Enabling Real-Time Measurement of Situation Awareness in Robot Teleoperation with a Head-mounted Display

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Enabling Real-Time Measurement of Situation Awareness in Robot Teleoperation with a Head-mounted Display

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Abstract: Situation awareness plays an important role in robot teleoperation tasks, which are essential in digitalisation and automation. Head-mounted displays have unique advantages for virtual reality and augmented reality environments. We present our approach to enabling real-time measurement of situation awareness in robot teleoperation with a head-mounted display. Test results showed that it provided more reliable data for situation awareness measurement than the post-trial subjective measure.

Keywords: situation awareness, robot teleoperation, head-mounted display.

1. Introduction

Operation of a mobile robot by a person from a distance has been applied across a variety of domains. Robot teleoperation has potentials to become an essential part in digitalization and automation of future work. Situation awareness (SA) is the ability to perceive elements within a volume of space, be able to comprehend the meaning of these elements and be able to predict the status of these elements in the future (Endsley 2000). It is the perception, comprehension, and projection of information relevant to the user regarding their immediate environment, which plays an important role in teleoperation tasks. It is also a primary basis for operators' performance (Endsley 1995). The present research investigates how to enable real-time measures of SA in robot teleoperation. In a robot teleoperation project (Hansen et al. 2018), a telepresence robot can be teleoperated by a user wearing a head-mounted display (HMD). The user-interface for teleoperation is presented as Augmented Reality (AR). This interface supports multimodal control by gaze, head, and hands for a variety of use-cases, including disabled people bound to bed that can drive a telerobot with head or gaze pointing only. Existing techniques for evaluation of SA, e.g., SART (Taylor 1990), and SA-SWORD (Snow and Reising 2000), based on subjective measures, may reflect subjective preferences rather than SA itself. Post-test questionnaires only capture SA at the end of the task, where early misperceptions or temporary confusions may be forgotten.

Real-time probes with objective measures may overcome the above-mentioned problems. However, challenges still exist in the implementation of such measures for robot teleoperation with an HMD. For example, when operators do not prioritize their primary task, then the secondary task (i.e., SA queries) is known to interfere with the primary task performance (Pierce 2012). Detailed analysis of tasks and SA are required for implementing this measure in teleoperation, and task-relevant queries need to be designed based on SA theories. In the present work, we examined the use of real-time queries that we have developed for research in teleoperation.

2. Methodology

We adapted the Situation Present Assessment Method (SPAM), which was originally developed for air traffic controllers (Durso et al. 1998), to robot teleoperation. Perception-related queries focused on the participants' ability to perceive relevant elements in the environment, e.g.

orientation, voice, presence, and position of a person present in the remote environment. Comprehension-related queries were used to investigate the operator's understanding of external signs in the room, i.e., a pie chart indicating their current progress, and of oral information about their progress status. Projection-related queries examined their ability to estimate the future status based on their perception and comprehension of the current situation in the environment, i.e., estimate the time or distance to finish the task.

A total of 16 participants participated in our experiment (Zhang et al. 2019). Each participant teleoperated a robot in 2 trials with hand control and 2 trials with gaze control. An HMD was used to provide a full 360-degrees view when turning the head around. The participants' task was to drive a telerobot through a maze marked on the floor in a remote room. The progress pie-charts were displayed on the walls of the room, and a person talked to them via the telerobot. The experimenter manually prompted a SPAM query when the robot passed certain areas in the maze or when a maneuver, e.g. a turn, had been done. When the participant passed graphical progress information on the wall, a query about comprehension was given. Queries appeared as a pop-up text box in the HMD (see figure 1). All of the queries were initiated with an introductory question: “Are you ready to answer a question?” This question was only used to measure response time, and the only possible answer the operator could give was clicking “Yes”. Then the actual query appeared. Once the query was answered orally, the participant's response time was again measured and the answer was written by the experimenter. After each of the four trials, a subjective workload questionnaire (NASA-TLX), and questions about their estimation of the total distance they had driven, task time duration, and their recollection of collisions with the maze barriers, and persons in the maze. In order to compare two methods of SA measures, a subjective SA questionnaire (SART) were also included in the post-trial questionnaires.

Fig. 1 A user wearing an HMD, and teleoperating a remote telepresence robot (left). Via the HMD display, he can see a Pop-up with a query about orientation (right).

3. Research outcomes

Log data, video recordings from the room, and screen recordings captured during the experiments were analysed. The analysis included the real-time objective measure, post-trial subjective measures, and accuracy of estimation and recollection. Workload-analysis was based on responses to the subjective workload questionnaire, and the two types of response times recorded in real-time measured workload and SA, respectively.

Data from real-time objective measure (SPAM) were analysed with ANOVA and followed up pairwise comparison with a Bonferroni correction. The results showed that the control method had significant impacts on the participants’ SA. The hand control method yielded a higher level of SA than the gaze control.

Our results also supported comparative analyses of two measurement approaches (SPAM and SART). With SPAM, we found a correlation of the response times to the introductory question from SPAM with the NASA TLX responses. With ANOVA and followed up a pairwise comparison with a Bonferroni correction, we found that control method had significant impacts on the response times to the introductory question, and the NASA TLX responses. When using the hand control, the participants self-reported lower level of workload, and needed less response time to answer the introductory questions.

A correlation between the real-time objective SA measure (SPAM) and the post-trial SA measure (SART) was also found. With ANOVAs and followed up pairwise comparisons with a Bonferroni correction, we found that the control method had significant impacts on the participants' performance. The participants had a higher percentage of accuracy in post-trial recollection and estimation when using hands compared to gaze. Distance estimation was closer to the actual operation for the real-time queries relative to the post-trial distance estimations.

3. Conclusion

A real-time measurement of SA in robot teleoperation with a head-mounted display has been implemented. With a small data size in our test (n = 16), it provided more reliable data and results than the post-trial subjective SA questionnaire.

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