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Study on the application of water quality monitoring technology based on unmanned ship

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ABSTRACT

Aiming at the difficulty of sampling and monitoring the water quality of seawater aquaculture environment, this paper puts forward the design scheme of on-line monitoring system using unmanned ship as monitoring platform. Unmanned ship loading of water quality monitoring sensors and control equipment, the use of remote control or ways of working independently, with a single point of mobile instead of multipoint distribution measurement, realize synchronous acquisition of the mariculture environment more information. By modular design of the system, the collected water quality information, and to collect the geographic location information of wireless transmission first place machine, PC server receiving and processing data and the results stored in the database. This paper introduces the automatic control system of unmanned ship, presents the data transmission and storage process of the monitoring network, and introduces the water quality data processing of the upper computer. The scheme proved the feasibility through physical construction and experiment.

Keywords: Unmanned ship; Aquaculture; Water quality monitoring; Data processing

1. Introduction

The department of agriculture has put forward the target of Chinese fishery, powered by technology, quality, efficiency as the center, to further improve Chinese fishery comprehensive production capacity and contribute to safeguard food security. Today, China's aquaculture industry is in a period of vigorous development. As an important link in aquaculture, the monitoring of water quality in aquaculture is gradually being monitored by artificial sampling and laboratory analysis. The water quality automatic monitoring system with 89C51 as the control core, such as Yuan et al. [1], can monitor multiple water parameters in real time. Huang et al. [2] research based on Global System for Mobile Communications, such as temperature, pH, dissolved oxygen measurement of mariculture monitoring system, improve the reliability of the collected data, via text message at the same time the way of remote monitoring; Chen et al. [3] studied the combination of CC2530 module and ZIGBEE network to build a wireless sensor network, which solved the problem of the field wiring difficulty, but there were more layout and maintenance difficulties. Using unmanned ship as a monitoring platform to replace multi-point distributed measurement with single point of mobile measurement can solve the above problems. Small vessels work on water surface, and most surface and profile measurement sensors can be equipped to carry out multi-information synchronous measurement of marine environment. The design of this scheme can promote the development of marine aquaculture industry, and effectively realize the target of information technology to promote the development of seawater aquaculture industry.

2. Design of data acquisition and control

The marine aquaculture water quality monitoring system mainly monitors the temperature, salinity, pH value and

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dissolved oxygen content of seawater. The monitoring system is mainly composed of two parts: the unmanned ship system and the shore-based monitoring system.

The unmanned ship system mainly includes the control center, power module, navigation module, water quality acquisition module and wireless data transmission module [4]. The control center of the lower plane is responsible for receiving instructions from the shore-based monitoring system to complete the control of the unmanned ship movement and information acquisition. The power module adopts the battery, which is responsible for the driving power of the unmanned ship. The navigation module adopts the STM32F103ZET6 microprocessor, which is equipped with GPS module and infrared obstacle avoidance module to complete the real-time positioning, navigation and obstacle avoidance of unmanned ship. The water quality monitoring module is equipped with DO sensor, pH sensor, temperature sensor, mainly to complete the DO, pH, water temperature data collection function; The wireless transmission module adopts ZigBee communication mode to complete data transmission between unmanned ship and shore-based monitoring system.

The overall block diagram is shown in Fig. 1.

2.1. Design of navigation module

In hull control, unmanned ship has autonomous cruise and manual remote control. Under the autonomous cruise mode, the unmanned ship can navigate the water according to the planning path, and encounter obstacles to avoid automatically and detect all kinds of data of the water body. The manual remote control is mainly used for emergency treatment and data acquisition of specific location data in close waters. The ship course controller control system adopts a fuzzy adaptive PID ship heading controller [5], as shown in Fig. 2. The terms "e" and "ec", respectively, indicated in the figure represent the error and error rate. The fuzzy controller is designed using the error "e" and error change rate value to the "ec" as fuzzy input, to PID parameters K_p, K_i, K_d as the output of fuzzy controller, based on the PID parameters K_p, K_i, K_d and input error "e" and error change rate "ec" fuzzy relation between the implementation of traditional PID parameters K_p, K_i, K_d online adjustment, so that the controlled object has good static and dynamic characteristics. In the system of unmanned ship avoidance, the input quantity of fuzzy controller is the variation deviation and deviation rate of the setting course and actual heading [4].

