



Obstacle Detection In Railways Using Iot

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Abstract: Railway safety is, in fact of paramount importance owing to the high accident rate often caused by some form of unexpected obstacle on a railway track, such as animals, vehicles, debris, and other foreign objects. Moreover, the current trackside obstacle detection systems are characterized by very high costs for maintenance, low distance coverage, and susceptibility to environmental wear and damage. The article discusses a novel IoT-based obstacle detection system for real-time detection and classification of obstacles utilizing LiDAR sensors and AI-enabled cameras mounted on the front of moving trains. It essentially shifts the mechanism of obstacle detection from the extensive trackside infrastructure to the train itself, thereby obliterating the latter. It thus identifies correct high-resolution, 3D obstacle images at a distance, ensuring differentiation between critical and non-critical objects, because the system combines LiDAR's ability to create high-resolution 3D maps with AI's object classification capabilities. Real-time computation within the edge device allows for sending alert messages immediately. It has better long-term monitoring integrated with cloud. Such innovative approach gives great benefits in enhancing railway safety systems by offering scalability, adaptability, and cost-efficiency. In addition to accuracy metrics, the system's performance will be evaluated using various environmental tests with very promising results in terms of obstacle detection accuracy, system reliability, and efficiency during operation.

Index Terms -Obstacle Detection, Arduino UNO, LIDAR, AI Enabled Camera

I. INTRODUCTION

Railways are playing a great role in the present transportation infrastructure of the world, carrying millions of passengers and freight tons daily. In contrast, railway systems are vulnerable to accidents caused by or near crossings, fallen trees, animals, or even pedestrians. There is thus an ever-growing need for a robust, reliable, and cost-effective solution to identify such an obstacle in real time.

Traditionally, trackside-based obstacle detection systems are composed of ultrasonic detectors, infrared cameras, and radar systems. Although these may work in specific areas, however, they have a few disadvantages. The installation of sensors over thousands of kilometers of railway tracks is expensive. Besides, servicing sensors from a distance is pain-staking. Trackside systems also wear and tear due to extreme environmental conditions, which are aggravated by extreme weather conditions.

II. BACKGROUND WORKS

Recent researches in radar-based systems have demonstrated some promising results and enhanced obstacle detection in cluttered environments. However, for densely populated areas, interference issues [1-4] are a major setback for radars and are expected to be involved in differentiating moving from stationary objects. In order to overcome these challenges, many studies have emerged suggesting the application of LiDAR sensors in autonomous vehicles and railway applications. LiDAR is a good choice for railway obstacle detection due to its reliable long-distance obstacle detection and support for high-resolution 3D maps [5]. Yoshida .et.al (2019) tested the effectiveness of LiDAR[6], in detecting objects on the tracks, even when visibility conditions are low .

Autonomously self-governing vehicles also combined AI to tackle real-time object classification with the efficiencies showcased using models like YOLO and SSD [7-8] where both methods are highly accurate and efficient. The YOLO model was

LiDAR is a technology commonly applied in the fields of autonomous vehicles; it can generate high-resolution 3D maps and measure exactly the distances between the sensor and detected objects. It therefore performs better than all other sensors, especially in those difficult or variant environments such as railway tracks. Meanwhile, the AI-enabled cameras are used more and more in object detection systems, which realize real-time object classification through deep learning models YOLO (You Only Look Once) and SSD (Single Shot Multibox Detector). While LiDAR and AI-based systems have successfully been implemented in various fields like automotive and robotics, their incorporation into the railway safety system has not been addressed much till now.

2.1 Contributions of the paper

1. This paper proposes an IoT-based obstacle detection system that flips the focus from what is trackside infrastructure to the trains themselves.
2. The proposed IoT-based obstacle detection system intends to improve railway safety with the shifting of the detection mechanism from trackside sensors to moving trains.
3. This proposed method uses LiDAR sensors for real-time distance measurements and AI-enabled cameras to identify and classify objects.

