

Application of Virtual Reality Technology to Mine Management

R Mark¹ and C Mallett¹

ABSTRACT

Coal mines are dynamic systems that change continually in size, shape, and condition. Large quantities of data about production, coal quality, ground stability, ventilation monitoring, equipment performance and location, vehicle and personnel movements and geology, are generated from all parts of the mine.

Internet technology and virtual reality technology are now being combined to provide an intuitive, multi-dimensional information system which can simultaneously display any information that can be collected and stored by a computer. Physical information is directly displayed as 3-dimensional objects in the mine model. Numerical and text information is dynamically linked to these objects and accessed by "clicking" on them.

All of the data can be integrated in real time into one information system with a 3-D graphical interface and user friendly controls. This interface will facilitate easy access to and integration of everything from real-time gas monitoring data and vehicle location to exploration drill cores, all within one application. Operators will use one simple intuitive interface which will manage information from the myriad of computer packages with different data structures, interfaces, languages and operating systems.

INTRODUCTION

This paper is about the future, the near future. Coal mining has become a very competitive business. International market forces continue to push the price of coal down while many of the costs of doing business continue to rise.

Community expectations of environmental and safety performance has changed the role of the mine management to include more than just maximising production while minimising cost. "Due diligence" is the catch cry of the nineties, requiring that mine managers weigh up all relevant information and make the "diligent" decision.

Improving technology including automation, instrumentation and advance geophysical techniques all combine to provide an overwhelming quantity of data. Increased expectations from the community and increased pressure from shareholders to keep the mine profitable in a tough economic climate require that good decisions be made quickly and with high degrees of confidence. Currently, it is difficult for mine operators to access all of the data necessary to make good decisions.

It has not been possible to collect and communicate the volume of information pertinent to controlling safety and productivity in a coal mine, but new systems are now available.

Virtual reality technology has been combined with the flexibility of internet communications by CSIRO Exploration and Mining to create a new method for integrating and communicating mine information. CSIRO has not developed the virtual reality software but has developed mine applications using freely available software. CSIRO developed this methodology as a tool for integrating disparate geological and mine data which were independently collected and manipulated using a lot of different software packages. The aim was to see relationships that were not apparent before the datasets could be combined. Key advantages of this new visualisation method are the ease of delivery of data, the intuitive interface and the fact that it is based on existing, readily available software. Less than 15 minutes training is required for anyone to begin "seeing" meaningful relationships between data sets.

¹ CSIRO - Exploration and Mining

HOW CAN VIRTUAL REALITY TECHNOLOGY IMPROVE MINE PERFORMANCE

Mine planning and operations

Day to day planning and operation of the mine involves the use and generation of data which falls into two broad categories, geology, and engineering. Geology data includes data gathered drill holes, seismic surveys, and geologists observations. This data is generally gathered and stored in three dimensional coordinates with qualitative data linked to stratigraphic and structural units. Engineering data includes the mine plan, services, equipment specifications, ventilation design and gas drainage. This data is typically stored in 2 D with attributes assigned to objects. As an example, the mine plan is shown in 2-D with the attribute that it is in a particular seam with a working section of X metres with Y metres of floor coal etc.

The potential of this method has been demonstrated via ACARP project C5026, Interactive Evaluation of Mine Plans with Integrated Geological Exploration (LeBlanc Smith, Caris and Soole, 1997). Two mines, one open cut and one underground were reconstructed in "virtual space" by combining and displaying a large number of different data sets. The primary objective of the project was to demonstrate the analytical advantage of 3 dimensional visualisation for mine planning and exploration. During the course of the project geophones were used down bore holes to monitor micro-seismic events associated with the operation of the longwall. The location size and character of events were interpreted from monitoring. When these events were replayed in 3 dimensions in time sequence in the virtual mine model and viewed in the context of known faults and joints, major structural problems become apparent which were previously not well understood. This new information was instrumental in the decision to change the mine plan to avoid difficult mining conditions.

The ability to combine datasets from different sources including faults, boreholes, mine plans, micro-seismic monitoring, etc. and to visualise them in four dimensions (3-D + time) adds a whole new ability to see previously obscure data relationships. Another potentially powerful aspect of the tool is the ability to build on previous datasets in real time as the mine progresses. Any data which can be extracted from the mining process in a digital form can potentially be used in real-time to update the model.

It must be stressed that this technology in no way replaces current mine planning or geological software packages it merely provides a method for communicating information and interacting with data from those packages and a variety of other sources simultaneously. This tool will enable persons involved in critical decision making processes to have access to more data more quickly in order to gain improvements in the quality of decisions and reduction of time required to gather information Table 1 displays how this technology might be used to enhance the understanding of mine data.

