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Original Research Article

Wireless Water Level Detection System

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Abstract: The irrigation system is crucial in ensuring that each field receives the necessary water supply to meet the crops' demands. It is essential to ensure that the water flow is consistent and uninterrupted and that the water levels are monitored and controlled. Therefore, this paper designs a wireless water level detection system that works automatically by reading the height of the water level using an ultrasonic sensor. Then, the water level data is sent to an application so that the users can monitor the height of the water in real-time. This system was designed using two main components: an HC-SR04 ultrasonic sensor and a NodeMCU microcontroller. The HC-SR04 periodically transmits data on the water level in real time, and then the NodeMCU uploads this data to the monitoring platform. Finally, the wireless water level detection system is tested in a laboratory environment. A solid linear regression was obtained between the measured and actual water level height (R2=0.99).

Keywords: Internet of Thing (IoT); wireless water level; water level; irrigation; HC-SR04 ultrasonic sensor; NodeMCU microcontroller

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1. Introduction

Generally, many types of irrigation are implemented in the agriculture sector. They cover from traditional methods of supplying water to rice paddies on a small scale using manual or low-tech irrigation techniques to modern high-tech approaches. Canal irrigation is a traditional method; the main canals are constructed to distribute water from the water source to different paddy fields. In addition to the main canals, subsidiary canals are dug to supply water to individual plots or terraces. These smaller canals branch out from the leading canal network, delivering water to specific areas. A siphon transfers the water from the main canals into the subsidiary canals. This traditional system of irrigation is popular for small-scale paddy farmers but is currently being improved by agencies responsible for the paddy sector, such as Lembaga Kemajuan Pertanian Muda (MADA), Lembaga Kemajuan Pertanian Kemubu (KADA) and Rancangan Felcra Seberang Perak (Trans Perak). In this type of irrigation, water sources were collected from significant river networks or regulated by reservoirs at the upstream site.

However, the shift towards direct seeding in rice farming because of mechanization has significantly impacted the demand for irrigation water. They make it much more critical for farmers to control the amounts and timing of water deliveries. Moreover, in practice, they also mean that planting and harvesting dates are less uniform than they used to be, so neighbouring farmers no longer demand water simultaneously. It is technically impractical to meet mechanised farms' increasingly individualized water demands through gravity-based surface flow systems like those supported in this scheme. Since the current irrigation network system cannot fine-tune and micro-plan water deliveries, the canals generally deliver more water per hectare than necessary (Toriman & Mokhtar, 2012).

In order to implement direct seeding in rice farming, a reliable water source is necessary. The water levels along the main canals must be maintained according to system guidelines. This ensures the supply of required flows to each location within the irrigation systems (Lee *et al.*, 2005). An improvement can be made following the actual conditions in the field related to the availability of water sources (Kusumastuti *et al.*, 2021). The flow rates of primary, secondary and tertiary canals must be monitored to efficiently distribute water to agricultural fields (Fan *et al.*, 2023).

Water level and flow rates have been simultaneously measured for hydrological data measurements (Mamat et al., 2022) and flood early warning systems (Yoeseph *et al.*, 2022). A novel approach for determining water discharge using water flow velocity, sectional area width, and sectional average depth was proposed by Prakash *et al.*, (2022). Their approach was more accurate than measuring at a single point and neglecting the stream's cross-sectional area based on the water's average velocity. However, the length of the cable that connects the sensor to the controller can affect the data's reliability (Hostalrich *et al.*, 2022) due to signal degradation, voltage drop, response time, noise and interference.

Several attempts have been made to provide an effective monitoring system to observe the level of water using an open circuit (Hernández-Nolasco *et al.*, 2016), a pressure sensor (López *et al.*, 2022) and an ultra-sensor (Lloret *et al.*, 2021; Prafanto & Budiman, 2018). However, a median filter must filter out noisy readings due to false spikes (Smith *et al.*, 2022).

