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Automated Plant Health Monitoring System by Using IOT

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ABSTRACT

The proposed IoT-Enabled Smart Agriculture and Environmental Monitoring System presents a low-cost, real-time solution for continuous monitoring and automated control of critical agricultural and greenhouse parameters using Wi-Fi–enabled embedded technology. The system is designed to enhance crop health, optimize resource utilization, and reduce human intervention by integrating multiple environmental and soil-related sensors with cloud-based data analytics. At the core of the system is a Wi-Fi–enabled microcontroller platform (such as an Raspberry Pi Pico W), which functions simultaneously as a Data Acquisition Unit (DAU) and a Local Control Unit (LCU). This controller interfaces with a diverse sensor suite that provides a holistic assessment of the agro-environment. The deployed sensors include a soil moisture sensor to assess soil water content and irrigation needs, a TDS (Total Dissolved Solids) or nutrient sensor to evaluate soil or water quality, an LDR sensor to detect ambient light intensity for crop illumination analysis, and an LM35 temperature sensor to accurately measure ambient temperature critical for plant growth and stress management. Sensor data are periodically sampled, digitized, and processed locally by the embedded control algorithm. The raw analog and digital signals are converted into meaningful engineering units, such as moisture levels, temperature in degrees Celsius, and light status. These values are continuously compared against predefined threshold limits stored in the controller. When abnormal or critical conditions are detected—such as low soil moisture, excessive nutrient concentration, or extreme temperature—the system autonomously activates

corrective mechanisms through relay-controlled actuators, such as irrigation pumps or auxiliary devices. Additionally, a buzzer provides immediate local alerts to notify nearby personnel of hazardous or out-of-range conditions.

KEYWORDS: ***Automated Plant Health Monitoring System, Internet of Things (IoT), Real-time Monitoring, Environmental Sensors, Cloud-based Data Analysis, Smart Agriculture, Automated Irrigation, Sustainable Farming Practices.***

INTRODUCTION

Agricultural productivity and plant health are highly dependent on continuous monitoring of environmental and soil parameters such as moisture content, temperature, light intensity, and nutrient concentration. Traditional plant monitoring practices rely largely on manual inspection and periodic measurements, which are often insufficient to detect sudden changes in growing conditions. These delays can result in plant stress, inefficient water usage, nutrient imbalance, and reduced crop yield. To address these limitations, automated and IoT-enabled monitoring systems have become essential for achieving precision agriculture and sustainable farming.The Automated Plant Health Monitoring System Using IoT is designed to provide real-time monitoring and autonomous control of critical plant growth parameters using the Raspberry Pi Pico W. In the proposed system, the Pico W functions as both a Data Acquisition Unit (DAU) and a Local Control Unit (LCU), utilizing its low power consumption, compact size, and built-in Wi-Fi capability to support continuous operation and remote connectivity. The system interfaces with multiple sensors, including a soil moisture sensor to assess irrigation requirements, a Total Dissolved Solids (TDS) sensor to monitor nutrient levels, a Light Dependent Resistor (LDR) to measure ambient light conditions, and an LM35 temperature sensor to track environmental temperature. The embedded control logic continuously acquires sensor data and converts raw readings into meaningful values for analysis. These values are compared against predefined threshold levels stored within the controller. When abnormal conditions are detected—such as low soil moisture, excessive TDS levels, insufficient light, or elevated temperature—the system automatically activates relay-controlled actuators to initiate corrective actions, such as turning on irrigation mechanisms. An audible buzzer is also triggered to provide immediate local alerts, ensuring timely human intervention when necessary.

RELATED WORK

Recent advancements in precision agriculture and IoT technology have significantly improved automated plant monitoring systems for sustainable farming applications. Several researchers have developed smart agriculture systems using microcontrollers and wireless communication to continuously monitor environmental and soil parameters. Existing systems commonly utilize sensors such as soil moisture sensors, temperature sensors, humidity sensors, and light sensors to observe plant health conditions in real time. IoT-based monitoring platforms integrated with cloud services enable farmers to remotely access sensor data and receive alerts regarding abnormal environmental conditions. Many studies have employed Arduino and NodeMCU controllers for automated irrigation systems, where water pumps are activated automatically based on soil moisture levels to reduce water wastage and improve crop productivity. Recent research also focuses on nutrient monitoring using TDS sensors to maintain proper soil fertility and improve plant growth efficiency.

Raspberry Pi-based agricultural systems have gained popularity due to their enhanced processing capability, wireless connectivity, and support for real-time data analysis. Researchers have further integrated relay modules and alert systems to automate corrective actions and notify users during critical environmental changes.

