Turbidity Monitoring of Freshwater Using Internet of Things Platform

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Abstract. This article discusses the development of the monitoring system of fresh water turbidity level. The objective of this article is to monitor the turbidity level of the water continuously and remotely. The monitoring system was developed by using a turbidity sensor and ESP32. The measured turbidity level in Nephelometric Turbidity Units (NTU) was then sent to the internet of things platform namely ThingSpeak cloud computing platform by using wireless fidelity (wifi) networks so that it could be accessed by using Android smartphone or computer. The obtained monitoring system was tested on the laboratory scale fresh water body placed in the acrylic box with dimensions of 25cm × 19cm × 31cm. The test results showed that the monitoring system was able to monitor the turbidity level constantly on various conditions, i.e. fresh water without any substance addition and when sedimentation substances were gradually added into the water body. The output of turbidity sensor (in volt) was linear with the obtained NTU level. In the future, the monitoring system should be enhanced for actual condition of fresh water especially for sources drinking water.

1. Introduction
Fresh water quality has to be monitored since it is a fundamental need of humans such as for drinking water, industrial processes, farming and other activities. Turbidity is one of parameters used for determining the level of suspended solid content of the water such caused by sediment, clay, soil, or any other substances. Turbidity will be stated as the clarity of the water. Turbidity level is expressed in Nephelometric Turbidity Units (NTU) [1]. The turbidity of the water body was mainly measured for drinking water resources and fish farming. According to the standard of the World Health Organization (WHO), the drinking water should have a turbidity level less than 5 NTU [2]. Drinking water with turbidity levels higher than 5 NTU could affect potential health problems.

Monitoring turbidity electronically has attracted attention from researchers for example research results in [3] where the system was developed for measuring turbidity level on a prepared water sample placed in a tube. The sample in the tube has to be prepared manually. In order to be able to show the actual turbidity level condition of the water, enough frequency sampling is needed [4]. The manual sample preparation has disadvantages in which it did not facilitate continued monitoring. Internet of Things (IoT) technology enables us to monitor any environmental variable continuously and remotely [5].
The objective of this article is to monitor the turbidity level of the water continuously and remotely. The measure turbidity level would be stored in the cloud so that it would be able to be monitored using computer or smartphone.

2. Method

2.1. System architecture
The proposed turbidity monitoring system consists of a turbidity sensor which is connected to the turbidity probe module. The turbidity probe module converts the level of turbidity into digital electronics signal which then sends it to the ESP32 microcontroller. The microcontroller then processes the signal produced by the turbidity sensor into the NTU scale and then sends the processed data to the cloud computing framework using wireless data communication (wifi). Finally, the NTU level of the water being monitored could be displayed on smartphone or computer. The general system architecture can be seen in Figure 1.

![Figure 1: Block diagram representing the general system architecture](image)

This system architecture of this article is different from which has been published by other researchers for example in [6] where the wireless sensor networks (WSN) architecture was used or in [7] where the measured turbidity of the water body was sent to the Personal Computer (PC) acting as both server and database by using Zigbee protocol or system in [8] where the measured turbidity level was stored in Firebase Server so that could be accessed via a website. The use of wifi in this article has benefits in the coverage range, i.e. between 30 and 100 meters in comparison to between 10-20 metres if using Zigbee protocol [9]. The Thingspeak cloud platform is used in this article because it provides simple and reliable services for IoT applications such as shown in [10].

2.2. Development steps
A software or a program was developed for the ESP32 microcontroller. The first process was sensor initialization functioning as a preparation process for the sensor to be able to connect to the ESP32. Secondly, the ESP32 read the data from the turbidity sensor and processed it into the NTU scale. In the computation process, the NTU scale was computed by using Equation 1.

\[ y = -26.7642X + 135.0524 \] (1)

Where \( y \) is the NTU level and \( X \) is the sensor output in volt. The overall computation step of ESP32 is presented in Figure 2a. The turbidity sensor has output between 0 and 5 volt. When connecting to the wifi prior to sending the processed data to the cloud framework, the communication data rate was set to 9600 baud. After that, the ESP32 was connected to the available wifi network (by inserting the ssid and password of the targeted wifi) and if the connection was successful then it was ready to send the data to the cloud framework. The part of the program for connecting the ESP32 to the wifi can be seen in Figure 2b.
After ESP32 successfully connected to the wifi, the next step was opening cloud framework at https://thingspeak.com/ for registering to get an account (sign up) and then to sign in. After sign in successfully, the next step was to configure the channel using My Channels menu which is the display page of data collection from the turbidity sensor. Every channel has its own unique Application Programming Interface (API) key which should be accessed by the ESP32. Whenever needed, the API key could be renewed by using the Generate New Write API Key button.

