Machine Learning-Based Approach for Predicting Elephant Movements to Mitigate Human Elephant Conflict

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1. Abstract

This research aims to develop a machine learning-based mobile application, Safe App, to predict elephant movements to reduce the impacts of human-elephant conflicts in rural Sri Lanka. Traditional prevention methods have been unable to manage hundreds of annual deaths. In this respect, the Safe App applies AI to predict movement, map the locations of elephants, and visualize high-risk areas using heat maps. It is an early warning system that will integrate machine learning and spatial analysis. The primary data is collected from the users' reported sights, and secondary data is collected from GPS-tracked elephant movements, enhancing predictive accuracy. Safe App provides AI-driven wildlife insights to help conservationists, authorities, and communities in improving human and elephant safety.

Keywords— *Elephant Movement Prediction, Machine Learning, Human-Elephant Conflict, Image Processing, Wildlife Conservation, Mobile Application*

2. Introduction

The conflict between elephants and humans is one of the most complicated conservation and public safety problems for rural areas of Sri Lanka, which accounts for hundreds of deaths each year from both sides. Traditional mitigation methods like physical barriers and manual monitoring systems, have shown limited effectiveness in preventing these deadly encounters. The increasing encroachment of human settlements into elephant habitats necessitates innovative technological solutions for conflict prevention. In addition, it is also crucial to safeguard elephants through these

efforts. By managing and preserving their habitats and the right strategies for conservation, we can promote the peaceful coexistence of humans and elephants. The Safe App is an innovative, artificial intelligence-driven solution that predicts elephant movements, maps elephant locations, maps elephant locations, heat map visualizations for high-risk areas, and delivers real-time alerts. The integration of machine learning and spatial analysis seeks to create an advanced early warning system for a potential conflict. This research examines the development, implementation, and initial results of the Safe App in selected rural communities, demonstrating its potential as a technological intervention for human-elephant conflict mitigation.

3. Research Background

The research paper by Nurul Su'aidah Ahmad Radzali, Azuraliza Abu Bakar, and Amri Izaffi Zamahsari[1] discusses the analysis of animal movement data using statistical applications and machine learning that has developed rapidly with various tracking devices. This study proposes a machine learning model to predict the behavioral diversity of Asian elephants using satellite collar data. The model development details comprise four stages: data collection, data labeling, all data classification, and primary classification model development. This model uses XGBoost data. and achieved 100% behavior classification accuracy when tested on footage from five elephants in Malaysian forest reserves from 2018 to 2020. The challenges faced comprise obtaining labeled data and accurate behavior predictions due to the lack of ecological context. The future intent is to develop the datasets as well as bring in more specialists in the domain to improve the results.

The research documents authored by Mrs. Bakhtawer Shameem and Prof. Bhavana Narain[2] cover the possibilities of utilizing deep learning methods for the identification and behavioral analysis of a single elephant. The study discusses the burden of tracking elephants kept under maintenance and the traditional identification methods which are often invasive and costly. Allowing for a change, the authors present an image-based approach with a non-invasive method using Convolutional Neural Networks (CNN) type electronic facial recognition systems of elephants taken to Tamor Pingla Elephant Rescue Center located in Chhattisgarh, India. It is done by detecting and cropping the region of the body of the elephant and then assisting the CNN model in identification and behavioral control. These images are self-collected into a dataset and the system was able to get 96.8% results for cropping and 97.01% results for identification of elephants. The authors also address the promises of unsupervised learning targeting the annotation of behavioral patterns and movement paths where the trained data is virtually zero. It shows how important it is to adopt machine learning in analyzing animal behavior to mitigate the human-elephant conflict. The next steps include increasing the amount of data, improving the behavioral analysis tool, and investigating implementable solutions in real-time.

