

ABSTRACT

The Minerals Council of Australia's member companies are striving for a vision of "an Australian minerals industry free of fatalities, injuries and diseases" (MCA, 2000). However, accidents still happen in mining industry with high frequency and severity. Improvement in safety is the number one priority challenge for the national minerals industry. Safety awareness and training by accident reconstruction using advanced computer graphics and 3D visualisation techniques are essential steps towards improving the safety performance of the minerals industry in Australia. Virtual Reality (VR) simulations are excellent tools for training, education, simulation of abnormal and dangerous conditions and solving complex problems. Although the concept of virtual reality has been known for decades, the widespread use of VR is only in the last few years. This paper describes the VR applications in the minerals industry. It also examines the applications of this evolving technology in the areas of education and training, reconstructions, simulation applications, risk analysis, hazard awareness applications and training.

The Advanced Computer Graphics and Virtual Reality in the Minerals Industry Research Unit (MineVR) at the University of Queensland, has recently been involved in developing VR applications for the minerals industry in conjunction with the various research centres. This paper describes the benefits of using advanced computer graphics and VR techniques in the minerals industry. It also examines the applications of this evolving technology in the areas of education and training, reconstructions, simulation applications, risk analysis, hazard awareness applications and training.

INTRODUCTION

The Virtual Reality (VR) expression reminds many people images of strange space-garbed computer nerds navigating through the oceans and jungles of dangerous electronic worlds. VR is not science fiction. It is a practical and revolutionary tool, an emerging technology that allows users to interact with computers in a whole new way. VR is no longer being used to merely play the latest computer games. VR is a continuously evolving new computer technology, which provides great opportunities for education and training. VR is used in many areas, such as flight simulators, and interact with computers and extremely complex data (Aukstauskas and Blarner, 1992). VR systems are real-time computer simulations of the real world in which visual realism, object behaviour and user interaction are essential elements (Denby and Schofield, 1999; Filigenzi et al, 2000 and Schofield et al, 1994).

Virtual Reality is also a simulator, but instead of looking at a flat screen and operating a joystick, the person who experiences VR is surrounded by a three-dimensional computer generated representation, and is able to move around in the virtual world and see it from different angles, to reach into it, grab it and reshape it.

As the power of VR increases so too do its applications. VR has already been shown to be an effective in many industries. Surgeons may use VR to plan and run out complex surgeries in three dimensions, which allows the surgeon to view past the skin of the patient before a knife is even picked up. Real estate agents may use virtual reality to give clients a walkthrough of an estate, from the comfort of their own home. The minerals industry has been slow to use the new technology (Kizil et al, 2001).

Virtual Reality (VR) provides the best tools for accident reconstruction, training and hazard identification by immersing the trainee in an environment as close to real world as possible. The use of high quality three-dimensional graphics, sound and dynamic simulation combine to form a uniquely engaging experience through safety, visualisation and education. VR provides many improvements for the minerals industry.

What Can Virtual Reality Do for Safety?



THE BENEFITS OF USING VR

Inadequate or insufficient training is often blamed for most of mining fatalities. It is envisaged that the use of VR based training will reduce these injuries and fatality numbers. Justifying the use of VR in the minerals industry to improve safety is difficult to sell without hard evidence and quantified numbers. It is obvious that a considerable proportion of operating cost results from operators or maintenance errors. Individuals or companies can estimate the cost of each unplanned shutdown or near miss by quantifying the effects of:

- Lost time injuries or deaths;
- Lost production (tonnes per day, selling price per tonne and number of lost days);
- Damaged equipment (cost to repair plus down time);
- Wastage of resources by:
- Regulatory compliance costs (paperwork, reporting, fines, public relations); and
- Contractual costs due to missed delivery deadlines.