COMMUNICATIONS

Better communication is the most direct benefit of this type of technology. The old saying goes "a picture is worth a thousand words"; if that is true a virtual world is worth a million.

On-site

Every person who has access to a computer on the mine site can potentially access the data which is pertinent to their jobs without installing any highly specialised software. This in itself is not unique and is already being done. What makes virtual reality technology unique, is that the data is communicated in a "real" framework with physical representations of the real world that add value and context to the data. The user is also empowered to see relationships between various data sets which previously were very difficult and time consuming to construct.

This system also has the power to deliver real time monitoring information to mine operators in context. For example, if an alarm generated by the system indicated that gas levels are exceeding hazardous levels and at the same time personnel and vehicle location are displayed, then an operator will be able to immediately assess potential hazards by seeing whether the area of the mine in which hazardous conditions are detected is occupied or unoccupied.

Off-site

There are no technological barriers to prevent the transfer of information across the internet in real or near real time. This technology would enable a mine operator to supervise exploration drilling from head-office, monitor progress in real time, and discuss the data with a consulting geologist while you are both accessing and viewing it in 3-D, in the context of other relevant mine data, from separate locations via the internet.

To the rest of the world

Mining companies are under increasing pressure to communicate with the outside world about the activities of their mine. Consultants, shareholders, government agencies and board members all have a need to understand what is happening at the mine. Different individuals will be interested in seeing different sets of data and the relationships between different sets of data. Currently it is very difficult for a lay person to visualise what a mine is like or to understand the mining process. This tool allows real mine data to be communicated in a format that can be easily understood by lay people. Investors, for example, would be able to tour a planned or operating mine on their desktop and to understand the planned recovery of resource and its potential value.

Corporate memory

Retrieving historical data or engineering experience is usually very difficult in mines. Information is effectively lost when staff move on. Repeated errors commonly result when new staff have no corporate memory of the mining experience to call on. In a virtual mine system, data once entered cannot be lost, and is always available to review along side the current situation.

Table 1 - Displays how this technology might be used to enhance the understanding of mine data

Data Set	Advantage of Virtual Reality (standalone)	Possible data set combination	Resulting new or improved capability (when combined)
Mine Plan	None	Geology, time	Better real-time control
Equipment	None	Stores, services, mine plan geology, time, longwall.	Automation, maintenance scheduling, efficiency improved reliability
Ventilation	3 D plus time	Geology, gas model, real time monitoring.	Visualisation (real time), simulations
Gas Drainage	3 D plus time	Geology, gas model, real time monitoring, drill holes.	Visualisation (real time), simulations
Geotechnical	3D plus time	Microseismic, stress, faults Mine Plan, Longwall face, etc.	Prevention of accidents, Improved visualisation.
Safety		Combination of various data sets ie. equipment geotechnical and services etc.	Prediction of hazardous conditions
Emergency		Combination of various data sets ie. equipment, geotechnical, personnel location, services, etc.	Emergency Management System providing rapid reconnaissance of all available data, quality assurance that all data that is available can be assessed. Training for self escape.
Surface Mine	3D plus time	High wall monitoring, vehicle movement, stockpile monitoring, etc.	Visualisation of process flow / efficiency of haulage. Vehicle and personnel tracking.

HOW DOES IT WORK?

The system which will be referred to as the "Virtual Mine" displays graphical data (any data that can be represented by an object located in x,y,z coordinates) as objects in an interactive "world" constructed using Virtual Reality Modelling Language (VRML), non graphical data (data which can be represented by a numerical value or a string of text) can be displayed in a number of ways: as an attribute of an object eg. color, transparency; as a structured query linked to a database via a JAVA applet (small program which links data to an object); or as an HTML (HyperText Markup Language) page which comes up in a separate window when a link is activated. All forms of data can be linked to either an object within the VRML world or a control button on the console of the VRML browser.

The software necessary to interact with the Virtual Mine is readily available on the internet, most PC's and workstations now have the appropriate software installed on them from the factory. An internet browser (Netscape, Explorer, etc.) and a VRML plug-in browser (Cosmo-Player) are all that's required. The images contained within this paper are screen shots of Netscape, and Cosmo Player.

While the techniques to build virtual mines are established the process is still somewhat tedious. Graphical data from the various geological and mine planning packages has to be converted to VRML using data translators which have to be programmed separately for every different data format. Databases containing the non-graphical data have to be structured and programs written to interpret that structure and retrieve the data. While anyone can easily use and view the data once it is constructed the set up entails considerable time and effort. This process is being continually improved with better translators and faster data acquisition methods.

