Research on the Improvement of Optimal Location Algorithms for Ship Commu nication and Navigation Equipment

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Abstract: With the continuous increase in the number and quality of marine ship operations, new requirements have been put forward for ship communication and navigation systems. However, the current communication delay in China's ship navigation will affect the ship's normal execution tasks. Based on this, this paper further studies the improvement of the optimal positioning algorithm in the ship communication navigation equipment, and provides a theoretical basis for improving the optimal positioning of the ship communication navigation equipment.

1. Research background

1.1 Literature review

At present, the navigation devices in ship operation mainly include global satellite positioning system, strap down inertial navigation system, as well as astronomical navigation system and geotext navigation system. With the continuous development of military and civilian industries, single navigation systems have been unable to meet the navigation needs of ships (Liu, et al., 2014). Therefore, it is necessary to use the new navigation design to accurately and quickly navigate the ship. At this time, the high-performance integrated navigation system has gradually entered the field of scholars' research. Among them, integrated navigation can provide more accurate navigation for ships with its superior performance (Wu, et al., 2011). Moreover, integrated navigation mainly uses single navigation devices to obtain measurement data, providing ships with more accurate position and heading information (Wang, 2017). In addition, some scholars have pointed out that the pilot boat plays an important role in the navigation process of the ship, not only can obtain the information collected by its own navigation equipment, but also can receive the information such as the distance of the ship through the automatic identification system of the ship, and other equipment. It can send information such as its own positioning information, heading, etc. to other vessels in the same field (Yu, 2013). Therefore, relevant scholars pointed out that in the course of navigation, the ship needs to use its own communication and navigation system, and further need to calculate its own sea area according to its location, heading, heading angle, and speed (Huang, et al., 2017). At present, experiments in this field are mainly focused on spacecraft docking, multi-mobile robots, and so on. In addition, in order to further study the frequency asynchrony of sampling in different navigation systems, relevant scholars use the mis-sequence delay fusion filtering to study the problem of delayed navigation of navigation information on navigation and navigation of ships (Zheng, 2017). However, at present, there are few studies on the specific navigation process of ships. Therefore, based on the above literature, this paper further studies the optimal positioning algorithm of ship communication navigation equipment, in order to make up for the relevant theoretical basis for subsequent research.

1.2 Purpose of research

As a major tool for maintaining national military security and territory, ships have developed rapidly in China. In recent years, compared with other maritime navigation equipment, ships have mainly used in the fields of investigation, anti-terrorism, patrol enforcement, etc., and have achieved great success. At the same time, as the standards for ship missions continue to increase,

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current navigation systems often fail to meet the navigation requirements of ships and affect the ship's ability to perform tasks, which will affect the development of related businesses. However, improving the navigation performance of the ship is costly and has high difficulty. Therefore, considering the cost factor, the form of coordinated navigation of various navigation systems has emerged, and the tasks of multiple navigation systems working together can achieve accurate positioning of the ship and improve work efficiency. Therefore, it is of great practical significance to study the optimal positioning algorithm of traditional communication navigation equipment.

2. Research on cooperative navigation location algorithm

With the continuous improvement of military demand, more and more marine offshore operations, and ship maritime missions are becoming more and more difficult. In order to solve this problem, more and more scholars have begun to study the improvement of ship communication navigation equipment positioning algorithm (Tang, et al., 2017). In this process, communication and navigation technology has become a key technology. Therefore, improving the accuracy of the ship navigation system has become the main research field of ship communication equipment positioning, but there are problems of high cost. In this process, in the face of this problem, collaborative navigation and positioning technology has become the main research direction, which can effectively reduce the cost of ship communication and navigation equipment, and navigation positioning is also more accurate. Co-navigation not only meets the positioning requirements of the ship's communication-to-line system (Li and Wu, 2018), but also saves a lot of costs and is the most optimized navigation optimization solution. At present, the main ship navigation equipment mainly includes the inertial navigation system, the GPS underwater acoustic Modem, and the Doppler velocimeter. Among them, the combination of Doppler and inertial navigation system can provide accurate positioning information for the ship, as well as corresponding speed and position information (Zhang, et al., 2017). Among them, GPS is used to correct the time, and the underwater acoustic Modem is mainly used to complete the communication between the ship and the ship. On this basis, the ship navigation navigation positioning algorithm is studied (Ge and Jiang,2017). Firstly, the principle of navigation and positioning of ship communication is studied, and the positioning model of navigation system is further established. After conducting theoretical and model research, the ship communication navigation equipment positioning algorithm is further studied and simulated.

