Early Warning System Using Smart Drone for Human-Wildlife Harmony

Dr.C.Poongodi[1], Ms.B.Dhivya Dharshini[2], Ms.S.Loga Sri[3], Ms.S.Logeshwari
[1,2,3,4]*Department of Computer Science and Engineering, Vivekanandha college of Engineering for Women Namakkal, India*

Abstract: Human-wildlife conflict (HWC) is becoming increasingly common all over the globe, occurring whenever human activities overlap with wildlife habitats. Confrontations with wildlife, like elephants, usually translate into crop raiding, damage to property, and even mortality, impacting people and conservation both.

This project employs cutting-edge drone and IoT technology to identify wild elephants in real-time through GPS and high-resolution imaging, including infrared cameras. When detected, the system triggers a piezoelectric buzzer to produce a deterrent sound, warning surrounding people and deterring elephants from human habitation.

Automatic alerts with accurate GPS coordinates are provided to local people and wildlife authorities to ensure quick and coordinated response to reduce human-wildlife conflicts. The solution prevents human loss of life, crop loss, and property damage while encouraging the coexistence of humans and wildlife.

I. INTRODUCTION

Human-wildlife conflict (HWC) is a serious problem that occurs when wild animals, especially elephants, invade human settlements, causing crop damage, destruction of property, and even death. With increased urbanization and habitat loss, such conflicts have increased in terms of frequency, threatening human communities as well as wildlife conservation. Conventional methods of mitigation like manual patrolling and physical barriers are inefficient, expensive, and time-consuming.

To address this immediate need, this project will use the latest drone and IoT technologies to offer a preemptive solution for early detection and deterrence of invading elephants. Using GPS for location tracking, high-resolution imaging (e.g., infrared cameras) for real-time detection, and automated alerting systems, this project hopes to reduce conflicts and improve safety.

The main goals of this project are real-time detection of elephants, precise localization and tracking, automatic alert and deterrent through piezoelectric buzzers, and effective communication with local people and wildlife authorities. With these accomplishments, the system can be an early warning device, minimizing human casualties, economic loss, and environmental disturbance. In addition, this project supports conservation by advancing a humane and non-invasive means of managing wildlife.

Furthermore, the incorporation of machine learning (ML) and artificial intelligence (AI) in pattern recognition and image processing increases the system's accuracy and efficiency. Through the continuous learning process with new data, the system becomes more effective in detecting and identifying elephants, making the response mechanism more reliable and intelligent in the long run.

1.Real time Tracking and Detection – Employing drones with GPS and thermal cameras to detect and track elephants in real-time.

2.Automated Deterrent and Alert System – Triggering piezoelectric buzzers to emit deterrent sounds, dissuading elephants from venturing into human settlements.

3.Effective Notification and Communication – Sending automatic notifications to local inhabitants and wildlife authorities with accurate GPS coordinates.

4.Intelligent and Flexible Implementation – Creating a user-friendly and flexible system for different landscapes and conflict zones.

5.Sustainable and Humane Method – Providing a non-invasive and environmentally friendly approach to addressing human-wildlife conflict.

II. RELATED WORKS

Human-wildlife conflict has been an emerging issue globally, especially in areas where elephant herds overlap with human population.

Human intrusion into elephant territories has resulted in frequent conflicts, which have caused fatalities, destruction of property, and interference with human populations as well as wildlife conservation. Scientists have, over the years, explored different measures for detecting and preventing elephant intrusions. Though conventional techniques like fencing, manual monitoring, and acoustic deterrents have been used, these methods tend to be inadequate because of high maintenance requirements, inefficiency in extensive landscapes, and poor real-time monitoring.

With improvement in sensor technology, artificial intelligence (AI), and the Internet of Things (IoT), new solutions have been developed to enhance elephant detection and monitoring. One of them is seismic sensing, which uses ground vibrations caused by elephants while in movement. As elephants make unique seismic signals, they can be differentiated from human activities and environmental noise. These signals can then be used to detect the presence of elephants at distant distances.

