International Core Journal of Engineering Volume 7 Issue 3, 2021
ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0057

Research on Automatic Berthing Method of Intelligent Ship

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Abstract

With the development of ships to intelligence, the contradiction between the reduction of the number of crew or the lack of experience makes the berthing manipulation of ships become one of the most difficult and complex manipulation. Most accidents are related to drivers' bad driving habits. Oar, rudder and other control actuators are usually designed for steady speed, but the actual berthing of ships is affected by wind, wave, current, shallow water, shore wall, shore suction, shore push and other effects, which makes ship manipulation more complex. Therefore, the study of automatic berthing control of ships has important practical significance. Based on this, this paper studies the method of combining the mathematical model of MMG ship movement, the nonlinear model under comprehensive factors and autonomous ship path planning based on ANN controller(ANN+PD controller), hoping to use automatic berthing technology to improve the berthing efficiency of ships and reduce the incidence of ship accidents in the berthing process.

Keywords

Automatic Berthing; MMG Model; Artificial Neural Network.

1. Introduction

In dynamic crowded environment, intelligent ship due to the speed decreases, the mobility will greatly abate, combined with the complexity of the environment and the increase of mobile obstacles, independent planning will greatly increase the difficulty, so many current independent planning method is suitable for the open environment cannot be effectively applied to intelligent ship autonomous planning in a complicated environment. The attention of people is the main object or in the global optimal path planning and autonomous collision avoidance planning method, for autonomous docking study is less, relatively intelligent ship as strongly nonlinear underactuated system, the berthing manipulate is one of the most complicated one of the most difficult operation, this paper combines the research status at home and abroad, from MMG ship motion mathematical model, under the combination of nonlinear model with ANN controller, the method of combining research methods of the intelligent ship automatic berthing.

On November 28, 2018, Wartsila successfully completed the DOCK TO DOCK test of a ferry that automatically sailed and berthed without intervention. During the test, the autonomous controller controlled the speed of the ferry and preset the ship position and course on the course. The Global Navigation Satellite System (GNSS) is being used AS the primary sensor, while Wartsila's Guidance Marine Cyscan AS will be tested AS a secondary position sensor for docking and docking. Tests have shown that the automatic berthing system can achieve better efficiency, greater safety, lower fuel consumption, and reduce exhaust emissions,see Fig.1, DOCK TO DOCK test.

Dalian maritime university Marine dynamic simulation and control of key laboratory of the ministry of transportation Gu Yupeng was studied based on the berth coordinates of autonomous unmanned

ISSN: 2414-1895 DOI: 10.6919/ICJE.202103_7(3).0057

ship berthing simulation research, autonomous docking for neural network controller can perform specific port docking, to expand to other without training data berth this problem, proposes a berth vertex as the origin, shoreline for axis coordinate system (berth coordinate system). The relative position in berth coordinate system is used to train the neural network controller.

Fig. 1 DOCK TO DOCK Test

2. Multi-factor Nonlinear Model based on MMG Ship Separation Method

2.1 The Concept of Mathematical Model of MMG Ship Motion

In this paper, the separation model structure proposed by the Japanese Manipulation Movement Mathematical Model Group is adopted, which decomposes the whole force of the ship into the separate force of the ship, the oar and the rudder and their mutual interference, which is called the MMG model. Although this modeling method is more complicated, the hydrodynamic equations of each independent system in the actual modeling process have physical basis.

In the process of MMG separation modeling, the coordinate system of ship MMG separation modeling is firstly established, see Fig 2.

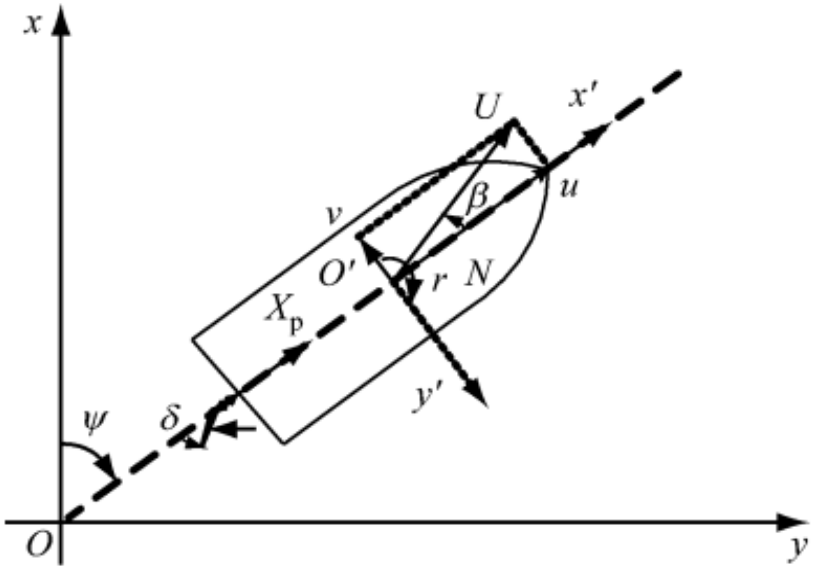

Fig. 2 Coordinate system of ship MMG separation modeling

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It can be known that the coordinate system of the MMG ship model includes the static coordinate system O-XYZ and the moving coordinate system O′-X′Y′Z′. Assuming that the ship is a rigid body and the depth and breadth of sea water are unlimited, the horizontal motion equation of the ship model can be obtained according to the MMG theory as follows:

$$\begin{aligned}(m+m_x)u-(m+m_y)vr &= F_x+F_y,\\ (m+m_y)u+(m+m_x)ur &= F_z+F_y,\\ (I_z+J_z)r &= F_z\text{。}\end{aligned} \tag{1}$$

