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Original article

Development of a Gridded Maritime Traffic DB for e-Navigation*

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Abstract

In the era of e-Navigation, it is important to deliver maritime traffic information from a shore based station to all navigating vessels. However, in a vessel boarding system, there is a limit to the amount of raw traffic data that can be processed. In this paper, we used the Automatic Identification System (AIS) data as metadata to build up the maritime traffic gridded database by projecting traffic data on a geographic coordinate system. In order to apply this database to the image layer for transferring to the ship efficiently, we have developed a maritime traffic display layer and route traffic information layer. All simulated data was collected and analyzed with the AIS in a Vessel Traffic Service(VTS) center.

Keywords: Maritime Traffic Layer, Maritime Traffic Gridded Database, Automatic Identification System (AIS)

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I. Introduction

In the process of e-Navigation implementation, the exchange of maritime safety data between the shore and vessel is one of the important issues of navigation safety at sea. Generally, maritime safety-related data, such as navigational warnings, hydrographic notes, and security-related information, is easily accessed by GMDSS facilities or other publications. The accumulated maritime safety data from a shore-based station can be effectively used to analyse maritime traffic, to develop products of ENC(Electronic Navigation Chart), and then be used to support S100-based ENC architecture of e-Navigation. To understand navigational environments around vessels, we need all the information related to the ship routes, traffic intensity, and the properties of the water area (IALA, 2013).

Maritime traffic information, such as traffic density, geometric collision candidates, and route traffic information, is related to the safety of navigation and is one of the important factors to estimate the level of risk in the water to be navigated. Around the harbor water area, maritime traffic data is mainly collected by a vessel traffic service (VTS) centre using a shore-based radar and an Automatic Identification System(AIS). In the past, there might have been no available information on actual traffic images of the water area to be navigated. At present, using AIS data over the interest of water area makes it possible to predict maritime traffic patterns. However, gathering maritime traffic-related information has many pitfalls in terms of processing raw traffic data and data transferring methods. For instance, the ship’s privacy is compromised by relevant laws and regulations in transferring the AIS data from a VTS to navigating vessels for traffic analysis. In addition, it takes a long time to transfer a large amount of the AIS data.

There are several papers that research the processing of vessel trajectories. Gerben et al(2010) used similar measures between trajectories enriched with geographical domain knowledge. The similarity was used in a classification setting to predict vessel types. Giuliana et al(2013) proposed the methodology which learns a statistical model for maritime traffic from AIS data. It is possible that it could extract traffic routes and detect anomaly vessel in an unsupervised way. The unit data value of this research is based on geographic coordinate value for processing the model.

In this paper, we pre-process trajectory data dividing unit cell length. And vessel trajectory data stored in accordance with geographical location-based cell into the maritime traffic gridded database. It has the advantage of a high speed in processing the vessel trajectory and the possibility of various uses. For practical application in e-Navigation, we have converted a gridded database to the maritime traffic display layer and the route traffic information layer.

This paper is organized as follows. Section 2 provides an overview of the AIS and its data. Section 3 presents the methods to construct a maritime traffic gridded database. Section 4 suggests possible maritime traffic layers using the database. The conclusion is drawn in Section 5.

II. Automatic Identification System and its Data

The AIS is an autonomous and continuous broadcast system operating in the VHF maritime mobile band(161.975 MHz and 162.025 MHz). The purpose of the AIS is to help identify vessels, to assist in target tracking, to enhance the safety of navigation in coastal areas, as well as to prevent collisions of vessels. The system provides information automatically, including the ship's identity, type, position, course, speed, navigational status, and other safety-related information to appropriately equipped shore stations, other ships, and aircraft. The information transmitted by the AIS can be seen in Table 1 (IMO, 2002).

