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# Big data driven intelligent collision avoidance of commercial fishing boats warning system

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## Abstract

**In recent years, the collision accidents of commercial fishing boats occur frequently, which can easily cause the destruction of fishing boats. The party's 20th report clearly stated that we should strengthen maritime safety supervision, develop the Marine economy, protect the Marine ecological environment, and speed up building China into a maritime power. This project proposes a collision avoidance warning system for service provider fishing boats, aiming to standardize the navigation of sea ships, reduce the traffic conflict in ship navigation, and provide reference for the safety management of maritime Ministry for coastal ships in Shandong. This project in absorbing and draw lessons from domestic foreign fishing boat accident analysis, prediction and early warning, on the basis of research results, according to the theory of accident control, big data thinking warning, prediction, monitoring, coordination of the four elements, for the Shandong coastal and even the global business fishing accident problems, on the basis of big data analysis, fusion of information technology, into the research object, eventually form commercial fishing boats collision early warning support and intelligent control.**

## Keywords

**Collision avoidance, early warning, big data, intelligence, fishing boats.**

## 1. Introduction

The system is based on Marine electronic chart, AIS, radar, GPS and other equipment. After opening, the ship accident history data and AIS data such as multidimensional data in Marine electronic chart layer, and in accordance with the "early warning-prediction, monitoring-decision", in the process of ship movement real-time access to the waters of the waters, risk factors and provide dangerous area navigation decision support, and provide dangerous area navigation alarm, abnormal navigation behavior alarm and collision warning safety navigation information. Through real-time collection, processing and analysis of massive data on the Marine environment, ship status, and traffic conditions, it provides comprehensive, accurate and timely information support for the maritime sector. Intelligent collision avoidance early warning system realizes the prediction and early warning of ship collision risk through intelligent algorithm and model. When the system detects the potential collision risk, it will issue early warning information to the crew and maritime departments in time, and take corresponding collision avoidance measures, which greatly reduces the probability of collision accident and guarantees the navigation safety.

# 2. key technology

## 2.1. Ship collision avoidance early warning based on trajectory prediction technology

Taking the navigation data of the past moment of the ship as the input and the navigation data of the future moment as the output, the navigation feature mapping relationship based on the time series is established by comparison, finally realizing the navigation prediction of the ship. Based on AIS data, we proposed a ship navigation prediction model based on Attention-LSTM neural network.

### 2.1.1. LSTM neural networks and attention mechanisms

LSTM neural network：

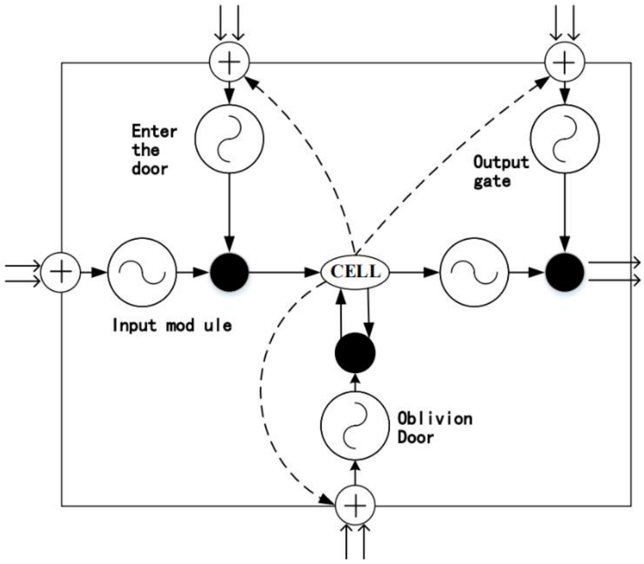


Fig 1.1 Structure of the LSTM cells

Given the input sequence xt, the input gate, forgetting gate and output gate are it, ft, ot respectively, and the memory unit Ct controls the memory and forgetting of the data through different gates.

Updated memory unit Ct: $\begin{cases} q_t = \tanh(W_q * [h_{t-1}, x_t] + b_q) \\ c_t = f_t C_{t-1} + i_t q_t \end{cases}$

Upupdated hidden state ht: $h_t = o_t \tanh( \ c_t)$

Attention mechanism：

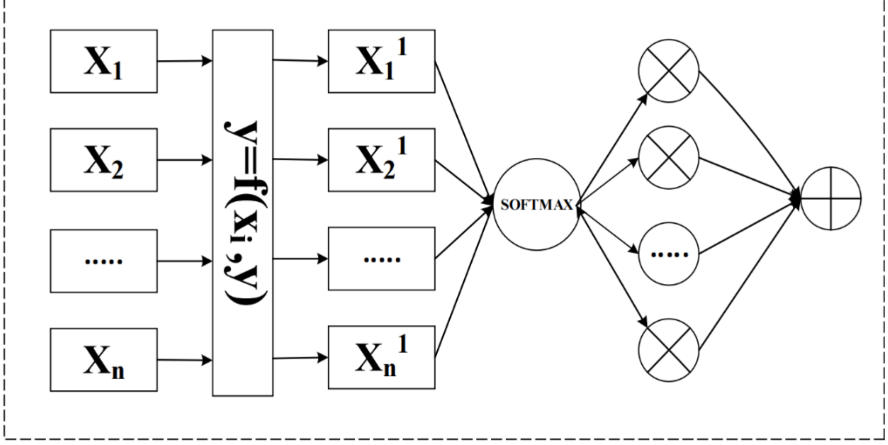


Fig 1.2 The Attention cell structure

In the Fig, Xi i is the input sequence, and Xi i 1 is the similar scalar calculated by Xi i simplification, which is mapped in the [0,1] interval by the normalization exponential function, namely "weight". The dot attention is the weight of Xi. The expression is as follows

$$\begin{cases} f(x_i, y) = (W_1 * x_i, W_2 * y) \\ Attention = \sum_{i=1}^{n} soft\max(f(x_i, y)) * x_i \end{cases}$$

