



Multi Node Water Quality Monitoring System of Fish Pond Based on Unmanned Ship Technology

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Abstract. In order to better improve the multi node water quality of fish pond, a design method of multi node water quality monitoring system of fish pond based on unmanned ship technology is proposed, the hardware configuration of the system is optimized, the operation process of system software is simplified, and the multi node water quality monitoring algorithm of fish pond is constructed, so as to realize the effective management of UAV ship and the real-time monitoring goal of water quality state of fish pond. Finally, it is confirmed by experiments, The multi node water quality monitoring system of fish pond based on unmanned ship technology has high practicability in the process of practical application.

Keywords: Unmanned ship technology · Fish pond · Multi node water quality monitoring · Monitoring system

1 Introduction

The water quality of pond water is very important for aquaculture. The water quality not only affects the growth rate of aquatic products, but also affects the quality of aquatic products [1]. Pond farmers' management of fish ponds is mostly based on experience and on-site observation. The renewal of water bodies is blind, either causing waste or damage during intervention. If the development trend of water quality can be predicted, the breeding environment can be intervened in time before water quality deterioration to prevent waste or loss caused by water quality deterioration. Therefore, it is necessary to monitor the water quality of breeding pond [2]. Whether the water body is suitable for fish growth has a great relationship with the substances contained in the water, among which the dissolved oxygen content, water pH, temperature and ammonia nitrogen content have the greatest impact on fish growth. Reference [3] proposes an intuitive remote monitoring framework for fish pond water quality based on cloud computing. In aquaculture, due to the openness of the surrounding environment, the changes of water quality parameters are nonlinear, dynamic, unstable and complex. The multi-sensor and private cloud integration framework is used to collect data in real time and enhance remote

monitoring capabilities. Reference [4] proposes to detect abnormal fish behavior using motion trajectories in a ubiquitous environment. First, an image enhancement algorithm is used to enhance the color of water images and enhance fish detection. Then a target detection algorithm is used to identify fish. Finally, the classification algorithm is used to detect the abnormal behavior of fish. Establish an automated system to monitor the fish farm, so as to reduce the cost and time of fish farmers, and provide a more efficient and simple operation mode. At present, most fish pond farmers breed based on personal experience. They judge whether the water environment of fish pond is conducive to the survival of fish through the phenomena of water temperature, water color and floating head of fish. This kind of judgment based on experience is not accurate or intelligent. There are also a few fish pond farmers who introduce monitoring systems, but their systems generally adopt 3G/4G mobile communication network or ZigBee network communication technology. In this way, the monitoring system has problems such as inflexible expansion of detection nodes and large long-distance transmission interference, and the cost is also very high when the number of detection sensors is large. In view of the above situation, this paper presents a design of fish pond water quality monitoring system based on unmanned ship technology.

2 Multi Node Water Quality Monitoring System of Fish Pond

2.1 System Hardware Structure Design

It is designed according to the project requirements of the fish pond monitoring system, involving the sensor collection technology of dissolved oxygen, pH value, conductivity and water temperature, the oxygen enrichment device and the fish pond area intrusion detection device. The system uses the corresponding sensors to detect these data of the water quality of the fish pond, and automatically starts the oxygen increasing device remotely when the dissolved oxygen is insufficient; Intrusion detection is carried out in the fish pond area by using infrared reflection sensors and video monitoring devices. In case of fish theft at night, the system can automatically start the alarm device. Each detection device in the fish pond contains relevant sensor modules and unmanned ship modules. The data collected by all detection devices in the fish pond is forwarded to the unmanned ship gateway through the unmanned ship node. The unmanned ship gateway uploads the data to the system's cloud platform in accordance with MQTT protocol. The general processing program of the cloud platform part of the system provides relevant interfaces for PC clients and Android clients to call. The cloud platform of the system includes an MQTT server, which establishes an MQTT connection with each gateway device. The gateway device uploads data to the cloud platform in real time through the corresponding MQTT connection. The cloud platform can also issue some control instructions to the oxygen enrichment device, alarm device Gate equipment, water pump and other equipment [5]. The lightweight data interaction technology of JSON data format is adopted between the system cloud platform and the PC client. The PC client of the system includes functions such as fish pond information overview, data analysis, fish pond monitoring and intelligent gate. In the fish pond overview, users can see various water quality data of the fish pond environment; The data analysis part can dynamically display the oxygen content and pH value of the collected fish pond through a broken line

diagram [6]; The fish pond monitoring part can help you understand the current fish pond environment in real time; There is also an intelligent gate function, which can be set to automatically open the gate and manually open the gate. When the water depth exceeds 3M, the gate will automatically open to discharge water, so that the water depth in the fish pond is always at a suitable position [7]. The system can be operated in the cloud in terms of data acquisition, remote control, unmanned ship, data analysis, early warning information release, decision support and so on, making the fish pond supervision easy and simple. The whole water quality monitoring system is composed of upper computer control terminal, coordinator, routing node, monitoring node and so on. The ZigBee module that can communicate with each other and automatically network is used for data transmission of monitoring nodes. The monitoring node is both a terminal node and a routing node. The network structure of unmanned ship equipment is shown in Fig. 1:

