AI-Driven Animal Intrusion Detection System for Agriculture: Real-Time Monitoring and Automated Response Using Deep Learning

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Abstract: **The AI-Driven Animal Intrusion Detection System is an advanced solution designed to monitor agricultural fields, detect animal intrusions in real-time, and trigger automated deterrents. This system helps protect crops, reduce manual surveillance efforts, and enhance field security using deep learning and IoT technology.**

The system utilizes an ESP32 microcontroller as the central processing unit, interfacing with an ESP32-CAM module for live video streaming, a pre-trained MobileNetSSD model for real-time animal detection, and Firebase for cloud-based monitoring.

The ESP32-CAM captures continuous video footage of the agricultural field, and the MobileNetSSD model processes frames to detect animals such as cows, horses, birds, and other intruding species. The detection results are sent to Firebase, allowing remote monitoring and data logging.

When an animal is detected, the system triggers an LED strip and buzzer as deterrents. If no intrusion is detected, the alerts remain off to conserve power. The ESP32 microcontroller retrieves data from Firebase, ensuring a seamless real-time monitoring process.

The system is programmed using Python and Arduino, enabling low-latency, high-efficiency processing. A local web server facilitates wireless communication and remote access. By integrating AI-driven detection, real-time alerts, and automated deterrence, this solution enhances agricultural field management, reducing crop damage and improving security.

Keywords: **ESP32-CAM_Module, ESP32-Micro Controller, AI- Driven Detection, Real-Time Alert System ,**

I.INTRODUCTION

The AI-Driven Animal Intrusion Detection System is a cutting-edge solution designed to protect agricultural fields from animal intrusions, minimizing crop damage and reducing the need for manual surveillance. By integrating ESP32-CAM, deep learning models, and IoT technology, the system ensures real-time monitoring and automated deterrence mechanisms.

The ESP32-CAM module, equipped with a pre-trained MobileNetSSD model, captures live video footage of the farmland. Using AI-powered object detection, the system identifies animals such as cows, horses, birds, and other intruding species. The processed data is sent to Firebase, enabling remote monitoring and real-time logging of intrusion events. For immediate response, the ESP32 microcontroller retrieves detection results from Firebase and triggers automated deterrents. If an animal is detected, an LED strip and buzzer are activated to scare away the intruder.

If no threat is present, the system remains in standby mode to conserve energy.
The system operates in real time with minimal latency, ensuring accurate and efficient animal detection. A web server hosted on the ESP32 microcontroller allows wireless communication and remote access. The hardware also includes WiFi connectivity for seamless data transmission and real-time field monitoring.

By combining AI-driven video processing, cloud-based data management, and automated deterrent activation, this intelligent system offers a robust and scalable approach to protecting agricultural lands. The use of Python and Arduino programming enables flexible deployment, making it suitable for various farm sizes and environments.

II.LITERATURE SURVEY

Leela V., Amirtha G., Jai Sree K.S., Harrish A.S., Govarthini M. (2024). *Animal Intrusion Detection*

System in Agriculture Using Deep Learning. Proceedings of the 2024 13th International Conference on System Modeling & Advancement in Research Trends (SMART).This paper presents a deep learning-based animal intrusion detection system designed to protect agricultural fields from damage caused by stray animals. The proposed system integrates a Wireless Sensor Network (WSN) with a YOLOv5-based image processing module to enhance detection accuracy. The implementation leverages Google Colab for scalable model training and deployment. By processing real-time image data, the YOLOv5 model effectively identifies and classifies intruding animals with high precision. Additionally, the WSN facilitates instant data transmission, enabling immediate preventive measures to be taken. Experimental results demonstrate that the system outperforms conventional intrusion detection methods in terms of speed and accuracy, making it a reliable solution for modern agricultural security.

S. R. Kolte and K. D. Kulat (2023). *Animal Intrusion Detection System for Agriculture Field Using WSN.* Proceedings of the International Conference on Computing Communication and Automation (ICCCA), 2023.This paper proposes an animal intrusion detection system for agricultural fields utilizing Wireless Sensor Networks (WSN) to prevent damage caused by stray animals. The system employs a network of sensors to detect movement and classify intrusions based on predefined parameters. By leveraging real-time data transmission, the system enables immediate alerts and automated countermeasures to safeguard crops.
Experimental evaluations highlight the system's efficiency in detecting intrusions with minimal false alarms, demonstrating its effectiveness as a proactive agricultural security solution.

