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Virtual reality applications in the Australian minerals industry

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Virtual Reality (VR) simulations are excellent tools for training, education, simulation of abnormal and dangerous conditions in mines and solving complex problems. Although the concept of VR has been around for nearly half a century, it has taken recent advances in hardware and software to bring this technology to within the budgetary reach of ordinary users and researchers. VR is now successfully being used in the minerals industry for: data visualization, accident reconstructions, simulation applications, risk analysis, hazard awareness and training.

The Institute of Sustainable Minerals Industry, Advanced Computer Graphics and Virtual Reality Research Group (SMI-VR) at the University of Queensland, established in late 2000, has been involved in developing VR applications for the minerals industry in conjunction with various research centres. This paper illustrates the benefits of using advanced computer graphics and VR techniques in the minerals industry with some examples of applications developed.

Introduction

Virtual Reality (VR) is a continuously evolving new computer technology, which allows users to interact with computers in a new way. VR provides great opportunities for the minerals industry and is described by Aukstakalnis and Blatner[1] as 'a way for humans to visualize, manipulate and interact with computers and extremely complex data'. VR systems are real-time computer simulations of the real world in which visual realism, object behaviour and user interaction are essential elements[2,3,4].

Virtual Reality is also a simulator, but instead of looking at a flat screen and operating a joystick, the user who experiences VR is surrounded by a three-dimensional computer generated representation, and is able to move around in the virtual world and sees 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 tool in many industries. Surgeons may use VR to plan and map out complex surgeries in three dimensions, which allows them 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.

Virtual Reality provides the best tools for accident reconstruction, training and hazard identification by immersing the trainee in an environment as close to the real world as possible. Through safety, visualization and education, VR promises many improvements for the minerals industry.

The benefits of using VR

Inadequate or insufficient training is often blamed for most of the mining fatalities. There is no doubt 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.

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 AU$600 millions is currently lost each year through unforeseen geotechnical problems for which even a 10 per cent saving will save AU$60 millions per annum[5]. 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.

Galvin[6] claims that the loss of revenue from a bord-and-pillar unit not being available for production is estimated to be between AU$40,000 and AU$90,000 per day. Galvin also claims that losses in revenue per day due to stoppage of the longwall face can be as high as a AU$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.

The difference between the conventional and VR training is that VR immerses trainees in realistic, functional simulations of workplace and equipment and it demonstrates mastery of skills through performance of tasks in multiple scenarios. Research Triangle Institute[8] 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 using VR training. This translates into tremendous savings in labour and travel expenses.

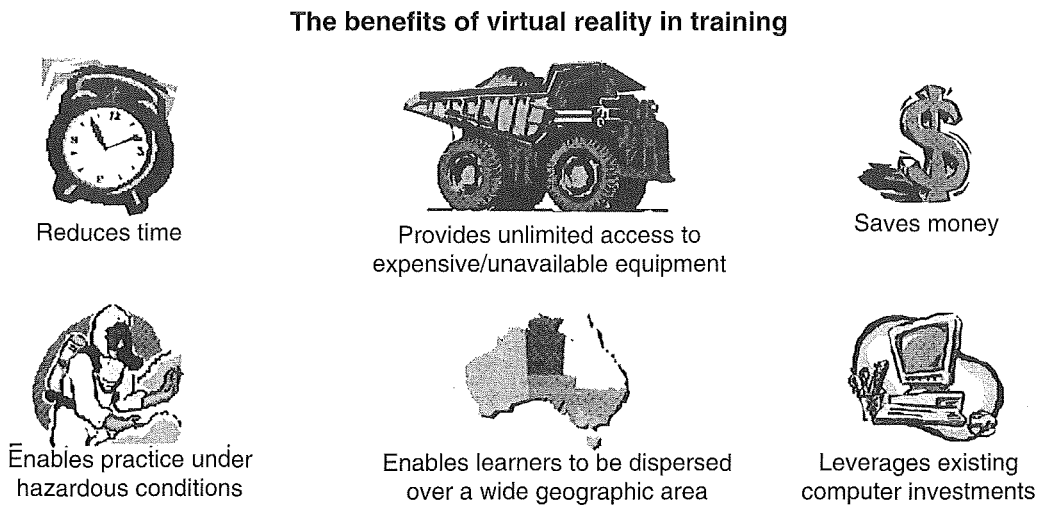

Figure 1. The benefits of using VR for training[7]

