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NCHRP IDEA Program

A Smart IOT Proximity Alert System for Highway Work Zone Safety

Final Report for
NCHRP IDEA Project 226

Prepared by:
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January 2024

NATIONAL ACADEMIES Sciences Engineering Medicine

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The NCHRP IDEA Program
Transportation Research Board
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Glossary

Include a glossary, if necessary, to define technical terms.

BLE	Bluetooth Low Energy
GDOT	Georgia Department of Transportation
EPU	Equipment Protection Unit
IoT	Internet of Things
IT	Information Technology
MUTCD	The Manual of Uniform Traffic Control Devices
PPU	Personnel Protection Unit

EXECUTIVE SUMMARY

Safety in construction is paramount, yet the U.S construction sector remains one of the most hazardous work environments among industrial segments. The Manual on Uniform Traffic Control Devices (MUTCD) 2009 defines a work zone as an area on a highway where construction or maintenance activities occur [1]. Unfortunately, visibility-related issues, often involving construction equipment and pedestrian workers, cause approximately a quarter of all construction fatalities. The US Department of Labor and Occupational Safety & Health Administration's data from 2012 and 2013 shows thousands of fatal work injuries, with nearly half of the 962 deaths on road construction sites between 2003 to 2010 resulting from collisions between workers and vehicles or equipment [2], [3]. This data emphasizes the urgency of improving current safety practices to ensure better protective conditions in work zones.

Construction projects pose significant safety challenges due to their dynamic nature involving various moving resources like heavy equipment and workers. As reported by the US Department of Labor [4], in 2020, the construction industry accounted for 21.2% of fatal injuries in the private sector, with struck-by accidents making up around 40% of these fatalities. Despite the use of technological advances, traditional safety measures in the construction sector have primarily been based on lagging information, which is historical data gathered post-accidents [5]. These traditional safety practices, although widely implemented, do not effectively allow proactive actions against potential hazards. Instead, there's a growing emphasis on using leading information, real-time data specific to a site, for hazard recognition [6]. However, current efforts to provide such proactive data face challenges, including a lack of efficient monitoring infrastructure, as methods using wireless communication or vision cameras have limitations [7], [8], [9], [10].

The preliminary study [11] and NCHRP-IDEA 187 were conducted by the Robotics & Intelligent Construction Automation Laboratory (RICAL) at Georgia Tech, developing construction worker alert systems based on Bluetooth proximity sensing using smart devices. Using the findings of these previous two studies, this project, in collaboration with the Georgia Department of Transportation (GDOT), validated the systems' practicality at active highway construction sites and proposed the need for PPUs that can operate independently in the field environment.

This study involved the development and validation of prototype devices for a proactive safety alert system in dynamic roadway work zones within the realm of smart IoT. In the initial phase of prototyping, a small Personal Protection Unit (PPU) was conceived and constructed, focusing on data communication with an Equipment Protection Unit (EPU). The subsequent phase of prototyping concentrated on enhancing the PPUs by reducing their size and extending battery life. The EPU, designed to interface with both Bluetooth mesh networks and the internet, facilitates wireless communication between devices and an online server. Leveraging the Bluetooth mesh network ensures a fault-tolerant system with straightforward connectivity and energy-efficient communication. A cloud server system was established to aggregate incident data, such as near misses, detected by the PPUs and EPUs. To validate the system, outdoor trials were conducted in controlled environments to verify the proposed functionalities. Continuous refinement ensued through industry feedback and simulated laboratory tests. In Fall 2023, business demo meetings were held with potential industry licensees to explore further development and commercialization possibilities. After gaining confidence in the product through a series of systematic tests, an industry beta testing phase and a commercialization plan were established.

Key findings during the research period include:

- In controlled environments, the Bluetooth proximity sensing system reliably operates in hazardous proximity situations within work zones.
- The system provides approximately 2.2 seconds of reaction time for both drivers and pedestrians.
- Outdoor testing highlights the impact of obstructions on proximity alert frequencies and accuracy, emphasizing the need for multiple devices for consistent results.
- A milestone is achieved with a patent application, and the system is being introduced for commercialization with plans for grant applications to bring the products to market.

IDEA PRODUCT

As shown in Figure 1, the proposed smart IoT proximity alert system performs proximity sensing at the construction sites. It transmits the data to a cloud server, thus activating alerts to pedestrian workers and remote managers in real time.

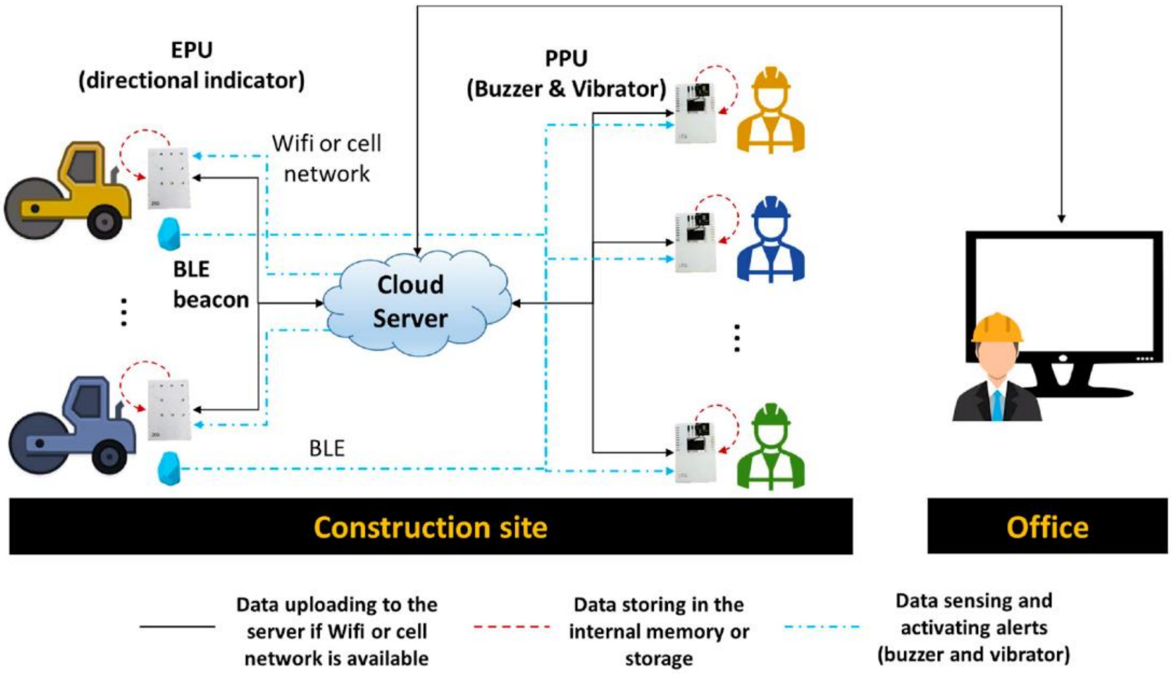
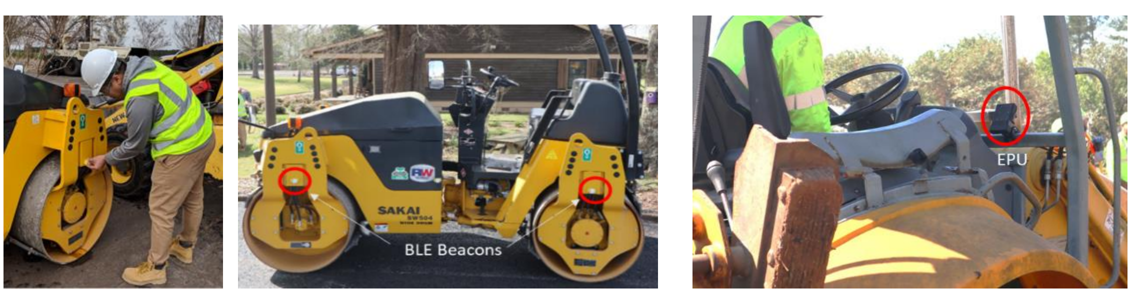


