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Characteristics of Ship Movements in a Fairway

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Abstract

In a coastal area, all of the vessels are always exposed to the potential risk, taking into the maritime accident statistics account over the last decades. To manage vessels underway safety, the characteristics of ship movements in a fairway should be recognized by VTS system or VTS operators. The IMO has already mandated the shipboard carriage of AIS since 2004, as stated in SOLAS Chapter V Regulation 19. As a result, the static and dynamic information of AIS data has been collected for vessel traffic management in the coastal areas and used for VTS. This research proposes a simple algorithm of recognizing potentially risky ships by observing their trajectories on the fairway. The static and dynamic information of AIS data are collected and the curvature for the ship trajectory is surveyed. The proposed algorithm finds out the irregularity of ship movement. The algorithm effectively monitors the change of navigation pattern from the curvature analysis of ship trajectory. Our method improves VTS functions in an intelligent way by analyzing the navigation pattern of vessels underway.

Keywords : AIS data, Navigation pattern, Ship movement, Ship trajectory monitoring, Maritime safety management, VTS.

1. Introduction

The increase of shipping has brought from the congestion of the maritime traffic, which also increases the potential risk for the maritime accident. The effective management of ship movements in a waterway is essential to reduce the rate of maritime accidents. Many researchers have been carried out to improve the maritime safety through the vessel CPA analysis and anti-collision control system [1][2].

The IMO has mandated the shipboard carriage of AIS since 2004, as stated in SOLAS Chapter V Regulation 19. As a result, the static and dynamic information of AIS data has been collected for vessel traffic management in the coastal areas and used for VTS[3][4]. Recently, e-Navigation strategic plan emphasizes the role of shore facilities to enhance the safety of navigation. It is expected that AIS data can be effectively utilized to support VTS and to manage the ship safety, taking into various information of ship movement account.

By using AIS data, the navigation pattern in time domain on a fairway can be analyzed. Several researches of building the effective safety system have been reported [5][6].

According to the accidents statistics in Korean coastal areas, the marine accident has been increased continuously over the last 5 years. The reason is that a lot of marine accidents by the human factor like the carelessness of navigator. The abnormal sailing ship having potential high risk may threaten normal voyage vessels on route.

There is a research on the abnormality vessel identification system utilizing the existing fuzzy logic. It is difficult to recognize traffic condition and pattern change only visually[7].

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This research proposes a simple algorithm of recognizing the potentially risky ships by observing their trajectories on the fairway. The static and dynamic information of AIS data are collected and the curvature of ship trajectory is surveyed. The proposed algorithm finds out the irregularity of the ship movement. The algorithm effectively monitors the change of navigation pattern from the curvature analysis of ship trajectory. If the system notices the irregularity of ship movement and warns navigator, it will contribute to the safety of navigation on fairway. Our method improves VTS functions in an intelligent way by analyzing the navigation pattern of vessels underway.

2. Method of Study

2.1. AIS messaging information

AIS data divides into the static, dynamic data for the efficient treatment of data. The AIS data has the three types of information which includes static data, variable information, dynamic information. And the AIS data also has the message for the weather or the safe navigation etc.

The content of static data is IMO number, signal letters and ships name, length and beam, form of the vessel, vessel's position by GPS, dangerous freight, destination port, estimated time of arrival, route plan etc.

The dynamic information is the external sensor, providing the location (the accuracy and the condition) of the vessel, UTC time, heading line, ground speed, azimuth, pilotable angle speed, angle of heel, pitching and rolling, additional information etc. And the safe related message includes represents meteorological messages soon[8].

Table 1 is the type of each AIS messaging information.

Table 1. Type of AIS message

Message ID	Description
1,2,3	Position –Scheduled & Special position report
4	Contains position, UTC, date and slot number
5	Static and voyage related data
6,7,8	Binary message to mobile or fixed station
9	Periodical alternate message
10,11	UTC/Date inquiry
12,13,14	Safety related point to point message
15	Request for a specific message type
16	Assignment of a specific report behavior
17	Differential corrections
18.19	Third source target input
20	Data link management
21	Proprietary data
22	Channel assignment

In this research, the real time implementation object message used no. 1, 2, 3 and no. 5 of AIS. The message No. 1, 2, 3 presents ship position in UTC. It utilized for the vessel resistance analysis through the location of ship and speed of the vessel.