When considering all these costs, the money invested in a VR model to train mine workers will be recovered in a very short time period with a bonus of improved safety record to the company. In Australian longwall mines alone, it is estimated \$600M is currently lost each year through unforeseen geotechnical problems for which even a 10% saving will save \$60M per annum (LeBlanc et al, 2000). VR technology has a role to play in cost reduction in this area through improved planning and communications, and this is only one facet of the industry.

The loss of revenue from a bored pillar unit not being available for production is estimated to be between \$40,000 and \$90,000 per day (Galvin, 1996). Losses in revenue per day due to stoppage of the longwall face can be as high as \$1 million per day, depending on the age and capacity of a longwall mine and its longwall equipment.

VR multimedia training can dramatically reduce the cost of delivering training by decreasing learning time for trainees and instructors, the need for expensive and dedicated training equipment (physical mock-ups, labs, or extra equipment for training purposes), and travel expenses. The benefits of using VR for training are illustrated in Figure 1.

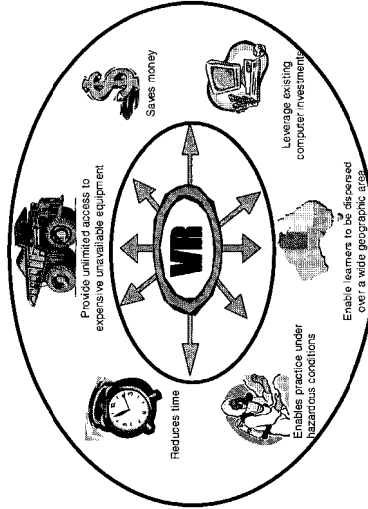


Figure 1. The benefits of using VR for training

The difference between the conventional and VR training is that VR immerses trainees in a realistic, interactive, and dynamic environment and they demonstrate mastery of skills through performance of tasks in multiple scenarios.

Research Triangle Institute stated that maintenance mechanics in remote field locations who require training on expensive equipment which is unavailable for trainee practice had showed a 4-to-1 factor improvement (RTI 2007). This translates into tremendous savings in labour and travel expenses. RTI claims that the duration of training can be reduced to 6% of that required for conventional classroom and laboratory (Figure 2).

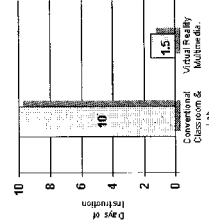


Figure 2. Virtual Reality training reduces learning time

APPLICATIONS OF VIRTUAL REALITY IN THE MINERALS INDUSTRY

A number of highly successful VR applications have been developed in the minerals industry for data visualisation, accident reconstructions, simulation applications, risk analysis, hazard awareness applications and training (training of drivers, and operators).

As virtual environments are supposed to simulate the real world, by constructing them one must have knowledge how to fool the user's senses. The user must be given a good feeling of being immersed in a feasible way. Figure 3 clearly shows that human vision provides the most of information passed to our brain and captures most of our attention. Therefore the stimulation of the visual system plays a principal role in fooling the senses and has become the focus of research. The second most important sense is hearing, which is also quite important. However, taste and smell does not play a significant role, except for some identification tasks when it becomes really essential. Smell and taste are not yet considered in most VR systems, because of their marginal role and difficulty in implementation (Mazuryk and Genvautz 2001).

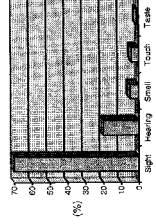


Figure 3. Contribution of each of the five human senses

Data Visualisation

Computer Graphics technology can be used to generate virtual environments of proposed developments. The interactive nature of virtual environments make it a natural extension to the 3D graphics that enable engineers, architects, and designers to visualise real life situations. They actually build them. For example, a computer generated virtual mine can be enhanced with 3D visualisation techniques to help design engineers to navigate around the mine to evaluate the design parameters and apply the necessary modifications before finalising the design. VR allows users the freedom to roam around the simulated environment and interact with the components with it. The same model can also be used for environmental and visual impact assessments. Figure 4 shows an example of an open pit mine, designed in Datamine mine planning software and graphically enhanced in a VR toolkit program for more realistic visualisation and simulation.

