Interactive Training for Fall Protection and Crane Safety

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.

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Ironmaking and steelmaking are hazardous processes. Some of the most costly factors in the industry are injuries and death resulting from workplace accidents.[1] A project was developed using interactive 3D safety training software to explore new ways in which training and education can impact accidents in the steel industry. Studies have found that severe injuries and fatalities from accidents are preventable. As indicated in a safety bulletin issued by the State of New York, approximately 95% of all workplace accidents are preventable by someone at the employee, supervisor, manager and/or corporate level.[2] This is also supported by a U.S. Occupational Safety and Health Administration (OSHA) area director in Appleton, Wis., USA, who had indicated, "Injuries such as amputation and fatalities from accidents are preventable."[3]

Fall protection is an area of safety that requires thorough understanding of the hazard and safety equipment. Incorrectly calculating the distance of potential falls or selecting incorrect types of fall protection equipment can result in fatality even if a worker is tied off to an anchor point.

Occupational falls remain a leading cause of unintentional injury in the United States.[5] According to the U.S. Bureau of Labor Statistics, slips, trips and falls increased 10% between 2013 and 2014.[6] Workplace falls are a common cause of death and disability.[7]

Many falls result in traumatic brain injury (TBI); however, this phenomenon has not been well documented or studied in the workplace for a number of reasons.[11] First, there are few reports that focus on TBI in the workplace. In addition, there is no system of reporting from hospitals to employers related to workplace falls and TBI. Thus, data cannot be reliably gathered and trends cannot be studied. Lastly, it is difficult to categorize levels of TBI based on secondary data.[7] Out of the roughly 1.5 million people who suffer TBI each year, it is known that approximately 1 million are treated and released from the hospital, while approximately 250,000 are hospitalized with long-term disability and 50,000 result in death.[7]

While many contributing factors to increased risk of unintentional injury such as age, gender and current health status have been identified, it is also important to consider how human factors may impact unintentional workplace injury. For example, workplace noise levels and noise-induced hearing loss have been found to correlate with increased risk of workplace accidents and injury.[8] Noise may contribute to accidents and injury by distracting workers, interfering with essential communication, and/or interfering with warning sounds or hazard communication.[9]

Stage control is used in many industries to eliminate or control for hazards. Stage 1 eliminates the hazard, while stage 2 controls for hazards through engineering control, warning devices, training and personal protective equipment. Within stage 2, Waehrer and Miller found that safety training appears to be effective in preventing incidents due to avoidable hazards.[4]

Safety training interventions have been shown to lead to positive effects on safety knowledge, adoption of safe work behaviors and practices, and safety and health outcomes. Methods of safety training can vary widely, however, ranging from passive (lectures, videos and pamphlets) to moderately engaging (programmed instruction, feedback interventions) to very engaging (training in behavioral modeling, hands-on training). More engaging training is generally found to provide the most positive impact, but all forms of safety training can be beneficial.[16] Video training is widely used due to its scalability, ease of implementation and lower cost.[15]

3D visualization for safety training has been used and evaluated in some industries to enhance the learning experience.[10] The use of 3D visualization implemented into scaffold safety training within the construction industry has been shown to improve understanding through pre-test/post-test assessment. Another industry that has developed visualization training materials is the mining industry. These virtual environments simulate a number of hazard conditions and replicate the results of neglected safety procedures and unsafe behaviors, resulting in virtual characters being injured or killed.[12] While these methods have been shown to be useful, there have been few efforts to develop similar projects in the steel manufacturing industry. In particular, the use of 3D visualization within video training has not been widely studied and should be investigated to determine the scope of its impact on safety training.

Previous projects conducted by the Center for Innovation Through Visualization and Simulation (CIVS) developed 3D visualizations and interactive software that re-created incidents in collaboration with Nucor Corp. and U. S. Steel Canada Inc.[13,14] The current study continues the development of these projects based on industry feedback and create an additional interactive 3D module focused on fall protection. One of the main items being explored in this study is the use of 3D visualization to re-create circumstances of real incidents, as opposed to a general or fictional incident. This is intended to tie general concepts of safety to a real environment and real circumstances, providing an additional sense of relevance to trainees. In addition to the incident itself, 3D visualization allows viewers to see the factors that lead up to and contribute to the incident. Using the virtual space of the 3D environment, it is possible to view the incident from multiple locations to provide additional insights such as what things looked like from the injured worker's point of view or from other key locations within the environment. Additionally, once an incident has been re-created, the environment and events can be modified to show how the incident could have been prevented. Leveraging these strengths of 3D visualization has potential to provide a new way of seeing how safety incidents occur so they can be avoided in the future.

