VIRTUAL REALITY IN MINE TRAINING

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Abstract

The use of virtual reality (VR) technologies to train miners is an evolving area in research and development. In July 2006, representatives of 14 international organizations met to discuss current VR-related efforts and explore ways to employ VR in the future. This paper gives an overview of the various approaches presented at the meeting and discusses directions for future implementation. An example of a training package that teaches mine map-reading skills is presented. The meeting was the first step to building collaborations for furthering VR applications for mining. Planning has begun for a 2008 meeting open to broader participation.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Introduction

Sixty-five miners died in the United States from January through October 2006. This is more than the total for any of the past three years. Complicating the industries efforts to reduce this number are the new miners rapidly entering the workforce as baby-boomer miners retire. Protecting the new *and* veteran miners requires fresh training approaches.

Rapidly changing technologies are allowing the evolution of mine safety and health training methods and materials. Miners around the world are encountering sophisticated computer programs during routine training sessions. In classes that some miners have called "safety jail", a new generation of miners becomes active participants in virtual reality simulations that bring the mine worksite to them.[1] This allows them to gain knowledge and skills in a safe and controlled environment. In the summer of 2006, representatives from organizations currently conducting VR-related research and development met and discussed those efforts.

The National Institute for Occupational Safety and Health (NIOSH) hosted the Virtual Reality in Mine Training workshop in Pittsburgh, Pennsylvania. The gathering included representatives of 14 organizations from 6 countries. (Table 1) The participants shared their work with the group on the first day of the meeting. The second day was devoted to discussions regarding areas where interests, efforts, and plans intersected and overlapped. Over the two days, the workshop attendees built a foundation for future information sharing and collaboration.

Virtual Reality Workshop Presentations

A representative from each participating organization gave a brief overview of their VR projects. Some highlights of the presentations are provided below not to summarize them, but to give an idea of the breadth of work being done around the world in this area of research and development.

CSIRO - VR in Mine Automation, presented by Con Caris

CSIRO has developed techniques for integrating complex, geo-spatial scientific data sets into web-accessible 3D models. This allowed previously dispersed data to be accessed throughout an organization so personnel can evaluate complex spatial data in a common environment and provided an interactive training tool for mine operations. It is now finding ways to provide data in real-time from an underground longwall system (Figure 1). One result will be a better description of the status of the mining process as it proceeds. Another is a training system that enhances the operator's understanding of his or her role in the longwall mining process.

Table 1. Organizations represented at the 2006 Virtual Reality in Mine Training Workshop and their main interests

Country	Organization	Areas*
Australia	CSIRO (Australian Commonwealth Scientific and Research Organization)	3,2,4
	University of New South Wales	2,3
	University of Queensland	1,2,3
	Western Australia Department of Industry and Resources	1,3
Germany	Deutsche Montan Technologie GmbH	2,3,4
	Deutsche Steinkohle	2,3,4
South Africa	University of Pretoria	2,3
Spain	AITEMIN (Association for Research and Industrial Development of Natural Resources)	4,2,3
United Kingdom	University of Nottingham	1,2,34
United States	National Institute for Occupational Safety and Health	2,1,3
	The Pennsylvania State University	1,2
	University of Missouri-Rolla	2,4
	Virginia Polytechnic Institute	2,3,1
	West Virginia University	N/A

*1-accident investigation, 2-mine worker and/or student training, 3-data visualization, 4-equipment simulation

