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Water Level Monitoring System in Water Utility Company Open Channels Based on *Internet of Things*

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ABSTRACT

Monitoring the water level in the open channels of the regional water utility company needs to be carried out to ensure the availability of raw water to be processed. This research focuses on making a prototype of a water level monitoring system in an open channel utilizing the WSN (Wireless Sensor Network) component as an application of the IoT (Internet of Things) concept. Monitoring the water level in the open channel is carried out using the infrared sensor GP2Y0A02KF0Y. The real-time measurement results are then sent using XBee wireless communication, then processed by the Raspberry Pi to be saved to a database and displayed on the website. The measurement data can be presented on the website in graphs and tables. The GP2Y0A02YK0F sensor has a measurement error of 1.02% with a correlation coefficient of 0.9998. The average delay in sending data to the website is 1 second. The monitoring system can work well when measuring the water level in an open channel. The advantages of this research are that the instrument used has a high level of accuracy at an affordable price, uses low power, is easy to operate, and can store and present real-time data.

Introduction

Clean water is generally consumed to meet public daily needs. One of the sources of clean water that is generally used by the public comes from the water utility company. The water distributed by the company comes from the dam's raw water, which has been processed into clean water. The raw water is transmitted to water treatment plants through open water channels, siphons, and tunnels [1]. An open channel has a water surface that is affected by air pressure. The water level in the open channel indicates the availability of water that needs to be treated by the water treatment intake [2]. However, the quantity of raw water in open channels may decrease because of anthropogenic activities, vegetation, evapotranspiration, rainfall, and water loss due to seepage. It will cause the water level to vary over time, and require periodic measurements [3,4].

Water level measurement can be done using a distance measuring sensor such as the infrared sensor GP2Y0A02KF0Y. The sensor uses of infrared light to measure the distance between the sensor and the object based on the triangulation method from the angle of the infrared light beam. The triangulation method can minimize the influence of ambient light interference, ambient temperature, and the color of the detected object [5,6]. Therefore, this sensor can be used to measure the water level outdoors.

Variable water levels require flexible monitoring and can perform remote monitoring in real-time. IoT connects things through the internet and supports human work and encourages the formation of the industrial revolution 4.0 concepts [7,8]. IoT can also be applied to identify, track, and monitor remotely [9]. Currently, a WSN system has been developed that supports fast measurements and accurate results built through the integration of IoT with sensors [7]. Information exchange in the WSN system is carried out through communication between nodes [10].

There are several studies related to the measurement of raw water that has been carried out previously. Among them is research by Dswilan et al creating a flood monitoring system using ultrasonic sensors that transmit water level data via wi-fi [11]. Another study was conducted by Abdullahi et al. and Nasution et al. by making a prototype for monitoring water flow and level using airflow and ultrasonic sensors [12,13]. Previous research still has shortcomings, such as measurements that can only be monitored directly, so that data access is still less flexible. Therefore, in this study, a water level monitoring system was created using an infrared sensor GP2Y0A02KF0Y by applying the IoT concept to unify water conditions in open channels of water utility companies. This research is expected to help Water Utility Company to monitor the availability and condition of water in open channels, with relatively affordable measurement costs, as well as the availability of a website that displays real-time measurement data and is easily accessible.

Experimental Method

System Design

This study applies a WSN system with a combination of sensor nodes and sinks nodes that are connected wirelessly. The sensor node contains devices for collecting and transmitting data, while the sink node consists of a data receiving component [10]. The sensor node component uses several sensors that can measure water conditions. The sensor used to measure the water level is the IR sensor GP2Y0A02YK0F. This sensor can be used to measure distances using infrared light with a measurement range of 20-150 cm. The GP2Y0A02YK0F sensor has an ADC signal output, so the sensor output pin is connected to the Arduino Uno's A1 port. The sensor is controlled using Arduino Uno R3 so that it can take measurements according to the given program. The measured data is then sent by the XBee coordinator to the sink node. The measurement data will be received by the XBee end device located at the sink node. The data is then managed by the Raspberry Pi to be stored in a MySQL database and displayed on the website.