Where, m is the mass of the ship, m_x and m_y are the mass of the accessories on the coordinate axes ox and oy when the ship moves in the water respectively; u and v are the components of ship speed in two coordinate axes respectively; r is the rotational angular velocity of the ship; $F_XF_YF_Z$ is the external force and moment received by the ship, I_Z is the moment of inertia of the ship around the oz axis, and J_Z is the moment of inertia of the accessory.

The nonlinear mathematical models of wind, wave, current, shallow water and shorewall effects are mainly considered.

2.2 The Nonlinear Model under Comprehensive Factors

The forces acting on a moving ship can be roughly divided into three categories: the first is the main force or control force, which is divided into the main control force and the auxiliary control force. The main control force refers to the propeller force and the rudder force, and the auxiliary control force includes the anchor chain force, side thrust, cable force and tug force. The second is external force, mainly including wind force, wave force and current force; The third is fluid power, mainly including inertial force, viscous force and other forces.

3. Autonomous Ship Path Planning Based on Artificial Neural Network

This module is mainly composed of ship heading control algorithm and ship speed control algorithm. In terms of heading, PD controller based on MMG model is used to establish the mathematical model of heading control. The ship heading control mainly includes course keeping and course changing. In terms of speed, a speed curve based on the offshore distance is established through simulation to determine the speed and stop and reverse the vehicle. Course keeping problem is aimed at the ship in a certain set course navigation. The course change problem is to set the course change, the ship needs to turn rudder. The course control studied in this paper is the course change control. For the autonomous berthing manipulation of intelligent ships, due to its large environmental factors, it is very important to control the berthing advance speed and maintain the safe and effective manipulation of the ships. Before approaching the berth, the speed should decrease progressively until it reaches the berth and is close to zero. If the ship sails too fast when it arrives outside the berth, it will be difficult for the main engine of the ship to control the ship position repeatedly, and the expected speed control requirements will not be met, so that the ship can not berthing smoothly. If you want to bring the ship under control, you need to take emergency measures to complete it. Control of ship advance speed refers to the deceleration process that starts from the moment when the ship is ready to berthing and stops the ship gradually until the ship arrives at the docking point outside the berth. The autonomous berthing algorithm of intelligent ships combines the above two control decision schemes, which can improve the berthing efficiency and the accuracy of docking.

Research from the training data of automatic, more accurate, with automatic berthing of the neural network training, judgment after training of artificial neural network in the wind, wave forces, the capacity of quay wall effect, the main conclusions of this study are as follows: in order to create training data in predictive intelligence ship hydrodynamic behavior at the same time, the mathematical model for the change, and the results of the modified model and experimental results are compared to port and starboard. These comparative results are quite satisfactory. Finally, a new method of generating training data with nonlinear programming (NPL) is proposed in the artificial neural network to ensure the optimal guidance of training data. Considering the repeated optimization

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technology, a virtual window is created to prepare the whole group of training data. The concept of virtual window creation enables the training data to include not only the change of rudder Angle of operational command, but also, for the first time, the change of the ship's initial heading Angle and position, which provides greater flexibility for the created network. In order to improve the robustness of the controller of the artificial neural network, the relationship is deeply learned, and the concept of double hidden layer is introduced. Using the minimum mean square error (MSE) value and the improved Lavenberg-Marquardt algorithm as the training function, two feedforward networks for steering rudder and propeller speed output are established respectively. The condition that the central controller has no interference is tested by using the trained artificial neural network to ensure the satisfaction of not only the training data used, but also the non-training data. When strong winds and big waves occur near the shore, the effectiveness of the neural network PD controller is proved again by studying different ship heading angles and positions. For further research, it is very important to conduct experiments to judge the effectiveness of the neural network PD controller in the actual situation,see Fig 4.

