AI and IOT Powered Intelligent System for Elephant Movement Detection and Prevention of Human Elephant-Conflict

S.Sinduja, S.Boomika, S.Deepa, B.Dharsani

[1]*ME, Assistant Professor, Department of Computer Science and Engineering, Vivekanandha College of Engineering for women, Tiruchengode*

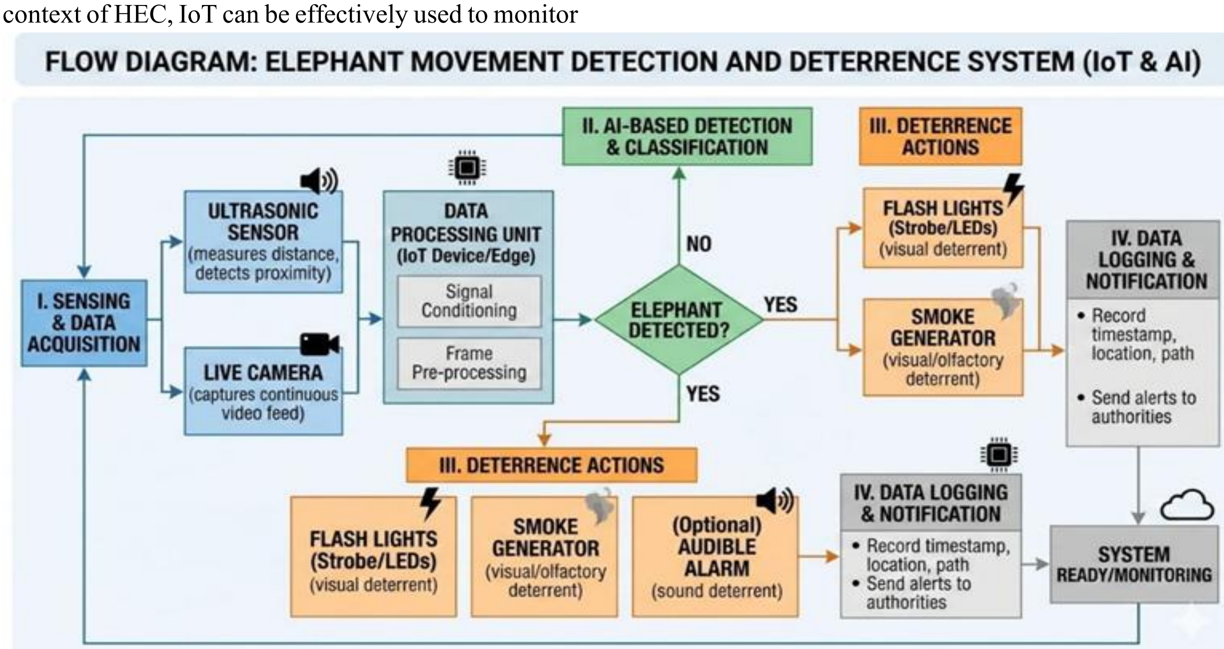
[2,3,4] *Department of Computer Science and Engineering, Vivekanandha College of Engineering for women, Tiruchengode*

Abstract- Human-Elephant Conflict (HEC) is one of the most critical challenges faced in agricultural regions located near forest boundaries. Rapid deforestation, habitat fragmentation, and increasing human population have forced elephants to migrate towards cultivated lands in search of food and water. This results in severe crop damage, economic loss, and threats to both human and animal life. Conventional approaches such as electric fencing, firecrackers, and manual monitoring are either expensive, ineffective over time, or harmful to wildlife. To address these limitations, this paper proposes an advanced Elephant Barrier System that integrates Internet of Things (IoT) technology with behavioral deterrent mechanisms. The system employs motion detection sensors and camera modules to identify elephant movement and capture real-time images. These alerts are transmitted to farmers through GSM or Wi-Fi communication systems. In addition, a sound-based deterrent mechanism generates high-frequency acoustic signals such as bee buzzing within the range of 3–10 kHz, which naturally repels elephants without causing harm. The proposed system operates using a microcontroller-based architecture supported by solar power, ensuring continuous functionality in remote areas. This dual-layer approach of detection and deterrence provides an efficient, low-cost, and eco-friendly solution. The system enhances farm security, reduces human intervention, and promotes sustainable coexistence between humans and wildlife.

Keywords-Human-Elephant Conflict, IoT, Elephant Detection, PIR Sensor, GSM Communication, Acoustic Deterrent, Smart Farming, Wildlife Protection, Real-Time Monitoring.

