SME Annual Meeting
Feb. 24-Feb. 27, 2008, Salt Lake City, UT

Preprint 08-054

EVALUATION OF A VIRTUAL REALITY SIMULATOR DEVELOPED FOR TRAINING NEW MINERS TO INSTALL ROCK BOLTS USING A JACKLEG DRILL

D. Nutakor, Univ. of Missouri-Rolla, Rolla, MO
D. Apel, Univ. of Missouri-Rolla, Rolla, MO
L. Grayson, Univ. of Missouri-Rolla, Rolla, MO
M. Hilgers, Univ. of Missouri-Rolla, Rolla, MO
R. Hall, Univ. of Missouri-Rolla, Rolla, MO
J. Warmbrodt, Univ. of Missouri-Rolla, Rolla, MO

Abstract

The ability of computers to create synthetic representations of the real world in virtual reality offers a number of opportunities to enhance training methods used in the mining industry. Unfortunately, the training effectiveness of virtual reality systems currently used in the mining industry has received only limited testing. Miner Simulation (MinerSIM), an augmented reality system with integrated hypermedia suitable for training underground miners in the basics of using a jackleg drill to install rock bolts in a virtual mine environment is in its evaluation process at the University of Missouri-Rolla Experimental Mine. This paper discusses evaluation methodologies of the MinerSIM system, which consists of experimental and control groups with control students learning via traditional lecture and text formats. Preliminary results from usability tests of the first part of MinerSim, which is an online tutorial on underground rock bolting, are presented.

Introduction

Miner Simulation (MinerSIM), which is an augmented reality system with integrated hypermedia that is suitable for training underground miners in the basics of using a jackleg drill to install rock bolts, is being evaluated at the University of Missouri-Rolla Experimental Mine. The fundamental goal of the MinerSim system was to create a prototype, which would demonstrate the feasibility of a virtual environment as a viable tool for training new inexperienced underground rock bolters. The ongoing evaluation is in two parts including (1) evaluation of a Web-based tutorial on underground rock bolting and (2) the evaluation of the virtual reality computer simulation system.

The overall goal of the multimedia part of MinerSim was to use a variety of stimuli (symbols, images, animation, sound, and videos) to introduce trainees to basic principles of ground control and rock bolting using a jackleg drill before they use the virtual reality computer simulator. The content is organized in modular format of three sections (scaling, jackleg drilling, and rock bolt installation) with quizzes at the end of each section.

The primary development software used for this part of the training module is Macromedia Flash (Flash Professional version 8). Flash allows incorporation of 3D models and animation (generated using Macromedia Fireworks version 8 and Swift 3D version 4.5) into its authoring environment. A programming language in Flash (Action Script 2.0) was used for creating audio and video, and also to add interactivity to the system. Figure 1 shows the interface of the first part of MinerSIM.

The second part of MinerSim involves the use of the virtual reality computer simulator in which participants will be exposed to the dangers of underground rock bolting in a virtual way after using the Web tutorial. Figure 2 shows a schematic diagram of major components of the simulator with the function of each component shown in Table 1 (see Nutakor et al., 2007 for details).

Figure 1. Interface of the first part of MinerSIM showing the three sections and their quizzes.

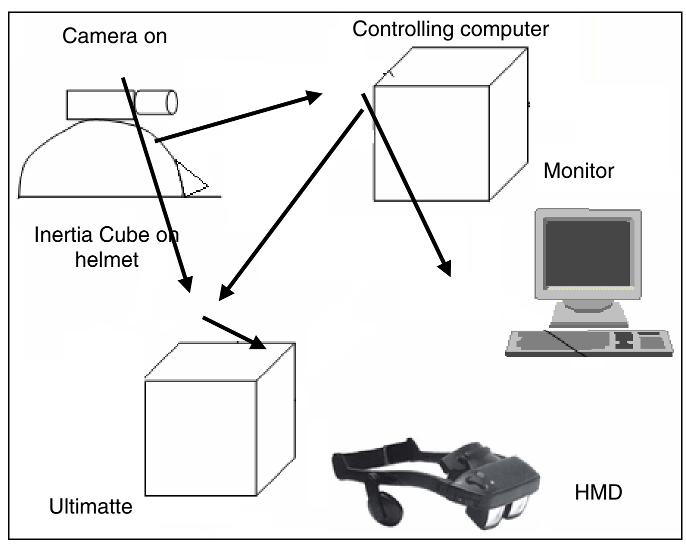

Figure 2. Major components of the computer simulator.

