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Concept Paper

RICEGUARD: IoT Noise-Enabled Scarecrow with Image Processing through Machine Learning and SMS Notification for Rice Crop Protection Enhancement

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Abstract

Purpose – This study intends to build a smart scarecrow that protects the rice yield especially when the grain is almost ripe. This will offer a dependable and effective method for safeguarding rice crops through the Internet of Things and machine learning image processing.

Method – The agile methodology was utilized in this study since it is suitable for the device's iterative development process.

Results – The mean result of the system evaluation is rated at 4.45, with an excellent interpretation from the user using the ISO ISO/IEC 25010:2011 tool.
Conclusion – The researchers were able to develop smart water irrigation for rice farming using IoT and micro-controller devices with solar panel support and the respondents also agreed that the Smart water irrigation for rice farming using IoT and micro-controller devices with solar panel support is practical and valuable.

Recommendations – Future researchers that will focus on the relevant study may consider integrating an autofocus camera into the system to enhance the image resolution, making it significantly more effective in threat detection within the covered area. It will also contribute to stability and enhance tracking capabilities, especially for moving subjects.

Research Implications - The research can help rice farmers protect their crops from bird attacks, especially when the crop is almost ready for harvest. This will enhance the farmers' production, leading to a higher income to support their families.

Keywords – Rice Agriculture, Internet of Things, Machine Learning, Automated Scarecrow, Arduino

INTRODUCTION

Rice is a significant crop in several developing countries throughout the world. The Philippines, specifically, is one of the Asian countries wherein rice is the primary essential food. The cultivation of rice significantly influences the nation's agricultural sector. It is because rice farming is one of the most significant development drivers for many nations' economies, societies, and cultural legacies. Rice is the most consumed food product for the global population and human consumption (Vinci et al., 2023). Rice holds vital importance, particularly for Filipinos and other Asians, despite the presence of alternatives like noodles and bread.

In the Philippines, rice continues to reign as the preferred choice for staple food. Rice is a member of the Oryza L genus, including about 25 species in the tropics and subtropics, and it requires special attention to thrive. The production of global rice demand, projected to reach 8.9 million by 2050, is still uncertain unless the problems and challenges in rice production are appropriately addressed (Binayao & Mantua, 2024). Hence, researchers continuously conduct studies to further develop techniques to improve rice farming methods and production. As technology progressed, it paved the way for the utilization of modern methods and devices in the agricultural sector.

Smart farming is an innovative technology for managing and improving farming operations, particularly in rice production as it is projected to be strongly influenced by the three areas of smart farming: Big Data, Machine Learning, and the Internet of Things (Alfred et al., 2021)

However, due to unavoidable circumstances, farmers have been experiencing significant crop loss. The primary threats were caused by bird attacks, thieves, and wildfires. Common tactics and strategies can often be brutal and useless for the farmers. Random shooting, catching, or poisoning suspects may bring relief for a while, but it fails to satisfy the problem for the future. Bird pests are one of the main threats to farmers. As a result, one approach for repelling bird pests is to utilize an automatic bird repellant. Bird scaring is one of the traditional methods used in the production of rice. It entails a variety of actions used to keep birds away from rice during a particular time when the crop is developing in the field. Birds are kept off rice farms during the milk stage of rice development. Grain-eating birds invade the rice fields during this stage and suck the milky grains, leaving behind broken stems, clipped panicles, and empty or poorly filled grains. In subsequent phases, as the grains ripen, birds also break the grains. Meager yields and whiteheads result from birds invading rice fields (Hardiansyah et al., 2023). To choose the optimal course of action, the social, economic, and cultural factors need to be considered. Nowadays, it is done with a standard scarecrow form, to deter birds and other animals from disrupting and consuming recently cast seeds and developing crops, a humanoid structure dressed in clothing has been built in an open field (Mapari et al., 2022).

The bird attacks on rice crops are the primary challenge of the farmers not only in the Philippines but throughout other rice-producing nations. Manolo Fortich rice farmers are experiencing this problem firsthand, especially during the later part of the farming, just before harvest. Flocks of birds are devouring the rice fields, and only indigenous manual repellant mechanisms are put in place to safeguard the rice crop. The emergence of the Internet of Things (IoT) with machine learning and SMS notifications provides an efficient and reliable solution for protecting rice fields. By deploying AI algorithms in image processing, the system can identify and analyze potential threats, focusing on the productivity of bird activities in the surrounding area (Dange et al., 2023).

This study will enhance potential farmers' income by preventing crop loss. The goal of this research is to offer a dependable and effective method for safeguarding rice crops. With relation to farming-related concerns, image processing equipment has a greater potential utility due to the quick development of digital technology. This problem has no easy solution. Animals nowadays are intelligent enough to figure out how to get around barriers like scarecrows and fences. Therefore, an automation system that can stop or, more likely, modify animals' thought processes is needed in the agricultural sector.

