IoT-Enhanced Smart Surveillance System for Wildlife Collision Prevention on Sri Lankan Roads

Amerasinghe N.D.K[1], Udara I.W.A.S.[2], Somabandu B.P.S.[3], Jayakody J.A.B.U.[4], Nelum Amarasena[5], Rivoni De Zoysa[6]
Faculty of Computing, Sri Lanka Institute of Information Technology
New Kandy Rd, Malabe, Sri Lanka
WildLife Department Baththaramulla, SriLanka
Wildlife department Minneriya, Sri Lanka

Abstract:- This research paper presents a mobile application-based solution for real-time road safety aimed at mitigating animal-vehicle conflicts in Sri Lanka. The proposed system is developed in response to the increasing incidents of animal-vehicle collisions, which pose significant risks to both human safety and wildlife conservation efforts. By combining knowledge-based case studies and crowd-sourcing techniques, the application aims to identify animal habitats and behaviors based on user location, enabling drivers to take proactive measures to prevent such accidents. Image processing is used to identify objects using YOLOv7 technology. Ultrasonic sensors, a microcontroller, the Doppler Effect, and relative velocity calculations are used to segment the signal-to-noise ratio and alert the driver of any nearby animals. The research also provides guidelines for implementing methods to reduce animal-vehicle collisions and raises awareness among the public regarding the importance of road safety in wildlife-rich areas. Upon detection of the animal, the system emits an anti-frequency range tailored to specific species, effectively deterring them from approaching the vehicle. Through the mobile application, users can access real-time alerts, receive feedback from others, and contribute to a collective effort in ensuring safer roads for both humans and animals.

Keywords:- *AVC (Animal Vehicle Collision), Animal Behavior and Habitat, Crowdsourcing, YOLOV7, Doppler Effect, Anti-Frequency*.

I. INTRODUCTION

Animal-vehicle collisions (AVCs) are a significant threat to biodiversity, human safety, and economic costs in Sri Lanka [1]. These collisions occur due to the close interaction between human and wildlife habitats, resulting in numerous accidents and environmental impacts. In Sri Lanka, an estimated 26,489 motor vehicle and animal accidents occur annually, causing significant human deaths, injuries, property damage, and other costs [2]. The lack of public awareness and negligence towards AVCs exacerbates the problem, leading to a lack of effective mitigation measures. Road networks often fragment animal habitats and home ranges, leading to a reduction in animal population size due to behavioral changes.

The Sri Lankan government and conservation organizations have implemented measures to reduce animal collisions, such as building wildlife crossings and promoting road safety awareness. Drivers must also be aware of the potential for AVCs and take steps to reduce the risk, such as slowing down and being alert for wildlife on the road.

The primary focus will be on conducting a knowledge-based case study to determine the habitat and behavior of animals in various locations [1]. This study will involve gathering and retrieving data to inform passengers, utilizing crowd-sourcing technologies to obtain additional details and insights from people. Additionally, an RSS feed will be used to obtain news and weather information for specific areas, enabling the notification of users in different locations when necessary.

The second aspect of the study aims to capture animals from moving vehicles, identifying their behaviors, and conveying information to users. It will focus on clear, high-quality footage of different animal types, enabling identification of direction and distance. Computer vision and image processing techniques will be employed to overcome human observation limitations and improve animal detection.

The third aspect, Unseen identification is highly effective in dark environments [19][20], as a signal is transmitted to the environment and processed to identify animals within a specified distance. Research has focused on frequency, frequency emission, and rollback frequency recovery after being hit by animals. Key factors include vehicle vibration, Doppler effect, moving object laws, and time.

The study proposes improved solutions for animal-vehicle collision mitigation, including guidelines for implementing techniques and public education. It involves projecting anti-frequency waves onto animals and providing instructions for responding in encountered scenarios. User feedback and experience are crucial, aiming to prevent conflicts and minimize tragic incidents [17].

II. LITERATURE REVIEW

Sri Lankan government and conservation organizations have implemented measures to reduce conflicts between humans and animals. These include building wildlife crossings and raising road safety awareness. Drivers should be aware of potential collisions and take steps to reduce risks, such as slowing down and being alert for wildlife. Solutions cover various parameters to prevent human-animal conflict.

As first we are having A knowledge-based case study explores identifying animal habitats and behavior using crowd-sourcing technologies. The study discusses data collection and retrieval methods for driver notification, utilizing crowd-sourcing technologies to identify dispersion factors and behavior. Data will be collected anonymously from the stakeholders as well as from targeted audience (Sri Lankan government agencies, NGOs, local communities, drivers and commuters, researchers and academics) whenever an incident is found or through past history and research. The varying factors like climate changes, news information that may help for user to be precautious will be notified through OpenWeatherMap API based the GPS locations and News API with RSS feeds. The gathered data will be analyzed and visualized in a statistical manner to ensure the application of technology to the proposed case study to alert the user in necessary circumstances.

