

Development of an AI-Integrated IoT System for Bird Detection and Repelling in Farmlands

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Abstract- Bird-related crop damage presents a persistent and significant challenge for farmers, particularly those cultivating small plots in developing regions. This study introduces and evaluates an AI-enhanced Internet of Things (IoT) system designed to detect and repel birds from farmland. The system integrates a Passive Infrared (PIR) motion sensor, an Arduino microcontroller, a GSM module, an LED indicator, and an LCD to enable real-time field monitoring and alert farmers via SMS and voice calls when it detects bird activity. Field trials conducted at ten sites in Gombe State, Nigeria, demonstrated 90% motion-detection accuracy, effectively distinguishing genuine bird intrusions from non-threatening environmental movements. The system correctly identified motion in eight of ten tests, with the alarm triggering as intended in seven cases, improving on the 87% detection rate reported by Pendhari et al. (2020). The system's consistent performance, prompt alerting, and operational stability indicate its suitability for deployment in diverse agricultural contexts. Future work will focus on adding power backup, refining detection algorithms to minimize false alarms, extending field trial durations, and integrating advanced artificial intelligence and machine learning techniques to further improve accuracy and adaptability.

Keywords: Passive Infrared Sensor, Light Emitting Diode, Liquid Crystal Display, Internet of Things (IoT), Bird Repelling System, Smart Agriculture

I. INTRODUCTION

One of the greatest and most pressing challenges farmers face in Nigeria and across Sub-Saharan Africa is bird-related crop damage. Agriculture is the predominant employer of labour and the primary source of livelihood for a large share of Nigeria's rural population, and it underpins the national economy. In agriculture, cereal crop (maize, wheat, rice, etc.) production is adversely affected by avian activity, especially during the harvest period, when large flocks of birds converge to consume cereal grains in the field

in a very short time. This can reduce yields or, in many cases, cause complete failure (Hippolyte et al., 2022). Some bird species known for destroying cereal crops include sparrows, pigeons, and crows (Hippolyte et al., 2022).

Historical attempts to prevent crop damage from birds have ranged from scarecrows and noisemakers to visual deterrents such as ribbons or flash devices, netting, and barriers. Studies show that habituation to stationary stimuli (such as scarecrows and noisemakers) is high, and these deterrents lose effectiveness over time (Pendhari et al., 2020). Netting and other physical barriers are usually applicable at a small scale and are prohibitively expensive to apply in large-scale farming. Furthermore, these methods require constant human observation, which is time-consuming and inefficient (Eduardo et al., 2023). Harvest losses can be as high as 15%-50% of yield and can significantly harm the agricultural industry (Pendhari et al., 2020).

The Internet of Things (IoT) is defined as the interconnection of multiple network-enabled devices that interact and communicate with each other in the natural environment (Praveen et al., 2020). The IoT influences precision agriculture by using interconnected devices such as sensors, actuators, and communication modules to enable continuous monitoring and control actions based on environmental conditions. In bird deterrence systems, IoT helps by continually surveying the area, detecting bird movement patterns, and applying a variety of stimuli to create randomness so habituation does not develop (Praveen et al., 2020). A GSM module for SMS and call notifications can further enhance the application, allowing it to operate regardless of the farmer's proximity to the field. Hence, this work will focus on the design, development and evaluation of an

enhanced IoT-based Bird Detecting and Deterrent System for agricultural farmlands, using an Arduino microcontroller, a PIR motion sensor and GSM-based real-time notifications, to serve as a significant contribution to Smart Agricultural Systems and as a feasible, extendable, and economical means to tackle the problem that has a significant impact on agricultural productivity and Nigerian farmers' livelihoods.

II. LITERATURE REVIEW

The interplay between agricultural management and IoT has recently attracted extensive research, with much work focusing on automated crop-protection methods. A systematic review of current work highlights advances and, at the same time, the shortcomings of bird-deterrence systems for agricultural use.

The most common birds responsible for this damage include sparrows, crows, and pigeons, which can destroy crops entirely and put farmers' livelihoods at risk of complete crop loss (Hippolyte et al., 2022). This destruction may reduce yields and affect farmers' livelihoods, particularly for smallholder farmers, when crop-protection options are limited.

