The Study on the Safety Domain of Aids to Navigation based on Automatic Identification System

Jianyong Li*, Chuanying Zhu*
Tianjin AtoN division, The Navigation Guarantee Center of North China Sea, Tianjin, 300456 China
*Corresponding author e-mail: lijy59843@163.com

ABSTRACT

To determine the safety domain of the aids to navigation (AtoN), this article used analytical geometry methods to get the three-dimensional gyration model of the AtoN in ideal condition. Based on the ship's automatic identification system (AIS) data around the AtoN, we could get the distribution of the closest passing points of the ships around the AtoN, study and explore the distribution pattern of these closest points, then perform the composite analysis with the turning radius of the AtoN. We could get the safety domain model of the aids to navigation based on the AIS data by taking the ships' distribution probability as the correction coefficient and modifying the turning model of the aids to navigation.

Keywords: Aids to Navigation, Safety Domain, Automatic Identification System, Navigation Guarantee

1. BACKGROUND OF THE STUDY

1.1 Background

The administrators of the aids to navigation frequently found the AtoN destroyed or chain twined by the fishing nets and other bad conditions in their daily work. These cases were mostly caused by the collision of the ships and the fishing activities around the AtoN. According to the study of relevant laws ,Administrative regulations, regulations, mandatory standards, technical standards, some articles in these above show that the behaviors of the ships , facilities in water or the operators, officers on deck should be in conformity with relevant regulations and technical standards of the AtoN. The officers on deck usually control the ships navigating as far as possible of the AtoNs. But the minimum distance between the ship and AtoN is not defined by a certain regulation but defined by the good seamanship.

1.2 Definitions

(1) The ship domain: Fujii (a Japanese professor of maritime transportation) thought that one ship should keep a certain distance off the other ship overtaken to keep safe. And the area around the ship overtaken was regarded as ship domain of the ship overtaken.

(2) Distance of closest point of approach (DCPA): There would be a minimum distance between one ship and other ship or objects when the ship was navigating on the sea.

1.3 Models related

There were many models about the ship's domain in the world and the Fujii model, Goodwin model, Coldwell model of the ship's domain were very classical and accepted by most scholars and many improvements were proposed by many scholars in maritime transportation engineering. The study of the AtoN domain is not enough and the gyration circle of the AtoN was usually regarded as its domain. We defined the safety zone of the AtoN as safety domain of the AtoN. This article studied the ships' movements around the AtoN based on the AIS data of the ships in the circle zone of 300 meters radius around the D1# buoy in Dongying port Shandong Province. There were some risk zones around the AtoN. There were risks to ships and the facilities affiliated. There was negative influence on the functions of the AtoN once the ships entered the safety domain of the AtoN.

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2. THE DEFINITION OF GYRATION CIRCLE OF THE ATON

We could get the gyration range of the AtoN according to the study of the mooring system of the AtoN(the buoy or the other mooring system) in ideal condition in fig.1.

