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Performance comparison of Limboto Lake Monitoring Prototype: Laboratory testing vs Real-World testing

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***Abstract*- Indonesia has around 15,000 lakes which are in crisis condition. There are 15 lakes that has been prioritized by the government to be conserved. The traditional way to monitor the condition of the lakes is by taking some samples of the lake and test it in the lab. IoT (Internet of things) technology could provide solution to monitor lake conditions online and real time. Therefore, this research aims to develop a prototype of lake monitoring system which is based on IoT technology. The prototype consists of several sensors namely water temperature, pH, turbidity. The prototype was tested in laboratory and the surface of Limboto Lake. The system consists of solar panel, accu battery, solar charge controller, ESP 8286, mobile wifi and sensors. The reading of the sensors is the transferred to a cloud application. The prototype was tested on laboratory at 27 of July 2018 and the surface of Limboto lake from 11.00 to 15.00 at 28 of July 2018. The laboratory testing showed that the system could transfer almost 6 hours. In the other hand, the system could transfer data for almost three hours at the surface of the lake. These two result might different due to the wave of the lake and high ambient temperature that influenced the performance of the system. Digital temperature reading shows that the ambient temperature was in the range of 30°C to 32°C. The water temperature read from the temperature sensor was in the range of 24.5 to 29.50. The pH sensor shows show values in the range of 7.08 to 7.55 and the turbidity value ready by the sensor was in the range of 20.47 to 20.56 NTU.**

***Keywords* – IoT, Limboto lake, Limnology, monitoring system**

I. INTRODUCTION

Indonesia has 840 big lakes and 735 small lakes which have been used for many human activities such as agriculture, tours and drinking water [1]. The lakes provide many useful resources to Indonesian people, however the quality of lake is gradually decrease. This is due to sedimentation, rapid population of Eichhornia Crassipes (known locally as Enceng Gondok), errosion and fish farming [2]. The Ministry of Environment of Republic of Indonesia has prioritized 15 lakes to be conserved. The lakes are Toba Lake (North Sumatera), Manijau Lake dan Singkarak lake (West Sumatera), Kelinci lake (Jambi), Rawa Lake (Banten), Rawapening lake (Jawa Tengah), Batur lake (Bali), Tempe lake dan Limboto lake (Gorontalo), Sentarum lake (Kalimantan barat), Cascade Mahakam lake (Semayang, Melintang, Jempang) (Kalimantan Timur), Sentani lake (Papua) and Limboto Lake[3]. Limboto Lake is one of the lake in Indonesia located at Gorontalo Province. It consists of 23 of lake and tributary as the inlet of the lake and 1 outlet of the lake [4].

Limboto Lake is one of the 15 lakes to be conserved. Therefore, the proposed online monitoring system would be able to help the authority to obtain information about the condition of Limboto Lake. Hence, this study aims to develop the online monitoring system of Lake Limboto in Gorontalo, Indonesia, so that lake condition can be measured and monitored.

II. LITERATURE REVIEW

Lake monitoring system is a system that integrates several sensors and communication devices in order to record and report lake conditions. Example of conditions monitored are pH, turbidity, dissolved oxygen, residual chlorine, conductivity, temperature, flourine, calcium hardness, total dissolved solids (TDS), magnesium hardness, manganese, sodium hydrogen sulfide, and oxidation reduction potential (ORP) [5]

Existing lake monitoring systems in Indonesia could be categorized into several methods, namely direct measurement [6][7], Landsat approach [8] and Internet incorporated sensors approach [9][10]. Based on literature review of lake monitoring systems application in Indonesia, a research gap was found. The use of IoT to monitor lake conditions has not been done before, especially at Limboto Lake. Therefore, this study aims to develop IoT based online system monitoring for Limboto Lake.

III. DESIGN OF THE PROPOSED SYSTEM

This section describes the system architecture, system requirement and its detailed of hardware-software implementation with basic structure and flow diagrams. The frame work of the proposed system uses IoT to report the lake condition in a real-time manner. Water condition

sensors namely pH, water temperature were used to monitor the lake continuously.
The entire system was tested in laboratory and on the lake surface. The data was sent to the cloud application through Arduino Mega microcontroller that connected to a Wi-Fi module and mobile Wi-Fi.