Moreover, fluctuations or ripples in the water can introduce errors in the water level measurements and, consequently, the water volume. It is necessary to install a weir to maintain a consistent water level and accurately measure the water level in a canal. Based on a previous study by Sasikala *et al.*, (2022), highly accurate water level measurement can be achieved using ultrasonic sensing with a 0% error rate. Thus, this work aims to design and develop a wireless water level detection at a weir system. Doing so aims to ensure effective monitoring of water levels in the primary canals, aligning with the irrigation system requirements. This approach helps monitor the appropriate water flow to all areas within the irrigation system. Although computerized water level monitoring systems exist, their usage is limited and varies significantly.

2. Materials and Methods

2.1 Overview of the System

The wireless water level detection system was designed to measure and monitor the water level in an open channel, especially an irrigation canal. The system consists of an HC-SR04 ultrasonic sensor that detects the water level, a NodeMCU ESP32 microcontroller or single-board computer that processes the data, and a communication protocol that allows the device to share information with other devices or a central server, as shown in Figure 1.

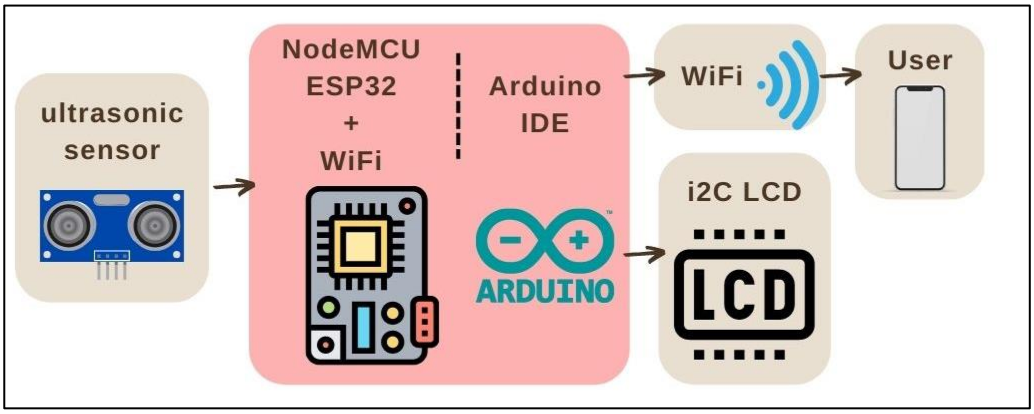

Figure 1. The architecture of the wireless water level detection system.

The ultrasonic sensor HC-SR04 continuously measures the water level. It transmits the data to the microcontroller, which processes it and makes decisions based on pre-defined algorithms or user-defined thresholds. The relevant information is then displayed on the LCD, which works independently of Wi-Fi availability. The NodeMCU ESP32 also acts as a WiFi firmware since it has a built-in WiFi module. It serves as the bridge between the hardware devices and the Blynk application, facilitating real-time data transmission. The data collected by the wireless water level detection system was analyzed in real time to monitor water levels accurately and rapidly. This data is crucial to reduce water usage and improve water resource management practices.

2.2 Ultrasonic Sensing for Height Measurement

The HC-SR04 ultrasonic sensor (Figure 2), a distance-measuring sensor based on reflected ultrasonic waves, was used in this study. A piezoelectric device in the ultrasonic sensor produces a piezoelectric ultrasonic wave directed to the target object. Then, the target will reflect the wave, which will be captured by the sensor, as shown in Figure 3. Then, the sensor measures the distance between a transmitting and a reflected wave.

Figure 2. HC-SR04 ultrasonic ranging module. (Prafanto & Budiman, 2018)

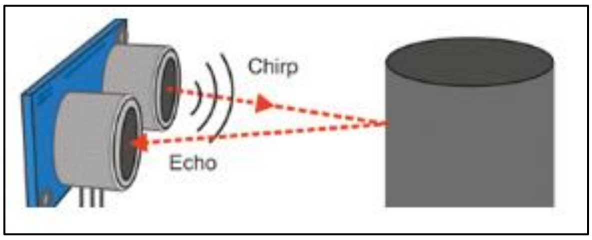

Figure 3. HC-SR04 captures reflected ultrasonic echo from a target to measure distance. (Prafanto & Budiman, 2018)

2.3 NodeMCU Microcontroller as System Controller

The NodeMCU ESP32, as shown in Figure 4, was used as the system's central controller. It is an open-source development board and firmware with a built-in WiFi module that enables developers to create Internet of Things (IoT) products. It is designed to simplify the use of Application Programming Interfaces (APIs) for hardware input and output, thereby reducing the complexity of hardware configuration and manipulation. The NodeMCU ESP32 is an improved version of the 8266 microcontroller, which has almost similar hardware to Arduino input and output (Anggrawan *et al.*, 2022).