I. INTRODUCTION

Elephants are among the most significant terrestrial mammals, playing a vital role in maintaining ecological balance and biodiversity. They are broadly classified into African and Asian elephants, with Asian elephants predominantly found in countries such as India, Sri Lanka, Nepal, and Southeast Asian regions. However, over the years, their population has drastically declined due to various factors such as illegal poaching, habitat fragmentation, and rapid urbanization. The continuous conversion of forest lands into agricultural and residential areas has significantly reduced their natural habitats, forcing elephants to migrate towards human settlements. Human-Elephant Conflict (HEC) has emerged as a serious environmental and socio-economic issue, particularly in regions where agricultural lands are located near forest boundaries. As elephants move in search of food, water, and shelter, they often enter farmlands, leading to large-scale crop destruction and economic loss for farmers. In some cases, these encounters also result in injuries or fatalities, affecting both humans and elephants. The situation becomes more critical in densely populated countries like India, where the overlap between human activities and wildlife habitats is increasing rapidly. Traditional methods used to mitigate HEC include electric fencing, manual guarding, use of fire, smoke, loud noises, and chili-based deterrents. Although these methods provide temporary relief, they suffer from several limitations. Electric fences are expensive to install and maintain, and elephants have been observed to breach them using their tusks or by pushing down fence structures. Manual guarding requires continuous human effort, which is not feasible due to labor shortages and safety concerns. Similarly, deterrents such as firecrackers and artificial noise lose effectiveness over time as elephants adapt to them. In addition to these challenges, most existing systems lack real-time monitoring and alert mechanisms, making it difficult for farmers to respond promptly to elephant intrusion. The absence of intelligent and automated systems further increases the risk of crop damage and human-wildlife conflict. With advancements in technology, there is a growing need to develop smart and efficient solutions that can address these challenges in a sustainable and eco-friendly manner. The integration of Internet of Things (IoT) technology in agriculture has opened new possibilities for real-time monitoring and automation. IoT-based systems can utilize sensors, communication modules, and data processing units to detect and respond to environmental changes instantly. In the context of HEC, IoT can be effectively used to monitor elephant movement, provide early warnings, and implement deterrent mechanisms without causing harm to wildlife. This paper proposes an Elephant Movement Detection System that combines motion sensing, real-time communication, and acoustic deterrent techniques. The system is designed to detect the presence of elephants using sensors, capture visual evidence through camera modules, and send alerts to farmers via mobile communication networks. Additionally, it employs high-frequency sound signals that exploit the natural behavioral patterns of elephants to repel them safely. The proposed system aims to provide a cost-effective, reliable, and non-invasive solution to reduce human-elephant conflict. By minimizing human intervention and ensuring continuous monitoring, the system enhances farm security and supports sustainable coexistence between humans and wildlife. Furthermore, the use of renewable energy sources such as solar power makes the system suitable for deployment in remote and rural areas with limited infrastructure.



II. LITERATURE REVIEW

[1] Elephant Movement and Spatial Behaviour Analysis (Wittemyer et al., 2007):
This study focuses on the spatial behavior of elephants and their dependency on large, distributed habitats for survival. It highlights that elephants require extensive areas for food and resources, leading to competition and movement across regions. The study emphasizes that failure to understand these movement patterns contributes significantly to human-elephant conflict. However, it does not provide technological solutions for real-time monitoring or prevention of conflicts.

[2] Elephant Movement and Resource-Based Migration (Bohrer et al., 2014):
This research explains that elephant migration is strongly influenced by the availability of food and water resources. It suggests that understanding spatial and temporal movement patterns can help reduce crop raiding and conflicts. While the study provides valuable ecological insights, it lacks practical implementation of automated detection or alert systems for farmers.

[3] Impact of Climatic Conditions on Animal Movement (Foley et al., 2008):
This work highlights how environmental factors such as rainfall and drought conditions affect elephant movement. During drought periods, elephants tend to migrate towards cultivated lands in search of food and water, increasing conflict with humans. Although the study explains the causes of conflict, it does not propose any technological framework for detection or mitigation.

[4] Elephant Behavior and Habitat Utilization (P. Fernando et al., 2008):
This study examines how ecosystem productivity influences elephant behavior and movement. It shows that elephants in less productive environments tend to travel longer distances, increasing the chances of entering human settlements. However, the research is limited to behavioral analysis and does not include monitoring or alert systems.

