Machine learning based Obstacle and wild animal detection for avoiding accidents on Railway Tracks

Prerana Sadanand Bulbule[1], Sandhya B [2], Sushmitha S S[3], Varsha S M[4], Sharath Kumar S R[5]

Prerana Sadanand Bulbule, Sandhya B, Sushmitha SS, Varsha SM, Sharath Kumar S R Department of ISE, JNN College of Engineering.

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Abstract: This study focuses on the critical task of detecting wild animals and obstacles in their natural environment. The proposed algorithm leverages deep learning techniques to classify and identify animals and obstacles based on image data, providing an efficient means of monitoring them. Given the diversity of animals and obstacles, manual identification can be challenging, making automation essential. By applying advanced image processing and deep learning algorithms, the system detects potential hazards and alerts train operators, helping to prevent accidents. The approach emphasizes long-range recognition for effective monitoring of wildlife and obstacles in railway environments.

Key Words: Long-range recognition, wild animal and obstacle detection, deep learning, image processing.

1. INTRODUCTION

Railway transportation is a vital component of infrastructure, connecting cities, facilitating trade, and providing an efficient mode of travel for millions of people worldwide. However, ensuring the safety of railway operations remains a significant challenge, particularly in regions where railway tracks intersect wildlife habitats or areas prone to obstacles. Accidents caused by the presence of wild animals or unforeseen objects on tracks not only result in the loss of human lives but also contribute to wildlife mortality and damage to expensive railway infrastructure. These incidents emphasize the need for an advanced, reliable, and real-time monitoring system to mitigate such risks.

Traditional methods for ensuring track safety, such as manual inspections, CCTV monitoring, or basic obstacle detection systems, are often limited in efficiency and scope. They require substantial human intervention, are prone to delays, and may fail to provide timely warnings in critical situations. With the advancements in technology, particularly in the fields of artificial intelligence (AI) and machine learning (ML), there is an opportunity to develop more robust and efficient systems that can overcome the limitations of traditional approaches.

Machine learning offers a dynamic and intelligent solution to detect obstacles and wild animals on railway tracks effectively. By leveraging powerful algorithms for image processing, object detection, and pattern recognition, ML-based systems can analyze vast amounts of visual and sensor data in real time. These systems can identify potential hazards, classify them with high accuracy, and generate immediate alerts to railway operators, enabling timely actions to prevent accidents. Additionally, such systems can be trained to improve their performance over time, adapting to different environments and scenarios.

This project aims to design and implement a machine learning-based detection system tailored to the unique challenges of railway safety. The system will utilize state-of-the-art object detection techniques to identify obstacles and wild animals, ensuring prompt hazard detection and response. By incorporating real-time processing and high accuracy, this solution not only enhances the safety of train operations but also contributes to wildlife conservation by reducing animal fatalities caused by train collisions.

The adoption of machine learning-based safety systems for railway tracks is a step toward modernizing infrastructure and aligning with sustainable development goals. By addressing the dual concerns of human safety and wildlife protection, this project demonstrates the transformative potential of technology in creating safer and more efficient railway systems.

2. LITERATURE REVIEW

“Machine Learning based obstacle detection for avoiding accidents on railway tracks” [1]. Machine learning-based obstacle detection systems are an innovative solution for improving railway safety by addressing the risks posed by obstacles such as animals or debris on tracks. These systems employ advanced ML algorithms to analyze real-time data from cameras and sensors, enabling accurate detection of hazards and timely alerts to train operators. By facilitating immediate action, they help prevent accidents, collisions, and derailments, significantly enhancing operational safety. Additionally, these systems provide continuous and automated monitoring of railway tracks, reducing reliance on manual inspections and minimizing human error. While the initial setup, including sensors and devices, may be costly and requires regular calibration and maintenance, the long-term benefits of improved safety and reduced accident-related losses outweigh these challenges.

"A remote surveillance system based on artificial intelligence for animal tracking near railway tracks "[2]. Artificial intelligence (AI) is widely utilized in remote surveillance systems for tracking wildlife near railway tracks, offering accurate and real-time observations. These systems support wildlife protection by providing valuable data on species health and habitat conditions through advanced sensors and remote devices. They enable close monitoring of animals from a distance and immediate responses to unexpected movements using automated actuators. AI-based surveillance improves safety by preventing animal-train collisions and efficiently covering large areas. However, challenges include high initial setup costs and performance limitations in adverse weather conditions, such as poor visibility.

