Design of simulation system for trajectory of ship

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Abstract. In order to master the ship's navigation dynamics in advance and take effective actions to avoid ship collision with bridge, a simulation system of ship's navigation trajectory is designed. The hardware part designs the ship operation controller, defines the controller pin function and connects the peripheral circuit. In the software part, Kalman filter algorithm is used to eliminate the interference in the attenuation process, calculate the trajectory of the ship, and complete the design of the system. Through setting up the experimental environment, controlling the ship navigation environment parameters, using the measuring instrument to measure the deviation value under the experimental environment as the standard value, the simulation experiment is carried out by using the system described in this paper. The results show that the minimum deviation value error of the simulation system designed in this paper can reach 0.1M, and has high simulation accuracy, which can provide support for marine safety prevention work By reference.

Keywords: Ship trajectory; Safety hazard; Kalman filter algorithm; Deviation value.

1. Introduction
With the rapid development of China's transportation industry, The shipping industry is booming. But at the same time, ship bridge collision accidents also happen frequently [1], therefore, it is particularly important to effectively prevent ship bridge collision accidents. The study of ship trajectory plays an important role in tracking, early warning and emergency management. Xu Tingting et al. [2] used BP neural network for prediction, and Xu Tieet al. [3] used Kalman filtering algorithm for smooth processing and prediction of ship trajectory. Due to their theoretical limitations, the above traditional methods cannot be applied in mobile communication environment with high requirements of real-time performance and anti-interference. In this paper, the ship trajectory controller is designed to simulate the ship trajectory, and the kalman filtering algorithm is adopted to eliminate the interference factors in the simulation process, so as to realize the high-precision calculation of the ship trajectory. The experimental results show that the method described in this paper has high precision, can provide reliable early warning for safety management personnel, and can guarantee the prevention of maritime safety.
2. Hardware design of ship navigation trajectory simulation system

2.1. Design the navigation controller of the ship

Controller to choose models for the MSP430 MCU as the core control chip, chip to connect two servo drives, servo drive control two parallel, respectively in the two servo drive series, an encoder to control two encoders, respectively in parallel a servo motor, servo motor respectively connected a reducer, control the speed of the ship sailing [4]. A control bus is used to connect a high pressure relief valve, which is equipped with a driver and asynchronous motor to provide power for the high pressure relief valve. A ejection spring is placed outside the high-pressure reducing valve of the controller. Spring parameters with a compression volume of 400mm and a free growth of 1200mm are selected. The mass of the control spring is not more than 1.5kg. A screw is set between the spring and the pressure-reducing valve to control the air pressure in the pressure-reducing valve to push the screw to cause the spring movement, and finally realize the ship navigation process.

A fixture evenly distributed along four circumference directions is selected as the main launching mechanism. The fixture in the launching mechanism is fixed with compression spring, and a trigger is connected with the thickened sleeve outside to realize the navigation control of the ship. After the controller hardware is connected, the peripheral circuit of the hardware part is designed to complete the hardware design of the simulation system.

2.2. Peripheral circuit

Before designing the hardware peripheral circuit, define the pin function of MSP430 MCU. The pin function is shown in Table 1:

| Pin ordinal | name            | function                |
|-------------|-----------------|-------------------------|
| 1           | RS422 TX+       | multi-function output   |
| 2           | VIN             | power input             |
| 3           | SYNC IN A       | multi-function output   |
| 4           | RS-232          | synchronous output signal|
| 5           | GND             | to end                  |

According to the pin function shown in Table 1, control pin 2 as the power supply pin, connect the positive and negative ends of 12V DC power supply, and control the ground end of RS232 interface to connect pin 4, so as to realize real-time data reception. After the function definition of the pin of the single-chip microcomputer is completed, an amplifier circuit is designed between the single-chip microcomputer and the controller hardware, as shown in Figure 1: The amplifier circuit shown in Figure 1 is used to control the on and off of the servo motor, to ensure that the controller disconnects the abnormal closed contact, to ensure the normal braking of the controller, and to reduce the pressure value of the ship. After the hardware design is completed, the ship's trajectory tracking mathematical model is established, the ship's trajectory is calculated, and the design of the software part of the simulation system is completed.
3. Design the software of ship navigation trajectory simulation system

3.1. Ship tracking

Considering the actual situation of ship movement, the tracking process is regarded as a process subject to first-order zero-mean acceleration and uniform velocity. During the acceleration process, the ship has partial attenuation, which can be expressed as:

\[ R(t) = E \{ a(t + \gamma) a(t) \} \]  

(1)

Where, \( a(t) \) denotes the acceleration of the ship, \( \gamma \) denotes the hardware maneuvering frequency, and \( E \) denotes the attenuation coefficient.

Kalman filtering algorithm is used to process the above tracking attenuation process to eliminate the interference of attenuation process on the tracking process. The elimination process can be expressed as:

\[ a'(t) = R(l) + \alpha a(t) \]  

(2)

Where, \( a(t)' \) represents the acceleration of the processed ship, \( \alpha \) and is the Kalman filtering coefficient. After eliminating the interference caused by attenuation process to the ship, the ship's navigation trajectory is calculated and the design of simulation system software is completed.

