Development of ARMSS: Augmented Reality Maintenance and Safety System

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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Comments are welcome. If you have questions about this topic or other safety issues, please contact safetyfirst@aist.org. Please include your full name, company name, mailing address and email in all correspondence.

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This article describes development and pilot implementation of an augmented reality (AR) system for steel industry workers that will provide safety information, equipment information and procedure information in the field. The project is being developed by students and staff at the Center for Innovation Through Visualization and Simulation (CIVS) at Purdue University Northwest in collaboration with Steel Dynamics and the Steel Manufacturing Simulation and Visualization Consortium (SMSVC). The Augmented Reality Maintenance and Safety System (ARMSS) provides a means for viewing safety information and procedures on an augmented reality headset out in the field or in virtual reality (VR) headsets for use in a training environment. An augmented reality headset displays digital information such as images and video, projected on see-through lenses in front of the wearer. The headset also includes a camera and sensors that allow it to track the environment and recognize key locations and markers on equipment. Using this capability, the system delivers workers with hazard information, step-by-step instructions, and animated guides for maintenance and safety procedures. The visuals are displayed on top of the equipment and the surrounding environment, directing the worker to the correct locations. The system also verifies a user's understanding through a built-in feedback and logging system. Development, pilot implementation and next steps will be discussed.

A variety of digital technologies have emerged with significant potential impacts to the steel industry, including machine learning, big data, simulation, augmented reality (AR), cloud computing, additive manufacturing, system integration, autonomous robotics, Industrial Internet of Things and cybersecurity, among other related technologies.[1–3] In the specific area of safety and maintenance, a variety of simulation and visualization applications have been developed for training.[4–7] This current research builds on these technologies and previous efforts to develop and pilot test augmented reality for safety and maintenance applications, under real-world conditions in the field in the steel industry.

Hazard awareness is becoming a critical part of workplace safety efforts in the steel industry. The application that is being created uses AR to develop tools to teach and verify hazard awareness for suppliers, contractors and employees to new areas of the plant.

The AR training system utilizing a headset or tablet is intended for use at the actual work site, with the user standing in a designated safe zone. The user views the surrounding area through the AR device, which uses a see-through display to overlay text, images and video on top equipment and structures in the area such as ladle metallurgy furnace (LMF), caster or rolling mill. The user's view is guided using arrows and text prompts to highlight relevant hazards in the work area. Danger zones, such as hot metal splash zones and underneath of overhead equipment, can be highlighted with different colors and supplemental text to explain hazards. The level of certain hazards may change over time depending on steps of the process such as charging the electric arc furnace (EAF) or rolling a bar through the hot strip mill.

After completing the hazard awareness training, the AR system will test user understanding by requiring users to identify hazards and ways to mitigate them in the work area. This presentation will cover development, pilot implementation, lessons learned and next steps.

Further, the steel production process is a complex web of interconnected processes; each being made up of dozens or even hundreds of different pieces of equipment working within strict time schedules. The various pieces of machinery have a wide variety of manufacturers and ages. This variation in age and origin is an unavoidable downside to the longevity and evolution of the steel industry.

One consequence of this is the mixed nature of information sources for equipment and machinery. Some manufacturers provide operation and maintenance documentation, while others may only provide basic operating guides. Some documentation may exist only as physical manuals while some suppliers offer digital copies for easier distribution. Finally, equipment may have no documentation at all, especially when developed entirely in-house.

Beyond simply what documentation exists is the question of how accessible that documentation may be. Different steel facilities have different procedures for storage and access to physical and digital documents. This can range from centralized document storage locations (sometimes located off-site at a separate location) to having documents distributed throughout the facility (with placement based on proximity to relevant equipment).

Training new employees will therefore often involve a mixture of methodologies that are dependent on the information source availability. For example, training a new technician to perform maintenance may entirely rely on hands-on demonstrations with experienced technicians due to lack of current documentation.

When a machine accident occurs, the injuries are often severe. Limbs are often crushed or amputated, and in extreme cases, a worker can suffer fatal injuries. Lockout-tagout is an important safety procedure used to ensure that dangerous machines are properly shut off and not started again during maintenance or troubleshooting procedures. It requires that hazardous power sources be isolated and rendered inoperable before any repair procedure is started. Many machines used in the steel industry are complex, spread across locations which are out of line-of-sight from each other, and may involve multiple members of a crew, across shift changes or long-term shutdowns. Such procedures are normally documented on-site but are often limited to text descriptions and lack an ability to track and verify individual steps of the procedure.