Geofence a specific area by drawing a virtual fence on a map and using geotargeting to send notifications to people meeting specific criteria and within a defined radius.

As the second point, we developed a motionless or moving animal identification concept to capture and identify its behavior in a moving vehicle. The concept also focuses on conveying the captured message to the user and driver, ensuring effective communication. Human eyes can become tired, distracted, or exhausted, limiting effectiveness and accuracy in animal detection. Computer vision can help reduce these limitations by allowing 24-hour rest for image processing.

The third point emphasizes the effectiveness of unseen identifications in low-light or dark environments. This innovative approach uses ultrasonic waves to transmit a specific distance, followed by processing and analyzing variations in frequencies to accurately calculate the animal's distance. The calculation considers the Doppler effect and moving object equations, ensuring timely notification of distance and animal identification. This system ensures essential information is relayed efficiently.

Enhanced alerting systems have been investigated to improve driver awareness and response to animal presence on the road. Studies have shown the effectiveness of different alerting mechanisms in reducing AVCs. Visual alert systems, audible alerts and vibrations can increase driver anticipation and response to animal presence. Comprehensive guidelines for unexpected animal interference are crucial in educating drivers on how to respond to unpredictable behavior [16].

III. METHODOLOGY

As illustrated in Fig. 1, the system uses geofencing, YOLOv7, and ultrasonic microcontroller technologies to detect potential collisions between stakeholders, researchers, and drivers. The mobile application collects and processes data in four main sections: geofencing using knowledge base case studies and crowdsourcing; seen identification; unseen identification; and the fourth and final section, generating timely and relevant notifications and alerts to notify drivers on how to avoid collisions based on the identified animal.

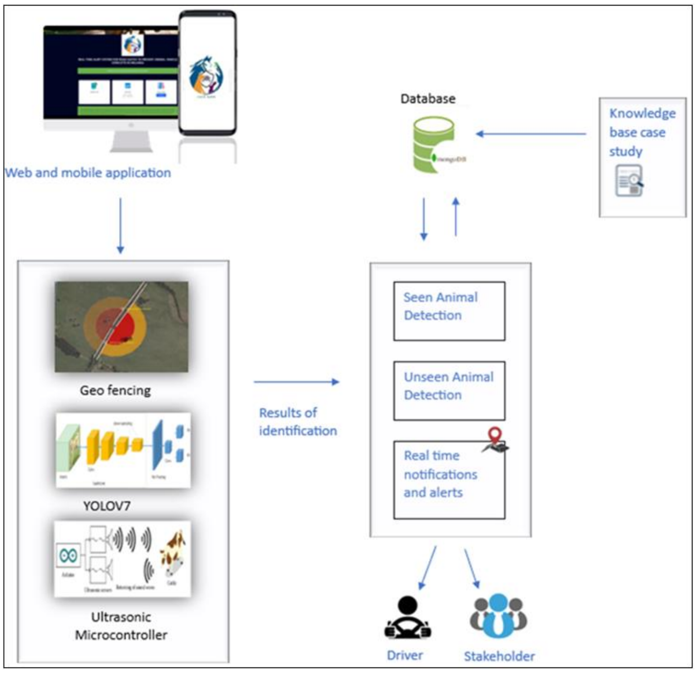

Fig 1 Overall System Diagram of the Proposed Solution

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A. Knowledge base case Study on Animal Habitat / Behavior and Application of Geo Fencing

➢ *Study Area of the Knowledge-based Case Study*

The Central and North Central Provinces of Sri Lanka have experienced significant animal-vehicle collisions since 2011 [1]. Key protected areas include Kaudulla (69 km2) and Minneriya (88.894 km2) National Park as depicted in Fig 2. The region's climate varies with 650mm annual rainfall occurring during wet seasons [4], and its habitat is dominated by trees, supporting a diverse wildlife population including 24 mammals, 170 birds, 8 reptiles, and 2 amphibians [3].

The study reveals a rise in AVCs in the region since 2011, likely due to increased road traffic and human settlements in wildlife areas. These vehicles can cause severe harm to animals and humans, resulting in death or serious injury.

