Design of water quality monitoring platform based on Embedded System

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Abstract. This paper designs and develops an embedded aquaculture intelligent water quality monitoring system based on STM32F103VET6, serial communication module and RS485 interface circuit. The system uses sensors to collect the temperature, pH value, dissolved oxygen, turbidity and other information of aquaculture water quality in real time. Through the water quality monitoring platform established in this paper, the water quality index method is used to evaluate the water quality, so that the farmers can obtain the abnormal alarm information and water quality comprehensive situation in time, and get the water quality improvement suggestions.

Key words: Aquaculture; Water quality monitoring; Embedded system; Water quality index method.

1. Introduction
Aquaculture has played an important role in solving the food crisis, improving the quality of life and increasing the income of relevant workers. In recent years, China's aquaculture output has reached 70 million tons, and the output of aquatic products accounts for more than 70% of the world, ranking first in the world, and the aquaculture area has reached nearly 20 million square meters[1]. With the rapid development of modern industry, higher requirements are put forward for the accuracy of water quality detection results in China. Water quality monitoring can timely, accurately and comprehensively reflect the quality and pollution of water environment, and provide data support for the protection and treatment of water resources.

This system uses STM32 embedded software and hardware to build an intelligent water quality monitoring system. Through the multi-sensor real-time collection of water quality information, provide water quality parameters analysis for users and related monitoring personnel, and give reasonable suggestions.

2. Design scheme

2.1. Overall design ideas
The system consists of a front-end control host placed in the fish pond, a server placed in the background, and a host computer for aquaculture personnel. Its structure is shown in Figure 1.
The fish pond is managed and controlled by an intelligent aquaculture host, which is responsible for transmitting the collected data to the server through the mobile communication data channel, and can also receive the control instructions from the server; the front end is equipped with sensors to collect the temperature, pH, dissolved oxygen, turbidity and other parameters of the aquaculture water body[2]; finally, the system evaluates the water comprehensively according to the above data Quality.

Through the water quality monitoring platform designed in this paper, farmers can obtain real-time abnormal alarm information and water quality comprehensive situation, so as to timely find problems and improve water quality, and minimize the losses of farmers due to lack of experience and improper management.

2.2. Introduction to water quality monitoring process
The system collects water quality data through sensors and analyzes them comprehensively, and obtains the comprehensive evaluation results of water quality. The specific detection process is shown in Figure 2.

![Flow chart of water quality detection](image)

**Figure 2.** Flow chart of water quality detection
3. Hardware design of detection system

The host hardware structure is shown in Figure 3, which briefly describes the relationship between the modules. The sensor information is obtained directly or through RS485 interface circuit. The information is processed by single chip microcomputer and transmitted to the upper computer to realize data storage and analysis.

**Figure 3. Hardware circuit structure of host**

3.1. Main control chip

STM32F103VET6, a 32-bit enhanced microprocessor based on Cortex-M3 core, is selected as the main control chip. It has 512k bytes of Flash and 64K bytes of SRAM, It contains three 12 bit ADCs, two 12 bit DACS, four general 16 bit timers and a DAC timer. It has I2C, SPI and other communication standard interfaces.

3.2. Information transmission and communication module

Considering the stability and reliability of communication, the system uses RS485 serial port protocol to realize the information transmission process between the system communication motherboard and each module. Considering the consistency with the power supply of the main control chip[3], the 3.3V differential transceiver SN65HVD11D of Texas Instruments is adopted. The specific circuit is shown in Figure 4.

