Enhancing Railroad Highway Grade Crossing Safety and Efficiency Through AI-Driven Cloud-Edge Integration

ABSTRACT
The integration of artificial intelligence (AI) and machine learning (ML) into the Railroad Highway Grade Crossing (RHGC) systems represents a significant milestone in enhancing both safety and operational efficiency. The fusion of various technologies enables the seamless integration of real-time identification, accurate forecasting, and prompt reaction to pivotal traffic situations. The research introduces a state-of-the-art architecture based on edge cloud technology. It integrates advanced computer vision algorithms for object detection and segmentation with a custom dataset for RHGC safety. In the proposed framework, we utilize a Weighted-box-Fusion (WBF) ensemble approach, integrating diverse object detection algorithms, such as YOLOv8M, YOLOv8L, and YOLOv8X, to enhance the detection of safety measures at RHGCs. Moreover, we incorporate a UNet segmentation model to identify approaching trains. The amalgamation of these methodologies leads to a fully automated, AI-driven safety mechanism for RHGC. The edge-cloud architecture is employed, with surveillance cameras linked directly to an edge server strategically positioned at grade crossings. This arrangement facilitates real-time data processing, ensuring efficient bandwidth usage and minimal latency by relaying only the necessary processed information to the cloud. Our ensemble model demonstrated an impressive precision rate of 97%, with the segmentation model achieving a higher rate of 98%. This system establishes a novel standard within the discipline, amalgamating artificial intelligence, edge computing, and cloud technology to augment safety and efficiency at grade crossings significantly.

Keywords: Cloud-Edge-Based Architecture, Real-Time Object Detection, Railroad Highway Grade Crossing (RHGC) safety, Segmentation technique.