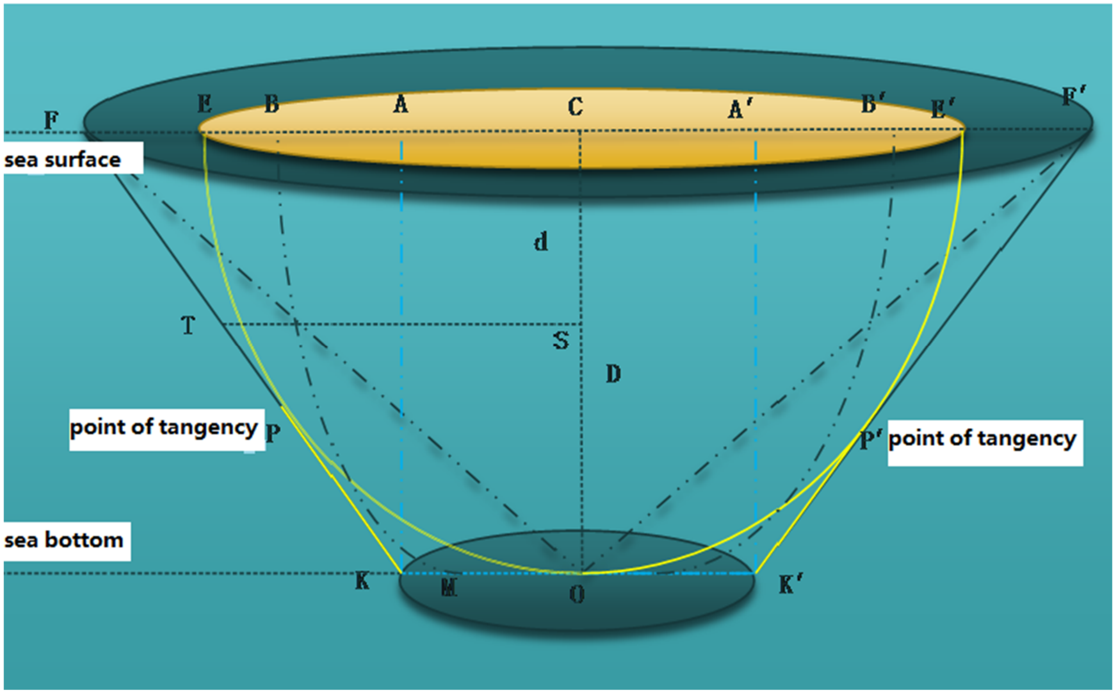

Fig. 1 The three-dimensional Schematic diagram of the gyration of the buoy

Points C, B, A were the position of the buoy in different conditions; point E was the limit position of the buoy on waters; F was the limit length of the chain when the chain of the buoy regarded as a straight line in ideal condition. D was the depth of water of the buoy in nautical charts. O was the designed position, OK was the maximum length of the chain in sea bottom; OMB was the state of the chain in the water. OE was the state of the chain in limit load. OF was the state of the chain in ideal condition. In order to make the model simply and easily used, this study selected the state of the chain of the buoy in ideal condition.

$$\mathrm{OK} = \mathrm{L} - \mathrm{D} \tag{1}$$

$$\mathrm{CF} = \sqrt{(\mathrm{L}^2 - \mathrm{D}^2)} \tag{2}$$

L was the length of the chain, and L was selected from two to five times of the depth of the water in practice.

The angle between the curved surface of AtoN gyration which the KF was in and the water level was θ ,so

$$\cot\theta = \frac{\sqrt{\mathrm{L}^2 - \mathrm{D}^2} - (\mathrm{L} - \mathrm{D})}{D} \tag{3}$$

According to the Equation (1)(2)(3), for the random depth in chart was d and the radius of the gyration cross section of AtoN was ST

$$\mathrm{ST} = \cot\theta \times (\mathrm{D} - \mathrm{d}) + (\mathrm{L} - \mathrm{D}) \tag{4}$$

Affected by the error of the AtoN position, the results amended were:

$$\mathrm{OK} = \mathrm{L} - \mathrm{D} + \Delta 0 \tag{5}$$

$$\mathrm{CF} = \sqrt{(\mathrm{L}^2 - \mathrm{D}^2)} + \Delta 0 \tag{6}$$

$$\mathrm{ST(d)} = \cot\theta \times (\mathrm{D} - \mathrm{d}) + (\mathrm{L} - \mathrm{D}) + \Delta 0 \tag{7}$$

According to the Equation (1)(2)(7), we could get the gyration range of the AtoN.

3. THE SAFETY DOMAIN MODEL OF ATON BASED ON THE AIS DATA

The depth of the Buoy D1# was 13.6metres. And the length of the chain of Buoy D1#was selected 3times of the depth. We consider the chain as a rigid body. The variation of depth caused by tides was ignored and the influence to the length of chain caused by the buoy body and the sinker was ignored. We could get the trace of Buoy D1# in one week of October 2021 like fig.2 in the Navigation Guarantee Operation Administrative System. (An aids remote monitoring system)

