Realization of key navigation parameters display and control software for underwater vehicle

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Abstract. In response to the key navigation parameter display and control requirements of underwater vehicle, this paper adopts the "module function black box" program concept, visual display, multi-threading and other key technologies to design a key navigation parameter display and control software for underwater vehicle. The software can quickly and efficiently set the PID parameters of the motor controller, achieving data visual display of key parameters of the control microcomputer. Through practical application, the software can not only monitor key navigation data such as attitude, depth, power supply voltage, rotational speed, and control microcomputer temperature of underwater vehicle in real time, but also control the start and stop of underwater vehicle. The software has the advantages of strong real-time data, good human-machine interaction, simple operation, and high degree of visualization.

Keywords: Underwater vehicle; navigation parameters; CAN communication; display and control.

1 Introduction

The development and progress of underwater vehicle is of great significance in economy, science and military[1][2][3]. Economically, the deep sea is rich in strategic metal minerals, energy and biological resources, which need to be explored and exploited by underwater vehicle. Scientifically, research on marine hazardous geology, installation and maintenance of submarine optical cable pipelines, marine rescue, and underwater archaeology all require technical support from underwater vehicle. Militarily, the attack, defense and confrontation of underwater vehicle is one of the key technologies related to modern ocean development and the competition for maritime dominance.

Real time tracking, monitoring, and control of key navigation parameters of underwater vehicle is one of the fundamental tasks to ensure safe navigation of underwater vehicle[4][5]. Monitoring key navigation parameters such as attitude, depth, rotational speed, power supply voltage, and temperature control of underwater vehicle is of great significance[6]. The reason is that:

The attitude parameter of underwater vehicle is key information for preventing accidental capsizing and evaluating the navigation ability of underwater vehicle [7][8].

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The depth parameter of underwater vehicle is key information for real-time understanding of the depth situation of underwater vehicle and avoiding unnecessary losses caused by excessive navigation[9][10]. The rotational speed parameter of underwater vehicle is key information for measuring navigation speed. The power supply voltage parameter of underwater vehicle is crucial information for maintaining the normal operation of all electrical equipment on the vehicle[11]. The temperature control of the underwater vehicle's control microcomputer is the key information to ensure that the control microcomputer operates normally within the safe temperature threshold. Monitoring the above navigation parameters is beneficial for improving the safety assurance and intelligence level of the aircraft, enhancing the service life of the equipment, and extending its service life.

Display and control software can monitor the key navigation parameters of underwater vehicle in real time during various stages of product research, trial production, and production, and provide information on the changes in key navigation parameters. Meanwhile, analyzing the monitored key navigation parameters can fully evaluate the performance of the product, thereby improving the development efficiency of underwater vehicle.

Therefore, from the perspective of software design, this article focuses on addressing the following issues: 1) The software utilizes CAN bus communication to achieve monitoring data transmission of various key navigation parameters of underwater vehicle, such as underwater attitude, depth, power supply voltage, rotational speed, and control microcomputer temper. 2)The software will provide real-time updates on the changes in monitoring data. It utilizes multi-threading technology to visually display attitude, depth, and rotational speed, which can dynamically display changes in parameters and facilitate real-time observation by users. 3)The software provides data storage function, which facilitates data playback and analysis in the later stage.

2 Software Requirements Analysis

According to the usage requirements of key navigation parameters display and control software for underwater vehicle, the required projects (functions) can be decomposed into:

2.1 Communication Interface

The software is designed based on the data format required by the underwater vehicle interface and high-level protocols, and implements a data reception and processing module that can be used to receive CAN communication data. At the same time, the software reserves serial communication and network communication interfaces to improve the adaptability of the software interface;

2.2 Data Analysis

Adaptive analysis and processing of key navigation parameters transmitted by motor control equipment and control microcomputer.

2.3 Visual Display

Sampling multi-threading technology completes the visual display of data such as attitude, depth, rotational speed, power supply voltage, and temperature of control microcomputer;

2.4 Data Saving

The software can save the original key navigation parameter data received by the display and control software, the calculated navigation parameters, and process record files to the local area.

2.5 Help Document

The software provides system assistance to improve software usage efficiency.

From the perspective of software functionality, data processing software mainly includes: 1) Good real-time data transmission ability and correct data parsing and solving ability; 2) Control command settings and responses, key data reading and responses should be traceable to facilitate data inspection; 3) Visualize the parameters and update the depth, attitude, and rotational speed parameters in real-time after calculation. With the accumulation of time, the dynamic changes of the parameters throughout the navigation process can be observed.

