An Attempt to Predict Manoeuvring Indices Using AIS Data for Automatic OD Data Acquisition

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***Key Words**: Ship Manoeuvring, Information System and Method, Intelligent Marine Control System*

1. INTRODUCTION

AIS (Automatic Identification System) is useful system to share dynamic and static information among sailing ships in close proximity. Recently, many researchers have been developed regarding safety assessment of ship and aids for navigation using ICT (Information Communication Technology), and that gives rise to AIS system to be used for these targets. However, since AIS is wireless communication system between ships and land stations, some data are missing and reliability of this system is still disputable. Furthermore, non-availability of some data, for example, rudder angle isn't available, usage of AIS is limited in academic research. Hence, in this research, by correcting or interpolating some lost or invalid data using various methods, sailed rudder angle and manoeuvring indices K and T is predicted. Moreover, in Osaka University, its own marine traffic simulation system[1] is under development, and the manoeuvrability of ship (K, T) is needed as an input data. It has been roughly determined depends on type of ship and ship length. But if these indices are predictable by AIS data, it would be easier to make these input data more appropriately and this is final target of this research.

2. AIS

AIS[2] is introduced for the purpose of aids for navigation, terrorism, search and rescue. Dynamic and static information of each ship is updated automatically and periodically.

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Recieved 6th April 2012
Read at the spring meeting 17th and 18th MAY 2012

2.1 Contents of AIS

Information of AIS is composed of dynamic and static one. Contents of dynamic information are received date and time, status (sailing, anchor), yaw rate, velocity, position and heading angle. On the other hand, IMO number, ship name, MMSI (Maritime Mobile Service Identity) type of ship, dimension, destination, ETA (Estimated Time Arrival) and current maximum draught are provided as static data.

2.2 Problem of AIS

Data lacking is the biggest difficulties of AIS. As mentioned above, because of wireless connection, many data are missing. In this research, rate of turn is essential data to predict manoeuvring indices and sailed rudder angle, but almost all this necessary data is lost. Therefore, rate of turn is predicted from heading angle by following steps.

1. Heading angle is interpolated linearly into every 1 (s)
2. Differentiate these heading angle numerically
3. Average of this calculated rate of turn in 10(s)

Predicted rate of turn is compared to measured data to confirm the accuracy as shown in Fig.1.

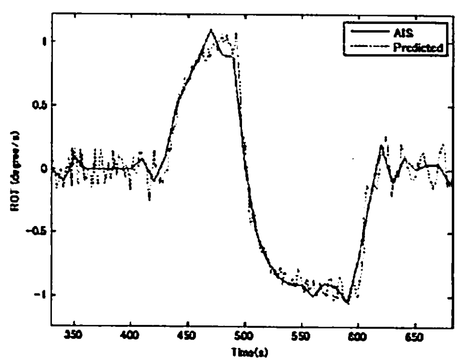

Fig.1 Comparison of rate of turn

As you can clearly see in this figure, both lines are quite similar and our methodology for predicting rate of turn seems to be appropriate.

3. OPTIMISATION METHOD

Optimisation method is applied to predict manoeuvring indices and steered rudder angle.

3.1 Mathematical model for Ship Motion

Nomoto's equation is applied to calculate ship motion in this research.

3.2 Objective function

There are two steps in optimisation. First one is to predict steered rudder angle by using initial value of K and T. Then, calculate K and T by the predicted rudder angle. In the first step, rudder angle is updated in each step and calculate heading angle and rate of turn from this refreshed rudder angle each time. Then, compare this calculated heading and rate of turn to measured one. Objective function is deference of these two lines. In the second step, K and T is refreshed each step but objective function is same as before.

3.3 Constraints

Only rudder angle is constrained in this optimisation. It is set as ±20(degree).

3.4 Initial value of K and T

In the first step of optimisation, initial value of K and T must be determined appropriately. In the second step, modified optimised rudder angle is considered from small to large one. This is because optimised rudder angle is strongly affected by initial value of K. Therefore, considering these varieties of rudder angle would help to make effect of initial value of K smaller. Finally, many combinations of K, T and rudder angle are acquired. In the matter of T, it doesn't disturb rudder angle, which means initial value of T will be also the optimised value of T. It is fixed based on actual manoeuvrability of existing ships[3]. And its value can be seen as Table 2.

Table 1 Initial value of T

Type	Length	T(s)	Type	Length	T(s)
Cargo	0-50	20	Passenger	0-50	10
	50-100	25		50-100	20
	100-150	35		100-150	30
	150-200	50		150-200	40
	200-250	60		200-250	50
	250-300	70		250-300	60
	300-	100		300-	80
Tanker	0-50	50	Container	0-50	20
	50-100	80		50-100	25
	100-150	100		100-150	35
	150-200	150		150-200	45
	200-250	200		200-250	55
	250-300	230		250-300	65
	300-	250		300-	90

3.5 Determining KT

After the optimisation, varieties combinations of K, T and rudder angle are acquired and one combination must be determined as manoeuvrability of ship. To do so, correlation between normalized K' and T' is utilised. Following figures are these examples[4].

