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Real Time AI-based Wildlife Detection and Deterrent System for Farmland Protection

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***Abstract*—The automated agricultural land protection system is a smart AI-supported solution designed to stop wildlife intrusion and protect crops by means of real-time detection, identification, and deterrence. The distance-based sensors are sensitive enough to continually monitor the immediate approach to the crops and their agent. Upon the first detection of the animal, an alert buzzer warns the farmer. Later, in case of an approaching animal, the AI process will commence by using the YOLO object detection algorithm, where it will effectively tell the species of the animal and subsequently excite the sending of a species-specific deterrent frequency to repel the intruder. In case of persistence of the animal or a tampering event, the farmer is notified through GSM communication signals. An electric shock pulse mechanism will also be raised along the perimeter to intensify protection against unauthorized entry. Sense modes, deterrents, and communication modules are part of the microcontroller, which operationally ensures that processing decisions through sensor data are realized instantly with timeless feedback for alerts. The system, therefore, provides effective, automated, and least disruptive deterrence of wildlife, which should reduce crop damage while obviating the need for human supervision circadian. With the aid of artificial intelligence technology and an intelligent deterrent approach, it aims to reinforce agricultural security and productivity, which presents a more sustainable alternative to the old-time methods of wildlife control**

Keywords— Agriculture, Crop protection, Farmer, GSM, Wildlife deterrence, YOLO

I. Introduction

Wildlife intrusions into agricultural lands have always presented a major concern as they threaten crop yield and lead to massive economic losses to farmers. For these reasons, farmers commonly employed outdated deterrent methods such as physical barriers or scare tactics to deal with wildlife. Unfortunately, such methods are often ineffective, expensive, and labor-intensive. To make matters worse, many animals become immune to these methods after some time and therefore, their long-term efficiency is decreased. Hence, there is a need for improved, reliable, automated, and the scalable solution that can promise adaptation based on the different behaviors of wildlife ontologies [1-2]. In this paper, an improved animal repulsion system is presented, integrating distance-based sensors with artificial intelligence (AI) using the YOLO object detection framework, and an active electric deterrent mechanism. The system is capable of detecting and classifying the wildlife approaching farmland in real time and providing a specific deterrent response by taking into consideration the detected species. It uses AI to solve the precise identification of identified species and its applying automated pasture wildlife responses. This solution provides an efficient and humane method of securing crops that is scalable with reduced human involvement and an improvement in the overall security of agricultural lands by modernizing the fight against the problem of wildlife intrusion.

II. Literature Review

Balakrishna et al. presents a system for protecting crops from wildlife intrusion that incorporates the Internet of Things and machine learning techniques. In this model, the heart of the system is Raspberry Pi, connected with a number of sensors and components such as Pi Camera and ESP8266 module. The detection portion runs on allowing animal approach to farmland by means of two types of image detection models: SSD and Region-Based Convolutional Neural Networks. Between the two models, SSD has the highest accuracy whilst remaining the fastest: therefore, it is deemed a real-time animal detection system. The system can also integrate Twilio API to send SMS alerts to support farmers, thus providing a scalable and cost-effective solution to secure crops against wildlife intrusion [3].

Sabina and Haseena suggest a deep-learning-based animal repellent system to reduce the human-wildlife conflict faced in agriculture. MobileNet SSD is used for animal detection and classification, which then triggers the alarming mechanism to repel adjacent wildlife while simultaneously sending notifications to the concerned authorities. Its aim is to provide a humane and effective means of repelling animals

without inflicting grievous harm. This work strikes the balance of a quick response and accuracy, enabling real-time work that is especially important in rural areas for crop protection [4].

Sudhakar et al. present a camera vision-based system for the detection and repellent of animals in agriculture that employs machine learning techniques. Faster R-CNN is utilized for real-time animal detection, whereas ultrasound technology emits high-frequency sound waves to repel the animals. The performance of the detection model is tested by means of a confusion matrix that reveals the model's effective detection and classification of various animals. The system raises timely alerts to farmers concerning the safety of both crops and wildlife, and the repelling of animals is humane since the methods to repel them are non-destructive in nature [5].

According to Sivasubramanian et al., therein lies an intelligent system for animal detection that employs AI and deep learning to protect agricultural fields from the intrusion of wildlife. Whenever any animal is detected, ultrasonic signals are then emitted to repel the animals humanely, so as to minimize their damage to crops to minimize the need for manual police action. This research proves that AI technologies can indeed be a future means of better crop protection [6].