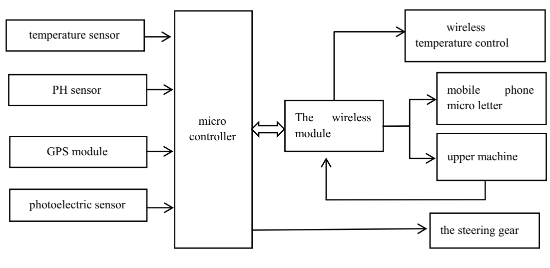

Fig. 1. Unmanned ship system block diagram.

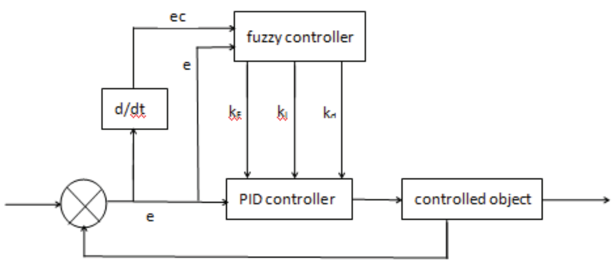

Fig. 2. Fuzzy adaptive PID control schematic diagram.

2.2. Data acquisition module

According to the water quality standard in Qingdao area, the following sensors are selected according to the inspection indexes of the farm: temperature, pH value, DO and so on.

DS18B20 is a digital temperature acquisition sensor. Its temperature range is between –55°C and 125°C. It only needs three wires and a 4.7K pull-up resistance to connect to the CC2530 I/O port to measure the temperature data. The circuit is simple, easy to read and use. Therefore, the temperature of the measurement is selected by DS18B20 digital temperature sensor.

ISFET technology can reduce the numerical error of acid and alkalinity under extreme pH condition, and is an advanced pH monitoring technique. Campbell Scientific CS526 pH sensor, ISFET technology, no glass bubble, easy to clean, probe safety and durable, suitable for monitoring pH in mariculture area. The pH measurement range is 0–14, can be normal working temperature range is: 0°C–70°C, the accuracy is 0.1 pH. Its output is 0–5,000 mV, the system will be the output signal after INA116 amplifier, as the MCU A/D reference voltage is 1.5 V or 2.5 V, so the sensor output voltage to pass after clipping into single chip microcomputer built-in A/D conversion circuit [6].

In the selection of DO sensor, two methods of determination of oxygen content were compared: iodine quantity method and electrochemical method. Because of chemical analysis and measurement methods, a large number of samples are consumed, which can be time consuming and cannot be monitored in real time. The low cost of electrochemical measurement, the accuracy of measurement can meet the requirements, and the real-time monitoring can be realized, so the oxygen content of seawater is measured by electrochemical measurement. The sensor type WQ401 was adopted, and its measuring range is 0–8 mg/L, operating temperature range is –40°C to 55°C. The range of measurement is: 3–6 mg/L, and the accuracy is ±0.5%. Output current from 4 to 20mA, after processing the I/V conversion circuit with 4–20 mA input/0–5 V output, then transmission to A/D conversion circuit within the single chip [7].

2.3. Wireless transmission module

Wireless transmission module mainly combines ZigBee wireless sensor network technology and GPRS wireless data transmission technology [8]. ZigBee wireless network module ZigBee self-networking includes the acquisition node, routing node and control node based on CC2530 chip, and the entire self-organizing network is based on the Z-Stack protocol stack, and the star structure is adopted. CC2530 builds powerful network nodes with less material costs. Various operating modes meet the requirements of ultra-low power systems. Short switching time between different modes further ensures low energy consumption. When the system runs, the router node is first initialized by wireless network, and then the self-organizing network is formed. After the network is formed, the router node receives the temperature data of each collection node and processes it and passes it to the control node. The control node then sends the owner's operation instructions to the control part to realize the feedback control. The excellent wireless reception sensitivity and strong anti-interference ability of CC2530 ensure the effectiveness and reliability of short distance communication.

3. Software system design and data processing design

The shore-based monitoring system is mainly the PC or mobile phone, and the user can query the water quality environment information in real time. PC system for monitoring water quality monitoring data, combining with clustering analysis and expert system, will output the results of the analysis, to help production staff find the problem in time, accurately the position of the locking problems, according to the variation of water quality indexes and timely regulation of environmental equipment, such as increasing oxygen system, insulation system, etc., to provide the best environment conditions farms.

