APPLYING VIRTUAL REALITY TO ONTARIO MINE RESCUE OPERATIONS

Alex Gryska, Manager Mine Rescue
Mines and Aggregates Safety and Health Association
(MASHA)

2005

ACKNOWLEDGEMENTS

Research relating to this Virtual Reality project was conducted by Dr. Paul Dunn, MIRARCO; Prof. Tammy Eger, Laurentian University and Mr. Matthew Haywood, MIRARCO.

Funding for the project was provided by the Workplace Safety & Insurance Board, Ontario, Canada.

Technical contributions regarding the design and content of this project were provided by Charlie Burton, Supervisor Ontario Mine Rescue of the Mines and Aggregates Safety and Health Association (MASHA). MASHA's Mine Rescue Technical Advisory Committee which consists of major Ontario mine employers, workers, government and MASHA staff provided feedback and ensured relevance during the development of the demonstration project.

ABSTRACT

Ontario mine rescue was first established to respond to underground mine fires. Today mine rescue crews are trained to tackle both fire and non-fire emergencies. Minor incidents can quickly escalate to impact on human life and property because of the enclosed environment and the unforgiving nature of underground mines. When an incident requiring the services of mine rescue teams occurs, good decisions need to be made by the teams responding to the emergency and by the control group that provides them guidance. Communication between the two is vital and a poor decision can result in serious consequences.

This project explores the benefits of using Virtual Reality (VR) as a simulation tool to aid in training mine rescue teams and as a decision-making tool for the control group during an emergency. The goal of this project was to determine what information to display in VR to best aid the rescue process, and to identify the most promising training methods using VR. Once determined, it was the purpose and objective of this development project to enable MIRARCO to detail a full proposal on the requirements to develop VR capability for mine rescue applications.

The outcomes from this project were a demonstration 3D model which highlights how a control group could use VR and its additional benefits to current best practice methods. The research documented in this paper is directed at defining the technology limitations and exactly what can be achieved to enhance control group training and mine rescue operations.

Several groups were asked to view the demonstration model in the Virtual Reality Laboratory (VRL) and were asked to provide technical input and advice regarding further developments. This resulted in the following recommendations:

1. Develop the model for more complex mining scenarios. Realistic fire fighting and other emergency scenarios should be investigated.
2. Incorporate mine ventilation network to accurately reflect smoke levels from randomly generated fires.
3. Incorporate geomechanics information into the emergency scenarios.
4. Use the VRL to transfer and educate the mining industry as to the issues faced by Mine Rescue Control Groups (MRCG) in emergency situations.

CONTENTS

LIST OF FIGURES

1. INTRODUCTION

Our existing mine rescue model was established in Ontario, Canada after an underground mine fire at the Hollinger Mine in Timmins took the lives of 39 miners in 1929. Since that time, the organisation has continued to evolve and today we provide emergency response to both fire and non-fire incidents. Equipping our teams with the best equipment available and training them to handle any foreseeable emergency is essential to their well-being and that of our mining industry.

The number of mine emergencies, requiring the services of our first responders, has continued to decline over the years and today sits at an all time low. This envious record can result in complacency which ultimately could result in tragedy if not addressed. MASHA recognizes these realities and is collaborating with academia and mine operators to make improvements that will result in better prepared mine rescue teams and control groups that guide them during emergencies.

Every incident that requires the services of Ontario mine rescue is investigated and analyzed to see if there are any inherent weaknesses or shortcomings that can be improved upon. This information is shared with our Technical Advisory Committee who cascade the information to their operations and also identify improvement opportunities including research.

The mandate of MASHA’s Technical Advisory Committee (TAC) is to provide advice and make recommendations regarding equipment used, the contents of the mine rescue handbook and identify areas of research that will result in improvement to the program. The committee identified VR application to mine rescue as a possible research project and recommended it be explored.

MIRARCO has been investigating VR applications and VRL technology for several years and have successfully applied this technology to mining-related projects. The benefit of this technology is most significant in circumstances where visualisation is critical to improved decision making. Because of the complexities of underground mining and the vast number of variables encountered during a mine emergency it was felt that applying VR technology to mine rescue would be a good fit.