This research by R. Vasanth and A. Pandian from SRM Institute of Science & Technology, Tamil Nadu, India,[3], aims to identify and enhance protection measures for elephants using a WUP (Weighted Uncertainty Prediction) methodology that predicts their movements. The data was obtained from synchronized cameras, GPS, and seismic sensors set around the area which could sense vibrations caused by elephants walking. The seismic data was checked for 0-20m and 20-40m ranges around the sensing units. The WUP algorithm solved the problem with a 99.5% detection rate at 20m and outperformed other methods in the F1

metric as well. While the study does effectively identify certain distinguishing footstep patterns of elephants, the authors highlight issues arising from the insufficient application of deep learning techniques. The authors recommended that new studies use deep learning techniques to improve the quality of predictions and decrease computational burden.

This research by A.H. Abbas, Mohammed I. Habelalmateen, Syukran Jurdi, L. Audah, and N.A.M. Alduais,[4] focuses on attempts to improve the traditional geofencing systems with additional machine learning techniques for real-time dynamic adjustment. The main problem this model addresses is the existence of static boundaries and an excessive amount of false positives. The concept of the model lies in a two-step process that consists of the collection and purification of location and movement data, and the application of predictive human behavior machine learning algorithms like Support Vector Machines SVM and clustering for dynamic adjustment of boundaries. The system incorporates GPS, Wi-Fi, and Bluetooth for tracking, as well as classifying the data into locations using the Haversine method.

This research by R.M.K.B. Rajapaksa, L.R.K. Kahandagamage, K. Nijamir, and B.D. Madurapperuma[5] utilizes modern applications for improved tracking of elephants in Sri Lanka through the web mobile application and geo-fencing system to resolve Human-Elephant conflict. The system tracks the movement of an elephant within GPS Geofenced areas such as Udawalawe National Park using face recognition identification of individual elephants with infrared cameras. By integrating all these technologies, mobile applications can supply real-time data which assists conservation activities and enables mitigation of HEC effectively.

This research by D.T.S. Wijesekera, M. C. S. T Amarasinghe, P.N. Dassanaike, T.H.H. De Silva, and N. Kuruwitaarachchi[6], integrate wireless sensor networks with seismic sensors and alarm systems to propose new ways to resolve the human-elephant conflict in Sri Lanka. Attempts are made to avert harm to mankind and elephants through efficient monitoring and early warning systems to achieve peaceful coexistence in the context of severe environmental degradation and intrusion problems.

Existing researchers have developed techniques to analyze and monitor elephant behavior through XGBoost[1], CNN facial recognition[2], and seismic sensors[3]. However, these methodologies are often fraught with narrow focuses that prevent them from being versatile in real-time situations. Because elephants are heavily mobile, and capable of changing their whereabouts due to numerous external factors, static models will prove to be inadequate for human-elephant conflict resolution in rural settings. The Safe App tackles these problems head-on, using AI-powered tracking, predictive analytics, and real-time information updates to create a cohesive, versatile early warning system. This serves as a cohesive and effective early warning system for the problems mentioned above. Instead of the usual approaches, the Safe App predictive analytics works in real-time, which makes it effortless for communities to manage risks. This research shows how the Safe App can combat conflicts between humans and elephants in an effective and realistic approach.

4. Statement of Problem and Goals

Human-elephant conflict is a serious problem in rural communities in Sri Lanka, where elephants frequently invade villages and destroy crops, homes, and human life. Retaliation against elephants leads to the death of these endangered animals. While effective mitigation of such conflicts is underway, there is still a dearth of

efficient, proactive systems that can predict and prevent elephant movements to protect vulnerable communities from recurring casualties and property damage. Traditional methods tend to be reactive instead of predictive and preventive to avert potential conflicts before they flare up.

The inability to predict, therefore, limits the ability to act proactively and puts both humans and elephants at risk, adding to the decline of elephant populations. That is a cyclic thing: destruction where both human communities and wildlife go down in losses. What urgently needs to be done are innovative solutions that can forecast elephant movements to reduce the frequency of such encounters and allow humans and elephants to coexist.

4.1 Project Objectives

4.1.1 Primary Objective:

Develop a machine learning-based predictive model to forecast elephant movements, minimize human and elephant encounters, and avert damage to property, crops, and injuries to both humans and elephants.

