A Study on Planned Route and Navigation Information by AIS -Safety and Efficiency Assessment in Osaka Bay -

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BIOGRAPHY

Doctor Tamaru is now an Associate Professor of Tokyo University of Marine Science and Technology. He gained his Doctor degree in the university in 2002 in the filed of automatic marine control. His fields of research includes Automatic Ship Control, Route Planning, AIS and Radar Network System.
Mr. Shimanoue get employed by the TST Corporation after graduate Kobe university of Mercantile Marine. His master thesis was about ocean meteorology. Now he is leader of Marketing Division.
Mr. Kuniyasu is now Senior researcher and developing a new marine traffic management system in Osaka bay.
Captain Ikuta is now a Vice General Manager of M.O. Marine Consulting, Ltd. His primary job is consulting for the government about port policy and logistics policy. His fields of research are marine traffic engineering and logistics engineering. He has a career as one of the writers of the OECD's report about logistics.

ABSTRACT

The marine traffic density of Osaka bay with Hanshin port that is under redevelopment is expected to increase. In the bay, ships into/out from Hanshin-port pass Akashi-kaikyo or Kitan-kaikyo(Tomogashima-suido). In addition, many fishing boats are around fishing area in Osaka bay. Therefore, ships should avoid approaching fishing boats, net and other obstructions in addition to other ships. For safety in Osaka bay, ships receive supporting information by VHF telephone and fax etc.
Recently, obligatory ships to install AIS can communicate with each other or AIS base station. If those ships are shared with all navigation information, collision risk will be reduced. In this paper, first, planned route that is safe and minimum time route calculated from navigation information received by AIS is obtained. Second, using actual information in Osaka-bay, possibility to improve a traffic environment in Osaka-bay that all ships navigate on the planned route is inspected. The planned route that is to avoid collision with other ship or obstructions (fishing net etc) is calculated by Dynamic Programming.
An actual navigated ship route was made from AIS information that observed by AIS receiver on coast of Osaka bay. Each ship's planned route is calculated basing on other ship's planned route, speed, current position and other information (fishing net etc). Other ships are assumed to navigate accurately on their planned route.
Using this method, the possibility to improve efficiency of marine traffic in Osaka-bay was suggested.

1. INTRODUCTION

In Osaka bay, The enforcement ordinance of the port regulations was to be amended on December 1st ,2007. Based on this amendment, Osaka Port, Kobe Port and Amegasaki-Nishinomiya-Ashiya Port were unified into Hanshin Port. Therefore, taxation and proceeding of port service is simplify. Because Hanshin-Port spreads to a general harbour transportation, users of the port expect that reduction in cost, expeditious service. By operation on those policy, ship traffic is expected to increased.
Osaka-wan is good fisheries. Therefore many fishing boats and merchant ships have a risk of collision. For safety of Osaka Bay, shared information system is considered with harbor master, shipping company and fishemen's association.
In this paper, Planned routes were calculated using those information and the method efficacy is confirmed.

2. OSAKA BAY

2.1 Merchant ships

Almost merchant ships pass from Tomogashima-suido to Hanshin Port, from Akashi Kaikyo to Hanshin Port and from Akashi kaikyo to Tomogashima Suido. So cross point of those route is incidence of risk of collision. In Fig. 2.1, trajectory of ship to install AIS for 3 hours are shown.