1.1 Research Objective

The research focused on producing a Virtual Reality (VR) environment for Mine Rescue Control Groups (MRCG). The purpose of the VR models was initially directed at training control groups; eventually, they may prove to be useful on mine sites as the control centre for mine rescue emergency response. The goal in this development project was to provide a demonstration model which would allow the environmental conditions to be adjusted, mine layout to be selected and would highlight the potential of VR for mine rescue control group training and integration of available data. The configuration would be established by the MRCG demonstration model in order to challenge teams or individuals in making good decisions in emergency situations.

The three objectives for the MRCG development project were:

1. To conduct a review of the full capability required for the VR model. This would include the detailing of communication and data requirements for control groups during emergency situations. Mines and Aggregates Safety and Health Association (MASHA) would provide guidance in this task.
2. To build a mine model for evaluation for mine rescue control group training. This would be used to determine the current capability and research required to produce a fully functional control group training environment. The MASHA Mine Rescue Technical Advisory Group would provide feedback in the generation of this model and in identifying control group training requirements.
3. To transfer knowledge on current VR safety capability with mine rescue interest groups, to get as much feedback as possible before preparing a full proposal.

1.2 Scope

The research design was focused on delivering the above objectives through the following:

1. Detailed review of control group training functions and meeting with mine rescue personnel to define the full scope and capability requirements for the VR model.
2. Build a VR model of a pre-determined mine site already used for control group training. Incorporate current capability into the VR model. Identify the research required to produce a fully functional control group VR training model.
3. Conduct workshops, with invited mine rescue groups, in the Virtual Reality Laboratory (VRL) with the demonstration VR model and obtain feedback on what is required for control group training.

The development project has lead to a full project proposal in 2005 which has resulted in obtaining funding for the next phase of the VR project.

2. OVERVIEW

2.1 Background

Mine rescue programs were first established solely to respond to fires underground. However, mine rescue crews today are trained to tackle all types of non-fire emergencies, and to rescue workers who may be trapped or injured. A “control group” is an assembly of individuals from a mine that verbally guide mine rescue teams during an emergency. These individuals have in-depth knowledge of their particular operation. Under most circumstances, they are located on surface and communicate via telephone with a team that is performing the task (fighting a fire, rescuing a trapped miner, re-ventilating a mine etc.). The composition of the control group varies with the nature of the emergency. It may consist of senior mine management, ventilation experts, and other specialists (e.g. ground control, electrical, mechanical, etc.). The group provides information and guidance to the mine rescue team(s) during response to an incident and ensures their safety. The control group is therefore responsible to make decisions that, if not managed appropriately, could potentially jeopardize the safety of a rescue team.

This project provided an opportunity to strengthen university – industry – H&S group links. Prior to this project, MIRARCO - Laurentian University together with MASHA have been working hard to enhance relationships with industry, to encourage trust between industry and academia, and to provide the highest-technology infrastructure available for industry-related research and development. This effort has resulted in various collaborations with industry and safety-oriented groups, and a growing reputation for innovative approaches to tackling complex research questions. The current research opportunity has expanded the existing links to other user groups in a mine, namely control groups and mine rescue personnel.

The methodology for this development project was as follows:

1. Basic Model Creation - Create a 3-D demonstration model for control group training (Management Program) of the fictional Regional Mine.
2. Model Integration - To make the model useful for control group training the following elements needed to be considered for inclusion:
    a. geomechanics data
    b. ventilation data
    c. simulation of communications from mine rescue teams to the control group
    d. simulation of randomly generated emergency situations

This objective of the development project was to create a sample mine and demonstrate the potential of using a VR environment for control group training and not to provide full MRCG simulation capabilities. Through meetings with the MASHA (TAC), feedback on the capability requirements was obtained. The end result is a "wish list" of capability requirements for MRCG training. These were then prioritized and incorporated into the proposal.

As this was the first attempt at combining both organizational mine rescue management information and interactive VR immersive environment for control group mine rescue training, the main intention of the development project was to create a small version of the simulator for review. This simulator was then presented to the TAC for feedback on the usefulness of this approach and to provide guidance on the future research and development required.

