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Automatic Irrigation and Weather Intelligence

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ABSTRACT

The Automatic Irrigation and Weather Intelligence System is developed to ensure efficient and automated water management for agricultural fields. The system integrates multiple sensors, including a soil moisture sensor and a rain sensor, to monitor environmental conditions that directly influence irrigation needs. A TDS sensor is included to measure soil nutrient levels, enabling farmers to understand soil quality and plan fertilizer requirements. Additionally, an IR sensor is used for theft or intrusion detection, providing security alerts for the farm area. A Raspberry Pi functions as the central controller, acquiring all sensor data and operating the irrigation pump through a relay. The system connects to an IoT cloud platform, where real-time data such as soil moisture, rainfall status, nutrient levels, weather information, and security alerts are stored and visualized. This allows users to remotely monitor field conditions and motor status from anywhere. Cloud intelligence model is used to predict short-term weather conditions such as rainfall, humidity, and temperature. These predictions help the system decide whether irrigation is required, thereby preventing unnecessary watering during rainfall or high soil moisture conditions. All sensor readings, motor status, and weather forecasts are stored in the cloud and can be viewed remotely by the user. By combining multi-sensor monitoring with IoT-based weather intelligence, the system ensures optimal water usage, enhances soil health awareness, reduces manual labour, prevents over-irrigation, and provides an additional layer of farm security. This solution supports modern precision agriculture and offers a reliable, automated approach to improve productivity and resource efficiency.

***KEYWORDS:** Raspberry PI – W, Soil Moisture Senso, TDS Sensor, Rain Sensor, IR Sensor, Relay Module, Water Pump, Battery, Cloud Intelligence, IOT (Cloud)*

INTRDOCTION

Agriculture is a critical sector that directly influences food security and economic stability, especially in developing countries. Efficient water management has become a major challenge due to climate variability, irregular rainfall patterns, and increasing demand for freshwater resources. Conventional irrigation practices are mostly manual or based on fixed scheduling methods, which do not consider dynamic soil conditions or environmental changes. As a result, these methods often lead to inefficient water usage, soil nutrient loss, and reduced crop productivity. Recent advancements in embedded systems, wireless communication, and the Internet of Things (IoT) have enabled the development of smart irrigation systems. Sensor-based irrigation systems utilize field-level sensors such as soil moisture sensors, rain sensors, and water quality sensors to monitor real-time agricultural conditions. These sensors provide continuous data about soil water content, rainfall occurrence, and dissolved solids in water. However, systems that depend only on real-time sensor data are reactive in nature and cannot anticipate future weather events.

Weather intelligence introduces a predictive dimension to irrigation automation by incorporating forecast data obtained from cloud-based weather services. Weather APIs provide short-term and long-term predictions of rainfall, temperature, humidity, and atmospheric conditions using meteorological models and satellite data. By integrating weather forecast information with real-time sensor readings, the irrigation system can make proactive decisions, such as delaying irrigation if rainfall is predicted or adjusting irrigation duration based on temperature and humidity trends. In the proposed system, the Raspberry Pi Pico W is employed as the central processing unit due to its dual-core RP2040 microcontroller, low power consumption, and integrated Wi-Fi connectivity. The Pico W interfaces with multiple sensors, processes Analog and digital signals, and communicates with cloud servers to retrieve weather forecast data.

RELATED WORK

To overcome manual dependency, timer-based automatic irrigation systems were introduced. These systems operate irrigation pumps at fixed time intervals using electromechanical timers or simple microcontrollers. Although they reduce labour effort, they fail to consider actual soil moisture, crop type, or climatic variations. As a result, irrigation may occur even when the soil is already wet or during rainfall. GSM-based irrigation systems have also been proposed for remote pump control through SMS alerts. Although GSM enables long-distance communication, it cannot directly support cloud-based APIs or weather forecasting services. Additionally, SMS-based systems incur recurring costs and provide limited data visualization and storage capabilities. Moreover, many existing systems do not store historical data for analysis and future optimization. The absence of cloud-based data logging and weather intelligence limits their ability to support long-term agricultural planning and intelligent decision-making.

