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Original Article

Design and Construction of a Real Time Monitoring System with Raspberry Pi and WhatsApp Applied in a Water Tank for Agriculture

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Abstract - *Water management is a critical aspect of modern agriculture. Efficient use of water resources can lead to increased crop yields and reduced costs. This article presents the design and construction of a real-time remote water tank monitoring system for agricultural applications using a Raspberry Pi and the WhatsApp mobile application. The system aims to provide farmers with an efficient and cost-effective solution to monitor water levels and control water inflow and outflow in a tank using two solenoid valves, enabling them to make informed decisions regarding irrigation, water conservation, and resource management. Tests suggest that integrating Raspberry Pi with the WhatsApp application is feasible and offers an accessible and user-friendly means for remote monitoring.*

Keywords - *Monitoring system, Real-time system, Water tank for agriculture, WhatsApp application, Rasperry Pi.*

1. Introduction

Agriculture, as the backbone of the world's food supply, faces a growing demand and unprecedented challenges today [1]. The need to increase food production to feed a continuously growing population has led to an intensification of agricultural practices [2]. However, this intensification is not without challenges, and one of the most pressing challenges is water management.

Water is a fundamental resource in agriculture, and its efficient management is essential to ensure optimal crop yields [3]. At a time when climate change is causing unpredictable weather conditions, and water scarcity is becoming a global concern, farmers are facing an increasingly complex task of balancing irrigation and water conservation [4]. Furthermore, in many rural areas, water supply infrastructure is limited, making water management even more critical [5].

One common challenge in agriculture is the lack of real-time visibility into water levels in tanks used for irrigation. Traditionally, farmers have relied on manual methods to monitor water levels, which are not only prone to errors but also consume valuable time and resources [6]. This often results in inefficient irrigation, water wastage, and, ultimately, crop and resource loss [7]. It is in this context that technology emerges as a key solution. The application of real-time monitoring technology can provide farmers with accurate and up-to-date data on water levels in their tanks, enabling them to make more informed decisions about irrigation [8]. These decisions, based on real-time data, can result in more precise and efficient water distribution, which in turn leads to a more sustainable use of water resources and increased crop yields [9]. This will require the use of some technology widely used by people so that system complexity is not an issue when monitoring water tanks. This article presents an innovative and affordable solution to address the current challenge of tank water care in agriculture: a real-time monitoring system based on Raspberry Pi and WhatsApp. This system allows farmers to receive instant notifications about the water level in their reservoirs and also provides them with a way to monitor environmental conditions that may affect irrigation.

By combining the versatile Raspberry Pi and the widely used WhatsApp messaging platform, this system becomes a powerful, easy-to-use tool for real-time data-driven decision-making. The ability to receive alerts and monitor water reservoirs from a smartphone, available to a large number of people, provides farmers with greater control and convenience in water management, which can significantly improve the efficiency and speed of their farming operations.

The information distribution in this document is divided as follows: Related work to this research is presented in Section 2. Subsequently, Section 3 develops and explains the completed methodology of this proposed system. In Section 4, the design and construction of the hardware and software system are detailed, as well as its implementation in a real agricultural environment. The analysis of the results and the discussions obtained are presented in Section 5. Finally, the conclusions of this research are found in Section 6.

2. Related Works

The use of real-time monitoring systems is widely employed in various reviewed studies, as evidenced by Muhammad et al.'s article [10], which utilizes a monitoring system with the WhatsApp application and Raspberry Pi 3 for home security. While this is a different application from crop monitoring, parallels in the use of these technologies can be established for real-time monitoring.

In another document [11], the authors also utilize the Raspberry Pi microprocessor for effective tracking in case of emergencies. Through an Android application, individuals send an alert signal in case of an emergency, allowing rescuers to respond as quickly as possible. Another paper [12] presents the analysis of an energy monitoring system of a switchgear industry in real-time using IoT; this was done thanks to the use of a Raspberry Pi due to its low cost and highly reliable technology to monitor the energy consumption of the industry; the Raspberry Pi uses the Node.js programming language to collect data from the energy meters of the industry and store them locally, to access them through a cell phone using Grafana, achieving useful results to minimize energy consumption.

