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DESIGN AND IMPLEMENTATION OF LARGE VESSEL NAVIGATION SYSTEM BASED ON BEIDOU CORS

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ABSTRACT

The ship's pilot can obtain the ship auxiliary information through the navigation system, when berthing system can display the parameters such as traverse speed and distance of the ship. But most of the system data show that there are insufficient precision. Taking the CORS system to obtain the location information, data Calculation of Berthing System based on Polar Coordinate Algorithm, this paper puts forward a solution to the "dead point" of the berthing and aiding system, which has a certain reference value for the design of the ship berthing assistance system.

Keywords: Berthing; Ship-based; polar Coordinates; CORS

INTRODUCTION

When the concept of smart ship is put forward, a lot of new equipment has been applied in vessels, especially in modern large vessels. But in some old vessel, the equipment was antiquated, the obtained information from old equipment cannot satisfy informatization. In this view point, ship berthing aids system come into our sight, which can support the pilot.

From the perspective of the location of the berthing aids system, it can be divided into two categories. One is the shore-based navigation device, such as the auxiliary berthing device of using infrared, sonar and radar[1],or using laser technology[2]; The other is ship-based navigation instrument, such as the auxiliary berthing device of using differential positioning[3-5]. Shore-based berthing auxiliary device is short range, it is hard to meet the information support in the process of the whole large ship berthing. From the perspective of ship-basedberthing system. The algorithm design based on the Beidou CORS system finally promote the construction ofship-based berthing information system.

SHIP-BASED NAVIGATION SYSTEM ALGORITHM

Ship-based navigation device including mainframe, slave and the display terminal. The mainframe and slave can obtain real-time position of vessel with high accuracy from Beidou CORS system. The display terminal real-time calculates ship heading, trend and the relative distance to dock, then combines with ECDIS information to auxiliary ship navigation and berthing. The design principle is shown in Figure 1, with the key lies in the way of solving the vessel's rectangular vertices.

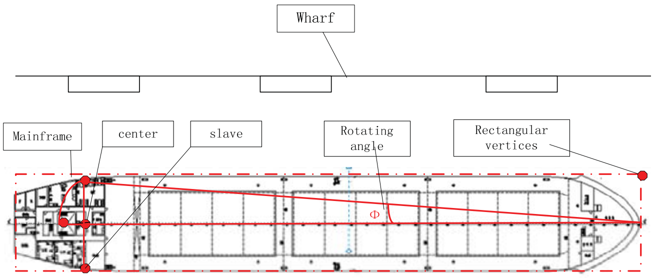

Fig. 1. Ship-Based Navigation system

CENTER ROTATING COORDINATE ALGORITHM

Three steps are required to complete this algorithm. Specially, the first step is using two sensors location information to determine the center, then combine with length and the width of the ship to solve vertices of the ship type rectangular. Using two consecutive vertexes coordinates and combine with the berth line linear equations to gain transverse speed of that vertex coordinates[6]. The vertex is thought to be the bow or stern. The detailed center position calculation is as follows, and the point P is on behalf of the sensor positions that stand on both sides of the bridge.

$$(O_X, O_Y) = \left(\frac{1}{2}(P_{1x} + P_{2x}), \frac{1}{2}(P_{1y} + P_{2y})\right)$$

The second step is to determine the rotation angle of the bow between default position (true north) and the current location of the bow. According to the above data, we can get any point on the rectangle. The calculations are based on the following equation:

$$(S_X, S_Y) = \left[L * \cos(\theta + \beta) + O_x, L * \cos(\theta + \beta) + O_y\right]$$

Where, *S* represents the new rectangular vertices (bow), L is the distance from rectangular vertices to the center O. The symbol β means the angle between vectors $\overrightarrow{OA}$ and $\overrightarrow{P_1P_2}$, and θ is the heading of the ship.

The third step is using two continuous S points, and the line of wharf to obtain the distance from S to the wharf, the rate of speed, steering and other information.

It is noteworthy that the location information send out by the sensing device sends is not very accurate, moreover, the result displayed by the system is after three overlay calculation, which also experienced three superposition error. Polar coordinates method can solute t is problem properly.

