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# **FENCEXONIC 2.0 – Hybrid Wild Animal Intrusion Prevention and Alert System**

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**ABSTRACT:** Wild animal intrusion into agricultural fields poses significant challenges for rural communities, including substantial crop damage, financial losses, and safety risks. This paper presents FENCEXONIC 2.0, an intelligent wildlife monitoring system that combines AI-based image classification with a hybrid communication framework. The system employs PIR and ultrasonic sensors for motion detection and distance measurement, integrated with a servo-mounted ESP32-CAM for image capture upon intrusion detection. Captured images undergo cloud-based AI processing to classify detected objects as animals, humans, or non-living entities, effectively minimizing false alarms. To ensure reliable communication in remote areas with limited connectivity, the system implements a dual-mode alert mechanism: WiFi enables image transmission and AI processing, while a GSM module provides SMS notifications as a backup when internet connectivity is unavailable. The proposed solution demonstrates cost-effectiveness, scalability, and suitability for real-world deployment in agricultural and forest-fringe environments, enhancing both safety and response efficiency.

**KEYWORDS:** IoT, Wildlife Intrusion Detection, AI Classification, ESP32-CAM, Hybrid Communication, Rural Safety, Embedded Systems, Sensor Fusion \*

## **I. INTRODUCTION**

Villagers in rural and forest-fringe areas face frequent threats from wild animals such as elephants, boars, and monkeys, leading to crop destruction, property damage, and safety risks. Agriculture remains the primary source of livelihood for a large portion of the population in these regions. However, traditional methods like manual guarding and electric fencing are either expensive, unsafe, or ineffective in the long term. Manual surveillance exposes farmers to life-threatening risks, while electric fences require high maintenance and can harm both animals and humans. Chemical repellents lose effectiveness over time and raise environmental concerns. Thus, there is an urgent need for an intelligent, low-cost, and reliable system that can accurately detect animal intrusion, reduce false alarms, and provide real-time alerts even in areas with limited internet connectivity.

The recent advancement in the Internet of Things (IoT), Artificial Intelligence (AI), and embedded systems has opened new possibilities for addressing these issues through automation and smart monitoring. IoT-based solutions enable devices such as sensors and microcontrollers to collect and transmit data wirelessly, allowing real-time detection, notification, and control. Utilizing these technologies, FenXonic 2.0 offers an efficient and affordable way to monitor farmlands and detect animal movements automatically. The system employs PIR and ultrasonic sensors connected to an

ESP32-CAM microcontroller, along with a servo-based rotational scanning mechanism for wide-area coverage. The PIR sensor detects motion by sensing infrared radiation emitted by warm bodies, while the ultrasonic sensor measures the distance of the moving object. By combining both sensor readings, the system accurately identifies the presence of animals while filtering out false triggers caused by wind or small objects. When an intrusion is detected, the ESP32-CAM captures an image, which is then processed using cloud-based AI classification to differentiate between animals, humans, and non-living objects. The system activates a buzzer and LED for local alerts and simultaneously sends IoT-based notifications through WiFi when available. In areas with limited internet connectivity, a GSM module ensures reliable communication by sending SMS alerts as a backup. The system design emphasizes low power consumption, cost-effectiveness, and environmental friendliness, making it suitable for real-world agricultural deployment..

## II. LITERATURE SURVEY

The issue of wild animal intrusion into agricultural lands has been extensively studied, spanning mechanical deterrents to AI-based systems. Early approaches like electric fencing and chili/beehive fences showed initial success but suffered from high costs, maintenance challenges, and animal habituation.

Sensor-based systems addressed these limitations. Kumar et al. used PIR sensors but faced false alarms from wind and birds. Bhattacharjee and Sarmah improved accuracy through PIR-ultrasonic sensor fusion. IoT enabled real-time alerts, though Singh and Sharma encountered network latency issues. Recent AI/computer vision advances enabled species classification, but Mishra and Yadav noted high computational/internet requirements unsuitable for rural areas. Liu et al. emphasized low-power, non-lethal solutions with reliable communication. Kim et al. proposed WiFi-GSM hybrid frameworks.

FenXonic 2.0 addresses these gaps by combining multi-sensor detection, edge AI image verification, hybrid communication, and solar-powered design within an affordable, non-lethal framework.

## III. PROPOSED SYSTEM

FenXonic 2.0, is an AI-enabled wildlife intrusion detection system designed to provide accurate and reliable monitoring for agricultural areas. It integrates multiple sensing technologies, including a PIR sensor for motion detection and an ultrasonic sensor for distance measurement, to confirm the presence of an object and reduce false triggers.