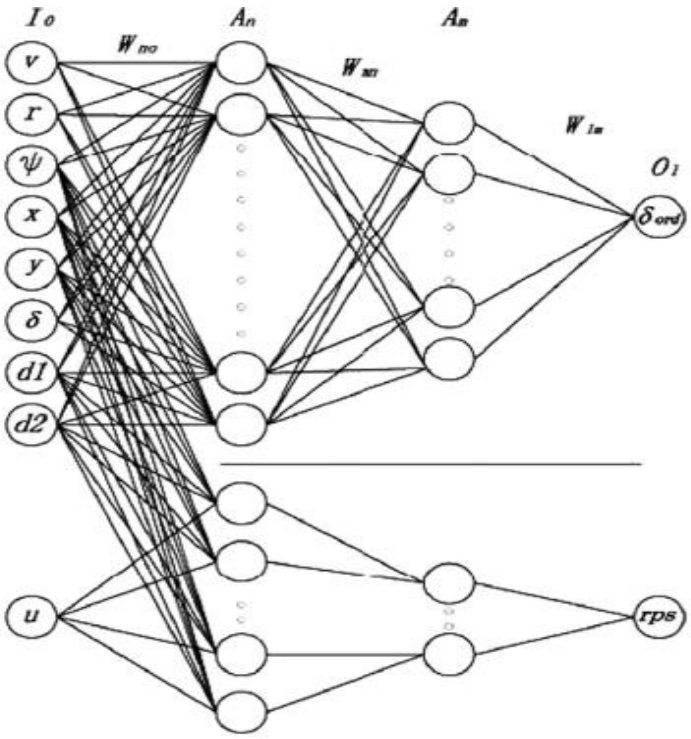

Fig. 3 Artificial neural network construction schematic diagram

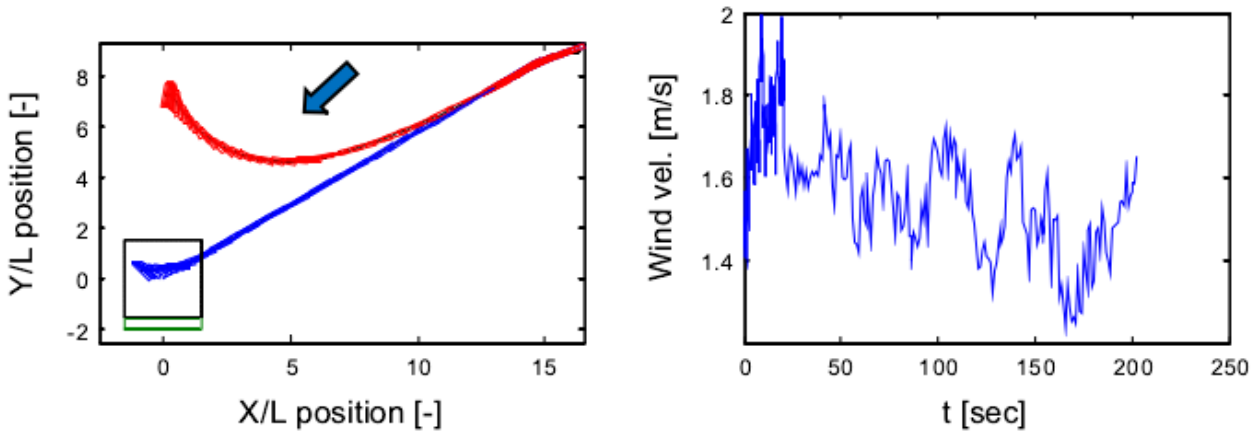

Fig. 4 Blue represents the ANN controller with disturbance, red represents steering without ANN

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The simulation function of Simulink module in Matlab is very powerful. The module can model, simulate and analyze the dynamic system, and has the characteristics of high programming efficiency, clear structure and short development cycle. Based on the established MMG ship model, this paper uses Simulink6.0 simulation environment to conduct simulation research on ship maneuverability, so as to verify whether the model can meet the accuracy requirements in the actual engineering.

4. Research significance

4.1 Improve the berthing safety of ships

The mathematical model based on the double log data and the mathematic model of MMG ship movement under shallow water and low speed conditions are established. Through the study of these two models, the algorithm of the ship's scheduled route and the motion characteristics of large ships are given, which enables the ship pilot to predict whether the ship can arrive at the designated location of berthing according to the calculated ship's scheduled route and find the problem in time, thus improving the safety of the ship's independent berthing.

4.2 Improve the independent berthing efficiency of large ships

Based on MMG model of ship model, the change course of ship automatic berthing for the choice of steering Angle and steering timing, under different course changed the curve of the steering Angle and steering, timing, and studies the stroke, ship and stop was obtained under the condition of different initial speed in the speed of the stopping condition - stroke curve. So that the ship in the actual berthing, to change the course and control the residual speed to provide the basis. It also provides the foundation for intelligent navigation.

4.3 To provide feasible suggestions for berthing without external force assistance

The research on the independent berthing of the ship has certain guidance for the same ship type without external force. In this paper, the method of autonomous berthing is of certain reference value for the berthing of ships without external force assistance.

4.4 It is of great significance to energy saving and emission reduction

Automatic docking and berthing of unmanned ships is of great environmental and economic significance because of its short operation time and high docking efficiency, which can save fuel consumption and reduce pollution emissions. Research on automatic berthing can reduce the number of tugs, reduce useless power consumption, further save energy and protect the environment.

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