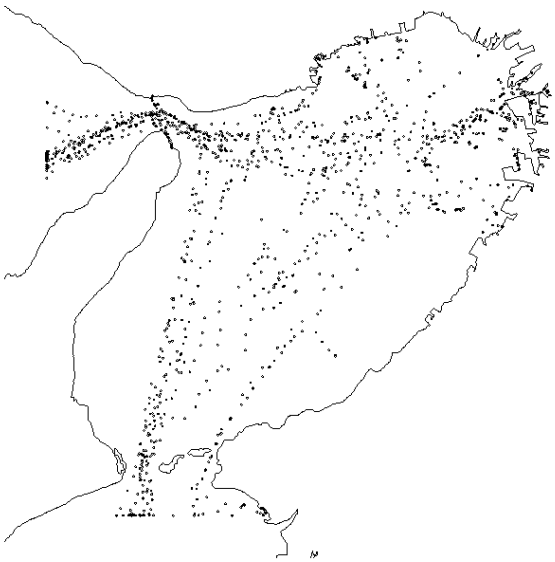

Fig 2.1 Tragectory of ship install AIS

Buoys for reduction of collishion risk are set at east of Akashi kaikyo Traffic route, North of Tomogashima suido and off Osaka-ku. A ship from Akashi kaikyo traffic route to Osaka or Kobe go through south of Akashikaikyo buoy. Fig.2.2 is shown buoys and recommendation route in the bay. Dotted line means ship's route that enter the bay. And solid line means ship's route that go out from the bay.

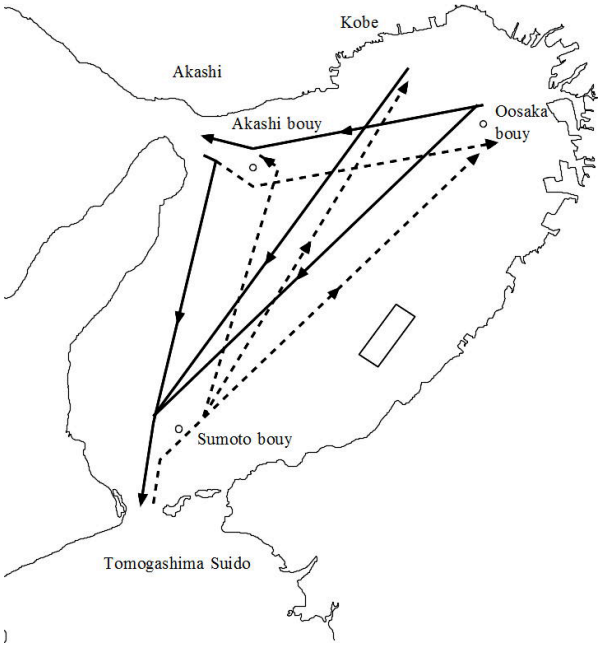

Fig 2.2 Recommendation route

2.2 Fishery in Osaka Bay

In this paper, two type fishing is considered.

Fig.2.2 is shown drift net. fishing boats start to work one hour after sunset. The drift net are placed adjusted by tide. This net length less than 3,000m, and it place under 5m below the sea level. Light buoys to show other ship are set on end of net. But rarely, navigator lost the small buoys, and ship snagged the net.

Fig2.3 is shown towing net and fishing boats. This fishing is towing long net (this is over 200m) by two boats and low speed (about 2 knots). Those boats are difficult to avoid other ship.

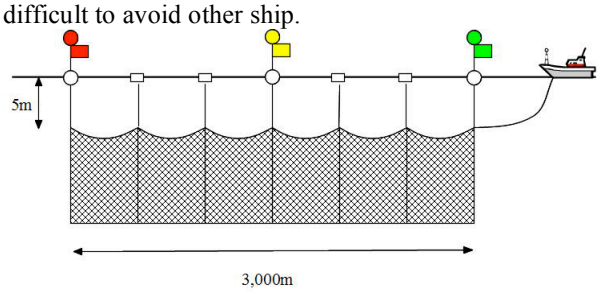

Fig. 2.3 Fishing by drift net

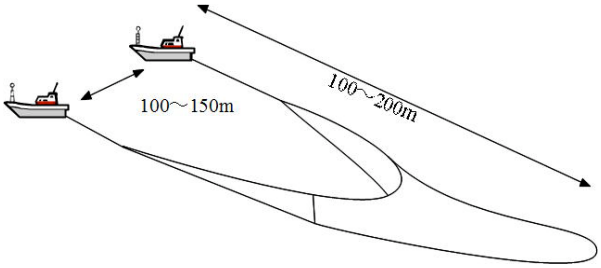

Fig. 2.4 Fishing by towing net

2.3 Trial of information share

At present, Information for safety is managed by each section.

