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A Study on Alarm System for Small Ship Safety Navigation in Ningbo-Zhoushan Port

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Abstract

There are many casualties and incidents occurring to ships every day, and collision accidents occurred between small and large ships in the Bay and the surrounding water. We have made an accident survey of Ningbo-Zhoushan Port. We analyzed the accident in geographic position and ship's type, and we found insufficient lookout and unsmooth communication are the main reasons. In view of the navigation environment, ship's manoeuvreability and the navigation equipment installed on ships, we set the standard DCPA (Distance to Closest Point of Approach) and TCPA (Time to Closest Point of Approach) of alarm for small ship. The alarm based on 3G network, it can be used to solve the insufficient lookout and unsmooth communication problems. We got some AIS (Automatic Identification System) data from Nagoya Port, and we put them in the ArcMap to simulate the proposed alarm system.

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1. Introduction

Ningbo is a seaport city in the northeast of Zhejiang province in China, it lies south of Hangzhou Bay and facing the East China Sea. It is the crossroad of the north-south shipping route and the important waterway of the Yangtze River. It enjoys the conditions with convenient traffic reaching in all directions. Outwardly the port links East Asia and the whole round-the-Pacific region within 1,000 sea miles to Hong Kong, Gaoxiong of Taiwan, Pusan, Osaka and Kobe. Ningbo Port has economic trade with over 560 ports from more than 90 countries and regions in the world. It comprises several ports (red symbol in Figure 1), which are Beilun (seaport), Zhenhai (estuary port) and old Ningbo harbor (inland river port), Daxie, Chuanshan etc. Now, Ningbo Port has a total of 191 berths including the 250,000 GT crude oil terminal and the 200,000 GT ore loading berth. There are 110 shipping lines for container transport and 480 regular liner services per month. The first 20 shipping companies of the world have all set up their agencies in Ningbo [1].

Zhoushan Port is located in the center of the southeast coast of China, having excellent deep water bay and comfortable international transportation. The water area of the bay is wide and the port pool is surrounded by islands forming national protection conditions with good avoiding wind and wave advantages. The port area has 11 port regions (green symbol in Figure 1) Dinghai, Shenjiamen, Gaoting, Sijiao, Liuheng, Jintang, Qushan, Maao, Laotangshan, Luhua port etc.

Ningbo-Zhoushan Port (Figure 1) has been the biggest port in the world for four consecutive years. In 2012, the annual cargo handling capacity is 744 million tons. At the same time it is the sixth biggest container ports in the world, the container handling capacity is 15.67 million TEU(Twenty-foot Equivalent Units) [2].

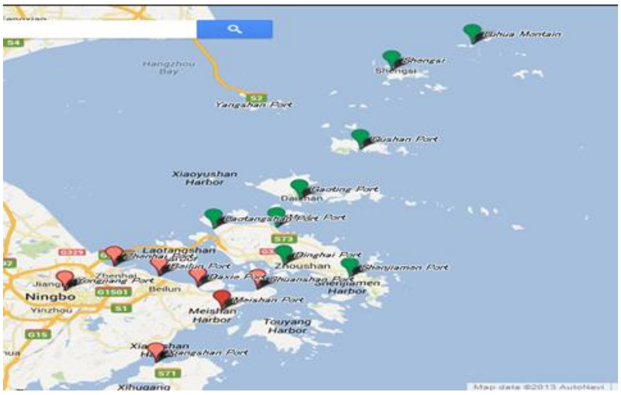


Fig.1. Ningbo-Zhoushan Port.

Figure 2 [3] and Figure 3 [4] are the data of inbound and outbound vessels of Ningbo-Zhoushan Port. From them, we know cargo ship accounts for the largest part in Ningbo port, and fishing boat accounts for the largest part in Zhoushan port. There are so many cargo ships and fishing boats, it would be one of the reason there are a lot of accidents.

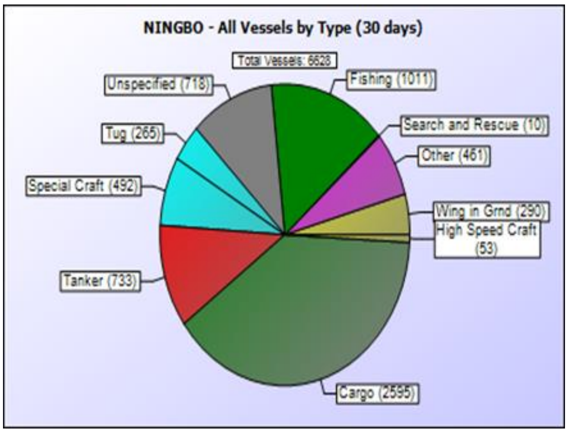


Fig.2. All ships by type in Ningbo.

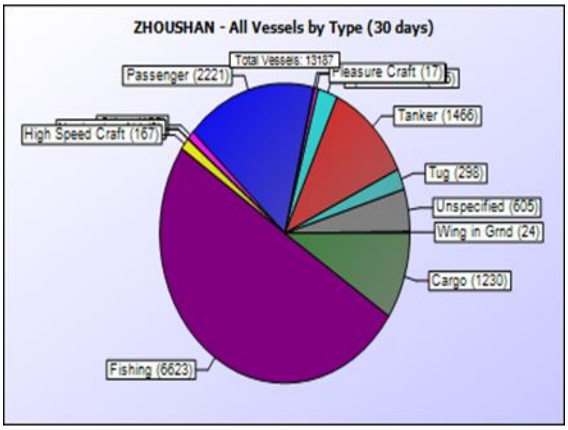


Fig.3. All ships by type in Zhoushan.