LITERATURE SURVEY

The evolution of irrigation systems has significantly progressed from traditional manual methods to intelligent IoT-based solutions. Early irrigation practices relied heavily on human judgment and fixed scheduling, which often resulted in inefficient water usage and inconsistent crop yield. With the introduction of sensor-based systems, real-time monitoring of soil moisture became possible, allowing automated irrigation control based on threshold values. These systems improved water efficiency to some extent; however, they were limited by their reactive nature, as they could not anticipate future environmental conditions such as rainfall or temperature changes. Recent advancements in Internet of Things (IoT) technology have enabled the development of smart irrigation systems that integrate multiple sensors and provide remote monitoring capabilities through cloud platforms. These systems utilize embedded controllers such as Arduino, NodeMCU, and Raspberry Pi to collect and transmit real-time data. Cloud integration allows storage, visualization, and analysis of agricultural parameters, enabling farmers to make data-driven decisions. Despite these improvements, many IoT-based irrigation systems primarily focus on monitoring rather than intelligent decision-making, and they often lack the ability to incorporate predictive environmental factors into their control logic. Weather intelligence has emerged as a crucial enhancement in modern irrigation systems, enabling predictive and proactive decision-making. By integrating cloud-based weather APIs, systems can access forecast data such as rainfall probability, temperature, humidity, and atmospheric pressure. This information allows irrigation systems to adjust watering schedules dynamically, for example, delaying irrigation if rainfall is expected or increasing water supply during high-temperature conditions. Studies indicate that combining real-time sensor data with weather prediction significantly reduces water wastage and improves crop productivity, making it a key feature in precision agriculture. Although significant progress has been made in smart irrigation technologies, several challenges still exist. Many systems lack comprehensive multi-sensor integration, particularly in areas such as water quality monitoring using TDS sensors and security features like intrusion detection. Additionally, issues related to scalability, power consumption, and system reliability in rural environments remain critical. Therefore, there is a clear need for a robust, low-cost, and intelligent irrigation system that integrates multi-sensor monitoring, weather intelligence, cloud connectivity, and automated control. The proposed system addresses these gaps by providing a holistic solution for efficient and sustainable agricultural water management.

EXISTING METHOD

Traditional irrigation methods such as flood irrigation and manual pump control are widely used in rural areas. These methods depend on human judgment and fixed schedules, which often lead to excessive water usage and uneven irrigation. They also require continuous human supervision, increasing labour cost and effort. Timer-based automatic irrigation systems were introduced to overcome manual control limitations. These systems activate water pumps at predefined intervals regardless of soil condition or weather changes. Although they reduce manual effort, they still lack adaptability and frequently result in over-irrigation or under-irrigation. Sensor-based irrigation systems improved efficiency by using soil moisture sensors to control irrigation pumps automatically. When soil moisture drops below a threshold, the pump is activated. However, these systems operate only on local sensor data and do not consider external factors such as rainfall prediction or atmospheric conditions. Some IoT-based systems using Arduino or Node MCU platforms enable remote monitoring through mobile applications. While these systems provide better visibility and control, they often lack multi-sensor integration, water quality monitoring, and security features. Additionally, limited processing capability and scalability restrict their performance in complex applications.

To overcome manual dependency, timer-based automatic irrigation systems were introduced. These systems operate irrigation pumps at fixed time intervals using electromechanical timers or simple microcontrollers. Although they reduce labour effort, they fail to consider actual soil moisture, crop type, or climatic variations. As a result, irrigation may occur even when the soil is already wet or during rainfall. GSM-based irrigation systems have also been proposed for remote pump control through SMS alerts. Although GSM enables long-distance communication, it cannot directly support cloud-based APIs or weather forecasting services. Additionally, SMS-based systems incur recurring costs and provide limited data visualization and storage capabilities. Moreover, many existing systems do not store historical data for analysis and future optimization. The absence of cloud-based data logging and weather intelligence limits their ability to support long-term agricultural planning and intelligent decision-making.