Overview of MinerSIM Evaluation

Sixteen students with no mining experience were randomly assigned to two groups (experimental and control) using the Research

Randomizer software. In order to create two random sets of participants, each participant was given an identification number. Then the Randomizer was used to generate two sets (representing the two groups of participants) of eight unique, unsorted numbers (representing the number of participants in each group) with a range from 1 to 16 (representing the total number of participants). The goal of random assignments was to give all participants an equal chance of being assigned to each group (regardless of how representative the participants are). In other words, random assignment equalizes pre-existing individual differences across experimental conditions. This makes it easier to infer any observed group differences due to the independent variable. Thus, random assignment tends to increase the internal validity of a study.

Table 1. Functions of Components of MinerSim.

Component	Function
Inertia Cube	Tracks the location of the trainee's head and sends data to the controlling computer
Controlling Computer	Produces the virtual environment and sends video to the Ultimatte
Camera	Captures details of the blue-room environment (hands, tools, blue walls) and sends video to the Ultimatte
Ultimatte	Takes the camera video and replaces anything blue with the video from the computer (the virtual environment)
Head-Mounted Display (HMD)	Takes combined video from Ultimatte which enables the trainee to see the virtual environment

The goals of the evaluation of the multimedia part include

- To collect quantitative data on participants' performance
- To determine participants' satisfaction with the online tutorial
- To identify any usability problems with the Web tutorial

The first goal of evaluation of the virtual reality computer simulator is to determine the degree to which the environment provided a realistic training experience, by considering participants behavioral and physiological responses within the environment, and their self report following the experience. A second goal is to determine the factors that appeared to be most important in mediating the degree to which the environment was experienced as realistic. The third goal is to identify additional functions that could be added to improve the effectiveness of the system.

A series of usability tests have been planned for the evaluation of both the multimedia part and the virtual reality simulation system in order to address some fundamental usability issues that often arise with complex augmented reality interfaces. Benefits of usability testing are associated with the increase of ease of use and productivity, and decrease in human error.

Evaluation of the Multimedia Part of MinerSIM

The evaluation process of the multimedia part of MinerSIM was divided into four main exercises, which are outlined below.

Exercise 1 involved all 16 participants taking quizzes (using a different set of questions for each group) on the three sections of underground rock bolting (scaling, jackleg drilling, and rock bolt installation), after which they used the tutorial and answered the same set of questions again. Participants in the experimental group used the online tutorial, while those in the control group used a hardcopy format of the tutorial, and therefore had no access to the videos and animation. The purpose of Exercise 1 was to quantify the amount of knowledge acquired by each participant by comparing participants' pre-tutorial and post-tutorial performances.

In Exercise 2, participants in both groups were given the same set of questions on the basics of underground rock bolting including the identification of tools used in rock bolting. The intent of this exercise was to compare the performance of the two groups to see if there was any significant difference. The JMP statistical program (Sall et al., 2001) was used to analyze data collected in Exercises 1 and 2, using the paired t-test for Exercise 1 data and the unpaired t-test for Exercise 2 data.

Exercise 3 involved only the experimental group in which participants were asked to complete a confidential survey questionnaire about their prior experience with an online tutorial, and their opinions on the overall effectiveness of the MinerSIM online tutorial. The main goal of this exercise was to determine participants' satisfaction with the online tutorial. The survey question formats used in this exercise included Dichotomous, Likert, and Filter or Contingency response format questions.

Considering the subjective nature of Exercise 3 in identifying problems associated with the use of the online tutorial, a Morae recording device is currently being used in Exercise 4 to capture live action feedback regarding usability problems. Morae is a software for usability testing and user experience research that helps identify site and application design problems. It is used to make critical design changes that improve customers' satisfaction. Morae records all of a user's interactions with a Web site, including desktop activity, audio, video, and a complete chronicle of system events, all synchronized into a single file. The recorder also allows one or more forms of remote observation. Observers view screen video, user video (picture-in-picture), and audio streams, which are automatically synchronized. Additionally, observers can record a digital video file of the displayed content, which can be viewed and shared immediately after the recording session. The Morae manager allows automatic calculation and graphing of standard usability metrics including effectiveness, efficiency, and satisfaction. Figure 3 shows the Morae recorder system setup.

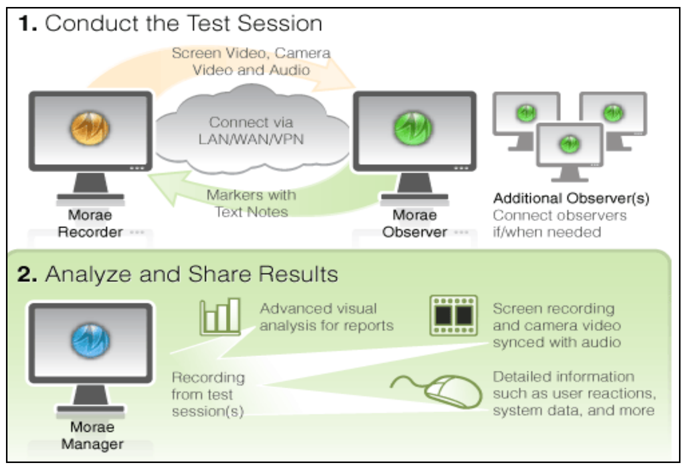

Figure 3. Morae Recording Device System Setup.