Seismic-Based Elephant Detection Through Deep Learning

One of the key contributions in this area is "GajGamini", a new seismic-based elephant detection system that makes use of deep learning methods. The research proposed a CNN (Convolutional Neural Network)-based model for real-time seismic vibration classification caused by elephants, humans, and ambient noise. One of the biggest challenges in this study was the non-availability of large datasets on elephant-induced vibrations, and this problem was overcome by collecting and analyzing several hours of movement data. The research showed that seismic sensors are very efficient in recording elephant footfall vibrations and discriminating between them and human activity with high accuracy. With just three seconds of computing time for every ten seconds of recorded material, the model proved to have a remarkable accuracy of 98.03%, underlining its feasibility for use in real-world conservation efforts in elephants.

The non-intrusive characteristics of this solution render it ideally suited for application within wildlife preservation parks, given its ability to disturb natural systems minimally yet provide real-time surveillance and auto-detection capabilities. This work highlights the use of seismic sensing as a effective alternative to existing monitoring methods with the ability to present an automatic, scalable elephant movement tracking system.

IoT-Driven Elephant Detection Through Seismic Signals

Another landmark study investigated the capability of IoT-based geophone sensors to sense elephant movement at a distance. This study presented a custom-built geophone-sensor interface efficiently acquiring and processing seismic signals produced by elephant footprints. The system design consisted of an instrumentation amplifier cascade array, a second-order Butterworth filter for signal purification, and a signal amplifier to improve the accuracy of detection. Unlike traditional methods that rely heavily on human observation, this automated approach ensures continuous, real-time tracking of elephant movements over significant distances.

The study's experimental phase involved testing the geophone-sensor interface in both controlled laboratory conditions and real-world environments. The experiments were conducted with tamed, semi-wild, and wild elephants, providing a comprehensive evaluation of the system’s robustness. The experiments proved that the system was stable within a frequency range of 1 Hz to 1 kHz and over temperature fluctuations between 10°C and 40°C. In addition, the system effectively identified seismic signals from elephants within a maximum range of 155.6 meters with an excellent detection rate of 99.5%. These results indicate the potential of IoT-integrated seismic sensing as a successful early warning system for human communities surrounding elephant habitats. Through the installation of geophone sensors in exposed regions, this approach can considerably mitigate human-elephant conflict by giving timely warnings, allowing proactive actions like activating deterrent systems or informing wildlife authorities.

The Role of Machine Learning in Wildlife Monitoring

Both of these works highlight the increasing importance of deep learning and machine learning in developing wildlife monitoring methods.

Conventional feature extraction in seismic signal processing is usually skill-intensive and demands human intervention, thus being less scalable for extensive deployments. By contrast, deep learning models, including CNNs, learn automatically the feature representation, greatly enhancing detection accuracy and efficiency.

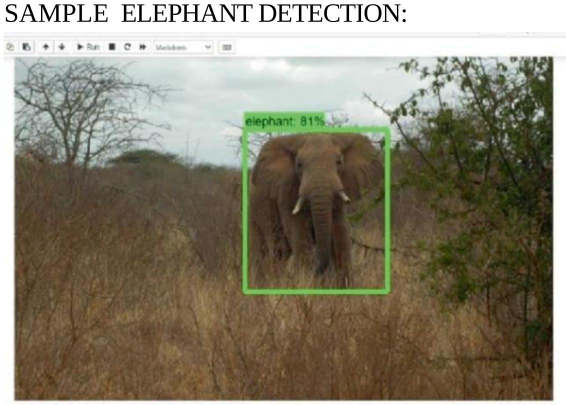
Additionally, the use of triplet loss functions within deep learning models has been investigated to enhance classification accuracy. By representing seismic signals in Euclidean space and calculating L-2 distances between similar and dissimilar signals, deep learning models are able to distinguish between various types of ground vibrations more effectively. The process assists in the training of models that are immune to environmental noise and terrain variations, allowing them to provide consistent performance across different field conditions.