LITERATURE REVIEW

The integration of IoT technology in agriculture has enabled continuous monitoring of environmental parameters such as soil moisture, temperature, and humidity using sensor networks. These systems collect real-time data and help farmers monitor plant conditions efficiently, reducing manual effort and improving productivity through automation and smart decision making [1]. Real-time plant monitoring systems using IoT devices allow remote access to environmental data through cloud platforms. This enables farmers to observe plant health conditions continuously and take immediate action when abnormal conditions are detected, thereby improving crop quality and yield [2][3]. IoT applications in smart agriculture have transformed traditional farming into a more efficient and data-driven process. These systems help in optimizing resource usage, reducing water wastage, and increasing agricultural productivity through intelligent monitoring and automation [4][5]. Cloud computing plays a crucial role in modern smart farming by enabling storage, processing, and visualization of large amounts of sensor data. Integration of

IoT with cloud platforms allows farmers to access real-time information from anywhere, improving decision making and operational efficiency [6].

EXISTING METHOD

Existing plant monitoring systems mainly depend on manual observation and basic sensor-based techniques for maintaining crop health and irrigation management. In traditional agriculture, farmers inspect plant conditions visually by observing soil moisture, leaf color, and growth patterns to determine irrigation and nutrient requirements. Although these methods are simple and economical, they are highly time-consuming and depend completely on human experience and judgment. Early symptoms of plant stress, water deficiency, or disease are often unnoticed, resulting in delayed corrective actions and reduced crop productivity. Some existing systems use individual sensors such as soil moisture or temperature sensors to monitor environmental conditions, but these systems generally operate independently without proper integration or real-time communication. The collected data is usually stored locally and cannot be accessed remotely, limiting continuous monitoring and immediate response to changing environmental conditions..

PROPOSED METHOD

The proposed IoT-based Automated Plant Health Monitoring System is designed to provide continuous monitoring and intelligent control of important environmental and soil parameters affecting plant growth. The system is developed using the Raspberry Pi Pico W microcontroller, which acts as the central processing and communication unit due to its compact size, low power consumption, and built-in Wi-Fi capability. Multiple sensors are integrated into the system to monitor real-time plant conditions, including a soil moisture sensor for measuring soil water content, an LM35 temperature sensor for environmental temperature monitoring, an LDR sensor for detecting light intensity, and a TDS sensor for analyzing irrigation water quality. The sensor data collected by the controller is processed continuously and compared with predefined threshold values stored in the system. Due to its scalability and intelligent automation capability, the system is highly suitable for precision agriculture and smart farming applications.

SYSTEM ARCHITECTURE

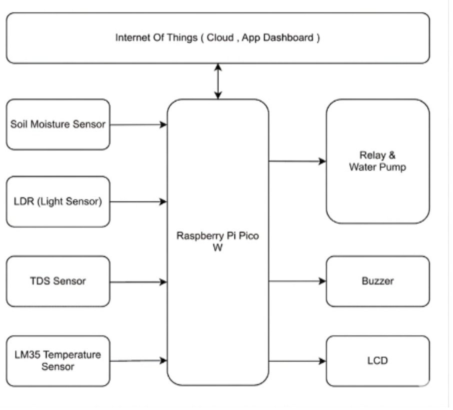

Fig 1: Block Diagram

METHODOLOGY DESCRIPTION

Environmental Data Collection: The system continuously collects real-time information related to soil moisture, temperature, light intensity, and water quality using multiple sensors.

Central Processing and Analysis: The Raspberry Pi Pico W acts as the main control unit that receives sensor readings and processes them continuously. The controller compares the sensed values with predefined threshold levels to identify abnormal environmental conditions. This intelligent processing enables accurate monitoring and automated decision-making.

Wireless Monitoring and Communication: The built-in Wi-Fi capability of the Raspberry Pi Pico W allows the system to transmit sensor data to the IoT cloud platform in real time. Users can remotely access plant health information through mobile or web applications from any location. Continuous cloud updates ensure efficient remote supervision and monitoring.

Automated Irrigation and Alert Operation: Whenever the soil moisture level falls below the required threshold, the controller automatically activates the relay-controlled water pump to provide irrigation. The buzzer generates immediate alerts during critical environmental conditions requiring attention. This automation reduces manual intervention and improves water management efficiency.

Display and User Interaction: The LCD screen displays real-time sensor readings such as moisture level, temperature, light intensity, and water quality values. This local display helps users quickly observe plant conditions without accessing the cloud platform.

SOFTWARE AND HARDWARE REQUIREMENTS

Raspberry Pi Pico W:

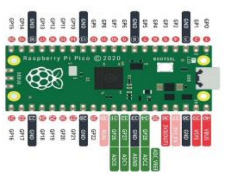

Fig 2: Raspberry Pi Pico W Microcontroller Board

The Raspberry Pi Pico W acts as the central controller of the system and performs data processing, sensor interfacing, and wireless communication.

