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METHODOLOGY OF INCIDENT RECREATION USING VIRTUAL REALITY

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ABSTRACT

Promoting a strong safety culture requires that the significance of unsafe acts be emphasized. This can be achieved vividly by accurate recreation of unsafe actions in the workplace, demonstrating explicitly how they resulted in a fatality or significant injury. Visual reconstructions of incidents can be realized today on personal computers. The approach described in this paper uses readily available PC software and hardware and results in output that can be presented to the intended audience using a variety of delivery methods. An actual incident involving a surface mining operation is reconstructed using Virtual Reality techniques. Use of the visualization approach to accident reconstruction as a training tool is discussed.

INTRODUCTION

In Occupational Safety and Health (OSH), a culture of prevention incorporates elements such as attitude, skills and knowledge, behavior, structures, procedures, systems, and, finally, financial and material resources. Education and vocational training play an important role in the promotion of prevention cultures. During education and training periods, individuals learn not only the skills and knowledge of a particular sector or profession, but also values and business cultures, including OSH cultures. Continuous training in OSH should be made available to all personnel. Particularly important is the training of safety specialists, safety representatives and safety managers (Hurmalainen, 2002).

The Mine Safety and Health Administration (MSHA) is empowered by statute to collect detailed information on accidents, injuries and illnesses that occur in the mining industry. Mine operators are required to report accidents, injuries, illnesses and certain other "reportable accidents" that affect both employees and non-employees on mine property. This reporting requirement has allowed MSHA to develop one of the best publicly accessible occupational injury databases available in the world. The database can also be accessed via the Internet at http://www.msha.gov.

Data from the MSHA database indicate that in the United States, between 1995 and 2001, approximately 146,000 incidents were reported to MSHA in all mines, with surface coal accounting for approximately 8 percent of the total (not including contractor incidents). Much effort has been, and is currently, expended to prevent such incidents. These efforts include enhancing the underlying technologies (Nieto and Dagdelen, 2002); developing accident prevention programs (MSHA, 2002); improving the work environment; continuous personnel training; etc.

Continuous personnel training as a means of establishing and promoting a strong safety culture in the mining environment is a major factor in preventing fatal and non-fatal incidents. Training should be delivered regularly to management and the workforce using a variety of methods. This paper presents a methodology of accident recreation using Virtual Reality techniques that can be used as training material.

TRAINING METHODS

Tracey (1992) defines training as "any learning experience provided to employees to bring about changes that promote the attainment of the goals and objectives of an organization." More practically, training can be defined as any program consisting of the presentation of information followed by an assessment of the trainee's retention of such information. Using this interpretation, showing a video of a haul truck crushing a pickup truck to a group of trainees would not be considered training. However, presenting the same video, followed by a discussion of the mistakes that lead to the accident, coupled with an evaluation of the trainee's understanding of the key concepts would be regarded as training (Weisiger et al., 2001)

Training can be delivered through a variety of methods, which are briefly outlined below (Weisiger et al., 2001; Cornell University, 2002):

• The traditional method of classroom and lecturer (chalk and talk method)

• The traditional method enhanced by various visual aids (PowerPoint presentations, video projections, etc.), in-class exercises, and problem solving activities, which aim to stimulate learners in a lecture environment

• Skills training by an apprenticeship type program delivered

outside the confines of the classroom
  • Computer-Based Training, which can be broadly categorized as:
    a. Simple presentation-type systems
    b. Interactive systems
    c. Simple virtual reality systems
    d. Fully-immersed virtual reality systems
    e. Web-based Training
  • A combination of the above methods

Focusing on Computer-Based Training (CBT), it is worth noting that such methods show great promise in all situations where training is needed. Training programs can take advantage of the flexibility and power afforded by current computing technology. Computers allow for the integration of various types of media in a single training package. The level of detail possible ranges from the most basic Microsoft PowerPoint presentation to a fully immersive Virtual Reality (VR) system, depending on the time and resources devoted to each project.

A multimedia training application can be developed at a significantly lower cost than a VR environment. Such a system can be created to address most, if not all, of the various learning styles of employees, using videos, animations, and audio files to meet the needs of both visual and verbal learners. Virtual Reality training applications, on the other hand, can vary from simple animations to fully immersive environments with true navigation capabilities (i.e. flight simulators, drill rig operation simulators, etc.). In all cases, users should be able to control the pace of the exercise/show, in order to better match their individual learning tempos.