3.1. Data collection design

The flow chart of the data acquisition program is shown in Fig. 3. Among them, the sampling cycle is controlled by the timer in the form of interruption, namely when the interrupt accumulate to a certain number, the microcontroller is through to various sensors measuring temperature, pH, command, oxygen sensor, after receives the measurement command to start the corresponding measure, and in the late 85 ms after will measure the results back to the STM32F103ZET6 MCU, after determine the check and correct the information to carry on the corresponding processing, so that to send to the cloud.

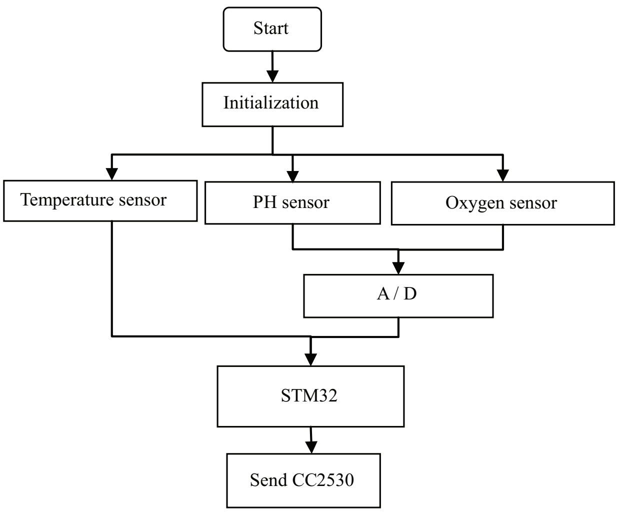

Fig. 3. Data acquisition flow chart.

3.2. Transmission of data acquisition

The monitoring terminal sensor on the unmanned ship can measure data in real time. The temperature sensor outputs a digital signal and feeds directly into the STM32F103ZET6 MCU. The pH value and DO measurement output are analog signals that are transmitted to the A/D conversion port of STM32F103ZET6 MCU, the processed data are transmitted to CC 2530, the receiver of CC 2530 receives the signal from STM32F103ZET6 MCU, and the data are preprocessed by adaptive weighted algorithm, which is then transmitted wirelessly to the cloud server. Monitoring center receives wireless signals from the cloud and displays them. At the same time, cluster analysis can be carried out to judge data anomalies.

As shown in Fig. 4, similar to the sensor nodes, the router nodes are initialized, and the data received by the wireless receiver are fused based on the adaptive weighting algorithm, and the fusion data are sent through the radio frequency module. Under the optimal condition of the minimum mean square error, according to the measured values provided by each sensor, the optimal weighting factor corresponding to each sensor is found in an adaptive way, which makes the result of the fusion X^ reach the best. The information sent by the N sensor nodes received by the routing node is variance of sigma 12, sigma 22, The true value of sigma N_2 is X^, and the measured values of each sensor are $X_1, X_2, \ldots X_n$ is independent of each other and is X^'s unbiased estimation. The weighting factors of each sensor are $N_1, N_2, \ldots N_n$, its algorithm flow is shown in Fig. 5.

3.3. Fuzzy C clustering mean algorithm

Set monitoring sample collection $X = \{x_1, x_2, \ldots x_n\} \subset R^s$, A set of finite sample sets of n patterns in the pattern space. Among them $x_k = \{x_{k1}, x_{k2}, \ldots x_{kn}\}^T \in R^s$. As one of the data samples, x_{ki} the monitoring of x_k the first indicator of the sample. Sample x_k with subset $\{x_i\}(1 \leq i \leq c)$ affiliation used $u_{ik} = u_{xi}(x_{ik})$

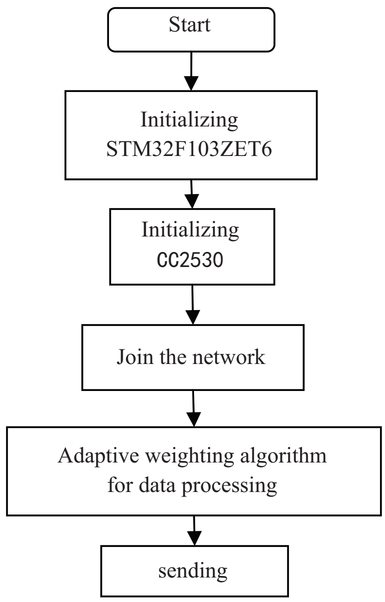

Fig. 4. Router node flow chart.