2.2. Curvature k for ship trajectory

In this paper, the curvature equation is used in order to analyze the curvature of the trajectory of the vessel. The curvature k of vessel trajectory can be calculated from ship's position in ship's position as a function of time.

$$k = \frac{d\phi}{ds} = \frac{d\phi/dt}{ds/dt} \tag{1}$$

$$k = \frac{d\phi/dt}{\sqrt{(dx/dt)^2 + (dy/dt)^2}} = \frac{d\phi/dt}{\sqrt{\dot{x}^2 + \dot{y}^2}} \tag{2}$$

The need for $d\phi/dt$ can be eliminated by the following identity:

$$\tan\phi = \frac{dy}{dx} = \frac{dy/dt}{dx/dt} \tag{3}$$

$$\frac{d\phi}{dt} = \frac{1}{1+\tan\phi^2} \cdot \frac{\dot{x}\ddot{y} - \dot{y}\ddot{x}}{x^2} \tag{4}$$

Substituting Eq. (4) into Eq. (3), Eq. (5) gives the final expression for the curvature calculated from the x and y time domain signals :

$$k = \frac{\dot{x}\ddot{y} - \dot{y}\ddot{x}}{(\dot{x}^2 + \dot{y}^2)^{3/2}} \tag{5}$$

3. Computer of Simulation

3.1. Monte Carlo computer simulation

This research used the Monte Carlo simulation in order to find out the characteristic of ship movement in a straight fairway.

First, the standard heading angle is designated as 45 degree. The heading angle is arbitrarily assigner. It has normal distribution with variance of 2 degree and 5 degree. At this time, ship speed is unchanged and it is fixed as v_1, v_2. And it appoints the initial position arbitrarily. Table 2 shows simulation condition.

Table 2. The simulation value condition

	Ship's Heading(°)	Variance (°)	Speed (m/sec)	Initial position (Lat, Long)
Ship 1	ϕ_1	2.0	v_1 =4	$S1_0(x1_0, y1_0)$
Ship 2	ϕ_2	5.0	v_2 =4	$S2_0(x2_0, y2_0)$

By using the designated value of Table 2, the location of the vessel as a function of time can be found through the Eq. (6).

$$ship_1\begin{cases} x_1 = x_{10} + v_1 \cdot \sin(\phi_1)\cdot ts \\ y_1 = y_{10} + v_1 \cdot \cos(\phi_1)\cdot ts \end{cases} \qquad ship_2\begin{cases} x_2 = x_{20} + v_2 \cdot \sin(\phi_2)\cdot ts \\ y_2 = y_{20} + v_2 \cdot \cos(\phi_2)\cdot ts \end{cases} \tag{6}$$

The sampled positions have the time interval of 20 s.

Figure 1 show the location of the vessel which are obtained through the Eq. (6) to the coordinate system around 45 drawing normal resistance. The trajectory of the real vessel implemented with the soft curve passing by the angular positions through the spline interpolation.

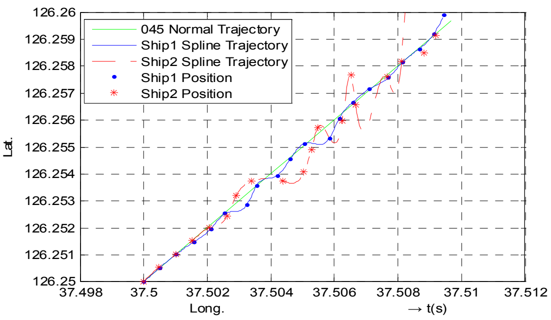

Figure 1. Result of the computer simulation of the vessel trajectory

In Figure 1, the latitude is plotted along the X axis, the longitude is plotted along the Y axis. The polynomial curve fit was computed using MATLAB's POLYFIT function using the result of the simulation. We used the curvature equation to calculate the interpolated trajectory and simulated the result of the curvature value, as shown in Figure 2.

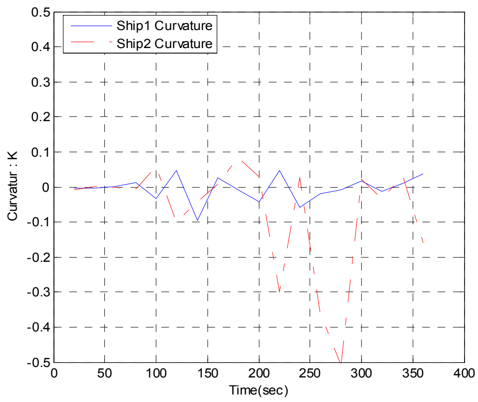

Figure 2. The change of the curvature according to the time evolution.

In figure 2, the time is plotted along the X axis, the curvature is plotted along the Y axis. It is shown the change of the curvature according to time in the straight fairway. Comparing the curvature value of 2 vessels, it is seen that the bigger deviation with the standard heading angle by the more zigzag movement, the bigger curvature value of vessel in the straight fairway. Through the simulations, we find the ship with large curvature which has irregularity of the ship movement. We know that the curvature can be used to recognize the characteristics of ship movement in a fairway.

3.2. The result of simulation by AIS data utilization analysis

In this research, we collect the read time AIS data of ships from real AIS Wando. This data includes the static of AIS data and dynamic data. The ship trajectories are simulated with real-time AIS data, as shown in Figure 3.