Conversion of data from existing data sets remains the most difficult task in constructing the virtual mine. In other areas of design, software vendors are beginning to provide VRML converters for 3-D output. If this trend continues and finds its way into the mining industry then the task will become much easier.

Because the virtual mine uses internet technology there are no inherent hardware requirements. Obviously, hardware limits the graphics quality, speed and quantity of data which can be accessed at any one time. However, internet applications are developed to be platform independent so there are no inherent hardware biases. PC, MacIntosh, or workstation, it doesn't matter so long as the computer has sufficient power to handle the data required at a speed which is acceptable to the user. The structure of the virtual mine also allows staff members in any field of expertise to access and use the data in for their own purposes in any combination.

WHAT HAS BEEN ACCOMPLISHED SO FAR

Two "virtual mines" have been constructed, one open cut and one underground both based on existing mines and illustrated in Figs. 1 and 2. Each one incorporates a variety of different data types, including:

- geological data, coal seams, faults, dykes, joints and strata information boreholes;
- geophysical data ,seismic, microseismic, stress;
- mine planning data;
- surface data, digital terrain models of surface topography, terrestrial photogrammetry, and aerial photography;
- video clips;
- animations of equipment movement; and
- monitoring data simulations.

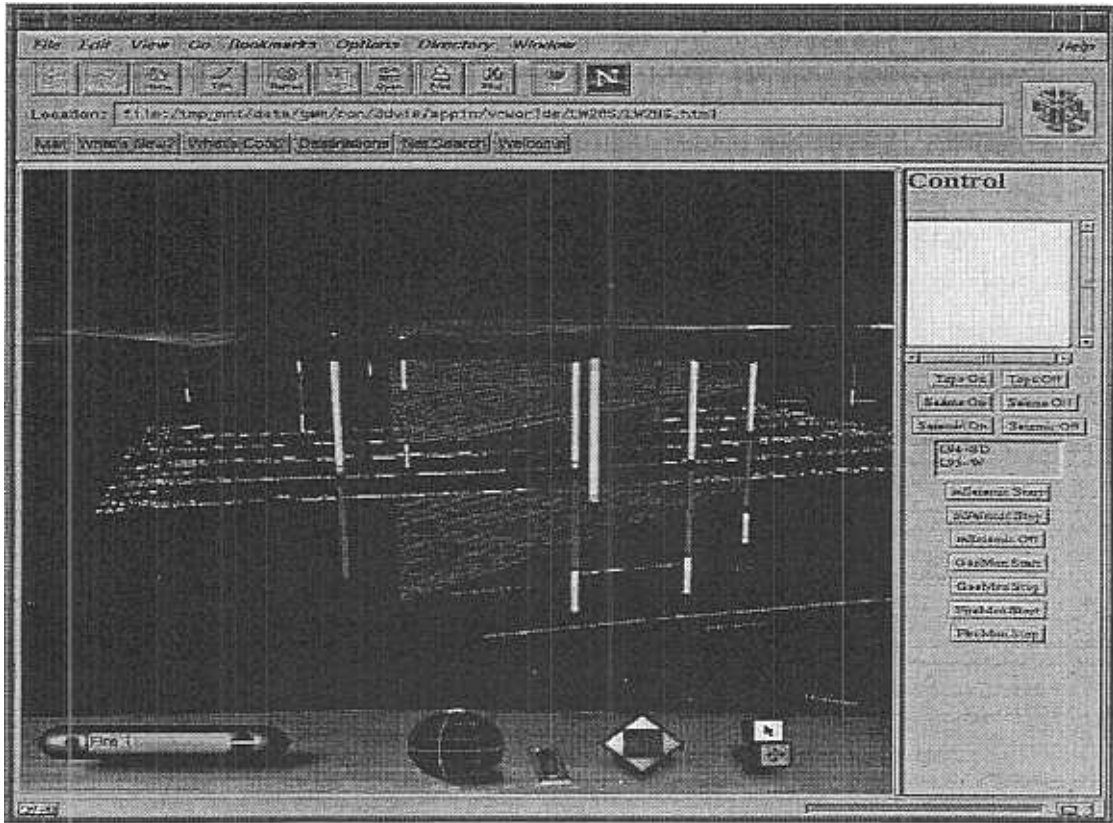


Fig. 1 - Underground virtual mine displayed with netscape and cosmo player

The demonstration projects have been successful in demonstrating the potential of the virtual mine as a visualisation and analysis tool. In the underground virtual mine, the ability to visualise in three physical dimensions plus time, the occurrence of microseismic events (rock movement) associated with the advance of a longwall face at the same time as the fault structure was instrumental in the decision making process.