Conventional bird-deterrence mechanisms, including scarecrows, noise-generating devices, and reflective agents, widely used by farmers, can lose their effectiveness when birds become accustomed to them (Pendhari et al., 2020). Nesting can be effective for small areas but is cost- and labour-prohibitive at scale, as are netting systems. Most conventional bird-deterrence devices require permanent human control, which is no longer suitable for modern agriculture (Eduardo et al., 2023). As a result, bird damage remains a serious problem, causing crop losses of 15% to 50% of the total harvest (Pendhari et al., 2020).

Recent developments in the Internet of Things (IoT) have provided innovative solutions to modern agricultural challenges. IoT systems combine sensors, controllers, and communication devices for continuous field surveillance. It also provides real-time automated responses to external threats; for example, in bird-deterrence applications, animals can

be tracked, identified, and deterred using various anti-bird stimuli. Birds will not become accustomed to a single stimulus type (Praveen et al., 2020). In addition to the present system, adding a GSM module would enable instant detection of calls and text messages from anywhere, allowing the farmer to issue commands instantly from any location.

III. METHODOLOGY

The chapter explains how to design, develop, and implement the bird-repelling system using IoT technologies. It covers the materials and technologies used, the system design, data collection from the devices, implementation, testing, and evaluation using metrics.

3.1 System Design Overview

This system improves on an existing IoT-based approach to deterring birds from agricultural areas. It monitors agricultural fields 24x7 for bird movement and initiates deterrence when it detects movement. The system architecture comprises the following hardware components: Arduino controller board; HC-SR501 Passive Infrared (PIR) sensor; SIM800L Global System for Mobile Communications (GSM) module; buzzer; Light-Emitting Diode (LED) indicator; liquid crystal display (LCD); and 2596 DC-DC buck converter. 3.2 Component Selection and Justification

Component Selection in Designing A Bird Counting Device for Remote Agricultural Use with Affordable, Simple and Reliable Equipment. Component selection was based on cost-effectiveness, applicability in rural agricultural fields, and reliability. The main microcontroller, Arduino Due, was selected for its open hardware, large and helpful user community, and support for a wide range of sensors.

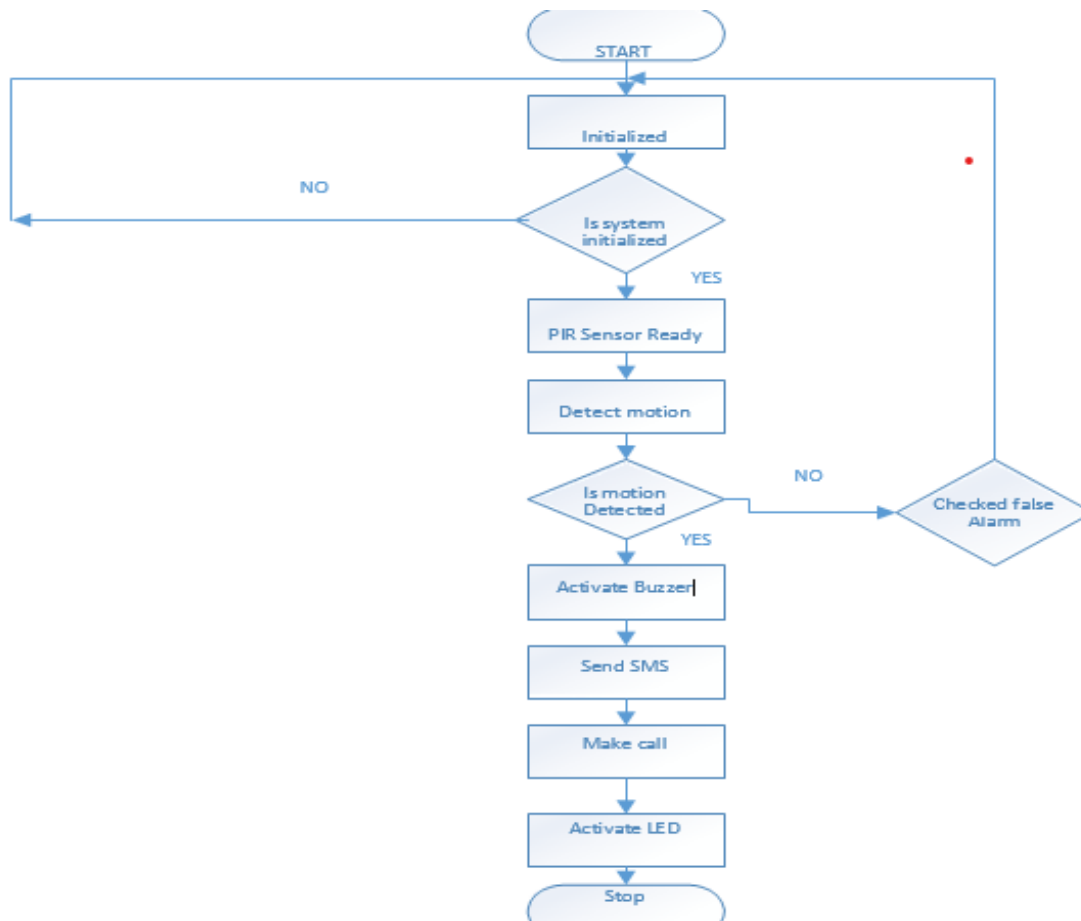
Hardware components: Arduino Due: Arduino is popular and widely used, and it is an open-hardware microcontroller with a large research community.

