Automated Irrigation System for Precision Farming

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***Abstract* – This paper presents a smart plant monitoring and irrigation system utilizing an ESP32 microcontroller integrated with ultrasonic and soil moisture sensors. The system detects the presence of plants using an ultrasonic sensor and receives real-time leaf health status from a camera module. Based on the leaf condition—underwatered, overwatered, or healthy—the system autonomously measures soil moisture and activates a water pump through a relay to irrigate dry plants. In case of overwatering, an alert buzzer is triggered. A servo motor is employed to dip and lift the moisture sensor for accurate soil readings. The robot moves forward continuously, stopping only to monitor and irrigate plants as needed. This automated approach optimizes water usage, improves plant health monitoring accuracy, and reduces manual intervention in agricultural practices**.

Keywords - IoT, Soil Moisture Sensor, Humidity Sensor, Temperature Sensor, Plant Monitoring.

I. INTRODUCTION

Agriculture is a vital sector that requires efficient resource management to ensure healthy crop growth and maximize yield. Traditional methods of irrigation and plant monitoring often involve manual observation and watering, which can lead to under or overwatering, affecting plant health and wasting resources. With advancements in automation and Internet of Things (IoT) technologies, smart agricultural systems have gained attention for optimizing water usage and providing real-time monitoring.

This paper presents a smart plant monitoring and irrigation system based on the ESP32 microcontroller, equipped with ultrasonic and soil moisture sensors. The system autonomously detects the presence of plants using an ultrasonic sensor and receives leaf health status through a camera module. Based on this information, it accurately measures soil moisture by dipping a sensor into the soil using a servo motor and controls a water pump via a relay to irrigate plants only when necessary. Additionally, it alerts the user in case of overwatering through a buzzer.

By automating the detection and irrigation process, this system reduces manual intervention, conserves water, and enhances plant health monitoring precision. Such smart farming solutions are essential for sustainable agriculture and can be easily implemented in various agricultural environments.

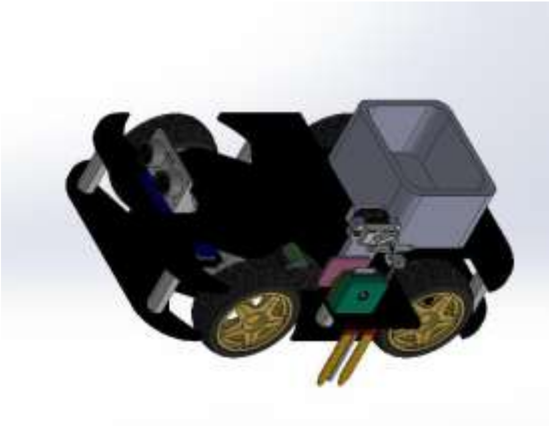
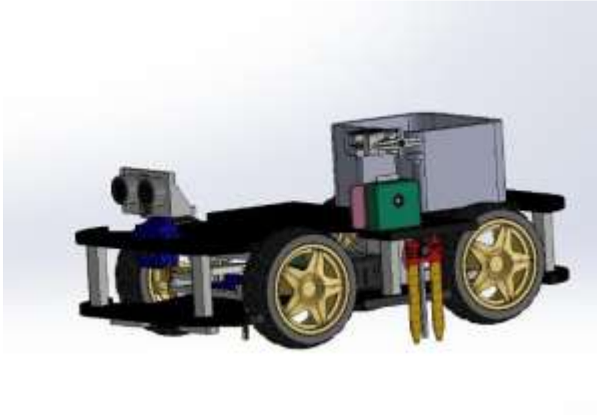

Fig. 1. Assembly of Robot

III. METHODOLOGY

The methodology is organized according to the system's functional requirements and the problem definition to automate plant health monitoring and irrigation.

A. *STAGE 1: CONCEPTUALIZATION:*

1) The system design begins with conceptual sketches of the plant monitoring robot, including sensor placement, actuator mechanisms, and overall movement strategy.