Applications of virtual reality in the minerals industry

Recent advances in virtual reality and the increase in the power of modern computers has allowed for the rapid expansion of VR applications. It is estimated that over 60,000 commercial companies and approximately 3,600 educational institutions now use VR throughout the world[9]. The mineral industry research and educational institutes in Australia have been more reluctant in embracing this technology compared to other countries and industries. The Institute of Sustainable Minerals Industry, Advanced Computer Graphics and Virtual Reality Research Group (SMI-VR) at the University of Queensland, has recently been established to promote this evolving technology and develop VR applications for the minerals industry. The SMI-VR research group has quickly established links with a number of national and international research centres, companies and educational institutions. The group has developed a number of successful VR applications for data visualization, accident reconstructions, simulation applications, risk analysis, hazard awareness applications and training (training of drivers, and operators).

The following are just some of the VR applications developed or under development by the SMI-VR research group:

- Drill rig training simulation
- Open pit simulation
- Underground hazard identification and barring down training simulation
- Instron rock testing simulation
- Accident reconstruction
- A library of three-dimensional mining equipment
- Ventilation survey and real-time monitoring simulations and
- Virtual mining methods.

Drill rig training simulation

Training is becoming a high priority for the minerals industry due to high injury and fatality rate[10,11,12]. Although there is no substitute for real world training, VR offers the necessary tools to reduce the cost of training and improve safety. Through the use of VR training, personnel can learn off site without disturbing production schedules or interfering and endangering expensive machinery with untrained personnel. BigTED[13] virtual drill rig system developed by SMI-VR group is a good example of such training systems (Figure 2). BigTED has fully functional control systems to operate the rig with visual warnings and three-dimensional sound effects. The simulation is made to emulate, as closely as possible, the actual lab drill.

BigTED has a number of components, which are included in VR simulations such as the drill rig, power pack and their control panels, power board, air compressor and water and hydraulic pipes. BigTED has been developed in a three-dimensional CAD package and assembled in SafeVR, which provides real-time user interaction in a simulated virtual environment. SafeVR is a revolutionary new tool that may be used to create training applications quickly and simply on a PC. This powerful software has been developed by the AIMS Research Unit at the University of Nottingham, UK[14].

BigTED provides two different simulations: equipment inspection and operators, training. In equipment inspection mode, the user navigates around the machine and inspects the rig, pipes, cables and sensors for any damage. The user is assessed based on the number of hazards identified and correctly dealt with.

In the operator training mode, the user is allowed to operate the rig in the same manner as in real life. The operation of the drill rig involves turning on the power, air and water supply in the right order and carefully applying rotation and thrust to the drill head without damaging it. The machine responds to any mistakes made by the operator with three-dimensional sound effects and pop-up text messages.

Open pit simulation

The majority of surface mines around the world employ large equipment such as haul trucks, dozers and excavators around the site. Their huge size together with the difficult environmental conditions introduces handling and visibility problems for truck operators. One way of improving the safety and increase the efficiency of the operations is to use a real-time truck and shovel dispatch and tracking system[15,16,17]. Safe, effective and reliable monitoring and control of mine operations can be performed over satellite and terrestrial communication links. MineStar[18,19,20] is a good example of integrating the Global Positioning System