The website architecture consists of a database for storing sensor data, the back-end processing the data and sending the results, and the front-end for user interaction with the system. When sensor data is received by the XBee coordinator, who is serially connected to the Raspberry Pi, the data will be stored in the MySQL database management system. The back-end is built using the Django framework that will connect the front end and the database. The front-end or user interface of the website is created using HTML (Hyper Text Markup Language), CSS (Cascading Style Sheet), and JavaScript. System testing in the field is carried out by installing measurement instruments in open channels. The instrument is installed in open channel according to the direction of the water flow, as shown in Figure 1.

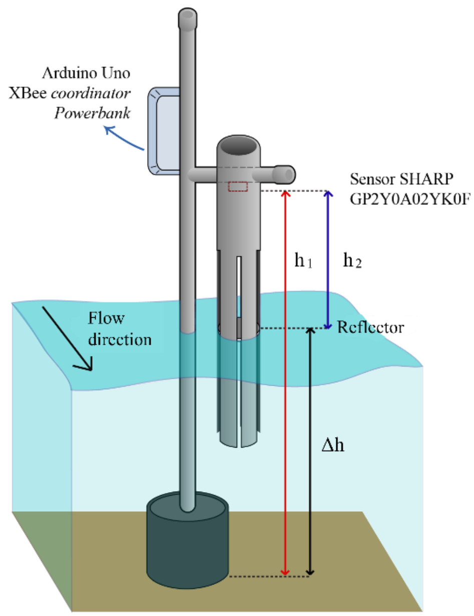


Figure 1. Schematic of measuring instruments placement in open channels

Measurement of water level is done by measuring the difference between the distance of the sensor and the bottom of the water channel to the distance of the sensor to the water surface. The equation for measuring water level is [13]:

$$\Delta h = h_1 - h_2 \tag{1}$$

Where:
Δh = Water level (m)
h_1 = Distance between the sensor and the bottom of water channel (m)
h_2 = Distance between the sensor and the water surface (m)

Sensor Calibration

Tests are carried out to see if the system functionality can work properly. Sensors are calibrated by comparing sensor data with standard measuring instruments. Then make sure the website can display measurement data from the sensor. Calibration is done by looking for linear regression, correlation coefficient and measurement error from the comparison of sensor measurement results to standard measuring instruments with the same units.

The linear regression equation is a sensor calibration factor that will be entered into the sensor program. The general form of a simple linear equation is shown in equation (2) [14]:

$$y = ax + c \tag{2}$$

where y is the dependent variable (the value measured by the comparison tool), x is the independent variable (the value measured by the sensor), a is the regression coefficient, and c is a constant [14].

The correlation coefficient is the degree of relationship between the variables x and y. The closer the value of r to 1, the higher the level of correlation between the x variable and the y variable. Correlation can be found by using equation (3) [14]:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \quad (3)$$

While the sensor measurement error can be known through equation (4) [9]:

$$Error\ (\%) = \left| \frac{Comparison\ tool\ value - Sensor\ value}{Comparison\ tool\ value} \right| \times 100\% \quad (4)$$

Result and Discussion

Sensor Calibration Result

The calibration of the GP2Y0A02YK0F sensor is carried out by comparing the distance for each 1 cm increase measured by the sensor with the meter in cm. The sensor calibration follows the results of Zielinski's research (2020) that the effective distance measurements made by the GP2Y0A02YK0F sensor are 20-70 cm with the reflected object material in the form of gray and not shiny zinc [15]. The graph of the sensor calibration results with the comparison of the GP2Y0A02YK0F sensor with the meter can be seen in Figure 2.

