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Railway Gate Automation System Using Lidar Technology

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Abstract:- Railway gate management technology using LiDAR (Light Detection and Ranging) offers several benefits for enhancing safety and efficiency at level crossings. LiDAR can accurately detect approaching trains and vehicles, providing real-time data on their speed and distance. It can identify obstacles or individuals near the tracks, reducing the risk of accidents. Traffic signals at railway gates can be adjusted dynamically based on real-time data, minimizing delays for vehicles when no trains are approaching. LiDAR sensor emit laser pulses and measure the time it takes for the light to return after reflecting off objects. They create precise 3D maps of the surrounding area. A computer or server that processes the raw data collected by the LiDAR sensors. This system integrates with the railway's existing signalling and control infrastructure. Overall, the deployment of LiDAR technology in railway gate management can significantly enhance safety and operational efficiency while providing valuable data for future improvements.

Keywords:- *3D Mapping, Detection and Rangging, Railway Signalling, Safety Enhancement, Operational Efficiency.*

I. INTRODUCTION

Railway crossings are key points of intersection between roads and rail tracks, where safety is paramount due to the potential risks posed by high-speed trains and the movement of vehicles and pedestrians. Traditional railway gate systems often depend on manual operation or basic sensors that trigger gate closures based on fixed timers or mechanical triggers. These systems are prone to several limitations, including delayed gate activation, false alarms, and the inability to detect obstacles on the tracks. This can lead to severe accidents, including train collisions with vehicles or pedestrians trapped at the crossing. This project proposes an automated railway gate system using LiDAR (Light Detection and Ranging) technology to address these safety concerns and improve efficiency. LiDAR is a highly precise sensing technology that uses laser pulses to measure the distance and speed of objects by creating a real-time 3D map of the environment. By integrating LiDAR sensors at railway crossings, the system can accurately detect an approaching train from several kilometers away and calculate its speed and time of arrival. The system also scans for obstacles, such as vehicles or pedestrians, near the tracks and in the gate area, ensuring that the gates only close when the path is clear. This real-time detection eliminates the need for manual intervention, minimizes human error, and significantly improves the overall safety of the crossing. In addition to train detection, the system enhances efficiency by dynamically adjusting the gate operation based on the train's speed and distance. This reduces unnecessary road traffic delays, as the gates are only closed when necessary. The use of LiDAR also offers a high level of reliability, as the technology works effectively in various weather conditions, including rain, fog, and low light. Overall, this project aims to modernize railway crossings by providing a cost-effective, automated solution that prioritizes safety and improves traffic flow, using LiDAR's advanced sensing capabilities for precise and timely gate operation. LiDAR (Light Detection and Ranging) is a remote sensing technology that uses laser light to measure distances and create detailed 3D maps of the environment. The system works by emitting rapid pulses of laser light that bounce off objects and return to the sensor. By measuring the time it takes for the laser pulses to travel to an object and back, known as the "time of flight," LiDAR can calculate the precise distance to each object in the sensor's range. This process happens at a very high rate, often sending out millions of laser pulses per second, enabling it to build a highly accurate 3D representation of the surrounding area.

II. STATE OF THE ART

- *[1] 3D-LIDAR Based Object Detection and Tracking on the Edge of IoT for Railway Level Crossing(2021)*

- Object detection is crucial for safety in areas like railway level crossings, where accidents canhappen. This work presents an edge IoT platform designed to quickly detect and track objects in thesecrossings. The system uses a low-resolution 3D LIDAR sensor to create detailed area maps. By processingdata on a compact, low-power device close to the sensor, the system reduces delays and avoids bandwidth issues that can occur with cloud processing. A lightweight algorithm is implemented to handle the largeamounts of data from the LIDAR while ensuring real-time performance. The method has been tested ona simulated railway crossing on a car road, proving its effectiveness for safety applications. [2]Monitoring Deformation along Railway Systems Combining Multi-Temporal InSAR and LiDARData(2019)

-Multi-temporal interferometric synthetic aperture radar (MT-InSAR) is a useful tool for monitoring the health of structures like railways and bridges. However, accurately linking radar data to physical objects can be tricky due to the limited precision of radar scatterers. This study presents a new method that combines MT-InSAR with LiDAR (laser

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scanning) data to improve monitoring. By using advanced processing techniques, the researchers can connect radar scatterers to specific points in the LiDAR data and correct their positions. They also introduced quality metrics to assess the results. The experiments showed that the radar data matched well with the LiDAR points, demonstrating the value of LiDAR for classifying radar scatterers effectively.

