Automated Bird Deterrent System: A Review

1st Muhammad Fauzan Hernadi
Mechatronics and Artificial Intelligence Study Program
Universitas Pendidikan Indonesia
Bandung, Indonesia
fauzanhernadi004@upi.edu

2nd Yusuf Haryo Timur
Mechatronics and Artificial Intelligence Study Program
Universitas Pendidikan Indonesia
Bandung, Indonesia
yusufht@upi.edu

3rd Roy Dongan Putra Manalu
Mechatronics and Artificial Intelligence Study Program
Universitas Pendidikan Indonesia
Bandung, Indonesia
roydpm724@upi.edu

4th Nabilah Khairunnisa
Mechatronics and Artificial Intelligence Study Program
Universitas Pendidikan Indonesia
Bandung, Indonesia
nabilahkh18@upi.edu

5th Diky Zakaria
Mechatronics and Artificial Intelligence Study Program
Universitas Pendidikan Indonesia
Bandung, Indonesia
dikyzak@upi.edu

*Corresponding author: dikyzak@upi.edu
Received: November 15, 2024; **Accepted:** April 18, 2025

***Abstract*— Bird pests pose a significant threat to agriculture, causing extensive crop damage and economic losses. Traditional bird repellent methods, such as scarecrows and loud noises, often lose their effectiveness over time as birds adapt. This paper reviews the development and effectiveness of an automated bird repellent system, integrating Internet of Things (IoT) and Artificial Intelligence (AI) technologies. The study used a systematic literature review (SLR) methodology, analyzing 20 articles published between 2015 and 2024. Key findings show that automated systems, utilizing sensors and AI algorithms such as YOLO, DenseNet, and Mask R-CNN, significantly improve bird detection and repellent accuracy. The DenseNet model, in particular, achieved a detection accuracy of 99.65%. The review highlights the need for further research to optimize sensor placement and assess the long-term impacts of this technology on bird behavior and agricultural ecosystems. This comprehensive review underscores the potential of automated bird repellent systems to improve crop protection and sustainability in agriculture.**

***Keywords*— bird pests, IoT, AI, algorithm, deterrent methods.**

I. Introduction

In agriculture, bird pests are a significant threat as they can cause extensive damage to crops, resulting in economic losses. Over the years, various bird deterrent methods have been developed, ranging from traditional methods such as scarecrows and loud noises, to modern technologies such as ultrasonic devices and solar power. While effective in the short term, conventional methods tend to be less efficient in the long term as birds can adapt. This includes traditional approaches such as visual and auditory stimuli, as well as more advanced technological options such as solar-powered electronic devices and ultrasonic wave systems. [1] in this literature, researchers used a scarecrow as a traditional method to protect their field, not an ordinary scarecrow but a solar automated scarecrow. He used to mix between a traditional method and modern method or technology.

Security in the agricultural sector is a significant challenge, especially in countries like Bangladesh where theft and vandalism are common problems in farmland [2]. To address this issue, an Internet of Things (IoT)-based agro-farm security system was developed. The system uses laser and vibration sensors connected to Arduino Mega and UNO, as well as a GSM module to send real-time notifications to farmers' mobile devices. Tests showed that the laser sensor had 100% responsiveness, while the vibration sensor achieved 90%, with an overall system efficiency of 90% in detecting intrusions. The system allows farmers to respond quickly to threats and protect their valuable assets.

In addition, the problem of birds damaging rice plants is also a major concern for farmers. To overcome this problem, an Arduino-based bird repellent device was developed that uses eight PIR sensors to detect the presence of birds and activates an industrial siren that produces a loud sound [3]. This tool is effective in detecting birds up to a distance of 6.5 meters and the siren sound with a sound pressure of around 150 dB successfully scares away birds. This tool is easy to install and maintain, economical, and can be used on a variety of crops, although its detection range is limited and its effectiveness depends on the placement of the sensors and siren [3][4].

Finally, the use of FMCW radar to detect and classify targets with the YOLOv5 model is also an important innovation [5]. Using the ColoRadar dataset and converting the data representation from polar to Cartesian, the YOLOv5 model is trained for target classification. The model achieves an average accuracy (mAP_0.5) of 0.89 with a computing power consumption of 12 BFLOPS, indicating that the YOLOv5 model is effective for target classification with high efficiency and low computing power consumption, suitable for embedded applications.

The increasing presence of birds in airport environments poses significant risks to aircraft safety, necessitating effective bird repellent systems. Traditional methods often lack real-time monitoring capabilities, leading to inefficiencies and higher operational costs. To address these challenges, this study proposes the development of a remote monitoring system for airport bird repellent equipment using STM32 microcontrollers [6]. The system aims to provide real-time data on the operational status of bird repellent devices, utilizing sensors to measure temperature, pressure, power voltage, and sound. Data is transmitted to a host computer via ZigBee technology, ensuring accurate and reliable monitoring within an 800-meter range. This innovative approach not only enhances the efficiency of bird repellent operations but also reduces maintenance costs, offering a robust solution for airport wildlife management.

