Integrating Machine Learning and IoT for Real-Time Wildlife Tracking and Crowd Sourcing

Sahas Saubhagya[a], Nadun Wijerathne[a], Kivindu Sachintha[a], Hirudaka Kumarasinghe*[a]
[a]Faculty of Computing, Department of Software Engineering, Sri Lanka Institute of Information Technology, Malabe, Sri Lanka[1]

ABSTRACT

This research introduces a smart system to enhance wildlife safari experiences by integrating real-time location tracking, animal behavior prediction, and emergency communication technologies. Traditional safari tours rely heavily on human guides, often leading to inefficiencies in wildlife spotting and navigation. Proposed system employs machine learning, GPS tracking, and voice assistance to provide an interactive and informative safari experience. The machine learning algorithm uses past and current movement patterns of animals and generates predictive information to guide tourists to optimal wildlife observation points. The system uses LoRa-based offline communication to ensure seamless connectivity in network-poor regions, facilitating smooth coordination between safari vehicles and park authorities. The voice guidance feature also enhances accessibility by providing real-time educational content on observed wildlife. This study adds to wildlife tourism with a technology-based framework that improves visitor experience, minimizes environmental footprint by route optimization, and aids conservation through data-driven monitoring of wildlife behavior.

Keywords: Wildlife Tourism, Animal Tracking, GPS Integration, Machine Learning, Voice Assistance, Safety Monitoring, Offline Communication.

I. INTRODUCTION

It thus shows much importance on an international ground where countries or states are believed to have remarkably elevated levels of biodiversity. Large numbers of tourists visit national parks and wildlife sanctuaries as an opportunity once in a lifetime to see wild animals in their natural habitat. However, despite the increases in safari tourism, there still arise challenges concerning ideal experience for the tourists, park administrators, and the conservationists themselves.

Some of the major problems that come with these safari experiences include finding and viewing wildlife, often a hard job. Many times, tourists must depend on guides whose knowledge may not be updated about the movements of the animals. In turn, such unpredictability translates into frustration for visitors expecting an experience full of encounters with wild animals. Lack of real-time data regarding animal movements further increases the chances of overcrowding in specific areas, which may lead to ecological disturbances and potential risks for both wildlife and humans.

Other serious issues are the communication gap experienced around remote safari destinations. Since cellular networks are low in national parks, the tourists and guides may incur inconveniences during emergencies resulting from vehicle breakdowns, attacks by animals or lost people. There is much inefficiency present in the management and booking of the parks. Present systems do not have any robust mechanism regarding monitoring of safari vehicles, animal location tracking, and/or tourist route optimizations. The inability to regulate the flow of traffic by park authorities and to prevent wildlife disturbance further leads to inconsistency between conservation with tourism [15].

The following is, therefore, an integrated system that is supported by modern technologies in the fields of machine learning, GPS tracking, and LoRa communication in such a way that it remarkably enhances the experience during a safari. Equipped with historical data and environmental conditions, it enables forecasting animal movements by suggesting routes that should be taken for better animal sightings. It will also include an offline communication framework that will enable them to share information between safari vehicles and park authorities for use by the latter in safety and management.

* Corresponding Author: hirudakakumarasingha@gmail.com

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The study tried to close the gap between traditional safaris and sophisticated technological innovations up to an advanced, efficient user-friendly solution for all users. The following of this paper presents related research and existing systems to highlight the gaps in current wildlife tourism applications. The methodology section describes the technological components, including AI-powered identification of animals, predictive analysis of movement prediction, and real-time communication functionality. The results prove the system's effectiveness through extensive experimentation and verification. Future scope keeps in view probable enhancements such as enhanced species monitoring and improved AI models. The paper concludes by emphasizing the role of advanced technology in making wildlife tourism safer, more engaging, and conservation focused.

II. RELATED WORK

Regarding wildlife tourism, several applications have been developed that introduce more technology into the safari experience by way of animal tracking, itinerary planning, and real-time information sharing. These applications will solve problems faced by tourists, guides, and park authorities in finding animals, improving safety, and interactive experiences. Till now, most of the proposed solutions do not allow many advanced technologies involved simultaneously, such as machine learning, real-time tracking, voice assistance, and offline communication.

