Research on ship domain in narrow fairways based on AIS data

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Abstract. In order to obtain the ship domain in narrow fairways, Combined with the automatic identification system of ships, it contains a huge amount of data and wealth of ship information. This paper deals with AIS data from zhou shan luotou water channel by using SQL 2012 database, We establish dynamic and static information database of narrow channel. Selecting target ship and calculating the distance and relative azimuth of other ship to the target ship at each moment, obtaining the single ship’s position distribution map, classifying the speed of ship, superimposing the single ship's position distribution map at same range of speed, get the specific types of position distribution map, the boundary of ship domain is determined by mathematical statistics, We study the ship speed in the interval of 6 ~ 8, 8 ~ 10, 10 ~ 12, 12 ~ 14, 14 ~ 16 knots at these five classes of ship domains, through analyzing, the length at the long axis and short axis are increasing with the speed of ship, the increase magnitude at the long axis is greater than short axis.

1. Introduction
Since the concept of ship domain was put forward in 60s of last century, it has been used in maritime traffic safety risk assessment, also, it has always been considered as one of the most effective theories to study ship traffic and ship behavior, and it is the focus of Chinese and foreign scholars[1]. The British scholar Goodwin statistics traffic flow on the Southern Beihai waters, constructed ship domain of open water combine to the international regulations for preventing collisions at sea, the model have three fan-shaped sectors by the port, starboard part and the rear part [2]. Pietrzykowski established ship domain in the open water through the statistical method[3]. Qi using the traditional Distance at Closest Point of Approach(DCPA) and Time to Closest Point of Approach(TCPA) and combine with the fuzzy theory, established the ship domain model of qiongzhou Strait by using AIS data[4]. Ding considered the type and length of ship, selected the AIS information from Chengshantou waters, and established different model of ship domain [5].

Above the area study on ship domain are the open waters, they did not take into account the influence of ship speed on the ship's domain, but in narrow fairways, because of the influence of channel width and ship performance, the ship speed has a great influence on ship scale and shape [6-7]. Therefore, in order to accurately calculate the ship domain in narrow fairways, it should be build model of ship domain in narrow fairways by using AIS data. Firstly, filtering those required ship information by using massive AIS data, as the target ship sailing and calculating the relative distance and azimuth of the other ships to the target ship at each moment, the single ship's position distribution map is formed, then composite the single ship's position distribution map according to the speed of the ship, get the specific type of ship's position distribution map, then the circular area is divided into a
series of fans, counting ship point at each region, then we using the method of documentation 8 to determine the boundaries of the ship domain.

2. algorithm

2.1 definition
The ship domain in narrow fairways is determined by the relative position from ship's encounter state, and the relative position consists of relative distance and orientation which other ships around the target ship. The relative position can be determined by selecting the target ship and observing the distribution of the ship in its vicinity. In addition, in order to more accurately calculate the ship domain in narrow fairways, we need to take into account the impact of ship speed on the ship's domain, due to the time is restricted which ship navigating in narrow fairways, the single ship's position distribution map is not complete, so it’s necessary to superimposed same type of ship's position distribution map. It can be classified into different type according to the target ship speed, we getting specific types of ship's position distribution map by superimposing same type of ship's position distribution map. The terms used in this article are as follows;

AIS data: receiving by ship automatic identification system, which contains the position of specific ship, navigation condition and ship size in continuous time.
Target ship: the ship to be analyzed for navigation more than a period of time in narrow fairways.
Other ships: all ships around target ship near 3 nautical miles.
Single ship distribution diagram: the distribution of ship around target ship at a given moment.
Single ship's position distribution map: superimposing the single ship distribution diagram at all moment.
The specific type of ship's position distribution map: we classify target ship and other ship in a standard (this paper to classify the ship with the speed range), superimposed on ship's position distribution map which meet conditions, so as to obtain The specific type of ship's position distribution map.

2.2 The principle of algorithm
The principle of algorithm: firstly, the AIS data was processed, a number of target ships are selected, the target ship is taken as the center, and the distribution of other ship around the target ship at each moment is calculated, as the target ship continues to sailing, the distribution of ships around each moment is superimposed to obtain single ship distribution diagram, the single ship distribution diagram is superimposed to obtain special ship distribution diagram based on the rule of ship speed, the algorithm flow chart as shown figure 1.

3. The method of calculation ship relative position
Step1: The AIS data processing: the main work is delete the Maritime Mobile Service Identity (Maritime Mobile Service Identity, MMSI) for 0 records; remove obvious error in the AIS data such as velocity >100, longitude>180, latitude>90, heading >360, the length and width is obviously does not meet the requirements.
Step 2: Target ship is selected: from the AIS data, we select those ship which speed and course are stabilize and navigating over a certain length of time.