PROPOSED METHOD

The proposed system is an Automatic Irrigation and Weather Intelligence System designed using Raspberry Pi Pico Was the core embedded controller. The system integrates multiple sensors such as soil moisture sensor, rain sensor, TDS sensor, and IR sensor to collect real-time data from the agricultural field.

Soil moisture and rain sensors are used to determine irrigation requirements, while the TDS sensor monitors water quality to ensure suitability for crops. The IR sensor provides an additional security feature by detecting unauthorized movement or theft near the irrigation setup. Based on sensor inputs, the controller automatically operates the water pump through a relay module. The built-in Wi-Fi capability of Raspberry Pi Pico W enables the system to connect to cloud platforms. Weather forecast data such as temperature, humidity, and rainfall prediction is obtained from cloud-based weather services. This weather intelligence is combined with sensor data to make predictive irrigation decisions. The system stores sensor readings and weather data in the cloud for monitoring and analysis. Farmers can access this data remotely, helping them understand field conditions and irrigation patterns. This data-driven approach improves transparency and supports better crop management strategies. The literature also highlights that most existing systems do not store historical data or support long-term analysis. Without cloud-based data storage and predictive models, farmers cannot analyse trends, optimize irrigation schedules, or plan resource usage efficiently. The absence of integrated weather forecasting further restricts the system's ability to make proactive irrigation decisions.

Overall, the proposed system offers a low-cost, energy-efficient, and scalable solution for smart irrigation. It enhances water conservation, improves crop yield, and provides a reliable platform for future expansion such as machine learning–based decision models. Limited due to their dependence on only local sensor data. They do not consider important external factors such as rainfall prediction, temperature variation, and atmospheric humidity. As a result, irrigation decisions are reactive and may still lead to unnecessary watering during

ARCHITECTURE

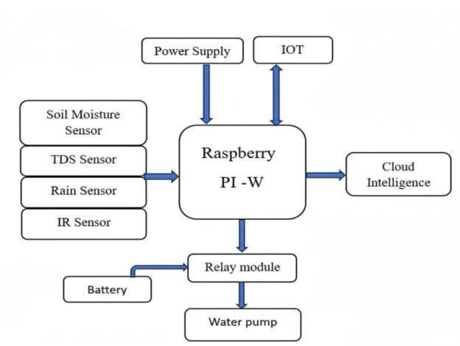

Figure 1: proposed method architecture

METHODOLOGY DESCRIPTION

The proposed Automatic Irrigation and Weather Intelligence System follows a structured approach that integrates real-time data acquisition with predictive analysis for efficient irrigation management. Initially, multiple sensors such as soil moisture, rain, TDS, and IR sensors are deployed in the agricultural field to continuously monitor environmental and security conditions. The soil moisture sensor measures the water content in the soil, while the rain sensor detects precipitation. The TDS sensor evaluates water quality by measuring dissolved solids, and the IR sensor provides intrusion detection. All sensor outputs, both analog and digital, are interfaced with the Raspberry Pi Pico W, which acts as the central processing unit. The collected data undergoes preprocessing, including filtering and calibration, to ensure accuracy and reliability in outdoor conditions.

The processed sensor data is then combined with weather forecast information obtained from cloud-based APIs, which provide parameters such as rainfall probability, temperature, and humidity. Based on this integrated data, a decision-making algorithm determines whether irrigation is required. If soil moisture is below the threshold and no rainfall is predicted, the system activates the water pump through a relay module; otherwise, irrigation is postponed to prevent water wastage. Simultaneously, all sensor readings and system status are transmitted to a cloud platform for real-time monitoring and analysis. This methodology ensures a proactive and intelligent irrigation process, reducing manual intervention, conserving water resources.