In order to provide a satisfactory VR training model for the MASHA advisory committee to critique, the following tasks and methodology were adopted:

Task 1: The content and delivery methodology for MASHA's existing control group training program were reviewed. A breakdown of detailed training objectives was produced. These objectives were met by the VR training simulator produced in the demonstration project.

Task 2: An interactive VR model of the current control group training mine was constructed. (The existing course materials are 2D paper mine plans and considerable work was needed to develop a fully interactive 3D stereo VR model).

Task 3: Appropriate safety documentation and communications were incorporated into the VR model to help demonstrate the problem-solving capability of the model. A mid-project review was conducted to evaluate the initial VR model development and identify the required documentation and communications to be incorporated. Emergency response documentation, safety procedures and real-time communications were incorporated into the demonstration model and thus identified the main training components requiring further investigation.

Task 4: A final review was held with the full MASHA advisory committee and was a primary evaluation for the project. Minutes were taken from the advisory group meeting where the VR training simulator was reviewed in the state- of-the-art VRL at Laurentian University.

Task 5: Following endorsement of the group training immersive VR model by MASHA's technical advisory committee, a full proposal was prepared for the WSIB Research Program.

The MRCG model was developed as follows:

1. Create the 3D mine model from the 2D mine plan in the MRCG training documentation.
2. Apply a texture to the 3D model by using a jpg image and manually aligning it to the 3D mesh for all viewable surfaces in the Regional Mine Model.
3. Set up the camera paths to allow for full rotation around the entire mine model.
4. Create all possible paths that the mine rescue team could take while trying to locate the mine emergency and/or trapped miners.
5. Create menus for accessing the mine documentation and link these to the appropriate documentation.
6. For the fire emergency scenario, develop a step-by-step outline of the correct way the control group should direct the mine emergency.
7. Create checkpoints where the mine rescue team will prompt the control group with information or for direction.
8. Create prompts to guide the control group to make the proper decisions at each stage of the emergency such that the less-correct decisions do not lead to a fatality situation but are corrected as the control group progresses through the emergency.
9. Create and texture a five-person mine rescue team for checkpoint cameras to view. This would result in greater realism when viewing the team's location within the mine and at each checkpoint.

Effective communication between the control group and mine rescue teams underground is critical to good decision making and problem solving. To thoroughly understand critical components of the mine and pertinent aspects relating to the emergency, information is grouped under the following topics and these were subsequently integrated into the demonstration model. During the exercise, information regarding the following topics is collected and recorded electronically.

1. Availability of air and water,
2. Electrical supply and distribution,
3. Mine ventilation,
4 Location of refuge stations,
5. Availability of tools and supplies,
6. Availability of communication between teams and control group,
7. Ground support in the mine,
8. Fuel storage underground,
9. Burning and cutting permits,
10. Type of hoist conveyance,
11. Explosives underground, its availability and distribution throughout the mine,

12. Location of escapeways,
13. Anticipated hazards and obstructions to travel,
14. History of mine gasses,
15. Location and number of workers,
16. Mine rescue teams and their availability,
17. First aid training,
18. Location of fresh air base,
19. Fire-fighting equipment and availability,
20. First aid equipment availability,
21 Fire procedures.

3. RESULTS

MASHA guided the development of detailed communication between the mine rescue teams and the control group based on real life experiences. It was decided that in order for the control group training to be most effective using the VR model, the simulation would function as though there was communication solely by using underground phones at specific checkpoints rather than having continuous communication via radio phones. The simulation has communication via text messages at these checkpoints to and from the mine rescue team. MASHA provided all relevant documentation with respect to mine procedures for their Regional Mine training model all of which were incorporated into the simulation. These included:

1. Mine description,
2. Emergency procedures,
3. Available mine equipment and personnel, and
4. Duties for mine personnel.

The *mine description* includes details relating to location of the mine, neighbouring operations, type of mine, extent of workings, production areas etc. This provides sufficient information for the control group to thoroughly understand the mine in which the emergency is unfolding and any limitations they are confronted with.

