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A Study on the Development of an Early Detection System for Altering Course of a Target Ship

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선회조기감지시스템 개발에 관한 연구

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Abstract : *This paper contributes to the development of an early detection system to detect the alteration of a target ship during early stages using the steering wheel signal via AIS communication. The feasibility of this system is also verified with a real ship trial. It was confirmed that the rudder angle on ECDIS was ordinarily marked green or red by the used rudder angle after the steering wheel operation. We were able to detect intentions for a change in course by a target ship quickly and efficiently avoid collisions. This system will contribute to more active VTS services and the analysis of marine accidents using the General Information Center On Maritime Safety & Security (GICOMS).*

Key Words : *Early detection system, Steering wheel signal, AIS communication, VTS, GICOMS*

요 약 : 본 논문에서는 조타기 작동 신호에 대하여 AIS 통신을 이용하여 상호 교환함으로써 상대선의 선회정보를 보다 신속히 파악할 수 있는 선회조기감지시스템을 구축하였으며, 이를 실선에 적용하여 해당 시스템의 실효성을 검증하였다. 조타 신호가 조타기를 작동함과 동시에 AIS를 통하여 송신되어 상대선의 ECDIS에 사용된 타각만큼 유색으로 표시되는 것을 확인하였다. 선회조기감지시스템을 통하여 상대선의 변침 상황을 조기에 감지할 수 있었으며, 이를 통한 선박 상호간 충돌회피가 조기에 가능할 것으로 판단된다. 또한, 의심 선박에 대한 VTS의 적극적 관제가 가능하고, 해양안전종합정보시스템을 통한 해양사고 분석에도 활용 가능할 것이다.

핵심용어 : 조타기 작동 신호, AIS 통신, 선회정보, 선회조기감지시스템, VTS, 해양안전종합정보시스템

1. Introduction

Out of all the marine accidents that occur, collision accidents most frequently occur and 70 % of marine accidents of merchant vessels are caused by collision. Huge efforts are ongoing in the maritime industry to prevent these collisions. Radar and AIS (Automatic Identification System) are regarded as key systems leading to safer navigations.

Watch officers receive a lot of key information from various devices, but more optimized and useful information is needed to make the most appropriate navigational judgments in good time.

In Northern Europe, one of the e-Navigation's tasks being performed is research to implement the route exchange function, the ability of share the ship's route from ship to ship and from ship to shore (Wilske and Lexell, 2011).

This route exchange function can determine the other vessel's course in advance and one can take measures to deal with it. Park et al.(2014) examined the effectiveness of this by comparing and analyzing the case based on their traffic situations in real coastal waters and collision case.

If this route exchange method is introduced, it will be easy to possibly determine the courses of surrounding vessels equipped with ECDIS (Electronic chart Display and Information system) and take appropriate action to avoid collision. However, information as to whether the other vessel would in fact move in the estimated direction or not, is not able to be checked until

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the time the vessel begins to turn.

According to the COLREGs (International Regulations for Preventing Collisions at Sea), this is regarded as the ship being situated in risk of collision when it is without a change of bearing and closing each other. In general, the ship can avoid other vessels and obstacles by checking the DCPA (Distance at Closest Point of Approach) and TCPA (Time of Closest Point of Approach) on the radar screen. However, when they are within close proximity each other, an eyesight check on how the other ship's heading changed is performed by the OOW (Officer of the Watch) but the DCPA and TCPA are not checked because the ship's radar and AIS indicates how the ship has turned later than in actuality.

Therefore to reinforce the route exchange system, radar and AIS, it is apt to utilize the early detection system using the steering wheel signal in early stages to quickly determine the target ship's intention to alter course (Jung et al., 2013).

Here, the steering wheel signal which is deduced from the wheel operation means not the actual rudder angle reached its intended angle but the command rudder angle (after this, the rudder angle). This is because the command rudder angle is used as part of the early detection system and it is the quickest way to highlight the intention of other ships to alter their course.

This paper will verify the efficiency of this developing early detection system in a real ship trial.