POLAR COORDINATES ALGORITHM

Using ship rectangle to establish polar coordinates, as shown in Figure 2:

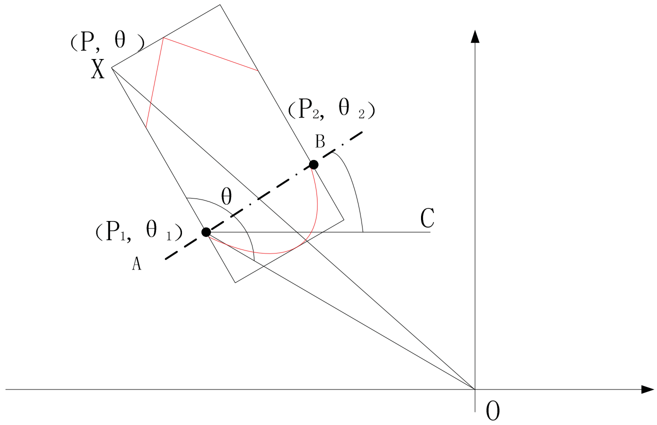

Fig. 2. Ship-Based Polar Coordinates

As shown in Figure 2, point A and point B are the measurement points. For calculation purposes, the rectangle can be regarded as a rectangular trap the ship, in order to eventually get to the animation when berthing, so just need get four rectangular coordinates of the vertices. And an example of X (P, θ) of the polar equation is as follows:

$$p^2 = L^2 + p_1^{\,2} - 2Lp_1 \cos(\angle XAO)$$

P is the length from point X to point O, L is a known quantity from point A to point X.The p1 is a known amount from point A to point O. Therefore, in order to solve point P, we need to solve $\angle XAO$ firstly.

When the angle between vector $\overrightarrow{AB}$ and X-axis positive is zero, the coordinates of point X is (X1, Y1+ $\overline{AX}$), where X is the abscissa point that accessed from direct. $\overline{AX}$ is a known quantity from bow to bridge.

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is between 0-90 degrees (counterclockwise), θ_{AB} represent the tilt angel of the straight line that passing point A and point B.

$$\begin{cases} \angle XAO = 90^0 + (180^0 - \theta_1) + \theta_{AB} \\ \theta_{AB} = \arctan(\dfrac{y_2 - y_1}{x_2 - x_1}) \end{cases}$$

Where (x1, y1) and (x2, y2) is converted from points A and B in polar coordinates.

When the angel between vector and X-axis positive is 90 degree, the point X is (x1, $\overline{AX}$ +y1).

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is between 90-180 degrees:

$$\begin{cases} \angle XAO = \theta_1 - (90^0 - \theta_{AB}) \\ \theta_{AB} = \arctan(\dfrac{y_2 - y_1}{x_2 - x_1}) \end{cases}$$

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is 180 degrees, the point X is (X1,Y1-L).

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is between 180-270 degrees, $\angle XAO = \theta_1 - 90^0 - \theta_{AB}$.

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is 270 degrees, the point X is (X1-L ,Y1).

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is between 270-360 degrees, $\angle XAO = \theta_1 + \theta_{AB} - 90^0$.

When the angel between vector $\overrightarrow{AB}$ and X-axis positive is 360 degrees, the point X is(X1,Y1-L).

The above situations are the angles between 0-180 degrees. However, if θ_1 involves angels between 0-90 degree, we need to determine first then summed up as one of the above situations. The other three rectangular similarly available, straight line that passing the quay can be obtained by measuring.

According to the above analysis, we can get the dynamic data of the ship when berthing.

PERFORMANCE MEASUREMENT

The Experiment is a cargo ship berthing Zhangzhou port. Length and width of the ship is 225 and 32 meters, respectively, with the tonnage as 64,000 tons. Test time interval is 1 hour and 10 minutes. The data recording interval is about 20 minutes before the completion of the ship berthing operation. Owing to output mode of the position sensor device using UDP broadcasts, we prepared two sets of equipment and two sets of display terminals that embedded in the center of the rotating coordinate algorithm and polar algorithm, respectively.

(1) Center rotating coordinate algorithm experiment

Test data are as follows:

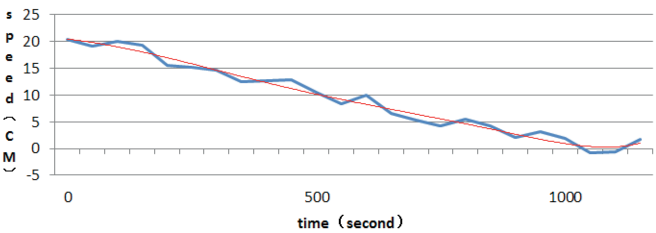

Fig. 3.Data of center rotating coordinate algorithm experiment

(2) Polar coordinate experiment

Test data are as follows:

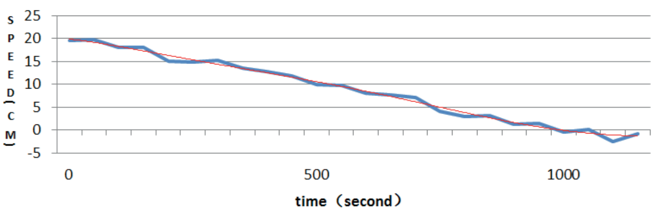

Fig. 4.Data of polar coordinate experiment

The blue line is the recorded testing data, and the red line is 6 degree polynomial fitting curve. By observing the degree of fit between the red line and the blue line, we can determine the extent of the available data.

