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Design and Implementation of Control System for Underwater Robot under Artificial Intelligence Background

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Abstract: The underwater robot based on artificial intelligence requires small size, stable motion, and its control system requires low power consumption, reliable performance, and easy operation. This article uses STM32F407 as the main control unit to build the underwater robot motion control system and designs the software structure and data collection process for the entire system. The thruster is tested for data, and the ROV spatial motion coordinate system is established. Then, in response to the characteristics of multiple control nodes, large communication volume, and strong real-time performance of the flexible long fin biomimetic thruster, the internal communication network of the control system was established using a field bus. Finally, the details of the software and hardware implementation of the control system were introduced. The experimental results showed that the control system had good control performance.

Keywords: Design and Implementation, Control System, Underwater Robot

1. INTRODUCTION

At present, major countries around the world are vigorously developing the marine industry. However, there are various uncertain and unknown factors in the ocean, and underwater robots have become the best tool to replace human operations due to their small size, high safety, deep operation depth, and long sailing time. It has been widely used in marine development. The underwater robot is a strong nonlinear system, and the motion of each degree of freedom is coupled with each other. In addition, the unknown gravity, buoyancy, and propeller installation of ROV under water bring difficulties to the design of controller. Establishing a universal, standardized, and practical mathematical model for ROV is a prerequisite for conducting control research on it. The overly complex mathematical model can lead to the complexity of the control system. The ROV designed in this article for underwater detection adopts an open-frame structure, equipped with sonar and attitude sensors.

The ROV can be controlled through cables on the shore console to complete actions such as forward, backward, upward, downward, left, and right turns. ROV structure, with a pressure chamber in the middle and buoyancy adjustment chambers on the left and right sides. The electronic cabin is used to install high and low frequency beacon machines, attitude sensors, and control circuits, and can also provide space for lithium batteries. The buoyancy chamber is used to provide buoyancy, which is composed of the center of gravity adjustment module and its drive control system. The center of gravity adjustment module controls the displacement direction and displacement amount of the counterweight by adjusting the steering and rotation amount of the drive motor, thus changing the axial displacement of the center of gravity of the whole carrier to generate pitching torque, thus controlling the pitching attitude of the carrier and Dynamic equilibrium along the axis.

The experimental model achieves self-stabilization of rolling degrees of freedom by configuring the center of gravity of the carrier downwards. The development purpose of this biomimetic underwater robot experimental model is to test the propulsion performance of a flexible long fin biomimetic thruster. Currently, only one flexible long fin biomimetic thruster is installed on the underside of the carrier. The thrust direction generated by the biomimetic thruster does not pass through the center of mass of the robot, which will generate an upward torque. In order to conduct stable navigation tests in water, a center of gravity control module is designed inside the robot to generate a balanced downward torque. In the future, multiple flexible long fin biomimetic thrusters will be installed on biomimetic underwater robots, making them capable of full attitude spatial motion. The underwater robot mainly consists of two parts: an underwater control platform and an underwater actuator. The underwater control platform is mainly a control box that can issue commands to the robot and receive status data from the underwater robot at different times.

The water control platform issues control commands, where the CAN bus serves as a bridge for information transmission between the control box and the underwater robot, and the underwater main controller controls each executing mechanism to make corresponding actions. The function of the heading control system is to maintain a constant heading angle of the underwater robot. The control loop uses a compass as a feedback sensor, and the deviation between the actual heading angle measured by the compass and the set heading angle is used as a closed-loop input, after PID adjustment, the voltage of the control motor is output, which is superimposed on the forward/backward and lateral navigation instructions issued by the upper computer operating mechanism. Then, after passing through the thrust distribution link and limiting amplitude, it is output to each DC motor, acting on the underwater robot carrier to maintain the set heading.

2. THE PROPOSED METHODOLOGY

2.1 Control system structure design

The lifting motion and depth control of ROV based on buoyancy regulation can reduce energy consumption. The diving and floating movements are achieved by adjusting the buoyancy on both sides to adjust the buoyancy of the cabin. ROV adopts dual propeller thrusters, arranged on both sides, parallel to the central axis. Through these two thrusters, both forward and backward thrust can be generated, as well as rotational torque, without coupling between the various degrees of freedom. The midpoint of the connecting line between two parallel thrusters should be in a straight line with the center of buoyancy and center of gravity to achieve balanced propulsion. A variable mass adjustment system is adopted in the buoyancy adjustment system, which adjusts the injection and discharge water volume of the left and right buoyancy tanks to reduce or increase the overall buoyancy, thereby generating a downward or upward force.

The control system controls the magnitude and direction of thrust, pitch moment, and yaw moment by adjusting the speed and direction of the biomimetic flexible long fin drive motor, the rotation amount and direction of the center of gravity adjustment module drive motor, and the deviation angle and direction of the "cross shaped" tail rudder fluid control surface. Therefore, the experimental model not only can achieve basic motion modes such as forward, reverse, braking, steering, and pitch maneuver, more complex three-dimensional motion modes can also be achieved through the combination control of the basic motion modes mentioned above. Traditional underwater robots are generally equipped with a propeller thruster and corresponding control driver. Each thruster only needs to control the speed to adjust the thrust size, with fewer control parameters and low communication data and real-time requirements. The control computer and each thruster controller can be achieved using traditional serial communication bus or parallel bus, without the need to expand the high-speed communication interface.

