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AI BASED REAL TIME ALERT VERIFICATION FOR LOCO PILOT TO PREVENT ANIMAL ACCIDENT IN RAILWAY TRACK

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ABSTRACT

This paper presents an AI-based real-time alert verification system designed to enhance railway safety by preventing animal-related accidents. Increasing incidents of train collisions with wild animals, particularly elephants, pose a serious challenge in forest and rural areas. Existing systems mainly rely on manual monitoring, which is not effective for real-time detection and response.

To address this issue, the proposed system integrates sensor-based detection with artificial intelligence techniques. A PIR sensor is used for initial motion detection, and an ESP32-CAM captures images for further analysis. The captured images are processed using a Convolutional Neural Network (CNN) model to verify the presence of animals.

Upon confirmation, the system activates multiple alert mechanisms including buzzer, LED indicators, GSM-based message transmission, and motor control to simulate train stopping. The system ensures real-time detection and verification, reducing false alarms and improving reliability. The implemented system demonstrates an effective and cost-efficient solution for enhancing railway safety and preventing animal collisions.

This proposed system achieves improved accuracy and reduced false alarms compared to existing methods.

KEYWORDS: Artificial Intelligence, Convolutional Neural Network (CNN), Animal Detection, Railway Safety, Real-Time Alert System, ESP32-CAM, PIR Sensor, GSM Communication

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1. INTRODUCTION

Railway transportation plays a crucial role in the movement of passengers and goods across different regions. However, railway tracks that pass-through forest and rural areas often face the problem of animal intrusion, leading to frequent accidents. Collisions between trains and wild animals, especially elephants, result in serious damage to wildlife and railway infrastructure, and may also affect human safety.

Most of the existing systems rely on manual monitoring, forest department alerts, or simple sensor-based detection methods. These approaches are not efficient in real-time conditions, as loco pilots may not be able to identify animals on the track due to poor visibility, high speed, or environmental factors such as darkness and fog.

To overcome these limitations, an intelligent system is required that can automatically detect and verify the presence of animals on railway tracks and provide timely alerts. With the advancement of artificial intelligence, image-based detection systems have become more accurate and reliable. In this work, a Convolutional Neural Network (CNN) is used to analyze images captured from the camera and verify the presence of animals.

The proposed system combines sensor-based detection with AI-based verification. A PIR sensor is used for initial motion detection, and the ESP32-CAM captures images for further processing. Once an animal is confirmed, multiple alert mechanisms are activated to notify the loco pilot and prevent possible accidents.

This system aims to provide a real-time, automated, and cost-effective solution to improve railway safety and reduce animal-related accidents.

2. LITERATURE REVIEW - 1

Linjie Niu,

“Automatic identification method of foreign body intrusion in railway transportation track based on improved leaderRank identification of key points”-2025.

- proposed an automatic identification method for detecting foreign object intrusion in railway transportation tracks based on an improved LeaderRank algorithm. In this method, key trajectory points are first identified using the improved LeaderRank approach, which helps in selecting optimal locations for monitoring devices. Real-time video data is collected from these locations, and an improved Gaussian mixture model is used for image segmentation to extract foreground images containing foreign objects. These processed images are then

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analysed using a hybrid deep learning model, which combines feature extraction and behaviour analysis for accurate identification of intrusions. The proposed system demonstrates improved detection accuracy and reliability. However, the method mainly focuses on object intrusion detection and does not include a real-time alert verification mechanism or integrated safety response system.

LITERATURE REVIEW -2

Shanaka Gunasekara,Maleen Jayasuriya,Nalin Harischandra, Lilantha Samaranayake, Gamini Dissanayake

"A Convolutional Neural Network Based Early Warning System to Prevent Elephant-Train Collisions"- IEEE 2021

- proposed a vision-based elephant detection system to address the issue of train–elephant collisions, particularly in regions such as Sri Lanka where human-elephant conflict is significant. The system utilizes a **Convolutional Neural Network (CNN)** model to detect elephants using RGB and infrared camera inputs placed near railway tracks, especially in high-risk hotspot areas. The model is trained using a dataset collected from wildlife parks and elephant habitats, ensuring robustness under varying environmental conditions such as low light and poor weather.
- A prototype early warning system was developed and tested, demonstrating reliable detection performance and adaptability to different lighting conditions. The system also highlights the importance of using large and diverse datasets for improving detection accuracy. However, the proposed approach mainly focuses on detection and early warning, and does not include integrated multi-level alert verification or automated safety control mechanisms.