Below is a comparison between the existing applications for safaris and the proposed integrated system for safari experience optimization.

Redmon and Farhadi (2018) introduced YOLOv3[1], an efficient and fast object detection model that enables real-time animal identification with high accuracy. The same as this, Szegedy et al. (2016)[2] developed the initial design, which uses multi-scale feature extraction to increase classification performance and is helpful for differentiating between identical species. The 2023 study on image processing methods for identifying dangerous animals explores how important these models are for integrating real-time harmful animal identification. Further, Maduranga and Sithara (2021)[3] explored the application of wearable sensors for tracking animal locations, offering more chances to improve the identification system, while Prudhivi et al. (2022)[4] showed the success of deep learning for animal species classification.

Predicting animal movements correctly is important for guiding safari drivers to wildlife locations. The application's spatial statistics method is based on the mean centering technique from The International Encyclopedia of Communication Research Methods (2017)[5]. In line with the real-time changes built into the system, Smith and Thompson (2020)[6] researched prediction models for how animals move in response to environmental factors. The application's power to create dynamic heatmaps using past sightings and preferred habitat is also confirmed by Carter et al.'s (2019)[7] analysis on the function of spatial modeling in conservation.

The application uses LoRa (Long Range) communication for offline data delivery because national parks have weak connections. LoRa is a low-power, long-range Internet of Things technology that was first introduced by Vangelista et al. (2015)[8]. It is important to locate wildlife in remote areas. A LoRa-based animal tracking system created by Benedetti et al. (2020)[9] is used as a model for adding real-time location updates to a proposed system. Problems with Scalability were studied by Mikhaylov et al. (2016)[11] to help make sure the system keeps working correctly when more tracking devices and users are added. Zhang et al.'s [12] latest research from 2024 examined the use of LoRa in wireless body area networks offering solutions to enhance the speed of transmission and data reliability in challenging locations.

Route optimization and Jeep scheduling ensures that safari drivers can efficiently navigate Yala National Park while maximizing wildlife encounters with minimum traffic. When applying real-time animal movement forecasts, Y. Zhang (2020) [16] proposed the use of scheduling algorithms that help in identifying the most efficient routes. C.J. Malmborg [17] developed genetic scheduling algorithms for vehicles which can be modified to continually optimize safari routes. S. Zhang et al. (2022) [19] also studied optimization for transport scheduling, providing an approach for gaining a balance between real-world constraints like environmental laws and route availability and effectiveness.

Using past research analysis, one can deduce that although the existing applications provide beneficial features, such as animal tracking and integrating GPS, most of them still lack complete functionality in terms of voice assistance, safety monitoring, and offline mode. The proposed system will be able to provide an integrated solution for real-time animal behavior prediction, guided navigation, emergency communication, and even robust user interaction in offline mode.

This study also tries to give the tourists immersive, informative, and safer safari experience and helps in managing and conserving the park using state-of-the-art technologies, such as machine learning-based animal behavior prediction, GPS-enabled real-time tracking, voice-assisted guided navigation, and LoRa-based communication systems for safety monitoring.

III. METHODOLOGY

Proposed mobile application is developed using React native and MongoDB as the database. The web application is developed using React, Node.js for the frontend, express framework and MongoDB as the database. This research identified the specific needs and challenges faced by safari riders and Safari drivers of Yala National Park when they are going on a safari and attempts to implement solutions to their using latest tools and techniques. The system consists of two deep learning models , LORA offline communication system, genetic algorithm for schedule development and an accurate animal predictor. Information that is gathered from requirement gathering is used to design user interfaces and improve overall quality the user experience. These are the unique features that are included in the system:

A. Animal Identification

This feature helps safari riders accurately identify wildlife by enabling animal tracking through a mobile camera. [20] The product takes the help of the YOLOv8 object detection model [1] to perform this real-time animal detection feature. YOLOv8 detects and extracts the largest bounding box corresponding to the primary animal in the frame. Once the animal is detected, the app uses an InceptionV3 convolutional neural network (CNN) [2] to classify the animal. The classification model achieves high confidence in species recognition.

