

User Evaluation of Visuo-Haptic Collocation System

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Abstract

In the encounter-type haptic display systems, visuo-haptic collocation is essential because a poorly collocated pair of virtual and real objects may hinder natural interaction. This poster presents user evaluation results of a visuo-haptic collocation system. By measuring performances of two tasks for pressing a button and grasping a steering wheel, the developed visuo-haptic collocation system can provide users with natural interaction experiences.

CCS Concepts

• **Human-centered computing** → *Virtual reality*; • **Software and its engineering** → *Virtual worlds training simulations*;

1. Introduction

One of the important applications of virtual reality technology is virtual training, which can provide trainees with experience of various practicing procedures by simulated environments without expensive real-world physical training systems [LK95]. Figure 1 shows the haptic augmented virtuality platform [LDOR16], in which an industrial robot can fetch a tool from a palette and takes a pose that matches the pose of the corresponding virtual tool. Precise matching two poses between the real and virtual objects can be made by the calibration method in [BBK*17]. The robot also has a one degree-of-freedom (1DOF) torque rendering device for steering sensation on the end-effector. A commercial motion tracker VIVE with HMD is used to provide fully immersive visual sensation and to track the user's head and hands while a trainee navigates and interacts with a virtual plant facility.

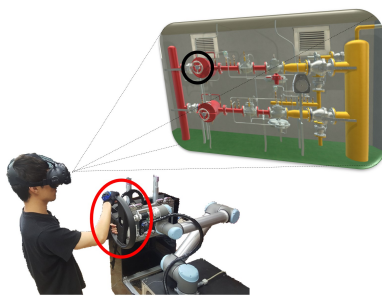


Figure 1: *Proposed haptic augmented virtuality system.*

The system in Figure 1 can provide trainees with multiple tools such as buttons, levers, and steering wheels by a robot during virtual training. Therefore, in a training scenario, a trainee tries to

reach his/her hands and to press an emergency button and/or grasp a steering wheel to stop the plant operation. In the virtual training setting like in Fig. 1, a trainee tries to press a virtual button or tries to grasp a virtual steering wheel while seeing it through a HMD. Then the robot must provide a real button or a real wheel to the pose of the virtual tool.

2. Coincidence of visual and tactile information

In virtual environments providing visual and haptic information together, collocation of visual and haptic objects (i.e. visual virtual and tangible real objects) is very important. Disagreement between two senses may seriously diminish task performance such as object targeting performance and eventually reduces significantly user immersiveness. For precise collocation of virtual and real objects, an accurate and efficient calibration method was applied to get a transformation matrix between the physical reference frame, centered on the UR10 robotic arm, and the tracking reference frame, provided by the HTC VIVE. Once calibrated, the robot can be controlled quickly to match the pose of the virtual tool with that of the corresponding real tool, resulting in the visuo-haptic collocation. The result of the calibration produced maximum 1 cm RMS position error. Following up the calibration, this paper presents user evaluation results by measuring reaction time and performance accuracy for the calibrated haptic augmented virtuality platform.

3. User evaluation

For user evaluation, two user studies are performed to examine how users' performance differs between the virtual and the real environments. In the real environment, a user interacts with a real tool with naked eyes while in the virtual environment, a user interacts with a virtual tool with a fully immersed HMD. In Experiment 1,

users performed a button press task, and in Experiment 2, they did a wheel grasp task. We had 20 male participants who were between the ages of 22 and 27 to conduct the two experiments.

3.1. Experimental Configuration

Our experimental hardware (Figure 2) included the real objects (a button and a wheel) attached to end-effector of robot, a tracker and a fully immersive HMD (HTC VIVE). Participants were asked to press a button or grasp a wheel in each experiment. The tracker attached on participants' hand tracks the location of their fingertip. The HMD provides a fully immersed visual display of the virtual world. Finally, the robot arm places the real object at a location that is collocated with the corresponding virtual object. The distance between the participants and the object is 50 cm apart to enable them to naturally behave when they interact with the object.

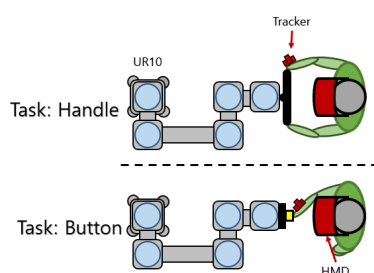


Figure 2: Examples of user evaluation tasks. left: pressing button, right: steering handle

3.2. Experimental conditions

Two factors were manipulated: the presence of HMD (with HMD vs. without HMD) and the position of participants (sit on vs. stand up). These two were within-subject factors. Each participant performed both experiments.

3.3. Experimental procedure

The experiment was composed of a training session and a measurement session for the two experiments, each of which contained 160 (20 times x 4 conditions in each experiment) individual trials for training and 40 (5 times x 4 conditions in each experiment) trials for the main experiments. The order of the experimental conditions was randomly presented to the participants.

4. Result and discussion

The data were analyzed using the lme4 package in R ([BMBW14], [Tea14]) with subjects and trials as crossed random effects. Dependent variables were analyzed using linear mixed effects (LME) models with the lmer function, and statistical significance was computed using the lmerTest package in R, which provides t values and degrees of freedom based on the Satterthwaite approximation. The categorical variables of HMD and position were included in the models as fixed effects.

In the button press task, the effect of HMD in reaction times

(RTs) were statistically significant such that slower RTs were observed when participants put on a HMD compared to when they did not put it on, $b = .3$, $SE = .06$, $t = 4.87$, $p < .0001$. However, the effect of position was not statistically significant, $b = -.009$, $SE = .03$, $t = -.25$, $p = .80$. In the handle grasp experiment, both effects were statistically significant in that RTs were slower in the HMD condition than in the non-HMD condition ($b = .07$, $SE = .02$, $t = 4.09$, $p < .001$), and that RTs were slower when participants sat down compared to when they stood up ($b = -.11$, $SE = .02$, $t = -5.22$, $p < .0001$). For the accuracy data, the effect of HMD was significant such that the position of button press was more accurate in the HMD condition than the non-HMD condition, $b = -.009$, $SE = .001$, $t = -5.92$, $p < .0001$. The effect of position was also significant such that the accuracy was higher when participants sat down and did the button press task compared to when they stood up and did the same task, $b = .37$, $SE = .004$, $t = 85.99$, $p < .0001$. A same pattern of results was observed in the handle grasp task such that HMD made participants more accurate in doing the task ($b = -.02$, $SE = .008$, $t = -2.52$, $p < .05$), and sitting down also made them more accurate ($b = .38$, $SE = .004$, $t = 87.37$, $p < .0001$). The results showed that the reaction time is somewhat delayed in the virtual environment with the fully immersed HMD because participants might attempt to conduct the tasks as accurately as possible. The increase in accuracy may be explained by the unfamiliarity of the virtual environment to some participants. In addition, comfortable sitting posture showed better performance.

5. Conclusion

This poster presented a user evaluation result for a haptic augmented virtuality system that collocates virtual and real objects. Two user studies explored effects of presence of HMD and user position. Results show that the 1 cm position error from the calibration method didn't have an unacceptably large influence on the task execution in the virtual environment. Participants who were unfamiliar with the movements in virtual reality would have had a considerable impact on the results of the evaluation. However, considering this point, the collocated system shows a sufficient level of visuo-haptic collocation in a virtual environment.

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