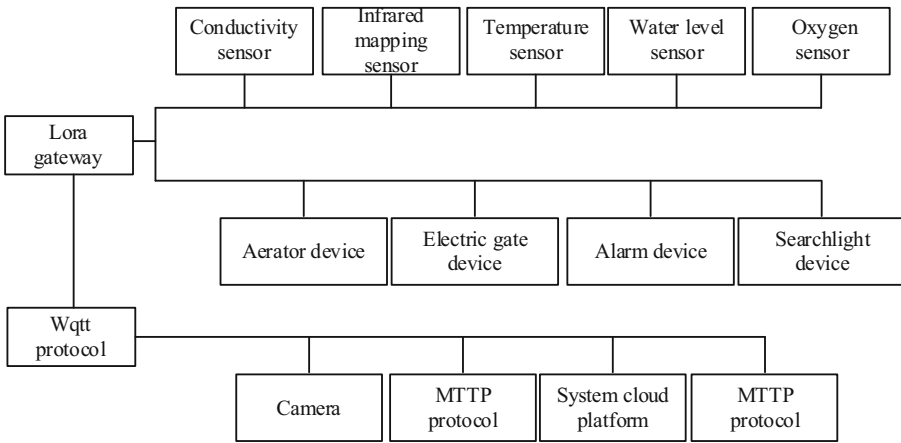


Fig. 1. Structure of unmanned ship equipment monitoring network

The monitoring terminal takes the personal computer as the hardware platform, provides a friendly interactive interface, and serves as the center of data centralization, analysis and processing of the system. The system monitoring terminal software receives and processes the data of wireless nodes, and can also start the response mechanism to deal with abnormal water quality. The monitoring software is VB6 The man-machine interactive control interface written by 0 can complete the functions of data acquisition, storage, management and analysis and historical data query. The coordinator is connected with the serial port of the monitoring terminal through RS-485 bus to 232 to monitor the water quality of the pond in real time [8]. In order to collect and upload the data of dissolved oxygen, pH value, water temperature and conductivity of fish pond water quality, the system needs to be equipped with nodes and gateways. Dora node first forwards the data to the gateway through the network, and then the gateway uploads the data to the system cloud platform through TCP network. Each node collects values every 2 min or so and sends data to the gateway according to the following data frame format. The communication baud rate is 115200 (network data sending and receiving has been realized in the project) (Fig. 2).

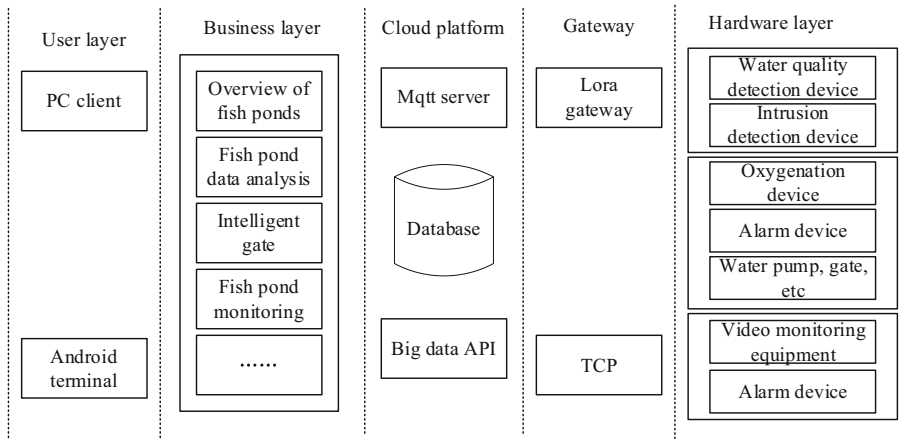


Fig. 2. System structure framework optimization

The main interface of the fishpond environment monitoring client of the system is shown in the figure. In this interface, you can overview the real-time environment of the fishpond. Click the “intelligent gate” navigation button in the main interface to enter the water level control setting of the fish pond gate. The fish pond intelligent gate interface can remotely control the fish pond gate through the “open gate” and “close gate” buttons in the fish pond gate, or select automatic control after setting the fish pond water level value. The system will automatically open the gate and discharge water when it is higher than the set value according to the comparison between the water level value collected by the fish pond water level detection device and the set value [9]. The “data analysis” function of the system is mainly to periodically display the data collected by the water quality monitoring sensors deployed in each area of the fish pond. In order to reduce the network flow of the system platform and ensure the dormancy of the acquisition terminal as much as possible, the system sets the acquisition cycle as 10 min, gives an alarm pop-up when the data is not within the set normal range, and pushes a reminder message to the system administrator. According to the different functions of each module, the intelligent monitoring and automatic oxygenation system is divided into: power supply module, data processing module, voice alarm module, wireless communication module and water quality identification relay module [10]. As an energy supply module, the power module plays a decisive role in the whole system and determines the normal working time of the monitoring system. The working time of the module will affect the promotion and use of the monitoring system. The system selects lithium battery as the power supply, and the output voltage is 5 V through the voltage transformation module to provide energy for the system (Fig. 3).