**Figure 4. Communication module circuit**

3.3. A/D conversion module

AD7928 is selected to realize A/D conversion in this system. It is a 12 bit ADC acquisition chip with high sampling accuracy, which can meet the basic voltage acquisition; it has 1M/MSPS data throughput, which can fully improve the acquisition speed; it has 8 channel input interfaces, and has flexible power consumption and clock speed management mechanism.
3.4. Sensor selection
Water quality data acquisition refers to real-time collection of water quality parameters by deploying water quality monitoring sensors underwater. The system measures 7 water quality indexes, and the sensor selection is shown in Table 1.

| Sensor model   | Measurement index | Range      | Accuracy   |
|----------------|-------------------|------------|------------|
| JF-D500A       | Temperature       | 0~80℃      | ±0.001℃    |
|                | pH value          | 0~14       | ±0.01      |
|                | Dissolved oxygen  | 0~20mg/L   | 0.1mg/L    |
|                | Turbidity         | 0~1000 NTU | 2%         |
| JZ-YXSY        | Nitrite           | 0~20ppm    | ±0.1%      |
| JF-NH4-485     | Ammonia nitrogen  | 0~1000ppm  | 0.1ppm     |
| JF-PB-485      | Lead ion          | 0~6000ppm  | 0.001ppm   |

JF-D500A: Multi parameter integrated digital sensor produced by Shanghai Jingfei Environmental Protection Technology Co., Ltd., which can simultaneously measure pH, dissolved oxygen, conductivity, turbidity and temperature; it adopts RS485 output and supports MODBUS protocol.

JZ-YXSY: It calculates the corresponding nitrite content in the liquid to be measured by measuring the current formed by the oxidation of NO2- on the working electrode surface in the solution. The sensor adopts three wire structure, 0-20mA output, and has the function of automatic temperature compensation.

JF-NH4-485: It uses three electrode system to determine ammonia nitrogen content: NH4+ electrode provides main measurement; K+ electrode and pH electrode are used to correct data. It adopts RS485 output, supports MODBUS standard protocol, and can modify address, baud rate and calibration by software.

JF-PB-485: It uses the current change caused by the adsorption of lead ions on the grid to obtain the lead ion concentration. Its output is RS485 mode with temperature compensation function.

3.5. Power supply circuit
The system is powered by a 220V/5V AC transformer. The 5V DC power supply is reduced to 3.3V by LM2596S step-down power supply module to meet the power supply requirements of the main control chip. The buck circuit is shown in Figure 4.

![Power supply circuit](image)

4. Design of water quality monitoring platform

4.1. Water quality evaluation index and water quality standard
Sufficient dissolved oxygen, suitable pH and low level of ammonia nitrogen and nitrite are necessary conditions for normal growth and reproduction of fish. The water quality monitoring platform designed in this paper can analyze and process the water quality data such as temperature, pH value, dissolved oxygen, turbidity, ammonia nitrogen and nitrite, and realize the real-time monitoring of water quality.
Water quality standard for Fisheries (Standard No. GB 11607-89) issued by China in 1990 specifies the water quality requirements, determination methods, and the basis and standards for the determination of inspection results, which are mainly used to prevent and control water pollution of fishery and aquaculture and ensure the normal growth and reproduction of fish, shrimp, algae and shellfish[6]. The following table is the reference standard for some water quality factors.

| Project       | Content          | Remarks                                      |
|---------------|------------------|----------------------------------------------|
| Temperature   | ≥30℃             | High temperature                            |
|               | 18-30℃           | Suitable temperature range                   |
|               | ≤18℃             | Temp too low                                 |
| pH            | 7-8.5            | Safe range of mariculture                    |
|               | 6.5-8.5          | Safe range of freshwater aquaculture         |
| Dissolved oxygen | ≥5mg/L         | Safety scope                                |
|               | 2-3mg/L          | The growth is slow and the feed coefficient is high |
|               | ≤1-2mg/L         | Flooding, even death                         |
| Turbidity     | ≥10 NTU          | Difficult to eat or breathe                  |
|               | <10 NTU          | Safety scope                                |
| Ammonia nitrogen | <0.2mg/L      | Safety scope                                |
|               | 0.2-0.5mg/L      | Fish feeding decreased,Weak swimming         |
|               | >0.5mg/L         | Unable to eat or breathe, or even die         |
| Nitrite       | <0.1mg/L         | Safety scope                                |
|               | 0.2-0.3mg/L      | The physical strength of fish declines and the resistance decreases |
|               | >0.5mg/L         | Easy to cause poisoning, serious death        |
| Lead          | ≤0.05mg/L        | Safety scope                                |

When the water quality is abnormal, the user can be reminded of the reasonable loss according to the water quality.

