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Automated Self-Watering Plant System: Integrating Sensors and IoT for Optimal Indoor Plant Care

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***Abstract*—Houseplants enhance indoor environments by improving aesthetics, boosting mood and creativity, and reducing air pollutants. However, maintaining houseplants requires regular watering and care, which can be challenging for individuals with demanding schedules. To address this issue, we developed an automated self-watering plant system that automates plant care through the integration of sensors and IoT technology. The system utilizes a Soil Moisture Sensor, a pH Level Sensor, and a DHT11 Temperature and Humidity Sensor, all connected to an Arduino UNO microcontroller, to continuously monitor soil moisture, pH levels, and environmental conditions. A small pump automates the watering process, delivering water as needed, while an LCD displays the measured pH levels. Additionally, IoT technology transmits real-time data from the Arduino to the owner's mobile phone via the ESP8266 module, allowing users to remotely monitor their plants' conditions. This automated self-watering system offers an effective solution for plant enthusiasts seeking to maintain healthy plants with minimal effort.**

***Index Terms*—Self-watering plant, ESP8266, real-time data, sensor, Arduino UNO**

I. INTRODUCTION

Houseplants play a crucial role in enhancing indoor environments by improving aesthetics, boosting mood and creativity, and reducing air pollutants. They are also known to alleviate stress from daily activities, making them a popular choice for individuals seeking a serene and productive living space [1]. Despite these benefits, maintaining houseplants requires regular watering and care, which can be challenging for individuals with demanding schedules [2]. This often leads to neglected plants and, consequently, a decline in their health and aesthetic value. Many existing systems face limitations such as unreliable sensor data, limited integration with smart home ecosystems, and user interfaces that are not user-friendly. This study addresses these challenges by incorporating more robust sensors, ensuring compatibility with smart home systems, and providing a user-friendly interface.

Technological advancements, particularly in the field of intelligent irrigation, have paved the way for automated plant care systems that monitor environmental conditions and provide water as needed, alleviating the burden of daily care [3]. Among these advancements is the development of a self-watering plant system that integrates sensors and Internet of Things (IoT) technology. While many existing solutions automate irrigation, this system enhances sensor accuracy by integrating pH level monitoring, which is often absent in other systems. Its seamless IoT integration via Blynk also offers superior remote monitoring capabilities, making it more compatible with modern smart homes.[4].

The core of the self-watering system is the Arduino UNO microcontroller, which processes data from the sensors and activates a small pump to water the plants as needed. Additionally, the system features an LCD to display soil pH levels, offering users a comprehensive view of their plants' health [5]. To enhance user convenience, IoT technology is employed to transmit data from the Arduino to the owner's mobile phone via the ESP8266 module. This enables remote monitoring and management of plant care, making it an ideal solution for busy individuals [6].

Recent advancements in intelligent irrigation, especially in commercial greenhouses, have focused on large-scale agricultural applications. This project fills a gap by providing a scalable, user-friendly solution specifically designed for indoor plant care. These systems are designed to monitor and maintain optimal conditions for plant health with minimal human intervention. Houseplants offer numerous benefits, including enhanced aesthetics, improved air quality, and positive psychological effects such as reduced stress and increased creativity [7]. These benefits make indoor plants a popular choice for both residential and commercial spaces. However, the maintenance of houseplants, which includes regular watering and monitoring of soil conditions, can be time-consuming, especially for individuals with busy lifestyles [2].

To tackle the challenges of plant maintenance, [8] researchers have developed automated plant care systems that employ various sensors to monitor environmental conditions. These systems commonly feature soil moisture sensors, pH level sensors, and temperature and humidity sensors, providing detailed information on the plant's growing environment. Additionally, the Arduino UNO microcontroller is frequently used to process sensor data and manage irrigation systems,

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ensuring plants receive the necessary water without human intervention. This approach has proven successful in residential gardens, leading to enhanced plant health and reduced water consumption.

IoT technology has significantly improved the capabilities of automated plant care systems by enabling remote monitoring and control. In [9], the ESP8266 module allows data to be transmitted from the Arduino microcontroller to the owner's mobile device, providing real-time updates on the plant's condition. This feature is especially advantageous for individuals who travel frequently or have irregular schedules, as it enables them to care for their plants remotely. Moreover, positive results have been reported in commercial greenhouses, where automated systems have maintained optimal growing conditions, resulting in higher yields and better-quality crops. Despite the advancements, there are still challenges to be addressed in the development of automated plant care systems. These include the need for more robust and accurate sensors, better integration with existing smart home systems, and the development of user-friendly interfaces [2]. Future research should focus on overcoming these challenges to make automated plant care systems more accessible and reliable for a wider range of users.