FIGURE 1 Overall flow of the Smart IoT proximity alert systems

The three core components of the systems are:

- Personal Protection Unit (PPU) for Pedestrian workers, which is a lab-designed wearable device that can be integrated into a watch-like wearable or safety vest. The PPU has functionalities of signal processing for proximity sensing of nearby equipment, alerting workers via vibration and/or sound, and transmitting the data to a cloud server through nearby EPUs.
- Equipment Protection Unit (EPU), which is a system of two components: small-sized BLE beacons mounted to the surface of construction equipment and a central processing unit that acts as a gateway between the mesh network and the cloud server (see Figure 2). The EPUs enable the PPUs to estimate the distance to the vehicle and provide internet access to the mesh network.
- A cloud server integrated with a visualization interface: The proximity sensing data measured is uploaded to the cloud server, allowing office managers to remotely monitor the situation in real-time when WiFi or cell network is available onsite.



(a) BLE Beacon Installation (b) EPU device on equipment

FIGURE 2 EPU components on equipment

A web-based user interface has been developed to visualize the situation and incident statistics in real time to maximize the benefits of the uploaded cloud server data (see Figure 3). In addition to visualizing the activated alerts on a site map, the user interface displays statistics on a dashboard (e.g., incident number per equipment, alerting frequency per PPU). This enables office managers to monitor the site remotely and provides data for future in-depth analysis of the safety and productivity of construction projects.

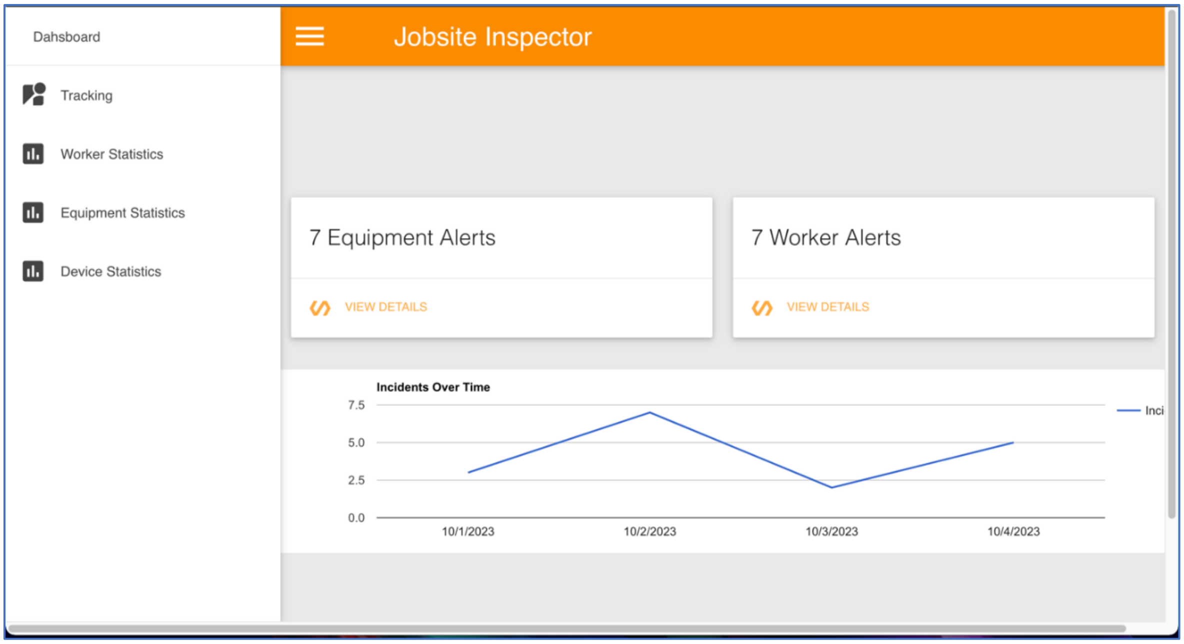


FIGURE 3 Proximity statistics through a web-based user interface

CONCEPT AND INNOVATION

The preliminary results of our study [11] show that Bluetooth proximity sensing and alerting systems using smart devices, such as smartphones and tablets, show high potential to promote safety in roadway construction work zones in terms of accuracy, cost, and user-friendliness. However, there were cases where smartphone use was not feasible due to construction site conditions and policies. Additionally, we found that workers prefer to use a portable standalone device rather than their personal smartphones due to privacy and battery preservation issues [13]. To overcome this, new wearable devices were prototyped as PPUs using small-sized, affordable electronic parts, while preserving the core technique (Figures 4 and 5).

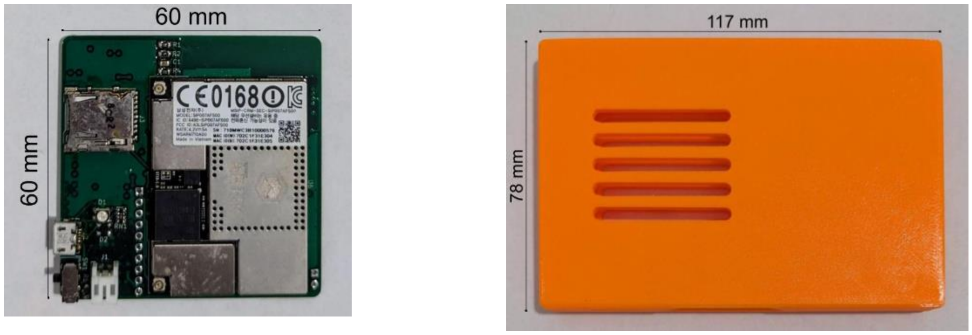


FIGURE 4 Version 1 of the lab-designed wearable PPU device without case (left) and with (right)

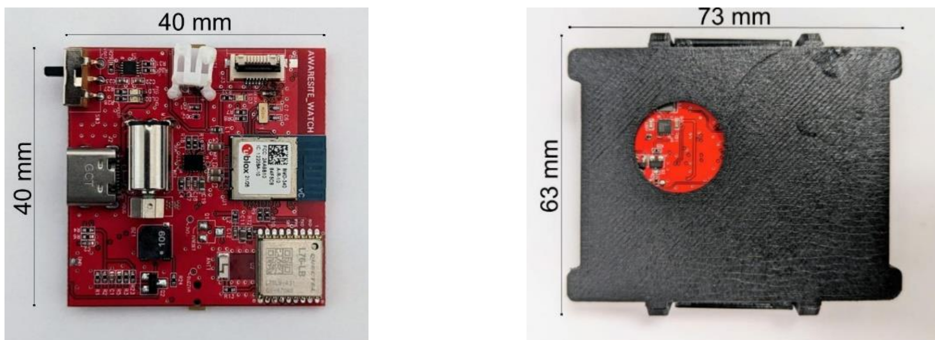


FIGURE 5 Version 2 of the lab-designed wearable PPU device without case (left) and with (right)

Version 1 of the PPU prototype consisted of a 60x60 mm circuit board equipped with Bluetooth and WiFi connectivity and a vibratory and auditory alarm. The board required a large battery due to its high-power consumption (peak ~1.5A at 4.3V), requiring an equally large case. The board functioned well and was extensively validated in several field tests with GDOT. From the field tests and feedback from participating workers, the team found that the high-power consumption led to heating issues and shorter battery life, making it impractical for long-term deployment (e.g., 24 hours). The research team, therefore, developed version 2 of the PPU.