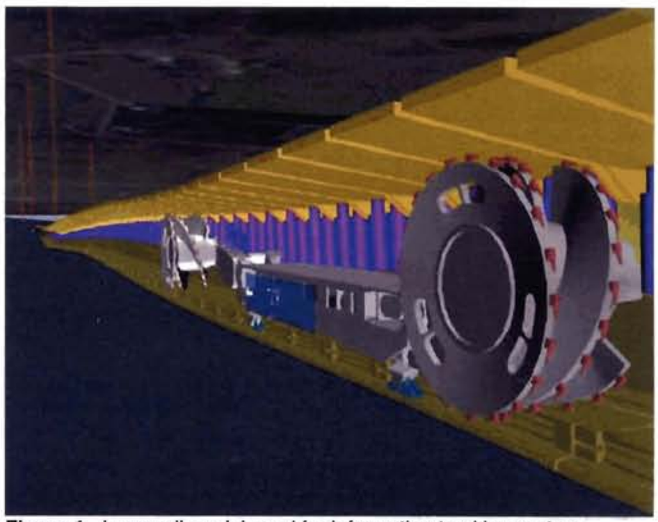

Figure 1. Longwall model used for information tracking system

University of New South Wales - Developing and Deploying Simulations, presented by Phillip Stothard

Three large-screen projection units create an underground coal mine in the UNSW's system. Their program is scenario-based and requires trainees to answer various safety-related questions as they "move" through the mine and thereby the story. Trainers interact with the trainees to clarify points, lead discussions, and answer questions, and can manipulate the progress of the training program.

University of Queensland - VR Research at MISHC (MINERALS INDUSTRY SAFETY AND HEALTH CENTRE), presented by Mehmet Kizil

Researchers and faculty at MISHC have created VR applications to address a number of mining industry issues such as safety training, mining engineering education, accident reconstruction, data visualisation, mine planning, and environmental hazard assessment. One of their simulations is used to teach drill rig operation (Figure 2). They also use VR to provide a holistic approach to learning in their engineering program. Assignment data, such as spreadsheets, photographs, schematics and textual descriptions, which were previously distributed via printed course materials, are now presented in the realistic context of a VR mine.

Figure 2. Left - simulated drill rig, Right - actual drill rig

Western Australia Department of Industry and Resources - The Use of Digital Photographs & Photogrammetry to Produce a Virtual Environment for the Use of Accident and Incident Investigation as well as Training Scenarios, presented by Ken Fowle

The WA Dept. of Industry and Resources uses 3D interactive virtual environments and digital photogrammetry to create tools for accident and incident investigations. Better understanding and presentation of past events can be used to prevent future ones. It is also supporting mining applications ranging from the analysis of rock mass structure to the monitoring of the mine environment using 3D imaging tools and 3D data analysis techniques.

Deutsche Montan Technologie GmbH and Deutsche Steinkohle - Knowledge-Based Maintenance and Training Systems for the Mining Industry, presented by Christian Medrow

Researchers at DMT and Deutsche Steinkohle believe virtual reality will assist the mining industry as it faces increasingly complex operating processes, rising equipment costs, increasing mechanization, and pressures to increase productivity while maintaining high safety standards.

They have developed VR longwall shield supports, a plough guide, and a tailgate drive for training purposes (Figure 3). They also see great opportunity for miners to use new technologies while doing maintenance tasks. They have created a program for a hand-held device to store information miners can use on the job (Figure 4). For example, maintenance workers can access machine information while doing their jobs and training for them.

AITEMIN - Virtual Reality as a Training Tool for Mine Machine Operators, presented by Carlos Catalina

One project objective at AITEMIN is to develop simulators that can be used to train mining machine operators. AITEMIN has created a VR simulator of a roadheader that provides realistic visual, sound and physical sensations (Figures 5 and 6). Along with the usual mock-up of the equipment and a computer-generated environment, a motion platform simulates the incline and feel of the machine. Plans are to build a simulator of a drilling rig next.

Figure 3. VR simulation of a tailgate drive

Figure 4. Repair assistance on PDA

University of Nottingham - Seeing is Believing: A Vision for New Media in Academic and Industrial Sectors, presented by Damian Schofield

Dr. Schofield has conducted research on the effects that viewing and interacting with VR environments have on the viewer. This issue will become increasingly important as realism of computer-generated accident recreations improves. Allowing a trainee to experience a "real" accident might be a valuable teaching tool (Figure 7). Reconstructions can be used not only in training, but also in prevention as the virtual accident is reviewed and the virtual environment modified to assess potential prevention strategies.