3 Overall Software Design

3.1 Development Environment

The software uses the C # programming language in the Visual Studio 2015 development environment. During software development, the SeeSharpTools software component based on Jianyi Technology's Ruishi Measurement and Control Platform is also used, which includes a series of ClassLibraries, which can provide convenient and easy-to-use signal generation, analysis, and display functions, significantly improving software development efficiency. The generated process record data, original received data, and solution results are saved in. txt format.

3.2 Software Framework

The key navigation parameter display and control software for underwater vehicle is designed based on demand analysis and functionality as follows:

Communication Protocol Design.

Based on the extended frame format in CAN2.0B[12][13], the software defines the CAN application layer protocol suitable for software and control microcomputer and motor controller, which includes: frame format and frame type definition, frame ID encoding definition, data domain definition, CAN bus application layer error handling strategy, etc. The format definition of ID (29 bits) is as Table 1.

Table 1. ID format definition.

Bit number	Definition	Bit count
ID28～ID26	Priority	3
ID25～ID24	Reserved	2
ID23～ID16	Information type	8
ID15～ID8	Send destination address	8
ID7～ID0	Send source address	8

System Architecture Design.

Adopting the "module function black box" programming concept, as shown in Fig. 1[14]. The software adopts a structure design of "function call+module function black box+editable help document". The module function black box realizes the main functions of the software. This structure has two advantages: first, the software has information hiding function, which can make the external details of the module unknown, making the system more robust and easier to maintain; Second, software modules have high independence, meaning that each module only involves its own functionality, with simple interface design, high cohesion, and low coupling.

Based on the relationship between various functions in Fig. 2 and the modular design concept of software programming, the software is divided into five major functional modules: CAN communication module, motor controller setting module, control microcomputer transmission data analysis module, key parameter visual display module, and data storage module. According to the principles of object-oriented programming, if data and its operation methods are combined as a whole, the five functional modules can be abstracted into five basic classes. The software functional modules are shown in Fig. 3, and the functions of each module are as follows:

The communication module is the connecttion part between software and underwater vehicle. This module is responsible for issuing and controlling commands for underwater vehicle, real-time transmission and reception of attitude and depth data for underwater vehicle, real-time transmission and reception of rotational speed and power supply voltage data for motor controller, control of propeller start and stop, and issuance of cable release instructions for underwater vehicle;

The motor controller setting module is responsible for parameter setting and response analysis of the PID control parameters of the motor controller.

The control microcomputer transmission data analysis module is responsible for solving the data transmitted by the control microcomputer, including attitude, depth, temperature, rotational speed, power supply voltage, etc.

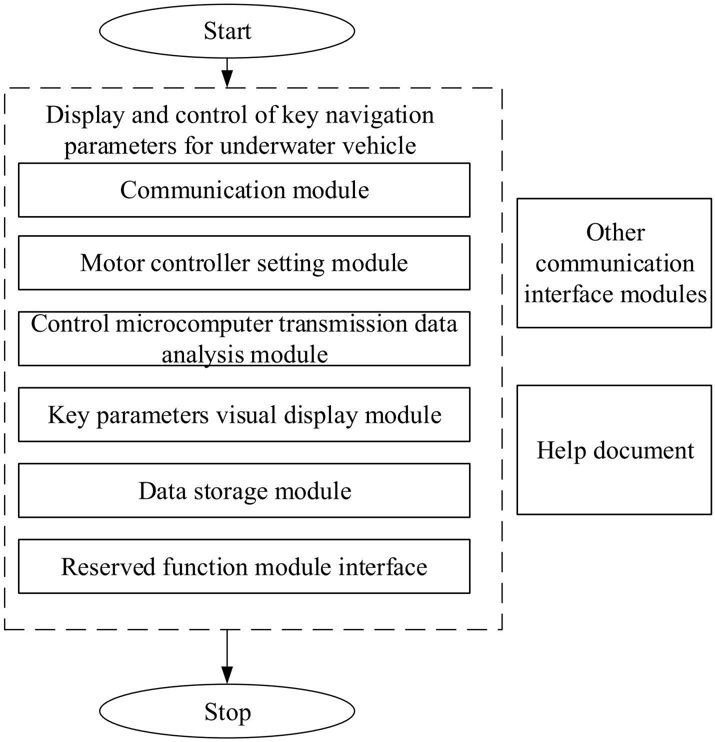

Fig. 1. "Module Function Black Box" Program Structure

The key parameter visual display module is responsible for dynamic real-time display of attitude, depth, and rotational speed.

