A Solar-Powered Smart Electric Fence with Automated Irrigation and IOT Integration

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ABSTRACT
With the global population projected to reach around 10 billion by 2050, agriculture faces immense pressure to adapt and meet the growing demand for food. To address this challenge, the integration of advanced technologies into agriculture is crucial. A key innovation in this transformation is the Internet of Things (IoT), which plays a vital role in monitoring crops and soil, providing precise, real-time solutions that enhance productivity. This has given rise to smart farming, where IoT helps farmers reduce waste, optimize resources, and increase yields.By using sensors, farmers can continuously monitor the condition of their fields and make informed, data-driven decisions to improve crop management. However, protecting crops from animals remains a significant challenge. Traditionally, high-voltage electric fences are used to deter animals, but these fences pose serious risks to wildlife. Our proposed solution addresses this problem by developing a smart fence that protects crops without endangering animals. Instead of relying on dangerous high-voltage shocks, our design uses piezoelectric technology to create a safe, intelligent fencing system that deters animals without causing harm.
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Keywords: Farming, Internet of Things, electric fencing, automated irrigation, solar power, piezoelectric.

I. INTRODUCTION

Crops on farms are frequently damaged by local wildlife such as buffaloes, cows, goats, and birds, leading to significant financial losses for farmers. Overpopulation and deforestation have worsened these issues, causing shortages of food, water, and shelter in natural habitats. As a result, animals increasingly encroach upon residential and agricultural areas, heightening human-animal conflicts that impact both lives and property. For instance, elephants and other wildlife can severely damage crops, grain stores, water supplies, and buildings, occasionally resulting in injury or even fatalities. Since every species plays a crucial role in the ecosystem, it is vital to find humane solutions to these conflicts.

One of the major economic issues faced by the country is agriculture as this is the sector which is source of livelihood for about 54% of Indians till date. Still today this sector is not well developed and faces lots of problems resulting into low productivity of crops. As 43% of land in India, is used for farming but contributes only 18% of the nation's GDP. The poor condition of agriculture in the country is the point of concern for Indians. The rural farmers in India suffer from poverty and most of them are illiterate so there is lack of good extension services. The problem of wild life attack on crops i.e., crop Vandalization is becoming very common in the states of Tamil Nadu, Himachal Pradesh, Punjab, Haryana, Kerala and many other states. Wild animals like monkeys, elephants, wild pigs, deer, wild dogs, bison, nilgais, estray animals like cows and buffaloes and even birds like parakeets cause a lot of damage to crops by running over them, eating and completely vandalizing them.

This lead to poor yield of crops and significant financial loss to the owners of the farmland. This problem is so pronounced that sometimes the farmers decide to leave the areas barren due to such frequent animal attacks Another major problem faced by Indian farmer is their dependency on nature and poorly maintained irrigation system. Current agricultural practice are neither economically nor environmentally sustainable and India's yields for many agricultural commodities are low. Poorly maintained irrigation system and almost universal lack of good extension service are among the factor responsible. Poor roads to market from village, rudimentary market infrastructure, and excessive regulation are few of the other concerned points for the agriculture sector in India.

In contemporary society, the integration of technology into traditional systems has revolutionized various sectors, including agriculture. One innovative solution is the implementation of a smart electric fence powered by solar energy alongside an automatic irrigation system. This amalgamation addresses multiple challenges faced by farmers efficiently.

The smart electric fence, utilizing solar power, offers sustainable energy generation, reducing reliance on conventional power sources and minimizing environmental impact. It enhances security by deterring trespassing and safeguarding crops from wildlife encroachment. Moreover, its smart features allow remote monitoring and immediate response to any breaches, ensuring continuous protection.

Simultaneously, the automatic irrigation system optimizes water usage by delivering precise amounts based on real-time environmental data and plant needs. This not only conserves water but also maximizes crop yield and quality. By streamlining farming operations, this combined system promotes sustainability, productivity, and profitability in agriculture, reflecting the adaptability and ingenuity of modern societal systems.

The fusion of a smart electric fence, reliant on solar power, with an automatic irrigation system driven by IoT technology, epitomizes a groundbreaking advancement in agricultural infrastructure. This innovative amalgamation adeptly tackles myriad challenges encountered by farmers, concurrently elevating security and efficiency within farming practices.

Foremost, the implementation of the smart electric fence fortifies defenses against intruders and wildlife, serving as a formidable barrier to safeguard crops and livestock. Its utilization of solar energy underscores sustainability, reducing reliance on conventional power sources and curtailing environmental impact.