In the literature related to water tank control, article [13] was reviewed, where a water tap system for toilets and water tank monitoring was developed using Arduino to control the water pump for automatically filling a water tank and to determine the amount of water in the tank using an ultrasonic sensor. Additionally, the Telegram application was used to inform recipients via text messages about the status of water taps, water pumps, and water levels.

In [8], the Internet of Things (IoT) was employed for monitoring a room using Raspberry Pi connected to sensors capable of reading temperature and humidity conditions. The data collected is displayed in a real-time graphical diagram and sent to users via the WhatsApp API. This document [14] presents the design of a system that utilizes a dissolved solids (TDS) sensor and an ultrasonic sensor to monitor the quality and level of water in the tank, transmitting the data to the real-time monitoring center through ZigBee, a wireless communication protocol.

Lastly, in [15], a system is presented for monitoring water tanks using an ultrasonic sensor installed in the water tank, connected to an Arduino device, and linked to a mobile application service that receives and manages tank water level measurements. In agriculture, significant advances have been made in the control and monitoring of irrigation with intelligent systems, as discussed in the article [16]. This article explores the most modern irrigation monitoring and control strategies that have been used in recent years for irrigation scheduling. It concludes that closed-loop irrigation control strategies are more efficient than open-loop systems that do not account for uncertainties. In addition, combining various soil-based, plant-based and climate-based monitoring methods in a predictive control modeling environment can significantly improve water use efficiency.

Furthermore, in [17], an exhaustive analysis of 94 articles related to the use of intelligent systems in the agriculture sector is conducted. The results indicate that the use of wireless communications such as Wi-Fi or ZigBee allows for better and cheaper maintenance, energy efficiency, ease of operation, and robust architecture.

3. Methodology

The article presents the design and development of a system capable of monitoring and sending real-time measurements of water level, temperature, and humidity from a water tank for agricultural applications. The complete design of the developed system can be observed in Figure 1.

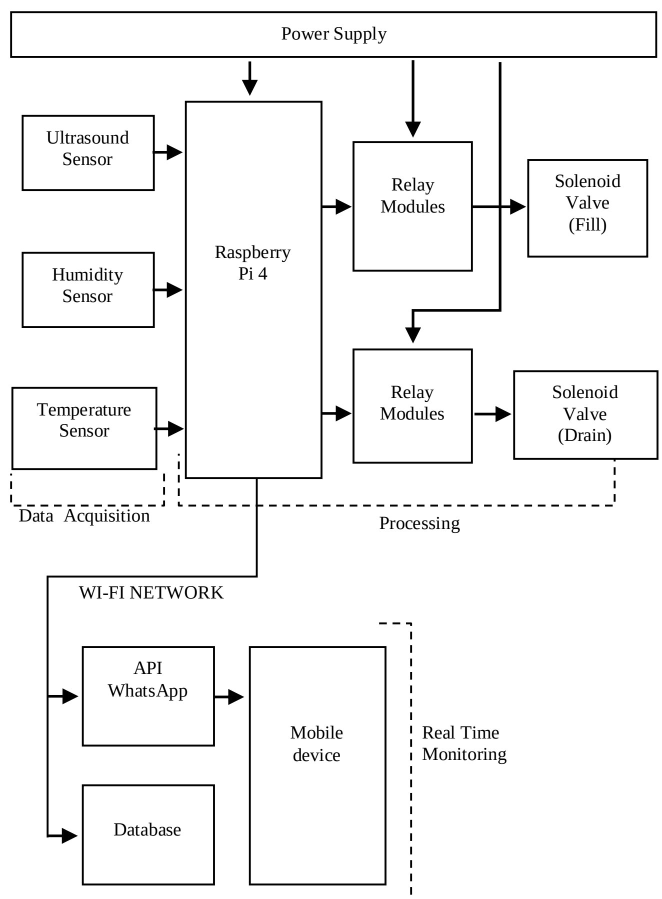


Fig. 1 Block diagram of the complete proposed system

The proposed water tank monitoring system consists of three stages:

- Data Acquisition: In this stage, the level, temperature, and soil humidity sensors send data through insulated cables to the Raspberry Pi microprocessor.
- Processing: The Raspberry Pi collects data from the sensors and analyzes it to properly control the filling and drainage valves of the water tank. In addition, all analyzed data is sent to a server via the Wi-Fi network generated by the Raspberry Pi.
- Real-Time Monitoring: The analyzed data is obtained on the server and, through a WhatsApp Application Programming Interface (API), data is sent to clients, allowing them to view it on their mobile phones and; in addition, this data is stored in a database. This allows optimal monitoring in real-time.