Several review articles have discussed various aspects of automatic bird repellents over the past five years. Micaelo et al [7] present a comprehensive review on bird deterrent solutions for crop protection and emphasizing the challenges and opportunities associated with various methods. The article categorizes deterrent techniques into six primary groups which include visual, auditory, chemical, exclusion, habitat modification, and removal methods. Baral et al [8] discuss bird repellent methods and emphasizes the transition from conventional techniques to electronic solutions such as solar-powered and ultrasonic devices. These devices use sound and visual stimuli to effectively scare birds and offer advantages such as easy installation, energy efficiency, and low maintenance. Suleiman et al [9] explain a methods and devices review used for autonomous bird pest control in agriculture and highlight the significant economic damage caused by pest birds. They evaluate current control methods and explore bird responses to these devices. While natural predators are effective, their unpredictability has shifted focus toward developing artificial systems that mimic predator behaviour. However, these article solely focus on the diverse methods and technologies of bird deterrents. There has been no comprehensive review article specifically addressing the integration of IoT technology with AI in automated bird deterrent systems.

Until now, several articles have discussed various aspects of automated bird pest deterrent technology, but none have provided a comprehensive overview of this topic. Although many methods, such as the use of sensors and AI algorithms, have been described, there is still a lack of research that comprehensively addresses their impacts and effectiveness. In this context, the author intends to compile an article that answers the following research questions (RQs):

- What is the effectiveness of automated technology in deterring bird pests in rice fields?
- How can the use of sensors be optimized to detect the presence of bird pests in agricultural lands?
- What AI algorithms are used in detecting and deterring bird pests?
- What is the accuracy level of the AI algorithms in this model?
- How does automated bird deterrent technology influence bird behavior in the long term?

This review uses a systematic literature review (SLR) methodology with articles sourced via Google Scholar. Various articles have utilized the SLR method in their study. Enos et al [10] conducted a SLR to collect and analyze relevant studies regarding the use of deterrent or frightening devices against birds considered agricultural pests. The search was conducted using the ISI Web of Science and Google Scholar databases, covering the years 1900 to 2020. In Web of Science, the authors performed two searches using the following search terms: (1) (bird OR blackbird OR starling OR sparrow OR parrot OR parakeet OR goose OR crow OR raven OR pigeon OR dove OR crane) AND (deterr* OR repell* OR “frightening device”) AND (crop OR agricult* OR orchard OR vineyard), and (2) (blackbird OR starling OR house sparrow OR parrot OR parakeet OR goose OR crow OR raven OR pigeon OR dove OR crane) AND (deterrent OR repellent OR deterrence OR repellence OR “frightening device”). This search resulted in an excessive number of studies in Google Scholar (n > 45,000), prompting the authors to use a more specific search term: bird AND experiment AND (“scaring device” OR “frightening device”) AND “crop damage”. The aim of this SLR is to comprehensively assess the effectiveness of various deterrent devices in reducing bird-related crop damage, identify gaps in the existing literature, and minimize bias by applying strict inclusion criteria to include only the most relevant and high-quality studies. DeLiberto & Werner [11] conducted a SLR to develop a current review and synthesis of chemical bird repellents that aim to assist wildlife researchers, ecologists, managers, and conservationists. They selected a total of 345 papers from google scholar.

This article employs SLR to gather information related to the previously formulated research questions (RQs) and provides an in-depth examination of the implementation of automatic bird deterrents. This study will review the effectiveness of automated technology in addressing bird pests, explore ways to optimize sensors for detecting their presence, discuss the types of AI algorithms applied, and evaluate the accuracy levels of the models used. Additionally, the long-term impact of this technology on bird behaviour will also be examined. The literature review aims to underscore the need for further research to develop more efficient and innovative techniques or strategies for utilizing bird deterrents in the agricultural sector, while also ensuring the sustainability of the technology itself and its ecological impact.

II. Methods

This article provides a literature review, with the method thoroughly detailed in the following sections

A. Article Selection

The selection of relevant articles was conducted using the Google Scholar database. The keywords employed in the search were based on ("Bird Pest Management" OR "Pest Bird System" OR "Automatic Bird Pest Repellent" OR "Bird Deterrence" AND "Internet of Things" OR "IoT" AND "Artificial Intelligence" OR "AI" OR "Machine Vision" OR “Airport”). The selected articles had to be openly accessible. Sources such as books, irrelevant articles, and reviewed articles were excluded from the selection process. The search was performed on Oktober 2, 2024, and the resulting data was presented in table 1:

TABLE I. Article Selection Process on Google Scholar Database

Article selection proses		
No	***Process***	***Number of Article***
1	Entering keyword ("Bird Pest Management" OR "Pest Bird System" OR "Automatic Bird Pest Repellent" OR "Bird Deterrence" AND "Internet of Things" OR "IoT" AND "Artificial Intelligence" OR "AI" OR "Machine Vision" OR “Airport”) in the	27 articles

	Google Scholar search based on title, abstract, and keyword	
2	Exclude book and literature review article	25 articles
3	Filter articles that are not relevant to the topic	21 articles
4	1 article is closed access	20 articles
Final number of articles used		**20 articles**

There are 27 articles scholar documents according to the keyword based on table 1. We only used 20 papers (74%) out of the total of 27 after applied the exclusion criteria.

B. Article Review Process

After selecting articles, the author took several articles and reviewed whether the article contained the 5 RQs in this literature review, then discussed and got the conclusion.

