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Internet of Things-Based Water Quality Control System

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ABSTRACT

Fish incubation, which involves the hatching of fish eggs, represents the process of embryogenesis until the embryo emerges from its protective shell. This intricate developmental journey is influenced by a combination of internal and external factors. External factors can be influenced by water quality that is not suitable for hatching fish eggs. Water quality, which includes temperature, dissolved oxygen, light intensity, salinity, and pH, is an important and limiting factor for living creatures that live in water, including chemical, biological, and physical factors. Poor water quality can prevent fish eggs from hatching and even cause death. The primary objective here is the creation of an Internet of Things (IoT)-based system designed for controlling water quality during fish incubation. This system is intended to aid fish farmers in ineffectively controlling the environmental conditions within their incubation ponds. The method used in designing IoT devices is research and development, and it uses the Arduino Mega microcontroller as the main device to run pH sensors, turbidity sensors, oxygen sensors, temperature sensors, and relay modules. Water Quality Control System The fish incubation was successful. The average time needed to change the water temperature from 28.5 to 29 degrees Celsius is 4 minutes and 7 seconds; change the dissolved oxygen level from 11 to 11.5 is 3 minutes and 33 seconds; change the pH value of the water from 6.9 to 7.1; and maintain turbidity below 5 with an average time of 5 minutes and 58 seconds. Controlling water quality can speed up the fish egg incubation process for 8 hours.

Introduction

The hatching of fish eggs is the result of embryogenesis until the embryo comes out of the shell. Embryo activity is influenced by factors from outside and inside the shell (Violita et al., 2019); (Alfath et al., 2020). Low egg hatchability can be affected by internal and external factors. External factors can be influenced by water quality that is not suitable for hatching fish eggs or harvesting is carried out with carelessness so that many fish eggs are damaged (Faris et al., 2023). Suboptimal water quality can interfere with the growth process. The development of fish life is very influential in supportive water quality will be very influential for aquatic animals living in it. Temperature, pH and DO are parameters that play an important role for fish. Temperature plays a very important role in regulating the activity of organisms, as it can regulate the speed of chemical reactions in the body and metabolism (Faris et al., 2023). Fish can live well on a cultivation medium that suits their needs. Under optimal conditions, fish can grow optimally. In less than optimal conditions, fish adapt more so that their growth is not optimal. To adapt to the environment, fish have tolerance and resistance to environmental changes in a certain range. Water quality management is an effort that can be taken to increase the productivity of fish farming activities. Water quality is said to be good if the physical, chemical and biological parameters of the water are by what is needed by the organism being maintained. The physical parameters of water quality include temperature, depth, brightness, TDS, TSS, etc. The chemical parameters of water quality include salinity, dissolved oxygen, BOD, COD, etc. Biological parameters of water quality include fertility, plankton abundance, etc (Scabra & Setyowati, 2019).

Internet of Things (United Kingdom: Internet of Things, also known as IoT for short) is a concept that aims to expand the benefits of continuously connected internet connectivity. The capabilities are such as data sharing, remote control, and so on, including on objects in the real world. The Internet of Things is a concept that aims to expand the benefits of continuously connected internet connectivity (Prasetyo et al., 2019).

The function of IoT is to collect data or information and then process the data so that it produces understandable meaning. IoT can transform information management to get intelligent systems and solutions that can be applied in homes, offices, hospitals, transportation, companies, schools and factories. IoT can create a complete internet environment and make it easier for people to access various smart technologies that have been integrated with automation that can be used anytime, anywhere (Megawati, 2021).

Research on water quality monitoring has been carried out a lot, including Araneta, et al. in designing a water quality monitoring system by utilizing pH sensors, turbidity sensors, TDS sensors, and temperature sensors which are then displayed on LCDs (Araneta, 2022). Primantara, et al. designed a monitoring system for water quality using pH, turbidity sensors, TDS sensors, and temperature sensors which then the data obtained is sent into a database and can be accessed through the web and mobile application (Primantara & Bhuana, 2021). Islam, et al. in designing a water quality monitoring system that will be used for fish farming. Setiowati, et al. in designing a water quality monitoring system by utilizing pH and oxygen sensors (Setiowati et al., 2022).