ACCIDENT RECREATION

Many unsafe acts are committed due to ignorance of the full consequences of the act. For example, many professional sports use videotape of performances for evaluation of flaws or improvements in form. Such tapes are important for the athlete because they not only show flaws in performance, but also the resulting consequences (Capelle, 1999). This concept actually used in many mining training materials. For example, many training videos use actors to portray unsafe working habits and show the results. Unfortunately, these videos and other training materials are limited in what they can realistically portray.

Accident recreation, as a means of accident prevention, has already been implemented by many state and private agencies around the world, including MSHA. This is because the study and description of incidents can be turned into very effective training material. The effects can be enhanced further, if such incidents are appropriately reconstructed in a CBT environment.

Accident Investigation

Accident recreation begins with the accident investigation. The purpose of an incident investigation is to find the root cause of the accident. This can be a very challenging procedure. It is very important to gather all available data that is relevant to the incident. Investigators must observe and note all conditions, locations and equipment involved in the incident. Photographs and/or video camera footage of the incident scene can be very helpful in both the investigation and the incident recreation. A plan of the incident scene should be developed to describe the circumstances of the incident. The physical evidence of what may have caused the incident should be documented (MSHA Handbook, 2000). All the physical evidence and information should be given to incident experts. These experts can analyze the information using a variety of tools. Thanks to the statute requiring that incident reports be filed with MSHA, mine

accident investigations are usually handled by experienced personnel.

General Accident Recreation

A general sketch of the area may be all that is necessary for a general recreation. This plan must also include the types of cameras and the locations from which any photographs or videos were taken. Dimensions, topography and distances that may clarify the events before, during, and after the accident must be included. It is important to note that all measurements should be recorded as accurately as possible, although it may not be necessary for these to be exact. It should also be noted that in many instances general accident recreation procedures involve static pictures and graphics, which are not realized as training material but as an investigation tool. With little extra effort, however, much of this material can be utilized for recreating the accident in a VR environment.

ACCIDENT RECREATION USING VIRTUAL REALITY TECHNIQUES

Required Accuracy

In the United States, admissibility of VR recreations in court has been denied for several basic reasons (Joseph, 1996). VR is considered a computer simulation that is supposed to be programmed to reflect reality. Hence concerns arise about factuality and scientific foundations. Because the facts presented are based solely on the data that is entered into the recreation, a VR recreation is considered by the courts to be a form of hearsay and, therefore, is possibly inaccurate. The four main issues are as follows:
  • The underlying scientific theory
  • The computer simulation program used
  • The accuracy of the data used
  • The incorporation of all needed data

Only recently have courts in other countries, such as the United Kingdom, allowed VR recreations (Schofield et al., 2002). Nevertheless, some simpler uses of VR are generally admissible. Environmental visualizations are amongst the most common of these.

A VR recreation for use in miner training need not meet the requirements established by the judicial system. Therefore, the recreation of an unsafe act that has been proven to result in injury need only be a generic case, rather than a specific, historically accurate case. This generic case should, however, be based on the actual actions and their actual results. Such a recreation can have the same effect as dramatizations; however, if done using VR, it will require no equipment or personnel.

Recreation Procedures: In order to achieve an accurate VR rendering, scaled drawings of all objects, people, surroundings, and equipment that pertain to the accident are needed. Using the general procedure outlined below, a mine or mining company can develop VR incident recreations for incorporation into standard training and safety materials.
  • The first step in creating a VR incident recreation is to collect data on an actual incident. The best source for this information is the MSHA accident reports. In most cases, there is enough information in the MSHA reports to generate a non-specific incident recreation.
  • The second step is to create VR models of equipment and miners. These models can be drawn and collected in a digital library. Equipment models can easily be generated using equipment specification diagrams provided by the manufacturers. There are also many software packages that allow the user to take a number of digital pictures of a piece of equipment from specific points, and then
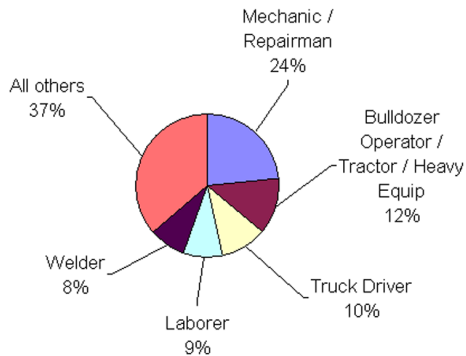
Figure 1: Job Title of Reported Surface Coal Injuries (1995-2001) based on MSHA data.
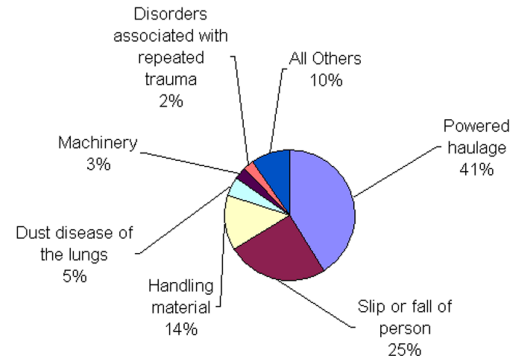

