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Accessible Control of Telepresence Robots based on Eye Tracking

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ABSTRACT

Gaze may be a good alternative input modality for people with limited hand mobility. This accessible control based on eye tracking can be implemented into telepresence robots, which are widely used to promote remote social interaction and providing the feeling of presence. This extended abstract introduces a Ph.D. research project, which takes a two-phase approach towards investigating gaze-controlled telepresence robots. A system supporting gaze-controlled telepresence has been implemented. However, our current findings indicate that there were still serious challenges with regard to gaze-based driving. Potential improvements are discussed, and plans for future study are also presented.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility technologies**;

KEYWORDS

Gaze interaction, eye tracking, telepresence robots, human-robot interaction, accessibility, assistive technology

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1 INTRODUCTION

Telepresence robots have become useful communication tools for people who are physically prevented from participating in events [Neustaedter et al. 2016]. According to [World Health Organization 2011], more than 190 million individuals are suffering from severe disabilities. Efficient social communication may be extremely difficult and frustrating for some of them due to motor control difficulties. Enabling accessible control of telepresence robots may bring new possibilities and potential benefits to them. Telerobots are typically controlled with hands, but a few previous studies have also demonstrated accessible hands-free control methods based on speech [Tsui et al. 2013], brain activity [Leeb et al. 2015], and gaze [Tall et al. 2009].

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2 PROBLEM STATEMENTS AND OBJECTIVES

The goal of our project is to develop a hands-free telepresence control method, which is simple, and easy to use for people who can only move their eyes, in order to improve their social interaction and quality of communication [Zhang et al. 2019]. Gaze can be used as accessible control method of telepresence robots for people with profound motor deficits. However, it needs to be explored how this control may influence users, and how to improve it.

In the first phase of our research, studies have been conducted based on our gaze-controlled telepresence system [Hansen et al. 2018]. Observation in a pilot study [Zhang et al. 2018] suggested that users were impacted by task complexity on their performance, situation awareness (SA), and subjective experience rating, when driving a gaze-controlled telerobot with gaze control.

3 APPROACH

We then aimed to evaluate the effectiveness and the challenges of the gaze control in an experimental comparison. We hypothesized that there were differences in users' SA, presence, performance, workload, and subjective experience between a control condition with gaze and a control condition with hands, when wearing a virtual reality head-mounted display (VR HMD). A within-subjects design was used in the experiment with a total of 16 able-bodied participants. The test subjects were sitting in a remote control room. The HMD (*FOVE*) and a joystick (*Microsoft Xbox 360 Controller*) were connected with a computer with *Unity*. The computer was connected to the telerobot via a wireless network. In the driving room, a telerobot carried a 360° camera, and a microphone. The camera was 1.3 m above the floor. Five ultra-sound receivers were mounted on the wall and a transmitter placed on top of the telerobot to track its position with an accuracy of approximately 1 cm. Plastic sticks on the floor were used to mark up the maze track that covered an area of 5 x 4m. Three sheets of A4 paper with a pie-chart hung on the wall to show how far the robot had driven at that position.

Each participant used gaze and hand control to navigate through two mazes with both control methods. In total four different mazes with a layout that were of similar length and complexity was used for the experiment. The order by which participants were exposed to each maze was counterbalanced. In total, 64 trials was conducted. There were two groups of independent variables: input method (gaze control & hand control), and order of trials with the same method (Trial 1 & Trial 2). Dependent Variables included the participants' SA, presence, workload, performance, post-trial estimation and recollection, self-assessment, and experience with the control methods.

The main task was to navigate the telerobot through a maze. Half of the participants did the first two trials using gaze control, and

half of them did the first two trails using joystick control. Before each gaze trial, a gaze calibration procedure for the headset was conducted. The experimenter observed their operation via an LCD display. When the telerobot passed certain areas in the maze or when a maneuver, e.g. a turn, had been done, a query pop-up in the control display was prompted by the experimenter. When the participants had given a verbal response, their response time was recorded in the system. In the remote driving room, a person was standing at three different positions during the trials. When the telerobot passed by, this person faced the camera and talked to the participants via the telerobot, providing information related to the remote environment. Log data from *Unity* and the telerobot, participants' response to questionnaires and pop-up queries were collected. At the end of the experiment, the participants were interviewed.