Table 1: Traffic Lists

Type of information	Information	Update rate
Static	· IMO and MMSI number · Call sign and name · Ship type · Length and beam · Location of GPS antenna	Every 6 minutes and on request
Dynamic	· Position and accuracy indication · Time · Course over ground · Speed over ground · Heading · Navigational status · Rate of turn	2-180 seconds depending on speed and course alteration

The dynamic information is updated automatically and the update rate depends on the speed and course alteration. Voyage-related information is entered manually. The information is received on shore by the coastal authorities such as a VTS for vessel monitoring. The AIS is mandatory for all ships of 300 GT and upwards and to all passenger ships (IMO 2003).

Although mainly used for safe navigation and VTS surveillance, historical AIS data can be used for modelling ship traffic for risk assessments (Marina and Maria, 2012). Furthermore, it can be used to calculate maritime traffic information for risk assessment of water area. In order to calculate this information and to display historical vessel trajectories, we used the AIS data as metadata to build up the maritime traffic gridded database.

III. Gridded Maritime Traffic DB

In this section, we propose the maritime traffic gridded database to enhance data reproducibility of vessel trajectories on the water area. This method will be useful to display vessel trajectories with consideration of traffic density and extraction of route traffic information. The structure of the maritime traffic gridded database is shown in Figure 1.

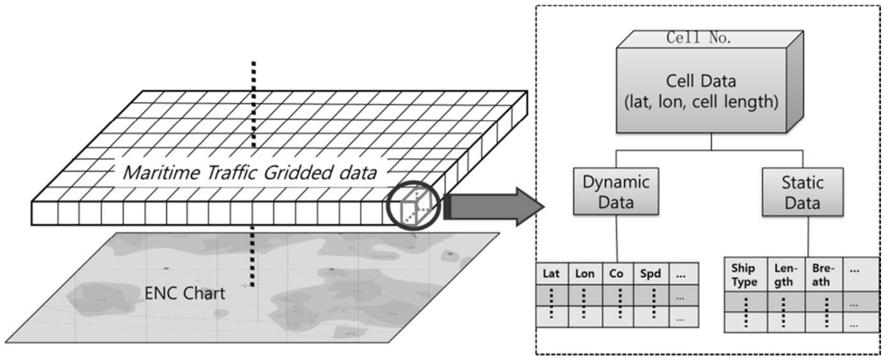

Figure 1: Structure of Maritime Traffic Gridded Database

The maritime traffic gridded database consists of a plurality of location-based cells dividing unit cell length. It saves dynamic and static data of vessel trajectory from AIS in each cell, respectively. A cell has a unique identification number.

In order to store the AIS data in the gridded database, we need to reallocate the AIS data onto the geographic coordinate cells of the maritime gridded database. Once the cell number of a vessel's position is assigned, the dynamic and static data of the present vessel is saved in the selected cell of the maritime traffic gridded database. Figure 2 shows the procedure of extracting maritime traffic gridded data from the AIS data.