The fish pond information acquisition module is composed of dissolved oxygen temperature integrated sensor AD590, pH sensor HH5-WQ201, methane gas sensor, multiplexer 74HC4051 and AD converter MA \times 1240. The dissolved oxygen temperature integrated sensor AD590 can be widely used to measure the dissolved oxygen content in various occasions, especially in aquaculture water, photosynthesis, respiration and

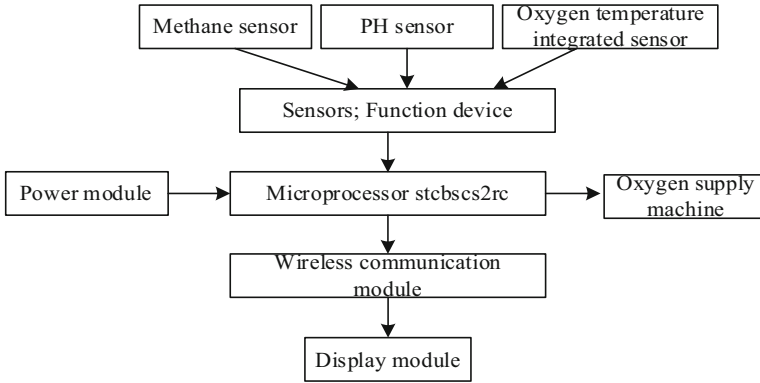


Fig. 3. Equipment structure of fish pond water quality monitoring and automatic control system

field measurement; Methane gas sensor is a general intelligent sensor. It is a high-precision methane sensor designed based on the principle that the appropriate micro power laser can be absorbed by different concentrations of methane. The sensor has the characteristics of small volume, low power consumption, stable performance, long service life of sensor elements and high sensitivity. It continuously detects the methane concentration in the air and transmits relevant data in real time. At the same time, the sensor also has the function of internal temperature and air pressure detection; The amplifier of pH sensor hhvq201 inside the sensor is a circuit with standard pH through data monitoring, and a plug is connected with the data collector at the end of the sensor connecting line. Specific voltage will be generated in neutral solution, and the voltage will increase by 0.25 for each increase of pH value; When the pH value decreases by 1, the voltage decreases by 0.25 (Fig. 4).

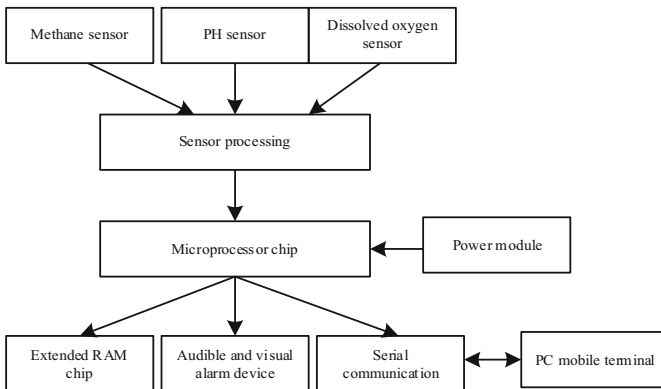


Fig. 4. System hardware configuration

The equipment control terminal controls the on-off of the relay by sending RS485 communication command, so as to control the operation of on-site execution equipment (water quality identification and circulating water pump). The system selects SR-311A485 control relay. The PCB of this type of control relay is made of FR-4 plate. It uses industrial chip and has lightning protection circuit. Its module address can be configured through RS485 communication, and the configuration set by jumper lock module can be used to prevent misoperation. The product has the advantages of power saving, energy saving, long service life and stable and reliable performance (Table 1).

Table 1. Equipment parameters of unmanned ship monitoring system

Technical attributes	Specific parameters
Electric shock capacity	10 A/30 V DC
Temperature range	-35 °C~+85 °C
Durability	110000 times
Rated voltage	DC10 ~ 25 V
Communication interface	RS498
Baud rate	9700 (default)
Default communication format	9700,

When designing the hardware circuit of the monitoring system, the modular design principle is adopted. Each module of the system hardware circuit is designed independently, and each module is connected by interface. This design method not only facilitates the hardware circuit to quickly find and solve problems in the debugging process, and improves the efficiency of hardware development, but also brings great convenience to the later maintenance and upgrading of the system.