4 PRELIMINARY RESULTS

Our main observation was that telepresence robots could be controlled by gaze. All the participants were able to finish the trials using gaze control. However, our results also suggested that there are still serious challenges for users of gaze control. When comparing gaze control with hand control, statistical analysis with two-way ANOVAs showed that participants had similar experience of presence and self-assessment, but gaze control was 31% slower than hand control. Gaze-controlled robots had more collisions and higher deviations from optimal paths. Moreover, with gaze control, participants reported a higher workload, a reduced feeling of dominance, and their situation awareness was significantly degraded. The accuracy of their post-trial reproduction of the maze layout and the trial duration were also significantly lower. These aspects were of great importance to human-robot interaction [Steinfeld et al. 2006].

5 PLANS FOR FUTURE WORK

Addressing the challenges, more features can be added to the system, e.g. collision avoidance and an interface map view. The interface for gaze control also needs to be improved to allow for more free examination of the environment without moving the telerobot at the same time. Most importantly, novice users need more practice with the gaze-controlled telerobots, in order to master this unfamiliar control method. Besides practices with the robots in real scenarios, training of gaze control in simulation-based environments (e.g. VR environments) might be a potential solution. VR provides totally immersive environments and is widely used in training for real task scenarios, e.g. with mining [Tichon and Burgess-Limerick 2011], for medical skill training [Izard and Méndez 2016; Reznek et al. 2002], and skill training for people with intellectual disabilities [Brown et al. 2016].

In the next phase of our plan, we aim to investigate potential impacts of gaze-control training in VR. A VR simulation environment (cf. Figure 1) has been build for practice with a virtual gaze-controlled telerobots. A between-group design with 32 participants is planned in our forthcoming study. We hypothesize that users who are tested in a real driving scenario show no difference in their performance, situation awareness and workload, between having been trained with the telerobot in a real driving task and having

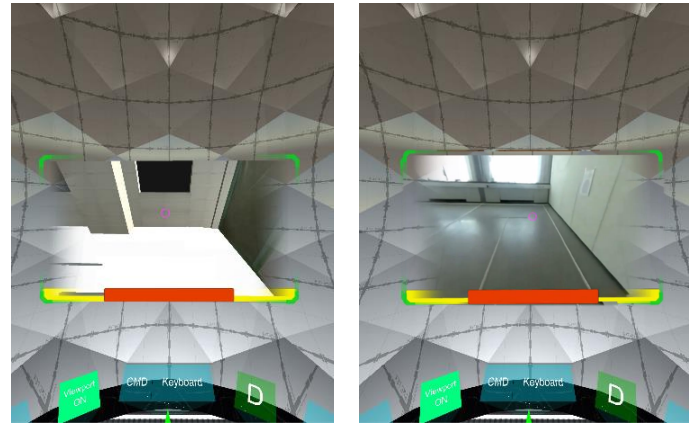


Figure 1: Control panels for teleoperation in a VR training environment (left) and in a real scenario (right). The small pink circles show the gaze course. In the driving mode, gaze movements are mapped to the virtual (left) or real (right) robot's movements. The live streams show the view of the telerobots.

been trained with a virtual telerobot in VR. There will be two groups of independent variables: training types (virtual robot in VR real robot in reality), training environments (same or different as the layout tested in). Dependent variables include the participants' SA, workload, performance, eye behaviour, post-trial estimation and recollection, self-assessment, and subjective experience with the control methods.

The test person will be seated in the lab and wearing a FOVE headset. The test person is then introduced to the devices and task: to remotely drive a gaze-controlled robot around an obstacle course, interacting with a live person, and reaching to the track goal. After this first assessment, the test person will be given training in VR or in reality for five trials. After the five training sessions, the test person is asked to do a remotely real driving of the gaze-controlled robot again. During the first and last driving task, SA queries and saccade test appear as pop-ups. When finishing the experiment, there will be an interview.

The main test is to navigate the telerobot through a maze in a lab twice. In between, each participant has will be given the same number of training trials.

There will be four training conditions, given to eight participants each: they are same layout in VR as the final test layout, a different layout in VR from the final test layout, same layout in reality, and a different layout in reality. In the driving room, a person will introduce himself to the participants and inform them on thier next task via the telerobot.

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