JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

IoT-BASED SMART AGRICULTURE SYSTEM: IMPROVING EFFICIENCY AND SUSTAINABILITY

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ABSTRACT:

Smart agriculture, enabled by the Internet of Things (IoT), represents an innovative approach to modernizing traditional agricultural practices. This project addresses the design for implementation and evaluation. An Internet of Things (IoT) system designed specifically for use in agriculture. The main goal is to improve agricultural efficiency, productivity, and sustainability through real-time monitoring, data analysis, and automated decision-making. The proposed system includes a network of interconnected sensors placed on agricultural land to detect various environmental parameters such as soil moisture, temperature, humidity, and sunlight intensity. These sensors communicate wirelessly with a central controller that processes the data and provides farmers with actionable insights through a user-friendly interface that can be accessed from a Smartphone or computer. Using IoT technology, farmers can remotely monitor and manage crops and optimize irrigation schedules, fertilization methods, and pest control measures based on real-time data. In addition, advanced analytical algorithms enable predictive modeling and early detection of potential problems, allowing farmers to take proactive measures to reduce risk and maximize yield. This project aims to address the challenges facing modern agriculture, including resource limitations, environmental concerns, and the need for sustainable practices. By integrating IoT into farms, farmers can make informed decisions, minimize resource waste, and increase overall productivity while reducing their environmental footprint. The effectiveness of this proposed IoT-based smart farming system is evaluated through demonstration experiments and performance evaluations in collaboration with local farmers. The results of this project are expected to contribute to the advancement of appropriate agricultural practices and promote sustainable development in the agricultural sector.

Keywords: IoT, smart agriculture, precision agriculture, environmental monitoring, sustainability, real-time data, decision support systems.

I. INTRODUCTION

The introduction of an IoT-based smart agriculture system sets the stage by highlighting the pressing need for innovative solutions in modern farming practices.

It acknowledges the challenges faced by farmers such as unpredictable weather patterns, resource scarcity, and the constant threat of pests and diseases. Against this backdrop, the introduction outlines the significance of leveraging cutting-edge technologies like IoT to revolutionize agricultural operations, maximize yields, and ensure sustainable food production. Furthermore, the introduction introduces the key components of the proposed smart agriculture system, including various sensors such as soil moisture, PIR, IR, DHT11, and smoke sensors, all integrated with the ESP8266 NodeMCU module for data transmission to the cloud. It emphasizes the system's capability to provide real-time monitoring and control functionalities, enabling farmers to remotely manage irrigation, deter pests, detect insects, and monitor environmental conditions. By offering insights into the objectives and components of the smart agriculture system, the introduction sets the stage for a detailed exploration of its design, implementation, and potential impact on modern farming practices.

II. LITERATURE REVIEW

Manual Irrigation: Traditional irrigation methods often involve manual labor or simple timers, leading to inefficient water usage and inconsistent watering patterns. This can result in overwatering, which wastes water resources, or underwatering, leading to crop stress and reduced yields.
Chemical Pest Control: Many farmers rely on chemical pesticides to control pests, which can have negative impacts on the environment, human health, and non-target organisms. Additionally, pests may develop resistance to these chemicals over time, rendering them less effective.
Visual Inspection for Crop Health: Monitoring crop health through visual inspection alone may not detect early signs of disease or nutrient deficiencies. This can result in delayed intervention, allowing problems to escalate and affecting overall yield and quality.
Limited Environmental Monitoring: Traditional farming practices may not incorporate real-time monitoring of environmental parameters such as temperature, humidity, and air quality. Without this data, farmers may miss opportunities to optimize growing conditions or mitigate potential risks.
Lack of Remote Monitoring and Control: Traditional farming methods cannot often remotely monitor and control farm operations. Farmers may need to physically inspect fields regularly, which can be time-consuming and labor-intensive, especially for large or remote farms.
Resource Inefficiency: Overall, traditional farming methods tend to be resource-intensive, relying heavily on manual labor, water, and chemical inputs. This can lead to higher production costs, environmental degradation, and reduced long-term sustainability.