In addition to reducing the board's footprint to just 40x40 mm, version 2 of the PPU significantly reduced power consumption (peak ~0.2A at 3.6V), enabling a much lighter and smaller battery while maintaining the same data-sensing quality. Reducing power consumption also resolved the overheating issues and ensured the battery lasted over 48 hours with regular use. The board's design maintains the capability for inter-device communication through a Bluetooth-based mesh network. As it is difficult to expect WiFi or cell networks to operate reliably in construction environments, the proposed design plans to use a Bluetooth mesh network to maintain independent networks between PPUs (e.g., workers) and EPUs (e.g., vehicles), and upload data to cloud servers only when one of EPUs is connected to a nearby hotspot or vehicle's own cell-network device. Thus, the EPUs can act as a gateway to the internet, forwarding messages between PPUs and the server. Through this, the proximity sensing data can be managed without loss while maintaining real-time alerts to workers.

Regarding proximity sensing, signal processing and alerting logic have been developed to reliably measure distance and alert pedestrian workers (Figures 6 & 7). The onboard logic and signal processing on the PPUs locate the worker's position relative to the construction equipment using multiple mounted beacons and decide whether the alerting module is activated. The alerting logic is defined to keep workers aware of potential hazards as long as they do not escape the hazardous area. By simultaneously utilizing signals from multiple attached beacons, more precise positions and accurate relative directions can be measured, and workers can receive reliable warnings.

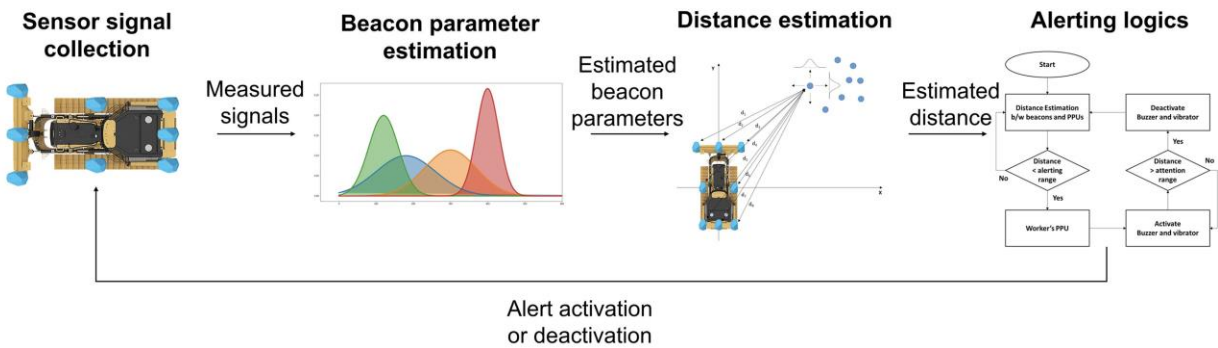


FIGURE 6 Information flow for signal processing and alerting logic

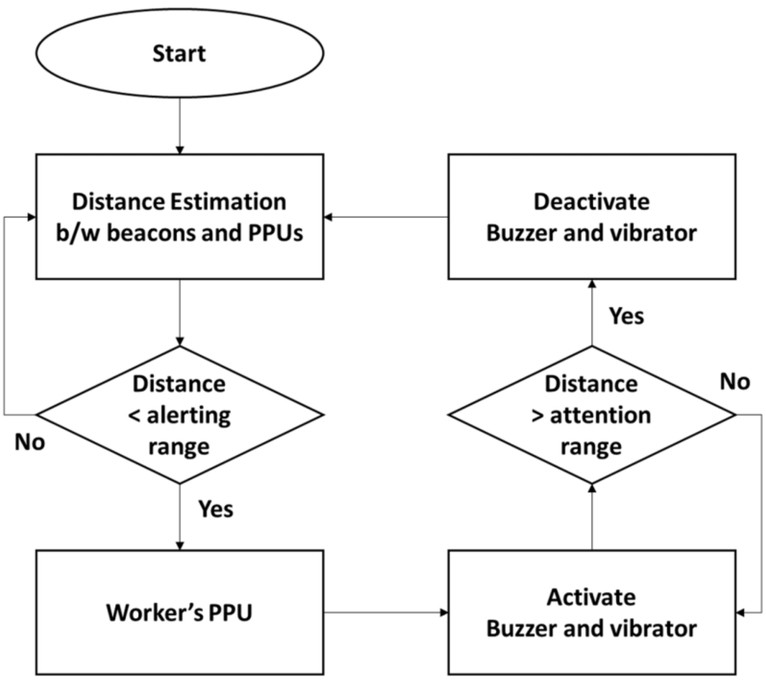


FIGURE 7 Detailed alerting logic of the proposed system

INVESTIGATION

The project spanned three years, with a one-year extension necessitated by delays in progress attributable to a shortage of electronic components amid the COVID-19 pandemic. The research team encountered a challenge when several electric components crucial to the original design became unavailable. Consequently, the team had to wait for the availability of alternative components in the market and subsequently modify the hardware system design. This adjustment in the existing prototype development process is illustrated in Figure 8.

