

# Evaluating Stereoscopic Video with Head Tracking for Immersive Teleoperation of Mobile Telepresence Robots

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## ABSTRACT

Our research focuses on improving the effectiveness and usability of driving mobile telepresence robots by increasing the user's sense of immersion during the navigation task. To this end we developed a robot platform that allows immersive navigation using head-tracked stereoscopic video and a HMD. We present the result of an initial user study that compares System Usability Scale (SUS) ratings of a robot teleoperation task using head-tracked stereo vision with a baseline fixed video feed and the effect of a low or high placement of the camera(s). Our results show significantly higher ratings for the fixed video condition and no effect of the camera placement. Future work will focus on examining the reasons for the lower ratings of stereo video and also exploring further visual navigation interfaces.

## Categories and Subject Descriptors

H.5.2 [User Interfaces]: Interaction Styles

## Keywords

Mobile Robots, Teleoperation, Head Tracking, Stereo Video

## 1. INTRODUCTION

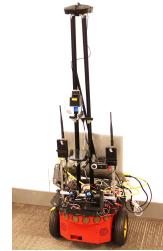
The use of mobile telepresence robots (MTRs) is currently increasing, which is reflected by an increasing amount of MTRs available on the market. Very few of the available MTR platforms incorporate autonomous navigation capabilities. Thus, the remote operator's task of manually navigating the robot through a space (e.g., to the next meeting) can be one of the major problems in the user experience of these devices. The reason for this is that usually, the UI for navigating MTRs shows one or more fixed camera views (e.g., forward and forward-down on the VGO)<sup>1</sup>. We argue that using fixed camera views may not be the most effective way of navigating MTRs as (1) the fixed viewpoint allows

<sup>1</sup><http://www.vgocom.com/>

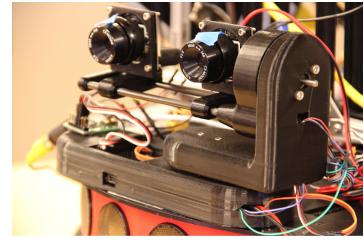
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HRI 2015 Portland, Oregon, USA

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(a) Robot Platform



(b) 2-Axis Gimbal

Figure 1: The robot platform (a) and 2-axis brushless gimbal with dual cameras (b) used in our study.

the user only a limited field of view and (2) it is difficult to effectively judge distances in the camera view, due to a lack of depth perception. The result is that the remote operator may have a reduced awareness of the position of the robot in a space, the position of obstacles relative to the robot or the best trajectory to take to navigate through a space.

To address this problem, we propose increasing the immersiveness of MTR navigation by using a head-mounted display (HMD) with head tracking. Head tracking is used to control a stabilized pan/tilt gimbal on which a pair of cameras is mounted to provide the stereo video feed. In this abstract, we present early results of a user study that we conducted using this setup. In particular, we evaluated qualitative feedback for use of stereo pan/tilt video with fixed 2D for a telepresence navigation task, and the effect of placing the camera (pair) on low or high level on the telepresence robot.

## 2. RELATED WORK

Robotic telepresence using a remote-controlled pan/tilt camera has been previously proposed by on several mobile robots, e.g., Fiala et al. [1] or Zalud et al. [5]. These, however, did not use stereo imagery. Martins et al. [2] conducted a user study of teleoperation with a robot that had a stereo camera pair which was mounted rigidly on the robot, thus the camera orientation was coupled to the robot's pose. Their usability study yielded positive results for a search-and-rescue task. Pittman et al. [3] studied immersive control of aerial robotic vehicles using an HMD As alternative to improving the user's immersion, semi-autonomous robot behavior for navigation assistance has been studied by Takayama et al. [4].

