Design of Marine Buoy Profile Information Monitoring System Based on Machine Vision

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Abstract. Based on the comprehensive investigation of the existing marine information platform, this paper puts forward an architecture model of the electronic information system of the marine platform, which optimizes the system hardware structure, system configuration model and system software function by combining with machine vision, so as to realize the effective monitoring of the marine buoy profile information, This paper describes the functional composition of the marine buoy profile information monitoring system, and comprehensively analyzes the reliability, safety and other characteristics of the marine buoy profile information monitoring system, which provides the basis for the design modeling, index decomposition and development integration of the electronic information system of the offshore platform.

Keyword: Machine vision · Ocean buoy · Information monitoring

1 Introduction

In the field of marine environmental monitoring, marine production and aquaculture, long-term, fixed-point and real-time vertical profile monitoring of seawater parameters in specific areas is often needed. The existing marine environment monitoring platform mainly obtains the monitoring data of the vertical profile of the underwater environment through the chain sensor buoy method in the specific sea area. Although this method can accurately monitor the water quality data of the same vertical profile at different depths, it needs to work multiple sensors at different depths to get more comprehensive underwater environment data, This is bound to increase the cost of the whole underwater buoy profile information monitoring system [1].

Aiming at the problems of high cost and poor reliability of traditional system monitoring, this paper introduces machine vision technology to design the marine buoy profile information monitoring system. The specific research ideas of this paper are as follows:

Using the lifting control method, only a single sensor can realize the accurate measurement of different depths of the same vertical profile. According to the function of

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the ocean buoy profile information monitoring system, analyze the system operation principle, realize the function optimization of the system software, and greatly reduce the cost of the long-term continuous monitoring system of different depths of underwater vertical profile.

2 Design of Ocean Buoy Profile Information Monitoring System

2.1 Hardware Structure of Marine Buoy Profile Information Monitoring System

The whole marine buoy profile information monitoring system is mainly composed of environmental monitoring sensor group, winding coil, underwater electronic cabin, anchoring device, underwater information acquisition device and surface floating ball [2]. The environmental monitoring sensor group is placed inside the underwater floating ball. It is used to complete the acquisition of temperature and deep salt physical quantity, and the anchoring device and winding coil are used to fix the system and realize the lifting function of underwater floating ball [3]. The main function of the underwater electronic cabin is to control the rotation of the winding coil, realize the actual number of turns and speed control operation, and display various configuration functions of the system hardware equipment, as follows (Fig. 1):