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SOFTWARE AND HARDWARE REQUIREMENTS

Raspberry pi pico w

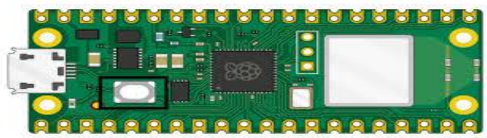

Figure 2.1: -Raspberry pi pico w

Raspberry Pi Pico W is the main controller of the system, responsible for collecting data from all connected sensors and processing it. It features built-in Wi-Fi, which allows communication with cloud platforms like ThingSpeak for data storage and analysis. The Pico W controls the overall operation of the system, including sending signals to the relay module for automatic irrigation control.

Rain Sensor

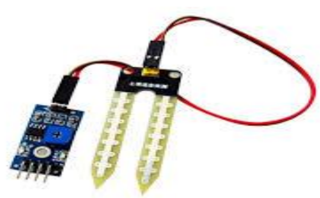

Figure 2.2: soil moisture sensor

The soil moisture sensor is used to measure the water content present in the soil. It provides real-time data that helps in determining whether irrigation is required or not. The sensor outputs analog signals based on moisture levels, which are read by the Pico W through ADC pins for accurate monitoring.

Rain sensor:

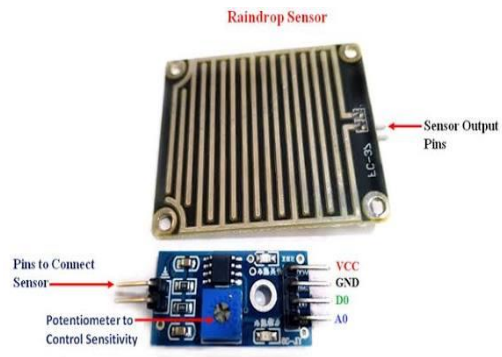

Figure 2.3: Rain sensor

The rain sensor detects the presence of rainfall in the environment. It helps in preventing unnecessary irrigation when natural rainfall is sufficient. The sensor sends a signal to the controller when rain is detected, allowing the system to make intelligent decisions regarding water usage.

TDS sensor

Figure 2.4: TDS Sensor

The Total Dissolved Solids (TDS) sensor is used to measure the concentration of dissolved substances in water or soil. This helps in analyzing the nutrient level and quality of the soil. The data from the TDS sensor assists in maintaining proper soil conditions for better crop growth.

IR Sensor

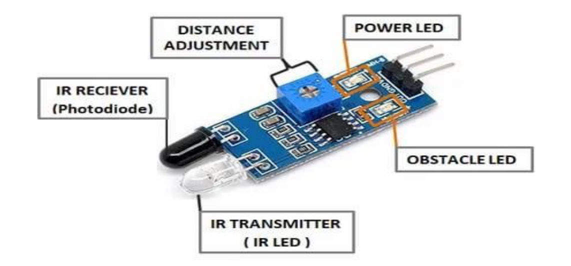

Figure 2.5: IR Sensor

The Infrared (IR) sensor is used for detecting objects or movement in the field. It can be used for basic security purposes or to detect intrusion. The sensor sends signals to the Pico W when an object is detected, enabling the system to respond accordingly.

Relay Module

The relay module acts as an electronic switch that controls high-power devices like the water pump.

Figure 2.6: Relay Module

It receives control signals from the Pico W and turns the pump ON or OFF accordingly. This allows safe and efficient automation of irrigation without direct human intervention.

Water pump

Figure 2.7: Water Pump

The water pump is responsible for supplying water to the agricultural field. It operates based on the signals received through the relay module.

Power Supply:

Figure 2.8: Power Supply

The battery is used as a power source to supply energy to the entire system, including the Raspberry Pi Pico W, sensors, and relay module. It ensures continuous operation of the system, especially in areas where a stable power supply is not available.

Arduino IDE

Figure 2.2.1: Arduino IDE

Arduino IDE is used as the development environment for writing, compiling, and uploading code to the Raspberry Pi Pico W. It provides an easy-to-use interface for programming in Embedded C/C++ and supports various libraries required for sensor interfacing and Wi-Fi communication. The IDE helps in debugging and testing the system to ensure proper functionality.

Weather API

Figure 2.2.2: Arduino IDE

The Weather API is used to fetch real-time weather data such as temperature, humidity, and rainfall conditions from online sources. This data is integrated into the system to improve decision-making for irrigation. By using API keys, the system can access accurate and up-to-date weather information for better analysis.

