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Remotely controlled water channel system for laboratory education utilizing internet of things and SCADA technologies

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ABSTRACT

This paper was discussed the hardware components of a remotely controlled water channel management system for laboratory education utilizing the internet of things (IoT) and supervisory control and data acquisition systems (SCADAs). The system consists of various sensors and devices included the air pressure sensor (mpx5010dp), water pressure sensor, ultrasonic distance sensor (JSN-SR04T) and solenoid water valve plastic. The air pressure sensor (mpx5010dp) was used to detect the water level in the manometer of the pitot tube, a water pressure sensor for detecting the pressure of water, an ultrasonic distance sensor (JSN-SR04T) for detecting the level of water in the channel, a solenoid water valve plastic with relay for protecting the motor when the water level in the tank reduces to 5 cm. These components work together to monitor and control the water channel system remotely, providing users with a more scalable, flexible, and accessible solution for laboratory education. Also, a web page was developed with an IoT and SCADA system for remote control and management of a water channel system that was used for teaching hydraulic and hydrological concepts to students.

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1. INTRODUCTION

The internet of things (IoT) and supervisory control and data acquisition (SCADA) systems are technologies that are increasingly being utilized in a variety of sectors: used in modern industrial and education [1], [2]. The integration of these technologies into educational laboratories can offer numerous benefits, such as enhancing the learning experience of students and improving the efficiency and effectiveness of laboratory operations [3]. IoT refers to the interconnected network of physical devices such as vehicles, buildings, and other objects that are embedded with sensors, software, and network connectivity which was allowing them to collect and exchange data [4], [5]. The SCADA systems are used to monitor and control industrial processes and infrastructure remotely, such as power plants and water treatment facilities [6]. The used of IoT SCADA systems in educational laboratories were helpful for students with a hands-on learning experience through simulates real-world scenarios and allows them to test and analyze data collected from remote control with various sensors and devices [7]. The integration of IoT SCADA systems into educational laboratories [8] can improve the efficiency and effectiveness of laboratory operations by automating tasks and enabling remote monitoring and control system.

In response to the limitations of commercial SCADA systems such as high costs and compatibility issues, various research communities worldwide have developed several open-source SCADA technologies. Rodriguez *et al*. [9] present a software architecture that can be used to develop educational laboratories using virtual industrial plants, which is implemented in MATLAB and used in laboratory virtual instrument engineering workbench (LabVIEW) through an appropriate protocol. The main objective of this approach is to facilitate students' learning of basic concepts and techniques for an industrial informatics course. Additionally, the authors present different virtual industrial plants that have been developed using SCADA systems to illustrate the use of the proposed architecture. These plants are designed to cater to the needs of students with different bachelor's and master's degrees in engineering at the University of Almeria. Rajkumar *et al*. [10] proposed a cost-effective open-source SCADA system that employs an Arduino Uno micro-controller as a sensor gateway and ZigBee radio devices for transferring data from their ground instrumentation equipment, including flow sensors, temperature sensors, level sensors, solenoid valves, and pumps. This system provided a low-cost and effective solution for monitoring and controlling different parameters in various applications. By utilizing open-source technologies, researchers can develop and customize their SCADA systems according to their specific needs and requirement, without being constrained by the limitations of proprietary systems.

Unde and Kurhe [11] described the development and implementation of an economical and open-source SCADA system that utilizes Thinger.IO and ESP32 Thing. SCADA technology allows for the management and real-time monitoring of dispersed processes through four basic components, including field instrumentation devices (FIDs), remote terminal units (RTUs), master terminal units (MTUs), and SCADA communication channels. The proposed IoT-based SCADA system is built on an internet of things architecture, which combines web services with conventional SCADA for more robust supervisory control and monitoring. Merchan *et al*. [12], developed an open-source SCADA system using Python, a high-level programming language. The proposed model consists of multiple levels, including the device layer for the plant being controlled, the controller layer with two programmable logic controllers (PLC), and the supervision layer with a human-machine interface (HMI) SCADA client and Python open platform communications-unified architecture (OPC-UA) server with a MySQL database, all installed on a Raspberry Pi3. Communication between the control devices is established via Ethernet. However, the SCADA system utilizes a significant number of components, which may result in increased power consumption and reduced reliability. Prokhorov *et al*. [13] designed an open-source SCADA system to monitor water levels and flow rates in a container, utilizing the Open-SCADA platform to generate HMIs for data display. However, a significant drawback of the Open-SCADA system is required a considerable amount of logic programming to ensure accurate data collection and display. Additionally, the software is not completely free, as customers are required to pay for subscriptions. These limitations should be taken into account when considering the feasibility of using the Open-SCADA system for water monitoring applications.

