テレイグジスタンスの研究(第 84 報)
—ヴァーチャル・ハンズの投影を用いたテレイグジスタンス・ロボットのための相互伝送—

Study on Telexistence LXXXIV
-Mutual Communication for Telexistence Robots using Virtual Hands Projection-

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This paper addresses the lack of physical arms in Telexistence robots by projecting operator's hands images into the remote environment. User hands are captured from the first point of view (FPV) using an IR camera mounted on user's HMD, and are segmented from the background. Those hands are then superimposed on top of of robot vision, and presented to user's HMD. In the robot place, a pico projector mounted on the robot head is used to project the same images of user's hands after being corrected into the remote environment objects. Using this method, it is possible to have a mutual understanding between the user and remote participants towards hand motion and interactions in the remote place.

Key Words: Mixed Reality, Remotely Operated Robot, Telexistence

1. Introduction

Telepresence systems have evolved in social activities and day-to-day communications. However, not all the telepresence robots provide a sense of presence to the user who is controlling. Furthermore, these type of robots provides minimum representation of the operator's body and state in the remote place and usually provides a limited representation of the user using a front display showing the head only. Though for social and communication applications, our bodies are considered an effective communication devices that embodies internal mental states to the others [1]. Previous works addressed the physical representation of the body for teleoperation and telexistence [2][5] . However, these approaches are not portable, too pricey and not efficient for mobile social contexts. Other approach is using image based embodiment for collaborative screens has been proposed and used in [3][4], however they do not apply for mobile telexistence applications, and were used for desktop applications.

A previously proposed mobile telexistence system [6] provides operators own hands visuals into his display (HMD) by capturing them, and segmenting their contour from the background and superimposing them on to the remote environment images. It was found that providing the virtual hands improved the sense of body presence in the remote place from the user perspective only, however it lacked the mutual hands representation in to the remote place. As a result, the remote participants were not aware of user's hands and actions with respect to his avatar body. Therefore, sometimes the remote participants get confused due to lack of visual clues of the operator interactions.

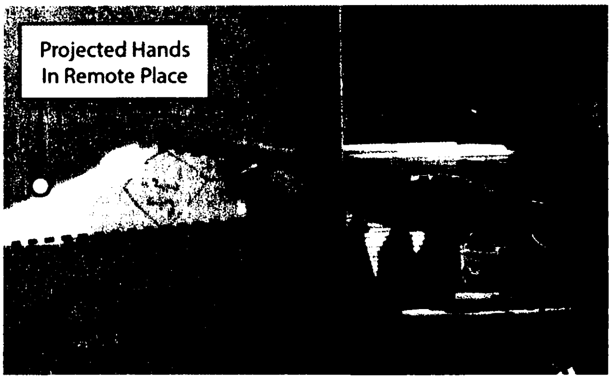

Fig. 1 Side-by-side pointing on remote object

In this paper, we propose a mutual body communication method for lightweight telexistence robots that lacks physical arms. As shown in Fig. 1, operator's hands are projected into the remote place objects using a pico projector mounted on the robot head and aligned with head movement. The virtual hands can be projected onto a physical table, remote user, or to any remote surfaces in order to provide the clue of user's hands interaction and intended actions. These virtual hands also provides the awareness for the user about his body, which are necessary for the sense of body presence.

The proposed method can be used in many applications to enhance the arms and hands representation of the operator at remote environment. With the proposed method, the remote participants could understand the intended interactions clearly though the operator cannot perform any physical manipulations.

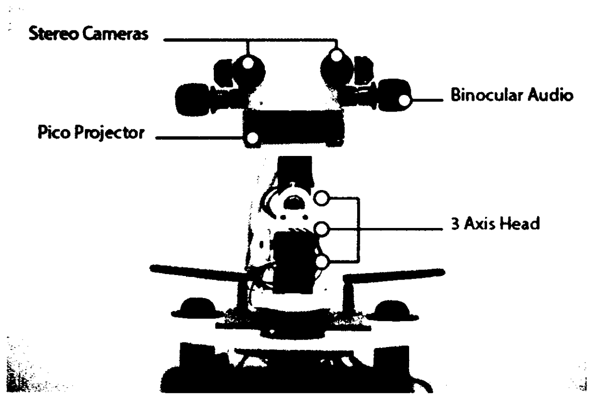

Fig. 2 Robot head design

2. System Implementation

The developed system is divided into a typical Master-Slave Telexistence systems, the master side is the controlling side where the user is located. In the user side, a set of tracking tools are used to capture user's head movement (Oculus DK2) as well as hand movement and visuals (Leapmotion). Robot movement is controlled using user's head movement, further details about the controlling method will follow.