For example, merchant ships (ferry ship or liner) are managed at harbor master. Ships install AIS are observed at basestation it managed the maritime safety agency or port radio office. Towing net and drift net are observed by radar observation system it managed the Workships Information Service Center. (The Workships Information Service Center stopped regular providing services on March 31, 2008.http://www.kald.co.jp/kokoanzen/).

If possible, fishery are reported about fishery zone. but it include many problem.

Fig.2.5. is shown radar image by the Workships Information Service Center.

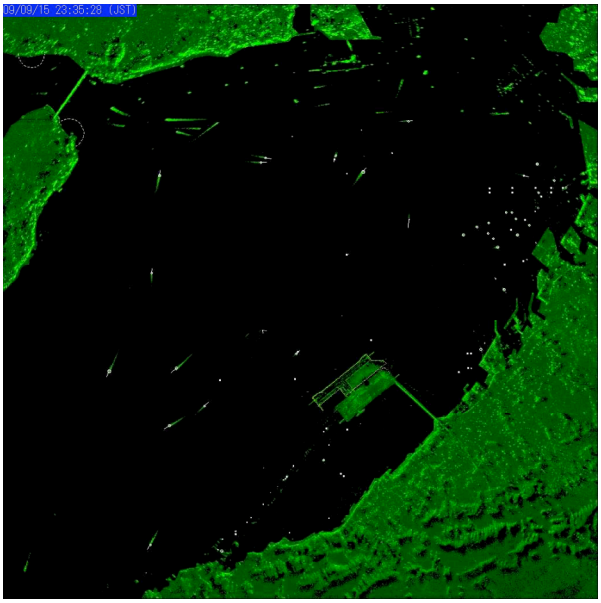

Fig.2.5 Radar image at Osaka bay

Fig. 2.6 and Fig.2.7 are shown a trial share system about fishing net and zone information.

