Transmission of Existence by Retro Reflective Projection Technology Using Handheld Projector

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Abstract

Our research aims to enable persons to communicate remotely with numerous participants while moving around freely in public spaces. To achieve this goal, we developed a novel remote communication system based on a mutual telexistence master-slave system. In this paper, we propose a system that transmits the operator's sense of existence to the participant using retro-reflective projection technology and a handheld projector, which solves the problem of a limited sense of the surroundings. Although stereoscopic presentation by motion parallax did not occur in this study, this system was expected to give the participant a stereoscopic view via the surrogate robot using a handheld projector.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 Introduction

In remote communication, mutual telexistence[1] is the concept in which the sense of existence of the self is transmitted to a remote environment, providing the sense that the self is actually in the remote environment. Our aim is to enable remote persons to communicate with numerous participants while moving around freely in public spaces. Figure 1 shows the primary concept of our research.

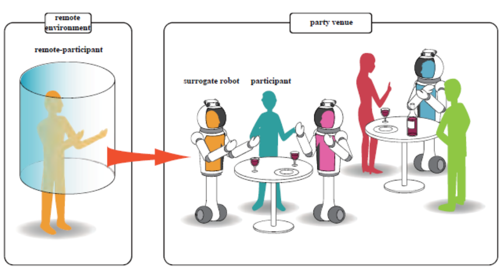

Figure 1: The concept of our research.

In the proposed remote communication system, it is necessary to (1) transmit the presence of the remote environment to the operator, (2) transmit the sense of existence of the participant in the remote environment to the operator, and (3) transmit the sense of existence of the operator to the participant. Previous research has addressed the first two points using a surrogate robot[2]. In this paper, we focus on transmitting the sense of existence of the operator to the participant. In order to achieve this, the images of the operator have to be three-dimensional to sufficiently represent the sense of existence to the participant. From a psychological perspective, human emotions such as enjoyment are transmitted through both the eyes and facial expressions[3]. Similarly, from physiology, we know that the forehead cortex and temporal pole are activated when others are within the line of sight in order to estimate their intentions[4]. This information highlights the requirement to transmit visuals of the operator's face, including their eyes and facial expression.

There have been several studies focused on transmitting the sense of existence of the operator to the participant. Anybots QB[5]and Texai[6] have transmitted the identity and expression of the operator by displaying their face on a display mounted on a surrogate robot. However, the display was not visible when the participant viewed the surrogate robot from the rear. In the transmission of an ideal sense of existence, there should be a post-figure of the operator. Furthermore, in the previous studies, everyone sees the same image when they look at the surrogate robot from different directions. Given that the surrogate robot ideally would accurately represent the operator, the appearance of the face must change according to the direction from which the surrogate robot is being viewed. Therefore, the accurate transmission of sense of existence is not possible using this previously studied method. Ishiguro et al. developed the robot Geminoid[7], which closely resembles a human being. They state that Geminoid transmits more sense of existence than a video conference. However, in remote communication systems that use a humanoid robot, the robot must closely resemble the operator so that the participant knows who the operator is. As a result, we are not aiming toward a system of this type because it is cost-prohibitive to prepare surrogate robots for each person using the system. Fuchs et al. developed Shader Lamps Avatars[8], which transmit the sense of existence of the operator through projections of the operator's facial image on a model of a human head. Using this method, the three-dimensionality of the face is transmitted, which allows participants to view the operator from any direction. However, short-range communication, such as a handshake, is difficult, because it is impossible for there to be anything between the projector and the head model. In TELESAR2[1], the sense of existence is conveyed using retro-reflective projection technology[9]. Using this method, the image is different at every angle, and therefore, contradictory occlusion does not occur. However, the viewpoint is limited to the position where the projector was placed. The presentation of a three-dimensional operator is not possible as the projecting image of the operator is a two-dimensional image.

