JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Naext-Generation Bird Management in Agriculture Using IoT-Enabled AI and Real-Time Deterrence

[1]J.Sukanya [2]Dr.S.Krishnaveni ,[3]S. Aafrin Banu , [4]H.Vahitha
Department of Computer Science
M.V.Muthiah Government Arts College For Women , Dindigul, India .

Abstract. Bird interference continues to pose a significant threat to crop yields in agricultural fields, resulting in economic losses for farmers. To address this challenge, this project presents a smart, AI-driven bird deterrent system that integrates Internet of Things (IoT) hardware and computer vision technologies. The system uses a system-connected camera to detect bird presence in real time, analyzing the data through machine learning algorithms to identify bird types and activity patterns. Once birds are detected, the hardware triggers non-lethal deterrent mechanisms such as sound and light based repellers. A user-friendly mobile application enables farmers to receive real-time alerts, view live monitoring data, track peak bird activity times, and remotely control the deterrent system. The system offers an affordable and eco-friendly solution, enabling automated bird deterrence with minimal manual effort, tailored for diverse farm settings. By combining AI insights with practical hardware implementation, the system enhances agricultural productivity and supports sustainable farming practices.

Keywords: Bird deterrent system, IoT in agriculture, smart farming, machine learning, real-time alert, crop protection, computer vision, mobile monitoring, sustainable agriculture.

1 Introduction

Modern agriculture is increasingly challenged by the need to protect crops from bird-related damages, particularly during sowing and harvesting periods [2], [12]. Birds feeding on seeds, fruits, and grains can lead to substantial economic losses for farmers. Conventional deterrent methods such as scarecrows, noise generators, chemical repellents, and physical barriers provide only temporary relief, are laborintensive, or may negatively impact the environment [2], [5], [12], [14]. Modern agricultural practices increasingly prioritize automation and sustainability, creating demand for effective, environmentally responsible bird deterrent systems
[1], [3], [6].

In response to this need, this research proposes a smart bird deterrent system that leverages the Internet of Things (IoT), machine learning, and mobile application technologies [1], [7], [8]. The system utilizes a computer vision-based detection mechanism that identifies bird presence and automatically triggers deterrent actions, such as the emission of targeted sounds or projection of laser beams, without causing harm to the birds [1], [9]. A distinguishing feature of the system is its ability to learn and adapt over time through machine learning algorithms, allowing for dynamic adjustments based on observed bird behavior patterns and improving response effectiveness in future interactions [1], [9], [11].

The mobile application integration enhances system utility by offering real-time alerts and remote control capabilities [8], [10]. Farmers can monitor field activity, review analytics such as peak bird activity periods, and manually activate deterrent mechanisms when needed [8], [10], [11]. Additionally, the system collects and stores long-term data regarding bird occurrences, enabling predictive analysis and better planning for crop protection strategies [10], [11], [14]. Designed with scalability and affordability in mind, the system uses open-source software tools like Python and OpenCV, combined with low-cost IoT hardware modules [13], [15]. Solar power options further enhance the sustainability of the system, minimizing energy dependency and supporting green farming initiatives [3], [4], [6]. Its modular design ensures that installation and maintenance can be performed with minimal technical expertise, making it accessible to farmers across varying scales of agricultural operations [7], [13], [15].

As climate variability and unpredictable wildlife behavior continue to pose threats to agricultural productivity, the development of intelligent, adaptive systems is critical [5], [6]. The proposed solution not only addresses immediate crop protection needs but also aligns with the broader goals of smart farming by creating a resilient, data-driven agricultural ecosystem [1], [2], [6], [14], [15]. Through the integration of IoT, machine learning, and mobile technologies, this system represents a forward-thinking approach to safeguarding crops while promoting sustainable, efficient farming practices.