Moreover, the automatic irrigation system, seamlessly integrated with IoT connectivity, revolutionizes water management by dispensing precise quantities tailored to real-time environmental cues. This dual approach not only conserves water but also augments crop yield and quality, ensuring optimal agricultural output.

Furthermore, the incorporation of IoT enables remote monitoring and control, empowering farmers to oversee operations from any location. This capability streamlines management processes, maximizing productivity while minimizing labor costs.

The synergy achieved through the convergence of a smart electric fence with solar power and an IoT-driven automatic irrigation system offers a comprehensive solution for modern agriculture, championing sustainability, security, and productivity in farming endeavors..

The Smart Fencing System utilizes the ESP32 microcontroller and GSM technology to provide a sophisticated solution for agricultural security and irrigation management. By integrating IoT capabilities, this system offers real-time monitoring, remote control, and automated responses, ensuring effective protection of crops and efficient irrigation.

Case 1: Continuous Data Upload to Thing speak Server

The core component of the smart fencing system is the ESP32 microcontroller, which gathers data from various sensors and controls the system's actuators. It connects to the Thingspeak server via Wi-Fi or GSM, enabling continuous data uploads. This data includes sensor readings on soil moisture, temperature, humidity, and intrusion detection.

Once connected, the ESP32 collects sensor data at regular intervals and sends it to the Thingspeak server through the GSM module. The Thingspeak platform processes and visualizes this data in real time, providing farmers with essential insights into environmental conditions and potential threats to their crops.

Case 2: Soil Moisture-Based Irrigation Control

A prominent feature of the smart fencing system is its automated irrigation control based on soil moisture levels. A soil moisture sensor placed in the field continuously monitors moisture content. When the sensor detects low moisture levels, indicating that the crops need watering, the ESP32 activates a DC water pump connected to the irrigation system.

Upon receiving the activation signal, the water pump irrigates the field, ensuring the crops receive adequate hydration. Once the soil moisture reaches the desired level, the ESP32 commands the pump to shut off, thereby conserving water and preventing over-irrigation.

Case 3: Intrusion Detection and Alert System

The system also features intrusion detection sensors strategically positioned along the perimeter of the field. These sensors detect unauthorized entry by animals or humans, such as attempts to breach the fencing. When an intrusion is detected, the sensor sends a signal to the ESP32 microcontroller.

The ESP32 then activates the GSM module to immediately alert the farmer via mobile phone about the security breach. This prompt notification allows the farmer to take swift action to protect their crops. Additionally, the system can trigger deterrents like lights or sirens to ward off intruders and further safeguard the crops.

II. LITERATURE SURVEY

Smart fencing systems utilize advanced technologies to enhance agricultural security and manage livestock. Recent studies explore various approaches, including the use of sensors and IoT for monitoring and controlling fences. For instance, research by Zhang et al. [1] presents a smart electric fence system integrated with IoT for real-time monitoring and control, improving the efficiency of livestock management and minimizing human intervention. Another study by Moyo et al. [2] investigates the integration of solar power in smart fencing systems to make them more sustainable and cost-effective.

Solar power is increasingly used to enhance the sustainability and efficiency of various systems. A study by Kothari et al. [3] discusses the benefits of solar energy for powering agricultural systems, including fences and irrigation setups. The research highlights how solar power can reduce operational costs and improve the reliability of remote agricultural technologies. Similarly, Jha et al. [4] explore the application of solar energy in smart agricultural systems, emphasizing its role in promoting sustainable practices.

Automated irrigation systems leverage technology to optimize water usage and improve crop yields. A review by J. Venkateswara Rao [5] explores various automated irrigation technologies, including those integrated with IoT. The study highlights how sensors and controllers can automate irrigation based on real-time soil moisture data, leading to more efficient water use. Another significant contribution by Shah et al. [6] investigates the integration of automated irrigation systems with weather forecasting data to enhance irrigation scheduling.

IoT technology plays a pivotal role in modernizing agricultural practices by providing real-time data and enabling remote control of systems. Research by Kumar et al. [7] explores IoT-based solutions for various agricultural applications, including smart irrigation and fencing systems. The study emphasizes the potential of IoT to improve decision-making and operational efficiency in agriculture. Another study by Singh et al. [8] focuses on the integration of IoT in smart agriculture, including its applications in enhancing farm security and automation.

