Technology Transfer Report:

Location and View-Frustum Tracking System of Workers for Safety Applications on Construction Work-zones

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Research Motivation and Background

The construction industry is infamous for its hazardous working environments due to workers-on-foot commonly needing to function at dangerous heights and in close proximity to other construction entities such as moving heavy equipment. These hazardous operations result in an increased risk of worker injuries and fatalities caused by fall hazards and struck-by object or equipment incidents. In 2016, the Bureau of Labor Statistics (BLS) noted that of the 991 fatalities in the construction industry, their preeminent causes were falls, struck-by object or equipment, electrocution, and lastly, caught-in/between equipment. It can be noted that the all of the above causes, dubbed the Fatal Four, and especially, falls, struck-by, and caught in-between equipment are caused due to a lack of situational awareness of the worker, that is further caused due to a lack of knowledge regarding their proximity to hazards (falls and equipment).

This lack of awareness persists due to the nature of construction sites requiring multiple activities to be conducted in the same space using different types of equipment, that result in congested, continuously changing, and dynamic worksites. Previous research studies that sought to increase the worker's situational awareness focused on developing various resource localization systems to prevent these hazardous interactions on site based on proximity of workers to hazards such as equipment and falls. However, the consideration of only proximity in the issuance of warnings these previously established systems typically ignores the inevitable necessity for workers to work in close proximity to equipment, which they are aware of. This situation results in the generation of false alarms, and eventually causes workers to become habituated to them and start to ignore them.

Previous support from PacTrans was used to develop a framework that utilized using real-time sensor data and virtual modeling to generate accurate warnings when a hazard is within close proximity to workers-on-foot and when the hazards is outside the worker's field of view. For this purpose it was assumed that a worker is unaware of a hazard if it is not within their field of view during the course of their work. The framework is shown in Figure 1.

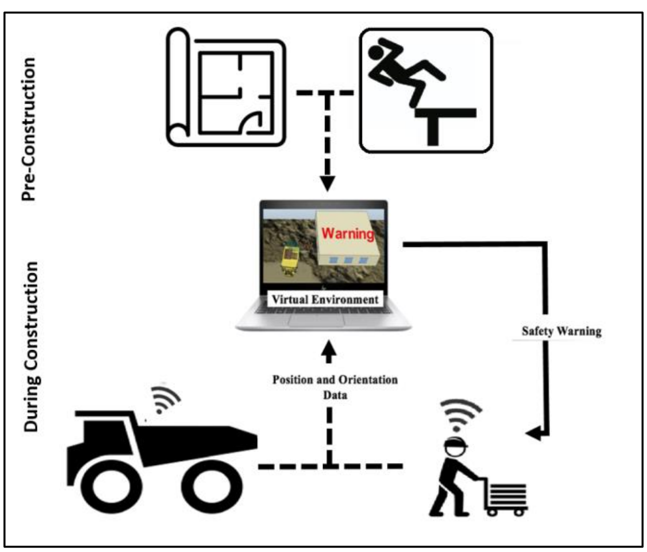

Figure 1: Overview of worker tracking framework

Localization and inertial measurement unit (IMU) sensors were attached to a worker's hard to track their location and orientation of their gaze while working on the jobsite. As seen in Figure 1, jobsite information such as site layout and previously-identified hazard information is modeled into a virtual model of the worksite. During the construction phase when work is being performed, the position of dynamic hazards such as construction equipment and the location and orientation of the worker's gaze is transmitted wirelessly to the virtual model, which then automatically checks for hazards and issues a warning to the worker in case of the detection of their close proximity to a hazard that is not in their field of view.

The hardware prototype that was developed for the research and which is meant to be worn by the worker is shown in Figure 2. It consists of a GPS receiver and IMU sensors including a gyroscope and accelerometer.

Figure 2: Hardware prototype developed for research

As can be seen from Figure 2, the prototype hardware is not appropriate for use in an actual construction setting due to the movement required from work and constrained spaces that they would encounter. Furthermore, the warning that was received from the virtual safety model could be communicated to the worker only using a LED bulb that would not be visible to them in the course of working.