2. Accident Survey

Ship accident always be divided into collision, grounding, capsize, sank, fire, disaster caused by windstorm, disaster caused by tide etc. In this paper, we only consider the collision, sank, grounding and capsize. If the ship collides with the other ship, and then sank, we put it in sank. If the ship capsize and then sank by oneself, we also put it in sank.

We got some accident data (Table 1) which happened in 2012 from Zhejiang Maritime Safety Administration [5]. There are 28 accident examples includes 40 ships. Though it's just a part of the data, it contained almost characters of the marine accident. It is useful to analyze the marine accident.

From the ship's type in Table 1, we know that cargo ship accounts the largest part 55.0%, and sand carrier is the same with fishing boat 20.0%. Tug boat and passenger ship is least. From the type of accident, we know the collision accident is most serious 62.5%, the second is sank accident, 22.5%. The third is grounding accident 10.0%, capsize accident is least 5.0%.

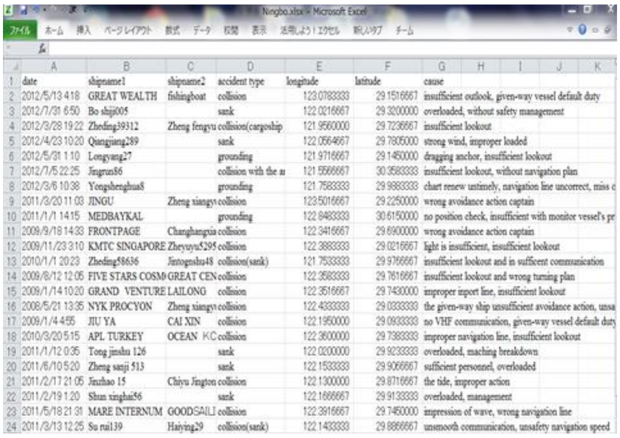
Table 1. Ship accident in Ningbo-Zhoushan Port in 2012.

Ship's Type / Accident	Cargo ship	Fishing boat	Sand carrier	Tug boat	Passenger ship	Total	Rate (%)
Sank	1	3	5	-	-	9	22.5
Grounding	3	-	-	-	1	4	10.0
Capsize	-	-	2	-	-	2	5.0
Collision	18	5	1	1	-	25	62.5
Total	22	8	8	1	1	40	100.0
Rate (%)	55.0	20.0	20.0	2.5	2.5	100.0	

2.1 Fishing boat accident

The provisions of regulation V/19 of SOLAS (Safety Of Life At Sea), 1974, as amended, requiring all ships of 300 GT and upwards engaged on international voyages, cargo ships of 500 GT and upwards not engaged on international voyages and passenger ships irrespective of size to be fitted with an AIS. The small ship without AIS will be the biggest problem in VTS (Vessel Traffic Services).

In the end of 2009, about 6,500 fishing boats have been equipped with Class-B AIS, which provides limited functionality and is intended for non-SOLAS Vessels; however, there are more than 30,000 fishing boats in Ningbo-Zhoushan Port. In 2008, province of Zhejiang government had given a standard for the safety information management system for the shipping boat. The engine power which under 44kw should install Class-B AIS, engine power under 44kw should install a GPS (Global Positioning System)/GPRS (General Packet Radio Service) one-key alarm system [6]. We know when the fishing boat working (drawing or releasing net), it is usually at a slow-velocity. Large ship can't resolve the dynamic (course, velocity) of the fishing boat with the Radar. In the bad weather, because the fishing boat is small target, in addition Radar clutter, it can't be displayed on the Radar screen. This may lead to an insufficient lookout to the large ship's navigator. Sometimes, when the fishing boat anchors in the night, nobody is on the bridge for lookout, they sometimes disregard the navigation law. Even though in sight of one another, the navigator of large ship has to use the radio telephone (VHF) to call the position of the small ship without AIS. As we know, the position changes at any time, in addition the linguistic barriers and noises of VHF, they can't have an efficient communication. In the recent survey (Figure 4), there are only 2 VHF calls in the 23 accidents. They haven't communicated successfully even one case.



date	shipname1	shipname2	accident type	longitude	latitude	cause
2012/5/13 4:18	GREAT WEALTH	fishingboat	collision	123.0783333	29.1516667	insufficient outlook, given-way vessel default duty
2012/7/31 6:50	Bo shiji005		sank	122.0216667	29.3200000	overloaded, without safety management
2012/3/28 19:22	Zheding39312	Zheng fengyu	collision(cargoship	121.9560000	29.7236667	insufficient lookout
2012/4/23 10:20	Qiangjiang289		sank	122.0564667	29.7805000	strong wind, improper loaded
2012/5/31 1:10	Longyang27		grounding	121.9716667	29.1450000	dragging anchor, insufficient lookout
2012/7/5 22:25	Jingrun86		collision with the a	121.5566667	30.3583333	insufficient lookout, without navigation plan
2012/3/6 10:38	Yongshenghua8		grounding	121.7583333	29.9883333	chart renew untimely, navigation line uncorrect, miss c
2011/3/20 11:03	JINGU	Zheng xiangy	collision	123.5016667	29.2250000	wrong avoidance action captain
2011/1/1 14:15	MEDBAYKAL		grounding	122.8483333	30.6150000	no position check, insufficient with monitor vessel's pr
2009/9/18 14:33	FRONTPAGE	Changhangxia	collision	122.3416667	29.6900000	wrong avoidance action captain
2009/11/23 3:10	KMTC SINGAPORE	Zheyuyu5295	collision	122.3883333	29.0216667	light is insufficient, insufficient lookout
2010/1/1 20:23	Zheding58636	Jintongshu48	collision(sank)	121.7533333	29.9766667	insufficient lookout and in sufficent communication
2009/8/12 12:05	FIVE STARS COSM	GREAT CEN	collision	122.3583333	29.7616667	insufficient lookout and wrong turning plan
2009/1/14 10:20	GRAND VENTURE	LAILONG	collision	122.3516667	29.7430000	improper inport line, insufficient lookout
2008/5/21 13:35	NYK PROCYON	Zheng xiangy	collision	122.4333333	29.0333333	the given-way ship unsufficient avoidance action, unsa
2009/1/4 4:55	JIU YA	CAI XIN	collision	122.1950000	29.0933333	no VHF communication, given-way vessel default duty
2010/3/20 5:15	APL TURKEY	OCEAN KC	collision	122.3600000	29.7383333	improper navigation line, insufficient lookout
2011/1/12 0:35	Tong jinshu 126		sank	122.0200000	29.9233333	overloaded, maching breakdown
2011/6/10 5:20	Zheng sanji 513		sank	122.1533333	29.9066667	sufficient personnel, overloaded
2011/2/17 21:05	Jinzhao 15	Chiyu Jington	collision	122.1300000	29.8716667	the tide, improper action
2011/2/19 1:20	Shun xinghai56		sank	122.1666667	29.9133333	overloaded, management
2011/5/18 21:31	MARE INTERNUM	GOODSAILI	collision	122.3916667	29.7450000	impression of wave, wrong navigation line
2011/3/13 12:25	Su rui139	Haiying29	collision(sank)	122.1433333	29.8866667	unsmooth communication, unsafety navigation speed