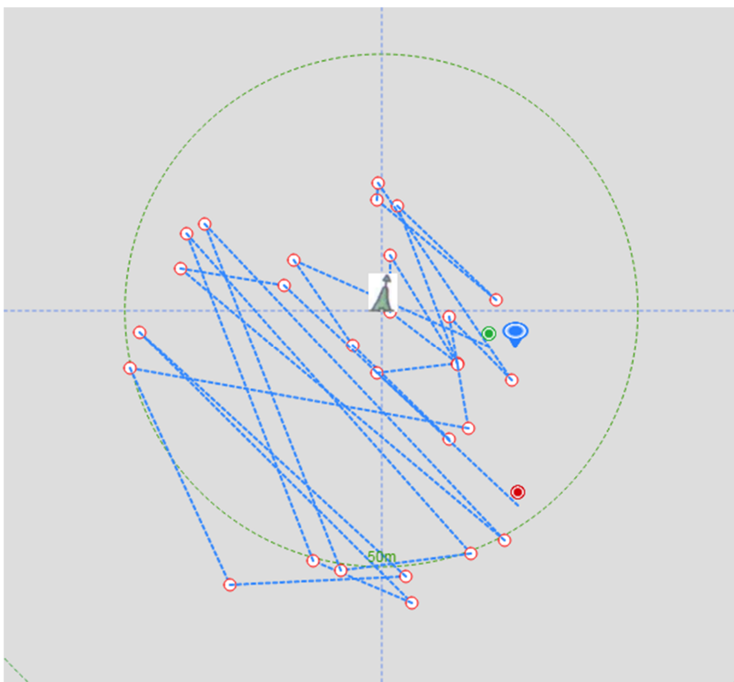

Fig. 2 The trace of Buoy D1# in one week

We could conclude that the the position of the Buoy D1# moved back and forth which would be caused by the alternating tides. This fig.2 shows that the maximum distance of Buoy D1# drifted was 58metres which was longer than the length of chain far and away. This result showed the position of the sinker was deviated from the designed position. We could estimate that the position of the sinker was southwest to the designed position, the relative bearing was 209°,distance was 20 meters. The ship and her equipments affiliated should not go into the gyration zone of the aids when she passed the buoys. Additionally we could get the radius of the gyration zone, the ST was 58.47metres.

The ships' AIS data in one week of October of 2021were selected to study and the ships were in the circle zone of 300metres radius around the Buoy D1#. We could get the relative position diagram by taking the position of Buoy D1# as original point. The fig.3 showed that.

