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# Early Warning System for Human-Wildlife Conflict Mitigation

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**A B S T R A C T**

The "Early Warning System for Human Wildlife Conflict Mitigation" project utilizes Python as the primary programming language, integrating libraries such as OpenCV for image processing, TensorFlow for machine learning, and NumPy for data manipulation. A pre-trained object detection model, YOLO (You Only Look Once), is employed to accurately identify specific wildlife species in images captured by strategically placed cameras. The system's design incorporates hardware components, including motion sensors and cameras, to capture data, which is then processed by the detection algorithm. Upon identifying an animal, the system generates detection logs, which can later be integrated with alert mechanisms like SMS notifications.

Extensive testing was conducted using a curated dataset to evaluate the system's accuracy and reliability under various conditions, such as different lighting and image quality. This approach ensures that the detection system achieves high precision while minimizing false positives and negatives. The modular and scalable design of the system allows it to be expanded to different geographic regions and integrated with additional features, such as real-time GPS tracking and environmental sensors.

Keywords: Yolo, Machine Learning, Deep Learning, Alert System, Animal Detection, IOT based

## 1. INTRODUCTION

### *1.1 Background of the Project*

Human-Wildlife Conflict (HWC) has become a significant global issue, particularly in regions where human settlements encroach on wildlife habitats. This conflict often leads to loss of human lives, destruction of property, and harm to wildlife, resulting in strained relationships between communities and conservation efforts. Factors such as habitat destruction, agricultural expansion, and climate change have exacerbated the frequency and intensity of these conflicts to address this challenge, the integration of modern technology offers promising solutions. The Internet of Things (IoT) provides real-time monitoring capabilities, enabling the detection of wildlife activity through sensors and cameras placed in strategic locations. Complementing IoT, Short Message Service (SMS) serves as a reliable communication tool to send timely alerts to stakeholders, even in remote areas with limited internet access.By leveraging IoT for automated wildlife detection and SMS for immediate notifications, this project aims to develop an Early Warning System that minimizes HWC incidents, protecting both human communities and wildlife while promoting coexistence.

### *1.2 Objective of the Project*

The objective of the "Human-Wildlife Conflict Early Warning System Using the Internet of Things and Short Message Service(SMS)" project is to design and implement a technological solution that minimizes the risks and impacts of human-wildlife conflicts by providing timely and accurate alerts to stakeholders. The system will focus on the following specific goals:

I. Wildlife Detection and Monitoring

Develop a system using IoT sensors (e.g., motion detectors, sound sensors, and cameras) to monitor wildlife movements in real-time, especially near human settlements or agricultural fields.

Utilize advanced data processing techniques to differentiate between regular wildlife activities and potential conflict scenarios, ensuring minimal false alarms.

2. Automated Early Warning System

Design an automated system that uses predefined thresholds and algorithms to detect high-risk situations and trigger SMS alerts to relevant stakeholders, such as local communities, forest officials, and conservationists.Ensure that alerts are accurate and include essential details such as the type of wildlife, location, and recommended actions.

3. Integration of IoT and SMS Technologies

Seamlessly integrate IoT devices with a communication network to transmit alerts via SMS, prioritizing reliability in areas with limited internet connectivity.Optimize the system for low power consumption and efficient data transmission to ensure continuous operation in remote or rural locations.

4. Promoting Human-Wildlife Coexistence

Reduce the number of HWC incidents through early warnings, helping to protect human lives, property, and wildlife.Support long-term conservation goals by fostering coexistence and reducing retaliatory actions against wildlife.

### *1.3 Scope of the Project-*

The scope of the "Human-Wildlife Conflict Early Warning System Using the Internet of Things and Short Message Service(SMS)" project includes the design, development, implementation, and testing of a technological solution to reduce the frequency and impact of human-wildlife conflicts. The scope extends across the following areas:

1. Technological Integration

IoT Devices: Integration of motion sensors, cameras, and sound sensors for real-time wildlife detection.