Fig.4. Accident data in Ningbo port (2009-2012).

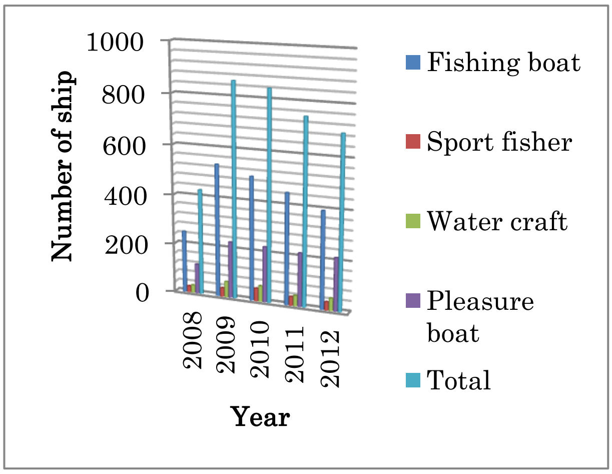


Fig.5. Small ship's accident in coast water of Japan.

From Figures 5 and 6, we know the small ship's accident is a very big problem in Japan coastal waters [7]. In 2011, there are 232 collision accidents of fishing boat and 145 collisions of pleasure boat in Japan coastal waters. They are 70% of all the marine accident. Insufficient lookout is 77% for fishing boat, 70% for pleasure boat.

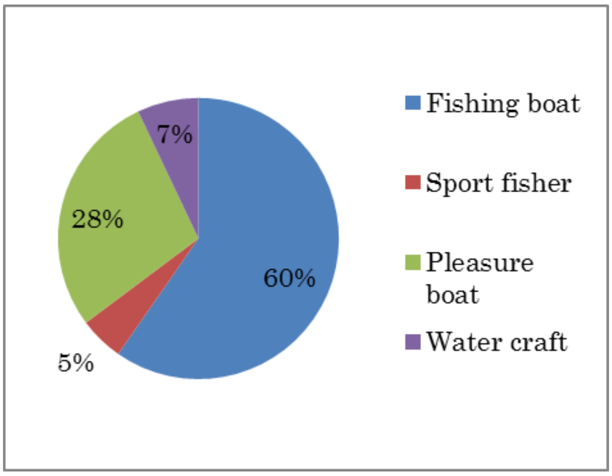


Fig.6. Proportion of accidents by ship 2008-2012.

From the accident data of Ningbo-Zhoushan Port and Japan coastal waters, we know the small ship is a common factor of marine accident in the world. In February 2012, we had investigated the Zhoushan Maritime Safety Administration and discussed with the VTS officers. Most causes of small ship's accident can be summarized as first, insufficient watch keeping; second, failure to aware of encountered ships; third, failure on the evaluation of collision risk and/or on decision for collision avoidance maneuver.

Based on the survey, we can say most of the accidents between small and large ships are due to insufficient lookout, however some of them are due to the information asymmetry and people ware. It is hard to raise the quality of fisherman to the level of a mariner because of the education levels. Moreover it is hard to promote the equipment installed on the small ship because of the cost problem.

In a perfect collision avoidance exercise, there four steps, firstly, the two ships in sight of each other; secondly, collision risk judgment; thirdly, take avoidance measure; and finally, to evaluate the collision avoidance action. If there is a wrong action in the procedure, it may lead to marine accident. In order to make the four steps safety, after we make a detailed survey on the accident black spot in Ningbo-Zhoushan Port. We will make a proposed alarm system for the small ship to solve the insufficient lookout problem and communication problem. When the target ship is near and with a collision risk with own ship, the alarm will be activated. This will solve the lookout and collision judgment problem. If the alarm activated, we will give some collision avoidance suggestion to the small ship's navigator to avoid wrong action. There are several problems need to be solves. Unify the information of small and large ships and VTS, set the standard value of alarm, finally, gave some collision avoidance suggestion.

2.2 Sand carrier accident

From Table 1, we know that sand carrier is also a serious problem in the port because of most of them sank or capsize. When we analyzed the data, we found the accident reason of sand carrier is most of them with a "V" shaped bottom, and if they overloaded, the center of gravity will become very high. When wind is strong with a large wave, the ship will capsize easily, and most of the sand carrier sank not to a collision, but to overload. Most of the sand carriers are under 1,000 GT. The dockworkers didn't make a load plan and sometimes the crew on board unqualified, they didn't make a navigation plan, in addition insufficient management of company, there are a lot of carrier's accidents happened. We recommend it to redesign the shape of the sand carrier's bottom, strengthen management of the ship management company, and increase the training of the crew.