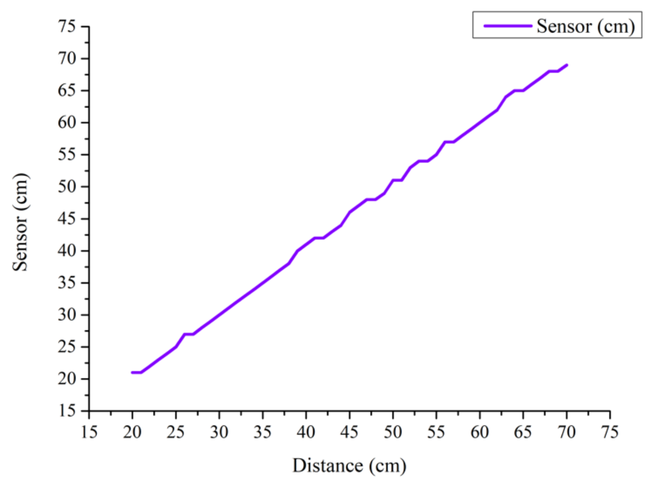


Figure 2. Comparison graph of GP2Y0A02YK0F sensor with meter

There is a slight difference between the sensor measurement results and the comparison tool. The level of correlation between the sensor and the meter is also very high because the correlation value obtained is close to 1, which is 0.9998. In addition, the large error obtained on this sensor is 1.02%, with an average measurement difference of 1 cm. The results obtained are better than research conducted by Zielinski, where the sensor accuracy rate is 98% with an error of 2% [15].

System Testing in the Field

The system testing is carried out in the field after the sensors are calibrated, and the measurement data can be accessed through the website. The location of data collection was carried out in an open channel at a water treatment plant on Abdullah Dg. Sirua street, Batua, Makassar City (5° 8' 59.7" S 119, 119° 28' 5.883" E). System testing was carried out for 3 days on

11, 15 and 16 March 2022 starting at 09:00 – 18:00 WITA. The placement of the measuring instrument is in the middle of the channel with a channel width of 5.87 m.

Measurement of water level using an IR sensor is carried out by entering Equation (1) in the microcontroller program. Where h_1 is equal to 1 meter, and h_2 is the result of measuring the distance between the sensor and the water surface. The measurement results are obtained in meters. Figure 3 shows a graph of the results of water level measurements carried out in the field with an average measurement per 10 minutes.

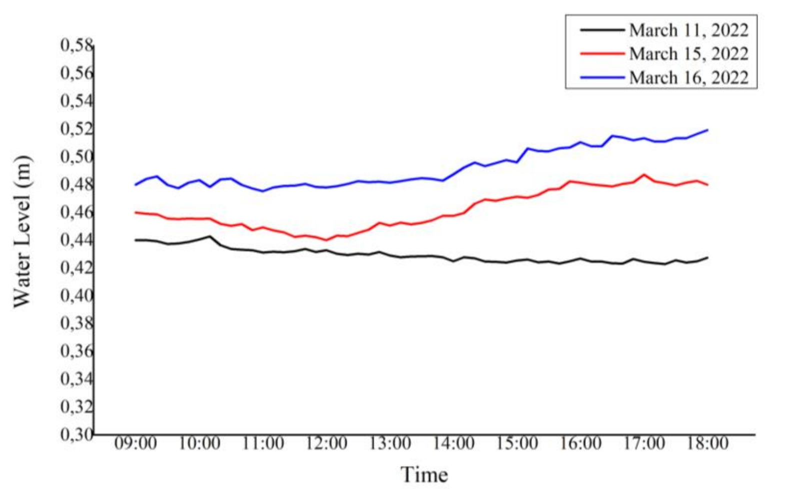
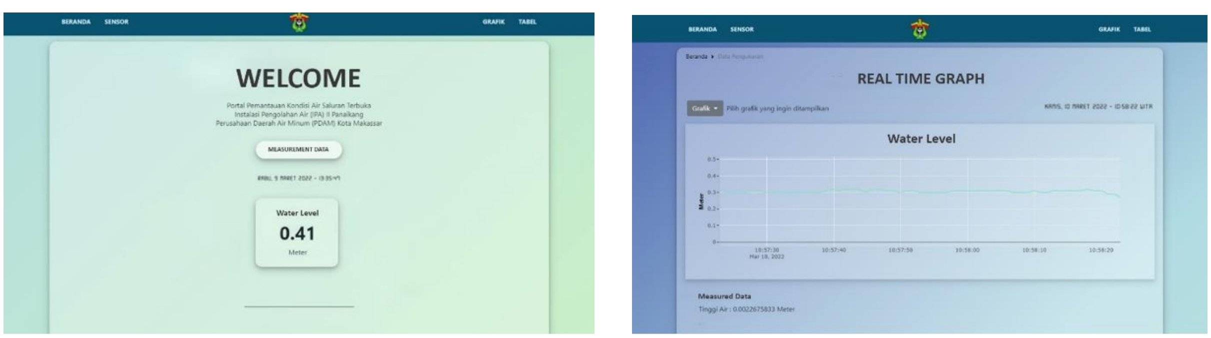