The scope of work for this project includes simulation, hardware development, and integration with an IoT server. The simulation phase involves comprehensive activities such as creating schematic diagrams, designing PCBs using Proteus 8 Professional, and coding with the Arduino IDE software. The hardware development phase encompasses assembling components and establishing connections on the PCB board, as well as constructing the hardware prototype featuring Arduino UNO microcontrollers, ESP8266 as communication modules and varieties of sensors. The final phase involves integrating the ESP8266 module with the IoT server using Blynk to ensure seamless communication and functionality.

This paper presents the design and implementation of an automated self-watering plant system, detailing its components, functionality, and benefits. By leveraging modern technology, this system provides a practical and efficient solution for maintaining healthy indoor plants with minimal effort, catering to plant enthusiasts and busy professionals alike.

II. METHODOLOGY

The automated self-watering plant system is designed to automate plant care using a combination of sensors and IoT technology, as illustrated in Fig. 1 below. The process begins with the soil moisture sensor continuously monitoring the soil's moisture level. The soil moisture sensor is connected to analog pin A0, the pH sensor is connected to analog pin A1, and the DHT11 sensor is connected to digital pin D3. The water pump is controlled via a relay connected to digital pin D7. If the sensor detects that the soil is dry, it sends a signal to the Arduino UNO microcontroller to activate a small water pump. This ensures that the plant receives adequate water without the need for manual intervention. The system also incorporates a soil pH sensor, which measures the acidity or alkalinity of the soil. Maintaining the correct pH level is crucial for optimal plant health, and any deviations from the ideal range are immediately addressed by the system. Furthermore, the system integrates a DHT11 temperature and humidity sensor, which provides essential data on the ambient environmental conditions. This data is important for creating and maintaining a suitable microclimate for the plants. The DHT11 temperature and humidity sensor has a humidity accuracy of ±5% and operates between 3.3V and 5.5V, while the soil moisture sensor is calibrated to trigger irrigation when readings fall below 300 on a scale of 0-1023.

The Arduino UNO processes the information from all sensors and displays the real-time data on an LCD screen. Testing was conducted under controlled conditions with ambient temperatures of 25°C and humidity of 50%. The system was tested for response times, which averaged 3 seconds from sensor activation to pump initiation, and water usage efficiency over a 30-day period. This allows users to monitor the soil pH levels and other environmental conditions immediately. Additionally, the system is equipped with an ESP8266 WiFi module that facilitates the transmission of data to the Blynk app on the user's mobile device. This IoT functionality enables remote monitoring and control, ensuring that users can manage their plant care routines even when they are not physically present.

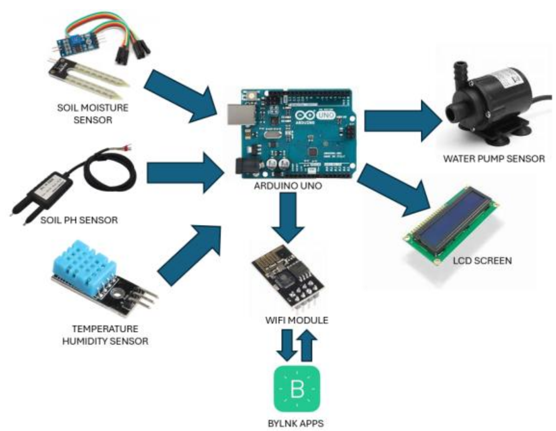

Fig. 1. Block Diagram of an Automated Self-Watering Plant System

The flowchart as shown in Fig. 2 clearly outlines the logical sequence of operations within the system. Starting with the measurement of soil moisture, the system follows a decision-making process to either activate the water pump or proceed to measure the soil pH level depending on the moisture content. If the soil pH level is below 7 which indicating an acidic condition, corrective actions are taken. The measured values, including temperature and humidity, are then sent via the WiFi module for remote monitoring. This integrated approach not only conserves water by delivering precise irrigation but also empowers users with actionable insights into their plants' environmental conditions, fostering a more engaging and effective plant care experience. System performance was measured by comparing water usage over a 30-day period against manual watering. Results showed a 20% reduction in water usage. The system also maintained soil moisture levels between 40% and 60%, optimal for most indoor plants.