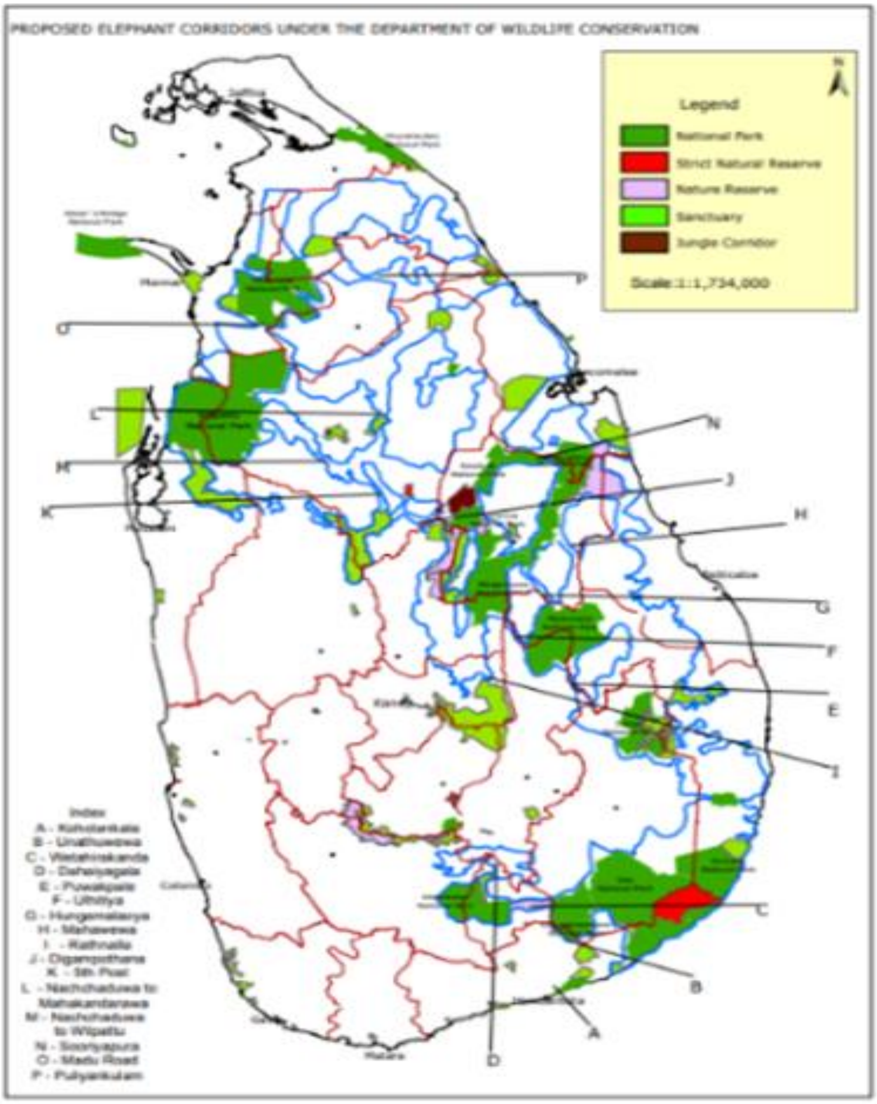

Fig 2 Identification and Classification of Wildlife Protected Areas in Srilanka

A study in Sri Lanka reveals high vehicle speeds, small-bodied animals, and nighttime driving are major factors contributing to animal-vehicle collisions (AVCs). AVCs result in 161 accidents annually, killing 40 species of animals.

Table 1 Causes of Elephant Deaths from 2010 to 2023.05.17

Causes of Elephant Deaths from 2010 to 2023.05.17		
Year	**Train Accidents**	**Road Accidents**
2010		-
2011		-
2012	9	-
2013	7	-
2014	10	-
2015	12	-

2016	12	-
2017	7	-
2018	16	-
2019	8	5
2020	3	3
2021	6	1
2022	14	3
2023.05.17	4	1
Total	108	13

The study utilized road surveys, driver surveys, and interviews with wildlife experts to identify drivers' main causes of AVCs. They believed high vehicle speeds were the main cause, with small-bodied animals more likely to be hit. Nighttime visibility made it difficult for drivers to identify animals, potentially causing accidents. Also, it highlights the importance of understanding the causes and factors of AVCs to develop strategies for wildlife conservation and road safety [1]. Measures to reduce AVCs in Sri Lanka include reducing vehicle speeds, raising driver awareness, installing wildlife crossing signs, and educating the public about the importance of wildlife conservation.

➢ The proposed smart system can identify animal behavior and interaction within roads. The system uses a knowledge-based case study methodology, which involves the following steps:

- Identify the research problem and objectives. The goal is to identify animal habitat and behavior according to different locations for future predictions.
- Gather anonymous data through crowd-sourcing platforms, by collecting information from stakeholders whenever an incident is reported, or through past history and research.
- Analyze the gathered data in a statistical manner to identify the dispersion factors of animal habitat, behavior, and varying factors like climate changes and news information.