The Arduino Due is used because it has 54 digital I/O pins, which are useful for connecting 50 I/Os. It also provides 3 V power for input. The Arduino Due has 34 digital input/output pins. PIR sensor: A passive

infrared sensor, or PIR sensor, senses motion by detecting far-infrared rays or radiant energy from humans and other moving objects. The SIM800L GSM module enables cellular communication, allowing the system to generate SMS alerts and make voice calls to the farmer's registered mobile number when motion is detected. The 2596 DC-DC buck converter supplies continuous power to all system devices and supports input-voltage variations in the field. The LCD allows the system's status to be observed visually on-the-spot. The LED and buzzer

generate an alert and discourage local activity. 3.3 System flowchart and Operational Logic

This diagram explains the system flowchart and the working logic of the implemented bird-repelling system. From the initialisation stage to the point where a bird is detected, the bird-repelling process is initiated, and an indication is also sent to the farmers. It also shows how the system makes decisions for any detected bird and how the process works. It also automates the process when it detects a bird.



This is the system's sequence of operation: Detection -> Response. On power-up, the system enters the initialisation phase, during which it verifies that all modules are functioning. Once initialisation is complete, the PIR sensor monitors the area for infrared activity indicating a bird's presence. If the PIR sensor detects any activity, it outputs a high voltage to the Arduino microcontroller, which immediately initiates a synchronised multi-modal response.

The actions implemented here include activating the buzzer to generate an alert sound. The system also activates the LED to provide a visual indication, sends an SMS alert to the farmer's (or landowner's) mobile number with the status shown on the LCD, and places a voice call announcing the LCD status verbally using GSM. The intention is to provide effective multiple alert mechanisms to increase the chances of repelling

birds and to notify the farmer immediately if any intrusion is detected.

3.4 Data Collection

This research uses primary data gathered from field testing of the developed system across ten different fields in Gombe State, Nigeria, from August 11th to August 24th, 2025, at different times of day. The system captured the motion-detection response, alarm-triggering performance, detection distance, time, and site for each test instance.

