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Development of smart solar power operated scarecrow

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Abstract

Crop depredation by birds and small animals continues to cause substantial yield losses in open-field agriculture, particularly in regions where conventional deterrent methods are labour-intensive, inefficient, or environmentally unsustainable. This study reports the development of a smart solar power operated scarecrow employing renewable energy, sensor-based detection, and automated actuation for intelligent crop protection. The system utilizes a photovoltaic module coupled with a rechargeable battery to provide an off-grid power supply, enabling continuous operation under variable field conditions. A microcontroller-based control architecture integrates a sound detection sensor to identify intrusion events, triggering a DC motor-driven mechanical arm mechanism and an audio deterrent module. The coordinated generation of dynamic visual motion and acoustic stimuli reduces habituation effects commonly associated with static scarecrow systems. Field testing indicated a measurable reduction in bird and small-animal intrusion frequency, while event-based activation minimized energy consumption and enhanced system efficiency. The mechanical structure demonstrated adequate stability and durability under outdoor conditions, and the overall system required minimal maintenance. The proposed solution offers a cost-effective, scalable, and environmentally benign alternative to chemical repellents and manual guarding. The study highlights the potential of integrating solar energy, embedded control, and automation technologies to advance sustainable and intelligent crop protection systems in precision agriculture.

Keywords: Introduction, materials and methods, result and discussion, conclusion, references

1. Introduction

Bird-induced crop damage represents a significant constraint to agricultural productivity, particularly in open-field farming systems where losses occur during critical growth stages such as planting, seedling establishment, and crop maturation. Traditional crop protection methods, including manual guarding, static scarecrows, chemical repellents, and fencing, are often labour-intensive, costly, environmentally unsustainable, or ineffective due to rapid habituation of birds and animals. These limitations highlight the need for intelligent, automated, and sustainable deterrent solutions. Recent advancements in renewable energy and embedded systems have enabled the development of smart agricultural protection technologies. In this context, solar-powered scarecrow systems integrated with sensors, actuators, and control units offer a promising alternative. Such systems operate autonomously using photovoltaic energy, enabling deployment in remote agricultural fields without reliance on grid power. Sensor-based detection of bird or animal activity triggers dynamic visual motion and acoustic deterrents, thereby enhancing effectiveness while minimizing energy consumption and human intervention. This study focuses on the development and evaluation of a smart solar power operated scarecrow designed to provide eco-friendly, cost-effective, and reliable crop protection. By combining renewable energy, automated control, and multi-modal deterrent mechanisms, the proposed system aims to reduce crop losses, labor dependency, and environmental impact while supporting sustainable and precision agriculture practices.

2. Materials and Methods

2.1 Development of smart solar power operated scarecrow

The development of the smart solar-powered scarecrow followed a systematic approach to ensure effective crop protection and efficient energy utilization. Initially, the agricultural field was assessed to identify crop type, field size, and common bird or animal threats. Based on this assessment, the physical design and placement of the scarecrow were determined for maximum coverage and environmental durability. Suitable motion or sound sensors were selected and positioned to accurately detect intrusion events. The system's power requirements were estimated, and an appropriate solar panel and rechargeable battery were integrated to ensure continuous, off-grid operation. A microcontroller-based control unit was programmed to process sensor signals and activate deterrent mechanisms only upon detection, thereby minimizing energy consumption. Mechanical motion and acoustic modules were incorporated to generate dynamic visual and auditory stimuli. The complete system was tested under controlled conditions before field deployment, followed by installation and periodic monitoring to ensure reliable and sustainable operation.

The following material was used to development of smart solar power operated scarecrow Materials Used 1) Arduino Uno 2) DC motor 3) Solar Panels 4) Spur Gears 5) Linkages and Arms 6) Mic Module 7) Speaker Module 8) Switches 9) Cables and Connectors 10) Base Frame 11) Supporting Frame

2.1.1 Solar Cell Panel

Solar panels, also referred to as photovoltaic (PV) panels, convert solar radiation directly into electrical energy through the photovoltaic effect. A solar panel consists of multiple interconnected solar cells that collectively generate usable electrical power; higher incident solar irradiance results in increased electrical output. Typical photovoltaic systems comprise one or more solar modules, interconnection wiring, and, when required, energy storage units or power conditioning devices. Most commercially available solar modules are fabricated using crystalline silicon or thin-film semiconductor materials such as cadmium telluride. When sunlight strikes the semiconductor surface, photons transfer energy to electrons, enabling them to move across the p-n junction. This charge separation, driven by the internal electric field, produces direct current (DC) electricity. The generated DC power can be stored in batteries or converted into alternating current (AC) using an inverter for practical applications.