The proposed system uses a knowledge-based case study methodology to analyze animal behavior and interaction on roads. By identifying potential risks and taking precautions, drivers can be more aware of potential dangers and take necessary precautions. The results can help drivers be more cautious while driving.

➢ *Methodology for Application of Geofencing and Geotargeting:*

Data from various sources is collected to identify animal habitats and behaviors. This data creates a geofence, allowing users to receive notifications based on targeting criteria within a defined radius.

- *The Methodology for Animal Habitat and Behavior Identification can be Summarized as follows:*

✓ Data is collected from a variety of sources.
✓ A geofence is created around a specific area.
✓ Notifications or filters are delivered to users who meet specific targeting criteria within the defined radius.
✓ Users are notified with relevant and proper notifications using the processed information.

Data collection is time-consuming and labor-intensive, but crucial for accurate results. Geofence can be created using technologies like GPS, RFID, Wi-Fi, or cellular data. Customized notifications include relevant information, such as animal type, sighting time, and location.

➢ *Process Information of News and Weather*

The data is analyzed to identify factors affecting animal habitats and behaviors, enabling predictions about future movements. The methodology uses the OpenWeatherMap API and News API to alert users of climate change and news events affecting animal behavior. Statistical methods are used to identify trends and patterns.

B. Seen Identification using Camera trap with YOLOv7 Algorithm.

The smart system detects animals using devices, image processing, YOLOv7, and human vision [8]. It uses relative velocity to identify movements. The camera trap setup is designed based on angle and distance, and the system uses Yolov7 algorithm and image processing to detect animals. The captured output message is sent to the user via an alert system.

➢ *Data Collection*

A study in the Habarana area identified elephants and deer as the most needed animal classes due to accidents. A diverse set of images was collected, covering angles, lighting conditions, backgrounds, and object poses, to train a robust model. For data collection purposes, we used a 1000 image set to train.

Images were categorized into training (80%-90%), validation (20-30%), and testing (10-20%) sets for model training, validation, and final evaluation. Training sets trained the model, validation monitored performance, and testing set evaluated.

➢ *Training the Detection Models*

To train YOLOv7 detection models for recognizing animals in images or videos, a series of stages are involved. Using the robowflow, bounding boxes and class labels were added to the obtained dataset. To guarantee a fair assessment, the dataset is carefully selected and segregated into training, validation, and test sets. The YOLOv7 architecture is set up, including class sizes and input image size. The model is initialized using pre-trained weights based on Darknet53, and data preparation techniques are used to expand the dataset [1]. The loss function is optimized using gradient descent methods, and parameters are updated over 100 training epochs.

Performance evaluations are conducted on validation and test sets, measuring mean average precision (mAP) [9]. The YOLOv7 model is now ready for deployment and inference in practical applications.

- *Use of Measure of Appropriate Angle and Distance from the Vehicle.*

The inverse perspective transformation method converts two-dimensional images into three-dimensional space images with a perspective using camera parameters. Real-world coordinates are calculated to estimate the distance between the camera and detected vehicle pixels in the transformed three-dimensional space.

- *Design the camera setup and convey the captured output message to user through the camera setup.*

The camera setup, the CPU converts the video into frames, pre-processes images, and applies an animal detection algorithm. Edge detection technique obtains animal outline, turning images into grayscale [10]. YOLOV7 object recognition algorithm compares data with pre-processed animal photos, finds animals, and measures distance before applying electromagnetic braking with varying strengths.

- *Evaluation Metrics*

The evaluation indices utilized in this study to measure the algorithm's performance were precision (P), recall (R), mean average precision (mAP), and F1 score [12].

Precision is the percentage of positive samples in samples with positive prediction outcomes. The following is the calculating formula:

$$Precision = \frac{TP}{TP + FP} \quad (1)$$

The percentage of the actual positive samples in the positive samples to the positive samples in the entire sample is how recall depicts the prediction outcome. The following is the calculating formula:

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

The model's precision in identifying negative samples is influenced by its ability to discriminate them. Higher precision indicates stronger identification, while recall measures its ability to locate positive samples. The F1 score, combining these two, indicates a model's reliability.