($u_{ik} \in [0,1]$) to represent, In order to record the membership function of multiple subsets, the matrix approach is used to record it [9].

X fuzzy C partitioned space:

$$M_{fc} = \left\{ U \in R^{cn} \middle| u_{ik} \in [0,1], \forall_i, k;\ \sum_{i=1}^{c} u_{ik} = 1 \forall_k;\ \ 0 < \sum_{k=1}^{n} u_{ik} < n, \forall_i \right\} \quad (1)$$

Among them clustering prototypes $P = \{p_1, p_2, \ldots p_c\}$, p_i ($i = 1,2,\ldots c$) Said class i class centers, $p_i \in R^s$. The calculation process of fuzzy C clustering mean (FCM) algorithm is to solve the process of dividing matrix and $U = [U_{ik}]_{c\times n}$ cluster prototype $P = (p_1, p_2, \ldots p_c)$ while ensuring that the objective function J_m is the minimum. The calculation of J_m is:

$$J_m(U,P) = \sum_{k=1}^{n}\sum_{i=1}^{c} u_{ik}^{m} d(x_k, p_i) \quad (2)$$

where $\sum_{i=1}^{c} u_{ik} \in [0,1], \forall_k; d(x_k, p_i) = \| x_k, p_i \|, m$ is the weight index, $d(x_k, p_i)$ said the difference between x_k and p_i measured by the distance between two vectors. Iteration rules are as follows:

$$p_i = \frac{\sum_{k=1}^{n} u_{ik}^{m} x_k}{\sum_{k=1}^{n} u_{ik}^{m}}, \quad (i = 1,2,\ldots c) \quad (3)$$

$$u_{ik}\left[\sum_{j=1}^{c}\left(\frac{d_{ik}}{d_{jk}}\right)^{\frac{2}{m-1}}\right]^{-1},\ \exists d_{ik} \neq 0,\ 1 \le i \le n$$
$$u_{ik} = 1,\ \exists d_{ik} = 0,\ k = 1;\ u_{ik} = 0,\ \exists d_{ik} \neq 0,\ k \neq i \quad (4)$$

The flow chart of the FCM algorithm in this paper is shown in Fig. 6.

Where n represents the number of samples, and epsilon is the iteration stop threshold. From the algorithm flow chart clearly shows that the time complexity of algorithm mainly concentrated in the partition matrix and matrix to solve clustering prototype model, in the final analysis, the factors affecting the efficiency of the algorithm is the number of samples n, n is the number of affected dividing matrix to solve the clustering prototype model and efficiency.

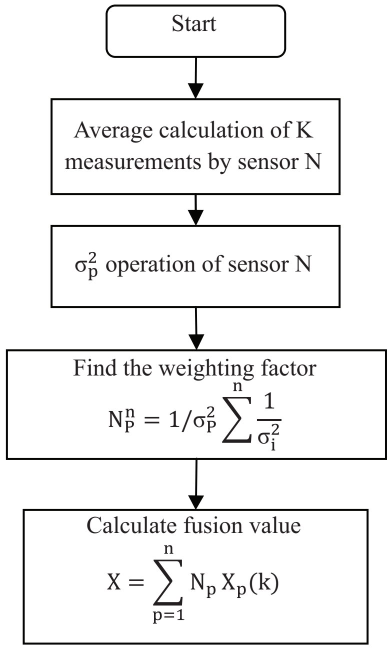

Fig. 5. Adaptive weighted algorithm flow.