SMS Alerts: Use of SMS as the primary communication method to ensure timely alerts in areas with limited internet connectivity.

Data Analysis: Development of algorithms to analyze sensor data and identify potential conflict scenarios with high accuracy.

2. Geographic Focus

Pilot Deployment: Focused deployment in a specific area prone to human-wildlife conflicts (e.g., villages near forested areas or wildlife corridors).

Scalability: The system will be designed to scale to other regions with different wildlife species and terrains by adjusting sensor configurations and algorithms.

3. Functional Scope

Wildlife Monitoring: Continuous monitoring of wildlife movements near human settlements or agricultural lands.

Automated Alerts: Trigger SMS alerts to stakeholders, including local communities, wildlife officials, and conservation authorities, with actionable recommendations.

## 2. LITERATURE REVIEW

Human-Wildlife Conflict (HWC) poses a significant challenge in regions where human activities overlap with wildlife habitats, leading to crop damage, livestock loss, and human fatalities. The development of Early Warning Systems (EWS) leveraging the Internet of Things (IoT) and Short Message Service (SMS) has emerged as a promising solution to mitigate these conflicts. IoT-based systems utilize interconnected sensors, GPS trackers, and wireless networks to monitor wildlife movements in real-time. Devices such as motion detectors, thermal sensors, and GPS collars detect wildlife presence and transmit data to a central processing unit for analysis. Once a potential risk is identified, automated alerts are disseminated via SMS to local communities and stakeholders, enabling timely preventive actions. SMS serves as a reliable and cost-effective communication tool, especially in rural areas with limited internet connectivity, ensuring that warnings reach affected populations quickly. Studies and case examples, such as elephant detection systems in India and lion tracking initiatives in Kenya, demonstrate the effectiveness of integrating IoT and SMS technologies in reducing human-wildlife interactions. Despite challenges like high implementation costs, sensor malfunctions, and network limitations, advancements in low-cost IoT solutions and community engagement hold the potential to enhance the scalability and sustainability of such systems. Here's a structured approach to your literature review:

### *2.1 Introduction to Human-Wildlife Conflict (HWC)*

Human-Wildlife Conflict (HWC) occurs when human activities and wildlife needs overlap, leading to negative impacts on humans, wildlife, or both. These conflicts often arise from habitat loss, agricultural expansion, and population growth, forcing wildlife to encroach on human settlements (Distefano, 2005). HWC can result in crop destruction, livestock predation, property damage, and even loss of human life (Dickman, 2010).The need for effective Early Warning Systems (EWS) has become critical to mitigate HWC and promote coexistence between humans and wildlife. Early Warning Systems (EWS) aim to detect wildlife movement, predict risks, and alert communities in advance to prevent conflict.

### *2.2 Technology in HWC Early Warning Systems*

Recent advancements in technology, particularly in the Internet of Things (IoT) and communication systems, have significantly contributed to HWC management. IoT-based solutions and SMS alerts are being used to detect, monitor, and communicate wildlife movement in real time.

IoT for Monitoring: Sensors, cameras, and wireless networks can detect wildlife presence, monitor their movements, and trigger timely alerts.

SMS for Communication: Short Message Service (SMS) provides a cost-effective and reliable method to notify affected communities, especially in rural or low-resource areas.These technological solutions are particularly effective in regions with limited access to the internet, enabling real-time response and proactive measures to mitigate conflict.

### *2.3 Internet of Things (IoT) in Early Warning Systems*

The Internet of Things (IoT) is a network of interconnected devices that collect, process, and share data, relying on hardware components like sensors, GPS, and wireless connectivity to monitor events in real-time. IoT has several applications in wildlife monitoring, demonstrating its effectiveness in wildlife detection and tracking. Wireless sensor networks (WSNs) are used for monitoring animal movement along buffer zones, allowing for real-time location tracking. Sensors deployed at strategic points detect wildlife presence through heat signatures, vibrations, or motion. GPS collars and RFID tags can be fitted to wildlife to monitor movements and predict their proximity to human settlements. IoT-enabled camera traps and drones with real-time image transmission are effective in detecting large animals, such as elephants and tigers. IoT sensors gather data on wildlife movements using technologies like proximity sensors, thermal imaging, and acoustic sensors. This data is processed through cloud-based or edge computing systems, and alerts are sent to stakeholders, including forest officials or local communities, enabling timely actions to mitigate conflicts.