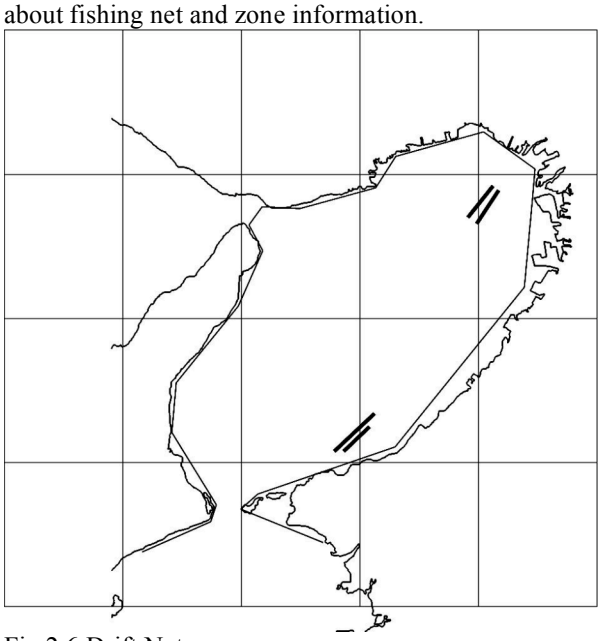

Fig.2.6 Drift Net

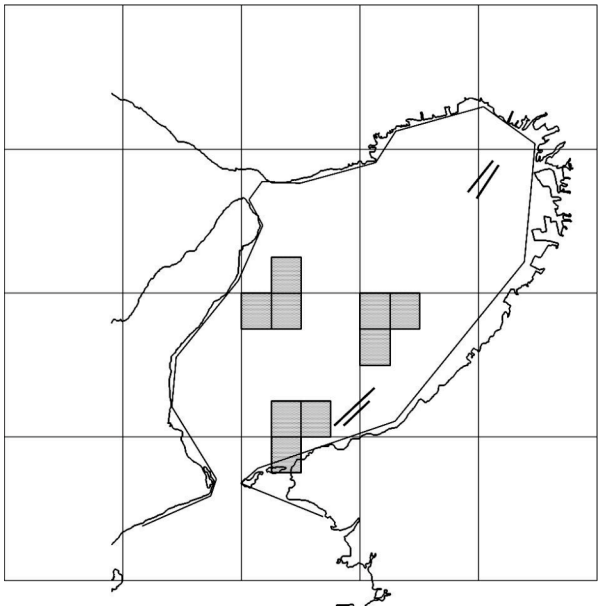

Fig.2.7 Towing Boats Area

Those information is important for ship navigate to easy selected route in the bay.
If the avoid route is optimized, traffic management is expected more safety and efficiency.
In this paper, planned routes using those information are calculated. And efficiency is inspected.

3. Planned Route

Almost marchant ships are go from Tomogashima-suido to Hanshin Port, from Akashi Kaikyo to Hanshin Port and from Akashi kaikyo to Tomogashima Suido. So cross point of those route will be incidence of risk of collision (See Fig 2.1).
The method to automatically calculate the planned route by Dynamic Programming (DP) using AIS and other ship's information (other ship's planned route, speed over the ground, and own ship's position, destination, own ship's speed over the ground) was developed.
Here, planned route is defined as minimum time route without dangerous encounters (On the optimal route, SJ value should be greater than predetermined or bumpers, fishing net and fishing zone are not overlapped)

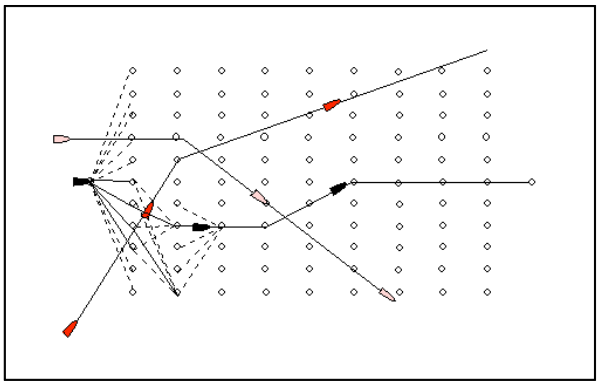

Fig. 3.1 Calculation of Optimal Route by Dynamic Programming

An algorithm of determining optimal route by DP is as follows.
The line from present posistion Po to destination Ps is equally divided into N parts. Vertical lines to this line. Po, Ps are drawn passing through these dividing points, and grids are set on these vertical lines(See Fig 3.1). The i-th grid on the k-th vertical line from Po is described as G(I,k). Minimum passage time from Po to G(k,I) is described as Tmin(k,I). Own ship passes to destination passing through these grids.
Minimum passage time from Po to G(k,I) is calculated by following formula.

$$T_{\min}(k,i) = \underset{j}{Min}\ \left\{T(G(k-1,j),G(k,i)) + T_{\min}(k-1,j)\right\}$$

there T(G(k-j),G(k,I)) is passage time from G(k-1,j) to G(k,I) means minimizing the right-term by j.
Between the grids, SJ value and bumper are calculated at interval of 1 minute. If SJ becomes less than the predetermined level, or two bumpers are overlap, calculation between these grids is stopped.
And fishing net(or fishing zone) and route from G(k-1,j) and G(k,j) is overlap, calculation between these grids is stopped.
Minimum passage time from Po to all grids G(k,j) (kk=1,2, ,N) are calculated, and minimum passage time from Po to Ps is finally obtained.
The Optimal route is determined by tracing the grids from Ps to Po.

SJ value is calculated by following formula.
(1) Crossing encounter
Give way ship

$$SJ = 6.00\Omega + 0.09R' - 2.32$$

stand on ship

$$SJ = 7.01\Omega + 0.08R' - 1.53$$

(2) Overtaking encounter

(3) Overtaking

$SJ = 54.43\Omega + 0.24R' + 2.77\,dR'/dt - 0.784$

Stand on vessel

$SJ = 3$

(4) Head on counter

$SJ = 6.00\Omega + 0.09R' - 2.32$

here,

$\Omega = |d\theta/dt| \cdot L_O/V_O$: Non-dimensional change rate of target ship bearing.