Based on this, the author made a prototype system for Fish Incubation Water Quality Control Based on the Internet of Things by utilizing Arduino Mega microcontrollers, NodeMCUs, and Firebase real-time databases.

Arduino Mega 2560 is a microcontroller development board based on Arduino using the ATmega2560 chip (Santosa & Wijayanto, 2022); (Tama et al., 2019). The

Arduino Mega is used to control the various sensors used and will transmit data to the NodeMCU. NodeMCUs are used as hosts or as data transfer modules in WiFi networks. This module has advantages in good data processing and storage (Ulum et al., 2022). Firebase Realtime Database is a real-time database stored in the cloud and supports multiple platforms such as Android, iOS and Web (Maulana, 2020).

The device made by the researcher can find out the water quality in the incubation pond and can take action to stabilize the water quality so that fish farmers only need to monitor it.

Method

The research methodology is a process that will be carried out in this research which begins with a search for literature studies, design and manufacture of tools, testing of tools and the entire device system. The process of designing and manufacturing tools will be described as follows.

Device Analysis

Device analysis is what is needed in building tools in this study. All tools and other supporting needs that will be used in this study are listed in Table 1.

Table 1
Tools and Materials

NO	Tools and Materials	Uses
1	1 Arduino Mega	As a data processor from sensors
2	1 piece ESP8266	As a module used to send data to the internet
3	1 Water PH Sensor	As a Reader of Water PH Value
4	1 x Turbidity Sensor	As a Reader The value of water turbidity
5	1 DO Sensor	As a Reader of Dissolved Oxygen Value in Water
6	1 Temperature Sensor	As a Reader of Temperature Values in Water
7	1 Piece 3 Channel Relay	As a Switch for water quality control device
8	1 x 20x4 LCD	To display the sensor value on the device

Scheme Design

Schematic Design is a series that connects pH sensors, turbidity sensors, Dissolved Oxygen sensors, temperature sensors, relay modules, ESP8266 MCU nodes, and 16x4 LCD with Arduino Mega Microcontrollers. The NodeMCU ESP8266 be used as a bridge between the Arduino Mega 2560 to send data from the DS18b20 temperature sensor, DFRobot SKU SEN0189 turbidity sensor, SEN0161 SKU pH sensor, SEN0237 SKU DO sensor, and relay module. The design of the IoT Scheme can be seen in Figure 1.

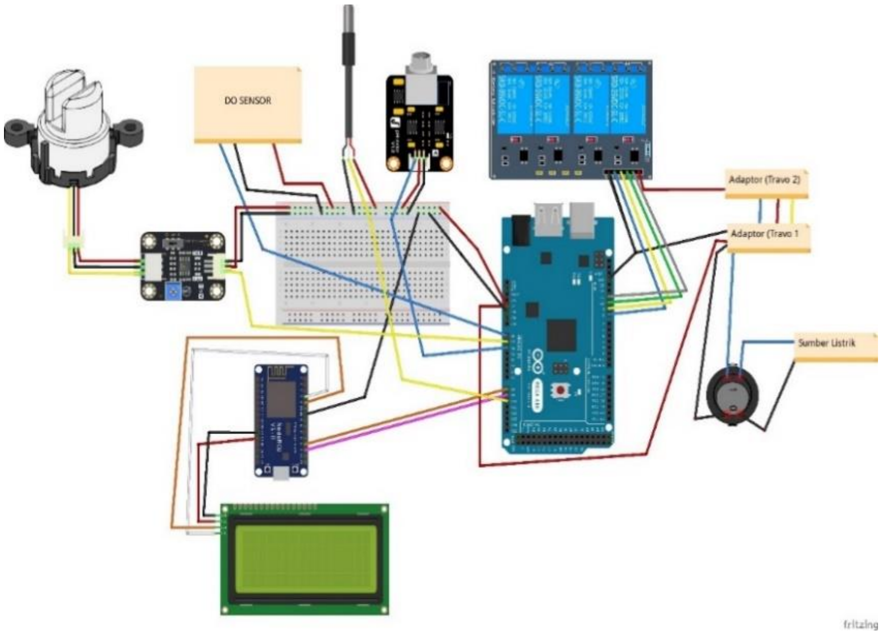

Figure 1 Schematic Design

The PH meter uses a probe made of a non-conductive glass cylinder that functions as the sensor. By utilizing HCl compounds that soak the electrode wire, this tool can measure the degree of acidity contained in water (HADIATNA & SUSANA, 2019).

