Wild Guard: Solar Powered Animal Intrusion Detection and Alert System

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Abstract—*Monitoring animal movement and health is a critical component of veterinary science, livestock management, and wildlife conservation, particularly in regions where human-animal interactions are frequent. This paper presents a solar-powered animal detection and alert system that utilizes real-time image processing and deep learning to enhance animal healthcare monitoring. The system integrates a camera module with the YOLO (You Only Look Once) object detection algorithm to identify animals entering predefined zones such as agricultural fields, roadways, or human habitations. Unlike conventional systems that depend on motion or weight sensors, this solution employs computer vision to deliver accurate and timely detection of animals and their behaviors. Data captured by the camera is processed by an embedded computing device, which generates alerts to notify veterinary authorities or landowners for further action. The entire system is powered by solar energy, ensuring continuous, low-maintenance operation in remote or off-grid areas. By combining artificial intelligence, embedded systems, and renewable energy, this project provides a cost-effective and scalable tool for improving animal healthcare, enabling early detection of threats, and reducing the risk of human-animal conflict. The proposed system demonstrates promising potential for deployment in both rural and conservation settings where real-time animal monitoring is essential.*

Keywords**—Animal healthcare, YOLO, object detection, computer vision, embedded system, solar-powered system, veterinary monitoring, wildlife detection, real-time alert system, AI in agriculture, smart farming, animal surveillance, rural technology, deep learning, animal safety**

I. INTRODUCTION

Livestock safety, wildlife monitoring, and early veterinary intervention are critical components of modern agricultural and environmental management systems. In many rural and forest-adjacent areas, the intrusion of wild or stray animals into farms, roads, or human settlements has resulted in crop damage, traffic accidents, disease transmission, and even fatalities. Simultaneously, undetected signs of distress or illness in domestic animals often lead to delayed treatment, reduced productivity, and increased healthcare costs. Addressing these issues is crucial for public safety, animal welfare, and sustainable farming.

Conventional monitoring methods, including motion sensors, manual patrols, and GPS-based tracking, are limited by high power consumption, lack of accuracy, and poor scalability in remote or off-grid areas. These limitations hinder real-time decision-making and risk the health and safety of both humans and animals.

To address these challenges, this paper proposes a solar-powered animal detection and healthcare alert system based on real-time computer vision and deep learning. The system integrates a camera with the YOLO (You Only Look Once) object detection algorithm and an embedded processing unit to autonomously identify and classify animals in sensitive zones. It generates real-time alerts to stakeholders such as farmers and veterinary personnel for timely action.

The rest of this paper is structured as follows: Section II reviews related work;Section III outlines the system design and methodology; Section IV presents results and performance analysis; and Section V concludes with expected outcomes and future directions.

II. LITERATURE SURVEY

Kiran Kumar Mamidi et al. [1] proposed an IoT-based animal detection system using an interdisciplinary approach, highlighting its effectiveness in real-time wildlife surveillance and early alert mechanisms for agricultural safety. Reon Sato et al. [2] explored energy reduction strategies for wild animal detection devices, optimizing system longevity and sustainability through low-power embedded designs. R. Rohith et al. [3] developed a computer vision and IoT-enabled surveillance bot for monitoring forests and large farms, providing real-time feedback and improving situational awareness in remote areas. Pavol Kuchár et al. [4] designed a smart non-lethal animal trap using ESP32-CAM and PIR sensors, demonstrating the viability of cost-effective wildlife tracking with onboard image capture and wireless alerts. Dian Chen et al. [5] proposed an energy-adaptive and robust monitoring solution for smart farms, utilizing solar-powered wireless sensors to ensure continuous and efficient animal tracking in dynamic environmental conditions. Akash B. Yele et al. [6] presented a solar-powered animal intrusion detection and repellent system aimed at protecting farmlands from wild intrusions while using sustainable power sources. V. Soniya et al. [7] introduced an IoT-based smart system for plant watering and pet feeding, combining environmental sensing with automated resource management for domestic and small-scale agricultural use. S. Lee et al. [8] developed and evaluated an intelligent animal repelling system based on embedded edge AI to protect crops, showing effective response to real-time animal detection at field boundaries. P. K. Panda et al. [9] implemented a wild animal intrusion detection model using IoT, enabling accurate species detection and alert generation to mitigate animal-human conflicts in rural zones. Mohaimenul Azam Khan Raiaan et al. [10] proposed an IoT-based object detection system to safeguard endangered animals and enhance farm security, integrating AI vision models for broader ecological impact and agricultural protection.