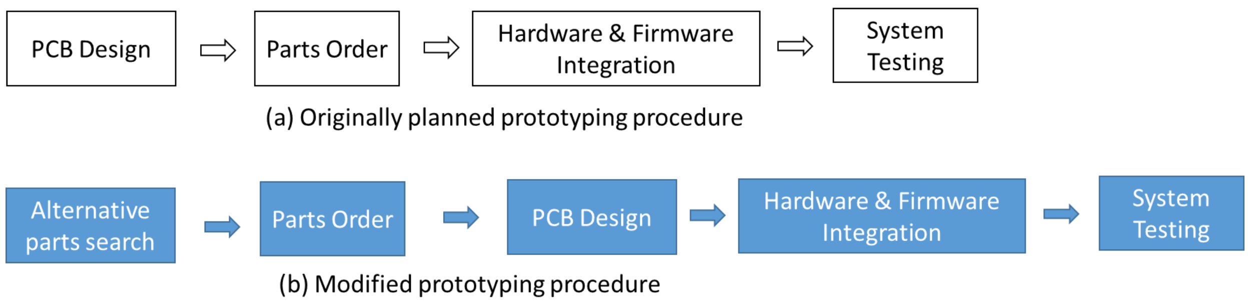


FIGURE 8 Comparison between original vs. modified prototyping procedures

Two prior investigations were conducted regarding the Bluetooth proximity sensing system. The first investigation measured the performance of a preliminary Bluetooth sensing system compared against commercial RFID and magnetic field sensing products [10]. During that investigation, the Bluetooth sensing system demonstrated advantages in cost, maintenance, and ease of installation while maintaining comparable performance. Combined with its potential for providing both sensing and communications between devices, Bluetooth was chosen as the more promising sensing technology compared to the alternatives. The second investigation focused on system development [13]. In particular, an iOS app was developed for Apple devices that could sense the approximate distance to nearby Bluetooth beacons and alert the user of incoming vehicles via auditory and visual safety alerts. An additional smart device was developed and mounted in the cabin to alert the driver of the presence and direction of nearby workers. Two field trials were conducted to verify the functionality and practicality of the system, including an onsite test trial at an active construction site. The trials provided promising results, demonstrating the system's effectiveness and receiving positive feedback from the construction workers. One limitation of the prior system was that it relied on smartphones, but not all employees were provided with smartphones by Georgia Department of Transportation (GDOT) . Additionally, workers had different preferences for carrying their phones in different positions, which could lead to the phone being obstructed, isolating Bluetooth signals, and lowering the accuracy of alerts.

To address these issues, a small Bluetooth-enabled smart device was developed in this research period to measure the Bluetooth signal strength from nearby beacons and trigger vibration and buzzer alerts. The PPU and EPU devices could easily be incorporated into safety vests or watch-like wearable devices. Initial PPU and EPU systems (Version 1) were extensively tested in field operations with GDOT and a construction company [14]. Four comprehensive evaluation tests with construction workers and equipment were carried out to evaluate the performance of the devices during road pavement and earth-moving construction work. Each worker was given a safety vest with a PPU, and each vehicle was equipped with the EPU system (Figure 9). A hotspot device connected the PPUs and the EPUs to the server. The alert triggering system achieved an average precision of 82.66% and an average recall of 96.25% over the four tests. With the version 2 system, two controlled outdoor tests were conducted to gauge their reliability and accuracy based on the orientation of workers and different line-of-site conditions, showing they achieved comparable performance. The details of the trials with version 2 of the prototype system and the results are described in the following sections.

FIGURE 9 Example of previously conducted field testing (image taken from [14]**)**

PRELIMINARY TESTING

The team designed a printed circuit board with wireless communication, data storage, and buzzing alert. Then, it integrated the PPU prototypes into a safety vest and watch-like wearable (Figure 10). Prior to the outdoor tests, a laboratory test was conducted to validate the alerting functionality of the proposed system. In detail, a proximity test using an EPU-equipped mobile platform to test whether a pedestrian worker would receive an alarm when a mobile robot approaches (Figure 11). More extensive outdoor tests were conducted after confirming that the alarm worked within a threshold distance in a controlled laboratory environment.

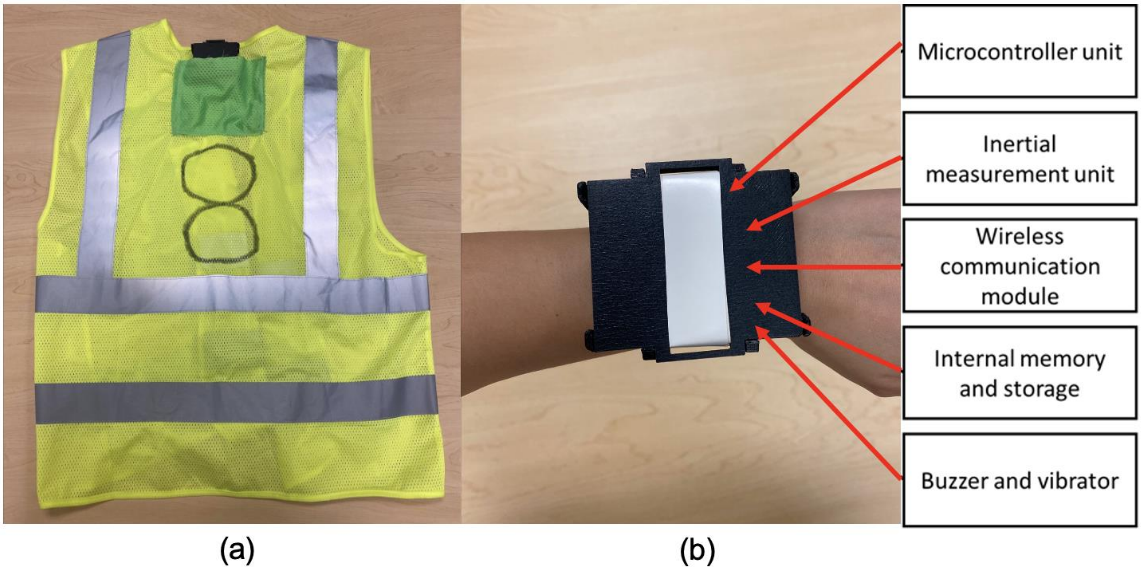


FIGURE 10 PPUs incorporated into (a) safety vests and (b) watch-like wearable devices

FIGURE 11 A worker with PPUs and an EPU-attached mobile robot for proximity safety alerting test (i.e., During COVID)

CALIBRATION

Prior to the outdoor tests, the sensor parameters were calibrated by measuring 100 samples of signal strengths received from 4 beacons at 3 different incident angles, measured at 7 different distances from the beacons: 3ft, 6ft, 9ft, 15ft, 21ft, 27ft, 39ft (equal to 0.91m, 1.83m, 2.74m, 4.57m, 6,40m, 8.22m, and 11.89m). Figure 12 shows the relative positions at which data was collected. Sensor parameters were then derived from the measurements and used during the trials. The same parameters were used for two trials and for both watch and safety vest PPU devices.

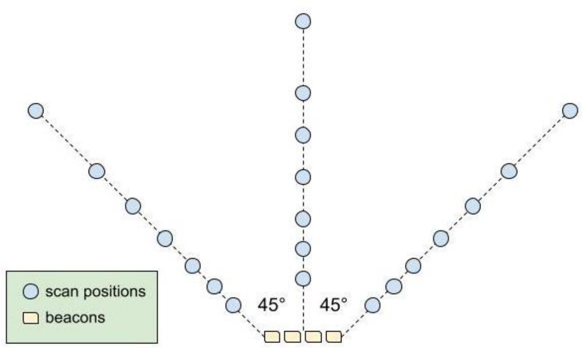


FIGURE 12 Calibration data was collected at 21 different positions at 3 different angles relative to the beacons

STATIONARY TEST

The first outdoor test was conducted to characterize the variability in the distance and directional estimates produced by the new PPU device. A mock construction worker wearing the safety vest and the watch versions of the device was stationed at various positions around the vehicle (see Figure 13). The vehicle (a large van) was equipped with 8 beacons (one at each corner and one in the middle of each side). The worker stood still, facing away from the vehicle at three different distances (2.5m, 7.5m, and 12.5m) in front of the vehicle. 150 distance measurements and directional estimates were collected at each location. The test was repeated 8 times at equally spaced angles around the vehicle (i.e., 0, 45, 90, …, 315 degrees). Thus, data was collected at 24 positions at 3 different distances and 8 different angles to the vehicle. The summary of results is shown in Tables 1 and 2, as well as in Figure 14.