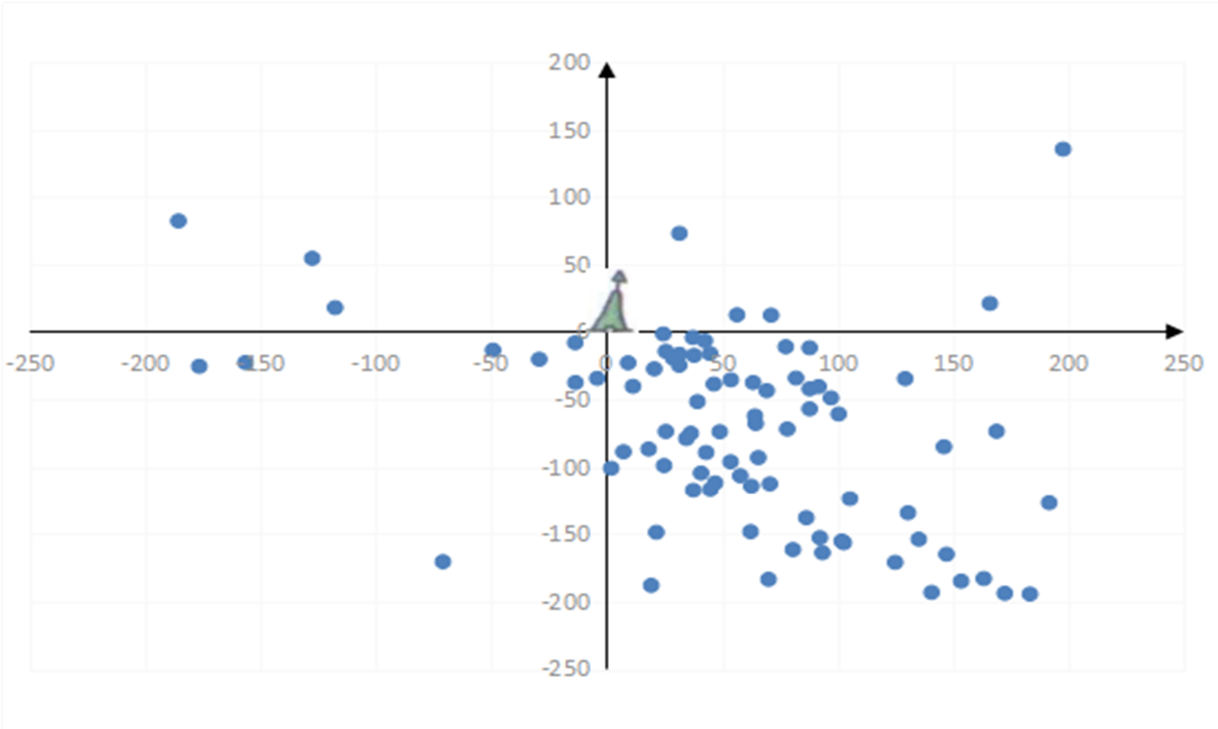

Fig. 3 The diagram of relative distribution of the ships' position

We could get 86 ships' traces which were 5 ships in the first quadrant, 3 ships in the second quadrant, 8 ships in the third quadrant, and 70 ships in the fourth quadrant. The percents of the ships in the four quadrants were 5.81%、3.49%、9.30%、81.40% and that was to say 81.40% of the traffic flow was northeast to southwest which was in accordance with the conventional direction of buoyage, the fig.4 illustrated.