Emergency procedures indicate what is to be done in the event of a fire including: who to call, what information to convey, where to go and how to request the injection of stench gas. The procedures integrated into the demonstration model are based on Ontario legislated requirements and standard mine rescue practices.

Availability of mine equipment and personnel provides information regarding distribution of workers throughout the mine, number of available mine rescue personnel on site and a detailed listing of available mine rescue equipment including where the equipment is located.

Duties of key mine personnel indicate the actions these individuals will take in the event of an emergency and these are integrated into the interactive working of the problem.

A 3D mine model was created from the 2D plans currently used in mine rescue control group training exercises (Figures 1-6). The “Regional Mine” model consists of an adit, a single shaft, one level consisting of an east and west drift, and a surface area with various buildings. The 3D model is viewable from all sides by manipulating a camera which can rotate around the mine model, allowing a control group to view the whole mine from any side or angle at any time. For the demonstration project, it was decided that a fire emergency scenario would be used with two randomly-generated fire locations so that it could be shown that the mine emergency can be different with each successive restart of the simulation. The Regional Mine documentation was added so that a review of procedures and available equipment could be accessed at any time during the simulation. While the simulation is running and once the emergency is conveyed to the user, options are presented to simulate the decision making process of the control group who would be in charge of managing the mine emergency.

Using a tree structure of successive decisions for prompts, the user of the mine simulation is guided through the decisions needed to properly instruct the mine rescue team through the emergency. With each step, the mine rescue team can be located in real time within the mine model. At pre-set checkpoints, the camera jumps into the model simulating the environment inside the mine, with textured drift walls, a five-man rescue team, and relevant emergency simulations, such as smoke in the case of the fire emergency in this development project. These checkpoints for the mine rescue team were based upon MASHA's recommendations from mine rescue training sessions using the Regional Mine model. It was also decided that rather than using a numerical scoring system, the penalty for making wrong or less correct decisions would be additional travel time.

Six separate workshops were conducted with target interest groups (five with the TAC and one with organised labour) to obtain feedback on what is eventually required for control group training. These sessions allowed for the gathering of as much feedback on the VR demonstration model as possible before submission of the full project proposal.

4. DISCUSSION

All objectives of the project were achieved and a demonstration MRCG training module was developed. The model has been presented to numerous groups during the development of the project and the feedback was extremely favourable. Control group trainees have viewed the model and indicated that the Virtual Reality model is a powerful training tool that will result in improved decision making. The Mine Rescue TAC recommended that the next phase of research integrate more complex fire and non-fire scenarios, a variable ventilation network and geomechanic elements to the model.

5. CONCLUSION

The 3D Regional Mine model was created from 2D plans and was used to determine capability and to identify the research required to produce a fully functional control group training environment. Communication and data requirements were incorporated into the VR model allowing for effective training for control groups during an emergency fire situation.

This development project was able to provide a MRCG simulation based on a relatively simple mine layout. It created a sample mine VR model which has demonstrated the potential of using a VR environment for MRCG training. This has been reviewed by the MASHA Mine Rescue Technical Advisory Committee and control group training attendees and their feedback on the improved decision-making capability has been very favourable. The main feedback from the advisory committee has been that site-specific training would be a major step forward in control group training.

The research in this demonstration project not only developed a technology that can enhance training, but will also be useful in helping mine rescue teams deal with emergency situations in a VR environment.

VRLs are proven to be excellent knowledge transfer and data comprehension facilities, where the impact of emergency situations on mine worker health and safety can be better understood and transferred efficiently to targeted individuals. The models definitely help raise awareness of emergency response situations to people outside of mine rescue operations.

6. REFERENCES

"Using Virtual Reality in Mine Rescue Operations" by Paul Dunn, Tammy Eger and Matthew Hayward, Laurentian University, 2005.

"Handbook of Training in Mine Rescue and Recovery Operations 2001" The Mines and Aggregates Safety and Health Association (MASHA).

7. FIGURES

VR MODEL SCREEN CAPTURES

The following are screen shots taken from the MRCGT module.

Figure 1. View of the Regional Mine with starting emergency situation.

Figure 2. Inside view of the rescue team reaching a checkpoint in the winze hoist-room.

