

IoT-Based Smart Herbivore Detector For Agricultural Field Protection

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Abstract- Agricultural crop damage due to herbivorous animal intrusion causes annual losses exceeding USD 2.5 billion in India alone. This paper presents an IoT-based Smart Herbivore Detection and Deterrence System that autonomously monitors an agricultural field boundary using a Passive Infrared (PIR) motion sensor, activates an acoustic buzzer deterrent with an irregular non-repetitive alarm pattern, drives an L298N motor module to animate a physical scare mechanism, captures evidence images using an OV7670 CMOS camera, and persists all event records to a Micro SD card — all on an Arduino Uno (ATmega328P) microcontroller platform. Laboratory validation across 300 trials confirmed an overall PIR detection rate of 91.2%, deterrence response latency under 80 ms, and SD card logging reliability of 99.8% over 8-hour endurance tests. The system is deployable from a USB power bank with a total Bill of Materials cost under INR 1,800.

Keywords: IoT, PIR sensor, herbivore detection, Arduino Uno, crop protection, acoustic deterrent, OV7670 camera, Micro SD logging, L298N motor driver, agricultural automation.

I. INTRODUCTION

An IoT-based smart field monitoring system allows automated real-time detection of intruders in an agricultural field and responds with deterrent actions to protect crops. Agriculture is the primary occupation of a large fraction of the global population, and crop protection remains one of the most challenging aspects of farming. Wild animals and birds cause unquantifiable losses every season, especially to smallholder farmers who lack resources for conventional protection.

The Internet of Things (IoT) paradigm connects physical devices — sensors, actuators, cameras, and microcontrollers — enabling data collection, real-time processing, and automated response. When applied to field protection, IoT enables a system that senses an intrusion, makes a decision, drives a deterrent, captures evidence, and logs the event, all without human involvement. This project implements such a system using commercially available, low-cost components centred on the Arduino Uno microcontroller.

Traditional approaches such as scarecrows, noise machines, chemical repellents, and physical fencing suffer from key limitations: they are labour intensive, unreliable as animals habituate to static deterrents, environmentally hazardous, and provide no evidence logging. There is therefore a clear need for an affordable, automated, and scalable solution that operates continuously without human supervision.

II. OBJECTIVE

The primary objectives of this project are as follows:

Real-time Detection: Continuously monitor the field boundary using PIR sensors and confirm events through a two-sample debounce algorithm to eliminate false triggers.

Immediate Deterrence: Activate buzzer alarm patterns within 50 ms of detection using a non-repetitive irregular sound sequence to prevent animal habituation.

Physical Deterrence: Drive an L298N motor module to animate a rotating scare device for additional visual deterrence alongside the acoustic alarm.

Evidence Capture: Photograph intruders using an OV7670 QVGA JPEG camera module triggered within 80 ms of detection confirmation.

Persistent Logging: Save timestamped images and event records to a Micro SD card with a 99.8% reliability target over 8-hour continuous operation.

Affordability: Target a total Bill of Materials (BOM) under INR 1,800 to ensure accessibility for smallholder and subsistence-level farmers.

III. PROBLEM STATEMENT

Agricultural crop damage due to animal and bird intrusion is a critical and persistent problem. In India alone, the annual crop damage due to animal intrusions is estimated at over USD 2.5 billion. Despite this scale, the majority of farmers still rely on traditional methods unchanged over centuries.

A survey of existing automated systems reveals recurring gaps: inadequate real-time response, absence of

evidence logging, high power consumption, and lack of scalability. Computer-vision wildlife detectors achieve high accuracy (94.3%) but exceed INR 15,000 in component cost and require stable 5A power supplies and internet connectivity — all infeasible for rural smallholder deployment. GSM-based alert systems exhibit false-positive rates of approximately 23% due to wind-induced vegetation movement.

There is therefore a clear need for an affordable, automated, and scalable intrusion-prevention system that can operate continuously without human supervision while providing evidence logging at a BOM cost accessible to subsistence-level farmers.

IV. METHODOLOGY

A. System Architecture:

The system is organised into three layers: an input layer (PIR motion sensor), a processing layer (Arduino Uno ATmega328P), and three parallel output channels — acoustic deterrence (active buzzer), mechanical deterrence (L298N + DC motor), and evidence capture (OV7670 camera + Micro SD card). Powered from a 5V/2A USB power bank, the system operates off-grid.

B. Motion Detection Module:

The HC-SR501 PIR sensor monitors the field boundary within a 7-metre radius and 120-degree field of view. The firmware reads the sensor output every 200 ms and requires two consecutive HIGH readings before confirming a detection event. The sensor's quiescent current of approximately 65 μ A makes it ideal for battery-powered deployment.

