ASEC 2025 Conference

The 6th International Electronic Conference on Applied Sciences

09–11 December 2025 | Online

MDPI

Development of an Automated Irrigation System with Remote Sensing for Rural Microentrepreneurs

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INTRODUCTION & AIM

Water is a finite and essential resource, whose preservation has gained prominence due to its intensive use in various sectors. In Brazil, agriculture is one of the largest consumers of freshwater and contributes significantly to the economy. In the Northeast, family farming represents about 89% of establishments and occupies 37% of the cultivated area, playing a central role in the local economy. [1].

According to the Food and Agriculture Organization of the United Nations (FAO), 70% of the water consumed globally is destined for agricultural irrigation, a percentage that reaches 72% in Brazil [2]. This scenario makes water scarcity a critical challenge, especially for rural micro-entrepreneurs who often do not have access to efficient irrigation technologies. Inadequate water use can result in waste, reduced productivity and economic insecurity.

To mitigate these problems, automated irrigation systems, integrated with sensors and microcontrollers, emerge as a promising alternative. Automation allows irrigation to be activated only when necessary, optimizing water consumption, reducing operating costs, and expanding monitoring capacity through remote sensing [3].

Therefore, this work aims to develop a SCADA system integrated with a smart device with wireless connectivity and sensors for temperature, rainfall, and air and soil humidity, intended for small rural producers. The system will allow real-time monitoring of soil conditions and automated irrigation activation in passion fruit cultivation.

METHOD

This work adopts an applied research methodology, integrating theory and practice through bibliographic review, tests in a controlled environment, and field validation. After the initial study, requirements were gathered, followed by the development of the hardware, firmware, and SCADA system, culminating in the assembly and installation of the prototype in a passion fruit crop.

- **Definition of System Requirements**

The functional requirements of the device were defined, including the materials list, the choice of sensors, and the circuit for data reading and water pump activation. Passion fruit was also selected as the reference crop for testing.

- **Hardware Development**

With the functionalities defined, hardware prototyping began, including the elaboration of the electronic schematic and the development of the PCB layout in Proteus. The project consists of a control module based on the ESP32, responsible for processing and communication, in addition to the set of ambient humidity and temperature sensors, soil moisture, and rainfall. Irrigation is activated by a relay module, and the system also has a dedicated power supply for the control and power circuits.

- **Firmware Development**

The firmware, programmed in C/C++ in the Arduino IDE, was developed to control irrigation and monitor humidity, temperature, soil, and rainfall sensors. Filtered reading routines, relay control, and feedback verification were implemented to ensure the correct activation of the loads.

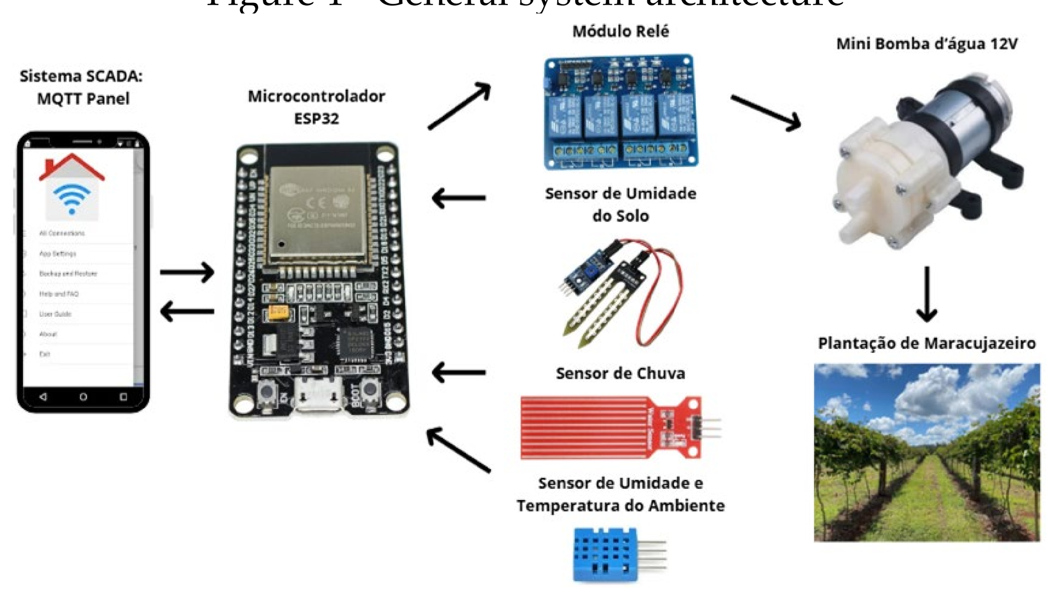
- **SCADA System Development**

The SCADA system was developed in the MQTT Panel application, using the MQTT protocol for remote monitoring and control. The created interfaces allow visualization of sensor data, activation of irrigation zones, and configuration of system parameters, facilitating complete supervision of the process.