LITERATURE REVIEW- 3

Gayathri N P, Geena Prasad, Chada Narasimha Reddy, Chapa Gagan Dwaz, Guru Aswin Dath , Maitreyee Awasthi, Deepa Indira Nai

"Wildlife Railgurad: A novel conservation technology to mitigate train-animal collisions in forest regions" – 2025

- Wild life Rail Guard system proposes a deep learning-based approach for real-time detection of wild animals, particularly elephants, along railway tracks. The system integrates advanced deep learning algorithms with camera systems installed at strategic locations to continuously monitor animal movement. Upon detecting animals, the system generates

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immediate alerts to train operators, enabling them to reduce speed and prevent potential collisions.

- In addition to real-time detection, the system utilizes data analytics to study animal behaviour and movement patterns, contributing to long-term wildlife conservation efforts. The approach emphasizes both safety and sustainability by balancing railway operations with environmental protection. However, the system primarily focuses on detection and alert mechanisms and does not incorporate multi-level verification or integrated hardware-based safety control systems.

LITERATURE REVIEW- 4

Moorthy V, Rukkumani V

"Deep vision-based wildlife intrusion detection with colour distribution preserved generative adversarial networks"- 2025

- Animal preservation is a significant issue and the human-elephant collisions (HEC) remains unidentified. Rail track is placed in forested areas and elephants are often struck by trains due to their bulk. These kinds of disasters are common in the southern green belt of India. To overcome these problems, this paper proposes a Deep Vision-Based Wildlife Intrusion

Detection with Colour Distribution Preserved Generative Adversarial Networks (DV-WID-CDPGAN). Here, the input images are taken from real time video, which are converted into individual frames. The input data is pre-processed under Data-adaptive Gaussian Average Filtering (DAGAF) to remove noise. Edge, line and rectangle Features are extracted utilizing Dual Tree Complex Discrete Wavelet Transform (DTCDT). Then elephant present and not present is classified using Colour Distribution Preserved Generative Adversarial Networks (CDPGAN). The Red Panda Optimization Algorithm (RPOA) optimizes the CDPGAN classifier for precise categorization. The proposed DV-WID-CDPGAN method is evaluated and compared with existing methods.

ELEPHANTS DEAD ON RAILWAY TRACK IN INDIA

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Year	Place	State	Number of Elephants
2024	Coimbatore forest division	Tamil Nadu	1
2024	Jalpaiguri Forest Range	West Bengal	5
2025	Alipurduar division	West Bengal	3
2025	Goalpara Region	Assam	2
2025	Sundargarh Area	Odisha	1

Table:1

3. PROPOSED SYSTEM

The proposed system aims to prevent animal-related accidents on railway tracks by implementing a real-time detection and alert verification mechanism. The system integrates sensor-based detection with artificial intelligence techniques to ensure accurate identification and timely alert generation.

Initially, a PIR sensor is deployed near the railway track to detect motion. When movement is detected, the ESP32-CAM module is triggered to capture images of the surrounding environment. These images are then processed using a Convolutional Neural Network (CNN) model to verify whether the detected object is an animal. This verification step reduces false alarms and improves system reliability.

Once an animal is confirmed, the system activates multiple alert mechanisms to ensure immediate response. A buzzer is used to generate an audio alert, while LED indicators provide visual warnings. In addition, a GSM module sends alert messages to the loco pilot or control system, enabling timely action.

The system also incorporates a safety mechanism using a motor control unit, which simulates train stopping action when a hazardous situation is detected. Furthermore, a GPS module is used to provide location details, which can help in identifying high-risk zones and improving monitoring efficiency.

The proposed system ensures real-time detection and verification, making it an effective and cost-efficient solution for reducing animal-related accidents on railway tracks and improving overall railway safety.

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The implementation of this system is expected to significantly reduce animal fatalities, particularly elephants, and may help prevent approximately 50 to 60 such incidents annually in high-risk areas.