[5] Wildlife Tracking Using Satellite and Communication Systems (Poveda & Jimenez, 2013):
This research introduces the use of satellite-based tracking and communication systems for monitoring wildlife movement. It enables accurate location tracking and data sharing for wildlife management. However, the system is costly and not suitable for direct implementation by farmers in rural areas.

[6] Elephant Tracking Using UAV and Image Detection (Suju & Jose, 2017):
This study proposes the use of Unmanned Aerial Vehicles (UAVs) and image processing techniques for tracking elephants. It provides real-time monitoring capabilities but requires high infrastructure and operational costs. The system is not practical for small-scale agricultural use.

[7] IoT-Based Irrigation and Monitoring Systems (Archana et al.):
This system uses humidity and vibration sensors to automate irrigation processes. It demonstrates the effectiveness of sensor-based monitoring in agriculture. However, it does not provide any mechanism for animal detection or farmer alert systems.

[8] Wireless Sensor Network for Environmental Monitoring (C.H. Chavan et al.):
This research presents a Zigbee-based wireless sensor network for monitoring environmental parameters. The system collects and transmits data to a central server for analysis. While effective for monitoring, it lacks features for wildlife detection and real-time alerts.

[9] IoT-Based Smart Irrigation System (G. Parameswaran et al., 2016):
This system uses temperature, humidity, and pH sensors to automate irrigation. Data is transmitted to a server for monitoring. However, the system requires internet connectivity and does not support animal intrusion detection.

[10] Automated Irrigation with GSM Alerts (Karan Kansara):
This approach integrates sensors with GSM technology to notify farmers about soil conditions. Although it provides remote communication, it is limited to irrigation and does not address wildlife intrusion problems.

III. METHODOLOGY

The proposed system is designed using a combination of hardware and software components to achieve efficient detection and prevention of elephant intrusion.
The methodology is divided into two main stages:
1. Detection Stage
PIR (Passive Infrared) sensors are deployed along the boundaries of agricultural fields to detect motion caused by large animals. These sensors identify changes in infrared radiation emitted by moving objects, enabling early detection of elephants. Once motion is detected, the microcontroller processes the

signal and activates the camera module. The camera captures real-time images of the intruding animal, which helps in verifying the presence of elephants.

The sensors are strategically placed to ensure maximum coverage of the farmland boundaries and minimize detection gaps. The system continuously monitors the environment, making it capable of detecting movement at any time, including night conditions. The captured data can be used for further analysis of animal movement patterns and frequency of intrusion. This stage ensures early warning, reducing the chances of elephants entering deep into the farmland.

2. Alert and Deterrence Stage

The captured images are transmitted to farmers through GSM or Wi-Fi modules. This allows farmers to monitor their fields remotely and take necessary actions. Simultaneously, the system activates a sound module that emits high-frequency acoustic signals such as bee buzzing. These sounds exploit the natural fear of elephants and act as a non-lethal deterrent. The system also includes a buzzer for local alerts, ensuring that nearby farmers are immediately notified of potential threats.

The alert system provides real-time notifications, enabling farmers to respond quickly to prevent crop damage. The use of acoustic signals ensures that elephants are repelled without causing any physical harm to them. The combination of visual alerts and sound deterrents increases the overall effectiveness of the system. This stage reduces dependency on manual intervention and improves the safety of both farmers and wildlife.

IV. SYSTEM ANALYSIS

1.1 Existing System

The existing systems used for preventing elephant intrusion mainly include electric fencing, manual guarding, and traditional deterrent methods such as noise and fire. Electric fences are widely used but are expensive to install and maintain. They can also be harmful to wildlife and are often breached by elephants using their tusks or body weight.

Manual guarding involves continuous monitoring by farmers, which is labor-intensive and not reliable. Methods such as firecrackers and drum beating are temporary solutions and lose effectiveness over time. Existing systems often require continuous monitoring by farmers, which increases workload and reduces efficiency. The absence of automated decision-making makes these systems less responsive to sudden animal intrusions. Maintenance of traditional systems like electric fencing can be costly and time-consuming in rural areas. These systems do not provide data storage or analysis for understanding long-term intrusion patterns.

Disadvantages:

1.High installation and maintenance cost
2.Requires continuous human effort
3.Not reliable in long-term use
4.Harmful to animals
5.Lack of real-time alert system

1.2 Proposed System

The proposed system introduces a smart and automated approach to detect and prevent elephant intrusion.

It integrates IoT technology with motion detection, real-time communication, and acoustic deterrent mechanisms. The system provides instant alerts along with visual confirmation, enabling farmers to respond quickly.