4.1.2 Secondary Objective:

- Human Safety & Property Protection: Provide current data to enable community evasion of high-risk areas, preventing potential conflicts.
- Wildlife Conservation: Reduce retaliatory elephant killings by identifying safe zones and guiding conservation efforts.
- Support for Tourism & Photography: Contribute towards safely tracking elephant movements by supporting wildlife photographers and tourism companies.
- Improved Decision Making: Authorities will be informed to demarcate safe zones and coexist with elephants.

The project deploys technology in the protection of humans and elephants alike, allowing a sustainable balance between rural communities and wildlife conservation.

5. Project Design

The Safe App is proposed to protect human lives and properties and will provide early warnings and predictions concerning elephant movements or conflicts. It has a structured alert system where users report elephant sightings, human casualties, or incidents of conflict. Users are required to first sign up and log in to the platform to ensure secure usage and authentication. They can submit alerts after they log in by selecting the type of incident, entering the relevant details, and pinpointing the exact location on the map.

This system incorporates a mapping system that acquires nearby locations through a map API and calculates distances and uses a machine learning model to identify the most likely next movement by elephants. The visualization of high-risk areas as heatmaps helps in decision-making at the route choice level. Along with this, the system can suggest safe routes to help a user avoid some dangers. Also, the system has the functionality to upload an image of an elephant, detect the elephant in the image, and provide details such as age likewise.

The application offers community engagement in terms of safety tips, where it provides space for posting one's safety tips, emergency contact, and discussions of the community by sharing their experiences and the latest local information about wildlife. Notification systems may update users about elephant movements and alert them of risks near a location. Each incident reported will be stored in the database to dynamically update the heat map with an aim of refining the

ML model for greater accuracy in making future predictions.

This system effectively combines user-generated data, geospatial mapping, and predictive analytics to mitigate human-elephant conflicts and promote coexistence.

6. Methodology

The project follows an experimental approach to develop the Safe App, designed to predict elephant movements and mitigate human-elephant conflicts. The app uses both primary and secondary datasets. Primary data includes app users' pinpoint location data, which helps track and predict elephant movement in relation to human activity. Secondary data consists of GPS tracker data from external sources, providing historical movement data of elephants that enhances the model's predictions.

A literature review was conducted to identify suitable machine-learning techniques and image-processing methods based on previous research in elephant movement prediction and image-based elephant detection. The Safe App integrates three core models:

1. **Elephant Movement Prediction Model:**
   The first model predicts the next probable location of an elephant based on its current location. This model uses primary data (app users' pinpoint location data) and secondary data (GPS tracker data from external sources) to make predictions and provide real-time alerts if an elephant is likely to move into high-risk areas.
2. **Elephant Movement History Model**:
   The second model allows users to select a location and determines if elephants have passed through that area. It uses secondary data (GPS tracker data) to count the number of times elephants have passed through that location, identifying high-risk zones based on historical movement patterns.
3. **Elephant Detection and Information Model:**
   The third model processes images uploaded by users to detect elephants and provide their details, such as age, and herd details likewise. This model uses both primary data (uploaded images from app users) and secondary data (images from external sources). The combination of primary and secondary data helps to enhance the model's ability to identify individual elephants more accurately and provide more detailed information about them.

The development of these models involved data collection, preprocessing, and the application of machine learning algorithms for classification and prediction. Primary data from app users' pinpoint location data helps improve the accuracy of predictions and provides context for elephant movement patterns, while secondary data from GPS trackers adds historical and geographical insights.

For testing the app, a specific area where elephants are frequently found is selected. This allows for accurate real-world simulation of elephant movements and provides valuable insights into the app's effectiveness in predicting and detecting elephants in high-risk zones. The following testing methods are used:

- **End-user testing:** The app is tested in a specific area, evaluating response time, result accuracy, and user interaction frequency.
- **Image validation:** Users label elephant images to verify the app’s accuracy in identifying details like age, and herd details. After testing and debugging, the final Safe App

- is deployed in the areas to mitigate human-elephant conflicts.