Plate 1: Solar Panel

2.1.2 Battery

A battery is an electrochemical energy storage device that converts stored chemical energy into electrical energy. It consists of one or more electrochemical cells with positive (cathode) and negative (anode) terminals. Rechargeable (secondary) batteries allow repeated charging and discharging through reversible chemical reactions. In this system, a 12 V battery composed of series-connected cells provides the required electrical output to power the electronic and mechanical components.

Plate 2: Battery

2.1.3 Arduino

The Arduino Nano is a compact, breadboard-compatible microcontroller board based on the ATmega328 or ATmega168 microcontroller. It provides functionality similar to the Arduino Duemilanove but in a smaller form factor, excluding a DC power jack and using a Mini-B USB interface. The board can be powered via USB, an unregulated external supply (6-20 V), or a regulated 5 V source, with automatic power source selection. An Arduino Nano I/O expansion shield is used to simplify connections with external sensors and actuators.

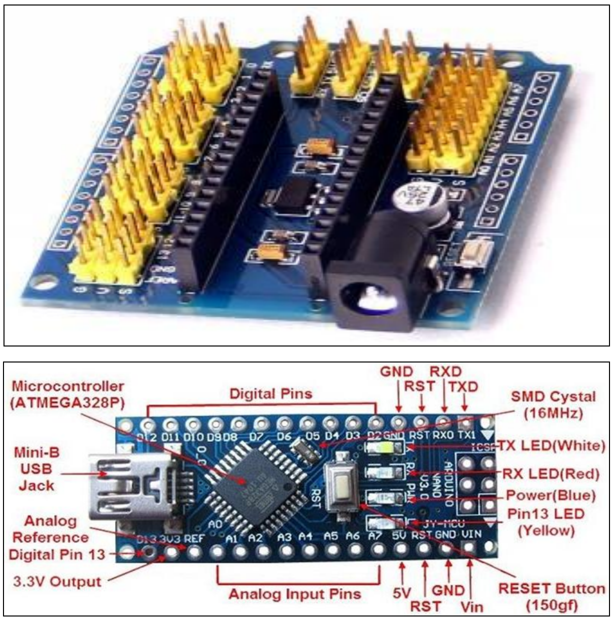

Plate 3: Arduino Microcontroller Board

2.1.4 Relay

A relay is an electrically operated switching device that enables a low-power control signal to switch high-voltage or high-current loads. It operates on the principle of electromagnetic attraction, where energizing the relay coil generates a magnetic field that moves an armature to open or close electrical contacts. When the coil is de-energized, a spring returns the contacts to their normal position. Relays provide electrical isolation and safe control of motors and other power devices.

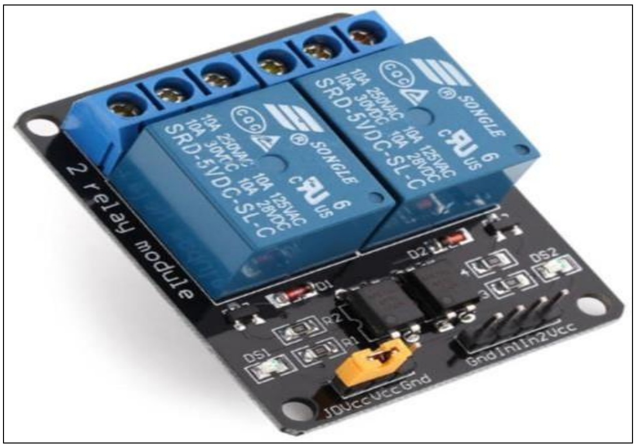

Plate 4: Relay

3.1.5 Microphone (Mic) Module

The microphone module is a sound detection sensor used to identify the presence of acoustic signals in the surrounding environment. It consists of a high-sensitivity microphone and signal conditioning circuitry, providing a digital output when sound is detected. The detection threshold can be adjusted using an onboard potentiometer. The module converts sound waves into electrical signals, enabling event-based activation of control systems.