III. BACKGROUND WORKS

Our proposed method focusses on an IoT-based obstacle detection system that flips the focus from what is trackside infrastructure to the trains themselves. The system will integrate LiDAR sensors, which measure distance very accurately and capture 3D maps of the surroundings, with AI-enabled cameras to classify detected objects through real-time image analysis.

3.1 Architectural Diagram

Our proposed IoT-based obstacle detection system as shown in Fig.1 that flips the focus from what is trackside infrastructure to the trains themselves

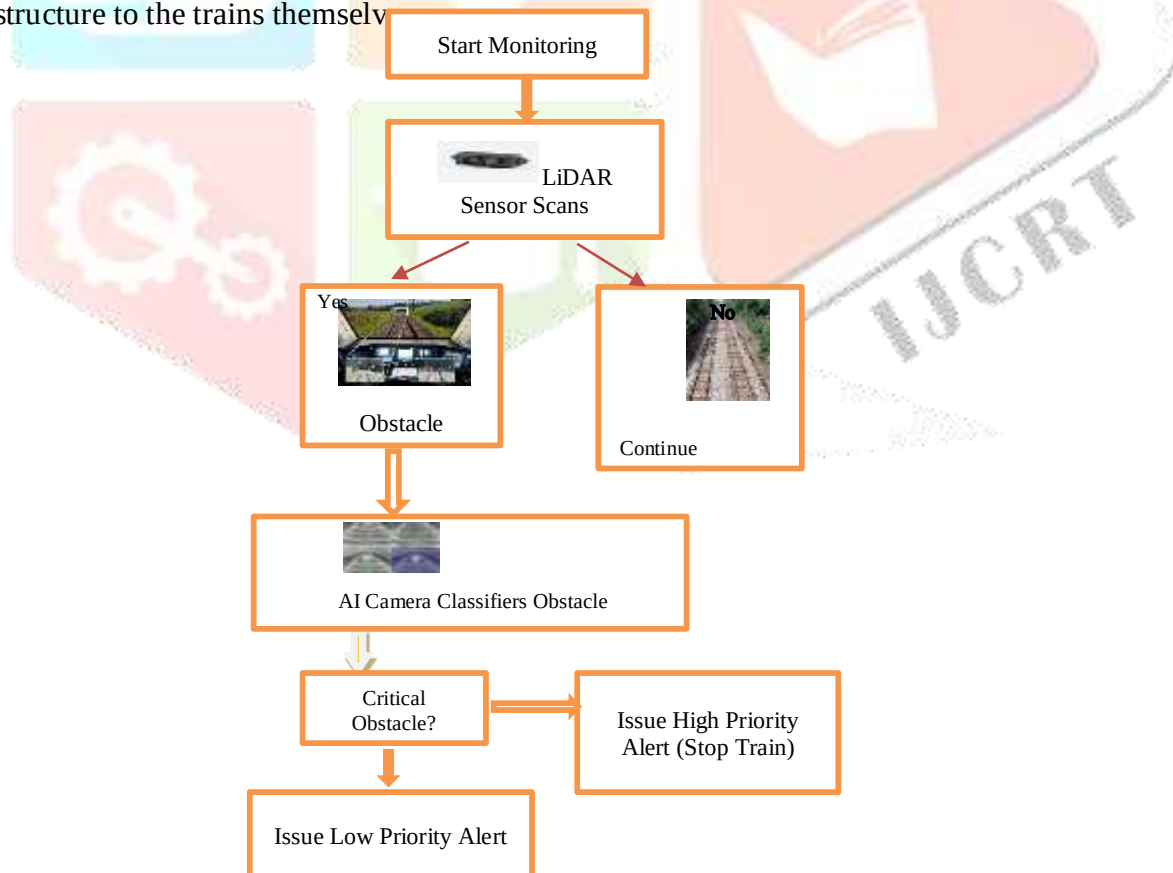


Fig.1. Steps in Proposed Obstacle Detection Model

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The proposed system of obstacle detection and classification has several advantages over traditional methods. First, this approach avoids the installation of costly trackside infrastructure, meaning that it is scalable and adaptable to a wide range of railway environments both urban and rural areas. Furthermore, the use of artificial intelligence enables obstacle type classification, reduces false positives, and allows the system to focus on high-priority, high-risk situations.