University of Missouri-Rolla - Virtual Reality Training of Jack-Leg Roof Bolters, presented by Michael G. Hilger

In Missouri, chroma key technology allows the creation of an augmented reality context for training underground mining roof bolters. A trainee uses a head-mounted display to see the virtual environment while learning to operate a jackleg drill. A small camera mounted on the trainee's hardhat provides input so the visual field matches the trainee's head movement. Researchers will test this technology with scenario-based training modules.

Virginia Polytechnic Institute - VE Initiatives at Virginia Tech: Immersive Virtual Environments for Mining and Engineering Applications, presented by Doug Bowman

Investigators at VPI are focusing on ways to reduce injuries and fatalities resulting from powered-haulage equipment in metal and non-metal mines. They have begun work on training applications for conveyor belts and haul trucks. Both cover hazard recognition and potential consequences of missing hazards during inspections and operation.

Figure 5. AITEMIN roadheader simulation - operator's compartment mockup with motion platform

Figure 6. AITEMIN roadheader simulation – operator's view in exercise

VPI has also developed AMADEUS (Adaptive and real-time geologic Mapping, Analysis, and DEsign of Underground Space) that provides 3D visualization (Figure 8) of information for digital imaging and image analysis, tomographic imaging, modeling and analysis of rock masses, and the design of tunnels and other underground spaces.

NIOSH Pittsburgh and Spokane Research Laboratories - Creating Games for Serious Safety and Health Training, presented by Timothy Orr

Researchers at NIOSH are exploring how the mining industry can effectively use "serious games" for mine training. They have used a game engine to create a portion of an underground coal mine. In this virtual mine, trainees have a first person vantage point as they walk or ride through the mine. The first training package in this virtual mine instructs new miners in how to read mine maps.

Figure 7. Scene from an accident recreation

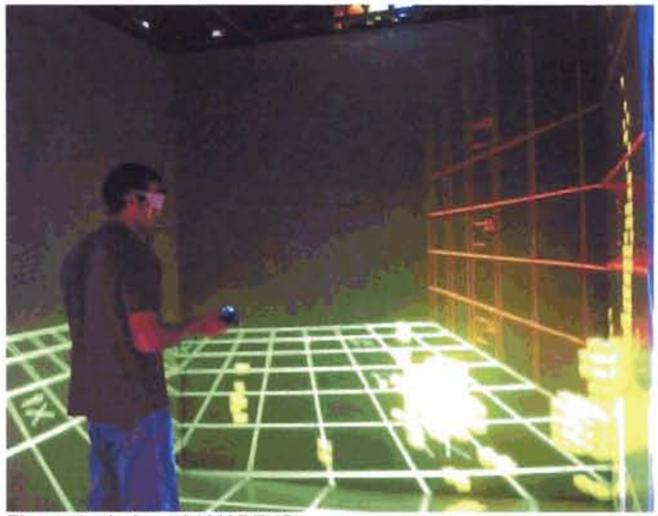

Figure 8. A view of AMADEUS

The Mine Navigation Challenge allows trainees to move freely in six entries and approximately 35 crosscuts of the virtual mine environment (Figure 9). They start the training by boarding the mantrip where the operator gives them their work assignment. The operator tells them to pick up tools and take them to the supervisor who is working at a certain location. They must use their map to plot their course and then virtually walk to the supervisor's location. To be successful, they must know where they can go (such as through a mandoor) and where they cannot (such as under the belt). When they have found the supervisor, he will give further instructions for the next task (Figure 10).

The research team reported that while the program is still under development, trainers and trainees were very positive about it during initial field tests. The project was designed to use this training scenario, once complete, in studies of effective deployment of this technology.

Workshop Summary

Participants came from all over the world, but their common interests were readily apparent. The shared languages of mining and of the virtual reality technology allowed them to learn from each other and to see how their knowledge and skill sets complement each other. As a group, the participants were addressing issues in the contexts of a wide range of mine settings. They were studying underground and surface operations and a variety of mining methods and processes.