2 Related Work

Several studies have examined the application of smart technologies in agriculture to mitigate bird-induced crop damage. These solutions employ a combination of IoT, machine learning, and vision-based systems for real-time monitoring and deterrence. Durgun [1] introduced an acoustic bird repellent system using edge computing and machine learning. The model detects bird sounds locally and triggers deterrents, reducing internet dependency and ensuring fast, efficient responses. Eduardo B. Micaelo et al. [2] discussed bird deterrent strategies for crop protection, highlighting the limitations of traditional methods. They emphasized the use of AI and IoT technologies to build smarter and more sustainable bird repellent systems. Hariadi et al. [4] implemented an autonomous deterrent setup for rice farms, using solar-powered microcontrollers to facilitate renewable energy usage and reduce manual effort. Chen et al. [9] proposed a wild bird repelling approach combining deep learning-based detection with a rotating laser system. Their method involves using a camera to identify birds in real time, followed by the activation of a laser beam to deter them, which led to a noticeable decrease in bird intrusions on agricultural lands. Kale et al. [12] conducted a study focused on bird-related crop damage in India, assessing the practicality of various bird repelling strategies adopted by farmers and their outcomes. Despite these advancements, many existing systems lack farmer-centric features such as mobile control, adaptive learning based on environmental data, and cost-effective scalability. The novelty of the proposed study lies in its integration of IoT, ML, computer vision, and a userfriendly mobile interface, offering predictive bird activity analysis and real-time response customization for sustainable crop protection.

3 Methodology

This research proposes a smart bird deterrent system that integrates hardware components, intelligent software processing, and IoT-based communication to ensure effective and sustainable crop protection. The system focuses on real-time detection, data-driven decision-making, and user control to reduce crop loss caused by bird activity. This structured methodology ensures that the bird deterrent system operates efficiently with minimal human intervention, while also offering flexibility and adaptability through cloud-based analytics and mobile interface support.

3.1 Hardware Configuration

The proposed system is powered by the ATmega328 microcontroller, which serves as the core controller for managing input sensors and activating deterrent modules. A sound sensor is employed to detect the presence of birds through acoustic signals. To ensure stable operation, the system includes monitoring components for both solar panel output and battery voltage levels. Figure 1 shows the overall architecture of the proposed system.

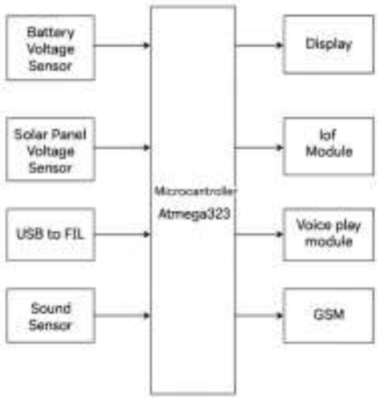

Fig. 1. Block Diagram of Smart Bird Deterrent System

The system features a voice playback module that emits pre-recorded bird-repelling sounds when activity is detected. A GSM module is used to send SMS alerts to farmers, while an IoT module enables cloud connectivity for remote access and data tracking. A display module presents live system status, and a USB-to-TTL converter is used for firmware uploading and serial communication. The entire unit is powered by a solar panel connected to a rechargeable battery, making it suitable for deployment in open agricultural fields without continuous grid access. This configuration allows for autonomous operation, remote communication, and reliable deterrent activation, offering a practical and energy-efficient solution for crop protection.

3.2 System Integration

The system is designed with IoT capabilities to allow remote monitoring and control. Data from the microcontroller is transmitted via Wi-Fi or LoRa modules to a cloud server for storage and analytics. A dedicated mobile application enables farmers to receive real-time alerts, manually control the deterrent system, and monitor field activity. Historical data such as bird detection frequency and active times are stored in the cloud, allowing for pattern analysis and system optimization. Google Firebase is utilized as the cloud backend, offering real-time database services and secure storage for event logs and system responses, thereby supporting data-driven improvements and remote accessibility. The integration of these components ensures both automation and user intervention when necessary.

3.3 Software Processing

The camera's visual data, along with acoustic and PIR sensor outputs, are fed into a lightweight convolutional neural network (CNN) running on an edge device. This network performs real-time binary classification to determine bird presence. Sensor fusion logic is employed to minimize false triggers by correlating multi-modal inputs. The CNN is optimized for the limited computational resources of the ESP32 board using TensorFlow Lite.

