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Review Of Automated Level Crossing System For Trains With Real-Time Obstacle Detection And Alerting Mechanism

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Abstract: Railway level crossings are critical points where road traffic intersects with railway tracks, often leading to accidents due to human error or malfunctioning systems. This review paper explores existing technologies and approaches for enhancing safety at these crossings, focusing on automated systems for real-time obstacle detection and gate management. Various sensor-based solutions, including infrared, ultrasonic, and image processing techniques, are examined for their effectiveness in detecting obstacles such as vehicles, pedestrians, or debris. These systems aim to alert both road users and trains through alarms, flashing lights, and barrier controls to prevent collisions.

Additionally, the review discusses automation of level crossing gates using GPS or track-based sensors to open and close gates without human intervention. Such automation reduces reliance on manual operations and minimizes the risk of errors, improving overall safety. The paper highlights the potential for integrating these systems into existing infrastructure, offering a cost-effective approach to modernizing railway crossings. Through the review of current technologies and studies, this paper aims to provide insights into the future development of automated, real-time safety systems at railway intersections.

Keywords— Safety system, Level crossing system, Real-time Obstacle Detection, train

I. Introduction

Railway level crossings are critical intersections where road traffic and trains converge, often leading to accidents due to human error, delayed responses, or malfunctioning barriers. This research paper introduces an "Automated Level Crossing System for Trains with Real-Time Obstacle Detection and Alerting Mechanism" to address these safety concerns. The system integrates advanced sensors, including infrared and ultrasonic sensors, along with image processing and object detection algorithms to monitor crossings for potential obstructions such as vehicles, pedestrians, or debris. Upon detecting an obstacle, it triggers alerts using audible alarms and flashing lights, while also controlling barrier systems to ensure timely and safe operations. Additionally, real-time alerts are sent to both the train driver and the railway control center, facilitating swift action to prevent accidents.

The proposed system further enhances safety by incorporating cloud-based data storage, which logs obstacle detection events, including images and metadata such as GPS location and time. This not only aids in future analysis and legal. Documentation but also helps optimize railway operations by reducing human error and improving traffic management at level crossings. By automating barrier controls based on the real-time location of trains, the system minimizes unnecessary delays for road users and ensures the safe passage of trains, making it a scalable and efficient solution for modernizing railway infrastructure.

II. Literature Survey

The first research paper, "Automatic Opening and Closing of Railway Gates and Signaling in Railways Using IoT", introduces an IoT-based system that utilizes sound vibration sensors and ZigBee transceivers to detect trains and manage gate operations without human intervention. While the system automates gate control and alerts for approaching trains, challenges include limited detection range of the sensors, vulnerability of ZigBee communication to disruptions, and difficulty detecting smaller obstacles. Proposed solutions include integrating LiDAR or radar for enhanced detection, using hybrid communication systems like LoRa or 4G/5G for better reliability, and incorporating AI for improved data analysis and safety. [1]

The second paper, "Automatic Railway Gate Control System using the 8051 Microcontroller", focuses on replacing manual gate operations with sensor-driven automation at unmanned railway crossings. This system reduces delays and human errors in gate control. However, it faces potential failures due to hardware malfunctions or power outages, which could jeopardize safety. Suggested improvements include adding redundant systems such as backup power sources, additional sensors, and real-time monitoring through GSM modules, alongside emergency protocols for manual overrides in case of system failure. These enhancements aim to ensure consistent and reliable gate operations. [2]

The research paper presents a high-precision laser monitoring system using enhanced non-uniform LiDAR scanning to improve railway safety by detecting obstacles on tracks. The system achieves superior resolution and reduces the false alarm rate to 2.00%, well below the typical 20%. It operates in diverse weather conditions, ensuring real-time detection of obstacles such as pedestrians, vehicles, or debris. However, the system faces challenges like performance degradation in fog and heavy rain, as well as high costs due to advanced technology. Proposed solutions include integrating advanced signal processing algorithms and fail-safe mechanisms to ensure uninterrupted operation, even in extreme conditions [3]

The paper, "Design of an Advanced Intelligent Automatic Railway Gate Controller System for Avoiding Accidents at Crossing Points Using Verilog HDL", proposes an automated system to prevent accidents at unmanned railway crossings. The system uses sensors to detect approaching trains, triggering alarms and automatically closing the gates. Once the train passes, the gates are reopened. The system is designed using Verilog HDL, and operates through proximity sensors that track train movement, ensuring timely gate control without human intervention. Disadvantages include the system's dependence on sensor accuracy and potential malfunctions, which may lead to failure in gate operations or delayed responses, especially in extreme weather conditions. Proposed solutions involve incorporating redundant sensors and backup power systems to ensure reliability, alongside real- time monitoring that alerts authorities in case of malfunction, allowing for immediate corrective actions. [4]