In general, incorporating IoT SCADA systems into educational laboratories holds the promising potential to enhance the quality of student's learning experience and optimize laboratory operations. However, there is still a need for additional research to comprehensively examine the advantages and limitations of integrating these advanced technologies into educational settings. This would enable us to fully understand how these systems can be best utilized to improve learning outcomes and streamline laboratory procedures. Therefore, IoT SCADA [14], [15] systems investigation is required to better understand the implications of implementing IoT SCADA systems in educational laboratories.

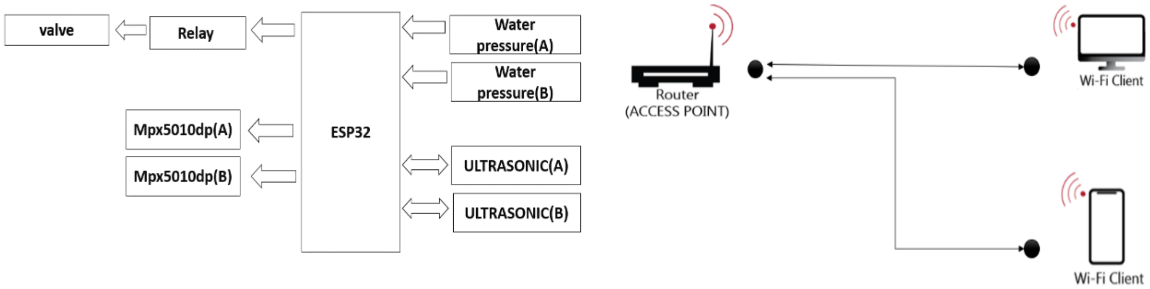
2. METHOD

2.1. Hardware equipment

The hardware is divided into two block diagrams. The block diagram of the proposed system is shown in Figure 1. Data acquisition described in Figure 1(a) and the block diagram of remote access was shown in Figure 1(b). The data acquisition system is consisting of several hardware components: the air pressure sensor (mpx5010dp), a water pressure sensor, an ultrasonic distance sensor (JSN-SR04T), a valve, a relay, and a microcontroller (ESP32). The system was measuring the speed of water and rate by finding a different level of water in U-manometer [16]. The two-air pressure sensor (MPX5010DP) [17] and the two water pressure sensors were used to detect the pressure of water upstream and downstream of the channel. the two ultrasonic distance sensors (JSN-SR04T) were used to detect the level of water in tank and channel [18]. The data acquisition syetem had a solenoid water valve made of plastic used to regulate the flow of water in the system. The valve will be activated by a relay when the water level drops below a certain point to keep the water supply remains consistent.

The proposed system also included a microcontroller (ESP32) that receives data from the various sensors [19] and activates the solenoid water valve when necessary. The microcontroller is also responsible for sending data to the remote-control system that allow user to monitor the water level remotely from web page. The use of an ultrasonic distance sensor, in particular, allows for precise measurement of the water level in a channel. The solenoidwater valve and relay [20] ensure that the water supply remains consistent, even in situations where the water level drops unexpectedly. the water level detection system described in this report is a sophisticated and reliable system that is suitable for use in various environments [21].

The Figure 2 was shown the wire connection of the valve and sensors with the microcontroller (ESP32). The system's versatility and convenience are further enhanced by the use of a microcontroller (ESP32), which allows for remote monitoring of the system.