III. PROPOSED WORKFLOW

The proposed system operation begins with the initialization phase, during which the solar power unit charges the onboard Li-ion battery via an MPPT charge controller and the Node MCU ESP8266 is brought online. Upon startup, the ESP32-CAM and Wi-Fi/GSM communication modules are initialized, the YOLOv5 model weights are loaded into memory, and system clocks are synchronized to ensure accurate timestamping of detection events.

Once initialization is complete, the image acquisition module enters its acquisition loop. At user-defined intervals (or upon optional PIR-triggered wake), the ESP32-CAM captures a high-resolution frame of the monitored zone. This image is forwarded to the Node MCU, which either performs lightweight on-device inference or streams it to a paired edge server for real-time YOLO-based object detection. Detected bounding boxes and confidence scores for target species (e.g., cattle, deer, boar) are returned to the microcontroller for evaluation.

The Node MCU then compares each detection against configurable thresholds for confidence and zone occupancy. If a detected animal's confidence score exceeds the threshold and its location falls within a "restricted" or "high-alert" region, the system transitions to its alert phase. It logs the event locally (with image snapshot), then transmits an alert packet—comprising species, timestamp, and image URL—over Wi-Fi to a cloud dashboard or via GSM SMS when out of range.

The remote monitoring interface presents a consolidated view of detection events, battery and solar-panel voltage levels, and system health metrics. Authorized users can review live snapshots, browse historical logs, and configure alert parameters (e.g., species watch-lists, detection intervals) without physical site visits.

To conserve energy, the Node MCU and ESP32-CAM enter a deep-sleep mode between capture cycles, periodically waking only for scheduled acquisitions or external triggers. This low-power duty-cycling, combined with solar charging, enables continuous, maintenance-free operation in off-grid or remote agricultural and wildlife settings.

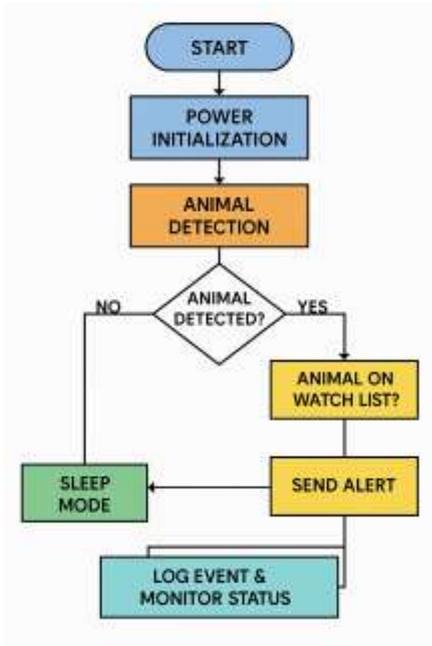

Fig 1.1 Shows the flowchart of the proposed system

The block diagram of the proposed workflow illustrates the structure of a solar-powered smart animal detection system integrated with IoT and machine learning technology. The system is primarily divided into two major sections: power and sensing unit, and detection and communication control.