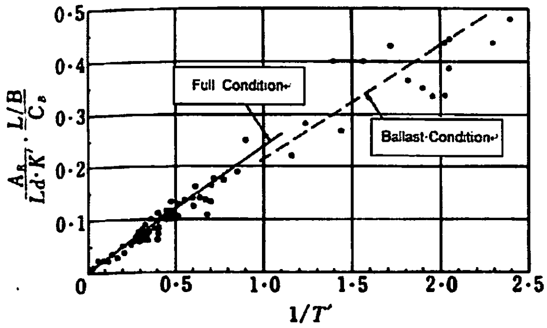

Fig.2 Correlation of K' and T'[4]

K and T is determined using above relationship finally. In this figure, area of rudder A_R needs to be fixed. It is calculated by following equation. This is requirement of DNV. (Kansai, 1984)

$$A_R = dL\left\{1+25(B/L)^2\right\}/100 \tag{1}$$

Where d: Maximum draught
L: Length over all
B: Beam

There is another correlation[5] between K' and T' as shown in Fig 3.

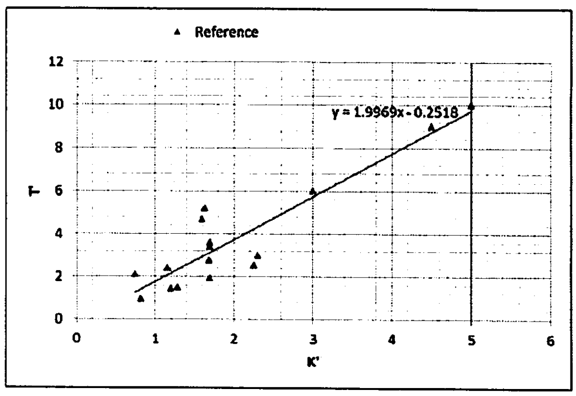

Fig.3 Correlation of K' and T'

Each dot is plotted based on manoeuvrability of existing ships. It can be seen that T' is twice bigger than K'. Thus, K and T is determined depends on Fig 2 finally, and is able to confirm whether this result is suitable or not by this Fig 3

4. RESULTS

4.1 Results for Fukaemaru

To validate our proposed methodology, predicted rudder angle, and manoeuvrability is compared to navigational data of Fukaemaru, which is training ship of Kobe University. After the validation, this approach is also applied to actual AIS data to calculate manoeuvring indices of arbitrary ship. Firstly, characteristics of Fukaemaru is introduced as Table.3, on the other hand, Table.4 shows her manoeuvrability

Table 2 Characteristics and of Fukaemaru

Type of ship	Training ship
Length over all	49.95(m)
Beam	10.00(m)
Draught	6.10/3.75(m)
Gross tonnage	449(t)
Displacement(Full)	776.5(t)
Block coefficient	0.53

Table 3 Manoeuvrability of Fukaemaru

Experiment condition	T(s)	K'	T'	Velocity(knot)
10(degree)	11.8	1.29	1.36	9.9

Initial value of K and T for optimisation is shown in Table 5.

Table 4 Conditions for optimisation

Maximum rudder angle	±20(degree)
Initial value of K	0.1(1/s)
Initial value of T	10(s)

Optimisation is carried out in this condition. Fig.4 shows the results for rudder angle.

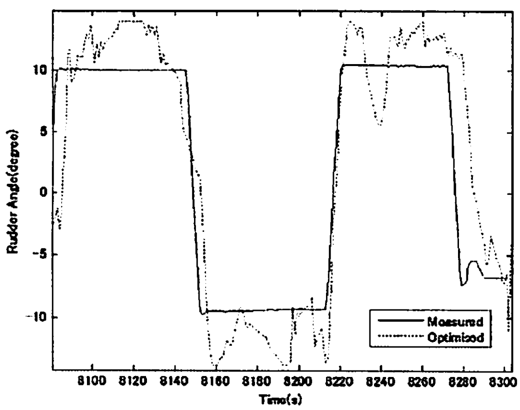

Fig.4 Comparison of rudder angle

As you can see, sailing timing is completely same, and this proves that objective function is suitable to find rudder angle. Manoeuvring indices from this optimisation can be seen below.

Table 5 Calculated manoeuvrability of Fukaemaru

Maximum rudder angle	T(s)	K'	T'	Velocity(knot)
10(degree)	10	1.09	1.15	11.2

Comparing this value to actual manoeuvrability on Table.4, this optimised result seems to be slightly smaller. This is because, regarding T', it is affected by initial value of T. Concerning about K', mean velocity is faster than experiment condition and this is the reason which makes differences. It is known that manoeuvring indices can be affected by strength of turning motion. Fig.5 and Fig.6 shows the relationship between manoeuvring indices K' or T' versus r_m'. This r_m' represents average strength of turning motion and can be calculated as follows;