ThingSpeak

Figure 2.2.3: ThingSpeak

ThingSpeak is a cloud-based IoT platform used for storing, analyzing, and visualizing sensor data. It allows the system to upload real-time data from the Pico W and perform analysis using MATLAB-based tools such as moving average prediction. ThingSpeak also enables remote monitoring and control of the irrigation system through cloud connectivity.

RESULTS AND DISCUSSION

The proposed system was successfully implemented and tested using the Raspberry Pi Pico W integrated with multiple sensors, including soil moisture and rain sensors. The system demonstrated reliable acquisition of real-time environmental data, which was transmitted to the ThingSpeak cloud platform via Wi-Fi communication. The sensor outputs were consistently stable, and the cloud platform enabled efficient data ThingSpeak also enables remote monitoring and control of the irrigation system through cloud connectivity.

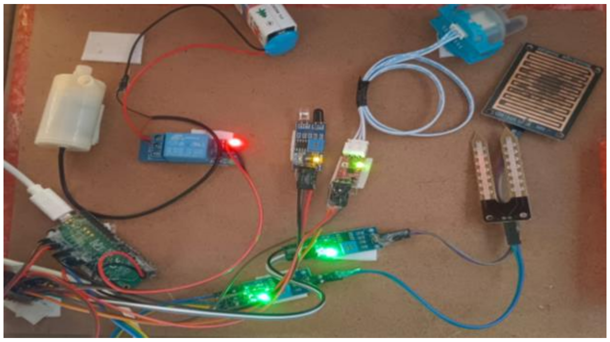

Figure 3.1: Hardware Output

Figure 3.2: - Output Page

The cloud-based analysis was performed using a moving average algorithm applied to recent sensor and weather API data, enabling short-term prediction of environmental parameters. Based on the analyzed data, control signals were generated to operate the relay module for automated water pump control. The system effectively minimized water wastage by avoiding redundant irrigation during rainfall conditions and low moisture thresholds. Experimental results indicate improved irrigation efficiency, reduced human intervention, and enhanced system reliability for smart agriculture applications.

CONCLSUION

The proposed Automatic Irrigation and Weather Intelligence System was successfully designed and implemented using the Raspberry Pi Pico W as the central controller. The system effectively integrates multiple sensors, including soil moisture and rain sensors, to continuously monitor environmental and soil conditions. The collected data is transmitted to the ThingSpeak cloud platform through Wi-Fi, enabling real-time monitoring, storage, and visualization of field parameters. This integration of hardware and cloud technologies ensures a reliable and efficient system for smart agricultural applications. The implementation of cloud-based analysis using a moving average method, along with real-time weather data obtained through a Weather API, enhances the decision-making capability of the system. Based on the analyzed data, the system automatically controls the irrigation process by activating or deactivating the water pump through a relay module. This approach reduces unnecessary water usage and ensures that irrigation is performed only when required. The system demonstrates significant improvements in water management, operational efficiency, and reduction of manual intervention.

FUTURE ENHANCEMENT

The proposed system can be further enhanced by integrating advanced user interfaces such as a dedicated mobile or web application for real-time monitoring and control. This would enable farmers to receive instant alerts, view live sensor data, and manually override irrigation operations when required.

Additionally, the system can be extended by incorporating a wider range of sensors, such as temperature, humidity, and pH sensors, to provide a more comprehensive analysis of environmental and soil conditions. These enhancements would improve the accuracy and adaptability of the system across different agricultural scenarios.

Further improvements can be achieved by expanding the system for large-scale agricultural deployments with multi-field monitoring capabilities. Integration of renewable energy sources such as solar panels can make the system more energy-efficient and suitable for remote locations with limited power supply. Advanced data analytics techniques can also be incorporated to improve prediction accuracy and optimize irrigation scheduling. These enhancements would increase the scalability, reliability, and overall performance of the system, making it a more robust solution for smart and sustainable agriculture.

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