III. RESULT AND DISCUSSION

A. Article Metadata

The metadata of the 20 articles used in the analysis is shown in table 2.

TABLE II. METADATA OF THE ARTICLES USED

Metadata of the articles used				
No	***Author***	***Year***	***Paper Title***	***Conference/ Journal Source***
1	Brown and Brown [12]	2021	Robotic laser scarecrows: A tool for controlling bird damage in sweet corn	Crop Protection
2	Bhusal et al [13]	2022	Automated execution of a pest bird deterrence system using a programmable unmanned aerial vehicle (UAV)	Computers and Electronics in Agriculture
3	Ali et al [14]	2024	AI-enabled IoT-based pest prevention and controlling system using sound analytics in large agricultural field	Computers and Electronics in Agriculture
4	Bhusal et al [15]	2019	Bird deterrence in a vineyard using an unmanned aerial system (UAS).	Transactions of the ASABE
5	Mohamed et al [16]	2020	The Efficacy of Visual and Auditory Bird Scaring Techniques using Drone at Paddy Fields Wan	IOP Conference Series: Materials Science and Engineering
6	Rohmah et al [17]	2024	Pest Control System on Agricultural Land Using Iot Electronic Controller	Journal of Applied Engineering and Technological Science
7	Zefi et al [18]	2023	Implementation of Appropriate Technology for Bird Pest Removal to Replace Scarecrow with Solar Cell Based on Internet of Thing at Usaha Tani Mandiri Kertapati Palembang.	Proceedings of the 6th FIRST 2022 International Conference (FIRST-ESCSI-22)
8	Arowolo et al [19]	2020	A Real Time Image Processing Bird Repellent System Using Raspberry Pi	FUOYE Journal of Engineering and Technology (FUOYEJET)
9	Chen et al [20]	2024	Automatic wild bird repellent system that is based on deep learning based wild bird detection and integrated with a laser rotation mechanism.	Scientific Reports
10	Marcoň et al [21]	2021	A system using artificial intelligence to detect and scare bird flocks in the protection of ripening fruit.	Sensors
11	Morley et al [22]	2024	Precision pest control using purpose-built uncrewed aerial system (UAS) technology and a novel bait pod system	Drone Systems and Applications
12	Werrell et al [23]	2021	A Sonic Net reduces damage to sunflower by blackbirds (Icteridae): Implications for broad-scale agriculture and crop establishment	Crop Protection
13	Romero et al [24]	2020	Biomimetric Drone for Controlling Bird Pests and Optimizing Citriculture	Research in Computing Science
14	Ritti et al [25]	2024	Detecting Intended Target Birds and Using Frightened Techniques in Crops to Preserve Yield	International Journal of Innovative Research in Computer Science and Technology (IJIRCST)
15	Mhandu et al [1]	2023	Design Of a Solar Automated Scarecrow	Proceedings of the IEOM International Conference on Smart Mobility and Vehicle Electrification
16	Sayem et al [2]	2023	IoT-based smart protection system to address agro-farm security challenges in Bangladesh.	Smart Agricultural Technology
17	Blümel et al [4]	2023	Algorithm for calculating distance and sensor-object angle from raw data of ultra-low power, long-range ultrasonic time-of-flight range sensors	Procedia CIRP
18	Olugbenga et al [3]	2020	Development and Implementation of Arduino-based Birds Repellent for Farmers.	International Journal of Science and Research (IJSR)
19	Lamane et al [5]	2022	Classification of targets detected by mmWave radar using YOLOv5	Procedia Computer Science

20	Yang et al [6]	2020	Design of Airport Wireless Bird Repellent Monitoring System.	IOP Conference Series: Materials Science and Engineering

Based on the data in table 2, 14 articles (70%) were sourced from international journals and 6 articles (30%) were obtained from international conference proceedings. This indicates that the topic of bird repellent control systems has garnered substantial attention in academic journals while contributions from conference proceedings remain significant. This opens opportunities for researchers to publish more works in both conferences and international journals thereby expanding the scope of research in this field.

