MPC-653
May 7, 2021

Project Title

Optimize the Work Zone Safety with Spatial Information Technology and Eye Tracker

University

University of Wyoming

Principal Investigators

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Research Needs

Construction in the United States has consistently experienced higher fatality and injury/illness rates (Weil, 2001). The U.S Bureau of Labor Statistics reported 845 fatalities within the construction industry in 2013 (U.S Bureau of Labor Statistics 2015). Human error is the main contributing factor to accidents in the workplace, especially among construction workers (Hasanzadeh et al., 2017). Contractors across the world have made an effort in improving workplace safety through PPE (Personal Protective Equipment), safety training, and hazard reducing methods on job sites. These strides have saved countless lives throughout the years. Unfortunately, evidence suggests that a large number of safety hazards remain unrecognized in construction workplaces. In fact, estimates suggest that up to 57% of hazards may remain unrecognized (Albert et al. 2014). More importantly, (Haslam et al., 2005) demonstrated that up to 45% of construction injuries could be attributed to hazard recognition and assessment failures. One of the most important things a contractor can do beyond those methods is to increase the hazard awareness of construction workers. It has been popular and low cost in the construction site that, contractors put vibrant neon colored markings (ribbon, tape, paint, etc.) on or in front of the potential safety hazards. The human brain will pick up on the bright colored markers and inform them there is a danger ahead. However, there has been very fewer research into the actual effectiveness of vibrant markers on hazard identification.

Eye-tracking is widely accepted as the most direct and continuous measurement of attention (Bhoir et al., 2015). Valiyousefi et al. (2015) investigate potential uses for eye-tracking technology in the construction industry, both during early conceptual design and the physical construction process. Considering the fact that eye-tracking enables researchers to deeply study construction workers' hazard-identification patterns, using eye-tracking technology in construction-safety research is gaining traction (Bhoir et al. 2015; Hasanzadeh et al. 2017; Dzeng et al. 2016). The collective knowledge produced by these studies demonstrated that eye-tracking technology can be used as a direct measure of attention to study the cognitive processes of workers that lead to accidents (Hasanzadeh, et al., 2017). Pinheiro et al. (2016) focus on gaze patterns in the pictures of an active jobsite with hazardous conditions. The gaze patterns were studied with a heat map then compared to real pictures/sketches to see the differences. Asadi et al. (2017) examine the psychological aspects affecting safety. The research attempts to apply eye-tracking technology in order to gain a better understanding of workplace safety from an average employee's perception. In response to the importance of tracking, automatic and real-time systems have been introduced to collect tracking data effectively.

Research Objectives

Most studies use eye-tracking technology to measure the impact of the attention and investigate the construction workers' safety cognitive. However, none of the previous studies has utilized eye movement data to improve construction site safety. The objective of the proposed research aims to integrate remote sensing and photogrammetry technology with Eye Tracker to analyze the effectiveness of construction safety signs. This research will also propose a new mechanism to optimize the layout of the construction safety sign based on the remote sensing and eye movement data.

Research Methods

Task #1 (Phase 1): Literature review will be conducted to investigate the following areas to support the research.

- Applications of Eye -Tracking
- Eye-Tracking Metrics
- How to measure the attention and the construction cognitive by monitoring eye movement
- Feature extraction from point cloud data for automatically detect construction safety sign
- Algorithm for optimizing the construction safety sign location

Task #2 (Phase 1): Design construction work zone lab environment and test eye tracker.

The research will be conducted first in the laboratory environment. An indoor construction environment will be established by the PI using an existing lab or empty conference room. The Department of Civil and Architectural Engineering will support the lab space. This grant funding would support the purchasing and installation of an eye-tracking system. The eye-tracker unit would be paired with a dedicated mobile control device and would be setup and calibrated. The eye-tracking system would be used to investigate participants' gaze location, attention allocation, behaviors related to distraction, pupil dilation, and time taken to respond to emergencies. Figure 1 demonstrates the hypothetical setup of the eye-tracking system. It is imperative to have an eye-tracker to complete this study, because the eye-tracker would allow for real-time recording and assessment of the participant's gaze and pupil dilation.

