Surface Mine Truck Safety Training*

Denis Cote Damien Ennis Benjamin Lucchesi
Nerissa Oberlander Keith Wesolowski
Department of Computer Science

Frederick C. Harris, Jr.
Department of Computer Science
fredh@cs.unr.edu

Pierre Mousset-Jones
Department of Mining Engineering
mousset@mines.unr.edu

University of Nevada
Reno, NV 89557

Abstract

In the surface mining industry, the cost of workplace accidents is high, and traditional safety training methods for equipment operators are costly and time consuming. This paper outlines the motivation for and development of an alternative training method, a VR-based simulator known as the Mine Vehicle Safety Simulator (MVSS), which can cut costs and improve mine safety. It further discusses implementation issues including the trainer and trainee interfaces, attempts to draw conclusions about the effectiveness of the MVSS with respect to traditional training methods, and outlines possible future work.

keywords: Surface Mining, Safety Training, Virtual Reality

1 Introduction.

Workplace accidents in the mining industry reduce production, increase costs, and result in temporary and permanent disabilities and even death to mine workers. They are always a major concern in day-to-day mining operations, where accidents can be expensive in terms of both cost and employee morale.

One of the most important tools for on-the-job accident prevention is worker training. However, the cost of accident prevention training is quite high, particularly when the training attempts to provide a realistic and compelling image of the risks that are associated with mining and the proper techniques for avoiding or managing those risks. Preparing video demonstrations, conducting safety training tours of work sites, and conducting on-site safety briefings can all be effective training tools, but each can be expensive and even disruptive to daily operations. As a general rule, the more realistic a training exercise, the more expensive.

Virtual reality technology offers an excellent approach to reducing both job accident rates and the high cost of training. The Mine Vehicle Safety Simulator (MVSS) developed at the University of Nevada is an example of such a virtual reality tool. It provides a cost-effective simulation of mine vehicle operation. As a simulation, MVSS provides the opportunity for realistic, flexible mine safety training at a substantial reduction in cost.

This paper provides a brief overview of the accident prevention challenge facing the surface mining industry with particular reference to off-highway haulage trucks that are typically used in this type of mining. It discusses the industry trend to explore new techniques for training workers and preventing accidents, describes the goals, concepts, and technology that underlie MVSS and provides an overview of its capabilities and operational modes. Finally, the effectiveness of MVSS as a training tool and its future potential is discussed.

2 Surface Mining.

The United States Occupational Safety and Health Administration (OSHA) stated in 1995 that industrial trucks are the second leading cause of fatalities in the private sector, second only to highway vehicle fatalities. On average, there are 107 fatal-

*This work partially supported by Newmont Gold Co., Echo Bay Minerals, the Nevada Division of Industrial Relations, and the Mine Safety Health Administration.

ities involving industrial trucks and 38,330 injuries annually in the work place. The Mine Safety and Health Administration (MSHA) reports that over the last few years accidents involving operators of off-highway trucks, such as the CAT 785 shown in Figure 1, in surface ground mining operations have resulted in between 15 and 20 fatalities per year and between 350 and 450 near fatalities per year [1]. Present training standards appear to be somewhat ineffective in reducing the number of accidents involving off-highway trucks. OSHA and MSHA both have been revising standards to increase their effectiveness by requiring initial and followup training.

Figure 1: A Cat 785.

Only trained operators who are specifically authorized to do so can operate off-highway trucks. The amount and type of training provided is dealt with on an individual basis. This training will be directly related to the operator's ability to acquire the skills that are necessary to safely operate the truck. A periodic evaluation of each operator's performance is required. Followup or remedial training is required, based primarily on incidents of unsafe operation, an accident or near miss, or deficiencies found in a routine periodic evaluation of the operator.

General attitudes towards industrial safety, environmental concerns, and industrial design have advanced significantly in recent years, and the mining industry has not been an exception.

The introduction of new safety and environmental legislation throughout the world has changed the emphasis of industrial law from prescriptive legislation toward adoption of more effective management systems.

Many mining companies have responded to these new ideas and initiated the introduction of modern management philosophies [2]. A range of new techniques have been applied to meet the new legislative and production requirements.

Large mining organizations are now looking for ways to improve their performance, including new technologies. The rapid advances in computer graphics and Virtual Reality provide a very "real" way through which complex ideas and information can be conveyed to a work force or to the general public. These new techniques allow videos, simulators, and planning systems to be developed quickly, efficiently, and relatively inexpensively. A typical individual's ability to remember information gained from an interactive three-dimensional computer environment is far greater than his or her ability to translate information from a printed page into the real world. This enhanced understanding has been extensively discussed by a number of authors.