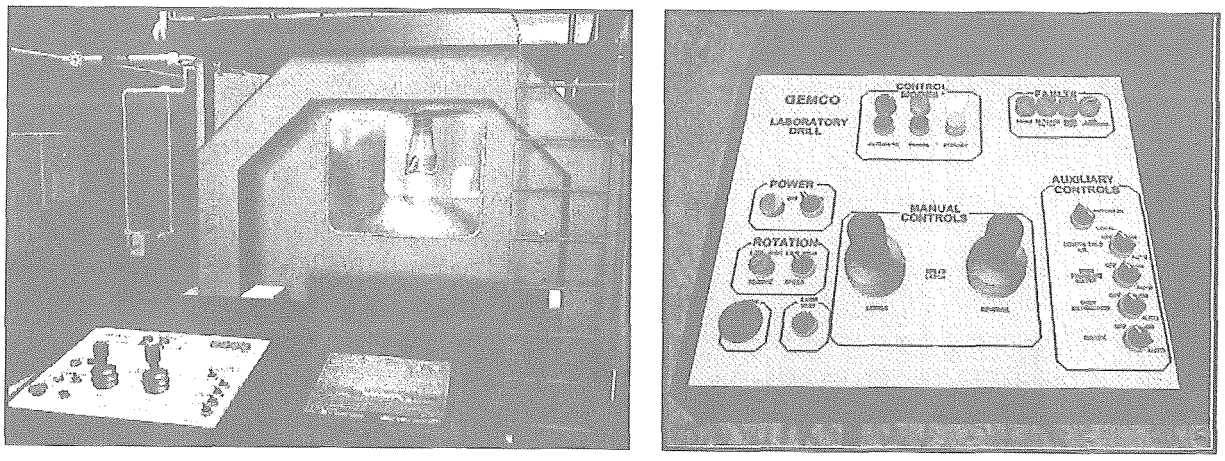

Figure 2. BigTED drill rig training simulation

(GPS) technology with mining software for the purpose of monitoring mining equipment and operations. MineStar is an integrated mining information system, developed by Caterpillar, Mincom and Trimble.

The SMI-VR research group is undertaking research into developing a hybrid system, which integrates virtual reality, (GPS) and the Internet for surface mining operations. The specific aims of this project are to:

- Improve the safety of mining operations by using VR technology to provide visually explicit information of the production
- Improve the productivity of mining operations in the area of real-time monitoring by introducing VR into real-time site monitoring systems in order to provide interactive and visually accurate, dynamic three-dimensional models of a mine site and its operations; and
- Develop an Internet based interface for real-time remote monitoring of mining operations.

Using this system, mine managers, supervisors and planners can visualize the operations in real-time, easily access information from equipment, such as production data and condition monitoring information anywhere around the world. With such a system, a specialist can remotely access data to solve a problem without having to be transported near the mining site, make better decisions and improve operational performance thus saving time and money. Figure 3 shows a trial virtual open pit to be used in this project.

Underground hazard identification and barring down training simulation

Virtual reality 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[2,21,22],. In addition to the assurance of safety, the use of a virtual training environment gives the trainer total control over many aspects of the trainee's performance[23]. 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.

The SMI-VR research group has developed a virtual barring down simulation system to provide improved hazard identification training for underground workers, primarily in relation to rock related hazards during barring down exercises. The major aims of this simulation are to:

- Expose a trainee to various hazardous situations without actually risking his/her life
- Take the trainee through a mine and test his/her ability to do a risk assessment in hazardous situations whilst tracking his/her individual scoring progress
- Provide training in the highly dangerous operation of scaling down rocks.

The trainee is required to successfully negotiate his/her way around the model identifying the hazards and selecting appropriate corrective actions (Figure 4).

Instron rock testing simulation

InstronVR has been developed to simulate an Instron rock testing machine and Uniaxial Compressive Strength testing practical at the University of Queensland. The aim of this simulation is to let students perform Uniaxial Compressive Strength tests on a number of rock samples from the comfort of their computer laboratory (Figure 5).

Currently implemented in the project are UCS tests for sandstone and marble, and a post-peak behaviour test for a sample of coalcrete (concrete and coal mixture). During the practical the machine is already set up to perform the test, so set-up of test conditions using the control panel is not required. The students are required to turn the Instron machine and its computer on and then choose a sample for testing. The test process cannot start until all the safety and operational requirements are met. After the test, the simulation produces a result file in Excel format, which students can save to a floppy disc.

