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Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection

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Abstract: *Agriculture plays a vital role in food production, but crop damage caused by birds and small animals remains a major challenge for farmers. Traditional methods such as fixed scarecrows, manual guarding, and fencing are often less effective over time and require continuous human effort. To address this issue, a Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection is proposed as an automated and energy-efficient solution.The developed system is designed to detect unusual sound activity near the crop field using a sound sensor module. When the detected sound level crosses a preset threshold, the sensor sends a signal to the microcontroller, which activates the scare mechanism. The system responds by operating a speaker to generate warning sound and a motorized arm mechanism to create human-like movement. This combined action helps in frightening away birds and animals before they cause damage to crops.To make the system suitable for agricultural fields and remote rural areas, the entire setup is powered using a solar panel and rechargeable battery. This removes the need for continuous external electricity supply and supports sustainable operation. The proposed system is simple in design, cost-effective, and easy to install. It also reduces manual labor and provides a practical approach toward smart farming.*

Keywords: Smart Scarecrow, Solar Energy, Crop Protection, Sound Sensor, Arduino, Agricultural Automation, Bird Deterrent, Renewable Energy, Embedded System, Smart Farming

I. INTRODUCTION

Agriculture is one of the most important sectors for human survival and economic development, but crop damage caused by birds and animals remains a serious issue for farmers. Birds often attack crops during sowing, seedling, and ripening stages, leading to considerable loss in yield and income [1]. In many farming areas, traditional crop protection methods such as manual guarding, fixed scarecrows, and noise-making devices are still used, but these methods are often less effective over time because birds gradually adapt to them [2].

To overcome this limitation, smart and automated protection systems are increasingly being explored in modern agriculture. Research has shown that sound-based and motion-based bird deterrent systems can provide better results than static scare devices [3]. Audible bird scarers and automated deterrent mechanisms have been studied as practical methods to reduce crop damage, especially when combined with renewable energy sources [4], [5]

The Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection is designed as an improved agricultural protection system that uses sound sensing, motion actuation, and solar power to deter birds and small animals from entering crop fields. The system detects unusual sound activity near the field using a sound sensor, processes the signal through a microcontroller, and activates outputs such as speaker sound and moving scarecrow arms to create a sudden scare effect [6]. Since the entire setup is powered by solar energy, it becomes suitable for rural and remote agricultural areas where regular electricity supply may not be available [7].

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This project provides a simple, eco-friendly, and low-cost solution for crop protection. It reduces manual effort, avoids harmful chemical repellents, and supports the concept of smart farming [8]. The proposed model is therefore a practical example of applying embedded systems and renewable energy in agriculture for sustainable field protection [9], [10].

II. PROBLEM STATEMENT

Crop damage caused by birds and small animals is a major challenge in agriculture, leading to significant reduction in yield and financial loss for farmers. Birds tend to attack crops during critical growth stages such as sowing, seedling, and ripening, which directly affects productivity. Traditional methods like static scarecrows, manual guarding, and noise-making devices are commonly used, but their effectiveness decreases over time as birds and animals become familiar with them.

In addition, manual monitoring of fields is labor-intensive, time-consuming, and not always reliable, especially for large farms or during night hours. The use of chemical repellents can also harm the environment, soil quality, and non-target species, making them less desirable for sustainable agriculture.

Furthermore, many agricultural areas, particularly in rural regions, face irregular or limited access to electricity, making it difficult to implement continuous electronic protection systems. Therefore, there is a need for an automated, energy-efficient, and eco-friendly crop protection system that can detect the presence of birds or animals and take immediate action to scare them away without human intervention.

III. OBJECTIVES

- To design an automated scarecrow system that can detect disturbances in the crop field using a sound sensor and respond without human intervention.
- To implement sound-based detection for identifying the presence of birds and animals near crops.
- To develop an effective scare mechanism using sound alerts and motorized arm movement to drive away pests.
- To utilize solar energy as a power source so that the system can operate in remote agricultural areas without external electricity.
- To reduce crop damage and manual labor by providing a low-cost, eco-friendly, and efficient crop protection solution.

IV. LITERATURE SURVEY

Wiens J. A. & Dyer M. I. (1977), in the study "Assessing Potential Impact of Granivorous Birds in Ecosystems," analyzed the impact of seed-eating birds on agricultural crops. The study highlighted that bird populations can significantly reduce crop yield depending on environmental and seasonal factors. It emphasized the need for effective crop protection methods to minimize agricultural losses.