For these reasons that severely inhibit the adoption of real-time localization and orientation tracking of workers on the construction site, this project sought to transfer the research performed previously into the industry through the use of an Augmented Reality (AR) glasses that could be worn at all times by the workers and which contained the necessary sensors and communication system required to implement the performed research on the field. The next section describes the work that was done to enable a more convenient implementation of the previous research to the field through the use of AR to deliver warnings to workers on the construction site.

Technology Transfer Using AR Glasses

The objective of the technology transfer effort to provide a suitable solution that could enable the tracking of worker position and orientation on the worksite and deliver effective warnings about potential hazards that the workers were in close proximity to, and were not aware of. Furthermore, the use of AR glasses in the construction industry is being actively investigated by researchers in both industry and academia as a means of communicating plans and drawings to worker on the site. This aspect of overlaying virtual content over the real world also has potential for being applied in delivering safety warnings to workers as a warning is delivered directly to their field of vision. Aside from the delivery of messages directly into the worker's field of view, AR glasses typically are equipped with location and orientation sensors as well as connectivity to the internet, which make them ideal for tracking workers on the site.

For this project, the suitability of delivering warnings to workers via a commercially available set of AR Glasses, Epson Moverio BT300[1], was tested along with a review of its capabilities in replacing the prototype hardware that was developed during the course of the research.

Epson Moverio BT-300

The AR glasses purchased for this project are shown in Figure 3 and consist of a pair of augmented reality glasses in addition to a handheld controller.

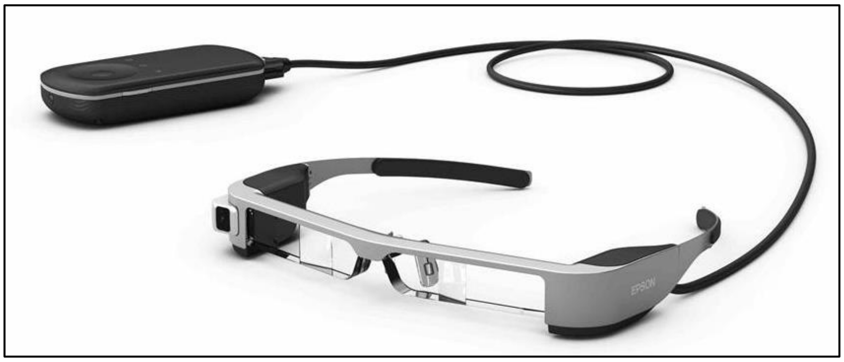

Figure 3: Epson Moverio BT-300

The glasses themselves contain a GPS receiver and motion sensors including a gyroscope and accelerometer and have wi-fi and Bluetooth connectivity. All of these functionalities that are built into the glasses precludes users from having to worry about mounting additional sensors to their person or hardhat. Additionally, Moverio provides a software development kit (SDK) that enables third parties to develop custom applications that utilize the hardware. The SDK was utilized to create a demonstration application on the Moverio to display a warning to the user on the field. Because the device runs an Intel Aton x5 processor, it is possible to display 3D graphics on the AR glass. Such functionality was tested by developing and deploying a test application from the Unity[2] game engine. Figure 4 showcases the proposed use of the AR glasses on the field to track the user and deliver warnings to them.

[1] Epson (2018) "Moverio BT300 Smart Glasses" <https://tech.moverio.epson.com/en/bt-300/> Accessed 7/25/2018

