On the use of AIS binary messages for exchanging navigational intentions in encounter situation

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Biography of the top author ----Dr. FUKUTO is working for National Maritime Research Institute JAPAN from 1986. He is a head of Navigation System Research Group and Ship Handling Simulator Cite in NMRI. His experience has covered from navigation systems to ship manoeuvrability. Now he engages in R&D of advanced navigation support systems using AIS and e-Navigation systems. In his position, he became an associate professor of Tokyo University of Marine Science and Technology in 2004.

Abstract---- This paper proposes a Navigational Intention Exchange Support System (NIESS) using AIS binary message.

Usually, assessing collision risks, decision making for taking collision avoidance actions and planning the avoidance manoeuvre are carried out based on an Officer of the Watch's predicted behaviour of encountered ships. Therefore, unexpected change of encountered ship's manoeuvre or improper prediction may cause near misses and collisions. Actually, many seafarers demand to have clear information of encountered ship's navigational intention such as "Passing down Port to Port".

VHF voice communication is effective way for exchanging such information. Actually, Automatic Identification System (AIS) increases VHF voice communication because the AIS function for identify target ship's name makes it easy to point a target ship for calling.[1] However, VHF voice communication still has shortcomings such as linguistic barriers and misunderstanding of voice messages. To overcome the shortcomings, information exchange system using internationally agreed coded data is useful.

To realize effective navigational intention exchange, a communication system based on AIS binary message is designed called Navigational Intention Exchange Support System (NIESS). The NIESS is a software for handling AIS binary messages and for a user interface which displays exchanging information on RADAR screen and which arrows to send demanded information. The information is exchanged between ships with each ship's NIESS.

This paper illustrates the concept of NIESS, the way and contents of information exchange by AIS binary message and future prospects for the NIESS.

Keywords---- Collision avoidance support, AIS, e-Navigation.

I. Introduction

According to a report of the questionnaire survey to active seafarers for studying near misses under ship's operation in 1997 [2], the most frequent cause for near miss in navigation is improper and / or illegal manoeuvre of encountered ship (18% of total 1923 reports). The next is encountered ship’s action without noticing the presence of own ship (12%). This result tells us that knowing of encountered ship future manoeuvre is very important for avoiding accidents and near misses.

In decision making for collision avoidance, an Officer of the Watch (OoW) predicts encountered

ship's manoeuvre based on information from navigation support systems and it from one's eyes. Then the OoW makes the decision for the action plan for collision avoidance manoeuvre based on the predicted manoeuvre, the OoW's code of conduct and related regulations. The prediction of encountered ship's manoeuvre is performed based not only on the information from navigation support systems but also on a large variety of obtained attribute of encountered ship such as kind of the ship, flag of the ship and guessed destination port of the ship. With direct exchange of navigational intensions between the own ship and the encountered ships, the uncertainty of encountered ship's manoeuvre and the way for passing by the encountered ship would be cleared and it would increase the safety of navigation dramatically. Actually, the study on marine accidents analysis for finding essential functions of shipboard navigation aids nominates communication support function for exchanging navigational intentions between ships [3].

On the other hand, the opportunity for use of many new navigation support systems based on information and telecommunication technology (ICT) is increased in recent years. The AIS and new Radars have been introduced to the market and the carriage requirement of ECDIS will be expanded to smaller ships. To apply these new equipments and ICT for safety navigation, the e-Navigation strategy and its implementation plan, that integrates new and existing information for making new service, has been discussed in IMO. The use of AIS binary message is an effective approach for making new service.

This paper provides the concept of Navigational Intention Exchange Support System (NIESS) and the way and contents of information exchange by AIS binary message and future prospects for the NIESS.

II. Navigational Intention Exchange Support System (NIESS)

A. Background

VHF radios and whistles are mainly used for exchanging navigation intensions now. The whistle is used to express navigation intension such as "Turn to left". However, it is difficult to know which ship submits the signal in congested area. The effective distance of the whistle signal is also too short to use collision avoidance manoeuvre. On the other hands, voice communication with VHF Radio has advantage in distance of calls, variety of information, weather condition and night time. But it still has problem in linguistic barriers and in understanding messages from noisy VHF radio. As the other method for sending navigational intention for turning, a turning indicator system using synchronized string of lights was developed, but it was not used actually.