Figure 1. Pupil Lab's Wearable Eye-Tracker with World Camera

In the lab environment, potential construction hazards will be pre-defined and be placed in the lab. An example would be a small ledge on a concrete floor between two rooms. While this may not sound like a huge risk, one misstep over this ledge could cause a worker to fall, potentially injuring the worker. The researchers plan to have two rooms with similar sizes and layout set up with hazards. One office will contain the hazards with no warning or safety labels, while the other contains similar hazards with proper warning labels. In order to make the rooms seem more accurate to a construction jobsite, the rooms will not be well lit, which is common on construction jobsites. Then, participants will stand in the doorway of each room and try to find all of the potential hazards with eye trackers. Figure 2 to Figure 4 explain the concept of room setting and a participant finding the hazards.

Figure 2. Room with warning label

Figure 3. Room without warning label

Figure 4. Construction workers finding job hazard with Eye Tracker

The research goal will be to determine how well the warning labels improve the speed and accuracy in which construction workers can locate and identify hazards while also determining if certain warning labels (different colors, size, etc.) make identification easier for workers than others. Using the video recording and eye tracking capabilities of the glasses, we will be able to gather data in order to determine where construction workers look first, what hazards they focus on, and lastly, the amount of time it takes for them to recognize all of the hazards. If the grant proposal is funded, the eye-tracking system will be purchased, installed, calibrated, and piloted during Summer 2021.

Task #3 (Phase 2): Design the scanner's location and perform 3D Laser scanning.

Once the laboratory test is completed, the project is moved to the real construction environment. In Phase 2 of the study, remote sensing technology is adopted to perform site mapping and optimizing the safety sign layout. The researcher will first collect digital point cloud data using a laser scanner. Currently, the PI has a Topcon's GLS-2000 laser scanner, as shown in figure 5. It is a compact, lightweight scanner that can accurately and quickly capture construction site in less than 3 minutes with a 360° scan, including images.

Figure 5. Topcon GLS-2000 laser scanner

Before starting laser scanning, the project's environment should be considered to determine the best time to collect data to minimize the noise from the construction site or other factors. Also, obstructions that may cause data voids or shadows should be identified. Fog, rain, snow, smoke, or poor weather condition should be avoided. The location of the scanner should be carefully established before scanning is performed. The scanner should be where no obstacle exists and at a stable location. Multiple scans will be performed to minimize the occlusion effect. Site conditions, project requirements, and available scanners should be considered to determine the distance of the scans. This project is targeted for twenty to twenty-five scans.

Task #4 (Phase 2): Data processing and detect construction safety signs.

The laser scanning data, also called point cloud data, will be registered and combined to generate a 3D environment of the real construction site. Generally, each point has its location information X, Y, Z, its color information R, G, B, and its intensity information. An algorithm will be developed to extract the construction safety sign based on its high reflection attributes.

Task #5 (Phase 2): Use Unmanned Aerial Vehicle (UAV) to create a base map of the construction site.

Unmanned Aerial Vehicle (UAV) systems as a data acquisition platform and as a measurement instrument are becoming attractive for many surveying applications in civil engineering (Siebert & Teizer, 2014). In this research, the PI plans to use UAV to capture the photogrammetry image and create a base map. All potential construction hazards will be defined and labeled in the base map. In addition, the construction logistic plan will also be integrated into the base map. DJI Phantom 4 Pro V2, as shown in Figure 6, has been widely used for the Architecture, Engineering, and Construction (AEC) industry as well as for the research project.

Figure 6. DJI Phantom 4 Pro V2

It is imperative to have an UAV to complete this study, because the UAV would allow for real-time recording of the construction activities and wide range mapping for the construction site. If the grant proposal is funded, the DJI Phantom 4 Pro V2 along with extra batteries, will be purchased, tested, and piloted with the help of the UW GIS department during Summer 2021. The actual data collection will be conducted during the Fall 2021 semester.

Task #6 (Phase 2): Track Construction workers with GPS to find the daily route.

