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Research on the Ship Dynamic Information Display and Simulation System Based On Electronic Chart

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Abstract. In order to minimize the risk of maritime navigation and ensure the navigation safety of ships, a ship dynamic information display and simulation system based on electronic charts is proposed and constructed. With the support of Visual-Studio development platform, we use ISO8211.LIB package library to analyze S-57 chart data and use linear projection transformation algorithms to improve the display rate of chart, and use the Douglas - Peucker algorithm to clean a large number of AIS track data approximate fitting plan route, and present a model of ship motion based on the gauss perturbation. The system implements the efficient and real-time display of the ship's dynamic and static information. It provides an economic and safe plan route, which integrates sea conditions. It also can control, monitor and replay the motion state of the ship during the simulation training in real time. The practical operation effect of this system shows that it has certain significance to improve the navigation safety of ships.

1. Introduction

The electronic chart system has brought great convenience to ship pilots, and it has played a significant role in guaranteeing the safety of ship navigation and improving the efficiency of ship navigation. The study of electronic chart is relatively early in foreign countries, and the largest electronic chart database supplier in the world today is C-Map Corporation. The electronic chart system developed by the company is relatively complete. It can realize the display of electronic chart and the function of automatic alarm of safety line [1]. Although the related research in China had started slightly later, domestic relevant Marine departments and electronic chart makers strive to advance to the international advanced level with the emphasis of our country on the sea. Therefore the development of China's electronic chart system has achieved remarkable achievements, and the gap with the international advanced level has been shortened constantly [2]. However, there are still many deficiencies in the existing electronic chart system, such as no hydrological and meteorological information, redundancy of system information, system delay, and imperfect simulation function [3].

It is very necessary to carry out simulation research on maritime navigation safety. In this paper, a dynamic information display and simulation system of ship information based on electronic charts is designed. The system is connected with the maritime data exchange platform, and it can obtain AIS, radar, VTS, hydrology and meteorology information, which can integrate with the chart information.



The system can realize the visual display of the ship dynamic information and provide a planned route that integrates the sea condition both economically and safely. During the simulated navigation process, it can not only issue the danger warning and alarm accurately and timely but also prevent the occurrence of the danger, so as to ensure the safe navigation of the ship.

2. The Srstem scheme design

2.1. System overview

Ship dynamic information display and simulation system based on electronic chart should not only be able to provide static information of the vessel for the ship regulators, can also provide dynamic information (hydrological, weather, etc.). The ship driving training process can be controlled, monitored and replayed in simulation training. And the system can change the difficulty of training, set up the training natural environment, traffic condition in order to prevent the occurrence of navigation danger of ships effectively. It provides a user-friendly interface for the ship regulators through the convenient operation of the graphics, dialog boxes, menus, toolbars, and so on. The following picture illustrates the nine modules of the system:

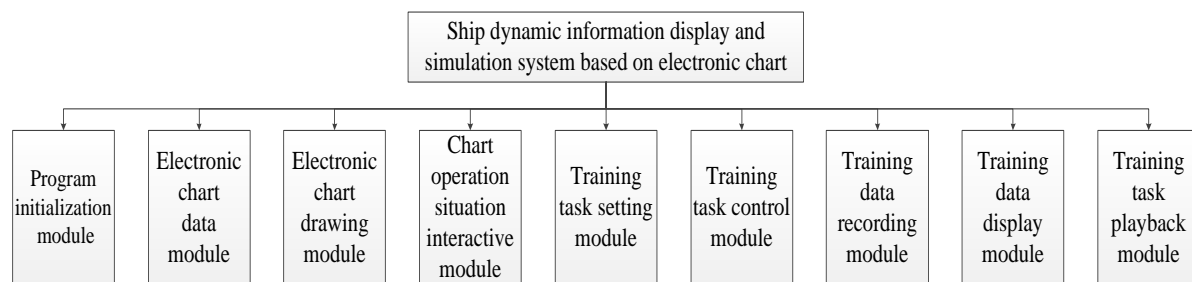


Figure 1. System module

2.1.1. Program initialization module. This module implements the initialization function, and it's configured in the initial state of the configuration, to receive other device information, according to the local configuration file.