3.4 Robotics Integration

To maximize coverage across wider areas, a motorized pan-tilt base has been added for repositioning deterrent devices such as lasers or buzzers. Controlled through PWM outputs from the ESP32 microcontroller, this robotic mechanism dynamically reorients based on the direction of detected bird activity. Integration with camera feed ensures targeted deterrence instead of static deployment, improving efficiency and adaptability. The hardware logic is embedded using C routines that manage servo angles and synchronization with detection modules.

4 Design

The design of the smart bird deterrent system integrates modular hardware and intelligent software to enable effective and automated crop protection. Figure 2 shows the design layout, illustrating the configuration of core components and their interconnections. It includes a high-definition (HD) camera and acoustic sensors strategically deployed across the agricultural field to provide continuous surveillance and real-time detection of bird activity. A Passive Infrared (PIR) sensor is also used to detect motion-based disturbances, enhancing the reliability of bird detection. These sensing units are interfaced with an ESP32 microcontroller, which functions as the central processing hub.

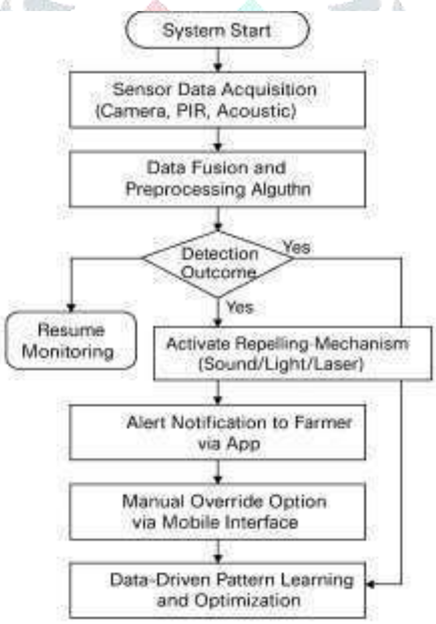

Fig. 2. Design Layout

Once bird activity is confirmed, the system automatically activates deterrent mechanisms such as ultrasonic buzzers, sound emitters, or laser modules. This hardware configuration is powered by a solar panel with a rechargeable battery, enabling uninterrupted operation in remote agricultural areas. Wireless connectivity, such as Wi-Fi, is integrated to transmit data to a cloud platform Figure2.1 explains the hardware implementation, showing how each component is connected physically. A mobile application allows users to access live monitoring, receive alerts, and manually control deterrent mechanisms.

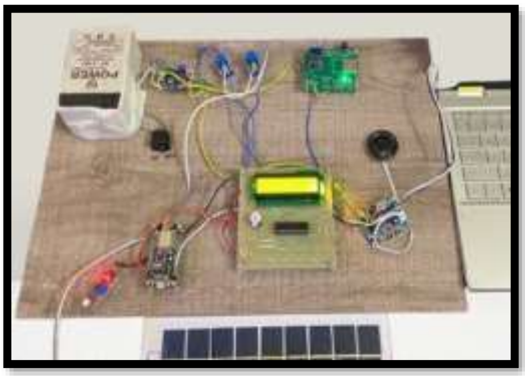

Fig. 2.1. Hardware Implementation

In Conclusion, this comprehensive design of the bird deterrent system not only focuses on immediate threat mitigation but also incorporates features that support predictive analysis and user control. With its integration of vision, sensing, and cloud-based intelligence, the system offers a scalable and sustainable solution tailored for smart farming environments. Furthermore, the system's energy efficiency and minimal maintenance make it a cost-effective solution for farmers adopting precision agriculture. Farmers can access and control the system via a mobile application, making it usable without specialized technical skills. Its adaptability and data-driven design mark a significant advancement in smart farming practices.