Unlike traditional methods, the proposed system is non-lethal and environmentally friendly. It reduces dependency on manual labor and ensures continuous monitoring.

The system supports remote monitoring, allowing farmers to access field data from any location. It operates continuously using solar power, making it suitable for areas with limited electricity supply. The integration of multiple components increases system reliability and reduces false detections. It provides a scalable solution that can be extended to detect other types of wildlife in the future.

Advantages:

1.Cost-effective solution
2.Real-time alerts and monitoring
3.Non-harmful to wildlife
4.Low maintenance requirement
5.High accuracy and reliability

V. SYSTEM DESIGN

The proposed Elephant Movement Detection System is designed using a layered architecture approach to ensure modularity, scalability, and efficient operation. Each layer is responsible for a specific function, enabling smooth data flow from sensing to user interaction. The system integrates hardware components such as sensors, microcontrollers, communication modules, and power supply units with software technologies to provide real-time monitoring and deterrence.

1) Sensing Layer

The sensing layer is responsible for detecting the presence of elephants in agricultural fields. This layer consists of PIR (Passive Infrared) sensors, which detect motion based on changes in infrared radiation emitted by moving objects. The sensors are strategically placed along the boundaries of the farmland to ensure maximum coverage. When an elephant enters the detection range, the PIR sensor senses the movement and generates a signal. This layer acts as the first point of interaction between the environment and the system. The sensing layer operates continuously and is capable of detecting movement during both day and night conditions. It ensures early detection of elephant intrusion, reducing the chances of crop damage.

2) Processing Layer

The processing layer is the core of the system and is responsible for analyzing sensor data and controlling system operations. It is implemented using a microcontroller such as Arduino ESP32 or Raspberry Pi. When the sensor detects motion, the microcontroller processes the input signal and triggers appropriate actions. It activates the camera module to capture real-time images and controls the operation of the buzzer and sound module. The processing layer ensures proper coordination between different components and executes the programmed logic efficiently. It also handles data transmission and system control functions.

3)Communication Layer

The communication layer enables the transmission of data from the system to the farmer. It uses GSM/GPRS or Wi-Fi modules to send real-time alerts and captured images. When an intrusion is detected, the system sends notifications to the farmer's mobile device. This allows farmers to monitor their fields remotely and take immediate action if necessary. The communication layer ensures reliable and fast data transfer, even in remote areas. It plays a crucial role in reducing response time and improving system effectiveness.

4) Deterrent Layer

The deterrent layer is responsible for preventing elephants from entering the farmland. It includes a speaker module that generates high-frequency acoustic signals such as bee buzzing in the range of 3–10 kHz. These sounds exploit the natural fear of elephants and act as a non-lethal deterrent. Along with the sound module, a buzzer is used to provide local alerts to nearby farmers. This layer ensures that elephants are repelled safely without causing any physical harm, promoting eco-friendly conflict management.

5) Power Supply Layer

The power supply layer provides the necessary energy for system operation. It includes solar panels, batteries, rectifiers, filters, and voltage regulators. The system uses solar energy to ensure continuous operation, especially in remote agricultural areas where electricity supply is limited. The battery backup ensures uninterrupted functionality during nighttime or low sunlight conditions. The power supply circuit converts AC to DC, filters fluctuations, and regulates voltage to maintain stable operation of all components.

6) Application Layer

The application layer represents the interaction between the system and the user. It includes mobile-based alerts and notifications sent to farmers. Farmers receive real-time information about elephant movement along with captured images. This enables them to make informed decisions and take preventive measures. This layer improves usability and accessibility, making the system practical for real-world deployment in rural areas.

VI. SYSTEM FLOW

The system follows a sequential process for detection and prevention:

1. The system is powered using a solar supply with battery backup and continuously monitors the environment using PIR sensors to detect motion based on infrared radiation changes.

2. When an elephant enters the detection range, the PIR sensor detects movement and sends a signal to the microcontroller for processing.
3. The microcontroller analyzes the signal and confirms the presence of a moving object in the monitored area.
4. Once confirmed, the microcontroller activates the camera module to capture real-time images of the intruding animal.
5. The captured images are processed and transmitted to the farmer's mobile device through GSM or Wi-Fi communication modules.
6. At the same time, a buzzer is activated to provide a local alert, and the sound module emits high-frequency acoustic signals to deter the elephant.
7. The system continues monitoring the area and repeats the alert and deterrent process if movement is still detected.
8. When no movement is detected, the system returns to idle mode while storing detection data for future analysis, ensuring continuous and automatic operation.