### 2.1.2. Multidimensional ship navigation prediction model

Neural network structure:

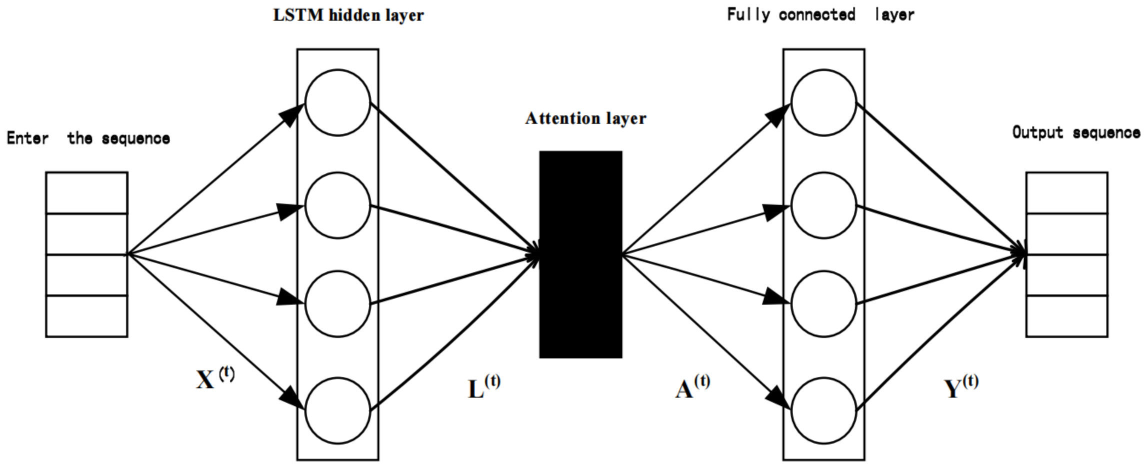


Fig 1.3 The Attention-LSTM network structure

topology structure:

Input:（MMSI,TIME）={LNG,LAT,COG,SOG}

Output:（MMSI,TIME）={LNG,LAT,COG,SOG}

In order to reduce the effect of the difference of the magnitude of each data, the input and output sequences also need to be normalized, and the value of each element of the data set vector is converted within [0,1]. The expression is:

$$x^* = \frac{x - x_{min}}{xmin_{max}}$$

In this paper, the number of nodes in the LSTM layer and fully connected layer is set to α, α {4,8,16,16,32,64,128,256}, α =64; the input layer steps are set to β + 1, β {2,3,3,5,5,6}, namely β, β [β - β], Y [t- (β -1)], β [t] as network input, and the prediction data Y [t + 1] at time t + 1 is used as network output. The initial setting is β =5; the number of iterations is θ, θ {1,500,1000,1500,2000,2500,3000}. Preliminary setting θ =1500. The cross-entropy loss function can be used to evaluate the difference between the current training results and the real distribution without affecting the convergence rate of the model, so it is taken as the cost function of the network, see formula:

$$Loss = -[y \log \hat{y} + (1-y)\log(1-\hat{y})]$$

In this paper, for the problems of astatic state and high noise in ship navigation, the adaptive moment estimation algorithm is adopted instead of stochastic gradient descent to calculate the gradient estimation matrix based on the training data and cross-entropy loss function, so as to set the adaptive learning rate for the parameters.

### 2.1.3. Comparative analysis

Experimental preparation:

The experimental programming language of this project is Python3.0, and the development tool is Spyder. The experimental data are from the AIS information of fishing boats in the waters of Chengshan Cape. After analysis, they were stored according to the field information of MMSI, TIME, LNG, LAT, COG, SOG, etc.

Experimental design:

200 sets of AIS were selected as the experimental data, and the first 180 sets were used as the training set and the last 20 sets as the test set after washing. In order to avoid model errors caused by differences in data distribution, selected data were used for standard Euclidean distance calculation. The results are shown in Table 1, which shows that the training set and the test set data have similar distribution.

Table 1 European distance

| project | LNG | LAT | COG | SOG |
|---|---|---|---|---|
| ρ | 0.243 | 0.230 | 0.310 | 0.170 |

Mean square error (MSE) and mean absolute error (MAE) are used to evaluate the indicators of ship navigation prediction. MSE refers to the square expectation of the difference between the predicted value and the true value, and the smaller the model works better; MAE can better reflect the real condition of the model error. The expression is as follows:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|y - \hat{y}\right|^2$$

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y - \hat{y})^2$$

Effect of topology on the Attention-LSTM model:

Number of neuron nodes: take α as {4,8,16,32,64,128,256}, and bring them into the model. Repeat 10 experiments are averaged, and the results are shown in Fig 1.4. When the number of hidden layer neurons is 128, the error indexes MSE and MAE achieve the minimum.