2.2 System Software Function Optimization

The design purpose of the intelligent monitoring system for fishery water quality is to dynamically monitor and regulate the water environment in the process of fishery breeding. Through the analysis of the overall functional requirements of the monitoring system, its client platform should have the following six functions. The functional structure diagram of the unmanned ship client of the intelligent monitoring system for fishery water quality is shown in Fig. 5.

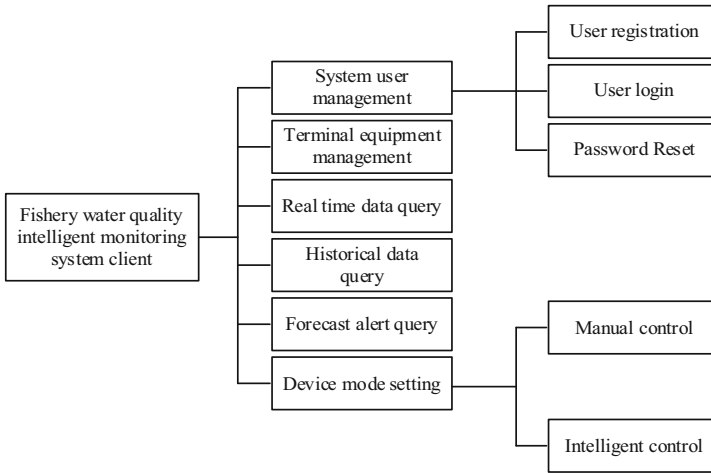


Fig. 5. System software function

The ZigBee module that can communicate with each other and automatically network is used for data transmission of monitoring nodes. The monitoring node is both a terminal node and a routing node. The monitoring terminal software takes the personal computer as the hardware platform, provides a friendly interactive interface, and serves as the center of data centralization, analysis and processing of the system. The system monitoring terminal software receives and processes the data of wireless nodes, and can also start the response mechanism to deal with abnormal water quality. The monitoring software is VB6 The man-machine interactive control interface written by 0 can complete the functions of data acquisition, storage, management and analysis and historical data query. The coordinator is connected with the serial port of the monitoring terminal through RS-485 bus to 232 to monitor the water quality of the pond in real time. Using wireless communication GSM requires short message protocol. The short message from the application layer sends the short message to the MSc through the transmission layer, relay layer, connection management sublayer cm and the following mobile management sublayer mm and wireless management sublayer RRM. It is divided into the following points: (1) Short message transmission layer (SMTL) service; (2) Information relay layer (Smrl) service; (3) Information (SML control management, mobile management, radio resource management sublayer) services. Denoising the collected aquaculture water quality is a crucial step in the process of prediction and early warning. Its working principle is to use signal processing to remove the interference factors hidden in the water quality data, avoid data deviation and ensure the accuracy of subsequent calculation intelligent prediction. When using the unmanned ship client, the breeding user needs to register as the system user first, and log in to the client according to the registered user name and password. The user can bind the field terminal equipment independently according to the demand, and the system will upload the user information and the bound equipment information to the database. After the binding operation is completed, the user can log in to the control interface for relevant monitoring operations. The process flow of unmanned ship monitoring operation is shown in Fig. 6:

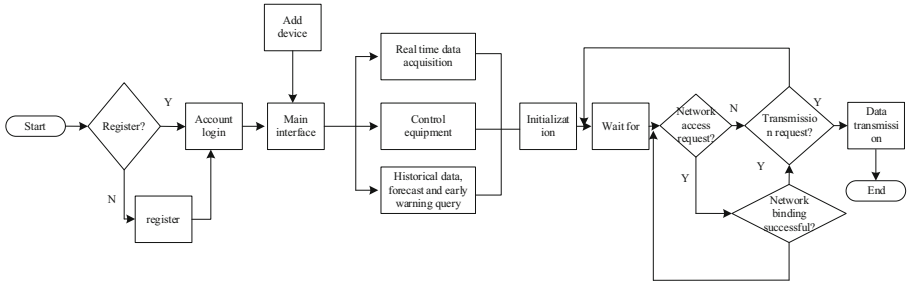


Fig. 6. Processing flow of unmanned ship monitoring operation

The monitoring system monitors the water environment parameters of the fish pond, opens or closes the on-site execution equipment according to the changes of the fish pond water environment, adjusts the water quality, and ensures the safety and stability of the fish pond water environment. The design of embedded control module is mainly aimed at the implementation of field control terminal. The control terminal is responsible for controlling the execution equipment on site, including water quality identification, circulating water pump, etc. The microprocessor of the control terminal connects the relay through the RS485 interface, and controls the on or off of the relay by sending the RS485 control signal, so as to realize the on or off of the on-site execution equipment. The automatic control flow chart of on-site water quality identification is shown in the figure. The control terminal adopts threshold control. The operation of water quality identification is automatically controlled according to the preset dissolved oxygen parameter standard, that is, the upper and lower limits of dissolved oxygen. When the dissolved oxygen concentration in the fish pond is less than the lower limit, the water quality identification is automatically turned on, and when it is greater than the upper limit, the water quality identification is automatically turned off. The automatic control flow of water quality identification is shown in Fig. 7:

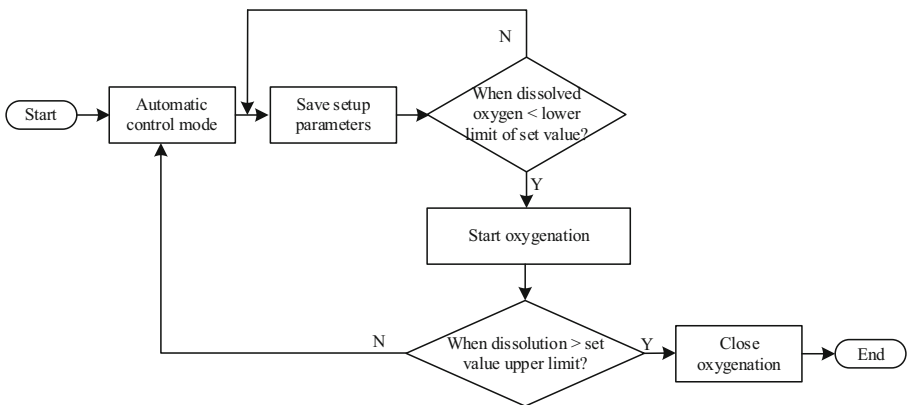


Fig. 7. Automatic control flow chart of water quality identification

Establishing the database of fishery water quality intelligent monitoring system is conducive to the effective storage and management of fishery water quality data and provide data support for fishery breeding management. The monitoring system can process and analyze the water quality data stored in the database. At the same time, fishery breeding managers can also export historical water quality data and make reports according to needs. The functions of the database mainly include storing user information, user binding equipment information, fish pond water quality data, etc. The system adopts MySQL relational database. According to the actual needs of the system, the data table structure is designed for information storage, mainly including user information table, user binding equipment information table, fish pond water quality data table and relationship correspondence table.

2.3 Realization of Multi Node Water Quality Monitoring in Fishpond

For the data interface of server, it mainly provides API for embedded terminal equipment and client. In the system, the data interface of the server is realized by post request. It responds to the data upload of the on-site water quality collection terminal and the data query of the unmanned ship client in real time. As soon as the cloud server receives the request information, it processes it immediately and returns the request result to the client or the on-site terminal device. The operation object of the data interface is MYSQL in the server, which relies on the database to respond to various request information. The persistence layer architecture selected in the data interface design is mybatis, and its specific structure is shown in Fig. 8.