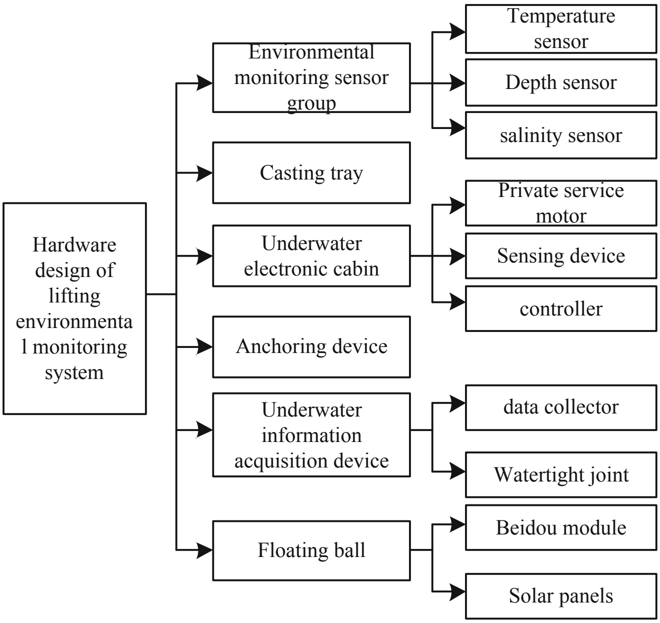

Fig. 1. System hardware configuration function

The profile information monitoring system of marine buoy in shallow water vertical section is mainly composed of underwater floating ball, underwater electronic cabin, winding coil and anchoring device. The underwater electronic cabin is mainly composed of servo motor, motor controller, voltage converter, watertight interface and other modules [4]. The underwater electronic cabin is placed in the inside of the winding coil. The underwater floating ball and the winding coil are connected by armored cable. One end of the armored cable is connected with the wave meter, temperature sensor and salinity sensor inside the underwater floating ball through a watertight connector to provide the working voltage and monitoring data transmission function. The other end of the armored cable is wound on the winding coil, and the armored cable joint is connected with the underwater cable from the underwater information acquisition device through the underwater connector, and the collected underwater environment data is sent to the underwater information acquisition device through the cable, and returned to the shore station system through the Beidou module for data processing, In addition to providing power for the underwater sensors, the underwater cable from the underwater information acquisition device also connects its branch connector into the underwater electronic cabin through the underwater connector to provide working voltage for the motor and motor controller in the underwater electronic cabin [5]. The marine buoy profile information monitoring system in this paper is different from the ordinary information system. The design, construction and implementation of the whole system are based on the special background of marine environment and resources. Therefore, in order to make the system run normally, the system function, process and composition design must follow certain requirements [6]. According to the system design objectives and planning from the system integration level, the marine buoy profile information monitoring system is composed of data acquisition subsystem, remote control subsystem, data management

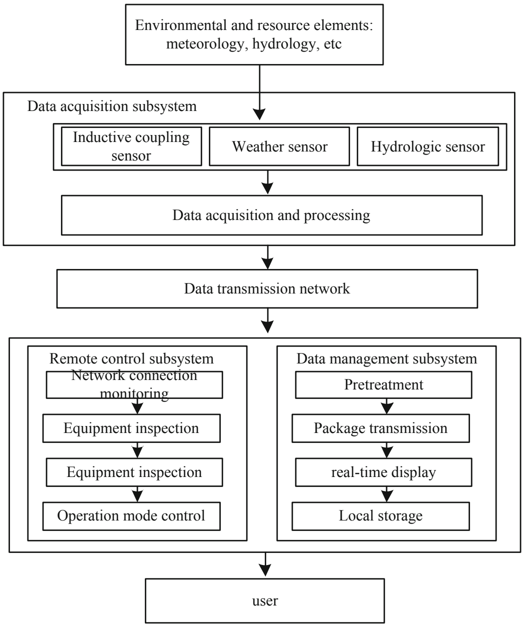

Fig. 2. Hardware configuration of ocean buoy monitoring system

subsystem, etc. the overall structure of the hardware configuration of the marine buoy monitoring system is shown in the Fig 2.

The architecture of the system can be divided into four layers: support layer, access layer, processing layer and information transmission layer, and the standard system, security system and guarantee system run through all layers of the system architecture. The architecture is as follows (Fig. 3):

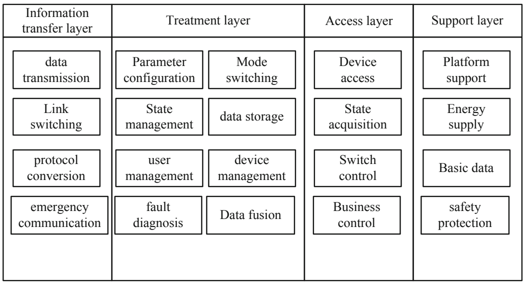

Fig. 3. System structure framework

The support layer is responsible for providing basic guarantee conditions for the system operation, which mainly includes platform support, energy supply, basic data, security protection and other functions [7]. Among them, support provides installation space and interface for carrying equipment, energy supply supplies power for carrying equipment through various power generation means, basic data provides various benchmark data for carrying equipment, and security protection provides environmental monitoring and intrusion protection for carrying equipment. The support layer is responsible for providing basic guarantee conditions for the system operation, which mainly includes platform support, energy supply, basic data, security protection and other functions [8]. Among them, platform support provides installation space and additional interface for carrying equipment, energy supply supplies power for carrying equipment through various power generation means, basic data provides various benchmark data for carrying equipment, and security protection provides environmental monitoring and intrusion protection for carrying equipment [9]. The processing layer is responsible for the processing of all kinds of state data and perception business data, as well as the management and control of the system. Among them, the state management is responsible for analyzing the state information of the access system equipment and forming the system work log; The fault diagnosis is based on the system work log and real-time equipment status information, and the fault solution suggestions are given. Data storage is responsible for saving all kinds of business data, status data and work logs of the system [10]. Data fusion is responsible for data fusion of access services to form a unified situation information; According to the configuration instructions issued by the information transmission layer, the software and hardware parameters of the equipment are configured; User management is to assign the permissions of different login users; The mode switching completes the system working mode switching according to the control instruction; The equipment management completes the business mode management and on-off control of the equipment according to the control instructions. The electronic information system of offshore platform is composed of floating platform system, integrated electronic information system and multi energy complementary intelligent power supply system. The system consists of intelligent control system, basic support system, multi-source target processing system and information transmission system. The system establishes communication links with users through different wireless transmission equipment to realize information exchange on the other side. In the system, the communication network is established in the form of switch to realize the internal information transmission of the system, and separate the internal and external network to ensure the information security of the system. At the same time, the internal real-time data bus is established to provide real-time data such as attitude and position to the user equipment. The working principle of the system is shown in the Fig. 4.