2. Concept and composition of the early detection system

2.1 Concept of the early detection system

As it is quicker to operate the steering wheel than ship's heading to be followed, it is judged that determining the target ship's intention to alter course would be more timely with a steering wheel signal, and AIS is judged to be the most appropriate communication system to quickly transmit the steering wheel signal to the target ship.

AIS acts to supply important information to the ships and VTS in order to avoid collision. Therefore the IMO has made it mandatory for all ships over 300 tons and for all passenger ships to install AIS. All information broadcasted by AIS is shown in the Table 1 and the information related to this research is COG, Heading, and ROT.

Table 1. Broadcast information from AIS

Information	Contents
Static	IMO number Call sign and name Length and beam Type of ship Location of antenna on the ship
Dynamic	Ship's position Course over ground (COG) Speed over ground (SOG) Heading Navigational status Rate of turn (ROT) (Optional) Angle of heel, pitch, roll (Optional)
Voyage related	Ship's draught Hazardous cargo Destination and ETA Route plan (Optional)
Short safety related messages	Contain an important navigational or meteorological warning

However, these informations appear normally after the actual turn of the ship takes place, especially for the huge vessels that take more than 30 seconds to start turning of the ship (Jung et al., 2013). Therefore the additional actual rudder angle information together with the ROT should be sent to the other ships and VTS via AIS.

The operation of the steering wheel can be automatic or manual by autopilot. The intention to alter course can be determined by the signal from the turn of a handle in case of manual steering (Hand or Follow-up) or the signal from the intentional turn of a dial in auto mode.

The information about the target ship's steering operation is shown to the colored marks with the operational direction and the used rudder angle on the ECDIS or radar, which is used to avoid potential collision. Using these marks may be possible if the AIS is able to transmit the navigational critical information in within two seconds.

The concept of this early detection system is same as in Fig.1, it is possible to determine the target ship's intention to alter course much quicker this way rather than it is for AIS to receive the heading information and the radar to detect the change in the target ship's course a substantial amount of time after the steering wheel operation.

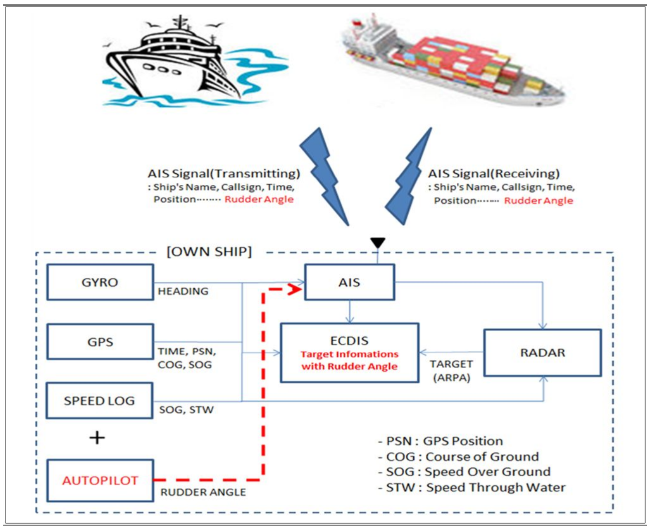

Fig. 1. Concept of early detection system.

The frequency of AIS updates is between every 2~10 seconds during the voyage in case of dynamic information (ITU, 2001). With respect to vessel movement prediction, Philipp et al. (2014) performed the availability of both static and dynamic AIS data and the evaluation of reporting intervals. On the study, almost all dynamic data fields were high available except for ROT and HDG, but they mostly did not comply with the reporting intervals described in ITU.

Therefore, more research concerning AIS data is required to identify the actual reasons for message loss and for the varying reporting intervals. As mentioned before, AIS is facilitated in all ships over 300 tons, passenger ships and VTS, and there are an increasing number of ships using this system, so the problem of information congestion is worsening with the limited AIS system. In order to solve these problems, a lot of research has been carried out broadening the frequency band and in future there is a need to decide on the level of priority or relevance of each factor of AIS data. This is certainly needed before applying AIS to this early detection system.

In order to utilize AIS in the early detection system, the steering wheel signal should be included as part of the dynamic information of AIS, and at the same time, the two-way system of AIS information should be enhanced to transmit and receive corresponding signals in less than two seconds, which is the quickest frequency within which to receive an information update on intentions of the target ship.