Adami et al.'s work describes a real-time animal-repelling system using artificial intelligence on the edge to keep ungulates from crops. This system is implemented by object detection algorithms based on YOLO (you only look once) and embedded hardware like Raspberry Pi and NVIDIA Jetson Nano in order to be able to detect species of animals that cause damage to crops and to turn on ultrasonic repellent devices to deter them. The performance evaluation of the proposed system included analysis of price, energy efficiency, and viability for such AI-empowered solutions for crop protection, providing insight into real-life agricultural applications [7].

According to Marichamy et al., the analysis and techniques of machine learning have been harnessed towards the development of a crop protection system that is characterized by the detection and repulsion of wildlife from agricultural fields. The Wildlife Detector uses MobileNet SSD to detect animals in real-time and sends alerts if dangerous animals are detected. By virtue of the use of IoT and AI technologies, this system is aimed at fast detection and hence a humane way to deter wildlife from destructing crops. The implications discussed in this paper stipulate how such machine learning mechanisms work toward conflict avoidance and food supply safety[8].

AI-driven surveillance system that protects farms from invading wildlife by utilizing deep learning methods has been proposed. The method comes with integrated camera, image processing along with deep learning model for real-time animal detection. Whenever an animal is detected, an image processing algorithm will be immediately triggered to deter the intruder and to classify it. The model goes ahead to portray itself with image processing and AI, which in turn help protect the crops while reducing the unit application of labor. This presents a cost-effective and efficient approach to small-scale farmers [9].

In a combination of deep learning and artificial intelligence, discussion on crop damage incurred from animals has gone through rough patches in this research paper, which highlights in detail the problem of animal raids faced by farmers in India, proposing an AI and CNN-based animal detection system that alerts for intrusion employing PIR sensors and sound alarms as a relatively more humane approach when compared to the traditional means of crop protection that include electric fencing and human guarding [10].

Kommineni et al. Introduce a novel paradigm applying computer vision and machine learning techniques for protecting agricultural crops from wildlife....By utilizing image processing for animal detection and identification on farmlands, the system will raise the alarm in order to divert animals away from crops. This AI-based animal recognition and alarming systems approach aims to reduce crop damage without any harm to the animals and is affordable and scalable for farmers [11].

The AI-based crop protection system proposed by Jyothi et al. incorporates the real-time monitoring of fields along with YOLOv3 for object detection, hence identifying animal intrusions into such fields. The video feeds are collected from cameras fitted on the farm and will trigger sound alerts that scare animals away. The proposed system implements not only instant alerts through emails and mobile notifications to farmers, but also provides a cost-effective alternative to traditional fencing and human surveillance, which secures crop safety at the same time saving on labor costs [12].

III. Methodology

The system uses modern sensors and AI and auto-deterrent methods for crop protection from unwanted animals. It uses distance-based sensors that cover the perimeter walls of the farmland, constantly checking for the presence of wild animals approaching the area. Once an animal is detected, the farmer is notified by means of a sound buzzer. When the animal moves still closer, the AI-based YOLO will detect the species and a proper species-related frequency will be applied for the deterrent. If an animal does not go away, or there is tampering with the system, it sends an alert through GSM communication so that the farmer can act immediately.

Additionally, along with the perimeter, an electric shock pulse mechanism is implemented as additional protection against unauthorized entry into the field. A microcontroller consolidates all components into one for real-time detection, classification, and activation of other features. This is illustrated in Fig. 1 to show the flow of operations within the system, detection, classification, deterrence mechanism and alerts.

The new alternative to the wildlife deterrent methods presented by this project is smart, environmentally friendly, and the easiest mode of getting work done. Existing wildlife deterrent methods still rely on manual surveillance that is labor-intensive, scare tactics that yield little success, and chemical repellents that harm the environment. The system thus enhances agricultural productivity while minimizing crop losses and also leads to sustainable farm management with all the highs and lows of AI and automation involved. The design can be scaled up or down to fit different agricultural settings, and therefore stands as a better opportunity to deal with problems in today's farming. The system is instantaneous, featuring 3 basic interrelated

elements that are monitoring, intelligence-based decision-making, and automated deterrence, thus providing farmers that real-time tool to fend off wildlife threats to their farms and crops. A systematic compilation of distance-based sensors, object detection driven by artificial intelligence, and automatic deterrent interventions would protect crops from wildlife invasion.