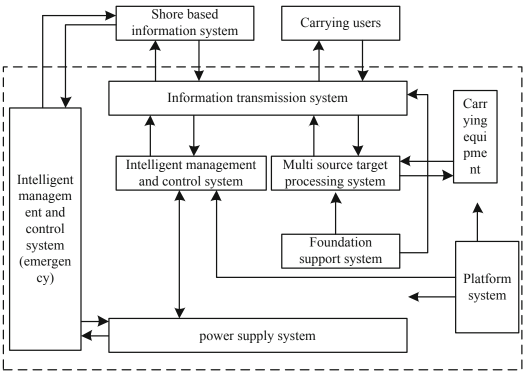

Fig. 4. System operation principle

The system provides stable marine physical carrier for the whole system equipment through platform and anchoring device, and is equipped with lighting, ventilation, sewage and fuel storage equipment, so as to provide physical environment guarantee for maintenance personnel to go on the stage for maintenance and diesel engine operation of energy subsystem, and is equipped with ballast water regulation equipment to realize platform draft regulation capacity under different water depth conditions. Through the platform monitoring, the status monitoring of the above equipment and local control of some equipment are completed, and the status monitoring data is reported to the intelligent management and control system through the internal network. The power supply system realizes the independent power generation on the sea through the complementary form of diesel engine, wind energy, photovoltaic and ocean energy. The power storage is completed by the battery to ensure the continuous operation of the system when the power generation means are interrupted, and provide time buffer for the system maintenance and repair in the case of lack of power generation capacity. The power supply system completes the external power transmission through the two bus forms of AC 220 V and DC 48 V, and uses the diesel engine to generate power to realize the power guarantee for the high-power equipment of the platform subsystem. At the same time, the power supply system reports all kinds of state information of its own power generation, storage and distribution to the intelligent management and control system through the internal network. The barocap sensor is proprietary to Vaisala. It is a kind of silicon capacitive absolute pressure sensor with high precision, high reliability and many other excellent characteristics. With its outstanding long-term stability, it minimizes the field calibration requirements in many application fields (Table 1).

Table 1. Performance parameters of hardware equipment

Parameter	Specifications
Accuracy (20 °C)	±0.3 hPa
Resolving power	0.1 hPa
Measuring range	500–1100 hPa
Working temperature	−40 + 60 °C
Voltage output range	0–5 V
Supply voltage	10–30 VDC
Current consumption	4 mA

In the working process of the system, because the stator of the servo motor in the underwater electronic cabin is fixedly connected with the transmission device, and the winding coil can be driven by the rotation of the stator of the servo motor relying on the engagement of the gear, the whole lifting control system can realize the constant speed winding in the positive and negative directions of the winding coil through the rotation of the motor. Because the winder is connected with the underwater anchoring device through the steel cable and is in a positive buoyancy state, the winder is always in a stable equilibrium state. When the winding coil winds the cable at a constant speed, the length of the cable between the winding coil and the underwater floating ball changes, so that a single group of sensors can monitor the seawater environment at different depths in the same vertical section. Because the vertical section ocean buoy profile information monitoring system designed in this paper uses a single sensor group to measure the underwater environment through lifting control mode, which replaces the traditional fixed chain measurement mode of multiple sensors, so that the whole system only needs to supply power to a single set of sensors of each underwater measurement device, It avoids the traditional way of multi-sensor group power supply. Therefore, the power consumption of the lifting underwater buoy profile information monitoring system is much smaller than that of the chain underwater monitoring system. In practical application, servo motor control winding coil rotation is not frequent operation, so it will not cause the overall power consumption burden of the system. Based on this, the system uses solar panels and battery power supply, and through the Beidou satellite, the underwater environment information data is transmitted to the shore station data center for post-processing. This kind of system power supply and communication mode replaces the traditional underwater cable power supply and data transmission mode, which not only saves the cost of power supply and transmission cable, but also avoids the maintenance cost required by long-term wear of underwater cable, and ensures the safety and stability of data transmission.