The components that are judged to be especially relevant to rudder signals among the information expressed by AIS are the heading, course over ground and the rate of turn. These are expressed a substantial amount of time after the operation of steering wheel as these respond to the actual alteration of the vessel's course. However, the steering wheel signals are activated straight way, and it is judged that there would be no confusion between these and other signals as these which signals are also colored as shown in Fig. 2.

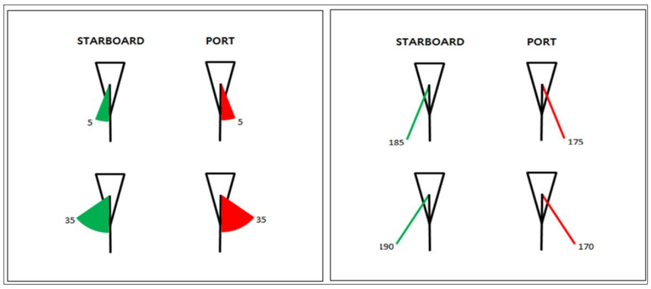

Fig. 2. Proposed AIS target symbols (it discriminates between hand mode (left) and auto mode (right) which autopilot is used).

2.2 Composition of early detection system

The hardware composition of the early detection system is a data processing system and an information display system. The former receives the steering data from the steering wheel as shown in Fig. 3, and extracts only the rudder angle data from the steering wheel operation and changes the data to the message signals of the AIS system and transmits them. The latter expresses only the rudder angle data on the ECDIS, which is extracted from the navigation data transmitted by AIS.

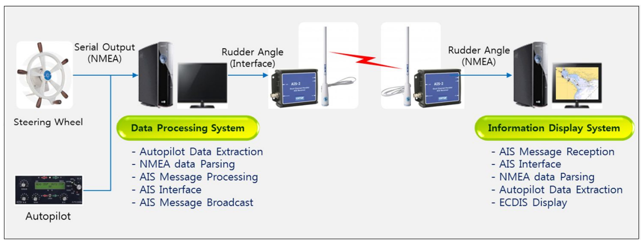

Fig. 3. Composition of early detection system.

The data processing system should extract the rudder angle data by receiving the serial output signal from the steering wheel and convert it into NMEA forms. However, there has proven to be little difference between the output forms whether the specifications of the steering wheel were installed on board.

This paper practiced an experiment for checking serial output signals and the subjects were two vessels T/S HANNARA and T/S HANBADA berthing at Korea Maritime and Ocean University, on July 13th and November 4th, 2013.

Fig. 4 shows the installation of the AD converter to change the serial output signal from analogue to digital NMEA using the steering wheel of T/S HANNARA.

Fig. 4. Serial output signal from the steering wheel of T/S HANNARA.

Fig. 5 is the format in which the serial output signals of T/S HANNARA and T/S HANBADA are stored on the processor (computer). In case of T/S HANNARA, the commanded rudder angle from the steering wheel is required to be changed to - 35° ~ 35° from the raw data which is expressed as - 3926 ~ 3956. In case of T/S HANBADA, the steering rudder angle was expressed right after the operation of the steering wheel had started.

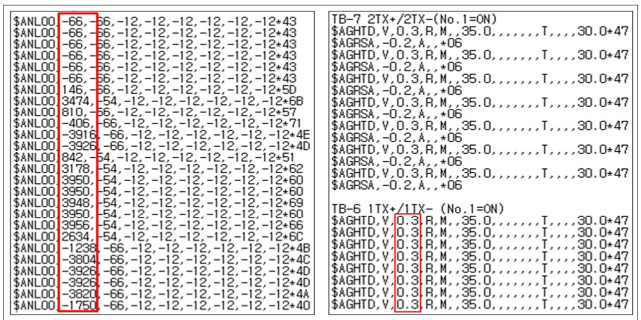

Fig. 5. Format of serial output signals of T/S HANNARA (left) and T/S HANBADA (right).

