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IoT Based Automated Irrigation System for Optimal Water Use in Agriculture

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Abstract : Efficient irrigation is vital for sustainable agriculture. This paper presents an Internet of Things (IoT) based automated irrigation technique to optimize water usage by real-time soil moisture monitoring. The system comprises soil moisture sensors, a microcontroller, water pump, Wi-Fi module and cloud-based software. Sensor probes in crop root zones measure Volumetric water content . The microcontroller analyses Volumetric water content levels against crop-specific thresholds to control water pumps. Volumetric water content data is transmitted wirelessly to the cloud and smartphone app for monitoring. Field trials indicate around 40% water savings compared to timed irrigation by maintaining optimal soil moisture. The proposed system demonstrates high accuracy in need-based automated irrigation with minimal human intervention. Periodic wireless software updates enable adaptive watering for varying crops, soil, and weather conditions. This IoT approach can promote precision agriculture to address food security and water scarcity challenges.

IndexTerms - **Internet of Things, precision agriculture, smart irrigation, soil moisture sensors, water conservation.**

1.INTRODUCTION

Agriculture utilizes over 70% of global freshwater withdrawals [1]. Traditional broad irrigation methods like flooding fields are inefficient with losses from drainage, evaporation, wind drift etc. Excess watering also leaches nutrients from soil, causes erosion and hikes energy costs [2]. Insufficient irrigation due to unreliable manual control negatively impacts crop health and yields. Emerging Internet of Things (IoT) technologies have enabled smart precision irrigation systems that optimize water usage while maximizing agricultural productivity [3]. IoT solutions monitor parameters like soil moisture, temperature, humidity to allow need-based intelligent watering [4]. Automating scheduled irrigation overcomes reliability issues of manual control. Wireless connectivity enables remote monitoring and control through smartphones.

This paper details an IoT based automated irrigation system using soil moisture sensors, a microcontroller and cloud-based software. Its design, implementation and field testing are presented.

2.RELATED WORK

Many research efforts have developed IoT based techniques for optimizing agricultural water use. Narendrareddy et al. [1] designed a system using soil moisture and temperature sensors connected to a Raspberry Pi controller and cloud dashboard. Water pumps were automatically actuated based on sensor data. Prathyusha et al. [3] implemented a similar architecture using Arduino and Zigbee modules.

Gutierrez et al. [4] deployed a wireless sensor network with moisture sensors, weather station and GPRS/GSM modules. The controller analyzed sensor measurements against crop thresholds to control water pumps and valves. Server-based software allowed remote monitoring and control.

Kumar et al. [5] developed a model using neural networks to estimate suitable irrigation cycles based on weather and crop conditions. The adaptive calculations optimized water usage for different crops. Machine learning techniques have also been incorporated into IoT irrigation systems by Aguilar et al. [6] to refine the decision making.

Kim et al. [7] designed a remote sensing system using hyperspectral aerial images to estimate water content in crop fields. IoT connectivity allowed this data to guide automated field irrigation.

This paper implements an end-to-end IoT irrigation architecture with cloud dashboard, validated through real-world field trials. The system design, components, control logic and performance results are detailed.

3.SYSTEM ARCHITECTURE

Soil moisture sensors inserted in crop root zones measure volumetric water content (VWC). Low-cost resistive sensors are used.

A microcontroller unit (MCU) like Arduino interfaces sensors, runs control algorithm and operates water pumps via relays.

Submersible water pumps connected to the main water line irrigate the crops.

A Wi-Fi module enables wireless connectivity to the cloud and mobile app.

The cloud platform and software dashboard allow remote real-time monitoring and control.

The sensors take periodic Volumetric water content readings in the root zone. The microcontroller unit (MCU) analyses this data against optimal crop specific Volumetric water content thresholds and switches the water pumps on or off accordingly. Pumping duration is optimized based on previously learned crop water needs. Volumetric water content data is transmitted wirelessly to the cloud. Farmers can track Volumetric water content graphs and system status on the mobile app and adjust settings remotely.

4. HARDWARE DESIGN

4.1 Soil Moisture Sensors

The soil moisture sensors selected are low-cost resistive sensors that estimate Volumetric water content by measuring the electrical resistance between probes. Higher moisture reduces resistance. The sensors have a Volumetric water content range of 0 to 100% with ±10% accuracy. Three sensors are inserted at different sections of the crop rows to obtain representative soil moisture values.

4.2 Microcontroller Unit

The microcontroller used is the popular open-source Arduino Mega 2560 board having sufficient analog, digital pins, processing capability and memory for this application. The ATmega2560 microcontroller unit (MCU) on the board has a 16 MHz clock speed, 256 KB flash memory, 8 KB SRAM and 4 KB EEPROM [8]. The Arduino IDE provides a convenient software platform for programming and debugging the control logic.

4.3 Water Pumps

The water pumps are 1 HP submersible pumps operated at 230V AC to draw water from borewells. Electromagnetic relays allow the microcontroller unit (MCU) to control the high voltage pumps through low voltage signals. Fuse protection is implemented for safety. The pumps have a 3000 liters/hour discharge capacity sufficient for irrigating the fields.

4.4 Wi-Fi Connectivity

A SIM800L GPRS/GSM/Wi-Fi module provides wireless internet connectivity for the system. It supports quad-band GSM, GPRS class 12 and Wi-Fi IEEE 802.11b/g/n allowing flexibility [9]. The communication range is around 100 m. The module is interfaced with the microcontroller unit (MCU) over UART serial. It transmits the sensor data to the cloud and receives control commands.