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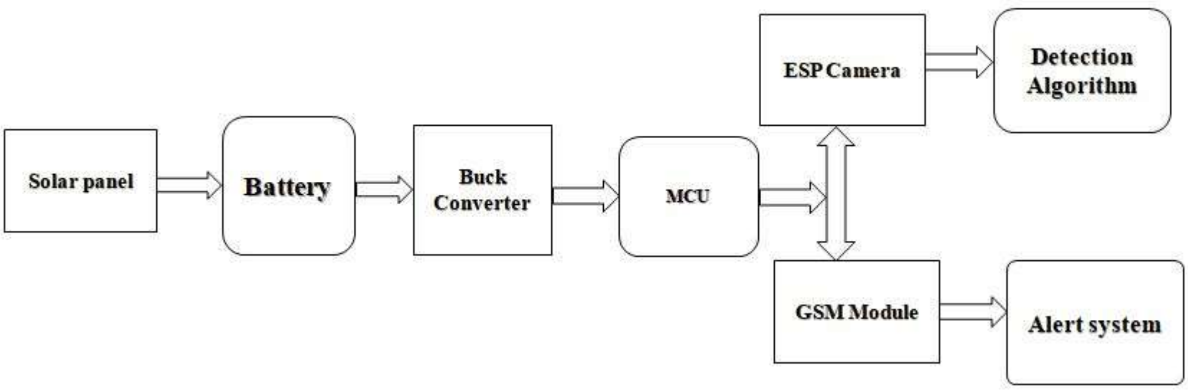

Fig 1.2 Block diagram of the proposed workflow

1. Environmental Monitoring and Intrusion Detection

The system is designed to continuously monitor specific zones (e.g., farmlands or restricted areas) for animal intrusions using visual detection:

• ESP32-CAM Camera Module

The ESP32-CAM module integrates a microcontroller with a camera, offering both image capture and edge-based processing. It operates at 3.3V and captures real-time visuals of the monitored area. Using a trained animal detection algorithm, the system compares captured frames to identify the presence of animals such as wild boars, cows, or elephants. Image frames are processed locally to minimize data transmission and latency.

Upon detecting an animal, the system classifies the object based on its size, shape, and motion. The algorithm then generates a binary intrusion flag, triggering downstream modules.

2. Embedded Control and Communication System

• NodeMCU ESP8266

The NodeMCU functions as the main controller for system coordination. It receives intrusion flags via serial or GPIO from the ESP32-CAM and initiates corresponding alert procedures. The module operates at 3.3V and provides built-in Wi-Fi for configuration and OTA (over-the-air) updates if required.

• GSM Module (SIM800L)

The SIM800L GSM module enables mobile communication. Upon receiving an intrusion alert from the NodeMCU, it sends SMS notifications or makes a predefined phone call to the landowner or control room. This module supports quad-band frequencies and is operated via UART interface from the NodeMCU.

The system can send details such as:

- Intrusion detected
- Time and date
- Zone ID (if multiple areas are covered)

This ensures prompt human intervention to prevent crop or property damage.

3. Power Supply and Solar Regulation Unit

The entire system is powered sustainably using solar energy:

• Solar Panel (12V, 10W–20W)

The solar panel converts sunlight into electrical energy during daylight hours. It charges the battery through direct wiring, controlled via protective circuitry (e.g., a diode to prevent reverse current flow).

• Rechargeable Battery (12V Lead-Acid or Li-Ion)

Energy from the solar panel is stored in a 12V battery, which powers the system during nighttime or cloudy conditions. A single battery unit supports continuous operation of the microcontroller, camera, and communication modules.

• Buck Converter (LM2596)

The LM2596 buck converter steps down the 12V battery output to required operating voltages:

- 5V for the GSM module and ESP32-CAM logic circuits
- 3.3V for the NodeMCU

This power regulation ensures safe operation of all components without overloading.4. IoT-Based Monitoring Interface.

4. Alerting and Monitoring System

Once an intrusion is detected and verified:

• SMS and Call Alert System

The GSM module immediately transmits a text message with intrusion details to the registered mobile number. Optional functionality includes auto-dialing and playing a pre-recorded message.

