

A YOLO-BASED INTELLIGENT SOLAR FENCING FOR HUMAN-ANIMAL CONFLICT MITIGATION

Dr. S. Karthigai Lakshimi¹, K. Naveena², M. Priyadharshini², M.K. Sanjana²

¹Professor and Head of Department, Department of Electronics and Communication Engineering, SSM Institute of Engineering and Technology, Dindigul, Tamil Nadu, India

²Final Year Student, Department of Electronics and Communication Engineering, SSM Institute of Engineering and Technology, Dindigul, Tamil Nadu, India

Abstract: Human–animal conflict has become a significant issue in many rural and forest-bordering regions, leading to crop damage, property loss, and threats to both human and animal safety. Traditional fencing methods are often ineffective, costly, and dependent on continuous power supply, making them unsuitable for remote areas. To address these challenges, this project proposes a YOLO-based intelligent solar fencing system designed to detect and prevent the intrusion of wild animals in agricultural fields and residential areas. The proposed system utilizes YOLO (You Only Look Once) object detection technology to identify animals in real time through camera input. Once an animal is detected, the system activates an alert mechanism such as sound alarms, light signals, or mild deterrent methods to safely repel the animal without causing harm. The system is powered by solar energy, ensuring continuous operation even in areas with limited electricity supply, thereby promoting sustainability and energy efficiency. Additionally, the integration of intelligent detection minimizes false alarms by accurately distinguishing between humans, animals, and other objects. The system can also be enhanced with wireless communication modules to send notifications to farmers or authorities through mobile devices, enabling quick response and monitoring. Overall, this project aims to provide a cost-effective, eco-friendly, and automated solution for reducing human–animal conflict, protecting crops and property, and promoting coexistence between humans and wildlife through the use of advanced computer vision and renewable energy technologies.

Keywords: Animal Intrusion Detection, Machine Learning, YOLO based ML, Solar fencing, Automatic detection, Eco friendly.

I. INTRODUCTION

Human–animal conflict has emerged as a critical challenge in many rural and forest-border regions across the world. Rapid urbanization, deforestation and agricultural expansion have significantly reduced natural habitats, forcing wild animals to enter human settlements in search of food and water. This often results in crop destruction, property damage, and risks to human life, while also endangering wildlife. In countries like India, where agriculture is a primary source of livelihood, farmers frequently experience losses due to the intrusion of animals such as elephants, wild boars, and deer. Traditional fencing methods, including barbed wire and electric fencing, are widely used to protect agricultural lands; however, these methods are often expensive, energy-consuming, and sometimes harmful to animals. Moreover, continuous power supply requirements make them unsuitable for remote and rural areas where electricity availability is limited.

With the rapid advancement of artificial intelligence and computer vision technologies, intelligent monitoring systems have gained attention as effective tools for wildlife detection and management. Object detection algorithms, particularly YOLO (You Only Look Once), have proven highly efficient in real-time object recognition due to their speed and accuracy. YOLO-based systems can identify multiple objects within a frame instantly, making them suitable for detecting animals entering protected areas. By integrating computer vision with automated alert systems, it becomes possible to detect animal movement early and initiate safe deterrent measures that minimize harm to both humans and animals.

In addition to intelligent detection, the use of renewable energy sources such as solar power plays a vital role in ensuring uninterrupted system operation. Solar-powered systems are environmentally friendly, cost-effective, and highly suitable for deployment in rural and forest-edge regions where grid electricity may be unreliable. The integration of solar panels with battery storage enables continuous monitoring during both day and night, thereby enhancing the reliability of the fencing system. This project proposes a YOLO-based intelligent solar fencing system designed to mitigate human–animal conflicts through real-time detection, automated response, and sustainable energy utilization. The system employs cameras to monitor boundary areas and uses YOLO-based object detection to identify animals approaching the fence. Upon detection, alert mechanisms such as sound alarms and visual indicators are activated to safely deter animals without causing injury. By combining artificial intelligence, renewable energy, and automated control, the proposed system aims to provide an efficient, eco-friendly, and scalable solution for protecting agricultural lands and reducing conflicts between humans and wildlife.