(a) (b)

Figure 1. Block diagram for (a) data acquisition and (b) remote access

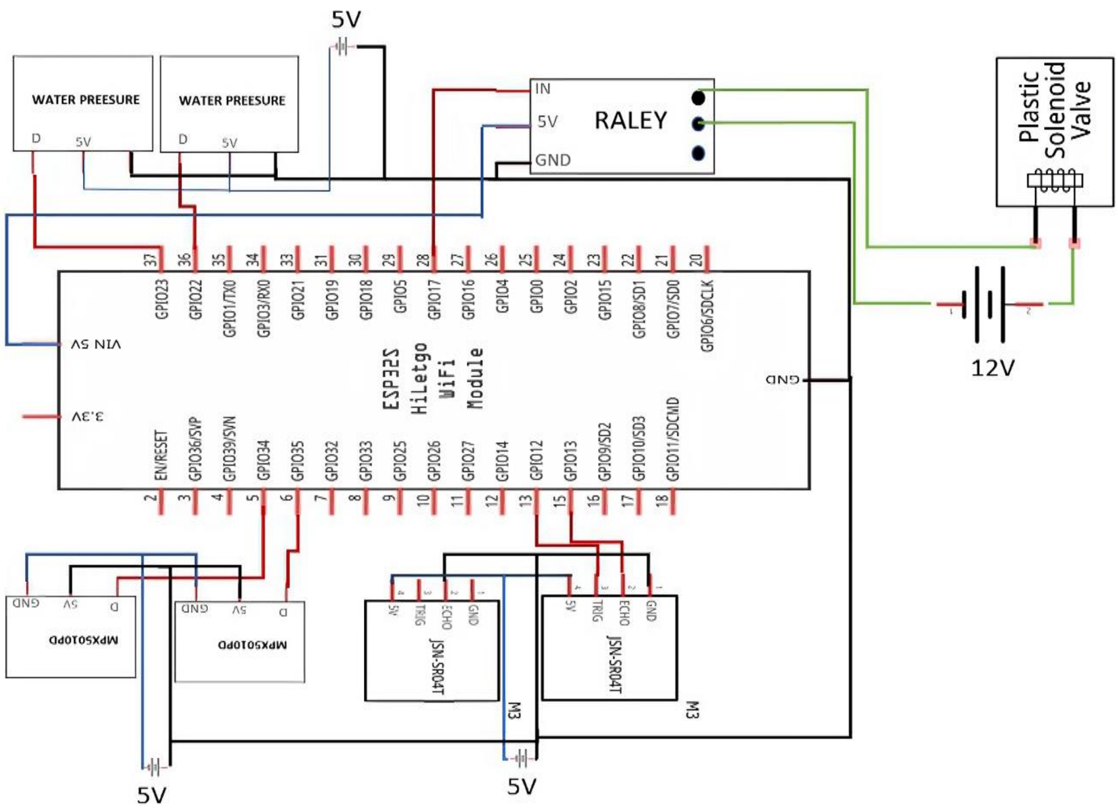


Figure 2. The hardware of the system

2.2. Software

The software utilized in the proposed system comprised hypertext markup language (HTML), cascading style sheets (CSS), and JavaScript for web page programming and an integrated development environment (IDE) for the microcontroller (ESP32) programming [22], [23]. Figure 3 was described the flowchart of the system. The data were analyzed and displayed data on a web page, one effective way to analyze and visualize that data is by using chart.js and amCharts.js [24], [25]. One of the key features of amCharts.js is its ability to handle large data sets, making it ideal for analyzing data from microcontrollers. Using these libraries, you can easily visualize data from your ESP32 and gain insights into how it is performing. In order to utilize chart.js, and a web server must first be established on the microcontroller (ESP32) to send the data [26]. The water channel level data was masured the ultrasonic sensor (JSN-SR04T), speed of the water by air pressure sensor (MPX5010DP), and water pressure by water pressure sensor. The data on web server can be visualized on a webpage using chart.js and amCharts.js by including the chart.js library and amCharts.js library in an HTML file and creating a chart instance in JavaScript code. The chart will display the speed of water and rate, as well as the water level difference in the U-manometer over time. The system also includes a bar chart to display the water level in the tank and channel and a donut chart to display the water level in the channel, tank, and pipes. Additionally, two gauges can be created to display the water pressure. Figure 4 shows a webpage for the system.

