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# A Haptic Augmented Virtuality System for Immersive VR Plant Training

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**Abstract**

*The risk to life and property posed by lack of trained employees in industrial facilities is an issue to which a wide research base has been applied to solve. This paper presents an on-going development of a haptic augmented virtuality system using an encounter type haptic display system and the Unity3D engine to provide fully immersive VR plant safety operation training. Since there are many different types of physical tools such as levers, valves, and buttons as well as these are installed in many diverse locations and orientations in plant facilities, an encounter type haptic display system is proposed. In the proposed system, many different types of physical tools are collocated in the fully immersed environment with the corresponding visual virtual tools for providing full haptic (kinesthetic) sensation. The collocation is made by a robot that can provide physical tools in arbitrary poses. For good collocation accuracy, a new calibration method is being developed and evaluated.*

Categories and Subject Descriptors (according to ACM CCS): I.3.4 [Graphics Utilities]: Virtual device interfaces

## 1. Introduction

One of the important applications of virtual reality technology is virtual training, which provides the trainee the experience of practicing procedures inside of a simulated environment [LK95] since virtual training environments are comparably effective to real world physical training methodologies. Additionally, it has been shown that adding haptic sensation to VR increases the effectiveness of training [AKH01].

In plant facilities, there are many different types of physical tools such as levers, valves, and buttons. Moreover, these are installed in many diverse locations and orientations. Therefore, conventional worn-type [WWH03], or held-type [CJG*11] haptic presentation methods are not suitable for providing haptic feedback for these diverse tools. In order to provide haptic feedback of various tools, we propose a new haptic augmented virtual training system using the encounter-type haptic display concept [LDO*16]. Some routine and emergency operations may be trained by the immersive VE including diverse haptic sensations.

In the proposed system in Fig. 1, a trainee wears a HMD for seeing fully immersed virtual plant facilities. While he/she is trying to grasp a virtual tool (e.g. wheel), a robot fetches out a physical wheel from a pallet and sets up the wheel with the same location and orientation as the virtual tool in front of the trainee. This requires an accurate and fast collocation between the physical and virtual tools, which is the core problem in the proposed haptic augmented virtuality system. For good collocation accuracy, a new calibration method is being developed and evaluated. In the proposed system, many different types of physical tools can be collocated in the fully immersed environment with the corresponding visual virtual tools for providing full haptic (kinesthetic) sensation.

## 2. System overview

The proposed encounter-type haptic display system shown in Fig. 1 consists of an industrial robot and a one degree-of-freedom (1DOF) torque rendering device. A commercial motion tracker 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 the virtual plant facilities.

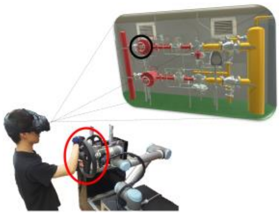

**Figure 1:** *Proposed haptic augmented virtuality system.*

### 2.1 Encountered tool display

To present various tools in many diverse poses, a robot is controlled to bring one of tools from a pallet (see Fig. 2) that houses a bunch of tools and presents it with a desired pose for haptic display. In addition, a torque rendering device is attached to the tip of the end-effector to provide various



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torque profiles to the trainee while he/she is rotating the tools. For good attachment and detachment of each tool to the torque rendering device, a connection mechanism was designed.

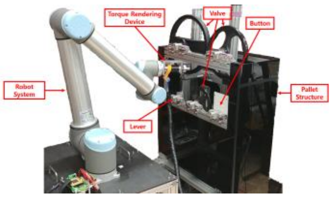


**Figure 2:** *Pallet and mounted 1 DOF torque rendering device.*

## 3. Physical/Virtual Co-location

The primary research challenge of the proposed haptic augmented virtuality system is the co-location of physical and virtual poses of a tool.

### 3.1 System Calibration

Figure 3 shows various transformations for calibration. $\boldsymbol{Tr}_{End}^{PRF}$ , $\boldsymbol{Tr}_{Local}^{VRF}$ are transformations in the robot and UNITY3D virtual worlds, respectively. Assuming known $\boldsymbol{Tr}_{Local}^{End}$ for each tool, the calibration process firstly finds $\boldsymbol{Tr}_{VRF}^{PRF}$ for co-location. Then, the pose of real tool $\boldsymbol{Tr}_{Local}^{RRF}$ can be found to provide haptic feedback for virtual tool with pose $\boldsymbol{Tr}_{Local}^{VRF}$.

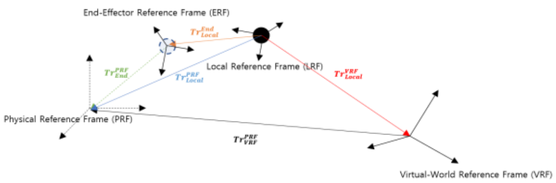


**Figure 3:** *Configuration of Encounter-type haptic system.*

### 3.2 Calibration Result

Error between the position of virtual model of vive controller that already co-located and position of virtual model rendered according to calibration result is measured. Average error is 4 *mm* and the maximum error is less than 1 *cm* for a cube of size (*30 cm* x *30 cm* x *30 cm*) evaluation space.

## 4. Training Process

For training, a trainee wears the HMD and two Vive trackers on their wrists for displaying hand avatars and receives visual instructions for a developed training scenario. Once the user is informed to begin the training procedure, the robot goes to the pallet that has many physical tools and fetch out the required tool and takes a desired pose in front of the trainee. The required virtual tool is then highlighted within the virtual environment. The user reaches out to grasp this virtual tool, and simultaneously grasps the physical tool presented by the encounter type haptic display. Upon completion of one of the manipulation tasks, typically rotating the tool to a certain position, the user is informed that the task is complete, and told to step back. Then he/she may advance to the next tool in sequence. If the physical tool must be changed, the previous tool is returned to the pallet, fetch out another tool. This repeats until all training procedure steps have been completed.

## 5. Conclusion and Future Work

In this paper, haptic augmented virtuality for industrial plant training has been proposed. This platform can provide a useful solution for virtual industrial training in terms of number of tools used, and provides various haptic display.

For future work, the effectiveness of the proposed simulator will be verified by objective and qualitative analysis in user studies.

**Acknowledgments**

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