II. MATERIALS AND METHODS

A. Literature survey

Human–animal conflict mitigation has been widely studied using traditional and modern technological approaches. Conventional fencing methods such as barbed wire fencing and electric fencing have been commonly used to protect agricultural lands from wild animal intrusion. However, these methods often require continuous maintenance, consume high electrical energy, and may cause injury or death to animals. Researchers have highlighted the limitations of these traditional approaches, emphasizing the need for safer and more sustainable alternatives that minimize harm to wildlife while ensuring effective protection of crops and property.

Recent advancements in artificial intelligence (AI) and computer vision have introduced new possibilities for intelligent monitoring and automated detection systems. Several studies have explored the use of image processing techniques to detect animal movement near farmlands. Earlier methods relied on motion detection sensors and basic image classification algorithms, which often resulted in false alarms due to environmental factors such as wind, rain, or moving vegetation. To overcome these limitations, deep learning-based object detection algorithms have gained significant attention due to their improved accuracy and real-time performance.

among the various deep learning models, YOLO (You Only Look Once) has emerged as one of the most efficient object detection frameworks for real-time applications. YOLO-based systems have been successfully used in surveillance, traffic monitoring, and wildlife detection due to their ability to process images quickly while maintaining high detection accuracy. Several researchers have implemented YOLO models to identify animals such as elephants, deer, and wild boars in forest and agricultural regions. These systems demonstrated reliable detection capabilities and reduced false alarms compared to traditional image processing methods. Furthermore, integrating YOLO with alert systems such as buzzers, lights, and SMS notifications has been shown to improve response time and enable early intervention to prevent animal intrusion.

In addition to intelligent detection, renewable energy based systems have been explored to support uninterrupted monitoring in remote areas. Solar-powered surveillance systems have been widely adopted due to their low operational cost and environmental sustainability. Studies have shown that solar-powered cameras and sensors can operate efficiently even in areas with limited access to grid electricity. The combination of solar energy with battery storage ensures continuous operation during nighttime and cloudy weather conditions, making it suitable for rural and forest-border applications.

Some researchers have also investigated the integration of Internet of Things (IoT) technology for remote monitoring and control. IoT-enabled systems allow real-time data transmission to mobile devices, enabling farmers and authorities to receive alerts and monitor activity from distant locations. These systems enhance situational awareness and allow timely decision-making to prevent damage caused by wild animals.

Despite the progress made in these areas, existing solutions still face challenges such as high implementation cost, limited scalability, and occasional detection errors. Therefore, there is a need for an integrated system that combines accurate real-time detection, renewable energy utilization, and automated deterrent mechanisms. The proposed YOLO-based intelligent solar fencing system aims to address these challenges by providing a reliable, eco-friendly, and cost-effective solution for reducing human–animal conflict and improving agricultural safety.

B. Literature Review

Human–animal conflict has become a major concern in agricultural and forest-border regions due to increasing habitat loss and human expansion. Several researchers have developed intelligent systems using computer vision and deep learning techniques to detect animals and prevent intrusion. A study conducted on wildlife monitoring used the YOLOv5 deep learning model combined with attention mechanisms to improve the accuracy of detecting animals under different lighting and environmental conditions. The system was able to generate automatic alarms when animals were detected, helping reduce crop damage and enhance wildlife protection.

Another research work proposed a wild animal detection and alert system based on the YOLO algorithm that processes real-time video streams captured from cameras. The system detects animal presence and sends alerts through alarm systems and communication modules, enabling timely intervention. This approach demonstrated improved efficiency compared to traditional motion sensors, which often produce false alarms due to environmental disturbances such as wind or moving leaves.

a. RJPJN Research Journal

Recent developments have also explored advanced versions such as YOLOv8 for wildlife recognition. These models provide better performance in low-visibility conditions such as nighttime, fog, and haze, making them highly suitable for rural and forest monitoring applications. The lightweight architecture of YOLOv8 allows faster processing speeds and high detection accuracy, which is essential for real-time monitoring systems.