4. Experimental Development

4.1. Hardware Configuration

The system implementation began with the setup of the necessary hardware. A Raspberry Pi 4 Model B with 4GB of RAM was mounted, along with a 64GB microSD card containing the Raspberry Pi OS, an operating system designed specifically for Raspberry Pi. The Raspberry Pi was placed near the water tank in a protected location to ensure continuous operation. Figure 2 shows the placement of the hardware system components.

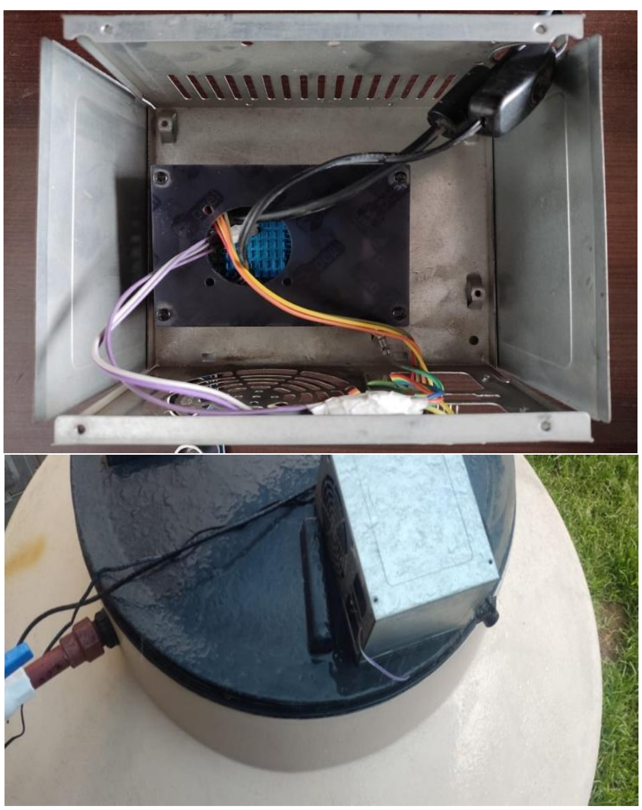


Fig. 2 Developed system installed in the water tank

An HC-SR04 ultrasonic sensor (U6) was connected to the GPIO pin of the Raspberry Pi 4 (U2) to measure the water level inside the tank. The ultrasonic sensor works by measuring the time it takes for an ultrasonic signal to travel from the sensor to the water surface and back. This time was converted into an accurate measure of the water depth in the tank. Other options available in the market are infrared sensors, but ultrasonic sensors were chosen for their low cost and high fidelity.

Additionally, a DS18B20 digital temperature sensor (U3) was used to measure the environment where the water tank was located. Furthermore, the YL-38 module (U4), in combination with the YL-69 soil moisture sensor (U5), was used to monitor the soil conditions in the area supplying the tank.

The operation of the YL-69 sensor is based on the soil's resistance to the flow of current, which varies inversely proportional to the moisture level. Therefore, measuring soil moisture is as simple as measuring the resistance between the two terminals of the YL-69 sensor. These sensors allow farmers not only to track the water level but also to understand the local environmental conditions that could influence water evaporation and crop health.

On the other hand, the Raspberry Pi is connected to two 12-volt solenoid irrigation valves, one responsible for filling the tank, while the other is responsible for draining it (U9 and U10, respectively) through two relay modules (U7 and U8), which allow or block the passage of water from the tank for filling and draining.

This action provides more optimal control and correct supply of water resources to the fields. Finally, the entire system is powered by a 5-volt direct current (DC) voltage source provided by the LM7805 module (U1), which is supplied with a 12-volt DC input voltage (VIN), also used to power the solenoid valves. The connections of the electronic components can be seen in Figure 3.

4.2. Algorithm Developed

4.2.1. Python Programming

Scripts were developed in Python for the Raspberry Pi. These scripts were responsible for interacting with the sensors, collecting real-time data, and processing the information. The ultrasonic sensor measured the distance from the water surface to the sensor and converted it into an accurate measurement of the water level in centimeters.

