Proactive Obstacle Monitoring and Prevention System

Mr. Ramakrishnan P Assistant Professor,

Electronics and Communication Engineering M.Kumarasamy College of Engineering Karur, Tamil Nadu, India [ramakrishnanp.ece@mkce.ac.in](mailto:ramakrishnanp.ece@mkce.ac.in)

Karthi A.S

Electronics and Communication Engineering M.Kumarasamy College of Engineering Karur,

Tamil Nadu, India [kk6383557880@gmail.com](mailto:kk6383557880@gmail.com)

Kavinraj S

Electronics and Communication Engineering M.Kumarasamy College of Engineering Karur, Tamil Nadu, India [subramanis45425@gmail.com](mailto:subramanis45425@gmail.com)

***Abstract*— Accidents caused by essence track barriers, such a****s animals, debris and people violations weighing important safety and operating risk. The project introduces an active obstacle and introduces the prevention system that integrates infrared (IR) and ultrasound sensor, wireless communication, GPS-based train positioning and bio-related preventive systems to increase rail security. The system detects obstacles when using IR and ultrasonic sensors and transmitting real-time alerts through the Lura wireless module. A GPS-based selective warning mechanism ensures that only trainers leading to an obstacle get information by optimizing communication efficiency. In addition, bioacoustics releases prevention systems ultrasonic sound waves to retreat to prevent conflict of wildlife. The system is powered by solar energy, which ensures energy efficiency and scalability in remote areas. Field experiments show high identification accuracy, rapid notification transfer and effective animal prevention, leading to cost -effective, scalable and reliable growth in rail security for this solution. By reducing the collision of trains with obstacles, it improves rail security, protection of wildlife and operational efficiency.**

***Index Terms*—rail security, obstacle detection, LoRa communication, GPS-based notification, bioacoustics detector, ultrasonic sensor, infrared sensor, real-time monitoring.**

# INTRODUCTION

Railways are an important way of transporting, but spores obstacles from animals, falling debris and human violation reduce significant security risk. International Union of Railway (UIC) reports 2000 train collisions with annual obstacles, causing fatal, deformity and infrastructure damage. In India, 20% of railway accidents include wildlife, while the United States causes millions of damage due to a pioneer.

Muthumani P

Electronics and Communication Engineering M.Kumarasamy College of Engineering Karur, Tamil Nadu, India [muthumani4002@gmail.com](mailto:muthumani4002@gmail.com)

Kavinesh C

Electronics and Communication Engineering M.Kumarasamy College of Engineering Karur,

Tamil Nadu, India [kavineshc24@gmail.com](mailto:kavineshc24@gmail.com)

European railway networks face frequent delays despite solutions such as fencing and monitoring distance. Wildlife, natural disasters and human activities are hindered. Countries such as India, Canada and Australia report high train accidents due to cattle, elephants and deer. In North America, moose and deer collisions often dip. In Kaziranga National Park in India, elephants often suffer from railway accidents. Strong winds, storms and landslides also help to track the obstacles, causing derailment in Japan and the United States. Innovation of urban rail networks worldwide, human violations have become an important cause of deadly people related to the train.

There are limits to existing security measures, including manual patrolling, CCTV monitoring and trace fence. They depend on human intervention, have high costs and fail to prevent small animals or fallen debris. Current systems really lack automatic notice and often cause false alarms. The project introduces an active obstacle and introduces the prevention system that integrates infrared and ultrasound sensors, LoRa-based train alert, GPS filtering and a bioacoustics preventive system. Leuze Odsl 30 Series IR sensor (100 meter interval) and Maxbotics MB2530 XL-Maxsonar-EAL Ultrasonic Sensor (30 meters interval) obstacles are detected, treated in real time by an ESP32.

With the help of solar and affordable technology, the system wants to offer low costs, energetic and real-time solutions. Sensors when using GPS-based filtration to reduce false alarms. AI ultrasonic signal optimization based on operated adaptive preventative and animal behavior and environmental factors are examples of future reforms. This method improves rail security, reduces the accident frequency and increases operational efficiency by mixing automated identification, selective train alerts and animal prevention agents.