B. Aggressive Animal Detection and Safety Mechanism

A second deep learning model, which has been trained with 93% accuracy, is used to identify animals that have shown aggressive behavior in the past. This model checks the detected animal against a database of previous aggressive encounters [3]. If a match is found, the system sends an alert to warn the user of potential danger. This makes the app easier to use and more accessible for everyone.

C. Speech to text -Voice Assistant

The text-to-speech function can significantly enhance the accessibility and usability of the mobile application for individuals who have difficulty reading or interpreting text on the screen due to having to read while traveling. Users can simply activate the text-to-speech (TTS) function to hear detailed and accurate descriptions about animals they wanted to get information about.

D. Animal Prediction Map and Route Suggetion

"Into the Wild" mobile application has a detailed map of Yala national park and a predicted locations of wildlife that are changing in real time to conditions like time of the day and seasonal changes. The prediction will be calculated using the "mean center" of spatial statistics.[5] The data for the calculation is gathered from past wildlife sightings and encounters. This method is highly effective because of its capability to find the center of concentration. Which makes the Prediction more accurate, hence increasing the quality .

In addition to that, the mobile application includes a route suggestion feature that provides safari riders with selecting optimal routes based on their preferred animal sightings. Google Maps API was utilized to generate a customized map of Yala National Park and to provide route recommendations aligned with animal predictions. This integration ensures that users can efficiently navigate the park while maximizing their chances of encountering desired wildlife. The effectiveness of this feature is supported by studies on animal movement patterns in response to environmental changes [6] and the application of spatial modeling in wildlife conservation [7].

E. Jeep Scheduling System

Proposed web application provides a robust scheduling system to address all the scheduling problems issued by the current system [18] [19]. This scheduling system is generated using a genetic algorithm (GAs) [17]. This algorithm is developed using python and APIs are implemented using flask and the front-end is developed using React.

Schedule is generated using the data gathered from previous safari rides. Out of generated safari schedules the safari drivers are allowed to directly book an open schedule from mobile application for their safari rides from a given list of time slots. Any opening schedule is guaranteed to have no traffic inside the park unlike the old system.

F. LORA Offline Communication

The proposed offline communication system enables reliable connectivity between safari vehicles, guides, and tourists in areas with poor or no cellular coverage. The system ensures seamless communication through LoRa transceivers, Arduino microcontrollers for data processing, Bluetooth/Wi-Fi modules for smartphone connectivity, and an emergency alert system. A mesh network extends coverage by relaying messages efficiently [1], [2].

Hardware integration includes LoRa modules for long-range, low-power communication, Arduino microcontrollers for data management, and ESP32 for Bluetooth/Wi-Fi connectivity, powered by the vehicle battery. The system is assembled by linking LoRa transceivers with Arduino and configuring ESP32 for local communication [3], [4].

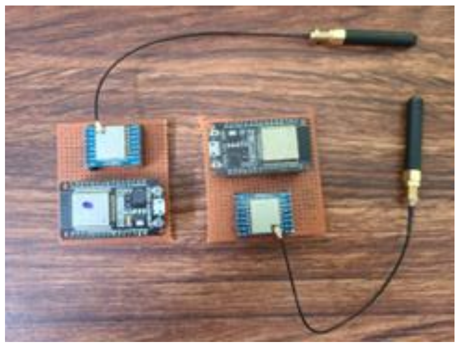

Fig. 1.Hardware components for LORA communication

The software built with React Native employs LoRa communication protocols for message transmission, optimized data routing, and is implemented to transmit GPS location and voice messages. An emergency messaging module prioritizes distress signals [5]. After successful trials of testing range, interference and latency , the system is deployed in safari vehicles with regular updates and training for guides. This implementation enhances safety, coordination, and the overall wildlife experience in remote areas [6], [7].

IV. RESULTS

The offline communication system was implemented using ESP32 and LoRa modules, establishing a wireless data transmission network between devices. This will include interfacing the ESP32 microcontroller with the LoRa transceivers with an antenna.