The average precision (AP), which is often determined independently for each category, is the average value of the greatest precision under various recall situations. The following is the calculating formula [12]:

$$AP = \frac{1}{11} \sum_{0.0.1.....1.0} P_{smooth}(i) \quad (3)$$

The average precision and mean AP values of each category are combined to get the mean average precision, or mAP. The following is the calculating formula [12]:

$$mAP = \frac{\sum_{j=1}^{S} AP(j)}{S} \quad (4)$$

Where S is the total number of categories and APs for all categories are added to form the denominator.

C. Unseen Identification using Ultrasonic Waves.

- *Data Gathering*

Firstly, A literature review explores the Doppler effect in animal identification, and a controlled environment test setup measures the effect caused by moving animals.

Equation 1: Doppler Effect Equation for Frequency Shift [22]. The Doppler effect equation for frequency shift can be expressed as:

$$f' = (v + vd) / (v + vs) * f \quad (5)$$

Where: f' is the observed frequency, f is the emitted frequency, v is the speed of sound, vd is the velocity of the detector (vehicle), vs is the velocity of the source (animal).

Equation 2: Doppler Effect Equation for Velocity Calculation. The Doppler effect equation can also be used to calculate the velocity of the moving animal. It can be expressed as:

$$v = (f - f') * v / (f + f') \quad (6)$$

Where: v is the velocity of the moving animal, f is the emitted frequency, f' is the observed frequency, v is the speed of sound.

Research investigated various signals for identifying animals in darkness, developed test setups to measure effectiveness, and conducted experiments to compare their effectiveness.

Research examined animal identification devices, identified key features, and conducted experiments to compare their performance in sending and receiving signals.

Experiments analyzed data to determine Doppler effect, effective signal, and best device for animal identification, leading to the development of an algorithm.

For the fourth objective, mathematical equations developed using Doppler effect and other theorems for moving objects, considering external variables like vehicle speed, vibration, wind, and time. Implemented in an algorithm, accurate outputs were provided to the driver, tested using the chosen device and signal.

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- *Statistical Analysis*

The second and third objectives analyzed data to identify the most effective signal and suitable device for animal identification, while the first objective developed an algorithm for animal identification.

- *Implementation*

The algorithm for animal identification tested accuracy using an Arduino-Uno and ultrasonic sensor, utilizing equations for the fourth objective and ensuring accurate outputs for the driver. This methodology combines literature review, experimental testing, data analysis, and algorithm development to create a mobile app for animal detection and identification in dark environments.

- *System Architecture*

The proposed smart system aims to detect animals near roads during dark hours and daylight hours using unseen identification methodology. Ultrasonic waves are emitted to a specific distance, and the difference between outgoing and incoming waves is used for calculations. A Passive Infrared (PIR) sensor is used to improve accuracy by identifying heat bodies in the vehicle's path. Principles related to moving objects, such as Doppler effect and relative velocity, are used to improve accuracy. External factors like vehicle vibration, speed, and wind are considered to provide the most accurate output. The system then compares the results to a database and uses proper methods to alert drivers with accurate information, such as distance, animal type, and precautions.

The ultrasonic waves emitter in a vehicle emits frequency waves while traveling, while the receiving device detects the incoming signal after being hit by an animal. An Arduino-Uno and ultrasonic sensors are used to capture these signals and calculate the distance to the animal based on differences in frequencies and other factors.

Ultrasonic sensors emit waves into the environment, bouncing back when hit by animals. The receiver calculates distance based on frequencies and other factors, determining the animal's proximity to the vehicle [18].

Fig 3 HC-SR04 Ultrasonic Sensor Module

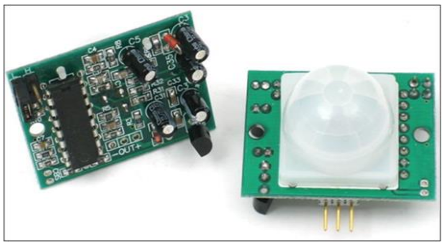
Fig 4: PIR Sensor

D. Solutions and Alternatives to Reduce AVC.

The proposed solution aims to intelligently detect and identify animals on the road using various methods, including visual fences, tracking, images, movements, and Doppler effect analysis. Upon detection, the system alerts users and provides guidelines based on case studies. Frequency waves are used as a deterrent, and alerts are delivered through audible, vibration, and visual notifications.

- *Data Collection*

Data on animal-vehicle collisions was collected through surveys, interviews, and observational studies, with primary data from drivers and stakeholders and secondary data from government reports and academic literature.

Surveys and stakeholder interviews were conducted to gather information on drivers' experiences with animal-vehicle collisions, awareness of alerting systems, and guidelines for reducing AVCs. Stakeholder interviews were conducted to obtain insights from wildlife experts, police officers, transportation authorities, and road safety professionals.