Recently, all ships except bellow 300GT engaged on any voyage and 500GT not engaged on international voyage, must have an AIS. AIS primarily have automatic ship to ship and ship to land based station communication function. It also has a function for handling binary messages which is used by user on demand. Unfortunately, user interface device of AIS is poor to operate it. On the other hand, amendment of the radar performance standard requests new radars to show the AIS information on its display from 2008. This means that new radars are expected to be a standard user interface device of the AIS. Because the radar display is used now and in future as the primary traffic surveillance display, it will be the best human interface for the AIS.

B. NIESS

To exchange navigational intensions effectively among encounter ships, we started to develop a navigational intention exchange support system (NIESS) by using AIS binary messages in 2007.

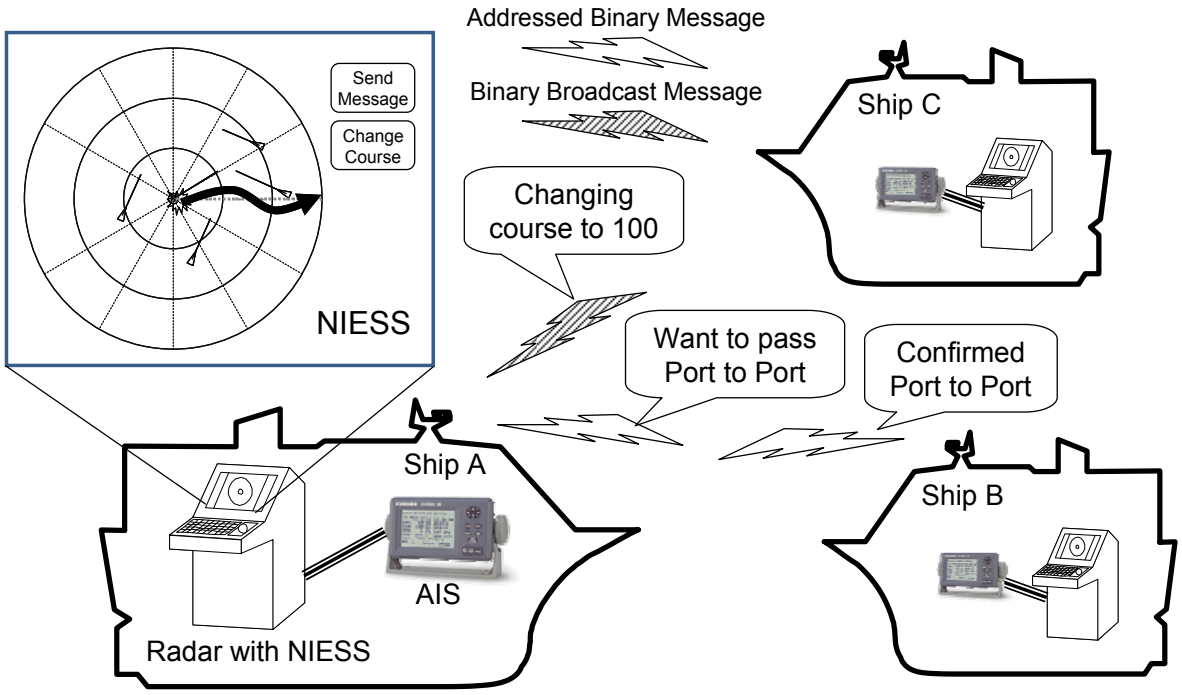

Fig. 1 Conceptual image of NIESS

Figure 1 illustrates the conceptual image of the NIESS. The NIESS is developed as an add-in software to the radar. It has a function for realizing simple and easy to use user interface for NIESS operations on the radar display and function for responding AIS binary messages. An AIS is directly connected to the radar. The NIESS controls the AIS for enabling two way communication of AIS binary messages.

The NIESS can send Addressed Binary Messages and Binary Broadcast Messages. In Figure 1, Ship A and Ship B exchange Addressed Binary Messages each other to confirm the way for passing by as "Port to Port". Ship A also sends a Binary Broadcast Message to Ship B and Ship C to notify Ship A is going to change its course to 100. Sending message is depend on the functions of the NIESS. Following is the functions that are implemented to a prototype of the NIESS.