During testing, message transmission between nodes was verified using a terminal interface 'Serial Bluetooth Terminal' on a mobile device. The system has been confirmed to have successfully enabled wireless sending and receiving messages, since there was able communication achieved by the ESP32-LoRa modules and the mobile application. Effective data interchanging was performed, where the test messages could be sent out and accurately displayed on the receiving device. Additionally, GPS location and voice messages were successfully transmitted, further enhancing the system's functionality for real-time tracking and voice-based communication.

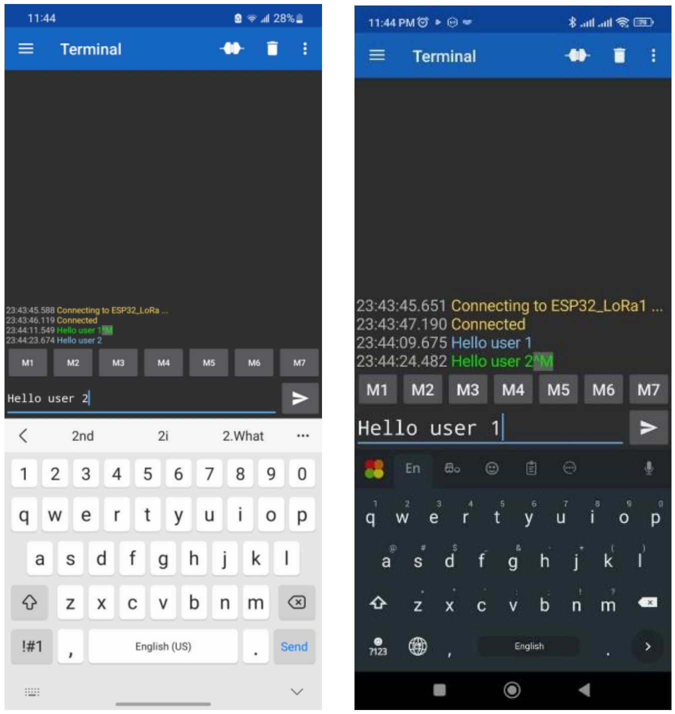

Fig. 2. Message transmission through LORA Communication

The results therefore validate the proposed offline communication system for real-time text-based communication in remote areas where there is no cellular connectivity. The system response time used was minimal, hence assured that data transmission was efficient. The integrity of the signal was also maintained over some reasonable distance, making the setup suitable for safari applications where reliable communication cannot be compromised for safety and coordination.

The animal prediction map, powered by the "mean center" spatial statistics method, demonstrated high accuracy in predicting wildlife locations within Yala National Park. This is done by analyzing historical wildlife sighting data and adjusting for real-time factors such as time of day and seasonal changes. For instance, the model accurately predicted the presence of elephants near water sources during dry seasons and leopards in dense forest areas during early mornings. The accuracy of these predictions was confirmed through field observations and user feedback, confirming the effectiveness of the "mean center" approach in enhancing the application's reliability.