2.1 Ship cooperative navigation and positioning technology

In the navigation and positioning of the ship, it is preferred that the pilot boat emits an acoustic pulse signal to the following boat through the principle that the water acoustic modem follows a fixed time interval. In the acoustic pulse signal, the time stamp of the transmission time of this signal is mainly included. When the following boat receives this signal, it can estimate the time consumption of the sound pulse signal transmission according to the time stamp of the signal, and further calculate the distance between different pilot boats. At this time, the pilot boat of the ship receiving the acoustic pulse signal sends a signal to the ship to the acoustic pulse signal. The signal mainly includes its own position information and time stamp. Then, the other pilot boats follow the above principle to send a sound pulse signal containing time stamps to other following boats for a fixed period of time. After the following boat receives the acoustic pulse signal sent by the pilot boat, the distance between the two ships and the position information between the ships are estimated. Further, according to the information of the received acoustic pulse signal, the position of the sound pulse is appropriately corrected to ensure normal navigation. According to the above navigation principle, the key technology of ship navigation lies in the estimation of the distance between the pilot boat and the following boat, and the signal transmission between the two, which puts a higher level of requirements on the performance of the underwater acoustic Modem. Therefore, many scholars have conducted extensive research on the underwater acoustic Modem and found that the US WHIO underwater acoustic Modem has better performance, can be applied in the AUV system, and can meet the communication requirements of the ship system.

2.2 Ship cooperative navigation positioning model

In order to ensure the positioning of the ship's communication and navigation equipment is more precise, it is necessary to establish a model for further research. First, at the moment, the position of the pilot boat and the following boat is indicated by (x_k^M, y_k^M, z_k^M) and (x_k^S, y_k^S, z_k^S). At the same time, the ship will be affected by the weather when sailing on the sea. For the sake of research, the impact of the weather is not considered here. In addition, the ship will also be affected by the sky when sailing. For the same reason, in order to facilitate the research, the study only considers the specific operation of the ship on the two-dimensional plane, so the ship's running track is set to:

$$\begin{cases} x_{k+1} = x_k + \delta t.V_k \cos\phi_k \\ y_{k+1} = y_k + \delta t.V_k \sin\phi_k \\ \phi_{k+1} = \phi_k + \delta t.w_k \end{cases}$$

Among them, V_k and ϕ_k represent the running speed and sailing angle of the ship at time t_k, w_k represents the heading angular acceleration, and δt represents the research period.

At the same time, taking into account the influence of noise on the underwater acoustic Modem, the measurement model is further optimized, the specific form is as follows: $\begin{cases} V_{mk} = V_k + w_{vk} \\ \phi_{mk} = \phi_k + w_{\phi k} \end{cases}$

Among them, V_{mk} and ϕ_{mk} represent the navigation speed and the angular acceleration estimation of the ship at time t_k, w_{vk} and $w_{\phi k}$ represent the zero-mean Gaussian white noise, which are independent of each other and independent of each other. The w_{vk} and $w_{\phi k}$ variances can be represented by σ_{vk}^2 and $\sigma_{\phi k}^2$. Based on the above theory, the equation for setting the ship's navigational motion can be expressed as:

$$X_{k+1} = f(X_k, u_k, w_k) = X_k + \Gamma(u_k + w_k)$$

2.3 Ship cooperative navigation positioning algorithm

According to the navigation and positioning model, the positioning systems in current ship communication navigation are mostly nonlinear models. Therefore, this paper uses EKF for algorithm design. According to the above analysis, the current ship navigation system prediction formula is:

$$\widehat{X}^S_{k+!,k} = f(\widehat{X}^S_k, u_k, o)$$

The predicted covariance is: $P_{k+1,k} = F_k P_k F_k^T + G_k Q_k G_k^T$

among them, $F_k = I + \delta t * \frac{\partial f}{\partial X_k^S} = I + \delta t * \begin{bmatrix} 1 & 0 & -\delta t.V_k \sin\phi_k \\ 0 & 1 & \delta t.V_k \cos\phi_k \\ 0 & 0 & 1 \end{bmatrix}$. After that, further analyze the measured value of $k+1$ at this moment, and make a prediction, which can be expressed by the following formula:

$$\widehat{Z}_{k+1,k} = h(\widehat{X^s_{k+1,k}}, X^{M1}_{k+1,}, X^{M2}_{k+1,},)$$

3. Study simulation

in order to further study the optimal positioning algorithm of ship communication navigation equipment, it is necessary to carry out simulation operations on the above research. in the simulation operation, it is assumed that the ship is not affected by the meteorological phenomena such as ocean and atmospheric currents on the navigation of the ship during the operation.

at the same time, in order to ensure the accuracy of the simulation experiment, the time delay caused by the underwater sound during signal transmission and the time difference due to the different clocks are not considered. during the simulation experiment, the heading information of the ship is mainly collected by the microcomputer mechanical gyroscope and used in the experiment. the speed of the ship is mainly provided by the log on the ship. in addition, the measurement noise following the speed and heading of the boat is represented by gaussian white noise with zero mean, and the variances of the two are represented by $\sigma_V^2 = (0.2^k)^2$ and $\sigma_V^2 = (0.5kn)^2$, respectively, and the variances of the two are independent and not related. in addition, the hydroacoustic modem ranging period is 1 s, and the ranging noise can be represented by $\sigma_R^2 = (5m)^2$.