LITERATURE REVIEW

Internet of Things

Bird attacks are a major threat and problem in the rice cropping business for crop coverage and automated pest control. Birds are one of the pests and destructive animals that are often encountered in rice fields. Farmers have traditionally used plastic ropes and scarecrows as a common measure to ward off bird attacks. This study proposes to compare and contrast different methods of bird detection through camera sensors and determine the most precise technique. The chosen technique is thereafter applied to drive away birds automatically using sound frequencies that are reputed to be undesirable to birds and thereby drive them away as pests. The design of the Bird Repellent device involves using computer vision through camera sensors for the detection of bird objects within every frame. A microcontroller then processes data. Upon detecting the bird object, the microcontroller activates an actuator producing the required sound frequency. The systems are engineered for monitoring and automatic control of bird attacks, maximizing crop yield in agriculture. The method leverages the Internet of Things (IoT) to establish a networked system that improves bird deterrence and safeguards crops (Roihan et al., 2020). Another IOT research in India was created on bird detection and bird repelling utilizing passive infrared (PIR) motion sensors to effectively detect bird movement, which was the basis of the model. Incorporating a repel mechanism that plays predator sounds through an MP3 module and megaphone to scare away birds from the fields (Riya et al., 2020).

Conventional scarecrows may not scare away birds effectively, resulting in damage to crops by birds during the cultivation period. Farms are subjected to invasions and harvest theft, requiring farmers and their guard dogs to stay on the farm premises for crop guarding. For the sake of efficiency, the crops in large areas will be broken down into smaller regions for surveillance, each with its crop safeguarding system. When the sensor senses an intruder, the alarm and lights turn on, essentially frightening away birds or other intruders from the field (Chan et al., 2019). Innovation over conventional scarecrows was achieved through the creation of electronic versions with multifunctional features, known as Multi-Function Electronic Scarecrows (MFESC). The scarecrows are made up of different components, with the sensor being the most important. With a digital camera, the sensor executes a variety of duties, including recording bird noises, sensing temperature and humidity surrounding plants, and sensing statistical data related to birds' activities. MFESC forwards all gathered data to a specialized data system it is linked to. The MFESC has two arms with cloth-like objects on each arm that vibrate upon bird detection. Furthermore, the scarecrow also creates noise and light to chase the birds away. Numerous electronic scarecrows are placed around the crop field, with one of them as the principal scarecrow. Any scarecrow that senses bird movement, sound, or light will send a signal to the principal scarecrow, which sets off the other scarecrows to start their movement, sound, and light functionality. The principal scarecrow gathers and reports information to the farm system related to the MFESC (Alneimi et al., 2020). Aiming towards Intrusion detection in agriculture from the Internet of Things (IoT) indicates that in developing nations such as India, where agriculture is a key source of livelihood for numerous individuals, it is important to ensure maximum crop yield. However agricultural fields tend to be exposed to animal assaults and crop loot, and farmers incur heavy losses. To solve this problem, the authors of this research present the design of a system that leverages Wireless Sensor Network (WSN) and Internet of Things (IoT) technologies to detect intruders in fields.

The system will improve security by detecting and informing farmers in real-time upon intrusion into their fields. The system is a mesh of wireless sensors positioned in a strategic array throughout the field (Abinaya et al., 2018).

Machine Learning

Deep Neural Networks (DNN) and the Internet of Things (IoT) are some of the technological innovations that have enabled real-time precise control, monitoring, and observation operations in contemporary agriculture. It is not simple to control animal interactions, however, particularly in protecting crops from animal intrusions. The current research proposes an integrated system where specialized ultrasonic techniques in repelling different species of animals are integrated with AI computer vision and Deep Convolutional Neural Networks (DCNN) for detection and identification of animals. AI computer vision and DCNN are utilized in the Animal Repelling Module for the identification and detection of the targeted species and sending to trigger specific frequencies of ultrasound.

With the aid of deep learning image identification technology, researchers have created a state-of-the-art method to address bird damage in conventional agriculture. Using cameras positioned around farms, the system, which runs on a tiny single-board computer with GPU capabilities like the NVIDIA Jetson Nano, detects flocks of birds in real time. It provides farmers with an efficient way to safeguard their crops by activating ultrasonic bird-repellent devices via LoRa wireless connection (Liaw & Li, 2021).