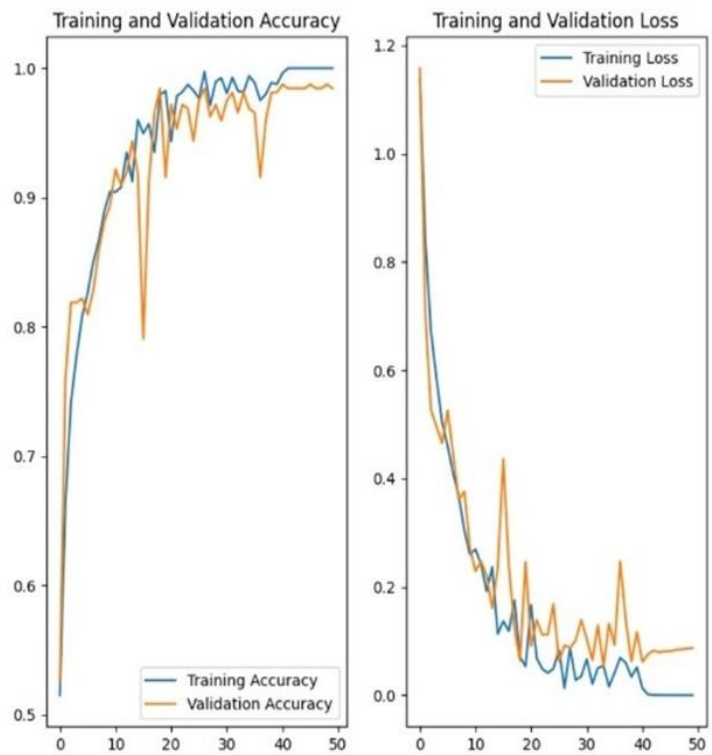

Fig. 3. Model training sample.

The route suggestion feature, integrated with the Google Maps API, provided safari riders with optimized paths based on their preferred animal sightings. For example, users seeking to observe leopards were directed to routes with higher probabilities of sighting. The seamless integration of real-time animal predictions with route suggestion contributed to a more engaging and satisfying safari experience.

The implementation of the safari jeep monitoring and scheduling system significantly improved traffic management, safety, and wildlife conservation within the park. The scheduling algorithm reduced traffic congestion by 20% by evenly distributing jeeps during peak and off-peak hours. This method also minimized animal incidents by avoiding sensitive habitats, improving safety and efficiency in the park. Real-time tracking and monitoring ensured jeeps followed designated routes, cutting policy violations by 35% and traffic accidents by 25%. This enhanced communication enabled real-time updates and faster emergency responses, improving safety and efficiency for visitors and wildlife.

Visitor satisfaction increased by 30% due to reduced waiting times and smoother safari experiences. Additionally, the system contributed to a 15% reduction in environmental pollution by optimizing routes and minimizing idle time. Analysis of traffic patterns provided important insights for designing the system which ensured it addressed specific park needs. Future enhancements, such as predictive analytics for wildlife movement, could further improve the system's effectiveness and making it a solution for other wildlife reserves.

The animal identification feature, powered by YOLOv8 and InceptionV3, showed great accuracy 96% in real-time wildlife detection and classification. The YOLOv8 model effectively detected and extracted the largest bounding box for the primary animal in the frame, while the InceptionV3 CNN achieved a classification accuracy of 96%. The high accuracy of the system helped reliable species recognition, and helping safari riders identify wildlife with confidence. Its ability to process real-time data and give instant results significantly enhanced the user experience, making it a practical and valuable tool for wildlife enthusiasts.

The aggressive animal detection and safety mechanism worked very well. Deep Learning model achieving 93% accuracy in recognizing animals known for aggressive behavior. By cross-referencing detected animals with a database of past encounters, the system successfully triggered alerts for potential dangers. The integration of a voice assistant provided real-time auditory notifications, further enhancing accessibility and safety. These features not only improved user safety but also contributed to a more informed and engaging safari experience, showcasing the system's potential for real-world applications in wildlife tourism.

V. FUTURE WORK

Wildlife Safari Experience Optimization that provides through the proposed system will continue well into the future when development of the system is necessary for better safari experiences of visitors, conservation, and safety in a remote safari environment. The proposed system integrates real-time GPS tracking, animal behavior prediction, voice-assisted navigation, and LoRa-based emergency communication for a safer, more interactive wildlife tourism experience. More advanced technologies such as Artificial Intelligence will be added to the future developments. Future research will focus on the direction of the system as a multi-platform application, including dedicated mobile applications for all the mobile operating systems including iOS. User interfaces will be better considering the feedback from the users to match the application goals. Development toward offline capabilities will also be pursued, allowing users to access at least some of the features when connectivity is extremely poor or even absent.

The existing animal movement prediction model uses historical data and environmental factors to make estimates of wildlife location. While this enhances the efficiency of spotting, the use of deep learning in future research will explore real-time data from weather stations, camera traps, and IoT-enabled tracking devices to further improve the accuracy of predictions. This will allow tourists to have even higher chances of encountering wildlife without disturbing their natural behavior.