RESULTS & DISCUSSION

Tests conducted in a controlled environment and in passion fruit cultivation demonstrated that the system exhibited stable operation and consistent sensor readings. Figure 1 shows the overall architecture of the system.

Figure 1 - General system architecture

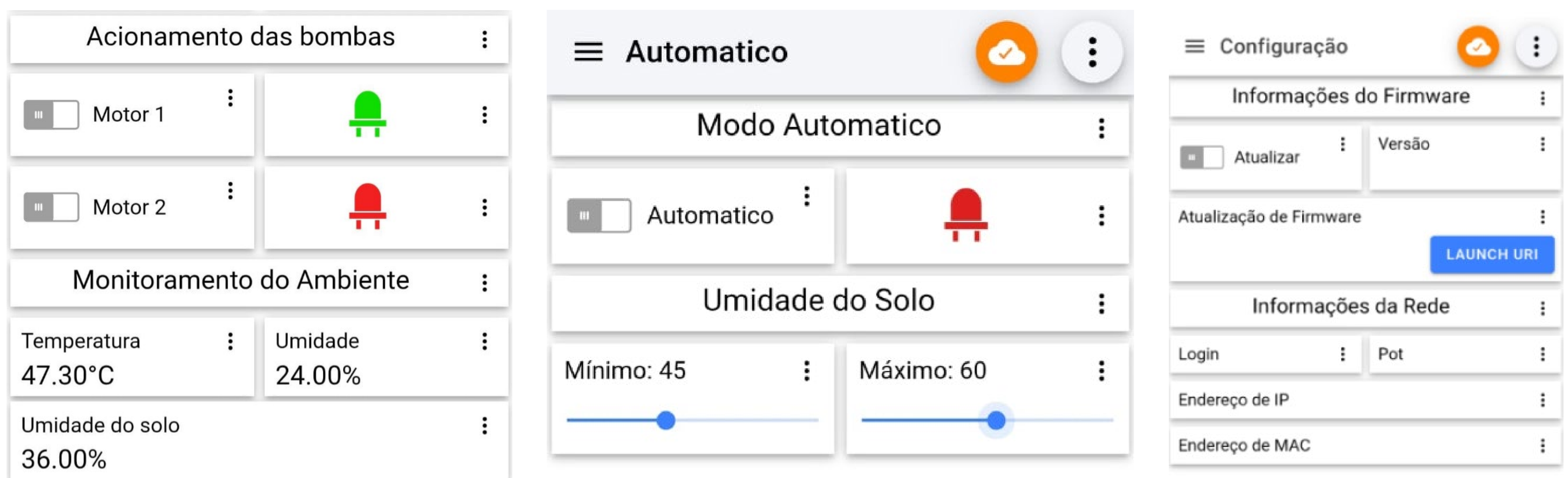


Source - Author

During the experiments, the system activated irrigation only when soil moisture values reached critical levels, resulting in a shorter total pumping time and, consequently, greater water use efficiency.

Communication via MQTT remained stable, ensuring continuous data updates in the SCADA system. The monitoring screens shown in Figure 2 demonstrate the interface used in the MQTT Panel application, allowing the user to monitor environmental parameters, make adjustments, and activate irrigation manually or automatically.

Figure 2 - (a) Manual monitoring and control screen; (b) Automatic control screen; (c) Configuration screen.



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Furthermore, Figure 3 shows the passion fruit plantation and the installed prototype, highlighting its practical application and the organization of the sensor and drive modules in the field.

Figure 3 - (a) Passion fruit plantation; (b) Prototype installed in the plantation.

Source - Author

CONCLUSION & FUTURE WORK

The results obtained demonstrated that the project met the established objectives, achieving a low-cost, modular, and scalable solution aligned with the needs of automation and sustainability in the agricultural context. As future work, the application of intelligent control techniques, such as weather forecasting and machine learning, is recommended to improve decision-making in irrigation. In addition, the adoption of photovoltaic power is suggested, making the system energy self-sufficient.

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