Surface Mine Truck Safety Training: Scenario Setup for a VR Driving Simulator*

Benjamin Lucchesi   Nerissa Oberlander
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 a Scenario Setup application for a virtual reality based simulator known as the Mine Vehicle Driving Simulator (MVDS), which can cut costs and improve mine safety. It further discusses implementation issues, attempts to draw conclusions, and outlines possible future work.

1 Introduction.

Workplace accidents in the mining industry reduce production, increase costs, and result in debilitating injuries or death to mine workers. Accidents are a major concern in day-to-day mining operations, where they can be expensive in terms of both cost and employee morale.

One of the most effective tools used to prevent on-the-job accidents is worker training. However, the cost of accident prevention training is high, particularly when the method attempts to provide a realistic representation of risks associated with mining vehicle operation and the proper techniques that avoid or manage those risks. Preparing video demonstrations, conducting safety training tours of work sites, and on-site safety briefings are all effective training tools. But these methods are disruptive to daily operations and expensive. As a general rule, the more realistic a training exercise, the more expensive.

Virtual reality (VR) technology based training tools offer an excellent approach to reducing both job accidents and the high cost of training. The Mine Vehicle Driving Simulator (MVDS) developed at the University of Nevada is an example of such a VR training tool. It provides a cost-effective simulation of mine vehicle operation. As a simulation, MVDS provides the opportunity for realistic, flexible mine vehicle safety training at a substantial reduction in cost.

This paper provides a brief overview of the challenges facing the surface mining industry with particular reference to off-highway mining vehicles that are typically used in this type of mining. It discusses the industry trend to explore new techniques, such as MVDS, for training workers and preventing accidents. It then describes the goals and technology that underlie the MVDS Setup (MVDSS) and provides an overview of its capabilities. Finally, the effectiveness of MVDSS 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 [4]. On average, there are 107 fatalities involv-

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

ing 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 vehicles, an example of which is 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 [3]. Present training standards appear ineffective in reducing the number of accidents involving off-highway vehicles. OSHA and MSHA both have been revising standards to increase their effectiveness by requiring initial and followup training.

Figure 1: An Off-Highway Mining Vehicle.

Only trained and authorized employees can operate off-highway vehicles. The amount and type of training provided is dealt with on an employee by employee basis and is directly related to the operator's ability to acquire the skills necessary to safely operate the vehicle. 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 advanced in this direction. The introduction of new safety and environmental legislation throughout the world has changed the emphasis of industrial law from prescriptive legislation to the adoption of more effective management systems. Many mining companies have responded to these new ideas and initiated the introduction of modern management philosophies [5]. A range of new techniques have been applied to meet new legislative and production requirements.

Large mining organizations are now looking for ways to improve their performance by utilizing new technologies. Rapid advances in computer graphics and VR provide a very "real" way to describe complex ideas. By applying VR technologies to training, mining companies are able to convey the risks involved in various job roles. This type of training is much more understandable by the operator than books, videos, and seminars. This enhanced understanding has been extensively discussed by a number of authors.

3 VR Technologies.

The value of virtual reality is that it can offer experiences that would otherwise be inaccessible to an individual, because such situations might be too expensive, too dangerous, occur at the wrong time, or in the wrong location. VR training can give the individual experience beyond training methods currently in use. One of the most successful examples of a VR application is commercial aircraft flight simulation. This extremely expensive implementation of VR provides a very realistic setting for pilot training that includes all of the sights, sounds, control motions, and physical movement associated with flying aircraft.

Hardware and software used to implement VR applications have improved dramatically over the last few years. High-end PC-class workstations, with the addition of a 3D accelerated video card, have the potential to support VR applications which were once restricted to expensive hardware-specific applications. In addition, a number of peripheral hardware devices, such as VR goggles, gloves, 3D sound, and motion tracking systems are designed to heighten the user's sense of reality and increase training effectiveness. Furthermore, software vendors are marketing a range of packages for developing VR applications.