The proposed system's hardware consist of Arduino Mega microcontroller, temperature sensor, pH sensor, turbidity sensor, mobile Wi-Fi, ESP 8266, solar panel, solar charge controller (scc) and a accu battery.

The skematic diagram of the prototype is shown in Fig. 1. The prototype consist of:

1. Arduino Mega
2. Solar Panel 20 Watt
3. Solar Charge Controller (scc)
4. Accu Battery 12 Volt
5. Mobile Wifi
6. Esp 8286
7. Step Down
8. Ph Sensor
9. Turbidity Sensor
10. Temperature Sensor

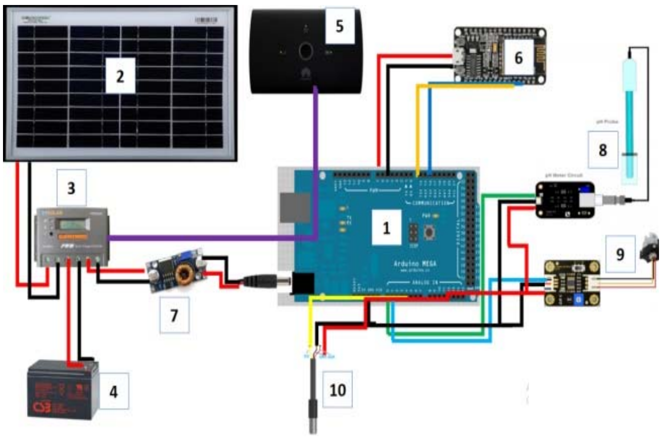

Fig. 1. Schematic diagram of the system

The details explanation of each component is described as follow

A. Solar Panel Module

The solar panel module consist of a 20 Watt solar panel that has dimension of 49 x 35 x 2,5 cm, a solar charge controller, a 12 Volt of an accu battery, and a step down regulator to convert the 12 Volt to 5 Volt output.

B. Dallas DS18b20 water Temperature Sensor
The temperature sensor directly using digital Pin of Arduino Mega to read the voltage. The connection of the sensor to Arduino Mega is shown in Table I.

TABLE I. PIN CONFIGURATION OF TEMPERATURE SENSOR

Temperature Sensor	Arduino Mega
Vcc	+5 Volt
Gnd	Gnd
D1	A2

The calibration process of the Dallas temperature sensor was by compare it to manual digital thermometer. Both temperature sensor and digital thermometer was tested using ice and boiled water. The measurement result should be 100°C for boiled water and 0°C for the ice. The temperature sensor showed values in the range of 0.1 to 0.4 for the ice and it showed 99.7°C to 100.1°C for the boiled water. The detailed of calibration process can be found in [12].

C. DFRobot analog pH meter sensor

Dfrobot analog meter output value was obtained using several steps [11]:

1. The analog pin values is stored in an array for a certain sampling time and converted to a voltage value using this equation:
$$\text{Voltage} = (\text{array value x } 5) / 1024 \quad (1)$$
2. The voltage value then converted to pH Value using following equation:
$$\text{phValue} = (3.5 \text{ x voltage}) + \text{offset} \quad (2)$$

Offset is the value that is initialized at the beginning of the program. The value of the offset is 0. The ph value of the fresh water is 7. If during testing in fresh water, the value of the ph is not 7, then the value of the offset would need to be changed using the following equation:
$$\text{offset} = 7 - \text{Ph Value of testing} \quad (3)$$

The calibration of the Ph sensor was done by tested it to the distillation water which has ph 6.6 and pure water which has ph 7. The sensor was directly connected to the laptop and the reading data showed in the serial monitor of Arduino IDE. Adjust the potentiometer that attach to the sensor until the value in serial monitor as closest as the ph of distillate water.

The detailed calibration process can be found in [11]. The pin connection of the sensor to Arduino Mega is shown in Table II.

TABLE II. PIN CONFIGURATION OF TEMPERATURE SENSOR

Ph Sensor	Arduino Mega
Vcc	+5 Volt
Gnd	Gnd
A0	A12

D. Analog Turbidity Sensor –DFRobot
An analog pin connected to the Arduino Mega to read the value and convert it to voltage. The voltage is then converted to turbidity value using the following equation:

$$\text{Turbidity} = 40 - (\text{Voltage}/4) \text{ x } 100 \quad (4)$$

In order to avoid the cap of the sensor inserted by water, a casing to protect the sensor was need to be made. This prototype used small plastic container to protect the cap of the sensor. The bottom holes of the casing also protected by candle glue in order to avoid from the water entering in. This casing is shown in Fig. 2.