FIGURE 13 The first field test with stationary data collection positions

TABLE 1 Summary of the Results for the Stationary Tests with the Safety-Vest PPU

Actual Dist (m)	Avg Predicted Dist (m)	Dist RMSE (m)	Dist STD_DEV (m)	Angle RMSE (deg)	Angle STD_DEV (deg)
2.5	2.838	0.257	0.724	10.03	2.16
7.5	7.541	0.762	1.531	7.34	5.65
12.5	12.036	1.531	3.071	23.92	9.50

TABLE 2 Summary of the Results for the Stationary Tests with the Watch PPU

Actual Dist (m)	Avg Predicted Dist (m)	Dist RMSE (m)	Dist STD_DEV (m)	Angle RMSE (deg)	Angle STD_DEV (deg)
2.5	7.084	4.821	1.443	23.93	10.56
7.5	16.367	9.308	2.695	20.21	8.56
12.5	33.092	21.683	6.449	28.30	24.45

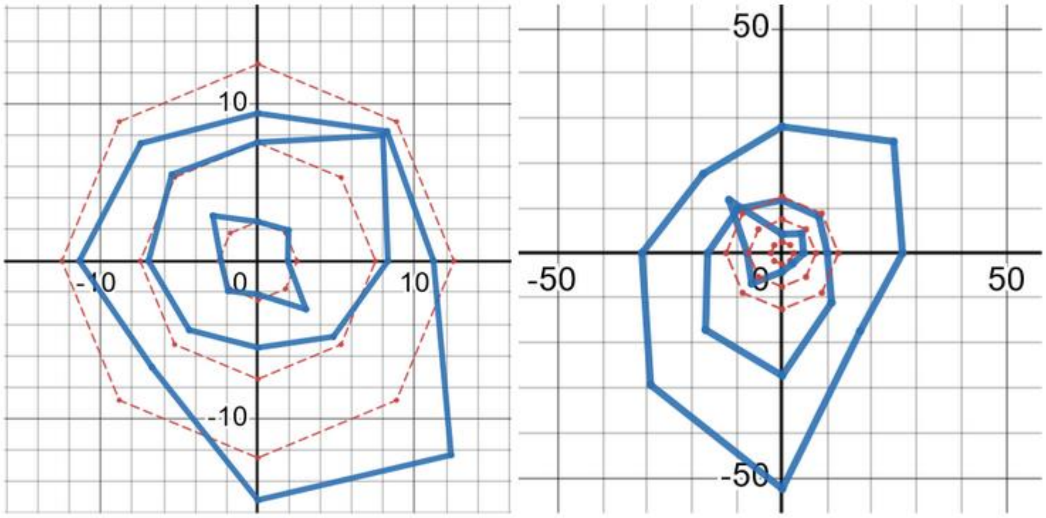


FIGURE 14 Plot of average predicted distance (blue) vs actual distance (red) in meters for each scan position. The left plot was produced by the safety-vest PPU; the right plot was produced by the watch PPU

Tables 1 and 2 clearly demonstrate one of the major limitations of the current device. Since the devices rely on measured signal strengths of Bluetooth beacons to measure distance and Bluetooth signals are strongly impeded by the human body, the measured distance to the vehicle is grossly overestimated when blocked by the worker's body. Since the worker held their arms slightly in front of their body and the watch was attached to the front of the arm, the Bluetooth signal strength was greatly attenuated, leading to significant overestimates for the distance. On the other hand, the safety-vest PPU was contained in a pouch on the workers back, giving it consistent line-of-sight to the vehicle, and it did not suffer from these effects. Additional research is needed to identify the best way to mitigate interference of signals due to the human body. One of the strategies is to incorporate multiple PPU devices into the safety vest (e.g., back, front, sides), guaranteeing that at least one has direct line-of-sight to the vehicle. If multiple devices are used, the devices could communicate with each other to simultaneously trigger safety warnings or redirect the warning to the watch PPU, whose vibration is the most likely to be noticed by the construction worker.

Despite this limitation, Table 1 shows that the PPU device can accurately predict the distance and the worker's angle with respect to the vehicle when in line of sight. The Root Mean Squared Error (RMSE) of the distance measurement was just 10-13% of the distance to the vehicle. The RMSE of the predicted worker's direction relative to the vehicle was also close to 10 degrees for distances below 10m and under 25 degrees for the 12.5m positions. This is in line with previous results obtained from prior iterations of the system using a smartphone app [13] and deemed sufficiently accurate to inform a vehicle operator of the position of nearby workers.

DYNAMIC TEST

The second field trial was conducted to evaluate the effectiveness of the PPU devices in alerting workers of incoming vehicles. Eight beacons were attached to the van in the same positions as in the first trial. Cones were placed every 3 feet (0.91m) starting from the worker's position. The pedestrian worker would stand to the side of the road facing away from the vehicle and raise their hand when they received a vibratory alert. The van would approach at 5 mph, passing the test subject at a safe distance (see Figure 15). A camera was stationed to record the side view and was later used to analyze the results. The PPU was set to trigger at 7m, and the actual trigger distance was recorded to the nearest half-cone interval (0.46m). The test was repeated twice, once with the watch PPU and once with the safety-vest PPU. Each set of tests consisted of 20 trials.

FIGURE 15 The mobile vehicle approaches the static worker from behind, and the worker raises their hand, indicating they sensed an alert from the PPU

To reduce noise in the distance measurements, the PPU implemented beacon-wise low-pass filtering. The observed trigger distance was recorded for each trial and is visualized in Figures 16 and 17. For the safety-vest PPU, 100% of the trials were triggered within +/- 4m intervals of the desired trigger distance. During all 20 trials, the closest the vehicle encroached on the worker before triggering a warning was 5.5m. While not directly comparable to the field operation tests conducted with GDOT due to the use of a different vehicle and test procedure, the results of the vest-type wearable suggest similar performance compared to [14] and show a slight improvement compared to the more similar test (scenario 2) conducted in [13]. For the watch PPU, 80% of trials triggered within a +/- 4m interval of the desired trigger distance. 15% of the trials failed to trigger in time and 5% of the trials triggered too early. The increased inconsistency of the watch test was likely due to the same limitation discussed in the stationary test (i.e., obstructions by the worker's body).

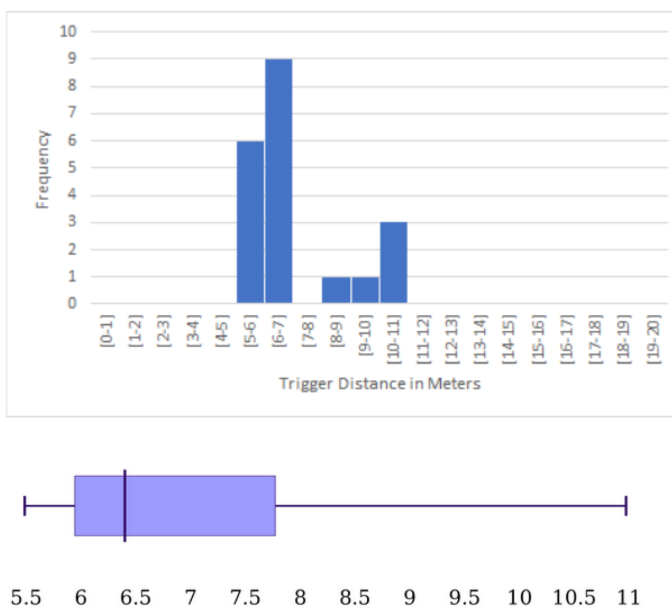


FIGURE 16 (Top) Histogram of the trigger distance for the safety-vest PPU; (Bottom) Box plot of the trigger distance for the safety-vest PPU in meters