The data storage module is responsible for locally saving the received raw key navigation parameter data, calculated navigation parameters, and process record files.

Process Design.

Clear algorithm and program expression for display and control software. The software adopts an object-oriented design method of "class+function", forming organizational relationships between different levels of data processing software, ensuring the portability, interoperability, and universality of software component.

Human-computer Interaction Design.

The software has completed four stages of interaction design around the "user centered" design concept: a) User requirement research stage; b) Human-computer interface analysis stage; c) Design and evaluation stage; d) Implementation and testing stage. To improve the human-computer interaction of the software through the above four stages, iterative optimization design will also be carried out based on user feedback in the future[15][16].

Modular Design.

According to the requirements analysis in Section 2, the software adopts the principle of single responsibility class design to complete the design of each functional module. Therefore, in the future, when customizing or extending software, modules with the same requirements should be directly called or extended within a single functional module with a single responsibility. This can also expand new classes to increase software resilience according to different needs.

Software Process.

The software flow is shown in Fig. 4, and the main process is as follows: start CAN communication, communicate with the motor controller to set PID parameters, and communicate with the control microcomputer to control the start and stop of the vehicle; Communicate with the control microcomputer to monitor key navigation parameters; Visual display of key navigation parameters.

The Start and Stop of CAN Communication.

Users can configure CAN communication by setting device type, device index, device channel number, working mode, filtering method, and baud rate. In general, the working mode and filtering method do not need to be modified. After completing the settings, click the "Open CAN" button to open CAN communication; At the end, click the "Close CAN" button to turn off CAN communication.

Communicate with the Motor Controller to set PID Parameters.

The user inputs the PID control parameters of the motor on the interface, clicks the "PID Settings" button. After receiving the parameter settings, the motor control machine responds with a command, and the software displays the resolved PID parameters to the user to check whether the PID setting command is successfully sent. Users can also complete the reading of PID setting parameters by clicking the "PID Read" button to check if the PID parameter settings are successful.

Communicate with the Control Microcomputer to Control the Start and stop of the Vehicle.

The start and stop control of the vehicle is mainly achieved through the start and stop of the propeller. When the vehicle needs to be started, the propellers are started, and the propellers rotate to drive the vehicle; When it is necessary to stop the navigation vehicle, it is achieved by turning off the propeller.

Communication with control Microcomputer to Monitor Key Navigation Parameters.

Data monitoring includes obtaining depth, attitude, rotational speed, and power supply voltage. The data refresh rate is 10Hz. Monitoring is mainly achieved through CAN communication between control microcomputer and software. After the user clicks the data monitoring button on the software, the software will send a CAN command, and the control microcomputer will respond to the command. After the response, the navigation parameters will be sent every 100ms. The software will analyze the key navigation parameters received and display them on the interface.

Visual Display of Key Navigation Parameters.

The visual display of key navigation parameters mainly completes the dynamic display of depth, attitude, and speed. After the user clicks the "Start automatic transmission" button, the control microcomputer sends depth, attitude, and speed information to the software at a refresh rate of 10Hz. The software adopts multi-threading technology to receive and display key parameters of data. One thread is responsible for receiving and parsing navigation parameters, while the other thread is responsible for visualizing navigation parameters. Visual display corresponds one-to-one with data monitoring changes, which is more intuitive than numerical display, and can observe the dynamic transformation of data. When the user clicks the "Stop automatic transmission" button, the visual display of key navigation parameters stops.

