Raspberry Pi Based IoT for Aquaculture Realtime Remote Monitoring System with Self Energy Harvesting

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**Abstract.** Temperature and pH are two essentails water quality parameters in shrimp culture. Therefore, monitoring these two variables is very important to improve productivity in aquaculture. In this study, a monitoring system was created to monitor the two variables in the pond. For this reason, Raspberry Pi IoT based hardware and software has been made to carry out the monitoring function. Monitoring data is automatically sent to online servers using a cellular internet network. For electrical power needs, remote devices are equipped with solar power plants. The results showed that the system could read the temperature and pH of the water accurately and sent it to an online server. There is a web-based calibration menu that allows users to easily calibrate sensors. Moreover, a user interface is also made to display the sensor readings data that has been stored in the database. In conclusion, the monitoring system is applicable for water quality data logger in the field operation with user friendly operation.

**Keywords**: Shrimp culture, remote monitoring, real-time, IoT, Raspberry Pi

1. Introduction

Shrimp (*Litopenaues vannamei*) is one of the main export commodities of Indonesian aquaculture. The productivity of shrimp production is highly dependent on the cultivation process carried out by pond farmers. One factor that is very influential on the production of shrimp culture is pond water quality. There are several variables that affect water quality including pH and temperature. Shrimp will grow well if the water temperature is between 26 and 30 °C [1] with a pH range from 6.5 to 8.5 [2]. Outside the range of values, will greatly affect the shrimp production [2].

Due to the importance of the pH and temperature in shrimp farming in ponds, it is necessary to monitor these variables regularly. Observation by direct measurement is very impractical. On the one hand, the data obtained is not real-time, so it is difficult to do analysis and action if there are variables that are in conditions outside the standard. On the other hand, recording data that is not automatic in a database makes observational data not easy to display or access quickly. Therefore, it is needed a monitoring system of pond water temperature and pH in real time and also monitoring data can be accessed easily at any time.

Data reading in real time can be done using a data logger as shown in [3]. In this work, the historical data is stored and accessed on site. This lack of flexibility to be accessed due to the necessary to visit the logger for accessing the data. It can be overcome by performing monitoring system remotely through communication network. Wahyuni & Wijaya [4] developed remote monitoring based on Xbee wireless...
network with limited coverage area. This distance limitation between the server and its measurement device can be overcome by utilizing the existing telecommunications network infrastructure such as the cellular telephone network. Kovacs et al. [5] made a remote data logger study for weather monitoring using GPRS GSM network data communication. ATMega64 microcontroller is used as the main component of the data processing processor before being sent to the server. In addition, a PC on site is needed to configure the device. Munandar & Syamsi [6] make Universal Data Logger based on SMS and GPRS Data dial services using GSM networks. The term universal here emphasizes the use of selected communication network choices, namely SMS and GPRS data dial. In both studies, it was not stated that data that has been sent and stored on the server can be accessed online using the internet network.

At present, the world trend of industry has entered the era of fourth generation called Industry 4.0. In further discussion, Lee et al. [7] explains that Industry 4.0 introduces the so-called "Smart Factory", in which Cyber-Physical Systems monitors the factory's physical processes or equipment and makes decentralized decisions. The system is supported by the Internet of Things (IoT) technology, where devices that are used can communicate and cooperate with one another and also with humans in real-time through internet networks [8]. IoT technology is being adapted in agriculture to support increased food security by implementing remote data loggers for agricultural system monitoring and automation [9] as well as monitoring agricultural land.

IoT based monitoring system is applied in aquaculture as well. A raspberry pi-based monitoring system has been studied in [10] with Wi-fi internet connection required for data transfer. On another study, pH and temperature aquarium monitoring system is developed in [11] where the sensed data is transferred to cloud system through Wi-Fi connection as well. Therefore, advanced study needs to be performed to enable it for outdoor and remote application due to limitation of Wi-Fi coverage area. Meanwhile, a system for water quality has been studied in [12] based on IoT with 3G cellular data transfer. However, the system was made only to detect threshold data and not for sending data continuously. On the other hand, there is no local database system so that the disconnection of the data connection makes the system lose history from sensor reading.

In this study, a real time monitoring system for the temperature and pH of shrimp pond water is based on Internet of Things (IoT). Both variables are measured using sensors and the database will be stored both on a remote device and on an online server. Sending data to an online server is done using a cellular network. Thus, this allows the data logger device to be installed in a remote area and easily moved if needed. Because in shrimp ponds there are rarely electricity sources from public power system, the equipment is equipped with solar power plants as a provider of electrical power devices.