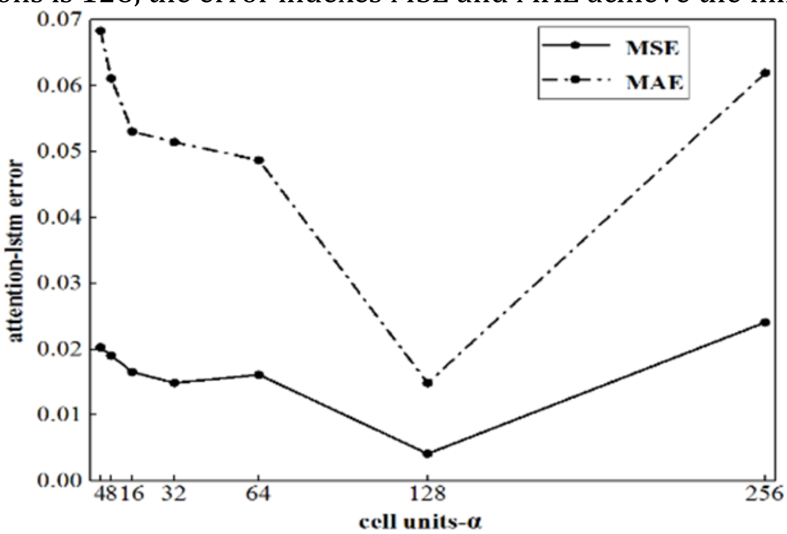


Fig 1.4 Neuronal error distribution

The β were taken as {2,3,4,5,6,}, successively brought into the model and repeated 10 times. The neural network errors corresponding to the different number of steps during the experiment are shown in Fig 1.5. When β + 1=6, or 6 steps in the input layer, the model fits the best.

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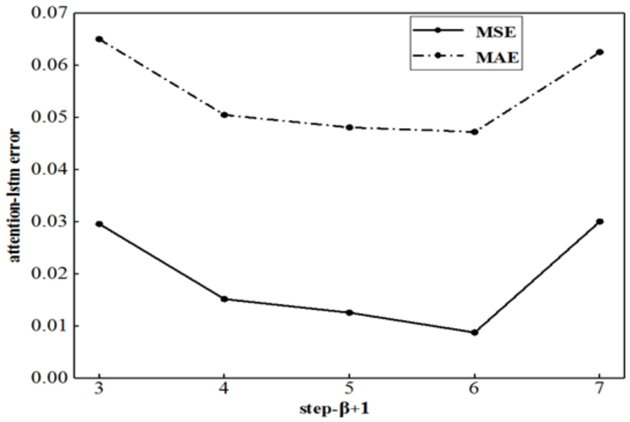



Fig 1.5 Step number error distribution of the input layer

Taking θ as {1,500,1000,1500,2000,2500,3000}, bringing into the model and running it 10 times, thus obtaining the error statistics at different number of iterations, see Fig 1.6. The model works best when the iteration number is 1000.

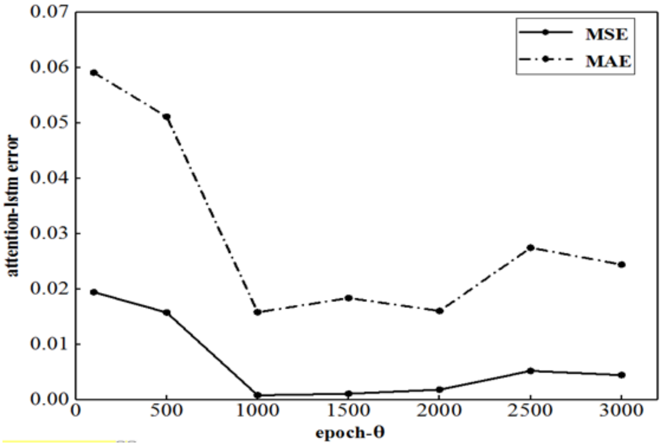



Fig 1.6 Error distribution of the number of iterations

Comparison of the different neural network models:

Ship trajectory prediction was performed using BP neural networks in past studies, with good results. In this paper, the BP neural network with a 4-14-4 structure and the Attention-LSTM model were selected to compare their prediction effect, and the results are shown in Fig 1.7.