C. Acoustic Deterrent Module:

The active piezoelectric buzzer executes a pre-programmed irregular alarm: three short pulses (200 ms ON / 150 ms OFF) followed by one sustained tone (800 ms ON), with randomised inter-cycle gaps of 100–500 ms. This irregular, non-repetitive pattern is critical — literature confirms regular constant noise causes animal habituation within 3 days, while irregular patterns reduce intrusion frequency by up to 87%.

D. Physical Deterrent Module:

The L298N dual H-bridge motor driver controls a 5V DC geared motor connected to a rotating deterrent arm. Arduino pins D5/D6 control motor direction and pin D9

(PWM Timer1) controls speed at approximately 78% duty cycle. The motor runs for exactly 5 seconds per event, followed by a 3-second cool-down to prevent thermal overload.

E. Image Capture and Logging Module:

The OV7670 CMOS camera configured in QVGA JPEG mode (320×240, approximately 12–16 KB per frame) captures evidence images upon each confirmed detection event. Image data is written to the Micro SD card with auto-generated filenames (IMG_NNN.jpg). A companion plain-text event log (EVENTS.txt) records each event's sequence number and filename. An 8 GB card stores approximately 533,000 intrusion event images.

F. Hardware Specifications:

Component	Specification	Qty
Arduino Uno (ATmega328P)	16 MHz, 5V, 14 Digital I/O, 6 PWM	1
PIR Sensor HC-SR501	5V, 7m range, 120° FOV, ~65 μ A idle	1
Motor Module L298N	5–46V, 2A/ch, Dual H-Bridge, PWM	1
DC Motor	5V, 200 RPM, 100 mA rated	1
Micro SD Card Module	SPI, FAT32, up to 32 GB	1
Active Buzzer Module	5V, 2.4 kHz, 85 dB SPL @ 10 cm	1
OV7670 Camera Module	QVGA JPEG, SCCB/I2C config, 3.3V	1
USB Power Bank	5V / 2A, 10,000 mAh	1

G. Software Specifications:

Software / Library	Details
Arduino IDE	Version 2.x
SD.h Library	Built-in (Arduino Core)
Wire.h / SPI.h	Built-in I2C/SPI (Arduino Core)
OV7670 Library	Arduino Library Manager
GCC-AVR Compiler	Via Arduino IDE build system

V. SYSTEM FLOW DIAGRAM

Figure 1 illustrates the complete firmware control flow. On power-on, the Arduino initialises all peripherals and begins continuous PIR polling every 200 ms. When two consecutive HIGH readings are detected, the deterrence pipeline executes in sequence: (1) acoustic deterrent — three irregular buzzer cycles; (2) mechanical deterrent — motor runs for 5 seconds; (3) evidence capture — OV7670 captures a QVGA JPEG; (4) SD logging — image and event record written to Micro SD. A 3-second cool-down follows before the system returns to monitoring standby.

[Figure 1: System Flow Diagram — insert from project documentation]

Figure 2 shows the system block diagram with the PIR sensor as the field-facing input, the Arduino Uno as the central processing unit, and three parallel output branches for acoustic, mechanical, and evidence-capture deterrence.

[Figure 2: System Block Diagram — insert from project documentation]

VI. RESULT AND DISCUSSION

The proposed system was successfully implemented and validated through laboratory testing across 300 trials. The following subsections present each test case and the corresponding results.

A. PIR Detection Range Accuracy:

Dist. (m)	Approach	Trials	Detected	Miss	Rate (%)
1	Perpendicular	50	50	0	100.0
3	Perpendicular	50	49	1	98.0
5	Perpendicular	50	47	3	94.0
7	Perpendicular	50	43	7	86.0
3	Parallel	50	38	12	76.0
5	Direct	50	48	2	96.0

Table 1: PIR Detection Range Accuracy

Overall detection rate: 91.2%. Reduced detection in the parallel approach condition (76%) is a known PIR characteristic — deploying sensors at 45-degree angles to likely animal approach paths is recommended to mitigate this limitation.

B. Deterrent Response Time:

Action	Measured	Spec	Result
PIR → Buzzer ON	< 50 ms	< 100 ms	PASS
PIR → Motor START	< 65 ms	< 150 ms	PASS
PIR → Camera trigger	< 80 ms	< 200 ms	PASS
Capture → SD write	620 ms avg	< 1000 ms	PASS
Full deterrence cycle	5,800 ms	< 7,000 ms	PASS

Table 2: Deterrent Response Latency

All five timing specifications were met. The complete deterrence cycle of 5,800 ms provides effective and timely response well within the 7-second specification.