(1). Confirming topological relation of each ship at collision situation

This function enables navigational intention exchange for confirming topological relation among encountered ships at collision situation. It has two phases. One is "Transition phase" and the other is "Confirmation phase". In "Transition phase", an offer of the topological relation at passing by, such as "Port to Port", is sent to the encountered ship. In "Confirmation phase", the repay for the offer, whether "yes" or "No", is sent back to the own ship. This function uses Addressed Binary Message.

(2). Notifying intentional course change

This function is used for notifying intentional course change of the source station ship to ships around. This function uses Binary Broadcast Message.

(3). Requesting VHF voice call

This function notifies the request to the target ship to make voice call with VHF Radio. When this function is initiated, the AIS symbol of the ship on target ship's radar display is highlighted to show the highlighted ship's demand. This function uses Addressed Binary Message.

L Click R Click Highlight

1. Before confirming the way for passing by

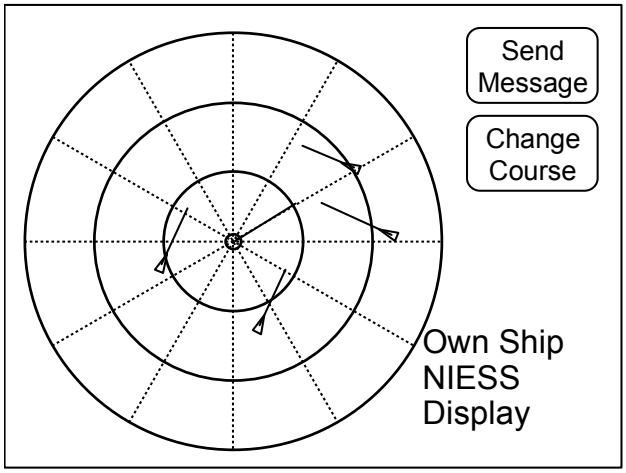

Fig. 2-1 Own ship radar display 1