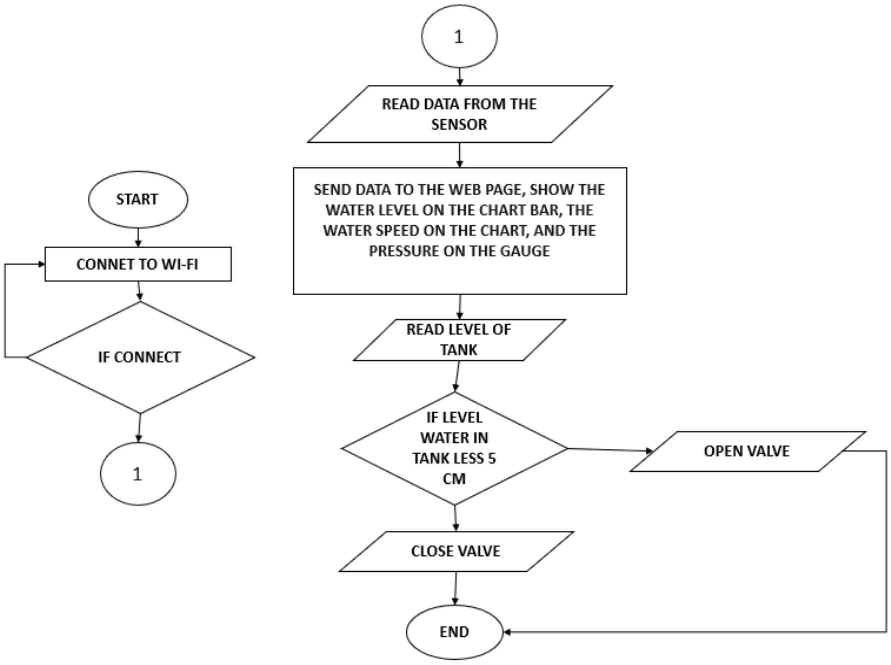


Figure 3. Flowchart of the system

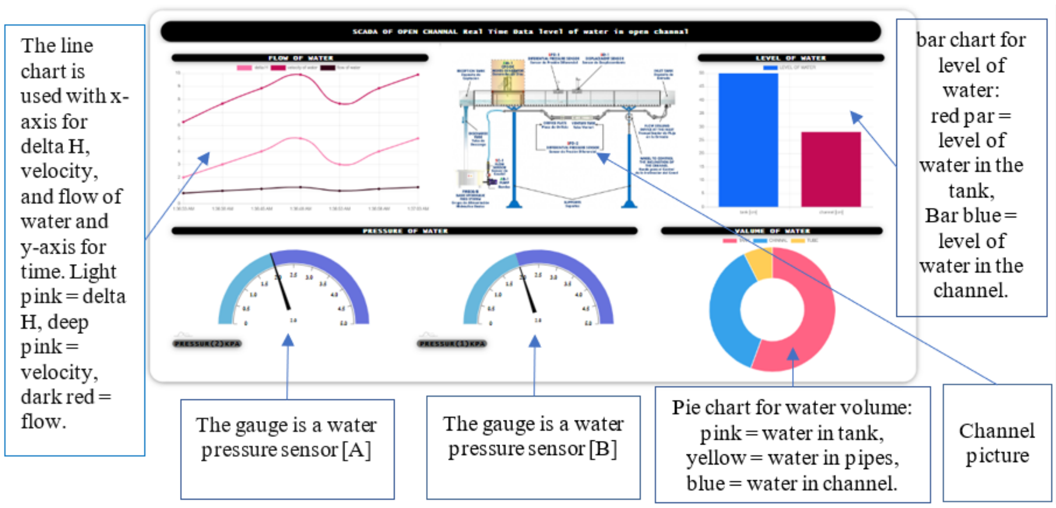
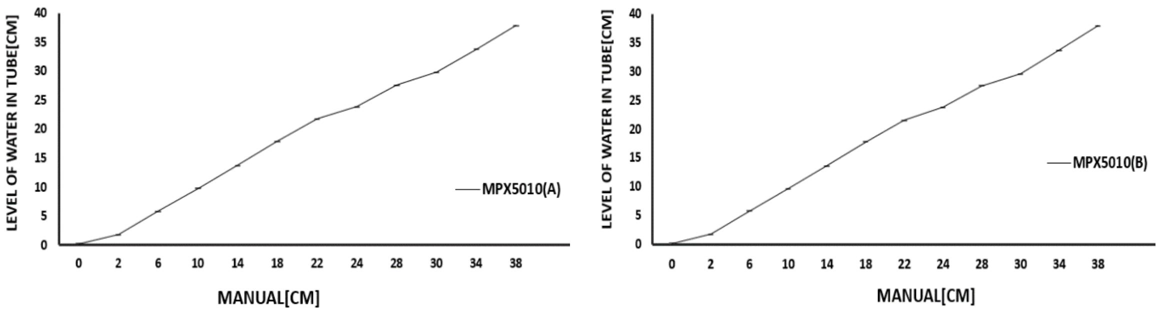