2.2 Function Optimization of System Software

The marine information system is deployed on the sea and unattended. After the failure, it needs to be repaired at sea, and the preparation time for a single maintenance is long and the maintenance cost is high. Therefore, the maintenance work should be carried out immediately only when the system has a serious failure that affects the task. When there is a general failure of the system that does not affect the task, it is generally not necessary to carry out the maintenance immediately, but try to carry out the maintenance together with the maintenance of important failures or regular maintenance. Therefore, the system reliability work should focus on the task reliability of the system, try to avoid serious failures, reduce the frequency of sea maintenance, and improve the availability of the system. According to gjb813–1990, the task reliability model of the system is established. Fault criteria of mission reliability: the system can not provide necessary survival guarantee, energy supply, intelligent control and data communication services for the carrying equipment during the mission, resulting in the carrying equipment unable to work, so the fault maintenance must be carried out immediately. Among them, the reliability of supporting equipment such as ventilation and exhaust, pressure transformation and oil supply for oil turbine power generation in the platform subsystem will be considered in the power supply subsystem. The block diagram model of mission reliability is shown in the figure below (Fig. 5):

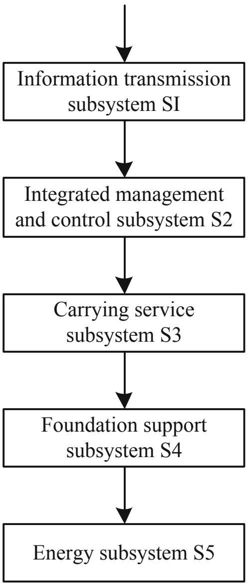

Fig. 5. Information monitoring task processing flow

Because the whole shallow water environment vertical profile monitoring system is composed of multiple underwater test units, when multiple monitoring systems send data to the underwater information acquisition device at the same time, the data acquisition device will not receive the underwater environment data transmitted by each set of marine buoy profile information monitoring system orderly, resulting in data loss or error. There are many kinds of PC software development languages, such as VB, C, C++, C #, Java and so on. We know C and C #, but the main software development tools for these two languages are VC++ and vs. the main differences between them are shown in the Table 2.

Table 2. System performance comparison results

	VC++ 6.0	VS
Development mode	The application is dialog based MFC	Windows form application
Development language support	C, C++	C, C++, C#
Development efficiency	Faster	Fast
Help system	Preferably	Fast
Code execution efficiency	Very high	Higher
Database support	Weak	Strong
Easy to learn	It's hard	Commonly

The multi parameter acquisition system of marine profile environment needs to realize the measurement of various marine environment parameters, store and analyze the data, and at the same time, it can control the sensor remotely and monitor the operation status in real time. The system software mainly includes the software of the lower computer, the communication protocol software and the PC user software. The system software structure is shown in the Fig. 6.

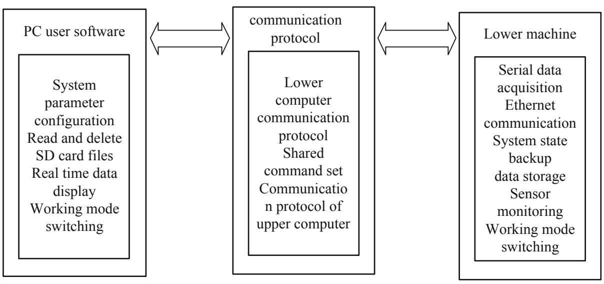

Fig. 6. System software structure

The lower computer software mainly includes the subroutine of initialization module, serial data acquisition module, Ethernet data sending and receiving module and real-time data storage module; The communication protocol software mainly realizes the normal communication between the upper computer and the lower computer by making software rules. PC user software mainly realizes the extraction and deletion of SD card files, underwater sensor parameter configuration and operation control, underwater node network parameter configuration, real-time data display, system status monitoring and other functions.

2.3 The Realization of Ocean Buoy Profile Information Monitoring

In recent years, with the rapid development of marine science and technology, more and more monitoring data have been accumulated. There are many important information hidden behind the surge of data. How to analyze it at a higher level in order to make better use of the data becomes more and more important. However, the original data often has many problems that affect the quality of data use. There are many reasons for these problems, as shown in the figure. Therefore, effective data preprocessing technology is an effective method to solve the problem of data quality and improve the accuracy of data decision-making (Fig. 7).

