Real Time Simulation of Route Design and Route Monitoring in Nautical Simulator under Human-Computer Interaction Model

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Abstract

The real-time simulation of maritime navigation safety is very important. Accurate and timely risk warning and alarm can avoid dangers and emergencies in flight. Route design and route monitoring are two important methods. In this paper, under the platform of autonomous intellectual property rights, Kriging is applied to the study of route design. The real time simulation of route design and route monitoring is completed, and the surface of the seabed is merged to find the value of water depth at any position. The automatic discrimination of the feasibility of the planned route is realized, which effectively avoids the inaccuracy of the route monitoring caused by the screen coordinates, and is verified by the navigation simulation. This method can not only improve the efficiency and accuracy of navigation simulator training, but also play an auxiliary role in the research of navigation and port planning, navigation safety evaluation and so on. The test results show that the simulation accuracy of the real time simulation model of route design and route monitoring proposed in this paper meets the actual requirements.

Keywords: Navigation Simulator, Route Design, Route Monitoring, Simulation Model.

1. INTRODUCTION

Route design and route monitoring are two important navigational functions that marine simulator should provide, especially for maritime traffic safety. At present, the most famous marine simulator products in the world, such as KONGSBERG in Norway, STN ATAL in Germany, and TRANSAS in Britain, all have corresponding functions of route design and route monitoring. However, our marine simulator products are not perfect in these two functions. The role of route design is to choose a safe and economic route in advance to avoid sudden problems in navigation so as to ensure the safe driving of the ship (Morales et al., 2015). The function of route monitoring is to monitor whether it deviates from the course during the course of navigation and makes alarm cue. The navigation simulator is a real time simulation system, which is not only used for training, but also for the research of waterway and port planning, navigation safety evaluation and so on (Smirnova and Tsvetkov, 2016).

Scholars at home and abroad have made some meaningful discussions on the route design and route monitoring methods (Chen et al., 2014). Christiansen discusses the route optimization design method based on decision support system; Gunnarsson macroeconomic model integration for the route design; Xu Kaiyu proposed a method of route planning and route monitoring, and based on the electronic chart system (ECDIS) implementation of the method (Nam et al., 2013). In this paper, a real-time simulation model of route design and route monitoring in marine simulator is proposed, and the "recommended route" in the navigation database is obtained. The "recommended route" is accurately modified by human-computer interaction, and the automatic identification of the feasibility of the planned route is realized. The improved geometric decision algorithm is used to realize the navigation route monitoring, and the simulation precision is improved effectively, and the function of the navigation simulator is improved.

2. THE FUNCTIONAL ARCHITECTURE OF ROUTE DESIGN AND ROUTE MONITORING

The marine simulator is a closed loop real-time simulation system in the loop. The route design and route monitoring module is a very important part of the navigation simulation process, which is completed by the chart system of our ship. Its architecture is shown in Figure 1. After receiving the training sent by the instructor station, the chart is transmitted to the radar and 3D visual machine according to the configuration of the ship's
hardware and software, and the simulation starts (Zhang and Zhao, 2015). In the process of simulation, in addition to receiving the information sent by the coach station, the chart also provides sea chart information for the route design module. According to the input information of the real-time calculation of the vessel position information of the simulation process, provide the route monitoring module (Keupp and Schöh, 2015). The result of route design and route monitoring is not only to display, monitor, and information, but also to be sent to the coach station for real-time display and monitoring.

![Diagram](image)

**Figure 1.** The architecture of route design and route monitoring module in the simulator

### 3. REAL TIME SIMULATION MODEL OF ROUTE DESIGN

#### 3.1 The basis for determining the feasibility

The planned route is designed to refer to the "recommended route" between the port area, which is obtained through the navigation database. According to the ship route information set the track allowable error, the steering point is set up by human-computer interaction, and the route is automatically connected from the steering point. At the same time, it is feasible to determine the steering point and route according to the position of the mouse (Carneiro and Novais, 2016). The key of route design is to determine whether the route is feasible in real time and accurately. The basis of judgement includes ship's sailing state and chart information in ship's navigation area.

The state of navigation of ships mainly includes the maximum draught, tonnage, maximum speed and circumflex radius of the ship. The ship's tonnage, the maximum speed, the width of the ship and the maneuverability of the ship determine the track allowable error with the planned route as the middle axis.