Turbidity

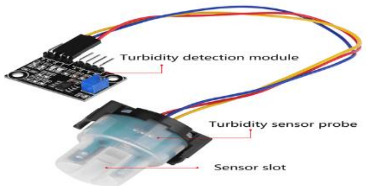

Fig 3: Turbidity

Turbidity indicates the clarity of water by measuring the amount of light scattered due to suspended particles present in the liquid.

Soil Moisture Sensor:

Fig 4: Soil Moisture Sensor

The soil moisture sensor is used to measure the water content present in the soil surrounding the plant roots. It helps the system determine whether irrigation is required by comparing moisture levels with predefined threshold values. This sensor enables efficient water management and prevents overwatering or dry soil conditions.

LM35 Temperature Sensor:

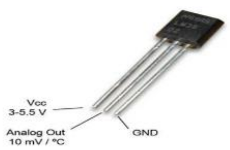

Fig 5: LM35 Temperature Sensor

The LM35 sensor is used to monitor the surrounding environmental temperature with high accuracy. It produces an output voltage directly proportional to temperature in degrees Celsius, making temperature measurement simple and reliable. The sensor helps detect abnormal temperature conditions that may affect plant growth and health.

Light Dependent Resistor (LDR):

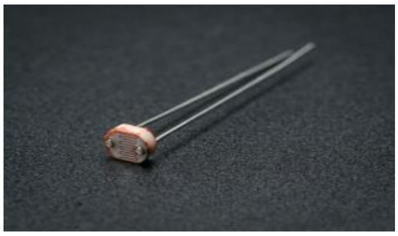

Fig 6: Light Dependent Resistor (LDR)

The LDR sensor is used to measure ambient light intensity available to the plants. Its resistance changes according to the amount of incident light, allowing the system to detect low-light or excessive-light conditions. This helps maintain suitable lighting conditions necessary for proper photosynthesis and plant development.

TDS Sensor:

Fig 7: TDS Sensor

The TDS (Total Dissolved Solids) sensor is used to monitor the quality and nutrient concentration of irrigation water. It measures the amount of dissolved substances present in water, which directly affects plant growth and soil fertility. The sensor ensures that plants receive suitable water for healthy development.

Relay Module:

Fig 8: Relay Module

The relay module is used to control high-power devices such as the water pump based on sensor readings. It acts as an electrically operated switch that allows automatic irrigation whenever soil moisture falls below the required level. This automation reduces manual effort and improves irrigation efficiency.

Water Pump:

Fig 9: Water Pump

The water pump is responsible for supplying water to the plants during low moisture conditions. It is automatically activated through the relay module whenever irrigation is needed. The pump ensures continuous and efficient water delivery for healthy plant growth.

Buzzer:

Fig 10: Buzzer

The buzzer is used to provide audible alerts whenever abnormal environmental conditions are detected in the system. It warns users about issues such as high temperature, low moisture, or poor water quality. This alert mechanism ensures quick human response and system safety.

LCD Display:

Fig 11: LCD Display

The LCD display is used to show real-time sensor readings and system status information locally. It displays parameters such as soil moisture, temperature, light intensity, and water quality values for easy monitoring. The display improves user interaction and helps in quick observation of plant conditions.

Software components:

Operating System and Development Environment:

The system uses a lightweight software environment to support real-time monitoring, sensor interfacing, and wireless communication. Programming is performed using Python language with embedded libraries for handling GPIO operations and IoT communication. The software platform ensures stable operation, low power consumption, and efficient execution of monitoring tasks.

Sensor Data Processing and Control:

The software continuously collects sensor readings from the soil moisture sensor, LM35 temperature sensor, LDR sensor, and TDS sensor. These values are processed and compared with predefined threshold levels to identify abnormal environmental conditions. Based on the analysis, the controller automatically activates irrigation and alert mechanisms for efficient plant management.

IoT Communication and Cloud Integration:

Wireless communication is achieved using the built-in Wi-Fi capability of the Raspberry Pi Pico W. The software transmits real-time sensor data to the IoT cloud platform, enabling remote monitoring through mobile or web applications. Cloud integration allows continuous data updates, storage, and accessibility from any location.

User Interface and Alert Management:

The software includes display and alert functionalities to improve user interaction and system safety. Real-time sensor values and system status are shown on the LCD display for local monitoring purposes. Audible alerts are generated using the buzzer whenever critical environmental conditions such as low moisture or high temperature are detected.