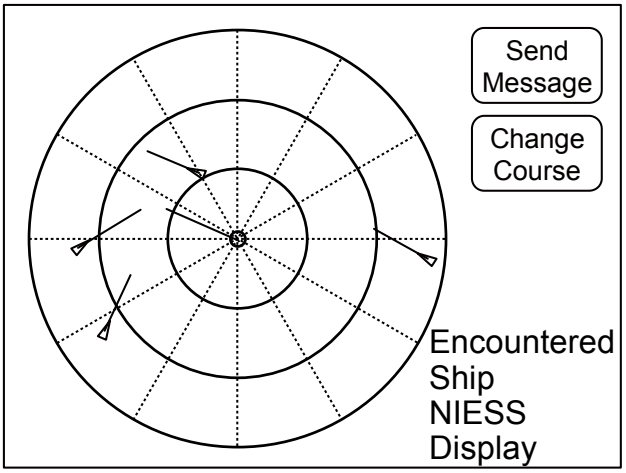

Fig. 2-2 Encountered ship radar display 1

2. Select encountered ship to communicate with right click

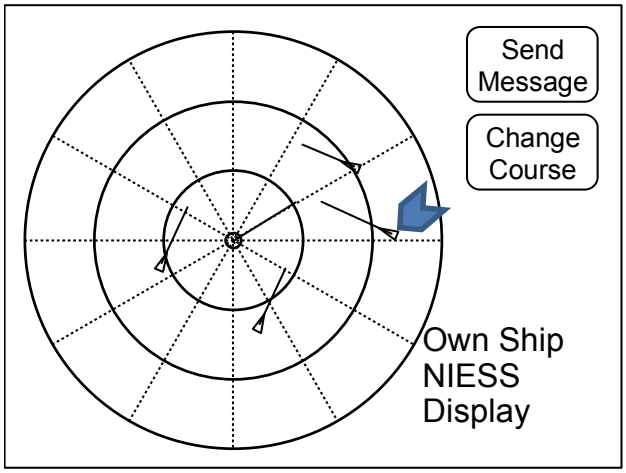

Fig. 3-1 Own ship radar display 2

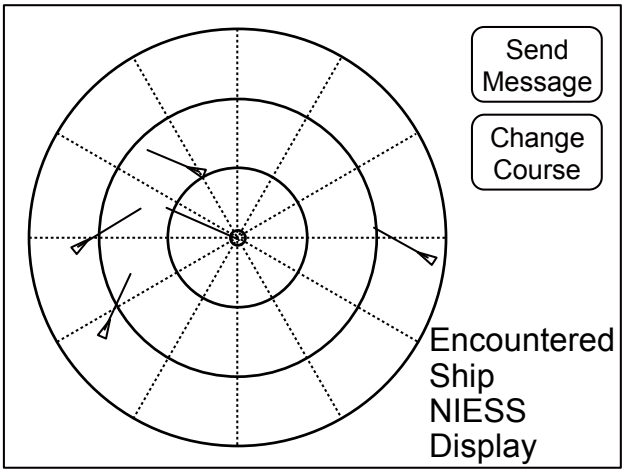

Fig. 3-2 Encountered ship radar display 2

3. Select passing side with right click

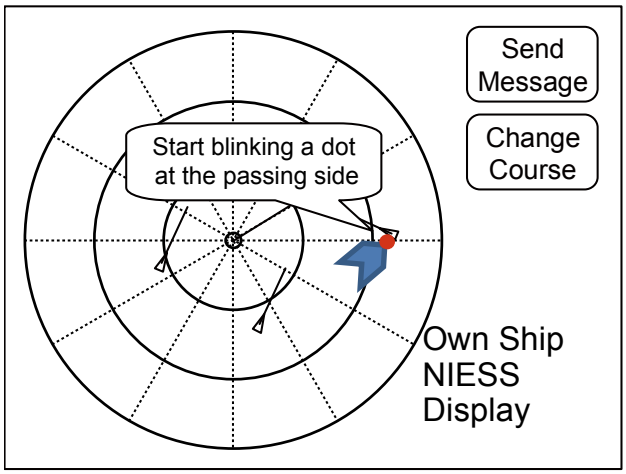

Fig. 4-1 Own ship radar display 3

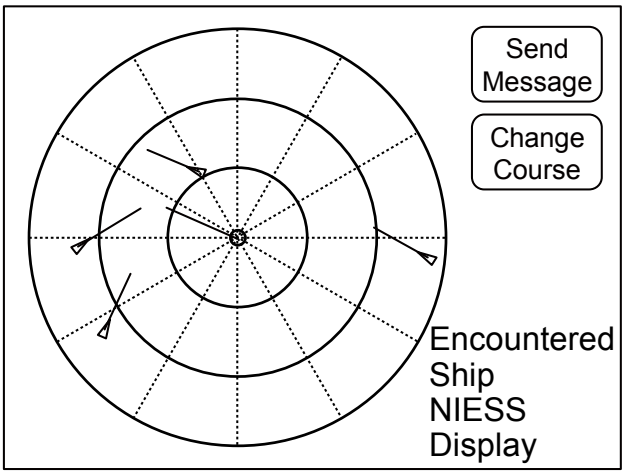

Fig. 4-2 Encountered ship radar display 3

L Click R Click Highlight

4. Send the message to encountered ship

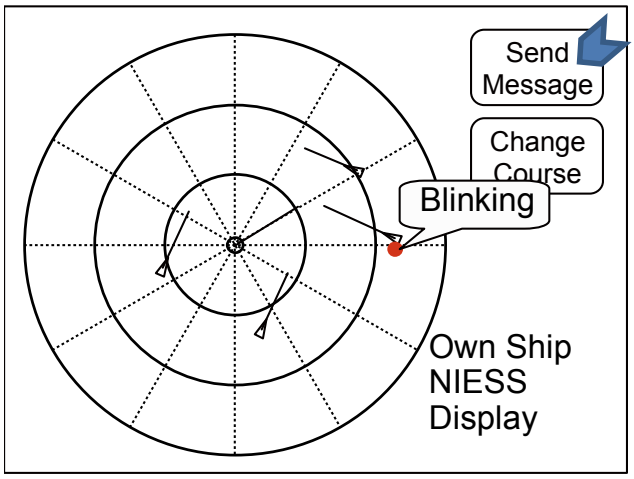

Fig. 5-1 Own ship radar display 4

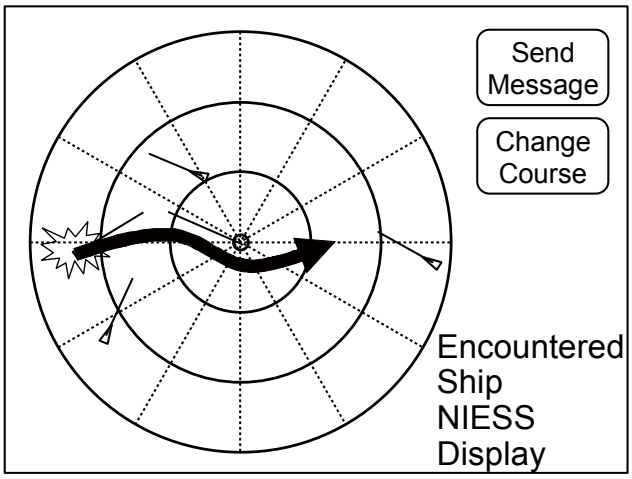

Fig. 5-2 Encountered ship radar display 4

5. Send reply for the offer form own ship

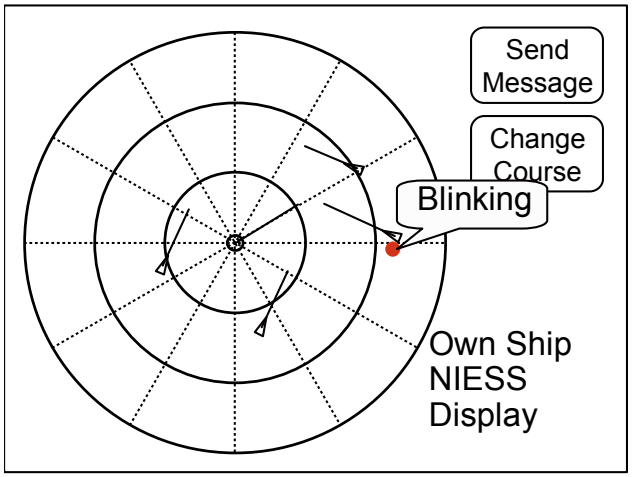

Fig. 6-1 Own ship radar display 5

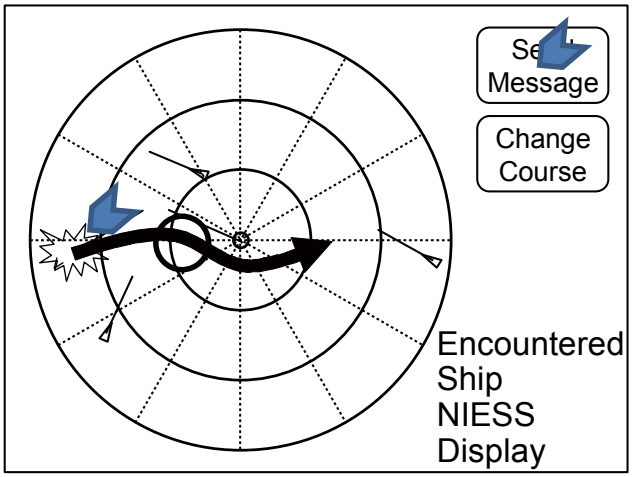

Fig. 6-2 Encountered ship radar display 5

6. Display exchanged information When the cursor points the target

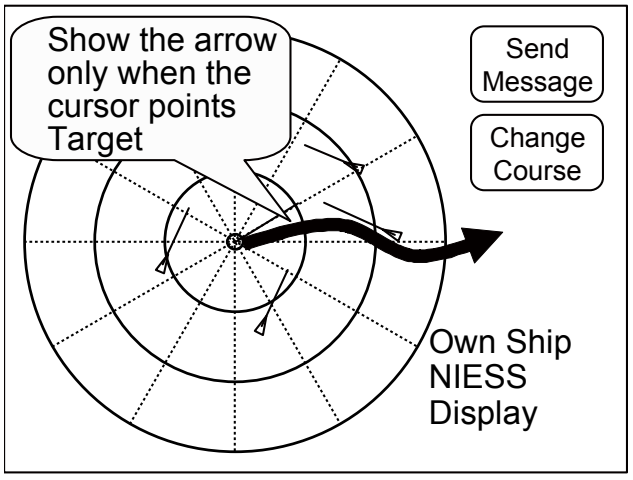

Fig. 7-1 Own ship radar display 6

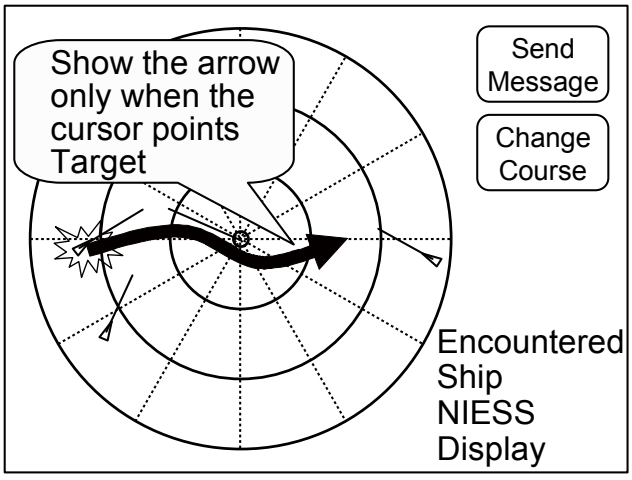

Fig. 7-2 Encountered ship radar display 6

Figure 2 to Figure 7 shows the procedure for confirming topological relation of each ship at collision situation.