The paper titled "Real-Time Obstacle Detection Over Railway Track using Deep Neural Networks" presents a system to detect obstacles on railway tracks using a deep learning model. It implements MobileNetV2 to classify real-time images captured from cameras installed at railway crossings. The model achieves 97% accuracy, effectively distinguishing between "empty track" and "obstacle track". The main disadvantages are the model's sensitivity to environmental changes and weather conditions, which can reduce its reliability, and the high computational cost for processing high- resolution images. The solution proposed includes using MobileNetV2 for its efficiency and ability to run on low-resource devices, making the system suitable for practical deployment. The study also recommends expanding the dataset to include diverse weather conditions for better performance. [5]

The paper titled "Safety at railway level crossings and Vision Zero" presents a safety analysis of railway level crossings using advanced mathematical modeling. The study focuses on improving safety by minimizing the negative effects of stray currents using track subgrade panels with appropriate resistivity. It highlights that subgrade resistivity plays a crucial role in reducing interference caused by stray currents that may damage signal systems and affect communication. Disadvantages of current systems include the incomplete insulation of tracks from the ground, leading to stray currents, and inadequate regulations for measuring panel resistivity. These stray currents can disrupt communication cables and damage the signaling system. The proposed solution is to use high-resistance track subgrade panels to mitigate the impact of stray currents and improve safety. [6]

III. METHODOLOGY

This methodology outlines the approach for detecting obstacles on railway tracks using a combination of object detection, lane segmentation, and sensor activation. The system is designed to detect obstacles within the railway track, trigger alerts, and manage level crossing gates to ensure safety for pedestrians and vehicles. The methodology also covers data storage on a cloud platform for future analysis and evidence, and the alert mechanism that notifies the train driver in real- time.

1. YOLO-based Obstacle Detection System Activated by Sensors

In this phase, the obstacle detection system uses YOLO (You Only Look Once), an advanced object detection algorithm, and is activated by proximity and infrared (IR) sensors to ensure efficient and timely detection of trains and obstacles.

1.1. Sensor Activation:

1.1.1. The system remains in a standby mode until a train is detected. Proximity sensors placed at a specific distance from the level crossing section detect an approaching train. Once the train is confirmed, the obstacle detection system is activated.

1.1.2. IR sensors assist in detecting the train's approach with higher accuracy by sensing motion and heat signatures, ensuring that the system is only engaged when necessary.

1.2. Obstacle Detection:

1.2.1. Once the sensors confirm a train's approach, the system closes the level crossing gates to prevent pedestrian and vehicle entry.

1.2.2. The YOLO algorithm is then applied to continuously monitor the railway track for any obstacles or humans in the path of the train. The detection happens within the railway lane, ensuring focus on the area of interest.

1.2.3. If an obstacle or human is detected and remains on the track for a predefined threshold time, the system captures images of the obstacle. These images are sent to a cloud storage system for analysis and evidence. Simultaneously, the alert mechanism is triggered to notify the driver.

