Interactive Training for Mobile Equipment Safety: Targeting Safety Attitudes and Beliefs

Hazards are ever-present in the steel plant environment, and a heightened awareness and emphasis on safety is a necessary priority for our industry. This monthly column, coordinated by members of the AIST Safety & Health Technology Committee, focuses on procedures and practices to promote a safe working environment for everyone.

This article features a report from one of the recipients of the 2016–2017 Don B. Daily Safety Grant.

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Mobile equipment strikes are one of the leading causes of fatalities in the steel industry. The project detailed in this paper was built on an existing fall protection simulator to integrate mobile equipment hazards and developed new modes of interacting with the simulator to target attitudes and beliefs of steel industry workers with different levels of experience. The software provides an interactive virtual environment where workers are guided through a work task and experience the consequences of unsafe behaviors. The virtual training scenario includes a task at height, but requires the trainee to move through a multi-hazard environment where they must demonstrate constant awareness of their environment to accomplish the task safely. The simulator can be used in multiple modes including first-person mode, where the trainee controls a virtual avatar to accomplish a task safely, and Buddy Mode, where the trainee observes someone else failing to follow safe procedures and must intercede before they harm themselves.

Introduction and Literature Review

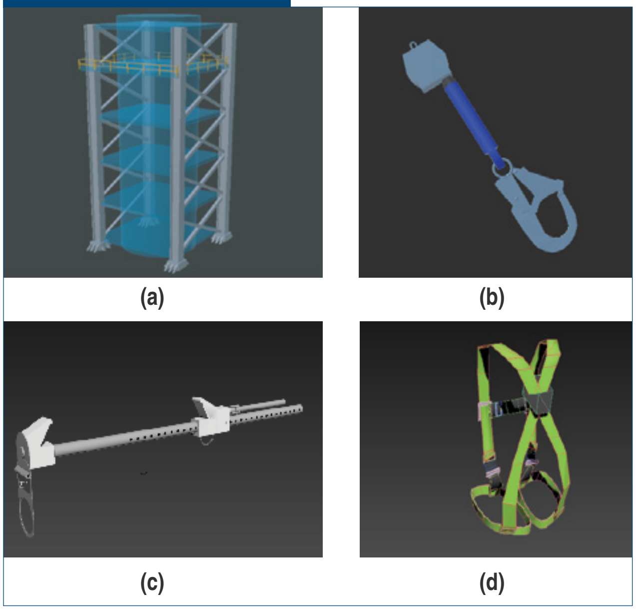
The iron- and steelmaking industry is home to many hazards.[1] Every year, workers are injured or killed due to improper safety procedures, putting a significant strain on families and co-workers. Compared with other hazards, falls are one of the leading causes of death in the steel industry.[2] The need for safety training has been emphasized by the industry, but it is often difficult to take effective steps toward increasing awareness of the consequences of improper safety procedures. It is essential to research the relative effectiveness of different methods for safety training. Because training methods involving more factors, such as behavior modeling and personal practice, help trainee engagement, workers often demonstrate more positive reactions to the training.[3] Intervention methods are classified according to their degree of engagement.

Learning management systems (LMS) allow instructors to manage learning material and evaluate students' performance over time. The primary reasons to adopt LMS are for compliance-related training, combining development and management, and for an external audience. In this project, one scenario was developed to evaluate users' operation and provide feedback. This can help users and supervisors judge whether they followed proper procedure.

Game-based learning provides deep engagement for trainees in various fields, from hazard identification and scaffold safety to coal mining safety training.[4] Using game-based training tools, learners can better understand work procedures and become familiar with the tools they will use during the work.

Compared with traditional and hands-on training, well-designed game-based learning has many advantages.[5] For example, it is low cost and low risk while being highly engaging. In addition, game-based learning provides an experience

Figure 1



3D models used in the training simulator: recuperator (a), lanyard (b), beam clamp (c) and harness (d).

similar to playing a video game. An interactive and multimedia game-based learning method can bring students to a more engaged learning environment where they can embrace learning, rather than see it as a task.

Methodology and Modeling

The safety simulator project is being developed using the Autodesk 3ds Max and Unity 3D software packages to produce an interactive 3D software that immerses trainees in a multi-hazard environment. While this project focuses on mobile equipment hazards, early feedback suggested that a simulator would be more effective by combining mobile equipment hazards with other hazards to create multi-hazard scenarios. In this way, trainees wouldn't immediately know what hazards they would be dealing with and would need to engage more deeply with the simulator and demonstrate constant awareness of their environment. So, mobile equipment was added to an existing safety training scenario that focused on fall protection, but required trainees to move through a complex work environment moving between buildings at ground level as well as at height.

The 3D environment within the virtualization is based on a real-world site, and employs a game-based learning method. The design of the simulator was accomplished through the following steps:

1. Modeling the environment.
2. Modeling characters and equipment.
3. Programming interaction.

Modeling — This simulator builds upon a fall protection simulator[2] that consists of a task at height involving a recuperator (Fig. 1a), with variable work heights. Before entering the work area, users must put on personal protective equipment (PPE) and choose the appropriate tools (Fig. 1b–d). The section modeled was the industrial environment itself. The default work area is located on the second floor. Other details, such as stairs and handrails, are also included in the model. Safety equipment was then added, including lanyards (Fig. 1b), beam clamps (Fig. 1c), harnesses (Fig. 1d) and other items.