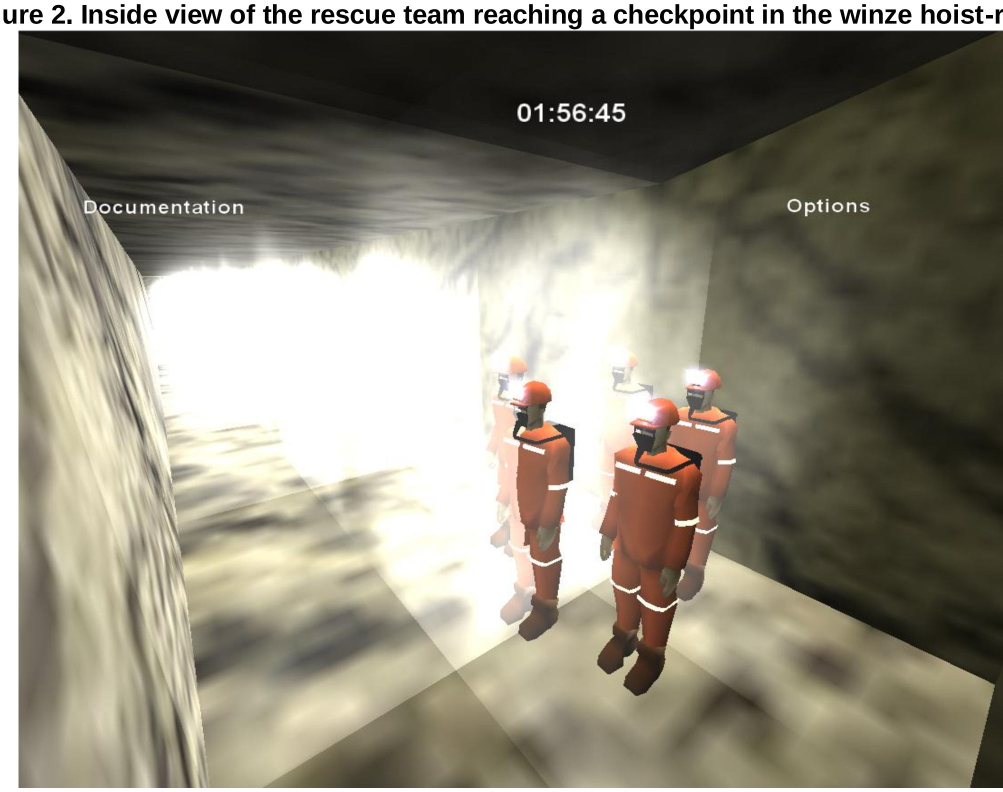

Figure 3. Rescue team reaches the hoist-room at 100 level.

Figure 4. Rescue team asks for a decision as to which direction they should go.

