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Precision Agriculture and Wildlife Surveillance Using IoT for Crop Protection and Health Monitoring

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Abstract

AI and IoT in smart agriculture are revolutionizing the industry through intelligent monitoring and control. The proposed system consists of a mobile app and several smart sensors that communicate with the application over a network. The sensors continuously provide values for several important agricultural variables, such as humidity, temperature, and soil moisture. This system makes water management efficient at the click of a button by enabling farmers to operate industrial pump sets remotely and optimize irrigation. The system also employs AI-driven animal recognition technology to identify common crop-destroying animals, such as birds, goats, cows, and buffalo. The farmer is instantly alerted of the intruder and the necessity to act when a warning buzzer is triggered and a photo is sent to them. Aside from protecting crops from damage, this ingenious hands-free approach considerably reduces the need for human labor, enhancing the safety and efficiency of farming.

Keywords: Arduino Board, Soil Moisture Sensor, Temperature Sensor, Rain sensor, Node MCU, LCD, Relay.

1. Introduction

As the population of the world increases, the agricultural sector needs to ramp up to cater to rising food needs in the face of environmental limitations like adverse weather and climate change [1-4]. IoT-enabled smart agriculture provides a sophisticated solution by

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employing sensors (soil moisture, temperature, and humidity) to track fields and mechanize irrigation systems [5-7]. It enables farmers to gain real-time field status remotely, making agriculture more efficient compared to traditional methods [8-10]. The implementation of IoT in agriculture has yielded many advantages, such as the cost and increased crop production. The main goal of this project is to improve agricultural output through remote monitoring and measurement of essential parameters like water availability, temperature, and soil moisture levels. Farm produce is usually greatly affected by local animals like buffaloes, cows, goats, and birds. Because farmers cannot always patrol their fields or set up full-scale barricades, we are suggesting an AI-based automatic system for crop protection. The system uses a webcam to recognize incoming animals through artificial intelligence-based identification. When an animal is detected, an alert is sent using a buzzer to scare it away, and a photograph of the identified animal is sent to the farmer's registered email. This groundbreaking strategy guarantees total crop protection and minimizes losses while boosting farm security, ultimately leading to sustainable agriculture.

2. Literature Review

Since Bolu et.al. [11] proposed that an automated irrigation microcontroller-based solar-powered system is employed to ensure the best quality water, which is tested by soil moisture sensors in agriculture. The review contribution [12] identifies the use of WSN for monitoring environmental and soil parameters to offer efficient irrigation with fewer manual interventions. The research [13] developed an Arduino and WSN-based automated farm monitoring system that enhances real-time decision-making and keeps the crops in the field. It also incorporates applications of environmental monitoring using Arduino. The research [14] also utilized the Arduino Nano with DHT11 sensors and a real-time DS3231 clock module to capture temperature and humidity measurements. This will contribute to tracking the environment and gathering the accuracy of agricultural and climate-sensitive uses in a credible manner. Mohan et. al [15] described an IoT-based Arduino for home appliances automation by focusing on the Arduino application within home environments. The author [16] enhanced the work using an Arduino-based home system in an economical, affordable, and scalable manner. David et.al [17] and Malav et.al. [18] described the apparent uses of Arduino in the remote control of household devices, which improved daily convenience and security.

Along with the Arduino automation system, research [19] implemented a radar system with Arduino for short-range security and obstacle detection purposes.

The rain detection system is a crucial application with Arduino and rain sensors alerting users to weather changes, which assists the automated environmental response system designed in the work [20]. Shree et. al. [21] suggested an appliance monitoring system that tracks the use of electrical devices through an Arduino, primarily used to promote energy conservation options. The system in place employs a Zigbee network for the transmission of measured agricultural parameters, but it is only useful in short-range applications.

It uses sensors to track temperature and soil moisture alone, ignoring important parameters such as water level in wells, which can cause water pump malfunction from dry running. It does not have rain detection or CO_2 monitoring, reducing the scope of environmental monitoring. In the present system, animal detection is based on cameras, ultrasonic sensors, and PIR sensors, which track a small area, and hence are ineffective for large agricultural lands. These constraints present the necessity for an innovative IoT-based smart farming system with increased coverage, better monitoring, and enhanced automation.