4. METHODOLOGY

4.1 SYSTEM OVERVIEW

The proposed system is designed to provide real-time detection and verification of animals on railway tracks to prevent accidents. The system integrates sensor-based detection with artificial intelligence techniques to ensure accurate and reliable operation.

The overall system consists of two main units: the transmitter unit and the receiver unit. The transmitter unit is placed near the railway track and is responsible for detecting motion using a PIR sensor and capturing images using the ESP32-CAM module. The captured images are processed using a Convolutional Neural Network (CNN) model to verify the presence of animals.

Once an animal is detected and verified, the information is transmitted to the receiver unit through wireless communication using Zigbee and GSM modules. The receiver unit processes the received data and generates multiple alerts such as buzzer, LED indication, and message notification to the loco pilot. Additionally, a motor control mechanism is activated to simulate train stopping for safety.

Thus, the system performs detection, verification, communication, and alert generation in real time, providing an effective solution to reduce animal-related railway accidents.

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4.2 HARDWARE COMPONENTS

4.2.1 ARDUINO UNO

Figure 1: arduino uno

The Arduino UNO is the main controller used in the proposed system. It is based on the ATmega328P microcontroller and is responsible for controlling and coordinating all the connected components.

In this system, the Arduino UNO receives input signals from sensors such as the PIR sensor and processes the data accordingly. It also communicates with modules like Zigbee, GSM, and GPS through serial communication. Based on the processed data, the Arduino controls output devices such as the buzzer, LED indicators, LCD display, and motor driver circuit.

The Arduino UNO plays a key role in executing the program logic, managing data flow, and ensuring proper functioning of both transmitter and receiver units.

4.2.2 PIR SENSOR

Figure 2: pir sensor

The PIR Sensor (Passive Infrared Sensor) is used to detect motion near the railway track. It works by sensing changes in infrared radiation emitted by objects, such as animals or humans.

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In the proposed system, the PIR sensor continuously monitors the surroundings. When any movement is detected, it sends a signal to the Arduino UNO, which then activates the camera module for further processing.
The PIR sensor acts as the first stage of detection, helping to reduce unnecessary image processing and improving the overall efficiency of the system.

4.2.3 ESP32-CAM MODULE

Figure 3: cam module

The ESP32-CAM is used in the system for capturing images of the railway track area. It is a compact module that consists of a built-in camera and Wi-Fi-enabled microcontroller.

In the proposed system, once motion is detected by the PIR sensor, the ESP32-CAM captures real-time images of the surrounding area. These images are then used for further processing and analysis. The captured images are passed to the Convolutional Neural Network (CNN) model to verify whether the detected object is an animal.

The ESP32-CAM plays a crucial role in enabling visual detection, making the system more accurate and reliable compared to sensor-only methods.

4.2.4 CONVOLUTIONAL NEURAL NETWORK

The Convolutional Neural Network (CNN) is used in the proposed system for image processing and animal detection. CNN is a type of deep learning algorithm that is highly effective in identifying and classifying objects from images.

In this system, the images captured by the ESP32-CAM are given as input to the CNN model. The model analyzes the image by extracting important features such as shape, texture, and patterns. Based on these features, the CNN verifies whether the detected object is an animal, with a primary focus on elephants.

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The use of CNN improves the accuracy of detection and reduces false alarms, making the system more reliable for real-time applications.

4.2.5 ZIGBEE MODULE

Figure 4: zigbee

The Zigbee module is used for wireless communication between the transmitter and receiver units. It operates on low power and is suitable for short-range data transmission.

In the proposed system, the Zigbee module transmits the detected and verified information from the transmitter unit to the receiver unit. Once the data is received, the receiver processes it and activates the necessary alert mechanisms.

Zigbee ensures fast and reliable communication between both units, enabling real-time data transfer and improving the overall efficiency of the system.

4.2.6 GSM MODULE

Figure 5: GSM

The GSM Module is used in the system for sending alert messages through the mobile network. It enables long-distance communication by using cellular connectivity.

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In the proposed system, once an animal is detected and verified, the GSM module sends an alert message to the loco pilot or control system. This ensures that the information reaches the concerned person in real time, even if the receiver unit is far away.

The GSM module improves the reliability of the system by providing an additional communication channel along with Zigbee.

4.2.7 GPS MODULE

Figure c: gps

The GPS Module is used in the system to obtain real-time location information. It works by receiving signals from satellites to determine the exact position in terms of latitude and longitude.