The DS18B20 sensor measured ambient temperature and the YL-38 and YL-69 modules measured soil moisture. The opening and closing system of the solenoid valve allowed the passage of water as needed, and all this data was recorded and stored in a database to have a complete history of each measurement. The scripts ran in a continuous loop, allowing for constant data acquisition.

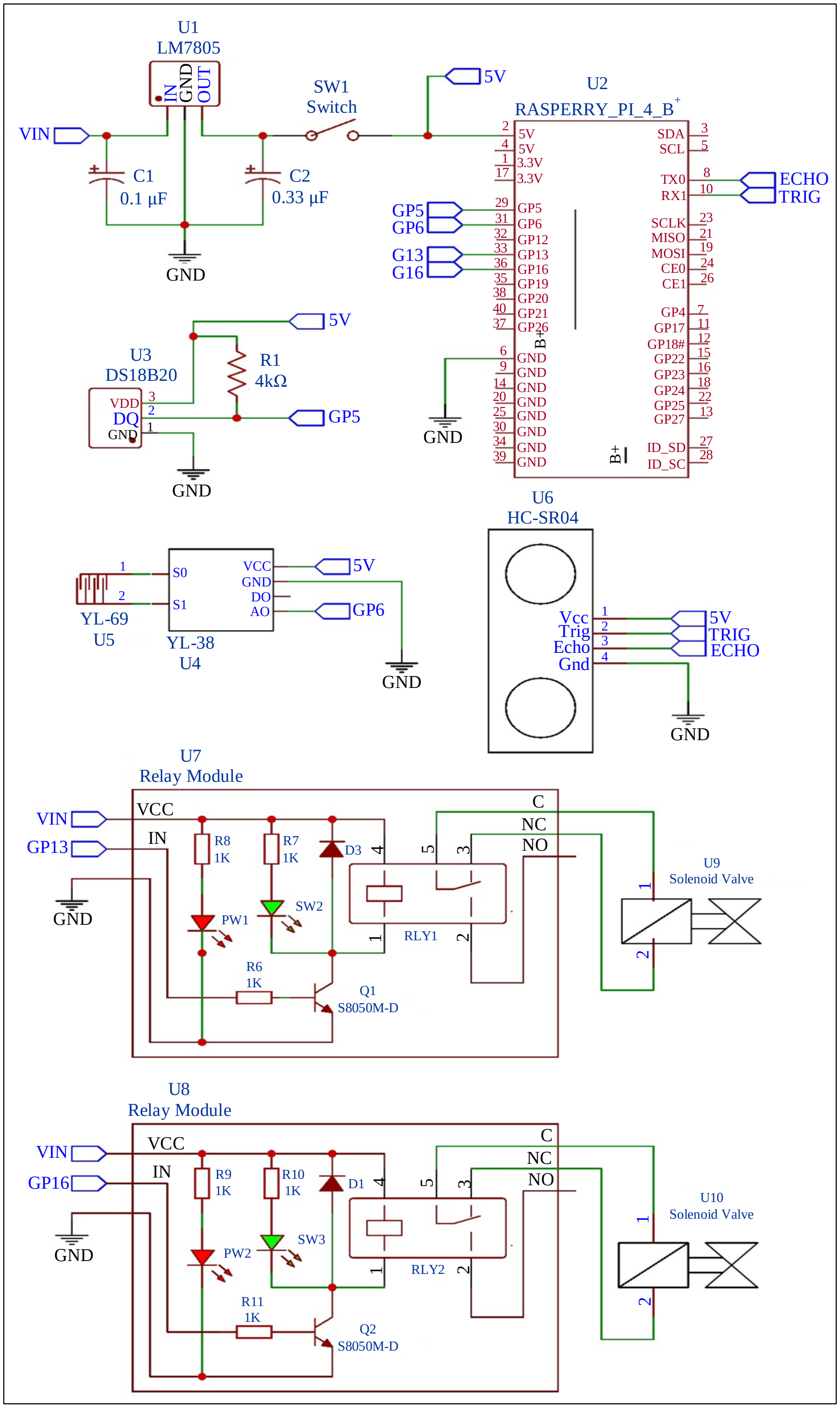


Fig. 3 Connections of the electronic components of the system

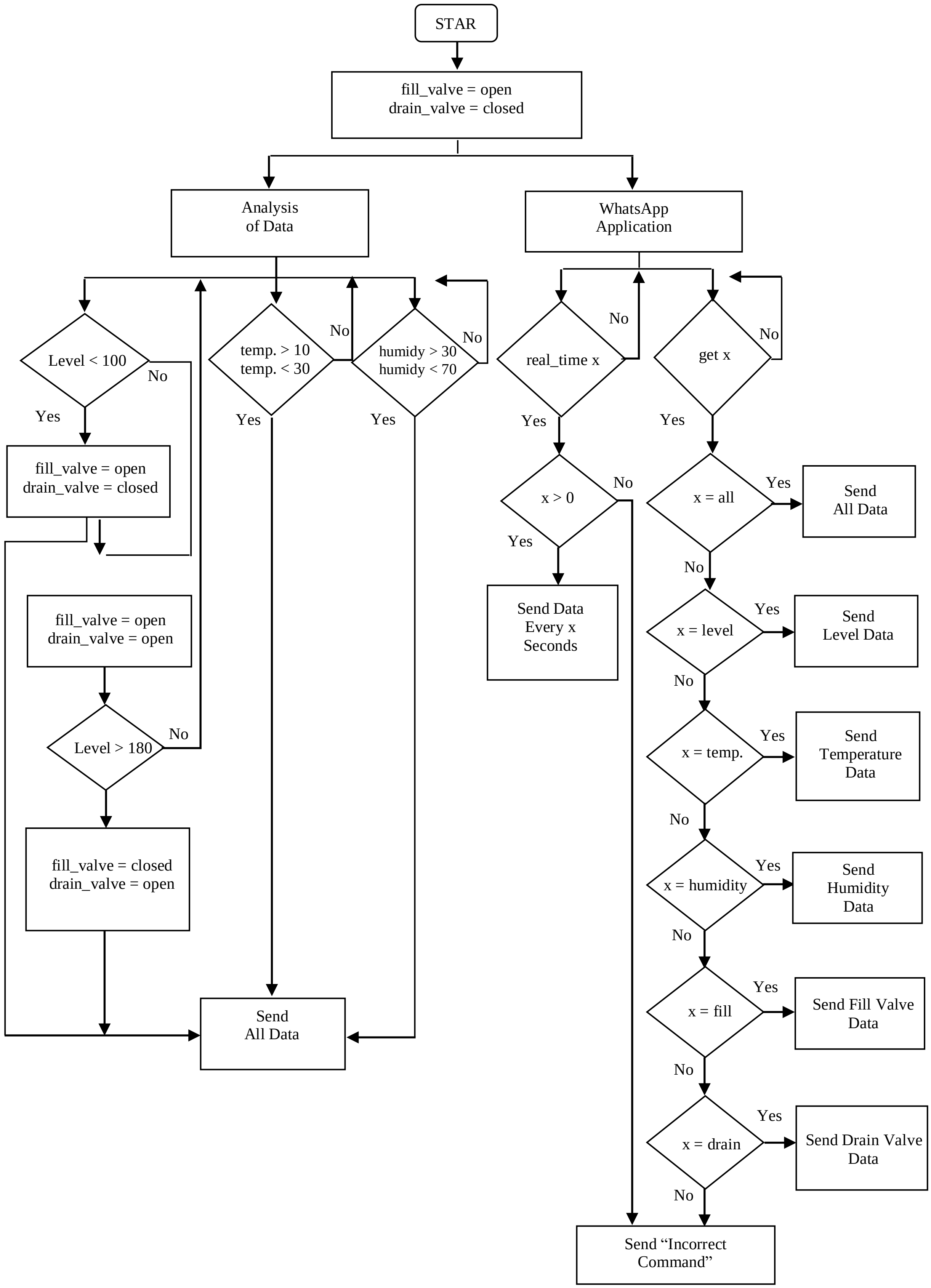


Fig. 4 System programming flow chart

4.2.2. Integration with WhatsApp Application

The Raspberry Pi was connected to the internet via a local Wi-Fi connection. A WhatsApp API was configured to enable communication between the Raspberry Pi and the farmer's WhatsApp number, which receives real-time notifications from the system. In the initial setup, a WhatsApp number was registered in the API, and authentication credentials were generated. A Python alert logic was programmed to compare the collected data with predefined thresholds. When the water level in the tank fell below a specific threshold or adverse environmental conditions were detected, the system sent a WhatsApp message to the farmer's number. This message included information about the situation, such as the alert time, water level, and environmental conditions.