2) Detailed 3D models and 2D drawings of the components and assembly are created using CAD software to ensure accurate fitting and integration.

3) The base and chassis are designed to support the ESP32 microcontroller, sensors, servo motor, relay modules, and water pump securely while allowing free movement

4) The ultrasonic sensor is positioned at the front to detect plant presence within a 20 cm range, while the moisture sensor is mounted on a servo arm for soil dipping.

5) Relay modules are selected for controlling the water pump and DC motor to simplify the motor control mechanism.

B. *FUNCTION OF SYSTEM:*

The proposed system is designed to autonomously monitor plant health and manage irrigation with minimal human intervention. The robot moves forward continuously, powered by a DC motor that is controlled through a relay module. An ultrasonic sensor mounted at the front detects the presence of plants within a predefined range. Once a plant is detected, the robot halts its movement and waits for the leaf health status to be received via serial communication from an external camera module. The camera analyzes the condition of the plant and transmits one of three possible statuses: "underwatered," "overwatered," or "healthy." If the leaf is identified as underwatered, a servo motor is activated to dip the moisture sensor into the soil for accurate moisture level detection. Based on the sensor's reading, if the soil is found to be dry, the system triggers a water pump through a relay to irrigate the plant. In the case of an overwatered condition, the system activates a buzzer to alert the user. If the plant is healthy, the robot simply resumes its forward motion without performing any additional tasks. After executing the appropriate response based on the detected status, the servo motor lifts the moisture sensor back to its original position, and the robot continues its path to monitor subsequent plants. This sequence ensures precise and efficient irrigation based on real-time plant needs.

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C. *DESIGN AND FABRICATION OF SYSTEM:*

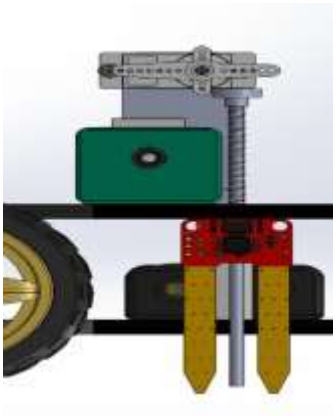
For the smart plant monitoring robot, the design of the moisture sensor actuator is critical to ensure accurate soil moisture measurements without damaging the plants or soil structure. A servo motor is used to precisely dip and lift the soil moisture sensor into the soil. The servo arm and sensor holder are designed to provide stability and smooth motion during dipping to avoid disturbing the plant roots.

The robot chassis is fabricated using lightweight materials to enable smooth movement across the field or garden. The frame securely holds the ESP32 microcontroller, sensors (ultrasonic and moisture), relay modules, water pump, buzzer, and power supply. The layout is optimized for easy maintenance and sensor calibration.

The design considerations include:

- Ensuring the servo motor arm can rotate accurately to positions 0° (lifted) and 90° (dipped).
- Designing a compact yet stable platform for the moisture sensor to prevent soil contamination or damage.
- The chassis supports a DC motor controlled via a relay for movement with enough torque to navigate soft soil.

After fabrication and assembly, the accuracy of soil moisture readings and the responsiveness of the irrigation system were tested and calibrated to ensure reliable operation.



