Analysis on Design Scheme of Autonomous Ship Cooperative Control

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Abstract. During this stage, the technology of autonomous ships is becoming more and more mature, which has been widely used in military or civil fields, especially in the field of marine survey. With the gradual maturity of independent ship technology, the advantages of independent ship such as voyage, manufacturing cost and independent control are increasingly prominent. In spite of the rapid development of related technologies of autonomous ships, autonomous ships alone are still unable to compare with autonomous ship formation. Autonomous formation cooperative work can not only effectively improve the phase ratio of operations, but also greatly improve the fault tolerance and maritime adaptability of operations. Therefore, there is only one main ship out to sea in production practice, most of which are several independent ships to achieve specific goals in cooperation [1]. In order to effectively improve the cooperative control of autonomous ship formation under the interference of harsh environment, such as air volume at sea, a design scheme of cooperative control for autonomous ship formation is proposed in this study. The results show that the design scheme can effectively improve the cooperative control ability of formation.

1. Introduction
At present, independent autonomous ships have made great progress in the research of collaborative control while independent ships still have great technical limitations when they perform tasks in the sea or other waters. Therefore, in order to improve the efficiency of surface operation of autonomous ships, in many cases, multiple autonomous ships complete tasks, such as maritime rescue, seabed resource exploration, and marine replenishment. At this stage, more and more researchers have focused on the research of collaborative control technology of autonomous ships [2]. On the basis of fully considering the problems of the autonomous ship itself, such as not modeling, even if the marine environment changes, etc. This paper considers potential change existing in the ship itself and navigation, such as the dynamics of not modeling, the uncertainty of model parameters and the disturbance of the marine environment that changes at any time [3]. Through the collaborative control design and research of the autonomous ship in this study, it can effectively improve the track tracking performance of the autonomous ship and improve the robustness of the autonomous formation.
2. Hardware design of collaborative control for autonomous ships

2.1 Overall scheme design of collaborative control system for autonomous surface vehicle

The main control unit of the autonomous ship is mainly divided into onboard control and shore control unit. The onboard control unit is mainly integrated a variety of sensors to collect information and receive the operation instructions of onshore personnel. In this study, PC104 is applied as the onboard hardware control unit, and VxWorks is used as the onboard software control system. The specific components are mainly consist of PC104 industrial computer, phins, GPS receiver, thrust motor, speed control module and wireless serial port communication [4]. The onshore control unit puts operation instruction into practice such as task assignment, hull control, channel information monitoring and other operations of the autonomous ship. The control carrier will take PC as the main operation platform, Visual C++ as the hardware operation system, and mainly consists of PC and the wireless serial communication unit.

![Figure 1. Overall scheme design of autonomous vessel.](image)

2.2 Control system of unmanned autonomous surface vessel

The control of the autonomous ship is mainly conducted by the onshore operation platform, such as command issuing, parameter setting, etc. The command is sent to the receiving unit of the autonomous ship after the above work is finished.

After receiving the command, the shipborne equipment starts to transmit the command parameters to each shipborne unit to start the command operation. The course angle information of the autonomous ship is mainly collected by the phins equipment, and the azimuth, longitude and latitude information of the autonomous ship is received by the GPS receiver, and then the received information is transmitted to PC104 through the serial port. After PC104, the received GPS and phins information are calculated and analysed[5]. The generated autonomous ship position, autonomous ship attitude, navigation speed and other information are transmitted to the shore command platform in real time through the wireless serial port [6]. Through the shore control unit and control algorithm, the staff analyze the received information of the course and task progress stage of the autonomous ship, and transmitted the analyzed parameters back to the autonomous ship through the shore control unit to form instructions. After that, the onboard system of the autonomous ship transforms the received
command parameters into motor signals and transmits them to the onboard equipment to drive the ship to finish the relevant tasks.

The autonomous ship and onshore operation personnel are mainly finished by the wireless communication serial port module. The autonomous ship's onboard wireless communication serial port module receives the command parameters of the onshore control system such as initial sailing, termination of sailing, and heading reference. The navigation information is transmitted to the shore control system in real time. For instance, the latitude, longitude and heading of the autonomous ship.

3. Design of autonomous navigation control unit

3.1 Requirements and characteristics of autonomous navigation

When unmanned ships carry out all kinds of marine tasks, they are likely to encounter severe weather. Generally, the sea breeze and bad weather accompanied by big waves will have a huge impact on the navigation of autonomous ships. It mainly has the following two points:

When the strong wind reaches a certain level, it will increase the wind pressure on the autonomous ship, which will force the autonomous ship to have a large lateral displacement and a severe lateral sway, moreover, it causes the autonomous ship to maintain the heading more tough.

When the autonomous ship comes to severe weather, the body of ship needs to continuously increase the rudder pressure to ensure heading, but this will cause the weakening of the autonomous ship's ability to maintain direction and reduce the operating performance of the autonomous ship.

Therefore, not only ensure extremely high heading accuracy and speed, but also sudden conditions should be considered. If the sea is stormy, the task will be completed smoothly to ensure that the hull is always on the right channel [7].

When the autonomous ship is in the state of autonomous navigation, concerning the set course and each channel point in advance, the information will be transmitted to the autonomous ship in real time through the course and speed control unit. Through the returned information, the shipboard system will control the given course and speed of the sub main body and adjust the attitude of the autonomous ship to ensure that the autonomous ship always sails on the precise route. During the process, information collection, detection of surrounding reefs and unidentified obstacles are completed to avoid in real time and finally the specified tasks are successfully completed.

3.2 Scheme of collaborative control unit for autonomous navigation

The block diagram of autonomous navigation collaborative control unit is shown in Figure 2.