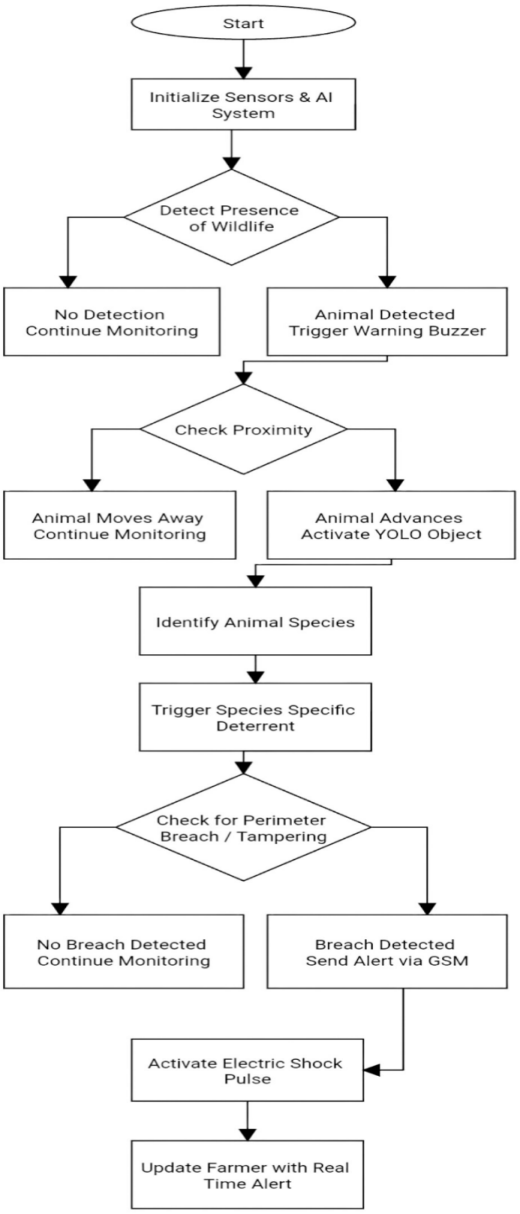

Fig. 1. Flowchart of the proposed system

Distance sensors continuously scan the distributed periphery for any impending animals that move within a preset range. In the event of any initial detection, the warning buzzer goes off to alert the farmer. When animals move closer, an AI-enabled YOLO object detection system instantaneously classifies the species and activates a deterrent frequency specific to the species in order to discourage further approach. In case of continual intrusion or in the event of any tampering, the system uses GSM communication to send immediate notifications to the farmer. In addition, an electric shock pulse mechanism is switched on all around the land to create a non-lethal deterrent to stop animals from breaching the perimeter. A microcontroller is used to control the entire system for reading sensors, programming alerts, and initiating deterrents in due time. By incorporating real-time monitoring, AI-based identification, and targeted deterrent mechanisms, the system presents an efficient and automatic solution for safeguarding agricultural lands from the threats of wild animals, ultimately reducing the need for constant human vigilance while limiting possible damages to crops. Fig. 2 illustrates the block diagram of the system, showing the integration of the various components such as sensors, AI processing, and the deterrent mechanisms controlled by the microcontroller. There are many advantages that the system brings to its end-user. First, it reduces human intervention to a minimum, where wildlife is detected, identified, and deterred automatically without constant human supervision. This saves time, labor, and operating costs for the farmers. Second, it increases accuracy and efficiency: AOI-based detection of species-specific deterrents to repel intruding animals minimizes false alarms. Third, it provides formal eco-friendly and sustainable protection: the system provides non-lethal deterrents and smart alert signals to keep crops in good condition, while in contrast to chemical repellents or harmful barriers, it maintains the ecological balance and conservation of wildlife.

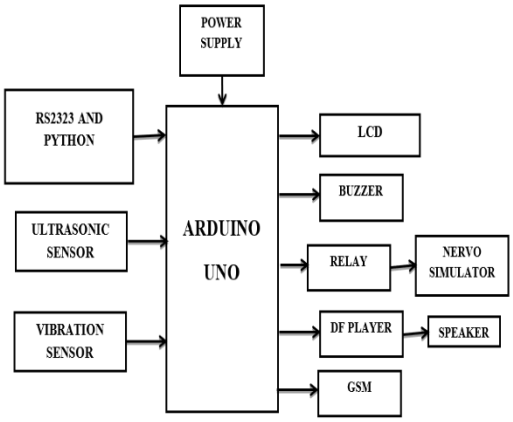

Fig. 2. Block diagram of the proposed system

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The Alert and Deterrence Module comes into play following the identification and detection process. It signals the farmer