A significant savings in resources can be realised by testing out virtual reality models prior to physical construction. The use of such virtual prototypes to augment (and significantly save) the application of VR to preventing costly mistakes has been proceeding slowly. This relatively slow pace does not appear to be due to limitations in VR itself; rather, it is related to finding efficient ways to merge VR technologies with current mining activities.



Figure 4. Open pit and underground sections of a graphically enhanced mine designed in Datamine

#### Accident Reconstructions

Mining by nature is a hazardous occupation. Accidents still happen with great frequency and severity. Improvement in safety is the number one challenge for the national minerals industry. Fatalities may result from equipment failure or human error. Accident investigators are often able to pinpoint the exact cause of the accident. However, the results of the accident investigations are published in a text format and are often difficult to absorb. As a result, mining personnel may not learn exactly which hazardous situation led to the on guard against. Only with successful education and effective training can miners recognise possible hazards, assess the risks and learn to implement the necessary procedures to control them.

Investigating an accident by reconstructing it using advanced computer graphics techniques is an essential step towards improving the safety performance of the minerals industry in Australia. This way people can then understand:

- Why it happened;
- How it could have been prevented; and
- How injuries or fatalities could have been avoided.

The MineVR research unit has recently completed reconstructing a mining accident but as the case is still in the court it cannot be published. AIMS research unit at the University of Nottingham has developed a number of accident simulations which have successfully been used to educate people in preventing similar accidents. The first of the two accidents shown in Figure 5 is a simulated underground mine accident which resulted in two fatalities, while the second one shows a road construction accident with one fatality.



Figure 5. Two examples of accident reconstruction developed by AIMS

#### Simulation Applications

VR is increasingly being used to simulate mining operations as it provides more realistic visualisation. The AIMS research unit has recently completed reconstructing a mining accident but as the case is still in the court it cannot be published. AIMS research unit at the University of Nottingham has developed a number of accident simulations which have successfully been used to educate people in preventing similar accidents. The first of the two accidents shown in Figure 5 is a simulated underground mine accident which resulted in two fatalities, while the second one shows a road construction accident with one fatality.



Figure 6. AIMS's open pit truck simulation VR model

- The virtual reality truck driving system includes:
- Realistic truck behaviour based on impulse and retarder curves;
  - Loading, unloading and dumping operation simulation;
  - Customisable site layouts which can be imported from mining CAD models;
  - Introduction of hazards into the simulation;
  - Realistic logging and lighting effects;
  - The ability to handle multiple exit junctions on the haul roads.

#### Risk Analysis

An example of where this can be successfully applied is infrequent process planning. The operation of a longwall face salvage has simulated and assessed by the AIMS Research Unit, which has recently undertaken research work funded by SIMIRAC (Safety in Mines Advisory Council) in two projects applying VR techniques to improve Free Steering Vehicle (FSV) safety (Schofield 1997). The first project investigated the ergonomic problems associated with FSVs, the second is to develop an FSV training simulator.

The application generates viewcubes which indicate, per frame of animation, the height that the driver of the vehicle can see above. Thus, in the image the driver can only see only about half of the mineworker.

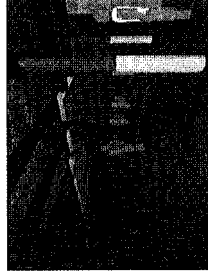


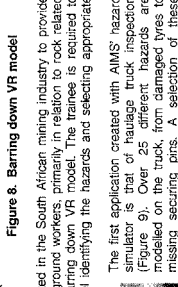
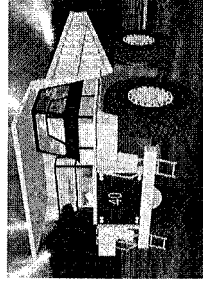
Figure 7. FSV training simulator

#### Hazard Awareness Applications

Mining production personnel frequently and unnecessarily expose themselves to hazardous situations. Research is being undertaken into the possibility of enhancing traditional training methods using computer based virtual reality systems. Hazard walkthroughs are being created in a variety of work place environments:

- Real workplaces can be created - making training more relevant;
- A variety of potentially hazardous situations can be created;
- Hazards as the trainee navigates through the virtual workplaces;
- In testing mode the trainee must carry out an inspection of the workplace, identifying hazards and assessing risk;
- Computerised logging of the inspection allows assessment;
- Hazard assessment can be considered as the first step in a quantitative risk assessment procedure.