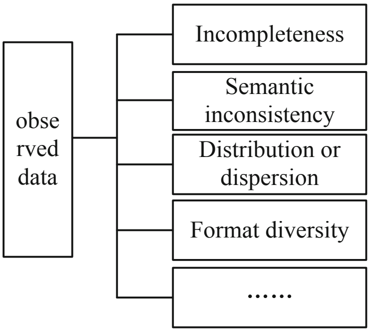

Fig. 7. Information management model of observation data monitoring

Through data preprocessing, the incomplete data can be complete, the wrong data can be corrected, the redundant data can be removed, the required data can be selected and integrated, the unsuitable data format can be converted to the required format, and the redundant data attributes can be eliminated, so as to achieve the same data type, data format consistency, data integration Data information refining and data storage centralization can improve data quality, data service accuracy and decision accuracy.

Data preprocessing is to clean, transform and select the original data before data application, so as to make it reach the minimum specification and standard required by the application algorithm for knowledge acquisition. In a word, after preprocessing, we can not only get the data set required by the mining system, but also reduce the cost of the application system and improve the effectiveness and comprehensibility of knowledge. The main tasks of data preprocessing are as follows.

Data cleaning: such as filling missing data, eliminating noise data, etc. The principle of data cleaning is to use the existing technical means and methods to clean the “dirty data” by analyzing the causes and existing forms of “dirty data”, and transform the “dirty data” into data that meets the data quality or application requirements, so as to improve the data quality of the data set.

Data conversion: the data will be stored in the database, data warehouse or file to form a complete data set, and the redundant data should be eliminated in this process. It is mainly to standardize the data, such as limiting the data value to a specific range. For some application patterns, the data needs to meet a certain format. Data conversion can convert the original data to the format required by the application pattern to meet the needs.

Data selection: eliminate the attributes that can not describe the key characteristics of the system, so as to get a refined set of attributes that can fully describe the applied object. For the mining system that needs to deal with discrete data, we should first quantify the continuous data so that it can be processed.

After the system is powered on, the control chip must first carry out the necessary configuration work, and then start the data acquisition work. The sampling period is set according to the density requirements of various meteorological factors in scientific research. Different sensors have different sampling frequency. The system samples the underwater sensor CTD every half an hour, collects the weather sensor every one hour, and obtains the GPS information every three hours, as shown in the figure. These processes are initiated by the buoy control system actively, and each sensor is powered on regularly or waked up by the controller for data communication, which is not the party initiating the communication actively. As the host of the system, the controller needs an accurate clock to ensure accurate data sampling and communication time. In the process

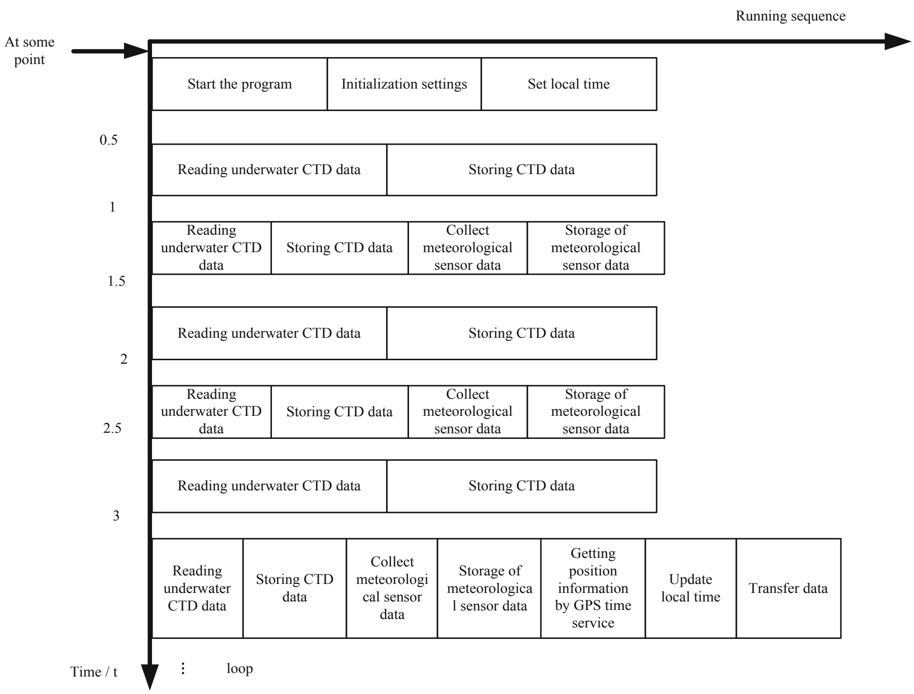

Fig. 8. Buoy information management system operation process

of communication between the controller and the GPS module, the satellite time at the moment will be obtained to calibrate the buoy time (Fig. 8).

