Analysis of Navigation for Entire Ship Voyage in Seto Inland Sea Using Automatic Identification System Data

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1. Introduction

The purpose of this study was to grasp the actual navigation situation of ships. The ship traffic was understood by an analysis of the navigation for the entire voyage across the Seto Inland Sea using automatic identification system (AIS) data. Data on the ships sailed between Kannon and Osaka, which the navigation route was used by a primary traffic route for transporting goods and materials in Japan. However, it is difficult for a ship to operate in this ocean area, because the route is narrow, and always crowded by many ships. Consequently, maritime accidents occur frequently. Thus, it is important to ensure the safety and efficiency of ship navigation in this ocean area.

In previous years, studies on maritime traffic were performed by dividing the Seto Inland Sea into small areas ①. There has been no study that tried to analyze the entire ocean area of the Seto Inland Sea. Therefore, the navigation for an entire ship voyage has never before been understood. In order to improve maritime safety and efficiency, and ensure an eco-friendly operation, it is necessary to understand the navigation behavior for the entire voyage. This study analyzed the actual navigation of a ship in the Seto Inland Sea, and determined the risk areas.

2. Analysis of Navigation for Entire Voyage

This study utilized data from an automatic identification system (AIS), which facilitates the exact and quantitative collection of ship navigation data over a long period. The research period was between March 1 and 7, 2012. The statistics on the vessel traffic and cargo type of every ship with an MMSI number were based on the AIS data. The total number of ships was 2589, and there were more than 1000 ships each day. Fig. 1 shows the trajectories of ships based on the position information included in the AIS data. The black dots indicate the tracking of the ships on day. In order to analyze the navigation for an entire voyage across the Seto Inland Sea, the target was defined as a ship sailing between Kannon Strait and Akashi Strait, without stopping at any of the ports when passing through the Seto Inland Sea. The target ships were extracted from the AIS data. If the position of a ship was included in the Kannon Strait area and Akashi Strait area, and speed was 4knots or more, the program has judged the ship to pass through them. Then, the target ship was obtained by combining the information about the ship's destination and position. According to the statistics for the extracted target ships with MMSI numbers, a total of 106 ships passed through the entire Seto Inland Sea during the investigation, and it was confirmed that 91 of these ships were cargo ships, 11 were tankers, and 6 were passenger liners. The tracking of these target ships said the entire of Seto Inland Sea is shown in Fig. 1 based on the red dots.

Analyzing ship operations while navigating over an entire voyage can contribute to safe and smooth operations. In order to assess the safety of ship navigating in the inland sea, we analyzed the total operations through encounters with other sailing ships. The approach was based on collision avoidance techniques by using the 1972 International rules for collision avoidance (COLREGS). According to the approach, the encounter situation is divided into three types: crossing, head-on, and overtaking. The AIS data transmission interval depends on the navigational status. Uneven data are transmitted based on the speed of the ship. Therefore, we interpolated the position on per second, and analyzed the data using 30 per-second. We developed a program to count the number of ships entering an area within one nautical mile of the ship using Hubeny’s distance formula, which considers the curve of the earth to calculate the distance between two places on a grid. Moreover, the calculations for collision avoidance are only executed when the collision avoidance conditions in the COLREGS have been satisfied. The analysis was carried out by a sample ship, which is a container ship. The total length is 148 m, and it has a maximum speed of 15.3 knots. The ship passed through Kannon Strait at 8:00 on March 5 and arrived in Akashi Strait at 0:00 on March 6, taking approximately 15 h to navigate 229 nautical miles before finally berthing at Kobe Port. As the results of analysis, the total number of ships that navigated the entire Seto Inland Sea from Kannon to Kobe was 1571 counts. Because the route of the inland sea is narrow at most places, especially in the Kannon Strait, Kurushima Strait, Bisan Seto, and Akashi Strait, the traffic route was congested. According to the results of the encounter analysis, the total number of encounter situations was 114 during the voyage, with the head-on situation having the largest count at 98 during the voyage. In addition, there were 10 instances of the crossing situation, and 6 instances of overtaking. These results indicated that the ship had a high collision risk when operating in the inland sea.

Fig. 1 Trajectories of ship in Seto Inland Sea and ship sailing between Kannon Strait and Osaka Bay
3. Risk Areas in Seto Inland Sea

Analyzing the ship congestion and presenting the risk areas for a ship sailing in the Seto Inland Sea can help operators understand the navigational situation before their voyage, and avoid maritime accidents. Moreover, the navigation schedule can be designed to avoid times of heavy traffic congestion based on the analysis results. Here, we analyze the congestion situation of ships based on their density distribution. The research area was divided into grid areas of 5 km × 5 km. Then, according to the ship positions, a sea area was divided into different regions, each of which was individually studied. In the study, the analysis method analyzed and evaluated the congestion density not only by considering the ship positions, but also by calculating the influence of the ship’s length on the traffic. The standard length of a ship was set at 90 m, because 90 m is the average length of the ships navigating the inland sea. Thus, if the length of a ship was 45 m, it would be converted to 0.5 ship, and if the length of a ship was 180 m, the converted value was 2 ships.

As an example of the results, Fig. 2 shows the distribution of ships navigating the Seto Inland Sea at 0:00, 6:00, and 18:00. High and low traffic densities are coded in black and red colors, respectively. Fig. 2(a) shows the density of the ship traffic at 0:00, where ships are shown to be crowded around the routes, except for the Akashi Strait. In addition, there was an increase in the number of ships anchoring outside Kobe and Osaka during this time in order to wait for a berth. From 6:00 to 9:00, when the ships began to enter the ports and prepared to unload their cargo, the traffic density near the ports increased further. In accordance with economic actions, the congested areas altered from the main traffic route to both ports throughout the morning. Fig. 2(c) shows the traffic density distribution at 18:00. As can be seen, the traffic flow through the route increased again. Based on the above vessel traffic analysis, we can elucidate the navigational situation of ships in the inland sea. In particular, the operating trend of various ship categories becomes clear. Moreover, we analyzed the congestion situation in the wide ocean area in terms of the density distribution. The congestion area is temporally dynamic and reflects the business hours of the harbor facilities. If ship operators understand the congestion situation beforehand, they can perform operations in a safer manner.

4. Conclusions

This paper presented the results of an important reference investigation on ship navigation across the entire Seto Inland Sea. Because the analysis utilized AIS data, the real navigation situation of ships was understood. The analysis results can help operators avoid congestion, and navigate efficiently in the inland sea. The main analysis results for the actual situation of ships are as follows:

1. The ship traffic in the Seto Inland Sea was determined.
2. Based on the analysis of the AIS data, we successfully extracted the navigation routes of ships sailing between Kanmon and Osaka.
3. The ship operations were analyzed specifically according to the encounter situation. Consequently, we found that ships were at a high collision risk when operating in the Seto Inland Sea.
4. Based on the analysis of the density distribution, we determined the risk areas at specific times in the Seto Inland Sea. In particular, the operating trends of various ship categories became clear.

The results of this study could be applied to ensure safe navigation and the development of an efficient and economic navigation schedule.

References