- *Development of Enhanced Alerting Systems*

The phase involved designing and developing alerting systems to enhance driver awareness and response to animal presence on the road. Various mechanisms, including audible, voice, vibration, and visual, were explored. Sensors and cameras were used to detect and trigger alerts. The design process involved prototyping, testing, and refinement to ensure effectiveness and user-friendliness.

- *Evaluation of Guidelines for Animal Interference*

Guidelines were created to guide drivers on handling unexpected animal interference on the road. They were evaluated through simulation exercises and driver feedback, assessing their clarity, practicality, and usefulness.

The research investigated high-intensity animal-vehicle accidents in Battaramulla, identifying common animals and identifying the species involved. The following animals were selected for further analysis based on their frequency of occurrence: elephants (94.4%), deer (83.3%), wild buffalos (27.8%), wild boars (22.2%), porcupines (22.2%), dogs (50%), and cats (38.9%).

After confirming the presence of these common animals, our research focused on collecting guidelines for drivers to follow when encountering them. These guidelines are intended to enhance road safety and mitigate the risk of collisions.

IV. RESULTS AND DISCUSSION

The data was analyzed using SPSS, with descriptive statistics for demographics. A Chi Square goodness of fit test was used to identify the primary respondents' taxon groups, AVCs, and their impact on roads. The study also examined drivers' perceptions of AVCs, their perception of road safety, and their awareness of necessary actions.

Spearman's rank correlation test was applied to determine the relationship between species' body mass and AVC risk, despite the small sample size and select species tested [4].

Over 1,700 animal-vehicle accidents have been documented in Sri Lanka since 2011, primarily on the Southern Motorway. Elephants, water buffalo, and deer are the most frequently involved animals. However, Sri Lanka has a larger diversity of animal species involved in vehicle-animal accidents, with collisions involving over 40 distinct species (Figure 4).

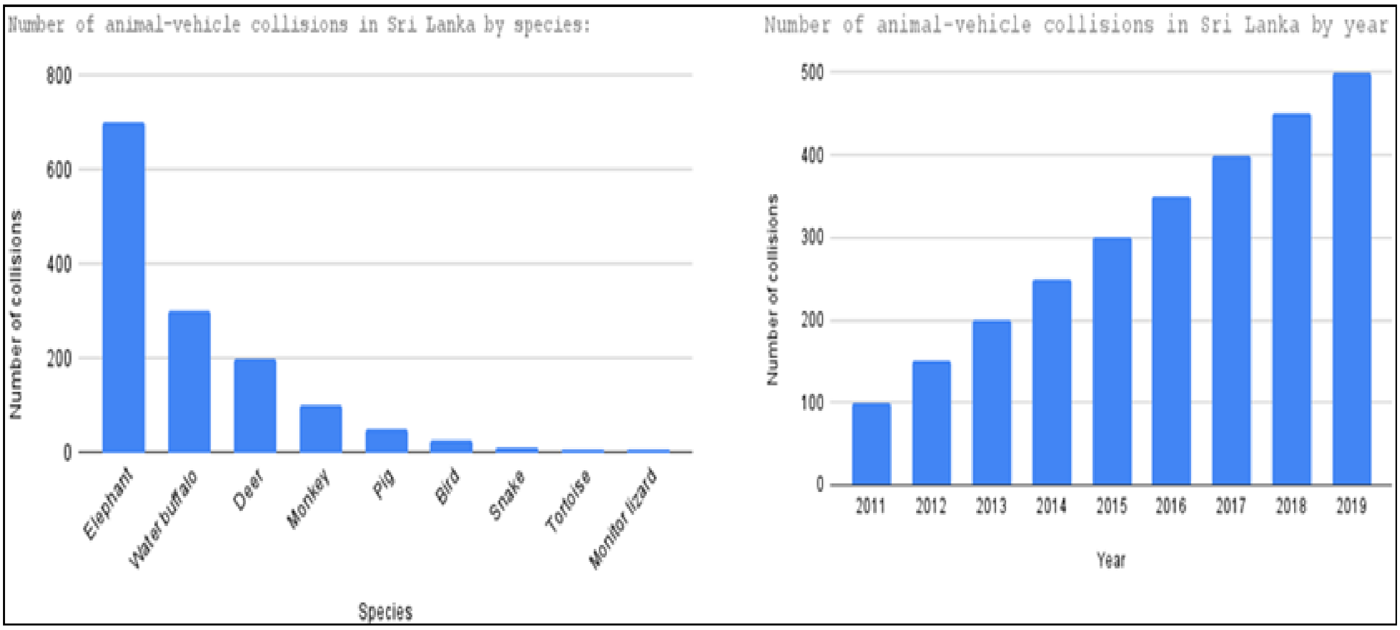

Fig 5: AVC Collision Statistics

Birds accounted for 58% of the total population, followed by mammals (24%), reptiles (11%), and amphibians (7%). Drivers felt mammals were most affected by AVCs (91.30%), followed by reptiles (3.40%), birds (9.50%), and amphibians (1.70%). Changes may occur at other times of the year, but the study was conducted during the wet season, assuming maximum species abundance.

