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AUTONOMOUS IRRIGATION SYSTEM

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Abstract: This study develops an autonomous irrigation system using ESP32, DHT11 sensor, water pump and hygrometer. The system monitors environmental conditions and triggers irrigation automatically, storing data in Firebase for visualization via a web interface. The results demonstrate efficiency and sustainability, suggesting potential for various agricultural applications and promoting precision agriculture.
Keywords: Automation, agricultural application, DHT11, irrigation, hygrometer sensor

INTRODUCTION

Technological evolution has enabled significant advances, from complex machinery to compact and efficient devices. In this context, the Internet of Things (IoT) has emerged as an important concept, connecting everyday objects to the Internet to enable their interaction and remote control [Rosa 2020]. This concept has applications in various areas, including automobiles and irrigation systems [Mouha 2021].

Automated irrigation has emerged as a sustainable and efficient solution for agriculture, especially in areas with limited water resources [Medeiros 2018]. Among irrigation methods, the drip technique stands out for applying water directly to the plant root zone, minimizing waste [Medeiros 2018].

Productive backyards represent a practical and sustainable alternative to conventional agriculture, promoting sustainable development around homes [Louro 2022]. Proper irrigation of these spaces is crucial to avoid wasting water, an increasingly scarce resource. Developing efficient, remote-controlled irrigation systems is essential to meeting this challenge [Louro 2022].

Automation allows farmers and gardeners to carry out their activities with greater efficiency and precision, improving the quantity and quality of products [Medeiros 2018]. Automated irrigation systems, such as the one proposed in this study, use sensors to continuously measure soil moisture and ambient temperature, triggering irrigation when necessary, which reduces water consumption and minimizes human error [Louro 2022].

This study proposes the development of an integrated irrigation monitoring and control system using the ESP32 platform. The system continuously measures soil temperature and humidity, triggering an irrigation pump when pre-set levels are reached. The operating principles of the system, the components used and the results of tests carried out under controlled conditions and in an indoor environment will be explored. It is hoped that this work will contribute to precision agriculture, offering an effective tool for the sustainable management of water resources and the optimization of agricultural production.

OBJECTIVES

GENERAL OBJECTIVES

This project aims to develop an autonomous irrigation system based on the ESP32 microcontroller, integrating the DHT11 temperature and humidity sensor and a water pump. The system aims to automate the irrigation of a plantation in an efficient and sustainable way. The DHT11 sensor will be used to measure the temperature and humidity of the environment. This data will be compared with pre-defined values, determining whether the ESP32 should activate the water pump to start the irrigation process. The main objective is to optimize the use of water resources and improve the efficiency of agricultural production.

SPECIFIC OBJECTIVES

a. Design and build the necessary hardware, including the integration of the DHT11 sensor and the water pump with the ESP32 microcontroller for collecting and acting on temperature and humidity data.

b. Develop the software to read the sensor data, send it to the online database (Firebase) and communicate with a web interface.

c. Implement a database in Firebase to store the temperature and humidity data collected by the sensor, ensuring data accessibility and security.

d. Create an intuitive web interface that allows you to view and analyze the data collected in real time, as well as manually control the irrigation system if necessary.

e. Carry out indoor experimental tests to validate the accuracy and effectiveness of the autonomous irrigation system in different environmental conditions, adjusting parameters as necessary to improve performance.

METHODOLOGY

SYSTEM COMPONENTS

The main components used in this project include the DHT11 temperature and humidity sensor, the water pump and the ESP32 microcontroller. The ESP32 is responsible for coordinating the system's general operations.

DATA COLLECTION

The DHT11 sensor and hygrometer capture temperature and humidity data from the environment. This data is acquired by the ESP32, which processes it and prepares it for storage.

DATA STORAGE

The temperature and humidity data, as well as the time the data was collected and the time the water pump was activated, are sent to Firebase. This database was chosen because of its real-time integration capabilities and ease of access via the Internet.

USER INTERFACE

The data stored in Firebase is made available to the end user via a web interface. This interface is designed to be intuitive and accessible, allowing the user to view environmental conditions in real time.

SYSTEM AUTOMATION

As an automation measure, the system has been configured to trigger a water pump automatically when certain temperature and humidity thresholds are reached.

This automation is managed by the ESP32, which sends a signal to activate the water pump, helping to regulate environmental conditions.

FLOW OF OPERATIONS (SYSTEM DIAGRAM)

a. Data collection: The DHT11 sensor and the Hygrometer sensor collect temperature and humidity data.

b. Processing: ESP32 processes the collected data.

c. Storage: The processed data is sent to Firebase.

d. Visualization: The data is displayed on the web interface for the end user.

The ESP32 monitors the data in real time and triggers the water pump if necessary. Figure 1 shows the system diagram with the flow of operations.