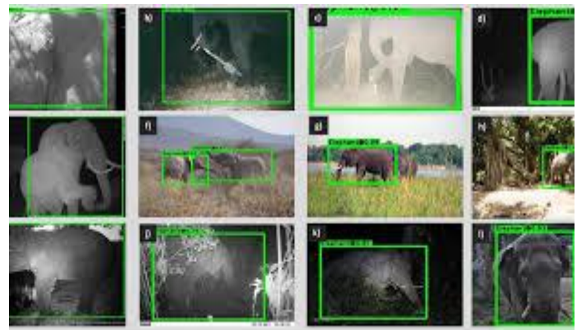
Implications for Our Project

Riding on the progress of seismic-based elephant detection, our project seeks to refine the precision, effectiveness, and scalability of self-sustained wildlife monitoring systems. By capitalizing on an integration of IoT sensors, machine learning algorithms, and real-time data processing algorithms, our work hopes to remedy some of the current limitations of elephant detection mechanisms.

Some key findings of the studies under review include the high efficiency of seismic sensors in long-distance detection of elephants, the superiority of CNNs over other machine learning models in classifying seismic signals, the effectiveness of triplet loss in minimizing misclassification, and the necessity of an IoT-based system for real-time wildlife monitoring and conservation alert.

SAMPLE ELEPHANT DETECTION:





III. METHODOLOGY

Module 1: Drone Module-The drone is the central unit, providing aerial monitoring and real-time tracking with autonomous or manual control for large-area surveillance, integrating detection, GPS tracking, and alert systems.

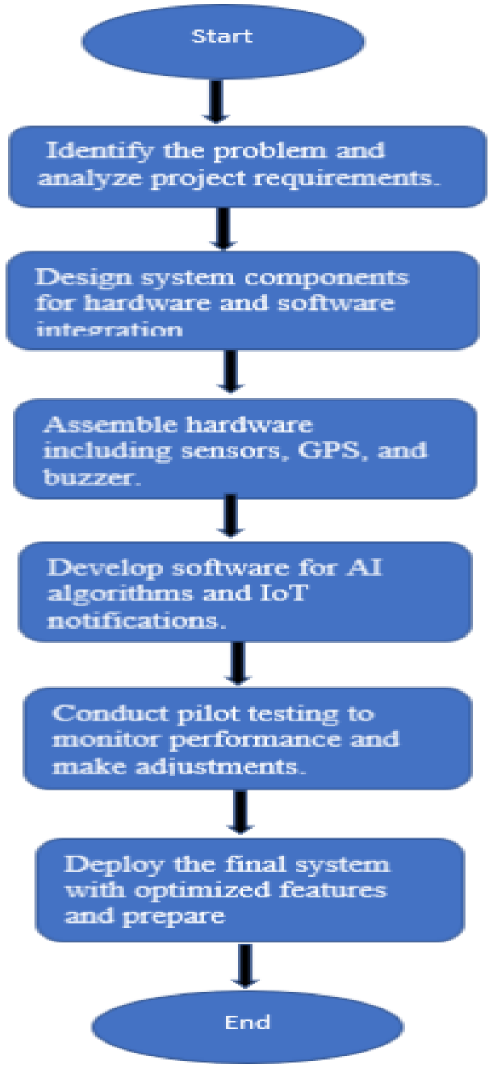
Module 2: Detection & Imaging-With high-resolution cameras and thermal sensors, the drone employs AI-based image processing and deep learning algorithms to identify and classify wildlife accurately, providing accurate identification even under changing environmental conditions.

Module 3: GPS & Location Tracking-Combined GPS and GIS-based tracking provides real-time location tracking, constantly updating wildlife movement information and optimizing autonomous flight routes for efficient routing and proactive conflict avoidance.

Module 4: Alert & Notification-When wildlife presence is detected, the system sends real-time alerts through SMS, mobile apps, and cloud dashboards, which enable quick response by conservation teams, authorities, and local communities through customizable notification thresholds.

Module 5: Buzzer & Deterrent-To avert human-wildlife conflict, the drone is equipped with a buzzer and deterrent system that releases scientifically proven sound frequencies and flashing lights to affect elephant movement without injury, offering a humane and effective method of intervention.

Module 6: Cloud Integration-All of the gathered information, such as images, GPS trace records, and alarm messages, are remotely stored in a cloud infrastructure to facilitate real-time access, centralized observation, advanced analysis, and predictive modeling for efficient management.



The existing elephant detection system depends on seismic sensors in the form of geophones to record ground vibrations caused by the movement of elephants. The signals are interpreted to confirm the presence of elephants, but it comes with a number of drawbacks. The range of detection is restricted since seismic vibrations decay with distance and hence is not suitable for large open spaces. Ground conditions like uneven terrain, rocky terrain, and forests can interfere with the accuracy of signals, resulting in false alerts or false negatives. Rain, wind, or other animals causing external noise further decrease reliability.