3.2. Trajectory calculation

The above tracking process is divided into three trajectory calculation stages, namely, straight into the turn stage, turn stage and turn straight after the turn stage. When the ship initially sets out, the ship maintains a constant angular velocity change. Let the time required for the ship's acceleration to maintain a constant value be \( t \), and the trajectory of the ship can be expressed as:

\[
\begin{align*}
   w(t) &= (0, \varepsilon, 0) \\
   a'(t) &= (\varepsilon, \kappa, 0)
\end{align*}
\]  

(3)

Where, \( \varepsilon \) denotes the angular velocity of the ship's motion, \( \kappa \) and denotes the Angle of change. When the ship is transitioning from straight to turning, it is assumed that the ship's trajectory is an arc. In this case, the ship's trajectory can be calculated as follows:

\[
\begin{align*}
   \tan \chi &= v r^2 \\
   w(t)' &= (\chi, \varepsilon, 0) \\
   a'(t)' &= (\varepsilon, \chi, 0)
\end{align*}
\]  

(4)

Where, \( v \) represents the ship's turning speed, \( r \) represents the radius, \( \chi \) represents the change of the Angle, \( w(t)' \) and \( a'(t)' \) represents the ship's angular velocity and acceleration respectively.
When the ship turns at the end, the trajectory of the ship is equal to the angular velocity change vector of the initial turn, but the direction is opposite, so the trajectory of the ship at this stage can be expressed as:

\[
\begin{align*}
\omega(t)^* &= (0, -\varepsilon, 0) \\
a'(t)^* &= (-\varepsilon, -\kappa, 0)
\end{align*}
\]  

(5)

In the above formula, the meanings of other parameters remain unchanged, \( \omega(t)^* \) and \( a'(t)^* \) respectively represent the trajectory of the ship when it turns to straight state at the end of turning.

Based on the calculation of the trajectory of the above three ships, the design of the simulation system software for the ship's trajectory is completed.

4. Simulation Experiment

4.1. Experiment related Settings

When the ship is under the influence of sea wind and waves in actual navigation, the ship will have certain angle changes, and the ship's overall movement trajectory will also be affected. Therefore, when verifying the performance of the simulation system, prepare the air control cabinet, wind direction finder and rangefinder, and set the parameters of the sailing ship, as shown in the table below:

| Ordinal | name                     | parameter |
|---------|--------------------------|-----------|
| 1       | Length of vessel/m       | 25        |
| 2       | width/m                  | 5.5       |
| 3       | Design draft/m           | 3.2       |
| 4       | Ship anti-rolling device | /         |

Tab. 2 Salvage vessel parameters

Under the parameters shown in table 2, places a high pressure gas cylinder on the outside of the experimental environment, simulation of wind environment, control of high pressure gas cylinder pressure value, measuring wind speed change under the pressure value, the ship set sail from the end of the recent route as the ship of the standard trajectory, using the rangefinder measurement ship the distance to the finish line, as the offset, the offset of the ship under different pressure, as shown in table 3: Taking the offset in Table 3 as the standard value, the trajectory simulation simulation system described in literature [2] and [3] and the navigation trajectory simulation system designed in this paper were respectively used to simulate the ship's navigation process, and the errors of the three simulation systems on the ship's navigation trajectory simulation offset were compared.

| Pressure value/MPa | wind speed/m/s | Ship offset /m |
|-------------------|----------------|---------------|
| 5.0               | 6.0            | 2.5           |
| 5.2               | 6.0            | 2.7           |
| 5.4               | 6.5            | 2.8           |
| 5.6               | 6.5            | 3.2           |
| 5.8               | 7.0            | 3.4           |
| 6.0               | 7.0            | 3.8           |
| 6.2               | 7.5            | 4.1           |

Tab 3 Standard deviation of skimming cable under different wind pressures

4.2. Experimental results and analysis

Three kinds of simulation based on the above experimental environment, control system simulation of ship sailing in the process of external pressure value and the change of wind speed value, as shown in table 3, three kinds of statistical computation simulation system of ship arrived at the end of the deviation,
the results as shown in table 4: the table 4 shows that there were three analog simulation system partially offset error. Ships under different gas pressure, average standard deviation is 3.2 m, the method of literature [2] the deviating from the average of 6.8 m, is much greater than the standard deviation value, the method of literature [3], the experimental results of the average deviation value of 4.9 m, deviation value compared with the present method [2] the results of small, simulate the deviation value of error is small, and the design of the simulation system to get the average deviation of a value of 3.4 m, and standard deviation values were similar, simulate the deviation of minimum error, suitable for use in the actual simulation.

| Pressure value/MPa | The offset/ m | The literature[2]methods | The literature[3]methods | In this paper, methods |
|-------------------|--------------|--------------------------|--------------------------|------------------------|
| 5.0               | 6.6          | 4.6                      | 3.2                      | 2.8                    |
| 5.2               | 7.4          | 5.1                      | 3.0                      | 4.6                    |
| 5.4               | 5.0          | 4.3                      | 3.1                      | 3.0                    |
| 5.6               | 6.2          | 5.6                      | 3.3                      | 3.0                    |
| 5.8               | 8.0          | 4.5                      | 3.5                      | 4.0                    |
| 6.0               | 7.6          | 5.4                      | 4.0                      | 4.3                    |
| 6.2               | 7.1          | 4.9                      | 4.3                      |                        |

5. Conclusion
The navigation path simulation equipment is an indispensable device in the process of ship construction. The design of the simulation system for the navigation path of a ship can obtain the ship's motion coefficient, reasonably arrange the location of the ship's starting transmitter, and improve the deficiency of the traditional simulation system with a large offset error. However, the simulation system has a large number of calculations and is difficult to implement, so it still needs continuous research and improvement.

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