4.2. Comprehensive analysis of water quality

The water quality monitoring platform designed in this paper uses the water quality index method [7] to conduct scientific analysis on the collected data, determine the water quality situation in a period of time and the frequency of water quality being threatened, so as to help farmers comprehensively evaluate the water quality of the aquaculture area.

The water quality index method is to analyze the water quality of aquaculture area by calculating the comprehensive water quality identification index (WQI):

i. Factor 1 (F1): During the evaluation period represented by F1, the percentage of elements that do not meet the environmental quality standards among the elements to be evaluated:

\[ F_1 = \left( \frac{N_{Y'}_{NV}}{N_{Y'}} \right) \times 100 \]  (1)

Among them, NV is the total number of elements to be evaluated; N'Y is the number of elements that do not reach the environmental quality.

ii. Factor 2 (F2): F2 represents the percentage of measurement results that do not meet the environmental quality standards in the elements to be evaluated:

\[ F_2 = \left( \frac{N_{Y'}_{NT}}{N_{Y'}} \right) \times 100 \]  (2)

Among them, NT is the total number of determination of all the elements to be evaluated; N'Y is the number of times that the environmental quality has not been reached.
iii. Factor 3 ($F_3$): $F_3$ represents the degree of deviation from the environmental quality standard for the determination results that do not meet the environmental quality standard. $F_3$ is calculated in three steps:

The first step is to calculate the over standard degree of a single measurement result of a certain element:

When the environmental quality standard is not greater than the target value:

$$D_i = \frac{NM_i}{M_{si}}$$

(3)

Among them, $D_i$ is the pollution index value of the $i$th excessive measured value; $NM_i$ is the measured value of the exceeding standard element; $M_{si}$ is the environmental quality standard value of the exceeding standard element.

When the environmental quality standard is not less than the target value:

$$D_i = \frac{M_{si}}{NM_i}$$

(4)

The second step is to add the exceeding degree of all the measurement results that fail to meet the environmental quality standard, and divide it by the total number of measurements (including the sum of the number of qualified and non-standard determinations):

$$nse = \sum_{i=1}^{N_T} D_i$$

(5)

The calculation formula of $F_3$ is as follows:

$$F_3 = \frac{nse}{0.01nse + 0.01}$$

(6)

The formula for calculating the comprehensive water quality index (WQI) of CCME is as follows:

$$CCMEWQI = 100 - \left[ \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right]$$

(7)

According to the value of CCMEWQI, the water quality in the aquaculture area can be judged. The judging rules are shown in Table 3.

**Table 3. Determination of water quality in aquaculture areas [7]**

| CCMEWQI value | Water quality of aquaculture area | Water quality description                                      |
|---------------|----------------------------------|----------------------------------------------------------------|
| 95-100        | Excellent                         | The water body is not threatened and close to nature            |
| 80-94         | Good                             | Water bodies are rarely threatened and rarely deviate from nature|
| 65-79         | Medium                           | Water bodies are occasionally threatened and occasionally deviated from nature |
| 45-64         | Pass                             | Water bodies are often threatened and often deviate from nature  |
| 0-44          | Fail                             | Water bodies have been threatened and deviated from nature      |

Using LabVIEW to export data for testing, you can get CCMEWQI values for several days. According to table 3, the water quality of the aquaculture area can be comprehensively evaluated.