Edge computing is transforming crop protection against ungulate attacks in modern agriculture. Virtual fences, blending computer vision and ultrasound emission, deter threats effectively. Tailored ultrasound signals for different ungulate species enhance efficacy, while IoT platforms address energy and connectivity constraints. Various edge computing devices, evaluating real-time object detection with custom models, achieve accuracy without compromising speed. A cost/performance analysis and implementation of best practices empower farmers and agronomists, enhancing decision-making and crop management in smart agriculture (Adami et al., 2021). Deep Neural Networks (DNN) and the Internet of Things (IoT) to develop and implement precise controlling, monitoring, and tracking applications. The created system combines AI Computer Vision using DCNN to detect and identify animal species and ultrasound emissions to repel them. The edge computing device activates the camera and utilizes its DCNN software to recognize the target. If an animal is detected, it sends a message to the Animal Repelling Module with specific instructions for generating the appropriate ultrasound based on the animal's category (Lekhaa et al., 2022). Deep learning algorithms, specifically Convolutional Neural Networks (CNN), are used to classify them as either wild animals or birds. Notifications containing the location of the detected wild animal or smuggler are sent to the farmers and the forest department via SMS, enabling efficient reduction of crop damage. The system identifies the animal or smuggler in captured images and repels them by playing corresponding sounds (Begum et al., 2022).

Another study utilizes Internet of Things (IoT) technology and machine learning techniques to tackle this problem. The system consists of a Raspberry Pi running a machine learning algorithm, connected to various components such as the ESP8266 Wireless Fidelity module, Pi Camera, Buzzer, and LED. Machine learning algorithms, precisely the Region- based Convolutional Neural Network and Single Shot Detection technology detect and classify animals in images. Experimental results demonstrate that the Single Shot Detection algorithm outperforms the Region-based Convolutional Neural Network algorithm. Lastly, the Twilio API integrated software allows for efficient information communication to farmers, enabling them to take prompt action in their farm fields (Balakrishna et al., 2021).

The related studies provided above hold information that the current study saw similarities in critical points and ways of implementing the system, researchers seek innovative ideas to fill the research gaps. It gave the researchers a guide and knowledge on how to develop a system that integrates artificial intelligence with machine learning and the Internet of Things. The research mentioned above supports the implementation of RICEGUARD: An IoT Noise-enabled Scarecrow with Machine Learning and SMS Notification for Rice Crop Protection Enhancement.

Recent studies stated that renewable energy, like solar panels, etc., should be included to sustain system power as the system will be placed in a field. Other studies also recommend using image processing units to identify targets more accurately and will not cause nuisance during false detection. They also apply the IoT-driven system as a gateway to inform the user via software if an unwanted guest will ever be detected. Additionally, through IoT, the user will be informed via SMS using the GSM module. To elaborate further, researchers promoted this kind of system to help the farmers boost their crop gross during harvest time and not lose their entire investment.

METHODOLOGY

In the development of the device, the researchers used the Agile Development methodology (Binayao & Mantua, 2024; Sigongan et al., 2023; Tubio II et al., 2023)

Plan

This phase included reviewing and assessing the requirements, including the study's key factors. Concepts and ideas about how the study flow was gathered through documentation. In project management, a Gantt chart is used to visually represent a project plan over time (Figure 1).

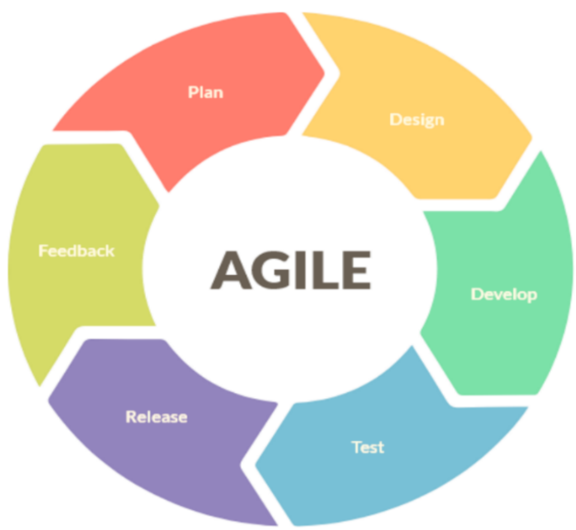

Figure 1. Agile Methodology

Design

Figure 2 shows the circuit connections for the main components of the system. The entire system operates seamlessly owing to the careful configuration of its elaborate network of several wirings and components. The relationships between various components of the circuitry have been thoughtfully planned to ensure optimal performance and reliability.