In the proposed system, when an animal is detected on the railway track, the GPS module provides the location details of that particular area. This information can be sent along with the alert message using the GSM module.

The GPS module helps in identifying accident-prone zones and enables better monitoring and response by providing accurate location data.

4.2.8. 16*2 LCD DISPLAY

Figure 7: LCD

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The 16x2 LCD Display is used in the system to display real-time information and system status. It is an alphanumeric display that can show 16 characters in each of the 2 rows.

In the proposed system, the LCD displays messages such as motion detection status, animal detection confirmation, and alert notifications. It helps the user to easily monitor the working condition of the system.

The LCD is interfaced with the Arduino UNO, which controls the display of messages based on system operations.

4.2.9. BUZZER

Figure 8: buzzer

The Buzzer is used in the system to provide an audible alert when an animal is detected on the railway track. It converts electrical signals into sound signals.

In the proposed system, once the presence of an animal is verified, the Arduino UNO activates the buzzer to generate a warning sound. This helps in immediately alerting the loco pilot or nearby personnel about the potential danger.

The buzzer acts as a quick and effective alert mechanism, ensuring timely response to avoid accidents.

4.2.10. LED INDICATOR

Figure S: Led

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The LED is used in the system to provide visual indication of alerts. It emits light when electrical current passes through it.

In the proposed system, LEDs are used to indicate different system states such as motion detection, animal verification, and alert generation. When an animal is detected, the Arduino UNO activates the LED to give a visual warning signal.

LED indicators help in quick visual identification of system status and enhance the overall alert mechanism.

4.2.11. MOTOR DRIVER CIRCUIT

The Motor Driver Circuit is used to control the operation of the motor based on the signal from the Arduino UNO. Since the Arduino cannot directly drive a motor due to limited current, a driver circuit is required. In the proposed system, the motor driver circuit is implemented using a transistor (such as BC547) and a relay. When an animal is detected, the Arduino sends a signal to the transistor, which activates the relay. The relay then switches the motor OFF to simulate the stopping of the train.

A diode is connected across the motor or relay to protect the circuit from back EMF. This ensures safe and reliable operation of the system.

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4.3. TRANSMITTER UNIT

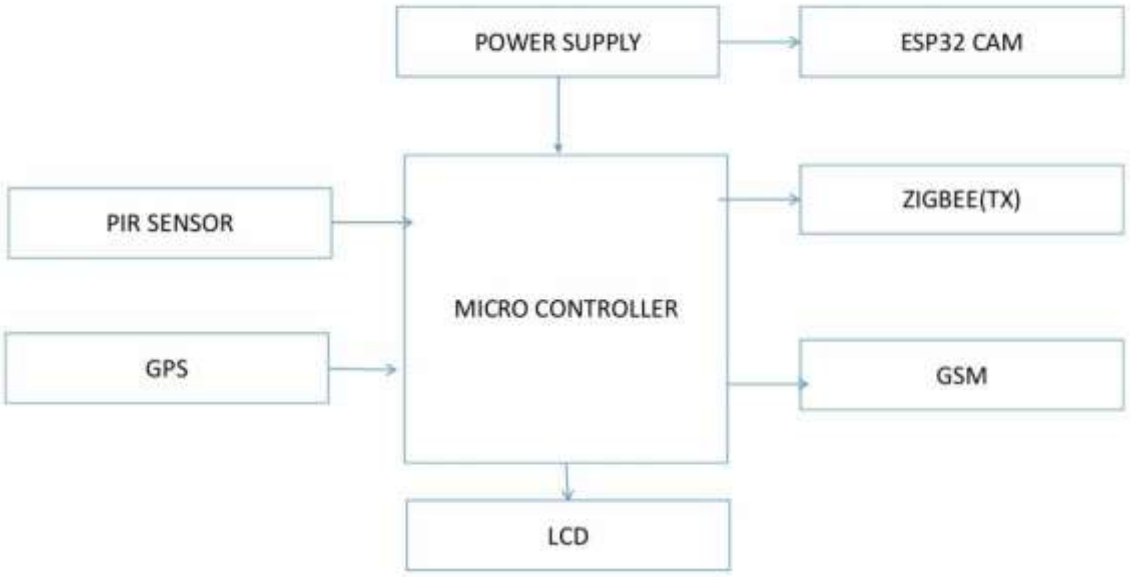

Figure.10. Transmitter unit block diagram

The transmitter unit is the main sensing and alert generation section of the system. Its primary function is to detect animal presence on railway tracks, capture data, and transmit warning signals to the receiver unit.