According to the influence of wind when sound wave propagates in the atmosphere, windsonic wind speed measurement process is as follows. At the same time, the time of the ultrasonic wave from transducer s to N and the time of the sound wave from n to s can be expressed by the relationship between speed, time and distance:

$$\begin{cases} T_1 = \frac{L}{c+V} \\ T_2 = \frac{L}{c-V} \end{cases} \tag{1}$$

The results of solving the quadratic equation are as follows

$$V = \frac{L}{2}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \tag{2}$$

$$C = \frac{L}{2V}\left(\frac{1}{VT_1} + \frac{1}{VT_2}\right) \tag{3}$$

L is the distance from transducer s to N, Ti and TA are the time of ultrasonic from transducer s to N and from n to s respectively, *C* is the speed of sound, and Y is the component of wind speed to be measured in the N direction of transducer. The other two ultrasonic transducers on the sensor can measure the component of wind speed in E or W direction with the same principle, which is the process of anemometer measuring wind speed and direction.

When the system transmits data, it adopts the control mode of CAN bus, and conducts data arbitration through the protocol of data acquisition unit, so as to ensure that only one set of system can use the channel to transmit environmental data in each time period. Based on the use of can technology, the following gives the process of fuzzy data assimilation of ocean observation information data, as shown in the Fig. 9.

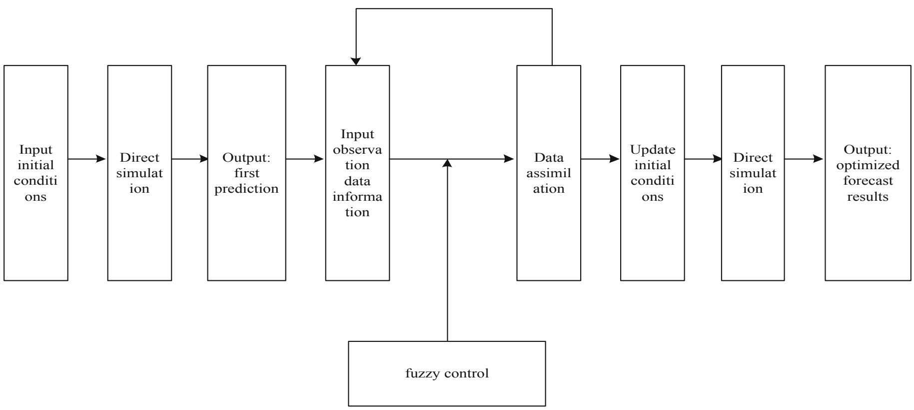

Fig. 9. The process of data assimilation of buoy information fuzziness

In fact, the key to solve the problem of data is the purpose of application. Here, many definite cases can be described by fuzzy conditional statements. For example, if two sets of data X and Y are interactive, we can consider them to be related, which can be described by the following statement:

$$R_i : IfX^i isA^i(n) ThenY^i isB^i(n) \tag{4}$$

The result obtained from the previous step is the formalization of fuzzy relation, and the de fuzzy formula is as follows:

$$y = \frac{R_i \sum_i^L y_i}{L - C} \tag{5}$$

According to the fuzzy basic representation, the central average method is calculated.

$$P(x) = \frac{\Pi_{i-1}^M \mu A_{ij}(x_i)}{\sum_{j=1}^L \prod_{i=1}^M \mu A_{ij}(x_i)} \tag{6}$$

$$\Delta y' = f(x) = P(x) \sum_{j=1}^L p_j(x) y_j \tag{7}$$

In order to obtain effective fuzzy prediction, there must be an overall measure of individual errors in the form of average error. Ape's formula is as follows:

$$APE = \frac{\sum_i^n |x_i - \hat{x}_i|}{\sum_i |x_i| - \Delta y'} \times 100 \tag{8}$$

Therefore, in a more general form, it is defined as the minimization of the following cost function:

$$J(x) = (x - x_b)^T B^{-1}(x - x_b) + \sum_{i=0}^n (y_i - H_i[x_i])^T R_i^{-1}(y_i - H_i[x_i]) \tag{9}$$

Under the premise of ensuring the stability and reliability of data transmission, the focus of the whole system software design is to complete the accurate winding operation of the winding coil by controlling the rotation of the motor. The specific system software flow chart is shown in Fig. 10:

After the control system is powered on and initialized, the motor controller writes the working mode to the servo motor and waits for the instruction from the upper computer. After receiving the upper computer instruction, judge the specific content of the instruction. If it is a speed instruction, write the corresponding command word after judging the motor speed and direction, and then write 0f, then the motor starts to work. If the received command is 0x1111 or 0x0000, it means that the motor holds the brake and continues to work after the motor stops holding the brake. If the motor controller receives the instructions from the host computer, it will send the working state information of the motor to the host computer, so as to achieve the research goal of real-time and accurate monitoring of the ocean buoy.