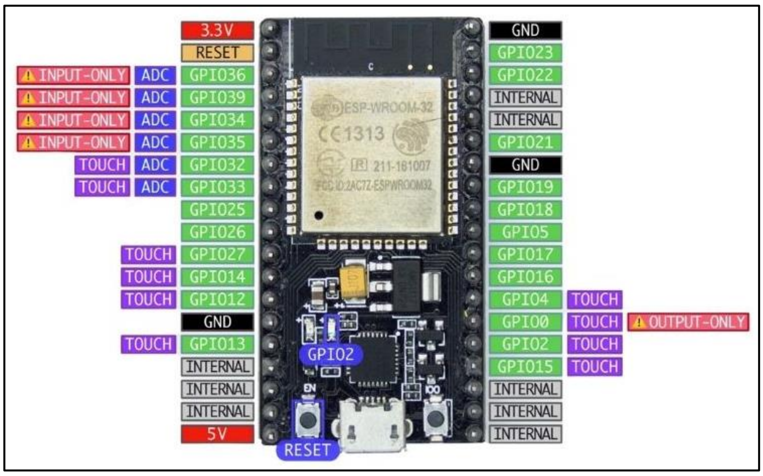

Figure 4. NodeMCU ESP32 board with built-in WiFi module. (Prafanto & Budiman, 2018)

The NodeMCU ESP32 was programmed using the compatible Arduino Integrated Development Environment (IDE) using the C language and encoded with several functions to control the actuation of both the automation and monitoring system. The IDE is installed with a specific ESP library to support the connection of the ESP32 board. The built-in WiFi module in the NodeMCU ESP32 is suitable for the application of wireless communication interfaces in this study.

The HC-SR04 ultrasonic sensor is connected to the NodeMCU ESP32 using four pins, namely VCC, GND, Trig, and Echo. The VCC and GND are used for power supply and grounding, while Trig and Echo are used for sending and receiving ultrasonic signals. The VCC, GND, Trig, and Echo pins of the HC-SR04 ultrasonic sensor were connected to the 5V pin, ground pin, GPIO 5, and GPIO 18 of the NodeMCU ESP32, as shown in Figure 5. When the sensor is triggered, it sends an ultrasonic signal that bounces off the object in front of it and returns to the sensor. The sensor then measures the time it takes for the signal to bounce back and calculates the distance based on the speed of sound.

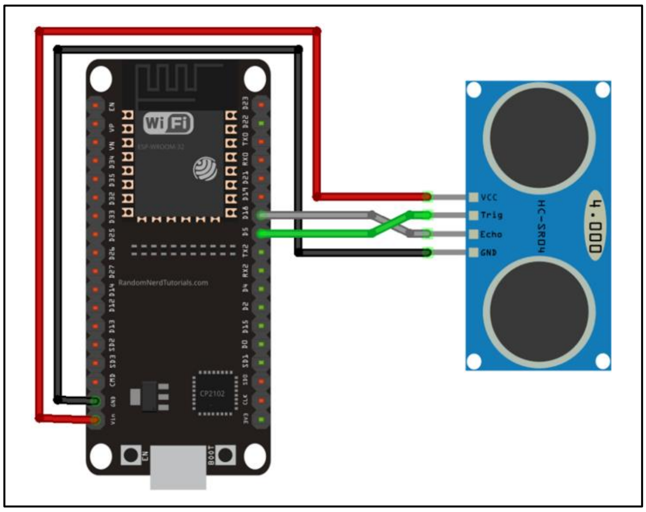

Figure 5. NodeMCU ESP32 with HC-SR04 ultrasonic sensor circuit schematic. (https://randomnerdtutorials.com/micropython-hc-sr04-ultrasonic-esp32-esp8266/)

For an alternative data display, an I2C LCD (Inter-Integrated Circuit Liquid Crystal Display) is connected to the NodeMCU ESP32 to display information from the microcontroller. The LCD will show a reading corresponding to the present water depth. The SDA (serial data), SCL (serial clock), VCC, and GND pins of the I2C LCD were connected to the SDA, SCL, 5V pin, and GND of the NodeMCU ESP32, respectively, as shown in Figure 6.

