Proposal of Traffic Flow Tube Model for Collision Risk Assessment Method of Congested Sea Area

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1. Introduction

Recently AIS (Automatic Identification System) data has been enabled to provide detailed navigation data, by which advanced collision avoidance analysis and detailed waterway analysis adapted to ship type and sea area become possible[1, 2]. Also in the field of collision risk assessment, simplified probability collision estimation models and statistical collision estimation methods, which are based on the past data, have been studied for decades[3, 4, 5, 6]. Now, a commercial maritime risk assessment software (IWRAP) has been developed in which such type of collision frequency calculation method is implemented[7] One of the difficulty of the conventional method is that it is necessary to model the sea area by comparatively simple legs, so that modeling by simple legs becomes difficult in the case of the congested sea area in which ship traffic flow is very complicated in that ships come from many directions and also go to many directions.

Therefore in this paper, we propose a new traffic flow representation model called Traffic Flow Tube (TFT) by which modeling of congested sea area and calculation of collision probability for the area becomes possible. In the basic concept of TFT model, ship traffic in the congested sea area is represented by many TFTs, and each TFT means a set of similar ship trails with almost same origin and destination (Fig.1). Secondary in this study, we develop a method to generate TFT model automatically from AIS data. As an example, the proposed method is applied to the generation of TFT model of Tomogashima channel to show the availability of the method.

2. Proposal of Ship Traffic Flow Representation Model

2.1 Concept of Traffic Flow Tube Model

In the proposed traffic flow tube model, similar ship trails are classified into one TFT by clustering algorithm in order to represent ship traffic flow for understanding of ship traffic tendency. It is necessary to represent the direction of traffic flow and ship traffic density distribution to understand traffic flow tendency and to evaluate collision probability. The detailed concept of TFT model is shown in Fig.2. TFT model is represented by base ship trail which represents center path of traffic flow tube using vectors showing direction of traffic flow, and by traffic flow width which shows width of the traffic flow as an index of probability density distribution (see Fig.2). The base ship trail is computed as geometric center of the classified similar ship trails. In order to express ship traffic density distribution along the TFT, traffic flow width is computed in each point of traffic flow tube. To decide the width of the TFT, probability distribution of passing location (distance from the base ship trail) is investigated from the data of all sub ship trails in the TFT. It is assumed that traffic flow distribution is normal distribution, and the half width of the TFT is defined as one standard deviation ($\sigma$) of the probability distribution of the distance.

Fig. 2 The concept of TFT model

2.2 Application of K-means Algorithm for Generation of TFT Model from AIS Data

In order to generate traffic flow tube, it is required that huge data of ship trail obtained from AIS data are classified into groups (TFTs) of similar trajectories. We apply K-means method[8] in this study, which especially often has been applied to huge data clustering[9]. K-means is clustering method based on cluster number $k$ determined in advance, and the data are classified into one of $k$ clusters by using the centroid of each cluster.

3. Case Study at Tomogashima Channel

Tomogashima channel is taken as a case study to apply the proposed method to generate a TFT model. The AIS data from March 1st to 3rd of 2015 is used in this case study. In this case study, analysis region is defined as north latitude from 34.0 to 34.5 degrees, and east longitude from 134.8 to 135.2 degrees as shown Fig.3 (a), and the extracted ship trails from the AIS data are shown in Fig.3 (b).

From the data in the above sea area, traffic representation by TFT model is generated by using the proposed clustering algorithm. Each centroid of cluster, in other words base ship

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trail, is represented as a set of connecting vectors, and TFT width is represented by two curves at both side of the base ship trail, which color takes same as each cluster as shown Fig.4. Enlarged figure of the TFT model is shown in Fig.5.

![Enlarged figure of the TFT model](image)

It is noted that the center of Tomogashima channel has been restricted by using virtual light buoy[10], so that navigation within 150[m] from the line Dn-Ds in Fig.3(a) is not permitted, where Dn is the position of north light buoy (north latitude 34.298 degree, east longitude 134.980 degree), and Ds is the position of south light buoy (north latitude 34.267 degree, east longitude 134.980 degree). We can observe from TFT model in Fig.5(1) that north-bound ship and south-bound ship do not overlap at the center of the channel. Furthermore, as for the north region as shown Fig.5(2), it is observed that south-bound ship and north-bound ship cross each other. Especially, it is found that 45.5% of whole ship trails(colored vectors[2–6, 8, 9, 11] in Fig.5 of north region), in other words the ship trails which belonging to the cluster except the cluster[0, 1, 7, 10] cross each other in the region of the quadrangle of Fig.5(2). It follows from this result that the traffic tendency of Tomogashima channel is extracted and characterized properly by the generated TFT model. Although Tomogashima channel is not so difficult to navigate, such a crossing situation might frequently occurs so that a potential risk might exist in this area, and this situation might obliged the ships which go through this tube to carry out collision avoidance action.

4. Conclusion

In this study, we proposed a new method called “TFT (Traffic Flow Tube)” for the representation of ship traffic flow in congested sea area. Additionally, we developed a method to generate TFT model automatically from AIS data based on the clustering algorithm called K-means method. By applying the developed method, it becomes possible to classify similar ship trails in the AIS data into one cluster with a characteristic property (probability distribution) of the ship flow. As a case study, the proposed method is applied to the generation of TFT model of Tomogashima channel. It is found that the tendency of ship traffic in this area can be properly observed and discussed from the generated TFT model, which shows the availability of the proposed method.

In the future, by using the proposed TFT model in this study, it is expected that collision probability assessment in the congested sea area becomes possible. Also it is expected that assessment of the effect of countermeasures, such as traffic flow modifications under the restrictions by modifying the base ship trail trajectory and the width of the TFT, becomes possible.

References