![Figure 2. Autonomous unit control structure chart.](image-url)

The cooperative working process of autonomous navigation of unmanned vessel is as follows:

1. When the autonomous ship is in cruise state, according to the plan, the multi ship route design module inputs each channel point. When the autonomous ship is in the condition of the mission, the
shore control system will send the mission destination parameters to the unmanned ship through the wireless communication system, and the unmanned ship pair will calculate the optimal path in terms of the GPS positioning through the multi ship route design module [8]. And on the basis of channel nodes and routing key points, each starting point of destination is designed.

2. The ship position information can be collected in real-time by the shipboard information processing unit. The shipboard heading control unit compares the commanded course with the current course to obtain the course deviation. PID control and related intelligent control algorithms are used to control the propulsion system to make navigation adjustment appropriately.

3. Collect the route information in time by the information collection and processing unit and compare the speed module of the autonomous ship with the current speed, in order to obtain the main engine speed which is suitable for the current speed and then transmit this parameter to the propulsion system control unit.

4. Collecting the real-time information of ship-borne detectors, ship-borne radar, AIS and other ship-borne instrument parameters through the information acquisition unit and transmit the calculated reefs or unknown barriers to the ship-borne avoidance module. The ship speed V and the given heading y are transmitted to the corresponding heading unit and speed control unit. After unit processing, the given heading V and velocity ψ are generated, and the two parameters finally generated are transmitted to the heading control unit and velocity control unit.

3.3 Model ship and its power system
The model bed in this study is made of fiberglass with lighter weight and higher strength, with a length of 4m and a width of 0.6m. The power system of the model ship is mainly composed of propeller and rudder, which mainly impels the ship and changes the course of ships. The power supply of the propeller is mainly diesel engine as the main power source and the power transmission is mainly through the servo motor to control the throttle of the diesel engine to control the speed; the control of the rudder is also realized through the servo motor and the linkage mechanism. The main power supply of the control system is lithium battery and storage battery. The positioning, speed, heading and other information on the model ship are obtained through GPS and digital compass. Autonomous ship and shore system transmit real-time signal parameters by the radio station. The shore control system mainly obtains real-time navigation parameters of the autonomous ship model and control data of onboard instruments, it sends out command parameters according to the actual situation [9].

3.4 Model ship control system composition
The control system of the autonomous ship model is represented in the figure below. The hardware system of the autonomous ship model mainly covers the central control module, the digital transmission radio communication module, the onboard motor module, the navigation parameter collection module and so on. The functions of each module of the system as follows:
1. The self-test ship is designed by the embedded platform with the features of applying the core control module and adopt EPCs and the main board of 9000 industrial computers as the onboard control platform designed and developed by Guangzhou Zhiyuan Electronic Co., Ltd.

2. The data transmission radio communication module mainly receives the command parameters of the shore control system and returns the navigation information data collected by GPS and electronic compass. The data transmission station adopts nd250a data transmission station produced by Japan Nisin electronics. The working mode of the station is half duplex communication mode and the communication baud rate is 2400bps.

3. Shipboard motor drive module: the servo motor mainly includes the drive control system and two servo motors. The drive control system mainly deals with the parameter information [10] sent by the shipboard control system and the PWM control signal. Unless the control system, the two common service clicks are used to control the angle of rudder and throttle.

4. Navigation parameter collection module: This module is mainly used to collect the latitude and longitude information of the autonomous ship model and the heading speed and other information.

The hardware facilities of this module adopt HOLUXM.87GPS module provided by Changtian Technology Company.

3.5 Software system of model ship control platform
1. Lower computer software design.

The lower computer of the system mainly adopts a modular configuration, including information collection system, communication system, active control system, drive system and other major systems. The specific system operation process is represented in Figure 4. C + is used for program design in the environment of visual studio 2018. The program will be compiled in the environment of visual studio 2018. Microsoft active sync software will be applied in synchronize the program and transfer it to the industrial control board. Meanwhile, the corresponding hardware circuit will be adopted for debugging [11].
Figure 4. Lower computer program information flow.

The information collection system of the simulated autonomous ship will collect real-time information such as positioning information, ship course, navigation speed and other information of the autonomous ship from serial port 2 and serial port 3. After the data are processed by each module, the navigation parameters of the autonomous ship are first transmitted to the upper computer by using the communication system. Then the acquired information is taken as the input of the autonomous control system [12].

2. Upper computer software design

With regard to the functional requirements of the autonomous ship control software, the upper computer monitoring system covers the following navigation information, including GPS electronic chart, serial port informational communication, parameter generation, shore remote control operation, ship route control, navigation trajectory control, active avoidance, etc. The main functional framework of the system is shown in Figure 5.
4. Conclusion
With the continuous expansion of marine research subjects and the strengthening of the frequency of activities, maritime affairs are gradually busy, and the frequency of maritime tasks such as shipping, scientific research, search and rescue has increased year by year. At this stage, the cost of maritime tasks and maritime safety supervision in China is comparatively high. Some vessels and equipment still fail to conduct relevant maritime operations in high-risk sea conditions and dangerous environments, which has seriously hindered the normal development of China’s maritime affairs [13].

With the continuous development of this research and the maturity of relevant technologies, the collaborative control operation of autonomous ships is gradually getting attention to from the industry. Because of the advantages of intelligent, fast sailing speed and being able to use to the high-risk environment, the development of the autonomous ship has become the next stage goal to accelerate the China’s marine industry development. With the later stage of technology development, the autonomous ship can also carry intelligent robots, underwater cameras, high-power light sources and ocean microscopes in the ship. On the basis of technology development, we carry out a variety of research projects, such as water quality monitoring, image acquisition, underwater non-uniform light field, marine microbial monitoring, etc.

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