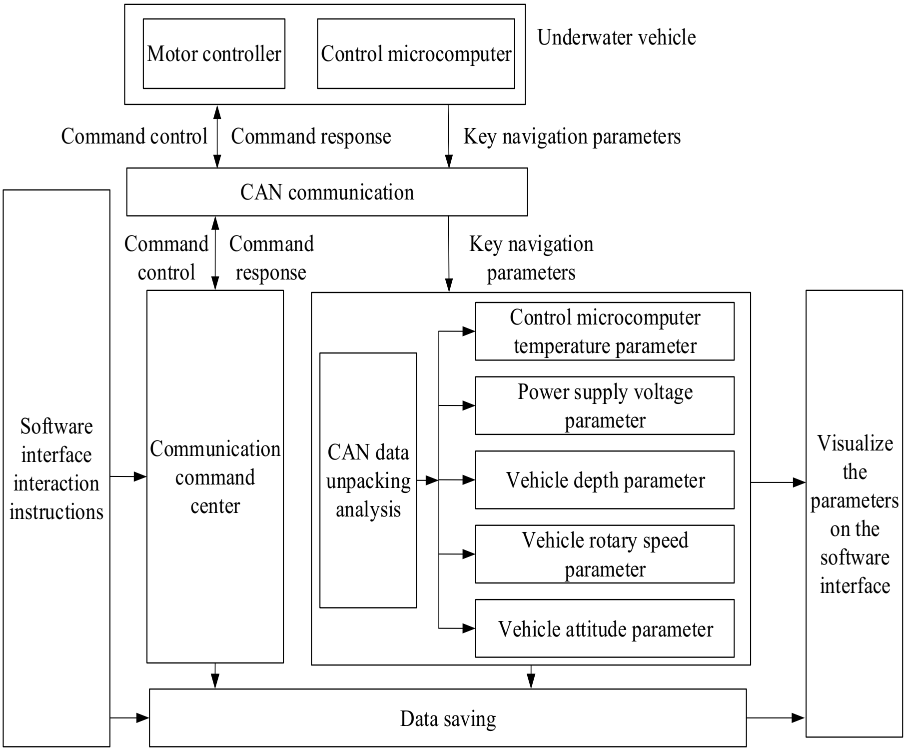

Fig. 2. Schematic diagram of the relationship between software data flow and functionality

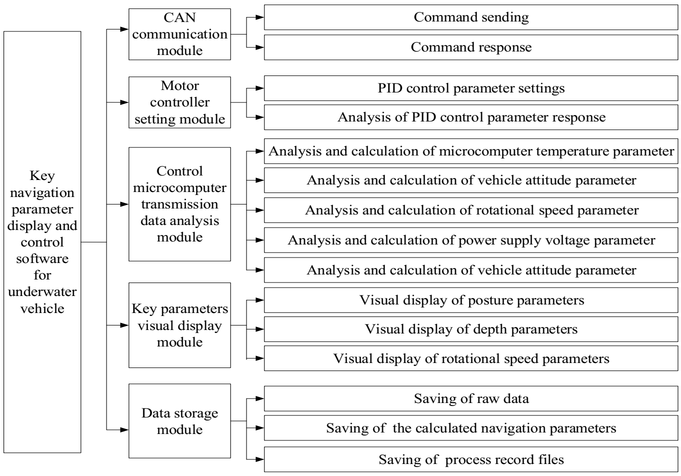

Fig. 3. Software Function Module Design.

4 Software Implementation and Testing

Complete the programming and implementation of the software according to the overall design concept, and the main interface of the software is shown in Fig. 5. The main interface of the software is roughly divided into three parts: control (CAN setting, PID setting and reading, spacecraft start stop control, and key data monitoring), raw data receiving records, and visual display of key navigation parameters. They correspond to the upper left, upper right, and lower parts of the main interface.