4.3. Application examples of water quality monitoring platform

In order to make users understand the status and trend of water quality parameters more clearly, the system uses LabVIEW to design man-machine interface, transmits data through serial communication, and outputs current data and parameter change waveform at the same time. Referring to the 20 day data of a aquaculture area [7], this paper will illustrate the functions of the water quality monitoring platform. The water quality data of the aquaculture area are shown in Table 4.
Table 4. Water quality parameters and evaluation results in 20 days

| Date | Temperature | pH  | Turbidity | Dissolved oxygen | Ammonia nitrogen | Nitrite | Lead | CCMEWQI | Water quality |
|------|-------------|-----|-----------|------------------|------------------|---------|-------|---------|--------------|
| 8/1  | 23.7667     | 8.02| 0.21      | 6.98             | 0.0322           | 0.022   | 0.006 | 86.88   | Good         |
| 8/2  | 20.8840     | 8.14| 2.06      | 6.44             | 0.0577           | 0.023   | 0.002 | 86.44   | Good         |
| 8/3  | 22.0919     | 8.20| 2.97      | 7.42             | 0.0470           | 0.022   | 0.007 | 87.89   | Good         |
| 8/4  | 21.6893     | 8.14| 0.25      | 6.70             | 0.0497           | 0.026   | 0.009 | 84.94   | Good         |
| 8/5  | 17.9974     | 8.06| 1.34      | 6.11             | 0.0441           | 0.026   | 0.002 | 85.84   | Good         |
| 8/6  | 20.0741     | 8.10| 2.32      | 6.34             | 0.0302           | 0.027   | 0.007 | 87.26   | Good         |
| 8/7  | 19.7642     | 8.19| 0.28      | 7.52             | 0.0279           | 0.023   | 0.003 | 86.28   | Good         |
| 8/8  | 23.4495     | 8.56| 1.22      | 8.10             | 0.0328           | 0.023   | 0.006 | 88.83   | Good         |
| 8/9  | 26.1124     | 8.22| 0.74      | 7.16             | 0.1440           | 0.024   | 0.005 | 83.06   | Good         |
| 8/10 | 21.0927     | 8.17| 2.36      | 7.12             | 0.0724           | 0.025   | 0.006 | 87.62   | Good         |
| 8/11 | 22.1672     | 8.26| 2.22      | 7.34             | 0.0674           | 0.023   | 0.004 | 88.63   | Good         |
| 8/12 | 21.3699     | 7.92| 2.14      | 7.50             | 0.0822           | 0.025   | 0.003 | 89.32   | Good         |
| 8/13 | 21.7937     | 7.67| 0.78      | 7.10             | 0.0564           | 0.021   | 0.002 | 88.64   | Good         |
| 8/14 | 21.6453     | 7.69| 1.37      | 7.29             | 0.0631           | 0.022   | 0.003 | 85.24   | Good         |
| 8/15 | 20.1975     | 8.11| 1.54      | 6.94             | 0.0463           | 0.021   | 0.004 | 86.23   | Good         |
| 8/16 | 20.1424     | 8.02| 1.83      | 7.02             | 0.0398           | 0.024   | 0.006 | 87.34   | Good         |
| 8/17 | 19.7330     | 8.23| 1.95      | 6.78             | 0.0455           | 0.022   | 0.005 | 86.67   | Good         |
| 8/18 | 21.2466     | 8.12| 2.16      | 6.89             | 0.0431           | 0.023   | 0.008 | 82.96   | Good         |
| 8/19 | 22.7493     | 8.35| 2.67      | 6.63             | 0.0582           | 0.024   | 0.004 | 84.64   | Good         |
| 8/20 | 22.0911     | 8.15| 4.36      | 6.44             | 0.0658           | 0.025   | 0.003 | 84.14   | Good         |

Through the data processing of the water quality monitoring platform designed in this paper, the change curve of water quality parameters is obtained, as shown in Figure 5. Click the export report in the upper right corner of the screen to get the analysis results and reasonable suggestions, as shown in Figure 6.

![Figure 6. User interface of water quality monitoring platform](image)
5. Summary
In order to assist relevant monitoring personnel to analyze water quality parameters, an intelligent aquaculture monitoring system based on STM32 is designed and developed. The system collects the temperature, pH value, dissolved oxygen value, turbidity and other information of aquaculture water quality in real time, and uses the water quality index method to evaluate the water quality comprehensively. Farmers can access the system remotely through personal computers and other terminals, timely obtain abnormal alarm information, analyze the comprehensive situation of water quality and get improvement suggestions. The system has been tested and runs well, which can provide technical support for the design and development of aquaculture monitoring system.

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