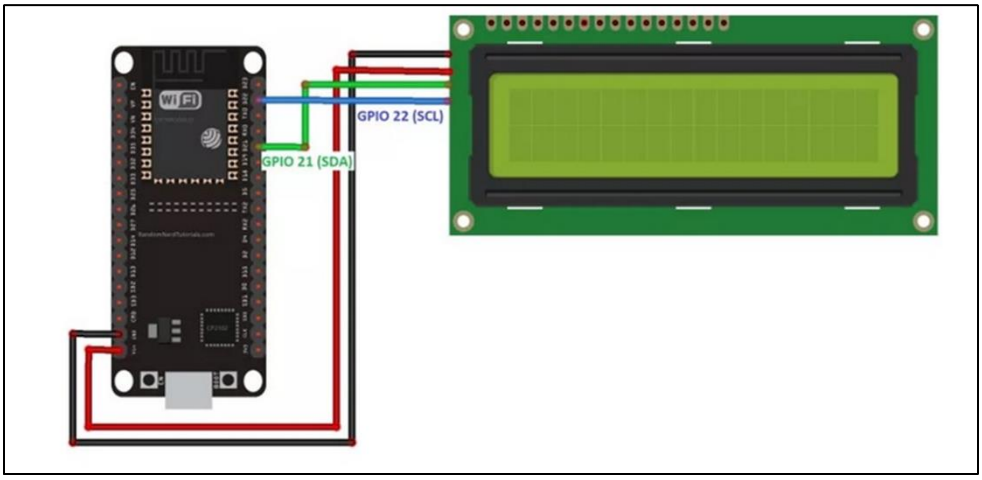

Figure 6. NodeMCU ESP32 with I2C LCD circuit schematic.
(https://medium.com/@figoagil/playing-esp32-is-easy-and-fun-lcd-display-44824edace8c)

2.4 Data Transmission to User

The Blynk IoT platform for an Android application was utilized to control Arduino over the Internet. In this study, the Blynk is used to control the ESP32 and project all acquired data from the sensors to the internet through Wi-Fi communication. Blynk is also a digital dashboard where the graphical interface for the monitoring system was created by simply dragging and dropping widgets (Safitri *et al.*, 2021).

2.5 Overall Programming Flowchart

The system's coding was designed to keep track of the water level passing through a weir system, as described in the following section. This system was created to gauge the water's height (h) as it passes through the v-notch.

The sensor will continuously monitor the water level in the canal and send the data to the microcontroller or IoT module. The module will process and send the data to a cloud server for storage and analysis. The data received from the IoT module is stored in the cloud, usually in a database. The cloud storage provides remote access to the data for further analysis and visualization. An LCD is utilized to create a user interface for presenting real-time data to the user. The data received from the IoT module is stored in the cloud, usually in a database. The cloud storage provides remote access to the data for further analysis and visualization. Finally, Blynk is used to develop a graphical user interface that displays data in diverse formats such as graphs, gauges, and virtual LEDs. The overall process flow for the wireless water level detection system is presented in Figure 7.

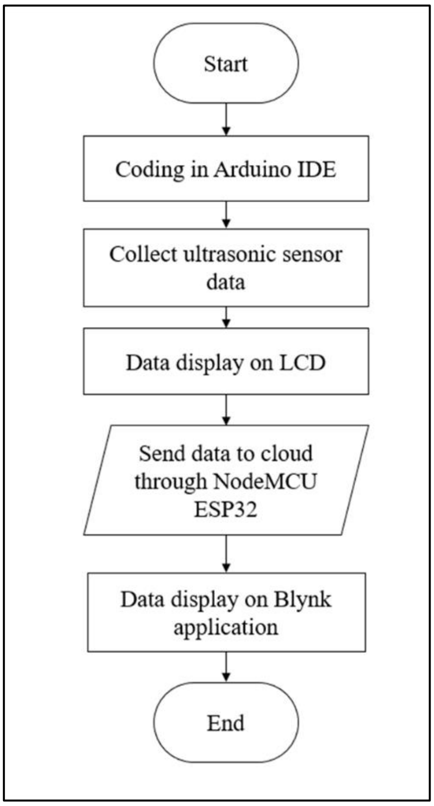

Figure 7. Overall process flow for wireless water level detection system.