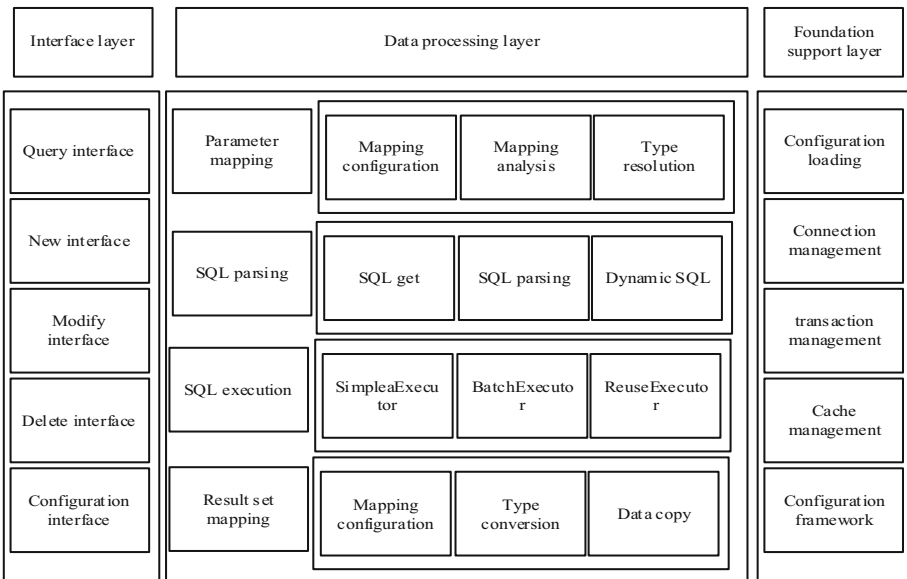


Fig. 8. Mybatis water quality monitoring application model

The application steps of mybatis are as follows: first write the configuration file of mybatis, create the database connection session, then configure the relationship mapping, complete the operation on the database, and finally end the session. Aiming at the problem of low accuracy in the prediction of fishery water quality parameters by support vector regression machine, this paper proposes and adopts the eemd-gwo-svr combined model prediction method based on set empirical mode decomposition method, gray wolf optimization algorithm and support vector regression machine. Firstly, EEMD is used to decompose the collected water quality data into a series of relatively stable characteristic modulus function components, and then the mixed noise sequence is eliminated. Then GWO optimization algorithm is used to optimize the C (penalty factor) and γ (kernel function parameters) parameters for Intelligent Optimization: use the optimized SVR to establish a prediction model for the fishery water quality data after noise reduction. According to the water quality environment of on-site fishery breeding in Jiangxinzhou, combined with the case analysis of breeding samples and relevant literature reference, the water quality early warning standard is constructed, and the fishery water quality early warning model is established based on the prediction of fishery breeding water quality data. The logic flow chart of fishery water quality prediction and early warning model based on unmanned ship is shown in the figure. Through dynamic prediction and early warning of environmental parameters of fish pond in Jiang Xin Zhou, the water quality in advance is adjusted according to the dynamic forecast and early warning information, and the water quality of aquaculture is refined.

The early warning model of fishery water quality is based on the data of water temperature, dissolved oxygen DO, pH, ammonia nitrogen and other parameters predicted by the water quality prediction model, so as to ensure the stability of aquaculture water quality in a suitable environment. By mastering the suitable water quality environment of cultured fish, and determining the alarm situation and dividing the alarm level according to the specific range of water quality parameters, we can carry out fishery water quality early warning. According to the actual needs of application, the alarm degree of fishery water quality early warning model is divided into four levels, and the emergency degree is no alarm, light alarm, medium alarm and heavy alarm from low to high. The specific description is shown in Table 2:

Table 2. Alarm level of water quality early warning model

Alarm level	Describe
No police	The water quality of the fish pond has not been damaged and is very suitable for fishery and aquaculture activities
Light police	Water quality parameters reach the appropriate upper or lower limit and last for a certain period of time, but are not enough to affect the normal survival of water organisms, which should be paid attention to
Central Police	The water quality parameters exceed the appropriate value of fishery breeding, and corresponding treatment measures need to be taken
Heavy police	The water quality parameters exceed the limit value of fishery breeding, and corresponding treatment measures need to be taken immediately

The water environment of fishery breeding is a comprehensive reflection of the changes of various water quality parameters. The quality of fishery breeding water is directly related to the output of fishery breeding. Therefore, it is necessary to monitor and analyze the important parameters in the fishery aquaculture water environment, and formulate fishery water quality standards in combination with examples, so as to provide reference for the early warning control of the monitoring system and ensure the safety of fishery aquaculture water quality. According to the fishery water quality standards, surface water environmental quality standards and other relevant regulations, and in strict compliance with the principles of scientificity, economy and timeliness, this system constructs the fishery water quality early warning standards in combination with the case analysis of fish pond culture samples in Jiangxinzhou and relevant literature references, and uses the key water quality parameters such as water temperature, dissolved oxygen, pH and ammonia nitrogen of fishery culture as the basis for judging the water quality alarm level, The standards of water environment parameters are shown in Table 3:

Table 3. Standard table of water environment parameters

Police level	Grade	Water temperature/°C	Dissolved oxygen (do)	pH value	Ammonia nitrogen
No police	Good	21–26	6–9	6.6–7.7	0–0.16
Light police	Middle	16–21 26–29	4–6 9–13	6.1–6.6 8.7–9	0.15–0.3
Central Police	Difference	5–16 29–31	3–5 12–16	4–7 9–11	0.2–0.4
Heavy police	Very bad	–11–5 31–51	0–4 16–21	0–5 11–15	0.4–10

In the system data manipulation interface, users can select real-time monitoring, remote control, system setting, historical data, data analysis, system management and other data manipulation functions according to their own manipulation needs. Among them, the real-time monitoring function is to monitor the water temperature information, pH value information and dissolved oxygen information on the water quality monitoring site, and the remote control function is to issue the water quality identification control command and conduct the oxygenation operation according to the water quality information monitored by the water quality on-site collection terminal; The system setting function is to safely set the upper and lower limits of various parameters of water quality, so as to create a safe growth environment for aquaculture organisms. The historical data function is to view the water quality monitoring information at a specified time by calling the system database according to the user's needs: the data analysis function is to display the collected data information in the form of a graph in front of the user to help the user classify the changes of water quality; The system management function is used to manage the user's personal account and number.

