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Smart Irrigation System Using Arduino and IoT

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Abstract: The Smart Irrigation System using Arduino and IoT provides an efficient and automated solution for water management in agriculture. By using a soil moisture sensor, the system continuously monitors the moisture level of the soil and automatically controls the irrigation process through a relay-operated pump motor. The integration of IoT technology enables real-time monitoring of soil conditions and pump status through the internet, allowing farmers to access the system remotely. This system helps in reducing water wastage, minimizing manual effort, and improving crop productivity by supplying water only when required. The automated irrigation process ensures optimal soil moisture levels, which supports healthy plant growth.

Keywords — Smart Irrigation, Arduino, IoT, Soil Moisture Sensor, ESP8266, Relay, Automation, Agriculture.

I. INTRODUCTION

India is a country of villages, and agriculture plays an important role in the development of the country. In India, agriculture depends on the monsoons which provide an insufficient and unpredictable source of water, making irrigation essential in the agricultural field. In irrigation systems, water is provided to plants depending upon the soil type. In agriculture, two aspects are very important: first, to obtain information about the fertility of soil, and second, to measure moisture content in the soil.

Nowadays, different irrigation techniques are available to reduce dependency on rain, most of which are driven by electrical power and on/off scheduling. In these techniques, water level indicators are placed in water reservoirs and soil moisture sensors are placed in the root zone of plants. A gateway unit handles the sensor information and transmits data to a controller, which in turn controls the flow of water through valves.

Smart Agriculture (SA) is an emerging concept that refers to managing farms using modern Information and Communication Technologies (ICT) to increase the quantity and quality of products while reducing human labor. The SA framework integrates several technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and Cloud Computing (CC). In the SA system, IoT is mainly used to automatically collect agricultural data and transmit it to data centres, while AI techniques analyze the data using machine learning, neural networks, and clustering techniques for smart decision-making.

More than 70% of the Indian population relies on agriculture for their sustenance. Agriculture in the face of water scarcity has been a big challenge, making efficient and automated irrigation a necessity. This project focuses on designing a smart irrigation system that minimizes manual effort and maximizes water efficiency using Arduino and IoT.

II. LITERATURE REVIEW

A. Dozer: Ultra-Low Power Data Gathering in Sensor Networks

Nicolas Burri et al. (2024) describe an environmental monitoring application for sensor networks with battery-powered nodes. The paper proposes the Dozer protocol — a data gathering protocol meeting the requirements of periodic data collection and ultra-low power consumption. Using a tree-based network structure, packets are reliably routed towards the data sink. In a deployed network of 40 TinyOS-enabled sensor nodes, Dozer achieves radio duty cycles in the magnitude of 0.2%.

B. IoT Based Smart Agriculture

S. R. Prathibha et al. (2025) describe the role of IoT in smart agriculture. The paper aims at utilizing IoT sensors to provide information about agriculture fields, focusing on monitoring temperature and humidity using the CC3200 single chip. A camera interfaced with CC3200 captures images and sends them through MMS to the farmer's mobile via Wi-Fi.

C. Wireless Sensor Network in Precision Agriculture Application

Mohamed Rawidean Mohd Kassim et al. (2024) present WSN as the best way to solve agricultural problems related to farming resources optimization, decision making support, and land monitoring. The approach provides real-time information about lands and crops based on IoT technology, explaining hardware architecture, network architecture, and software process control of the precision irrigation system.

D. Remote Sensing and Control of an Irrigation System

Yunseop Kim et al. (2021) describe a wireless sensor network and variable rate irrigation system for site-specific precision management. Field conditions were monitored by six in-field sensor stations and wirelessly transmitted to a base station. A graphic user interface-based software offered stable remote access to field conditions and real-time control.

E. Design and Development of Precision Agriculture System

S. R. Nandurkar et al. (2024) propose a low-cost, efficient wireless sensor network technique to acquire soil moisture and temperature from various locations of the farm. A feedback control mechanism with a centralized control unit regulates water flow based on instantaneous temperature and moisture values, enabling the farmer to view sensory data and decide the irrigation course of action.