2.6 Experimental Setup for Sensor Testing

The experiment was carried out at the Hydraulic lab of Universiti Putra Malaysia, as shown in Figure 8, whereby the sensor was placed parallel to the weir v-notch. Subsequently, the hydraulic bench flow control valve was gradually opened to enable water to enter the channel until it flowed over the weir plate. The sensor measured the water level (h) three times to calculate an average reading, and these measurements were compared to the actual water level height to ensure accuracy. The Blynk app platform was used to monitor the data (water level) measured by the sensor. This data could be helpful for researchers to monitor water levels in irrigation systems, enabling them to manage irrigation for crop cultivation efficiently.

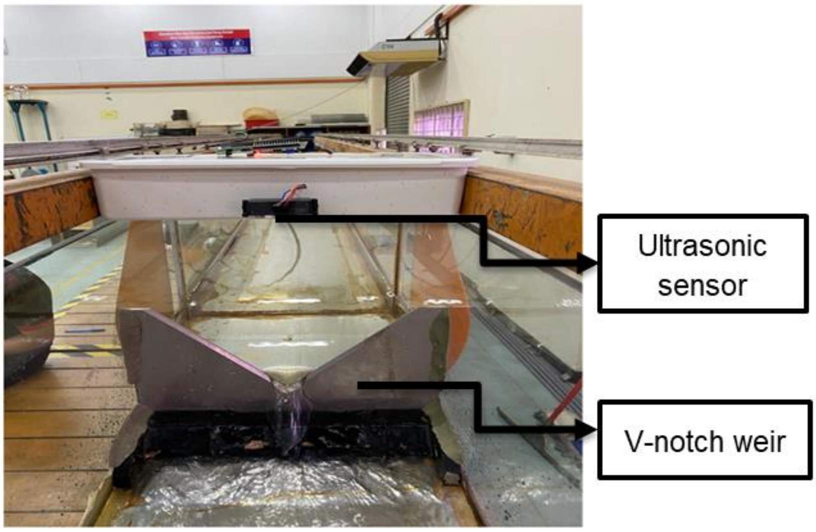

Figure 8. The wireless water level detection system was placed on the v-notch weir.

2.7 Error Measurements

The water level measured using the wireless water level detection system was compared to the actual height of the water level using the manual measurement method. The accuracy was assessed using absolute error (AE), relative error (RE), mean squared error (MSE), and root mean squared error (RMSE). The formula for each error measurement is shown in Table 1. AE measures the magnitude of the difference between the measured and actual height. RE quantifies the absolute error as a percentage of the actual height. MSE calculates the average of the squared differences between the measured and actual height. RMSE is the square root of the MSE, measuring the average magnitude of errors.

Table 1. Error assessment and its formulas.

Type of error	Formula
Absolute Error (AE)	|Observed Value - True Value|
Relative Error (RE)	(Absolute Error / True Value) * 100%
Mean Squared Error (MSE)	Σ((Observed Value - True Value)^2) / n, where n is the number of observations
Root Mean Squared Error (RMSE)	√(MSE)

3. Results and Discussions

Table 2 shows three readings of measured height, the corresponding average obtained through the wireless water level detection system, and the actual water level height from manual measurement. A ruler was used to measure the water level height directly. The AE ranges from 0.01 cm to 0.12 cm, reflecting the slight difference between the average measured height and the actual water height. The RE falls within the 0.1% to 3.6% range, indicating that the difference between the measured and actual heights is relatively tiny. The

MSE is 0.0078 cm2, which suggests that the measured heights are, on average, very close to the actual heights in the dataset. RMSE of 0.088 cm indicates that the average magnitude of the errors is low, which suggests that the model or prediction has a high level of accuracy. In addition, a trendline with an R2 value of 0.99, as shown in Figure 9, can be interpreted as a solid linear relationship between the measured height and the actual height, indicating small differences between the two measurement methods.