B. Article Review Results

TABLE III. ARTICLE REVIEW

	Article Review					
No	***Author***	***RQ1***	***RQ 2***	***RQ 3***	***RQ4***	***RQ5***
1	Brown and Brown [12]	The automated laser scarecrow technology has proven to be effective in minimizing bird-related damage in sweet corn fields. Over a three-year study, results indicated that areas protected by lasers experienced significantly less damage compared to control areas. For instance, in 2017, the control sections recorded an average of 48.4 damaged ears of corn per plot, while the laser-protected areas had only 14.6 damaged ears (P = 0.0002). These findings suggest that this technology could serve as a valuable alternative for reducing bird damage.	The scarecrow design, equipped with light sensors, allows the system to operate automatically at dawn and dusk, aligning with bird activity patterns. To enhance effectiveness, the incorporation of additional sensors, such as cameras for bird detection, could be very beneficial. The collected data could be used to dynamically adjust the laser's movement patterns, providing a more accurate response to the presence of birds.	Although this study does not specifically mention AI algorithms, there is potential to apply machine learning to analyze data from sensors and identify bird behavior patterns. Developing algorithms that can process data from the laser system and other monitoring tools could enhance detection effectiveness and response to birds.	There is no specific information regarding the accuracy of any AI algorithms used in this study. However, the statistical analysis conducted using TTEST PROC indicates that the laser scarecrow significantly reduced bird damage. To evaluate the accuracy of any algorithms that may be used, further research is necessary to assess detection outcomes and responses to bird presence.	This study suggests that the long-term effects of using laser scarecrows require further investigation. Given that birds can adapt to new environments, additional research on habituation is crucial to understanding their responses to lasers over time. Various factors, such as food availability and environmental conditions, can influence bird behavior and the technology's effectiveness in the long run.
2	Bhusal et al [13]	The integrated audio-visual technique shows better results compared to using UAVs visually alone. RME (Random Motion Events) enhances effectiveness by altering the UAV's movement patterns, reducing the likelihood of birds becoming accustomed to it. ABSS (Audio Bird Scaring System) plays predator sounds and distress calls, adding an element of uncertainty that makes birds more fearful. Field patrol missions and target interception can be conducted continuously without landing, extending operational time until the battery is depleted.	The ZED stereo vision camera provides 3D depth information and early warnings of approaching birds. The integration of Python with the ZED SDK enables real-time video processing, detecting up to 30 FPS. The effective sensing range is optimized to 15 meters for quick detection of small birds. The GPU-based background subtraction algorithm utilizes the CUDA library to accelerate processing and enhance efficiency.	ResNet-18 is used as the classification model for detecting birds and background with high accuracy (>90%). MobileNet V1 was also tested; however, the former algorithm, ResNet-18, was chosen because it provides a higher frame rate (550 FPS vs. 450 FPS).	The bird pest control technology based on UAVs demonstrates a success rate of 92% in short missions and 90% in longer missions. This indicates that the technology is quite effective, although there are limitations, such as 3D positioning issues without GPS.	The use of RME with random movements (360-degree rotation, sudden elevation changes, and hovering) makes the UAV unpredictable, reducing the risk of habituation. Dynamic audio-visual techniques prevent birds from adapting to repetitive patterns, enhancing long-term effectiveness. Previous studies (Bhusal et al., 2019b) support that this approach is more effective in reducing birds' dependency on specific areas.
3	Ali et al [14]	This research proposes an AI and IoT-based system that can significantly reduce	This system utilizes Passive Infrared (PIR) sensors to detect the body heat of insects, which can	This study employs advanced algorithms, particularly the DenseNet model, to analyze sound	The DenseNet model demonstrates an outstanding detection accuracy of 99.65%, with	The use of ultrasonic waves in this system significantly impacts pest behavior by

		dependence on pesticides. With a detection accuracy of 99.65%, this technology is effective in recognizing and repelling pests, including birds, which can potentially damage crops. The high level of effectiveness indicates that automated systems can significantly mitigate damage caused by pests.	be adapted to identify bird pests. By combining PIR sensors for heat detection and sound analysis to verify the presence of birds, detection effectiveness can be enhanced. Furthermore, utilizing real-time data and feedback from IoT networks can improve accuracy in identifying threats from birds.	data and identify pests. This model is known for its effectiveness in managing complex datasets. For birds, a similar approach can be applied by training the model on bird vocalizations and combining sound analysis with image recognition techniques to effectively detect bird species and behaviors.	additional metrics showing high sensitivity (99.53%) and specificity (98.06%). While this data pertains to insect detection, it suggests that the same AI models could achieve high accuracy levels in bird detection if trained on relevant datasets	creating discomfort. When applied to bird repelling, continuous exposure to this technology may alter bird behavior over time. However, further research is needed to assess long-term habituation effects, as birds may adapt if the repellent is not varied enough or if they have access to alternative food sources. The primary goal is to create an environment where birds feel uncomfortable and prefer to avoid the area.
4	Bhusal et al [15]	Automated technology, such as the use of unmanned aerial systems (UAS), has proven to be highly effective in reducing bird presence in agricultural areas. Research indicates that the implementation of UAS with bird control methods can decrease bird activity by over 300% compared to days without drone flights. By combining various deterrence strategies, such as auditory distress calls and varying flight patterns, the effectiveness of the system significantly increases.	The optimization of sensor use can be achieved by integrating different technologies, such as infrared sensors and machine vision systems for automatic detection. In the discussed study, a machine vision system was designed to detect, track, and count birds. Utilizing advanced algorithms for motion recognition and counting can enhance the accuracy and efficiency of bird pest detection.	In this context, AI algorithms used include neural network-based models, such as DenseNet, for bird detection and counting. These algorithms are trained to recognize sound and movement patterns of birds and integrate data from sensors to optimize the detection process.	The proposed DenseNet model achieves a bird detection accuracy of 99.65%, with a sensitivity of 99.53%, specificity of 98.06%, recall of 98.89%, precision of 99.29%, and an F1 score of 98.87%. This indicates that the AI algorithms in this model are highly effective in detecting bird pests.	The use of automated bird deterrent technology can impact bird behavior over the long term. Birds may become more wary of areas where this technology is frequently employed, potentially altering their migration patterns or feeding habits. However, further long-term research is needed to fully understand the overall effects of this technology on bird behavior and agricultural ecosystems.
5	Mohamed et al [16]	The study indicates that using a combination of reflective boards and auditory stimuli (like ultrasonic and predator sounds) is more effective at scaring away birds compared to other methods, achieving a 22% success rate. However, effectiveness diminishes as the drone's altitude increases, suggesting that flight height should be carefully considered for optimal results.	The deployment of drones with cameras and microphones can be enhanced for real-time detection of birds. By analyzing data from these sensors, farmers can identify the presence of birds and respond accordingly by activating appropriate deterrent devices.	-	The text does not provide specific data regarding the accuracy of the AI algorithms used. However, the research indicates that the combination of auditory and visual methods was effective in scaring birds, suggesting potential for using algorithms to enhance detection and deterrence accuracy.	The findings suggest that birds may become accustomed to or desensitized by the drone's presence over time, particularly with random flights. This indicates that deterrence methods may require updates or combinations with other techniques to maintain their effectiveness over time.
6	Rohmah et al [17]	Automated bird pest control systems showed a success rate of 70% when using both sound and movement mechanisms, compared to 50% when only sound was used	The system utilized Passive Infrared (PIR) sensors to detect bird movement.	-	-	-