The system is built around the ESP32-CAM module, which processes sensor data, controls a servo-based scanning mechanism, and captures images of the detected object. These images are analyzed using an AI-based classification model to identify whether the object is an animal, human, or non-living entity, thereby improving detection accuracy.

When an animal intrusion is confirmed, local alerts such as a buzzer and LED are activated to scare away animals and notify nearby farmers. Additionally, remote alerts are sent through WiFi, while a GSM module provides SMS notifications in areas with limited connectivity. The system uses sensor fusion combined with AI verification to ensure accurate detection and minimize false alarms.

### 3.1 System Modules

The proposed system consists of the following modules:

1. **Sensing Module** – The sensing module detects animal movement and sends signals to the system.
2. **Processing and AI Module** – The processing and AI module analyzes sensor data to identify animals and make intelligent decisions.
3. **Alert Module** – The alert module notifies users and triggers alarms when animal presence is detected.
4. **Power Supply Module** – The supply module provides stable power to all system components for continuous operation.

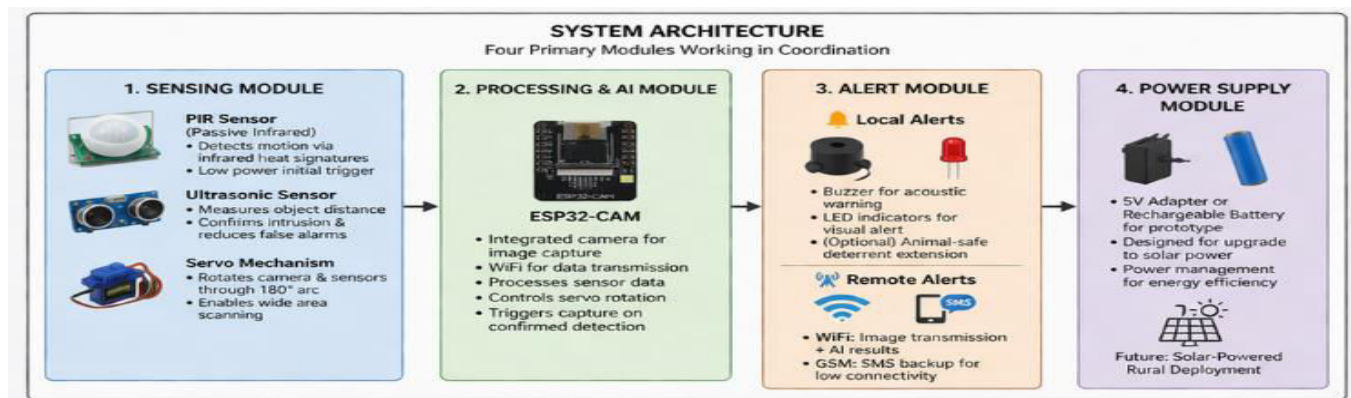
## IV. SYSTEM ARCHITECTURE

The system architecture of the AI-enabled Wildlife Intrusion Detection System is designed to prevent human-wildlife conflict by integrating sensing modules, processing and AI components, and alert mechanisms. The architecture

follows a modular approach where each component detects animal movement, analyzes data intelligently, and triggers timely alerts to ensure safety and protection.

#### 4.1 Sensing Module:

- a. **PIR Sensor (Passive Infrared):** Detects motion based on infrared heat signatures emitted by moving objects. Provides initial intrusion trigger with low power consumption.
- b. **Ultrasonic Sensor:** Measures object distance to confirm intrusion and reduce false alarms triggered by small animals or environmental factors.
- c. **Servo Mechanism:** Rotates the camera and sensors through a 180° arc, enabling comprehensive area scanning and increased coverage with a single sensor unit.



*FIG: System Architecture*

#### 4.2 Processing and AI Module:

**ESP32-CAM:** Functions as the central controller and image capture unit, featuring:

- Integrated camera for image capture
- WiFi capability for data transmission
- Processing capability for sensor data collection
- Control logic for servo rotation
- Trigger mechanism for image capture upon confirmed detection

#### 4.3 Alert Module:

##### a. Local Alerts:

- Buzzer activation for immediate acoustic warning
- LED indicators for visual alert to nearby villagers
- Provision for high-frequency animal-safe deterrent extension

##### b. Remote Alerts:

- WiFi-based image transmission with AI classification results
- GSM-based SMS backup for low-connectivity scenarios

#### 4.4 Power Supply Module:

- 5V adapter or rechargeable battery for prototype operation
- Designed for upgrade to solar-powered system for real-world rural deployment
- Power management features for energy efficiency