III. MATERIALS AND METHODS

HARDWARE REQUIREMENTS:

The hardware requirements are

- Arduino Uno
- NodeMCU ESP8266
- Soil Moisture Sensor Module
- L298N Motor Driver
- Mini Water Pump
- Temperature & Humidity Sensor
- Gas Sensor
- Infrared Sensor
- Passive Infrared Sensor
- Buzzer
- Servo Motor
- LCD Display

SOFTWARE REQUIREMENTS:

The software requirements are

- Operating system: Windows
- Programming Language:
- Arduino IDE
- Things speak IoT Platform

❖ ARDUINO UNO

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

Fig.1 Arduino Uno

It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.

❖ NODEMCU ESP8266

The NodeMCU ESP8266 development board comes with the ESP-12E module containing an ESP8266 chip having a Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency.

Fig.2 NodeMCU ESP8266

NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects. NodeMCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interfaces.

Features of NodeMCU ESP8266:

Wi-Fi Connectivity
Microcontroller
Arduino Compatibility
GPIO Pins
Analog Inputs
Communication Interfaces (SPI, I2C, UART)
Low Power Consumption
IDE Support

❖ SOIL MOISTURE SENSOR MODULE

This soil moisture sensor module is used to detect the moisture of the soil. It measures the volumetric content of water inside the soil and gives us the moisture level as output.

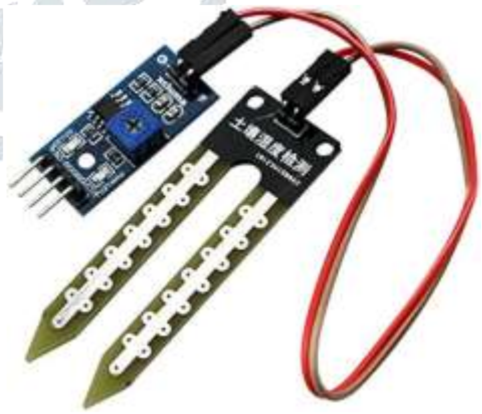

Fig. 3 Soil Moisture Sensor Module

The module has both digital and analog outputs and a potentiometer to adjust the threshold level.

❖ **L298N MOTOR DRIVER MODULE**

This L298N Motor Driver Module is a high-power motor driver module for driving DC and Stepper Motors.

Fig.4 L298N Motor Driver Module

This module consists of an L298 motor driver IC and a 78M05 5V regulator. L298N Module can control up to 4 DC motors, or 2 DC motors with directional and speed control.

❖ **MINI WATER PUMP**

This is a low-cost mini submersible type water pump that works on 3-6V DC. It is extremely simple and easy to use. Just immerse the pump in water, connect a suitable pipe to the outlet, and power the motor with 3-6V to start pumping water. This motor is small, compact, and light.

Fig.5 Mini Motor Pump

It can be controlled from a microcontroller/Arduino using our DC Motor Drivers or one of our Relay Boards.

❖ **TEMPERATURE & HUMIDITY SENSOR**

DHT11 Temperature and Humidity Sensor Module is pre-calibrated with resistive sense technology coupled with an NTC thermistor, for the precise reading of the relative humidity and surrounding temperature DHT 11 break-out board is a very popular, low-cost sensor, the breakout provides easy installation of the DHT11 sensor module.

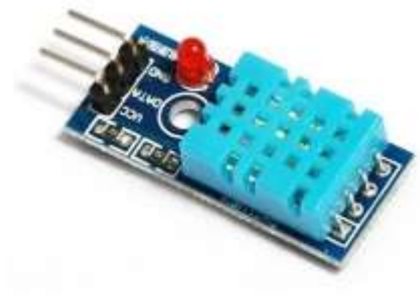

Fig.6 Temperature and Humidity Sensor

The board is also equipped with- a performance 8-bit microcontroller which is connected to the DHT11 sensor module. The output of the DHT11 is in the form of a digital signal on a single data pin. The sensing update frequency is to be measured at every 2sec (0.5Hz).

❖ **GAS SENSOR**

MQ2 gas sensor module is highly useful for gas leakage detection at home or in industry. The sensor module can detect h2, LPG, CH4, CO, Alcohol, Smoke, or Propane. It is highly sensitive and very first responder. Depending on the requirements of sensitivity, the sensor can be adjusted with a Potentiometer.

Fig.7 Gas Sensor

MQ2 is an analog output sensor that is commonly used as a combustible gas sensor in the MQ sensor series. It is a Metal Oxide Semiconductor (MOS) type gas sensor. The output voltage of the gas sensor increases if the concentration of gas increases. The sensitivity of the sensor is adjustable by the Potentiometer.