7	Zefi et al [18]	The automated bird repellent system effectively replaced traditional scarecrows. The system showed a more efficient bird deterrence approach by automating the process with a wiper motor, speaker, and sound activation to scare birds, reducing manual labor, and improving effectiveness near the harvest season.	-	-	-	-
8	Arowolo et al [19]	The bird repellent system was effective in real-time bird detection and repelling. The system was able to distinguish between birds and other moving objects thereby making it more reliable compared to traditional motion detection systems	The system uses a camera sensor combined with image processing technique through Haar cascade classifiers to detect bird	Haar cascade classifier, Local Binary Patterns (LBP), and Histogram of Oriented Gradients (HOG)	The Haar feature-based cascade classifier attained an accuracy of 76% surpassing the performance of the LBP classifier (72%) and the HOG classifier (27%).	The article showed that the system effectively repelled birds during the testing phase by generating predator sounds and suggesting a potential immediate behavioral influence.
9	Chen et al [20]	The proposed automatic bird repellent system demonstrated a daily bird repulsion rate (BRRd) of 40.3%. Field experiments revealed that the system effectively reduced the number of wild birds, although its efficacy was impacted by environmental factors such as sunlight and the birds becoming habituated to the laser paths.	The system optimized bird detection by using a visible light camera combined with a deep-learning-based model (Mask R-CNN).	The system employed the Mask R-CNN algorithm for bird detection which allowed for high precision in identifying wild birds in the images.	The optimized Mask R-CNN model achieved a precision of 86.5% and a recall of 6.9% when it tested under the optimal experimental conditions which included a confidence threshold of 0.95 and an Intersection over Union (IoU) of 0.1	The study showed that wild birds gradually adapted to the paths of the laser scans and resulting in a decline in the effectiveness of the repelling mechanism over time.
10	Marcoň et al [21]	The proposed system demonstrated a significant reduction in bird presence by detecting and scaring bird flocks using AI-based algorithms.	The system used a camera setup connected to an NVIDIA Jetson Nano microcomputer.	Convolutional Neural Network (CNN)	The bird flock detection reached a precision of 83.4%, while the detection accuracy for larger flocks was even greater at 100%. Additionally, the system demonstrated a high F1 score of 97.1% for bird flocks that indicated its effectiveness in real-time detection and repelling of pests	the system is designed to reduce bird habituation by only activating when a flock is present. This approach minimized the chance that birds will become accustomed to the deterrents and potentially maintaining effectiveness over the long term.
11	Morley et al [22]	While the automated systems in this journal, such as UAS equipped with bait dispersal, have shown accuracy in managing pests, these systems are mostly targeted at animals such as squirrels, not birds.	This system uses sensors that can be enhanced using real-time kinematic methods for precise tracking and targeting in pest control.	Not specifically mentioned for birds, but algorithms focus on UAV control and precision.	-	No long-term bird behavior impact is covered, as focus remains on mammals .
12	Werrell et al [23]	Sonic Net technology can reduce up to 63.6% of sunflower crop damage caused by blackbirds by blocking the birds' communication pathways, causing	-	-	-	Over time, birds will continue to avoid the treated area as the Sonic Net prevents habituation by making the birds feel an increased risk of predation.