3. Proposed System

The suggested system is an energy-efficient edge-fog cloud architecture for a smart agriculture environment based on IoT. The system is designed to minimize energy consumption and enhance the efficiency of smart agriculture by sharing computing and storage resources between various layers, The system consists of three layers: the edge layer, the fog layer and the cloud layer. The edge layer comprises sensors and devices that gather field data, such as temperature, moisture, ultrasonic, rain, and CO2. The field data gathered at the edge layer is processed locally through low-power microcontrollers, saving energy. The fog layer would comprise high-power computing resources, e.g., edge servers, which process and analyze the data collected at the edge layer. The fog layer also encompasses storage resources that hold historical data and provide real-time access to the data. The proposed system incorporates a cloud layer to increase computing and storage capacity, facilitating advanced data analysis and machine learning algorithms for better agricultural management. The cloud-based platform centralizes system monitoring, configuration, and data management while maximizing water and fertilizer use, minimizing waste, and increasing resource efficiency. Additionally, an AI-powered real-time animal monitoring system based on OpenCV and IoT-based alerts is integrated to provide farm security. As soon as an animal enters the field, the camera takes a photograph of it, processes the image through feature extraction, fusion, and dimension reduction, and then sends an alert to the farmer. This system helps avoid crop loss and increases agricultural productivity by allowing timely corrective measures. Furthermore, the incorporation of AI-based animal monitoring enhances farm safety, maximizes animal welfare, and reduces risks linked to animal intrusions. This system employs AI and OpenCV to detect animals in real-time. The steps begin with image acquisition, pre-processing, and compression. A dataset of images is used to train the model. A visual block diagram of the animal monitoring setup is illustrated in Fig.1.

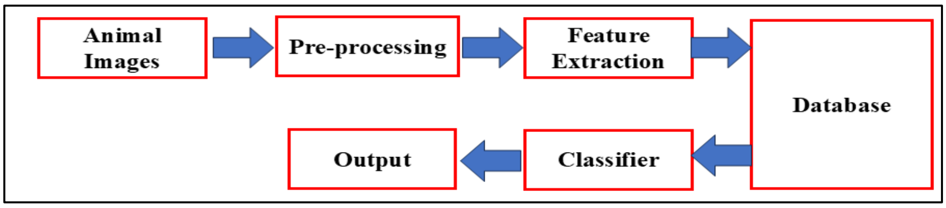

Figure 1. Block Diagram of Animal Monitoring [22]

Feature extraction provides consistent and real-time operation, followed by feature fusion and dimension reduction to compact the image and develop the desired pattern. The block diagram of the proposed system provides details on modules required. The proposed system needs several hardware devices, such as a soil moisture, sensor for measuring soil, a temperature sensor for climate measurement, a rain sensor to check for rain, and a CO_2 sensor to measure air quality. A camera is incorporated for real-time animal detection, along with an ultrasonic sensor for the detection of objects. Automated irrigation is achieved through a water motor, which is controlled by an Arduino Uno and Node MCU that handle data processing and wireless transmission. A Liquid Crystal Display offers real-time system feedback, and power supply guarantees constant operation. The system employs the Arduino IDE for microcontroller programming and Python for implementing AI-powered image processing and automation. The hardware and software combination provides effective smart farming processes with robust monitoring, automation, and security. Fig.2 shows a structured diagram of crop health monitoring.