The system also does not have real-time deterrents and alerts, which result in delayed response and enhanced risk of human-elephant conflict. As geophones are stationary in a particular location, the system is hard to scale and cannot change according to varying elephant migration patterns, decreasing its efficiency in dynamic settings. Drawbacks are:

- Limited detection range, ineffective in large areas.
- Environmental factors disrupt seismic signal accuracy.
- Susceptible to external noise, leading to false alerts.
- No real-time alert or deterrent system.
- Fixed installations lack flexibility and scalability.

The new system brings to the fore a drone-based method of detecting and monitoring elephants, overcoming the shortcomings of conventional seismic-based techniques. Driven by high-resolution cameras and thermal imaging detectors, drones will take real-time aerial images of forested areas. Image processing algorithms such as deep learning-based object detection models will be employed to correctly detect elephants even in thick vegetation or hilly areas. Such a solution is more scalable and flexible, bypassing the environmental constraints and limited range of seismic sensors. Moreover, GPS-based tracking of locations will update elephant locations in a cloud-based system in real time, enabling wildlife conservation groups to track movement patterns and act in advance against possible human-elephant conflict.

To boost security and response effectiveness, the system also features real-time warning and deterrent capabilities. As an elephant is detected approaching human habitation or farmlands, automated notifications will be delivered to the authorities, farmers, and surrounding communities through SMS or mobile apps. The system also includes sound-based deterrents like buzzers that will gently drive elephants away from conflict areas without causing any damage. Cloud integration facilitates smooth data processing and storage, allowing for historical analysis to aid better decision-making in wildlife conservation. Utilizing drone technology, AI-based detection, and IoT-based alerting, this solution provides a more precise, real-time, and adaptive method of elephant monitoring with much lower false detections and better human-wildlife coexistence.

The Future updates will enhance detection capability, increase coverage, and augment system automation. With advanced AI, improved sensors, and IoT frameworks, there will be real-time monitoring and data-driven information. Renewable power solutions and automatic deterrents will also maximize the efforts in human-elephant conflict prevention.

- Advanced AI Models: Enhance the accuracy of elephant detection with the use of more sophisticated deep learning models such as transformers for improved object recognition in challenging settings.
- Multispectral & LiDAR Sensors: Add multispectral vision and LiDAR sensors for improved perception in heavy foliage and nighttime vision.
- Autonomous Drone Navigation: Create AI-powered autonomous drones to navigate and patrol autonomously without human control, enhancing coverage and efficiency.
- Real-time Behavior Analysis: Apply behavioral analysis algorithms to forecast elephant movement patterns and identify distress or aggression cues.

CONCLUSION

This project introduces a sophisticated drone-based system for elephant detection and tracking, overcoming the shortcomings of existing seismic sensor technology. With the integration of AI-driven image recognition, GPS location, and real-time alert systems, the system improves detection efficiency and response speed. Incorporating deterrent features also assists in reducing human-elephant conflicts by ensuring the safety of both wildlife and communities. With scalability and flexibility, this method offers a better and more adaptable solution for wildlife conservation and conflict avoidance. Advances in AI models, sensor technology, and automation in the future will continue to improve the performance and reliability of the system.

OUTPUT CONTAINS DRONE SURVEILLANCE AND ELEPHANT DETECTION

In summary, the project introduces an advanced drone-based system for elephant detection and monitoring that replaces the inefficiencies of conventional seismic-based systems. Through the combination of aerial observation, image processing, and real-time alerting, the system maximizes the effectiveness of wildlife tracking and human-elephant conflict mitigation. The drone takes live images, identifies elephants through AI-based image detection, and sends data for instantaneous response.

The deployment guarantees increased coverage, flexibility in handling dynamic situations, and enhanced precision in monitoring elephant movement. Through real-time notification and deterrent functions, the system greatly minimizes response time, reducing threats to humans and wildlife. AI-powered behavior analysis, multi-sensor fusion, and cloud-based predictive analytics could be future developments that further enhance wildlife conservation efforts.

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