In the robot side (slave), a 3 Degrees of Freedom (DOF) head is used to physically map user's head rotational motion at the remote place, Fig. 2 shows the construction and main components used in the head design. FullHD stereo cameras and binaural microphones are used to enable bidirectional visual and auditory communication to the user from robot side. The robot provides to the remote participants user's video and voice in the remote place via a LCD display and a speaker mounted on the front side of the robot. This enables to see the user's top body and arms during interactions. The robot designed with fully wireless and mobile platform that allows free motion in remote places. Also it has a pico projector for displaying user hands in the remote place. Table 1 lists the specifications of the cameras and projector used in this work.

The captured Hands movement and visuals are used to provide visual feedback to user's side, as well as to be projected in the robot's side. The user observe his own hands motion over robot's vision. To present user's hands in the remote place, the captured

Table 1 Specifications of the used cameras and projector

	Camera	Projector
Model	Logitech C615	Beampod Lumex MX65
Field of view	90° with lens	34°
Resolution	1920x1080	640x480 (native)
Brightness	-	65 Lumen
Weight	320g with lenses	100g

images using the mounted camera on the HMD are first segmented to isolate the hands from the background. Then those segmented hands are superimposed on the visual stream from the robot side, so the user can have awareness of his hands presence. The position and size of the captured hands are preserved in the FPV with his hands, so the pointing remains natural. Those hands are sent to the robot side and projected using a pico projector (Model: Lumex Beampod) that is mounted on the head module. Fig. 3 shows the FPV superimposed hands on the remote robot's vision, as well as the virtual projected hands. There is a slight position mismatching in the picture, to fix this, a calibration step is required to be applied to extract projection matrix and fix the mapping.

2.1. Motion Control

One of the main goal of this method is to free the hands from any joysticks or keys to control the motion of the robot, and to allow an intuitive interactions with the remote environment and participants. Thus it was important to consider the approach to control robot's movement in the remote place.

In a previous work [7] it was proposed to use the entire body motion as a method to control the motion of a camera in a virtual world. We propose in this work to use head motion as a method to control the speed and rotation of the mobile robot in the remote place. Fig. 4 shows the motion mapping between user's head and the applied direction to the robot. The speed is measured as the difference with the original calibrated position/orientation of the head. The advantages of using this method is: 1) it frees the hands from any controllers so the user can use his hands for other interactions, and 2) it provides a natural optical flow with the head movement.

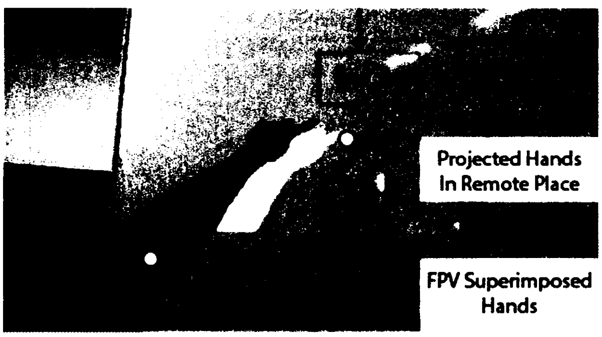

Fig. 3 User's FPV with hands being superimposed and projected

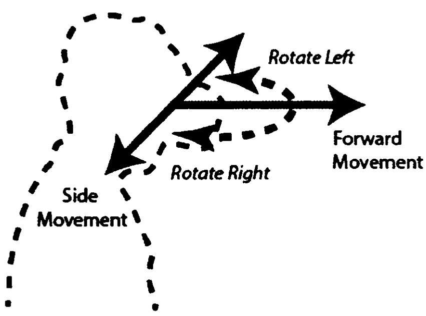

Fig. 4 Body based motion to control robot movement

2.2. Hands Capturing and Segmentation

In the user side, the hands are captured using an IR camera mounted on the front of the HMD. The camera provides 110°field of view which covers HMD FoV, and thus it is possible to capture user hands with no cropped areas. Though the resolution of the cameras are relatively low (640x240), up sampling step is necessary to smooth out the edges.

The advantages of using IR camera compared with RGB camera is the possibility to capture objects close to the camera using the returned intensity, in our case we capture hands visuals effectively. However there is a resulting noise from the background. We apply a nonlinear filtering function on the captured images, this function removes the pixels which color intensity are below a certain threshold. The results of applying the filter can be seen in Fig. 5.