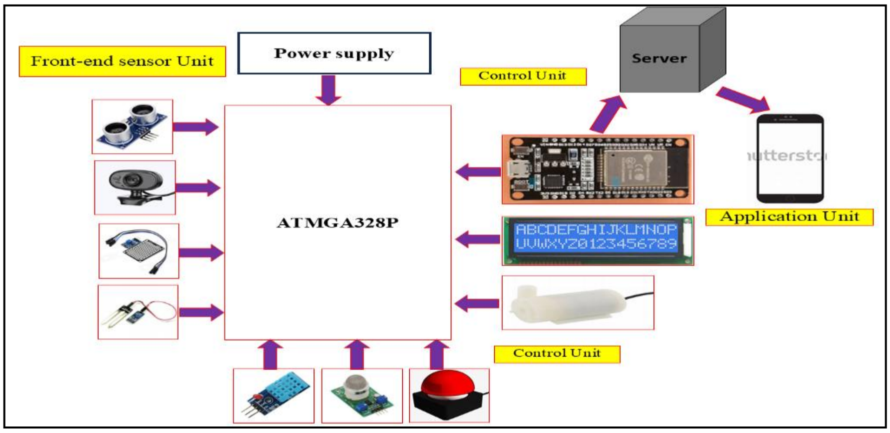

Figure 2. Block Diagram of Crop Health Monitoring

A. Soil Moisture Sensor

A soil moisture sensor is a device utilized to determine the level of moisture in the soil. Upon detecting a water deficit in the field, the sensor provides a high-level output, while the output changes to a low level under normal circumstances. It acts as an indicator for watering plants and regularly monitors the moisture level in the soil. The technology is used extensively in agriculture, land irrigation, and horticultural gardening. Fig. 3 shows the soil moisture system.

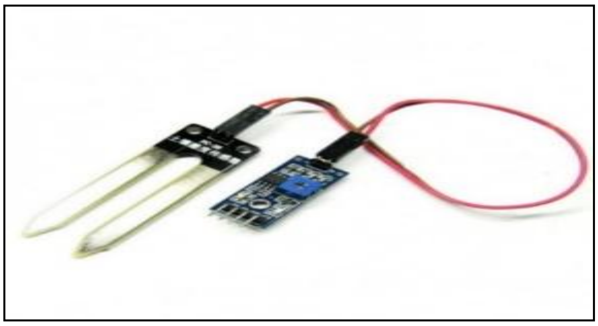

Figure 3. Soil Moisture Sensor

B. Temperature Sensor

A humidity sensor is a tool that monitors and measures the amount of moisture in the air while taking the ambient temperature into account. Fig. 4 shows the temperature-sensing mechanism.

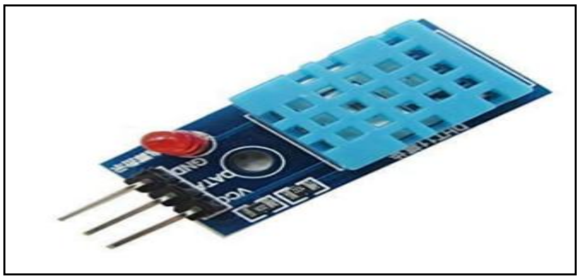

Figure 4. Temperature Sensor

It gives readings for relative humidity, which show how much moisture is present in relation to the air's maximum capacity at a specific temperature and are expressed as a percentage. Variations in relative humidity result from the air's ability to retain more moisture as the temperature rises.

C. Rain Sensor

A device that detects rainfall and turns on is called a rain sensor or rain switch. It has two main purposes: it saves water by turning off automatic irrigation systems in the event of rain and protects a car's interior by automatically turning on windshield wipers when rain is detected. The rain sensor monitoring system is shown in Fig. 5.

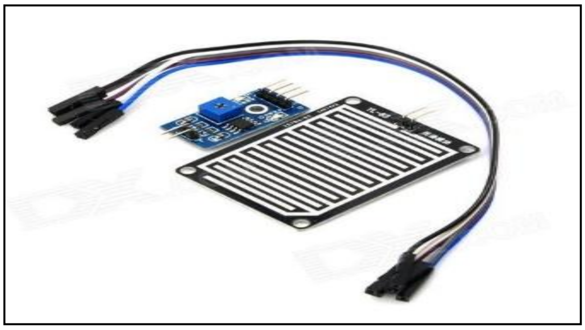

Figure 5. Rain Sensor

D. Ultrasonic Sensor

Ultrasonic transducers convert ultrasonic waves into electrical signals and vice versa. A device that can send and receive these waves is called an ultrasonic transceiver, and many ultrasonic sensors are designed to function as transceivers. The transducers used in radar and sonar systems, which assess target characteristics by analyzing radio or sound wave reflections, function similarly to these sensors. The ultrasonic sensing system is shown in Fig. 6.