# LITERATURE SURVEY

Rail safety research has led to the development of various obstacles to detecting technologies including radar, LiDAR, thermal imaging and data view. Radar-based systems use radio waves to perform well in a state of low visibility and perform well, but suffer from high costs and limited resolution. LiDAR provides high-resolution 3D imaging, but is expensive and weather sensitive. Thermal imaging detects obstacles based on the signature of heat, making it useful to identify living objects, although efficiency decreases in a warm environment. The AI- produced computer vision provides real-time image- based identity with high accuracy, but requires important calculation resources. Comparative studies indicate that although AI-based systems provide better accuracy, their viability is forced to treat strength and environmental dependence.

IoT development has greatly improved the railway monitoring through real-time tracking and automatic notice. China’s Smart Railway IoT system uses 5G-competent sensor, while Indian Railways has piloted LoRa WAN-based monitoring, which achieves 80% efficiency to prevent train conflicts with elephants. European rail network utilizes IoT and AI analyzes for future maintenance. Inspired by these innovations, the LoRa-based notice integrates the adapted obstacle communication.

Ultrasonic bioacoustics that have shown a promise to reduce animal -related railway accidents. Research indicates that species-specific ultrasonic frequency range effectively drops animals without loss. In Kaziranga National Park in India, ultrasonic emitters have reduced the deadly by 60%, while in Alaska the speed-active prevention has reduced deer- related train collision by 70%. The project improves existing methods with an AI-driven adaptive preventive systems that adjusts frequencies based on dynamically detected animals.

While existing technologies offer different trade charges in costs, accuracy and viability, the project proposes a low price, scalable solution that integrates IR and ultrasonic sensors with LoRa-based notification and adaptive bio-related internment. By taking advantage of IoT and AI-operated innovations, the system aims to detect real-time obstacles and increase rail security through efficient communication.

# METHODOLOGY

1. *Overview of System Components*

The proposed active obstacle and prevention system consists of several interconnected components that work together to detect obstacles, classify them and take real-time preventive

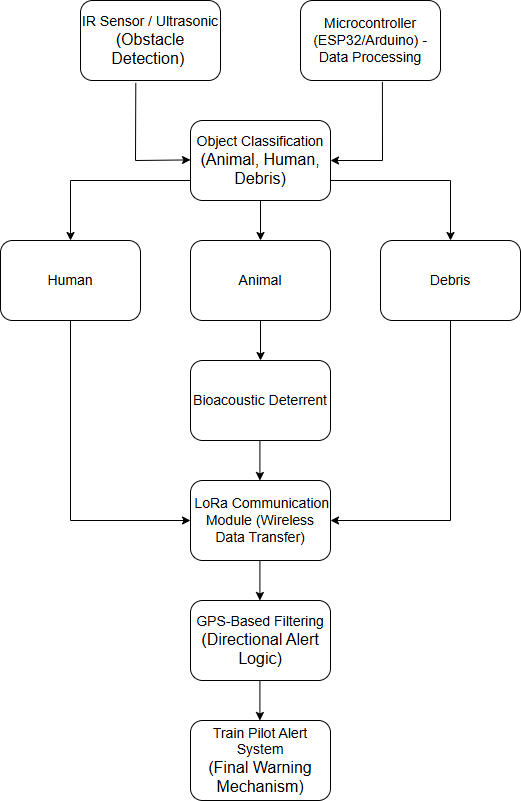


Fig. 1. Block diagram of Proactive Obstacle Monitoring and Prevention System

measures. The most important components of the system include:

* 1. Object identification sensors (infrared and ultrasonic sensor) Infrared sensor (Leuze ODSL 30 Series): Long distance barriers are used to detect (100 m interval). MaxBotix MB2530 XL-MaxSonar-AEL ultrasonic sensor: High-precision detection of smaller distance obstacles at 30-meter intervals.
  2. ESP32 Microcontroller unit classes obstacles after treating the sensor data. GPS is administered by communication sensors between units and LoRa module.
  3. LoRa communication module wireless low power data allows long-term transport.
  4. GPS-based train tracking system Determines the condition of the train and the direction of movement. The filter is warned only to ensure that the alert only reaches the train.
  5. bioacoustics preventive system Ultrasonic sound waves down the animals before entering the grooves. Uses species specific frequencies to optimize efficiency.
  6. Solar Energy Management System Provides strength to the entire system at remote railway places. Uses battery storage for continuous operation during the night.