One or more flexible long fin biomimetic thrusters are configured in the biomimetic underwater robot, and each flexible long fin biomimetic thruster includes a set of more than control nodes. The motion parameters of each node require real-time control, which puts higher requirements on the speed, real-time performance, and interconnectivity of the communication network. New high-speed buses and extended communication interfaces must be adopted. The power part of the underwater robot is composed of thrusters installed in four different positions, which are controlled by corresponding drivers. Upon receiving control information, the drivers will drive the thrusters and make reasonable adjustments according to our requirements to drive the robot's motion. The embedded control system detects the motion status of the submarine through detection devices and transmits data to the surface computer through the network, The surface computer calculates the control amount based on predetermined tasks and preset algorithms, and then transmits the control amount to the submersible, which is then controlled by an embedded system to control the motion device of the submersible.

The main control module is the control center of the experimental model, connected to the remote-control receiver, the underlying drive control system of each functional module, the programmable instruction memory, and the carrier attitude sensor. Its function is to receive remote control commands, manage system operation modes and onboard electrical equipment, and forward control parameters of the underlying module. Based on the control system structure and communication network design, it is necessary to select equipment that meets various performance indicators to build the control hardware subsystem. Console computers do not require high hardware requirements and can use ordinary personal desktop computers or laptops.

2.2 Control Scheme and Simulation Analysis of Inclination and Diving Depth Based on Artificial Intelligence

The console computer is equipped with a drilling operating system, and the program is written with advice. It has a good interactive interface and main functions include start stop control, parameter setting, status detection, and data analysis. The attitude sensor adopts an inertial measurement unit, including a fiber optic gyroscope and a high-precision accelerometer, which can directly output two attitude angles of pitch and roll. The control computer is installed inside the underwater robot, requiring fast calculation speed, rich interfaces, small size, low energy consumption, and fast development. Therefore, an industrial computer with outstanding comprehensive performance is selected.

The stability of the underwater vehicle can be defined as the ability to return to the equilibrium state after being disturbed without any corrective action. In the design of the hardware scheme of the motion control system, the response speed of the overall scheme is related to the stability control of the underwater vehicle. Based on this, the motion control system of the underwater vehicle is designed. The motion control software of the underwater vehicle is written under the Real-time operating system QNX, Including network communication module, serial communication module, sensor data acquisition module, data management module, and controller module.

QNX operating system is characterized by good real-time performance. Multi process technology is used to manage the control algorithm, sensor information processing and thrust distribution algorithm under the framework of Real-time operating system, to improve the real-time performance and reliability of dynamic positioning control system. Construct a motor drive circuit with AT89C51 microcontroller as the core to construct a motor speed servo control circuit. The microcontroller retrieves the speed feedback signal and compares it with the target speed signal sent by the main control module through the CAN bus and uses a digital PID algorithm to achieve stable speed control. The pitch and balance control module also adopts the same drive control circuit structure as the propulsion control module.

The communication expansion card includes two bus interfaces and a router serial interface, installed with an operating system. The control computer program mainly includes flexible long fin fluctuation parameter control algorithm, attitude calculation, balance control, etc. The balance control node and each joint control node adopt a widely used series of microcontrollers, which communicate with the control computer through communication interface circuits and are connected to the motor drive controller through serial ports. Covering the main control unit, communication unit, detection unit, driving unit, and auxiliary unit in the entire motion control system, the entire system is controlled by the motion controller STM32F407 in the main control unit.

The CAN bus enables bidirectional communication between underwater robots and water control boxes, serving as a bridge for information transmission; The detection modules in the entire control system include 9-axis attitude sensor, leakage detection sensor, water depth sensor, and temperature sensor. The expanded interfaces include wireless communication interfaces, GPS expansion reserved interfaces, sonar reserved interfaces, and gyroscope reserved interfaces, making the robot's functions more complete in the future; The power unit is a thruster and a center of gravity stepper motor installed in four different positions, which are respectively driven by an electric regulator and a stepper motor drive board. The auxiliary unit includes a camera, LED light, and laser. The LED light is controlled by the controller through a control board, and the relay controls the operation of the entire underwater motion control system.

3. CONCLUSION

This paper introduces the structure and sensor system of the open shelf underwater detection robot and designs the ROV Embedded controller based on the AT91RM9200 Processor design. The mathematical model of ROV is established, and the method of ROV vertical plane coordinated motion control is proposed. The underwater vehicle Embedded controller based on STM32F407 is designed, and the specific implementation methods of each functional module are introduced in the later research, algorithm control will be further carried out on underwater robots to improve their accuracy, and real-time underwater monitoring and control will be carried out after the robot's sealing is improved.

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