2.1.2. Electronic chart data management module. This module can read and analyze the data of electronic chart (ENC). According to the digital data transmission standard (IHO s-57) used by the international organization for hydrographic survey (IHO), it builds a special model and algorithm to extract the information of shoreline, contour line, isobathic line and water depth points which are used for the drawing of electronic chart.

2.1.3. Electronic chart drawing module. The module implements the display function of the chart. It reads the shoreline, isobathic curve and water depth points extracted from the s-57 standard electronic chart data. And it displays the vector chart data consist of spatial data and attribute data for symbolization, and visualizes the chart data according to s-52 standard.

2.1.4. Chart operation situation interactive module. The module is charge of the interactive function. Interactive operation such as target drawing, target symbol library management, route map, file management, chart operation, chart layer control, object management, view management and window management are implemented in this module.

2.1.5. Training task setting module. The module realizes the setting of training task. The tasks include the setting of the training area type (voyage in open water area, coastwise navigation, narrow sea water, crowded water driving, shallow water, narrow water area, narrow channel, river and etc.), the setting of driving training courses (driving in and out of the port of the ship, driving away from the dock,

driving under bad conditions, driving in fog, towing, etc.), the setting of the initial motion state of the main ship, the planned route and the working state of instruments and equipment, the setting of the relevant information of the target ship (such as type, initial motion state, initial equipment state and planned route, etc.), the setting of the sailing natural environment (such as date, wind speed, wave height, tide and visibility, etc.).

2.1.6. Training task control module. This module realizes the record function of simulation data. According to the running condition of simulation training process, relevant data are recorded, including ship dynamic information (recording position, course, speed, ship heading, etc.), ship driving data in the process (course change, speed change, host control change, steering gear change, etc.), ship motion status data, route traffic status data (time, target ship position, target ship course, target ship speed data, target ship speed data, etc.).

2.1.7. Training data recording module. This module realizes the record function of simulation data. According to the running condition of simulation training process, relevant data are recorded, including ship dynamic information (recording position, course, speed, ship heading, etc.), ship driving data in the process (course change, speed change, host control change, steering gear change, etc.), ship motion status data, route traffic status data (time, target ship position, target ship course, target ship speed data, target ship speed data, etc.).

2.1.8. Training data display module. This module realizes the display function of the simulation data, For example, the driver's training data is displayed in a window or a form. The data includes all attributes data of the training target, the information of ship the CPA/TCPA data, the incident report.

2.1.9. Training task playback module. This module realizes the playback function of simulation, which can replay the whole situation evolution of the training process according to the training data recorded automatically by the computer in the process.

According to the functional analysis of the above modules, the operation process of the system is as follows:

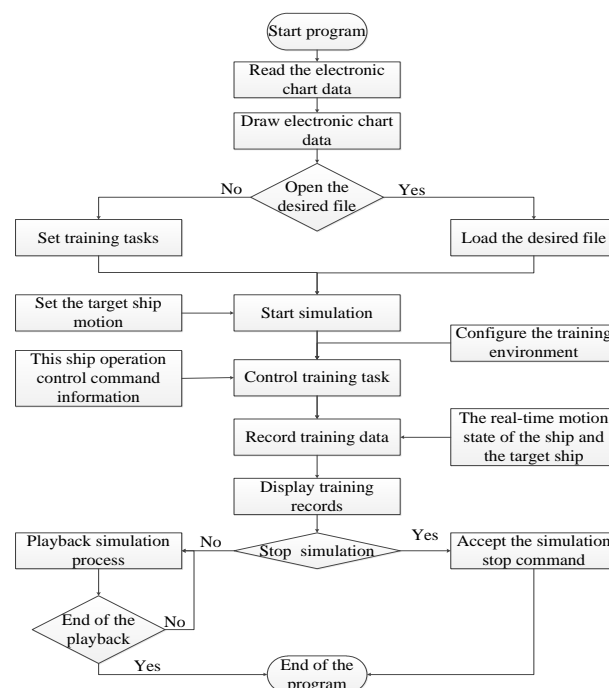


Figure 2. System operation process

3. Key technology

3.1. Analysis of S-57 electronic chart data

The packaging standard at the bottom layer of s-57 chart files uses ISO/IEC8211 standards for the purpose of transferring data in different computer systems. Although data encapsulated by the ISO/IEC8211 standard is convenient for data transmission, it is not able to quickly query and read the display object directly. A chart file (data interchange file) consists of one or more logical records, each of which consists of header, destination and field sections. The first record is data description record (DDR), and the subsequent records are data records (DR) [4].