4.2.3. Sending Real-Time Alerts

The data sent to the WhatsApp application works by accessing two different functions incorporated into the software system's programming through messages with keywords. These three functions are:

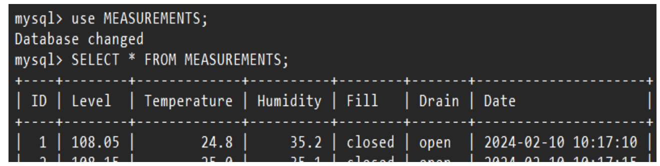
- real_time X: Sending this phrase via the application initiates the data sent from the sensors every X seconds. The value of X can range from 0 to 3600, with 0 halting the data sending.
- get X: The application sends a single message with the requested sensor and valve data, with possible options including: "all", "level", "temperature", "humidity", "fill", "drain".
- Any other message sent will result in an automatic response of "incorrect command."

Additionally, the system features automatic alert sending, which activates when any of the measurements exceed the previously configured threshold. This action immediately sends a message with the values of all sensors and the status of the valves.

The alert logic was designed to operate in real-time, ensuring farmers receive immediate notifications about any changes in water levels in the tank or adverse weather conditions. This allowed them to take timely measures to manage irrigation and conserve water efficiently. The successful implementation of this system enabled farmers to have greater control and visibility over their water resources, contributing to the improvement of the efficiency of their agricultural operations and water conservation, which is a critical resource in agriculture.

4.2.4. Database Storage

The data obtained from the ultrasonic, temperature, and humidity sensors, as well as the data on the opening and closing of the solenoid valve, are stored locally in a database created with MySQL software on the Raspberry Pi. The database records the date and time of each measurement along with the water level, temperature, and humidity values, and when the water tank solenoid valve is closed or opened. This allows farmers to access a historical record of data to make informed decisions. In Figure 5, a screenshot of the locally stored database can be observed.



```
mysql> use MEASUREMENTS;
Database changed
mysql> SELECT * FROM MEASUREMENTS;
+----+--------+-------------+----------+--------+-------+---------------------+
| ID | Level  | Temperature | Humidity | Fill   | Drain | Date                |
+----+--------+-------------+----------+--------+-------+---------------------+
|  1 | 108.05 |        24.8 |     35.2 | closed | open  | 2024-02-10 10:17:10 |
```

Fig. 5 Capture of the database developed in MySQL

5. Results and Discussion

5.1. Real-Time Monitoring Results

During the system implementation, real-time monitoring of water levels in the irrigation tank was successfully achieved. The ultrasonic sensors provided precise measurements of the water level, with a resolution of centimeters. Data was continuously collected and recorded in the local database of the Raspberry Pi.

Additionally, the temperature and humidity sensor allowed farmers to understand the environmental conditions that could affect water evaporation and, therefore, irrigation. This provided a more comprehensive view of the conditions in the tank's surroundings. The level measurements in centimeters made by the HC-SR04 ultrasonic sensor throughout one day, with a sampling of one hour, can be seen in Figure 6.