Exercise 1 was carried out from October 8 through November 14, while Exercises 2 and 3 were carried out from November 19 to December 5, all in 2007. Exercise 4 is ongoing, and its results together with evaluation results from the virtual reality computer simulator will be published in a subsequent article.

Preliminary Evaluation Results

Analysis of Exercise 1 Data

Parametric and non-parametric analysis of Exercise 1 data using the JMP Statistical Discovery Software indicated that the participants' post-tutorial mean scores are significantly higher than the pre-tutorial mean scores (p values less than 0.05) for all the three sections. Figures 4 and 5 show participants' mean scores for the experimental and the control groups, respectively.

Differences in pre-tutorial and post-tutorial mean scores are 28%, 25%, and 28% for scaling, jackleg drilling, and rockbolt installation respectively for the experimental group; and 26%, 26%, and 38% for the Control group. Significance probability values for all the three sections at the 95% significance level from the parametric paired t-tests are the same as the results obtained from the Wilcoxon's non-parametric tests. The results are shown in Table 2.

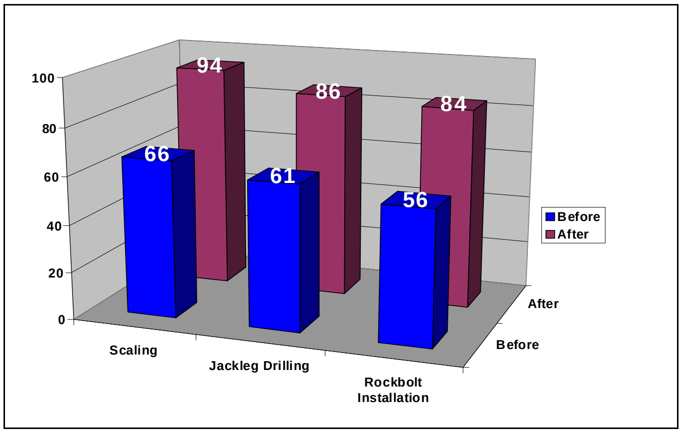

Figure 4. Pre-tutorial and post-tutorial mean scores for the experimental group.

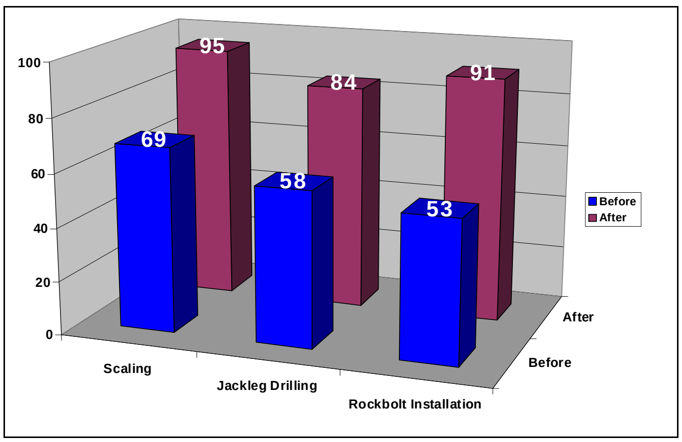

Figure 5. Pre-tutorial and post-tutorial mean scores for the control group.

Table 2. Significance Probability Values.

Group	Scaling	Jackleg Drilling	Rockbolt Installation
Experimental	0.0003	0.001	0.0008
Control	0.0017	0.0002	0.0001

Analysis of Exercise 2 Data

The unpaired Student's t-test performed at the 95% confidence level using the data obtained in Exercise 2 indicated that the mean score for participants in the Experimental group is significantly higher than the mean score for the participants in the Control group (p values from both t and f tests are 0.04 for a two-sided test). It is important to note that no significant difference was detected in terms of the average time taken by the two groups in completing the exercise. Figure 6 shows a one-way analysis plot of test-score versus participant group.