"An IoT based Monitoring System to Detect Animal in the Railway Track using Deep Learning Neural Network" [3]. Animal deaths due to collisions with trains have become a major global concern, disrupting ecosystems and threatening the survival of certain species, many of which are classified as endangered by the International Union for Conservation of Nature (IUCN). An IoT-based monitoring system using deep learning neural networks offers a promising solution by providing real-time detection of animals on railway tracks, preventing accidents and enhancing safety. This system generates immediate alerts to prevent collisions, improving overall safety. However, the system's high setup and implementation costs, along with the technical complexity involved in integrating hardware and software, pose significant challenges.

"Arduino-based Railway Line Tracking System for Mitigating Animal Accidents" [4].Unprotected wildlife, particularly elephants, remains highly vulnerable to accidents with trains, contributing to a significant rise in animal deaths over the years. An Arduino-based railway line tracking system offers a cost-effective solution to mitigate such accidents, providing an affordable and customizable way to enhance railway safety. This system is easy to implement, making it accessible for various railway safety applications. However, its limitations include lower processing power compared to more advanced systems and the need for a consistent power supply to ensure continuous operation.

The "Efficient Multisensory Barrier for Obstacle Detection on Railways" [5] proposes a system that combines multiple sensors to enhance the detection obstacles on railway tracks. By integrating various sensory inputs the system aims to improve reliability, and safety in railway operations. Utilizes multiple sensors to improve accuracy and enhance safety by detecting obstacles in real time. The system minimizes estimation errors by considering the statistical noise of the channel, though false alarms can occur when noise is not zero mean or its covariance matrix is unknown. While it significantly enhances railway safety, the system comes with the disadvantage of high installation and operational costs, as well as the complexity of integrating and calibrating various sensors.

"Railway accidents prevention using ultrasonic sensors" [6].Indian Railways, with its vast network spanning over 65,000 km, is one of the largest and most vital railway systems in the world, serving millions of passengers daily. However, despite its importance, accidents remain a significant concern. Railway accident prevention using ultrasonic sensors offers an affordable and widely available technology for accurate obstacle detection. This system can enhance safety by identifying potential hazards on the tracks. However, it has limitations, including a restricted detection range and susceptibility to interference from environmental noise or extreme weather conditions, which may impact its performance.

"Railway Accident Reduction By Passenger Detection Using Machine Learning Techniques" [7], The research on railway accident reduction through passenger detection using machine learning techniques focuses on identifying passengers standing on platforms or in front of train paths to provide timely warnings to train drivers. The system utilizes CCTV footage as input to detect obstacles and potential hazards. This technology enhances safety by identifying passengers near danger zones and enabling real-time alerts for quick preventive action. However, its disadvantages include high initial implementation costs and the need for specialized expertise for system integration and ongoing maintenance.

"Sensing Dangers and Threats in Railway Track with Intimation using IoT"[8], The use of IoT for sensing dangers and threats on railway tracks aims to address the risks associated with unmonitored tracks, which often lead to accidents involving both humans and animals. Many fatalities occur when individuals, particularly those who fall asleep on tracks, are struck by trains, and wild animals, such as elephant herds, frequently face similar dangers. IoT-based systems provide real-time detection, offering immediate identification of track issues and enabling early warnings to prevent accidents. However, the system's high installation and maintenance costs, along with potential connectivity issues in remote areas, can disrupt the monitoring process and limit its effectiveness.

"System for Identifying and Avoiding Obstructions on Railway Tracks in Forest Areas" [9], Rail transport is a widely used and efficient mode of public transportation in India, offering benefits such as cost-effectiveness, environmental sustainability through electric trains, and suitability for heavy cargo shipments. However, railway systems in forested areas face the challenge of obstructions on tracks, which can lead to accidents. A system designed to identify and avoid such obstructions provides improved safety by enabling early detection and real-time alerts, allowing for quick responses to potential hazards. Despite its advantages, the system comes with high installation costs, particularly in remote areas, and its accuracy can be compromised by harsh weather conditions.

"A novel object detection system for improving safety at unmanned railway crossings"[10], The primary goal of this research is to prevent collisions at unmanned railway crossings, where roads and railway tracks intersect without monitoring, leading to potential accidents involving humans and animals. The proposed object detection system improves safety and efficiency by automating the detection process and enabling wireless monitoring. However, the system's effectiveness is dependent on an uninterrupted power supply and stable network connectivity, which can pose challenges in ensuring continuous operation.