Summers R. W. (1985), in the paper "The Effect of Scarers on the Presence of Starlings in Cherry Orchards," studied the behavior of starlings in orchards using different bird scarers. The results showed that scare devices were effective initially, but birds gradually adapted to repeated signals. This study suggested the need for dynamic and varying scare techniques.

Coleman J. & Spurr E. (2001), in the research "Farmers' Perceptions of Bird Damage and Control in Arable Crops," investigated how farmers manage bird-related crop damage. The study revealed that traditional methods such as shooting and noise devices are widely used but are not always reliable. It highlighted the demand for improved and automated protection systems.

Clarke T. L. (2004), in the work "An Autonomous Bird Deterrent System," proposed the use of automated systems combining sensors and control mechanisms for bird detection and deterrence. The study demonstrated that integrating sensing technologies with control systems can improve the efficiency of crop protection.

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Koyuncu T. & Lule F. (2009), in the paper "Design, Manufacture and Test of a Solar Powered Audible Bird Scarer," developed a solar-powered system that uses sound signals to scare birds. The study showed that solar energy-based deterrent systems are effective and suitable for remote agricultural areas, but continuous use of the same sound may reduce effectiveness over time.

Mohan Kumar D. (2013), in the article "Solar Powered Bird Scarer Circuit," presented an electronic circuit design for a bird deterrent system using sound generation and solar power. The study demonstrated a low-cost and practical approach for protecting crops, highlighting the importance of integrating renewable energy with electronic control systems.

Comparison Table

Author & Year	Technology Used	Key Feature	Limitation
Wiens J. A. & Dyer M. I. (1977)	Ecological crop damage analysis	Studied impact of birds on crop yield	No practical deterrent system proposed
Summers R. W. (1985)	Sound-based bird scarers	Initial reduction in bird presence	Birds adapted over time
Coleman J. & Spurr E. (2001)	Traditional bird control methods	Identified common farmer practices	Methods were labor-intensive and less reliable
Clarke T. L. (2004)	Autonomous bird deterrent system	Introduced automated detection and deterrence	Complex system implementation
Koyuncu T. & Lule F. (2009)	Solar-powered audible bird scarer	Renewable energy-based bird protection	Repeated sound reduced long-term efficiency
Mohan Kumar D. (2013)	Electronic solar bird scarer circuit	Low-cost and simple design	Limited detection and scare range

V. WORKING OF SYSTEM

5.1 Block Diagram

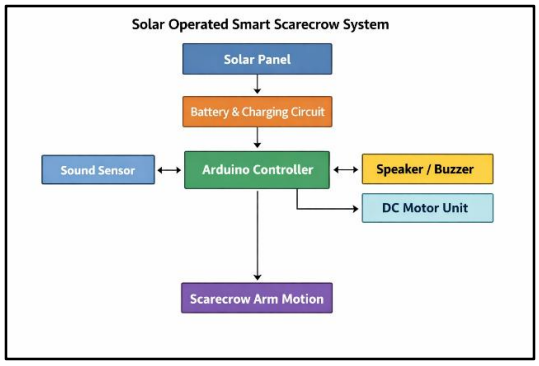

Fig.1.Block Diagram

5.2 Description of Block Diagram

The Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection is designed to automatically detect disturbances in the field and activate scare mechanisms to protect crops from birds and animals. The complete working of the system is based on the interaction of different functional blocks, as shown in the block diagram above.

1. Solar Panel

The solar panel is the main renewable energy source of the system. It converts sunlight into electrical energy and supplies power for charging the battery. Since the system is intended for outdoor agricultural use, solar energy makes it suitable for remote areas where regular electricity may not be available.

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2. Battery and Charging Circuit

The energy generated by the solar panel is stored in a rechargeable battery through a charging circuit. This stored energy is used to operate the system during cloudy conditions, evening time, or whenever direct sunlight is unavailable. The charging circuit ensures proper battery charging and safe power distribution to the electronics.

3. Arduino Controller

The Arduino microcontroller acts as the main control unit of the system. It receives input from the sound sensor, processes the signal, and decides whether the scare mechanism should be activated. It also controls the output devices such as the speaker and DC motor.

4. Sound Sensor

The sound sensor continuously monitors the surrounding sound level in the field. When birds or animals create unusual sound near the crop area, the sensor detects it and sends an electrical signal to the Arduino controller. This makes the system automatic and responsive.

5. Speaker / Buzzer

The speaker or buzzer is one of the main output devices used to scare away birds and animals. Once activated, it produces a loud warning sound or disturbing noise that helps in driving pests away from the crop field.

6. DC Motor Unit

The DC motor is used to generate movement in the scarecrow structure. It is connected to the arm mechanism through gears or linkages. When the Arduino gives a command, the motor rotates and produces motion in the scarecrow.