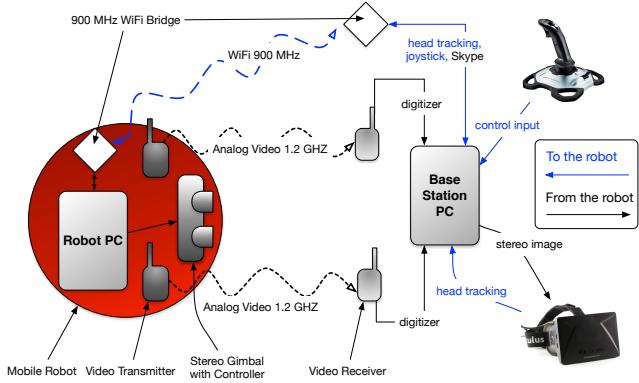


Figure 2: Hardware architecture of our telepresence robot with head-tracked stereo video feed.

### 3. ROBOT PLATFORM

We used a Pioneer 2-DX mobile robot base<sup>2</sup> with a custom superstructure (Figure 1(a)). We used ROS<sup>3</sup> to allow control of the robot’s motion via a joystick. We used an Oculus Rift V1<sup>4</sup> as the HMD, which also provided the head tracking the information for the gimbal.

The stereo camera pair is mounted on a custom-built 2-axis brushless gimbal (Figure 1(b)), using an AlexMos [] brushless gimbal controller. To capture the stereo video feed, we used two 1/3 inch CCD analog video cameras with 4 mm C-Mount lenses, providing a horizontal field of view of about 90° (close to that of an individual human eye). Video images were transmitted via 1.2 GHz analog video transmitters. At the teleoperator’s station, the video is digitized and processed for viewing on the Oculus. Figure 2 shows an overview of our robot’s system architecture.

### 4. USER STUDY

We conducted a preliminary user study to gather qualitative feedback about telepresence navigation tasks using head-tracked stereo vision vs. a standard 2D camera feed. Secondly, we were interested in user feedback about the placement of the camera pair, either at a *low* position 10 cm above floor level, or on at an a *high* position 150 cm above floor level. The reason for this is that we assumed that placing the camera at the low position could have direct advantages for robot control and obstacle avoidance, while the high position might be more suitable for a telepresence application.

**Study Design** We invited 5 participants from an industrial research lab (2 female). The participants were aged between 20 a 60 to participate in our study. The assigned task was a simulated telepresence scenario in the office space of an industrial research lab. The participants were asked to drive the telepresence robot from a starting location, to a meeting location, have a brief conversation with a colleague and then navigate the robot back to the starting location.

**Results** An ANOVA on the SUS scores with *visualization type* and *camera placement* as factors results in a significant effect for *visualization type* ( $F_{1,16} = 7.004, p = 0.0176$ ).

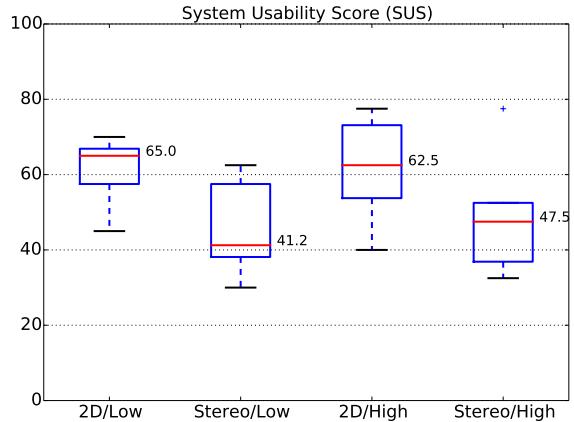


Figure 3: System Usability Scale (SUS) evaluation results for four study conditions. Our results show a significantly higher SUS score for the 2D conditions, both for the low and high camera positions.

*Camera placement*, however, did not have a statistically significant effect.

### 5. CONCLUSIONS AND FUTURE WORK

In this poster we presented a robot platform that allows navigation using a stereo HMD with head tracking. The results of an initial usability study suggest a higher SUS rating for the baseline condition consisting of a fixed 2D camera. We did not observe any significant effect for the SUS ratings of the low or high camera placements. In future work we will analyze the reasons why stereo has been rated worse, and work to improve the usability of this approach. Furthermore, intend to evaluate robot navigation tasks using a VR view that is driven through the robot’s sensors and localization system.

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<sup>2</sup><http://mobilerobots.com>

<sup>3</sup><http://www.ros.org>

<sup>4</sup><https://www.oculus.com/>