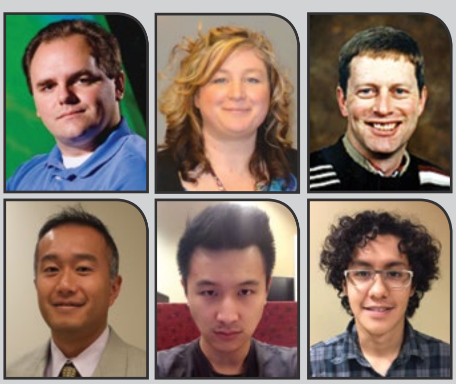
Interactive Incident Visualization for Steel Industry Safety Training

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.

Authors



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This article is the second in a series of Safety First articles featuring the reports from the recipients of the 2014–2015 Don B. Daily Safety Grant.

Ironmaking and steelmaking are hazardous processes. Some of the most costly factors in the industry are injuries and death resulting from workplace accidents.[1] According to the U.S. Bureau of Labor Statistics (BLS), nearly 3 million non-fatal workplace injuries and illnesses were reported by private industry employers in 2012.[2] Of those, a preliminary total of fatal work injuries was 4,383.[3] Although the total number of fatal work injuries that year was the second lowest since 1992, when the Census of Fatal Occupational Injuries (CFOI) was first conducted, these could have been saved. According to the BLS, the manufacturing sector was the only industry to record increased injury and illness rates in 2010. Furthermore, although the number has declined slightly, manufacturing sectors accounted for 322 fatalities in 2011. 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.[4] This is also supported by a U.S. Occupational Safety and Health Administration (OSHA) area director in Appleton, Wis., USA, who indicated, "Injuries such as amputation and fatalities from accidents are preventable."[5] Studies have found that severe injuries and fatalities from accidents are indeed preventable. Waehrer & Miller found that safety training appears to be effective in preventing incidents due to avoidable hazards.[6]

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.[7] 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 (e.g., training in behavioral modeling, hands-on training). More engaging training is generally found to provide the most positive impacts, but all forms of safety training can be beneficial.[8] Video training is widely used due to its scalability, ease of implementation and lower cost.[9]

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 hazardous conditions and replicate the results of neglected safety procedures and unsafe behaviors, resulting in virtual characters getting injured or killed.[11] While these methods have shown to be useful, there is little emphasis on using them 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.

One of the main items being explored in this study is the use of 3D visualization to re-create a real incident, as opposed to a general or fictional incident. This is intended to tie safety concepts 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 events that led up to and factors that contributed 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. In 2014, the project team used 3D models and animations to make a passive video simulating a real incident. This year, the team is using a 3D game engine to create an interactive simulation, building on previous work and adding additional scenarios. The project team is working to develop 3D models, animations and interactive software. The current research focuses on two incidents. The first is based on an incident that involves remote operation of an overhead crane that results in a heavy box landing on the trainee's foot. The second incident is based on charging a furnace with wet scrap that results in a large explosion.

Overhead Crane Chain Storage — Building on a previous project to develop a 3D animation that re-created an incident,[12] 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.[8] In particular, multiple forms of engagement are being developed in the software, such as interacting with a virtual instructor avatar, including dialogue, and providing each trainee with choices and feedback based on his or her decisions.

The overhead crane chain storage scenario involves a chain storage box that is dropped on an employee's foot. The 3D environment provides an avatar instructor who describes the task of lowering the chain into the storage box and introduces the trainee to the crane's remote control, which can move the crane up, down, east, west, north, south, as well as stop. An additional set of controls allows the trainee to control his/her own avatar while performing the designated task. The hazards in the environment have real consequences, and virtual injuries can and will happen if safe practices are not followed.

During the scenario, the trainee is forced to encounter difficulties in storing the chain; specifically, the overhead crane tends to sway as it is being lowered, causing the chain to begin falling outside of the box. The trainee is given options to move around to a different vantage point, call a supervisor for help, move forward to help guide the chain into the box and other options. Each option provides feedback to the trainee, but he/she is eventually forced to make an unsafe choice, resulting in the chain catching on a section of the box, lifting it briefly, and dropping onto their foot. The forced incident

Figure 1

3D simulation of the security camera view of the area where the overhead crane chain storage incident occurred.

is intended to show the trainee the real consequence resulting from the unsafe action.

The technical approach of the incident re-creation involves several steps to collect appropriate data, create 3D models, and animate characters and equipment to re-create the circumstances surrounding the incident. The selected incident was chosen based on the availability of information to successfully re-create the environment and actions leading up to and immediately following the incident. In particular, a video source of the incident was found to be particularly useful. The video was from a distance, so it did not provide a clear view of details during the incident; however, it did provide a general view of the large pieces of equipment, the injured worker and the sequence of events. This source video, combined with descriptions of the event from personnel and the accident investigation report, provided sufficient detail to devise a re-creation of the event.

While general 3D models of the environment could be created from the source video, there was not sufficient detail to discern certain pieces of equipment, so additional data gathering was necessary. Project personnel traveled to the site of the incident and took additional photos for reference in modeling equipment and surrounding structures.