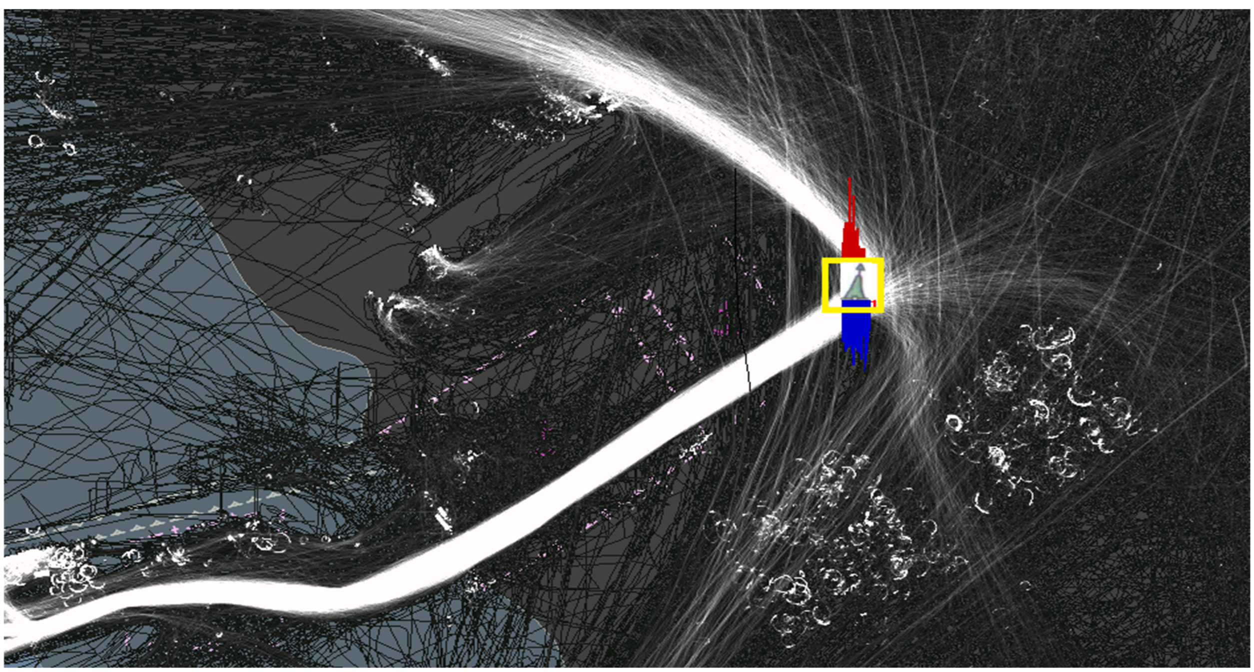

Fig. 4 AIS flow of ships

Tab. 1 The ships gone through the AtoNs' winging range

Ships' DCPA	Quantity	Percents
<38.47(Δ0=0)	10	11.63%
<58.47(Δ0=20)	18	20.93%

Influenced by the accuracy of the BeiDou or GPS, the location of the positioning antenna, sinker sinking flow etc, the real position of the sinker was not the designed position. We could get the minimum error about 10 meters by the positioning equipments and good seamanship of the buoy tenders. This study selected the error of sinker was 20meters and we could get the information of the ships which went through the gyration zone of Buoy D1#, the Tab. 1 showed that.

We could put the positions of ships which went through the gyration zone (swinging zone) and the AtoN trace together in fig. 5. The points stood for the closest points to the AtoN and the broken lines stood for the trace of the Buoy D1#. We could see that some ships went through the swinging zone of the AtoN.

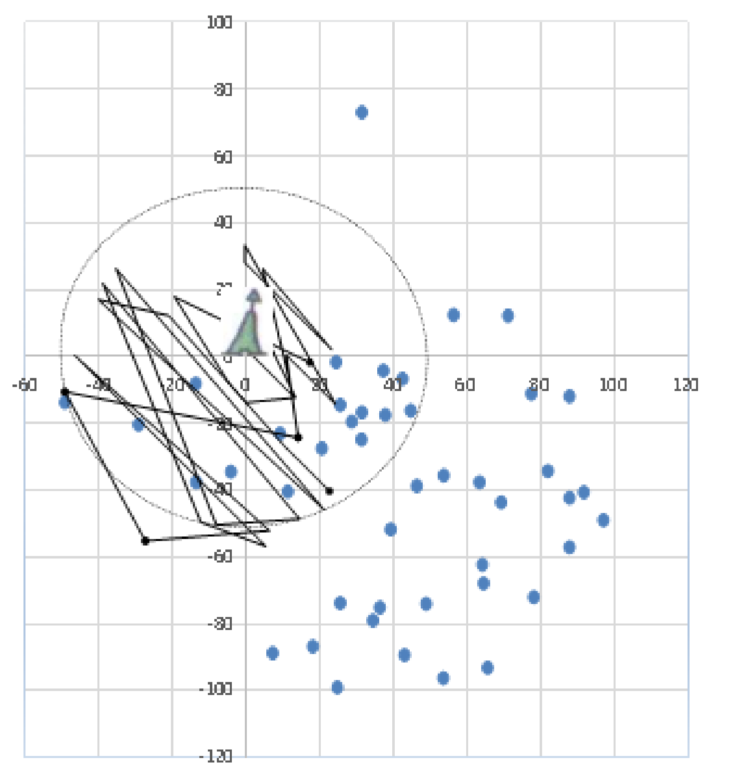

Fig. 5 The distribution of the ships in the winging zone

We could get the scatter diagram of the closest points of the ships which went through the swinging zone. And we could compute the convex hull of the scatters by using the MATLAB.The fig.6 illustrated that.