Accident reconstruction

Mining by nature is a hazardous occupation. Accidents still happen with great frequency and severity. Investigating an accident by reconstructing it using advanced computer graphics techniques is an essential step towards improving the safety performance of the minerals industry. This way people can then understand:

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

The SMI-VR research group has developed a number of

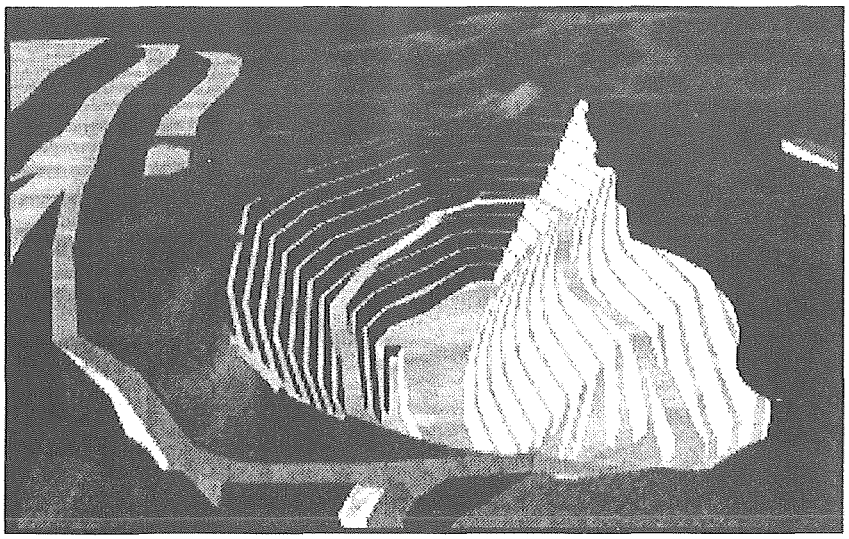

Figure 3. A virtual open pit

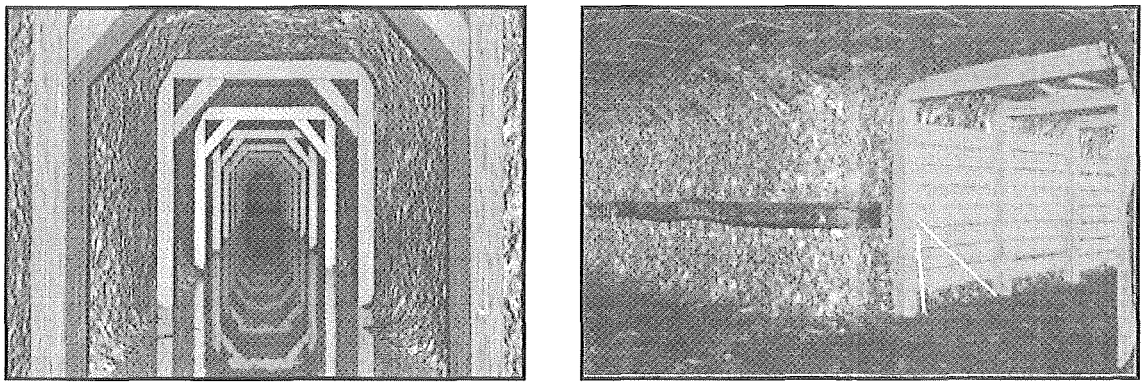

Figure 4. Barring down simulation

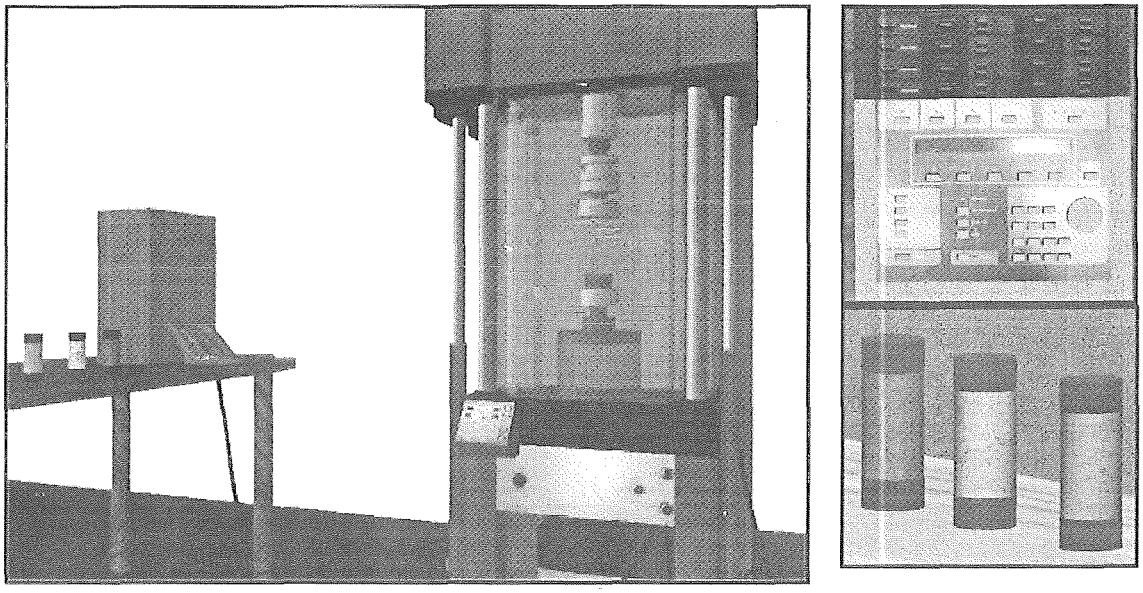

Figure 5. InstronVR and virtual rock samples and control panel

accident reconstruction projects, which were well received by the mining companies and their employees.

A library of three-dimensional mining equipment

The SMI-VR research group has developed a large number of very high quality three-dimensional models of mining equipment and machinery such as; loader, shovel, truck, longwall shearer, chocks, etc. Figure 6 shows some examples of the models developed. This library is a great resource for future training or simulations projects.

Ventilation survey and real-time monitoring simulations

The mining industry has been using computer software for ventilation design, simulations and real time monitoring of gas detectors and ventilation sensors. Almost all of this software provides two-dimensional or simple three-dimensional user interfaces. The SMI-VR research group has been undertaking research into developing a software which will:

- Enable the user to visualize and navigate around the mine in a three-dimensional virtual environment
- Provide the tools to the user to carry out ventilation surveys (pressure and quantity surveys, etc.) in the virtual mine
- Provide a real time monitoring system.

The user will be able to move around the mine and visit the stations points, which will have some displays and sensors. The results of the real time monitoring system will also be stored in a database file for further analysis and future references.

Virtual mining methods

Virtual reality is increasingly being used as an educational tool. There are increasing demands today for ways and means to teach and train individuals without actually subjecting them to the hazards of particular simulations. VR is an emerging computer technology, which has strong potential to overcome a number of limitations of conventional teaching methods. The most important benefits of using VR in education are that it is highly immersive, interactive, visually oriented, highly sensory, colourful and generally exciting and fun[24]. Bell and Fogler[24] state that VR is not an appropriate medium for delivering written information and substitute for traditional educational methods. However, when used properly, it can enhance traditional methods to the benefit of some students.

The use of VR in mining education has a number of benefits. For example, underground developments can be shown through a transparent layer of rocks to visualize. This gives students a better understanding of how the developments are constructed and their orientations in respect to the orebody. Figure 7 shows two examples of educational VR simulations developed by SMI-VR.