Unity Programming — Unity is a flexible and powerful development platform for creating multi-platform 3D and 2D games and interactive experiences. In Unity 3D, a general industrial virtual environment was developed, including buildings, terrain and additional equipment. This was done by importing 3D models created in Autodesk 3ds Max into Unity and adjusting the scale and surface detail to enhance

Figure 2

First-person view in the simulator (a) and the simulation's control menu and user interface (b).

Figure 3

(a) (b)

Menu screens: login system (a) and mode selection (b).

realism. A first-person view is activated when the simulator is launched to provide the user with an interface capable of real-world working procedures (Fig. 2a). By using Unity's user interface (UI) system, an easy-to-understand UI was created (Fig. 2b). The simulator was programmed in the C# language. When using this simulator, a user can utilize the keyboard and mouse to click buttons and operate the avatar (virtual character). In order to increase the immersion of the experience, the user is able to hear environmental sounds in the virtual environment. The character and environmental animations, such as the avatar's walking animation and doors opening and closing, were generated within the Unity 3D engine. As this software will be used to evaluate a user's fall protection knowledge, a login system was added before entering the simulator. A report card showing the trainee's performance and adherence is shown at the end of the scenario.

Results

Simulator — The fall protection simulator was improved based on industry feedback and integrated with mobile equipment hazards. The resulting interactive simulator allows users to experience the consequences of their actions in a representative environment. When launching the simulator, the trainee can log in as a guest, or track progress using a login system (Fig. 3a).

The simulator includes multiple options for usage (Fig. 3b). In Practice Mode, the user receives basic instruction on the basic operations and general order of operations for running the simulator. This is intended for those users who are not experienced in computer use, or have not yet memorized the procedures for fall protection. Once the user is familiar with this simulator, he or she can proceed to the assessment mode, which presents him or her with a fall protection scenario without any external instruction or aid. This mode can be used either individually with one user per computer, or as part of group instruction with the instructor at the controls, but only acting based on input from the class. This forces trainee participation and engagement. Task Mode provides instructors with a method of skipping to specific tasks within the simulator if they wish to use the simulator in short segments spread throughout a class rather than all at once (e.g., jumping to certain points focusing on mobile equipment or another point focusing on anchor point selection). Buddy Mode puts the trainee in the position of an observer viewing someone else go through the fall protection scenario. In this mode, the trainee must be conscious of the safety of others and intervene if they see someone who is acting unsafely before they harm themselves.

Regardless of the mode, the scenario includes PPE selection and inspection, moving through a hazardous environment and avoiding mobile equipment, assessing and choosing fall protection equipment, selecting proper anchor points, and maintaining continuity of being tied-off while working at height. PPE items are located on a table near the starting point of the scenario. Some PPE items are in poor condition, providing users with their first challenge: identifying damaged PPE and choosing the correct equipment to use. A damaged or worn-out piece of equipment can fail and may cause serious injury or death in the event of an accident.

In the real world, workers should always be aware of their surroundings to minimize accidents. After leaving the starting area, a forklift will cross the path of the user. Users will be struck by the vehicle if they are not paying attention and proceeding with caution. Once the user has allowed the forklift to pass, he or

Figure 4

(a) (b)

In the simulation, the user avatar can look around to see and avoid a forklift (a). Signs are posted in the area warning about mobile equipment (b).

she will walk to a desk near the work area to choose a lanyard and other tools which may be used in the work area. In some cases, the length of one lanyard is not enough to reach the work area, requiring the use of a temporary anchor point, such as a beam clamp or beam strap. Correctly using the beam clamp and beam strap is an important aspect of fall protection.

Mobile Equipment — Mobile equipment such as fork trucks are present throughout the scenario as the trainee travels to the work location to carry out their task at height. When using one of the first-person modes, the trainee must be continuously aware of their environment, looking around corners and using appropriate walkways as they move through the environment to see and avoid getting in the path of moving equipment (Fig. 4a). Signs reminding trainees to be cautious of moving equipment and blue lights located on mobile equipment are some of the ways used in the simulator to help the trainee think about being aware of his or her environment (Fig. 4b).

Targeting Attitudes — One of the challenges in implementing a virtual simulator is addressing the variety of trainee attitudes, both toward safety and toward the virtual training medium. While the simulator follows many of the standards for 3D environments and usability, the first-person mode may not be preferred by some trainees since it requires actively controlling the computer and puts them in situations where they could experience an incident due to issues with controlling their avatar rather than their understanding of safety. In addition, some workers may be resistant to being put in the shoes of a new employee when they have been working in the industry for many years and are already very familiar with safety policies and procedures. Buddy Mode was developed to address this issue.