2. 3 High frequency accident place in Ningbo Port

There are 23 accidents [8] with position information of Ningbo Port (Figure 4 & Figure 7). When we put them in the Google Maps, we found there are three accident black spots, open sea of Xiangshan (Figure 8), Chuanshan Port and north anchorage ground of Xiazhimen (Figure 9). The reason is there a high-density in North anchorage ground of Xiazhimen and the speed of tide is about 2~4 knots. When navigator tried to pass the head of an anchored ship, they always be pushed to the anchoring ship by the current, especially in poor visibility condition. There were 4 collision accidents happened in poor visibility situation. The position of Chuanshan Port is very particular, if the navigator only uses the radar, they may loss the target due to the visual disturbance. The open sea of Xiangshan is the crossing of merchant ships, that's the reason there are a lot of collision accidents.

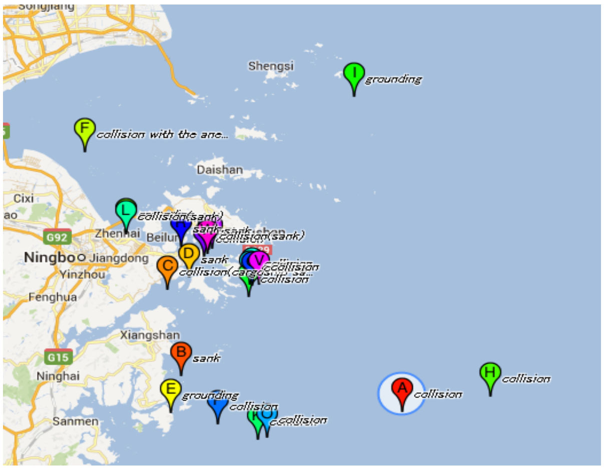


Fig.7. High frequency accident place in Ningbo port.

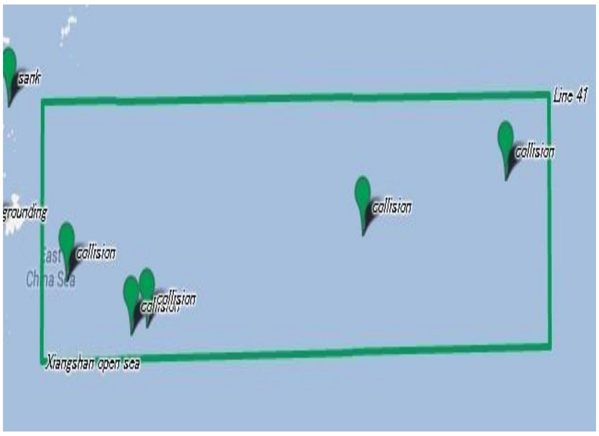


Fig.8. Accident black spot in Xiangshan open sea.

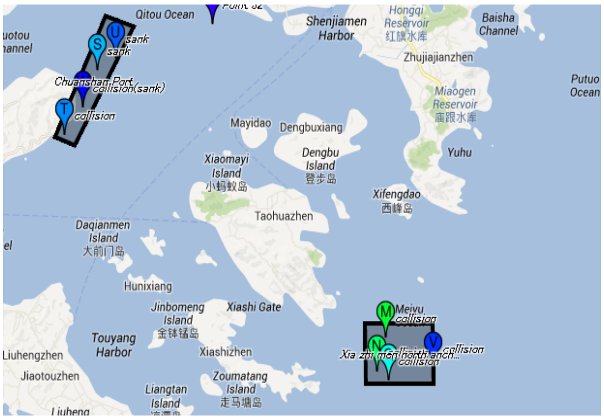


Fig.9. Accident black spot in Chuangshan Port & North anchorage ground of Xiazhimen.

3. Methodology

According ship's type and spot of the accident, we will make a proposal alarm system for the small ship based on 3G network. In our study [9], we have investigated the 3G network capacity wireless communication service in Ningbo-Zhoushan area. It can meet the needs of sending a message, giving a call and video communication. Our idea is apply a PDA (Personal Digital Assistant) for the fishing boat and connect with the GPS to display the ship's position, velocity, course etc. Meanwhile, use the PC (Personal Computer) to connect with AIS, Radar to display the information of large ship. The construction is Figure 10. We can use the 3G network to share the information between small and large ships. We would like to install some software like Skype, which can be used to communicate with each other in emergency situation.

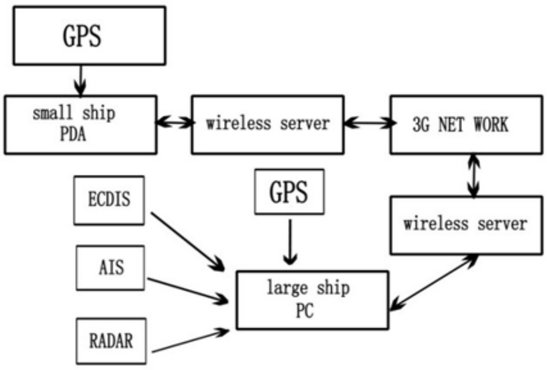


Fig.10. Information exchange system between small and large ships.

3.1 Standard of DCPA and TCPA

DCPA is the closest distance between two ships, it is the most import parameter to evaluate the risk of collision. TCPA is used to illustrate the urgency of accounting. As we know, on the large ship, the officers use ARPA/Radar to set a guideline to warn. For 10,000 GT ship on the open sea and in the restricted visibility, when DCPA is smaller than 2NM, it is considered as a dangerous distance for the two ships to pass clear with each other. How to set an appropriate DCPA and TCPA is important for a small ship in Xiangshan water. When we set the limit of DCPA and TCPA, we usually consider the ship's manoeuvreability, visibility, velocity ratio, navigation environment and the navigator's psychological quality etc.