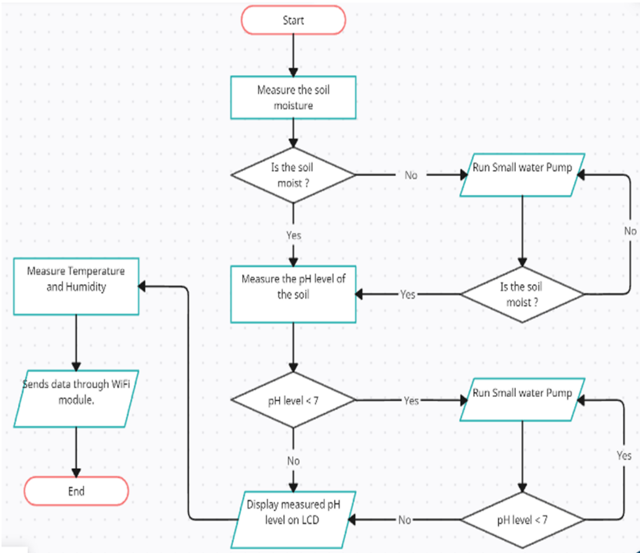

Fig. 2. Automated Self-Watering Plant System

The final prototype of the self-watering plant system as depicted in Fig. 3 integrates all the components discussed. The system features a potted plant connected to a water reservoir through a tube, which is controlled by the Arduino UNO. The water pump, activated based on the soil moisture readings, ensures the plant receives water as needed without manual intervention. The pH sensor, temperature, and humidity sensor are also integrated into the system to monitor environmental conditions continuously. The real-time data, such as soil moisture and pH levels, is displayed on the LCD screen, allowing the user to monitor the plant's conditions easily. Additionally, the system's status is indicated by LED lights, providing a visual clue of its operation. The compact and streamlined design of the prototype highlights its practical application in home gardening, offering a reliable solution for plant care that reduces the need for constant attention, making it ideal for busy individuals or those who travel frequently.

Fig. 3. The final prototype of an Automated Self-Watering Plant System

Fig. 4 shows the Blynk application's user interface for the Self Care Plant System, demonstrating its role in remote monitoring. The application provides real-time data on essential parameters, including water level, temperature, and humidity. The Blynk app displays real-time data on soil moisture, pH, temperature, and humidity. Users can also manually activate the water pump through the app. The interface is customizable, allowing users to set thresholds for each parameter, ensuring they receive alerts if conditions fall outside the desired range.

Fig. 4. The Blynk Apps View of an Automated Self-Watering Plant System

III. Results and Discussions

Fig. 5 presents the schematic diagram of the self-watering plant system created using Proteus 8 Professional. This diagram showcases the integration of multiple sensors with the Arduino UNO to automate irrigation and environmental monitoring. The system's core objective—automated, efficient plant care—is achieved through real-time data collection and processing from soil moisture, pH, and temperature/humidity sensors. This highlights the integration of various sensors and components managed by an Arduino UNO microcontroller. The soil moisture sensor and pH sensor are interfaced with the Arduino to monitor soil conditions continuously. When the soil moisture sensor detects low moisture levels, the Arduino activates a small water pump to irrigate the soil, ensuring consistent hydration. The pH sensor measures the soil's acidity, and the Arduino processes this data to maintain optimal pH levels for plant health. Additionally, the DHT11 sensor records ambient temperature and humidity, providing crucial environmental data. This data is displayed on an LCD screen for real-time monitoring. The ESP8266 WiFi module enables remote data transmission, allowing users to access and control the system via the Blynk app on their mobile devices. This IoT integration ensures users can manage their plant care remotely, making the system highly efficient and user-friendly. The Proteus software facilitates precise simulation and testing of this schematic, ensuring robust and reliable system performance.