MVSS is example of how such virtual reality technology can be adapted to the needs of a specific industry.

3 Implementation of MVSS.

The project specifications dictated that the simulation be useable on MS Win 9X/NT systems, as the sponsoring companies primarily use Windows-based PC's for their information systems. MVSS was designed using the Open Inventor Graphics API [3]. The Open Inventor API had a number of advantages for the project. It is powerful and flexible while having a reasonable learning curve, which leads to a remarkably rapid development time.

The mine vehicle safety simulator can accept multiple graphic file formats for input of mine terrain data. Currently supported formats include Surpac and a variety of proprietary formats. This flexibility is accomplished through a set of utilities, one for each file format supported, which process and output the mine data to a common file format. MVSS can then read this common file format. Support for additional terrain formats can be added by implementing a utility to convert to a common file format.

MVSS can provide a variety of training exercises for the vehicle operator. The experiences that are provided for the operator can be organized into two categories. The first category is experiences relating to the process of adhering to specific mine vehicle operation regulations. These so-called "rules of the road" for mine vehicle operators differ considerably from Department of Motor Vehicle regulations for regular highway vehicles, the rules most people including new mine vehicle operators, are familiar with. For example, in most mines, mine vehicle operators are required to drive on the left rather than the right side of the road. The second category relates to the physical operation of the mine vehicle.

MVSS provides a rich variety of simulation scenarios for operator regulations. The operator can be exercised and tested in basic procedure adherence, responding to static hazards, and responding to dynamic hazards (involving other moving objects). Any combination of rules and conditions can be set up through MVSS, with the most basic scenario being an exercise in driving on the proper side of the road in the mine setting. The interface for setting these options is shown in Figure 2. Another simple scenario can monitor whether the trainee adheres to correct speed limits in the mine, such as the 25-mph maximum speed limit. At the opposite extreme, a more challenging scenario could involve requiring that the trainee respond to multiple moving vehicles behaving in an irregular manner.

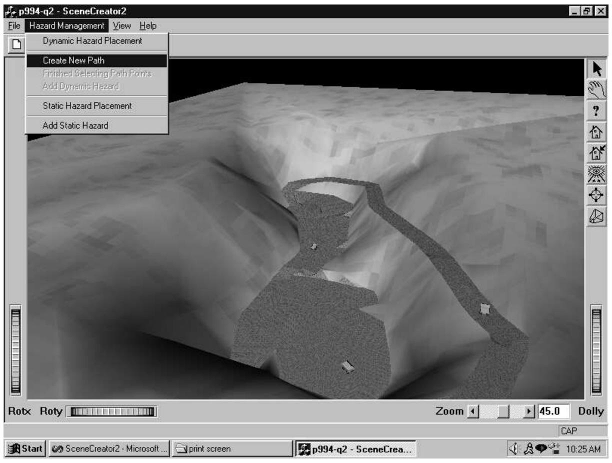

Figure 2: Setting up the Simulation.

MVSS can also be used to teach the trainee the layout of the mine, such as the location of the loader, dumpsite, and other important landmarks. Regulations relating to static hazards can be introduced. These are regulations, unique to surface mines, regarding vehicle operation in the proximity of static objects, with the regulations varying depending on the type of object. The static objects that can be presented to the trainee by MVSS include cones, persons, pick-ups, loaders, and other trucks. One scenario might involve placing a pick-up in the vicinity of a loader, such that the pick-up is a nuisance to loading operations. The trainee could then be tasked with safely carrying out loading operations under the increased stress.

The most challenging scenarios MVSS can present to trainees include dynamic hazards such as persons, pick-ups, loaders, and other trucks. A typical scenario could involve the trainee approaching a loading zone with a moving pick-up added to complicate the process. As with any of the simulations, the trainee's response to the situation can be scored. The most extreme scenarios could involve the trainee responding to single or multiple moving vehicles behaving irregularly or dangerously. An example would include a pick-up that sneaks behind the trainee's truck, positioned to cause an accident should the trainee ignore any of the required procedures for safely reversing his or her truck. An example a situation a trainee is faced with is shown in Figure 3.