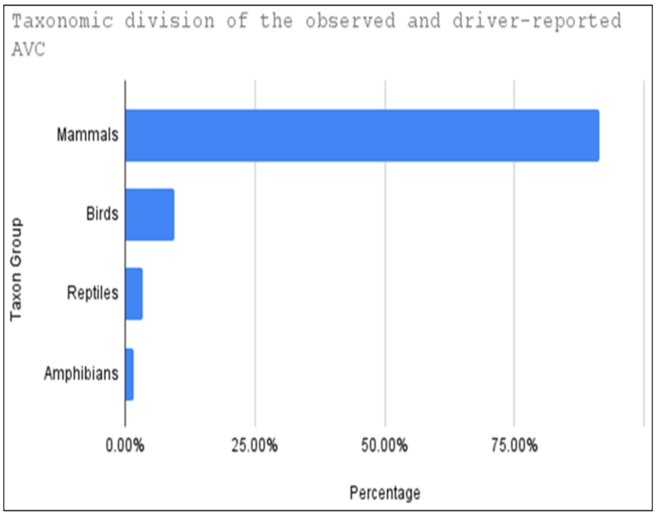

Fig 6: Taxonomic Division of the Observed AVC

The majority of the 100 drivers—85%—indicated that AVCs happened more frequently at night, while just 10% reported that they happened during the day. The remaining 5% reported that AVCs happened both during the day and at night (2 = 77.523, df = 2, p = 0.001).

AVCs caused significant anxiety among drivers, with 65% stating they were a big problem and 35% not. Common causes include animal behaviors, darkness, sluggish movement, adverse weather, and high vehicle speeds. The least likely causes were intentional collisions and poor roads.

Geo fencing in mobile applications can mitigate wildlife vehicle collisions by creating wildlife corridors, connecting different habitats and allowing animals to move safely. This allows drivers to be alerted of animals' presence, allowing them to slow down or take other precautions to avoid collisions.

Geo fencing can help mitigate wildlife vehicle collisions by creating warning systems using wildlife cameras, motion sensors, and other devices. These systems alert drivers of potential collisions when animals are detected, reducing the risk of accidents. A knowledge base case study will create a database of potential AVC locations and animal corridors, enabling geofences. An alert will be sent to a monitoring system when an animal enters or leaves a geofence, reducing animal-vehicle collisions by alerting drivers.

Geo fencing is a promising technology for mitigating WVCs. Geo fencing is a cost-effective method to warn drivers of wildlife presence, reducing collisions, injuries, and fatalities in wildlife-related areas.

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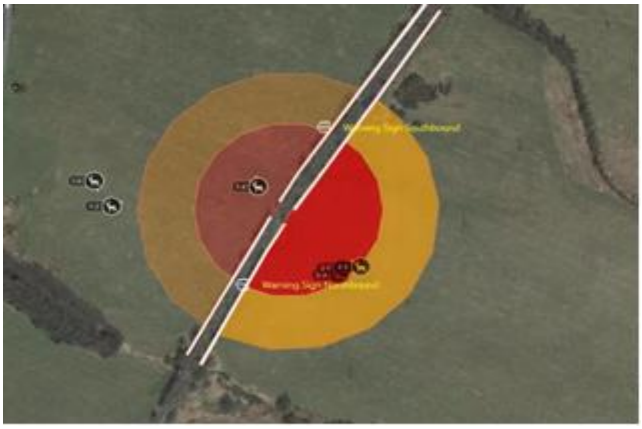

Fig 7: Geofencing Identification

The YOLOV7 algorithm-based Python was used for animal recognition, achieving 96.4% training. When the dataset comprises numerous classes, a single number is required to evaluate the model's performance. The mAP value was determined as a consequence. The mAP value is the mean average of the computed average precision and F1 [11].

Fig 7 shows precision curve with recall, while Fig 8 shows F1 curve with confidence, evaluating trained models.

The experimental findings are displayed in Figure 3.1, and the metrics were recalling rate, mAP@0.5, and mAP@0.5:0.964.