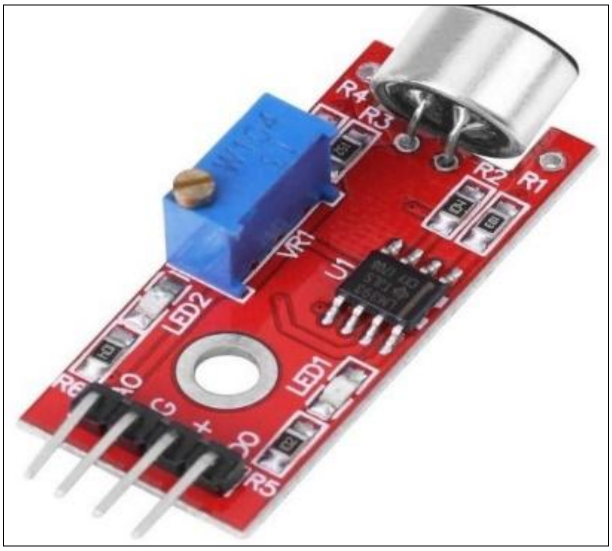

Plate 5: Sound Detection Sensor Module

2.1.6 Spur Gears

Spur gears are cylindrical gears with straight teeth parallel to the axis of rotation and are commonly used for mechanical power transmission. In the proposed system, two spur gears (60 mm diameter and 12 mm thickness) transmit rotational motion from the DC motor to the scarecrow mechanism. The meshing gears enable efficient torque transfer and speed reduction, allowing slow and forceful arm movements required to simulate human motion.

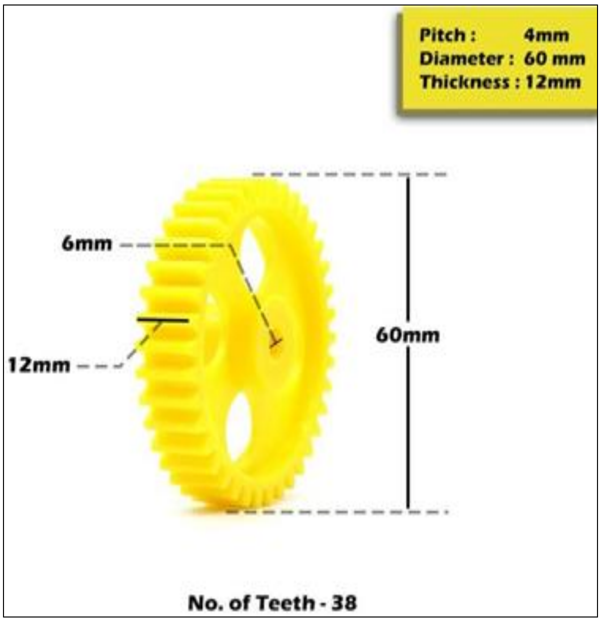

Plate 6: Spur Gear

2.1.7 DC Motor

A 12 V, 30 RPM DC motor is employed to provide low-speed, high-torque mechanical motion. The motor operates on the principle of electromagnetic induction, where current flowing through the armature in a magnetic field generates rotational force. A gear reduction mechanism lowers the rotational speed while increasing torque. Motor speed and direction can be controlled by regulating the supply voltage or reversing polarity, making it suitable for solar-powered applications.

Plate 7: DC Motor

3. Design Procedure

The fabrication process begins with the preparation of a base stand using iron material to ensure structural stability. A solid iron rod or hollow iron pipe is selected as the vertical support, with its lower end welded to an iron base plate and embedded into the soil to withstand wind and vibration. This structure serves as the primary load-bearing frame for the rotating mechanism and electronic assembly. A wooden enclosure is then fabricated to house the electronic components, including the Arduino controller, relay module, MP3 player, battery, and wiring. Openings are provided for the speaker, ventilation, and maintenance. The enclosure is securely mounted at the top of the iron stand, and a wooden roof plate is fixed above it to support the solar panel at an optimal inclination. The arm rotation mechanism is constructed using a 12 V, 30 RPM DC geared motor mounted below the enclosure. The motor shaft is coupled to a gear or linkage system that drives lightweight wooden arms through pivot joints, producing side-to-side motion. Finally, the electrical system is assembled by integrating the solar panel, charge controller, battery, and control circuitry. Upon sensor detection, the Arduino activates the relay to drive the motor and simultaneously triggers the audio module to generate deterrent sounds.