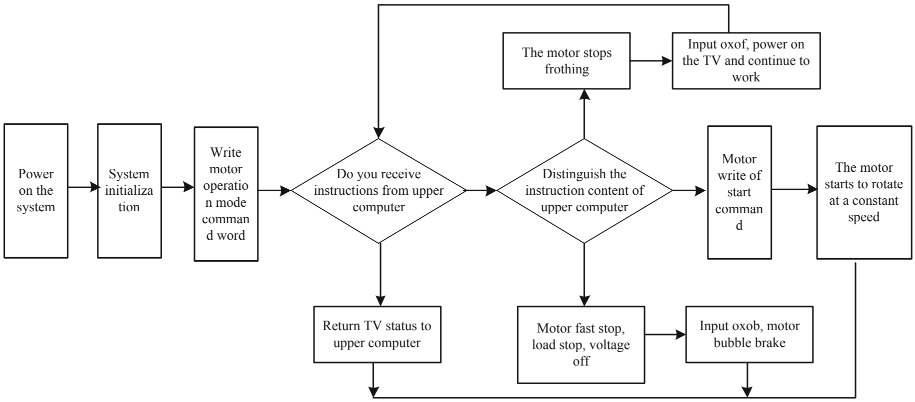

Fig. 10. System operation process optimization

3 Analysis of Experimental Results

The system performance was tested in depth in laboratory environment, and the conversion accuracy of AD was verified by using NAV meter and high precision voltage source. A series of joint commissioning experiments have been carried out in the National Laboratory of marine science and technology pilot. The calibration process of the system is as follows: the output of high-precision constant current source is taken as the voltage to be measured, and the measurement result of the system is taken as the measurement value VMS; At the same time, the nanovoltmeter measured the voltage and took the result as the standard value vstd. Because the NAV meter selected in the calibration process is of high precision and resolution of 1 nv. Even if the range is increased to 10 V, the resolution can be kept within 1 uv, and the accuracy is better than 3 ppm. Therefore, the results of Nav table can be used as the accurate value for system reference. Then, the fitting curve and fitting equation of vstd VM and each channel are obtained by using the least square method. After the measurement process, the measurement results need to be calibrated by this fitting equation to obtain more accurate measurement values. Several voltage values are selected for measurement, five values are tested for each voltage value, and the average value is obtained as the measurement result of this point. The least square fitting is carried out with origin. The least square fitting function and its coefficients of each analog conversion channel are listed in the Table 3.

Table 3. Parameters of fitting curve

Passageway	Slope	Loading distance
Pressure	1.0012	−5.72341E-6
Precipitation	1.00184	−9.81E-3

(*continued*)

Table 3. (*continued*)

Passageway	Slope	Loading distance
Wind speed	1.00013	−9.16752E-6
Temperature	1.00034	−8.08157E-5
Wind direction	1.00012	−5.42655E-5
Compass	1.00033	−1.82208E-4
Long wave	1.00391	−6.46393E-4
Shortwave	1.00287	−1.46E-3

Through the VI editor, the underwater data acquisition program and the communication program of the buoy platform are written respectively. Through GDB debugging tool, you can easily debug programs in the Linux system of the host, and set breakpoints for debugging. Compile to generate executable file, write makefile file.

The underwater data acquisition system mainly tests the data receiving of multiple serial ports and the storage of SD card. At the same time, open and receive 6 channels of serial port data, and each channel sends channel * string to test the bit error rate. Where * is the channel number, debug the serial port to connect the Linux system of PC. Save the collected data to the file/MNT/sdcard/collect.txt. For several consecutive data transmission, each test time is 1 h and 3 h, and there is no bit error, so the reliability of the system is high.

In order to analyze the monitoring effect of the designed system and compare the measurement error of the marine buoy profile information monitoring system before and after use, the mean value of the measurement error under 30 iterative experiments is obtained, as shown in Fig. 11.

According to the analysis of Fig. 11, after the calibration of the designed system, the measurement error of analog quantity is greatly reduced and the measurement accuracy is significantly improved.

Furthermore, the accuracy and stability of single point voltage measurement are studied. In the same environment, the actual application performance of the traditional monitoring system and the detection system in this paper are compared and analyzed. The horizontal part in the figure is the expected value, and the specific detection results are shown in the following Fig. 12.