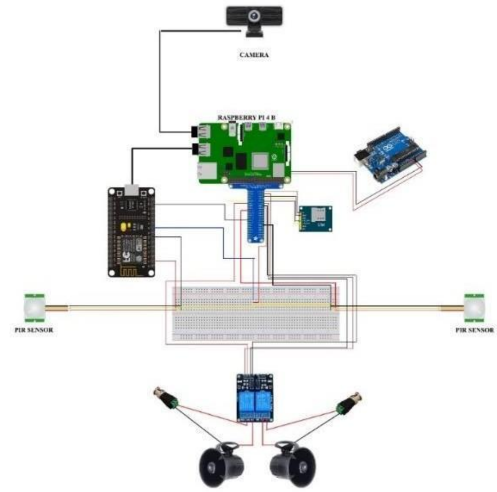

Figure 2. Circuit Connection of the Main Components

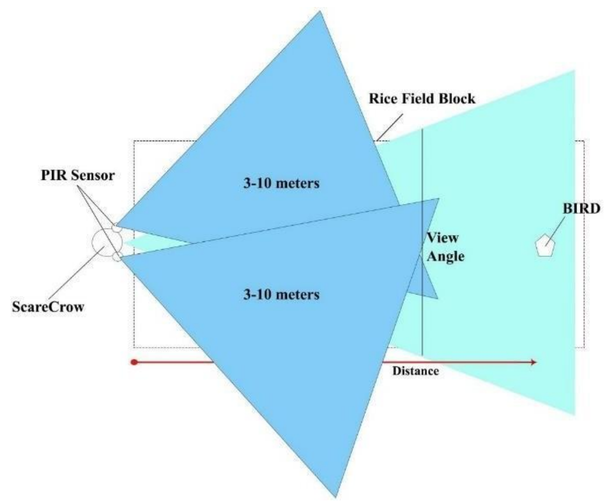

Figure 3. Circuit Connection of the Main Components

Figure 3 shows the system's actual plotting design once deployed in the rice field. Two methods that were used in the device's design are also included in this phase. The application's architectural framework was the other, and the former was its visual design. The researchers convened during the first iteration and presented the project idea. Then discussion and presentation of the requirements needed followed. The researchers scrutinized the entire process. To achieve the greatest outcomes, the researchers looked for potential instruments. The Block Diagram, Use-Case Diagram, and System Design Architecture were utilized in the study development.

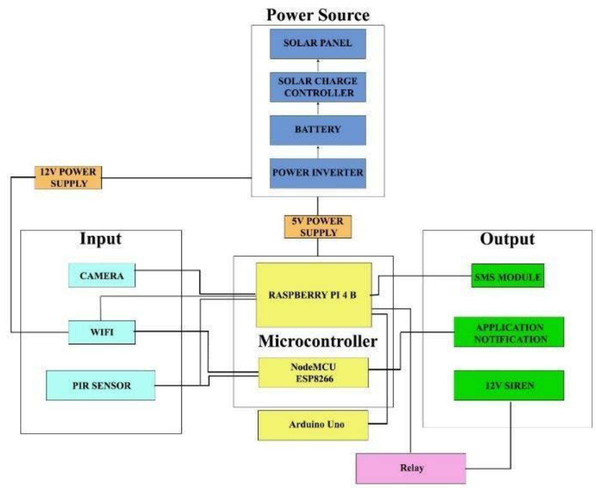

Figure 4. Block Diagram

The block design in Figure 4 begins with the addition of a solar panel to the system as a power supply to get it ready for use. The system is placed on the rice field when the user powers it up, and the system starts its task. A camera supported by Raspberry Pi 4 performs image and video processing that can be used to identify birds who have entered the field. A PIR sensor was placed over the prototype body, detecting the movement nearby and triggering the sound of the siren. After it detects and identifies the movements in the field, an SMS Alert is sent to the owner so they can be notified of what happens. Lastly, the owner may access the footage on the SD card and examine it.

Develop

The researchers employed Arduino IDE and Thonny Python IDE to program the prototype. The two primary programming languages utilized for creating the system were C++ and Python. To improve the system's functionality, a Convolutional Neural Network (CNN) algorithm was specifically added to use machine learning for images. The hardware platform utilized to implement these algorithms was the Raspberry Pi 4b. To maximize energy efficiency, a 55W solar panel and a PWM 10A solar charge controller. An E-bike battery was utilized for energy storage. A twin 12V siren system was also installed in a strategic location to produce auditory alerts in response to inputs from PIR or video sensors.