Turbidity sensors are module sensors that work to read turbidity in water turbidity particles cannot be seen by the direct eye. The more particles in the water indicate that the level of turbidity of the water is also high.

The ds18b20 sensor is a temperature sensor that can measure temperature in the range from -55°C to 125°C. In addition, DS18B20 has a built-in ADC and provides temperature measurements with selectable resolution values from 9-bit to 12-bit for a fairly high accuracy of ±0.5°C over a temperature range between -10°C to +85°C (Wijaya & Wellem, 2022).

The DO sensor is used to detect oxygen levels in the water. This sensor has 4 input pins, namely Analog Signal Output, VCC (3.3-5.5 V), GND, and Probe Cable Connector. The probe used is a galvanic probe that does not require polarization time and is available at any time.

Device Flow Design

The way the fish incubation water quality control system works is by assessing the water condition through pH sensors, turbidity sensors, temperature sensors, and dissolved oxygen sensors. The relay will take action according to the value displayed by the sensor. A relay with a heater connection will take action when the temperature sensor value is below the ideal temperature of incubation. A relay with a water filter connection will take action if the pH and turbidity values are outside the ideal value of incubation. The relay with the aerator connection will take action when the dissolved oxygen value is below the ideal value of incubation. The value of the sensor is then sent to the NodeMCU which will then be sent to Firebase.

Results and Discussion

The results and discussion were divided into four stages, namely the results of the design of the device, sensor testing, testing the time needed to control water quality, and testing the hatching of fish eggs. The sensor testing stage is carried out by comparing the sensor value with the value of the measuring instrument or solution that has been tested in the laboratory so that the sensor value has a high level of accuracy. The time required test is carried out by testing the average time it takes to control the water quality value.

Results of Tool Design

The IoT design for the Fish Incubation Water Quality Control System is implemented using Arduino Mega and NodeMCU. The Arduino Mega functions to control the entire sensor and relay module. Meanwhile, nodeMCU is used to send data to a database which is then displayed on the Android application. The prototype of the Fish Incubation Water Quality Control System can be seen in Figure 2.

Figure 2 Prototype of the Fish Incubation Water Quality Control System

The data obtained by the sensor will be transmitted by the Arduino Mega to the NodeMCU. Next, the NodeMCU will send the received data into Firebase in time. The data stored in Firebase Realtime is the overall sensor value and the status of each relay. The appearance of the Android application is as follows.

Figure 3 Android App Display

Sensor Test Results

The results of the sensor test are carried out to determine the level of accuracy of the sensor. The temperature sensor test is carried out by comparing the values obtained by the sensor and the thermometer can be seen in Figure 5 (a). The oxygen sensor test was carried out by comparing the values obtained by the DO sensor and the DO meter seen in Figure 5 (b). Figure 5 (c) shows the process of testing a pH sensor by comparing the sensor value to pH. Meanwhile, Figure 5 (d) shows the process of testing turbidity sensors by measuring the values obtained by sensors whose turbidity values have been tested in the laboratory.

(a) (b)

(c) (d)

Figure 4 Temperature sensor test (a) Oxygen centrifuge test (b) pH sensor test (c) Turbidity sensor test (d)

The test is carried out by comparing the value obtained by the sensor with the value obtained by the measuring instrument. The closer the sensor value is to the value obtained by the measuring device, the more accurate the sensor value will be. In Table 2, the results of the temperature sensor test by comparing the values obtained by the sensor and the thermometer were carried out 13 times and obtained a Root Mead Squared Error (RSME) value of 0, meaning that the value obtained by the sensor was accurate.