❖ **INFRARED SENSOR**

IR Sensor Module is used for various Robotic Applications, Object Detection, Visitor Counter, etc. COMPATIBLE WITH ARDUINO, RASPBERRY PI, ARM, AVR, PIC, 8051, etc. Useful for various Robotic Applications, Object Detection, a

Visitor Counter, etc. this is a High-accuracy good quality IR sensor.

Fig.8 Infrared Sensor

Infrared Obstacle Avoidance IR Sensor Module (Active Low) has a pair of infrared transmitting and receiving tubes. When the transmitted light waves are reflected, the reflected IR waves will be received by the receiver tube. The onboard LM393 voltage comparator circuitry does the processing and the green indicator LED comes to life.

❖ PASSIVE INFRARED SENSOR

PIR Motion Sensor is used for all-purpose security systems. All live objects whose body temperature is more than 0 degrees Celsius emit the heat in form of infrared radiation through their body. These radiated signals are invisible to the human eye.

Fig.9 Passive Infrared Sensor

These signals can be detected by using a PIR sensor which is specially designed for such purpose. In the passive infrared (PIR) sensor, the passive word indicates PIR sensor does not generate or radiate any energy for detection purposes. They detect the infrared radiation emitted or reflected from humans or animals.

❖ BUZZER

A **buzzer** is a small yet efficient component to add sound features to our project/system. It is a very small and compact 2-pin structure hence can be easily used on breadboards, Perf Board, and even on PCBs which makes this a widely used component in most electronic applications.

Fig. 9 Buzzer

This buzzer can be used by simply powering it using a DC power supply ranging from 4V to 9V

❖ SERVO MOTOR

Servo Motor SG90 Mini is special among all the available servo motors because its operation is very different from that of a standard servo. Instead of going to a specified angle, this servo will be static at a 1.5ms pulse, a longer pulse gives forward rotation and a shorter pulse gives backward rotation.

Fig.10 Servo Motor

It equips Carbon Fiber Gears which makes the servo motor much lighter than the same metal gear motor. It is a Digital Servo Motor that receives and processes PWM signals faster and better.

❖ LCD DISPLAY

The term LCD stands for liquid crystal display. It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc.

Fig. 11 LCD Display

These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simple programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc.

❖ ARDUINO IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus.

Arduino IDE Default Window

Fig. 12 Arduino IDE

It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

❖ **THING SPEAK IOT PLATFORM**

ThingSpeak is an IoT platform for users to gather real-time data; for instance, climate information, location data, and other device data. In different channels in ThingSpeak, you can summarize information visualize data online in charts, and analyze useful information.

Fig.12 Thing Speak IoT Platform

ThingSpeak can integrate IoT: bit (micro: bit) and other software/ hardware platforms. Through IoT: bit, you can upload sensor data to ThingSpeak (e.g. temperature, humidity, light intensity, noise, motion, raindrop, distance, and other device information).

EXISTING SYSTEMS

Traditional farming practices often rely on manual irrigation methods or simple timers, resulting in inefficient water usage and inconsistent watering patterns. This can lead to overwatering, wasting water resources, or underwatering, causing crop stress and reduced yields. Additionally, farmers commonly resort to chemical pesticides for pest control, posing risks to the environment, human health, and non-target organisms. Moreover, visual inspection alone may not suffice for monitoring crop health, potentially missing early signs of disease or nutrient deficiencies, thereby impacting overall yield and quality. Furthermore, traditional farming practices often lack real-time environmental monitoring, neglecting parameters like temperature, humidity, and air quality, which are crucial for optimizing growing conditions and mitigating risks. The absence of remote monitoring and control further complicates matters, requiring farmers to physically inspect fields regularly, which can be labor-intensive and time-consuming. Overall, traditional farming methods tend to be resource-intensive, relying heavily on manual labor, water, and chemical inputs, resulting in higher production costs, environmental degradation, and reduced long-term sustainability.