- *An Enhanced Algorithm for Concurrent Recognition of Rail Tracks and Power Cables from Terrestrial and Airborne LiDAR Point Clouds(2017)*

-This study presents an improved algorithm for identifying railroad assets from LiDAR point clouds. It works on any slope, uses Eigendecomposition for selecting rail points, and efficiently processescomplex datasets. Tested on two datasets—one from a terrestrial scanner and another from an airborne platform—the algorithm identified all objects with over 95% accuracy and precision, demonstrating its effectiveness in simple and complex environments.

- *Review of Laser Scanning Technologies and Their Applications for Road and Railway Infrastructure Monitoring (2019)*

-Improving infrastructure resilience is crucial for reducing vulnerability to hazards like extremeweather and human-made events. A key part of resilience is preparation, which involves predicting risks, monitoring infrastructure, and using systems to anticipate and prevent damage. This work reviews currentmethods and technologies for efficient, automated infrastructure monitoring, focusing on LiDAR (Light Detection and Ranging) data processing, especially for roads and railways. It discusses important applications for monitoring transport infrastructure and compares various commercial terrestrial LiDAR systems to highlight available sensors and tools for remote monitoring.

- *Automated Inspection of Railway Tunnels' Power Line Using LiDAR Point Clouds(2019)*

-Transport networks need regular inspections for safety, and LiDAR technology has become akey tool for this. This paper presents a LYNX Mobile Mapper System method to automatically inspect overhead contact lines in railway tunnels. The process involves creating a 3D point cloud and classifyingit into contact wires and other points. The method was validated in three tunnels, producing accurate resultsthat meet Spanish standards.

- *[6]A Benchmark for Lidar Sensors in Fog: Is Detection Breaking Down?(2018)*

- Level five autonomous driving means cars can drive themselves in all conditions, not just sunny weather. Fog, rain, and snow make it hard for these cars to see their surroundings. In this study,they tested four advanced lidar sensors in a fog chamber to see how they perform in bad weather. Andfound common issues and disturbance patterns with these sensors and explored how adjusting their settings can enhance their performance. This is crucial because many detection systems rely on clear lidar data and may struggle in challenging conditions.

- *Quantifying the Influence of Rain in LiDAR Performance(2017)*

LiDAR systems are crucial for self-driving cars, and this study looks at how rain affects theirperformance. We tested six different surfaces to see how rain impacts three key factors: range, intensity,and the number of points detected. The range measurements remained stable, with changes of less than20 cm, mainly due to how we averaged the data. However, as rain intensity increased, both the intensityof the LiDAR signal and the number of points detected decreased. The biggest drop in detected pointswas on pavement, but the intensity there wasn't greatly affected by rain. Other materials showed similar patterns in intensity and point detection.

- *Instant Object Detection in Lidar Point Clouds(2017)*

In this study, we introduce a new method for classifying objects in Lidar point clouds collectedfrom urban areas. Using data from a Velodyne HDL-64 Lidar, we focus on identifying vehicles and pedestrians around the moving sensor. Our approach includes several steps: first, we divide the point cloud into areas representing the ground, short objects, and tall objects. Next, we use a unique two- layer grid to analyze these areas and group points that correspond to different urban objects. Then, we create depth images of these objects and use a convolutional neural network for initial classification. Finally, we refine this classification by considering the layout of the scene. We tested our method on real Lidar data, successfully identifying 1,485 objects from various urban settings.

- *A Review of LiDAR sensor Technologies for Perception in Automated Driving*

After over 20 years of research, Advanced Driver Assistance Systems (ADAS) are now common in modern vehicles, and automated driving systems are moving from testing to real-world use.These systems rely on sensors to gather information about the vehicle, its surroundings, and other road users. Choosing the right sensors and their placement is crucial for effective design. This paper reviews current and emerging sensor technologies, focusing on LiDAR. We analyze how LiDAR works, its prosand cons, and common types. We also suggest ways to improve LiDAR's recognition accuracy in various weather conditions. Finally, we introduce new LiDAR sensors being researched and propose an innovative multi-sensor fusion approach to enhance system performance, discussing its feasibility.