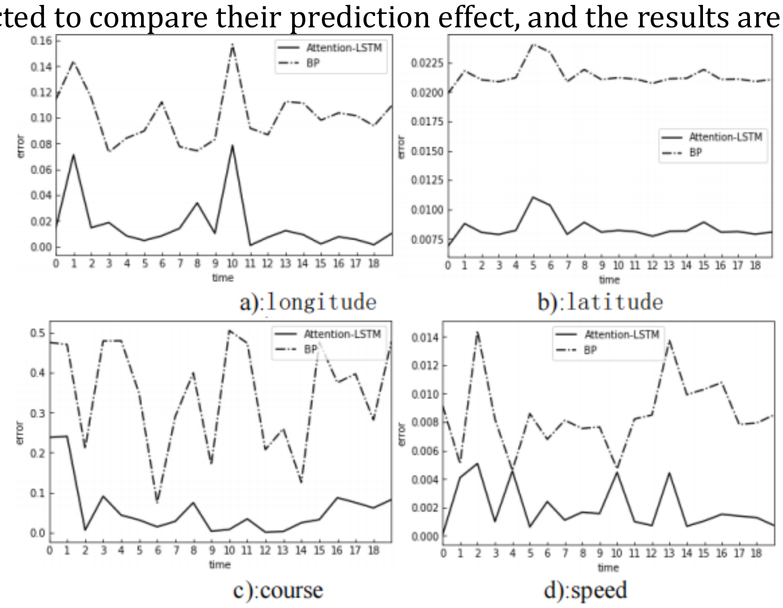


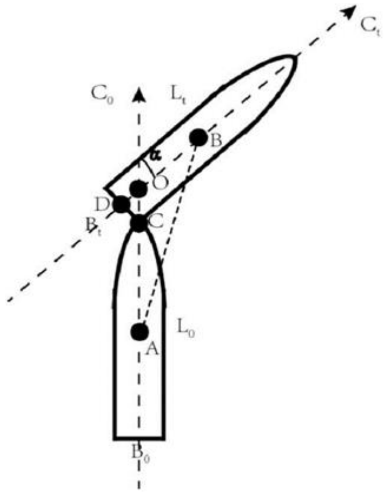

Fig 1.7 Prediction results

In the 20 tests, the error curve of the two types of models showed irregular shocks, but the prediction error based on the Attention-LSTM neural network model was smaller than the BP neural network model, that is, the model proposed in this paper has higher accuracy for ship navigation prediction.

### 2.1.4. Comparative analysis

Critical collision distance:

In this paper, any sharp Angle β, the target ship bow Ct, our ship bow C0, and the clockwise Angle of our ship bow and standard ship bow α (when Ct-C0> 0, α = Ct-C0, otherwise α = Ct-C0 + 360). Lt and Bt are the length of the target ship, and L0 and B0 are the captain and width of our ship.details are as follows:

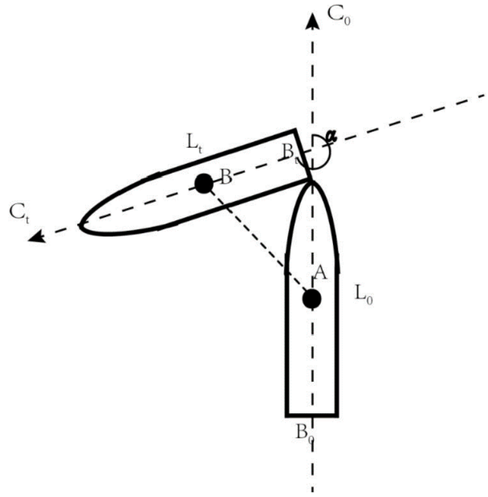



I ship passed the stern of the target ship

As shown in the Fig, at this time, α meets β α <180- β, CD = Bt / 2, DO = (Bt cotα) / 2, CO= (Btcscα) / 2, AO=L0 / 2 + (Btcscα) / 2, CD = Bt / 2, DO = (Bt cotα) / 2, CO= (Btcscα) / 2, AO=L0 / 2 + (Btcscα) / 2, BO = Lt / 2- (Bt cotα) / 2, According to the cosine theorem, the critical collision distance is:

$$d_{MSPD} = \frac{1}{2}\sqrt{(L_0 + Bt\csc\alpha)^2 + (L_t - B_t\cot\alpha)^2 + 2(L_0 + B_t\csc\alpha)\ (L_t - B_t\cot\alpha)\ \cos\alpha} + 2P$$

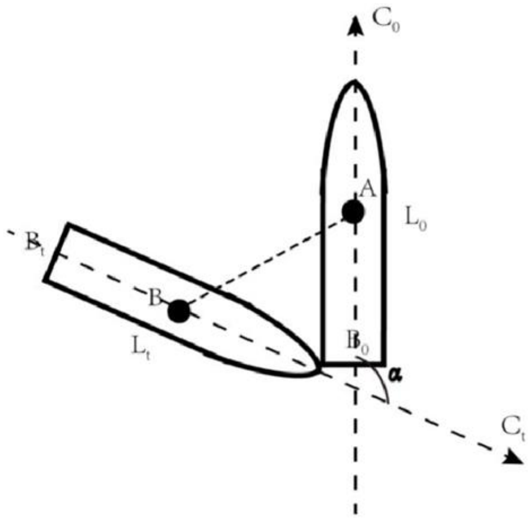
Where AO> 0 and BO> 0, namely Lt-Bt cotα> 0 and L0 + Bt cscα> 0, available:α> arctan (Bt / Lt), i. e. β =arctan (Bt / Lt).




See here, and similarly follow:

$$d_{MSPD} = \frac{1}{2}\sqrt{(L_0 - Bt\csc\alpha)^2 + (L_t + B_t\cot\alpha)^2 + 2(L_0 - B_t\csc\alpha)\ (L_t + B_t\cot\alpha)\ \cos\alpha} + 2P$$

Where, α <360-arctan (Bt / Lt), i. e., β =arctan (Bt / Lt), shall be met.