VII. IMPLEMENTATION

The proposed Elephant Movement Detection System is implemented by integrating both hardware and software components to achieve real-time monitoring and deterrence. The core of the system is a microcontroller such as Arduino ESP32, which is responsible for controlling all operations. The hardware components including PIR sensors, camera module, GSM/Wi-Fi module, buzzer, and sound emitter are connected to the microcontroller. These components are installed along the boundaries of agricultural fields to ensure effective coverage and early detection of elephant movement. The system is designed in such a way that it can operate autonomously without the need for continuous human supervision.

The PIR sensors continuously monitor the surroundings and detect motion based on changes in infrared radiation. Once movement is detected, the signal is sent to the microcontroller, which processes the input and activates the camera module. The camera captures real-time images of the intruding animal, providing visual confirmation to the farmer. This image-based verification improves the reliability of the system by reducing false alarms. The communication module, either GSM or Wi-Fi, is then used to transmit the captured images and alert messages to the farmer's mobile device, enabling remote monitoring of the field.

In addition to detection and alerting, the system incorporates a deterrent mechanism to prevent elephants from entering the farmland. Upon detection, the microcontroller activates a buzzer for local alerts and a speaker module that generates high-frequency acoustic signals such as bee buzzing. These sounds are specifically chosen based on the natural behavior of elephants, as they tend to avoid such frequencies. This non-lethal approach ensures that elephants are safely repelled without causing harm, making the system environmentally friendly and suitable for wildlife conservation.

The entire system is powered using solar energy with battery backup, ensuring uninterrupted operation even in remote areas where electricity supply is limited. A power supply unit consisting of rectifiers, filters, and voltage regulators is used to provide stable power to all components. The implementation also supports continuous monitoring and automatic operation, reducing the need for manual intervention. Overall, the system is designed to be cost-effective, reliable, and easy to deploy, making it practical for real-world agricultural applications.

VIII. COMPONENTS

The system consists of the following components:

1.Microcontroller (Arduino ESP32)
2.PIR Sensor for motion detection
3.Camera module for image capture
4.GSM/GPRS module for communication
5.Speaker for acoustic deterrent
6.Buzzer for local alert
7.Solar panel and battery
8.Power supply circuit with rectifier and regulator
9.IoT communication modules

IX. CONCLUSION AND FUTURE WORK

9.1CONCLUSION

The proposed Elephant Movement Detection System provides an effective and reliable solution to reduce Human-Elephant Conflict in agricultural areas. By integrating IoT technologies such as PIR sensors, camera modules, and GSM/Wi-Fi communication, the system enables real-time detection and monitoring of elephant movement. The use of image capture ensures accurate verification of intrusion, while instant alerts allow farmers to respond quickly. This reduces crop damage and minimizes economic loss, making the system highly beneficial for farmers living near forest regions.

Another important aspect of the system is the use of non-lethal deterrent mechanisms. The acoustic signals, such as high-frequency bee buzzing sounds, are designed based on the natural behavior of elephants, ensuring that they are safely repelled without causing harm. This eco-friendly approach supports wildlife conservation while addressing agricultural challenges. In addition, the system reduces dependency on manual labor and eliminates the risks associated with traditional methods like electric fencing and firecrackers.

The implementation of solar power with battery backup ensures continuous operation, even in remote and rural areas where electricity supply is limited. The system is cost-effective, easy to install, and requires minimal maintenance. Overall, the proposed solution offers a sustainable and practical approach to protect crops, improve farmer safety, and promote coexistence between humans and wildlife.

9.2 FUTURE WORK

The proposed system can be further enhanced by incorporating advanced technologies to improve its performance and functionality. One of the major improvements is the integration of artificial intelligence and machine learning algorithms for accurate animal classification. This will enable the system to distinguish between different types of animals and respond accordingly, increasing its effectiveness and reducing false alerts.

Future developments can also include the use of cloud-based platforms for storing and analyzing data collected from the system. This will help in tracking long-term animal movement patterns and provide valuable insights for both farmers and wildlife authorities. The development of a dedicated mobile application can improve user interaction by providing real-time notifications, system status updates, and remote control features.

Additionally, the system can be expanded to monitor multiple locations and detect various wildlife species, making it more scalable and versatile. Integration with forest department systems can support large-scale wildlife monitoring and conservation efforts. These enhancements will further improve the efficiency, usability, and impact of the system in real-world applications.

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