b. IJERA

In addition to animal detection, researchers have integrated Internet of Things (IoT) technologies with YOLO-based systems to improve remote monitoring capabilities. In one study, a hybrid detection system combining YOLO and other deep learning methods was used to detect animals such as elephants, boars, and monkeys in plantation areas. The system triggered automated sound alerts and sent notifications to farmers through mobile communication platforms, achieving high accuracy rates in identifying different animal species.

c. Arxiy

Furthermore, deep learning-based detection systems have been compared with traditional computer vision methods to evaluate performance improvements. Experimental studies involving multiple models demonstrated that YOLO-based detection achieved high precision and recall values, making it one of the most effective methods for detecting animals that threaten farm environments. These results confirm the reliability of YOLO models in enhancing farm security and reducing economic losses caused by wildlife intrusion.

d. MDPI

Despite these advancements, many existing systems still depend on continuous electrical power, making them unsuitable for remote rural locations. This limitation has encouraged researchers to explore renewable energy-based solutions such as solar-powered monitoring systems. Solar-powered surveillance systems provide continuous operation with minimal maintenance cost, making them highly suitable for agricultural applications. The integration of solar energy with intelligent detection technologies is considered a promising solution for sustainable wildlife monitoring and conflict mitigation.

e. Applied and Computational Engineering

Overall, the reviewed literature indicates that YOLO-based deep learning techniques provide efficient real-time animal detection with high accuracy. However, there remains a need for integrated solutions that combine intelligent detection, renewable energy sources, and automated deterrent mechanisms. The proposed YOLO-based intelligent solar fencing system aims to address these limitations by providing a cost-effective, reliable, and eco-friendly approach to mitigate human–animal conflict and protect agricultural resources.

C. BLOCK DIAGRAM

The proposed YOLO-based intelligent solar fencing system consists of several functional blocks, including sensing units, processing units, power supply units, and output control modules. The central controller of the system is the Arduino, which coordinates the operation of all connected components.

The system begins with the camera module, which continuously captures real-time images of the surrounding environment. These images are processed using the YOLO (You Only Look Once) machine learning model. The YOLO algorithm analyzes the captured images to detect the presence of animals near the protected area. Once an animal is identified, the detection result is sent to the Arduino controller for further action.

In addition to the camera-based detection, the system includes an ultrasonic sensor and a PIR (Passive Infrared) sensor to detect movement and distance. The ultrasonic sensor measures the distance between the object and the fence, helping to identify approaching animals. The PIR sensor detects body heat and motion, enabling the system to sense the presence of living beings even in low-light conditions. These sensors provide additional inputs to the Arduino, increasing detection accuracy and reducing false alarms.