Figure 4. Page of the system

3. RESULTS AND DISCUSSION

In order to verify the accuracy and effective measured data with therretical result in water channel. The webpage was desined to enabled remote monitoring and control of the water channel system, that is help students to visuals, observe and analyze its in real-time behavior. Students could adjust system parameters and see immediate results through line chart, gauge bar chart and pie chart in the webpag. The proposed system was to determine the velocity of water across a pitot tube using two air pressure sensors (MPX5010DP), the water pressure was maintained at 5kPa, and the water level was determined by two ultrasonic sensors (JSN-SR04). The two air pressure sensors (MPX5010DP) were allowed for precise measurement of the water level in the U-manometer tubes, which were connected to the pitot tube. Figure 5 was presented the accuracy of air pressure sensor (MPX5010DP) readings and compares them with theoretical results. The result of the first air pressure sensor is shown in Figure 5(a) and the result of the second air pressure sensor is shown in Figure 5(b). Figure 6 was shown a comparison between the readings obtained by the SCADA system and the manual readings. The results demonstrated that the readings obtained by the SCADA system are converging with the manual readings, indicating that the system is accurate and reliable. This is an important to observed the system can be used with confidence to monitor water levels in real-time, without the need for manual measurements. Overall, the MPX5010DP sensors and the SCADA system provided an accurate and efficient method for monitoring water levels in a range of applications.



(a) (b)

Figure 5. Accuracy comparison manual versus (a) air pressure sensor (MPX5010DP) [A] and (b) air pressure sensor (MPX5010DP) [B]

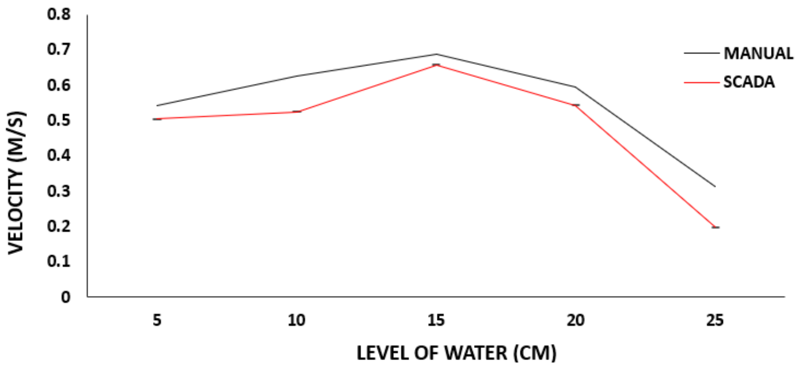


Figure 6. The difference in water speed readings between the SCADA system and manual measurements

The ultrasonic sensors (JSN-SR04) were utilized to determine the water level in both an open channel and a tank. Water level measuring apparatus was employed. The results obtained from the ultrasonic sensors were shown in Figure 7, which demonstrated consistency and accuracy in the measurements. As the distance from the fixed point of measurement increased, the correction value increased as well. This suggests that the accuracy of the measurements was maintained even at greater distances from the fixed point. Overall, the use of ultrasonic sensors proved to be an effective and reliable method for measuring water level in both open channels and tanks.

To measure the water pressure, two sensors were employed, one in upstream of the channel characterized by high pressure and the other downstream of the channel. The sensors were used to collect five samples of the water level in the channel set at different levels, and the results were compared with manual readings obtained from the manometer. The convergence of the values between the two sensor readings and the manual readings was demonstrated by the results presented in Figure 8. The first water pressure sensor results shown in Figure 8(a) and the second water pressure sensor results shown in Figure 8(b), which showed a low standard deviation. The efficiency of the sensors in detecting water pressure was confirmed. Overall, the combination of the microcontroller (ESP32), with the air pressure sensor (MPX5010DP), water pressure sensors, and ultrasonic sensors (JSN-SR04) enabled the precise and accurate measurement of water velocity, water pressure, and level in the flow channel.