Methodology

The Augmented Reality Maintenance and Safety System (ARMSS) provides a means for viewing safety overlays and complex procedures on an augmented reality headset or other display out in the field where they are needed, or on virtual reality (VR) headset in a training environment. An augmented reality headset displays digital information such as images and video, projected on see-through lenses in front of the wearer. The headset also includes a camera and sensors that allow it to track the environment and recognize key locations and markers on equipment. Using this capability, the system delivers personnel with hazard information and step-by-step instructions and animated guides for various maintenance and/or safety procedures. The visuals are displayed on top of the equipment, directing the worker to the correct locations, and visually verifies understanding of hazards in the area and logs when each step is completed.

Maintenance and Safety Procedures — While AR can be useful in many situations, this research specifically chose potential applications based on existing maintenance and safety procedures that were suitable for adapting to AR. Procedures were evaluated, and a library of target "AR-assisted" procedures are being developed. To be considered for inclusion the library for this pilot project, the procedures need meet the following requirements:

1. Documentation of procedure must be current and complete.
2. Procedure must be able to be completed by a single individual (communication between multiple AR devices is possible for future applications but is beyond the scope of this project).
3. Preference will be given to complex multi-step procedures that will benefit from the use of augmented reality.
4. Preference will be given to procedures that can be easily evaluated using factors such as time-to-complete or accuracy (for potential comparison of effectiveness using AR-assisted vs. traditional approach).

AR Development — The AR software has been developed using the Unity 3D engine[8] and Microsoft Visual Studio. Scripts and custom functionality were developed in C#. The AR software is being deployed and tested to multiple devices for comparison and feedback including:

Figure 1

HoloLens 2 augmented reality (AR) headset with Trimble hardhat attachment.

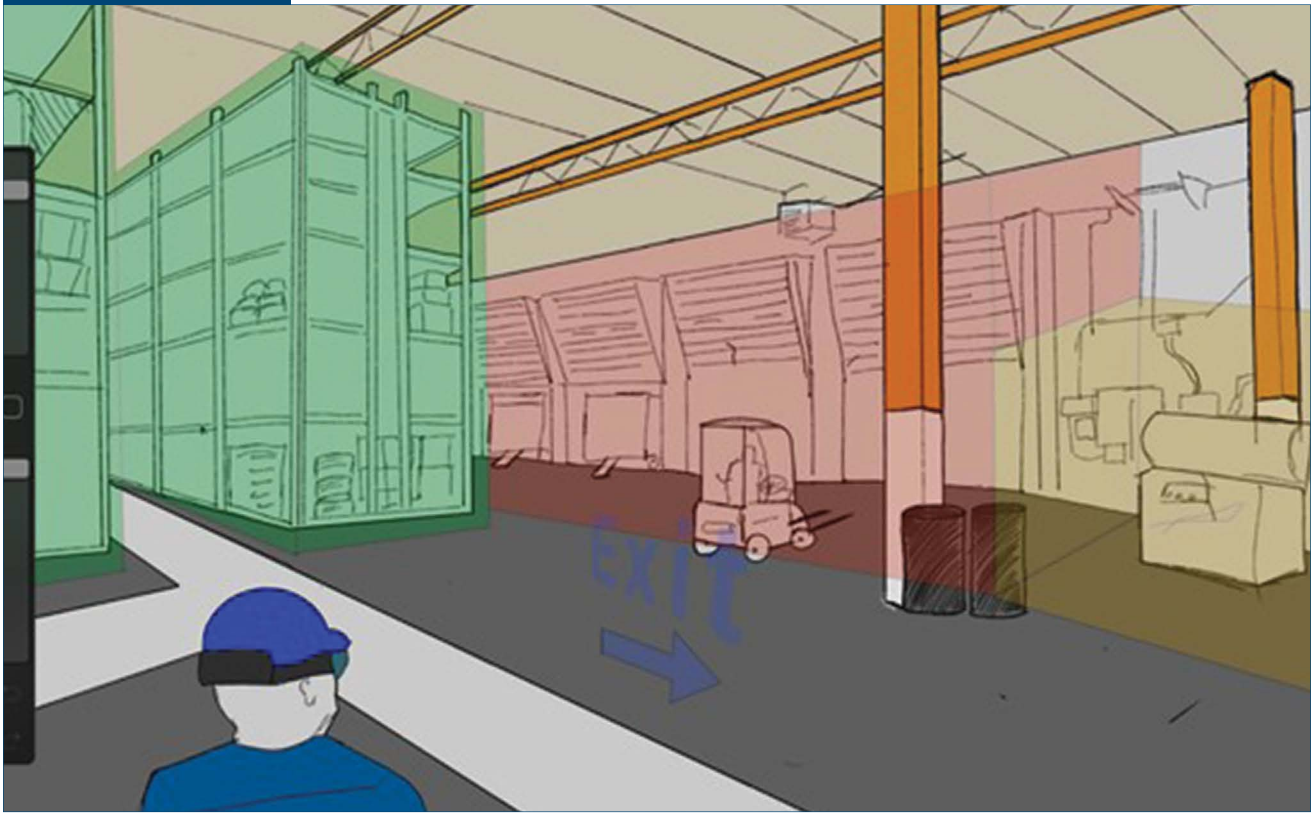
- Microsoft HoloLens M.
- Microsoft HoloLens 2 (Fig. 1).
- Android Tablet.