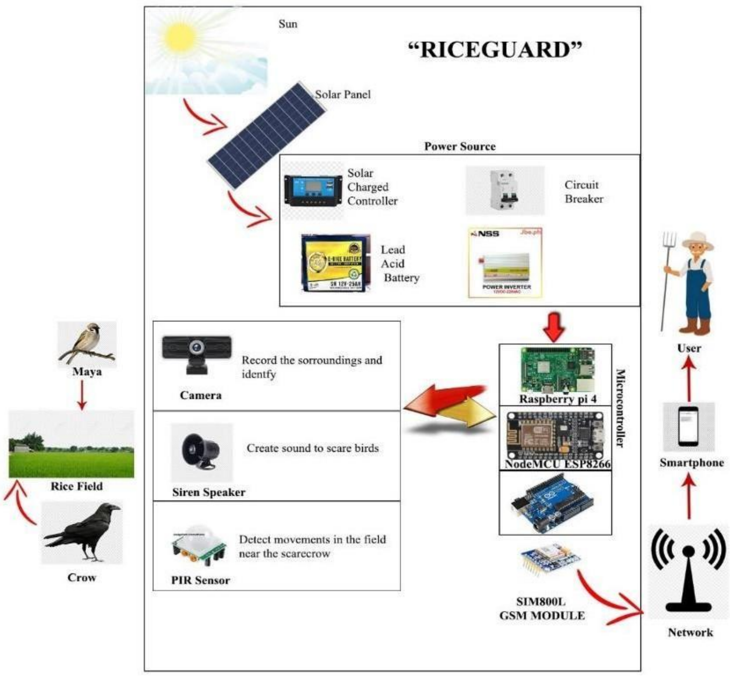

Figure 5. RICEGUARD's System Architecture

Figure 5 shows the system architecture that outlines the essential components needed for implementing the system. The architecture is divided into three main categories: 1) Power Source, encompassing components responsible for system activation; 2) Camera PIR Sensor, covering elements designed to detect and deter birds; and 3) Microcontroller, constituting the parts of the system that execute the code, manage recordings, and assign tasks to the various components. The following is the list of the hardware components:

- Raspberry Pi 4 Model B Starter Kit This is used to execute machine learning algorithms that recognize images using the built-in camera input. It is successful at identifying and categorizing items. Broadcom BCM 2711 Quad-core Cortex-A72 (ARM v8), 4GB LPDDR4-3200 SDRAM, and 64-bit SOC @ 1.5GHz.
- Arduino Uno R3 The ATmega328P microcontroller has the following specifications: operating voltage of 5V, recommended input voltage of 7–12V, input voltage (limit) of 6–20V, digital I/O pins of 14 (six of which provide PWM output), analog input pins of 6, DC current per I/O pin of 20 mA, DC current for 3.3V pin of 50 mA, 32 KB of flash memory (0.5 KB used by bootloader), SRAM of 2 KB (ATmega328P), EEPROM of 1 KB (ATmega328P), and clock speed of 16 MHz.
- Raspberry Pi T-Cobbler GPIO Breakout This adapter will make it simple to interface the GPIOs on the Raspberry Pi computer board with a breadboard. The T-Cobbler Plus is built and has a 40-pin ribbon cable.
- Gsou T16s (1080P) Webcam This is to assist the Raspberry Pi in taking pictures of birds in rice fields. The T16s model offers a 1280x720 resolution, a 78° field of vision, a wide-angle lens, a built-in microphone, and 30 frames per second for both 720P and 1080P.

- SIM800L V2 5V Wireless GSM GPRS Module This part can send messages, make calls, and transfer data via GPRS when it is connected to a Raspberry Pi and NodeMCU.
- Alarm Siren Speaker The purpose of this is to produce sound when the cameras and sensor detect motion. -The specifications include 0.39 × 0.39 inches, rated voltage of DC 12V, standby current of 600mA, alarm current of 1200mA, and volume of 110 dB.
- Infrared Motion Sensor This is used to check for infrared heat at its detecting angle and to detect motions. The sensor detects energy emitted by the human body, animals, and a variety of other objects. It compares this energy with the snapshot and activates if there has been a recent change. Its dimensions are 28 x 36 mm, its operating temperature range is 0 ℃ to 70 ℃, its supply voltage is 5 volts, and its detect distance is 3 to 7 meters.
- 55-Watt 12 Volt Monocrystalline Photovoltaic Solar Panel
- This is used to harvest solar energy or sunlight, and turn it into electrical power. The dimensions are 65x48x5 cm, the maximum power voltage (VMP) is 12 V, and the maximum output power (PM) is specified at 55 W.
- Battery 12v25Ah Gel Battery This is employed as a means of storing the electricity produced by solar power systems, which are triggered if the solar panels are unable to provide sufficient power. Lead acid application is regulated by a deep cycle valve.
- 10A PWM 12V Solar Panel Regulator Charge Controller Solar Battery Charger LCD Display USB This controls the voltage and current that the solar panel generates and sends to the battery. This stops the battery from being overcharged. It is a 10A type that runs at 12V with a maximum solar panel input of 25V and 120W.
- Nodemcu esp8266 It is utilized for GSM module and PIR sensor control, as well as USB serial communication with Raspberry Pi. Operating temperature ranges from -40°C to 125°C. The Tensilica LX106 CPU has a clock frequency of 80–160 MHz, 64 kB RAM, and 96 kB data storage. It also supports the Wireless Standard 802.11 b/g/n. The operating voltage ranges from 3.0-3.6 V (which may be adjusted by 5V microUSB). The operating current is 80 mA.
- 5V Relay Module Contact types include NC and NO. TTL Control Signal: 5VDC to 12VDC (some boards may operate with 3.3VDC); Maximum AC: 10A 250VAC; Maximum DC: 10A 30VDC.
- CHINT Circuit Breaker The overload, short circuit, and isolation features of CHINT are provided by miniature circuit breakers. It is extensively utilized in industrial and building power distribution, as well as in the control and protection of several pieces of equipment that require operational current.