R. K. Patel et al. (2023). *An IoT-Based Animal Intrusion Detection System for Agricultural Land.* Proceedings of the 2023 5th International Conference on Computing Methodologies and Communication (ICCMC), pp. 354- 359.This paper presents an IoT-based animal intrusion detection system designed to enhance the security of agricultural lands by preventing crop damage caused by stray animals. The system integrates a network of IoT- enabled sensors and cameras to detect animal presence and transmit real-time alerts to farmers. The proposed approach leverages machine learning techniques to classify detected animals and trigger appropriate countermeasures. Experimental results indicate that the system provides high detection accuracy and efficient real-time monitoring, making it a reliable solution for smart agricultural security..

III. DESIGN OF HARDWARE

Microcontroller: ESP32 microcontroller
An antenna for Wi-Fi and Bluetooth signals, A voltage regulator to safely convert input power to 3.3V.The ESP- WROOM-32 module housing the ESP32 chip and memory. A boot button to enable programming mode. USB input for power and programming, And a CP2102 chip for USB-to-serial communication with a computer

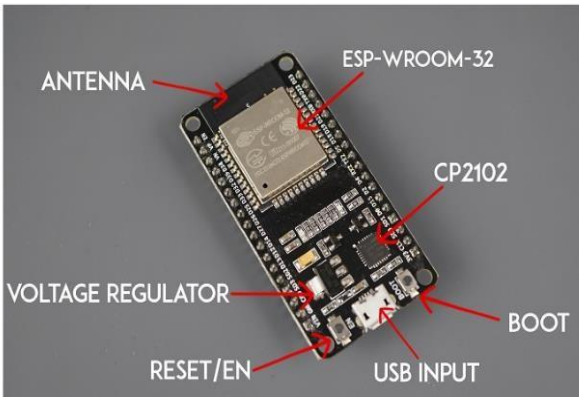
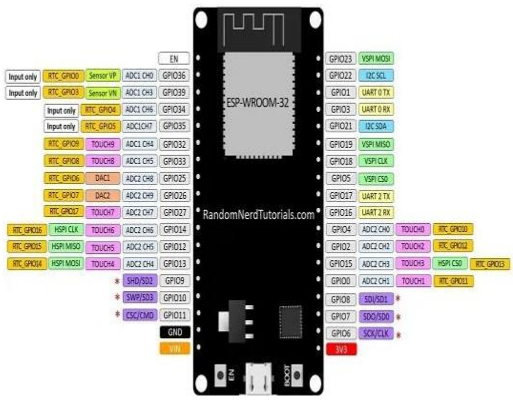


Fig: ESP-micro controller

ESP32 GPIOs Pinout:
The ESP32 chip has 48 pins, each with multiple functions, though not all are exposed on every development board. The popular ESP32 DEVKIT V1 DOIT board typically has 36 usable GPIO pins for connecting peripherals. These pins can be used for various purposes like reading sensor data, controlling motors, or communicating with other devices.



Each ESP32 board includes power pins like 3V3, GND, and VIN for powering the board or other devices. GPIO pins are referred to by their assigned numbers, and with the ESP32's multiplexing feature, any pin can be configured as UART, I2C, or SPI by specifying it in the code. This flexibility allows developers to optimize their designs by assigning functions as needed. Default pin configurations may vary by board manufacturer, but generally, each GPIO retains consistent functionality across models. For example, GPIO5 is often the VSPI CS0 pin, and GPIO23 is the VSPI MOSI pin for SPI communication. Additionally, some GPIOs have specialized functions, such as PWM, ADC, or DAC capabilities, making them suitable for specific tasks like signal generation or analog input/output.

It's important to refer to the specific pinout diagram for your development board to ensure proper usage and avoid conflicts, as some pins may be dedicated to specific functions like booting or flashing the device. Additionally, some pins on the ESP32 are input-only, output-only, or have specific limitations (like those used for touch sensing or external interrupts). Therefore, careful selection of GPIOs can help maximize the performance and functionality of your project.

To Scan People: ESP32 – Camera (Camera + Microcontroller):
The ESP32-CAM module is a low-cost, full-featured microcontroller based on the ESP32-S chip. It integrates a small OV2640 camera module, multiple GPIOs for peripheral connections, and a microSD card slot for storing images or files. The module supports Bluetooth, WiFi, and BLE Beacon and is powered by two 32-bit LX6 CPUs with a frequency range of 80MHz to 240MHz. It features a stage pipeline architecture, a Hall sensor, an on- chip sensor, and a temperature sensor.