Figure 3. Graph of average water level data per 10 minutes

The results of water level measurements on system testing in open channels for three days have different average levels. The water level on the first day of March 11, 2022, had an average of 0.43 m. The water level increased by an average of 0.45 m on the second day on March 15, 2022, which could be caused by light rain at 14:58 – 15:04 WITA. Likewise, on March 16, 2022, the water level reached 0.5 m due to moderate rain which occurred at 16:08 – 18:00 WITA. Changes in water level can also occur according to environmental conditions in the upstream area of the channel at the time of data collection. The results of these measurements are displayed on the website shown in Figure 4.



(a) (b)

Figure 4. Website display on (a) home page and (b) graphic page

The website page created consists of a home page, a graph page, and a measurement data table page. Figure 8 shows the webserver view for the home page. The measurement result data can be accessed in tabular form on the table page. Data display requests are made by filling in the desired measurement time range on the form. The results displayed can be in the form of minute data or hourly data. Figure 5 shows the table page on the website.

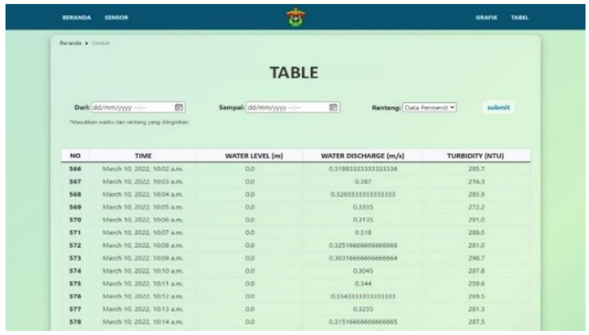


Figure 5. Website display for data table page

Testing the monitoring system in the field is needed to see the system's functionality in measuring environmental conditions in real-time. The smaller the delay in sending data, the more accurate the sensor's data collection time will be. The results of the data transmission test can be seen in Table 1.

Table 1. Delay in sending data from database to website

Delivery Time	Receive Time	Delay Time
10:29:07	10:29:08	1 second
10:29:08	10:29:09	1 second
10:29:09	10:29:10	1 second
10:29:10	10:29:12	2 seconds
10:29:11	10:29:12	1 second
10:29:12	10:29:13	1 second
10:29:13	10:29:14	1 second
10:29:14	10:29:15	1 second
10:29:15	10:29:16	1 second
10:29:16	10:29:16	0 second

The test results based on Table 1 the average delay time is 1 second. The same test was carried out by Hasanah et al. obtained a delay of 2 seconds. The difference in the delay in data transmission can be caused by the quality of the internet network [16]. Data transmission is also sometimes interrupted, so the internet network must be reconnected immediately.

Conclusion

The design and manufacture of the instrument has been carried out by assembling the electronic components used in the study. The instrument is water-resistant, so it can measure the water level in the water utility company's open channel on Abdesir Street, Batua Village. The error value of the IR sensor GP2Y0A02YK0F is 1.02% with a very high correlation coefficient between the sensor and the comparator is 0.9998. The average results of open channel water levels are 0.43 m, 0.45 m, and 0.5 m with an average delay time of sending data to the website is 1 second. The research results can facilitate monitoring of water availability in water utility companies' open channels. They can be applied to measuring water levels in various locations such as rivers, reservoirs, dams, or water tanks.

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