The calibration of the turbidity sensor used pure fresh water as the set point. Fresh clean water should have turbidity in the range of 0 to 5 NTU [13]. If the reading sensor is more than this value, than the equation is needed to be adjust.

Fig. 2. The casing to protect the cap of turbidity sensor

Table III shows the pin connection of Ph sensor to Arduino Mega.

TABLE III. PIN CONFIGURATION OF TURBIDITY SENSOR

Ph Sensor	Arduino Mega
Vcc	+5 Volt
Gnd	Gnd
A0	A11

E. Mobile Wi-Fi to transmit data

The mobile Wi-Fi that is used to transmit the data to cloud application is Huawei E5673. It used 4G data connection provided by a local provider.

The prototype was programmed using Arduino IDE. The flowchart of the program is shown in Fig 3.

IV. TESTING OF THE SYSTEM IN LABORATORY AND LIMBOTO LAKE

The testing in the laboratory took place at July 27 2018 at 11.00 to 17.00. The testing in laboratory is shown in Fig 4. The battery of the system was full charged before the testing started.

The system ran well and could transfer data for each 30 minutes for almost 6 hours. There was no need to restart the system during testing. The water used was fresh water from the tap.

Fig. 5 shows the reading of the sensors in the laboratory. Since the water used was tap water there was no significant changes in the reading value of the ph, turbidity (NTU) and water temperature (^{O}C).

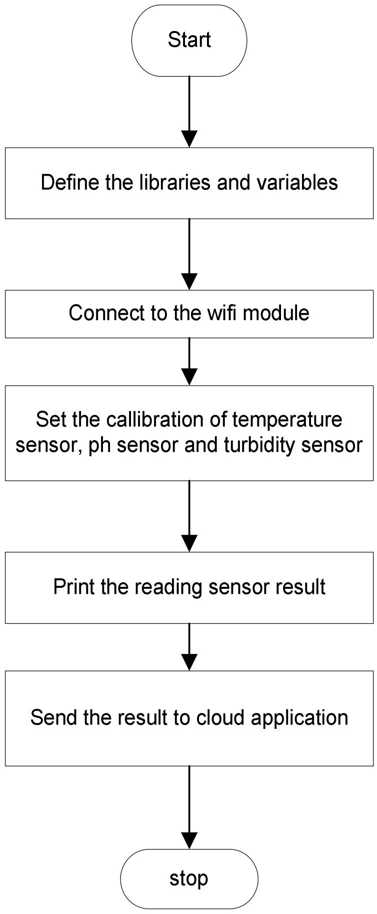

Fig. 3. The flowchart of the program

Fig. 5 shows that the Ph of tap water is 7.05, the turbidity is 2.11 to 2.14 NTU and the water temperature is the range of 25 to 25.6 ^{O} C. The prototype's performance comparison during laboratory condition and real-world testing is shown in Table IV.

Fig. 4. The testing of the prototype in the laboratory

The system was tested on the surface of Limboto Lake from 11.00 to 16.00 East Indonesian time at 28th of July 2018, at the coordinate of 0^o 34'18.699". The prototype was carried by a traditional boat of local fishermen. The testing of prototype at the surface of Limboto Lake is shown in Fig. 6.