Figure 2: Accident, Injury or Illness Classification of Surface Coal Truck Drivers (1995-2001) based on MSHA data.

compile the pictures into a 3D model.

• The third step is to create VR models of mining activities (i.e., a shovel loading, a shovel dumping, etc.) and mine environments. The mining activities can easily be generated for several different situations and added to the library. Also, typical mining environments that present dangers such as high walls, haul roads, etc., can be created or generated and included in the mining environment library. For some specific incidents, it will be necessary to use mine design software to create the mining environment. This does not present a major problem because most mine design software are capable of creating a Digital Terrain Model (DTM) that can be used in the 3D software used for the mine accident recreation. A detailed approach to recreating an incident is included in the next section.

• The final step is to combine these libraries of miners, equipment and environments into a configuration. When these libraries are in place, an incident can be depicted in a dynamic form very efficiently and effectively. For individual mining companies, listing the typical equipment that is used in the mining process, such as haul trucks, can start creation of these libraries, excavators, etc. then begin to make models of the equipment.

Computer Tools: The main computer software tools used to develop a VR recreation are:

• Computer Aided Design (CAD) software, and
• Three-dimensional rendering software.

The hardware requirements can generally be satisfied by modern desktop computer configurations. Usually such computers need to be equipped with above average memory space and a good graphics card to meet software requirements.

VR RECREATION OF ACTUAL INCIDENT

Selecting an Accident with High Training Impact

To demonstrate the procedures involved in creating a VR recreation, a specific case study was chosen. The case chosen for this demonstration was selected for a high training impact and, thus, had to meet the following criteria:

• A common accident at surface coal mines
• The direct result of unsafe work practices
• An unsafe work practice that would be difficult to recreate with live equipment and miners
• An unsafe practice that could be changed

The first step in the selection process was to identify who is normally injured at surface coalmines. This was accomplished using MSHA's 30 CFR part 50 information. As already mentioned, this data is available on the MSHA website. It is actually the raw data entered

by MSHA from form 7000-2, filed by mine operators. To complete this task, data for a six-year period was reduced and incident statistics were generated.

Figure 1 shows the job title of all reported surface coal injuries from 1995 to 2001. This chart shows that mechanics or repairmen are the most likely to be injured and that truck drivers or dozer operators are the next most likely occupations to be injured.

It was decided that it would be beneficial to analyze accident types for truck drivers and to examine the data to determine whether accidents resulted from a particular unsafe behavior that met the criteria set out above. Figure 2 shows the accident, injury or illness classification that is assigned by MSHA to the reported accident. Although the majority of accidents are classified as powered haulage, a large percentage of the accidents are "slip and fall". While investigating the "slip and fall" accidents it became clear that there were several accidents that involved truck drivers jumping from their trucks.

The average incident involving a truck driver jumping from the vehicle resulted in approximately 52 days lost. The average surface coal powered haulage accident results in approximately 32 days lost. From 1995 to 2001 there were two fatalities that involved a truck driver jumping from the cab.

Because surface haulage is associated with large percentage of accidents, a high volume of truck driver training material is currently available, including several VR training applications related to truck driver training. However, the "slip and fall" incidents, as described above, present a different aspect of truck driver "training". Therefore, one of these two fatalities was chosen to be modeled in a VR recreation. The desired result of this recreation is to promote the use of seat belts and proper pre-shift checks.

In this accident a fuel truck driver was driving an old fuel truck because his normal fuel truck was being serviced. While driving down the haul road the brake appeared to fail. The driver jumped from the truck, rolled an unknown distance and was killed by his injuries. There were no witnesses to the accident. The fuel truck continued down the haul road and struck an idle Caterpillar 777B haul truck. The fuel truck burst into flames. A general diagram of the accident area and photographs are available in the accident report generated by MSHA. The accident was recreated using this information.