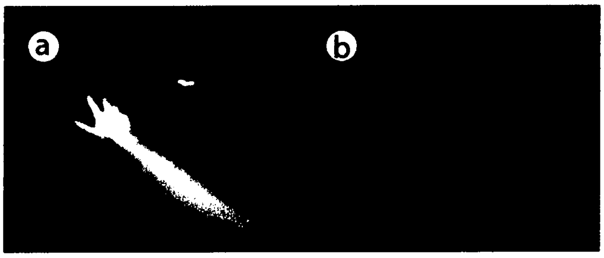

Fig. 5 Hands before and after segmentation from the background

The captured and processed images are then used in the user side as superimposed images over the remote feedback, providing the operator awareness about his body presence. Those images are also streamed into the robot side in order to be projected in the remote place.

2.3. Projector Calibration

Due to the displacement between the projector position and the camera position in the robot side, and the difference between both fields of view, the projection of the hands directly will result mismatch scale and position when observed by the operator from the FPV. Thus it is necessary to measure this displacement and scale by calibrating the projector with respect to one of the cameras.

The goal of the calibration process is to determine the amount of displacement (*dx,dy*) between the projected image and camera's captured region. Also to extract the relative scale between the projected image and the field of view of the camera (*Rw,Rh*). This process is done at a specific projection distance (*D*).

Fig. 6 shows an illustration of the top and side views of calibration setup. The parameters (***Wp,Hp***), (***Wc,Hc***) represents the size of projection and capture for the projector and the camera respectively. An automated process is done to extract those parameters by projecting a chessboard image into a specific distance (*D*) which is set to 100 cm as representation of hands reach. The relative scale of the projected images (*Rw,Rh*) is calculated as the ratio between (***Wp,Hp***) and (***Wc,Hc***). This ratio is used as a cropping factor for the projected hands, and the displacement (*dx,dy*) is used to shift the cropping region of hands images.

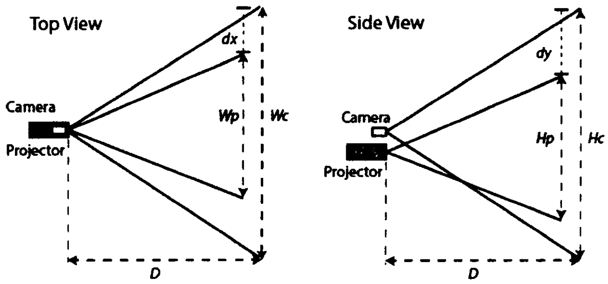

Fig. 6 Top/Side views of camera/projector FoV and projection size

This calibration gives matching results for images projected at the calibrated distance (D). However it is affected when the images are projected at different plane, resulting mismatching size and shift of hands position. To improve the results, a depth sensor is necessary to be used to calibrate the projected images. For our application, with projections within the range D ± 30cm, no significance distortion was observed, though hands ghost started to appear (As shown previously in Fig. 3).

3. Conclusion

In this paper, an image-based approach was used to provide mutual visual information of operator hands in Telexistence robots. The hands are captured from the user side using an IR camera mounted on his HMD, and then superimposed on the remote images. Those hands are also streamed to the robot side and projected using a pico projector mounted on the head of the robot. Using this method, it is possible for the participants to understand where the user is pointing at or what the user is intended to do with his hands in the remote environment.

Acknowledgments

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References

[1] Benthall, J., and Polhemus, T. "The body as a medium of expression." *Allen Lane*, 1975.

[2] Fernando, C. L., Furukawa, M., Kurogi, T., Kamuro, S., Sato, K., Minamizawa, K., and Tachi, S. "Design of telesar v for transferring bodily consciousness in telexistence." *In Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on, IEEE*, pp. 5112–5118, 2012.

[3] Ishii, H., and Kobayashi, M. "Clearboard: A seamless medium for shared drawing and conversation with eye contact." *In Proceedings of the SIGCHI conference on Human factors in computing systems, ACM*, pp.525-532, 1992.

[4] Kunz, A., Nescher, T., and Kuchler, M. "Collaboard: a novel interactive electronic whiteboard for remote collaboration with people on content." *In Cyberworlds (CW), 2010 International Conference on, IEEE*. pp. 430–437, 2010.

[5] Leithinger, D., Follmer, S., Olwal, A., and Ishii, H. "Physical telepresence: shape capture and display for embodied, computer-mediated remote collaboration." *In Proceedings of the 27th annual ACM symposium on User interface software and technology, ACM*, pp. 461–470, 2014.

[6] Saraiji, M. Y., Fernando, C. L., Mizushina, Y., Kamiyama, Y., Minamizawa, K., and Tachi, S. "Enforced telexistence: teleoperating using photorealistic virtual body and haptic feedback." *In SIGGRAPH Asia 2014 Emerging Technologies, ACM* 2014.

[7] Marchal, M., Pettré, J., & Lécuyer, A. "Joyman: A human-scale joystick for navigating in virtual worlds." *In 3D User Interfaces (3DUI), 2011 IEEE Symposium on*. pp. 19-26. 2011