Test

Figure 6 shows the Machine Learning model training. The types of birds tested to validate the accurate identification are Eurasian Tree Sparrow "Maya", Crow "Uwak", Buff-Banded Rail "Tikling", and White-Eared Brown. This was a critical stage in the development process that was intended to improve the system's image classification accuracy. The researchers used a dataset of 220 photos using Google Colaboratory that fell into four different categories to build the machine-learning model. The result was impressive, and all the categories had precise predictions. The evaluation of the Convolutional Neural Network (CNN) model was conducted using a quantitative analysis approach, primarily measuring accuracy and validation performance.

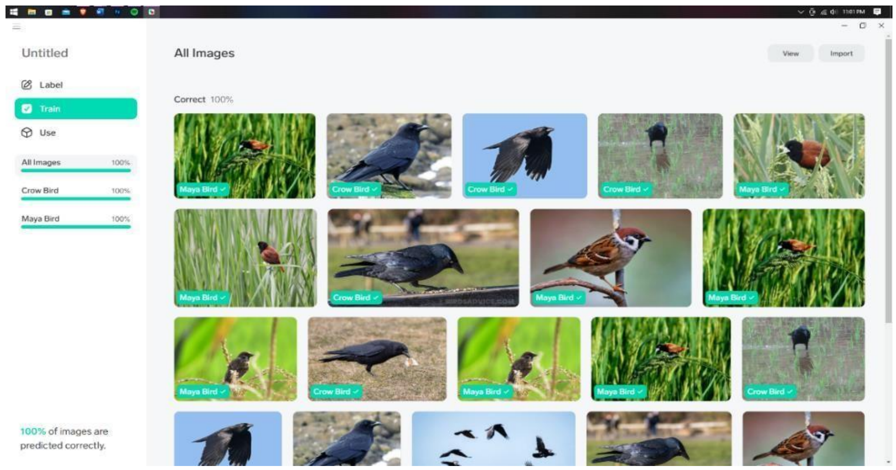

Figure 6. Machine Learning Model

The evaluation utilized a confusion matrix to analyze precision, recall, and F1 scores for each bird category. Additional metrics, including accuracy, loss, and classification reports, assessed overall performance. The dataset of 220 images was split into training, validation, and testing sets for unbiased evaluation. The model was trained in Google Collaboratory with multiple optimization iterations. Validation testing followed, using a separate dataset to verify accuracy. A confusion matrix identified misclassifications, and key performance metrics were calculated. Final accuracy testing on the held-out dataset confirmed the model’s reliability, achieving precise predictions across all four bird species.

RESULTS

Figure 7 shows that the system successfully detects and classifies the bird, the system then automatically sends an SMS notification to the owner. This notification contains information to the users about the detected bird in the vicinity, enabling real-time monitoring and documentation. The integration of machine learning with an SMS alert system enhances the efficiency and responsiveness of the detection framework, ensuring timely updates and effective data utilization.

Figure 8 shows that the bird was successfully identified by the system and then the system automatically sends a real-time notification to the developed mobile application. This feature enables users to receive instant updates on detected species, enhancing monitoring and data collection. The integration of machine learning with mobile notifications improves accessibility, allowing users to stay informed even when they are not actively using the system.