3.1. Working Principle

The operation of the solar-powered scarecrow is based on the integration of solar energy harvesting, sensor-based detection, and automated motion and sound generation for crop protection. The solar panel mounted on the upper structure converts sunlight into electrical energy, which is regulated by a charge controller and stored in a 12 V rechargeable battery. This stored energy supplies power to the entire system, enabling operation during low-light conditions and at night. The Arduino microcontroller functions as the central control unit and continuously monitors signals from the microphone sensor positioned outside the enclosure. When birds or animals approach the field, sound disturbances are detected and transmitted to the controller. The Arduino processes the signal and activates a relay module, which switches on the 12 V, 30 RPM DC geared motor. The motor drives a linkage mechanism that produces continuous swinging motion of the wooden arms, creating a visual deterrent. Simultaneously, the controller triggers an MP3 module to emit pre-recorded scare sounds through a speaker. After a predefined duration or in the absence of further disturbance, the system is automatically deactivated to conserve energy.

3.1.2 Programming Code

```
// Pin definitions
const int soundSensorPin = 2; // Sound sensor digital output
const int relayMotorPin = 8;          // Relay for motor
const int relaySpeakerPin = 9; // Relay for speaker

// Duration for relay ON time (milliseconds)
const unsigned long relayOnDuration = 5000; // 5 seconds

void setup() { pinMode(soundSensorPin, INPUT);
pinMode(relayMotorPin, OUTPUT);
pinMode(relaySpeakerPin, OUTPUT);
// Ensure both relays are OFF initially
digitalWrite(relayMotorPin, LOW);
digitalWrite(relaySpeakerPin, LOW);
Serial.begin(9600);
Serial.println("Sound sensor relay control ready.");
}

void loop() {
int soundDetected = digitalRead(soundSensorPin);
if (soundDetected == HIGH) { // Sound detected
Serial.println("Sound detected! Turning on relays.");
// Turn both relays ON digitalWrite(relayMotorPin, HIGH);
digitalWrite(relaySpeakerPin, HIGH);
// Keep them ON for 5 seconds delay(relayOnDuration);
// Turn both relays OFF digitalWrite(relayMotorPin, LOW);
digitalWrite(relaySpeakerPin, LOW);
Serial.println("Relays OFF after 5 seconds.");
// Small cooldown to prevent rapid retriggering delay (500);
}
}
```

Plate 8: Developed Scarecrow

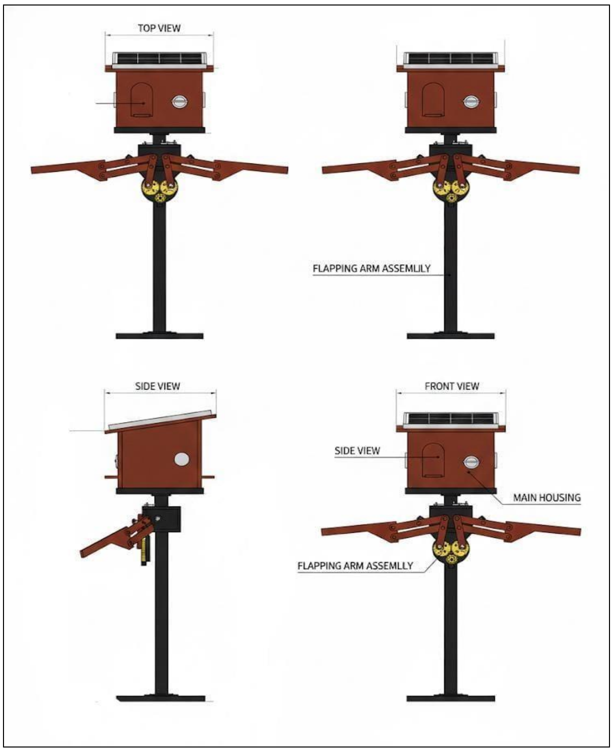

Plate 9: Isometric view of Scarecrow

4. Results and Discussion

Field testing of the solar-powered smart scarecrow demonstrated its effectiveness in reducing crop damage from birds and small animals. The system successfully deterred intrusions through continuous arm movement (driven by a 30 RPM DC motor) and variable deterrent sounds emitted via an MP3 player and speaker. The solar panel provided reliable charging to the 12 V battery, ensuring uninterrupted operation of the DC motor, Arduino microcontroller, MP3 module, relay, and microphone sensor throughout day and night. Sensor-based activation (via microphone) conserved energy by triggering responses only when external disturbances were detected. Farmers reported that the dynamic motion and randomized sound patterns were significantly more effective than traditional static scarecrows, as birds exhibited reduced habituation. The wooden upper structure and iron stand exhibited sufficient durability and stability under outdoor conditions, while the overall design remained eco-friendly, low-cost, and low-maintenance. Further enhancements, including integration of an insect trap (using solar-powered light or bait attraction), a high-frequency buzzer for low-light conditions, and human voice mimicry (e.g., recorded shouting, clapping, or warnings), substantially improved multi-threat protection. These additions enabled layered deterrence against birds, animals, and pests, while minimizing chemical pesticide use and supporting sustainable farming practices. Although performance varied slightly under adverse weather (e.g., high wind, rain, or background noise), which affected sensor sensitivity, the system proved reliable, energy-efficient, and adaptable. Overall, the advanced solar-powered scarecrow represents a practical, intelligent, and renewable-energy-based solution for minimizing manual labor, crop losses, and environmental impact in modern agriculture. Future optimizations in sensor calibration and control algorithms could further enhance robustness across diverse environmental conditions.