ISO8211 LIB is written by C plus plus open source libraries, which is specifically used to parse the S - 57 format data software tools, encapsulating the operation on S - 57 chart files of the underlying function. Its library files mainly include five categories: DDFModule (reading records from the encapsulated files), DDFRecord (reading data records from the data files), DDFField (reading and instantiating the middle fields), DDFFiledDefn (reading the middle field information) and DDFSubFiledDefn (reading the sub-fields).

This paper uses ISO8211.LIB library to analyze electronic chart data. The specific data analysis process is as follows:

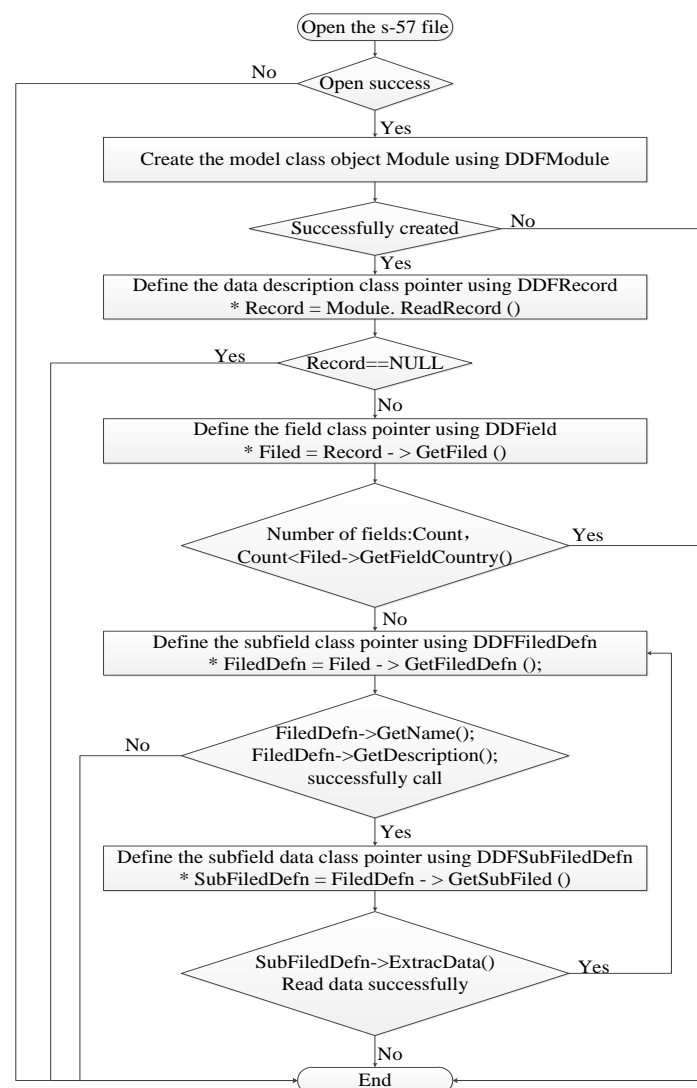


Figure 3. Chart data analysis process

3.2. Linear projection transformation

In the chart files, we utilize the manner of longitude and latitude to store the space information of object in order to only represent a target location accurately. The display of electronic chart data requires the transformation of the object from three-dimensional information on the earth surface to two-dimensional information on the computer screen. That is necessary to convert the geographic coordinate value into the Mercator coordinate value through the equiangular orthographic cylinder projection, and then convert the Mercator coordinate value into the screen coordinate value after certain operation. In the case, the nonlinear conversion speed, which is convert from geographical coordinates to the ink-clip coordinate, directly affects the efficiency of the electronic chart display.

Equilateral cylinder projection is the most commonly used projection method in nautical charts. Here (ϕ, ω) is the geographic coordinate of an object, the basic latitude of projection is θ , the Mercator coordinates are (x, y) , the radius of the earth ellipsoid is r , and the first eccentricity of the earth ellipsoid is a , so the formula of Mercator orthographic projection is [6]:

$$x = a \times \omega, y = a \times q \quad (1)$$

$$a = \frac{r}{\sqrt{1 - a^2 \sin^2 \theta}} = \cos \theta \quad (2)$$

$$q = \ln \tan\left(\frac{\pi}{4} + \frac{\phi}{2}\right) - \frac{a}{2} \ln \frac{1 + a \sin \theta}{1 - a \sin \theta} \quad (3)$$

In this case: ϕ is the latitude in the geographic coordinate system, ω is the longitude in the geographic coordinate system, a is the radius of the basic latitude circle, q is the same latitude.