Students can be taken to a mine site and be given a tour of the mine in an immersive and realistic environment to introduce them to the operations and hazards. VR techniques can also be used to teach students how:

- to operate a machine
- a truck-shovel simulation works
- to carry out dangerous operations such as blast tie in and blasting exercise
- to carry out a laboratory test i.e. Uniaxial Compressive Strength
- a mine is developed and a mining method is utilized, etc.

Edgar[25] claims that we only remember 10% of what we read, and 20% of what we hear, but that we retain up to 90% of what we learn through active participation. Therefore, VR can help students in long-term retaining of material.

Conclusions

Virtual Reality offers limitless possibilities in training, simulation and education. 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. The SMI-VR research group is committed to use this technology to develop further applications for the minerals industry.

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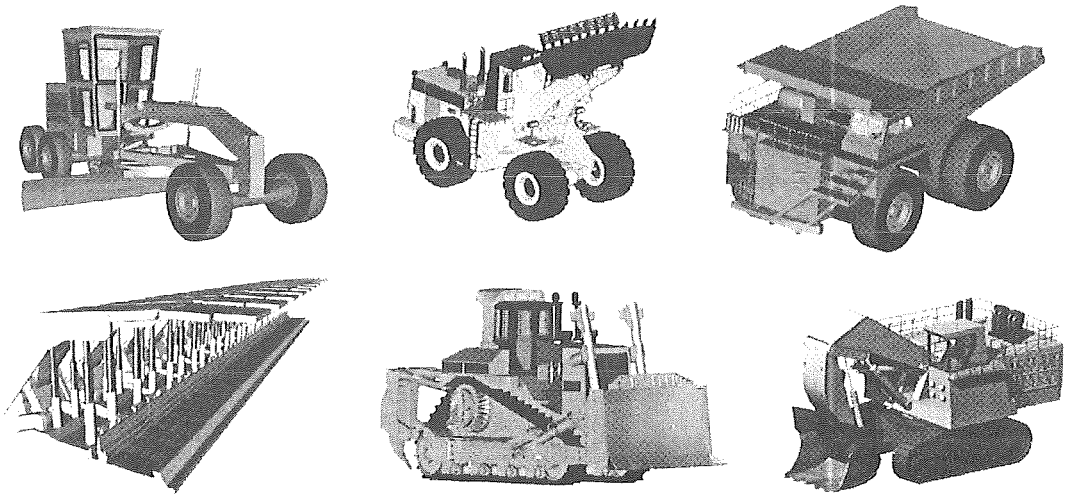

Figure 6. Examples of three-dimensional models of mining equipment

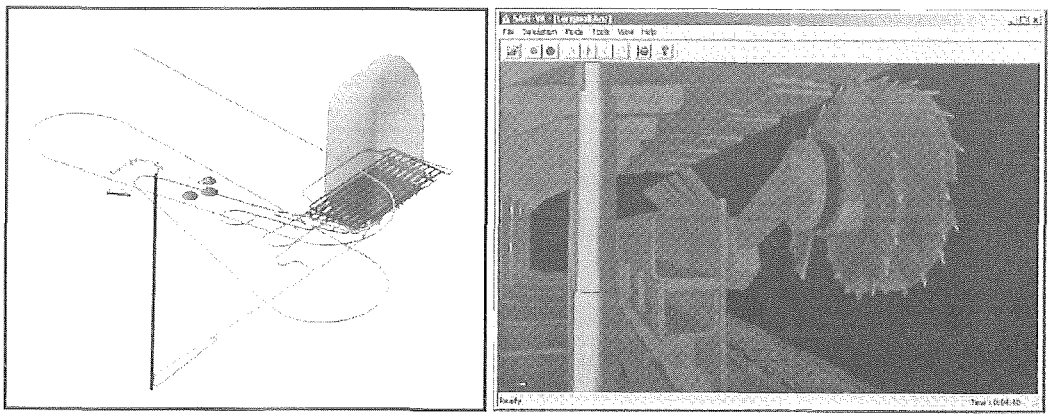

Figure 7. A three-dimensional representation of a block caving method and longwall simulation

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