1. Sensor Deployment on Trains:

The LiDAR sensor and AI-enabled camera are mounted on the front of each train. This sensor arrangement ensures continuous monitoring of the tracks ahead as the train moves along its route. LiDAR Sensor: Continuously scans the environment and generates a 3D map based on distance measurements.

AI-enabled Camera: Captures images and video streams of the area ahead of the train and uses AI models to classify the detected objects.

2. Collection and Pre-processing of data: The LiDAR sensor scans tracks in real time; it measures distances between obstacles that appear to the trains during scanning. The AI camera captures images at set intervals or whenever there may be a potential obstacle present, as detected by the LiDAR sensor. The data for both sensors are fed into an Edge Processing Unit, such as that provided by Raspberry Pi or NVIDIA Jetson device, installed on the train.

Preprocessing: Noise is filtered out and relevant features, such as object boundaries and distances, are extracted on the edge device for analysis.

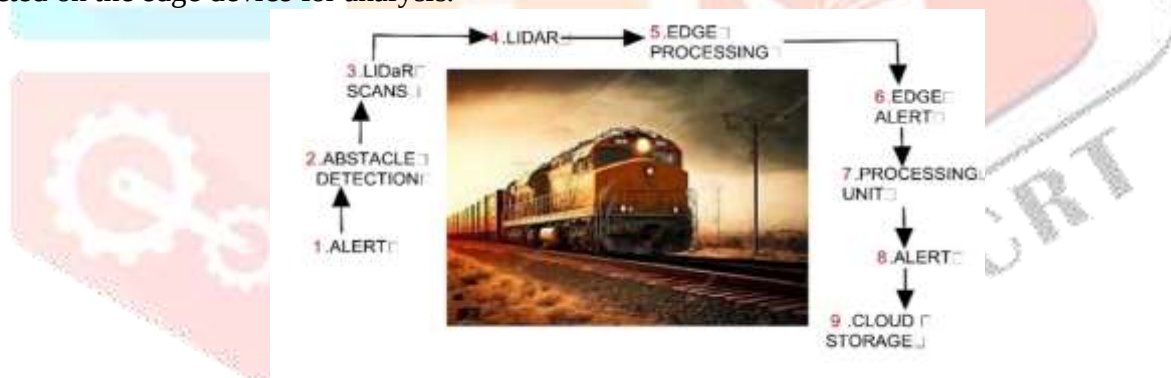


Fig.2. Proposed Obstacle Detection Model

3. Obstacle Detection / Classification LiDAR Data Processing: The point cloud, being 3D data from the LiDAR sensor, is analyzed to detect the presence of objects in the path of the train, and distances between the train and obstacles are measured to determine possible collisions.

4. Object Classification Using AI: The AI-enabled camera, equipped with pre-trained models (such as YOLO or SSD), analyzes the captured images to classify objects. The models can distinguish between different types of obstacles such as animals, vehicles, debris, and pedestrians.

5. Decision-Making Process : Once an obstacle is detected and classified, the system determines the severity of the situation. This involves: Critical Obstacles: Large objects, such as vehicles or animals, that could cause major accidents. Immediate alerts are generated for these. Non-Critical Obstacles: Smaller objects, such as debris, that do not pose an immediate danger but should still be logged and reported.

6. Real-Time Alerts and Communication: When an obstacle is detected critical, the edge processing unit will send a notification to the train driver, indicating an active immediate response signal, such as slowing down or stopping the train. The data are also transmitted to the central control center using GSM or Wi-Fi for further monitoring of the track conditions and planning. Data logging Cloud Integration: All these data are logged in a cloud for long-term monitoring and analysis, from which railway authorities can monitor track conditions and plan maintenance activities.

7. System Feedback and Continuous Learning: The system can get better with the passage of time by collecting feedback on the accuracy of object classification and obstacle detection. Machine Learning Model Updates: The AI models can be updated from time to time using the data gathered, thus increasing the accuracy of the classification and reducing false positives from time to time.

