A Digital Twin Platform for Monitoring Risky Events of on-Site Construction Workers

Ren Jye Dzeng
National Yang Ming Chiao Tung University, Taiwan

Abstract:

Safety is a critical concern in construction management. While training, education, and personal protective equipment (PPE) help mitigate risks, real-time monitoring technologies offer promising advancements. Recent progress in deep learning has enabled the automated identification of hazardous events, such as workers not wearing helmets or entering restricted zones, though most studies focus on a limited set of scenarios. Given the complexity and dynamic nature of construction sites, these technologies hold practical potential.

Meanwhile, developments in IoT sensors, AI-based event recognition, and cloud computing have paved the way for more intelligent monitoring systems. Digital twin technology—already applied in industries like aerospace and automotive—offers a virtual representation of real-world processes and enables visualization, simulation, and anomaly detection. Though still emerging in the construction industry, digital twins can be developed from Building Information Models (BIM), which are widely used for design coordination, interference checks, and construction animation.

This research presents a real-time digital twin platform for detecting and visualizing risky events involving construction workers. The system leverages built-in sensors (GPS, accelerometer, gyroscope, barometer) in smartphones worn by workers to trace their movements and identify hazardous events such as stumbling, falling, or losing consciousness. These events are animated within a 3D BIM environment, providing safety managers with immediate visual feedback.

A three-layer architecture—Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS)—underpins the platform, supporting scalability, customization, and extendability. Edge, fog, and cloud computing are integrated for efficient and scalable distributed data management.

The system detects fall-related incidents with good performance using a hierarchical threshold algorithm and Gated Recurrent Unit (GRU) networks. Experimental results show that the waist is the optimal position for sensor placement, achieving 95.2–98% sensitivity and 100% specificity for falls, and 76.86–79.13% accuracy for predicting precursors to such events.