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| **Component** | **Protocol used** | **Functionality** |
| Sensors (IR, Ultrasonic) | 12C, Analog | Detect obstacles and measure distances |
| Microcontroller (ESP32/Arduino) | Serial UART | Processes sensor data & executes  algorithms |
| GPS Module | NMEA (UART) | Retrieves real- time train location |
| LoRa Module | LoRa WAN | Sends wireless alerts to approaching trains |
| Train Alert System | MQTT  (Future Scope) | Enables real- time notifications |

1. *Working Principle*

The system works in a five-stage process, which ensures real-time detection and the mitigation of railway track barriers. The detailed work theory is explained below.

Step 1: Detect obstacles using the sensor Infrared and ultrasonic sensors are distributed with railway tracks at predetermined intervals. The IR sensor detects stable or moving elements within its limit. The ultrasonic sensor provides accurate distance measurement of the obstacle. The sensor data is sent to ESP32 microcontroller for further treatment.

Step 2: Object classification (animals, debris or human violation) Microcontroller sensor processes data and determines the type of obstacle. Object is done based on classification: size and size analysis (for humans, animals and debris). Movement properties (animals show irregular movements, debris remain stable). If an animal is detected, the bioacoustics deterioration system is activated.

Step 3: bioacoustics Preventive System Activation (for animals) If the detected barrier is classified as an animal, the system triggers ultrasonic detective modules. This preventive high frequency is released in the area Ultrasonic waves:

12-16khz for elephants, 16-22 kHz for deer, 20–24 kHz for cattle. Ultrasonic waves encourage animals to move away from the railway track without damaging them.

Step 4: LoRa-based train alert system (if hindered) If the barrier persists on the field, a real-time warning is transferred to the LoRa communication module. GPS filtration ensures that only trains that move against obstacles receive notifications. It prevents false alarms and optimizes communication efficiency. Step 5: Train pilot receives warning and takes grip The train pilot receives a real-time warning on the board system. The pilot can then: reduce the speed, activate emergency brakes, be prepared for manual intervention. In order to integrate sensor- based detection, selective notification and ultrasonic deterioration, the system ensures active prevention of railway

accidents.

# SOFTWARE IMPLEMENTATION

1. *Object identification algorithm*
   1. *Overview:* The algorithm for detecting obstacles is responsible for detecting obstacles on railway tracks using infrared (IR) and ultrasonic sensors. It classifies the detected object into categories such as animals, human testers or debris. If an animal is detected, the bioacoustics repelling system is active to pick it up. If the barrier persists on the track, the system checks the GPS-based train direction and sends a warning through LoRa wireless communication to coming towards trains.

Table. 1. Communication Protocols

* 1. *Algorithm Flow:* The algorithm to detect the obstacle follows these steps:
     1. Read the sensor input from IR and ultrasonic sensor.
     2. Process object classification (animals, human or debris).
     3. If an animal is detected, activate the bioacoustics repelling system.
     4. If the obstacle remains, you must determine the direction of train movement when using GPS.
     5. If a train comes, you can send a notice through LoRa communication.
     6. Interpretation of Main Functions:
        1. readUltrasonicSensor(): A distance from ultrasonic sensor sounds measurement.
        2. readIRSensor(): If an object is present within the IR sensor, check.
        3. classifyObject(): User predetermined rules to classify the object detected.
        4. activatebioacousticsSystem(): emits ultrasonic waves to retreat.
        5. isTrainApproaching(): It uses GPS-based train tracking to determine if a train is moving towards a barrier.
        6. sendAlert(): LoRa sends a warning to the locomotive pilot through the module.

1. *Selective Train Alert Algorithm*
   1. *Overview:* The selective train alert algorithm ensures that only trainers who grow to an obstacle receive a notice, leaving false alarm and unnecessary information.
   2. *Algorithm Flow:* The algorithm to alert the train follows these steps:
      1. Find the obstacle using the sensor.
      2. Show object classification (animals, debris or human).
      3. If the barrier persists, then get the place for the train using GPS.
      4. Calculate the direction of the train movement in relation to the barrier.
      5. If the train moves towards a barrier, you can send a notice through LoRa.
      6. If the train disappears, you can ignore the notice.
   3. Interpretation of Main Functions:
2. getTrainGPS(): The GPS location of the train achieves.
3. getObstacleGPS(): Receives the GPS location of the obstacle revealed.
4. calculateDistance (train, obstacle): calculates the distance between the train and the barrier.
5. isMovingTowardObstacle(train, barrier): It determines whether the train distance for obstacles declines.
6. sendLoRaAlert(): The train sends a notification message to the pilot.
7. ignoreAlert(): If the train disappears, pressing unnecessary notice.
8. *System Integration and Software Workflow*