Once the 3D models of the environment were complete, virtual cameras were placed to show the events leading to the incident from key points of interest, such as an external observer's point of view or the location of the injured worker (Figures 1–4). Timing can also be adjusted to slow down important moments leading up to and including the incident, allowing the camera to zoom in for closer views and highlight critical factors that are important for viewers to understand.

Figure 2

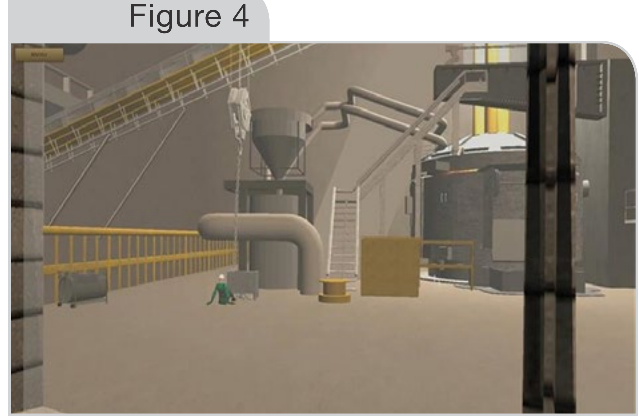
The interactive scenario allows trainees to identify hazards and experience real consequences to unsafe practices. Here, the trainee's avatar is remotely controlling a crane to lower a chain into a storage box, which poses several hazards.

Figure 3

The first-person point of view provides an up-close look at the situation as the chain is being lowered into the storage box and the resulting consequence of the box getting dropped on the foot.

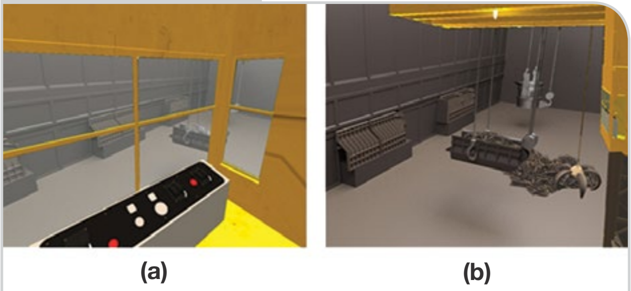
Bad Scrap Charging — The second incident involves operating a crane to add scrap and hot metal to a basic oxygen furnace (BOF). The crane operator in this scenario needs to be aware of multiple hazards and choose the right actions to avoid any of the multiple incidents that could potentially occur. As 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 placing it in the scrap box. The trainee then needs to pick up the scrap box and dump the scrap into the BOF vessel.

Figure 4



A trainee's choices in dealing with the chain falling out of the box can lead to re-creating the recorded incident where the chain catches on the box, lifting and dropping it on the trainee's foot.

Figure 5



The trainee can control the crane to conduct the BOF tasks from the control panel (a). He/she can also view the floor from multiple locations (b).

He/she 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. The trainee is able to avoid the unsafe scrap and is provided options for dealing with the situation, but is eventually forced to use the unsafe scrap so he/she can witness the consequence of the unsafe behavior.

Second, another person is introduced to the scenario; this person walks across the floor when the trainee first picks up the molten metal. The trainee is free to stop or proceed as he/she sees fit, but if he/she proceeds, the trainee is again forced into an incident in order to see the result of unsafe behavior; the person on the floor is severely injured from the resulting eruption. In addition to the primary hazard of the eruption, a secondary hazard occurs due to 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 chain storage 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 firsthand. Taking part in the incidents, receiving feedback based on their choices and viewing the consequences 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

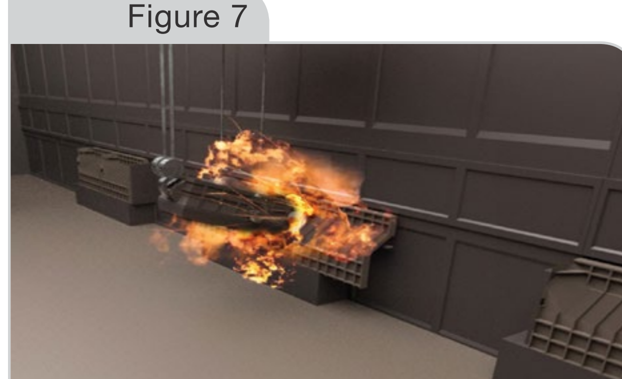
The current research provides two interactive training scenarios through 3D re-creations of real incidents that occur in the iron- and steelmaking industry. Trainees use software to interact with an avatar instructor, operate equipment and make choices based on hazards that they encounter while performing 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.

Additional work is needed to test and improve the scenarios and methods of interaction based on feedback from industry personnel. 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 scenario, with the goal to implementing the most effective elements of the interactive safety

Figure 6

The trainee is given choices to avoid unsafe practices, but is eventually forced into using unsafe scrap.

Figure 7



Multiple variations of the scenario can lead to different results, ranging from proper operation up to a severe eruption, which can cause zero visibility from dust and injure personnel on the floor.

training in a practical fashion that can be integrated into safety training throughout the industry.

Acknowledgment

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