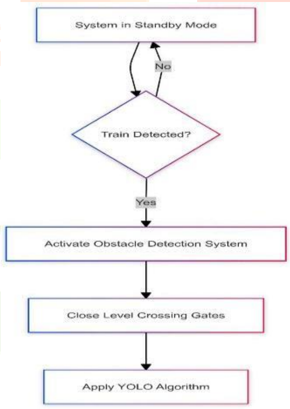

Fig.3.1: Initial setup flow

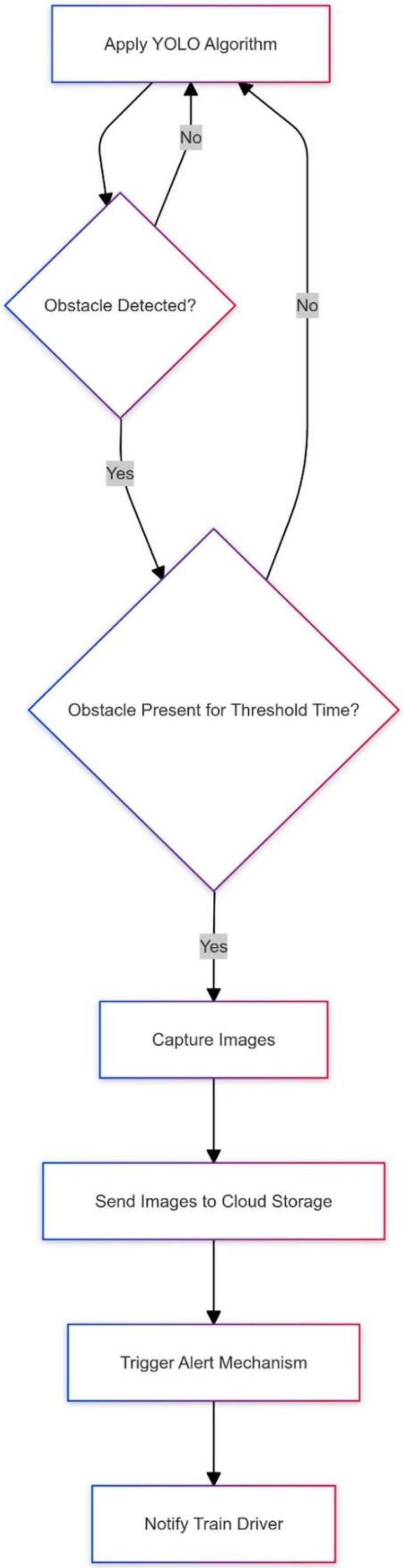

Fig.3.2: YOLO-based obstacle Detection

2. Alert Mechanism for Safety Protocol

The alert mechanism ensures safety for both pedestrians and train operators during train passage.

2.1. Pedestrian Warning: When an obstacle is detected or a train approaches, an alarm or buzzer is activated at the level crossing to warn pedestrians and vehicles. This helps clear the tracks and prevent accidents.

2.2. Driver Alert: Simultaneously, a real-time alert is sent to the train driver, providing key information such as:

2.2.1. Obstacle notification.

2.2.2. Obstacle location (e.g., 500 meters ahead).

2.2.3. Recommended actions like speed reduction or emergency braking.

The alert is transmitted through a secure communication system, with a mechanism to monitor the driver's acknowledgment. If no response is received, secondary emergency protocols are triggered

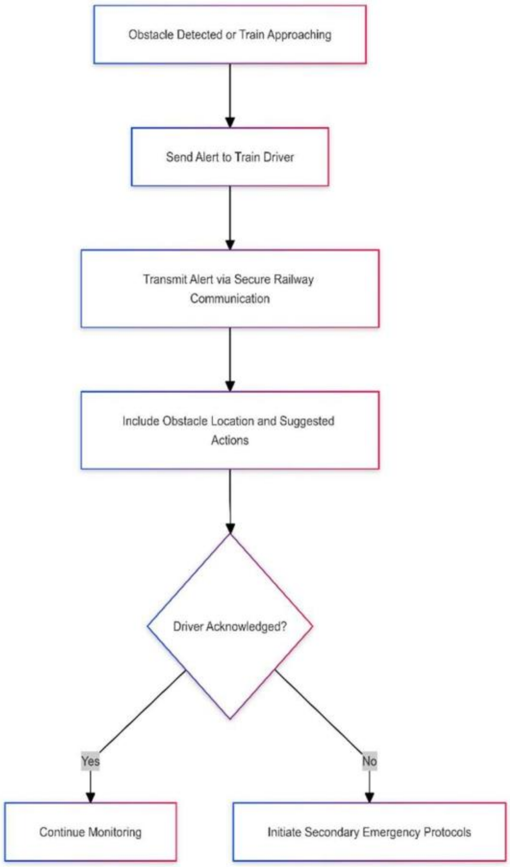

Fig.3.3: Alert mechanism

3. Gate Control and System Reset

After the train has safely passed the level crossing, the system automatically resets itself, ensuring the safe passage of road vehicles and pedestrians.

3.1.Gate Reopening:

Once the train has cleared the level crossing section, the system automatically opens the gates to allow road traffic and pedestrians to cross the tracks safely. This automation ensures that minimal human intervention is required for gate management.