4.3.1. Power Supply

The entire transmitter unit is powered by a regulated power supply. It provides the required voltage (typically 5V/3.3V) to components like the microcontroller, sensors, and communication modules. A stable supply ensures continuous and reliable operation in outdoor conditions.

4.3.2. Microcontroller

Functions: The microcontroller acts as the brain of the transmitter unit. It receives input signals from sensors and processes them to take necessary actions.

Function:

- Reads data from PIR sensor and GPS
- Controls ESP32-CAM for image capture
- Sends alert signals through ZigBee
- Communicates with GSM module for notifications

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4.3.3. PIR Sensor (Passive Infrared Sensor)

The PIR sensor detects movement of animals by sensing infrared radiation changes. Working:

- When an animal enters the sensing range, it detects heat variation
- Sends a signal to the microcontroller
- Triggers further actions like image capture and alert transmission

4.3.4. GPS Module

The GPS module provides the exact location (latitude C longitude) of the detected animal. Purpose:

- Helps identify the exact position of the animal on the railway track
- This location data is sent along with alert messages

4.3.5. ESP32-CAM

The ESP32-CAM module is used for image capturing and monitoring. Functions:

- Captures real-time images of the detected animal
- Can be used for AI-based animal classification (if implemented)
- Sends visual data for verification

4.3.6. ZigBee (Transmitter)

The ZigBee module (TX) is responsible for wireless communication. Working:

- Sends alert signals from transmitter to receiver unit
- Provides low power and long-range communication
- Ensures fast data transmission

4.3.7. GSM Module

The GSM module is used for sending alerts via mobile network. Functions:

- Sends SMS alerts to railway authorities
- Can include GPS location and detection status
- Works even in remote areas with network coverage

4.3.8. LCD Display

The LCD display shows real-time system status. Displays:

- “Animal Detected”
- GPS coordinates
- System status messages

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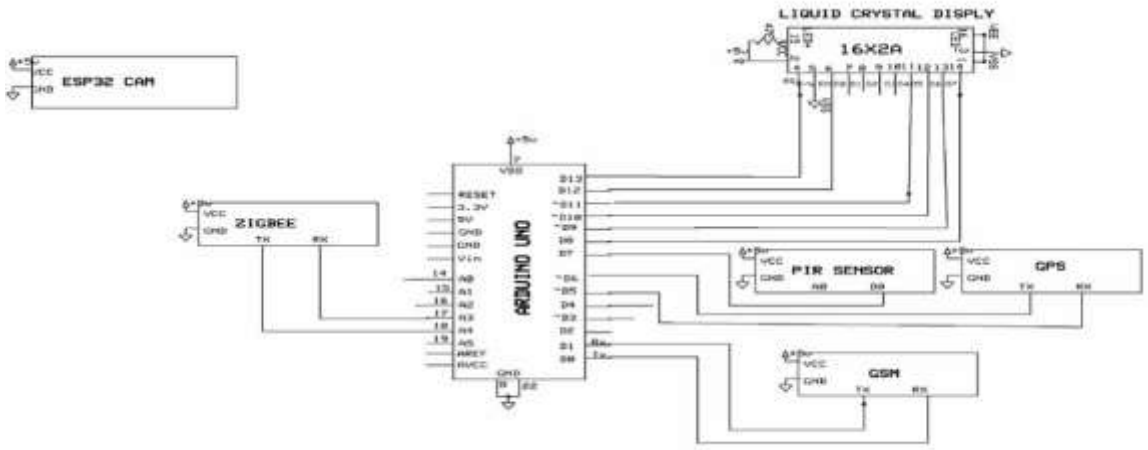

Figure.11. Transmitter unit circuit diagram

The transmitter unit consists of an Arduino UNO, PIR sensor, ESP32-CAM, Zigbee module, GPS module, GSM module, and a 16×2 LCD display. The Arduino UNO acts as the main controller that manages all the components.

