

Embedded-Based Intelligent Robot for Irrigation System

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ABSTRACT

Agriculture faces increasing challenges due to water scarcity, labor shortages, unpredictable climatic conditions, and the need for efficient resource utilization. This paper presents an Embedded-Based Intelligent Robot for Irrigation System designed to automate essential agricultural operations such as soil digging, seed sowing, soil leveling, irrigation, and environmental monitoring. The proposed system employs a W78E052DDG microcontroller as the central processing unit, along with soil-moisture, temperature, and humidity sensors, DC motors, relay drivers, an obstacle detector, and a Wi-Fi/Bluetooth communication module. The soil-moisture sensor continuously monitors soil conditions, and the controller activates the water pump according to predefined moisture requirements. Wireless connectivity enables remote monitoring and control through a mobile device. The robot also incorporates obstacle detection to improve navigation and operational safety. The proposed approach reduces manual intervention, improves water utilization, and supports sustainable agricultural practices. The project demonstrates the potential of embedded and IoT technologies for developing affordable and multifunctional smart farming systems.

Keywords— Smart agriculture, intelligent irrigation, embedded system, agricultural robot, soil moisture, IoT, Bluetooth, W78E052DDG, automation.

INTRODUCTION

Agriculture is one of the major sectors supporting human society, but conventional farming practices continue to depend considerably on manual labor and traditional irrigation methods. Water scarcity, labor shortages, unpredictable weather, and inefficient utilization of agricultural resources create significant challenges for farmers. The project source identifies the need for an intelligent agricultural system capable of performing essential field operations while reducing human effort and improving resource utilization.

The proposed Embedded-Based Intelligent Robot for Irrigation System combines embedded control, sensing, wireless communication, and mechanical actuation to perform multiple agricultural activities. The robot is designed to dig soil, sow seeds, level the soil, and spray water, while operating from a battery-powered system. Its sensing arrangement enables monitoring of soil moisture, temperature, and humidity, allowing irrigation operations to be performed according to the observed field conditions.

The system further incorporates Wi-Fi/Bluetooth connectivity for remote monitoring and control. A farmer can operate and monitor the robot using a mobile device, reducing the requirement for continuous physical presence in the field. Obstacle detection is included to assist navigation and prevent collisions, while relay-controlled devices operate the water pump and other outputs according to commands from the microcontroller.

The objective is therefore to develop a multifunctional agricultural robot that can automate digging, seed planting, irrigation, and soil monitoring while addressing water scarcity and labor-related problems. By combining sensors, a microcontroller, motors, relays, and wireless communication, the system provides a practical approach toward smart and sustainable agricultural automation.

Literature Survey

Bhaskar Krishna et al. [1] presented the implementation of a smart irrigation system using real-time embedded system technology, where soil-moisture and temperature sensors are used with a microcontroller to automate irrigation according to field conditions. The system improves water management and reduces unnecessary irrigation, although its flexibility for integration with existing irrigation infrastructure may be limited. Nikita Malik and Rahul Mittal [2] proposed an IoT- and machine-learning-enabled smart irrigation system to automate crop irrigation, reduce water wastage, and improve adaptability to local climatic conditions. However, the use of machine-learning techniques may increase processing requirements and implementation costs, particularly for large-scale agricultural applications.

M. Krishna et al. [3] developed a smart irrigation system using Raspberry Pi that monitors soil moisture, fire conditions, and water levels and provides alerts to farmers through mobile and email communication. Although the system provides effective monitoring, additional driver circuits or relays are required for interfacing high-voltage devices, increasing system complexity. Vasudev Parvati et al. [4] proposed an automated irrigation system based on embedded computing technology using soil-moisture and temperature sensors for efficient water management. The system is suitable for automated irrigation, but buried sensors may experience signal attenuation, resulting in weaker connectivity and data loss. Ahmed Hassan [5] developed a wirelessly controlled robot-based smart irrigation system using Arduino, primarily focusing on reducing water wastage during agricultural irrigation. However, continuous operation may result in high power requirements and increased battery maintenance.