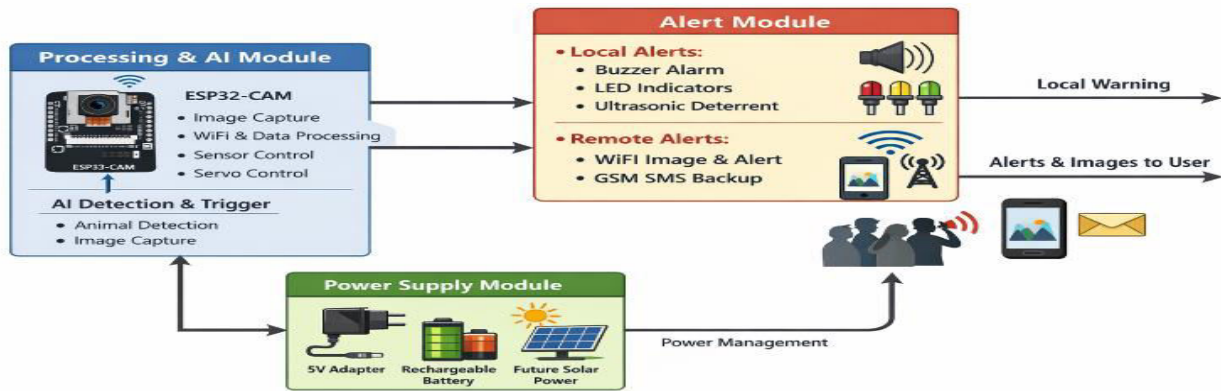


FIG: AI Processing Module

**B. Working Principle**

The system operates through a sequential detection and alert process:

- Initial Detection:** PIR sensor continuously monitors the area for motion. Upon detecting movement, the system activates the ultrasonic sensor.
- Distance Confirmation:** Ultrasonic sensor measures the distance to the detected object. If the object is within the predefined intrusion zone, the system proceeds to image capture.
- Image Acquisition:** The servo mechanism rotates the ESP32-CAM toward the detection direction, and the camera captures an image of the intruding object.
- AI Classification:** The captured image is transmitted via WiFi (when available) to cloud-based AI services for classification. The system identifies whether the object is an animal, human, or non-living entity.
- Decision Logic:** Sensor fusion (motion + distance) combined with AI classification results determines the appropriate response. Only confirmed animal intrusions trigger full alerts.
- Alert Generation:**
  - Local alerts (buzzer and LED) activate immediately
  - Remote notifications sent via available communication channels
  - WiFi preferred for image-based notifications
  - GSM SMS serves as backup for non-connectivity situations

**C. Key Features**

- Intelligent Detection:** Multi-sensor fusion reduces false alarms compared to single-sensor systems
- Hybrid Communication:** Dual-mode (WiFi + GSM) ensures reliable alert delivery
- AI-Based Verification:** Cloud-based classification improves detection accuracy
- Cost-Effective Design:** Utilizes affordable, off-the-shelf component.
- Scalable Architecture:** Can be deployed as single units or networked arrays
- Rural Suitability:** Designed for challenging environmental conditions



FIG: Key Features



*FIG: Deployment Scenario*

## V. METHODOLOGY

The proposed system is designed by combining hardware, software, and AI to create a smart surveillance solution that can detect, analyze, and respond to events in real time.

### 5.1 Hardware Implementation

- 1. ESP32-CAM Module:** The ESP32-CAM acts as the brain of the system, handling image capture, sensor coordination, and communication through built-in Wi-Fi.
- 2. Sensor Suite:** A PIR sensor is used to detect motion, while an ultrasonic sensor verifies how close an object is, helping reduce unnecessary false alarms.
- 3. Actuator & Indicators:** A small servo motor allows the system to scan different directions, while a buzzer and LEDs provide instant alerts and system status.
- 4. Communication Redundancy:** To ensure alerts are always delivered, a GSM module sends SMS notifications when Wi-Fi is not available.
- 5. Power Management:** The system uses a main power supply with battery backup, allowing it to continue working even during power cuts.

### 5.2 Software Implementation

- 1. Sensor Interface Layer:** The software continuously monitors sensor inputs and responds quickly when motion or proximity is detected.
- 2. Camera Control Module:** Images are captured only when needed, which helps save memory and improves overall efficiency.
- 3. Communication Protocols:** The system sends data to the cloud using Wi-Fi, and switches to GSM communication if the network fails.
- 4. Decision Logic & State Machine:** A simple state-based logic controls how the system moves from detection to alert, ensuring smooth operation.
- 5. Power Management:** To save energy, the system enters sleep mode when idle and wakes up automatically when activity is detected.