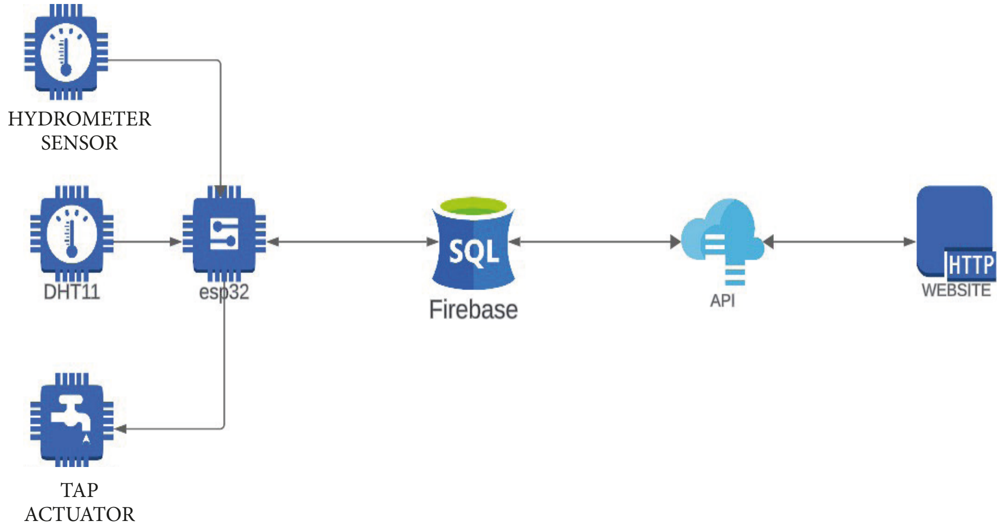

Figure 1. Flow of Operations (system diagram).

RELATED WORK

The use of autonomous irrigation systems has been widely studied and implemented on different scales and with different technologies. Previous studies have explored the integration of soil moisture sensors with microcontrolled systems to optimize the use of water in agriculture.

De Moura and Nobre [de Moura and Nobre 2022] developed an intelligent automation and control system for lettuce irrigation, using Arduino and controlled by an Android mobile application. The system, made up of equipment that is readily available on the market, was validated in the field and proved to meet the requirements of ease of operation and reduced labor costs.

Henriques [Henriques 2021] used the ESP32 microcontroller to monitor soil moisture and temperature data in home planting environments. The data was sent to the TagoIIo IoT platform, where it was displayed using graphs on dashboards.

Pereira [Pereira 2020] integrated soil moisture sensors with a weather forecast API using the Raspberry Pi microcontroller board. This system increased agricultural production by up to 2.5 times compared to non-irrigated areas.

De Abreu Ribeiro and Junior [de Abreu Ribeiro and Junior 2022] guided students from a school to automate the institution's vegetable garden using the ESP32 microcontroller, sensors and actuators, controlled by a mobile application for automatic irrigation.

Caetano, Azguetin and Filho [Caetano et al. 2020] combined IoT with localized irrigation systems in tomato fields. Using an Arduino microcontroller, data was collected and analyzed to help farmers make decisions.

The prototype developed in this work uses the ESP32 microcontroller in conjunction with the DHT11 temperature and humidity sensor and a water pump actuator. The system automatically releases water when necessary, and the data is stored in an online database (Firebase). The data recorded includes temperature, humidity, time of capture and time of pump activation. This data can be viewed via a web interface, allowing efficient monitoring and control of the irrigation system.

RESULTS

The results achieved the expected goal. The DHT11 sensor and the hygrometer sensor read the data, and this data is sent to the Firebase online database with the information in real time. This data, in turn, is displayed on a web page that communicates with Firebase to collect the data.

Figure 2(a) shows the front view of the circuit in its bench testing phase. On the left-hand side of the image, you can see the hygrometer sensor immersed in a beaker with the soil used for the tests. You can also see the protoboard with the ESP32 and the DHT11 humidity and temperature sensor. Figure 2(b) shows the top view of the prototype with the soil dry, and Figure 2(c) shows the same view of the circuit, but with the soil wet, so that the measurements and the automatic activation of the pump could be carried out.