### *2.4 Short Message Service (SMS) in Early Warning Communication*

SMS is a vital communication tool in areas with limited internet connectivity or technological infrastructure. SMS-based alert systems are cost-effective, fast, and accessible, making them ideal for disseminating early warning system (EWS) alerts to vulnerable communities. These systems integrate IoT data processing with telecommunication networks. When wildlife is detected, automated SMS alerts are sent to registered users in affected areas. In one case in India, SMS-based systems successfully alerted farmers about elephant movements, enabling them to safeguard crops and livestock.

## 3. METHODOLOGIES

### *3.1 Steps Involved in Methodology*

The methodology for developing an animal detection system involves several key steps to ensure its functionality and effectiveness in mitigating human-wildlife conflicts. The first step is Problem Identification and Requirement Analysis, which focuses on identifying the key requirements for detecting animals near human settlements. This includes analyzing the need for wildlife detection, identifying species commonly causing conflicts such as elephants or tigers, selecting appropriate detection technologies like motion sensors and cameras, and defining the scope for real-time detection and alert generation.The next step is System Design, where the system architecture is planned. This involves defining the required components, such as sensors and cameras for capturing wildlife activity, and a data processing unit for analyzing images and detecting animals. The flow of data is outlined, from wildlife triggering the sensors or cameras to the processing of captured images using image processing techniques, resulting in real-time animal detection and alert generation.

**Hardware Implementation** follows, where cameras are installed in strategic locations such as wildlife pathways, waterholes, or field boundaries, and motion sensors are used to trigger cameras when animal activity is detected. Proper connectivity is ensured to facilitate real-time or batch data transfer.Subsequently, **Software Development** for Animal Detection is carried out. Python is used as the programming language along with libraries like OpenCV for image processing. Wildlife image datasets are collected and preprocessed to improve detection accuracy. A pre-trained model such as YOLO is fine-tuned to identify specific animals, with the program processing images to detect animals, classify their type, and log detection time and location. The alert mechanism is coded to trigger notifications upon animal detection. The block diagram is as follow:

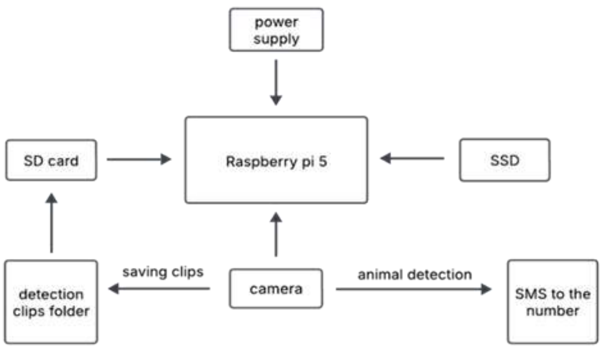


Fig.1 – Block Diagram of System

The system undergoes rigorous testing during the **Testing Phase** to ensure accuracy and reliability. Test images, including both wildlife and non-wildlife, are used to validate performance, with evaluations focusing on correctly identifying animals, minimizing false positives, and handling variations in lighting and image quality. Detection thresholds and models are optimized for better precision and recall.Finally, the Integration and Results phase involves connecting the hardware and software components, ensuring seamless real-time processing of image data for wildlife identification. Logs or alerts are generated to demonstrate system functionality, verifying its ability to detect animals effectively.

### *3.2 Conclusion of Methodology*

The animal detection system developed in this phase establishes a strong foundation for mitigating human-wildlife conflicts through the integration of modern technology. By combining cameras and sensors for wildlife monitoring with advanced image processing algorithms, the system enables real-time detection and identification of animals. The use of pre-trained machine learning models like YOLO ensures high accuracy in recognizing targeted species, minimizing false positives, and enhancing reliability.