Combining solar power, IoT, and automated systems represents a growing trend in sustainable agricultural practices. A study by Patel et al. [9] examines the synergy between solar energy and IoT in agricultural systems, highlighting how this integration enhances operational efficiency and sustainability. The research shows that solar-powered IoT systems can improve both security and irrigation management. Additionally, Li et al. [10] explore the design and implementation of integrated systems that combine renewable energy with smart technologies for comprehensive agricultural solutions.

III. System Architecture

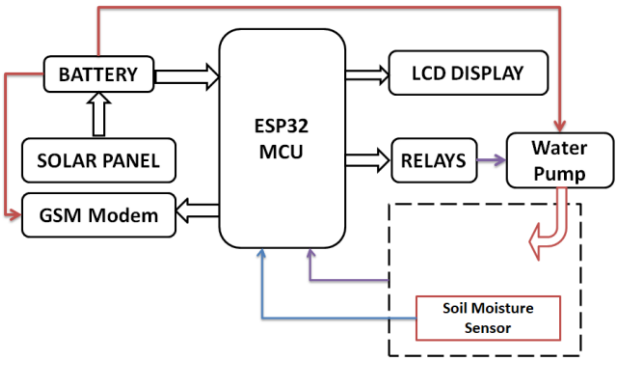

Fig 1. System architecture

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Furthermore, the incorporation of IoT enables remote monitoring and control, empowering farmers to oversee operations from any location. This capability streamlines management processes, maximizing productivity while minimizing labor costs.

Integrating a solar-powered smart electric fence with an IoT-driven automatic irrigation system represents a significant leap forward in agricultural technology. This combination effectively tackles various challenges faced by farmers, enhancing both security and efficiency.

The smart electric fence provides robust protection against intruders and wildlife, securing crops and livestock. By utilizing solar power, it supports sustainability efforts, minimizing reliance on conventional energy sources and reducing environmental impact.

Simultaneously, the automatic irrigation system, powered by IoT technology, transforms water management. It ensures precise water distribution based on real-time environmental data, conserving resources while improving crop yield and quality.

IoT integration further enables remote monitoring and control, allowing farmers to manage their operations from any location. This feature simplifies management, increases productivity, and reduces labor costs.

Overall, combining a solar-powered smart electric fence with an IoT-enabled irrigation system delivers a holistic solution for modern agriculture, advancing sustainability, security, and efficiency.

IV. Hardware Implementation

ESP32

Arduino is an excellent platform for beginners in microcontrollers and embedded systems. It offers a variety of affordable sensors and modules, making it ideal for both hobbyist projects and commercial applications. As technology evolves, the Internet of Things (IoT) has gained prominence, enabling devices to connect over the internet to exchange information. In the DIY realm, IoT projects typically focus on home automation and smart home applications. However, commercial and industrial IoT projects often involve more complex technologies such as machine learning, artificial intelligence, and wireless sensor networks. For any IoT project, internet connectivity is essential. This is where the ESP8266 and ESP32 come in. The ESP8266 is a great choice for adding Wi-Fi connectivity to projects. For more advanced systems that require Wi-Fi, Bluetooth, high-resolution ADCs, DAC, and additional features, the ESP32 is the ideal option. The ESP32, developed by Espressif Systems, is a cost-effective System on Chip (SoC) microcontroller and a successor to the ESP8266. It offers both single-core and dual-core variants of the Tensilica 32-bit Xtensa LX6 microprocessor, with integrated Wi-Fi and Bluetooth capabilities. The ESP32, like the ESP8266, features built-in RF components such as a power amplifier, low-noise receive amplifier, antenna switch, filters, and RF balun, which simplifies hardware design by reducing the need for external components.

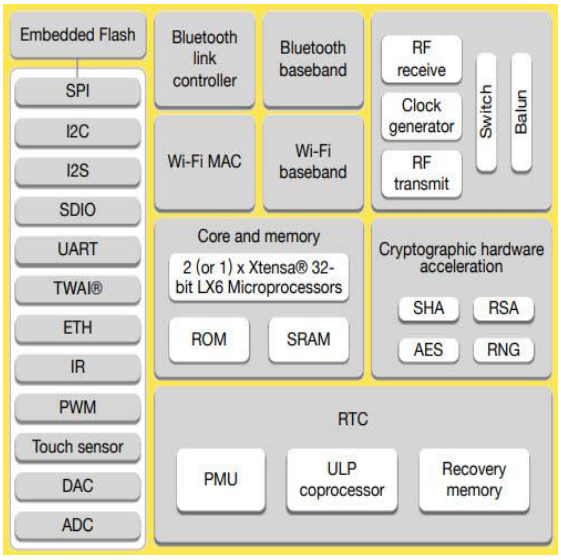

Fig 2. The ESP32 Development Board.