by turning on a buzzer to give warning signals while scaring the intruder at first. Continuous advances toward it will emit species-specific deterrent frequencies to deter it. It notifies the farmer instantly via GSM network to send electric shock pulse mechanism protection if the intrusion or meddling persists. It is active and automated to respond to wildlife threats with little human interference. In its role of control center, this module functions like a CPU, linking all other components through the microcontroller. It controls sensor data, AI identification processing, and control of deterrents. It also takes care of GSM communications, giving the farmer instant alerts about an intrusion. It functions so effectively, with ease of detection, classification, and application of deterrents with little or no complication. It is the module on which one will depend in ensuring system reliability, automated decision-making and continuous protection of farms.

In summary, the solution envisaged integrates advanced AI technology with real-time monitoring and non-lethal deterrent methodologies into a comprehensive automated offering for agricultural land protection. The system thereby contributes towards agricultural security with respect to maintaining ecological balance, aided by the sensors and YOLO-powered AI detection model. In its scalable design and nature of adaptation to various agricultural ecosystems, the solution provides relevance to modern farmers with an efficient and sustainable way of securing their crops.

IV. Results and Discussion

This part focuses on describing the outcomes attained by the animal detection and deterrence systems for the monitoring after their deployment, implementation, and testing. The detection and deterrence detection animal system uses a combined YOLO-based object detection with the Arduino-based sensor network for real-time animal monitoring and detection. Then comes a discussion of the following results: detection accuracy, system performance, response time, and overall effectiveness.

A. Detection Accuracy and Performance

The YOLO-based object detection model was trained and tested using both animal dataset images and real-time video feed. The system is capable of detecting, classifying, and identifying different animals such as Buffalo, Elephant, Rhino, and Zebra in quite different environments. The model performed very well in both daylight and low-light conditions, as illustrated in Fig 3. Therefore, its robust performance was guaranteed at all times of the day.

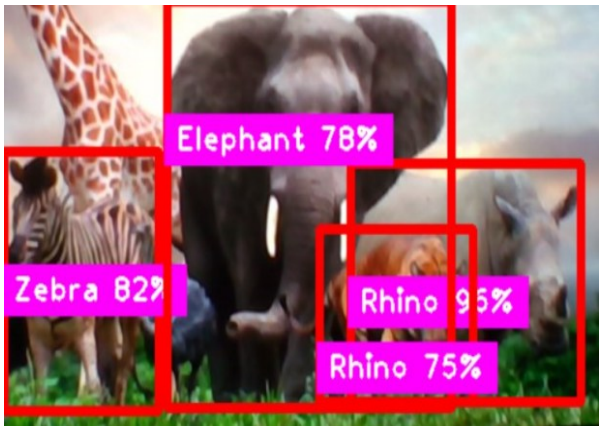

Fig 3 Object detection on wildlife with bounding boxes

The YOLO framework was used for training and testing of the animal and live video feed data detection model. It performed well for animal recognition, i. e. Buffalo, Elephant, Rhino, and Zebra detection and classification in various environments. As depicted in Fig. 3, it functions very well under both daylight and dim light conditions: therefore, resistant to the differences in times of day.

Table I shows how YOLO assessed detection efficiency in respect of confidence for all the species concerned. It shows that, in this case, species like Rhino and Zebra had detection confidence levels of 75 to 95 percent. Buffalo and elephants were slightly lower confidence levels yet still above 50, indicating they can be quite well categorized but to some slight degree less.

TABLE I: DETECTION ACCURACY FOR DIFFERENT ANIMAL CLASSES

Animal Class	***Detection Accuracy (%)***	***Confidence Range (%)***
Buffalo	89.9	50-95
Elephant	78.0	50-90
Rhino	95.0	75-99
Zebra	82.0	75-88

As illustrated in Fig. 4, the average inference time, very important for real-time detection, was found to be between 90 and 105 ms. Since it is established that this inference time is enough to support real-time monitoring, with immediate detection and action being taken when animals approach, this finding indicates the balance between accuracy and speed in the system, allowing for efficient animal detection without compromising performance.