In this paper, we use velocity ratio of the 10,000 GT-class ship's general practice on the open sea to get a suitable avoidance action time (AT) and avoidance action distance (AD) for the small ship in Xiangshan water. Then use the small ship's manoeuvreability to set the DCPA and TCPA. In the port, ship's speed should below 8 knots [10], we assume two ships' speed is 8 knots in port. On the open sea, in good visibility condition the 10,000 GT ship should take avoidance action at 3~4 NM, and in restricted visibility condition, should take avoidance action at 4~6 NM [11]. For security we use 4 and 6 NM to calculate the TCPA. On the open sea, assume two ships' speed is 15 knots in a small angle crossing situation, the relative speed is 30 knots, and from it we can get the AT, when AD is 4 and 6 NM, the AT is below;

$$AT_g = 4/30 \times 60 = 8\ (\text{min}) \qquad (1)$$

$$AT_r = 4/60 \times 60 = 12\ (\text{min}) \qquad (2)$$

Case in the port and nearby,

$$AD_g = 8/60 \times 16 = 2.1\ (\text{NM}) \qquad (3)$$

$$AD_r = 12/60 \times 16 = 3.2\ (\text{NM}) \qquad (4)$$

AT_g: Action time in good visibility condition
AT_r: Action time in restricted visibility condition
AD_g: Action distance in good visibility condition
AD_r: Action distance in restricted visibility condition

From the results, the small ship should take avoidance action at 2.1 NM in good visibility condition and 3.2 NM in restricted visibility condition. Though auto alarm should be earlier than the action, from the considered length and manoeuvreability of small ship, we propose to set the cordon at 2.1 NM in good visibility condition, and 3.2 NM in restricted visibility condition. In view of the delay of navigator manoeuvre, we add 1 min, and set the TCPA 9 min in good visibility condition, TCPA 13 min in restricted visibility condition for the small ship in port.

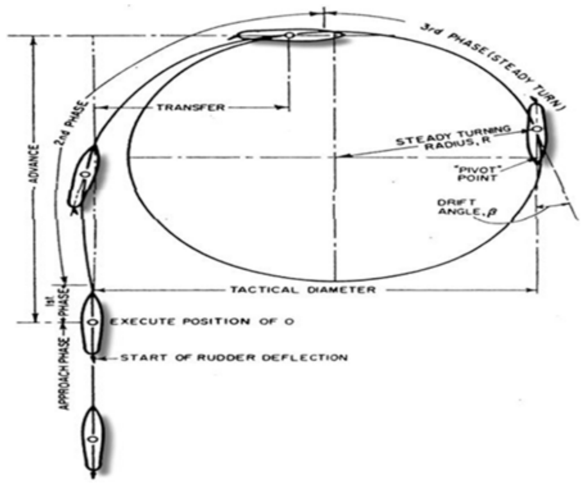


Fig.11. Ship's Turning Circle [12].

In the calculation, Figure 11 should be referred, regarding the diameter, the length of small ship is usually less than 50 m, the shortest stopping distance (SSD) is about 6~8L (L: ship's length). For security, we set 8L. Turning circle- when a ship's course change 90 °, the Ad (advance) is about 2.8~4L, and the tactical diameter (D_T) should under 5L, general practice 3~4L, so we adopt 4L, SSD 400 m, Ad 200 m, and the D_T 200 m. In general condition, when the DCPA is under 0.5 NM, it make the large ship's navigator uneasy, it may lead the navigator make an incorrect avoidance maneuver. And most accident happened when the DCPA is 0.5 NM. We can set the values as follows,

DCPA = 0.5 NM + 400 m (5)

Whereas, on the open sea in good visibility condition DCPA 1NM, in poor visibility condition DCPA 2NM is recommended. So in the port, in good visibility condition, we recommend setting DCPA 0.7NM, in restricted visibility condition DCPA 1.4NM.

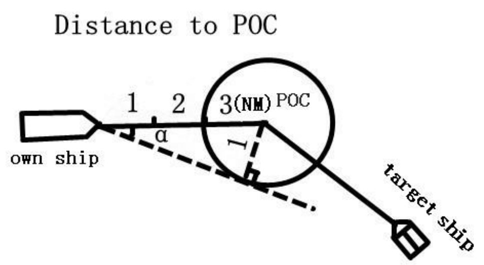


Fig.12. Alter course to provide a passing distance of 1 NM.

From the DCPA and TCPA we can use Figure 12 to calculate when to alter course.

POC: point to collision

Speed = Distance/time.

From Figure 12, safe passing distance = distance to POC × sin α, we get as follows;

In good visibility condition

$0.7 \times 1852.0 = 2.1 \times 1852.0 \sin\alpha$

$\sin\alpha = 0.3$

$\alpha = 17°$

It means when we want to keep a safe passing distance at 0.7NM, we should alter course 17° when the distance is 2.1NM.

In restricted visibility condition

$1.4 \times 1852.0 = 3.2 \times 1852.0 \times \sin\alpha$

$\sin\alpha = 0.44$

$\alpha = 26°$

It means when we want to keep a safe passing distance at 1.4 NM, we should alter course 26° when the distance is 3.2 NM.

3.2 Assess the value of DCPA and TCPA

Considered the alarm should be earlier than the avoidance action time, we set TCPA=9 min, DCPA=0.7NM in good visibility condition, in restricted visibility condition, TCPA=13min, DCPA=1.4NM. We use the weighted-average (ρ) method [13], [14] to assess the value of DCPA and TCPA.

$\rho_i = (a \cdot DCPA_i)^2 + (b \cdot TCPA_i)^2$ (i= 1,2,…,n) (6) [13]

'a', 'b' is the weighted value.