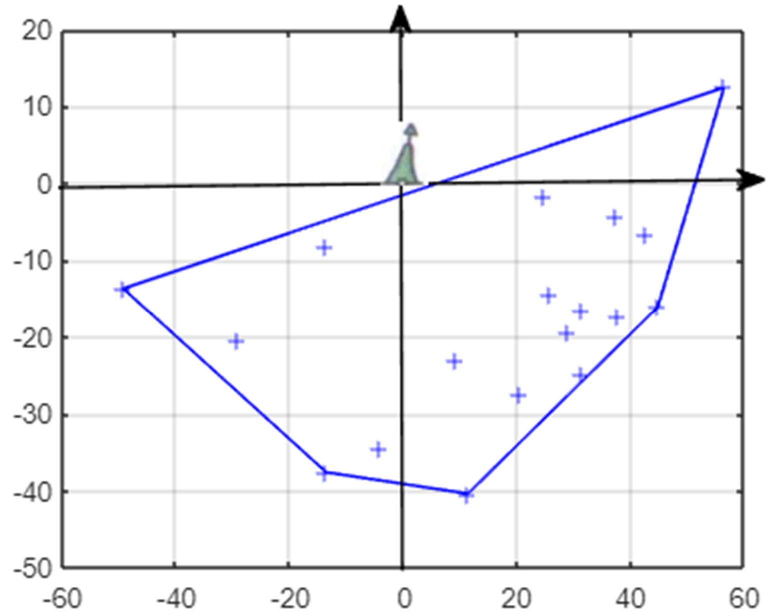

Fig. 6 The set of the closest points of the ships

There were distinct characteristics on the distribution of the closest points. The 5.5% of the ships were closest to the Buoy D1# where the bearing is 0°~90°. The 66.7% of the ships were closest to the Buoy D1# where the bearing is 90°~180°. The 27.8% of the ships were closest to the Buoy D1# where the bearing is180 0°~270°. To reduce the probability of collisions between the ships and the AtoN, this study used the probabilities of the ships going through the swinging zone of the Buoy D1# from each bearing as correcting coefficient to correct the swinging range of the AtoN. The safety domain was illustrated by the Fig. 7.

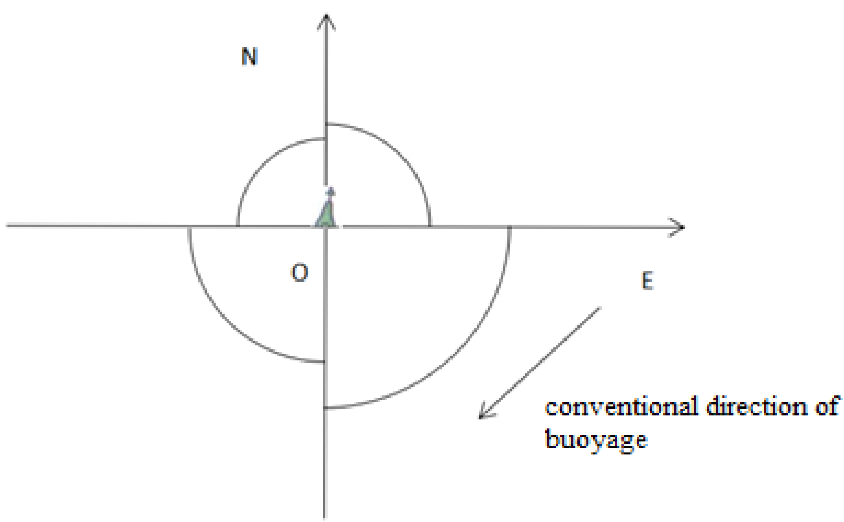

Fig7. The safety domain of the AtoN corrected by the AIS data

The first quadrant was a circular sector with radius 61.39meters. The second quadrant was a circular sector with radius 58.47meters. The third quadrant was a circular sector with radius 74.72meters. The fourth quadrant was a circular sector with radius 97.47meters.

4. CONCLUSION

(1)The safety domain model corrected by the AIS data could mostly reduce the quantity of ships went through the swinging zone and reduce the probability of collision between ships and buoys. That could keep buoys protected and ships safe.

(2)In practice there would be errors between the real position of the buoy and the designed position of the buoy. The errors above would amplify the range of the safety domain of the AtoN and reduce the navigating area of ships because the waterways were limited. So we should reduce the errors between the real position of the buoy and the designed position by advanced technology and good seamanship. Additionally we should recover the buoys once moved as soon as possible.

(3) The ships should keep safety distance to the buoys. The officers on deck should pay much attention to considering the safety domain of the buoys.

(4)Because the dimension, maneuvering performance, draft of different ships were different, the sucking effects when the ships passed the buoys were different. In conclusion, the safety domain of the buoys was different for different ships. The officers should keep good seamanship to avoid going through the safety domain of the buoys.

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