5. Conclusion

The solar-powered smart scarecrow successfully demonstrates an effective, eco-friendly, and sustainable approach to crop protection. By harnessing renewable solar energy, the system powers automated deterrent mechanisms—including dynamic arm movement, randomized sounds (buzzer, human voice mimicry), and optional light effects—while eliminating dependence on grid electricity. Sensor-based activation (microphone/PIR) ensures energy-efficient operation, significantly reducing crop damage from birds and small animals with minimal habituation compared to traditional scarecrows. The design, featuring a sturdy iron stand and wooden structure, offers durability, low cost, and ease of maintenance, making it highly suitable for small to medium-sized farms, especially in remote rural areas. Field results confirm reduced labor requirements, noticeable decrease in crop losses, and added farmer convenience. This project promotes sustainable agriculture by minimizing chemical repellents, manual monitoring, and environmental impact while encouraging renewable energy adoption. Although further enhancements in sensor precision, weather resilience, insect control, and IoT integration could further optimize performance, the current system proves to be a practical, reliable, and scalable solution for modern intelligent crop protection.

References

1. Ajayi ABA. Development of a renewable energy powered avian pest scarer. Bulletin of Engineering. 2022;15.
2. Barakat U, Hashim S, Ramli A, Hashim F, Samsudin K, Al-Baltah I, *et al*. SCARECROW: scalable malware reporting, detection, and analysis. Convergence Journal of Information Technologies. 2013.
3. Mano B, Sandhiya R. Design and fabrication of solar powered bird scarer. International Journal of Science and Research Archive. 2024;13(2):1024-1033.
4. Chomtip P, Homnan M, Pramuksan N, Rakyindee W. Wise scarecrow. In: Proceedings of the International Conference on Measurement Technology and Mechatronics Automation; 2011;3:294-297.
5. Koyuncu T, Lule F. Design, manufacture and test of a solar powered audible bird scarer. International Journal of Agricultural and Biosystems Engineering. 2009.
6. Salian MC, Poojary PH, Suvarna VV. A review on auto-mechanized scarecrow for agricultural purpose. 2023.
7. Nankinov D, Ivanov N, Nikolov B, Dalakchieva S, Gluhchev G, Trifonov D. Electro-acoustic influence on birds. Cybernetics and Information Technologies. 2007;7:106-111.
8. Nagaraju P. Solar based birds repeller to protect crops from birds and animals. Electronics and Communication Engineering. 2019;9.
9. Pandit P. Scarecrow with solar powered and sound sensing mechanism. 2023;8.
10. Uzma R. Design and implementation of low-cost solar powered bird repellent technique for prevention of high economic crops. 2021;8:360-362.
11. Caglam C, Onemli F. The effects of sowing date and sowing density on bird damage in sunflower (*Helianthus annuus* L.) cultivars. Journal of Tekirdag Agricultural Faculty. 2005;2:50-57.
12. Li S. Intelligent audio bird repeller for transmission line tower based on bird species variation. Materials Science and Engineering. 2019;592:012142.
13. Summers RW. The effect of scarers on the presence of starlings (*Sturnus vulgaris*) in cherry orchards. Crop Protection. 1985;4(4):520-528.
14. Vickery JA, Summers RW. Cost-effectiveness of scaring brent geese (*Branta bernicla*) from fields of arable crops by a human bird scarer. Crop Protection. 1992;11:480-484.
15. Suryawanshi VR. Design, manufacture and test of a solar powered audible bird scarer and study of sound ranges used in it. 2015;4.
16. York DL, Cummings JL, Engeman RM, Davis JE Jr. Evaluation of Flight Control and Mesurol as repellents to reduce horned lark (*Eremophila alpestris*) damage to lettuce seedlings. Crop Protection. 2000;19:201-203.