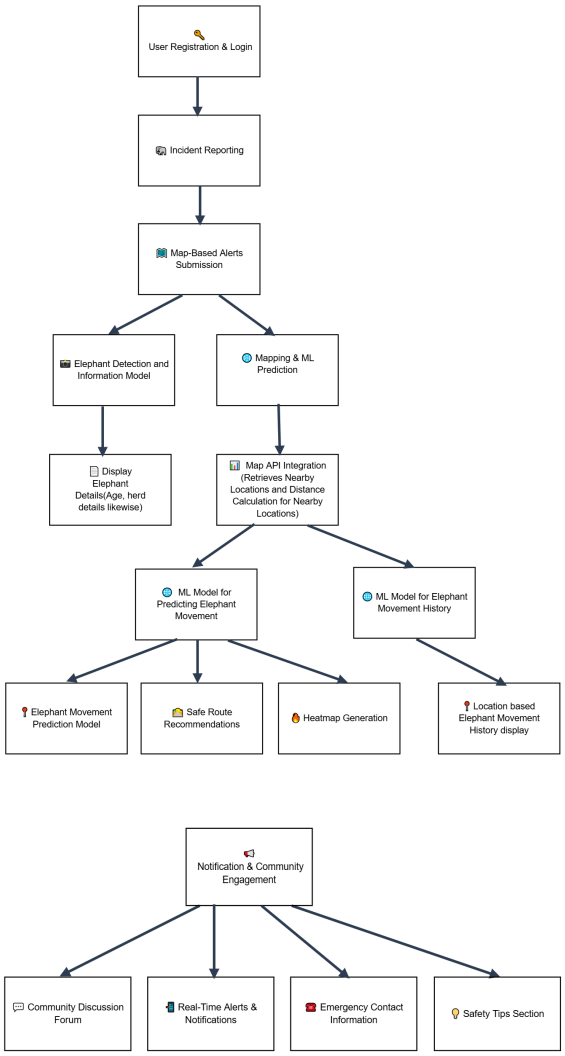


Figure 1: Research Design

7. Conclusion

The Safe App successfully addresses human-elephant conflict through AI-driven prediction and community engagement. Initial deployments show promising results in reducing encounters and property damage. The integration of machine learning models with user-reported data creates a robust early warning system that serves both conservation and community safety goals.

8. Future Works

- Enhanced Prediction Accuracy - Improve the machine learning model by integrating additional data like incorporating elephant behavior research, weather patterns, seasonal trends, and real-time IoT sensor data for more accurate elephant movement predictions.
- Multi-Language and Offline Mode - Add support for Sinhala, Tamil, and English, with offline functionality for low-connectivity areas.

References

[1] N. Radzali, A. Bakar, and A. Zamahsasri, “Machine Learning Models for Behavioural Diversity of Asian Elephants Prediction Using Satellite Collar Data,” *J. Inf. Commun. Technol.*, vol. 22, pp. 363–398, Jul. 2023, doi: 10.32890/jict2023.22.3.3.

[2] B. Shameem, “Deep Learning for Elephant Behavior from Location and Rehabilitation in Captivity,” p. 2022, Jan. 2024.

[3] R. VASANTH and A. PANDIAN, “PROVISIONING AN UNCERTAINTY MODEL FOR ELEPHANT MOVEMENT PREDICTION USING LEARNING APPROACHES,” *J. Theor. Appl. Inf. Technol.*, Feb. 2024.

[4] A. Abbas, M. Habelalmateen, S. Jurdi, L. Audah, and N. Alduais, “GPS-based location monitoring system with geo-fencing capabilities,” *AIP Conf. Proc.*, vol. 2173, p. 020014, Nov. 2019, doi: 10.1063/1.5133929.

[5] R. Rajapaksa, L. Kahandagamage, K. Nijamir, and B. Madurapperuma, “Web-Mobile Based Application to Detect the Elephants’ Intrusion in Sri Lanka: A Geofencing Based Approach,”

Dec. 2022.
[6] D. T. Wijesekera, M. Amarasinghe, P. N. Dassanaike, T. H. H. Silva, and N. Kuruwitaarachchi, “Modern Solution for Human Elephant Conflict,” pp. 1–6, May 2021, doi: 10.1109/INCET51464.2021.9456214.