7. Scarecrow Arm Motion

The moving arms of the scarecrow create a human-like action, making the system more effective than a static scarecrow. The sudden movement combined with sound creates a stronger scare effect and increases the chances of repelling birds and animals from the field.

5.3 Working of System

The working of the proposed system begins with the solar panel, which absorbs sunlight and converts it into electrical energy. This energy is stored in the battery and used to power the entire setup. The sound sensor continuously monitors the environment for unusual sound activity caused by birds, animals, or other disturbances near the crops.

Whenever the sound level exceeds the preset threshold, the sensor sends a signal to the Arduino controller. The controller processes this input and activates the scare mechanism. As a result, the speaker or buzzer produces a loud sound while the DC motor starts rotating. The motor movement is transferred to the scarecrow arms through a linkage mechanism, creating a waving or moving effect.

The combination of sound alert and arm movement helps in frightening birds and animals, thereby reducing crop damage. After a short duration, the system returns to standby mode and continues monitoring the surroundings for the next disturbance.

Thus, the system provides an automatic, solar-powered, and eco-friendly solution for crop protection in agricultural fields.

VI. SYSTEM DESIGN

6.1 System Design Overview

The Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection is designed as an automated agricultural protection system that helps in preventing crop damage caused by birds and small animals. The system is built by combining electronic sensing, mechanical movement, sound generation, and solar power supply into a single working unit.

The complete design is divided into four main parts: input section, control section, output section, and power section. The input section consists of the sound detection sensor that continuously monitors the surrounding environment. The control section contains the Arduino microcontroller, which receives the sensor signal and processes it. The output

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section includes the speaker and motorized arm mechanism, which create a sudden scare effect. The power section consists of the solar panel, battery, and regulator circuit, which provide uninterrupted energy for the system.

6.2 Components Description with Specifications

1. Arduino UNO

Description: Arduino UNO is the main microcontroller board used to control the entire system by processing sensor inputs and operating the output devices.

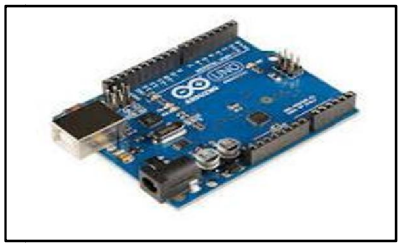

Fig.2.Arduino UNO

Specifications: ATmega328P, 5V operating voltage, 14 digital I/O pins, 6 analog inputs, 16 MHz clock frequency.

2. Sound Sensor / Mic Module

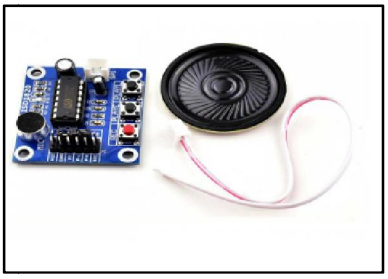

Fig.3.Mic Module

Description: The sound sensor detects surrounding sound disturbances and sends a signal to the controller when the sound level exceeds the threshold.

Specifications: Operating voltage 3.3V–5V, LM393 comparator, analog/digital output, adjustable sensitivity, current 4–5 mA.

3. DC Motor

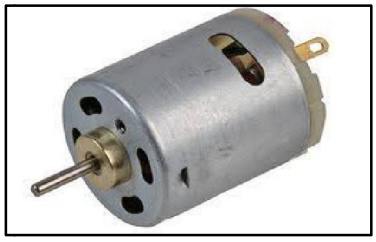

Fig.4.DC Motor

Description: The DC motor converts electrical energy into mechanical motion and is used to move the scarecrow arms.

Specifications: 6V–12V DC motor, moderate torque output, suitable for rotational motion and linkage operation.

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4. Solar Panel

Fig.5.Solar Panel

Description: The solar panel converts sunlight into electrical energy and charges the battery for continuous operation of the system.

Specifications: 6V / 12V panel, photovoltaic type, lightweight outdoor use, renewable energy source.

5. Voltage Regulator / Charging Circuit

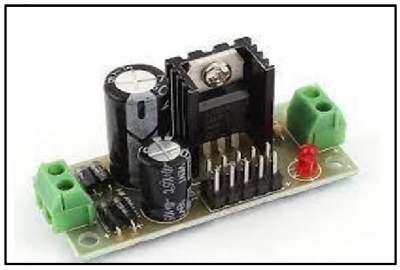

Fig.6.Regulatory Circuit

Description: The regulator circuit maintains proper voltage and ensures safe charging and power supply to all electronic components.