The early detection system only extracts the rudder angle from the output data as a serial output signal and transmits it to AIS. At the transmitting stage, it extracts the necessary rudder angle data after analyzing the steering wheel's NMEA signals and creates a message to enable the transmission of the output rudder angle data to AIS. It also has another function as an interface for AIS. At the receiving stage, it is composed of a function used to express the extracted rudder angle data again on the ECDIS after extracting the data from the NMEA signals on AIS.

Fig. 6 shows AIS Message forms for transmitting AIS information. It uses NMEA 0183 BBM (UAIS Broadcast binary message) for the rudder angle data and considers the transmitting interval when transmitting the rudder angle data with AIS. The rudder angle data received through AIS is shown as NMEA 0183 VDM (VHF data-link message). In Fig. 7, it explains the data transmission and the data structure in order to provide the rudder angle into the 'Encapsulated data' in Fig. 6.

```
!--BBM,x,x,x,x,xx,s--s,x*hh<CR><LF>
Number of fill-bits , 0 to 5
Encapsulated data
ITU-R M.1371 message Id (8 or 14)
AIS channel for broadcast of the radio message
Sequential Message identifier , 0 to 9
Sentence number , 1 to 9
Total number of sentences needed to transfer the message , 1 to 9
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Fig. 6. AIS Message forms for transmitting AIS information.

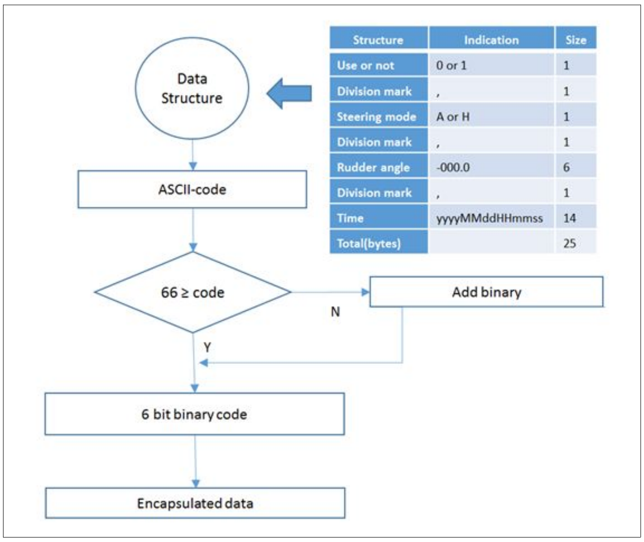

Fig. 7. Data structure and coding for transmitting.

3. Real Ship Trial

Fig. 8 shows the results of the experiment of the early detection system installed on board the T/S HANBADA that departed for coastal navigation on November 6th, 2013. The left part shows AIS which transmits the rudder angle data and a laptop with a program to load the rudder angle data on AIS which were installed on the bridge of T/S HANBADA. The right part shows the inside of the office at Korea Institute of Maritime and Fisheries Technology. The AIS here receives the rudder angle data and there is also a laptop with a program to express the received rudder angle data from the AIS on ECDIS.

Fig. 8. Experiment of early detection system at T/S HANBADA (left) and KIMFT (right).

Fig. 9 shows that T/S HANBADA departed from the pier of KMOU, passing vicinity of the breakwater and passes by incoming vessel. It was confirmed that the rudder angle on ECDIS was ordinarily marked green or red by the used rudder angle, as the vessel used the steering wheel after the departure.

It shows T/S HANBADA altered its course to starboard 10 degrees. In vicinity of the T/S HANBADA, vessels in almost caught up in head-on situations can confirm in earlier stages that the T/S HANBADA altered course to starboard 10 degrees.

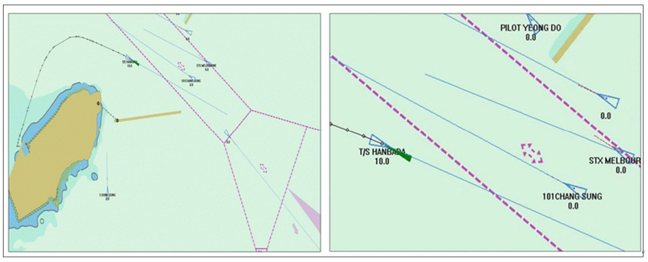

Fig. 9. T/S HANBADA altered course to starboard 10 degrees.

Throughout this real ship trial, it was confirmed that the vessel's rudder angle data can be transmitted and received in two seconds intervals from AIS and we suggest that the rudder angle data shown on ECDIS can contribute significantly to collision prevention.

4. Application Plans

The early detection system can be utilized as a means to appropriately determine and deal with the intentions other vessels to avoid collision. It can also be considered to be the fastest and the most accurate sign to determine the intended course of other vessels, because the steering wheel operations are shown on ECDIS right after the vessel steers.

There are three advantages: Firstly, it is easy to recognize since these marks include the steered rudder angle, the steering direction and they are colored. There are few restrictions caused by tension in an urgent situation because the intention to alter course is transmitted and received automatically without needing to take any action. It is not a time consuming form of communication, unlike its manual VHF counterpart.

Secondly, in the beginning, VTS operation just received a report of vessel's position, but the role of VTS has become much more important due to the necessity of information offering guidance for safe navigation with the increase of dangers caused by a speedy upsurge in vessel traffic. In addition, VTS started to practice the surveillance duty of navigation to keep the order for preventing accidents at sea. The roles and functions of VTS have become more significant since it started more active VTS services as recently there were big oil spills and accidents which involved the loss of human life.