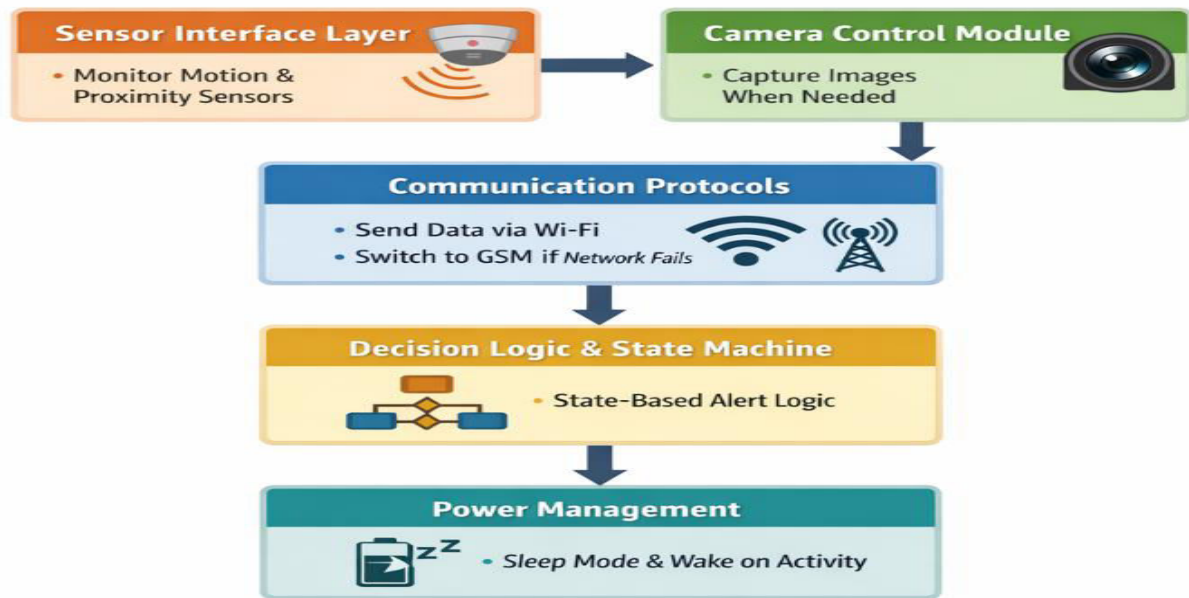


FIG: Methodology

### 5.3 AI Integration

1. **Cloud Architecture:** Captured images are sent to a cloud-based AI model that quickly identifies whether the object is a human, animal, or something harmless.
2. **Dataset & Training:** The model is trained on a large dataset of different images, helping it achieve high accuracy in real-world conditions.
3. **Inference & Decision Making:** Based on the AI result, the system decides how serious the situation is and triggers alerts accordingly.
4. **Fallback Mechanism:** If the internet is unavailable, the system still works using sensor data and sends alerts through SMS.
5. **Data Privacy & Security:** All data is securely transmitted, and images are automatically deleted after a short period to protect privacy.

## VI. IMPLEMENTATION

The FenXonic 2.0 system was developed by combining embedded hardware, cloud-based AI services, and a user-friendly mobile application to create an efficient and practical surveillance solution.

### 6.1) Hardware Setup

The prototype was built using simple yet effective components that work together to detect and respond to activity in real time. At the core, the ESP32-CAM handles image capture and communication through its built-in Wi-Fi.

To detect movement, a PIR sensor is used, while an ultrasonic sensor helps confirm how close an object is, improving accuracy. A small servo motor allows the system to rotate and monitor a wider area instead of staying fixed.

For alerts, a buzzer and LED provide immediate local indication, while the GSM module ensures messages can still be sent even when internet connectivity is unavailable. The system is powered using a 5V adapter during testing, with the option to integrate solar power for real-world deployment.

### 6.2) Software Implementation

The software side was developed to ensure smooth interaction between all components and reliable performance.

- 1) **ESP32-CAM Firmware:** The firmware was written using the Arduino IDE, where sensor readings, image capture, servo movement, and communication were all managed in a coordinated way using relevant libraries.
- 2) **AI Integration:** Captured images are sent to a cloud-based AI service, which analyzes them and returns labels with confidence scores. The system considers detections valid when confidence exceeds a set threshold, helping reduce false alerts.
- 3) **Mobile Application:** A mobile app built using the Blynk platform allows users to receive notifications along with images and detection results. It also supports multiple users, making it useful for both farmers and officials.
- 4) **GSM Communication:** In cases where Wi-Fi is unavailable, the GSM module sends SMS alerts with basic details like location and time, ensuring the user is always informed.