- *Lidar Technology and its Applications(2018)*

Collecting geo-data has traditionally been a difficult and costly process, but recent advances in remote sensing have made it much easier. In the last decade, new techniques for automatically gathering 3D geo-data, especially Digital Elevation Models, have gained popularity. LiDAR technology, which uses various laser sources and improved detectors, has become a reliable tool for atmospheric research. This paper reviews several LiDAR systems, like Differential Absorption LiDAR and Airborne LiDAR, detailing their specifications and uses. It also discusses the successful applications of LiDAR in Environmental Engineering, highlighting its potential, particularly in India. Case studies include air quality research in Pune, monitoring

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atmospheric components in New Delhi, and studying ozone levels in Gujarat, showing how LiDAR can provide valuable environmental insights.

➢ *The evolution of LiDAR and its Application in High-Precision Measurement (2020)*

LiDAR is a key technology in remote sensing that collects detailed and accurate data about theEarth's shape and surface features. This paper discusses the evolution of LiDAR technology, highlighting major companies and their products. It also reviews current research focuses and application cases to showcase LiDAR's characteristics and functions. Looking ahead, the future of LiDAR will focus on new radiation sources, integrating multiple sensors, and exploring new mechanisms. Additionally, the paper offers suggestions for advancing high-precision LiDAR systems domestically.

➢ *LIDAR TECHNOLOGY (2022)*

LiDAR (Light Detection and Ranging) technology has been around since the 1960s and has become a widely used sensor as technology has improved. It is utilized in various fields, including automation, agriculture, archaeology, IT, and atmospheric studies. This paper discusses how LiDAR works, its different types, history, and applications. LiDAR can measure distances between objects andcreate 3D digital models of areas. It's especially known for producing accurate georeferenced spatial data about the Earth's shape and surface features. Recent advancements in LiDAR mapping systems have allowed researchers and mapping professionals to explore both natural and built environments with unprecedented accuracy and cost-effectiveness, enhancing our understanding of human civilization.

➢ *RESEARCH AND APPLICATION OF LiDAR TECHNOLOGY IN CADASTRAL SURVEYING AND MAPPING(2020)*

The government places great importance on the rights to use rural land, and China is currentlyworking on a large-scale project to map and confirm rural house sites. Traditionally, this has been done using total stations or manual RTK measurements, which are labor-intensive and complex. Given that China has hundreds of thousands of villages, adopting new technologies for rural land surveys is essential for improving efficiency and quality. LiDAR scanning technology offers benefits like high efficiency, flexibility, reliability, and accuracy, making it a better choice than traditional methods. Thispaper focuses on the AS-300H multi-platform LiDAR system from Huace Navigation, which combinesUAV and vehicle LiDAR for cadastral surveying. It demonstrates that using LiDAR for mapping rural land reduces labor intensity while increasing efficiency and accuracy. The paper also discusses the pros and cons of LiDAR technology, providing valuable insights for those involved in rural housing and land mapping.

➢ *Automotive LIDAR Technology(2019)*

There are many different LIDAR designs because various companies are trying to meet the specific needs of the automotive industry, such as performance, cost, and size. Each design uses different technologies and approaches to achieve high-resolution distance measurements, which are crucial for Advanced Driver Assistance Systems (ADAS) and self-driving cars. Since there are no strict standards yet, companies are experimenting with different methods to see which one works best, leadingto a diverse range of competing products.

➢ *Research, Application, and Innovation of LiDAR Technology in Spatial Archeology*

Environmental changes and human activities threaten archaeological sites, especially in remoteareas. Our research in Guatemala shows that LiDAR can help us create new models to understand theselandscapes. However, detecting features can be challenging, leading to false positives or negatives, so skilled modeling is essential. While LiDAR is often used rigidly in science, in Spatial Archaeology, we highlight the need to blend scientific analysis with creativity to fully explore archaeological contexts. LiDAR effectively combines objective data with artistic insights from the humanities.

➢ *A Survey of LIDAR Technology and its Use in Spacecraft Relative Navigation*

This paper reviews modern LIDAR sensors and their potential use for spacecraft navigation. It covers both current LIDAR technologies used in space, like scanning and flash LIDAR, as well as emerging technologies from other fields. The paper explains how each type of LIDAR works, along with their advantages and disadvantages. Overall, it offers a thorough overview of how LIDAR can enhance navigation for spacecraft.

III. CONTRIBUTION OF THIS WORK

In this paper, the theoretical concepts of LiDAR technology and the existing systems related to railway safety mechanism and existing systems for railway gate management has shown. The comparative study of various distance sensors with TF-LC02 LiDAR sensor is explained. The ranging and other parameters of the distance sensor has compared with TF-LC02 LiDAR Sensor.