As noted by Foley, van Dam, et al. [2] "Interactive graphics is a field whose time has come." Software Application Programming Interfaces (APIs) that draw geometric objects for developing graphically intensive software are becoming standardized. One such low level API is OpenGL. The challenge of using a low level graphics API for developing software is that the application developer must make a substantial effort to create even the simplest 3D object. To reduce the complexity of developing graphically intensive software, toolkits built on top of low level graphics APIs are used. These toolkits focus development on user interaction and scene management rather than drawing objects.

One method of implementing this type of high-level toolkit utilizes scene graph technology (SGT). Scene objects such as cameras, lights, and geometry allow the programmer to concentrate on scene composition. Examples of APIs that implement SGT include Open Inventor, Java3D, and Fahrenheit. In addition, these packages are windowing system and platform independent.

4 Mine Vehicle Driving Simulator.

The first project our group developed was the Mine Vehicle Driving Simulator (MVDS). MVDS simulates driving mine vehicles in an open-pit surface mine. One of the project specifications dictated that the simulation be usable on high-end PC-class workstations. MVDS was designed using the Open Inventor API [6]. We chose the Open Inventor API because it incorporates a powerful and flexible implementation of scene graph technology.

In order to accommodate a variety of mine terrain formats, we have designed utilities for MVDS to process and output the data to an Open Inventor compatible file format. We currently have several utilities to process mine terrain data files. Support for additional terrain formats can be added by implementing a utility to convert these to the Open Inventor compatible file format.

One of the main goals of MVDS is to allow the trainers to observe the reactions of new vehicle operators without having to be in the vehicles with them while they are learning to drive. This will give the trainers a better idea of how the trainees will react to the hazards in the mine. MVDS also allows trainees to get the basic feel for how the vehicles will react before they actually step inside the real vehicle. With different weather conditions that can be simulated in a mine, operators will have a fairly good idea of how these vehicles will react during less than ideal conditions.

5 Scenario Setup for MVDS.

Once a prototype of MVDS was completed the trainers that used it asked whether training scenarios could be added. The additions that were recommended can be organized into two categories. The first category relates to adhering to specific operation regulations, particularly when you interact with

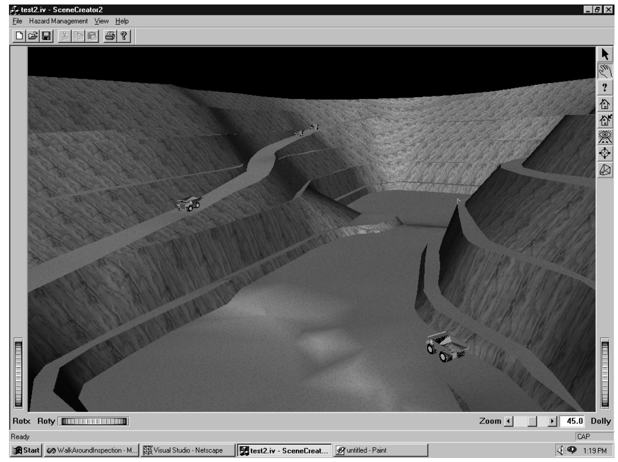

Figure 2: Setting up a scenario with MVDSS.

other moving and stationary vehicles. These "rules of the road" for mine vehicle operators differ considerably from Department of Motor Vehicle regulations for highway vehicles. For example, in most mines, operators are required to drive on the left rather than the right side of the road. The second category of additions they recommended relates to the physical operation of the mine vehicle. This will teach the trainees how the vehicle "feels" on the road. The trainee will have to deal with the effects of having wet, icy, or muddy roads; how the slope of the haul road effects acceleration and breaking; and how other environmental conditions, such as fog, will effect driving in the mine.

In addition to the rules of the road, MVDS can be used to teach the trainee the layout of the mine, such as the location of the loader, dump site, and other important landmarks. In order to do this, the location of these things in the scenario can be changed as the mine itself changes.