When the baseline latitude is θ_2 , it can be obtained by the above formula:

$$\frac{x_2}{x} = \frac{a_2 \times \omega}{a \times \omega} = \frac{a_2}{a}, \frac{y_2}{y} = \frac{a_2 \times q}{a \times q} = \frac{a_2}{a} \quad (4)$$

$$\frac{a_2}{a} = \frac{\cos \theta \sqrt{1 - a^2 \sin^2 \theta_2}}{\cos \theta_2 \sqrt{1 - a^2 \sin^2 \theta}} \quad (5)$$

Therefore, the coordinate transformation of Mercator coordinates of different datum latitude charts can be changed from non-linear transformation to linear transformation by multiplying the proportional factor a_2/a . This can not only greatly improve the display efficiency of electronic chart data, but also change the calculation required in navigation operations from spherical calculation to two-dimensional plane calculation, making the calculation simple and intuitive.

3.3. Route design simulation algorithm

The route design is the foundation of the nautical operation and also indispensable for the safe navigation of the vessel. At present, there are many methods for calculating planned routes, such as the ECDIS route design based on network model [7], the route design based on ant colony algorithm [8], the route design based on route binary tree [9] etc. These calculation methods, however, are only based on chart data, which do not take into account the effect of hydrologic factors on the route.

The AIS data has a record of the true navigation situation of ship. In the actual course of navigation, it contains the hydrology, the weather, the safety, and the economic factors. Therefore, the approximate fitting of AIS track point to planned track point can generate a planned route that combines the sea condition information, the economy and safety. The AIS information includes the static data, the dynamic data and the voyage data [10]. The data amount of dynamic data is huge, so

Douglas Peucker algorithm is used in this system to clean and compress a large number of AIS track points.

The Douglas-Peucker algorithm is a popular curve approximation algorithm which connects the first and the ends of a known curve to a straight line, and seeks the shortest distance from other points to the straight line. When d_{max} is less than D , the intermediate point of all curves is deleted, when d_{max} is more than D , then the distance maximum point is reserved, the concrete realization process is shown in figure 4. The core of this algorithm is to use as few points as possible to describe the morphological features of the original objects as accurate as possible [11].

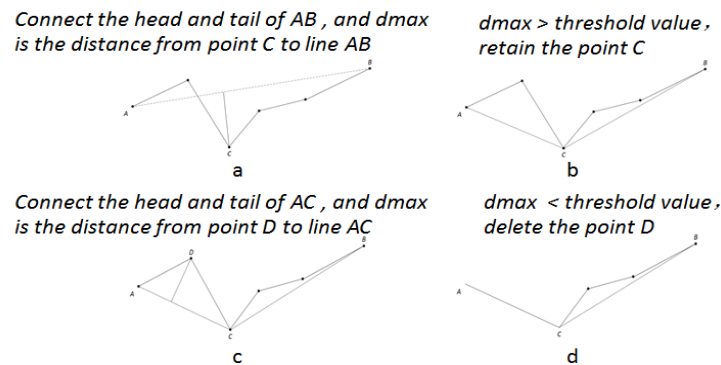


Figure 4. Douglas-Peucker algorithm

In summary, the process of generating routes in this system is as follows:

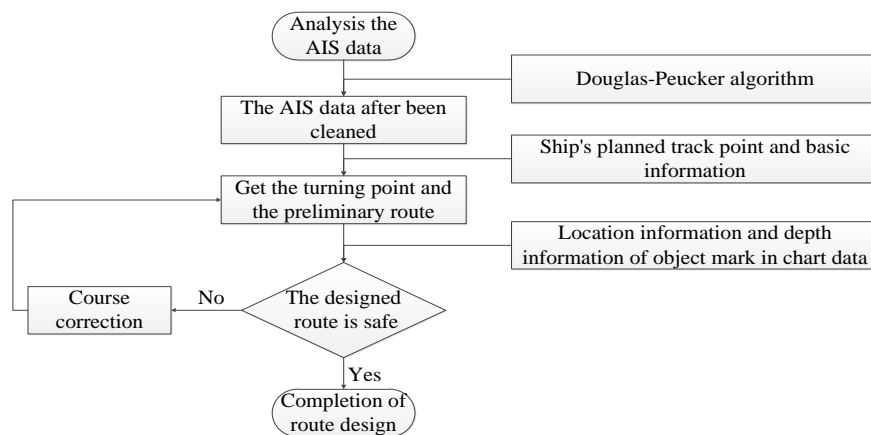


Figure 5. Generating route

3.4. Motion model based on Gaussian disturbance

There are many interfering factors in the actual navigation of the ship. So it's not possible to consider all the factors in the building of a moving line. To make the ship's movement more reasonable, the system introduced a random disturbance that satisfies the Gaussian distribution. The random disturbance term refers to the error caused by the uncertainty of the data itself. When we assume that the random disturbance is independent and obey the mean to 0, the variance has the normal distribution of the same, and the random disturbance has a Gaussian distribution [12].

The method of adding Gaussian disturbance in the uniform linear motion of ships is as follows: For the general motion equation of a straight line with constant speed, k is the k th track point, t is the time difference between two track points, x , y and h are components of distance in x , y and z axes, v_x , v_y and v_h are components of velocity in x , y and z axes:

$$X(k+1) = \Phi X(k) \quad (6)$$

$$X = \begin{bmatrix} x \\ y \\ h \\ vx \\ vy \\ vh \end{bmatrix} \quad \Phi = \begin{bmatrix} 1 & 0 & 0 & t & 0 & 0 \\ 0 & 1 & 0 & 0 & t & 0 \\ 0 & 0 & 1 & 0 & 0 & t \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (7)$$

The output equation of general uniform linear motion is

$$Y(k) = X(k) \quad (8)$$

The formula 9 introduces the output equation of the Gaussian disturbance of location and the Gaussian disturbance of velocity, in which is a Gaussian disturbance, is the disturbance variance of the Gaussian disturbance, is the variance of position disturbance, is the disturbance variance of velocity:

$$Y(k) = X(k) + GV(k) \quad (9)$$

$$G = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad (10)$$

$$Q = \begin{bmatrix} q_{1,1} & 0 & 0 & 0 & 0 & 0 \\ 0 & q_{2,2} & 0 & 0 & 0 & 0 \\ 0 & 0 & q_{3,3} & 0 & 0 & 0 \\ 0 & 0 & 0 & q_{4,4} & 0 & 0 \\ 0 & 0 & 0 & 0 & q_{5,5} & 0 \\ 0 & 0 & 0 & 0 & 0 & q_{6,6} \end{bmatrix} \quad (11)$$

$$q_{1,1} = q_{2,2} = q_{3,3} = q_p \quad q_{4,4} = q_{5,5} = q_{6,6} = q_v \quad (12)$$

4. Simulation of the system

Based on the above technologies, this paper builds a ship dynamic information display and simulation system of electronic chart by using Visual Studio development platform. The user can import the ENC file as required and perform basic operations on the chart, as shown in figures 6