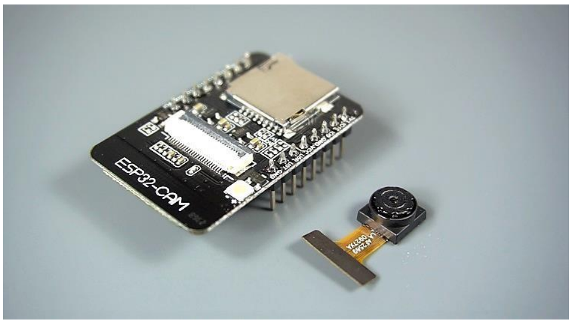
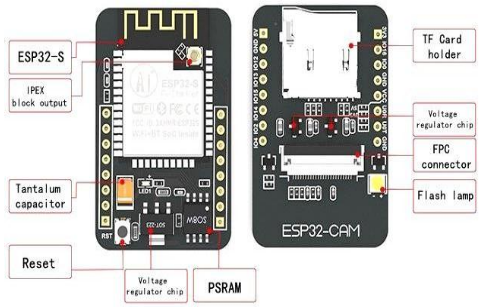
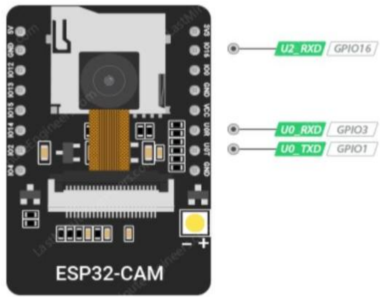


Fig: ESP32- camara

ESP32-S:MODULE



ESP32 CAM Pin Configuration:
The ESP32-S chip originally has 32 GPIO pins, but due to internal usage for the camera and PSRAM, the ESP32- CAM provides only 10 GPIO pins for external use. These pins can be programmed for different functions, like UART, SPI, ADC, and Touch, based on the application.



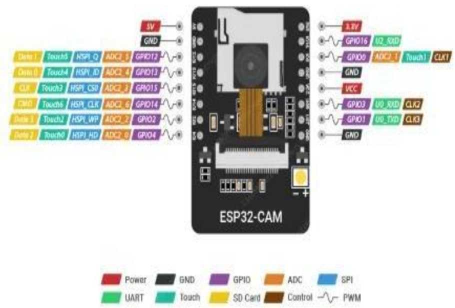
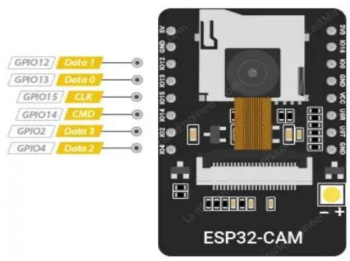


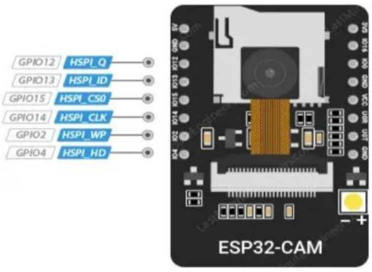
Fig: ESP32 CAM Pin configuration

MicroSD Card Pins:
The general GPIO for other input/output tasks Fig: DS18b20 temperature sensor



SPI Pins:
The ESP32-CAM features only one SPI (VSPI) in slave and master modes.
It also supports the general-purpose SPI features listed below:

- 4 timing modes of the SPI format transfer
- Up to 80 MHz and the divided clocks of 80 MHz
- Up to 64-Byte FIFO



UART Pins:

The ESP32-S chip actually has two UART interfaces, UART0 and UART2. However, only the RX pin (GPIO 16) of UART2 is broken out, making UART0 the only usable UART on the ESP32-CAM (GPIO 1 and GPIO 3). Additionally, because the ESP32-CAM lacks a USB port, these pins must be used for both flashing the device and connecting to UART devices such

WS2812 LED:

The WS2812 is a popular model of individually addressable RGB LED, used widely in various lighting applications. Each LED in the series can be controlled independently, allowing for dynamic color changes and effects. Each WS2812 LED contains a red, green, and blue (RGB) LED in one package, which can produce a full spectrum of colors by adjusting the brightness of each LED. Uses a single-wire data protocol (unidirectional) for communication, allowing multiple LEDs to be chained together. The WS2812 is power-efficient, drawing minimal power, especially when showing colors with low brightness.

It includes the necessary internal circuitry for PWM (Pulse Width Modulation) dimming, which enables smooth color changes. Typically 5V, making it compatible with standard power supplies and microcontrollers. Can be controlled by a range of microcontrollers (such as Arduino, ESP32, Raspberry Pi) using libraries designed for easy integration.