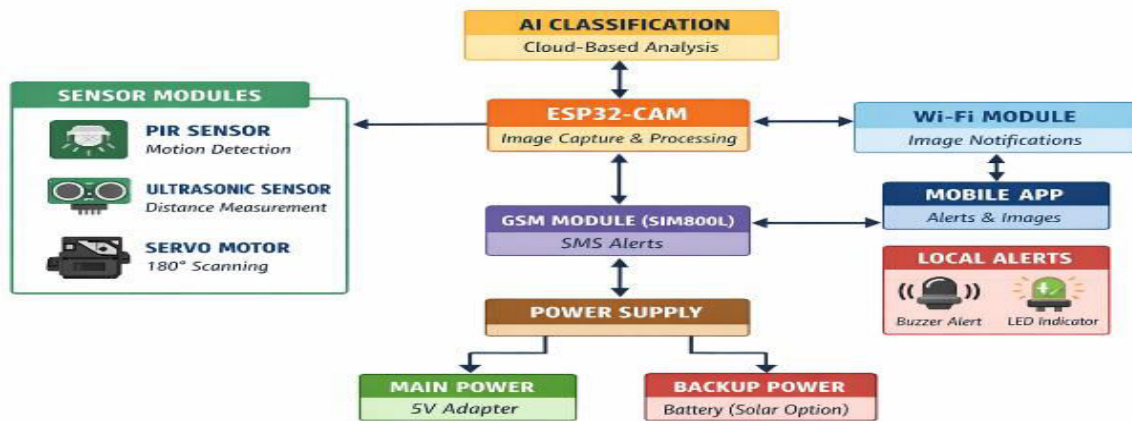


FIG: Software Implementation

### 6.3) System Deployment

The system is designed to be practical and easy to install in real-world environments like farms. It is typically mounted on a pole at a height of around 2–3 meters to get better coverage. With the help of the rotating servo, it can scan a wide area instead of focusing on a single direction. For remote locations, solar power can be used to keep the system running continuously. Additionally, multiple units can be deployed together to cover larger areas, making the system scalable and suitable for wide agricultural field.

## VII. RESULTS

### A. System Performance

The prototype performed reliably across all its components during testing.

**Detection Accuracy:** The PIR sensor was able to consistently detect motion within its expected range, while the ultrasonic sensor helped confirm how close the object was. The servo mechanism also worked smoothly, allowing the system to scan a wide 180° area in small steps.

**AI Classification:** The AI model was able to correctly identify whether the detected object was a human, animal, or something else. This significantly reduced false alarms compared to using sensors alone. The classification process typically took around 3–5 seconds.

**Alert Delivery:** Local alerts like the buzzer and LED were triggered almost instantly after detection. Notifications sent over Wi-Fi, including images, reached users within a few seconds, while SMS alerts via GSM acted as a reliable backup when internet was unavailable.

**B. Comparative Analysis**

When compared to traditional systems, FenXonic 2.0 shows clear improvements.

The use of AI helps in reducing false alarms by a large margin, making the system more dependable. It is also much more cost-effective than conventional CCTV-based solutions, while still providing intelligent monitoring.

Additionally, the combination of Wi-Fi and GSM ensures that alerts are always delivered, and the rotating mechanism allows a single unit to cover a wider area efficiently.

**C. Limitations and Challenges**

While the system performed well overall, a few practical challenges were observed. The AI system depends on internet connectivity for best performance, which can be a limitation in remote areas. The GSM module, although useful, consumes more power when active.

Also, image quality can drop in low-light conditions, and in some cases, animals blending into the environment may make detection slightly more difficult.

**VIII. CONCLUSION**

The proposed AI-enabled wildlife intrusion detection system provides an intelligent and cost-effective solution to reduce human-wildlife conflict in rural and agricultural areas. By integrating PIR and ultrasonic sensors with a servo-based scanning mechanism and ESP32-CAM, the system ensures accurate detection and image-based verification. The use of AI classification minimizes false alarms, while the hybrid communication model (WiFi + GSM) guarantees reliable alert delivery even in low-connectivity regions. Compared to traditional methods such as electric fencing and manual surveillance, the system offers improved safety, efficiency, and scalability. Overall, the project demonstrates a practical, non-harmful, and deployable solution suitable for real-world agricultural and forest-fringe environments.

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