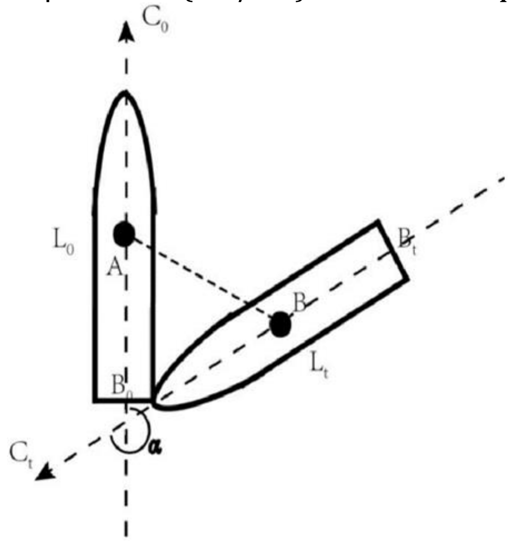



I have crossed the target ship's bow

As shown, the same is true:

$$d_{MSPD} = \frac{1}{2}\sqrt{(L_0 - B_0\ \cot\alpha)^2 + (L_t + B_0\ \csc\alpha)^2 + 2(L_0 - B_0\ \cot\alpha)\ (L_t + B_0\ \csc\alpha)\ \cos\alpha} + 2P$$

Where α> arctan (B0 / L0), i. e. β =arctan (B0 / L0), meets the requirements.

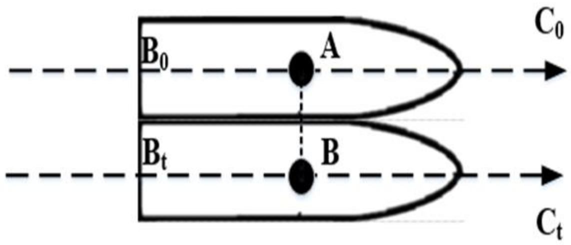



As shown, the same is true:

$$d_{MSPD} = \frac{1}{2}\sqrt{(L_0 + B_0\ \cot\alpha)^2 + (L_t - B_0\ \csc\alpha)^2 + 2(L_0 + B_0\ \cot\alpha)\ (L_t - B_0\ \csc\alpha)\ \cos\alpha} + 2P$$

Where, α <360-arctan (B0 / L0), i. e., β =arctan (B0 / L0).

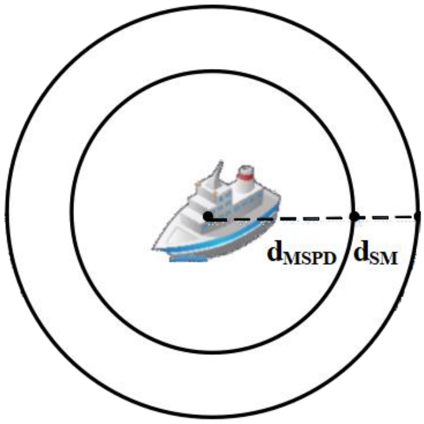
Our ship and the target ship are similar to or in the same direction




As shown in the Fig, the width and positioning error of the two ships are mainly considered, and the critical distance is:

$$d_{MSPD} = \frac{B_0}{2} + \frac{B_t}{2} + 2P$$

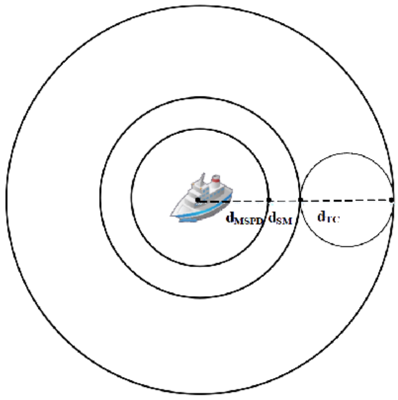
Meet safety margin:




According to the experience of several merchant ship captains, when the safety margin is 2 / 3 of the critical value, it can better meet the minimum surplus demand of the merchant ships, namely:

$$d_{SM} = \frac{2}{3} d_{MSPD}$$

Ship handling allowance:




Use the empirical formula, which is usually (2.8~4) times that of the captain. According to the maximum principle, the ship handling allowance is:

$$d_{TC} = 4L_t$$

Conflict Warning of Ship Movement:

Let the two-ship spacing be d and the critical collision distance be dMSPD, The safety margin is dSM, The manipulation safety margin is dTC. The early warning process is provided as follows:

