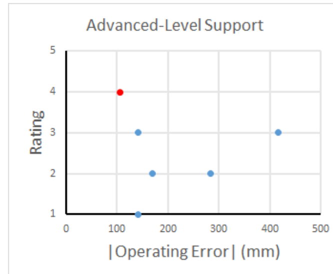

Fig. 7. Operating errors and rating in a evaluational questionnaires in each subjects about the advanced-level support system. A red dot is an advanced subject. Blue dots are beginner subjects. Operating error of the advanced subject is the smallest in this graph and evaluates this system higher than any other beginners.

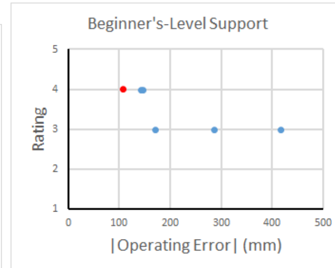

Fig. 8. Operating errors and rating in a evaluational questionnaires in each subjects about the beginner-level support system. A red dot is an advanced subject. Blue dots are beginner subjects. Operating error of the advanced subject is the smallest in this graph. All of beginners evaluate this beginner-level support system the same or higher than advanced-level support system in Figure 7.

TABLE II
RATING DATA OF THE ADVANCED SUBJECT AND AVERAGE RATING OF THE BEGINNER SUBJECTS.

	Advanced-level support	beginner-level support
Beginner	2.2	3.4
Advanced	4	4

V. CONCLUSION

To reduce burden of operating robot, we proposed the movement support system based on operating level in 2 degrees. An advanced people rated the both systems high. Beginner people, however, rated the beginner support system higher than the advanced support system. Therefore, the movement support system need to be skill-based. Our future prospects are to consider other situations. For instance, following and passing each other. The assist system will be developed in each situations. An experiments will be performed with more subjects and change experimental conditions.

REFERENCES

[1] T. Fong, I. Nourbakhsh, and K. Dautenhahn, (2003). *A survey of socially interactive robots, Robotics and Autonomous Systems*, vol. 42, pp. 143-166.

[2] H. Nakanishi, (2011). *Social Telepresence and Robotics*, Journal of the Robotics Society of Japan, vol. 29, no. 1, pp. 23-26, 2011.

[3] M. Murakami, H. Nakanishi, D. Nogami, H. Ishiguro, (2008). *Analysis of Social Telepresence Experienced by a Robot's Operator [in Japanese]* IPSJ SIG Technical Report, 2008-HCI-129, pp. 27-34.

[4] S. Ogami, K. Yamamoto, K. Tanaka, H. Nakanishi, (2013). *Smoothing Audio Communication via Presentation of a Remote Partner's Body Motion [in Japanese]* , IPSJ, vol. 54, no. 4, 1462-1469.

[5] Kristoffersson, Annica, Silvia Coradeschi, Amy Loutfi, *A review of mobile robotic telepresence. Advances in Human-Computer Interaction*, (2013): 3, 2013.

[6] Mika Yasumoto, Hiroko Kamide, Yasushi Mae, Kenichi Ohara, Tomohito Takubo, Tatsuo Arai, *Personal space for the humanoid robot and a presentation method*, The Robotics and Mechatronics Conference, "2A2-D18(1)"-"2A2-D18(4)" 2010.

[7] Michael L Walters, Kerstin Dautenhahn, Ren te Boekhorst, Kheng Lee Koay, Christina Kaouri, Sarah Woods, Chrystopher Nehaniv, David Lee, Iain Werry, *The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. Robot and Human Interactive Communication*, 2005. ROMAN 2005. IEEE International Workshop on. IEEE, 2005.

[8] Nakauchi, Yasushi, and Reid Simmons, *A social robot that stands in line.* Autonomous Robots 12.3, 313-324, 2002.

[9] Wilma A. Bainbridge, Justin Hart, Elizabeth S. Kim, Brian Scassellati, *The effect of presence on human-robot interaction.* Robot and Human Interactive Communication, 2008. RO-MAN 2008. The 17th IEEE International Symposium on. IEEE, 2008.

[10] Michael L Walters, Kerstin Dautenhahn, Ren te Boekhorst, Kheng Lee Koay, Christina Kaouri, Sarah Woods, Chrystopher Nehaniv, David Lee, Iain Werry, *The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment.* Robot and Human Interactive Communication, 2005. ROMAN 2005. IEEE International Workshop on. IEEE, 2005.

[11] Mumm, Jonathan, Bilge Mutlu, *Human-robot proxemics: physical and psychological distancing in human-robot interaction.* Proceedings of the 6th international conference on Human-robot interaction. ACM, 2011.

[12] TOHYAMA, Takashi and OSHIO, Atsushi and UCHIDA, Toshio and NISHIGUCHI, Toshifumi, (2006). *A Study of Factors Affecting Personal Space : Height, Eye Contact, and Version [in Japanese]*, Journal of the College of Humanities, 2006, vol. 16, pp. 115-128.

[13] Ando, Noriaki, Takashi Suehiro, and Tetsuo Kotoku. *A software platform for component based rt-system development: Openrtm-aist.* International Conference on Simulation, Modeling, and Programming for Autonomous Robots. Springer Berlin Heidelberg, 2008.

[14] Range Finder component. Available at: [1] [Accessed 2016/08/15]

[15] Game Pad component. Available at: [2]. [Accessed 2016/08/15]

[16] Yohei Yamaguchi, Shota Mitsumura, Yoshifumi Kokubo , Eri Shimokawara, and Toru Yamaguchi. *Proposal of Home-Use Telepresence Robot System Considering User's Personal Space* 2015 RISP International Workshop on Nonlinear Circuits, Communications and Signal Processing (NCSP'15), Kuala Lumpur, Malaysia, 28AM2-2-3 (February 27 - March 2, 2015).

[1] http://www.openrtm.org/openrtm/ja/project/NEDO_Intelligent_PRJ_ID157

[2] http://www.openrtm.org/openrtm/ja/project/NEDO_Intelligent_PRJ_ID052