Buddy Mode was developed with the mindset that we should not only be concerned with our own safety, but also with the safety of those around us. While in this mode, trainees observe a computer character who is a relatively new employee going through

Figure 5

In Buddy Mode, the stimulation provides a STOP button for the trainee to intervene and help a "new employee" character.

Figure 6

Choices made in Buddy Mode help the new employee avoid incidents.

the same fall protection scenario performed in the other modes. This worker is programmed with unsafe behaviors and will experience harm or even be killed if the human trainee doesn't intervene. Fig. 5 shows the computer character walking outside of a designated crossing, not noticing a fork truck. A large STOP button is available throughout Buddy Mode for the trainee to use to intervene. Upon clicking the STOP button, the trainee is presented with various options to get the computer-controlled new employee's attention and offer guidance to be more safe (Fig. 6).

If the trainee doesn't intervene, the new employee will be struck by mobile equipment or experience a number of other incidents (sometimes fatal) throughout the scenario (Fig. 7).

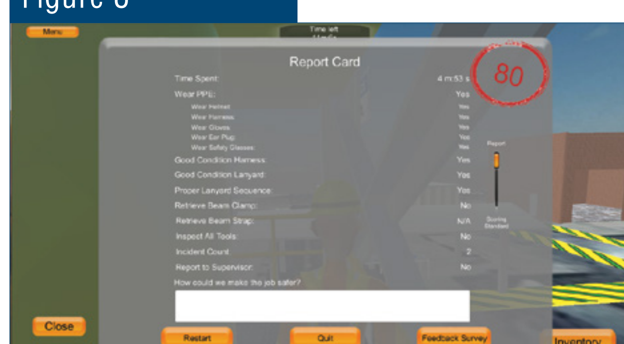
As incidents do occasionally happen despite a worker's best efforts, incidents are randomly generated within the simulator. Every incident will test whether users were adequately prepared, with the result being subsequently recorded on the final report. After an incident has occurred, users have the option to use a personal radio to call for help. However, if the user did not collect the radio from among the tools and equipment at the start, they will be unable to call for help. In this way, users are forced to see the consequence of not following the correct procedures, as seen in Fig. 7.

After finishing the work assignment, the user still needs to safely exit the work area, which will require anchoring to an additional point and removing any additional temporary anchor points they may have installed during the job. After safely exiting the work area, a final report will be displayed giving feedback, as seen in Fig. 8. This report is also displayed after the user's "death," if they have suffered an incident without proper protection, in which case the report will contain an explanation of what choices could have prevented their injury or death. In addition, the final report is recorded to the user's personal file after the conclusion of the simulation. With this, users

Figure 7

A fall incident in the safety simulator.

Figure 8



A report card is displayed at the end of the scenario to provide feedback on the trainee's performance.

can examine in which sections they made mistakes. After going through the practice and assessment modes, users should have some basic knowledge of fall protection.

Future Research

The next steps for developing this simulator is to gather data on its effectiveness. A comparative study of safety records before and after implementation of this simulator in standard employee training will determine whether it has a positive impact on employee adherence to safety regulations, and how that impacts the frequency of injuries and fatalities. It is expected that the use of this simulator will increase employee retention of information and lead to safer practices, thereby resulting in fewer injuries and fatalities.

Conclusions

This project explores the use of 3D virtualization in safety training. As development on this project is ongoing, scenarios will be added to include additional industrial environments. The project is expected to provide 3D interactive training based on real incidents that occur in the steel industry. Trainees can use this simulator to operate equipment, make choices based on the hazards they will encounter in the real world and see the results of unsafe actions. This virtual training method is intended to be practical, efficient and cost-effective, immersing the user in the scenario and providing true-to-life experiences without placing the user in harm's way.

Acknowledgments

The authors wish to thank the AIST Foundation for supporting this research through the Don B. Daily Safety Grant. The research was also supported through the Steel Manufacturing Simulation and Visualization Consortium (SMSVC).

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Did You Know?

A Foundry Prepares to Plunge Into the Abyss

A Finnish steel foundry has been contracted to help build a submersible that will take Chinese researchers to the deepest point on Earth. In a statement, Tevo Lokomo Ltd. said castings for the submersible will be made at its foundry in Tampere, Finland.

The foundry is working in conjunction with Rainbowfish Deepsea Equipment & Technology Co. Ltd. to build the manned submersible, which will carry researchers down nearly 7 miles into the Marianas Trench in the Pacific Ocean.

The submersible, which is being made from the foundry's Vaculok maraging steel, will have to withstand pressures a thousand times greater than those at sea level. Vaculok is an ideal material for the venture due to its superior material properties.

Close cooperation between Tevo Lokomo and the Chinese specialists began in 2015 with a project for material research and testing. The project was completed in April 2017 after successful pressure tests conducted at the Rainbowfish laboratory in Shanghai, China.

The multi-phase project will culminate in 2020 when a group of scientists will descend into the depths of the Marianas Trench, and conduct scientific research work in circumstances not touched by humans yet. The venture will also break the depth record set by the film director and explorer James Cameron.