Use statistical and experimental method to get it.

When the ship from port side, a = 5, b = 0.5

When the ship from starboard side, a = 5, b = 1

'ρ_i' is smaller, the risk of collision is higher.

'i' is the number of survey.

To eliminate the difference dimensions of DCPA and TCPA, use an equation to indicate the importance of DCPA and TCPA. When the target ship's bearing in different zone, it will be given different value of "m" refer to Figure 13.

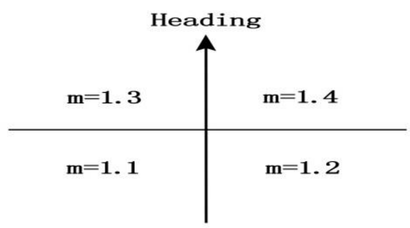


Fig.13. Weighting coefficients distribution of TCPA [14].

$DCPA_p = m \cdot TCPA_p$ (7) [14]

$DCPA_p$: The importance of DCPA in collision avoidance

$TCPA_p$: The importance of TCPA in collision avoidance

From equations (6) and (7), the equation (8) shows as below,

$$\rho = (a \cdot DCPA)^2 \quad + \quad (b \cdot TCPA/m)^2 \qquad (8)\ [14]$$

In the study [14], they had investigated some navigators to obtain an average value of ρ. Here we had got the value of DCPA and TCPA, we put them in the equation (8) to get a ρ and compare it to the survey.

For example in good visibility condition, when the target ship is on the starboard bow, we get a = 5, b = 1, m = 1.4, TCPA =9, DCPA = 0.7. The result is below,

$$(5\times0.7)^2 + (1\times9/1.4)^2 \quad = \quad 53.6$$

In restricted visibility condition, when the target ship is on the starboard bow, we get,

a =5, b=1, m=1.4, TCPA=13, DCPA=1.4. the result is below,

$$(5\times1.4)^2 + (1\times13/1.4)^2 \quad = 135.2$$

In the previous study [14], the value of ρ is 89.3 for large ship with length of 150m on the open sea. Because we are on the side of small ship and in Xiangshan water, the ρ should be smaller than 89.3. In order to test the value 53.6 and 135.3, we should investigate the navigator of small ship, and then give a discussion.

3.3 Features and principle of activate the alarm

When the small ship is in port or nearby, there are so many ships to activate the alarm. This may insensitive the navigators. According to the collision risk, the alarm sets up for priority area, and we use the encounter situation to assess collision risk.

Regarding the velocity ratio of two meeting ships, P = VO / VT. VO is velocity of own ship, VT is velocity of target ship. P is bigger the avoidance boundary is smaller. If the VO is bigger, the risk of collision is higher. This means the low velocity ship should take an earlier avoidance action. Because own ship is small ship, in most time the small ship is the low velocity ship, so we should take an earlier avoidance action than the large ship.

In the Figure 14, the zones of Ⅰ, Ⅱ, Ⅲ are levels of the dangerous zone. When the target ship enters the zone Ⅰ, it will be acquired and with red color, in zone Ⅱ with yellow color, in zone Ⅲ, with green color. When the DCPA and TCPA meet the set, the alarm will be activated, and the target ship can be set with flashing. When the DCPA is 0, the PPC (point of possible collision) also be displayed with flashing.

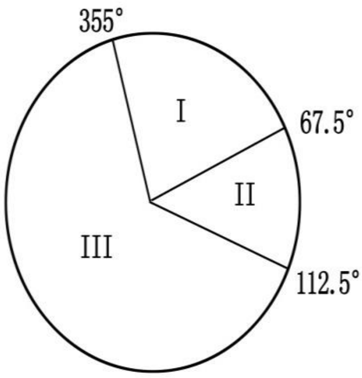


Fig. 14. Levels of dangerous zone of target ship.

4. Simulation

We got some AIS data from Nagoya Port to set a proposed alarm for the ships. There are 14 ships, according the inbound and outbound time, we divided them into 7 groups. For calculating the distance, DCPA and TCPA between two ships, we use Python to deal with data. Considering the function of AIS, time interval of each point is set as 6 seconds. All the calculation is made in Excel. At last, we use ArcMap to read the data from Excel.

4.1 Methodology of distance, DCPA and TCPA

First, we use the ArcMap to change the spherical coordinate system to Gauss plane coordinate system.

Distance between two ships:

Distance =

$$\{(POINTX_1 - POINTX_2)^2 + (POINTY_1 - POINTY_2)^2\}^{1/2} \quad (9)$$

$POINTX_1$: own ship's geometric longitude abscissa.

$POINTX_2$: target ship's geometric longitude abscissa.

$POINTY_1$: own ship's geometric attitude ordinate.

$POINTY_2$: target ship's geometric attitude ordinate.

We can use the Figure 15 to calculate the bearing relation (α & β) between own ship and target ship. And get the equation as follows.

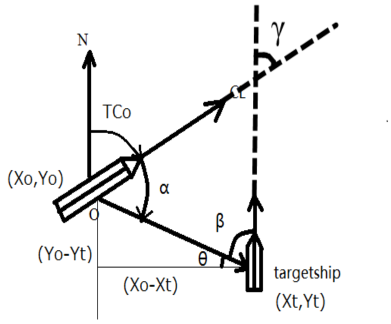


Fig.15. Bearing relation between own ship and target ship.

$$TB_t = TC_o + \alpha$$

$$\tan\theta = (Y_o - Y_t) / (X_o - X_t) \qquad (10)$$

Relative bearing from own ship

$$\alpha = 180^\circ - TCo - (90^\circ - \theta) \qquad (11)$$

Relative bearing from target ship

$$\beta = 360° - (180° - (TC_o - TC_t) - \alpha) \qquad (12)$$

If α，β is negative, change it to absolute value. If it is in the third quadrant, minus 180°, e.g. if α is − 184°, ABS(α)=184°,then minus 180°, equal to 4 °.