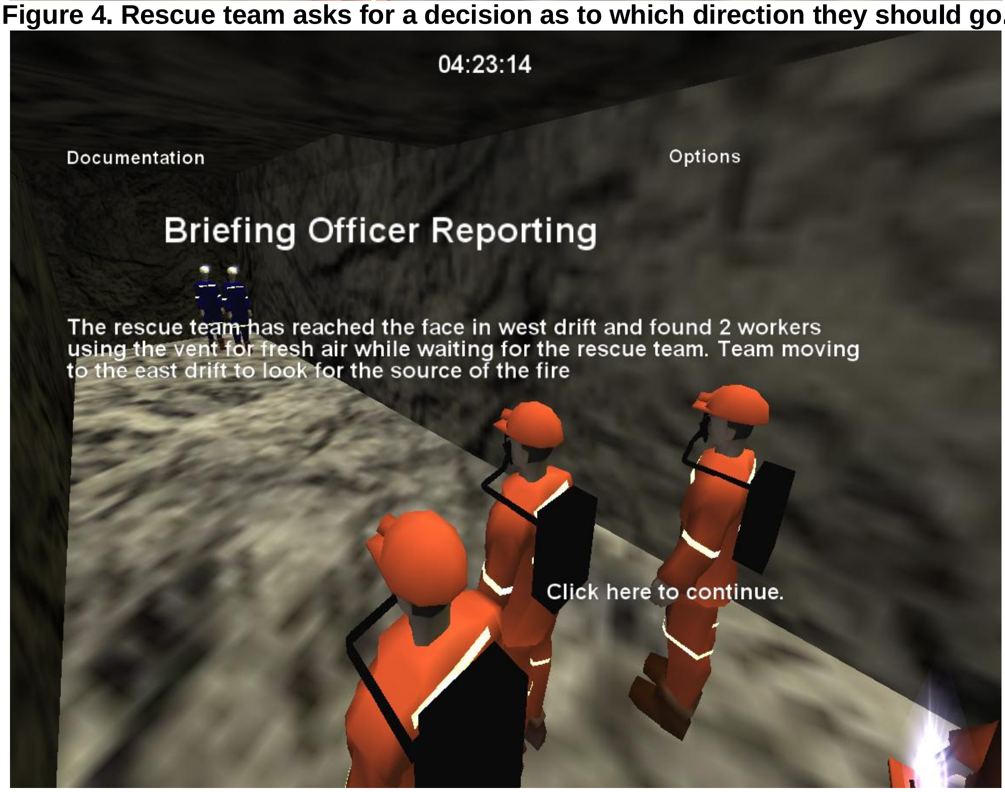

Figure 5. Rescue team finds 2 of the missing workers in the west drift.

Figure 6. Rescue team locates the fire in the east drift.

Figure 7. First person view as the rescue team nears the fire.

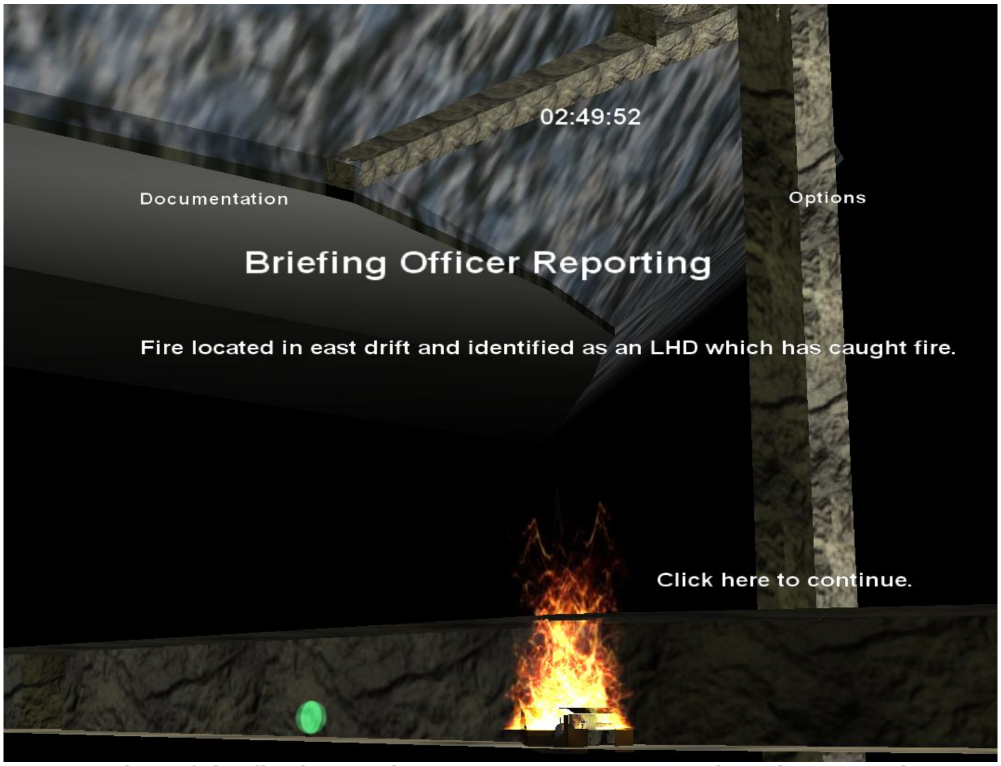

Figure 8. Location of the fire is now known, rescue team location shown as the green dot.