3. PROPOSED METHEDOLOGY

The proposed methodology for obstacle and wild animal detection on railway track by using deep learning and Yolov8 algorithm.

Data Collection and Dataset Preparation:
The data collection and dataset preparation involve assembling a diverse collection of images and videos captured from various distances and under different environmental conditions. This dataset includes subjects such as humans, obstacles, and wild animals, captured from multiple angles and ranges to reflect real-world scenarios like surveillance, protection, and crowd monitoring. The dataset will also include labeled images or videos of railway tracks featuring various obstacles, including wild animals, debris, and damaged infrastructure. These images will cover a range of lighting conditions, weather, and environmental settings to ensure the robustness and accuracy of the detection model.

Image Preprocessing:
In the image preprocessing step, the images are resized and normalized to ensure consistency before being fed into the YOLOv8 model. To enhance the model's robustness and generalization capabilities, data augmentation techniques such as flipping, rotating, and scaling are applied. These techniques help create diverse variations of the images, improving the model's ability to accurately detect obstacles and wild animals under different conditions.

Model Training:
The YOLOv8 model is trained on the labeled dataset to detect objects in real-time by predicting bounding boxes around obstacles with high confidence and assigning appropriate labels, such as "animal" or "object." During training, techniques like early stopping and checkpoint saving are employed to prevent overfitting and ensure the model generalizes well. The model's performance is evaluated using key metrics, including Precision (accuracy in identifying objects), Recall (ability to detect all objects), and MAP (mean Average Precision), which provides an overall measure of the model's effectiveness in object detection.

Deployment:
After training, the YOLOv8 model can be deployed on a camera system installed along railway tracks to process live video feeds and detect objects or animals in real-time. The model can be deployed on edge devices, such as NVIDIA Jetson or Raspberry Pi, equipped with attached cameras for on-site processing. The system is set up using fixed cameras mounted on poles along the track for continuous monitoring, as well as drones to monitor tracks in hard-to-reach areas. These cameras and drones capture live video, which is then processed by the YOLOv8 model to identify potential threats in real-time.

Model Optimization:
Model optimization is a crucial step to improve the system's performance in real-world applications. It involves techniques like model quantization, which reduces computational precision to accelerate inference, and pruning, which removes unnecessary parameters to decrease the model's size without sacrificing accuracy. The optimized model is deployed on edge devices such as NVIDIA Jetson or Google Coral, which are mounted on trains for real-time data processing. These edge devices are chosen for their ability to process data locally, minimizing reliance on external infrastructure and ensuring low-latency performance for timely obstacle and animal detection.

Real-World Application Testing:
Real-world application testing is performed to assess the system's effectiveness under diverse operational conditions. The system is deployed on trains traveling through various terrains, including dense forests, open plains, and mountainous regions, and is tested in different environmental settings such as daylight, nighttime, fog, and rain. Key performance metrics, including detection accuracy, response time, and system robustness, are measured. Additionally, the system's ability to function in high-speed scenarios and its performance in challenging situations, such as detecting overlapping objects or partially visible animals, are thoroughly evaluated to ensure reliable operation in real-world environments.

Final Evaluation and Recommendations:
The final evaluation consolidates the findings from real-world testing to assess the system's reliability and feasibility. Key performance indicators, such as precision, recall, and F1-score, are analyzed to evaluate detection accuracy. Challenges identified during testing, including issues caused by adverse weather conditions or high-speed scenarios, are reviewed, and potential solutions are suggested. Additionally, the evaluation considers the system's scalability, energy efficiency, and compatibility with existing railway safety protocols, ensuring that it can be effectively integrated into current operations while maintaining optimal performance in various environments.

4. SYSTEM ARCHITECTURE

The system architecture for long-range human recognition is engineered to process, identify, and track human figures in large-scale surveillance scenarios, including aerial surveillance or security camera systems. It incorporates a combination of components to replacing the challenges associated with detecting and recognizing humans from significant distances. These challenges include issues like occlusion, low image resolution, and varying environmental conditions, such as changing lighting or weather. The architecture is designed to be modular, allowing for flexible modifications and continuous improvements as new techniques and technologies emerge.