Figure 6. Ultrasonic Sensor

E. Web Camera

A webcam is a type of video camera that uses a computer network to record and broadcast live video. The video stream can be saved, viewed, or transmitted to other networks, such as the Internet, or sent as an attachment in an email after it has been received by the computer. It is also possible to send the video stream to another location. The webcam that is part of the monitoring system is shown in Fig. 7.

Figure 7. WEB Camera

F. CO_2 Sensor

A CO2 sensor is a device that measures the amount of carbon dioxide present in the atmosphere. Numerous applications for these sensors are common, such as monitoring indoor air quality, managing HVAC systems, and tracking greenhouse gas emissions. CO2 sensors detect variations in the electrical conductivity or infrared radiation of a gas sample. The CO2 used in the system is shown in Fig. 8.

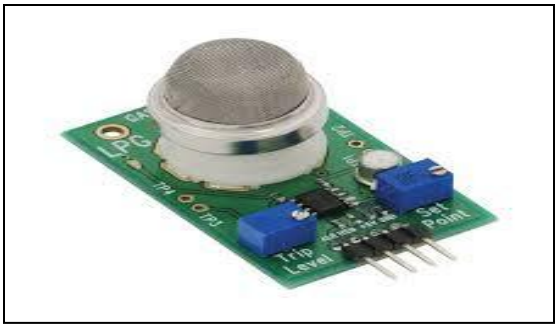

Figure 8. CO_2 Sensors

G. Node MCU

Espressif Systems, the company behind the well-known ESP8266 SoC, created the ESP32, a low-cost System-on-Chip (SoC) microcontroller. Tensilica's 32-bit Xtensa LX6 CPU powers this more recent model, which comes with Bluetooth and Wi-Fi built in. It offers single-core and dual-core options. Like the ESP8266, the ESP32 has a number of built-in radio frequency components, such as a power amplifier, low-noise receiver amplifier, antenna switch, filters, and RF balun. Because it requires few external components, this integration makes device creation easier. The NodeMCU board utilized in the system is depicted in Fig. 9.

Figure 9. Node MCU Board

H. Power Supply

A power supply is a device that converts electrical energy from a source into the appropriate voltage, current, and frequency required for optimal operation in order to deliver electrical energy to a load.

I. Liquid Crystal Display

One kind of flat-panel electronic display that creates images by using the light-modulating properties of liquid crystals is called a liquid crystal display (LCD). Liquid crystals, in contrast to other display technologies, create images by manipulating the passage of ambient or backlight light rather than directly emitting light. Both fixed-image displays, such as digital clocks and seven-segment indicators, and general-purpose displays, such as computer screens, use LCDs. They are widely used in many different applications due to their low power consumption, clarity, and adaptability. These include IoT-based systems for real-time data visualization in automation projects and smart farming. The liquid crystal display module used is shown in Fig. 10.

Figure 10. Liquid Crystal Display

J. Water Motor

One kind of DC motor that helps move fluids is a pump motor, which transforms electrical energy from direct current into mechanical energy. It works on the basis of the idea that the torque produced by a current-carrying conductor in a magnetic field causes rotational motion. We call this phenomenon motoring action. Pump motors are essential to automated irrigation in Internet of Things (IoT)-based smart farming systems because they provide the best possible water distribution based on real-time sensor data, increasing productivity and decreasing water waste. The water motor utilized in the system is depicted in Fig. 11.

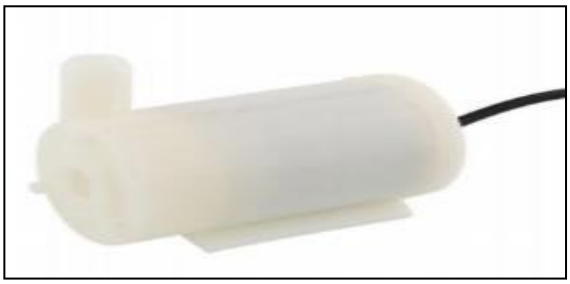

Figure 11. Water Motor

K. Arduino IDE

C and C++ were used to create the versatile Arduino Integrated Development Environment (IDE). It is intended for coding and uploading to Arduino-compatible boards, including those made by other companies and using third-party cores.