After having API Key information on the channel, the next step is to enter the API Key in the ESP32 program code to be able to send sensor data to the user’s channel. The sensor data will be sent to the channel based on different fields namely field1 will be filled with the voltage variable and field2 will be filled with the turbidity variable from the calculation results on the sensor.

3. Results and discussion

3.1. Obtained monitoring systems and experimentation

All hardware circuits were placed in a plastic box to protect them from water splash and any impact while the turbidity sensor is connected to the microcontroller with a cable so that it can float in the middle level of the water body. A rechargeable battery was used for providing power to all hardware instruments. An extension cord was attached to the battery for the charging process if the battery capacity becomes low. The actual appearance of the obtained system can be seen in Figure 3a. The monitoring system was tested on a laboratory scale water body environment. The water body was placed in the acrylic box with the dimension of 25 cm x 19 cm x 31 cm. In the experiment, freshwater which was used as sources of drinking water for daily life was used. The acrylic box was equipped with a water filter system. The box of the monitoring system was placed on top of the acrylic box and the turbidity sensor is placed in the water body. The setup arrangement of the experiment is presented in Figure 3b.

The turbidity was placed floating of the water body of the experimental box so that enabled it to sense the water in the middle level of the water body [11]. A wireless internet (wifi) facility was provided in the area of experiment area. The experiment process could be explained as

```c
Serial.begin(9600);
WiFi.disconnect();
WiFi.begin("Pekerti", "rassdinggcyo");
while (((WiFi.status() == WL_CONNECTED)) { delay(300);
  Serial.print("-.");
  pinMode(SENSOR, INPUT);
  Serial.println("Mulai");
}
```
follows. First, the fresh water was placed in the acrylic box. Secondly, the monitoring system was turned on, and the voltage output of the turbidity and its NTU level resulted. The voltage of output of turbidity sensor was measured directly in the output port of the turbidity sensor while the NTU level of the water was displayed on the smartphone using ThingSpeak platform. Thirdly, the voltage and corresponding NTU level were recorded once every two minutes for 30 minutes. In the first 10 minutes, there was no substance added to the water body with the water filter turned on to maintain the fresh water in the very good condition. Fourth, for the next 20 minutes, the soil/clay sediment was gradually added into the water body with a water filter turned off while both voltage output of the turbidity sensor and its corresponding NTU level were recorded every two minutes.

The measurement testing results are presented in Table 1. Results in Table 1 shows that initially the value of turbidity sensor output voltage and NTU level were arguably high for fresh water and then it became stable for the next four measurements when the water filter was effectively working for more than two minutes. When the sediment was gradually added to the water body (measurement number 6 to 14), it can be seen that the turbidity sensor voltage and NTU level were also to change gradually as the physical appearance of the water body was also gradually to change to become unclear. The measurement results of Table 1 shows that there is a linear relationship between the turbidity sensor output and the NTU level as presented in the form of graphics shown in Figure 4.
Table 1: Measurement testing results of proposed monitoring systems

| Measurement No. | Sensor Output (V) | NTU  |
|-----------------|-------------------|------|
| 1               | 4.9               | 4.1  |
| 2               | 5.02              | 2.05 |
| 3               | 5.03              | 1.51 |
| 4               | 5.03              | 1.51 |
| 5               | 5.03              | 1.51 |
| 6               | 4.68              | 4.71 |
| 7               | 4.71              | 3.31 |
| 8               | 4.7               | 3.66 |
| 9               | 3.02              | 65.6 |
| 10              | 2.9               | 66.7 |
| 11              | 2.66              | 67.88|
| 12              | 1.93              | 79.57|
| 13              | 1.62              | 89.63|
| 14              | 1.16              | 96.82|

The ESP32 sent the data to the ThingSpeak cloud platform every 5 seconds. When the sensor data is successfully uploaded to the channel of the ThingSpeak cloud platform, the channel stats display will look like Figure 5 for laptop which can be accessed by opening the link https://thingspeak.com/channels/808992. 808992 is the Channel ID of the user.