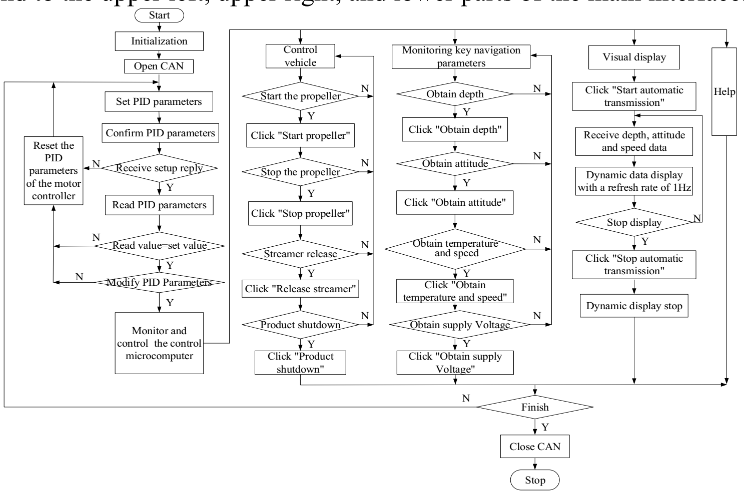

Fig. 4. Software flowchart

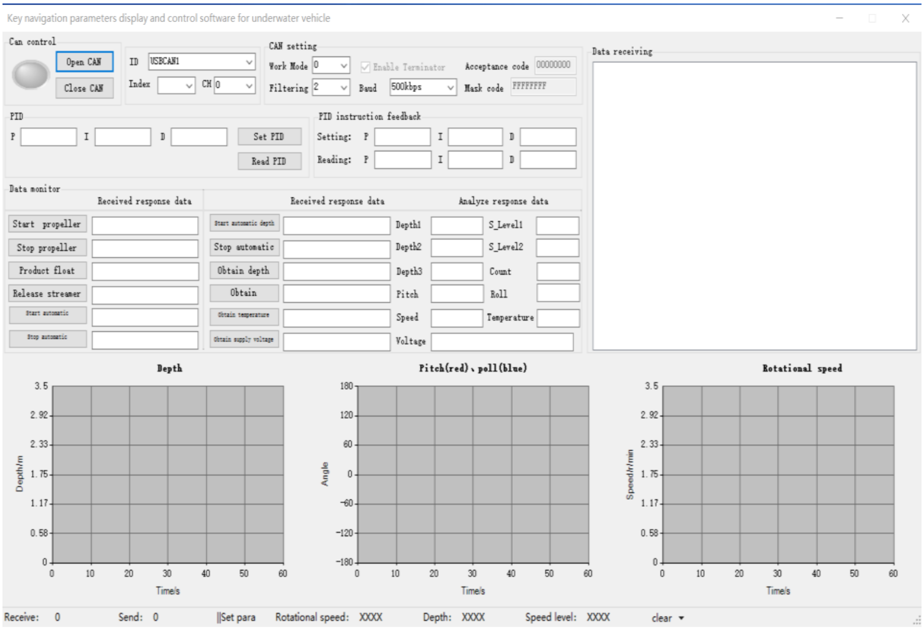

Fig. 5. Software main interface

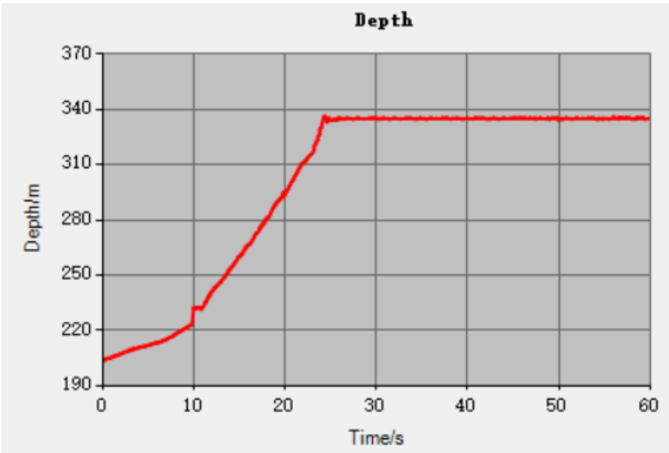

Fig. 6. Depth monitoring result.

In a certain experiment, Fig. 6 shows the depth results of underwater targets monitored by the software. The experimental results show that the depth of the underwater target increases slowly after entering the water. After about 11 seconds, the speed of the underwater target sinking into the water increases. After about 25 seconds, the depth is stable at about 335 meters. The results show that the software has good real-time performance.

5 Conclusion

The display and control software for key navigation parameters of underwater vehicle is suitable for the current development needs of underwater vehicle informatization, and can command and dynamically monitor the key navigation parameters of a certain type of underwater vehicle. The display and control software adopts the "module function black box" program concept, visual display, and multi-threading technology. Through functional modular design and reliability analysis, the development efficiency of the software has been improved.

In addition, as various underwater unmanned aerial vehicles gradually become new types of underwater combat platforms, the level of information technology of underwater vehicles will become higher and higher. Therefore, higher requirements are put forward for display and control software. The following two points are worth considering and researching:

1)Improve the universality and adaptability of the software, so that it can adapt to various types of underwater vehicles. It is also possible to shorten the software development cycle by improving module encapsulation.

2)Improve the robustness and stability of software. The method is to evaluate the robustness of the software by inputting faults, and optimize the software based on the evaluation results to ensure better reliability and safety in complex underwater environments.

3)Software execution efficiency issues. The intelligent level of underwater vehicles in the future will be increasing, and there will be more and more key parameters that need to be monitored. The more types of data to be monitored, the more complex the structure, and the more parameters to be visualized, the longer the time consumption. Therefore, the issue of software execution efficiency must be considered, which can be achieved through optimizing data structures, improving program control structures, and implementing data strategies.

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