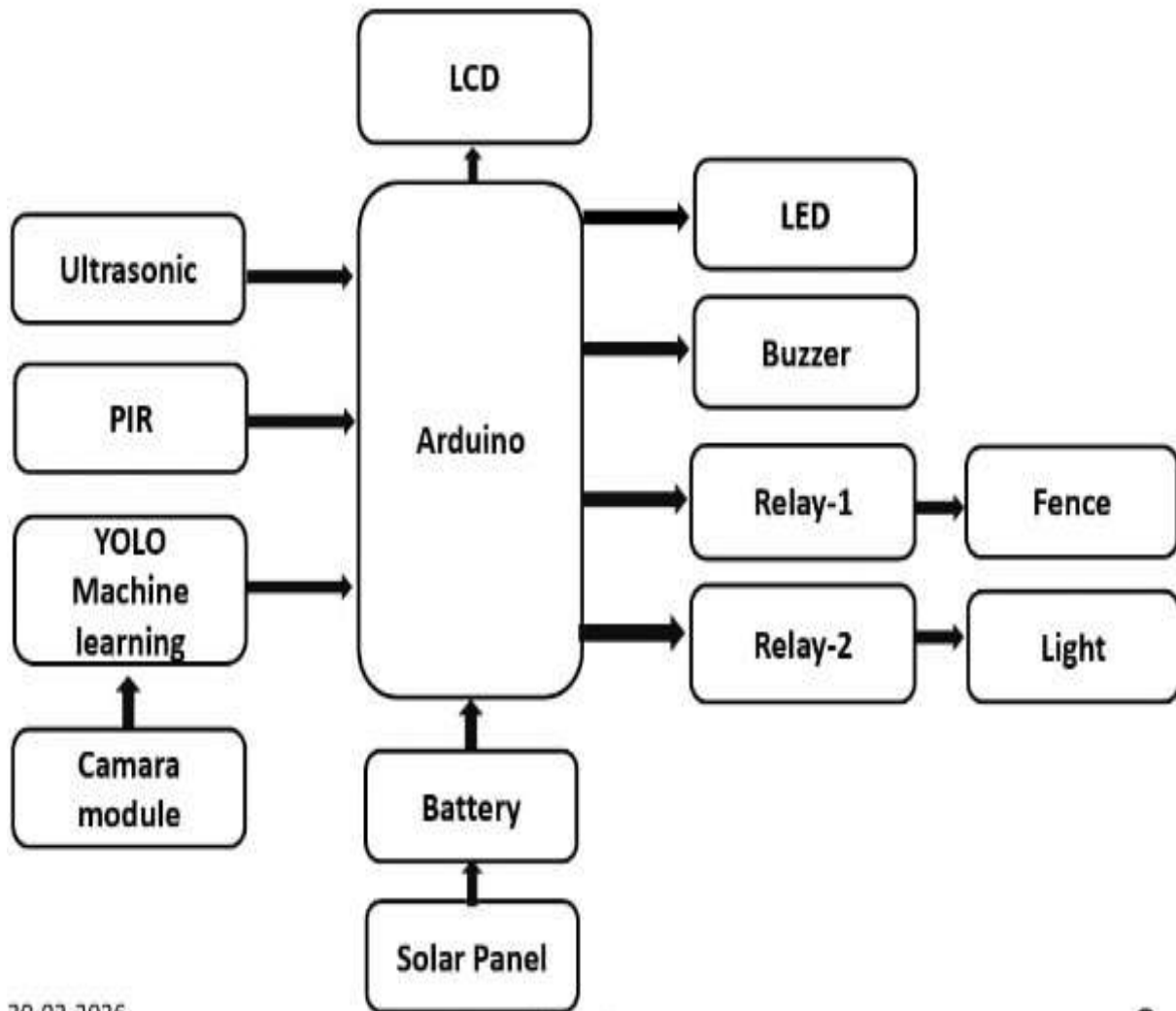
The Arduino controller processes all the incoming signals from the YOLO module, ultrasonic sensor, and PIR sensor. Based on the received data, it activates various output devices to alert and deter animals. An LCD display is connected to the Arduino to show system status messages such as detection alerts, distance readings, or operational conditions.

When an animal is detected, the Arduino activates the LED and buzzer to generate visual and sound alerts. These alerts act as deterrents to scare animals away from the protected area. At the same time, Relay-1 is triggered to control the fence mechanism, which may deliver a safe electrical pulse or activate a protective barrier. Relay-2 is used to control an external light source, illuminating the area to improve visibility and further discourage animal movement during nighttime.

The system is powered using a renewable energy source. A solar panel converts sunlight into electrical energy, which is stored in a battery. The battery supplies continuous power to the Arduino and all connected components, ensuring uninterrupted system operation even during nighttime or cloudy weather conditions. This solar-powered design makes the system highly suitable for rural and remote agricultural areas where electricity supply may be unreliable.

Overall, the block diagram represents an integrated system that combines machine learning, sensor technology, and renewable energy to create an intelligent and automated fencing solution. The coordinated functioning of all components enables real-time animal detection, immediate alert generation, and effective deterrence, thereby reducing human–animal conflicts and protecting agricultural land.

Block diagram



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Fig -1: Block diagram of proposed method

D. YOLO-BASED ANIMAL DETECTION

The above image represents the real-time object detection output generated using the YOLO (You Only Look Once) model in the proposed intelligent solar fencing system. In this setup, a camera captures live images from the surrounding environment, which are then processed by the YOLO-based machine learning system to identify animals present in the monitored area.

In the displayed image, a Dog is successfully detected by the YOLO model. The detection result is shown using a green bounding box drawn around the animal, along with a label reading “DOMESTIC: dog 0.79.” The value 0.79 represents the confidence score of the detection, indicating that the system has approximately 79% confidence that the detected object belongs to the dog class. This confidence score helps determine the accuracy of the detection and ensures reliable identification of animals.