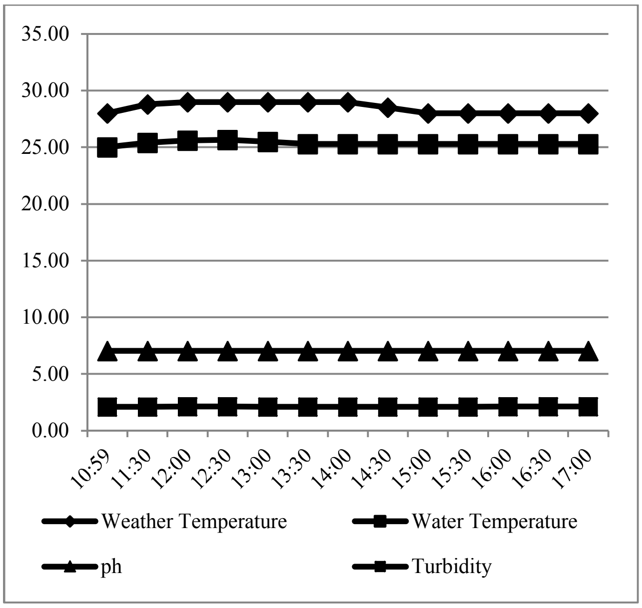

Fig. 5. The reading data from the sensors at laboratory

Initially, the system was projected to run until 17.00. However it could only transfer data up to 15.00. The prototype was programmed to transfer the data in every 30 minutes. Restart actions needed to be taken 2 times at 12.35 and 14.35 since the system did not transferred data during that time. After this restart action the system was able to transfer data. However, additional restart actions were also taken at 15.35, 15.40 and 15.50 but still the system could not transfer data. Therefore the experiment was stopped at 16.00 and the system was removed from water at 16.10.

TABLE IV. PERFORMANCE COMPARISON IN LABORATORY AND AT LIMBOTO LAKE

No	Location of testing	Testing time	Restart Action	Environment Maximum Temperature	Running Time	Water Source
1	Laboratory	July 27th 2018 11.00 to 17.00	0	29 ^{O}C	6 Hours	Fresh water tap
2	Surface of Limboto Lake	July 28th 2018 11.00 to 15.00	2	32 ^{O}C	4 Hours	Lake water

The system was checked to discover the causes of the problems. It was found that:

Fig. 6. The testing of the prototype at the surface of the lake

1. Water entered the turbidity sensor which caused short circuit in the sensor and shut down the Arduino Mega.

2. A cable that connected the SCC to the mobile Wi-Fi was broken. It might be due to the heat inside the casing of the prototype.

3. The small and high speed waves at the surface of the lake caused the power jack that connected the SCC to Arduino Mega loose. This caused the system to shut down due to lack of power supply.

Fig. 7 shows the water temperature, pH and turbidity data read from the sensors at the surface of the lake. The ambient temperature was measured by using digital thermometer. The graph shows that ambient temperature was in the range of 30°C to 32°C. The water temperature was in the range of 24.5 to 29.50. The pH is in the range of 7.08 to 7.55 and the turbidity of the lake was in the range of 20.47 to 20.56 NTU.

V. CONCLUSION AND RECOMMENDATION

Drawing on the experiment result described above, it can be concluded that the system can provide data up to 6 hours in the laboratory testing. On the other hand, the system can provide data up to 3 hours in the real-world implementation. The temperature of the environment and the tides of the lake influenced the performance of the system. Based on the previous experiments, it is recommended to use heat resistant cable in the real-world implementation.

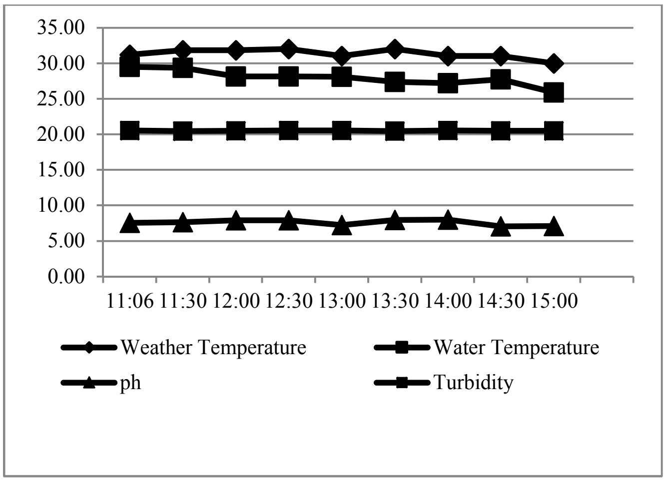

Fig. 7. The reading data from the sensors at Limboto Lake testing

The addition of a fan inside the casing of the prototype is necessary to reduce heat inside the casing. In addition, the special casing of the turbidity sensor to protect water from entering the cap of the sensors would need to be improved.

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