The PIR sensor is used to detect motion near the railway track. When motion is detected, the ESP32-CAM captures images of the area for further analysis. The captured data is then processed to verify the presence of animals.

The Zigbee module is used for wireless communication to transmit the detected information to the receiver unit. The GPS module provides real-time location details of the detected event, while the GSM module is used to send alert messages to the loco pilot or control system.

The 16×2 LCD display shows system status and detection information. All components are powered using a regulated +5V power supply, and communication between modules is established through digital and serial connections.

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4.4. RECEIVER UNIT

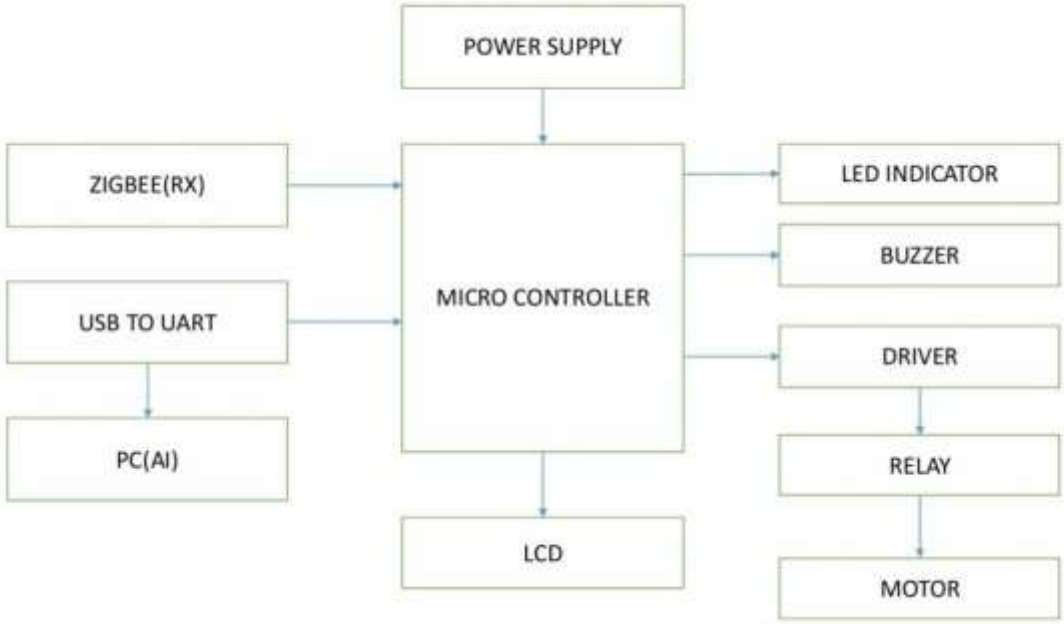

Figure.12. Receiver unit block diagram

4.4.1. Power Supply

Provides required voltage to all components like microcontroller, ZigBee, and output devices.

4.4.2. Microcontroller

Acts as the main control unit. Functions:
• Receives data from ZigBee
• Processes alert signal
• Activates buzzer, LED, and motor system

4.4.1. ZigBee (Receiver)

- Receives wireless alert signal from transmitter
- Sends the data to microcontroller

4.4.2. USB to UART C PC (AI)

- Used for data communication and monitoring
- Can connect to a PC for AI processing or logging data

4.4.3. LED Indicator

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- Glows when animal is detected
- Gives visual alert

4.4.4. Buzzer

- Produces sound alert
- Warns nearby people or railway staff

4.4.5. Driver, Relay C Motor

- Driver: Amplifies signal from microcontroller
- Relay: Acts as a switch
- Motor: Can be used to control gate or stopping mechanism