		them to stay away due to the perceived presence of other predators.				
13	Romero et al [24]	Biomimetic drones are designed to mimic the behavior and sounds of predators to scare away birds and reduce bird damage to crops. These drones can also be controlled automatically based on a predetermined schedule.	This drone system uses thermal and infrared cameras to monitor crops and detect disturbances that allow for a rapid response in preventing birds.	To optimize drone flight paths and ensure efficient crop monitoring, a DERT (Dynamic Environment Random Tree) Algorithm is required which prioritizes areas based on bird activity and optimizes drone work.	DERT algorithm is designed to reduce computational complexity and efficiently allocate drones to areas most affected by bird pests.	Drone technology designed to mimic the behavior and sounds of predators with varying patterns allows birds to become unfamiliar with the deterrent, creating a long term deterrent.
14	Ritti et al [25]	YOLO-based AI and Iot-enabled object detection technology, can prevent crop damage as it detects approaching bird species and triggers automatic prevention such as alarms and buzzers.	For species-specific classification, the system combines webcam feeds with YOLOv3 object detection and a ResNet100-based CNN. Additional IoT components, such as ESP32 and IR sensors, provide real-time monitoring.	The algorithms used are YOLOv3 and ResNet100 which function to classify bird species in real-time to ensure accurate prevention.	In this system, YOLOv3 is operated with high accuracy with real-time object detection so that it can analyze images at 30 frames per second.	If used over a long period of time, this AI-based deterrent can cause bird-induced disturbance to protected crops.
15	Mhandu et al [1]	Automated scarecrow technology is more effective than traditional scarecrows at reducing crop damage because it uses motion sensors, sound transmitters, and lights that can cover 0.75 hectares.	This system using a combination of 3 PIR (Passive Infrared) sensors can improve the detection accuracy of birds and other pests with a range of 50 meters and a detection angle of 120 degrees.	The scarecrow system uses programming for triggering sensors and sound emitters .	The system shows high accuracy in detecting birds through motion sensors.	Automated deterrents that combine sound, movement and light can keep birds away for a longer time compared to traditional scarecrows.
16	Sayem et al [2]	-	This system describes the use of laser and vibration sensors to detect unauthorized access to agricultural land. The laser sensor showed 100% responsiveness, while the vibration sensor showed 90% responsiveness.	-	-	-
17	Blümel et al [4]	-	This system develops the use of multiple ultrasonic sensors and algorithms to detect multiple objects with distance and angle information. This approach can be adapted to optimize the use of sensors in detecting bird pests in agricultural land by improving spatial detection and accuracy.	-	-	-
18	Olugbenga et al [3]	The automated technology developed in this system uses PIR sensors and industrial sirens to detect and repel birds. Test results show that this device is effective in detecting birds up to 6.5 meters away and produces a sound with a sound pressure level of about 150 dB which is enough to scare birds.	The use of sensors can be optimized by placing them above vegetation to avoid obstacles that can affect their sensitivity. In addition, the number of sensors and sirens can be increased to cover a wider area.	-	-	-
19	Lamane et al [5]	-	This system implements the use of FMCW radar	This system uses the YOLOv5 algorithm for	The YOLOv5 model in this system achieved an	-

			and YOLOv5 model to detect human presence in heatmap images, but does not specifically address sensor optimization for detecting bird pests in agricultural land.	target classification and detection on heatmap images generated from FMCW radar.	average accuracy rate (mAP_0.5) of 0.89.	
20	Yang et al [6]	This system leverages the effectiveness of remote monitoring systems for bird repellent equipment at airports, which use sensors and wireless technology to monitor and control the equipment in real-time.	The use of sensors in the system includes temperature sensors, pressure sensors, power supply voltage sensors, and sound sensors. These sensors collect data and transmit it wirelessly to a central system for real-time monitoring and control. The optimization involves ensuring accurate data collection and reliable wireless transmission.	-	-	-

C. Answering RQs

The success of automated bird pest deterrents is influenced by several factors, including the method of deterrence, the species of birds (for instance, some birds may not be affected by the devices because they are too small), the timing when birds forage around agricultural areas, the birds' adaptation to the deterrent methods, the AI algorithms used [2], [3], [4], [20], [19], [21], as they affect the accuracy of the model, and the consistency of the model's application over time, which encourages birds to avoid areas perceived as hazardous. A brief description of the factors influencing the model is as follows:

- **Deterrent Method:** The method used to deter birds impacts the outcomes because employing different techniques, such as using devices that emit sound waves to scare birds or utilizing drones, affects the accuracy of targeting and enhances overall effectiveness.
- **Bird Species:** Not all birds inhabiting rice fields or agricultural areas belong to the same species. Some birds are large, like crows, while others are small, like sparrows. The effectiveness of the model depends on the specific conditions present at the location.
- **Time and Season:** There are times when birds forage in the fields and times when they perch in their nests. Assessing the right timing for when birds leave their nests to search for food is crucial.
- **Bird Adaptation:** Birds that are accustomed to disturbances in the fields caused by traditional methods, such as scarecrows, develop behaviors that allow them to predict where disturbances might occur. However, new devices may confuse birds, making them unsure about the new forms of disturbances.
- **AI Algorithms:** The algorithms used influence detection accuracy and deterrent effectiveness, which significantly contributes to the overall success of the model.
- **Consistency:** Continuous application of the model increases birds' wariness of areas deemed hazardous.

In relation to RQ1, numerous automated bird deterrent technologies, such as drones, lasers, and sound nets, were identified during the assessment. The amount of bird damage in agricultural fields was greatly decreased by these technologies. For example, using UAV-based systems [13] and robotic scarecrows demonstrating [12] encouraging outcomes, often reduces crop damage caused by birds by more than 60%.

In relation to RQ2, this article reviews shows that optimizing the placement of sensors such as Passive Infrared (PIR) and thermal cameras that are critical in bird pest detection (e.g., height and angle) [14][17][1] and integrating them with AI and IoT systems can improve detection accuracy. This combines real-time data analysis with sensor networks to cover larger areas efficiently.