To realize easy operation, all operations for the NIESS is designed to perform only with trackball. The NIESS needs only two buttons on the radar screen for sending messages and specifying modes.

Following is the procedure to confirm "Passing by Port to Port" from own ship. For this function, there is two phases named “Transfer phase” and “Confirmation phase”. The left hand figure is for own ship’s radar display and the right hand figure is for encountered ship’s display.

Table 1 Procedure for confirming "Port to Port" passing

(Transition phase)

Step 1: Own ship selects an encountered ship by clicking AIS symbol on RADAR;

Step 2: Own ship selects passing side by clicking AIS symbol;

Step 3: Own ship send an AIS binary message for offering passing side. Then, the encountered ship receives the message and it is shown on the radar display as an arrow;

(Confirmation phase)

Step 4: The encountered ship accepts the offer by clicking the arrow and it sends the replay message for accepting the offer;

Step 5: Own ship receives the message and the acceptance is displayed as the arrow with a circle in a few second; and

Step 6: Once the confirmation is established, the confirmed way is displayed when the cursor is on the target.

III. Feasibility study on the NIESS

To check the NIESS functions and to find shortcomings of the NIESS in watch operation, a series of simulator experiments were carried out.

A. NIESS simulator

Two prototypes of the NIESS and an AIS marine traffic simulator was developed for demonstrating the NIESS operation. Figure 8 is a display of the NIESS and Figure 9 is a system diagram of the NIESS simulator. Two yellow box is a ship. Each ship has a radar display with the NIESS function and a ship controller. Green box is the AIS marine traffic simulator, which provides ship information using AIS message expressing sea traffic condition. The AIS marine traffic simulator and each NIESS are connected to a LAN. We can connect as many ships as we want. The AIS marine traffic simulator calculates the movement of ships in the simulated area and output AIS sentence to the LAN. Basically, the ships generated in the AIS marine traffic simulator moves along the planned course for each ship. When the control of the ship is switched to the ship controller, ships will be handled with the controller.

The messages are transferred through a LAN. AIS static and dynamic data messages are generated and submitted only from the AIS marine traffic