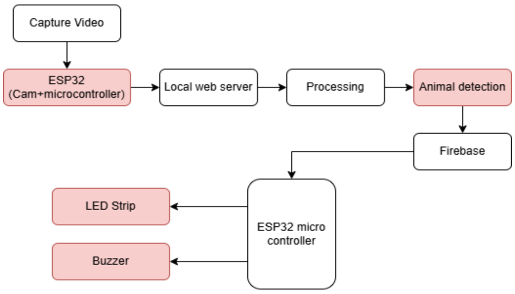
Fig: WS2812 LED

Project Description:

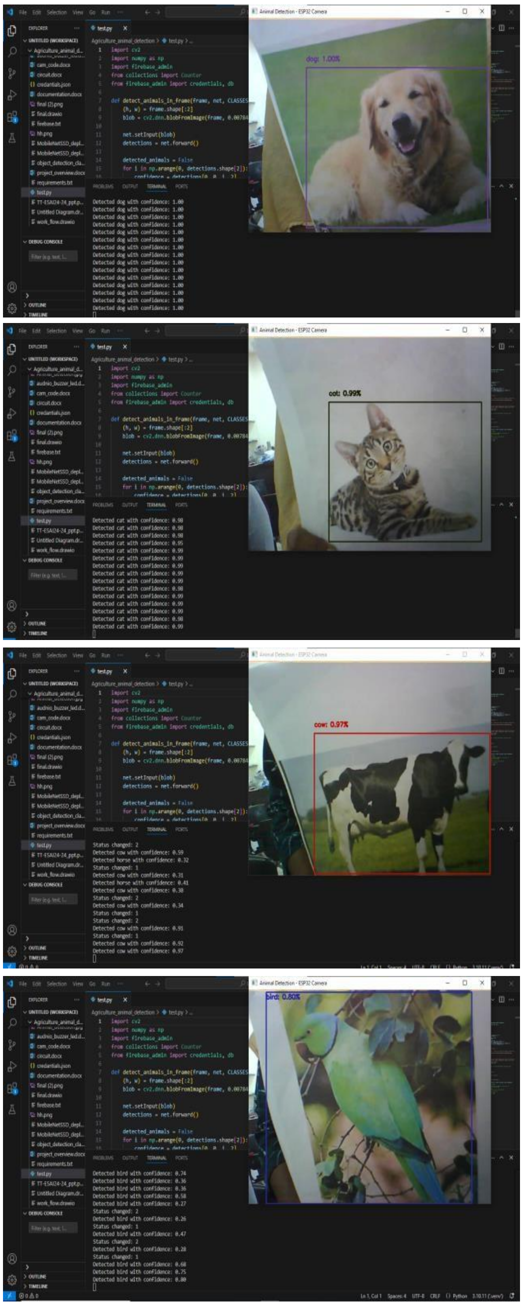
This Chapter Deals With Working AI-Driven Animal Intrutuion Detection System In Agriculture Fields It Can Be Simply Understood By Its Block Diagram & Circute Diagram

Block Diagram:

ESP32 Microcontroller, ESP32 Camera , ESP32 Buzzer, ESP32 LED.



RESULT



CONCLUSION

The AI-Driven Animal Intrusion Detection System for Agriculture is a smart solution designed to protect crops and resources by providing real-time monitoring and automated responses to animal intrusions. Using ESP32 microcontrollers, ESP32 cameras, and deep learning, the system detects animals in agricultural fields and triggers immediate deterrent actions, such as activating LEDs and buzzers.

The system captures live video with ESP32-CAM modules, analyzes each frame to identify animals, and sends updates to Firebase for event logging. If an animal is detected, the system responds instantly; if not, it conserves power by turning off deterrents. This automated approach reduces the need for manual intervention, saving time and effort.

The system is scalable, allowing for the addition of more modules to cover larger areas, and is ideal for farms of various sizes. By automating animal intrusion detection and response, it enhances crop protection, reduces damage, and offers a cost-effective solution for modern agriculture, contributing to more efficient and sustainable farming.

FUTURE WORK

Model Enhancement:

Integrate real-time environmental data (weather, field activity) to improve animal detection accuracy. Machine learning will help the system adapt and differentiate between animals and non-animal movements, optimizing response times and deterrent activation.

Real-Time Integration and Scalability:

Combine AI video analysis with sensor data for precise location-based alerts. Cloud integration enables remote monitoring and scalability, allowing farmers to manage large areas efficiently from a central platform.

Industry Collaboration and Continuous Improvement:

Partner with agricultural tech providers and agencies to integrate the system into broader management platforms. Real-time data sharing and feedback will ensure continuous system optimization, enhancing crop protection and sustainability.

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