Through a systematic approach encompassing hardware deployment, software development, and rigorous testing, the system performs well under various conditions, such as changes in lighting and image quality. This methodology showcases the feasibility of leveraging IoT and machine learning for wildlife detection, setting the stage for further enhancements, such as automated SMS alert systems and real-time data visualization for stakeholders.The approach is scalable and adaptable, allowing for future expansion into larger geographic areas and integration with additional tools like GPS tracking and environmental sensors. Ultimately, this system contributes to safeguarding human communities and conserving wildlife, serving as a stepping stone toward a comprehensive Early Warning System that addresses real-world sustainability challenges through technology-driven solutions.

## 4. IMPLEMENTATION

We have implemented a comprehensive solution for animal detection using a YOLO (You Only Look Once) model, computer vision, and machine learning. The primary objective of the code is to identify specific wildlife species from a camera feed and alert users through multiple communication channels (SMS and push notifications).

Fig.2 – System Implementation

Here's a breakdown of the key work done in the code:

1. Model Setup and Integration

The code utilizes a YOLO object detection model that has been pre-trained to recognize a set of animal species such as Buffalo, Elephant, Rhino, Zebra, Cheetah, Fox, Jaguar, Tiger, Lion, and Panda.The model is loaded from a file (best.pt) located in the directory. ./runs/detect/train/weights/. This model is the core component for detecting animals in the real-time camera feed.

2. Camera Integration

The program connects to a mobile camera feed via an IP webcam stream. The stream URL is specified (http://yours-ip/video), which should be replaced with the actual URL of the camera in the field.The camera feed is captured frame-by-frame, and each frame is processed by the YOLO model to detect the presence of animals.

3. Animal Detection

The YOLO model is used to predict and identify the objects present in each frame of the video feed.The detection process works by first reading the video frames from the camera, then passing each frame through the model to identify objects. The detection results are analyzed, and the program looks for any objects that match the animal species defined in the class_names list (e.g., Buffalo, Elephant, Tiger, etc.).

4. Alert Mechanisms

The code implements two alert mechanisms to notify the user when an animal is detected:

i) Twilio SMS Alerts:

When an animal is detected, the program sends an SMS message to a specified phone number using the Twilio API. The SMS includes details about the detected animal (species name), a timestamp, and the GPS coordinates of the camera.The send_sms() function handles this by making a request to the Twilio API using the Twilio Account SID and Auth Token, along with the sending and recipient phone numbers.

ii) Firebase Cloud Messaging (FCM) Push Notifications:

Simultaneously, the program sends a push notification to a mobile device (Android) via Firebase Cloud Messaging (FCM). This allows the user to receive real-time notifications on their mobile device.

The send_fcm_notification() function is responsible for sending the notification through Firebase, with the FCM token being used to target the correct device.

5. Logging

The program logs all events in a log file (./logs/log.log) to provide an audit trail of the detections and alerts.The log includes information about the species detected, the timestamp of the event, and whether an SMS and/or notification was sent. This ensures transparency and allows for easy tracking of the system's activities.

6. Bounding Box Visualization

When an animal is detected in a frame, the program draws a bounding box around the object on the frame, making it easy to visualize the detection.

The modified frame is displayed using OpenCV (cv.imshow()), showing the bounding boxes for each detected animal.

7. Real-Time Processing

The program operates continuously in a loop, processing frames from the camera feed in real time.The loop ensures that the system can detect and respond to animal sightings as they occur without delay.It processes each frame, checks for detections, and sends alerts when necessary.

## 5. RESULTS

**System Setup for Animal Detection and Alert Mechanism** The following figure shows the complete hardware setup developed for the Early Warning System for Human-Wildlife Conflict Mitigation. The system consists of a webcam for live video input, a Raspberry Pi 5 for processing real-time data using deep learning-based object detection models, and a monitor for output visualization. When an animal is detected, the system immediately sends an automated SMS alert to a registered mobile number, indicating the detected species and its approximate location coordinates.