3.2 Data Flow Diagram

LiDAR scans the tracks for potential obstacles. AI Camera captures images and runs object classification models. Edge Processing Unit analyzes the data and decides the severity of the obstacle. Real-time alerts are generated for the train operator and control center. Cloud Storage retains data for long-term monitoring and analysis.

1. LIDAR (Light Detection and Ranging): LiDAR is Light Detection and Ranging, a remote sensing technology that measures the distances of objects with laser light and develops an intricate 3D image of the surroundings.

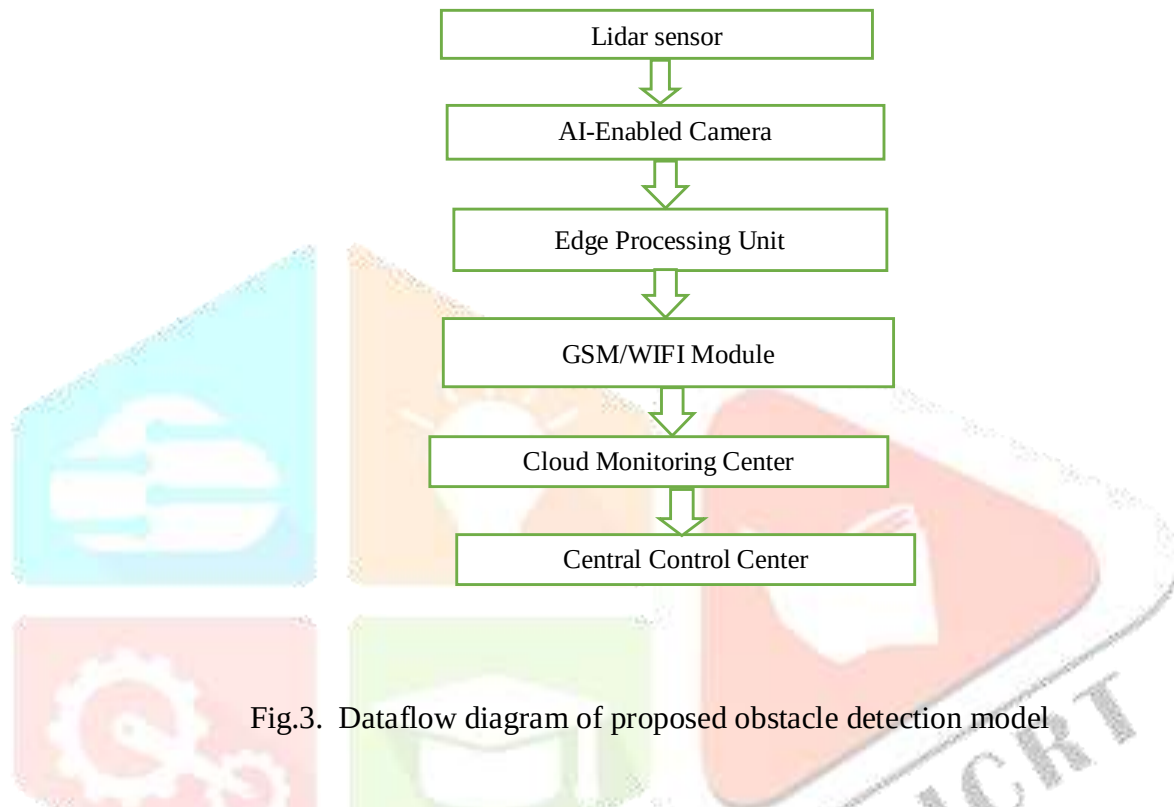


Fig.3. Dataflow diagram of proposed obstacle detection model

It basically works by releasing laser pulses and recording how much time it takes for the reflected pulses back to the transmitter when hitting an object. Data gathered can be used for various applications. Mapping and Surveying: High-resolution topographical maps and 3D models of landscapes. Autonomous Vehicles: Helping vehicles perceive and avoid obstacles. Forestry: Measures the height and density of the forest canopy. Archaeology: The hidden structures hidden under vegetation come to life. Urban Planning: Helps in the design and analysis of the city's infrastructure. LiDAR systems can vary very significantly in operational distance depending upon their design and intended application. There are short-range LiDAR systems, which are typically used for applications in, say an autonomous vehicle or close-range scanning but have a range up to about 100 meters. A medium-range LiDAR would be well-suited for mapping and surveying and usually has a range that is generally a few hundred meters up to about 200 to 500 meters. Long-Range LiDAR: High end 1 to 5 kilometers or more.