2. Materials and Methods

In this session, the proposed methodology will be discussed which starts with a general discussion of the system to the design of each sub-system.

2.1. General System

In general, the system created as shown in Figure 1. In accordance with what is in the picture, there is a sensor module that functions to read the temperature and pH of pond water. Whereas the mini server acts as the main processor that reads the data from the sensor module stores it and then sends the data to the online server. For each sensor reading, it is also necessary to record the reading time so that the Real Time Clock (RTC) module is needed to provide accurate time data. The Wi-Fi router has two functions at the same time, namely providing access to the device directly at the location of the device and also providing a connection to the cellular internet network with the addition of a 4G LTE modem. On the server side, there is a database system that stores sensor reading data that has been sent by a remote device and also provides a web-based application to display the data.

The data flow from the system as shown in Figure 2. Input data from the sensor is read by Raspberry Pi, then calibrated first and then stored from the local database in Raspberry pi. Stored data is marked if it has not been sent. Then a collection of data that has not been sent periodically is sent to an online
server and then marked if the data has been sent. On the server side, data will be stored in a database and then displayed in the form of web pages.

Fig 1. General System of IoT Raspberry Pi Based Monitoring System

Fig 2. Data Flow from Sensor to Online Server

2.2. IoT Based System Design

The discussion of the design of this system is divided into three parts. The first is related to hardware design, then software design and then solar power system design.

2.2.1. IoT Remote Data Logger Hardware Design. The hardware design is shown in Figure 3. There are two sensors used, the DS18B20 temperature sensor and the liquid pH sensor. Another one is the mini server uses Raspberry Pi 3+. The output of the temperature sensor uses a 1-wire protocol so that data is connected to pin 7 on the Raspberry Pi. While the output of pH sensing is an analogue voltage variable, so an ADC module is needed to be read by Raspberry Pi. For the reason, this study uses the EMS Pi Logger module which is a Raspberry Pi Shield that has ADC (MPC3202) and RTC (DS1370) features. The connection from ADC to Raspberry Pi uses the SPI protocol while RTC uses i2c. To save the operating system of the Raspberry Pi and its applications and databases, a micro SD card with a capacity of 16GB is used.

For connectivity, two devices are needed. The first is the TL-MR3020 Wi-Fi Router and Huawei E3372 3G / 4G modem. Actually, the cellular modem can be connected directly to the USB port of the Raspberry Pi. But not done in this study for reasons of computability and user convenience. Reconfiguration is required if a SIM Card is changed with a different mobile network operator. On the
other hand, the use of a Wi-Fi router makes it easy for users to connect to the device to perform maintenance on the site.

Fig 3. Hardware System Design

2.2.2. IoT Remote Data Logger Database Design. Databases on remote devices have two main functions: the first saves sensor reading data and the second saves system configuration data which includes calibration settings, station identity, and also online server identity for the purpose of sending data over the internet network.

2.3. Acquisition and Transfer Data
Figure 4 is a flowchart for reading sensor data and also sending data to the server. Starting with the sensor reading, the software then calibrates for the correct reading. After that the data will be stored in a database with a sign that the data has not been sent to an online server. The period for reading the sensor data is done once every minute. After that, the data will be sent to the online server every 12 hours. Every data that has been sent will be given a sign that the data has been sent.

Fig 4. Flowchart for Data Acquisition (a) and Sending Data to Server (b)

2.4. Important Script
The system carried out in this study uses the Python programming base on the Raspberry Pi as a core language other than PHP as the user interface. Therefore, this subsection discusses important scripts in the system, especially those related to data acquisition.
2.4.1. Data Acquisition and Calibration. Acquisition and calibration data are the important part of this system. Sensor readings certainly need to be tested periodically to get accurate readings. This reading adjustment is done in software where the calibration parameters are stored in the database on the Raspberry Pi. In this study, there are two types of sensors, namely a temperature sensor that uses Onewire communication and a pH sensor with a variable voltage output signal. Below is a Python code on the Raspberry Pi to calibrate the output voltage signal reading from the pH sensor read by the Raspberry Pi ADC. As for the temperature sensor, it also uses a similar method.

```python
#ConnectDB
db = MySQLdb.connect("localhost","dbUser","dbPassword","db_name")
curs=db.cursor()
#get data, calibration, and store
curs.execute("SELECT StationSensorID,LowOutput,HighOutput, LowValue, HighValue FROM sensor_detail")
data=curs.fetchall()
vref=5
for row in data:
    StationSensorID = row[0]
x1 = row[1]
x2 = row[2]
y1 = row[3]
y2 = row[4]
inADC = 0;
v=readADC(inADC)
dataSensor=round(((float(v)-x1)/(x2-x1))*(y2-y1)+y1,2)
curs.execute("INSERT INTO sensor_data (DateTime, StationSensorID, value, status, x_value) VALUES (CURRENT_TIMESTAMP,'%s', '%s' , 0,%s')"%(StationSensorID,dataSensor,v))
db.commit()
db.close()
```