Step 3: other ship is selected: the target ship as the center, we selecting those ship which time difference $\Delta t < t$, because most of the AIS data broadcast time interval in $2S \sim 3min$, so this paper $t$ is take for 3 min, when there is more than a moment in $t$ time,we select shortest time away from the center of the time.

Step 4: The position distribution of other ships: taking the target ship as center, we calculate relative position of the ship around target ship at any given moment. Relative positions are made up of distance and relative orientation. Because the broadcast time interval of AIS data from each ship is not consistent, so the other ship position converted to the target ship at the same time, the conversion formula as follows;

$$V_{A_1} = V_{A_0} + \frac{t_1-t_0}{t_2-t_0} (V_{A_2} - V_{A_0})$$

$$A_i = A_0 + \frac{V_{A_0} + V_{A_i} (t_1-t_0)}{V_{A_0} + V_{A_2} (t_2-t_0)} (A_2 - A_0)$$

Where $t_1$ is a time of the target ship, $t_2, t_3$ is the closest two time of other ship to target ship. $V_{A_1}$ is speed of the ship alongside target ship at the time $t_1$, $V_{A_0}, V_{A_2}$ is the time $t_0, t_2$ corresponding speed, $A$ is the position of other ship.

Step 5: Calculates the relative position of the other ship to target ship. The relative positions include the distance $D$ and relative azimuth $B$.

The distance $D$ is calculated as follows;

$$D = \sqrt{(\lambda_2 - \lambda_1)^2 + (\phi_2 - \phi_1)^2}$$

$$C_1 = \tan^{-1}\left(\frac{\sin B \times \tan D_1 - \sin \phi_1 \times \cos D_1}{\cos \phi_1 \times \cos D_1}ight)$$

Where $\lambda_1, \lambda_2$ is longitude, $\phi_1, \phi_2$ is latitude, $D_1$ is the difference longitude between two ship.

4. The analysis traffic flow in narrow fairways from Zhoushan luotou channel

The luotou channel at southern sea area of Zhoushan is an important part of ship navigation channel, the length and width of the channel are 8 and 1.2 nautical mile respectively[9]. It is a typical narrow water area, therefore, this paper selects the luotou channel as the research area. Firstly, filtering out incomplete and error AIS data information, the latitude and longitude range is chosen respectively as
29.9168N～29.9656N, 121.9909E～122.1197E, the time is selected January in 2016. We establish database of luotou water channel, we are obtain distribution of ship speed by statistical analysis of AIS data, the distribution of ship speed as shows figure 2. According to figure two we can find that ship speed in 2～6, 6～8, 8～10, 10～12, 12～14, 14～16, over 16 knots, the number of ship are respectively 18, 180, 430, 382, 218, 120, 1; the percentage are respectively at 1.33%, 13.28%, 32.18%, 28.19%, 16.09%, 8.86%, 0.07%. We can conclude that the ship speed mainly distributes in 6 to 16 sections, therefore, we study the ship speed in the interval of 6～8, 8～10, 10～12, 12～14, 14～16 knots at these five classes of ship domains.

5. The calculate method of ship domain in narrow fairways

5.1 The method of determining the boundary of ship domain

We using the methods of literature 8 " a ratio of ship distance excluded" to determine the domain boundaries. The steps are: firstly, we take the target ship's bow of 0 degrees to the center, rotate clockwise at 5 degrees intervals, divide the azimuth into 72 sectors, secondly, respectively statistic the number of ship point at each sector, and sort distance to the target ship, Finally, we find out the critical points, then 72 points are synthesized ellipse by MATLAB software, in this paper, we choose the critical value is equal to 95% .

5.2 The calculation of ship domain

The figure 3 of a, b, c, d, e respectively corresponding to the speed in the interval 6～8, 8～10, 10～12, 12～14, 14～16 knots these five cases of the ship’s domain. We can find that the length of long axis are respectively 0.565, 0.614, 0.652, 0.735, 0.909 nautical mile, and the length of short axis are respectively 0.264, 0.282, 0.3, 0.357, 0.381 nautical miles. The length distribution curve of the long axis and short axis are shown in figure 4. We can conclude that the length at the long axis and short axis are increasing with the speed of ship, the increase magnitude at the long axis is greater than short axis.
FIGURE 3. The distribution of ship domain

FIGURE 4. The length distribution of long axis and short axis

6. Conclusion
In this paper, we establish the model of ship domain in narrow channel by using massive AIS data, and considering the effect of ship speed, calculating five types of ship domain, the experimental results show that the length at the long axis and short axis are increasing with the speed of ship, the increase magnitude at the long axis is greater than short axis. The shortcomings of this paper do not take into account the influence of ship type and length, these will be my next steps to be studied.

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