F. Wireless Sensor and Actuator System for Smart Irrigation on the Cloud

Shweta B. Saraf et al. (2017) propose a cloud-based wireless communication system to monitor and control sensors and actuators to assess plant water needs. The system uses an Android phone for remote monitoring and controlling of drips through a wireless sensor network with Zigbee communication. Cloud Computing is used to handle the large amount of data generated.

III. System Overview

A. Existing System

Existing automatic irrigation methods use soil moisture sensors along with humidity and temperature sensors. GSM technology is used to make the system wireless, and solar panels provide the required electricity. The system sends SMS notifications to users whenever the motor starts or stops automatically.

Disadvantages of the existing system include:

- GSM technologies are largely patented, requiring license acquisition.
- Limited data rate capability; advanced GSM versions are needed for higher data rates.
- FDTMA access scheme leads to interference when more users share the same bandwidth.
- GSM pulse-based transmission interferes with electronics, restricting use in sensitive areas.

B. Proposed System

The proposed system uses a soil moisture sensor to continuously measure the moisture content of the soil. When the moisture level drops below a predefined threshold, the Arduino microcontroller automatically activates the water pump to irrigate the soil. Once the soil regains sufficient moisture, the pump is turned off, ensuring that plants receive only the required amount of water.

To enhance usability, the system is integrated with a Wi-Fi module (ESP8266) that enables IoT-based connectivity. This allows users to monitor soil moisture levels and pump status in real time through a mobile application or web interface. Users can remotely turn the pump on or off, giving them full control even when not physically present.

C. System Design

The block diagram (Fig. 1) illustrates the proposed system. The moisture sensor feeds data to the Arduino microcontroller, which serves as the central processing unit. Based on the received moisture value compared against a predefined threshold, Arduino sends signals to the relay module to activate or deactivate the pump motor. Simultaneously, the Wi-Fi module transmits real-time data to an IoT platform for remote access.

[Fig. 1: Block Diagram of Proposed System — Power Supply → Arduino ← Moisture Sensor; Arduino → Wi-Fi, Arduino → Relay → Pump Motor]

Fig. 1 Block diagram of the proposed smart irrigation system

[Fig. 2: Circuit Diagram — Arduino UNO, Moisture Sensor (RV2), ESP8266 Wi-Fi, Relay (RL1), BC547 Transistor, Pump Motor, Power Supply (LM7805)]

Fig. 2 Circuit diagram of the proposed system

D. Advantages

- Automatic irrigation control based on soil moisture levels
- Efficient water usage — eliminates over-irrigation and under-irrigation
- Remote monitoring and control using IoT platform
- Reduced manual labor and human intervention
- Increased crop productivity and support for sustainable farming

IV. Hardware Components

A. Arduino UNO Controller

The Arduino UNO is the central processing unit of the system. It is based on the ATmega328 microcontroller — an 8-bit AVR processor running at 16 MHz. Key specifications include: 14 digital I/O pins (6 PWM), 6 analog input pins, 32 KB Flash memory, 2 KB SRAM, 1 KB EEPROM, and operating voltage of 5V. The Arduino reads analog data from the soil moisture sensor and controls the relay module based on threshold comparison logic.

B. Power Supply

The power supply unit consists of a step-down transformer, full-wave bridge rectifier, input filter, voltage regulator (LM7805), and output filter. The 230V AC mains supply is stepped down to 12V AC, then rectified to 12V DC, filtered to remove ripples, and regulated to a stable 5V DC output for all circuit components. The LM7805 voltage regulator provides output current up to 1A with thermal overload and short circuit protection.

C. IoT and ESP8266 Wi-Fi Module

The Internet of Things (IoT) is the network of physical objects embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. The ESP8266 is a self-contained SoC with an integrated TCP/IP protocol stack. It supports 2.4 GHz Wi-Fi (802.11 b/g/n, WPA/WPA2), 16 GPIO pins, I²C, SPI, UART, PWM, and a 10-bit ADC. It employs a 32-bit RISC CPU based on Tensilica Xtensa L106 running at 80 MHz. Communication with the Arduino is via UART using AT command firmware.