Tabel 2
Hasil Pengujian Sensor Suhu

Sensor Suhu Ds18b20	Thermometer Measuring Instrument	Error	Square Error
19.5	19,5	0	0
20.12	20,1	0.02	0.0004
21.07	21	0.07	0.0049
21.57	21,5	0.07	0.0049
22.14	22	0.14	0.0196
22.58	22,5	0.08	0.0064
24.08	24	0.08	0.0064
24.59	24,5	0.09	0.0081
25.09	25	0.09	0.0081
26.1	26	0.1	0.01
26.6	26,5	0.1	0.01
27.1	27	0.1	0.01
30.62	30,6	0.02	0.0004
Number of Square Errors			0.0892
Amount of Data			13
Root Mean Squared Error (RMSE)			0

In Table 3, the test results carried out by the Dissolved Oxygen sensor by comparing the values obtained by the sensor and the DO meter measuring instrument which were carried out 5 times obtained a Root Mean Squared Error (RMSE) value of 0.02. This value shows that the dissolved oxygen sensor can accurately check the condition of the oxygen contained in the water.

Table 3
Dissolved Oxygen Sensor Test Results

Sensor DO	DO Meter	Error	Square Error
3.9	4	0.1	0.01
6.7	6.8	0.1	0.01
7.5	7.5	0	0
7.9	7.9	0	0
8.4	8.5	0.1	0.01
Number of Square Errors			0.03
Amount of Data			5
Root Mean Squared Error (RMSE)			0.02

The test for pH sensors uses a comparison of the values obtained by the sensor with the values obtained by the pH meter by measuring the values in 6 solutions with different acidity levels. The results of the pH sensor test can be seen in Table 4. Based on Table 4, the Root Mean Squared Error (RMSE) value obtained is 0.01 which shows that the sensor can accurately assess the acidity level of water.

Table 4
Ph Sensor Test Results

Sensor pH	pH Meter	Error	Square Error
2.3	2.25	0.05	0.0025
3.0	3.03	0.03	0.0009
4.0	4.01	0.01	0.0001
6.3	6.38	0.08	0.0064
9.4	9.52	0.23	0.0529
10.4	10.34	0.06	0.0036
Number of Square Errors			0.0664
Amount of Data			6
Root Mean Squared Error (RMSE)			0.01

In Table 4, the results of the turbidity sensor test were carried out by checking the NTU values in 4 water solutions that had previously been examined in the laboratory. Based on Table 5, the result of the Root Mean Squared Error (RMSE) is 0.06 which proves that the value obtained by the turbidity sensor can be said to be accurate.

Table 5
Turbidity Sensor Test Results

Sensor pH	pH Meter	Error	Square Error
1.47	1.53	0.06	0.0036
5.55	5.01	0.54	0.29
10.17	10.67	0.5	0.25
87.97	87.94	0.03	0.0009
Number of Square Errors			0.544
Amount of Data			4
Root Mean Squared Error (RMSE)			0.06

Control Time Test Results

The control time test is carried out on the incubation aquarium which has been designed in such a way that the water content in the aquarium is below the value required in the incubation process. The results recorded were in the form of the average time needed to control the water coolant in the incubation pond for each control device in as many as four experiments.

The control test of the water temperature was carried out by calculating the time needed to increase the temperature from 28.5 to 29 degrees Celsius using a water heater that has a power of 75 Watts and is connected to one of the relays on the IoT device. The experiment was carried out 4 times with the fastest time being 3 minutes 56 seconds and the longest time being 4 minutes 23 seconds. The average time it takes to raise the water temperature is 4 minutes 07 seconds. The results of the water temperature control time test can be seen in Table 6.

Tabel 6
Hasil Pengujian Kontrol Suhu Air

The experiment	Initial Temperature Value	Target temperature	Time
1	28.5	29	4m 23s
2	28.5	29	3m 56s
3	28.5	29	4m 01s
4	28.5	29	4m 09s
		Average Time	4m 07s

Table 6 shows the results of the control time test needed to control the water on the dissolved oxygen parameter. The test was carried out by calculating the time it takes to increase the oxygen level in the water from 11 to 11.5 mg/L using an aerator with a power of 2.5 Watts that is already connected to one of the relays on the IoT device. The experiment was carried out 4 times so that the fastest time was 5 minutes 24 seconds and the longest time was 5 minutes 41 seconds. The average time obtained to increase the oxygen level in the water was 5 minutes and 58 seconds.