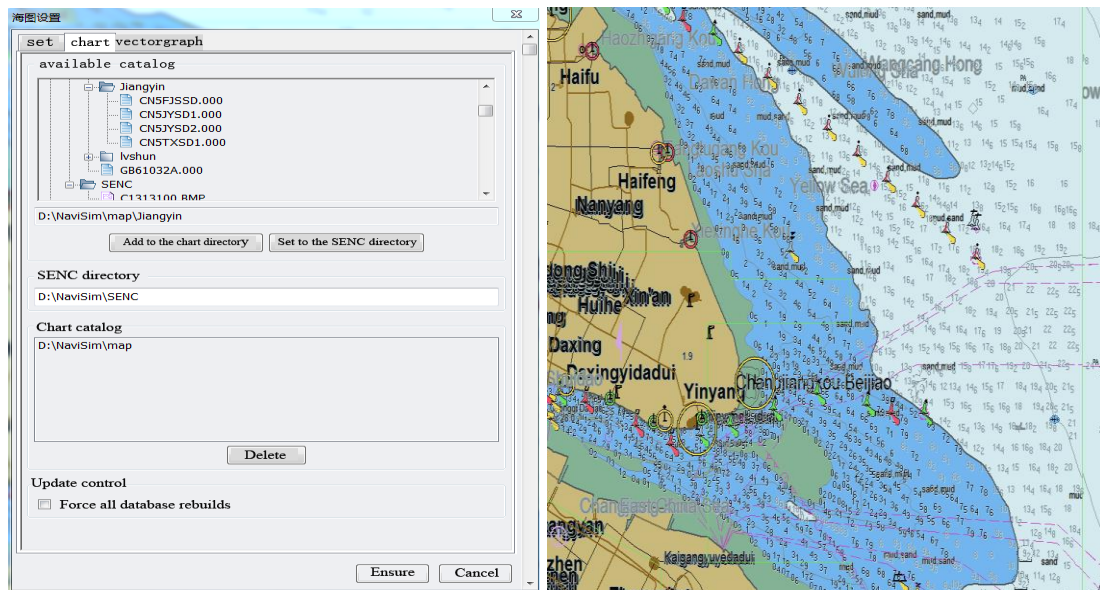


Figure 6. Set chart and Show chart

In figure 7 users set the basic information and the planned shipping routes, and set the navigation environment information. The system automatically generates a smooth sailing curve.

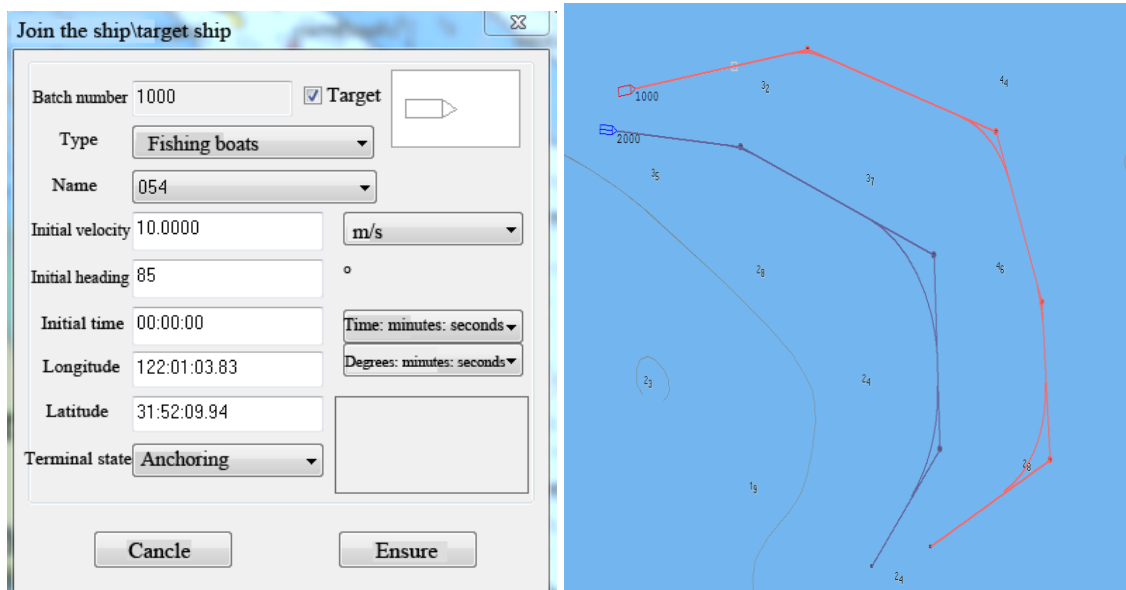


Figure 7. Sets the basic information and plane routes

Figure 8 shows the setting of navigation environment information and the fault information. It shows the simulation according to the setting environment and fault.