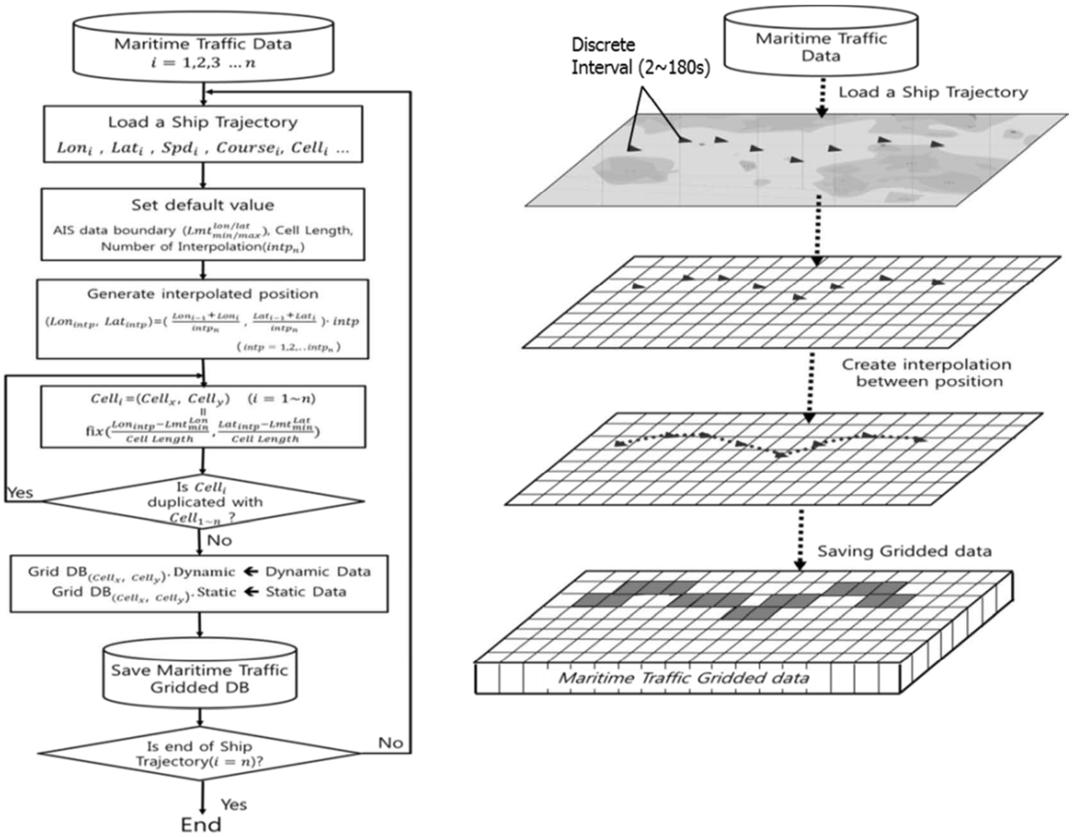

Figure 2: The Procedure of Extracting Maritime Traffic Gridded Data from AIS data.

As the AIS data is saved in a chronological order and the ship trajectories have discrete intervals of 2~180 seconds, a ship's trajectories on the gridded coordinates may be duplicated in the same cell or a blank cell may occur. Therefore, the data needs to be sorted out by the ships' MMSI and interpolated over time between vessel trajectories. The extraction of maritime traffic gridded data includes the following steps:

① Sort the AIS data by a ship's MMSI and time series.
② Load a ship trajectory and set a default value (cell length, the AIS data boundary, number of interpolation).
③ Generate interpolated positions (Lon_{intp}, Lat_{intp}) between the ship trajectories.
④ Calculate the cell number of the gridded database by dividing the AIS data boundary ($Lon_{intp} - Lmt^{Lon}_{min}$ or $Lat_{intp} - Lmt^{Lat}_{min}$) interval by it's cell length
⑤ If $Cell_i$ is a duplication of another $Cell_{i \sim n}$.
⑥ Stack up the AIS data of $Cell_i$ on Grid DB($Cell_x$, $Cell_y$). Dynamic and Grid DB($Cell_x$, $Cell_y$). Static

IV. Maritime Traffic Information Layer

Maritime traffic gridded databases create many potential ways in which we can produce various maritime traffic layers. Conversion to a maritime traffic information layer from the gridded database reduces the data capacity, which makes it possible to faster transfer traffic information from the shore base station to the vessel.

4.1. Maritime traffic display layer

Calculation of the number of a vessel in a cell is performed by counting the ships entering into the cell. It is highlighted as traffic volume on a heat map which displays colours from minimum traffic volume (yellow) to maximum traffic volume (red) in accordance with traffic quantity. Minimum and maximum traffic values are user selected options. In Figure 3, there is a coloured cell in the waterway grid highlighting the amount of the traffic quantity in the cell. After calculating all gridded cells, a maritime traffic display layer is produced. Figure 4 is the maritime traffic display layer and the grid number of MOKPO waterway built in by using the AIS data for a month.