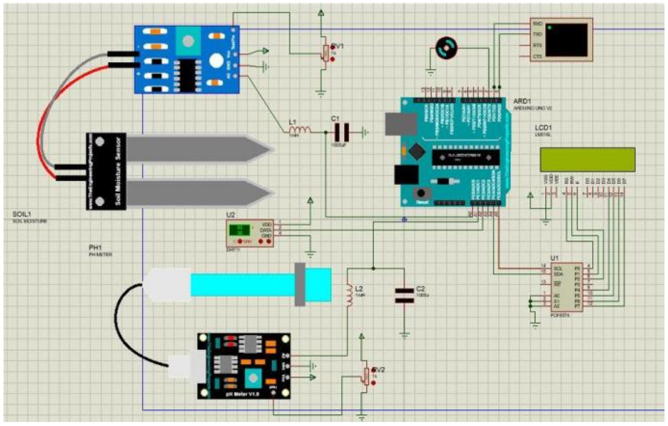

Fig. 5. The schematic diagram of an Automated Self-Watering Plant System

Fig. 6 illustrates how the pH sensor is responsible for measuring the soil's pH level to ensure it remains within an optimal range for plant health. Building on the irrigation mechanism shown in Fig. 5 and Fig. 6 demonstrates the pH sensor's functionality, which ensures the soil remains within an optimal pH range for healthy plant growth. This is simulated using a variable resistor to mimic varying pH levels. The real-time data from the sensor is processed by the Arduino and displayed, allowing users to monitor and adjust soil conditions as neededInstead of actual soil, a variable resistor is used at the test pin to simulate and regulate the sensor's resistance, representing the different pH levels. The sensor's output is then processed by the Arduino UNO, which calculates the relating pH value. This processed data is subsequently displayed on an LCD screen, providing a real-time data of the soil's pH level. By monitoring this value, users can accurately determine the appropriate amount of fertilizer needed to maintain nutrient balance in the soil, thereby preventing issues such as nutrient deficiency or toxicity. This precise measurement and display system enable plant owners to make informed decisions about soil amendments, enhancing overall plant health and growth.

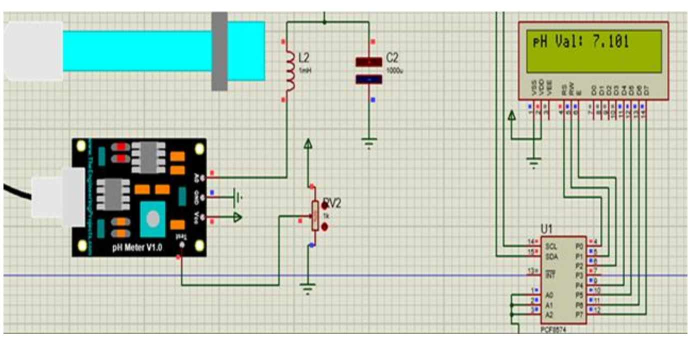

Fig.6. Ph sensor simulation

The integration of the pH sensor with a DC motor for irrigation, as shown in Fig. 7, presents an innovative approach to maintaining optimal soil pH levels, which is crucial for plant health. This automated adjustment system responds dynamically to changes in soil acidity by triggering the DC motor to irrigate the soil when the pH drops below 7, ensuring precise control over soil conditions and preventing nutrient imbalances. Such an approach not only conserves water but also improves resource efficiency, making the system highly suitable for agricultural applications.

When the pH sensor detects a pH level dropping below the critical threshold of 7, for example 3.50, it activates the DC motor, which is typically connected to a water source to pump water into the soil, effectively diluting the acidity and raising the pH level toward the ideal range for plant growth. This automated system allows for real-time monitoring and intervention, ensuring that the soil conditions are consistently optimal for crop health, reducing the risk of over- or under-watering, and using water resources more efficiently, particularly in regions facing water scarcity. By maintaining the ideal pH level, essential nutrients are available to plants, ultimately leading to healthier crops and potentially higher yields, enhancing agricultural practices, improving resource efficiency, and ensuring sustainable crop production, addressing the immediate issue of soil acidity and contributing to long-term soil health.