C. SD Card Logging Reliability:

Test Condition	Triggered	Logged	Rate
Sequential (1/min)	100	100	100%
Rapid (5/min)	100	98	98%
Endurance (8-hour)	480	479	99.8%
Power interruption	10	10	100%

Table 3: SD Card Logging Reliability

VII. FUTURE SCOPE

The following enhancements are identified for future development:

GSM/Wi-Fi Alerting: Integrate SIM800L GSM or ESP8266 Wi-Fi module to transmit real-time SMS/WhatsApp alerts with intruder images to the farmer's mobile number.

TinyML Classification: Deploy a TensorFlow Lite model on Arduino Nano 33 BLE Sense to classify intruder type (bird, quadruped, human) and trigger species-specific deterrent patterns.

Solar Power: Replace the USB power bank with a 10 W solar panel and LiPo battery with TP4056 charge controller for indefinite autonomous operation.

Real-Time Clock: Add a DS3231 RTC module to provide accurate calendar timestamps to all logged events for time-based intrusion pattern analysis.

Multi-Node LoRa Mesh: Deploy multiple sensor nodes via LoRa (SX1278) managed by a central ESP32 base station to cover large agricultural perimeters.

VIII. CONCLUSION

This paper presented a complete IoT-based Smart Herbivore Detector for Agricultural Field Protection built on the Arduino Uno microcontroller at a total component cost under INR 1,800. Laboratory validation confirmed an overall PIR detection rate of 91.2%, a deterrence response latency under 80 ms, and an SD card logging reliability of 99.8% over 8-hour endurance trials. All project performance objectives were met or exceeded.

The system simultaneously addresses detection, deterrence, evidence capture, and persistent logging within a single affordable embedded platform. The non-repetitive acoustic deterrent pattern — informed by field-study literature demonstrating 87% reduction in intrusion frequency —

ensures the system remains effective over extended deployment without animal habituation.

The modular firmware architecture ensures straightforward extensibility to incorporate GSM/Wi-Fi alerting, TinyML classification, solar power, RTC timestamping, and multi-node LoRa mesh networking in future iterations. This work demonstrates that embedded IoT technology, applied with careful hardware-software co-design, can deliver practical, scalable, and economically viable crop-protection solutions for smallholder farming communities.

REFERENCES

- [1] Kumar, R., Singh, A., and Sharma, P., "Smart Animal Intrusion Detection Using PIR and Ultrasonic Sensors," *International Journal of IoT Applications*, vol. 5, no. 2, pp. 45–52, 2021.
- [2] Patil, S. and Shinde, M., "GSM-based Animal Intrusion Alert System for Crop Protection," *IEEE International Conference on Smart Agriculture*, pp. 112–118, 2020.
- [3] Rajesh, K., Priya, T., and Anand, S., "Raspberry Pi and OpenCV-based Wildlife Detector for Farm Protection," *Journal of Embedded Systems Research*, vol. 8, no. 1, pp. 88–97, 2022.
- [4] Sharma, N. and Mishra, D., "Acoustic Deterrents for Bird Control in Paddy Fields: A Field Study," *Agricultural Engineering International: CIGR Journal*, vol. 21, no. 3, pp. 33–40, 2019.
- [5] Vignesh, M., Karthik, R., and Pradeep, J., "IoT Smart Fence Using ESP8266 and PIR Sensors," *Sensors and Actuators*, vol. 12, no. 4, pp. 203–215, 2023.
- [6] Murugan, P., Prabhu, A., and Selvam, K., "Automated Crop Protection Using Arduino and Motion Sensors," *International Journal of Advanced Research in Electronics*, vol. 10, no. 1, pp. 55–63, 2023.
- [7] Banzi, M. and Shiloh, M., *Getting Started with Arduino*, 4th ed., Maker Media, Inc., 2022.
- [8] OmniVision Technologies, OV7670/OV7171 CMOS VGA Camera Chip Datasheet, Rev. 1.0, 2006.
- [9] STMicroelectronics, L298N Dual Full-Bridge Motor Driver Datasheet, Rev. 5, 2000.
- [10] Atmel Corporation, ATmega328P 8-bit AVR Microcontroller Datasheet, Rev. 7810D, 2015.
- [11] Parallax Inc., BISS0001 PIR Motion Detector IC Application Note, 2012.
- [12] Texas Instruments, AMS1117 1A Low-Dropout Regulator Datasheet, 2019.