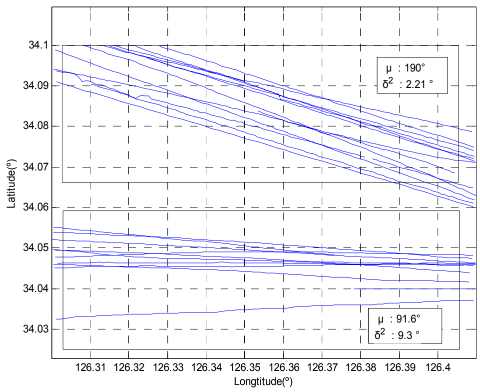

Figure 3. Simulation of Vessel Trajectory distribution at 2012 in Wando waterway by AIS Data.

In Figure 3, the latitude is plotted along the X axis, the longitude is plotted along the Y axis. The value of ship's average and its variance are 2.2° and 9.3°, respectively. Figure 4 shows the trajectory of ship with the variance 18.5°.

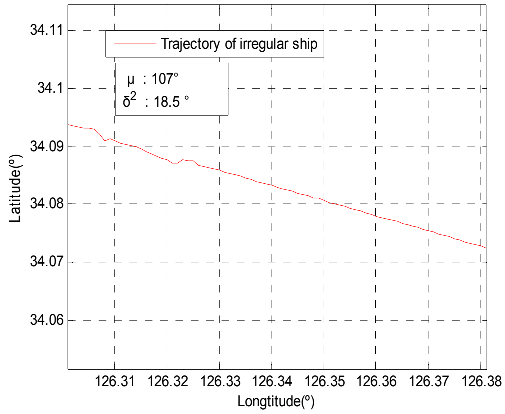

Figure 4. Result of simulation the irregular ship trajectory .

The irregular vessel's average course is 107 degree.

We used the curvature equation to calculate the interpolated trajectory and simulated the result of the curvature value. This result is shown in figure 5.

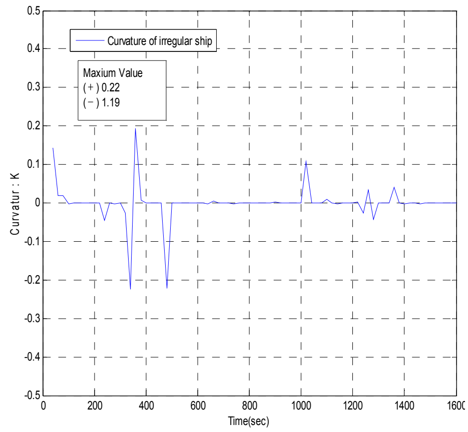

Figure 5. The change of the curvature of irregular ship.

The curvature value change is not worse than the result of computer simulation. However, actual data simulation knows that value of the curvature changes about straight line route. We know that it become one element in which about change of the trajectory and curvature analyze the motion of the vessel through the result of simulation.

3.3 Marine Accident Case Analysis

This study analyzed the ship collision between M/V Golden Rose and M/V Jinseong in 2007. Table 3 is the AIS data of Golden Rose and Table 4 is the AIS data of Jinseong. Result of two vessel's trajectory is shown in figure 6.

Table 3. AIS data of Golden Rose

No	Lat. 38° 14' N	Long. 121° 42' E	Co.	No	Lat. 38° 14' N	Long. 121° 42' E	Co.
1	48.6	9.6	177	18	27	10.7	197
2	47.8	9.8	177	19	25.8	10.2	203
3	47	10	177	20	25.4	9.6	211
4	46.2	10.2	177	21	25.2	9	220
5	45.4	10.4	177	22	25	7.8	240
6	44.6	10.6	177	23	24.8	6.6	256
7	43.8	10.8	177	24	24.6	6	259
8	42	11	177	25	24.65	5.4	260
9	40.2	11.2	177	26	24.6	4.8	262
10	37.2	11.4	176	27	24.65	4.4	263
11	32.4	12.1	177	28	24.6	3.6	268
12	31.8	12	179	29	24.4	3.2	269
13	30.6	11.42	182	30	25.2	2.4	279
14	29.4	11.3	184	31	25.25	1.2	288
15	28.2	11.2	188	32	25.8	0.7	299
16	27.6	10.9	189	33	26.4	0.6	307
17	27.4	10.81	194	34	26.45	0.3	311