In this study, we focus on retro-reflective projection technology that enables short-range communication, like a handshake. In TELESAR2, the fact that the viewpoint was limited to the position where the projector was placed disturbed the transmission of the sense of existence. This problem is solved by using small projectors, which have recently become available. The small projector can be used in two ways: handheld and head-mounted. For this study, we opted for the easily usable handheld type. It is known that three-dimensionality occurs through motion parallax[10]. The reproduction of motion parallax seems to impart a stereoscopic view to the participant who sees the surrogate robot via the handheld pro-

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jector. In this paper, we propose a system that transmits the sense of existence of the operator to the participant using retro-reflective projection technology and a handheld projector.

2 PROPOSED METHOD

Our aim is to enable people to communicate with remote participants while moving around freely in public spaces. To achieve this purpose, we focused on a master-slave system using a surrogate robot. In the proposed remote communication system, it is necessary to transmit the following:

1. The presence of the remote environment to the operator.
2. The sense of existence of the participant in the remote environment to the operator.
3. The sense of existence of the operator to the participant.

To achieve these three requirements, we suggest a system that transmits the sense of existence of the operator to the participant. The requirements of the system for transmitting the sense of existence are thus examined.

To transmit the sense of existence of the operator to the participant, it is important to transmit a three-dimensional image of the operator, particularly their facial expression and eyes. During communication, the facial expression must also be visible to multiple participants, because it is assumed that there will be numerous participants surrounding the surrogate robot. Similarly, it should be usable at the close distance required for physical contact. In addition, it should be possible to use the system regardless of who the operator is. As a result, we focused on retro-reflective projection technology, which can satisfy all of these requirements. In TELESAR2, it became an issue that the viewpoint was limited to the position where the projector was placed, as this disturbs the transmission of sense of existence. This problem is solved in our system by using a handheld projector. Additionally, the reproduction of motion parallax should give a stereoscopic view to the participants, who view the surrogate robot via a handheld projector.

We will now describe the projection of the operator to the surrogate robot using retro-reflective projection technology in order to satisfy the further requirements of the system. In retro-reflective projection technology, a retro-reflector is used as the projection plane. A retro-reflector strongly reflects the incident light in the direction of the light source. Using this, the image is presented differently when viewed from different angles to account for multiple participants. For the projection of the operator to the surrogate robot using retro-reflective projection technology, it is necessary to affix a retro-reflector as a projection plane to the head of the surrogate robot and to project the image of the operator captured by the camera from the projector near the eye.

In order to project the face of the operator on the projection plane, it is necessary to affix a projection plane to the head of the surrogate robot and that projection plane must be of a sufficient size. In addition, the projector, which would be held in the left hand to free the right hand for communication, must be of a sufficiently small size and weight for handheld portability. For the communication with the operator, the handheld projector must not cover either the eyes or the face of the person who holds it. However, it is acceptable for one eye to be covered, because half mirrors are necessary in front of the eye. For the reproduction of motion parallax, it is necessary that the camera captures whether the operator moves the position of the projector of the surrogate robot. Accordingly, the camera must have a movable mechanism. To assess the direction of movement, the measurement of the relative position of the projector and the retro-reflective projection plane is required. On the other hand, the operator needs an immersive display to transmit the sense of existence to the participant. However, the display must not cover the face of the operator, in order to capture the image of the operator's face. Furthermore, the camera capturing the image of the operator must not hinder the display.

In an ideal system that satisfies the requirements described, the participant is transmitted the identity of the operator and their facial expression. Furthermore, the participant should not sense that there is the projected image of the operator on a projection plane but that there is the operator.

3 SYSTEM CONFIGURATION

Figure 2 shows the configuration of the system that presents the sense of existence of the operator. The relative position of the projector and the retro-reflective projection plane affixed to the surrogate robot is measured using a motion capture system, i.e., OptiTrack (Natural Point Inc). By placing a marker in the projector and projection plane, it is possible to acquire each position at a frame rate of 100 fps within an error of 0.2 mm.