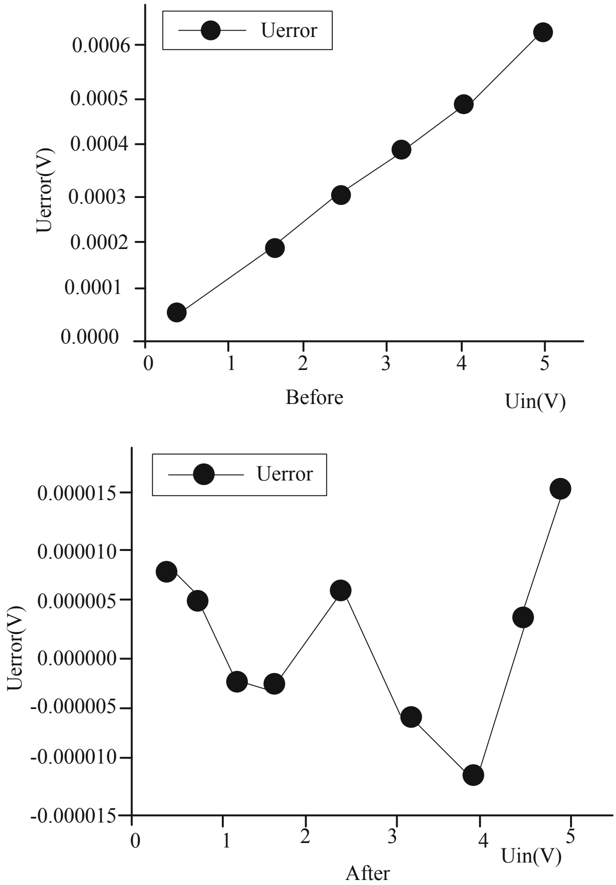

Fig. 11. Deviation between measured value and standard value

Based on the monitoring results above, the proposed information monitoring system of buoy profile has higher accuracy in the practical application process and fully meets the research requirements.

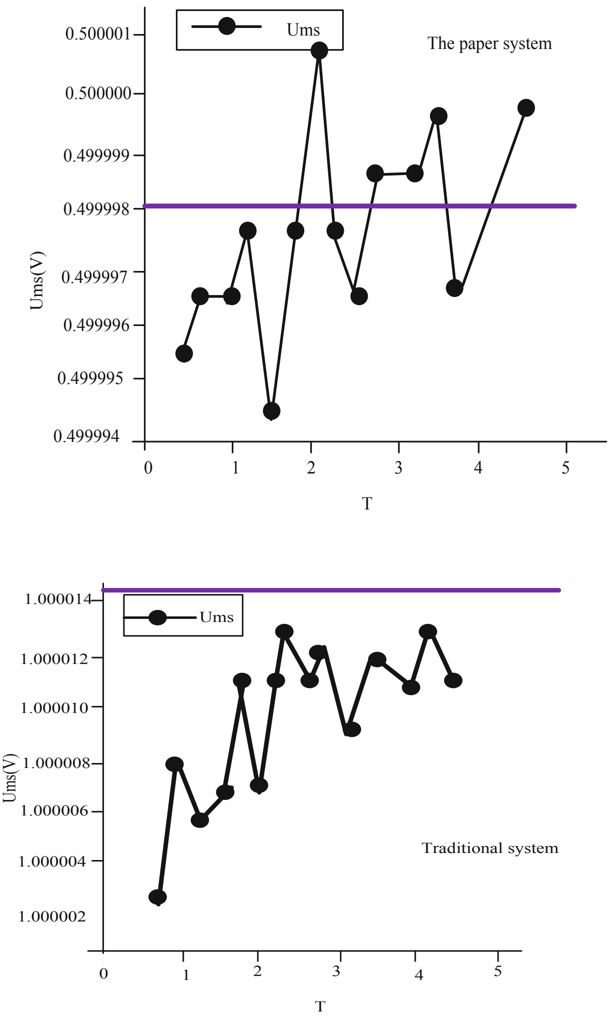

Fig. 12. Monitoring results of system performance comparison

4 Concluding Remarks

This paper designs an ocean buoy profile information monitoring system based on machine vision. The hardware structure of the marine buoy profile information monitoring system is designed, the fuzzy data assimilation process of buoy information is optimized, and the fuzzy prediction method is used to realize the stable transmission of the data of the information monitoring system and the effective monitoring of the marine buoy profile information. It provides scientific design ideas and methods for design modeling, index decomposition, development integration and function joint test of offshore platform electronic information system.

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