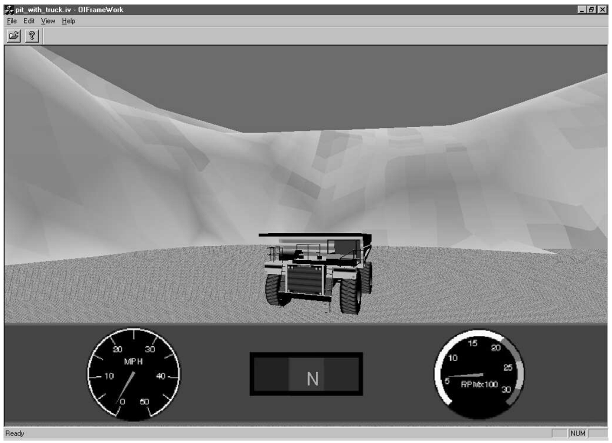

Figure 3: Another hauling truck to avoid.

The second category of training provided by MVSS provides the trainee with a feel for the physical operation of the truck. The actual Caterpillar trucks operated by the trainees can weigh up to 170 tons empty and 460 tons when fully loaded with rock. Obviously, these trucks behave and respond very differently from any passenger vehicle or even highway trucks that the trainee might have previously encountered. Furthermore, there is a considerable difference in the behavior of these trucks in their loaded and unloaded states. Therefore, experiences that give trainees a feel for handling these vehicles can be of great value. MVSS currently supports gearing, breaking, steering and the general handling characteristics of the Caterpillar trucks. But MVSS is unable to provide the feel of slipping when an unloaded vehicle accelerates or de-accelerates too rapidly.

Another training dimension provided by MVSS includes allowing trainees to respond to equipment malfunctions. The graphical display of the cab, dashboard and gauges is modeled to have the same appearance as the actual layout in the Caterpillar trucks. MVSS can test the trainee by displaying these gauges showing malfunctions such as low oil, high engine temperature, low battery power, and other mechanical problems.

After completing the simulation, the trainees will receive their performance results. These results are in the form of a text file. The results file details the trainee's performance during the simulation. In addition, immediate feedback is given when a catastrophic event such as a collision occurs.

4 Conclusions & Future Work

Although virtual reality simulators are not new, employing such simulators to reduce training costs and reduce accident rates is relatively new to the mining industry. Presenting hard statistics on current costs, in addition to well-founded predictions of cost savings incurred by the use of virtual reality simulators, will help attract interest from the mining industry. In addition, many mining professionals are probably not aware of what is possible with the current state of virtual reality technology. Therefore, participation in industry conferences to demonstrate current technology should help the use of simulators, such as MVSS, gain mining industry acceptance.

Although MVSS has many training capabilities that can improve workplace safety, there are significant opportunities to improve the system.

Making the hardware of the simulator more realistic can enhance immersion of the trainee into the physical experience of operating a truck. The current MVSS hardware is shown in Figure 4. Hardware, in this case, includes output devices, such as large-screen monitors and displays; and input devices, such as realistic accelerator and brake pedals, gear shifters, and steering wheels. More ambitious implementations could be built around an actual truck cab, much as commercial jet simulators are based on an exact duplicate of the aircraft's cockpit.

MVSS software can also be improved. Simple improvements to MVSS could include a broader variety of hazards to challenge the trainee. For example, due to the structure of surface mines, small rock slides can occur onto the haul road. Therefore, the addition to MVSS of a falling rock in front of a moving truck would improve the simulation. The current version of MVSS supports just one trainee at a time. A distributed MVSS would allow adding additional trainees to the same simulation. It is quite reasonable to imagine the equivalent of a complete surface mining operation within a single simulation, with many trainees concurrently engaged in their specific assignments and interacting with each other. Depending on the implementation of the distributed MVSS, the trainees might not even need to be located in the same physical area.

Figure 4: MVSS Trainee Interface with steering wheel, gear shift, and gas/brake pedals.

The current version of MVSS could be further improved by adding sound support. Sound has a large effect on the realism of any virtual reality system. For example, the engine sound of a Caterpillar hauling truck can be loud and fatiguing. In a real truck, this engine sound could effect the ability of the trainee to concentrate and respond to a given situation. A MVSS with sound support would add this realism, better preparing the trainee for actual mine operations. Sound support would also increase the number of simulation scenarios possible. As an example of a scenario not possible without sound, consider one that included the production of engine noise that simulated a specific engine problem, with the trainee's recognition of the sound and response scored.

References

[1] Mine Safety Health Administration (MSHA). Injury tables (1996-1998). MSHA, Denver CO.

[2] B. G. Staley. Culture shock-changing attitudes to safety in mines. In *Proc. of Safety, Hygene and Health in Mining*, pages 263–273, Harrogate, England, 1992. Institution of Mining Engineers.

[3] Josie Werecke. *The Inventor Mentor.* Addison Wesley, Reading, MA, 1994.