3.2.System Deactivation:

After the train passes, the proximity sensors detect the absence of a train, and the obstacle detection system is deactivated. The system then returns to standby mode until another train is detected. The efficient deactivation of the obstacle detection system helps conserve resources and prevent unnecessary alerts or alarms

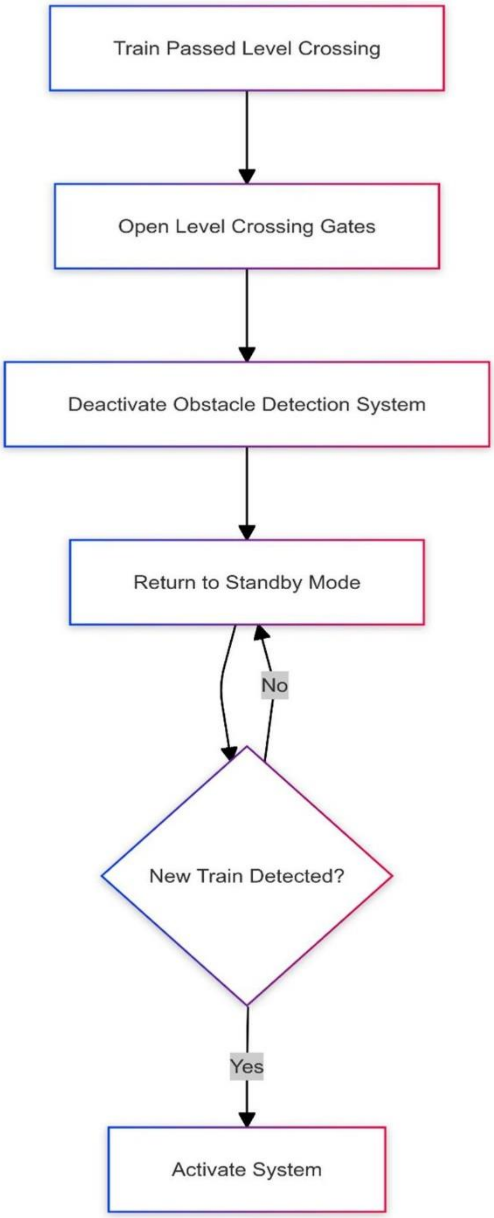

Fig3.4: Gate Control and Safety Reset

4. Cloud-based Image Storage and Analysis System

The final phase involves the storage and analysis of images and data related to obstacles detected on the tracks.

4.1. Image Capture and Storage:

4.1.1. When an obstacle is detected, the system captures relevant images or video frames, annotated with metadata such as GPS coordinates, time of detection, and classification of the obstacle.

4.1.2. These images are compressed and uploaded to a cloud platform using secure API protocols. The cloud storage system ensures that all data is backed up for redundancy and logged for tracking purposes.

4.2. Data Analysis:

4.2.1. Railway authorities can access the stored images for future analysis to improve safety protocols and refine the detection algorithms. The stored images also serve as legal evidence in case of an incident or near-miss situation.

IV. Conclusion

The "Automated Level Crossing System for Trains with Real-Time Obstacle Detection and Alerting Mechanism" represents a transformative advancement in railway safety and traffic management. As railway crossings continue to pose significant risks due to human error, stalled vehicles, and unpredictable pedestrian behaviour, this system provides a comprehensive and intelligent solution that addresses these challenges head-on.

By leveraging advanced technologies such as real-time object detection, sensor fusion, and cloud integration, the system significantly reduces the likelihood of accidents at level crossings. Unlike conventional systems that rely heavily on human operation and fixed schedules, this automated approach continuously monitors the crossing in real time, detecting any obstacles—be it vehicles, pedestrians, or debris—with a high degree of accuracy. This ensures that only genuine threats trigger safety responses, reducing false alarms and enhancing trust in the system's reliability.

The inclusion of automated gate control not only improves safety but also optimizes traffic flow. By precisely coordinating gate closures with train arrival times, the system minimizes unnecessary delays for road users, reducing congestion and enhancing commuter satisfaction. Audible alarms and flashing warning lights serve as an additional safety layer, ensuring that all road users, regardless of sensory limitations, are made aware of oncoming trains.

One of the most crucial aspects of the system is its ability to store critical data—such as captured obstacle images, timestamps, and sensor readings—on a secure cloud platform. This feature ensures transparency, allows for post-incident analysis, and serves as valuable evidence in legal scenarios. It also paves the way for long-term improvements through data analytics, enabling authorities to identify trends and optimize crossing operations accordingly.

Furthermore, the integration of real-time alerting systems that directly inform train drivers empowers them to make informed decisions in critical moments, potentially saving lives and preventing large-scale damages. This proactive communication bridges the gap between track-side intelligence and in-cabin response, creating a cohesive and responsive safety ecosystem.

In essence, this system modernizes railway infrastructure with a balanced focus on safety, efficiency, and technological foresight. It showcases how intelligent automation and data-driven decision-making can coalesce to address real-world transportation challenges. As urbanization and transportation demands continue to grow, implementing such smart systems will be pivotal in shaping safer, smarter, and more sustainable transit networks for the future.

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