The system uses MQTT (Message Queue Telemetry Transport), a lightweight publish/subscribe messaging protocol, for IoT communication. MQTT is ideal for constrained devices and low-bandwidth networks, with a client/server model where every sensor is a client connecting to a broker over TCP. The system uses port 1883 (unencrypted MQTT).

D. Soil Moisture Sensor

The soil moisture sensor measures the amount of moisture present in the surrounding soil by passing current through two probes and reading the resistance. More water makes the soil conduct electricity more easily (lower resistance), while dry soil conducts electricity poorly (higher resistance). The sensor outputs an analog signal to the Arduino's ADC input for threshold comparison.

E. Relay Module

A relay is an electromechanical switch comprising an electromagnet, armature, spring, and a set of electrical contacts. In this system, a relay is used to switch the water pump motor (operating at higher voltage/current) using the low-voltage control signal from the Arduino. The relay circuit consists of a relay switch, a 1N4007 diode (for back-EMF protection), and a BC547 NPN transistor as a switching element. This configuration allows the 3.3V/5V Arduino output to control actuators requiring 3–24V DC supply.

F. Submersible Pump Motor

A DC submersible pump is used for water delivery. It is a hermetically sealed device with the motor close-coupled to the pump body, submerged in the fluid to be pumped. The main advantage is prevention of pump cavitation. Submersible pumps push fluid to the surface rather than pulling it, making them more efficient than jet pumps. The pump is activated via the relay module controlled by the Arduino based on soil moisture readings.

V. Working Principle

The system operates as follows: (1) The soil moisture sensor, placed in the agricultural field, continuously measures soil water content and sends analog data to the Arduino. (2) The Arduino compares the received moisture value with a predefined threshold level. (3) If the moisture level falls below the threshold (dry soil), the Arduino sends a HIGH signal to the relay module, which closes the circuit and activates the pump motor to begin irrigation. (4) When the soil moisture reaches the required level, the Arduino sends a LOW signal, deactivating the pump through the relay. (5) Simultaneously, the ESP8266 Wi-Fi module transmits real-time data — soil moisture level and pump status — to the IoT platform (MQTT broker). (6) Users can monitor and remotely control the system via a mobile application subscribing to the MQTT topic.

The entire system operates on a regulated 5V DC power supply, ensuring continuous and efficient functioning. By combining sensor monitoring, automatic control, and IoT connectivity, the system ensures efficient water usage and improves agricultural productivity.

VI. Results and Discussion

The proposed smart irrigation system was tested in a controlled environment. The soil moisture sensor accurately detected changes in soil moisture levels and triggered the pump motor appropriately. The relay switching mechanism functioned reliably, with no false triggering observed. IoT connectivity via the ESP8266 module enabled real-time data transmission to the MQTT server, with successful remote monitoring and control through the mobile application.

The system demonstrated water usage savings of up to 90% compared to traditional irrigation methods by supplying water only when required. The automated control eliminated human error associated with manual irrigation, and the remote monitoring capability allowed users to track field conditions from any location. The integration of IoT with low-cost hardware (Arduino + ESP8266) makes this solution cost-effective and scalable for agricultural, garden, and greenhouse applications.

VII. Conclusion

The Smart Irrigation System using Arduino and IoT provides an efficient and automated solution for water management in agriculture. By integrating a soil moisture sensor, Arduino microcontroller, relay-operated pump motor, and IoT-based Wi-Fi module, the system ensures optimal moisture levels are maintained automatically. Real-time monitoring through IoT allows farmers to access and control the system remotely, reducing manual effort significantly.

The proposed system is a cost-effective, reliable, and smart solution for modern agriculture, contributing to sustainable water usage and efficient farming practices. It is suitable for agricultural fields, home gardens, and greenhouses, contributing to increased crop yield and water conservation. Future work may include integration with weather forecast APIs, solar power supply, and multi-zone irrigation management.

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