IV. MATERIAL AND METHODOLOGY

➢ *Material Used:*

- TF-LC02 LiDAR Sensor
- IR Sensor
- HC-SR04 Ultrasonic Sensor
- ESP-32 Module
- DC Motors
- L298N Motor Driver

➢ *System Design:*

- *Sensing Mechanism*

✓ Lidar Placement: Mount the TFLC02 sensor at a strategic location where it can detect oncomingtrains at a safe distance.

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- ✓ Detection Range: Determine the effective range and angle for accurate detection.

- *Control Logic*

- ✓ Threshold Configuration: Set a distance threshold (e.g., 100 meters) for the train's approach.
- ✓ Control States:

  - Idle: Gate is open, and no trains are detected.
  - Closing: Gate is closing when a train is detected within the threshold.
  - Closed: Gate is fully closed while the train passes.
  - Opening: Gate opens after the train has cleared the crossing. User Interface

- ❖ Local Monitoring: Simple LED indicators or a small display to show the status of the gate.
- ❖ Remote Monitoring: Mobile app or web interface for real-time status updates.

➢ *Block Diagram*

Fig 1: Block Diagram

This block diagram illustrates a system that employs a LiDAR sensor for the purpose of obstacle detection, processes the gathered data to facilitate real-time decision-making, controls a gate mechanism, and issues notifications. Below is a detailed explanation of each component: LiDAR Sensor (Obstacle Detection): The system initiates with a LiDAR sensor, which plays a crucial role in identifying obstacles within the environment. LiDAR, or Light Detection and Ranging, utilizes laser light to ascertain the distance and dimensions of objects. Data Acquisition System: The information gathered by the LiDAR sensor is relayed to the Data Acquisition System. This system is responsible for capturing and formatting the data for subsequent processing. Data Processing Unit: Following data acquisition, the information is directed to a processing unit that filters, interprets, and prepares the data for decision-making purposes. Real-Time Analysis and Decision Making: At this stage, the system conducts a real-time analysis of the processed data and makes decisions based on established rules or algorithms. For instance, if an obstacle is detected within a specified range, the system may opt to activate the gate control. Control System (Gate Control Mechanism): This component receives directives from the decision-making module and manages a physical gate control mechanism. It may open, close, or halt the gate in response to obstacle detection. Notification System (Alert and Monitor): The concluding component of the system is the notification system, which provides alerts and monitors the operational status. This allows operators or users to stay informed about actions taken, such as gate operations or real-time obstacle detection.

➢ *Safety Features:*

- *Redundant Sensors:*
  Use of additional sensors to verify the presence of the object train.

- *Timer Functionality:*
  Ensuring that the gates remain closed for the specific duration after passing the train.

- *Alarm System:*
  Integrate the alarm to alert pedestrians when the gate is closing.

V. RESULTS AND CONCLUSION

The comparison between various sensors using different parameters is shown in TABLE 1.

Table 1: Performance Comparison of Various Distance Sensors

Features	LiDAR	IR Sensor	Ultrasonic Sensor
Operation	Reflected laser light to measure distance	Infrared light to measure distance	Reflected sound waves to measure the distance
Range	Very long range (Up to some Km)	Short range (Up to some Cm)	Medium range (Up to some meters)
Accuracy	Very High	Moderate	Moderate
Compatibility	Highly compatible for 3D mapping	Low compatibility	Depends upon the wave frequency
Environmental Compatibility	Can affected by dust and particles	Sensitive to ambient reflections	Can affected by fluctuation in temperature
Power Consumption	High	Low	Low
Costing	High cost	Low cost	Moderate

The table provides a comprehensive comparison of three types of sensors commonly used for distance measurement: LiDAR, Infrared (IR) Sensors, and Ultrasonic Sensors. Each sensor operates on a differentprinciple, with LiDAR using laser light, IR sensors relying on infrared light, and ultrasonic sensors usingsound waves.

In terms of range, LiDAR sensors excel with long-range capabilities, often reaching several kilometers, while IR sensors are limited to short to medium distances of a few meters, and ultrasonic sensors provide a medium range, typically effective up to 4–5 meters. LiDAR offers very high accuracy, often to sub- centimeter levels, making it suitable for applications requiring precise measurements. IR and ultrasonic sensors provide moderate accuracy, with IR sensors being affected by ambient light and ultrasonic sensors typically achieving about ±1 cm accuracy.