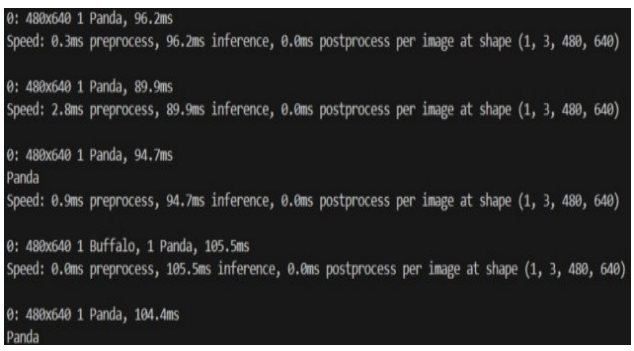

Fig 4 Inference log

B. System Integration and Response

The integration of the detector model with a hard device was done in a way that would give a solid and responsive deterrent system. This was made possible through an Arduino microcontroller, ultrasonic sensors, vibration sensors, and GSM module, all permitting detection to happen real-time and consequent action on the animal being at a distance less than the set limits.

When animals invaded the perceived radius of 100 meters, the detection system equipped with ultrasonic sensors thereafter displayed the distance in kilometers on an LCD interface and then this auditory deterrent is triggered via a DF Player module. To create noise and scare away animals at a maximum distance, as exhibited in Fig 6 the vibration sensor triggers to display the value of 1 only when the animal tries to damage the kit or otherwise value 0.

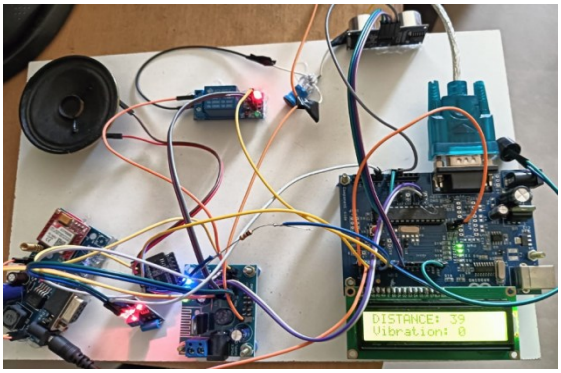

Fig 5 Photograph of the circuit setup

Nevertheless, if the animal did not stop when it was 50 meters away, the user activated a third line of defense with an electric shock applied by a nerve stimulator. This way, the animal would be kept at a distance from entering the perimeter of the monitored area, for example, a farm. Real-time notifications were sent to the user through the GSM module if the animals were within range of their property. This made it possible for users to implement proactive countermeasures, for example, by employing some extra manual deterrents or calling the local authorities.

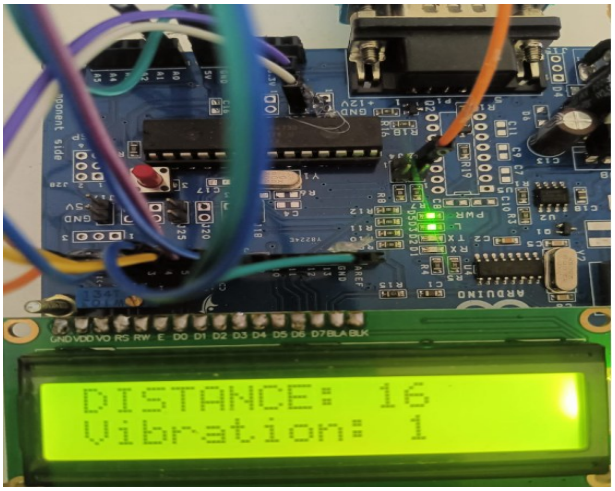

Fig 6 Illustration of distance and vibration detection

V. Conclusion

The envisioned automated farm protection system against wildlife is worked on with an incorporation of state-of-the-art sensor technologies, artificial intelligence, and automation of deterrent mechanisms. Custodial to this, the AI-backed YOLO object detection, distance-based sensors, and species-specific deterrent responses offer a valuable, open-scale sustainable solution to minimize crop destruction by wildlife. To this, there shall proffer a notification sent out under GSM standard architecture in alert to farmers, while counter-rating intruders with non-lethal electric shock pulse system enhances strength all along perimeters. By and large, this system hugely cuts back the need for manual interventions, improves precision, and eco-friendlier methods of wildlife control in charge of the conventional methods of deterrence. Its modular and configurable design should allow for easy integration in any agricultural setting, presenting itself as an answer to modern tough challenges in farming. Future upgrades may add to the body the AI model filtering by a fine grain so that accuracy in detection could be improved, other types of deterrent mechanisms might be included for better specification-oriented repulsion, and solar integration might turn it into an efficient energy-consuming system. Dealing with the long-standing issue of wildlife entering farmlands helps the system to produce more agriculture and food while also giving farmers more means of effective crop protection.

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