3 Analysis of Experimental Results

Taking a pond as the object to test the system, the node in the system automatically transmits the collected data to the upper computer every hour, and the upper computer stores and analyzes the received data. The node selection button can display the data at this node. In order to verify the stability and reliability of remote data and information transmission of the system, the GPRS DTU unmanned ship module is tested in this paper. Firstly, build a test platform and connect it according to the connection scheme between the unmanned ship module and the on-site acquisition terminal and the server of the monitoring center. Secondly, write the program, generate HEX file, and use the burning software to burn the program into the single chip microcomputer through the USB port. Thirdly, start the SMS card GPRS traffic service and install it in the SIM card slot to connect the line. Finally, turn on the system hardware equipment and server software, collect data by using temperature sensor, pH sensor and dissolved oxygen sensor, transmit data information through GPRS DTU module, and check whether the data received by the server of the monitoring center is different from the data at the sending end. The construction of the experimental network environment is a typical star network. The wireless access point is located at the core of the star network. The data communication between all stations in the network can only be realized by forwarding data packets through the wireless access point in the center. It can be seen that the operation security of wireless WiFi AP is very important in this network topology, and general wireless routers can meet the needs of experimental testing. The specific flow of the experiment is shown in Fig. 9.

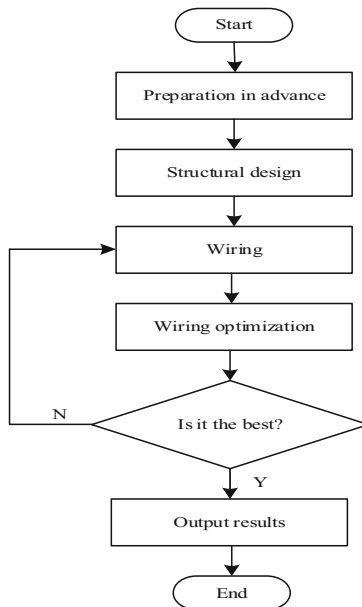


Fig. 9. Experimental flow chart

Table 4 shows the test sample data:

Table 4. Test sample data

Test group No	Test value	Field data	Server data	Accuracy (%)
A	Water temperature/°C	11.9	11.9	100
	pH value	7.6	7.6	100
	Dissolved oxygen (mg/L)	8.5	8.5	100
B	Water temperature/°C	18.7	18.7	100
	pH value	7.6	7.6	100
	Dissolved oxygen (mg/L)	8.1	8.1	100
C	Water temperature/°C	23.8	23.8	100
	pH value	7.5	7.5	100
	Dissolved oxygen (mg/L)	7.5	7.5	100

NB-lot signal quality directly reflects the communication situation of unmanned ship. By understanding the signal quality of on-site NB-lot, we can give better play to the advantages of unmanned ship monitoring communication. By using the “AT+CSQ” instruction on the NB-lot chip SIM7020C, the signal quality of its NB lot can be obtained. The instruction can detect the strength index and channel bit error rate of the received signal. Use the serial port tool to send the “AT+CSQ” command to SIM7020C, and the chip replies “+CSQ:30,0”. Where “30” is the return value of signal strength and “0” is the return value of channel bit error rate. The corresponding relationship between the return value of the instruction and the actual situation is shown in Table 5:

Table 5. Correspondence between return value and actual situation

Signal quality	Return value (integer)	Actual value
Signal strength (RSSI)	0	Rssi < = -111 dBm
	1	-109 dBm < = rssi < -106 dBm
	2	-106 dBm < -rssi < -104 dBm
	3-31	-104 dBm < -rssi < -48 dBm
	32	-48dBm < = rssi
	99	Unknown or undetectable
Channel bit error rate (BER)	0	ber < 0.2%
	1	0.2% < = ber < 0.5%
	2-4	0.5% < = ber < 1.7%
	5-6	1.7% < = ber < 6.4%
	7-8	Basically unable to communicate normally

By comparing the test results of various test methods under the same test conditions and conditions, it is found that pH is a main reference index for monitoring the health status of water bodies. The test results of pH value of water quality are shown in Fig. 10:

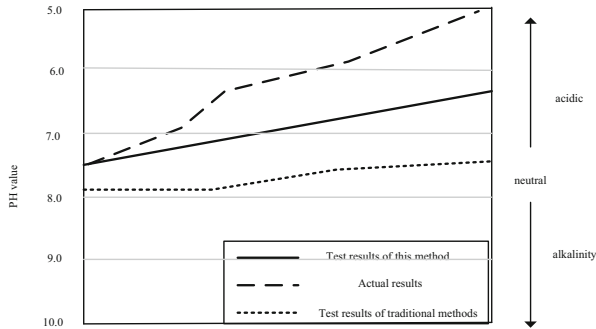


Fig. 10. Test results of pH value of water quality

Through the comparison of the above tests in Fig. 9, it can be seen that the pH value of the water quality pH test conducted by the rotating grid method described in this paper is 6.5–4.5, which belongs to weak acid. Compared with the measured pH value, the conventional detection method is 7.0–6.5, which belongs to neutral. There is a great difference between the model and the measured value, which verifies the accuracy of the algorithm in the actual test. Because the samples in the same sea area contain different impurities and pollution components, the impact on the water body is also different (mentioned earlier), so there may be some subtle differences during the test, which can be ignored here. By comparing with pH value, the acquisition accuracy of data is compared, and the results are shown in Fig. 11:

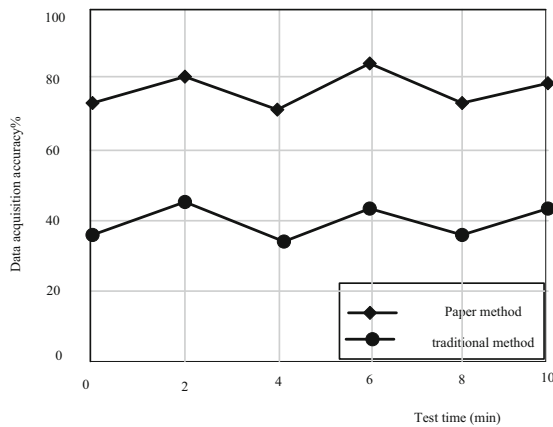


Fig. 11. Comparison of test results

As can be seen from the above Fig. 11, compared with the conventional water sample test, the accuracy of the water sample test data used has been greatly improved compared with the conventional method. The test results show that this method is feasible and can solve the practical problems.

To sum up, the fish pond multi node water quality monitoring system based on the unmanned ship technology can verify the accuracy in the actual test. The accuracy of the water sample test data used has been greatly improved compared with the conventional method. The method in this paper can better solve the actual problem.

4 Conclusion

The designed fish pond water quality monitoring and automatic oxygenation system arranges sensors, power supplies, displays, data processors and wireless communication modules beside the pool. In the layout process, a small container is used to replace the environment of the pool, an ordinary wire is used to replace the waterproof wire, and a lithium battery is used to replace the large energy storage battery, ignoring the small factors of the system. The test results show that the water quality monitoring and automatic oxygenation system of the fish pond can accurately monitor the water quality of the pond and achieve the expected results. At the same time, the monitoring personnel can timely understand the water quality environment of the fish pond through the display. The test shows that the system is stable and has a good market scene.

Although the above research has made some progress, due to the short time, further research can be carried out in the following aspects:

- (1) In the future, we can check the dissolved oxygen concentration and temperature of the fish pond water body, pay attention to other impact factors that need to be monitored, and increase the diversity of the monitoring system. Therefore, we need to gradually increase the monitoring capacity of the system in the later stage.
- (2) Considering the cost in depth, with the addition of pH value monitoring, temperature monitoring, video security monitoring and so on in the later system, it is easy to increase the cost of the monitoring system.
- (3) In terms of wireless communication, the monitoring system can adopt the technically mature WiFi wireless communication technology, giving priority to external interference to wireless communication, which needs to be studied in the later stage to increase the security of the monitoring system.

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References

1. Rand, J.M., Nanko, M.O., Lykkegaard, M.B., et al.: The human factor: weather bias in manual lake water quality monitoring. *Limnol. Oceanogr. Meth.* **20**(5), 288–303 (2022)
2. Qiu, Q., Dai, L., Rijswick, H., et al.: Improving the water quality monitoring system in the Yangtze River basin—legal suggestions to the implementation of the Yangtze river protection law. *Laws* **10**(25), 1–13 (2021)
3. Sivakumar, S., Ramya, V.: An intuitive remote monitoring framework for water quality in fish pond using cloud computing. *IOP Conf. Ser. Mater. Sci. Eng.* **1085**(1), 012037 (2021)
4. Anas, O., Wageeh, Y., Mohamed, E.D., et al.: Detecting abnormal fish behavior using motion trajectories in ubiquitous environments. *Procedia Comput. Sci.* **175**, 141–148 (2020)
5. Jing, L., Siyu, F., Yafu, Z.: Model predictive control of the fuel cell cathode system based on state quantity estimation. *Comput. Simul.* **37**(07), 119–122 (2020)
6. Huang, Y., Wang, X., Xiang, W., et al.: Forward-looking roadmaps for long-term continuous water quality monitoring: bottlenecks, innovations, and prospects in a critical review. *Environ. Sci. Technol. ES&T* **56**(9), 5334–5354 (2022)
7. Tsafack, J., Tchuenchieu, D., Mouafo, H.T., et al.: Microbial assessment and antibiotic susceptibility profile of bacterial fish isolates in an aquaculture production site in Mefou Afamba division of Cameroon. *Environ. Sci. Eng. B* **10**(1), 20–30 (2021)
8. Jia, J., Qiu, S., Bai, R., et al.: Design and application of intelligent river water quality monitoring and early warning platform based on soa. *Comput. Appl. Softw.* **38**(02), 13–18+26 (2021)
9. Kuang, L., Shi, P., Ji, Y., et al.: Data fusion method for water quality monitoring using WSN based on improved support function. *Trans. Chin. Soc. Agric. Eng.* **36**(16), 192–200 (2020).
10. Zhang, J., Sheng, Y., Chen, W., et al.: Design and analysis of a water quality monitoring data service platform. *Comput. Mater. Continuum* **1**, 389–405 (2021)