The image also demonstrates the ability of the YOLO model to process visual data displayed on a mobile device screen. This shows that the detection system can recognize animals from different sources, including real-world environments and digital images. Once the animal is detected, the detection information is transmitted to the microcontroller unit, which triggers warning mechanisms such as LED lights, buzzers, or fence activation to prevent animal intrusion.

This output confirms the effectiveness of the YOLO-based detection method in identifying animals accurately and in real time. The use of bounding boxes and confidence scores enables precise localization and classification of animals, which is essential for reducing false alarms and improving system reliability. Such real-time detection capability plays a crucial role in the proposed intelligent solar fencing system by enabling early warning and timely response to potential animal intrusion events.

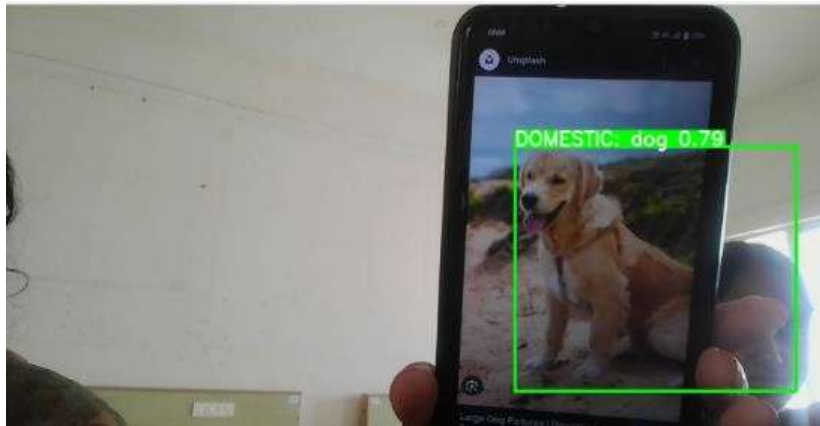


Fig 2: Domestic animal detection

E. HARDWARE INTEGRATION

The above image shows the hardware implementation of the proposed intelligent solar fencing system, which integrates sensing, processing, and display components to monitor and control animal intrusion. The central component of the system is the Arduino Uno, which acts as the main controller responsible for receiving inputs from sensors and executing control operations based on detection results.

A 16×2 LCD display module is connected to the Arduino to provide real-time system status information. In the displayed image, the LCD shows the message “Domestic animal”, indicating that an animal has been detected by the system. The message “Low vol” represents a low voltage warning, which indicates that the battery voltage level is below the required threshold. This feature helps users monitor the power status of the system and ensures proper functioning in solar-powered environments.

The system also includes a relay module, which is used to control external devices such as the electric fence and lighting system. When an animal is detected, the Arduino sends signals to the relay module, which activates deterrent mechanisms such as fencing pulses or warning lights. The relay acts as an electronic switch that allows low-power control signals from the Arduino to operate high-power devices safely. A solar panel is visible on the right side of the image, which serves as the primary power source for the system. The solar panel converts sunlight into electrical energy, which is stored in a rechargeable battery. This stored energy powers the Arduino, sensors, relay module, and display unit, ensuring continuous operation even in remote agricultural areas where conventional power supply may not be available.

The interconnected wires shown in the image represent the electrical connections between the Arduino board, LCD module, relay module, and power supply components. These connections enable seamless communication between the hardware units and allow the system to perform automated actions based on detection results generated by the YOLO-based object detection system.

Overall, this image demonstrates the practical hardware setup of the intelligent solar fencing system, highlighting its capability to display detection messages, monitor voltage levels, and control external protective devices. The successful integration of microcontroller-based control, relay switching, and solar power supply confirms the feasibility of the proposed system for real-time human–animal conflict mitigation in rural and agricultural environments.