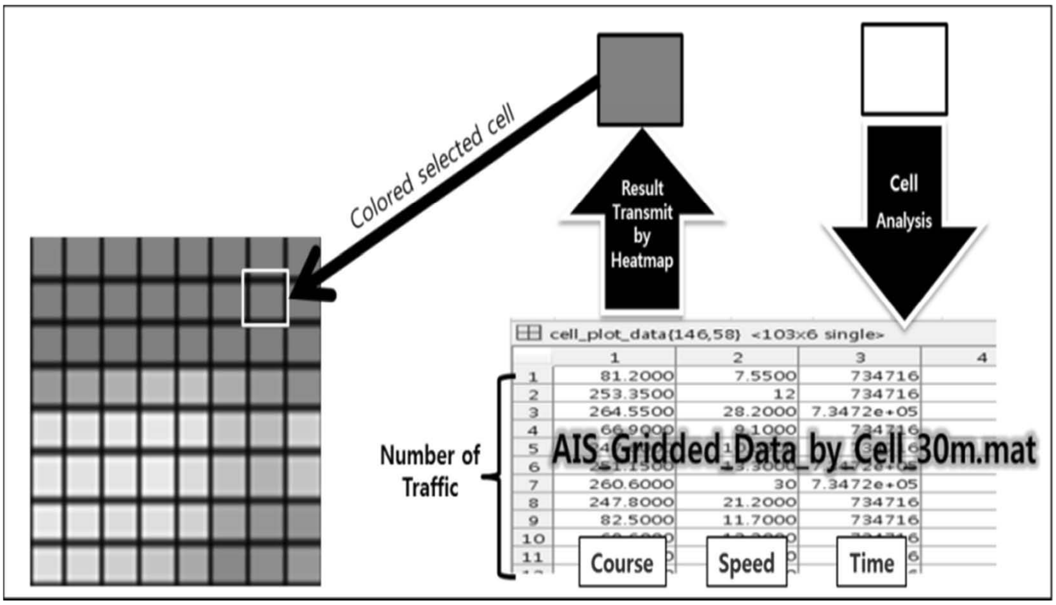

Figure 3: The Flow of the Extracting the number of ship from Maritime Traffic Gridded Data for display

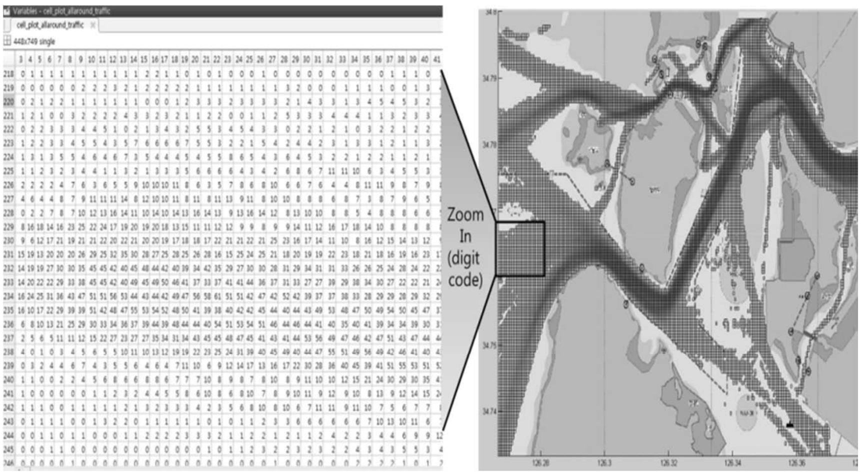

Figure 4: The maritime traffic display layer and its grid number of MOKPO waterway.

4.2. Route Traffic information layer

Calculating route traffic information is also possible by using the maritime traffic gridded database. It represents route traffic information that consists of the amount of traffic quantity, mean speed, traffic distribution (Kim et al, 2013). To calculate route traffic information, we set gate lines across the route in a green line at a right angle (Figure 5) and find the cells in which the gate line goes through. It also considered the direction of the traffic flow as forward and backward direction calculated by start and end waypoints. The number of traffic quantity is calculated by summing data length of the selected cells by the gate line. The lateral traffic distribution mean (μ) and standard deviation (σ) in the same direction are given as Eq.1 and Eq.2.

$$\mu = \frac{\sum_{i=1}^{n} d_i \cdot q_i}{\sum_{i=1}^{n} q_i} \qquad (1)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (d_i - \mu) \cdot q_i}{\sum_{i=1}^{n} q_i}} \qquad (2)$$

where q_i: the number of traffic quantity of the selected cell i ,
d_i: the distance between the centre of selected cell i and the centre of the route,
n: the number of the selected cell.