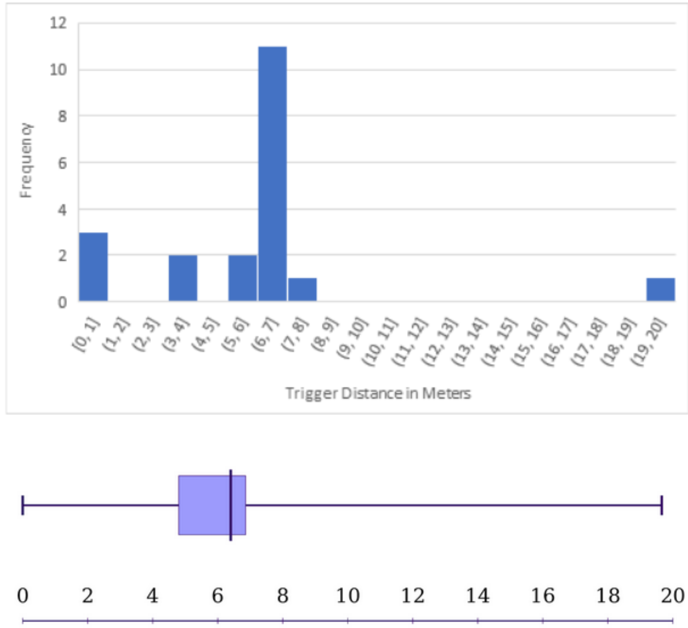


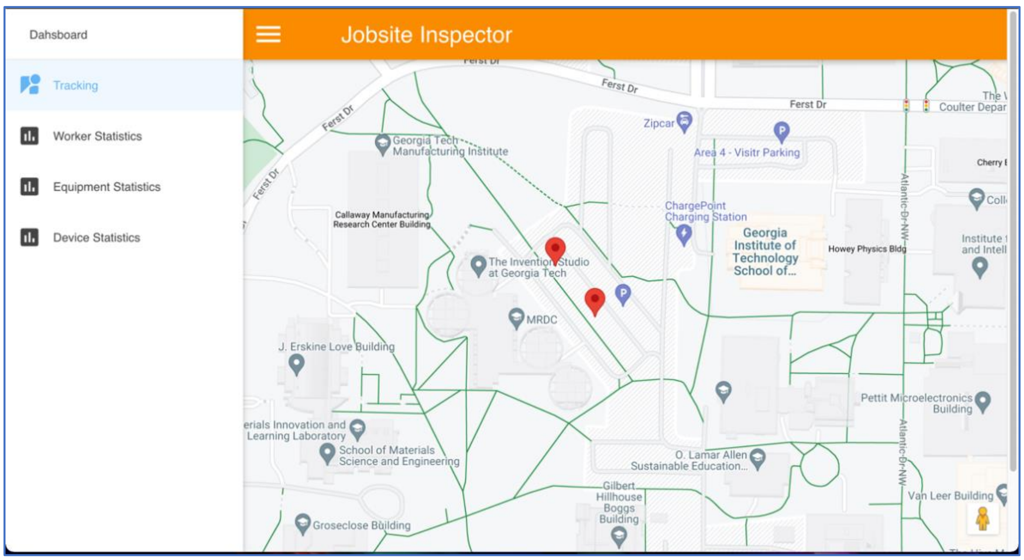
FIGURE 17 (Top) Histogram of the trigger distance for the watch PPU; (Bottom) Box plot of the trigger distance for the watch PPU in meters

In summary, this demonstration indicates that current devices effectively deliver reliable safety alerts for slow-moving vehicles. In the safety-vest test, the worker received a warning when the closest encroachment was about 5m, with a reaction time of approximately 2.2 seconds for both pedestrians and drivers. This aligns closely with the National Highway Traffic Safety Administration's (NHTSA) findings regarding driver reaction time, covering perception, decision, and action (e.g., braking), typically ranging from 1.5 to 2.5 seconds [15]. A previous study demonstrated a swift average response time of 280 ms to vibration alerts from a wristband while walking [16]. While most road construction equipment operated at slower speeds in work zones during our field tests due to the narrow and busy working environment, higher-speed vehicles necessitate an earlier alert trigger programmed in PPU and EPU to ensure sufficient travel distance for a reaction.

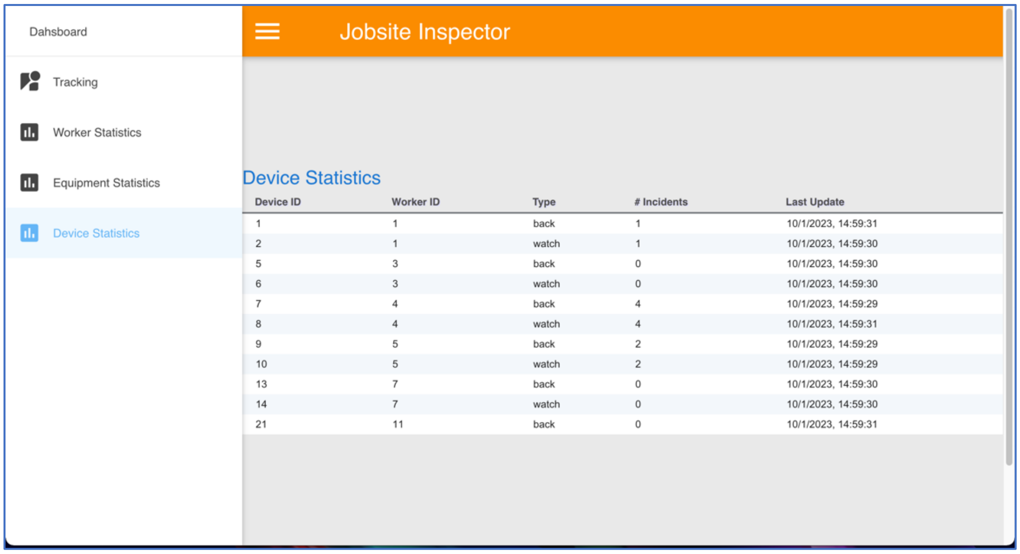
WEB-BASED USER INTERFACE DEVELOPMENT

The team designed and developed the web interface to analyze and visualize the proximity alert data uploaded to the cloud server using the Constrained Application Protocol, which is an internet application protocol for constrained devices. Based upon interviews and requests from field construction managers, the web interface features a log-in page with the ability to restrict permissions and an interactive dashboard with four pages: Tracking, Worker Statistics, Equipment Statistics, and Device Statistics (Figure 18). In detail, the Tracking page displays a map with markers indicating the location of PPUs & EPUs in construction sites and other statistic pages show the proximity alert database grouped by worker, equipment, and device, respectively. In the future, we plan to improve the web interface by surveying the satisfaction of field managers and workers.