In the script above, the sensor data is calculated based on the two-point linear equation \((x_1, y_1)\) and \((x_2, y_2)\) where the \(x\) and \(y\) variables are obtained from the measurement results when testing. The value of \(x\) is the value of the sensor output reading, while the value of \(y\) is the reading of the comparator test. Subset 1 shows the first test with conditioning fluids with a low pH while subset 2 shows the second for liquids conditioned with high pH. Moreover, this method is only suitable for sensors giving a linear reading.

2.4.2. Scrontab Autorun Script. Sensor data acquisition is carried out periodically as well as sending data to online servers. In this study, setting the running period for the script was done using the crontab feature in the Raspbian operating system used. The following is a crontab script that is used to run the data acquisition process (logger.py) and also sends data to an online server (sendingdata.py).

```
pi@raspberrypi:~ $ crontab -l
* * * * *  sudo python /home/pi/logger.py
0 */12 * * *  sudo python /home/pi/sendingdata.py
```

2.5. User Interface Design
To make it easier for users to maintain, especially in terms of sensor calibration, web-based software is created for remote monitoring device as depicted in Figure 5. In general, there are three main types of menus namely menus related to device identity, configuration menus for sensor calibration, and also menus for displaying sensor reading data. Thus, users without programming background or computer configuration can calibrate the sensor if needed. On the server side, a web interface is also made to view the data that has been stored.
2.6. Solar Cell Based Power System Design

The electrical power source in this research uses solar energy. Thus, the system can be installed ponds even though there is no electricity network from the public electricity company. To meet the electrical power requirements of the tool, it is necessary to calculate the power requirements so that the design specifications of the solar panel system can be determined namely the WP solar panel and also the battery capacity [13]. Based on the measurement result, the equipment made requires an electric current of 1A for a voltage source of 5V. Thus, the power needed can be calculated that is 5W. For a day and night, it takes as much as 120-watt hours (Wh) of power.

It is assumed that in a day's radiation, the sun shines optimally to be converted into electricity for 4 hours. So, from the calculations needed 30-watt peak (WP) solar panels to obtain the 120Wh. Battery capacity on the market is usually expressed in units of ampere hour (Ah). If the battery used has a 12V voltage, to store power of 120Wh, a battery with a capacity of 10Ah is needed.

3. Result and Discussion

A remote data logger device that is produced with a temperature sensor and pH sensor is shown in Figure 6. This tool has been tested in Laboratory of Fish Reproduction, Universitas Brawijaya.
The test results showed that the system created could function properly. For this trial, the data reading period was made every minute while the data transmission was set every minute. The results showed that the system automatically sent data to the server and could be accessed online. Figure 7 is a display of temperature data, while the pH data is shown in Figure 8. This monitoring system will be beneficial to optimize the shrimp production because of allowing users to monitor water quality (pH and temperature) in real-time so that they can promptly detect and fix the problem. Uddin et al. [14] suggested that the implementation of a monitoring system based on the internet of things improved the production and survival rate of freshwater shrimp (Macrobrachium rosenbergii) in Bangladesh.

There are some works have been done about water monitoring such as by Bookingkito Jr. [15] and Huan et al. [16]. However, they did not provide user friendly sensor calibration menu in their work. This item is important for maintaining sensor data accuracy in the field application. In this work, the feature is provided by web-based application. Sensor calibration is done by comparing the sensor
reading values with portable measuring devices and then configuring the calibration menu that has been made.

Based on the result, the system has several advantages, namely real time (can be installed in remote areas) and easy to operate. However, one of the weaknesses of this system is that power requirements are still relatively high for the size of remote devices. Therefore, in the future the system can be developed with hardware that does not consume a lot of system power which is made easy to be operated by even an unskilled person.

4. Conclusion
In this study, a remote data recording platform was created to monitor the temperature and pH of shrimp pond. This system has been tested in a laboratory and is ready to be implemented in ponds. The test results showed that monitoring data can be sent properly on an online server and can be accessed using the internet network. This tool can also meet its own energy needs by using its own solar power plants.

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