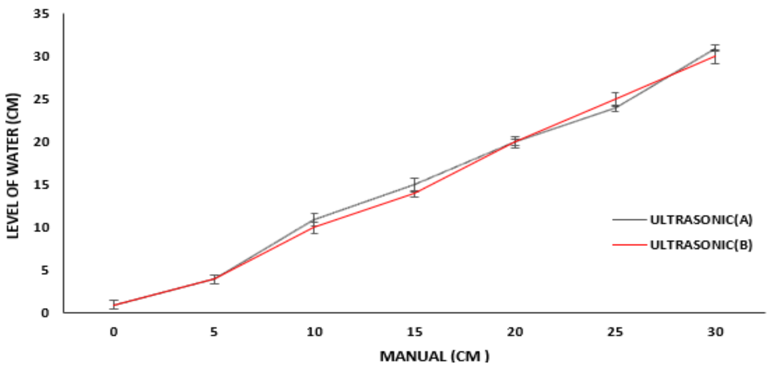
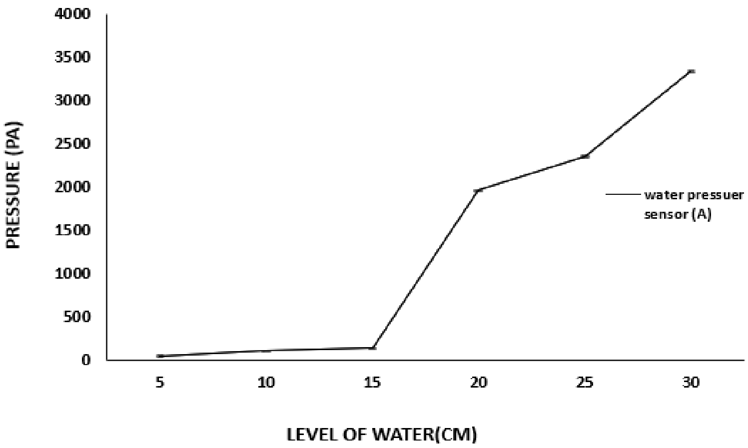
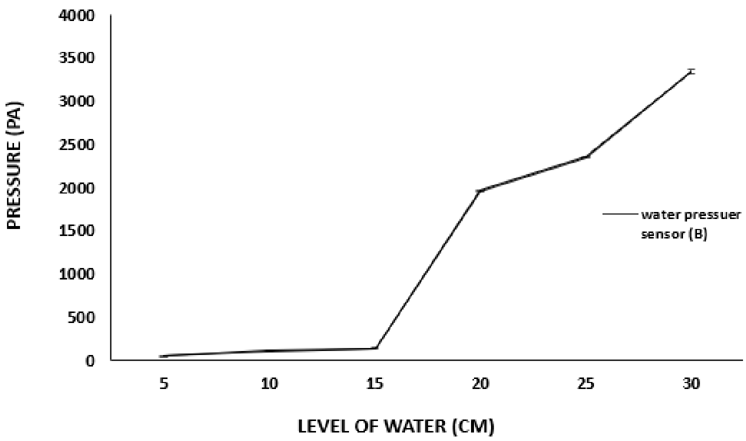


Figure 7. Accuracy comparison of the ultrasonic sensors (JSN-SR04) with the manual



(a)



(b)

Figure 8. Comparing the reliability of manual with (a) water pressure sensors [A] and (b) digital water pressure sensors [B]

4. CONCLUSION

In conclusion, this paper described the development of a water level detection system that utilizes IoT and SCADA technologies. The system includes hardware components such as air pressure sensors, water pressure sensors, ultrasonic distance sensors, valves, relays, and a microcontroller (ESP32), as well as software components such as HTML, CSS, JavaScript, and chart.js. The combination of these components provided an accurate and reliable method of measuring water level, water speed, and water pressure, as well as regulating the flow of water in a water supply system. The system is designed to provide accurate measurements of the water level and ensure that the water supply remains consistent. The use of an ultrasonic distance sensor allows for precise measurement of the water level in a channel, while the solenoid water valve and relay ensure that the water supply remains consistent, even in situations where the water level drops unexpectedly. The system's versatility and convenience are further enhanced by the use of a microcontroller (ESP32), which allows for remote monitoring of the system. For future work, it is important to note that factors such as water viscosity and temperature may affect the accuracy of the measurements, and further studies may focus on addressing these limitations to improve the precision of the results. The study may concentrate on investigating these elements and creating techniques to take them into consideration.

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