Ship navigation area chart information: including along the planned route within the region to navigation information (such as the reef, reef, intertidal, sinking, prohibited area etc.) for any scale level any geographic coordinates of the location of the depth point identification and nautical chart.

One of the core problems in the algorithm of route design feasibility is to get the depth value of any geographical coordinates (Chen and Liu, 2016). Then we can judge whether the depth of the ship's location and the ship's own parameters, such as the maximum draft, are feasible (Zhang et al., 2011). Ship's sailing state parameters can be accurately obtained by ship motion model database, and chart information can also be obtained through S-57 electronic chart database, while the known water depth data are only discrete, fixed location depth values. Li Yuanhui Hardy was improved by the multiquadric method to calculate the value of water depth, make the appropriate improvements to the indicator Kriging method, and to amend the order deviation, surface fitting for seafloor topography, to obtain any geographic coordinates of the location of the depth value (Zhao et al., 2016).
3.2 The Kriging method is used to determine the depth of water at any position

Craig Fa is not a simple weighted average. According to theoretical proof and practical experience, it has constituted a complete set of methodological system, which is quite reasonable and accurate. The indicator Kriging method (IK) is a nonlinear estimation method proposed by Journel. It does not need to assume the distribution type of the random function (RF) in advance, and also eliminates the adverse effects of a few specific values (outlier) on the calculation results. Its main purpose is to estimate the uncertainty of the random function Z(U) at the non sampling point. First, we need to transform the data into instructions (Liu and Cheng, 2011). Then we use the simple Kriging or ordinary Kriging to estimate the cumulative distribution function (cdf) at the estimated point. Based on that, we can solve all kinds of estimation and simulation problems. The calculation method for calculating the cumulative distribution function and the depth of the water depth is given.

The cumulative distribution function is estimated to try to analyze the local uncertainty of RF at the point of view. Using the K threshold Zk, we can convert the continuous random function Z(U) into K indicating random functions.

\[ I(u, z_k) = \begin{cases} 1, & Z(u) \leq z_k \\ 0, & Z(u) > z_k \end{cases} \quad k = 1, 2, 3 ..., K \quad (1) \]

The corresponding observation value \( z(u) \) can also be converted to an indication value:

\[ i(u, z_k) = \begin{cases} 1, & Z(u) \leq z_k \\ 0, & Z(u) > z_k \end{cases} \quad k = 1, 2, 3 ..., K \quad (2) \]

At this point, the mathematical expectation of \( I(u, z_k) \) is:

\[ EI(u, z_k) = P\{I(u, z_k) = 1\} = P\{z(u) \leq z_k\} = F(u, z_k) \quad (3) \]

It is the value of the cumulative distribution function (cdf) of the random variable \( z(u) \) at \( z_k \). Kriging estimates for RF \( I(u,z_k) \):

\[ I^*(u, z_k) = \sum_{a=1}^{n} \lambda_a I(u_a, z_k) \quad (4) \]

\[ E^*[I(u,z_k) | (n)] = P^*\{z(u) \leq z_k \} | (n) = F^*(z_k | (n)) \quad (5) \]

This estimate is essentially an estimated value of the conditional cumulative distribution function (ccdf) of RF \( Z(u) \).

3.3 Route design simulation model

The planned route is designed to refer to the "recommended route" between the port area, which is obtained through the navigation database. The steering point is set up by human-computer interaction according to the navigation error of the ship route. The route is automatically connected by the turning point, and the steering point and the route are determined according to the point position of the mouse (Popovich et al., 2016). The simulation process is shown in Figure 2. The following method is used to determine the steering point and the feasibility of the route.
4. REAL-TIME SIMULATION OF ROUTE MONITORING

Route monitoring need to provide real-time position of the ship, each machine cycle chart (0.5s) according to the operator's input to calculate the ship's position, display the ship and target ship dynamic graphics display in their view. At the same time, the ship's information is sent to the coach station, the visual system, the radar display machine and the instrument. The purpose of the route monitoring is to warn and alarm the deviation from the route. When XTE is at a distance, the DR algorithm is used to calculate the time and distance that may deviate from the route and prompt information. If the route deviates from the route, the alarm is prompted, and the flow chart of its simulation algorithm is shown.