Fig.4 . Lidar

3. ESP32 Controller:ESP32 is a low-cost, low power system-a-chip microcontroller with integrated wi-fi and dual mode Bluetooth.ESP32 has 34 GPIO pins each pin can be used as General purpose input, output or connected to an internal peripheral signals.



7. **Arduino Software** :An official software presented by Arduino.cc, that is mainly used for writing, compiling and uploading the code in almost all Arduino modules/boards. Arduino IDE is open-source software and easily ownloadable & installable. Arduino IDE is an open-source software, designed by Arduino.cc and mainly used for writing, compiling & uploading code to almost all Arduino Modules. It is an official Arduino software making code compilation too easy that even a common person with no prior

It works on the Java Platform, which has inbuilt functions and commands that are of much importance in debugging, editing, and compiling the code. It is supported by a wide variety of modules for Arduino, which may include Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro, etc

The train is installed with edge processing units, which enable real-time processing of LiDAR sensor and AI camera information. Alerts with minimal latency are then generated; thus, critical obstacles would immediately trigger the action response. Integration with IoT and Cloud

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over the numerous trains in real-time. For analysis purposes to further improve safety protocols and define persistent pitfalls, historical data are stored in the cloud.

IV. RESULTS AND DISCUSSION

4.1 Accuracy Metric: The performance of our proposed obstacle detection model is evaluated various environmental conditions. Important metrics used included detection accuracy, classification accuracy, false positive rate, and system latency.

Table.4.1 :Performance analysis

S.No	Existing Methods	Metrics		
		Accuracy ratio	Response time	False positive rate
1	Ultrasonic sensor[13-14]	85	1.2	10
2	Infrared sensor [15]	80	1.0	15
3	Vision based system [16]	90	0.8	15
4	Proposed method [LiDAR+AI camera]	98	0.5	3

In Table.1 we have compared the accuracy values with already existing models and our proposed model. In which our system achieves high detection accuracy for all types of obstacles, with the highest detection accuracy being shown at 98.5%.

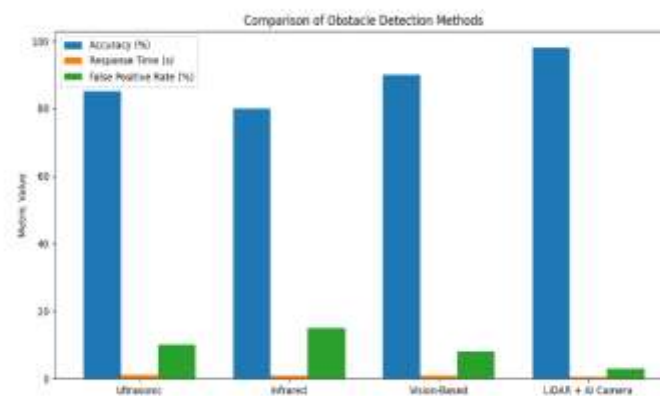


Fig.8.Comparison graph

V. CONCLUSION

The paper discusses an innovative solution related to the problem of obstacle detection within rails using IoT technology and now employs LiDAR sensors and AI-enabled cameras mounted on trains for this purpose. This reduces the prerequisite of expensive installations on tracks and provides a scalable, adaptable solution by detaching such detection infrastructure from the tracks. The AI allows for real-time classification, which increases the accuracy of the detection process while reducing false positives. Performance evaluations prove that the system is efficient, with a total accuracy in detecting 98.5%, which is acceptable and adaptable for railway safety enhancement purposes.

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