The resolution of these sensors also varies significantly, with LiDAR creating highly detailed maps thanksto its high resolution, IR sensors providing low resolution, and ultrasonic sensors offering moderate resolution that depends on the frequency of the sound waves used. Environmental sensitivity is another important consideration, with LiDAR being affected by conditions such as rain, fog, and dust, IR sensorsbeing susceptible to interference from ambient light and reflections, and ultrasonic sensors being less sensitive to light but impacted by temperature and humidity.

Finally, the cost and power consumption of these sensors vary, with LiDAR being the most expensive andconsuming more power due to its advanced technology and precision, while both IR and ultrasonic sensorsare generally low-cost and have low power requirements, making them suitable for applications where cost and energy efficiency are priorities. This comparison highlights the specific advantages and limitations of each sensor type, allowing for informed choices based on the requirements of a given application.

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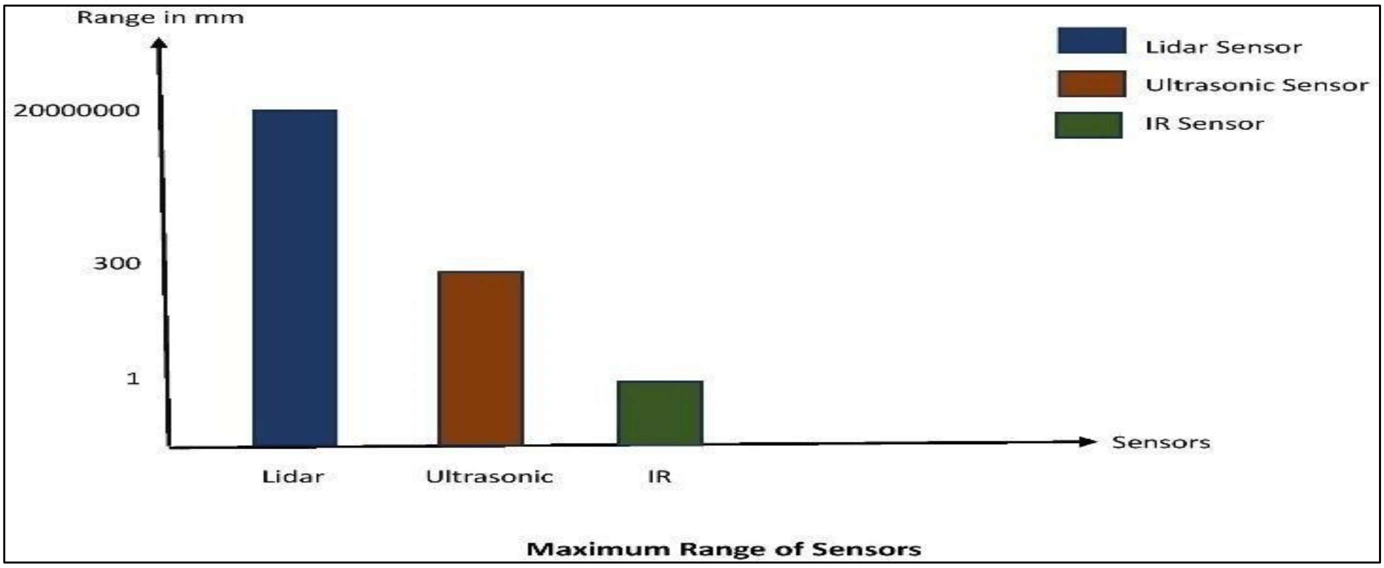

Fig 2: Comparison of Sensors in Term of Range

The bar chart effectively illustrates the maximum range capabilities of three different types of sensors: LiDAR, Ultrasonic, and Infrared (IR) sensors. The vertical axis represents the range in millimeters, whilethe horizontal axis lists the three sensor types.

The LiDAR sensor, depicted in blue, has a significantly higher range compared to the other sensors, reaching up to approximately 20,000,000 mm (20 kilometers). This makes LiDAR suitable for long- distance applications. The ultrasonic sensor, represented in brown, has a medium range capability, extending to about 300 mm (or 30 centimeters), which is much lower than LiDAR but still useful for applications requiring moderate distance measurement. Finally, the IR sensor, shown in green, has the shortest range among the three, reaching just a few millimeters. This limited range makes IR sensors suitable for short-distance applications, such as proximity detection.

In summary, the chart highlights the vast difference in range among these sensors, with LiDAR being idealfor long-range applications, ultrasonic for medium-range, and IR for short-range purposes.

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