Specifications: High efficiency regulation, stable DC output, suitable for low-power embedded systems.

6. Spur Gears

Fig.7.Spur Gear Model

Description: Spur gears are used to transmit motion from the motor shaft to the scarecrow arm linkage mechanism.

Specifications: Straight-tooth gear type, rotational motion transfer, used for torque and speed conversion.

7. PCB Board

Description: The PCB board is used for mounting and interconnecting the electronic components of the system.

Specifications: Insulated fiberglass board, conductive copper traces, compact circuit assembly platform.

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8. Resistors

Fig.8. Registers

Description: Resistors are used to limit current and maintain proper electrical operation in the circuit.
Specifications: Fixed resistor type, commonly 220Ω, 1kΩ, 10kΩ values, ¼ watt rating.

9. Capacitors

Fig.9. Capacitors

Description: Capacitors are used for filtering, smoothing, and temporary charge storage in the circuit.
Specifications: Electrolytic / ceramic type, values such as 10µF, 100µF, and 0.1µF.

10. Transistors

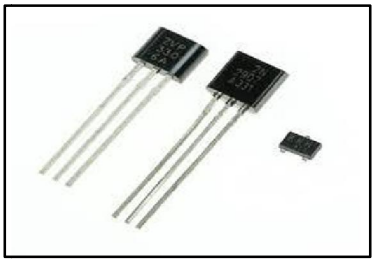

Fig.10.Transistors

Description: Transistors are used as switching devices to drive the motor or other output components.
Specifications: NPN transistor type, three-terminal semiconductor, used for signal amplification and switching.

VII. MATHEMATICAL EQUATIONS

1. Solar Power Generation Equation

$$P = V \times I$$

Where:
P= Power (Watts)
V = Voltage (Volts)
I = Current (Amperes)

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Explanation:
This equation represents the electrical power generated by the solar panel, which is used to operate the system.

2. Battery Backup Time Equation

$T = \frac{C}{I}$

Where:

T = Backup time (hours)

C = Battery capacity (Ah)

I= Load current (A)

Explanation:
This equation is used to calculate how long the system can run using the stored battery power.

3. Sound Detection Threshold Condition

$S > Sth$

Where:

S = Detected sound level

Sth = Threshold sound level

Explanation:
When the detected sound exceeds the threshold value, the system activates the scare mechanism.

VIII. RESULTS

The developed Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection was tested under different field-like conditions to evaluate its working performance. During testing, the sound sensor was able to successfully detect nearby disturbances such as clapping, bird-like sound, and sudden environmental noise within its sensing range. Once the sound level crossed the preset threshold value, the Arduino controller responded immediately and activated the scare mechanism without noticeable delay.

The output section of the system performed effectively during operation. The speaker/buzzer generated a sharp warning sound, while the DC motor-driven arm mechanism produced visible movement similar to human hand motion. This combined response created a sudden scare effect, which is useful for driving away birds and small animals from the crop area. The mechanical movement was smooth and repeated properly during multiple trials, showing that the linkage mechanism worked satisfactorily.

The solar power unit also showed stable performance during testing. The solar panel was able to charge the battery under daylight conditions, and the stored energy was sufficient to operate the controller, sensor, and output units. This confirmed that the system can function without direct external electricity, making it suitable for rural and remote agricultural fields.

Overall, the test results indicate that the proposed system is simple, effective, and practical for crop protection. The project successfully demonstrated automatic sound detection, timely scare response, and reliable solar-powered operation. Hence, the developed smart scarecrow system can be considered a useful low-cost solution for reducing crop damage in agricultural applications.

IX. CONCLUSION

The Solar Operated Smart Scarecrow System Using Sound Detection for Crop Protection is an effective and practical solution for reducing crop damage caused by birds and small animals. The developed system successfully combines sound sensing, automatic control, mechanical movement, and solar power to provide a smart alternative to traditional scarecrow methods. Unlike conventional scarecrows that remain fixed and lose effectiveness over time, the proposed system reacts automatically whenever a disturbance is detected in the field.

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The project demonstrated that the sound sensor can identify unusual sound activity and trigger the scare mechanism in a timely manner. The combined action of speaker sound and moving arms helps create a stronger scare effect, making the system more useful for agricultural crop protection. In addition, the use of solar energy makes the system independent from external electricity and suitable for remote rural areas.

Overall, the proposed model is low-cost, eco-friendly, easy to implement, and suitable for smart farming applications. It reduces manual effort, supports sustainable agriculture, and offers a reliable way to protect crops. Therefore, this project can be considered a beneficial and innovative approach toward modern agricultural field security.

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