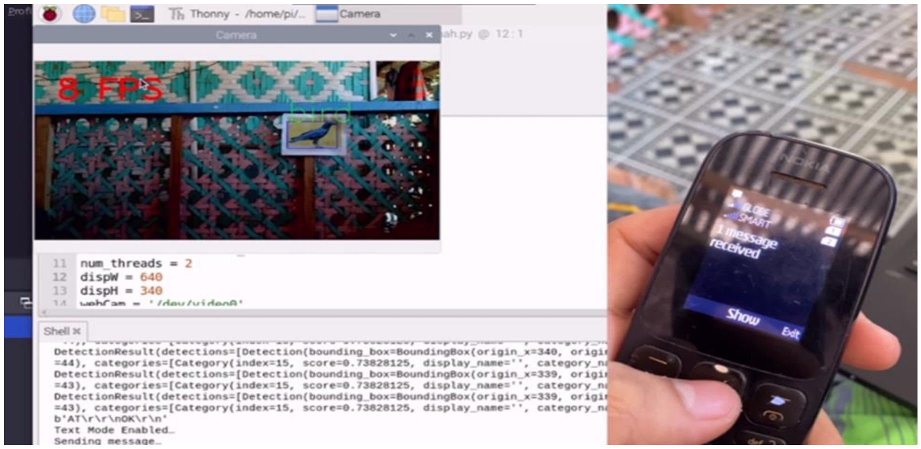

Figure 7. Machine Learning Detection and SMS notification

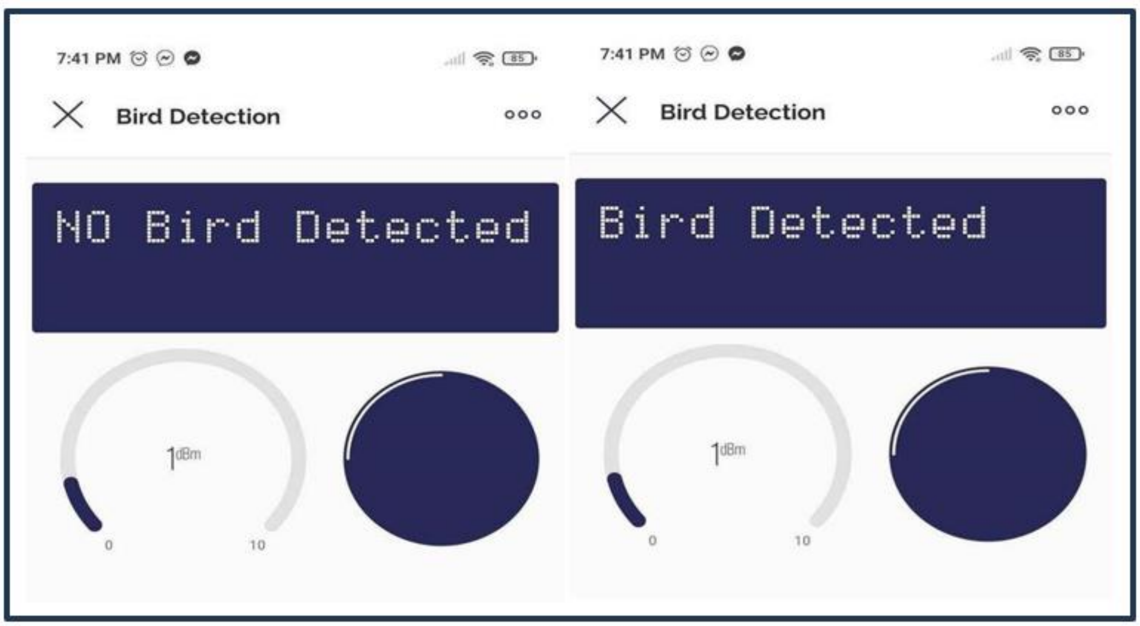

Figure 8. Machine Learning Detection and Mobile Application notification

RELEASE AND FEEDBACK

The system is divided into three main categories: 1) Power Source, encompassing components responsible for system activation; 2) Camera PIR Sensor, covering elements designed to detect and deter birds; and 3) Microcontroller, constituting the parts of the system that execute the code, manage recordings, and assign tasks to the various components (Figure 9).

Figure 9. RICEGUARD ACTUAL SYSTEM

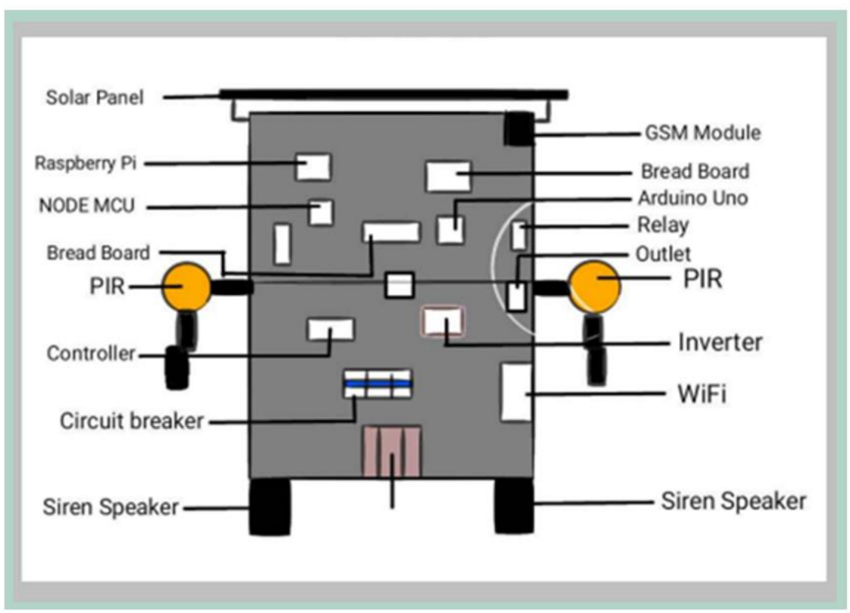

Figure 10. RICEGUARD ACTUAL SYSTEM PARTS

Figure 10 shows the different parts of the RICEGUARD system. Testing the System to ensure its effectiveness and reliability. First is, through Unit Testing: The researchers test each component separately to ensure they function correctly. Test the image processing algorithm on sample images to ensure it accurately detects birds, Test the SMS notification system to confirm that messages are sent promptly and contain relevant information. Test the NodeMCU Module to verify the connectivity of Riceguard to the internet, ensuring that real-time data is reflected in the Application for viewing. Test the Siren Speaker with specific decibel levels required to deter bird pests.