In relation to RQ3, several AI algorithm models, such as YOLO, Mask R-CNN, and DERT, are used in bird pest detection [20][24][5]. These models help in classifying birds and optimizing drone flight paths. Not only AI algorithmic models, machine learning models also improve the detection of bird species and behavior, enhancing the response of deterrent systems.

In relation to RQ4, the DenseNet model showed a detection accuracy of 99.65%, with a sensitivity of 99.53%, a specificity of 98.06%, a recall of 98.89%, a precision of 99.29%, and an F1 score of 98.87% [14][15]. In addition, the Haar Cascade Classifier achieved an accuracy of 76%, while Local Binary Patterns (LBP) had an accuracy of 72%, and Histogram of Oriented Gradients (HOG) only 27% [19]. The Mask R-CNN model showed a precision of 86.5% and a recall of 6.9% [20]. Flock detection of birds achieved a precision of 83.4%, with a detection accuracy for large flocks reaching 100% and an F1 score of 97.1% [21]. The YOLOv5 model in this system achieved an average accuracy (mAP_0.5) of 0.89 [5]. These data show the effectiveness of various AI algorithms in detecting and repelling bird pests.

In relation to RQ5, overall, the article highlights that automated systems using technology can have a long-term impact on the process of reducing bird pests. However, technology also needs to adjust patterns (e.g., random flight paths) so that it can be more effective in preventing habituation.

IV. Conclusion

This article reviews articles listed on Science Direct and Google Scholar regarding automatic bird repellent systems in agricultural areas. The search keywords used are based on. ("Bird Pest Management" OR "Pest Bird System" OR "Automatic Bird Pest Repellent" OR "Bird Deterrence" AND "Internet of Things" OR "IoT" AND "Artificial Intelligence" OR "AI" OR "Machine Vision" OR “Airport”). The search was conducted on September, 17, 2024 and obtained 20 articles. Other researchers will have a great opportunity to publish articles on the topic of automatic bird repellent systems in international journals, as this topic remains limited. After the review is complete, it can be concluded that accuracy, precision, F1 score, sensitivity, specificity, and AI algorithms are the parameters most controlled by researchers, compared to the other parameters mentioned above. Automatic bird repellent systems utilize several AI algorithm models, such as YOLO, DenseNet, Mask R-CNN, and DERT. These models assist in classifying birds and optimizing the flight paths of drones. The DenseNet model is the most effective AI algorithm for classifying birds and detecting their presence. This model has the highest success rate compared to others, although the percentage of success rates is not significantly different, being no less than 27% when evaluated from the aspects of detection accuracy, sensitivity, specificity, recall, precision, and F1 score. Overall, researchers successfully managed bird pest populations in agricultural areas with an accuracy rate ranging from 72% to 99%, considering the models and AI algorithms used.

References

[1] M. M. Mhandu, A. Musarurwa, and L. K. Gudukeya, “Design Of a Solar Automated Scarecrow,” Proc. IEOM Int. Conf. Smart Mobil. Veh. Electrif., pp. 440–451, 2023, doi: 10.46254/ev01.20230036.

[2] N. S. Sayem et al., “IoT-based smart protection system to address agro-farm security challenges in Bangladesh,” Smart Agric. Technol., vol. 6, no. October, p. 100358, 2023, doi: 10.1016/j.atech.2023.100358.

[3] A. Olugbenga, O. F. O, and O. D. Itakorode, “Development and Implementation of Arduino-based Birds Repellent for Farmers,” Int. J. Sci. Res., vol. 9, no. 5, 2020, doi: 10.21275/SR20512000949.

[4] K. Blümel, F. Tagliaferri, and M. Kuhl, “Algorithm for calculating distance and sensor-object angle from raw data of ultra-low power, long-range ultrasonic time-of-flight range sensors,” Procedia CIRP, vol. 118, pp. 1061–1065, 2023, doi: 10.1016/j.procir.2023.06.182.

[5] M. Lamane, M. Tabaa, and A. Klilou, “Classification of targets detected by mmWave radar using YOLOv5,” Procedia Comput. Sci., vol. 203, pp. 426–431, 2022, doi: 10.1016/j.procs.2022.07.056.

[6] X. Yang, C. Wang, Z. Chen, and D. Wang, “Design of Airport Wireless Bird Repellent Monitoring System,” IOP Conf. Ser. Mater. Sci. Eng., vol. 768, no. 7, 2020, doi: 10.1088/1757-899X/768/7/072076.

[7] E. B. Micaelo, L. G. P. S. Lourenço, P. D. Gaspar, J. M. L. P. Caldeira, and V. N. G. J. Soares, “Bird Deterrent Solutions for Crop Protection: Approaches, Challenges, and Opportunities,” Agric., vol. 13, no. 4, pp. 1–29, 2023, doi: 10.3390/agriculture13040774.

[8] S. S. Baral, R. Swarnkar, A. V. Kothiya, A. M. Monpara, and S. K. Chavda, “Bird Repeller – A Review,” Int. J. Curr. Microbiol. Appl. Sci., vol. 8, no. 02, pp. 1035–1039, 2019, doi: 10.20546/ijcmas.2019.802.121.