Key elements of the architecture include data preprocessing, which prepares the input data for effective analysis, and feature extraction, which identifies important characteristics of the human figures in the captured images or video feeds. The system also employs advanced human detection models, such as deep learning algorithms, that are optimized for long-range recognition. Additionally, tracking mechanisms are implemented to ensure continuous and accurate human identification, even in dynamic or complex environments. This combination of components ensures that the system can reliably recognize and track humans over long distances, providing robust performance across a wide range of real-world scenarios..

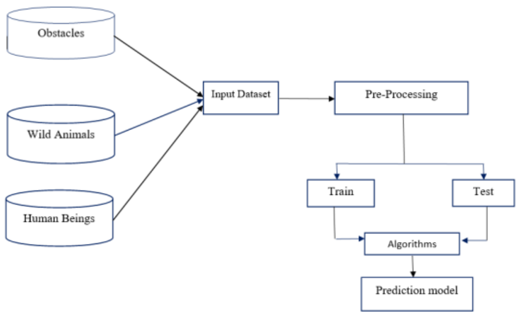

Fig 1: System Architecture

The components of the proposed system are explained below:

Data Collection and Data Samples:
Data collection involves the use of high-resolution and thermal cameras, combined with LIDAR sensors, to record images and videos of railway tracks under diverse conditions such as daytime, night-time, rainy weather, and fog. The dataset includes samples featuring wild animals, various obstacles like rocks and debris, as well as unobstructed tracks. These images are meticulously labelled with bounding boxes and class labels, forming the foundational data required to train the YOLOv8 model for precise object detection and classification on the tracks.

Data Preprocessing:
In the data preprocessing stage, the collected data is resized to meet YOLOv8's input requirements, normalized for consistency, and augmented using techniques such as rotation, cropping, and adjustments for brightness and contrast. These steps are designed to improve the model's generalization ability and robustness. Additionally, annotations are carefully validated to ensure accurate labelling of the objects, ensuring the quality and reliability of the training data for optimal model performance.

Bounding Box Detection:
In bounding box detection, YOLOv8 processes the pre-processed data in real time by dividing images into grids and predicting bounding boxes, class labels, and confidence scores for detected objects. This enables the model to accurately identify and localize obstacles or animals near railway tracks, providing precise information about their position and type. The confidence scores help assess the reliability of each detection, ensuring that only the most accurate results are considered for further action.

Analysis and the Output:
The analysis of the output involves applying confidence thresholds to filter out low-quality detections, ensuring only reliable predictions are considered. Bounding box accuracy is evaluated using metrics such as Intersection over Union (IoU) to assess how well the predicted boxes align with the actual objects. Critical detections trigger alerts, notifying operators of potential hazards. Additionally, the results are visualized by overlaying bounding boxes and class labels on live video feeds, providing operators with real-time information to take appropriate action.

5. RESULTS

The results of using the YOLOv8 algorithm for detecting obstacles and wild animals on railway tracks demonstrate a highly accurate and real-time detection system. The model efficiently identifies and localizes objects such as wild animals and obstacles (e.g., rocks, debris) with high precision and recall, even under challenging conditions like low light or adverse weather. Detected objects are surrounded by bounding boxes, correctly classified, and assigned confidence scores. Critical detections trigger alerts, allowing for timely intervention by train operators or automated systems. Evaluation metrics, including Intersection over Union (IoU), precision, and recall, reflect the system's reliable performance, with minimal false positives and negatives. This enhanced detection system significantly improves railway safety by preventing accidents and ensuring the smooth operation of trains.

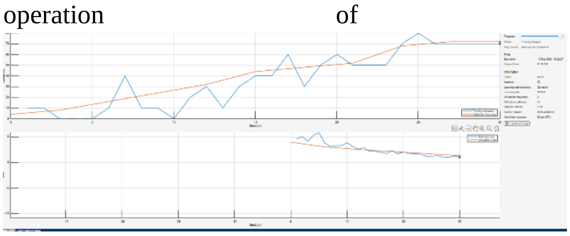

Fig 2: Accuracy of the training

6. CONCLUSION

In conclusion, the use of the YOLOv8 algorithm for detecting obstacles and wild animals on railway tracks provides an efficient, real-time solution for preventing accidents. The system accurately identifies and classifies objects, even in challenging environmental conditions, by integrating high-resolution cameras, thermal sensors, and LIDAR data. The YOLOv8 model's ability to detect and localize obstacles with high precision and minimal latency enables timely alerts and interventions, significantly enhancing railway safety. This approach holds great potential for widespread deployment across railway networks, helping to improve safety and reduce the risk of collisions.

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