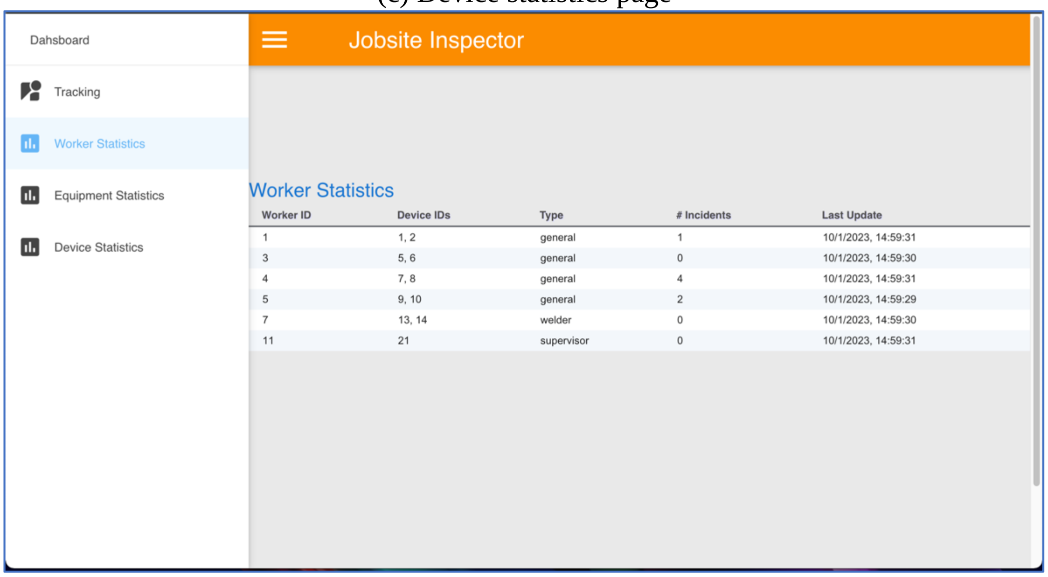
(a) Log-in page



(b) Proximity alert tracking page



(c) Device statistics page



(d) Worker statistics page

FIGURE 18 Web-based user interface page design details.

PLANS FOR FUTURE IMPLEMENTATION

The current proximity system (version 2) has been primarily tested in controlled environments. While this has provided valuable data for development and system verification, the research team plans to continue to test and improve the system by conducting field trials with DOTs and construction contractors to further investigate the practical considerations of the technology and incorporating additional features previously suggested by workers in previous field trials [14]. Some of the additional features suggested include having an easy way to set different alert distances for different equipment types and factoring in the vehicle's speed relative to the worker to dynamically alter the alert distances, reducing the number of nuisance alerts. These changes could help reduce excessive or false alerts which can decrease the chance of workers becoming desensitized to the alerts and boost overall responsiveness to dangerous situations. Additionally, the team intends to investigate the best approach for overcoming the line-of-sight limitation by enabling multiple PPU devices to coordinate their alerts (allowing for using multiple PPUs in a single safety vest), providing a more consistent line-of-sight to the vehicle. Further development of the user interface and server to enable greater functionality is also planned.

In support of the commercialization efforts, VentureLab and the Office of Technology Licensing at Georgia Tech have been actively involved in assisting with the patenting and licensing process. A PCT application was filed in 2021, followed by the submission of a patent to the USPTO through a third-party law firm. The patent, titled "TRACKING AND ALERT METHOD AND SYSTEM FOR WORKER PRODUCTIVITY AND SAFETY," has been published [12]. The patent aims to aid in the formulation of cooperative collaborations with industry partners to bring the technology to market.

Interest from the corporate sector has been expressed in licensing and adopting the technology. Over recent months, numerous meetings have taken place with industry experts with a track record of successfully commercializing IoT devices. Negotiations are underway with one of these industry members for a potential collaboration. Leveraging the shared expertise from our industry partner has the potential to accelerate the ongoing development of our product, facilitating a quicker dissemination of our system. This, in turn, could contribute to broader adoption, ultimately enhancing safety at roadwork and construction sites. The research team intends to explore additional industry partnerships by pursuing state-wide commercialization support grants, such as those offered by the Georgia Research Alliance and SBIR/STTR programs.

CONCLUSIONS

The existing safety measures followed by construction site workers in roadwork zones are insufficient in effectively preventing collisions between pedestrian workers and construction equipment, as demonstrated by the continued occurrence of injuries and fatalities. While our prior work (NCHRP-IDEA 187) has taken steps to address this issue by developing a Bluetooth proximity sensing and alert system, the prior system relied on smartphones, limiting its accessibility and practicality for deployment in active construction work zones. To address this problem, the research team has developed a self-contained, compact PPU device to detect the distance and direction of nearby construction vehicles. Paired with EPUs integrated into each vehicle and supported by a cloud-based server for data storage, these devices create a proximity sensing and alert system. This system is designed to alert workers of approaching vehicles and continuously record safety incidents. The introduction of this developed system into highway work zones is anticipated to enhance construction safety, monitor the working environment, and decrease the accident rate for pedestrian workers.

The new PPU device is made from inexpensive off-the-shelf components and is tightly packaged into a small form (40 x 40 mm without the battery and case). This enables it to be easily integrated into wearable devices or safety equipment already worn by construction workers (e.g., safety vests). The device can also communicate through Bluetooth and form a mesh network to ensure reliable communications between the devices and a cloud-based server.

Multiple outdoor tests were conducted in a controlled setting to verify the functionality and accuracy of the newly developed PPU devices. The device was tested with static and mobile vehicles to verify the accuracy of the distance measured and processed proximity alerts. The test results show that when PPUs are in line-of-sight to the vehicle, the devices provide accurate distance estimates and reliable warnings of oncoming vehicles. The results also indicate that the performance was strongly impacted by an obstruction (e.g., human body) between the device and the Bluetooth beacons, thus suggesting special considerations be taken to ensure that at least one PPU device maintains line-of-sight to the vehicle. The designed smart IoT proximity alert system can provide meaningful and reliable alerts notifying workers of hazardous proximity situations. While workers should still follow and rely on required work-zone safety protocols and always maintain situational awareness, the designed proximity system should be used as a secondary layer of defense for preventing collisions between equipment and workers. The research team plans to continue to work to improve the reliability of the system and to work with industry partners to commercialize it into a competitive product.

In summary, the primary outcomes from this research study include:

- In controlled environments, the experimental results indicate that the Bluetooth proximity sensing and alert system can deliver reliable outcomes in hazardous proximity situations within work zones.
- The system affords approximately 2.2 seconds of reaction time for both driver and pedestrian workers.
- Outdoor testing reveals that the frequencies and accuracy of proximity alerts are influenced by obstructions between the vehicle and the PPU device. This suggests deploying multiple devices in the safety vest to maintain line-of-sight to the vehicle and ensure more dependable and consistent results.
- A significant milestone has been reached with a patent application. The system is now being introduced to industrial entities for commercialization efforts, and plans are in place for commercialization grant applications to bring the products to the market.

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APPENDIX: RESEARCH RESULTS

Sidebar Info

Program Steering Committee: NCHRP IDEA Program Committee

Month and Year: January 2024

Title: A Smart IOT Proximity Alert System for Highway Work Zone Safety

Project Number: 226
Start Date: January 19, 2021
Completion Date: January 15, 2024

Product Category: New or improved tool or equipment

Principle Investigator:
Yong K. Cho, Ph.D, Professor
E-Mail: yong.cho@ce.gatech.edu
Phone: (404) 385-2038

TITLE:
A Smart IOT Proximity Alert System for Highway Work Zone Safety

SUBHEAD:
Intelligent IoT devices for proximity detection and safety surveillance in highway construction zones.