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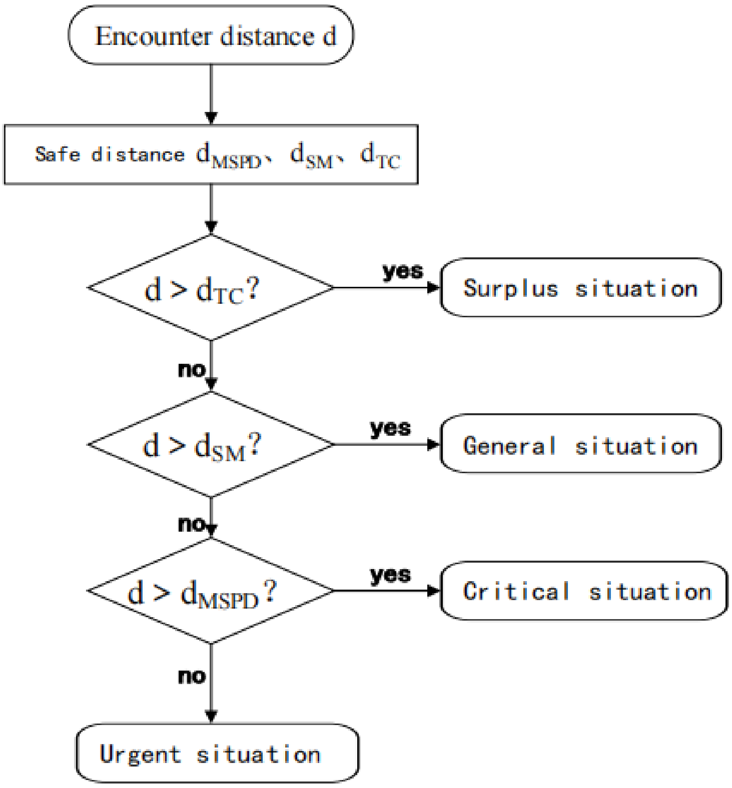
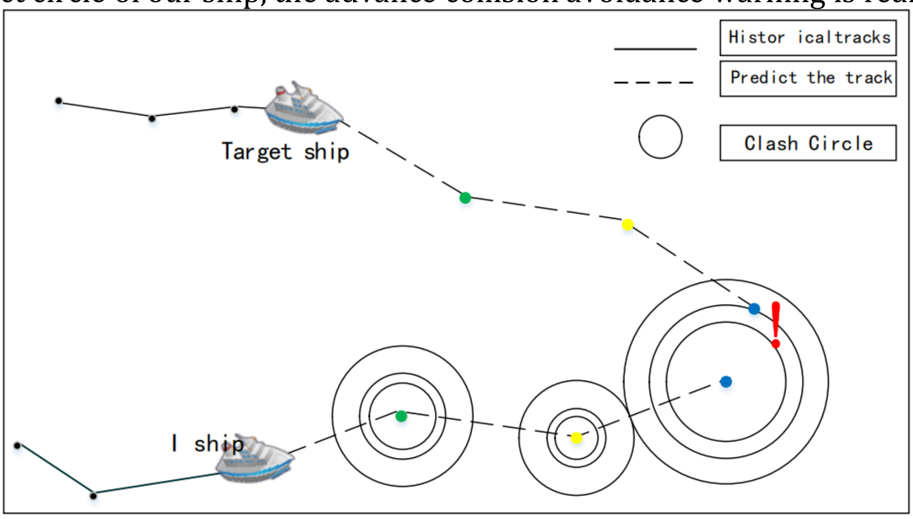



Among them, when the two ships are in the surplus situation; when the two ships are in the general situation, remind the driver to correct in time; when the two ships are in the critical situation, the warning reminds the driver to take urgent measures to avoid the urgent situation; when the ship is in the urgent situation, the two drivers communicate to avoid collision.

Combined with the distance model of ship safety meeting, the conflict circle at each point is drawn to determine the distance of our ship safety meeting at each point. Finally, combined with the early warning model, by comparing the intersection of the trajectory of the target ship and the conflict circle of our ship, the advance collision avoidance warning is realized.




## 2.2. Ship collision assistance system based on identification and identification technology

### 2.2.1. Ship visual target detection

The ship target detection system of this system is mainly used in the densely active area of fishing boats. The merchant ship carrier camera or shore-based camera in the fishing area detects the image and recognizes the appearance of the ship. When the target ship enters the lens field, the target detection in the area of the image where the ship is located. The extracted features are detected by the SVM (Support Vector Machine) classifier, and finally the precise positioning of the visual information of the ship target in the video or image is obtained.

### 2.2.2. Ship visual image recognition

Convolutional neural network:

The convolution layer receives the input image of the input layer or the feature graph of the input of the previous layer, performs the convolution operation through the N convolution cores, and then activates it with the activation function, and inputs the resulting N new feature graph to the adjacent subsampling layer. The downsampling layer downsamples the input feature graph, which can effectively extract the representative local features and reduce the calculation complexity formula:

$$x_j = f\left(\sum_{i \in M_j} x_i^{l-1} * k_{ij}^l\right) + b_j^l$$

The fully connected layer includes the input layer, the hidden layer and the output layer. The feature graph of the upper layer is stitched into one-dimensional input, and the final output result is obtained by weighted sum and activation

$$x^l = f\ (\overline{w}^l x^{l-1} + b^l\ )$$

The convolutional neural network is trained by the back-propagation error, and the adaptive adjustment of the convolution kernel is constantly made in the training of the error reduction.

The ship image classification model adopts the AlexNet model framework to improve the performance of convolutional neural networks. See Fig 2-1 for the specific structure.