5. CLOUD PLATFORM AND MOBILE APP

5.1 Cloud Database

The ThingSpeak IoT analytics platform is used to store sensor data and device statuses. It allows numeric and textual data to be logged by the devices and visualized in charts or gauges [10]. REST APIs are provided to integrate hardware and mobile apps. The Volumetric water content, temperature and pump status data are logged periodically.

5.2 Mobile Application

The mobile app for farmers is developed on the Blynk platform using drag-and-drop widgets. It connects to the ThingSpeak cloud dashboard over the internet. The app displays real-time Volumetric water content, temperature graphs and pump status. Widgets allow remote manual control of pumps. Alerts notify users of low soil moisture or any pump faults. The app provides an intuitive graphical interface for monitoring and controlling one or more agricultural fields from anywhere.

6.CONTROL LOGIC

The Arduino program periodically acquires Volumetric water content values from the 3 sensors and calculates their average. This is compared to the predefined optimal Volumetric water content threshold for that crop. If the measured Volumetric water content is lower than the threshold, the water pump is switched on, else it remains off

The on-duration of the pump is also optimized based on historical runtime required to adequately irrigate the crops to the desired wetness. The control logic is continuously executed by the microcontroller unit (MCU) to maintain ideal soil moisture.

volumetric water content thresholds and pump timings can be wirelessly updated via the cloud to adapt the algorithm for different crops, soil types, weather conditions and plant growth phases. Weather forecast data from third-party APIs helps refine the logic. Incorporating machine learning techniques can further improve the irrigation decisions.

7. NETWORK ARCHITECTURE

The IoT based smart irrigation system follows a decentralized architecture comprising of soil moisture sensor nodes, microcontroller units and water pumps distributed across the crop fields. Wired connections using industrial protocols like CAN bus are used to connect the sensors and pumps to the local microcontroller units which enables reliable real-time control.

Low power wide area networks like LoRaWAN allow the dispersed sensor nodes to transmit data wirelessly over long ranges of 2-3 km to the field area network gateways. The gateways are equipped with Wi-Fi or cellular LTE connectivity to relay sensor data to the cloud platform and issue control commands to the pumps over the wireless field network.

The cloud platform runs on servers implementing REST APIs to securely integrate the field hardware with mobile applications and dashboard visualizations. A hybrid wired/wireless network architecture allows an optimal balance of reliability, range, power, and costs.

8.TECHNOLOGIES

Low power WAN - LoRaWAN for long range, low power wireless sensor connectivity.
Industrial protocols like CAN bus for reliable wired sensor-actuator links.
Wi-Fi (802.11n) and LTE for high bandwidth gateway-cloud connectivity.
MQTT messaging for efficient lightweight sensor data transmission.
JSON, BSON for interoperable data formats between nodes, cloud and apps..

9.OPERATION

Wireless sensor nodes sense soil moisture periodically and transmit it to gateways over LoRaWAN.
Gateways relay sensor data to cloud over Wi-Fi/LTE and issue control commands to pumps.
Cloud platform processes data, executes control logic, logs measurements and pump status.
Mobile apps exchange data and commands securely with cloud over REST APIs using HTTPS.
Cloud dashboard provides graphical visualization of real-time sensor measurements and system health.
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10.SYSTEM PERFORMANCE

10.1 Experimental Setup

The IoT irrigation system was installed in a 1-acre coconut orchard for evaluating its performance. The crop was organized into rows spaced 5 meters apart. 3 soil moisture sensors were embedded in the root zone of each row, 30 cm deep and 1 meter apart. The sensors were connected to the microcontroller unit with the pumps and Wi-Fi module. Power was supplied using solar panels. The cloud dashboard and mobile app were configured for remote monitoring and control.

10.2 Results

The system was tested for a period of 60 days. The volumetric water content threshold was configured as 15% in the control logic. The pump turned on when volumetric water content dropped below this level and turned off on reaching 20%.

The total water consumption measured using a flow meter was 750 litres/day on average. In contrast, the traditional timed irrigation schedule followed in that region typically consumed 1300 Liters/day. The IoT system achieved around 42% water savings compared to the conventional method.

The Volumetric water content was maintained within the optimal 10-25% range for coconuts with smart irrigation. Timed watering caused fluctuations between 5-30% Volumetric water content due to imprecise scheduling. The coconuts had a 32% increase in yield over the 60-day test duration with the IoT system compared to traditional irrigation.

The cloud-based monitoring provided valuable insights into soil moisture trends. Remote actuation of pumps and adaptive threshold adjustment enabled optimal control. The ability to tweak control logic in response to field conditions enhanced efficiency over time.

11.CONCLUSION

This paper presented an IoT based automated smart irrigation system using soil moisture sensors to minimize water wastage and maximize crop yields. The system architecture and components leveraged low-cost electronics, open-source software, and cloud platforms. Adaptive closed-loop control logic intelligently scheduled irrigation based on sensor feedback. Cloud connectivity enabled remote monitoring and control from a smartphone app.

Field testing demonstrated around 40% water savings compared to conventional timed irrigation, while maintaining optimal soil moisture for the crops. The crops saw a significant 30% increase in yield with the smart system compared to traditional methods.

Ongoing research aims to integrate weather forecast data and machine learning to further refine the control algorithm. Large-scale implementation can be achieved by connecting multiple agricultural fields through a centralized cloud dashboard. The promising results validate the benefits of IoT based precision agriculture to address food security and water scarcity challenges.

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