Within the roles of VTS for safe navigation, officers offer information to the vessels usually based on the data of AIS and the radar. However, since data about the ship's heading from the AIS and radar is received by an officer subsequent to the time the action really took place, there are some cases where the vessel had already steered before the officer made a call to the ship which can be dangerous. In addition to this, there are frequent cases of false reports saying that the vessel had steered when in fact it hadn't.

Therefore, it is predicted that the instructions will become much easier since determining the course alterations could be made much faster by utilizing the early detection system which marked with the vessel's rudder angle.

Thirdly, the steering data, which is important for accident analysis, can be utilized from the course recorder installed on board or on the VDR (Voyage data recorder) which has the data stored in it, but it is more easier to analyze any accident by utilizing the AIS data stored in the steering wheel signals on GICOMS.

In addition, since the heading stored in the course recorder does not immediately change at the time of turning the steering handle, there could be some difference between the steer and the actual intention of the steer. Therefore, it is judged that the intention of steering can be determined more accurately if utilizing the system above.

5. Conclusion

By transmitting the steering wheel signals through AIS, the early detection system, which is assumed to be able to reduce the risk of collision by quickly determining the other vessel's intention to alter course, has been developed throughout the real ship trial.

Throughout this real ship trial, it was confirmed that the vessel's rudder angle data can be transmitted and received at regular two seconds intervals by AIS and that the rudder angle data shown on the ECDIS can significantly contribute to the collision prevention.

As the role of VTS has becoming increasingly important due to the necessity of information it offers for safe navigation at a time of increased risk of dangers caused by an speedy upsurge of vessel traffic, it is predicted that the instructions will become much easier since determining the course alterations could be made much faster by utilizing the early detection system which marked with the vessel's rudder angle.

In addition to the steering data, which is very important data for accident analysis, the course recorder installed on board or VDR (Voyage data recorder) which has stored data in it can be used, but it is easier to analyze any accident by utilizing the AIS data stored in the steering wheel signals on GICOMS.

This experiment was focused on the transmission and reception of the rudder angle in normal conditions between the ship to shore installed the early detection system. It will also be the subject of future research investigating how significant the early acquisition of this information actually helpful to collision prevention by experiment between the ships.

Also, the HMI (human machine interface) test should be followed to determine whether the symbols are really easy to see or maybe they are too small or too encumbering. The most important thing still needed is a human factors analysis in a simulated environment to determine the effects of such a system and how the HMI should be designed to allow unambiguous information that does not clutter on the ECDIS or radar.

The follow-up research requires the involvement of various real ship trials to determine how reliable this early detection system is, as well as continuous improvement work through multilateral verifications from simulation targeting deck officers, a master or pilot. Also, suggestions on how to apply the system through the IMO, ITU and the other international organizations to AIS and efforts for the obligatory installation of the system on real ships should be continued.

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