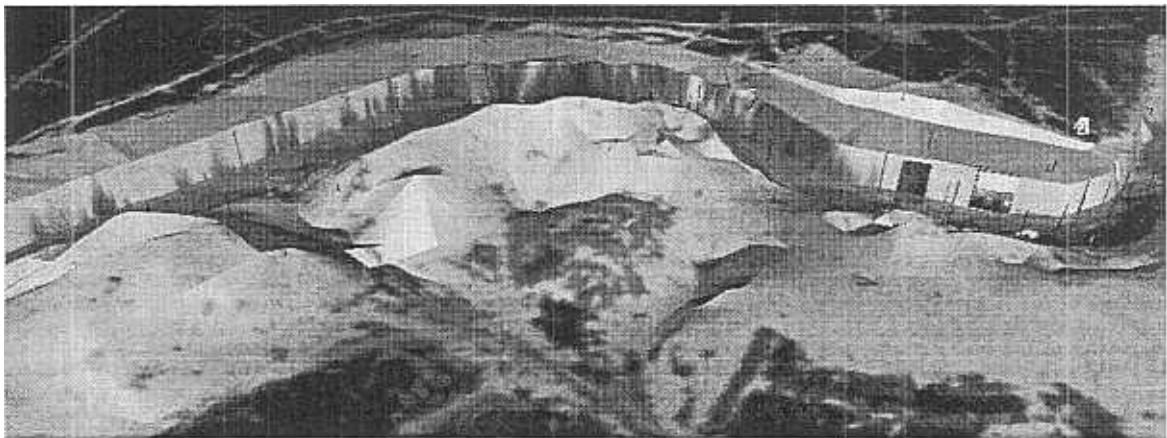


Fig. 2 - Opencut virtual mine

The open cut virtual mine demonstrated the ability to integrate photogrammetric data both areal and terrestrial with survey and drill-core data to add meaning and to improve the mine model. The open cut mine also demonstrated the ability to incorporate video clips and streamed location data (for mine trucks) in to the system as shown in Fig. 3.

In addition, the underground virtual mine was used as basis for simulating the display of real time data. Gas monitoring and personnel tracking were simulated by generating a series of numbers and text information which were then streamed into the model and displayed graphically and as text obtained by clicking on an object (monitoring location) in the mine.

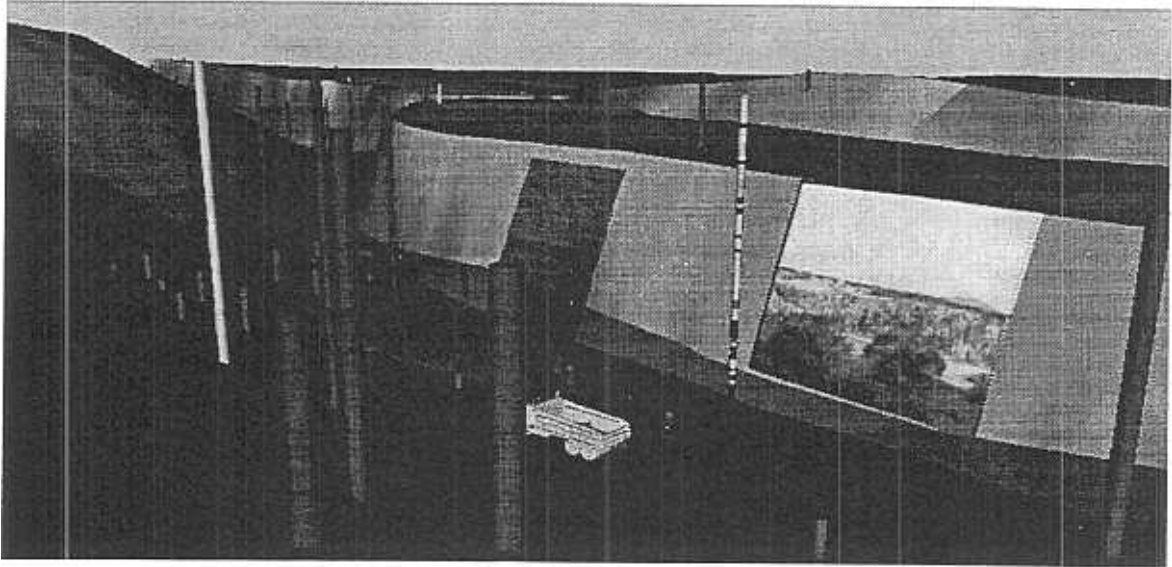


Fig. 3 - Open cut mine showing boreholes, vehicle location, video panel and 3-D terrestrial photogrammetry integrated into the model