In addition, practical implementation in the field was considered such as wearability with other personal protective equipment (PPE). One device that was tested was a modified HoloLens 2 with hardhat attachment flip-up display that is safety rated as shown in Figs. 1 and 3.

AR story boards were developed for each documented procedure, showing how each piece of safety information or maintenance steps were to be viewed when using an AR device. It was expected many steps will be viewed as a combination of photo or video with overlaid text instructions. Where applicable, 3D models of some equipment were used in combination with animations, but preference was given to developing AR materials that could be developed rapidly and require less 3D modeling/animation expertise (to promote rapid development of additional AR-assisted procedures in the future).

AR targets are intended to be captured from the mentor's plant location. Photos, video, 3D models and text information will be registered to each step of the target procedure and viewed overlaid through the AR display on top of or next to the appropriate physical object in the area. The combined visual of real-world object and AR superimposed information will be captured for each step and shown to an industry mentor and members of the Steel Manufacturing Simulation and Visualization Consortium (SMSVC) to provide feedback and revise the AR placement. Video of each potential procedure was captured to summarize the process and judge the implementation of AR in the environment.

Figure 2



An example AR story board to demonstrate color overlays to show different hazard areas.

Figure 3

HoloLens 2 hardhat flip-up capability (left) and air-tap for interacting with virtual object (right), (Trimble XR10).

Development inside Unity 3D involved the Mixed Reality Toolkit to develop basic interactions such as colored overlays to represent different hazard areas, pop-up menus, multiple choice questions and directional arrows to guide the user's view toward specific areas. A mesh representation of a test environment was used while developing the interface to act as a stand-in for the depth-mesh that is calculated by the HoloLens 2 sensors (Fig. 4)

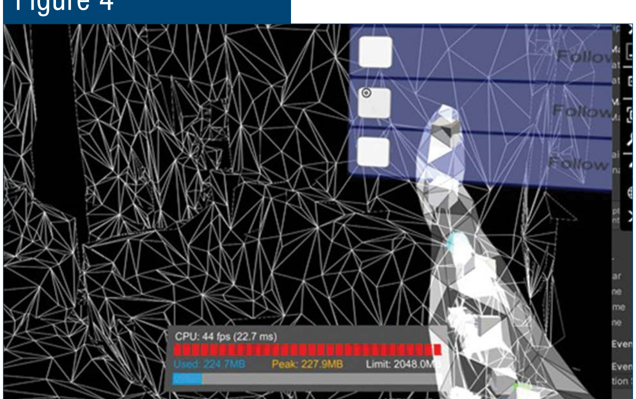
Results and Discussion

A system was developed to place colored overlays based on top of hazard areas. The overlays change based changing activities in the environment such as crane moving through the area carrying a ladle (Fig. 5). One particularly significant application provided safety orientation information for personnel in hazardous areas of the plant. Hazards for a target area were identified by safety personnel that were then coded into various types of colored overlays to show locations and severity of the different types of hazards. Users are given on-screen instructions and overlays to display labels on top of various equipment (Fig. 6). Users were then given a series of tasks to search for and find different types of hazards such as hot metal splash zones, falls from height, electrical hazards, explosion hazards and various others. Once the user located the specified hazard, colored overlays were virtually painted on top of the boundaries of the hazard so they could see the locations and ranges of the various type of hazards. Additional information was also displayed such as various colored lights in the area to indicate different types of activities happening. Sounds were also included to explain the purpose of different types of audible alarms in the area.

The system was developed for use with both AR and VR. For AR applications, safety personnel identified a designated "safe viewing zone" where users were able to wear the AR headset and view the environment safely without worrying about mobile equipment or other hazards approaching them while viewing the orientation. Keeping the user located in single location also safeguarded against the possibility of them being distracted by the overlays and safety training information.

The VR version of the system uses 360° video of the area and similar interactive overlays and information to provide related experiences separate from the work environment such as in a training room or pulpit.

Figure 4



AR development environment with mesh representation of HoloLens2 depth sensor data.

Figure 5

Overlays being displayed on top of a crane-suspended ladle.

Figure 6

Pop-up labels display as the user's view passes over potential hazard areas.

Conclusions

Augmented reality has already shown a variety of useful applications in industry, however few standards exist. New applications such as those described in this research and testing continue to be important to discover how AR can be best applied to provide safe utility in the field. This research will continue improving developments to the hazard awareness/training applications, as well as further develop maintenance applications such as step-by-step procedures for guiding users to carry out and verify lockout-tagout-tryout and other safety or maintenance-related work out in the field.

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