5 Summarized Algorithm

The smart bird deterrent system operates in several key steps. First, real-time monitoring is conducted using high-resolution cameras, acoustic sensors, and Passive Infrared (PIR) motion detectors to detect bird presence. The captured visual and sensor data is processed through a Convolutional Neural Network (CNN) model deployed on the ESP32 microcontroller. Once bird presence is detected, deterrent devices such as ultrasonic buzzers, sound emitters, or lasers are immediately activated. The event data and timestamps are then transmitted to the cloud (Google Firebase) via Wi-Fi or LoRa for storage and analysis. Farmers receive real-time alerts via a mobile application, enabling them to manually control the system. Finally, historical data is analyzed to identify patterns in bird activity, which allows for model refinement and system optimization. This algorithm ensures a reliable, automated, and scalable solution for smart crop protection, minimizing crop damage with minimal human effort while enhancing field monitoring through intelligent, data-driven insights.

6 Result

The implementation of the IoT-powered smart bird deterrent system has brought significant improvements in crop protection, resource efficiency, and overall field management. Before the system was introduced, farmers primarily relied on manual bird scaring techniques such as scarecrows, reflective objects, or frequent field monitoring. These conventional methods were not only labor-intensive but also provided inconsistent results, leading to a high rate of crop damage.

Figure 3 shows a consolidated bar chart illustrating both crop health status outcomes and performance metrics before and after deploying the smart deterrent system. Initially, only 40% of the crops were successfully protected, while 60% suffered damage due to bird intrusions, pests, inadequate irrigation, and environmental stress. After implementing the system, crop survival increased to 90%, with only 10% loss attributed to rare, uncontrollable factors like unexpected weather changes or pest outbreaks. In addition to improved crop protection, the smart system also enhanced key agricultural performance indicators. Protection and security measures increased from 45% to 95%, productivity from 48% to 90%, timely response from 50% to 89%, and real-time monitoring from 20% to 80%. These gains are credited to the automated bird detection and deterrence capabilities, which eliminated delays caused by manual intervention and ensured faster, datadriven responses.

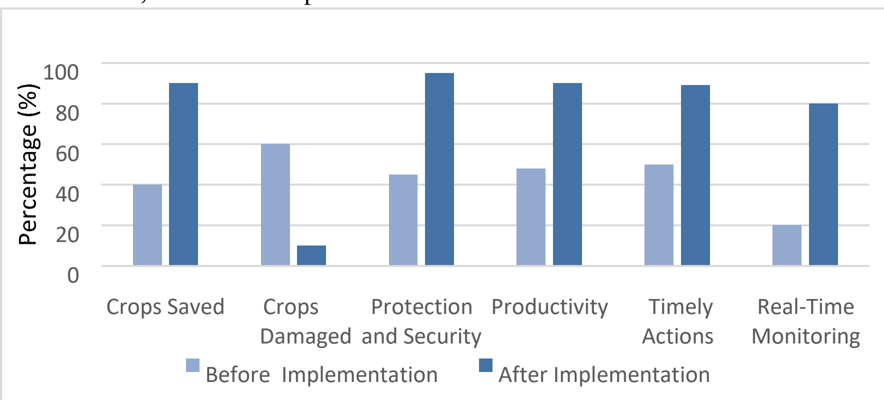

Fig. 3. Performance Evaluation of Traditional vs Smart Bird Deterrent Methods

In Further analysis Figure 3.1 shows highlighted the system's response efficiency under varying intensities of bird activity. Traditional manual methods exhibited minimal variation in performance, maintaining a steady response rate of approximately 45%, regardless of bird density. In contrast, the AIoT-based smart system demonstrated scalable and adaptive performance— achieving over 70% efficiency during moderate bird activity and exceeding 90% efficiency during periods of high activity.