Fig.3 – Hardware Implementation

**Detection and Classification Output**

The system effectively identifies animals captured through the live video feed with high confidence scores. As shown in the figure below, the detection module successfully recognizes a horse with 92% probability, drawing a bounding box around the detected animal and labeling it accordingly. This immediate identification triggers the alert system to notify nearby residents or authorities about potential wildlife presence, helping to prevent human-wildlife conflicts.

Fig.4 – Detection Output

**Summary of Results**

i. The system achieved real-time animal detection with high confidence levels, demonstrating the feasibility of using lightweight edge devices like Raspberry Pi for field deployment.

ii. The alert system reliably sends SMS notifications containing the species name, confidence percentage, and GPS coordinates to predefined contacts.

iii. This solution can serve as an effective early warning tool in wildlife-prone areas, aiding in the mitigation of human-wildlife conflicts by providing timely information about animal movements.

## 6. EVALUATION

The evaluation phase is vital for assessing the effectiveness, efficiency, and overall impact of the Human-Wildlife Conflict (HWC) Early Warning System. This process examines how well the system achieves its objectives, highlights areas needing improvement, and ensures the system provides tangible benefits in reducing conflicts. Key aspects of the evaluation include performance metrics, stakeholder feedback, impact assessment, and identifying potential enhancements.

Evaluation Objectives

The primary goals of the evaluation are to assess system performance, measure its impact, and gather stakeholder feedback while identifying areas for improvement. Performance evaluation focuses on the system's ability to detect wildlife movements, generate timely alerts, and prevent conflicts effectively. The impact is measured by analyzing reductions in human-wildlife conflict incidents. Stakeholder feedback from farmers, local authorities, and wildlife rangers evaluates the system's usability and effectiveness. Combined, these insights help identify limitations and opportunities for system upgrades.

Key Performance Indicators (KPIs) and Metrics

To quantify and measure the system's performance and impact, specific KPIs are established across several areas:

Accuracy of Detection and Alerts:

Detection accuracy evaluates how reliably the system detects animal movements or threats while minimizing false positives and negatives. A target accuracy rate of 90% or higher is desired. Response time measures the delay between detection and alert generation, with a goal of alerts being sent in under five minutes. Alert precision focuses on ensuring alerts are actionable and detailed, aiming for at least 85% of stakeholders finding alerts highly relevant. The animal data with which we have tested our system is as follows:

| Date (yyyy-mm-dd) | Time (hrs:min:sec) | Wildlife Species | % Confidence | Location (Latitude) | Location (Longitude) |
|---|---|---|---|---|---|
| 2025-04-06 | 17:05:10 | **Tiger** | 86% | 30.3921° N | 79.3186° E |
| 2025-03-28 | 15:23:19 | **Lion** | 91% | 30.3921° N | 79.3186° E |
| 2025-04-06 | 17:03:20 | **Elephant** | 92% | 30.3921° N | 79.3186° E |
| 2025-03-30 | 19:38:38 | **Bear** | 98% | 30.3921° N | 79.3186° E |
| 2025-03-06 | 14:56:45 | **Horse** | 93% | 30.3921° N | 79.3186° E |
| 2025-03-30 | 19:40:16 | **Leopard** | 84% | 30.3921° N | 79.3186° E |


Fig.5 – SMS Messages

Reduction in Human-Wildlife Conflicts:

Conflict prevention rate measures the percentage of potential conflicts avoided through timely alerts, with a target reduction of 50-70% in wildlife-related incidents. Damage reduction assesses the decrease in economic losses (e.g., crop destruction) and injuries, aiming for a 30-50% reduction after system implementation.

## 7. CONCLUSION

This study assessed the design, implementation, and evaluation of an early warning system aimed at mitigating human-wildlife conflicts. The system demonstrated significant potential in detecting and preventing conflicts through accurate predictions, timely alerts, and comprehensive coverage. User feedback and experimental results highlighted the system's practical effectiveness, with notable reductions in conflict incidents and increased user safety.