Methodology

The goal of this project is to develop interactive software to create more engaging safety training in the steel industry. Previously, the project team worked with 3D models and animations to make a passive video showing a real incident. Later work used a 3D game engine to create an interactive simulation and additional scenarios. The project team is now building on previous methods to develop 3D models, animations, and interactive software targeted at fall protection and revising previous developments with overhead crane safety.

This project is creating a web-based interactive 3D environment that allows trainees to control an avatar (a virtual character) and make choices that will either cause or avoid an incident in a 3D steel industry environment. This interface provides a more engaging experience for trainees when compared with passively watching a video, and allows them to make choices and experience consequences that are often lacking in traditional safety training environments. The project is being accomplished through the following steps:

1. Develop an interactive 3D training module for fall protection training that allows trainees to select different types of fall protection equipment, such as harnesses and lanyards, and experience the resulting consequences if a fall were to occur.
2. Modify previously developed interactive 3D training modules for crane safety based on industry feedback to provide additional instruction scenarios for both crane operators and those working in the vicinity of cranes.
3. Integrate multiple types of feedback for trainees, including post-incident discussion with an avatar supervisor and positive reinforcement.
4. Collaborate with steel industry employees to ensure the interactive environment correctly simulates the real working environment, test and revise of the interactive environment, and plan for the most appropriate way to deploy for real training situations.

The project utilizes 3D models and Unity 3D programming scripts that were developed for a steel industry environment and created some additional models specific to a fall hazard. Unity 3D and Unreal

Engine (Fig. 2) are platforms for developing interactive 3D environments. 3D models of the environment, equipment and characters, and additional interactive elements will be coded to provide trainees the ability to move an avatar around within the environment, click on certain objects, and interact with text and buttons to make choices that could result in causing or preventing the incident. Working with industry collaborators, the authors will identify critical or most frequently occurring scenarios/situations so that this interactive program will enhance existing industrial training and provide realistic conditions and procedures.

Figure 1

Selection and inspection of personal protective equipment in the fall protection module.

Figure 2

3D animation development environment.

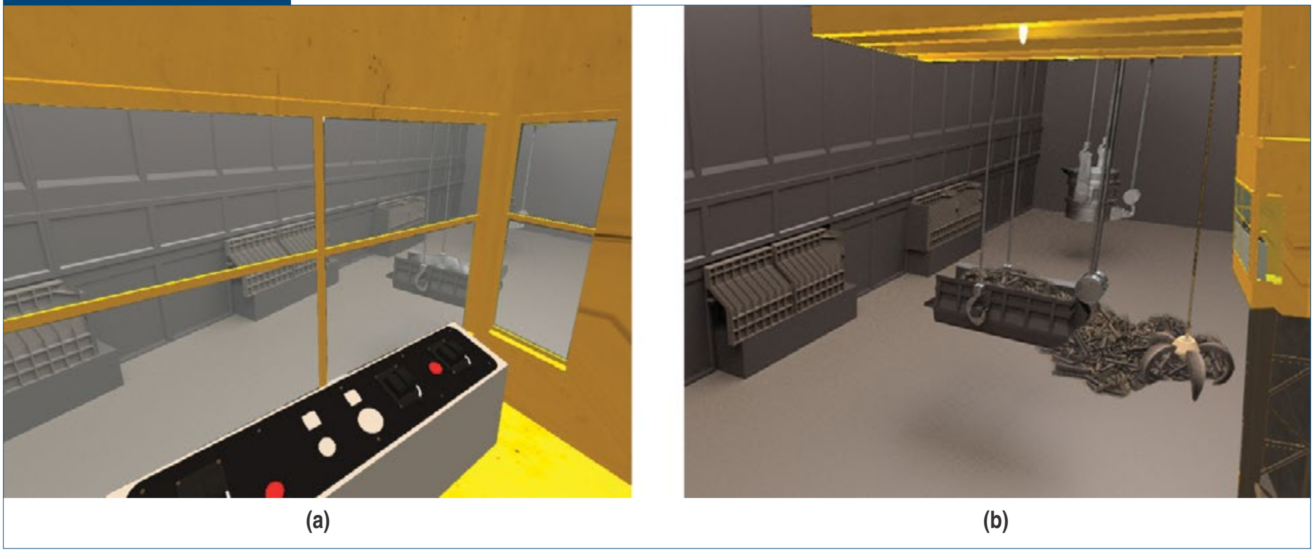
The result of this project will be a web-based interactive environment, which could be later accessed by AIST and steel companies. A preliminary version of the software will be hosted privately on a CIVS server for collaborators to test and provide feedback. The interactive environment will then be revised based on the feedback to produce a more beneficial environment to be used for future pilot testing.