Virtual reality technology is also being investigated in the South African mining industry to provide improved hazard identification training for underground workers, primarily in relation to rock related hazards (Schofield 1997). Figure 8 shows a barring down VR model. The trainee is required to successfully negotiate his way around the model identifying the hazards and selecting appropriate corrective actions.



#### Training

Virtual Reality has the capacity to make in depth training exercises available to all employees of a company at any time. Training will no longer be restricted to a limited number of time when operators have to stand with their feet on the ground. They now be trained up on a computer to the job training, however, the use of a VR system alongside real life training can greatly increase the effectiveness and safety during training while reducing the costs. The main advantage in using virtual reality is that mistakes can be made during training without damaging any equipment.

- Virtual Reality provides the best training by immersing trainees in situations that are as close as possible to the real world.
- The use of high quality 3D graphics, sound and dynamic simulation combine to form a highly engaging experience.
- Trainees can learn to recognise and state the most appropriate solution (Williams et al, 1998).

Figure 9. Truck inspection model

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educational tools to prevent any recurrences. These two techniques can provide good safety practices as well as boost production.

There are increasing demands today for ways and means to teach and train individuals without actually subjecting the individuals to the hazards of particular situations. VR is an emerging computer technology which has strong potential to overcome a number of limitations of conventional training methods. VR simulation models can be used to train mine workers in a number of areas including driving simulations, operating equipment and identifying hazards in various situations (Kizil and Joy 2000).

There are many benefits to using VR simulations in training situations, with respect to the CMTE drill rig, developed by the MineVR research group, these are mostly to do with saving time and operating costs for the equipment. A less obvious benefit is that the training can be undertaken at any time, in any place, and by any number of operators. Familiarisation with the operation of the equipment and visualisation of how it drills into a rock is now possible (Figure 10).

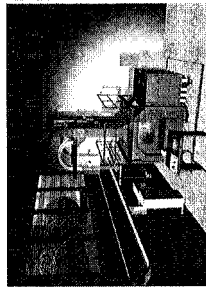


Figure 10. Virtual drill rig developed by MineVR for CMTE

Thus, when the time comes for a user to use the equipment in real life, he/she will already be familiar with its operational principles, which will save time and money. Proficiency in using expensive equipment may be gained before actually using it so that the equipment is used more efficiently (i.e. much less down-time for training purposes). Also, by training operators on a computer, all operators will be taught the same information. The only way information can be left out of the training process is if it is not included in the simulation.



Figure 11. Waste site inspection VR simulation

The MineVR research group is currently developing a virtual reality simulation of a waste site and its gas production facilities to conduct field investigations more efficiently and effectively. On completion the model will be used for hazard recognition, visual and environmental impact assessments (Figure 11). This software application will simulate a range of hazards and non-compliances on the landfill site. The trainee will be assessed in his/her ability to find, identify and categorise these non-compliances.

A prototype VR model has been developed by CSIR in South Africa to increase mine workers' ability to identify hazardous ground conditions and reduce occurrences of rock fall related accidents (Figure 12). In the model being

developed. Trainers are required to successfully complete the tasks assigned, the model identifying the hazards and selecting appropriate corrective action (Squech 2001).

The researchers at the National Institute for Occupational Safety and Health (NIOSH) in the U.S. have been developing a number of VR applications to train surface and underground mine workers and rescue personnel in hazard recognition and evacuation routes. OUMAC II (underground mine rescue) VR systems have been developed complete with vehicles, equipments and various hazards (Figure 13).