The participant group had a nominal modeling variable with codes for the two categories, "C" and "E" representing Control and Experimental groups, respectively. The test score data contains the response of interest, which is the continuous variable. Individual test scores are indicated with filled circles. The center lines of the means diamonds (green color) are the group means (68% for Control and 82% for Experimental), while the top and bottom of the diamonds form the 95% confidence intervals of the means. The quartile box plots (red color) show estimates of standard deviation in each group. The lower edge of the rectangle represents the lower quartile, the higher edge represents the upper quartile, and the line in the middle of the rectangle is the median. The interquartile range (the height of the boxes) indicating the variance in test scores is higher for the Experimental group. Additionally, results from power analysis indicates that based on the differences and variances in performance, only a total sample size of 13 subjects is required to detect a significant difference at 0.05. It is, however, important to note that the analysis assumes that the data are independent and normally distributed.

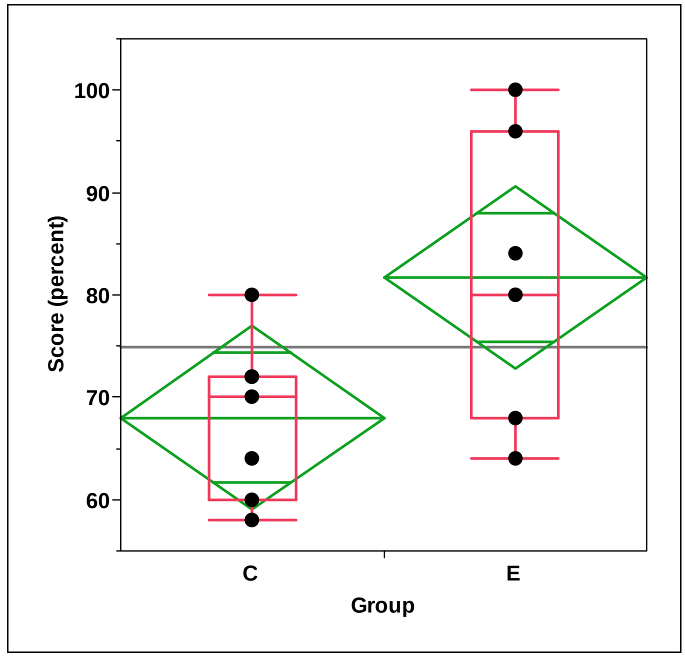

Figure 6. One-way analysis of test score by group.

Analysis of Exercise 3 Data

Table 3 shows the mean questionnaire scores of the Likert scale items consisting of seven closed-ended questions given to the participants in Exercise 3.

Table 3. Mean Responses on Questionnaire and Scales.

Item	Mean score*
The rate at which the Web page downloads.	5.00
How easy it is to get around the site.	4.88
Visual appearance of the site.	4.00
Quality of the videos.	4.13
How satisfied you are with the knowledge acquired in rock bolting.	4.75
How well the practice questions are related to the tutorial.	4.63
Overall effectiveness of the tutorial as a training tool.	4.75

*Scale: (1 = very poor; 2 = poor; 3 = fair; 4 = good; 5 = very good)

Results indicated that participants rated the overall effectiveness of the tutorial as a good training tool (total mean score is 4.75). Other responses received indicated that all the eight participants have been using internet for more than five years. Also, each participant had used an online tutorial to learn a task in the past.

When the participants were asked to indicate which of the four aspects of the tutorial (video, text, animation, and photograph) was most helpful to them in learning about underground rock bolting; five participants indicated videos, while each of the remaining three indicated photographs, text, and animation. Additionally, all the participants recommended using the online tutorial to train new inexperienced underground rock bolters.

Representative comments aimed at improving the tutorial include

- Reorganizing jackleg drilling and rock bolt installation sections into sub-sections to avoid overloading a user with information in one section.
- Practice questions need to be more uniformly distributed taking into consideration the contents of the videos and the

text material.

- Non-documentary videos need to be replaced with documentary types, so that a user will understand all activities being carried out in the video.

Conclusions

The results obtained from this preliminary usability test indicated that a Web-based tutorial (if designed well) could be a very useful learning tool in teaching a trainee the basics of performing a task before the person uses a virtual reality computer simulator. It can be concluded from the questionnaire results that the tutorial was easy to use and participants benefited from its contents. However, representative comments aimed at improving the tutorial will be carefully considered during the re-design stage. It is acknowledged that the usability test involved a small number of participants, and therefore the results obtained cannot be generalized as representative opinions of other sample populations.

References

1. Nutakor, D., Apel, D.A., Grayson, R.L., Hall, R., Hilgers, M., and Warmbrodt, J. “Virtual Reality Simulator for Training Miners to Install Rock Bolts Using a Jackleg Drill”. SME Preprint No. 06-039 for 2007 Annual Meeting in Denver, Colorado, 5 pp.
2. Sall, J., Lehman, A., and Creighton, L. (2001), “JMP Start Statistics, A Guide to Statistics and Data Analysis”, 2^{nd} ed., SAS Institute Inc., Canada, 491 pp.