WHAT WAS THE NEED?

Despite the strong emphasis on safety, the construction sector remains one of the most hazardous industries in the U.S. Almost half of the fatalities on road construction sites result from collisions between workers and vehicles or equipment. About a quarter of all construction fatalities are attributed to visibility-related issues. Traditional approaches to tracking safety incidents in construction rely on historical or post-accident data, often lacking the ability to take proactive measures against potential hazards or actively alert involved parties of impending incidents. Consequently, there is a pressing need for an improved system to monitor proximity-related events (e.g., a vehicle backing up too close to a construction worker) and promptly warn concerned parties about potential hazards. If implemented well and with privacy in mind, such a system could help identify hazardous situations before they turn into accidents and ultimately save lives.

WHAT WAS OUR GOAL?

The goal was to develop an IoT-based smart device capable of tracking and alerting workers of proximity hazards, such as approaching construction equipment.

WHAT DID WE DO?

The research team developed a proactive safety alert system based on Bluetooth proximity sensing and smart devices. As part of the system, the researchers developed a small wearable device that can estimate a construction worker's proximity to construction vehicles and alert both the worker and the vehicle operator to each other's presence. Additionally, the researchers worked on the supporting infrastructure to automatically record and visualize safety incidents captured by these devices to help identify and proactively manage hazardous worksite situations. The team collected industry feedback and validated the system's functionality through outdoor tests.

WHAT WAS THE OUTCOME?

The research team effectively developed a prototype for the smart wearable device, showcasing its ability to accurately predict distance and relative position to equipment. Outdoor tests confirmed the device's reliability in alerting workers about approaching equipment. The team investigated the device's line-of-sight limitation and identified a strategy that involves modifying the current system for future testing. Furthermore, a web-based user interface was created by the team to analyze and visualize the collected proximity alert data from the system.

WHAT IS THE BENEFIT?

The developed smart wearable devices, along with the rest of the proximity alert system, can potentially reduce road work and construction site injuries and fatalities. Construction sites can be noisy and busy environments. The system can warn of and prevent harmful collisions by providing targeted alerts for proximity hazards to the involved pedestrian workers and equipment operators. Additionally, the real-time data collected by the devices and the developed user interface can help site managers proactively mitigate safety hazards by identifying dangerous practices, locations, and issues for their specific worksite.

IMAGES

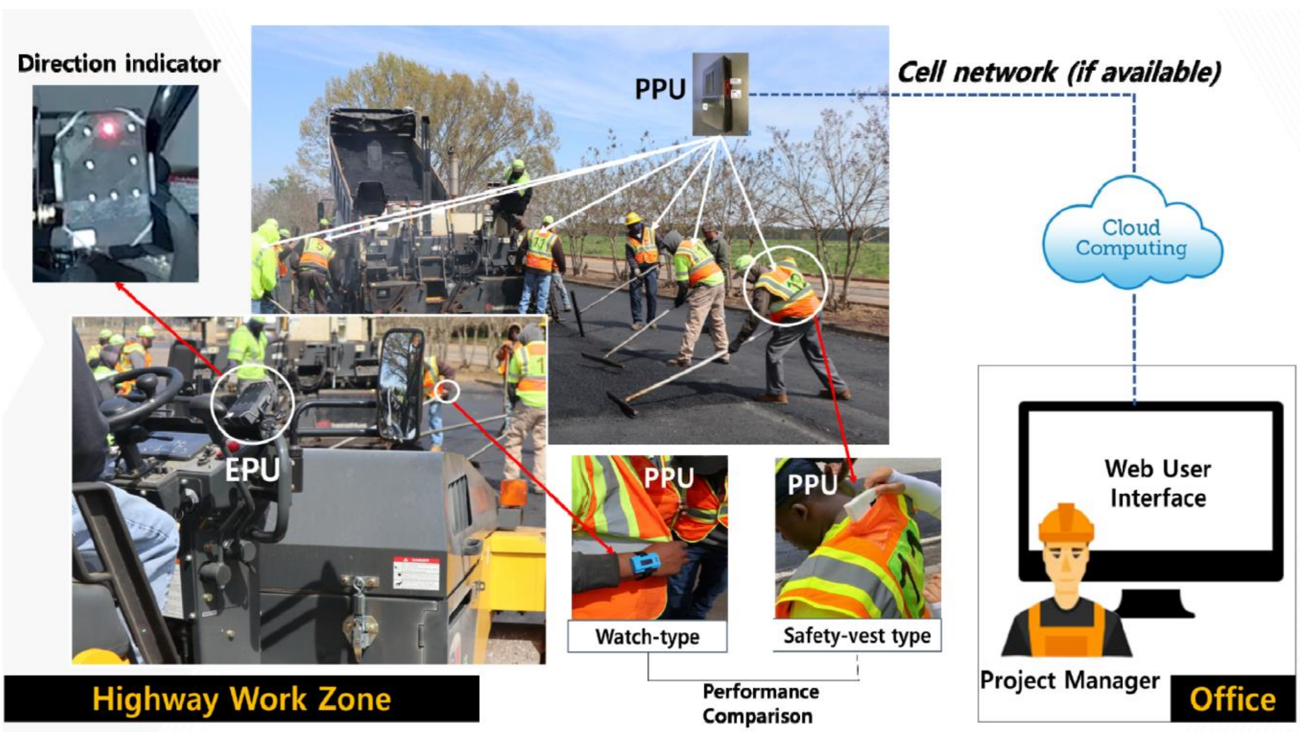

FIGURE Conceptual design of the smart proximity alert system for construction

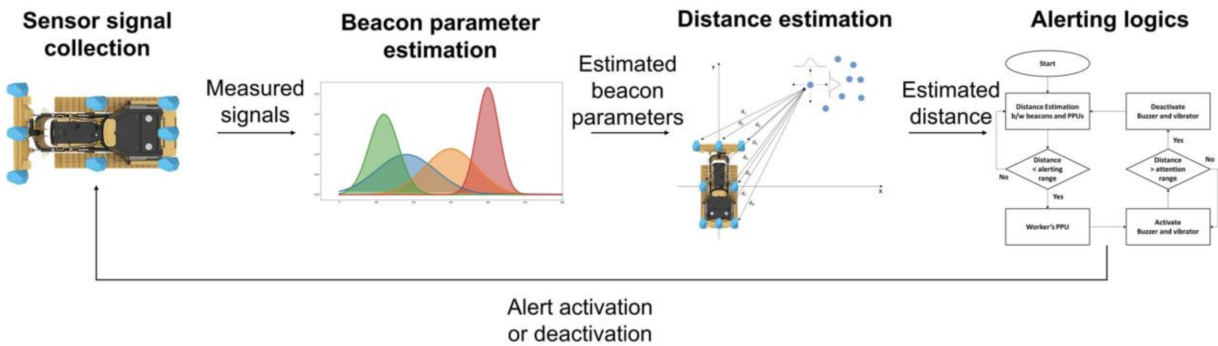

FIGURE Information flow for signal processing

FIGURE Outdoor trials of the smart proximity alert system; evaluation of alerting functionality for hazardous situations