Fig. 8 Radar display of the NIESS

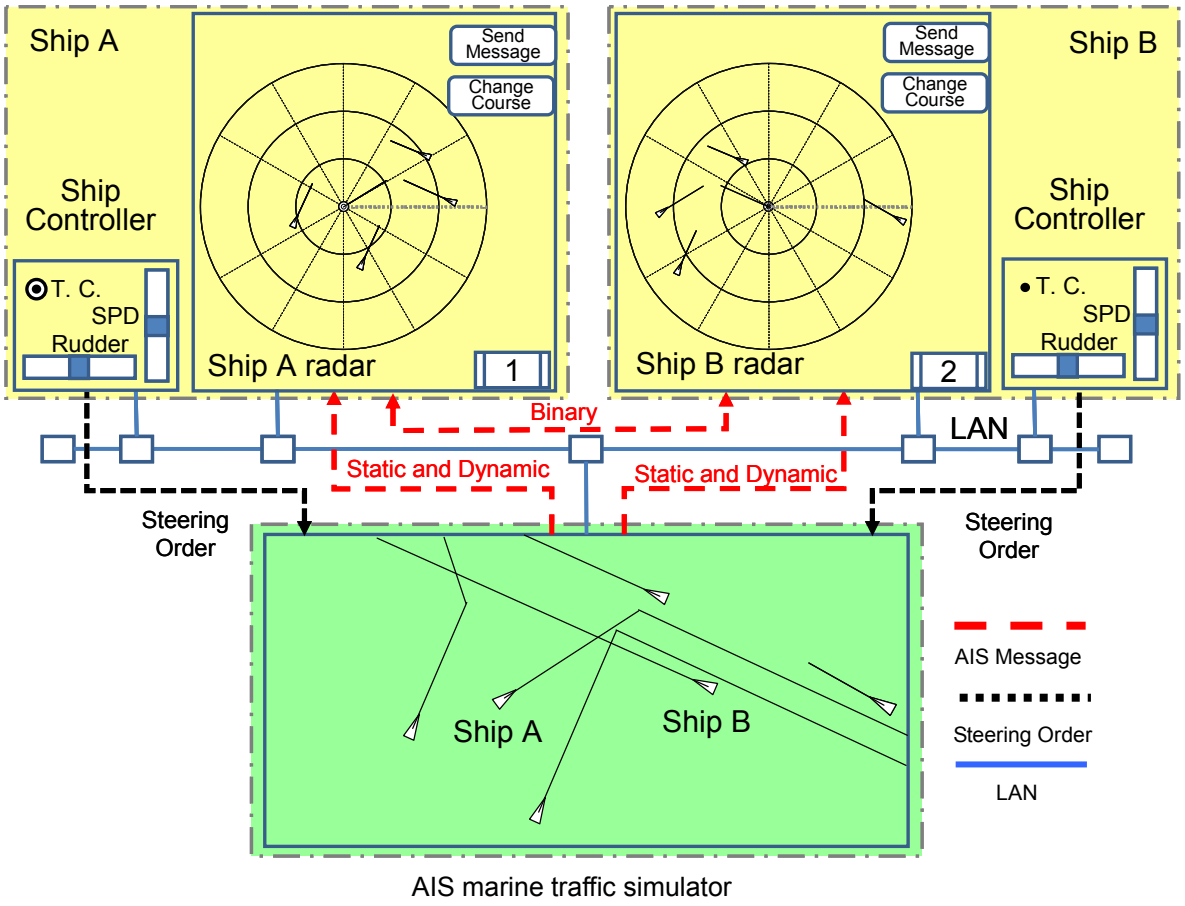

Fig. 9 System diagram of the NIESS Simulator

simulator. AIS binary message is submitted only from the NIESS. The I/O between the simulator and the NIESS is designed to use actual AIS sentence as actual AIS does.

B. Scenario

To confirm the feasibility for the use of the NIESS in actual watch operation, two ship basic encounter scenarios and three ship relatively complex scenarios are made. The three ship scenarios are designed based on the set of situation selected by Prof. IMAZU[4] as difficult pattern of meeting for collision avoidance.

C. Simulator Experiments

After the explanation of the system and practices to familiarize the operation of the NIESS, simulator experiments were carried out. Two licensed subjects are participated the experiments.

Following is the procedure of one simulation run.

1. Each subject is assigned a ship to operate.
2. Starts the simulation. Subject operates their ships with their ship controller to keep their initial course.
3. If necessary, the subject communicate with demanded ships using the NIESS and avoids collision.
4. When all collision threats were cleared, end the simulation.

Ship's position, speed, course, heading, rudder angle, state of autopilot and AIS sentences are recorded in AIS marine traffic simulator.

About 40 minutes is required to perform one scenario.

D. Result

Figure 10 shows an example of the result. In this experiment, there is three ships named Ship A, Ship B and Ship C. Ship A and Ship B go to the north and Ship C goes to the south. Three ships are in danger of collisions. In Fig.10, red, black and blue filled circles are each initial position. All ship is going to keep one's initial course. Thick solid lines are each track. Comments with arrows show the position and content of exchanged information with the NIESS.

In this scenario, Ship A has a difficulty in collision avoidance Ship A is approaching to Ship B gradually in crossing situation, and it is also encountering with Ship C in head-on situation. Ship A is blocked right turn for avoiding Ship C by Ship B. In the simulation run, firstly, Ship A communicates with Ship B and then communicates with Ship C to confirm a passing pattern. This early stage confirmation makes watch officers easy by reducing uncertainly.