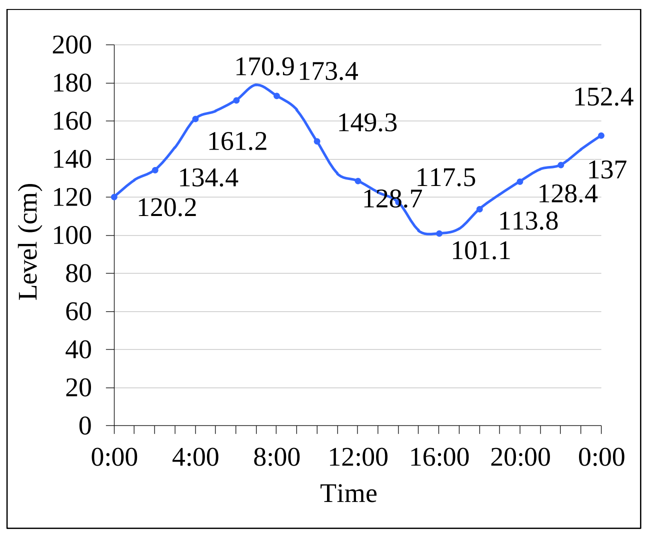
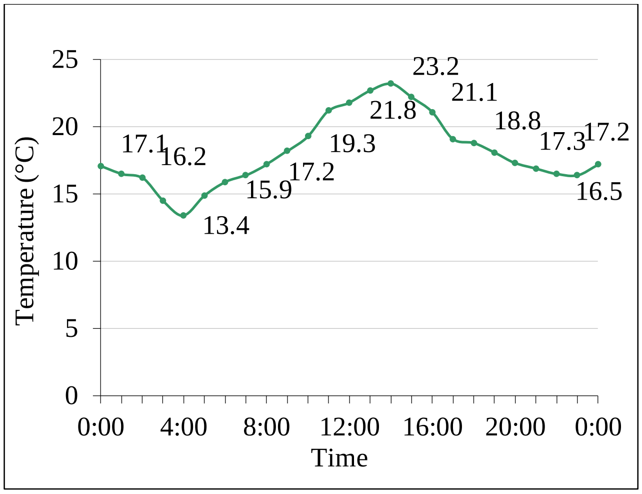
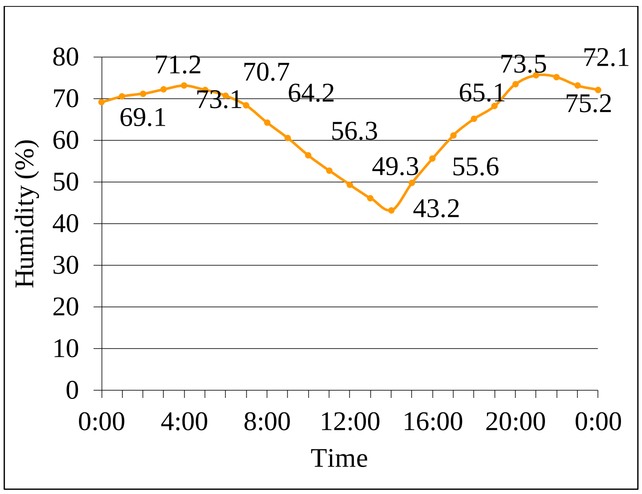


Fig. 6 Level measurements during a day

Figure 7 displays graphs of temperature and humidity measurements taken over the course of a day; in both figures the measurements are taken every hour to be able to graph correctly. In Figure 7 (a), temperature measurements conducted by the DS18B20 sensor are depicted, while in Figure 7 (b), humidity measurements conducted by the YL-38 and YL-69 sensors are shown.



(a)



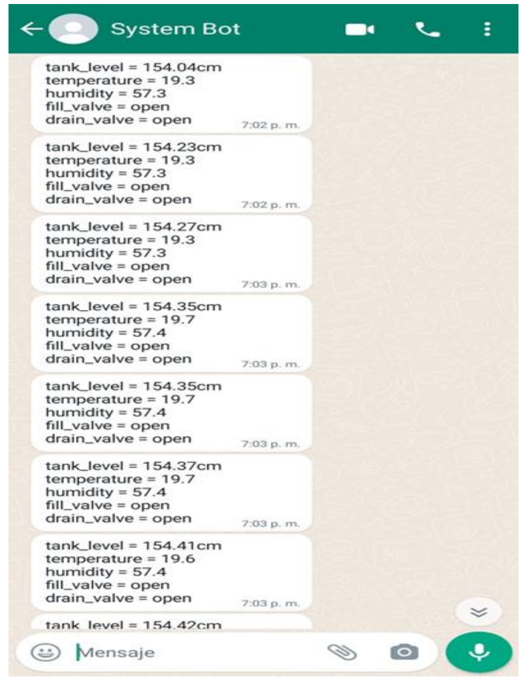
(b)

Fig. 7 Graph of the measurements made by the sensors (a) Temperature measurements, and (b) Humidity measurements.