The MVDS Setup program (MVDSS), shown in Figure 2, will allow on-site trainers to make new scenarios for trainees to navigate as the mine and operating regulations change. The trainers will be able to change the entire feel of the mine by moving shovels, loaders, and closing routes the trainee may have used in the past. With this kind of flexibility for configuring the mine, a trainer can test the trainee's ability to handle situations that can occur in the mine.

When designing a scenario, objects added by the trainer fall into two classifications, static and dynamic hazards. A static hazard may be something like a traffic cone used to close off an area of the operation, or a surveyor's truck parked on the side of the road. A dynamic hazard could be another mine vehicle operating in the mine. When placing a hazard, the trainer selects a location in the mine, and a hazard to go there. If the trainer is placing a dynamic hazard, the location is a path (or series of locations) the hazard will follow at a pre-defined speed. With these hazards in place, regulations relating to static and dynamic hazards can be reviewed, since regulations vary depending on the type of hazard. Any object that is modeled in an Open Inventor compatible file format can be added as a static or dynamic hazard. We currently provide cones, people, pick-ups, loaders, and other vehicles.

The second category of training provided by MVDS provides the trainee with a feel for the physical operation of the vehicles. Off-highway mine vehicles are significantly different than passenger vehicles or highway trucks that the trainee might have previously driven. Furthermore, there is a considerable difference in the behavior of these vehicles in their loaded and unloaded states. Training that gives trainees a feel for handling these vehicles can be of great value. MVDS currently supports gearing, breaking, steering, and the general handling characteristics of the mining vehicles.

MVDSS can be used to configure the vehicle state (such as load), weather, and haul road conditions. The trainer can keep the hazards the same, but change the type of whether conditions that are present in the mine or change the load that the vehicle is carrying. By doing this the trainer will be able to see how well the trainee will be able to react to the different types of driving conditions.

Once a scenario is fully configured, this information can be saved to a file which is used by MVDS. Scenarios can also be re-loaded and modified to reflect changes in the mine and MSHA regulations over time. This gives trainers the flexibility to build a library of scenarios used to test the skills of vehicle operators.

6 Conclusions and 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. Some of our previous work dealing with pre-operational vehicle inspection, the Mine Vehicle Inspection Simulator (MVIS) [1], has shown that the industry is quite willing to expand their training into new technological areas. Response to MVIS and prototypes of MVDS have generated strong interest in development of more training tools of this type.

Future improvements to MVDS include a broader variety of hazards to challenge the trainee. For example dynamic scenery, such as rock slides, will allow the trainer to evaluate the trainees response to a broader range of unexpected situations. Our current implementation of MVDS supports one vehicle operator. A distributed version of MVDS would allow multiple vehicle operators to interact with each other in the same simulation. It is 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.

With these and other improvements to MVDS, such as sound, the MVDSS would help provide safety trainers with a wide variety of possibilities to effectively train new hires in the correct and safe operation of mining vehicles.

References

[1] Damien Ennis, Benjamin Lucchesi, Nerissa Oberlander, Keith Wesolowski, Frederick C. Harris, Jr., and Pierre Mousset-Jones. Surface mine truck safety training: A VR approach to pre-operational vehicle inspection. In *Proceedings of APCOM'99 Computer Applications in the Mineral Industries 28th International Symposium*, Colorado School of Mines, Golden, Colorado, October 20-22 1999.

[2] James D. Foley, Andries van Dam, Steven K. Feiner, John F. Hughes, and Richard L. Phillips. *Introduction to Computer Graphics.* Addison Wesley, Reading, MA, 1997.

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

[4] Occupational Safety Health Administration (OSHA). Powered industrial truck operator training. *Internet WWW page, at URL:* `http: //www.osha-slc.gov/FedReg_osha_data/FED_19950314.html`, 1995.

[5] 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.

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