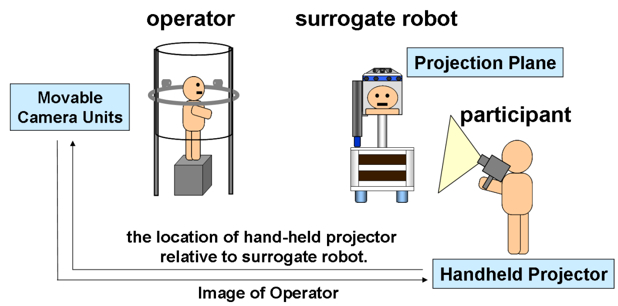

Figure 2: System configuration.

We adopted an immersive full-color autostereoscopic display, "TWISTER"[2], as the display that the operator uses and six movable camera units (Figure 3) installed with TWISTER for capturing the image of the operator. By using TWISTER, movable camera units can capture an image outside of the display. Movable camera units are moved on a circular rail with a 1.2-m radius that centers on the operator. The height is equal to the viewpoint of the operator for the circular rail. A movable camera unit, Firefly MV (Point Grey Research Inc.), is mounted and pointed towards the operator. This movable camera unit follows the position of the projector for the surrogate robot, and captures the image of the operator for projection. The position of the movable camera units was controlled using PID control. Though the Firefly MV has a maximum resolution of 752x480 pixels, a resolution of only 480x350 pixels was used for the image of the operator, with a central focus on their eye. The image of the operator is preserved in the computer that controls the movable camera unit at 30 fps and it is transmitted to the projector via the network.

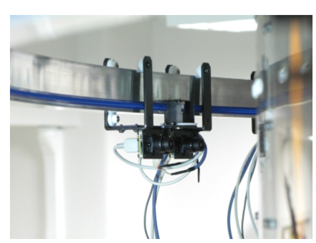

Figure 3: Movable camera unit.

The handheld projector is composed of a projector, outer packaging, half mirror, and marker (Figure 4). The projector is a SHOWWX (Microvision Inc., refresh rate: 60 Hz, resolution: 640x480 pixels, vertical angles of view: 25 degree) laser projector. The outer packaging was designed according to the requirement that coverage of the operator's face is minimized. As a result, the projector was located near the face. The marker was placed for OptiTrack. The dimensions of the handheld projector were 60 mm x 150 mm x 175 mm, and the weight was 220 g, including the projector and its battery.

The projection image was made using OpenGL and OpenCV. After the captured image of the operator is loaded, it is stuck as a texture on the plane calculated from the projector and surrogate robot position/posture that was obtained from OptiTrack. This plane was always vertical for the optic axis direction of the projector, and the size was decided from the angle of field of the camera that captures the image of the operator. This image is converted considering the configuration of the projector and half mirror. The refresh rate of the projected image is 60 Hz, which is equal to the refresh rate of the projector.

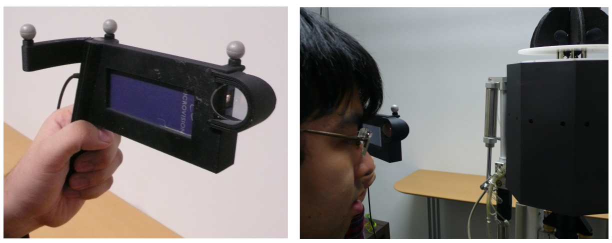

Figure 4: left: Handheld projector unit, right: Image of using projector unit.

Figure 5 shows the retro-reflective projection plane. It was made along an omnidirectional camera device. The projection plane is of a sufficient size to project the face of the operator in its real scale. The height of the projection plane is set at the height at which eye contact between the operator and the participant was possible. The marker for OptiTrack placed in the upper part. So that the camera is not blocked, a hole of 9-mm diameter was made in front of lens.

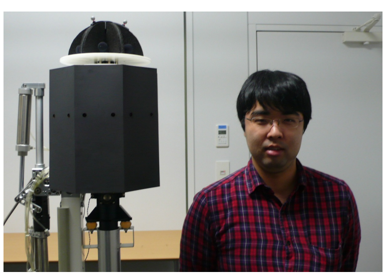

Figure 5: Retro reflective projection plane.