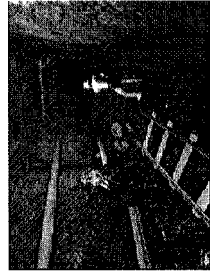


Figure 13. Scene from virtual mine training program

environment gives the trainer total control over the VR environment. The VR environment can be readily modified, either to provide new challenges through adjusting levels of difficulty or to provide training prompts to facilitate learning. It gives an opportunity to pause training for discussion or other means of instruction, and enables the recording of a full history of the trainee's performance.

Virtual environments are being used not only to produce a realistic simulation for training purposes, but also in the actual operation of the equipment itself. Although robotic arms have long been used in combination with remote cameras and other instruments to allow users to operate from a distant location (teleoperation), with recent advances in position and force sensing gloves and other interface technologies, VR is seen as offering a more natural and intuitive form of instruction.

#### CONCLUSIONS

Rheingold (1991) claims that the citizens of the twenty-second century might find it hard to understand how the human race ever managed to make do without the assistance of VR systems, just as the usefulness of antibiotics, modern plumbing, electrical refrigerators and literacy are taken for granted today. Better medicines, new thinking tools, more intelligent robots, safer buildings, improved communications systems, man-viciously effective educational media and unprecedented wealth could result from intelligent applications of VR. A number of social effects, less pleasant to entertain-twentieth-century sensibilities, might also result from the same technologies.

VR represents a unique historical opportunity. We now understand something about the way telephones, television and computers expanded far beyond the expectations of their inventors and changed the way humans live. We can begin to see how better decisions might have been made twenty and fifty years ago, knowing what we know now about the social impact of new technologies.



Figure 12. Rock fall VR simulation

Using the game graphic engine, the user navigates the mine identifying and avoiding the hazards (Filigenzi et al., 2000).

The most common work-related applications of virtual reality are those that utilize its immersive and interactive capabilities for training purposes. Training VR is currently used to train operators of various kinds of equipment, where initial training in a virtual environment can avoid the expense, danger, and problems of monitoring and control associated with training in the real life situation. For example, VR can be used to train individuals to perform tasks in dangerous situations and hostile environments, such as in an underground mine accident or toxic gas environment. In addition to the assurance of safety, the user can receive instant feedback on their performance. The virtual environment can be readily modified, either to provide new challenges through adjusting levels of difficulty or to provide training prompts to facilitate learning. It gives an opportunity to pause training for discussion or other means of instruction, and enables the recording of a full history of the trainee's performance.

Virtual environments are being used not only to produce a realistic simulation for training purposes, but also in the actual operation of the equipment itself. Although robotic arms have long been used in combination with remote cameras and other instruments to allow users to operate from a distant location (teleoperation), with recent advances in position and force sensing gloves and other interface technologies, VR is seen as offering a more natural and intuitive form of instruction.

The ten to twenty years we still have wait before the full impact of virtual reality technology begins to hit affords a chance to apply foresight-our only tool for getting a grip on runaway technologies.

According to Rheingold (1991), the genie is out of the bottle, and there is no way to reverse the magic of VR research but there are young jinn and still partially trainable. We cannot stop VR, even if that is what we discover is the best thing to do. But we might be able to guide it, if we start thinking about it now.

The use of VR simulations in the minerals industry will become more prevalent in upcoming years, the hardware required to run a virtual reality system is now available even to home users at an affordable price. Simulations can be made for any situation and often modified if needed for a similar situation. VR is an effective tool for use in training situations.

Virtual Reality offers limitless possibilities in training, simulation and education. Although the minerals industry has been slow to embrace virtual reality technology, the number of VR applications in the mining industry is increasing. VR has a great potential to increase productivity, better utilize time and most importantly improve safety awareness and therefore reduce incidents. VR technology looks promising in improving the mining industry's safety record and saving lives.

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