Table 7
Do Air Control Test Results

The experiment	Initial DO value	Target DO	Time
2	11	11.5	5m 24s
3	11	11.5	6m 41s
4	11	11.5	5m 50s
5	11	11.5	5m 56s
		Average Time	5m 58s

In Table 8, the test results of the control time needed to control the water on the water pH and turbidity parameters obtained an average time of 3 minutes and 33 seconds with 4 experiments carried out. The water parameters are controlled so that the pH value of the water is stable at 7 and the turbidity value is below the value of 10 NTU using a water filter. The fastest time needed is 3 minutes 10 seconds and the longest time needed is 4 minutes 10 seconds.

Table 8
Ph and Water Turbidity Test Results

The experiment	Initial pH value	Final pH Value	NTU Initial Value	NTU Final Score	Time
2	6.8	7.1	5	4	3m 19s
3	6.9	7.1	4	0	3m 10s
4	6.8	7.1	5	5	3m 32s
5	6.7	7.1	4	1	4m 10s
Average Time					3m 33s

Fish Egg Hatching

Fish egg droplet testing was carried out at the Ringdikit Fish Seed Center. The test was carried out by moving several kakabans into an incubation pond that was equipped with a water quality control system. There are two stages, namely preparing mature broodstock and the fish hatchery process, as well as the incubation process.

Mature broodstock selection is needed to increase the percentage of success in hatchery. The characteristics of mature broodstock are that female broodstock has a characteristic belly that looks enlarged and when the belly of the female brood is held it will feel soft, while the male brood has a characteristic that when the belly of the fish is slightly pressed, the eyes will release sperm fluid. It is also recommended that the weight of both broodstock fish be the same to increase success.

The hatchery process is carried out for 24 hours by isolating the broodstock with 1 female broodstock compared to 2 male broodstock. In the process, the mother fish will release fish eggs which will then attach to the prepared kakaban and will be fertilized by the male mother. The selection of mature broodstock can be seen in Figure 6 (a). Figure 6 (b) shows the fish hatchery process.

Figure 6 Fish broodstock selection process (a) Fish hatchery process (b)

The next stage is to carry out the process of hatching fish eggs in the incubation pond by taking a sample of a kakaban with several fish eggs ranging from 1000 to 3000 eggs. The water condition in the research incubation pond is regulated to remain stable by setting the water heater to turn on when the temperature value reaches a value of 28 and will turn off when the temperature value reaches 29 so that the water temperature remains stable at 29 degrees Celsius. The aerator is set to turn on when the oxygen reaches a value of 11 and will turn off when it reaches a value of 11.5 so that the oxygen value will be stable above 11 mg/L. The water filter pump is left on to keep the water in the pool flowing, to prevent the occurrence of unpleasant odours caused by eggs that have failed to hatch, and to keep the pH value of the water stable with a value of 7 and turbidity with a value below 10. The incubation process of fish eggs can be seen in Figure 7.

Figure 7 Incubation process of fish eggs

The results of the fish egg hatching test were obtained that the hatching process in the research pond with regulated and stable water quality at a certain value required a faster hatching time of 8 hours compared to the pond pond with the same percentage of egg hatching success.

Conclusion

The results of the experiment in this study show that the water quality measurement sensor gets a value (error value/accuracy value). The average time needed to maintain the water temperature between 28.5 to 29 degrees Celsius is 4 minutes 7 seconds, the average time needed to produce dissolved oxygen levels between 11 to 11.5 is 3 minutes 33 seconds, the time needed to maintain the water pH value from 6.9 to 7.1 and maintain turbidity below 10 NTU for 5 minutes 58 seconds. Controlled water quality among vulnerable temperature values above 28 degrees Celsius, oxygen above 11 values, pH with a value of 7 and turbidity below 10 NTU can shorten the time it takes for eggs to hatch for 8 hours with the same percentage of successful hatching compared to not controlling the water quality in the incubation pond. Thus, the water quality control system for fish incubation is well-tested according to its function.

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