The reviewed studies demonstrate the growing application of embedded systems, IoT, wireless communication, and sensor-based monitoring in smart agriculture. However, the existing approaches generally focus mainly on irrigation or monitoring rather than integrating multiple agricultural operations into a single mobile platform. The proposed Embedded-Based Intelligent Robot for Irrigation System addresses this gap by combining soil-moisture-based irrigation, environmental monitoring, obstacle detection, wireless remote control, and agricultural operations such as soil digging, seed sowing, and soil leveling.

PROBLEM STATEMENT

Traditional agricultural practices require considerable human effort for irrigation, seed sowing, soil preparation, and field monitoring. Conventional irrigation can also result in inefficient water utilization, while limited remote accessibility and changing environmental conditions make field management more difficult. The proposed system addresses these challenges through a multifunctional embedded robot capable of monitoring soil conditions, controlling irrigation, performing agricultural operations, detecting obstacles, and providing wireless remote control.

OBJECTIVES

The main objectives of the proposed system are:

1. To develop a multifunctional agricultural robot capable of digging soil, sowing seeds, leveling soil, and watering crops.
2. To monitor soil moisture, temperature, and humidity using sensors and control irrigation according to field conditions.
3. To provide wireless remote monitoring and control through Wi-Fi/Bluetooth connectivity.
4. To reduce manual labor and water wastage while improving agricultural productivity.
5. To incorporate obstacle detection for safer movement of the robot in the field.

PROPOSED SYSTEM

The proposed system consists of a power supply, W78E052DDG microcontroller, Wi-Fi/Bluetooth module, soil-moisture sensor, DHT11 temperature and humidity sensor, DC motors and motor drivers, relay driver and relays, obstacle detector, buzzer, and reset and clock circuits. The microcontroller serves as the main control unit and processes sensor information before generating control signals for the motors, water pump, fan, and other connected devices.

The soil-moisture sensor provides continuous information about the condition of the soil. When the moisture level falls below a predefined threshold, the controller activates the irrigation mechanism through the relay driver. The DHT11 sensor provides temperature and humidity information, while the obstacle detector assists in avoiding collisions. The DC motors provide movement and positioning of the robot, and wireless communication allows the farmer to remotely operate and monitor the system.