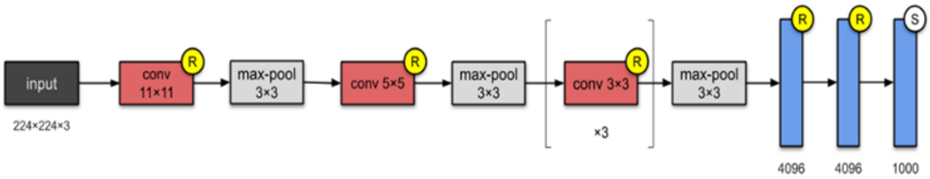



Fig 2-1 The AlexNet model framework

AlexNet The Convolutional network has 60 million parameters, 8 network layers- -5 convolutional layers and 3 fully connected layers. Compared with traditional convolutional neural networks, AlexNet stacks more network layers, which is suitable for classification training of image data sets. The implementation takes the linear rectification function as the activation function, using the overlapping pooling of convolutional neural networks.

Ship image recognition:

The Alexnet-CNN convolutional neural network structure solves the problem of inaccurate information exchange between ships to a certain extent, greatly reduces the incidence of various ship collision accidents, and improves the navigation efficiency of ships.

The experiment uses 1500 training samples and 300 test samples, which can achieve the recognition rate of up to 90% in the data set, which is sufficient to prove the robustness and adaptability of convolutional neural network than the traditional recognition algorithms.

### 2.2.3. Ship nameplate identification

Image acquisition:

First of all, one camera was used to conduct a large range of real-time monitoring of passing ships in the basin, and then the dynamic image sequence analysis method was used to obtain important information such as ship position, speed and heading. Finally, the other two cameras were used to close up the ships and get the ship nameplate images.

Image preprocessing:

The images were grayscale by weighted average method, defined as follows:

$$Grayg=0.299R+0.578G+0.114B$$

The gray value of all pixels in the grayscale image is set to 0 or 255, so that the image presents a clear black and white differentiation, so as to divide the target object in the image and the background. The thresholding method is used to complete image thresholding.

Image localization and segmentation:

Image positioning and segmentation First, the positioning method based on grayscale image is used to determine whether there is a nameplate in the image to be inspected. If so, the nameplate position can be accurately and quickly located, and then the nameplate based on cluster analysis method is used to segment the nameplate from the whole image.

Character recognition:

Character recognition was completed by combining template matching with a neural network. Representative characters are extracted from the segmented image characters, then matched with the sample set one by one, and finally find the characters with the closest similarity to complete ship identification.

## 2.3. Dynamic simulation of collision avoidance based on unity3D

The project uses 3D Studio Max to establish a model of the simulation system. First, physical photos of different ship types were collected, and polygon grid modeling, mapping processing, smooth modification and model rendering were performed in 3D Studio Max software, obtaining model resources in FBX format and packaged respectively, so as to complete the establishment of three-dimensional models of merchant ships and fishing boats. The renderings of the 3 D modeling are shown in Fig Fig 3.1.

Fig 3.1 3 D modeling effect diagram of commercial fishing boats

The motion simulation of two scenarios is set, which is respectively for the avoidance warning of ships in dense fishing area and the collision avoidance through trajectory prediction in fog. The simulation effects are shown in Figs 3-3 and Fig 3-4.