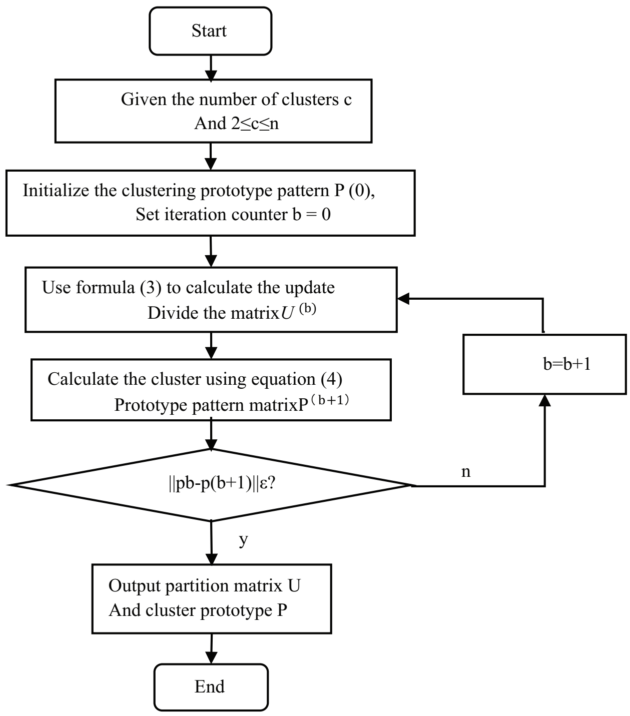

Fig. 6. FCM algorithm flow chart.

4. System testing

An aquaculture pool of a sea cucumber breeding farm in Qingdao was selected. The system function was measured. The culture pool was about 480 m long and 150 m wide. The unmanned ship was equipped with temperature sensor, pH sensor, three DO sensors and four sampling points automatically. The test results were compared with the standard product collection data, as shown in Table 1. Compared with the reference value, the measurement error of the experimental data is small, the data have a high consistency and can meet the actual use demand. The error of the sensor itself is the main factor that leads to the error between the measured value and the actual value, but the multi-thread remote concurrent communication is realized through the widely covered 4G network. The error of network transmission is small, and the data acquisition terminal can be transmitted to the

Table 1
Seawater quality monitoring data sheet

Sensor number	Collection point-1		Collection point-2		Collection point-3		Collection point-4	
	Measured value	Reference value	Measured value	Reference value	Measured value	Reference value	Measured value	Reference value
T-1	9.1°C	9.7°C	9.3°C	9.8°C	9.3°C	10°C	9.1°C	9.7°C
T-2	9.6°C	9.7°C	9.8°C	9.8°C	10°C	10°C	9.7°C	9.7°C
T-3	10.2°C	9.7°C	10.4°C	9.8°C	10.2°C	10°C	9.8°C	9.7°C
O-1	10.13 mg/L	10.16 mg/L	10.24 mg/L	10.28 mg/L	10.23 mg/L	10.26 mg/L	10.06 mg/L	9.87 mg/L
O-2	10.17 mg/L	10.16 mg/L	10.26 mg/L	10.28 mg/L	10.26 mg/L	10.26 mg/L	9.87 mg/L	9.87 mg/L
O-3	10.13 mg/L	10.16 mg/L	10.53 mg/L	10.28 mg/L	10.53 mg/L	10.26 mg/L	9.63 mg/L	9.87 mg/L
P-1	8.12	8.13	8.11	8.11	8.09	8.12	8.11	8.13
P-2	8.13	8.13	8.11	8.11	8.11	8.12	8.13	8.13
P-3	8.12	8.13	8.13	8.11	8.13	8.12	8.13	8.13

monitoring center for centralized monitoring and remote scheduling in real time, and the timely alarm of the fault information can be realized, and the production efficiency is improved.

In the water quality monitoring system of the unmanned marine aquaculture, the water quality parameters are collected through the carrier sensor, and the data collected by the sensor are transmitted to the monitoring center through the wireless network. The FCM algorithm is used to cluster the data, taking into account the leakage and error transmission in the data transmission. Mining repeated abnormal data from the historical data of the public database is considered normal if the detected water quality anomaly matches the record library. Otherwise, it is considered an abnormal event. Cluster analysis results are concentrated at the origin, and the probability of anomaly occurrence is small. The water quality data of farms are within the normal range.

5. Conclusion

This design scheme based on the present situation of water quality monitoring method in mariculture technology, designed the aquaculture water quality monitoring system based on unmanned ship, implementation of aquaculture water quality disaster early warning and production management. The system uses three layer architecture, the completion of the sea cucumber breeding in the environment of water, oxygen, temperature and pH detection, and by using the FCM algorithm to handle data samples, solved the aquaculture water quality monitoring system in the fixed the problem such as measurement and data processing, so as to realize a wide range, low cost, low power consumption real-time remote monitoring, control and remote data sharing design goal.

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