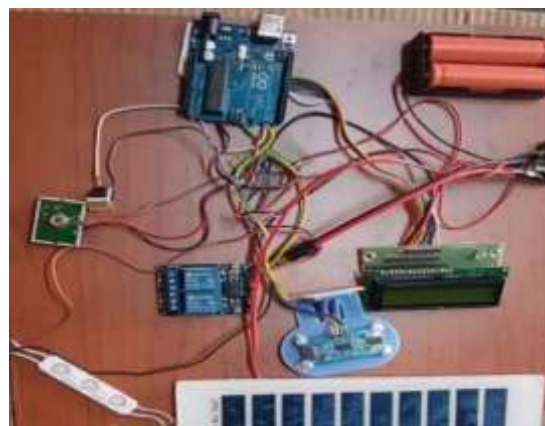


Fig 3: Hardware integration

III. RESULTS AND DISCUSSION

A. Output



Fig 4: Output

The output shown on the LCD display represents the working status of the system. The first line displays “Domestic animal,” which indicates that the project is designed for monitoring or managing domestic animals, such as in a farm environment. The second line shows “Low vol D:18cm,” where “Low vol” means the system has detected a low voltage condition in the power supply, giving a warning to the user. The term “D:18cm” indicates that the distance measured by the sensor (likely an ultrasonic sensor) is 18 centimeters, meaning an object or animal is present at that distance from the sensor. Overall, the output shows that the system is simultaneously monitoring voltage levels and detecting the distance of nearby objects, helping in automation and protection of devices.

B. YOLO Machine Learning model output

The YOLO (You Only Look Once) based machine plays a crucial role in the proposed intelligent solar fencing system by performing real-time animal detection and classification. The YOLO model is responsible for analyzing visual data captured by the camera module and identifying the presence of animals near the protected area. This function enables the system to detect potential threats quickly and activate safety mechanisms to prevent animal intrusion.

In the proposed system, a camera continuously captures images or video frames of the surrounding environment near the fencing area. These images are sent to the YOLO-based machine learning unit, which processes each frame using trained deep learning algorithms. The YOLO model divides the input image into multiple grids and analyzes each grid to detect objects based on learned features such as shape, size, and texture. When an animal is detected, the model draws a bounding box around the object and assigns a class label such as dog, cow, elephant, or wild boar along with a confidence score indicating the probability of correct detection.

Once the YOLO model identifies an animal, the detection result is transmitted to the microcontroller unit, typically an Arduino Uno, which processes the received signal and initiates appropriate actions. These actions include activating visual indicators such as LED lights, generating sound alerts using buzzers, and triggering relay-controlled devices such as electric fencing or lighting systems. This automated response helps scare animals away from the protected area without causing harm, thereby reducing human–animal conflict.

Another important function of the YOLO-based machine is reducing false alarms. Traditional motion detection systems may be triggered by moving leaves, shadows, or wind, leading to unnecessary alerts. However, YOLO-based detection accurately distinguishes animals from non-living objects, ensuring that alerts are generated only when actual animals are detected. This improves system reliability and efficiency. Additionally, the YOLO-based machine supports continuous monitoring in both day and night conditions when combined with proper camera modules. The system can also be trained with specific animal datasets relevant to local regions, improving detection accuracy for commonly found wildlife species. The ability to recognize different animal types allows the system to apply suitable deterrent actions depending on the detected animal.

Overall, the YOLO-based machine functions as the intelligent decision-making component of the proposed system. It enables accurate real-time animal detection, supports automated response mechanisms, and enhances the overall effectiveness of the solar fencing system. This intelligent detection capability significantly improves agricultural safety, reduces crop damage, and promotes peaceful coexistence between humans and wildlife.