It is the key algorithm to determine whether the ship is in the range of the route and is the simulation of the route monitoring. Xu Kai Yu Ren uses WINDOWS API function to judge, but API function uses screen coordinates, which will cause certain errors, and can not meet the requirements of safety and accuracy. The accuracy of the algorithm is improved by a series of coordinate transformations, as shown in Figure 3.

In this paper, an improved point location algorithm is proposed to monitor the route. First, various coordinate transformation models in the electronic chart are set up. According to the flow chart shown in figure 3, the coordinates of the drawing board corresponding to the coordinates of the screen are converted into geographic coordinates, and then according to the parameters of the current user operation speed, rudder angle, heading and so on. The current position of the vessel is calculated in real time (geographical coordinates), which can accurately judge the position point in the range of polygon route. In order to speed up the discrimination, first calculate the outer rectangle within the range of the route, and judge whether the ship is in the outer rectangle. If it is satisfied, the further judgment point (u) is within the polygon (u|R0), in which UL is the NN of the structure array of the route range polygon points. The program uses the ray method, which leads to a ray T (u, v) from the level to be tested, and calculates the number of intersection points between the T and the UL lines. It is recorded as n. According to this principle (even outside the n odd u in ul or u not in ul) to determine whether the polygon. Because the algorithm uses the more accurate geographic coordinates, and in each of the 0.5 s in the solution of a position, so they can meet the accuracy of route monitoring and can meet the real-time.
5. TEST AND ANALYSIS

Dalian Port (sea chart No. 11381) is taken as an example of the international standard S-57 format (sea chart No. 11381), with a scale of 1:40000. The position of the ship is set at will, the route design and the route monitoring simulation are carried out. Because the coastal route is rather complicated, first, extract the recommended route from the database, then modify the route through human-machine interaction. At the same time, we use the automatic route determination algorithm to exclude the obstructing area, the forbidden area and the land area, and get the possible navigation area. To determine the water depth in the course range by the Kriging method, it is possible to determine whether the route is feasible and the following steps are as follows:

1. 2188 points of original water depth data are extracted as sample data.
2. The calculation error conditions of the Kriging method are lagged 2m; the angle tolerance limit is 30 degrees, and the distance tolerance error limit is 1 m. The parameters are shown in table 1 according to the original data fitting.

Table 1. The calculation parameters of the variation function

<table>
<thead>
<tr>
<th>Maximum variation/m</th>
<th>Nugget</th>
<th>Base value</th>
<th>The axis length parameter of the ellipsoid/m</th>
<th>The axis length parameter of the ellipsoid/m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>First axis</td>
<td>Second axis</td>
</tr>
<tr>
<td>55.643</td>
<td>0.342</td>
<td>1.827</td>
<td>55.643</td>
<td>53.4</td>
</tr>
</tbody>
</table>

Taking the route area as the calculation area, the calculation range of its waters is defined as follows: the grid size (actual distance) is X direction 15 m, Y direction 10 m, and the number of grids is X direction 849, Y direction 785.

The Kriging method is used to calculate the water depth grid. According to the definition of the grid area, we calculate the water depth of each grid point and compare it with the ship's water intake using the improved water depth decision method.

In the navigation simulator, the simulation test is carried out in conjunction with the visual system. The operator manipulates the ship from its starting position to the destination. The planned route can be corrected in real time, and the feasibility of the planned route is automatically discriminate. The whole simulation process does not touch the shore, the grounding, and the collision. The improved route monitoring algorithm can accurately monitor whether the course deviates. When the ship surpasses the route range, the upper left corner of the screen will generate automatic alarm for route monitoring.

6. CONCLUSIONS
The real time simulation model of route design and route monitoring is put forward on the platform of autonomous intellectual property rights. The Kriging method is applied to the study of route design, and the surface of the seabed is merged to find the value of the water depth at any position. According to the navigation information and chart information of the ship, the planned route can be modified by human-computer interaction, and the automatic identification of the feasibility of the planned route is realized. The decision algorithm of route monitoring is improved, which effectively avoids the inaccuracy of channel monitoring caused by the screen coordinates. The method is verified by a high quality marine simulator and the method is accurate and reliable.

REFERENCES

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