Figure 11 shows the researchers demonstrating the system functionalities to the end-users, providing a comprehensive overview of its capabilities and features. The researchers actively addressed queries and ensured a thorough understanding of how the system operates in real-world scenarios. Valuable feedback was recorded, which is important for refining the system.

Figure 11. System Demonstration and Rice Farmers Evaluation

Table 1 shows the Increasing Distance with The Corresponding Accuracy Of The System; 5 Trials for each bird species. As you can see there is a direct relationship between distance and the Accuracy rate of bird detection during the testing phase. Meanwhile, table 2 displays the ISO/IEC 25010:2011 system evaluation results from the users. The users commended the system. Thirty (30) people in total. Five (5) owners, ten (10) caregivers, and fifteen (15) farmers participated in the system evaluation. The outcomes and general average of the assessment were revealed using the Likert Scale. The applicability and functionality with a mean score of 4.40. The farmers commended the functionality of the system to be used in the actual rice field to address their concerns with bird attacks when the rice produced grains.

The performance efficiency mean is 4.21, which displays the capability of the system to work consistently. The compatibility mean is 4.07 since there was no issue of incompatible peripherals. The usability mean is 4.46, and the farmers were able to use the system with ease. The reliability mean is 4.12 since the SMS and image recognition of machine learning are consistent. The security mean is 4.21, the system provides proper authentication to use the system. The maintainability mean is 4.16 since the system is easy to maintain to its optimum performance. Lastly, the portability mean average is 4.38. The system can be transferred from one location to another location in the rice field. An evaluation of "Excellent" was found based on the overall weighted average of 4.25. The farmers discovered that the system is practical and effective in addressing their urgent issues regarding bird attacks in rice fields.

Table 1. Increasing Distance with the Corresponding Accuracy of the System

Distance(m)	**No.of Trials**	**Bird Detected**	**No. of Detection in 1 minute**	**Accuracy**
1	20	Yes	20	100%
2	20	Yes	20	100%
3	20	Yes	20	100%
4	20	Yes	20	100%
5	20	Yes	20	100%
6	20	Yes	20	100%
7	20	Yes	20	100%
8	20	Yes	20	100%
9	20	Yes	20	100%
10	20	Yes	11	99%
11	20	Yes	15	100%
12	20	Yes	12	99%
13	20	Yes	9	99%
14	20	Yes	13	99%
15	20	Yes	7	98%
16	20	No	0	0%
17	20	Yes	1	81%
18	20	No	0	0%
19	20	No	0	0%
20	20	Yes	1	81%

Table 2. ISO/IEC 25010:2011 Evaluation Over Result

Characteristics	Mean	Verbal Interpretation
Functional Sustainability	4.40	Excellent
Performance Efficiency	4.21	Excellent
Compatibility	4.07	Very Good
Usability	4.46	Excellent
Reliability	4.12	Very Good
Security	4.21	Excellent
Maintainability	4.16	Very Good
Portability	4.38	Excellent
Overall Weighted Mean	4.25	Excellent

CONCLUSIONS AND RECOMMENDATIONS

The study has successfully gathered the necessary hardware and software components to achieve its research objectives, including the integration of tools and technology into the smart scarecrow. The device garnered commendation and widespread acceptance among landowners, caretakers, and farmers in Manolo Fortich, Bukidnon. The RICEGUARD was exceptional in terms of giving significant and convenient solutions for safeguarding rice yields. The system was assessed by using ISO ISO/IEC 25010:2011 for its effectiveness and practicality. It is strongly recommended that future researchers consider integrating an autofocus camera into the system to enhance resolution, making it significantly more effective in threat detection within the area. The addition of such components would contribute to the system's stability and enhance its tracking capabilities, especially for moving subjects.

PRACTICAL AND SOCIAL IMPLICATIONS

This study enhances smart irrigation systems, which solve issues of water availability, scarcity, and droughts in agricultural practices. It is also important to examine the effect of smart irrigation systems on the yield and quality of crops since the optimal management of water resources during growing seasons increases the productivity and nutritional value of the crops. In addition to these technical aspects, this study is also noteworthy from a social perspective. RICEGUARD offers farmers reasonable innovative solutions for resourceful irrigation that raise the efficiency and yield of crops while decreasing water usage and improving resource management, which helps empower farmers. As a result, these innovations economically benefit farming through reduced production costs and increased profits. Furthermore, smart irrigation systems have an investment return by serving food security and ensuring a steady supply of quality agricultural products. More importantly, responsible farming and greater productivity enable agriculturally dependent communities to combat climate change and improve their standard of living, which makes the environment better for all.

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DECLARATIONS

Conflict of Interest

The authors declared that there is no conflict of interest with this research.

Informed Consent

No direct, private personal information was used in the conduct of this research.

Ethics Approval

As no private and personal information was used in the research, ethics approval is not necessary.

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