$R' = R/\{(L_O + L_T)/2\}$:Non-dimensional distance between own ship and target ship

$dR'/dt = V_R/V_O$: Non-dimensional relative speed between own ship and target ship

$d\theta/dt$: Change rate of target ship bearing (rad/min)

L_O : Length of own ship (m)

L_T : Length of target ship (m)

V_O Speed of own ship (m/min)

V_R Relative speed between own ship and target ship(m/min)

R : Distance between own ship and target ship (m)

Fig.3.2 is shown bumper model. The bumper that is combine the circle and ellipse the size decided by ship's length is approximated to the rectangle because of the calculation.

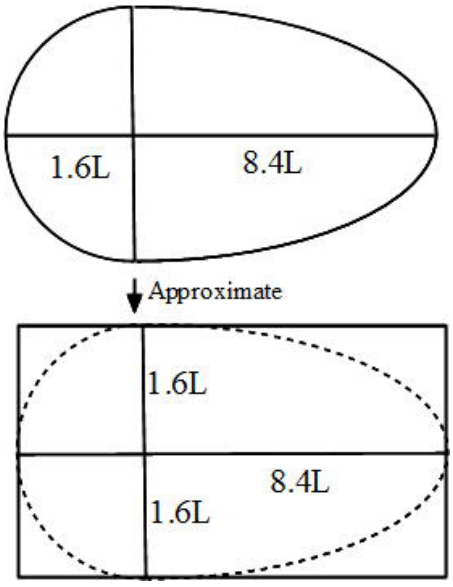

Fig. 3.2 Approximation of Bumper model

3. Simulation of Planned route

Fig. 4.1 is shown planed routes simulation.(it is not consider fishing net and fishing area)

Ship's data used actual observed data by AIS. The plannd routes were calculated from the ship with early observed time. 2nd ship is calculated using planned route of 1st ship by DP. Thereafter, other ship's planned routes are similarly calculated.

A time of all ships are arrival at destination position is 2 hour 24 min, if all ship is navigate on planned route, the time is 2 hour 22 min So the method is suggested a safety and minimum time route.

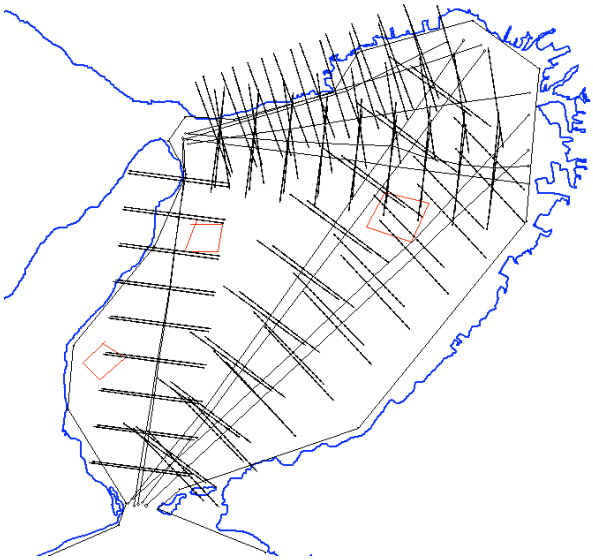

Fig.4.1 Planned Route of All ship

But in the bay, limitation for coastline or fishing net etc is set. Origin and destination points are decided by based buoys (See Fig.4.2)