$$\dot{\varphi}_m = \sqrt{\sum_i \dot{\varphi}^2(t_i)/(N+1)} \tag{2}$$

$$r_m' = \dot{\varphi}_m \pi L/(180U) \tag{3}$$

Where, φ: heading angle

N: Total number of data

L: Ship length

U: Mean velocity

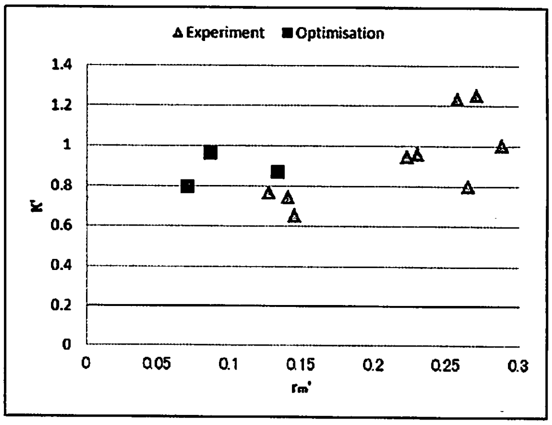

Fig.5 Correlation of r_m' and K'

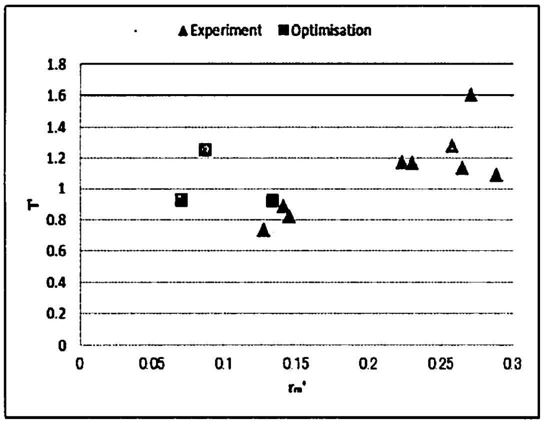

Fig.6 Correlation of rm' and T'

In these figures, when turning motion is strong, which means rm' is big, optimisation result shows good agreement with experimental data. It could confirm that proposed method is appropriate to predict manoeuvring indices when ship is changing her course. This is because when ship keeps its course, yaw rate or heading angle is not affected by rudder angle but disturbance is dominant, for example, wind, wave and tide.

4.2 Results of arbitrary ships

From the analysis of Fukaemaru, our method turned out to be reasonable to predict manoeuvring indices. Thus, it is also applied to actual AIS data.

In Fig 7, triangle shows the result of optimisation, and circle is exactly same as previous figure. From this figure, the result shows that same correlation between K' and T'. This suggests manoeuvring indices are predicted successfully.

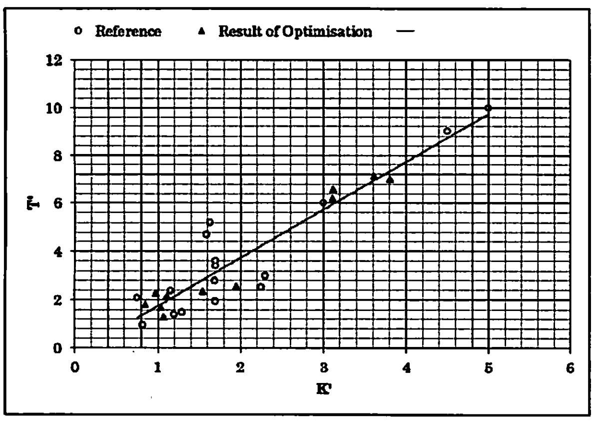

Fig.7 Correlation between K' and T'

5. CONCLUSION

In this research, the method to predict manoeuvring indices K and T using AIS is proposed. This proposed method is validated by the experiment of Fukaemaru and relationship of K' and T'.

From Fig.5 and Fig.6, it concluded that it is possible to predict appropriate manoeuvring indices only by using data which ship is changing her course, it is not always that easy to find these data. Hence, to develop some automatic system to find appropriate data will be one of our future tasks. Meanwhile, our final goal of this research is to get manoeuvring indices of arbitrary ships in close proximity only by AIS to create OD data automatically, to do so, calculation time needs to be much smaller. At this moment, it takes 1 to 4 hours for each ship. And also, input data for this calculation should be got automatically. Currently, we have to find some good data, when ship is changing her courses, by ourselves and it takes so much time. Some system to find useful data automatically should be invented, in this sense. These are our future tasks.

6. REFERENCES

1) F.Sakai: Installation of Automatic Collision Avoidance System in Ship Handling Simulator, *Master thesis of Osaka University*, Japan, 2011
2) K.Hata: Assessment of AIS Communication Traffic Volume in Congested Sea Area, *Doctor thesis of Osaka University*, Japan, 2008
3) K.Inoue: *Theory and practice of ship handling*, Seisanndo, Japan, 2011
4) Handbook for Designing Ships ver.4: *The Kansai Society of Naval Architects*, Japan, 1984
5) E.Kobayashi: Prediction of Manoeuvring Indices by Optimisation Method, *Master thesis of Osaka University*, Japan, 1978