PLANS FOR THE FUTURE

The virtual mine developments by CSIRO prove the value of the tool to existing mine operations, with integration of disparate data sets and the intuitive display of complex data. It represents a critical step toward the holy grail of a comprehensively monitored and controlled mining system. Although many potential mining applications remain to be explored, current applications could be implemented by mining service providers now, and plans for the commercial implementation of the technology are underway. It is hoped that it will be available as a commercial service to the mining industry this year. The package would include the integration of geoscience data, survey data, photogrammetry, mine design and time sequenced monitoring data from various sources.

CSIRO is continuing research in a number of areas. The first of these is in improved software capabilities. The software tools are being developed on a worldwide basis, with many organisations developing and releasing products into the internet environment. Keeping pace with these developments and establishing which may be useful for mining applications is a major activity.

Most programs are made with the games and other bulk usage markets in mind, and can rarely be directly used for other purposes without some adaption or interface. For real applications new software is required to allow the automatic updating of VRML files from sensor data, so visualisations can represent realtime data. Another key to the visualisation of large datasets typical of mine sites is techniques which allow sampling of data at a scale appropriate to the application in use. When zooming in on areas of interest, the appropriate level of detail is drawn from a database, without all the data having to be stored continuously. CSIRO is also investigating the virtual workbench, which is a physical workstation

where the operator manipulates tools actually within the 3D model. This includes tactile feedback from surfaces and objects in the workspace.

Another area of development is in the capabilities of different computer hardware systems. A common question is 'What sort of computer do I need to run this?' There is not enough experience yet to answer this. All the software can operate on a PC as well as a workstation, but how practical this is for real datasets has to be demonstrated.

Virtual reality techniques open many new opportunities for mining applications, with the possibility of completely new ways of approaching mining tasks. Developing these new opportunities is not only the function of the virtual reality research team, but extends across of the areas of mining research. All groups are asking how this new tool can be applied to their areas and are working to exploit its capabilities. In addition to the first underground and surface models we have described here other applications being developed are in gas drainage, ventilation, equipment status, mining system simulation (a virtual longwall), geotechnical performance, microseismic monitoring, safety, emergency response procedures, equipment and vehicle tracking, rehabilitation and environmental monitoring.

To fully implement the potential of many of these applications new or modified equipment, monitoring and communication will be required. An example of these support research developments is a new communication system (LAMPS) which is to provide robust and wireless communication for data throughout an underground mine.

It could be an essential module of a personnel and equipment tracking and monitoring in a virtual mine model. Of more interest in surface mines are techniques for highspeed mapping of exposures such as highwalls with photogrammetry and laser ranging technologies. The output of these methods could be incorporated directly into the 3D virtual mine datasets.

A feature of a fully developed virtual mine will be the capability to quickly integrate data from different areas. Although we are working to find ways to utilise this capability in operations, it will obviously be of enormous benefit for the times when things do not go as planned. If an event occurs it will be possible to see who might be the cause, what the effect on the rest of the operation might be, and the status of the remedial services. In the extreme case of a major mine emergency this technology will provide an invaluable tool to assess the situation and a basis for rescue and recovery of the mine. In its simulation mode, a virtual mine system could be used to develop training and establish operating procedures.

CONCLUSION

Virtual mine technology is opening the window on the mine of the 21st century. The virtual reality technology provides one of the key building blocks required for safe, regulated, and optimised mining.

It is essentially a communication tool to present all relevant data in an understandable format for decision making. It provides a way to reduce very complex and diverse data sets into the essential elements without loss of data quality. It turns data into powerful information.

Virtual reality technology will impact profoundly on all aspects of society, and the mining industry has the opportunity to share in the benefits. It is not just a nifty bit of software that kids play games with. It is a paradigm shift in our ability to manage our increasingly complex activities.

The technology is available now, and applications will be introduced throughout the industry in the years ahead, in areas where it provides new capabilities. As its use spreads we will reach a position where a mine will be able to access and visualise all its data in 3D and through time, and all decisions made in the light of best knowledge and historical experience.

REFERENCES

LeBlanc Smith G, Caris C and Soole P, 1997. Interactive Evaluation of Mine Plans with Integrated Geological Exploration *ACARP Final Report C5026*.