RESULTS AND DISCUSSION

Experimental Setup:

The hardware prototype consisting of the Raspberry Pi Pico W microcontroller, soil moisture sensor, LM35 temperature sensor, LDR sensor, TDS sensor, relay module, and water pump was assembled and powered using a regulated supply. The microcontroller was programmed to continuously collect sensor data and transmit it to an IoT cloud platform via Wi-Fi. Threshold values were predefined for soil moisture, temperature, light intensity, and water quality. Any deviation from these values triggered automatic irrigation or alert notifications on the cloud dashboard.

The experimental results clearly demonstrate that the proposed system successfully overcomes the limitations of traditional plant monitoring methods. Unlike manual observation, the system provides continuous, real-time monitoring of plant conditions using IoT technology.

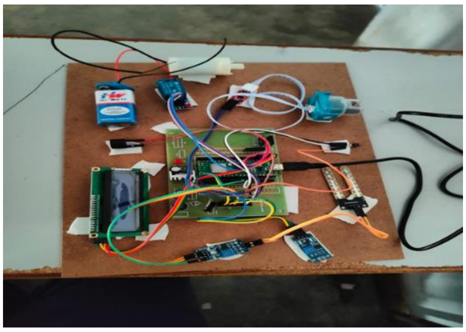

Fig 12: Project Implementation

The ability to automatically control irrigation based on soil moisture levels ensures efficient water usage and improves plant health. The integration of multiple sensors provides a comprehensive understanding of environmental conditions, enabling better decision making. The system is cost-effective, scalable, and suitable for both small-scale and large-scale agricultural applications. However, its performance depends on internet connectivity, and network limitations in rural areas may affect real-time monitoring. This limitation can be addressed in future work by integrating alternative communication technologies.

Results

Soil Moisture Monitoring Performance

The soil moisture sensor successfully measured the water content in the soil and updated data in real time.

Observation: Accur ate moisture readings were obtained continuously. The system automatically activated the water pump when moisture levels dropped below the threshold. Water supply was stopped once optimal moisture levels were reached.

This confirms that the system effectively supports automated irrigation.

Temperature Monitoring: The LM35 sensor reliably measured the surrounding temperature of the plant environment.

Observation: Temperature readings were stable and accurate. Any abnormal temperature variation was detected instantly. Data was continuously updated on the cloud platform.

This demonstrates the system's ability to monitor environmental temperature conditions effectively.

Light Intensity Monitoring

The LDR sensor successfully detected variations in light intensity.

Observation: Light levels were accurately measured under different lighting conditions. Low-light conditions were identified immediately. Data helped in understanding plant exposure to sunlight. This confirms the system's effectiveness in monitoring light conditions for plant growth.

Water Quality Monitoring

The TDS sensor measured the quality of water used for irrigation.

Observation: Water quality readings were consistent and reliable. Poor water quality conditions were detected effectively. Data helped ensure safe irrigation for plants. This shows the system's ability to maintain proper water quality for plant health.

Analysis of Cloud Dashboard Visualization

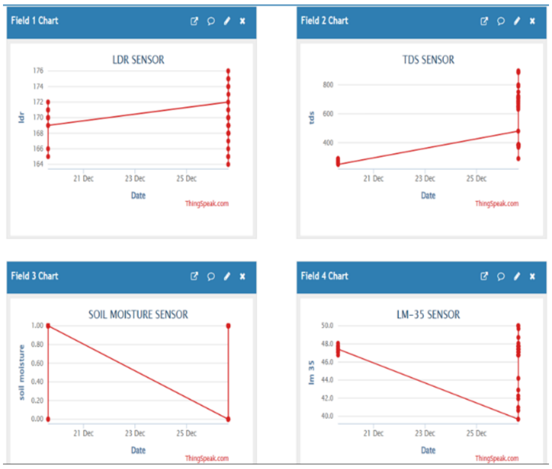

Fig 13: Cloud Dashboard

The cloud dashboard displayed real-time sensor data in a clear and user-friendly format.

Analysis: Real-time updates were displayed without delay. Remote monitoring was possible from any internet-enabled device.

CONCLUSION

The proposed IoT-based Automated Plant Health Monitoring System successfully provides real-time monitoring and intelligent control of important environmental parameters affecting plant growth. By integrating multiple sensors with the Raspberry Pi Pico W, the system ensures efficient irrigation, reduced water wastage, and improved plant health through automated decision-making. The low-cost, scalable, and energy-efficient design makes the system highly suitable for precision agriculture and smart farming applications.

FUTURE SCOPE

The system can be further enhanced by integrating advanced communication technologies such as GSM, LoRaWAN, or satellite communication for remote agricultural areas. Future improvements may also include AI and machine learning techniques for disease prediction, smart irrigation scheduling, and automated climate control. Additional sensors and image-processing technologies can further improve monitoring accuracy and support large-scale agricultural deployments.

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