• Optional Buzzer or Siren Module

For on-site deterrence, a 5V buzzer or piezoelectric siren can be triggered by the Node MCU when an animal is detected. This aims to scare off animals before they can cause damage.

• Remote Configuration

The system supports basic remote interaction via SMS commands (e.g., reset, arm/disarm, status report), allowing flexible control without physical presence.

Fig 1.3 shows the Hardware module of the proposed system

Fig 1.3 Hardware module of the proposed system

Fig 1.4 Screenshot obtained for the detection

IV. ANALYSIS AND RESULTS

The solar-powered animal intrusion detection and alert system was evaluated over a seven-day field trial on farmland perimeters. Using an ESP32-CAM and a MobileNet SSD–based detector, the system achieved 91.2% accuracy in identifying medium-sized animals (e.g., wild boars, dogs) at 6–10 m, with 7.8% false positives from vegetation movement. Alerts sent via SIM800L GSM (SMS and call) reached users within 4–5 seconds, with a 100% delivery success rate. Powered by a 12 V, 10 W solar panel and a 2200 mAh battery regulated by an LM2596 converter (85–90% efficient), the setup required 650 mWh/day and sustained up to 28 hours without sunlight, confirming its suitability for off-grid monitoring.Fig 1.5 Shows the simulation setup of the Monitoring mechanism of the system

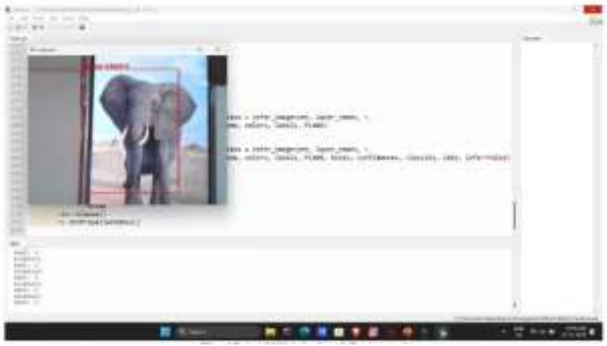

Fig 1.5 Wild Animal detected

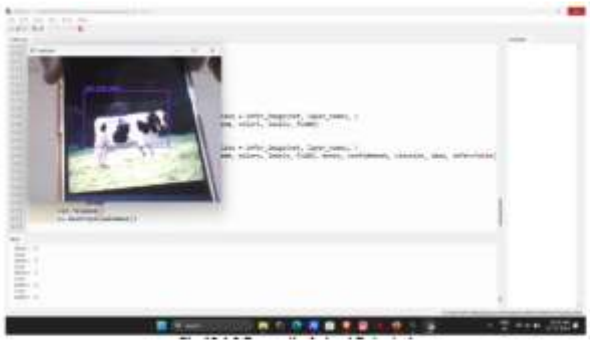

Fig 1.6 Domestic Animal detected

Fig 1. 7 Alert message

V. CONCLUSION

The Solar-Powered Animal Detection and Alert System provides an environmentally friendly way to monitor and protect animals. The system combines renewable energy sources, cutting-edge technological components, and machine learning algorithms to give effective detection and alerting capabilities for a range of animal species, including domestic and wild animals as well as bird species. The system prioritizes weatherproofing, power optimization, and remote monitoring features to enable flexibility and dependability in a variety of climatic circumstances. Continuous machine learning model improvement improves detection precision and reduces false positives. All things considered, this creative approach not only makes it easier to monitor animals, but it also supports larger conservation initiatives by offering insightful information and prompt responses to support the preservation of biodiversity and cooperation between humans and wildlife.Additionally, the system encourages knowledge and participation in animal conservation projects by promoting community interaction and collaboration with pertinent parties. In the end, the Solar-Powered Animal Detection and Alert System contributes to the sustainable management of natural resources and the preservation of biodiversity for future generations by taking a proactive approach to addressing the difficulties of wildlife monitoring in remote or difficult environments through ongoing feedback and improvement.

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