TB_t: true bearing of target ship

TC_o: true course of own ship

Xo, Yo: longitude and latitude of own ship

Xt, Yt: longitude and latitude of target ship

$$\text{DCPA} = \frac{D|V_o * \sin\alpha + V_t * \sin\beta|}{\sqrt{V_o^2 + V_t^2 + 2 * V_o * V_t * \cos(\alpha - \beta)}} \qquad (13)\ [15]$$

$$\text{TCPA} = \frac{D(V_o * \cos\alpha + V_t * \cos\beta)}{V_o^2 + V_t^2 + 2 * V_o * V_t * \cos(\alpha - \beta)} \qquad (14)\ [15]$$

V_o: velocity of own ship

V_t: velocity of target ship

D: distance between target ship and own ship

α: relative bearing from own ship

β: relative bearing from target ship

4.2 Data processing

The reporting interval of AIS data is different with each other. We use the first and the last point of the same time, and divide the data every 6 seconds. For example, Figure 16 is a part of the original data. We only use the ship's name; longitude; latitude; SOG (Speed Over Ground); COG (Course Over Ground) and data sending time UTC (Universal Time Coordinated). Figure 17 is a part of processed data. The longitude and latitude have been changed to rectangular coordinates (POINT_X & POINT_Y). Figure 18 is the data with DCPA and TCPA.

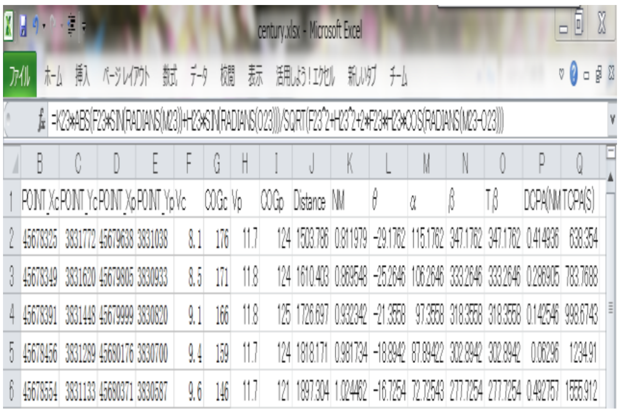
AIS履歴データ PORT MENIER IMO:9358852
2012.05.30 20:20-21:20 JST

IMO番号	船名	ｺｰﾙｻｲﾝ	緯度		経度		位	対地速	対地進	真船首	回頭率	航海	目的地	到着予定時間	船の	長	船の	喫水	ｾﾝｻの	船種	移動局送信時刻UTC	データ受信
9358852	PORT	V7NL3	34 36.1100	N	136 56.5500	E	1	11.8	132	130	0	0	POHANG-SC	06/01 06:00	190	32	6.7	1	70	2012/05/30 11:20:05	2012/05/
9358852	PORT	V7NL3	34 36.0900	N	136 56.5800	E	1	11.7	132	130	0	0	POHANG-SC	06/01 06:00	190	32	6.7	1	70	2012/05/30 11:20:15	2012/05/
9358852	PORT	V7NL3	34 36.0500	N	136 56.6400	E	1	11.8	132	130	0	0	POHANG-SC	06/01 06:00	190	32	6.7	1	70	2012/05/30 11:20:35	2012/05/
9358852	PORT	V7NL3	34 36.0200	N	136 56.6800	E	1	11.8	132	130	0	0	POHANG-SC	06/01 06:00	190	32	6.7	1	70	2012/05/30 11:20:46	2012/05/
9358852	PORT	V7NL3	34 36.0000	N	136 56.7100	E	1	11.7	132	130	0	0	POHANG-SC	06/01 06:00	190	32	6.7	1	70	2012/05/30 11:20:57	2012/05/

Fig.16. Original data from AIS.

IMO	shipname	x	y	t	SOG	COG	Heading	POINT_X	POINT_Y
9358852	PORT	136.958	34.59167	2012/5/30 11:25:04	11.7	124	123	45679638	3831038
9358852	PORT	136.9583	34.59153	2012/5/30 11:25:10	11.7	124	123	45679664	3831024
9358852	PORT	136.9585	34.59139	2012/5/30 11:25:16	11.7	124	123	45679689	3831009
9358852	PORT	136.9588	34.59126	2012/5/30 11:25:22	11.7	124	123	45679714	3830995
9358852	PORT	136.9591	34.5911	2012/5/30 11:25:28	11.7	124	123	45679740	3830978

Fig.17. Processed data every 6 seconds.



=K23*ABS(F23*SIN(RADIANS(M23))+H23*SIN(RADIANS(O23)))/SQRT(F23^2+H23^2+2*F23*H23*COS(RADIANS(M23-O23)))

POINT_Xc	POINT_Yc	POINT_Xp	POINT_Yp	Vc	COGc	Vp	COGp	Distance	NM	θ	α	β	Tβ	DCPA(NM	TCPA(S)
45678325	3831772	45679638	3831038	8.1	176	11.7	124	1503.786	0.811979	-29.1762	115.1762	347.1762	347.1762	0.414936	638.354
45678349	3831620	45679805	3830933	8.5	171	11.8	124	1610.403	0.869548	-25.2646	106.2646	333.2646	333.2646	0.286905	783.7688
45678391	3831448	45679999	3830820	9.1	166	11.8	125	1726.697	0.932342	-21.3558	97.3558	318.3558	318.3558	0.142546	998.6743
45678456	3831289	45680176	3830700	9.4	159	11.7	124	1818.171	0.981734	-18.8942	87.89422	302.8942	302.8942	0.06296	1234.91
45678554	3831133	45680371	3830587	9.6	146	11.7	121	1897.304	1.024462	-16.7254	72.72543	277.7254	277.7254	0.492757	1555.912

Fig.18. Process data to get DCPA & TCPA.