4 RESULT AND DISCUSSION

Figure 6 shows a demonstration image of the proposed system. By using the constructed system, it was confirmed that the expression of the operator was transmitted and that it was possible to observe the operator from any viewpoint. Furthermore, this system achieved the previously described requirement that it must be able to be used at close proximity and regardless of the identity of the operator.

However, a person who tested the system reported that they only sensed through the projection. In other words, stereoscopic presen-

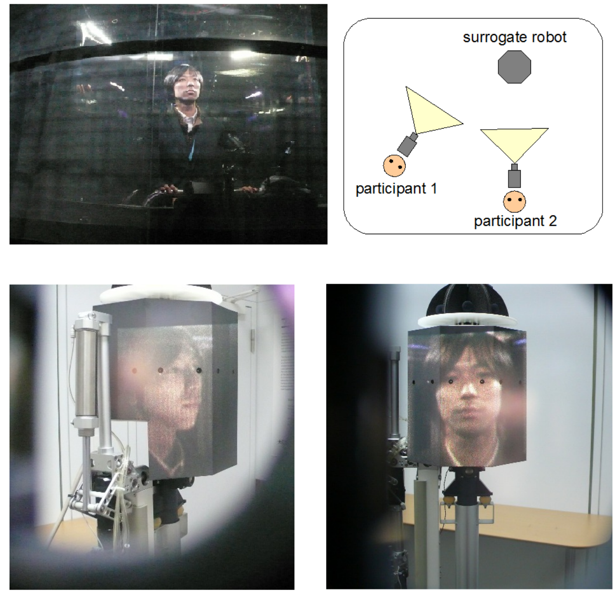

Figure 6: Result of projection of the operator. upper left: operator image from the outside TWISTER, upper right: location of participants and surrogate robot, lower-left: image of the operator from participant 1, lower-right: image of the operator from participant 2

tation by motion parallax did not occur. As a result, the sense of existence of the operator was not transmitted to the participant.

This cause considers two. The first is difference between the location of movable camera unit relative to the operator and the location of hand-held projector relative to surrogate robot. The movable camera units follow the position of the projector for the surrogate robot, and capture the image of the operator for projection. The delay of following, however, is not avoided. To solve the problem, it is necessary to convert the image which compensates for difference of the relative position assuming the delay of tracking. The second is that projected image can not follow the movement of trembling hand. In the ideal system, projected image is recalculated in a moment when the projector move. Because actually the refresh rate is limited, the projected figure of the operator is blurred until projected image is recalculated. Use of the projector which refresh rate is high is one solution. It is also considered that the projector is fixed to the head because the movement of the head is less than the hand.

This could be caused by two different factors. The first possibility is the difference between the location of the movable camera unit relative to the operator and the location of the handheld projector relative to the surrogate robot. The movable camera units follow the position of the projector for the surrogate robot, and capture the image of the operator for projection. The delay caused by tracking, however, cannot be avoided. To solve this problem, it is necessary to convert the image, which compensates for the difference of the relative positions assuming the tracking delay. The second possible cause is that the projected image cannot follow the movement of a trembling hand. In an ideal system, the projected image is recalculated the moment the projector moves. However, because the refresh rate is limited, the projected figure of the operator is blurred until the projected image is recalculated; therefore, the use of a projector with a higher refresh rate is one potential solution. It is also possible that using a head-mounted projector would contribute to fixing this problem because the head moves less than hands do.

With regard to the projector, it is thought that the handheld projector, used to project the image of operator adds stress to the participant because the participant has to hold the handheld projector and gaze at the surrogate robot for communication. In order to solve this problem and increase the stability of the projector, we will develop a head-mounted projector.

5 CONCLUSION

This research aims to enable people to communicate remotely with numerous participants while moving around freely in public spaces. In this paper, we propose a remote communication system that transmits the sense of existence of a remote person to the participant using retro-reflective projection technology and a handheld projector. It was confirmed that it was possible to observe the figure of the remote person from any viewpoint. However, stereoscopic presentation by motion parallax could not be carried out. An investigation into a system to solve this problem is currently underway.

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