D. *ELECTRICAL CIRCUIT DIAGRAM FOR THE PROPOSED DESIGN:*

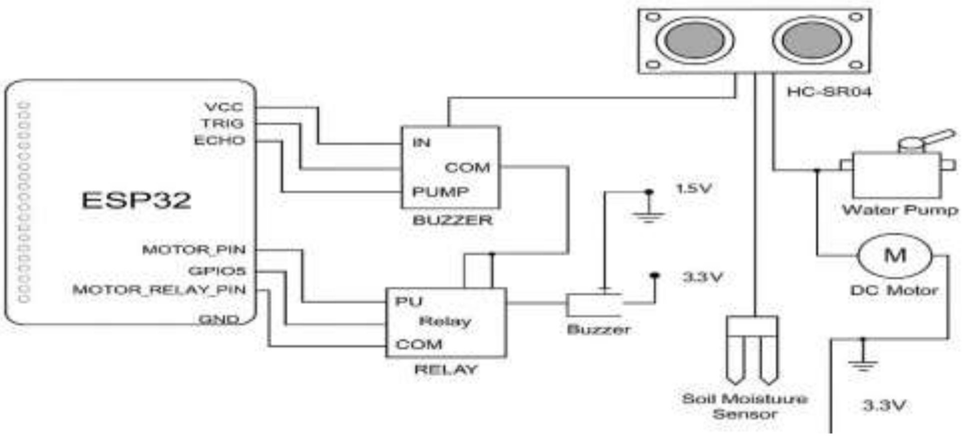


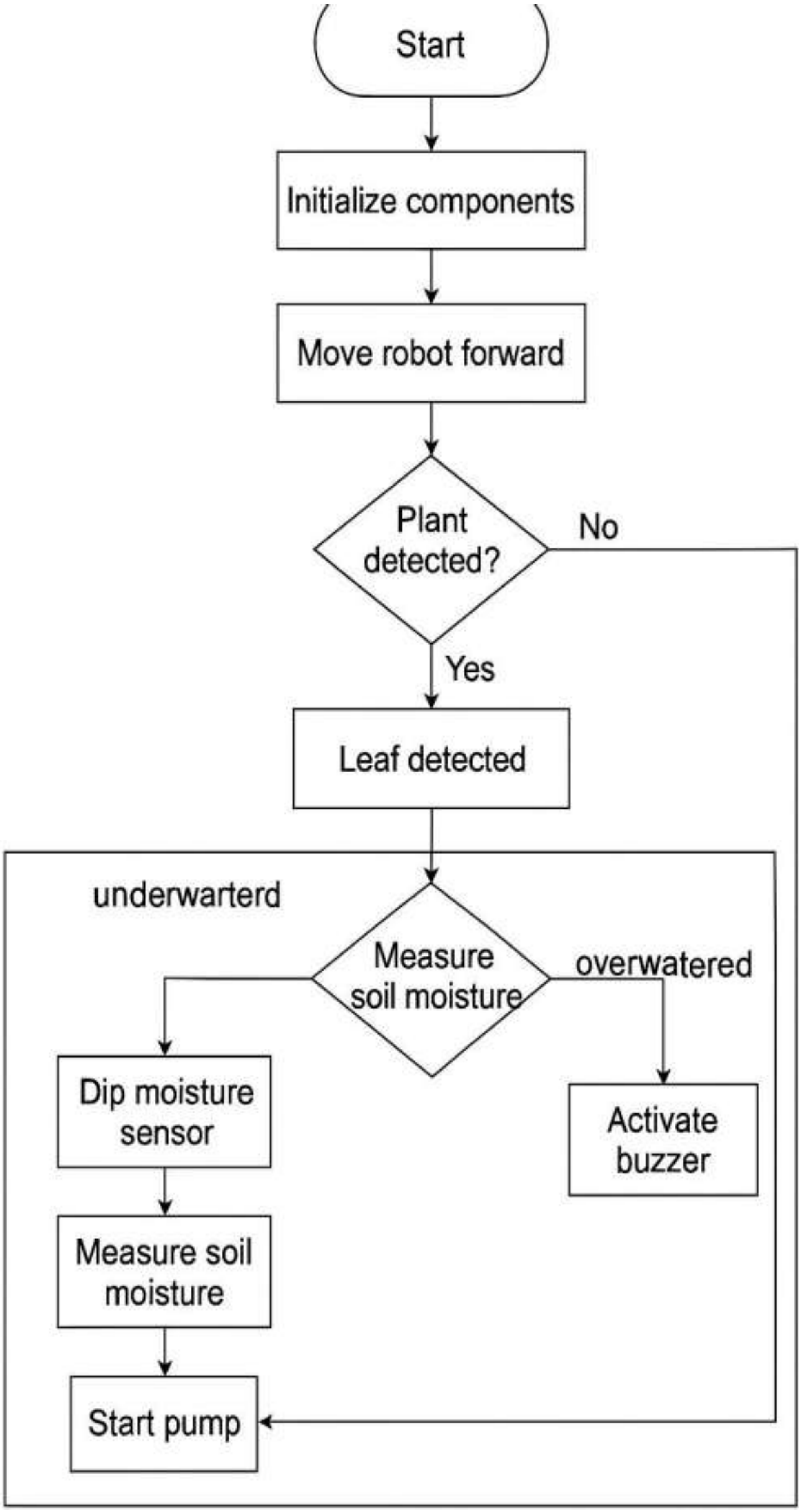
Fig. 4 . Circuit Diagram of System

This Fig. 4 shows the basic electrical control system for an automated plant monitoring robot, which uses a microcontroller as its central processing unit. The microcontroller is powered by a regulated power source and coordinates all the system's operations based on sensor inputs and control logic. The ultrasonic sensor is used to detect the presence of a plant within a predefined range and is connected to digital input pins. A soil moisture sensor provides analog data to monitor soil conditions in real time. The servo motor, controlled via a PWM signal, dips and lifts the moisture sensor into the soil. Relay modules are employed to control both the DC motor for movement and the water pump for irrigation, functioning as binary ON/OFF switches. A buzzer is integrated into the circuit to signal overwatering alerts. All components share a common ground to maintain circuit stability, and flyback diodes are used to protect the microcontroller from voltage spikes generated by the relays. Optional safety features, such as limit switches, can be included to prevent the robot from exceeding its operational boundaries. This setup allows for autonomous decision-making and precision irrigation based on plant health conditions.

E. COMPONENT OF THE SYSTEM:

- Microcontroller-ESP32
- Ultrasonic Sensor
- Soil Moisture Sensor
- Servo Motor
- Relay Modules
- DC Motor
- Water Pump
- Buzzer
- Power Supply
- Chassis Frame
- Wheels and Support Structure
- Camera Module

F. CONTROL ALGORITHM AND OPERATIONAL SEQUENCE:


Start
Initialize components
Move robot forward
Plant detected?
No
Yes
Leaf detected
underwarterd
Measure soil moisture
overwatered
Dip moisture sensor
Activate buzzer
Measure soil moisture
Start pump

III. RESULT AND ANALYSIS:

When the system is powered, the indication LED lights up to confirm that the plant monitoring robot is operational. The robot moves forward continuously using a DC motor controlled via a relay. When a plant is detected within range by the ultrasonic sensor, the robot halts and waits for leaf health data from the camera module. The servo motor accurately dips the moisture sensor into the soil for moisture measurement, and the water pump activates as needed to irrigate dry soil. The buzzer sounds alerts when overwatering is detected. The robot then resumes movement, repeating the cycle for subsequent plants.

Experimental Parameter	**Result**
Plant Detection Accuracy	±1.5 cm
Soil Moisture Measurement Consistency	±3% variation
Irrigation Activation Time	3 seconds
Servo Actuation Time (Dip + Lift)	3 seconds
Buzzer Alert Duration	1 second
Movement Cycle Duration per Plant	10–15 seconds

Table I. Experimental Results of the Automated Plant Monitoring and Irrigation System

IV. CONCLUSION

The developed automated plant monitoring and irrigation system successfully demonstrates a practical approach to precision farming. By integrating sensors and actuators under microcontroller-based control, the system is capable of detecting plant presence, assessing leaf health conditions, and responding with targeted irrigation or alert mechanisms. The robot efficiently automates the task of monitoring plant conditions, reducing human effort while ensuring optimal water usage. Experimental results confirm the system's ability to perform reliable moisture measurement, accurate plant detection, and consistent response cycles. The modular design allows for future enhancements such as wireless data logging, solar power integration, or multi- directional navigation. Overall, the system presents a low-cost, scalable solution for smart agriculture applications aimed at sustainability and resource efficiency.

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