[9] I. Suleiman, A. Babawuya, and B. Salihu, “A Review of Bird Pest Repellent Systems in Farms a Review of Bird Pest Repellent Systems in Farms,” First Int. Bus. Manag. Conf., vol. 19, no. 1, pp. 1–13, 2021.

[10] J. K. Enos, M. P. Ward, and M. E. Hauber, “A review of the scientific evidence on the impact of biologically salient frightening devices to protect crops from avian pests,” Crop Prot., vol. 148, no. June, p. 105734, 2021, doi: 10.1016/j.cropro.2021.105734.

[11] S. T. DeLiberto and S. J. Werner, “Applications of chemical bird repellents for crop and resource protection: a review and synthesis,” Wildl. Res. , vol. 51, no. 2, 2024, doi: 10.1071/WR23062.

[12] R. N. Brown and D. H. Brown, “Robotic laser scarecrows: A tool for controlling bird damage in sweet corn,” Crop Prot., vol. 146, no. November 2020, p. 105652, 2021, doi: 10.1016/j.cropro.2021.105652.

[13] S. Bhusal, M. Karkee, U. Bhattarai, Y. Majeed, and Q. Zhang, “Automated execution of a pest bird deterrence system using a programmable unmanned aerial vehicle (UAV),” Comput. Electron. Agric., vol. 198, no. October 2020, p. 106972, 2022, doi: 10.1016/j.compag.2022.106972.

[14] M. A. Ali, R. K. Dhanaraj, and S. Kadry, “AI-enabled IoT-based pest prevention and controlling system using sound analytics in large agricultural field,” Comput. Electron. Agric., vol. 220, no. March, p. 108844, 2024, doi: 10.1016/j.compag.2024.108844.

[15] S. Bhusal, K. Khanal, S. Goel, M. Karkee, and M. . Taylor, “Bird deterrence in a vineyard using an unmanned aerial system (UAS).,” Trans. ASABE, vol. 62, no. 50, pp. 9–10, 2019.

[16] W. M. W. Mohamed, M. N. M. Naim, and A. Abdullah, “The efficacy of visual and auditory bird scaring techniques using drone at paddy fields,” IOP Conf. Ser. Mater. Sci. Eng., vol. 834, no. 1, 2020, doi: 10.1088/1757-899X/834/1/012072.

[17] R. N. Rohmah, Y. Oktafianto, Nurokhim, H. Supriyono, and A. Supardi, “Pest Control System on Agricultural Land Using Iot Electronic Controller,” J. Appl. Eng. Technol. Sci., vol. 5, no. 2, pp. 1011–1019, 2024, doi: 10.37385/jaets.v5i2.4592.

[18] S. Zefi, S. Siswandi, E. Hesti, and C. Ciksadan, “Implementation of Appropriate Technology for Bird Pest Removal to Replace Scarecrow with Solar Cell Based on Internet of Thing at Usaha Tani Mandiri Kertapati Palembang,” Proc. 6th FIRST 2022 Int. Conf., pp. 400–406, 2023, doi: 10.2991/978-94-6463-118-0_41.

[19] O. Arowolo, A. Adekunle, and J. Ade-omowaye, “A Real Time Image Processing Bird Repellent System Using Raspberry Pi,” FUOYE J. Eng. Technol., vol. 5, no. 2, pp. 101–108, 2020.

[20] Y. C. Chen, J. F. Chu, K. W. Hsieh, T. H. Lin, and P. Z. Chang, “Automatic wild bird repellent system that is based on deep - learning - based wild bird detection and integrated with a laser rotation mechanism,” Sci. Rep., no. 0123456789, pp. 1–15, 2024, doi: 10.1038/s41598-024-66920-2.

[21] P. Marcoň et al., “A system using artificial intelligence to detect and scare bird flocks in the protection of ripening fruit,” Sensors, vol. 21, no. 12, 2021, doi: 10.3390/s21124244.

[22] C. G. Morley, P. Solaris, G. Quinn, K. E. Ross, and B. J. Peterson, “Precision pest control using purpose-built uncrewed aerial system (UAS) technology and a novel bait pod system,” Drone Syst. Appl., vol. 12, no. 1080, pp. 1–13, 2024, doi: 10.1139/dsa-2023-0104.

[23] A. K. Werrell, P. E. Klug, R. N. Lipcius, and J. P. Swaddle, “A Sonic Net reduces damage to sunflower by blackbirds (Icteridae): Implications for broad-scale agriculture and crop establishment,” Crop Prot., vol. 144, no. October 2020, p. 105579, 2021, doi: 10.1016/j.cropro.2021.105579.

[24] A. Romero, E. S. D. la Cruz, A. Ochoa, and A. Hernández, “Biomimetric Drone for Controlling Bird Pests and Optimizing Citriculture,” Res. Comput. Sci., vol. 149, no. 6, pp. 61–74, 2020, [Online]. Available: http://www.cic.ipn.mx

[25] A. Ritti and J. Chandrashekhara, “Detecting Intended Target Birds and Using Frightened Techniques in Crops to Preserve Yield,” Int. J. Innov. Res. Comput. Sci. Technol., no. 5, pp. 24–27, 2024.