We take time nodes 500 as segmentation to observe Figure 3, the tested curve and the fitting curve alignment is higher before 500, and emerged many inosculation with weak point after500.The reason for this is explained as follows: with the passage of time, the ship dock distance become more and more close, subsequently, the seep of ship is slower. In the case when transverse sheep movement becomes slower, the positioning precision of DPGS tends to present alargerleap, leading to a highly inconsistent results between the measured curve and the fitting curve. We take time nodes 500 as segmentation to observe Figure 4,which seems similar to Figure 3. However, compared with these two, it is clearly seen that the data fitting degree is higher than that in Figure 4. Meanwhile, Figure 3 has a higher activity of data. In the center rotating coordinate algorithm, rectangular vertex coordinates are made on the basis of the original coordinate in two. Because the error of original coordinate position by superposition of the secondary, soothe fitting curve and original curve is not in consistent with each other. On the contrary, polar coordinate method can be directly obtained through the final numerical, with a single superposition of error, thus the fitting curve and original curve matches perfectly, which is much better.

Although Figure 4 fits better, in some conditions, the original curve and the curve fitting still have larger difference, the reasons are the presence of “Bad”. Here, “Bad” is due to external factors, such as the impact of positioning accuracy, the ionosphere, the distance between RTK terminal and the RTK base station, shelter materials and other factors so that at some extent while positioning error is large, “Bad” error position occurs.

BAD SOLUTIONS

Occasional “bad” does not mean the point is unavailable, however, we need to pay attention to continuous “Bad”. There are two decision for continuous “Bad”, the first situation is when the current ship’s position indeed changed significantly; the second one is the continuous positioning error caused by external factors. To deal with this situation ,the system will retain “Bad” temporary. Only the continuous dates have more than 10 times of “bad”, the system is updated to display the real “bad”, otherwise the staging point will be completely filtered out. In this way, we can ensure that the displayed speed in the system is more stable, and also ensure the “security”.

BEIDOU CORS SYSTEM USE IN NAVIGATION SYSTEM

Improving data “security” from the source to solve positioning error is feasible, therefore, it is necessary to adopt a positioning system with high precision. At present, the most main GNSS high precision real-time dynamic positioning technology, CORS technology has many advantages. CORS is widely applied in navigation, berthing system. CORS technology navigation docking device has the following advantages: high positioning accuracy, safe and reliable data, no error accumulation, high work efficiency, CORS automation homework, reduced job requirements, simple operation, strong ability in data processing [7,8].

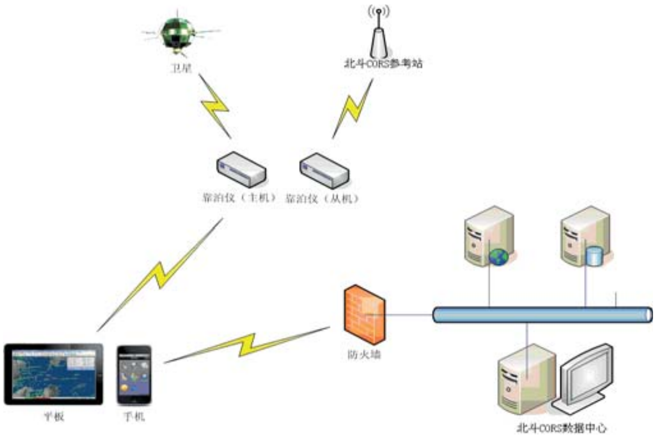

Fig. 5. Beidou CORS ship navigation system framework

CONCLUSIONS

We obtain real-time cm-level positioning accuracy by using Beidou CORS system and ship berthing dynamic data by polar coordinates to provide powerful information to support the pilot berthing. This paper compared the "center rotating coordinates" and "polar coordinate" method, and analyzed the error source of these two methods. The measured data in this paper is discrete. We use polynomial fitting method to fit the data to determine how jump data, but this might still be insufficient. We will be targeted for research in further. After the test, the system can meet auxiliary information requirements when ship berthing. No matter how to improve the navigation technology, navigation of ships is inseparable from the operation. Human factors play a decisive role in the process of ship's safe navigation. Ship berthing can't just rely on a method of positioning or depend on the berthing auxiliary system to determine ship position and berthing speed. We encourage to use all methods of locating to obtain position data in case one method fails while the others are working well.

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