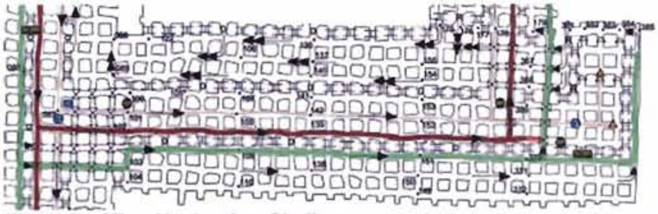

Figure 9. Mine Navigation Challenge map

Figure 10. Mine Navigation Challenge virtual miner

Some organizations were working exclusively in the mining industry. Even in those cases, programs were addressing the needs of a heterogeneous audience. They focused on miners, managers, engineers, and/or students who differed in terms of age, gender, ethnicity, experience levels, and language. Workshop participants found targeting their work to the appropriate segment of the industry to be a common project requirement. They also found that most of them were addressing similar issues, such as meeting the needs of miners from different generations.

Defining the audience was particularly an issue when discussing how they will interact with the computer. Generally, younger individuals have more experience and comfort with technology. As this becomes increasingly the case, computer interfaces need less explanation. At this point, however, participants were struggling with how best to present the programs in ways the audience can effectively interact with the programs. The choices ranged from computer keyboards with mice to full-scale mockups of equipment controls. Some participants were exploring newer interfaces, such as heads-up displays and interfaces with haptic (or touch) feedback. Many participants explained research in this area as important components of their projects.

A related concern was how to deploy the programs. Some programs were designed for desktop or laptop PCs. Others require special facilities for simulators or expensive projection equipment. Participants discussed and demonstrated efforts to bring VR to PDAs and mobile phone screens. The group agreed that technologies will continue to advance and offer new ways to provide VR. Participants also recognized that in the training area, deployment is tied to the role of the live instructor. Current mine safety and health instructors will have varying levels of interest in, understanding of, and facility with new technologies. Participants reported plans to continue exploring how instructors, live or virtual, can and should be included in VR-based training sessions.

Participants acknowledged that some interface and deployment decisions would correspond to the task done by the VR program. Presentations showed VR products for accident reconstruction and investigation, equipment simulations, scenario-based training simulations, simulators that show processes, and visual display of various kinds of data. In some cases, VR projects were attempting to make the mine environment or equipment available in the classroom or control room. In others, the technology was carrying information, training, or record keeping to the work-site.

All of the workshop participants reported evaluation activities were ongoing or planned. Researchers have assessed the technologies they are using, the content conveyed by that technology, and the success of product users. A limited amount of evaluation data was available, but the group was encouraged by the results of the initial studies.

In Summary

Virtual reality offers great promise to the mining industry. The workshop held in the summer of 2006 showed that researchers in universities and other research organizations are seeking ways to help the industry capitalize on its potential. Workshop participants projected that miners, managers, engineers, trainers, and students will encounter VR in many tasks, such as those below, in the future.

- sharing mining operations data
- visualising unseen buried ore bodies or gas seams
- demonstrating mine plans to employees or surrounding communities
- training on simulators instead of high-cost equipment
- assessing trainees' performances in virtual mines
- practicing high-risk tasks
- reconstructing accidents for analysis and prevention
- observing production progress from the surface in real-time
- training on-demand and at the work-site
- record keeping
- recruiting potential employees

Participants at the Virtual Reality in Mine Training Workshop plan to continue their research in this area and improve their efforts through collaboration. They will communicate and plan ways to assist each other with common tasks and reduce duplication of effort. The workshop was the first step. The group appointed a leadership committee to define the group and work out the logistics for future interactions. This may include student and staff exchanges, sharing of other resources, and jointly funded projects. A group website serves as an easily accessible venue for communication. Group members have been sharing what they learned during the workshop through presentations and papers in their home countries. They also plan to hold a meeting open to anyone with an interest in this topic. Initial plans are for this gathering to take place in Australia in 2008.

References

1. Cullen, ET; Camm, TW; Jenkins, FM; and Mallett, LG, (2006) Getting to zero: the human side of mining, NIOSH Information Circular 9484, page 14.