BLOCK DIAGRAM

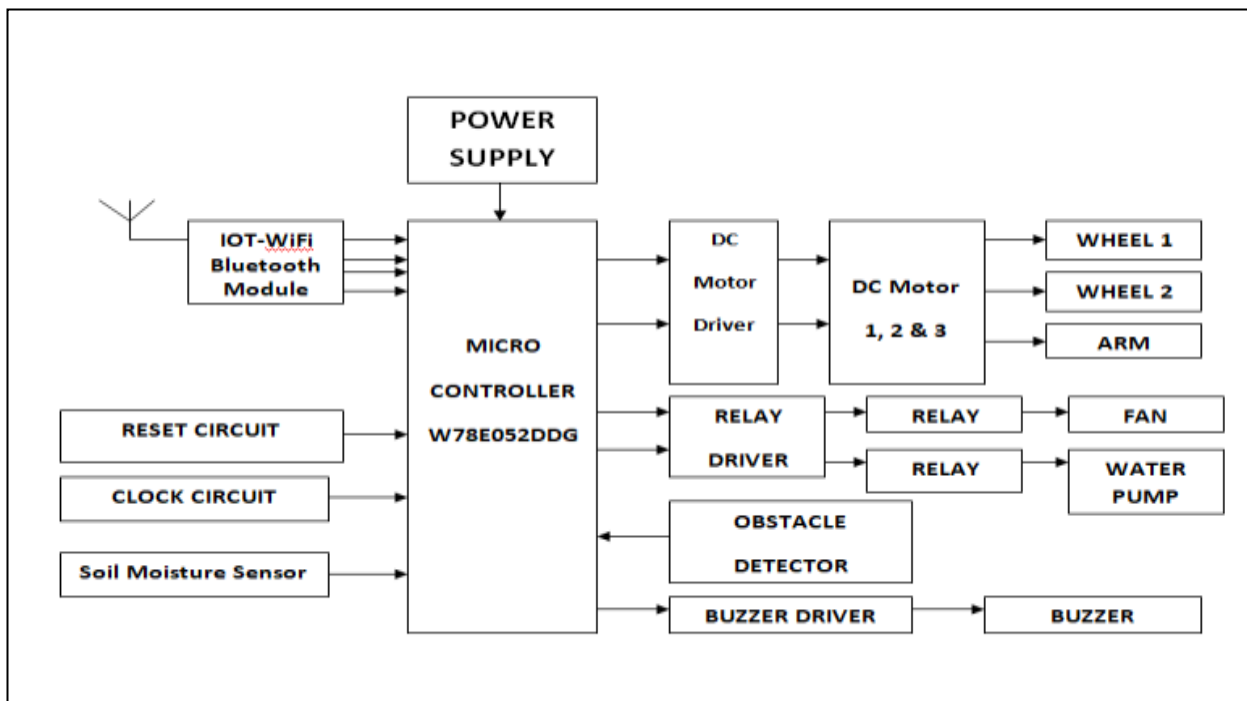


Fig 1 Block Diagram

METHODOLOGY

The operation begins with a stable power supply that energizes the controller, sensors, communication module, motors, and relay-controlled loads. The W78E052DDG microcontroller receives inputs from the soil-moisture sensor, DHT11 sensor, obstacle detector, and wireless communication module. Based on the programmed conditions, it processes these inputs and generates corresponding control signals.

The robot moves through the agricultural field using DC motors and associated drivers. Individual motors are used for wheel and arm movement to provide positioning flexibility. When the soil-moisture value indicates insufficient moisture, the microcontroller operates the relay to activate the water pump. The obstacle detector continuously checks the robot's path and enables the controller to modify movement when an obstacle is detected. A buzzer provides audible alerts during important operating conditions. Reset and clock circuits support synchronized operation and system resetting.

The robot is intended to perform multiple field operations, including soil digging, seed sowing, soil leveling, and water spraying. Wireless connectivity enables the user to control the system remotely through a mobile device, thereby reducing direct manual intervention. The overall methodology integrates sensing, decision-making, actuation, navigation, and communication into a single agricultural robotic platform.

RESULTS AND DISCUSSION

The developed concept provides automated irrigation based on soil-moisture information and supports real-time monitoring of environmental conditions. According to the project results, the system is intended to optimize water usage by detecting soil moisture and adjusting irrigation operations. Automation reduces manual intervention and can decrease labor requirements. The system also supports remote monitoring and control through IoT connectivity.

The integration of obstacle detection improves the operational safety of the robot by allowing it to identify objects in its path and modify its movement. The multifunctional configuration also makes the system applicable to activities such as irrigation, seed sowing, soil preparation, and field monitoring. The project identifies sustainability, reduced water and labor costs, real-time monitoring, and customization for crop requirements as important advantages of the proposed approach.

However, practical deployment involves limitations. The project identifies high initial cost, technical complexity, maintenance requirements, environmental limitations, power-supply constraints, IoT security risks, and limited adaptability to different crop and field conditions. These factors should be considered during large-scale implementation.



Fig 2 Hardware Setup

CONCLUSION

The Embedded-Based Intelligent Robot for Irrigation System provides a multifunctional approach to agricultural automation by integrating embedded control, sensors, wireless communication, motors, relays, and irrigation mechanisms. The proposed robot is designed to reduce manual effort while performing activities such as soil digging, seed sowing, soil leveling, irrigation, and environmental monitoring. Soil-moisture-based irrigation helps improve water management, while obstacle detection and remote control contribute to safer and more convenient operation.

The proposed system demonstrates the potential of embedded and IoT technologies for addressing important agricultural challenges such as water scarcity and labor shortages. Future integration of artificial intelligence, solar

power, automated fertilization, weed removal, and pest-control mechanisms could further improve the capabilities and sustainability of the agricultural robot.

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