The obstacle detection and selective alert algorithm are integrated into firmware of microcontroller, which ensures real

-time detection, preventive and warning. Software Work Flows Includes the following steps:

1. The sensors detect a barrier and transfer data to ESP32 microcontroller.
2. The microcontroller classifies the object as an animal, debris or human.
3. If an animal is detected, the ultrasonic deterioration system is activated.
4. If the obstacle persists, GPS-based train alert algorithm is triggered.
5. LoRa communication transfers a notice to get closer to trains as they move towards obstacles.
6. The train receives pilot alert and takes appropriate measures.
7. *Efficiency of Selective Alerting*
   1. Without GPS filtering: This system generates a warning on the basis of detecting the barrier without assessing the train movement. This leads to a high false warning rate of 35%, causing unnecessary warnings. The response time is 300ms, which makes the system accelerated but less reliable.
   2. With GPS filtering: This system verification of the movement of the movement of the train before sending a notice reduces false notifications by only 5%. It significantly improves the system’s reliability and prevents unnecessary notifications.

# EXPERIMENTAL SETUP

1. *Experimental setup*

To detect optimal barriers and achieve a warning transfer, the system was distributed at an interval of 100-meters along the railway track. The layout consisted of an integrated hardware and software configuration, which ensures spontaneous operations in different circumstances.

1. *Hardware configuration*

The system used a combination of sensors and communication modules to detect obstacles, classify elements, transmit alerts and activate the prevention mechanism. Leuze ODSL 30 Series Infrared Sensors, with 100-meters identification area, with a long-distance barrier, while Maxbotics MB2530 XL Ultrasonic sensor, with 30-meters range, secured an accurate detection with a short range. ESP32 microcontrollers were responsible for 915 MHz LoRa module interface, real -time data processing and decision making for wireless transmission of notice to railway personnel. A u-Blox Neo-6M GPS module was included to track train spaces and to track filter warning based on the direction of movement, which reduces unnecessary alerts. In addition, a 12–24 kHz ultrasonic bioacoustics emitter was integrated to withdraw animals from railway tracks, which reduced the risk of infiltration of wildlife. The system was powered by a 20W solar panel, which ensures energy efficient and durable operations, especially in remote places where the network is not available.

1. *Software configuration*

The system software was designed to process sensor data in real time, communicate effectively and activate the preventive mechanism. ESP32 Microcontroller handled real-time data collection and processing, and secured rapid response to detected obstacles. A LoRa-based wireless communication net- work enabled long-term alert transfer, and secured reliable information for the train pilot. The GPS-based selective warning mechanisms ensured that notifications were only transferred to get closer to trains, which reduced unnecessary alarms. In addition, the automatic bioacoustics repelling system activated ultrasonic sound waves with high frequency when animals detected, effectively repelling them with railway tracks.

1. *Response time*

An important aspect of rail security is the response time from detecting obstacles to a vigilant transfer time. The system effectively detects obstacles and processed information within 900 milliseconds (1 second), ensuring real-time responses. The degradation of the response time showed that the sensor detected obstacles within 150ms, followed by 200ms for object classification (separation of animals, human or debris). If an animal was detected, the bioacoustics-related prevention was activated within 250ms, while the GPS module filtered the notice within 300ms and notified the notice. The overall response time is 1 second.

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| **Features** | **LIDAR based system** |
| Detection accuracy | 92% |
| Response time | ~1.5s |
| False alarm rate | 8% |
| Cost | Very high |
| Weather dependence | High |
| Power efficiency | Medium |
| Animal repellence | No |

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| **Features** | **Thermal imaging** |
| Detection accuracy | 89% |
| Response time | ~2s |
| False alarm rate | 10% |
| Cost | High |
| Weather dependence | Low |
| Power efficiency | Medium |
| Animal repellence | No |

Table. 2. LiDAR-based system Features

# EXISTING SYSTEM

Over time, rail security systems have changed, different methods have been used to identify obstacles and defer accidents. Lidar and thermal imaging are the most commonly used systems; Each has the advantages and disadvantages.