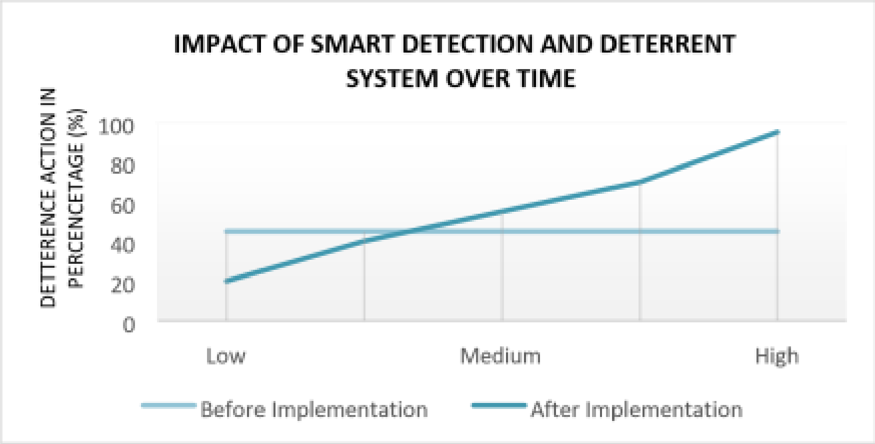

Fig. 3.1. Impact of System over time

The CNN was trained on a dataset of approximately 4,500 images that included both bird and non-bird scenarios captured in varied environmental conditions. The dataset was split into 70% training and 30% testing sets. Augmentation techniques such as random flipping, rotation, and brightness adjustment were applied to improve generalization.

Training Parameters:

- Epochs: 30
- Batch Size: 32
- Learning Rate: 0.001
- **Performance Metrics:**
- Accuracy: 92.8%
- Precision: 93.2%
- Recall: 91.7%
- F1 Score: 92.4%

To validate robustness, five-fold cross-validation was performed, yielding a mean accuracy of 91.6% with low variance. These results confirm the model's reliability in real-time classification tasks when deployed on constrained hardware. These results underscore the system's intelligent response capabilities, enabling real-time deterrent actions tailored to dynamic field conditions. and ensuring more effective crop protection. In addition to immediate deterrence, the system's capability to store and analyze bird activity patterns over time contributed to smarter agricultural planning. With historical data accessible via the cloud, farmers could identify peak intrusion periods and optimize the deterrent schedule accordingly. This data-driven approach enabled predictive protection and improved decisionmaking regarding crop cycles. Powered by renewable energy sources such as solar panels and equipped with a rechargeable battery, the system remained functional even in remote or off-grid farming areas, reinforcing its sustainability and cost effectiveness. Overall, the adoption of this IoT-based solution has resulted in a dramatic improvement in agricultural efficiency, reduced crop losses, and enhanced user convenience. The system's scalability and autonomous operation position it as a promising tool for the future of smart farming and sustainable agriculture.

7 Conclusion

The Smart Bird Deterrent System developed in this study addresses a persistent challenge in agriculture—crop loss due to bird activity—by integrating Internet of Things (IoT), sensor fusion, and renewable energy sources. Built around the ESP32 microcontroller, the system connects high-definition cameras, PIR motion sensors, and acoustic detectors to monitor bird presence in real time. Upon detection, deterrents such as ultrasonic buzzers, laser pointers, or sound-based repellents are triggered to prevent crop damage through non-lethal means. The inclusion of solar power ensures continuous operation, even in off-grid farming areas, while Wi-Fi or LoRa modules facilitate cloud-based data transmission. A dedicated mobile application allows farmers to receive instant alerts, track field activity, and control the system remotely, reducing manual intervention and improving operational efficiency. In addition to real-time deterrence, the system stores historical data in the cloud, enabling analysis of bird activity trends and supporting predictive planning for future crop protection. This approach shifts traditional farming practices toward a more proactive, data-driven model. The design is modular and scalable, allowing customization based on field size or crop type, and its low maintenance requirements make it practical for both small and large-scale farms. Overall, the proposed system offers a reliable and farmer-friendly solution that merges automation, sustainability, and accessibility to enhance agricultural resilience and productivity.