The solenoid valve also demonstrated proper functioning, as the system could open and close it as required based on sensor measurements. The system proved to be a valuable tool for irrigation optimization. Farmers were able to make more informed irrigation decisions based on real-time data. When water levels dropped below the threshold, farmers received alerts that allowed them to schedule irrigation efficiently, avoiding water wastage and optimizing its use. This responsiveness to changing conditions in the field significantly contributed to water conservation.

5.2. Alert System Results

The implemented alert logic proved to be effective. When water levels fell below the established threshold, or adverse weather conditions were detected, the system sent immediate alerts to the farmer's phone via WhatsApp. This allowed farmers to act in time to adjust irrigation or apply corrective measures because a large number of people have their cell phones at their fingertips. Two images of the WhatsApp application receiving messages from the monitoring system can be seen in Figure 8.



(a)

(b)

Fig. 8 Testing notifications in the WhatsApp application (a) Application receiving messages in real-time, and (b) Application receiving messages requested by the user.

Table 1. Measurements stored in the database

ID	Tank Level (cm)	Temperature (°C)	Humidity (%)	Fill Valve	Drain Valve	Full Date
1	101.25	22.8	55.2	Open	Open	2024-01-10 11:00:00
2	101.22	22.7	55.1	Open	Open	2024-01-10 11:00:05
3	100.87	22.7	55.2	Open	Open	2024-01-10 11:00:10
4	100.42	22.6	55.3	Open	Open	2024-01-10 11:00:15
5	100.21	22.4	55.3	Open	Open	2024-01-10 11:00:20
6	100.05	22.5	55.2	Open	Open	2024-01-10 11:00:25
7	99.97	22.4	55.2	Open	Closed	2024-01-10 11:00:30
8	99.91	22.4	55.1	Open	Closed	2024-01-10 11:00:35
9	99.93	22.5	55.1	Open	Closed	2024-01-10 11:00:40
10	99.97	22.4	54.9	Open	Closed	2024-01-10 11:00:45
11	100.11	22.3	55.0	Open	Open	2024-01-10 11:00:50
12	100.02	22.3	55.1	Open	Open	2024-01-10 11:00:55
13	100.14	22.4	55.1	Open	Open	2024-01-10 11:01:00

The ability to monitor and receive real-time alerts about the water level in the tank provided farmers with greater control over their water resources. This translated into more efficient water resource management, which in turn had a positive impact on the sustainability of agricultural operations. The implementation of the system helped address the challenge of water scarcity in many agricultural regions. The ability to access data and receive alerts via WhatsApp provided farmers with convenient remote access to the monitoring system. This allowed them to monitor their water tanks and make decisions from anywhere with internet access. The WhatsApp interface proved to be an effective option for real-time communication, as it is widely used and easy to use.

5.3. Data Logging Results

The system generated a comprehensive data log that included the date and time of each measurement along with the values of water level, temperature, and humidity. This provided farmers with a data history that they could use for trend analysis and long-term decision-making. Table 1 displays some data stored in the database over a one-minute period.

6. Conclusion

This study has presented the design and implementation of a real-time monitoring system using Raspberry Pi, and WhatsApp applied to a water tank for agriculture. The results obtained and the discussions presented highlight the effectiveness of this system as a valuable tool for efficient water management in agriculture. The successful implementation of the system allowed farmers to monitor and receive real-time alerts about water levels in their tanks, leading to more informed decision-making regarding irrigation. This resulted in a significant reduction in water waste and increased efficiency in water resource management in agriculture.

Additionally, integrating the WhatsApp messaging platform as an interface for real-time communication proved to be a wise choice, as it provided farmers with convenient remote access to the system. Tests demonstrated the effectiveness of sending sensor and solenoid valve data in real-time and the proper storage of data in a database. The accessibility and convenience provided by WhatsApp allowed for constant monitoring of water levels and an immediate response to alerts, enhancing farmers' management capabilities. This system not only contributes to water management efficiency and conservation of water resources but also aligns with the goals of sustainable agriculture.

While the results of this implementation are promising, opportunities for improvement are acknowledged. In future implementations, the incorporation of an automated irrigation control system and the integration of weather forecasts could be considered to further enhance irrigation management and decision-making. Additionally, for configuring the WhatsApp API, there are plans to develop a mobile application in the future to facilitate the setup of the farmer's phone number.

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