4.3 Simulation results

We received 14 ships' AIS data from Nagoya, Figure 19. They were divided into 7 groups by time. Here we selected 1 group data, CENTURY and PORT. We simulated the ship's track by ArcMap (Figure 20) and Google Maps (Figure 21) separately. We can display the distance, DCPA, TCPA between two ships. When the DCPA and TCPA match our standard, the line turns to red color, as Figure 22.

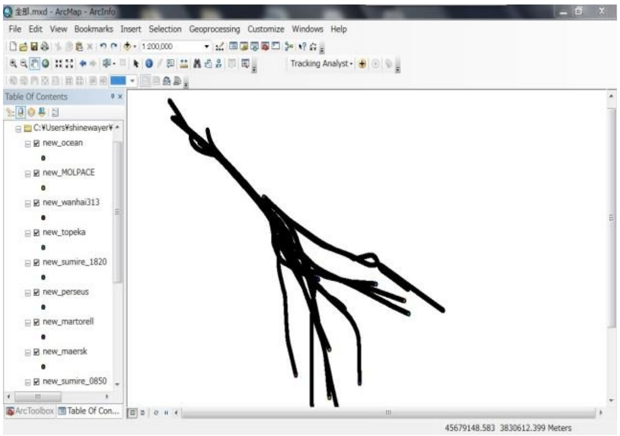


Fig.19. Display AIS data by ArcMap.

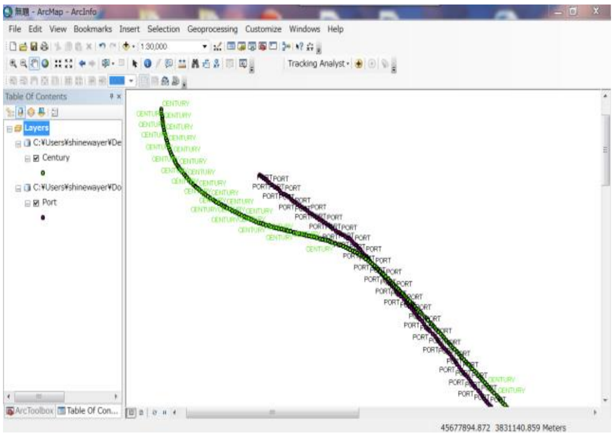


Fig.20. Track of Century & Port by ArcMap.

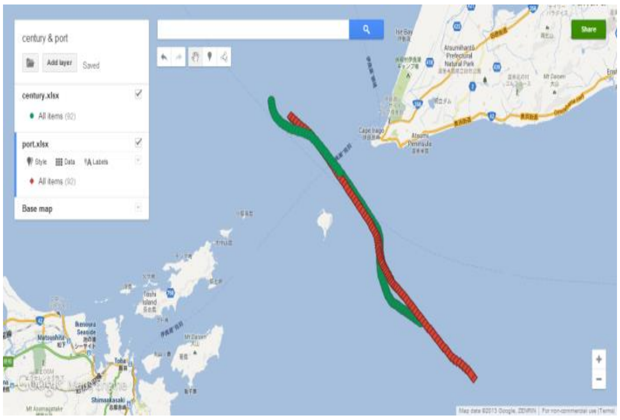


Fig.21. Track of Century & Port by Google Maps.

For example, in Figure 22, according our standard, DCPA< $0.7 \times 1852.0 = 1275$m & TCPA< $9 \times 60 = 540$s, the two points will be lined and change to red color. At the same time, alarm will be activated.

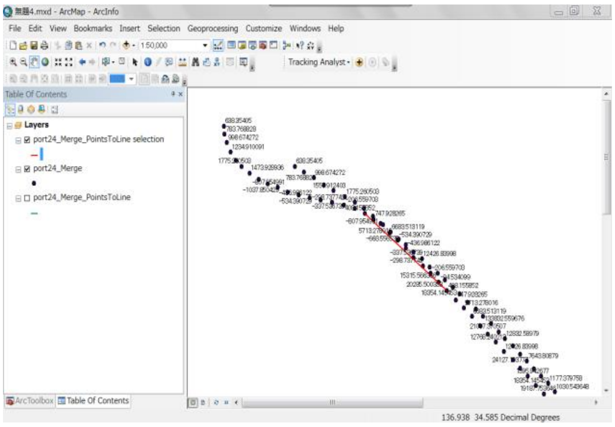


Fig.22. Line the alarm points.

5. Conclusion

In this study, we focused on the marine accident happened in Ningbo-Zhoushan Port, analyzed the character of fishing boat and sand carrier. After that, based on the accident black spot, we gave some suggestions for the navigators. In the end, we made an alarm system for the small ship based on the navigation environment of Xiangshan water and the manoeuvrability of small ship. The DCPA and TCPA standard is based on the accident data and the character of Ningbo-Zhoushan Port. To decrease the cost and solve the weak point of Radar, the alarm based on 3G network, only use the GPS data from small ship and AIS data from large ship to calculate the DCPA and TCPA.

At last, we use the ArcMap to simulate the data from Nagoya Port. Because the data is not from Ningbo-Zhoushan Port, it only was used to confirm our methodology. The results are extremely satisfactory. On the other hand, this is just a proposed alarm system. According to the insufficient of accident data, and we haven't done an investigation to the small ship's navigators in Ningbo-Zhoushan Port. The minor detail of the alarm system needs further discussion. The e-Navigation has been called for years, along with the development of internet, we believe in the near future free communication between shore to shore, shore to ship, ship to shore and ship to ship will be realized. By then, ship accident will be significantly reduced.

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