Another notable feature of the ESP32 is its production using TSMC's ultra-low-power 40 nm technology. This enables the ESP32 to be ideal for battery-powered applications, such as wearables, audio equipment, baby monitors, and smart watches. Its efficient power management ensures extended battery life for devices that require energy efficiency.

Regulated Power Supply

A regulated power supply is an electronic circuit designed to convert unregulated AC (alternating current) into a stable DC (direct current) output. Initially, it uses a rectifier to transform the AC input into DC. The main function of this power supply is to deliver a consistent voltage or current to a circuit or device that requires precise power parameters.

Although regulated power supplies usually provide a DC output, some configurations may offer AC output. Regardless, the key objective is to maintain a stable output voltage or current, even with fluctuations in input voltage or load conditions.

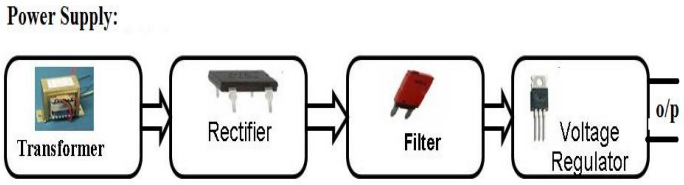

Fig 3. Regulated Power Supply.

Liquid Crystal Display

Liquid Crystal Display, a widely used electronic display module found in devices such as mobile phones, calculators, computers, and televisions. LCDs are popular due to their affordability, ease of programming, and flexibility in displaying custom characters, special symbols, and animations.

An LCD screen utilizes liquid crystal technology to create visible images. The 16×2 LCD display is a basic and commonly used module in DIY projects and various circuits. It features a display capable of showing 16 characters per line over 2 lines, with each character represented in a 5×7 pixel matrix.

Character LCDs are available in several sizes, including 8x1, 8x2, 10x2, 16x1, 16x2, 16x4, 20x2, 20x4, 24x2, 30x2, 32x2, and 40x2. Prominent manufacturers such as Philips, Hitachi, and Panasonic offer customized character LCDs for their products. Regardless of size or manufacturer, these LCDs have similar functionalities, displaying characters, numbers, special symbols, and ASCII characters, and generally feature a standard pin configuration of either 14 or 16 pins.

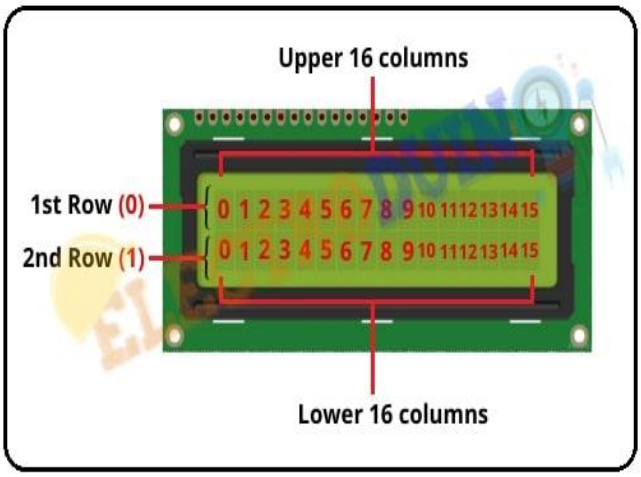

Fig 4. LCD 16×2 Pin Diagram

GSM Modem

GSM modem offers a user-friendly serial interface, ideal for a range of GSM functions. It supports sending SMS, making and receiving calls, and other GSM operations via simple AT commands. Utilizing the popular SIM900 module, the modem provides dependable performance. Its standard RS232 interface ensures straightforward connection to microcontrollers and computers, allowing for easy integration and control.

Fig 5. GSM (SIM 800L) module.

Soil Moisture Sensor

Soil moisture sensors are designed to measure the water content in soil, which is crucial for managing irrigation and optimizing plant growth. These sensors typically work by measuring properties that correlate with soil moisture since direct measurement requires removing and drying soil samples, which is impractical for continuous monitoring**.**

Fig 6. Soil moisture sensor

Relay

A relay is an electro-mechanical component that operates as a switch. It uses an electromagnet to control one or more sets of contacts, allowing it to open or close a circuit. When a DC voltage is applied to the relay coil, it generates a magnetic field that moves the contacts between different states, such as opening or closing the circuit.

