A Rule-based Safety System for Autonomous Heavy Construction Equipment

Development of a Rule-based Safety Checking System for Autonomous Heavy Construction Equipment

Kyungki Kim, CPWR Small Study, 2025.

Overview

Between 2013 and 2022, over 1,000 road construction workers were fatally injured at job sites, with more than 9% of those deaths involving struck-by or caught in-between incidents with construction equipment. Many of these fatalities could be prevented by automatically detecting objects—including workers—around moving equipment, accurately determining the locations of these objects, and identifying potentially unsafe situations and alerting workers. Previous attempts to provide this kind of protection, such as systems that give workers signal-emitting tags, have not produced accurate and robust detection. In this project, the research team focused on placing advanced sensing and perception technologies on heavy equipment to enable real-time hazard detection and enhance situational awareness. The system was first evaluated through 3D simulations to identify potential hazards and create safety protocols tailored to the assessed risks. The researchers then evaluated and optimized these configurations on real-world construction equipment to enhance their effectiveness; they also refined the system's detection algorithms.

Key Findings

- The project established a pioneering framework for sensor-based perception with heavy construction equipment, pointing the way for significant advancements in mitigating risks facing workers in construction zones.
- The field evaluation of the system showed high accuracy, with an average error of 27.1 cm (10.67 inches) in human detection and an average error of 50.1 cm (19.72 inches) in vehicle detection within a 5-meter range.
- This system achieved full 360-degree visibility and accurate detection of hazards.
- This study demonstrated that it is feasible to use simulation environments to determine sensor configuration, which can then be successfully implemented in real-world applications.
- More advanced hazard detection logic and alerting methods, as well as the utilization of on-site internet connectivity for real-time reporting, should be explored in future research to further enhance the system's ability to detect and respond to unsafe situations.

For more information, contact:
Kyungki Kim: kkim13@unl.edu

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