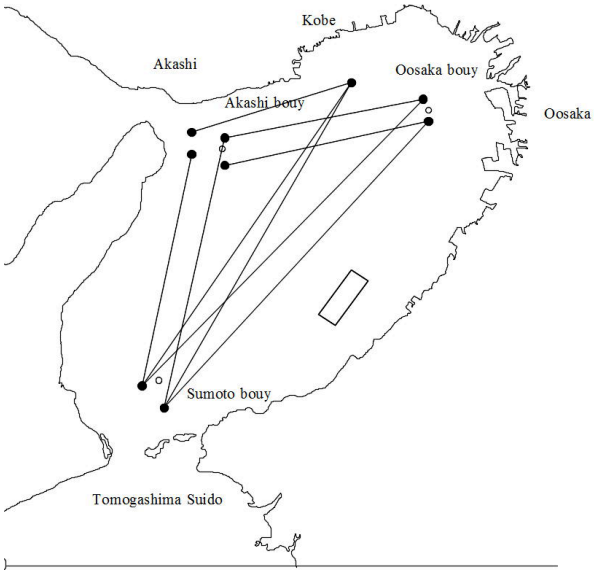

Fig. 4.2 Origin-Destination points

Fig 4.3 is shown one ship trajectory. Each ship's origin and destination points are decided closest point from O-D point shown in Fig 3.2.

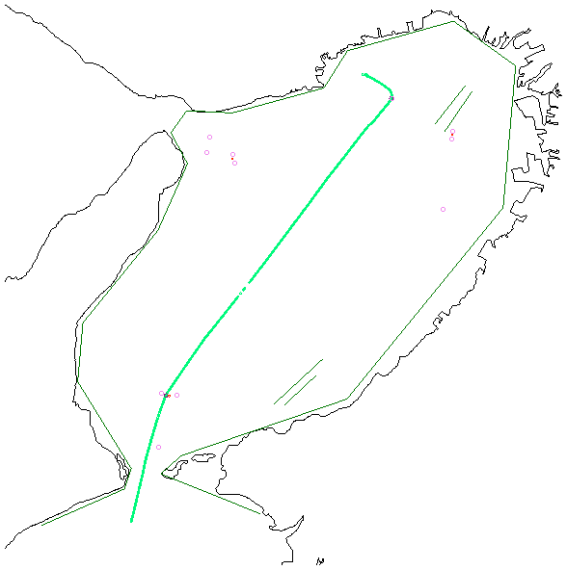

Fig. 4.3 One ship's trajectory and Origin, Destination Point

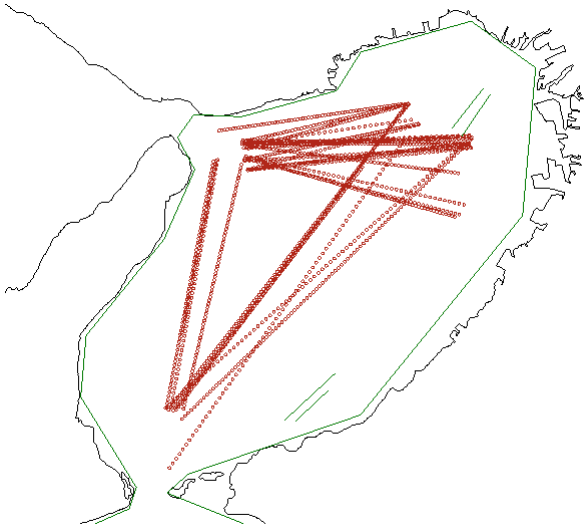

Fig. 4.4 All ship's planned routes

Fig.4.4 is simulation scenario that is made from actual ship installed AIS (It observed June 25ht 2008 18:00-21:00). In this simulation, drift nets are placed actual observation data. Towing net boats area is supposed by sample data(See Fig.2.7).
The result are shown in Fig 4.5. The rectangle in Fig.4.5 is saling prohibition area that towing boats are working.

Fig.4.5 All ship's planned route at 18:00-21:00 with avoid towing ship area

5 CONCLUSION

In this study, planned route using dynamic programming was inspected at Osaka Bay. AIS information and information of Radar observation system are important to make optimal route. Especially, Osaka Bay is wide area using DP, and there are many ships and fishing net. This DP is effective method because of various situation is included.

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