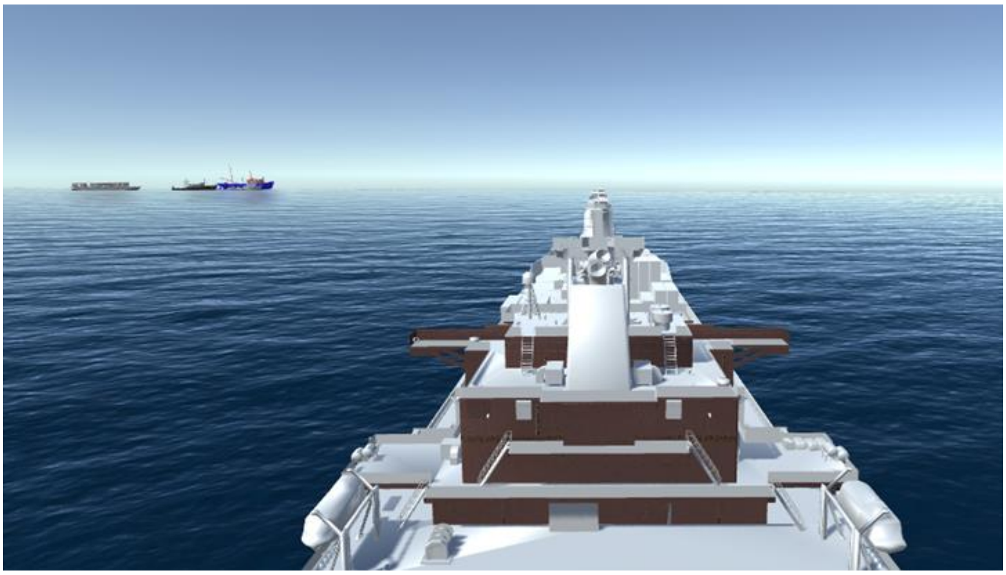


Fig 3.3 Avoid early warning of ships in dense fishing areas

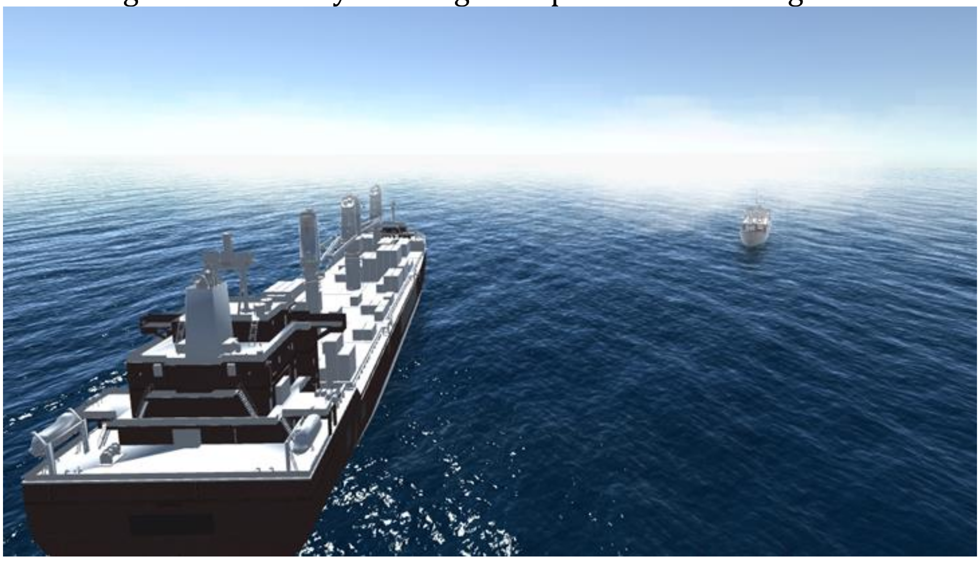


Fig 3.4 Avoid avoidance on a single ship

# 3. Research areaInsufficient research and future plans

## 3.1. Shortage of research

### 3.1.1. Lack of high-accuracy flight track prediction

At present, the ship track prediction technology often has insufficient accuracy and poor generalization. In maritime environments, especially those far away from land, communications and data transmission may be limited. Due to the propagation characteristics of radio waves on the sea surface, data transmission may be disturbed or delayed, which may affect the real-time and accuracy of track data, thus affecting the accuracy of track prediction.

### 3.1.2. Lack of accurate ship target detection

The water traffic environment is complex and changeable, such as weather, hydrological conditions, channel conditions and other factors may affect the movement state of ships. In addition, the interaction and communication between ships may also be affected by noise, interference and other factors, leading to the system cannot accurately obtain and analyze ship dynamic information.

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#### 3.1.3. Lack of integrated display of multi-source and heterogeneous information

The intelligent collision avoidance early warning system of commercial fishing boats requires a large amount of ship dynamic data to train and optimize the model. However, due to diverse data sources, inconsistent data formats and uneven data quality, insufficient model training or weak model generalization ability may result, thus affecting the accuracy of ship target detection. Due to the uneven data quality, the system may be unable to accurately obtain and analyze the ship dynamic information, thus affecting the integration and display of multi-source heterogeneous information.

### 3.2. Future plan

#### 3.2.1. Build the ship conflict diagram

On the basis of ship track prediction, the ship conflict diagram is constructed to determine the status of the ship through the distance between our ship and the target ship in the future, so as to realize the early warning. By analyzing and comparing the interaction and conflict between different ships, it can provide the decision basis for the navigation, scheduling and management of ships.

#### 3.2.2. Sound navigation information for fishing boats

Through the shipboard or shore-based camera, the serious shortage of AIS information and radar information in weak horsepower and wooden structure ship information capture is compensated from the perspective of visual recognition, and the navigation information of fishing boats is improved, providing sufficient criterion for commercial fishing boats to avoid collision, and the safety of navigation in the fishing area is improved.

#### 3.2.3. Integrated data

Based on Marine electronic chart, multi-source heterogeneous data such as ship accident history data, ship dynamic and management data, AIS data, electronic chart and weather data are integrated and displayed on the same platform (mobile terminal and computer end). Establish a unified data model to ensure seamless data from different sources. Using the ETL (extract, transform, load) tool, the data of each data source is cleaned and converted and loaded into the data warehouse.

#### 3.2.4. Build marketing channels

Personal marketing channel construction —— adhere to high frequency and high transmission volume:

Through the way of resource exchange, users can be promoted on online platforms often used by shipping enterprises such as wechat public account, Weibo and shipping forum.

Cooperate with Weihai Maritime Safety Administration to provide the required hardware for the use of regional ships, rapidly expand the cognition, attention and use of this project of shipping enterprises, and take advantage of the characteristics of strong mobility of shipping personnel to spread the product value. According to the successful model, it is copied to all provinces and cities in stages, and held various innovative and promotion activities with wide participation.

Collective marketing channel to build —— product development and promotion:

The early warning support and intelligent control system for commercial and fishing boats is an innovation and entrepreneurship project supported by Shandong Communications University and Shandong Provincial Department of Communications of our university. It has strong practicability and high novelty in the shipping field, and can effectively improve the safety of maritime navigation. Relying on the strong practical use, under the recommendation and connection of professional instructors, we actively cooperate with institutions to promote.

This project is precisely targeted to improve the navigation safety of commercial fishing boats, plus the enthusiasm of many entrepreneurs for public education,

Actively form strategic cooperation with websites and TV stations, promote projects on their entrepreneurial channels, and attract organizations

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