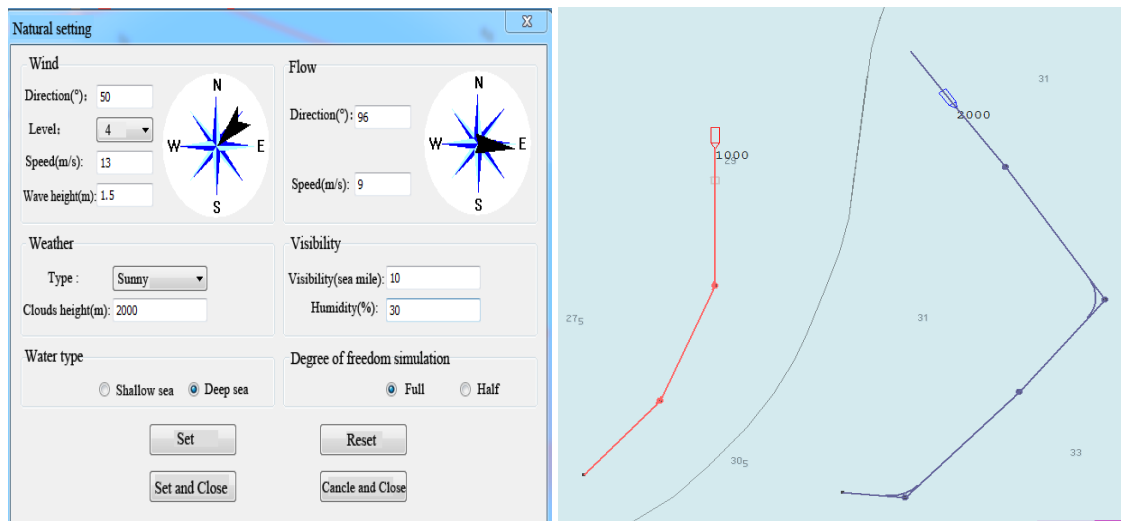


Figure 8. Sets the navigation environment information and stat simulation

Figure 9 shows the alarm function provided by the event window during the simulation:

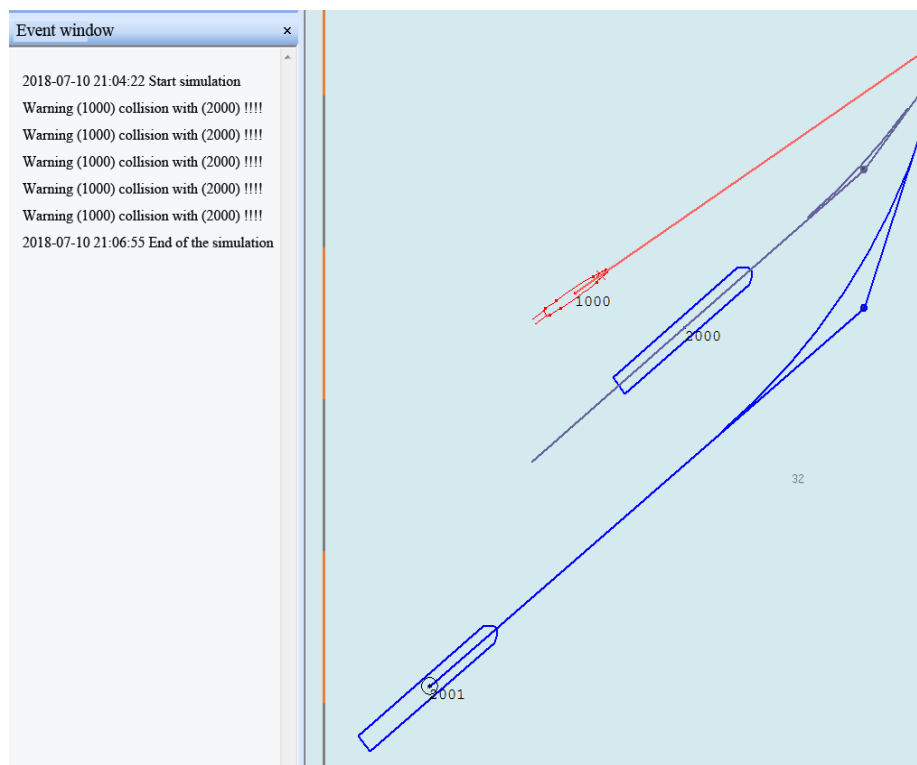


Figure 9. Alame function

5. Summary and Prospect

This paper uses electronic chart display technology, Internet technology, image processing technology to create a simulation system based on the electronic chart system that can provide real-time ship dynamics information and prevent the flight risk of ship. The system can display the ship dynamic and static information in real-time and provide a plan route which merge the hydrology, meteorology and other sea state information. In addition, it can also monitor and replay the simulation training.

In the process of follow-up studies, the related sailing experience can be referred to establish an expert assessment and audit model, and the system can give out the evaluation of training results based on the related data which are recorded by the simulation training system automatically.

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