Table 4. AIS data of Jinseong

No	Lat. 38° 14' N	Long. 121° 42' E	Co.	No	Lat. 38° 14' N	Long. 121° 42' E	Co.
1	12.6	26.4	5	18	21.61	17.4	321
2	13.8	26.41	1	19	22.2	16.2	318
3	14.4	25.8	0	20	23.4	14.4	314
4	15	25.81	359	21	24	12	309
5	15.6	25.82	357	22	24.6	11.2	307
6	16.2	25.23	355	23	24.61	10.8	304
7	16.8	24.6	352	24	24.62	10.2	301
8	17.4	24.61	351	25	24.63	9.6	300
9	18	24	347	26	24.64	9	296
10	18	23.4	347	27	24.65	8.4	293
11	19.2	22.21	346	28	24.66	7.8	291
12	19.21	22.2	341	29	24.65	7.2	288
13	19.8	21.6	340	30	24.64	6.6	283
14	19.81	21	336	31	24.64	6	282
15	20.4	19.8	332	32	24.63	4.8	279
16	21	19.2	327	33	24.01	3	274
17	21.6	18	323	34	24.02	1.6	271

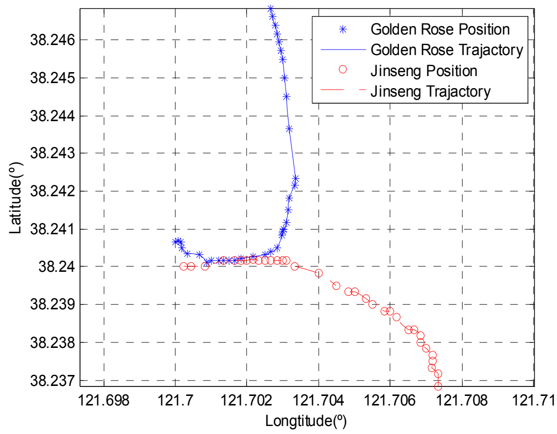

Figure 6. Trajectory simulation of ships in collision.

We used the curvature equation to calculate the interpolated trajectory and simulated the result of the curvature value. Result of Golden Rose and Jin-castle curvature are shown in figure 7-8.

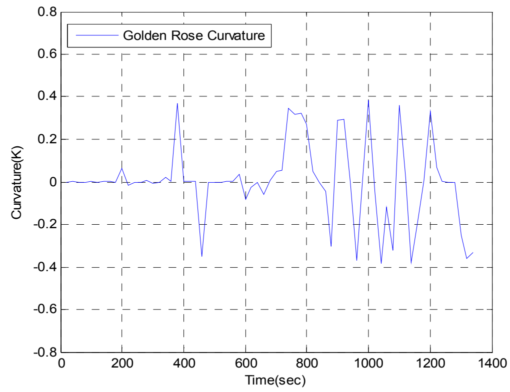

Figure 7. The change of the curvature for Golden Rose ship.

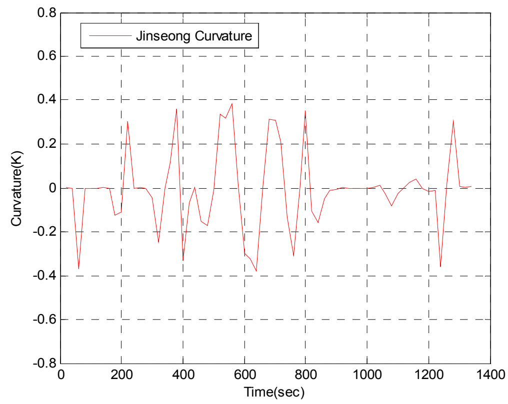

Figure 8. The change of the curvature for Jinseong ship.

Golden Rose and Jinseong hastily were turning for collision avoidance when collision was imminent. When Golden Rose turned to the right-hand side and Jinseong turned to the left-hand side, curvature values fluctuate greatly. The maximum value of the curvature of Golden Rose are (+)0.38, (-)0.38 and the maximum value of the curvature of Jinseong are (+)0.38, (-)0.37. In case of Jinseong, the curvature was higher than normal value due to movement fluctuate in straight route before turn left side.

Conclusion

The effective management of ship movements in a waterway is essential to reduce the rate of maritime accidents. The reason is that a lot of marine accidents by the human factor like the carelessness of navigator. The abnormal sailing ship having potential high risk may threaten normal voyage vessels on route.

In this research, the static and dynamic information of AIS data are collected and the curvature of ship trajectory is surveyed. Monte Carlo simulation was carried out to find out the characteristic of ship movement in a straight fairway. Through the simulations, we find the ship with large curvature which has irregularity of the ship movement. We know that the curvature can be used to recognize the characteristics of ship movement in a fairway.

This research proposes a simple algorithm of recognizing the potentially risky ships by observing their trajectories on the fairway. The proposed algorithm finds out the irregularity of ship movement. We calculate curvature from ship trajectory.

The algorithm effectively monitors the change of navigation pattern from the curvature analysis. If the system notices the irregularity of ship movement and warns to the navigator, it will contribute to the improvement of vessel safety on fairway. Our method improves VTS functions in an intelligent way by analyzing the navigation pattern of vessels under way.

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