4.4.6. LCD Display

- Displays messages like
- "Animal Detected"
- System status

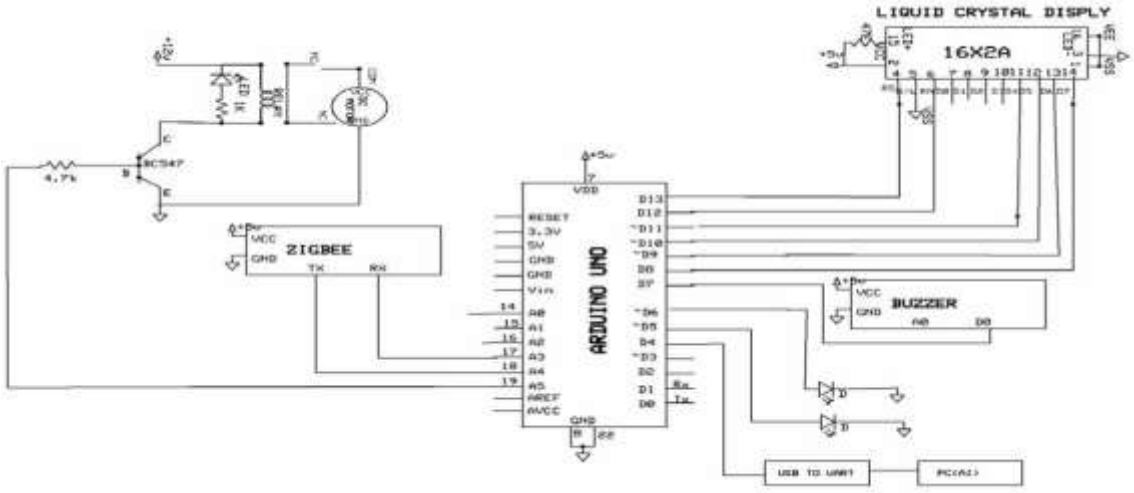

Figure.13. Receiver unit circuit diagram

The receiver unit is designed to receive data from the transmitter unit and generate alerts to ensure railway safety. The main component used is the Arduino UNO, which acts as the central controller of the system.

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The Zigbee module is connected to the Arduino through TX and RX pins and is responsible for receiving wireless data from the transmitter unit. Once the data is received, the Arduino processes the information and activates the alert system.

A 16×2 LCD display is connected to the Arduino to show system status and alert messages. The buzzer is used to provide an audio alert when an animal is detected, and LED indicators are used to display visual warnings.

The motor driver circuit, implemented using a transistor (such as BC547) and a relay, is used to control the motor. When a hazard is detected, the Arduino sends a signal to the driver circuit, which switches off the motor to simulate train stopping. A diode is connected across the motor to protect the circuit from back EMF.

All components are powered using a regulated +5V power supply, and proper grounding is maintained for stable operation.

4.5. RESULTS

The proposed AI-based real-time alert verification system was successfully designed and implemented to detect animals on railway tracks and generate timely alerts. The system was tested under different conditions to evaluate its performance and reliability.

Initially, the PIR sensor effectively detected motion in the monitored area and triggered the ESP32-CAM to capture real-time images. The captured images were processed using the Convolutional Neural Network (CNN) model, which accurately verified the presence of animals, especially elephants.

The system demonstrated a significant reduction in false alarms compared to traditional sensor-based detection methods. The integration of image-based verification ensured that only valid detections resulted in alert generation.

Upon successful detection, multiple alert mechanisms such as buzzer, LED indicators, and GSM-based message transmission were activated instantly. The Zigbee communication between transmitter and receiver units worked efficiently, ensuring fast and reliable data transfer.

The motor control mechanism was also tested and successfully simulated the stopping action when an animal was detected. Additionally, the GPS module provided accurate location details, which can be used for monitoring high-risk areas.

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Overall, the system achieved reliable real-time detection, improved accuracy, and effective alert generation. The results confirm that the proposed system is a practical and cost-efficient solution for reducing animal-related accidents on railway tracks.

4.6. CONCLUSION

This paper presents an AI-based real-time alert verification system to prevent animal-related accidents on railway tracks. The proposed system integrates sensor-based detection with image processing using a Convolutional Neural Network (CNN) to accurately identify animals, especially elephants.

The system uses a PIR sensor for initial motion detection and an ESP32-CAM for capturing images, which are then verified using CNN. Upon confirmation, multiple alert mechanisms such as buzzer, LED indicators, GSM communication, and motor control are activated to ensure safety.

The implementation of transmitter and receiver units with wireless communication provides real-time monitoring and quick response. The system successfully reduces false alarms through verification and improves reliability compared to traditional methods.

Overall, the proposed system offers a cost-effective, efficient, and practical solution to enhance railway safety and reduce animal–train collisions. Future improvements can include night vision support, thermal imaging, and integration with advanced IoT systems for wider deployment.

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