LiDAR-based systems:

Another popular way of detecting obstacles is Lidar (light detection and range). It uses laser pulses to make a 3D map of the railway environment, which provides better precision with an accuracy of 92%. However, LiDAR is very sensitive to weather conditions. In fog, rain or snow reduces the laser beam, reduces the reliability of the detection. In addition, LiDAR is extremely expensive and requires sustained repetition, making it impractical for the large-scale railway network. Despite efficiency, LiDAR is not a viable alternative for cost-effective, extensive implementation of rail security.

Thermal Imaging Systems:

Thermal cameras rely on the signature to detect objects, making them very effective in relation to low light and night. They are usually used to detect people and animals on railway tracks. However, their identity is lower than accuracy (89%) LiDAR, and they struggle to detect non-living obstacles, such as fallen branches or rocks, as they do not emit heat. In addition, the thermal image system has high costs and significant power is consumed by limiting their scalability to long-distance railway tracks.

Table. 3. Thermal Imaging System Features

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| **Features** | **Proposed system (IR + Ultrasonic + LoRa)** |
| Detection accuracy | 98% |
| Response time | <2s |
| False alarm rate | 4% |
| Cost | Low-cost & scalable |
| Weather dependence | Low (Reliable in all conditions) |
| Power efficiency | High (Solar-powered) |
| Animal repellence | Yes (85% success rate) |

Table. 4. Proposed System Features

# PROPOSED SYSTEM

To address the boundaries of existing rail safety solutions, active obstacle and prevention system infrared (IR) provides sensors, ultrasonic sensors and LoRa wireless communication a low price, scalable and energy-efficient alternative.

Hindrance and accuracy:

The system combines infrared (IR) and ultrasonic sensors to improve the accuracy of high identification (98%),

radar, LiDAR and thermal imaging.

Bioacoustics system:

The bioacoustics detection mechanism of the suggested system, which uses certain sound frequencies to entice animals away from railroad tracks, is one of its distinctive features. Traditional rail safety systems lack the ability to avert animal interactions, which this method has demonstrated an 85% success rate in doing.

Train alert in real time and LoRa communication:

Train alert in real time and LoRa communication One of the most important innovations in the proposed system is GPS- based selective train alert. When an obstacle is detected, the system LoRa (long distance) uses wireless communication just to inform trains that go towards obstacles. This prevents unnecessary notice and reduces communication costs and ensures rapid response time in less than 2 seconds.

Energy efficiency and cost-effectiveness:

Unlike expensive lidar or radar-based solutions, the proposed system is cheap and solar powered, making it suitable for large railway networks. The system only uses 9W in the top station and 4W in passive mode, ensuring long-lasting stability in remote areas without external power sources.

# CONCLUSION

Proactive obstacle monitoring and prevention system has shown extraordinary efficiency in increasing rail security by correcting and stopping the trace. Over time, the system gives real-time alerts over time to train pilots so that immediate preventive measures can train the system pilots. Its cost affect and scalable designs make it a viable alternative for expensive LiDAR or radar-based detection systems, which are also able to use a lot in budget-composed railway networks. In addition, solar-operated, energy-efficient architecture ensures uninterrupted operations in distance railroad businesses, and reduces the dependence on external power sources. A unique aspect of our system is the integration of bioacoustics repellent, and achieves 85% success in preventing animals from railway tracks, and prevents wildlife conflicts significantly and promotes ecosystem protection. The effect of the system spreads beyond the prevention of accidents by improving operating efficiency through directional notification, and ensuring that only relevant trains receive information, which reduces unnecessary alerts. As a result, railway operators can reduce delays, increase passengers security and optimize network performance. Furthermore, integration will further improve system functions with an AI-based object classification, ma- chine learning algorithm and automatic braking to adapt to AI-based object classification, bioacoustics detection to reduce

future promotion, to reduce false alarms. By offering a cost effective, scalable and energy-efficient solution, this innovation determines a new standard in rail protection, and ensures active intervention, collision prevention and adapted railway operations.

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