4. Discussion

Compared to a manual monitoring system, the proposed system has the benefit that monitoring systems could be done in a distance so that the person who incharge of the monitoring task does not need to be around of the water body location. Also, the person do not need to manual recording frequently since the NTU level has been recorded and displayed in the form of graphics automatically. However, the proposed system still as a prototype so that it could be enhanced for some perspectives for example by adding a notification systems such as applied in [12] and by...
adding an algorithm of decision support system such applied in [13] or machine learning such as in [14] so that if the turbidity level is above the certain level the system will provide a suggestion or recommendation what should be done. Furthermore, a machine to machine architecture such as applied in [15] also could be considered especially where the turbidity monitoring system would be implemented in the wide area for example for rivers, dams, or lakes. Moreover, the cost analysis including development cost and operational cost should also addressed in the future so that it could be used for developing turbidity monitoring system with high accuracy but low cost [16].

5. Conclusion
The system for monitoring turbidity level of the fresh water body has been successfully developed. The experiment results showed that proposed system was able to measure the NTU level constantly either when the freshwater body was not added by the sediment, i.e. between 1.51 and 4.1 NTU or either when sediment was gradually added to the water body, i.e. between 4.71 and 96.82 NTU. The ThingSpeak cloud platform received data from the ESP32 every 5 seconds so that it could be accessed by using a smartphone in the form of continuous graphics. Since the proposed system was still in the form of a prototype, future works could be addressed for enhancing the monitoring systems for actual water body environment especially for drinking water sources.

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References
[1] Uhrich MA and Bragg HM 2003 US Geol. Surv. Wat.-Res. Inves.s Rep. 03–4098 1.
[2] Gorchev HG and G. Ozolins 2011 WHO Chron. 3 104.
[3] Nuzula NI, Sakinah W, and Endarko 2017 AIP Conf. Proc. 1788, 030108 (2017) 030108-1.
[4] Villa A, Folster J, and Kyllmar K 2019 Env. Mon. and Ass. 191 1.
[5] Martínez R, Vela N, Aatik AE, Murray E, Roche P, and Navarro JM 2020 Water 2020 12 1096.
[6] Chowdury MSU, Emran TB, Ghosh S, Pathak A, Alam MM, Absar N, Andersson K, and Hossain MS 2019
Proc. Comp. Sci. 155 161.
[7] Warungase P, Worlikar A, Mhatre J, Saha D, and Salunkhe G 2017 Int. J. of Eng. Res. & Tech. (IJERT) 5 1.
[8] Rahman MM, Bapery C., Hossain MJ, Hassan Z, Hossain GMJ, Islam MM 2020 Int. J. of Mult. and Cur. 
Ed. Res. (IJMCER) 2 168.
[9] Chen Y, and Han D 2018 Aut. in Cons. 89 307
[10] Azath M, Balakumar S, and Alemu B 2020 Int. J. of Emer. Tr. in Eng. Res. 8 6912.
[11] Trevathan J, Read W and Schmidtke S 2020 Sensors 2020 20 1993
[12] Supriyono H, Majid A and Harismah K 2020 Int. J. of Emer. Tr. in Eng. Res. 8 5163.
[13] Sowjanya M and Dharani DL 2020 Int. J. of Emer. T. in Eng. Res. 8 6738.
[14] Ashwini C, Singh UP, Pawar E, and Shristi 2019 Int. J. of Sci. & Tech. Res. 8 1046.
[15] Supriyono H, Fakliansyah N and Harismah K 2020 Int. J. of Adv. Tr. in Comp. Sci. and Eng. 9 8546.
[16] Gillett D and Marchiori A 2019 Sensors 2019 19 3039