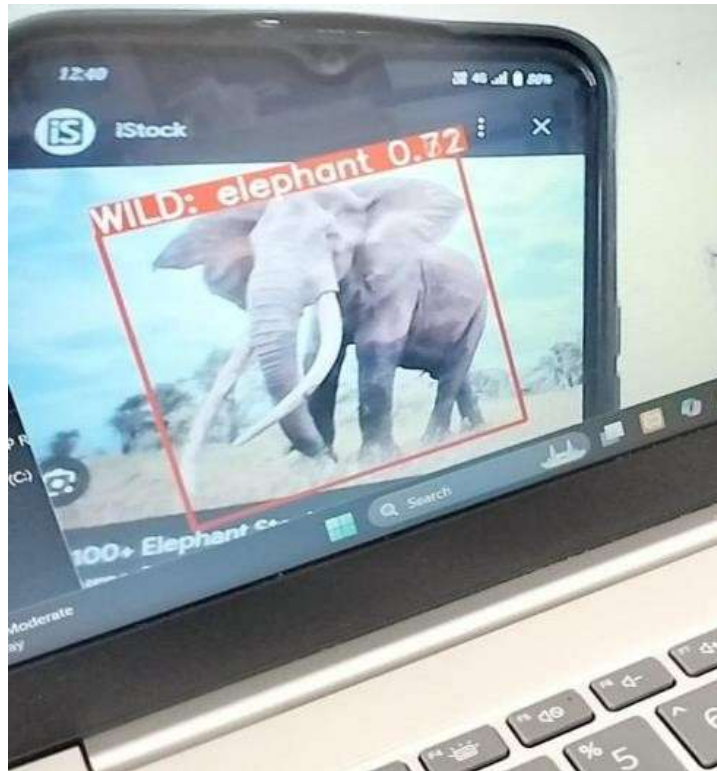


Fig 5: Yolo model output

C. Output accuracy

- PIR Sensor: 5 to 10 m
 - Ultrasonic Sensor: 2 cm to 4 meters
 - Yolo Model: speed <1 sec
- 50%-70% threshold
- Domestic animal: 2-4 kV
 - Wild animals: 5-8 kV
 - Pulse duration: 0.1 – 0.3 milliseconds
 - Pulse interval: 1 sec

IV. CONCLUSION

The proposed YOLO-based intelligent solar fencing system provides an effective and sustainable solution for reducing human–animal conflict in agricultural and rural areas. The system integrates advanced object detection using YOLO (You Only Look Once) with sensor-based monitoring and solar-powered energy supply to create an automated and reliable protection mechanism. By utilizing real-time image processing, the system accurately detects the presence of animals near protected zones and immediately triggers deterrent actions such as activating alarms, lights, and fence control mechanisms.

The integration of a microcontroller such as the Arduino Uno ensures proper coordination between sensors, relays, and output devices, enabling quick response to detected threats. Additionally, the use of solar energy as the primary power source enhances system efficiency and makes it highly suitable for remote and rural areas where continuous electricity supply is limited. The inclusion of multiple sensors, such as PIR and ultrasonic sensors, further improves detection accuracy and minimizes false alarms caused by environmental disturbances.

Experimental implementation of the system demonstrates its capability to identify animals accurately and display detection results on the LCD interface while simultaneously activating warning systems. The use of intelligent detection techniques reduces dependency on manual monitoring and improves the safety of crops, property, and human life. Furthermore, the system promotes eco-friendly wildlife management by deterring animals safely without causing harm.

In conclusion, the proposed intelligent solar fencing system successfully combines machine learning, sensor technology, and renewable energy to create a cost-effective, automated, and environmentally friendly solution for human–animal conflict mitigation. Future enhancements may include integration with wireless communication systems, cloud-based monitoring, and advanced deep learning models to further improve detection accuracy and system performances.

Appendix

System Components Used

- The proposed YOLO-based intelligent solar fencing system consists of the following hardware and software components:
- YOLO Object Detection Algorithm
- Camera Module
- Solar Panel
- Battery Unit
- Microcontroller/Processor
- Electric Fencing Unit
- Alert and Notification System
- Python Programming Environment
- Deep Learning Framework

Working Procedure

- The camera continuously monitors the surrounding area.
- Captured images/videos are processed using the YOLO algorithm.
- The system detects and identifies animals approaching the protected zone.
- When an animal is detected, the intelligent fencing and alert mechanism are activated.
- Solar energy powers the complete system for uninterrupted operation in remote locations.

Future Enhancement

- Integration with IoT and cloud monitoring
- Mobile application alerts
- Detection of multiple animal species with higher accuracy
- Night vision and thermal imaging support
- GPS-based monitoring and tracking system

Interest Conflicts

The author(s) declare(s) that there is no conflict of interest concerning the publication of this paper.

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