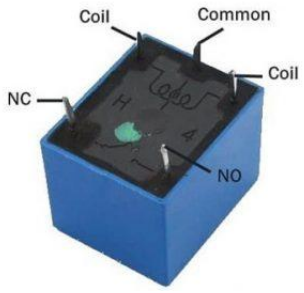

Fig 7. Relay

V. Working

Modern technology integrates an automated irrigation system powered by the Internet of Things (IoT) with a solar-powered smart electric fence to enhance both animal management and agricultural practices. This advanced approach combines several crucial elements into a unified and effective solution.

The system relies on solar energy to power both the irrigation system and the electric fence, promoting sustainability and reducing reliance on conventional power sources. IoT sensors embedded in the irrigation system and along the fence continuously monitor environmental conditions, soil moisture levels, and animal activity. This data is transmitted to a central control hub, where it is processed in real-time using sophisticated algorithms.

Users can remotely access and manage the system via mobile devices, enabling real-time monitoring and adjustments. This combination of solar power and IoT technology ensures a highly efficient, sustainable, and user-friendly solution for contemporary agricultural and animal management needs.

Fig 8. Project Kit

The system functions by harnessing solar energy through a solar panel to charge a battery. The battery's charge is monitored via a dedicated display unit. This energy powers several components, including an LCD display, a custom PCB with an ESP32 microcontroller and GSM module, the electric fencing around the plantation, and a 12V DC motor for irrigation.

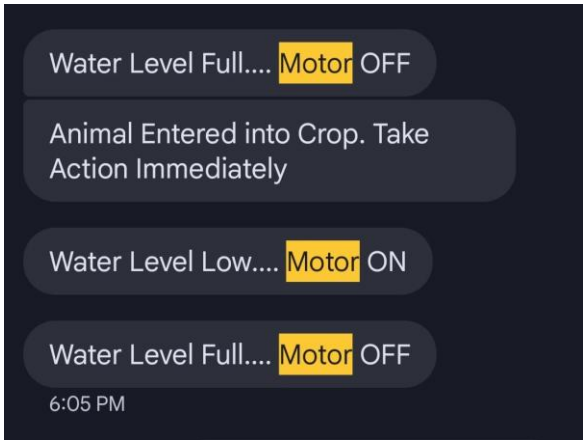

Fig 8. Messages Displayed

Automatic irrigation is controlled by a soil moisture sensor. When the sensor detects low moisture levels or registers a reading of "0" in the Thingspeak application, it triggers the motor to water the plants. Simultaneously, the system sends a notification to inform the user of the low moisture level and the initiation of irrigation.

For security, the GSM module detects any breaches in the electric fence, such as cuts, and sends detailed information about the breach location to the user. This integrated approach ensures effective irrigation management and provides prompt alerts for any security issues.

VI. CONCLUSION AND FUTURE WORK

In conclusion, the Smart Fencing System leverages ESP32 and GSM technology to offer an effective solution for crop protection and irrigation management. By integrating sensors, actuators, and communication modules, the system provides continuous monitoring, automated responses, and real-time alerts. This approach enhances agricultural security, optimizes irrigation efficiency, and conserves water. With capabilities including data uploading to the Thingspeak server, irrigation regulation based on soil moisture, and intrusion detection, the system equips farmers with valuable insights and timely interventions, thus improving crop yields and promoting sustainability.

Future enhancements for the system could include:

1. **Predator Deterrent Integration:** Introduce deterrent features such as motion-activated lights, ultrasonic repellents, or non-lethal deterrents like water sprays to enhance the fence's effectiveness in protecting against predators.
2. **Community Engagement Platform:** Create a platform for users to exchange experiences, best practices, and insights about the smart fencing system. This would foster collaboration, facilitate knowledge sharing, and support continuous improvement.
3. **Data Analytics for Crop Management:** Employ data from IoT sensors to gain comprehensive insights into crop health, growth patterns, and water usage. This data-driven approach could optimize crop management practices, improve yields, and reduce resource consumption.
4. **Emergency Response Integration:** Link the system with local authorities or wildlife conservation organizations. In case of a breach or threat, automatic alerts could be sent to designated responders for rapid intervention, minimizing potential damage and enhancing overall safety.

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