Figure 5 shows data in a cell, the route, gate line, and traffic distribution of each gate line.

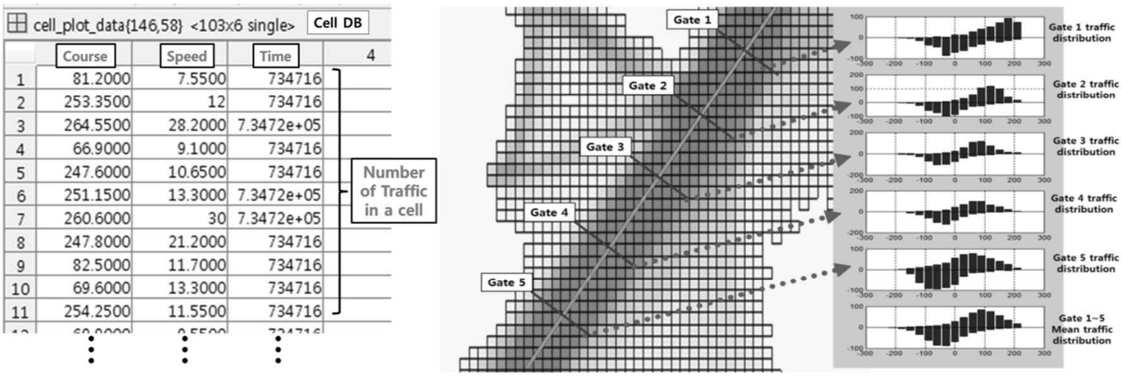

Figure 5: Data in a Cell(left) and Calculation Route Traffic Information using Gate Lines(right)

As a result of calculation, Table 2 shows the results of the route information of the MOKPO port.

Table 2: The results of Route Information of MOKPO port

No.	Start Waypoint	End Waypoint	Q_f	Q_b	μ_f	μ_b	σ_f	σ_b	v_f	v_b
1	34.77828333 126.3682667	34.78818333 126.3561	789	737	120.2	1.8	39.7	35.1	9.7	8.6
2	34.78818333 126.3561	34.7878 126.34805	636	730	159.4	0.5	48.5	35.3	9.3	10.1
3	34.7823 126.3435833	34.7579 126.3225	406	398	77.2	-20.9	50.8	48.0	9.8	10.3
4	34.7878 126.34805	34.7823 126.3435833	565	609	114.7	15.1	46.3	38.8	9.3	9.9
5	34.7823 126.3435833	34.78016667 126.3375833	200	206	-43.4	-85.6	68.9	72.2	9.0	9.1
6	34.7556 126.3167	34.76545 126.29805	466	475	91.0	-26.5	48.6	44.2	14.2	11.4
7	34.7579 126.3225	34.7556 126.3167	206	312	72.4	-28.3	70.7	54.5	10.6	9.7

Where Q_f is the mean value of the number of traffic quantity of the selected cells along the route direction,

Q_b is the mean value of the number of traffic quantity of the selected cells against the route direction,

μ_f and σ_f are the mean value of the traffic lateral distribution of the selected cells along route direction,

μ_f and σ_f are the mean value of the traffic lateral distribution of the selected cells against route direction,

v_f is the mean value of the vessel speed of the selected cells along the route direction, and

v_b is the mean value of the vessel speed of the selected cells against the route direction.

V. Conclusions

In order to transmit the safety information related maritime traffic, we suggest the maritime traffic gridded database by projecting AIS trajectories on location-based cells dividing unit cell length. It is possible to create many useful maritime traffic information layers. In this paper, we converted the gridded database to the maritime traffic display layer and the route traffic information layer for transferring information with high speed and low capacity. It will support the electronic navigation chart for mariners. In the process of e-Navigation implementation, we expect that this method will be effectively used to routinely transfer maritime traffic information to a ship.

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