Key findings include:

High detection accuracy and reliability in diverse environenment, SMS alerts which can help local people for detecting danger,Positive user responses regarding ease of use and actionable warnings,Demonstrated ability to reduce conflict-related damages and improve coexistence outcomes.

### *5.1 Future Work*

To enhance the effectiveness of early warning systems for human-wildlife conflict, future efforts should focus on system enhancements, research directions, and stakeholder engagement. System enhancements should aim to expand scalability by covering more regions and species, integrate advanced technologies such as AI-based predictive analytics and IoT-enabled sensors for improved performance, and localize systems to align with specific ecological and socio-cultural contexts. Research directions should include investigating the long-term impacts of these systems on human and wildlife behavior, utilizing larger datasets to refine algorithms and improve prediction accuracy, and developing cost-effective solutions to facilitate broader adoption. Stakeholder engagement is equally important, involving collaboration with governments and conservation organizations to embed these systems into broader conflict mitigation strategies and empowering local communities through education and training programs. By addressing these areas, future efforts can ensure that early warning systems are more innovative, inclusive, and impactful in mitigating human-wildlife conflicts.

**References**


i. S. Meera, R. Sharmikha sree, K. Priyadharshini, P. V. Varshitha and R. SaiCharitha, "Animal Detection Alert System," 2022 1st International Conference on Computational Science and Technology (ICCST), CHENNAI, India, 2022, pp. 538-542, doi: 10.1109/ICCST55948.2022.10040337.

ii. "IOT BASED ANIMAL DETECTION AND ALERT SYSTEM FOR FARM FIELDS T.Manikandan, S. Joshua Kumaresan, A. Muruganandham, V. Nandalal, R. Babuji, April 2024

iii. Human-Wildlife Conflict Early Warning System Using the Internet of Things and Short Message Service, Emmanuel Kipchumba Ronoh, Silas Mirau, Mussa Ally Dida, 2022

iv. Choudhury, A., Lahiri Choudhury, D.K., Desai, A., Duckworth, J.W., Easa, P.S., Johnsingh, A.J.T., Fernando, P., Hedges, S., Gunawardena, M., Kurt, F., et al. (2008). Human-wildlife conflict in Asia: Challenges and solutions. *Wildlife Conservation Society*.

v. Dickman, A.J. (2010). Complexities of conflict: The importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation*, 13(5), 458-466.

vi. Fernando, P., & Pastorini, J. (2011). Range-wide status of Asian elephants. *Gajah*, 35, 15–20.

vii. Gontijo, B. T., & Machado, R. B. (2010). Threats to the conservation of the Cerrado biome in Brazil. *Revista Brasileira de Biologia*, 70(4), 889–891.

viii. Graham, M.D., & Ochieng, T. (2008). Uptake and performance of farm-based measures for reducing crop-raiding by elephants in Laikipia, Kenya. *Conservation Biology*, 22(4), 991-999.

ix. Gupta, B.K., & Surana, S. (2019). IoT-enabled early warning system for mitigating human-elephant conflict. *Journal of Wireless Sensor Networks*, 11(2), 45-53.

x. Hazzah, L., Borgerhoff Mulder, M., & Frank, L. (2009). Lions and warriors: Social factors underlying declining African lion populations and the effect of incentive-based management in Kenya. *Biological Conservation*, 142(11), 2428-2437.

xi. Karanth, K. K., & Nepal, S. K. (2012). Local residents' perceptions of benefits and losses from protected areas in India and Nepal. *Environmental Management*, 49(2), 372-386.

xii. Sitati, N.W., Walpole, M.J., Smith, R.J., & Leader-Williams, N. (2003). Predicting spatial aspects of human-elephant conflict. *Journal of Applied Ecology*, 40(4), 667-677.

xiii. Sukumar, R. (2003). The living elephants: Evolutionary ecology, behavior, and conservation. *Oxford University Press*.