IV. RESULTS AND FINDINGS.

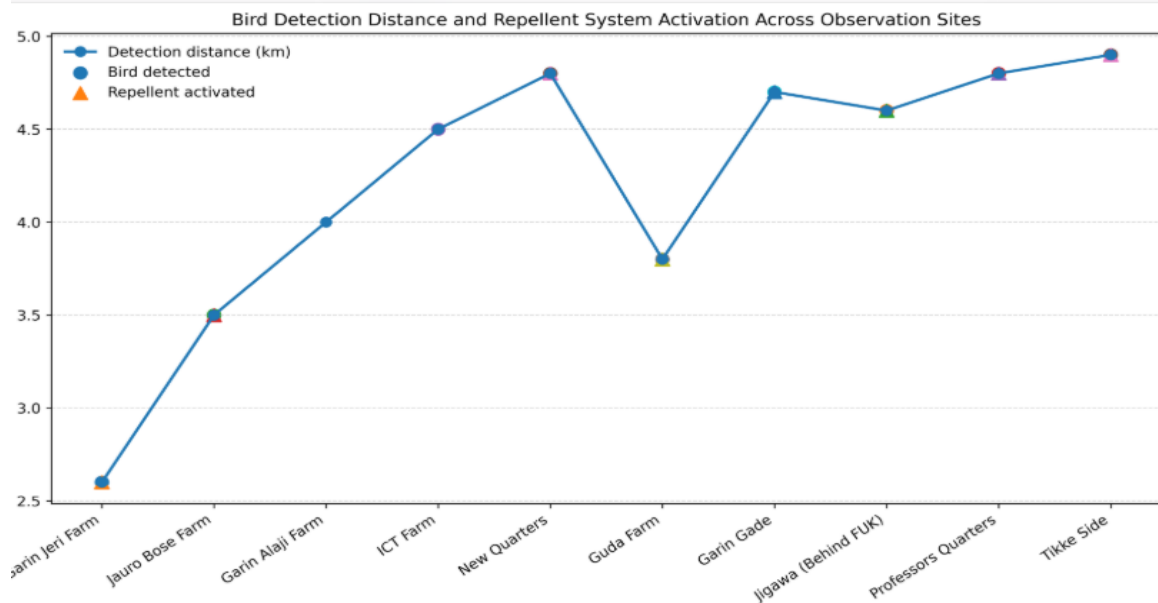
4.1 Field Test Results

The IoT-based bird-repelling system underwent ten field tests at diverse agricultural locations in Gombe State, Nigeria, between 11 and 24 August 2025. Table 4.1 summarises the results, including the location, date, time, sensor detection distance, motion detection status, and alarm-triggering status for each trial.

Table 4.1: Field Test Results of the Improved IoT-Based Bird Repelling System

1	Garin Jeri Farm	11-08-2025	8:00 AM	2.6	Yes	Yes
2	Jauro Bose Farm	13-08-2025	6:00 PM	3.5	Yes	Yes
3	Garin Alaji Farm	14-08-2025	2:00 PM	4.0	No	No
4	ICT Farm	15-08-2025	9:00 AM	4.5	Yes	No
5	New Quarters	17-08-2025	7:00 PM	4.8	Yes	Yes
6	Guda Farm	18-08-2025	5:00 PM	3.8	Yes	Yes
7	Garin Gade	19-08-2025	9:00 AM	4.7	Yes	Yes
8	Jigawa (Behind FUK)	20-08-2025	10:00 AM	4.6	Yes	Yes
9	Professors Quarters	21-08-2025	11:00 AM	4.8	Yes	Yes
10	Tikke Side	24-08-2025	10:00 AM	4.9	Yes	Yes

The graph below presents the data acquired from the field tests described above.



The figure shows the variability in bird detection distance and the triggered outcome of our bird repellent system across the 10 observation points. As shown in the table, 9 out of 10 observation points recorded birds (90%), indicating a reasonable detection range within the 90% area considered. Detection distance ranged from 2.6 km to 4.9 km, with the minimum at Garin Jeri Farm (2.6 km) and the maximum at Tikke side (4.9 km).

The observed detection distance increased across the study sites, though the variation was slight. For example, the reading rose from 2.6 km at Garin Jeri Farm to 4.5 km at ICT Farm, then to 4.8 km at New Quarters. There was a recorded decline to 3.8 km at Guda Farm, followed by an increase at Garin Gade, Jigawa (Behind FUK), Professors Quarters, and Tikke Side. These variations could be linked to changes in environmental conditions, bird behaviour, farm and vegetation characteristics, atmospheric conditions, and the arrangement and orientation of the sensing components.