PROPOSED SYSTEM

The proposed IoT-based smart agriculture system aims to address the shortcomings of traditional farming methods by integrating advanced technologies for real-time monitoring, automated control, and data-driven decision-making. The system consists of various components: a sensor network, including soil moisture sensors, PIR sensors for pest detection, IR sensors for insect detection, DHT11 sensors for temperature and humidity, and smoke sensors for environmental monitoring; an ESP8266 NodeMCU Module functioning as the central processing unit to collect and transmit data to the cloud; automated control mechanisms triggered by sensor data to manage irrigation, deter pests, and generate alerts; an on-site LCD for local monitoring; a mobile application enabling remote access to sensor data, alerts, and system control; and cloud analytics for storing and analyzing sensor data, providing insights into crop health, environmental conditions, and pest activity trends. This comprehensive solution empowers farmers with actionable insights and automated control capabilities, fostering smart and efficient farming practices that optimize resource usage, mitigate risks, and maximize productivity while promoting sustainability and environmental stewardship.

IV. WORKING

The hardware setup for the project involves installing soil moisture sensors, PIR sensors for pest detection, IR sensors for insect detection, DHT11 sensors for temperature and humidity measurement, and smoke sensors for environmental monitoring across the field. The ESP8266 NodeMCU module serves as the central processing unit to collect data from sensors and communicate with the cloud and peripheral devices. Software development includes creating firmware for the NodeMCU module to collect and process sensor data, implementing algorithms for data analysis and automated control, developing a mobile application for remote access and control, and setting up a cloud-based analytics platform for storing data and generating insights.

BLOCK DIAGRAM:

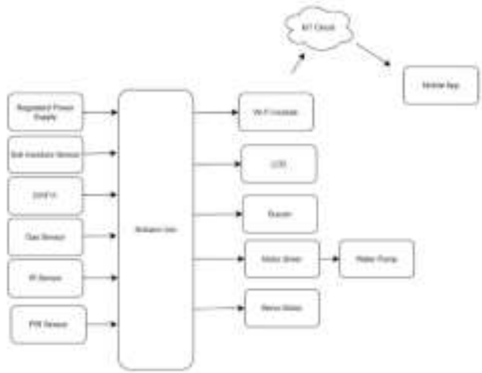

Fig. 13 Block Diagram of Smart Agriculture

Integration involves combining hardware components with firmware, configuring the NodeMCU module to connect to Wi-Fi and communicate with the cloud, testing communication between sensors, the module, and the cloud, integrating the mobile application with the cloud platform for remote monitoring and control, and conducting comprehensive testing to ensure functionality, reliability, and usability of the entire system.

V. RESULTS AND DISCUSSIONS

Fig.14 Real-time LCD Display Values

The above figure displays the values of various components such as soil moisture, temperature, humidity, gas level, infrared sensor data, and passive infrared sensor data on the LCD, providing real-time information to the user.

Soil Moisture Sensor Data:

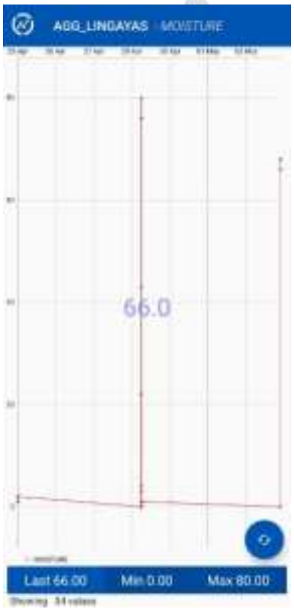

Fig. 15 Soil Moisture Sensor Data in Thingspeak App

The above figure presents the data collected from the soil moisture sensor, showing variations in soil moisture levels over time

Temperature Sensor Data:

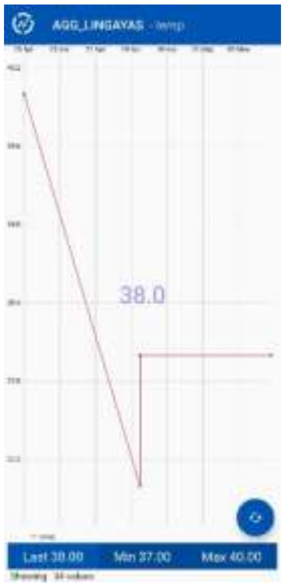

Fig. 16 Temperature Sensor Data in Thingspeak App

The above figure showcases the temperature data recorded by the temperature sensor. It demonstrates the temperature trends over a specific period, highlighting fluctuations in temperature throughout the day.