Fall Protection — The fall protection module provides trainees with a simulated work task at height. They control a character walking around the environment and must do the following tasks: select and inspect appropriate personal protective equipment (PPE) (Fig. 1), demonstrate awareness of their environment by looking around for hazards on their way to the worksite, identify when a lanyard is needed, choose appropriate anchor points, return to the ground safely after the task, and identify ways to make the work environment safer. The trainee's actions are tracked along the way and they are provided immediate feedback and a summary report after completing the work and returning safely to the ground. Based on the trainee's selections, their avatar will either complete the task safely, or experience a fall and be subjected to the results of their equipment choices. For example, if the trainee incorrectly assesses a fall hazard and chooses a retractable, or selects an unsecured tie-off point, he or she will experience the results of a fall and potentially hit the floor.

Crane Safety — Building on a previous project to develop a 3D animation that re-created an incident,[14] the current research converted the animation into an interactive package. The interactive scenario puts trainees in the shoes of a virtual avatar and introduces them to hazards that can cause an avoidable incident.

Several key elements are included in this interactive scenario, based on studies on the effectiveness of safety training methods. In particular, multiple forms of engagement are being developed in the software such as interacting with a virtual instructor avatar, including dialogue, and providing trainees with choices and feedback based on their decisions.

Figure 3



The trainee can control the crane to conduct the basic oxygen furnace (BOF) tasks from the control panel (a), but can also view the floor from multiple locations (b).

A crane simulator is being developed that involves operating a crane to add scrap and hot metal to a basic oxygen furnace (BOF) (Fig. 3). The crane operator in this scenario needs to be aware of multiple hazards and choose the right actions to avoid any of multiple incidents that could occur. As in the previous scenario, an instructor avatar provides an introduction to the scenario and description of the task. The trainee is tasked with picking up scrap from a pile on the floor and pacing it in the scrap box. They then need to pick up the scrap box and dump the scrap into the BOF vessel. The trainee will then pick up a vessel full of molten metal and tilt it into the BOF, adding it on top of the scrap.

During the tasks, a number of hazards are present that require the trainee to pay special attention to avoid an incident. First, some of the scrap on the floor is wet/icy. This is unsafe scrap and can potentially cause an eruption later when the molten metal is poured on top of it (Fig. 4). The trainee is able to avoid the unsafe scrap and is provided with options for dealing with the situation, but is eventually made to use the unsafe scrap to force them into seeing the consequence of the unsafe behavior.

Figure 4

The trainee is given choices to avoid unsafe practices, but is eventually forced into using unsafe scrap. Multiple variations on the scenario can lead to different results ranging from proper operation (a) up to a severe eruption (b), which can cause zero-visibility from dust and injure personnel on the floor.

Figure 5

A beta version of the simulator is being used to get feedback and further improve the software.

In addition, a pedestrian is introduced walking across the floor when the trainee first picks up the molten metal. The trainee is free to stop or proceed as they see fit, but if they proceed, they are again forced into an incident in which they will see the result of unsafe behavior, causing the person on the floor to be severely injured from the resulting eruption. In addition to the primary hazard of the eruption, a secondary hazard occurs due to all the dust and soot in the building filling the air immediately after the explosion, creating a zero-visibility situation in which personnel attempting to flee the area of the explosion can easily trip or fall.

Both the fall protection scenario and the BOF scenario provide choices for trainees to avoid hazards, but eventually force them to observe the consequence of unsafe practices. Many personnel have heard secondhand accounts of injuries or deaths that have occurred from incidents such as those portrayed in the current research, but have not seen these incidents themselves. The process of taking part in the incidents, receiving feedback based on their choices and viewing the results of unsafe practices firsthand is intended to help trainees respect the equipment and environments they will be working in so they may better avoid incidents in the real world.

Summary and Future Work

The current research provides two interactive training scenarios through 3D re-creations of real incidents that occur in the iron- and steelmaking industry. Trainees use software to interact with an avatar instructor, operate equipment and make choices based on hazards that they encounter while performing designated tasks. Trainees are eventually forced into viewing the consequences of unsafe actions, which can result in catastrophic failure of equipment and severe injury to the trainees themselves and to others.

The simulator is continuing development and is now being beta tested with collaborators in the steel industry (Fig. 5). Virtual reality is being explored as an additional method to interact with the scenarios and increase the level of immersion within the scenarios. Future work will include evaluation of the effectiveness of the various methods of interaction within the training scenarios, with the goal of implementing the most effective elements of the interactive safety training in a practical fashion that can be integrated into safety training throughout the industry.

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