# Augmented and Virtual Reality Research and Development

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## Summary

A virtual reality (VR) laboratory was established in Halden in 1996. Early work focussed on developing VR software applications, however since 2000 there has been a greater focus on fundamental research. Novel applications of virtual reality and, more recently, wearable augmented reality (AR) systems, have been investigated in order to provide Halden Project member organisations with recommendations and guidelines to enable decision makers to determine when and if it is appropriate to use these promising technologies. Computer hardware cost and performance is becoming less of a limitation to the application of advanced, interactive, 3D virtual environments to solving real-world challenges, so there is now increasing interest in how to apply the technology effectively.

To test new concepts, specific extensions to existing experimental methodologies have been found to be necessary to adequately assess the performance of VR and augmented reality system users. Important activities have included the development of human performance measures with a focus on sense of presences measurements, which are commonly used to assess VR applications, and measures related to simulation validity. As experiments are dependent on reliable and robust measurement techniques, a system for data logging directly from virtual environments has been developed and continues to be improved. A lightweight eye-movement tracking system for additional data collection and performance measurement has been developed which can be used to support data registration for detailed analysis and performance assessment of navigation and interaction issues. The goal of this work has been to provide adequate performance assessment tools and an infrastructure to effectively handle VR and AR experiments.

Early identification of potential human factors guideline violations and corrective input into the control room design process are important to achieve a cost-effective process. VR technology makes it possible to evaluate and refine design proposals at an early stage of the process. While this enables end-users to be more easily brought into the design process and errors to be caught early on, if virtual mock-ups are to replace physical mock-ups then the validity of using a virtual prototype needs to be demonstrated. Two experiments have been conducted to investigate the use of VR as a tool for control room verification and validation.

The first experiment compared verification tasks performed by subjects in a real control room with equivalent tasks performed in a virtual prototype of the same room. The results of this experiment were encouraging. It was found that VR offered a viable tool for performing design guideline verification tasks, but that further refinement of the 3D tools to test the model was necessary to support some specific tasks more effectively. It was also found, unsurprisingly, that features in the 3D model that were to be tested need to be detailed enough to support testing. In a follow-up experiment, a more detailed model and improved software were used, while a more realistic setting was tested, with design teams consisting of people with both human factors and operational experience. The results of this second experiment confirmed the results of the first experiment, and provided sufficient data for recommendations about the use of VR for this purpose. While VR was found to be a generally effective alternative to a physical prototype, it is recommended that it be used only for validated guideline categories (i.e. guideline categories that the technology is advanced enough to support). For example, VR is considered inappropriate for guidelines related to the comfort of seating.

As VR technology enables users to traverse artificial environments and manipulate objects in them, it is a potentially useful tool for planning the complex task of decommissioning nuclear installations, as well as preparing for maintenance activities during outages. In the Halden Project, the use of 3D graphics for visualisation of otherwise invisible radiation levels has been a topic of research and development and a visualisation tool, called the "Halden Viewer", has been developed that enables users to explore 3D models of nuclear facilities and visualise associated radiation data sets, typically dose-rate data. In addition to support for 3D navigation and radiation visualisation, the tool also provides a facility for the user to store "viewpoints" with annotations that can be distributed electronically to other users, enabling it to be utilised as a collaborative tool. Radiation can be visualised as either a flat surface or a terrain, both of which are 2D slices though a 3D volume of data, but presented in such a way that they clearly indicate where it is safest to be located in the environment in order to minimise radiation exposure. The terrain metaphor presents the radiation levels as virtual valleys and peaks. The user can thus see which areas to avoid in the near vicinity, while also being able to see peaks behind other physical objects while remaining at a familiar ground level.

To test the radiation visualisation concept in a novel and potentially very useful manner, a prototype wearable computer system has been developed that combines the radiation visualisation technique with a tracking system. The tracking system is used to align the 3D radiation terrain visualisation with the user's view of the physical environment, seen through a see-through head-mounted display, depending on the users location and head orientation. In addition to visual information, spatialised stereo haptic and auditory information can be used to give the wearer additional indications of radiation levels.

An empirical investigation has been carried out in the Halden Reactor to assess the system, with a number of experienced operators amongst the test subjects. The subjects' radiation awareness was found to be the same as that of a control group that used paper maps. However, unlike paper maps, the digital radiation information seen by the user of the system can be updated quickly and easily. The haptic and auditory information was found to have a positive effect on radiation awareness. Pre-registered radiation data was used in the experiment, but the system could potentially be fed with live data from radiation sensors, providing current information to workers, increasing safety through improved radiation awareness. The available, off-the-shelf, hardware technology was found to be too fragile for use outside the scope of a controlled experiment, however the operators who participated unanimously agreed that the technique demonstrated was effective and that they would like to have something similar available to use in the future, when more accurate and less obtrusive hardware becomes available.

Current work in the area of wearable computer systems is focussing on using wearable technology to improve communication between control centres and field operators, using a combination of augmented and virtual reality for information presentation. Based on the feedback from the experiment outlined above, it was found to be necessary to examine technologies that enable field operators to work with both hands free while using the system. Working prototype software and hardware systems for using eye movements, speech recognition, and head movements to interact with the system have been developed and integrated with the Halden Project's user interface management system, PICASSO-3, for an experiment that will be run during 2004. Additionally, an ultrasound-based position tracking system has been installed that provides more accurate position tracking. Preliminary tests of the new system are very promising.

Related work is being carried out in the area of maintenance training, where the effect on learning of different types of VR display technology, such as desktop, projection screen, and head-mounted display systems, is being compared. The results will be used to provide recommendations to assist in making informed decisions about the requirements and cost-effectiveness of VR systems for maintenance training.

Virtual models are digital documents that can easily be distributed to multiple users to support collaborative work. However, shared environments enable multiple participants to simultaneously experience and interact with a virtual environment and each other. Geographically remote experts can work together with other members of a team to simultaneously discuss design or maintenance issues. Shared training systems enable groups of workers to acquire teamwork skills while the physical environment that they are training to work in is unavailable, or impossible, to train in. Current effort in the Halden Project is focussed on determining the requirements for using shared, environments for different application areas in order to effectively apply VR and AR technology in networked multi-user environments.