L. Python

Python is a high-level, interpreted, and flexible programming language that is used in many different applications. Procedural, object-oriented, and functional programming are among the various programming paradigms that it supports.

4. Results And Discussions

The automated soil health monitoring system, based on IoT, showed enormous enhancements in farm management by allowing for real-time tracking of essential environmental parameters. The system effectively combined different sensors to monitor soil moisture, temperature, CO_2 content, and rainfall, enabling farmers to make informed decisions for optimal irrigation and fertilization. Through the use of cloud storage and cloud computing, the system provided effortless access to real-time data, enhancing efficiency and minimizing resource wastage. The smart crop protection system identified and kept wild animals away from the fields. Based on AI-powered animal identification with OpenCV, the system detected intruding animals through image capture and processing. The real-time detection system initiated an instant buzzer alarm, effectively chasing away animals before they could. The snapped images were also forwarded to the registered email of the farmer through IoT, enabling timely intervention. Field trials indicated that the system substantially reduced crop loss from animal intrusions and proved to be a credible and affordable substitute for conventional fencing or regular surveillance. This project has achieved sound and effective results. It was implemented practically, and the system proved effective in achieving the needed objectives. The system proved very reliable in monitoring soil health, irrigation management, and crop protection from wild animals. The results aligned with the desired outcomes, demonstrating the viability and performance of the IoT-based smart agriculture solution. Below are the actual working images of the program, visually presenting the execution of the system and real-time monitoring of data. These images are screenshots of the system interface, sensor data, and real-time animal detection notifications, showcasing the effective combination of IoT and AI in agricultural surveillance and defense. Fig. 12. a) Hardware kit b) Blynk app c) Animal detection d) Program output e) Mail notification.

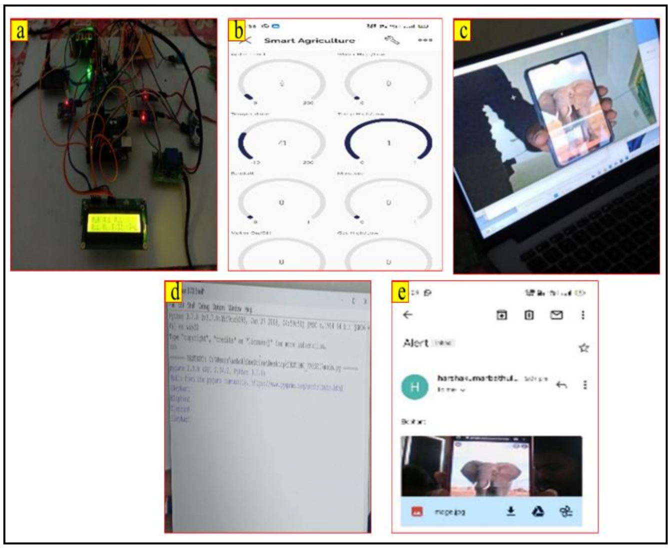

Figure 12. a) Hardware Kit b) Blynk App c) Animal Detection d) Program Output e) Mail Notification

5. Conclusion

There is an automated monitoring system for soil health based on IoT technology that measures important agricultural parameters. By scrutinizing various conditions in the fields, the system enables farmers to make informed decisions based on real-time environmental requirements. In this way, we are enhancing a capable of regulating agricultural monitoring in areas where human oversight is not feasible. We are developing a system that tracks the expensive crops and manages all climatic conditions effectively. Furthermore, we have created an automatic crop protection system against wild animals; in this system, farmers do not have to spend the whole day barricading the fields because we will implement artificial animal recognition. This system employs various webcams capable of detecting wild animals approaching the field. When wild animals are detected, a buzzer is triggered to scare them away from the fields. In addition, the image identified for the animal is sent to the owner's email address. This ensures complete protection of crops against animals, hence protecting farmers from potential losses.

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