In this research, participants will be selected to wear personal GPS during their daily construction activities. The personal GPS will track the worker's daily route at the construction site. The researcher will collect the data and predict the most common route in the construction site. Then the route will be highlighted in the base map created by the UAV, and it will be programmed and integrated into the point cloud data that was captured by the laser scanner.

Task #7 (Phase 2): Use the eye tracker to detect the person's cognitive and awareness of the safety sign.

A random ten participants will be selected to wear the eye tracker and walk along the route, which is defined in Task #6. Those participants have no knowledge of the construction site and have not been to the construction site before. The first purpose of this task is to determine how many potential Jobsite hazards that each people can be aware of. The second is to determine if the construction safety sign helps people identify the potential hazard.

Task #8 (Phase 2): Perform simulation and improve safety sign layout.

Once the data was collected from the eye tracker, it will be integrated into the point cloud data. The simulation will be performed to optimize the location of the construction safety sign.

Task #9 (Phase 2): Prepare for research report and publications.

Expected Outcomes

The proposed project is an entirely new way of improving construction jobsite safety. The project relies on two key factors. First, the Eye-Tracking technology is used to analyze the effectiveness of construction safety signs. Second, a new mechanism will be developed to optimize the layout of the construction safety sign based on the remote sensing and eye movement data. This research increases the construction field's understanding of the variables that impact attentional allocation and provide a novel approach for improving construction site safety by using Eye-tracking technologies and remote sensing. The outcome of the study will make a significant contribution to the existing research.

First, the eye-tracking metrics which characterize the variation in construction workers' attention will be identified while searching for jobsite hazards. Second, given the established link between eye movements and cognitive processes, this research will lay the foundation for using remote sensing and eye-tracking technologies to further study the role of cognition in construction safety. Last but not least, this research can make a significant contribution to practice. More effective interactive methods should be applied to improve safety ratings instead of conventional teacher-student training.

Relevance to Strategic Goals

The expected outcomes of this project are directly related to the following primary goal: Safety. Construction site safety is of paramount concern to citizens and construction professionals. While many studies have highlighted the importance of attention in reducing the number of injuries in the construction industry, few have attempted to measure the actual effectiveness of vibrant markers on hazard identification. This research proposes a new way of assessing and improving construction jobsite safety. The outcome of the study will make a significant contribution to construction safety.

Educational Benefits

The results from this project will provide many educational benefits to improve construction workers' safety awareness. A master's student majoring in civil engineering or construction management will be hired in the fall 2021 to assist principal investigators in completing this project. The eye tracking and laser scanning technology will be introduced in the CM2000 course. The result of this study will be shared in the construction safety class.

Technology Transfer

The PI is committed to research that is both transparent and transformative. The findings of this research project will be disseminated to other researchers, professionals, and practitioners in several ways. We plan to share results with the research and professional community through presentations at local, national and/or international conferences such as the American Society of Civil Engineers (ASCE), Construction Research Congress (CRC), and Transportation Research. In addition to the project report and presentation, we plan to prepare one manuscript and submit it for publication in ASCE or construction safety journals. The project result will also be shared with construction and engineering students in the construction safety class.

Work Plan

The workplan for the proposed one-year project is shown below and described in detail in the Research Methods.

Research Task	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1. Literature review on work zone safety signage layout.	■											
2. Design construction work zone lab environment and test eye tracker.	■	■	■									
3. Design scanner's location and perform 3D Laser scanning.		■	■	■								
4. Data processing and detect construction safety sign.			■	■								
5. Use Unmanned Aerial Vehicle (UAV) to create a base map of the construction site.				■	■	■						
6. Track Construction workers with GPS to find the daily route.					■	■	■	■				
7. Use the eye tracker to detect the person's cognitive and the awareness of the safety sign.					■	■	■	■				
8. Perform simulation and improve safety sign layout.							■	■	■	■		
9. Prepare for research report and publications.											■	■

Project Cost

Total Project Costs: $93,359
MPC Funds Requested: $45,986
Matching Funds: $47,373
Source of Matching Funds: University of Wyoming, faculty salary

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