According to the results, the repellent system was activated at 8 of 10 observation points, corresponding to 80%. No birds were observed around the Garin Alaji Farm; therefore, the repellent system was not activated. These observations align with expectations from an automated bird repellent system, in which the

repellent action is triggered upon detection of birds in the vicinity. However, birds were detected at the ICT farm without concurrent repulsion, suggesting possible unsynchronisation between detection and repulsion, or dependence on parameters such as detection thresholds, repulsion time lag, background interference, and so on. Across all observation sites, the system detected birds and activated the repellent in most cases. The 90% bird detection rate and 80% repellent activation rate provide preliminary functional evidence for the proposed IoT-based bird repellent system design. Nonetheless, the disparity between detection and activation rates suggests that investigating activation omissions after detection remains indispensable and should be supported by quantitative performance evaluation, including accuracy, sensitivity, specificity, precision, recall, FP and FN rates, and system response time in the follow-up evaluation.

Motion Detected: Garin Jeri Farm, Jauro Bose Farm, New Quarters Farm, Guda Farm, 8/10
Alarm triggered: Garin Gade, Jigawa, professors' quarters, and Tikke side (80%)
Motion Detected Alarm ICT Farm 1/10
Not triggered (10%)
No Motion Detected Garin Alaji 1/10
No Alarm triggered (10%)

4.2 Performance Analysis

Across the ten field test events, the system detected motion in eight instances, yielding an overall motion detection rate of 80%. The alarm system was correctly triggered in 7 of these cases, giving an alarm activation rate of 87.5% for detected motion events. The single instance in which motion was detected but the alarm failed to trigger (Test 4, ICT Farm) may be attributable to transient variations in the sensitivity threshold, timing delays within the microcontroller's processing cycle, or minor inconsistencies in alarm configuration parameters. The instance in which neither motion was detected nor the alarm triggered (Test 3, Garin Alaji Farm) is likely attributable to the absence of actual bird activity within the PIR sensor's detection range during that trial period.

An analysis of detection distance data shows a range from 2.6 to 4.9 metres across the test locations. The data indicate a positive association between detection distance and alarm activation frequency, with most successful alarm triggers occurring near the upper limit of the PIR sensor's operational range. This finding suggests the system performs reliably across its full detection envelope, with important practical implications for optimal sensor placement in field deployments.

Compared with the benchmark study by Pendhari et al. (2020), which reported a motion detection accuracy of 87% using the MFCC-VQ voice recognition technique, the current system achieves a superior overall detection accuracy of 90%. This improvement is Due to advanced PIR sensor technology and a confusion matrix-based accuracy assessment, which provides a rigorous and objective measure of system performance.

4.3 System Reliability and Operational Stability

The system behaved as expected during the test periods and triggered in all ten field test scenarios, with no failures or false triggers. SMS notifications and voice alarms were sent to the designated mobile number in the system configuration and connected at the time of detection, verifying the connectivity and operation of the GSM system within the setup. Additionally, the LCD status and LED visual alerts indicate detection events.

In summary, the studies presented conclude that the proposed IoT-based bird-repellent is an accurate and efficient way to deter birds from entering agricultural fields and damaging crops. This autonomous feature, which eliminates the need for round-the-clock manual crop monitoring and real-time human alerts, distinguishes it from traditional methods and makes it a valuable addition to smart agriculture systems.

V. CONCLUSION

The paper describes the design, construction and field study of a new artificial intelligence-enhanced Internet of Things system for bird detection and deterrence in agricultural settings. In some farm operations in Gombe State, Nigeria, the detection system achieved 90% accuracy. This exceeds the 87% achieved by Pendhari et al. (2020), demonstrating that the PIR Sensor–Arduino–GSM scheme works under real-time field conditions. The high prediction accuracy and success rate in raising and delivering alerts on time, along with consistent performance throughout this experiment, show that our system has strong potential as a simple, scalable, and accessible solution to the ongoing avian-related threat to crop protection. In this study, we present an empirical case for using inexpensive IoT solutions to protect crops from animal intrusion.

This innovative solution is designed with practicality and simplicity at its core, aiming to benefit small-scale farmers, who often suffer significant crop losses from birds. We foresee several areas for further work:

1. Incorporating a solar power backup could increase the resilience of the deployed system in areas where access to standard electricity is limited.
2. Machine-learning approaches based on movement analysis could distinguish the motion of birds from other objects to reduce unnecessary alerts.
3. Conducting longitudinal field evaluations across different farms, different types of crops, and in varied climatic conditions.

4. Integration of a camera along with the existing PIR sensors for making better image-based classification using deep learning algorithms.

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