Humidity Sensor Data:

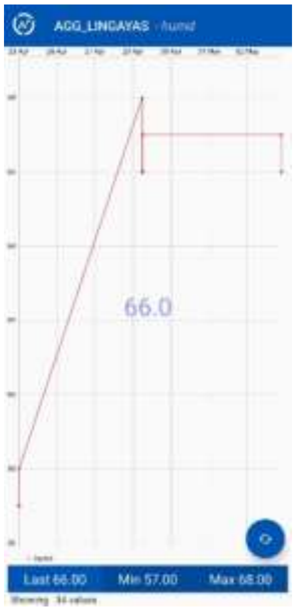

Fig.17 Humidity Sensor Data in Thingspeak App

This figure illustrates the humidity data captured by the humidity sensor. It visualizes the humidity levels over time, providing insights into humidity variations and their impact on crop growth and environmental conditions

Gas Level Sensor Data:

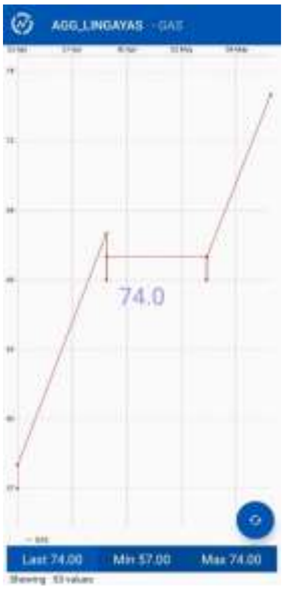

Fig. 17 Gas Level Sensor Data in Thingspeak App

The above figure displays the data collected from the gas level sensor, showing the concentration of gases such as CO2 or methane in the environment. It helps in monitoring air quality and detecting potential hazards or pollution sources.

Infrared Sensor Data:

Fig. 18 Infrared Sensor Data in Thingspeak App

The above figure presents the data recorded by the infrared sensor, indicating the presence of objects or obstacles in the vicinity. It showcases the detection range and sensitivity of the infrared sensor, aiding in obstacle avoidance or proximity sensing applications.

Passive Infrared Sensor Data:

Fig.19 Passive Infrared Sensor Data in Thingspeak App

CONCLUSION

The IoT-based smart agriculture system offers a revolutionary solution to the age-old challenges of traditional farming, ushering in a new era of efficiency, productivity, and sustainability. By integrating cutting-edge technologies like sensors, data analytics, and cloud computing, the system enables real-time monitoring, automated control, and data-driven decision-making across all aspects of farm management. With optimized resource usage, timely interventions, and remote monitoring capabilities, farmers can maximize crop yields, minimize losses, and promote environmental stewardship. Moreover, the system's advantages in labor savings, data-driven decision-making, and remote accessibility not only enhance farm efficiency but also improve the overall quality of life for farmers. Its applications extend beyond crop farming to include greenhouse management, livestock production, aquaculture, and environmental monitoring, showcasing its versatility and potential impact across diverse agricultural sectors. In essence, the IoT-based smart agriculture system signifies a transformative shift towards precision, efficiency, and sustainability in agriculture, empowering farmers to overcome challenges, optimize operations, and cultivate thriving and resilient farms for future generations. With ongoing technological advancements, the future of agriculture holds promise, with the IoT paving the way for sustainable and prosperous farming practices worldwide.

APPLICATIONS

Crop Management: The system can be used to monitor and manage various aspects of crop growth, including irrigation, fertilization, and pest control, to optimize yield and quality.
Greenhouse Monitoring: In greenhouse environments, the system can monitor temperature, humidity, and light levels, providing ideal growing conditions for plants and optimizing greenhouse operations.
Livestock Management: Sensors can be deployed to monitor animal health, behavior, and environmental conditions in livestock farming, improving animal welfare and productivity.
Aquaculture Monitoring: The system can monitor water quality parameters such as pH, dissolved oxygen, and temperature in aquaculture systems, ensuring optimal conditions for fish and shellfish growth.
Precision Agriculture: By collecting and analyzing spatial data on soil and crop conditions, the system enables precision agriculture practices such as variable rate irrigation and fertilization, optimizing resource usage, and maximizing yield.
Environmental Monitoring: Beyond agriculture, the system can be applied to monitor environmental parameters in natural ecosystems, urban green spaces, and industrial sites, supporting environmental conservation and management efforts.

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