experiment 1: the pilot boat of the ship moves linearly at a fixed speed toward the same route. among them, the coordinates of a in the pilot boat are (0,0), the unit of displacement speed measurement is meters, the navigation angle is set to 5°, and the navigation degree is set to 10 knots. the starting point coordinates of the pilot boat b are (25, 5). like the displacement unit of the pilot boat a, it is expressed in meters, but the sailing angle is 60°, and the speed is also reduced by 1 knot, which is 9 knots. in addition, the starting point coordinates of the following boat are located between the pilot boat a and the pilot boat b. the unit of the sailing speed can also be expressed in meters. the sailing angle is 42°, and the speed is one less than the pilot boat b, which is 8 knots. the specific running time is it is 60 minutes.

through experiments, it is found that the influence of the two pilot boats on the positioning of the following boats should be distinguished during the actual operation of the ship. in the first half of the pilot boat operation, since the starting angles of the pilot boat and the following boat are relatively fixed, the two sailing boats exhibit similar navigational directions in adjacent ranging, resulting in weaker experimental results. therefore, in the latter half of the ship's operation, the errors in co-localized x-axis and y-axis positions become more and more obvious, and as time increases, the error value increases. at the same time, the initial speed of the pilot boat and the following boat in the second half is different, and the speed of the pilot boat is also increased, making the observation of the experiment more obvious.

experiment 2: in order to verify that the ship under multi-pilot conditions, verify that the pilot boat maneuvering mode will affect the positioning accuracy of the following boat, experiment 2 is carried out. among them, the positioning of the pilot boat a is the same as the experiment one, and the origin is (0,0), and the heading angle is 5°. in the second experiment, in order to ensure the accuracy of the experimental results, the angular velocity was further budgeted, and the initial angular velocity of the pilot boat a was 0.08. the coordinates of the pilot boat b are (25, 5) and the sailing heading angle is 60°. in order to ensure the accuracy of the experiment, the pilot boat b will turn once in 30 minutes. at this time, the sailing heading angle is 0°, and the starting point coordinates of the sailing boat are the same as the experiment one, which is (10, 2.5). in order to play the real role of the following boat, the initial heading angle was set to 30° and the angular velocity was -0.05 in experiment 2. the speeds of the above three types of boats are 10 knots, 9 knots and 8 knots respectively.

it can be seen from experiment 2 that when the following boat uses the communication navigation and positioning to estimate the positioning, the estimated navigation trajectory is significantly different from the actual navigation trajectory. moreover, errors in positioning tend to accumulate over time. at the same time, when using single navigation for navigation and positioning, the navigation trajectory is calculated to be similar to the navigation trajectory in reality, and the positioning error increases with time, showing a trend of reduction. when the pilot boat and the following boat sail with the parabolic downward opening, since the movement modes of the pilot boat are quite different, it can be considered that the pilot boat and the following heading direction are different in the adjacent ranging. therefore, the results of experiment 2 can be considered to have strong observability, and the location information is more accurate by means of co-location.

4. Conclusion

In this paper, the communication system positioning algorithm for ship navigation is firstly analyzed and analyzed. The principle of ship communication and navigation equipment positioning is analyzed, and the manager model is deeply analyzed. Based on this, EKF navigation is used to carry out algorithm research, and then simulation research is carried out. The results show that different Navigation devices have a significant impact on positioning.

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References

[1] Liu M., Feng X.l., Shi J.j., et al. (2014). Optimal positioning algorithm for relative navigation of ships, China Navigation, 37(4), 6-10.

[2] Wu Y. Q., Qi H.L. (2011). Research on Navigation and Positioning Algorithm Based on LEA-5HGPS Module, Journal of Automation & Instrumentation, 26(1), 1-5.

[3] Wang H. (2017). Research on RFID Positioning Algorithm for Ships in Marine Complex Multipath Environment, Ship Science and Technology, 39(16), 145-147.

[4] Yu J.W. (2013). Research on Surface Localization Algorithm of Moving Guides in Wireless Sensor Networks, Ship Electronic Engineering, 33(8), 61-63.

[5] Huang Y.B., Ma S.G., Wu Q. (2017). Current Status and Development Trend of Communication Navigation Technology for Fishery Vessels, China Water Transport (2nd Half), 17(3), 83-85.

[6] Zheng G.C. (2017). Research on Ship Navigation Path Planning Based on Genetic Algorithm, Ship Science and Technology, 39(10), 76-78.

[7] Tang C.L., Xiao G.Q., Li M. (2017). Research on Wireless Communication Network Location and Routing Strategy for Ship Remote Control System, Ship Science and Technology, 39(20), 114-116.

[8] Li J.F., Wu X.Y. (2018). Anomaly Data Location Technology for Ship Communication Network [J]. Ship Science and Technology, 40(6), 148-150.

[9] Zhang J.X., Du Z.L., Ding .G. (2017). Research on Ship Personnel Security Management System Based on Beidou Rescue and ISPS Rules, Ship Engineering, 40(2), 59-64+74.

[10] Ge L.H., Jiang T.T. (2017). Research and Implementation of Automatic Tracking Mode and Mathematical Method Acquisition for Ship Weitong, Computer Knowledge and Technology, 13(22), 224-226.