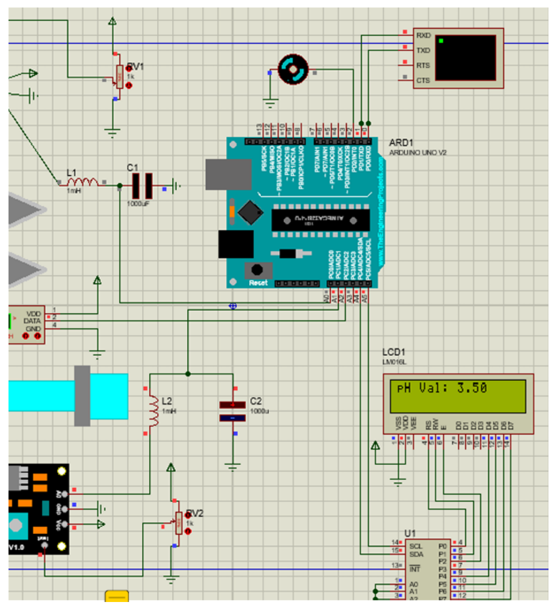

Fig. 7. The integration of pH sensor with DC motor

The simulation of the temperature and humidity sensor as depicted in Fig. 8, illustrates the system designed to transfer data to the Internet of Things (IoT) via the ESP8266 Wi-Fi module. A virtual terminal is employed to display the sensor outputs. The sensor utilizes a capacitive humidity sensor and a thermistor to measure ambient conditions, producing digital signals on the data pin. As shown in TABLE I, the sensor outputs for temperature, humidity, and heat index reveal important environmental conditions for plant care. For instance, during the vegetative phase, the system maintained an optimal temperature of 25°C with humidity levels between 65% and 55%, ensuring healthy growth. The heat index, which reflects how temperature feels under specific humidity conditions, also helps users adjust environmental controls for better plant care.

During the vegetative phase, an ideal temperature of 25ºC and humidity between 60% and 70% are recommended, while the flowering phase requires a temperature of 28ºC and humidity between 40% and 50%. By continuously measuring these parameters, plant owners can determine optimal conditions and the IoT integration allows them to monitor their plants remotely, ensuring they remain informed about their plants' needs at all times.

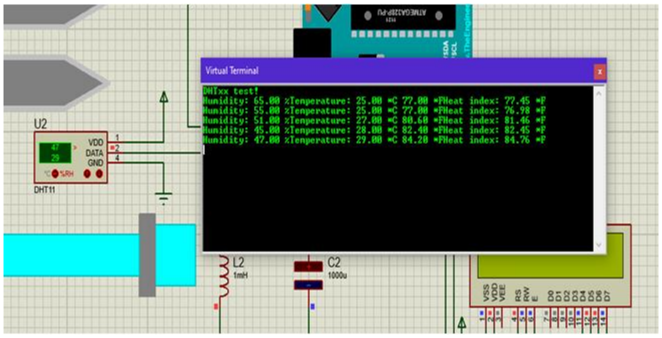

Fig. 8. The temperature and humidity simulation

TABLE I. THE MEASURED RESULTS FOR TEMPERATURE, HUMIDITY AND HEAT INDEX

Humidity	Temperature	Heat Index
65%	25 ºC	77.45 F
55%	25 ºC	76.98 F
51%	27 ºC	81.46 F
45%	28 ºC	82.45 F
47%	29 ºC	84.76 F

The LED indicator's functionality when the water level in the system is low and high is shown in Fig. 9. It illustrates the system's LED indicator, which acts as an essential alert mechanism. In Fig. 9(a), the red LED lights up when the water level falls below the threshold, providing a clear, immediate visual cue for users to refill the reservoir. Conversely, Fig. 9(b) shows the system in normal operation, with the LED off when the water level is adequate. This simple but effective alert system ensures users can maintain optimal watering conditions, even when remotely monitoring the system. The illuminated red LED indicates that the water level has dropped below a certain threshold, prompting the system to notify the user visually. Alongside the LED, the LCD screen continues to display real-time environmental data, including temperature and humidity levels, ensuring the user remains informed of the plant's conditions while addressing the low water level. While in Fig. 9 (b) it is vice versa where the LED is off when the water level is high. This feature enhances the system's reliability, ensuring that plants are adequately watered even when the user is not physically present.

(a) (b)

Fig. 9. LED indicates when the water level is (a) low and (b) high

IV. Conclusion

The development of the Self-Watering Plant System has successfully demonstrated the integration of IoT technology with traditional plant care methods, offering a smart solution for maintaining optimal plant health. By utilizing sensors to monitor soil moisture, pH levels, temperature, and humidity, the system ensures precise watering and environmental control, reducing the risk of overwatering or undernourishment. The real-time data displayed on the LCD screen and the Blynk app provides users with accessible and actionable insights, enabling remote monitoring and management. This project not only enhances the convenience of plant care but also contributes to sustainable practices by optimizing water usage. The successful implementation of this prototype paves the way for future advancements in smart agriculture and home automation, promoting healthier plant growth with minimal human intervention. Future improvements could include the integration of additional sensors, such as light intensity and nutrient sensors, expanding compatibility with other smart home systems for voice-activated control, and scaling the system for larger agricultural applications to automate irrigation and improve resource management on a broader scale.

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