References

1. Durgun, M.: Acoustic-Based Bird Repellent System Utilizing Edge Computing and Machine Learning. In: *2023 Innovations in Intelligent Systems and Applications Conference (ASYU)*, Sivas, Turkey, pp. 1–8 (2023)

2. Micaelo, E.B., Lourenço, L.G.P.S., Gaspar, P.D., Caldeira, J.M.L.P., Soares, V.N.G.J.: Strategies, difficulties, and prospects of bird repellent techniques for safeguarding crops. *Agriculture* **13**(4), 774 (2023)

3. Muminov, A., Jeon, Y.C., Na, D., Lee, C., Jeon, H.S.: Design and Implementation of a Solar-Driven Bird Repeller Using Sound Deterrents. In: *2017 International Conference on Information Science and Communication Technologies (ICISCT)*, Tashkent, Uzbekistan, pp. 1–4 (2017)

4. Hariadi, T.K., Wimala, G., Hayati, N., Widyasmoro, Purwanto, K., Prihatmoko, P.: Design of Automatic Birds Repellent System for Rice Field Using Microcontroller and Solar Panel. In: *2024 4th Int. Conf. on Electronic and Electrical Engineering and Intelligent System (ICE3IS)*, Yogyakarta, Indonesia, pp. 144–148 (2024)

5. Dagvadorj, G., Dorjsuren, T., Dorjsuren, B.: Bird repellent on sea buckthorn harvest. *Mongolian Journal of Agricultural Sciences***15**, 27–31 (2022)

6. Nnebedum, B., Oyewande, O., Adepitan, O., Omeje, M., Akinplu, A.: Solar Powered Soil Condition Activated Irrigation System with Automated Bird Repellent. *IOP Conf. Ser.: Earth Environ. Sci.***331**, 012045 (2019)

7. Suleiman, I., Babawuya, A., Oyewole, A., Adepoju, A.D., Nuhu, A.A.: A Review of Bird Pest Repellent Systems in Farms. *ResearchGate* (2021)

8. Abdulmana, S., Mapa, F., Chewae, M., Samae, S., Kahae, R.: Smart Bird Farm. *ResearchGate* (2022)

9. Chen, Y.C., Chu, J.F., Hsieh, K.W., Lin, T.H., Chang, P.Z., Tsai, Y.C.: Automatic Wild
Bird Repellent System Based on Deep Learning and Laser Mechanism. *Sci. Rep.***14**, 1– 12 (2024)

10. Phetyawa, S., Kamyod, C., Kim, C.G.: Utilization and Obstacles of IoT-Based Bird Deterrent Systems in Smart Farming. In: *Int. Symp. on Intelligent Signal Processing and Communication Systems (ISPACS)*, pp. 1–6 (2022)

11. Chen, Q., Xie, J., Yu, Q., Liu, C., Ding, W., Li, X., Zhou, H.: An Experimental Study of Acoustic Bird Repellents for Reducing Bird Encroachment in Pear Orchards. *Front. Plant Sci.***15** (2024)

12. Kale, M., Balfors, B., Mörtberg, U., Bhattacharya, P., Chakane, S.: Damage to Agricultural Yield due to Farmland Birds, Present Repelling Techniques and its Impacts: An Insight from the Indian Perspective. *J. Agric. Technol.***8**(1), 49–62 (2012)

13. Siahaan, Y., Wardijono, B.A., Mukhlis, Y.: Design of Birds Detector and Repellent Using Frequency Based Arduino Uno with Android System. In: *2017 2nd Int. Conf. on Information Technology, Information Systems and Electrical Engineering (ICITISEE)*, Yogyakarta, Indonesia, pp. 239–243 (2017)

14. Hong, H., Cho, Y., Woo, S., Song, S.: Development and Practical Realization of a Bird Deterrence Mechanism. *J. Korean Soc. Manuf. Process Eng.***18**(8), 104–109 (2019) 15.Singh, P., Krishnamurthi, R.: Empowering Agricultural Security with IoT and Deep Learning Driven Real-Time Alert Systems. *J. Agric. Technol.***8**(1), 49–62 (2024)