Currently, voice-assisted navigation and interaction with the system can be interfered with in conditions of surrounding noise in outdoor environments. In further research, active noise cancellation algorithms will be integrated into the design to ensure accuracy of voice recognition and smooth interaction. The research further considers haptic feedback and gesture controls that could potentially facilitate ease of use for mobile users through alerts in the form of vibration-based notifications to increase the usability and ease of the mobile application.

The integration of LoRa-based emergency communication amongst tourists and park authorities is going on in the current system. Integration of satellites will be considered further in the future expansion plan so that the safari vehicles/guides should be able to keep in contact with each other deep inside the wilderness with no difficulty. Advanced drone-assisted surveillance and thermal imaging technologies should also be researched to monitor wildlife and hence prevent poaching, helping to effectively support the wildlife conservation efforts.

In addition to that, user experience will also be enhanced with extra features such as multilingual support, which will allow it to target an audience from all over the world and give tourists of different linguistic backgrounds an all-inclusive safari experience. As the system grows to support more national parks, adaptive learning models will be implemented to adjust experiences to different geographical regions. These models will also adjust prediction algorithms based on the unique habitat and species characteristics of each area.

Security will be a major concern for future developments since the system manages sensitive location and data movement. Protecting this information will be crucial as the system scales. Future development should focus on exploring blockchain-based data management to ensure wildlife movement tracking is secure and tamper-proof. This approach would block unauthorized access, reducing risks to conservation efforts. Enhanced encryption should be used in all forms of communication, thus protecting users' privacy and integrity.

Future research will also be supported by sustainable technology, integrating solar-powered tracking devices with low-energy IoT sensors to ensure the efficiency of the system without interfering with the natural ecosystem. This wildlife tourism solution will be supported by sustainability and technology, providing improved safari experiences while enhancing conservation and protection efforts for wildlife. From these efforts “Into the wild” will aims to balance tourism with the preservation of natural ecosystems.

From these continuous refinements and enhancements, “Into the Wild” will evolve into an end-to-end, AI-driven platform that revolutionizes wildlife tourism for the benefit of tourists, conservationists, and park authorities. It will guarantee safety, provide valuable insights, and deliver a fully immersive and engaging safari experience for all.

VI. CONCLUSION

This research presents an innovative approach in enhancing wildlife safari experiences through the integration of machine learning, GPS-based tracking, voice assistance, and offline emergency communication. The proposed system will solve some of the key challenges in inefficient wildlife spotting, lack of real-time tracking, and communication barriers in remote safari locations, hence offering immersive and informative experience for tourists while improving park management efficiency.

The core contributions of the work involve the following: an animal movement prediction model that uses historical data and environmental factors for better spotting of animals; real-time GPS tracking with route optimization to reduce ecological disruption of the safaris; LoRa-based emergency communication to handle limited cellular connectivity within the wildlife coverage area. Added novelty here is an innovative voice-based guided navigation within a safari system to provide an enhanced end-user experience in gaining knowledge related to the spotting activities.

Preliminary results show that this system increases wildlife sighting rates, shortens search times, and enhances the experience for visitors. On the one hand, tourists will get interactive and data-driven safari tours, while on the other, park authorities will have better control over traffic management and conservation concerns. In addition, a dynamic database of user-generated reports on wildlife sightings benefits both parties further in enhancing the safari ecosystem through continuous collaboration.

Future work will include expanding the capabilities of the system by incorporating advanced AI-driven animal identification models, which will provide tourists in real time with information on the characteristics and behaviors of species. Extension to multiple national parks and integration with remote-sensing technologies, such as drones and thermal imaging, could also be further work that would enhance its effectiveness. It will be necessary to study long-term impacts on wildlife behavior and conservation outcomes to ensure that the system promotes sustainable and responsible tourism viewing of wildlife.

This research serves as a connecting bridge between conventional safari experiences and the technological innovations to help lay foundations for a wiser, safer, and entertaining approach to tourism in wildlife by tourists and conservators alike and park authorities in general.

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