Tools Used

• Carlson Software's SurvCADD was used as the CAD package, and
• Disceet's 3D Studio MAX was used for the three-dimensional rendering software.

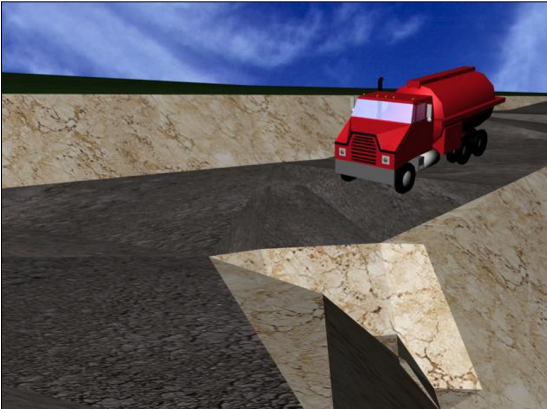**Figure 3: View of the Fuel Truck from Road Level**

Figure 4: View of the Fuel Truck from an Elevated Position

Figure 5: View of the Caterpillar Truck in Front of the Fuel Truck.

Modeling the Accident

The first step to bringing this accident into a VR recreation was to draw a generalized mine. This could be done in a CAD or a mine design program. In this case the mine was drawn using several functions in SurvCADD. Once the mine was drawn, a DTM was created, also using SurvCADD. The DTM is a collection of triangle surfaces that was used in this case to describe the surface of the haul road. After the DTM was created, all work in the CAD program was completed.

In the next step, the DTM was directly imported into 3D Studio MAX. A material was then applied to the DTM to give it a similar appearance to the mine involved in the incident. 3D Studio MAX offers the user unlimited potential to organize scenes and precisely manipulate objects. However, the user should simplify complicated

scenes (accidents) to allow for ease of application.

With the mine in place, the vehicles were created. The fuel truck was not directly available in the model library. However, it looked very similar to a water truck that was in the library. 3D Studio MAX was used to change the trailer on the water truck to more closely resemble a fuel truck's trailer. In the case of the Caterpillar haul truck a model was created from scratch using 3D Studio MAX functions.

With the mine and vehicle models ready, an animation could be done to recreate the accident. First the vehicles were placed in the approximate locations where they would initially have been before the accident. The animation performed had the following sequence:
  • the truck ran down the haul road,
  • the truck door opened,
  • a man jumped out of the cab and rolled on the ground
  • the fuel truck collided with the haul truck and an explosion was created

Several virtual cameras were placed in the scene so that the accident could be seen from a variety of vantage points. Static pictures of this animation sequence are shown in Figures 3-6.

Modeling Output

Most rendering packages (including the 3D Studio MAX platform) offer a variety of output scenarios for any given animation sequence:
  • Static prints
  • Video presentations
  • PC-based interactive animations
  • Web-based interactive animations

In this case, the animation was exported into virtual reality modeling language (VRML) so that it could be viewed using a web browser. The latter was tested using the web browser plug-in Cosmo Player.

SUMMARY AND CONCLUSIONS

Continuous personnel training should be used as a means of establishing and promoting a strong safety culture in the mining environment in order to help prevent accidents. Low cost VR reconstruction of accidents is a valuable training tool, in the same way that many professional sports use videotape of performances for game evaluation

Although computer generation of VR requires large amounts of computer memory, processing power, and high-speed human interaction (Durlach and Mavor, 1995), such requirements can easily be met by today's personal computers. Advancements in computer technology have generated low cost high-powered personal computers that are capable of processing complete VR based accident recreations.

This paper details a straight-forward procedure (based on a case study) that can be used by mining or mine support companies to develop compelling health and safety training programs using actual accident scenes as the working base.

During compilation of the case study, it was verified that surface haulage is a major source of accidents, but also that "slip and fall" incidents made up a large proportion of haulage accidents. Although a high volume of truck driver training material is currently available, a different aspect of truck driver "training" was presented by modeling the consequences of abandoning a moving fuel truck with failed brakes. The purpose of this recreation is to promote safe equipment handling at all times, including emergencies, as well as to promote rigorous pre-shift checks.

Figure 6: View of the Fuel Truck as is Collides with the Caterpillar Truck

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