proximity-triggered hazards and time-triggered hazards. A proximity-triggered hazard is one that would appear when training vehicle moved close to it. For example, when the vehicle approached a surveyor's truck, the surveyor may walk out in front of the vehicle from behind his truck. A time-triggered hazard is one that occurs at a certain time in the simulation. For example, a truck may begin moving from a parked location, or a rock slide may occur.

3.3.4 *Distributed architecture*

To further enhance the realism of the simulation, we are considering creating a distributed version of MVDS which will allow multiple trainees to be in the same simulation at the same time. The trainees will have to interact with each other as well as with other hazards that may already be in the scenario. Trainees will have to deal with unpredictable behavior of other trainees, completely eliminating the possibility of the trainee memorizing the situation being presented.

A distributed version of MVDS will also allow trainers to watch the trainees from a separate room, where trainees will not be aware of the close monitoring. The trainer will have multiple views of the simulation: one of the entire mine, with all of the trainees' positions, and one shadowing a specific trainee. When shadowing a trainee, the trainer will be able to get detailed information on what the trainee is doing. The trainer will be able to see the distance between the trainee's vehicle and other vehicles in the area, read all of the gauges on the trainee's dash, and have a small window showing the 3D model of the mine that the trainee can currently see out of the windshield. This will allow the trainer to monitor those trainees that are just beginning more carefully than the experienced ones, without hanging over their shoulder.

Another advantage of a distributed version of MVDS will be faster reaction to user input. By taking the computationally intensive portions of MVDS and dedicating a machine to those processes, the graphics will be displayed on the trainee's machine at a much faster rate. This will also allow the computationally intensive portions to run faster as well, since they will not be competing with the graphics for the machine the trainee is using. By separating the graphics and other portions, we will be able to improve the performance and capabilities of the entire program.

4 CONCLUSIONS AND OTHER PROJECTS

Initial responses to MVIS [1] and MVDS [2] have been extremely positive. The fact that these tools have been developed for the PC platform has been very appealing to the mining industry, since most companies use this platform.

There remains a great deal of work that can be done with VR in the areas of mining and mine safety. Besides the enhancements to the products we have outlined in this paper, we are also investigating applications for underground mines. Our investigations would complement the research already under way in the development of the Mine Emergency Response Interactive Training Simulation (MERITS) [3] being done at the NIOSH Pittsburgh Research Lab.

Mine regulations require extensive emergency training for underground mine personnel. Current training programs take considerable time and effort on the part of miners, supervisors, and trainers and do not adequately prepare mine personnel to handle complicating factors such as blocked routes, failure of lighting, and reduced visibility due to smoke. A VR training system would improve the convenience and quality of training, allowing a mine to better equip its personnel to handle emergencies. VR training would also provide rescue teams better training for emergencies in many mines without having to visit those mines for training.

Although virtual reality simulators are not new, employing such simulators to reduce training costs and accident rates is relatively new to the mining industry. VR training brings together the cost effectiveness of written and video-based training materials with the training effectiveness of practical experience.

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