In all the simulation runs, navigational intension exchanges using the NIESS in advance help watch officers effectively in decision making. The NIESS is also rated good in clear display of target ships and its agreed way.

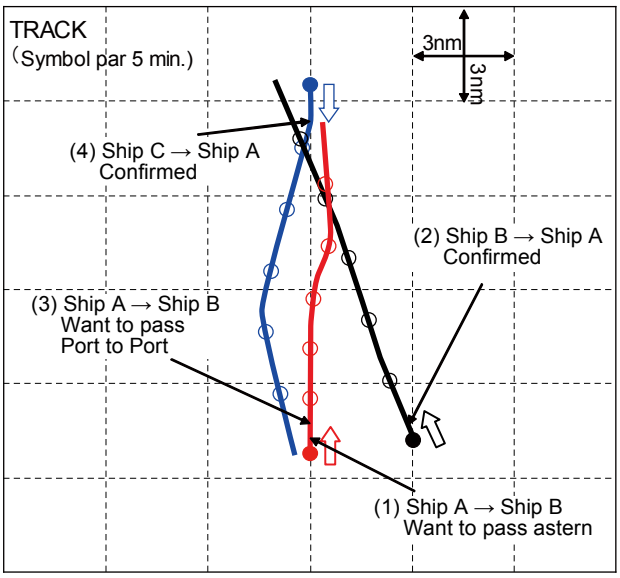

Fig. 10 A track of simulator run

From the result of experiments and remarks from subjects, the improvement points for the NIESS are shown below

1. Improve the way to display passing side and its expected track for avoiding collision, especially when the target ship is near to own ship.
2. Develop the way for cancelling or changing the confirmed information.
3. Improve user interface for the NIESS especially by a trackball.
4. Simplify the display of the NIESS not to disturb radar operation.

In addition, the demands of the additional contents for the NIESS following need to be considered.

1. Function to request a target ship to change course , speed and so on.
2. Function to broadcast intended speed change.

IV. Conclusions

We proposed a Navigational Intention Exchange Support System (NIESS) and developed a prototype of the NIESS for studying the feasibility of it in actual watch operation. The feasibility study was carried out based on a series of simulator experiments. Through the experiments, we found that there is no serious problem for the use of the NIESS even in relatively complex and difficult encounter situation of collision avoidance.

The merits of the use of the NIESS is pointed out as following.

(1) Hesitations in necessary communication between ships caused by linguistic barriers will be reduced by using non-verbal and graphical user interface of the NIESS.

(2) Miscommunications and false recognition due to the use of voice communication will be reduced by using coded information in information exchange.

(3) The NIESS makes it earlier than conventional way to recognize encounter ship's manoeuvre and to make decisions for collision avoidance. The earlier decision makings provides safer and efficient collision avoidance manoeuvre.

(4) Display of the information of confirmed navigational intension and its target ship makes it easy to understand.

On the other hand, we also found the points to improve as following.

(1) Function for cancelling or modifying exchanged information is needed.

(2) Display method for expressing passing side, especially for short range target should be improved.

(3) Trackball operations for the NIESS functions should be simplified to make it easy to use and understand.

To realize the NIESS, international agreement of the use of the AIS binary message for the NIESS is needed. Therefore, we will work international maritime organizations, such as IMO, to agree to use the AIS binary message for the NIESS.

We also planed a series of field tests, a series of usability tests and a study on additional functions for the NIESS.

Acknowledgements

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References

[1] Nick Bailey, AIS: Implications for Collision Avoidance, Proceedings of INTERNATIONAL SYMPOSIUM INFORMATION ON SHIPS, ISIS2006 (In CD-ROM)

[2] Hayama IMAZU and Tamaki URA, Study on Near Misses under Ship's Operation, The Journal of Japan Institute of Navigation, Vol. 109, 2003, In Japanese

[3] Junji FUKUTO and Yasuyuki NIWA, A method for identifying essential functions of shipboard system under the e-Navigation strategy, IMO NAV 53/13/1, 2007

[4] Hayama IMAZU, Study on the method of collision avoidance, doctoral thesis, 1987, in Japanese