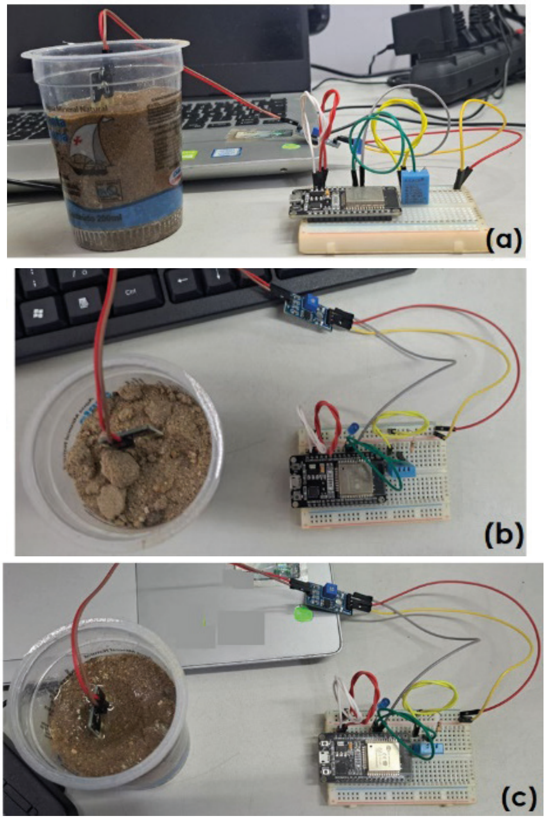

Figure 2 - Views of the circuit on the bench. Front (a); Top with dry earth (b); Top, with wet earth (c).

The system acquires data from the environment, which is stored in the database and reported to the user. The status of the pump and the time it is active are also displayed. Figure 3 shows how this data is displayed on the web page.

DISCUSSIONS

The results obtained with the autonomous irrigation system demonstrate the effectiveness and practicality of implementing the ESP32 microcontroller in conjunction with the DHT11 sensor, a water pump and a hygrometer sensor. The accuracy of the temperature and humidity readings by the DHT11 sensor, together with the hygrometer sensor, proved to be adequate for the system's needs, enabling efficient irrigation control. The choice of Firebase as the online database enabled data to be stored and accessed quickly, facilitating remote monitoring via the web interface.

The system proved efficient in controlled tests and performed satisfactorily, which suggests that it can be scaled up and adapted to different types of crops and environmental conditions, adapting its air temperature and humidity data along with soil moisture. The automation provided by ESP32 significantly reduced the need for manual intervention, promoting a more rational use of water and contributing to agricultural sustainability.

However, some limitations were identified. The accuracy of the DHT11 sensor, although sufficient for the project, could be improved by using sensors with better acuity. In addition, the dependence on a stable Internet connection for Firebase to function can be a critical point in rural areas with limited network infrastructure. Hybrid solutions that combine local storage and periodic synchronization with the online database can mitigate this problem.

TIME	TEMPERATURE	HUMIDITY	HYGOMETER	PUMP STATUS	ACTIVE PUMP SCHEDULE
2024-07-04 08:54:10	23.00			✗	2024-07-04 08:49:59
2024-07-04 08:53:59	23.00	49.00	65	✗	2024-07-04 08:49:59
2024-07-04 08:53:49	23.00	49.00	66	✗	2024-07-04 08:49:59
2024-07-04 08:53:39	23.00	49.00	65	✗	2024-07-04 08:49:59
2024-07-04 08:53:28	23.00	49.00	66	✗	2024-07-04 08:49:59
2024-07-04 08:53:18	23.00	50.00	66	✗	2024-07-04 08:49:59
2024-07-04 08:53:07	23.00	50.00	66	✗	2024-07-04 08:49:59
2024-07-04 08:52:57	23.00	50.00	66	✗	2024-07-04 08:49:59
2024-07-04 08:52:44	23.00	50.00	68	✗	2024-07-04 08:49:59
2024-07-04 08:52:32	23.00	50.00	67	✗	2024-07-04 08:49:59
2024-07-04 08:52:23	23.00	51.00	67	✗	2024-07-04 08:49:59
2024-07-04 08:52:14	23.00	51.00	68	✗	2024-07-04 08:49:59
2024-07-04 08:52:03	23.00	51.00	69	✗	2024-07-04 08:49:59
2024-07-04 08:51:53	24.00	52.00	75	💧	2024-07-04 08:49:59
2024-07-04 08:51:32	24.00	52.00	75	💧	2024-07-04 08:49:59

Figure 3 - System data displayed via web page.

FINAL CONSIDERATIONS

The development of the autonomous irrigation system using the ESP32 microcontroller and the DHT11 sensor, together with the hygrometer sensor, showed promising results, demonstrating its potential to make a significant contribution to precision agriculture. The proposed system not only automates the irrigation process, but also offers a sustainable and efficient solution for managing water resources.

The integration of humidity and temperature sensors with the ESP32 platform, combined with real-time data storage in Firebase and an intuitive web interface, allows for continuous monitoring and effective control of the environmental conditions of plantations. These elements are essential for implementing smarter and more sustainable agricultural practices.

This project can serve as a basis for future research and development, especially in rural areas where access to technology is limited. Incorporating more precise sensors, adapting to different types of crops and improving the network infrastructure are all viable ways for the system to evolve.

Therefore, the autonomous irrigation system developed represents a significant advance for agricultural automation, offering an effective tool for farmers and gardeners looking to optimize water use and improve the productivity of their crops. It is hoped that this work will inspire new initiatives and contributions to sustainable agriculture, in line with the global objectives of preserving natural resources and increasing production efficiency.

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