[2] Unity (2018) "Unity Game Engine" https://unity3d.com/ Accessed 7/25/2018

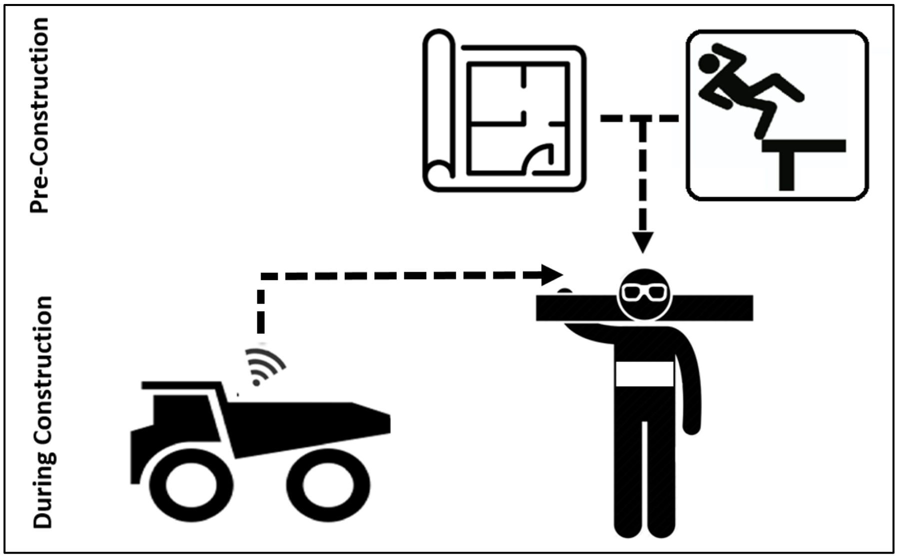

Figure 4: Framework incorporating AR glasses into safety warnings

As seen in Figure 4, the framework presented consists of significantly simpler lines of communication requerd between its components when compared to the initially developed framework in Figure 1. The site layout and hazrd information are loaded directly into the AR glasses and position information from dynamic hazards is directly streamed into the glasses to enable real-time safety checks. This obviates any lag that might be caused in communication from the safety check and delivery of warning to the worker. For this research, a sample warning was displayed to the worker using the AR glasses interface which was worn outdoors. Figure 5 shows a close-up of the AR glasses as it would be worn with a hardhat on construction sites.

Figure 5: Close-up of AR Glasses on typical construction worker

While it was too bright to capture the warning displayed on the AR glasses outdoors, Figure 6 presents a demonstration of the proximity warning as it would appear in the glasses and within the worker's field of view.

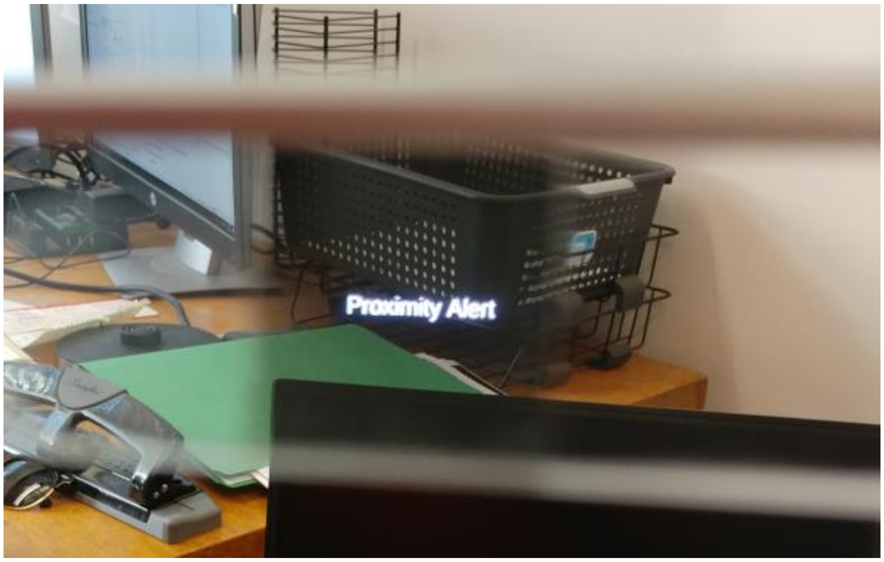

Figure 6: Snapshot of view to worker with digital warning overlaid on real world content

Future Steps

Due to an unforeseen delay in obtaining the actual hardware itself, the PI has not had the opportunity to demonstrate this tool to contractors. However, its utility will be showcased to industry stakeholders during the PI's educational session at the Associated General Contractors Oregon-Columbia Chapter Summer Convention on August 10th 2018. Apart from gaining industry support, future activities include deploying the full functionalities of the previously developed warning system to the device. This involves extending the communication capabilities on the glasses to receive communication that is streamed from sensors placed around the construction site and which will be proceed on board the AR glasses.

It is expected that this technology transfer activity showcases a novel use of Augmented Reality in the construction industry by focusing on a safety application. This utility can be extended for other activities such as monitoring and maintenance operations for facilities wherein embedded sensor devices can "talk" to the AR headset and display contextual relevant information gleaned from the latest data directly to the wearer. Such development can greatly increase the safety and productivity of construction workers on work zone and other construction worksites.