Table 2. Accuracy assessment based on measured and actual height.

1st reading	2nd reading	3rd reading				
Measured Height of Water, H_{mea} (cm)	Measured Height of Water, H_{mea} (cm)	Measured Height of Water, H_{mea} (cm)	Average Measured Height of Water, H_{mea} (cm)	Actual Height of Water, H_{act} (cm)	Absolute error (cm)	Relative errors (%)
2.7	2.68	2.39	2.59	2.5	0.09	3.60
4.45	4.33	4.43	4.4	4.5	0.10	2.22
6.67	6.65	6.53	6.62	6.5	0.12	1.85
8.52	8.77	8.44	8.58	8.5	0.08	0.94
10.36	10.69	10.47	10.51	10.5	0.01	0.10
				Total Error	0.40	
				MSE (cm^2)	0.0078	
				RMSE (cm)	0.088	

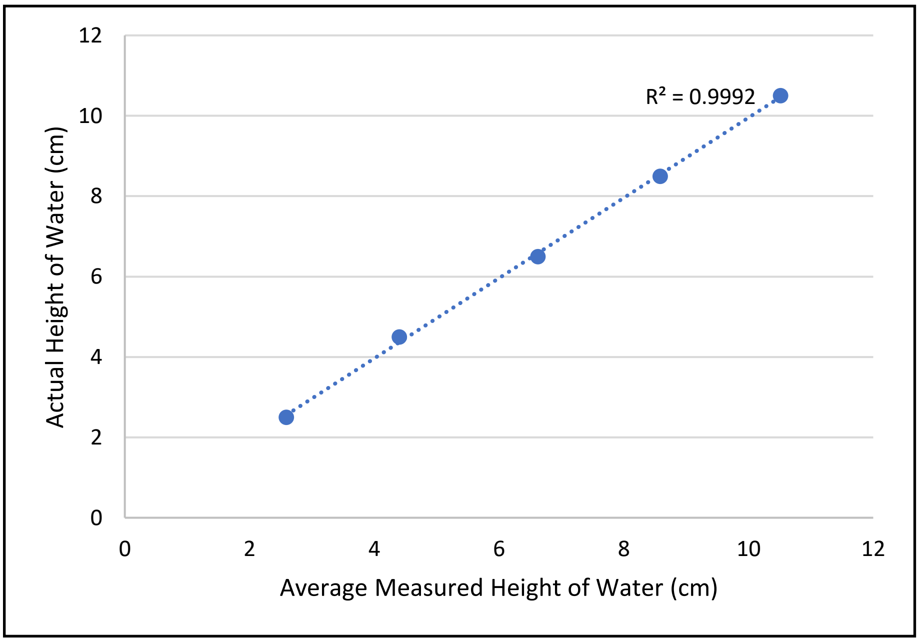

Figure 9. Linear regression between measured height and actual height of water.

4. Conclusions

This research proposes a solution to wirelessly measure the water level at a weir system in real time. The experiment was conducted in a controlled environment with minimal water disturbance, resulting in measured heights that closely matched the actual heights during the experiment. Further study should be conducted in the actual conditions of irrigation canals, which may experience water ripples and other disturbances. This project will continue to be improved, with new features added to create an intelligent irrigation monitoring and control system.

Author Contributions: Norulhuda bt. Mohamed Ramli conceptualized the project. Noorellimia bt. Mat Toridi supervised the project and manuscript writing. Muhammad Idham Haiqal b Amri, Muhammad Shamir Sadiq b. Mohd Hisham, Nur Shafiqah bt. Ismail, and Anelka Dau Anak Kupo contributed to the design and implementation of the system and data analysis. Norulhuda bt. Mohamed Ramli, Nurulhuda bt. Khairudin, and Samsuzana bt. Abd Aziz contributed to revising the manuscript.

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