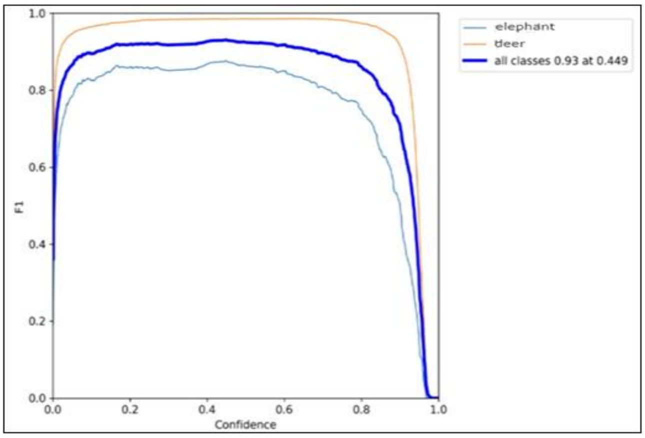

Fig 8: Precision Curve Diagram for Trained Data

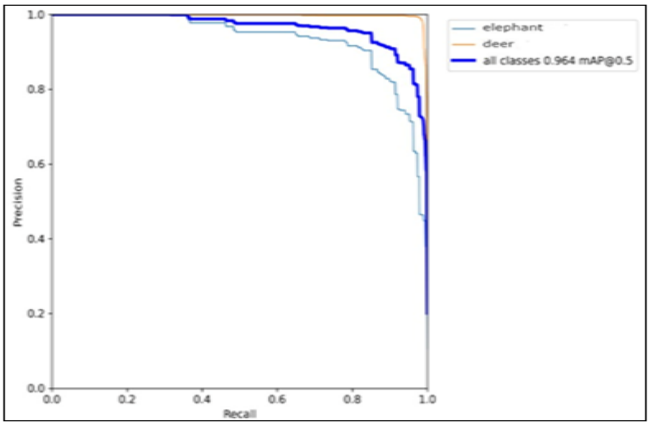

Fig 9: F1 Curve Diagram for Trained Data

For the YOLOV7, model was trained using 1000 image configurations, two classes, 100 steps per epoch, and a minimum detection confidence of 0.9. The supplied image dimensions were 1024 × 1024. Following training, images were inferred on the webcam for detection and the animals were properly recognized via the webcam.

The Doppler effect and ultrasonic sensors were used for unseen animal detection and identification in the dark. Experiments revealed the frequency shift of received signals was proportional to animal velocity. Ultrasonic signals effectively detect animals in the dark due to Doppler effect frequency differences. Arduino-Uno microcontrollers and ultrasonic sensors are chosen for accurate distance calculations and precise outputs. An algorithm with mathematical equations is developed, enhancing driver safety by accurately identifying animals in the dark.

The proposed methodology for animal detection and identification in darkness is confirmed through experimental and data analysis. The combination of Doppler effect, ultrasonic sensors, and the algorithm results in a reliable and accurate system alerting drivers to animals near the road. The Arduino-Uno microcontroller and ultrasonic sensors are suitable for implementing the system architecture.

The proposed system alerts drivers to potential animal hazards in low-light conditions, improving road safety. Future research should refine and optimize the system by expanding the database of animal characteristics and incorporating additional sensors or technologies.

This study investigated the effectiveness of a system to reduce animal-vehicle collisions by providing alerts to drivers upon animal detection using audible, visual, and vibration cues. The system also emitted anti-frequency waves. Advanced sensors and algorithms accurately identified animals near the roadway, providing timely warnings and capturing drivers' attention to potential animal hazards.[17]. Anti-frequency waves were used to deter animals from crossing roads, but their effectiveness varies depending on species and individual animals. Further research is needed to explore the specific frequencies that are most effective in deterring different animal species.

The results section presents research findings on alerting system effectiveness, driver behavior impact, anti-frequency wave projection deterrence potential, and user feedback insights.[17]

V. CONCLUSION AND FUTURE WORK

In Conclusion, this study proposes a mobile application in Sri Lanka to reduce animal-vehicle collisions. The application uses methods like knowledge-based case studies, geofencing, and geotargeting to identify areas where animals are likely to be present and notify drivers of potential hazards. The Sri Lankan application aims to improve road safety for humans and animals by using YOLOv7s for detecting wild animals in natural habitats. This is the first system to detect wild animals during dark hours and mitigate collisions. The application aims to accurately and timely identify animals, with future expansion. The study highlights findings, contributions, potential applications, and benefits, while providing research directions and recommendations for enhanced alerting systems. The study emphasizes the importance of enhanced alerting systems and guidelines in reducing animal-vehicle collisions and suggests policy interventions, technological advancements, and public awareness campaigns for future work in this area.

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