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Metrics for Marine Traffic Safety Estimation with Respect to Data of Automatic Identification System

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Abstract. The paper is devoted to the problem of ensuring navigation safety on the sea. The task of determining patterns of motion parameters (clustering) in a multidimensional phase space (coordinates, velocity, course, etc.) is considered. It is proposed to refer to the retrospective data on the movement of vessels provided by the Automatic Identification System (AIS) and available on open Internet resources. One of the results of solving a general problem is the idea of the intensity of movement in the water area. The paper introduces a set of traffic intensity metrics based on the number and trajectory properties of vessels passing through certain water area.

1. Introduction

Safe navigation is one of the main categories that are associated with the operation of maritime transport. With a high intensity of water traffic, safe navigation requires compliance with the rules of navigation and following a specific scheme of safe movement (rules of movement) [1].

The rules of navigation on a specific water area, as a rule, prescribe the observance of a certain traffic pattern, depending on the geography of the water area and the characteristics of its traffic. Often there are various options for such a scheme; the choice in favor of one or another of them is due to the need to ensure maximum traffic safety and practical considerations [2].

One of the most important indicators determining navigational safety of the water area is traffic intensity. Its high value serves as a motive for a thorough study of the existing traffic pattern and the use of technical tools that provide decision support in a complex navigation environment [3]. A promising way to assess traffic intensity and other properties of water area traffic is to use data from an automatic identification system (AIS). [4]

The problem with the use of AIS data provided by open Internet resources is the limited accuracy of determining the navigation parameters of ships and the low frequency of receipt of information. [5-8] The paper discusses the format of the presentation of the initial data on the movement and the existing limitations, proposed models to estimate the intensity of movement. The results obtained make it possible to build a stable picture of high-loaded sections of offshore areas from the point of view of various metrics, and also open up the possibility to identify those ships that do not fit into the predetermined or dynamically determined movement frames (templates, clusters) of a particular marine area.

2. Method and materials

Consider the basic model representation of the problem. Ship traffic data available on open Internet resources like [9] are a multitude of tuples of the form

$$\{SID,\ LAT,\ LON,\ V,\ K,\ TIME,\ AGE\} \tag{1}$$

where *SID* is the vessel identifier; *LAT* – geographical latitude; *LON* – longitude; *V* – movement speed; *K* – course; *TIME* – data arrival time; *AGE* is the age of the data that determines the actual point in time to which they correspond. In addition, additional information is available about each ship: type, flag, port of destination, etc.

In the event that it is required to carry out modelling of ship movement over a specific local water area, the characteristic dimensions of which usually do not exceed hundreds of kilometres, it is advisable to move from the geographical coordinates of the vessel to local rectangular ones, transforming them according to the rule:

$$x = R\cos(LAT)\sin(LON - LON^*);$$

$$y = R\sin(LAT - LAT^*),$$

where *R* is the average radius of the Earth when represented by its sphere; *LAT** and *LON** – respectively, the latitude and longitude of the point, taken as the beginning of the local rectangular coordinate system.

Let us consider three possible metrics of traffic intensity: “number of vessels”, “velocity of vessels”, “size of vessels”.

The metric “number of vessels” determines the number of vessels that moved (or rested) in a certain section of the marine area per unit of time.

The “velocity of vessels” metric determines the “amount of movement” in a certain part of the marine area: the number of vessels that passed per unit of time, taking into account their speed. The faster the ship moves, the more its “weight” u_i in the metric (for example, the metric is increased by one for every 10 m/s):

$$u_i = \left[\frac{V_i}{10}\right] + 1$$

where V_i is the ship’s speed, [ ] is the operation of dropping the fractional part. The value of the “velocity of vessels” metric on a section of the marine water area is defined as the sum

$$u = \sum_{i=1}^{n} u_i$$

Resting ships in the metric “velocity of vessels” are not counted.

The “size of vessels” metric defines the “total length” of ships that have passed through a certain part of the sea area. The longer the ship, the greater its “weight” in the metric (for example, one for every 100 meters of length)

$$u_i = \left[\frac{L_i}{100}\right] + 1$$

where L_i is the length of the hull. The value of the “size of vessels” metric is defined in the same way as the previous one, as the sum of u_i. Resting ships in the "size of vessels" metric are also taken into account.

3. Results

These metrics were calculated on real traffic data of several marine areas. This paper presents the results for the Tsugaru Strait and Tokyo Bay.

Figures 1-3 show the results of calculations of the traffic flow in the Tsugaru Strait. The traffic data for 24 hours was processed, containing about 200,000 records of type (1). The water area was divided into square sections with a side of 1 km.

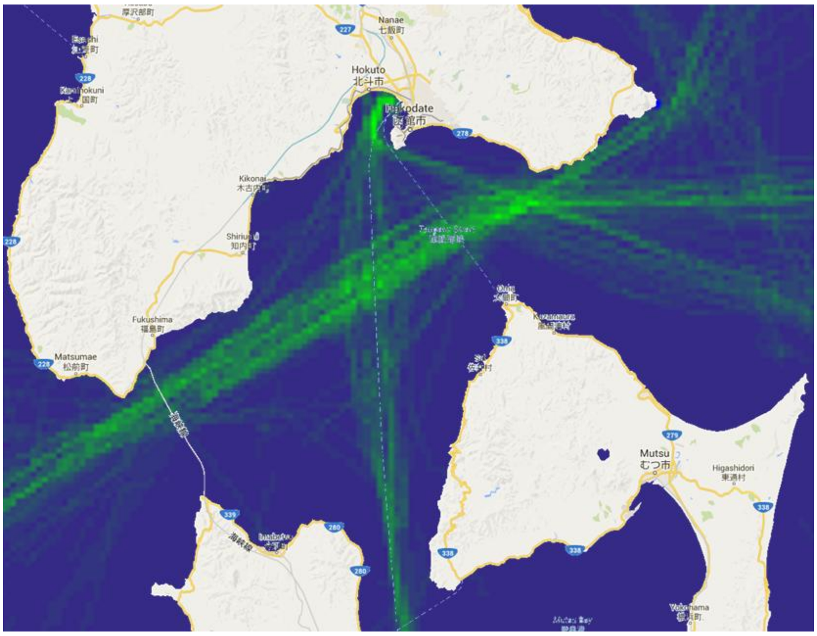

Figure 1. The results of the calculation of the metric “number of vessels” in the Tsugaru Strait.

Figure 1 shows the “number of vessels” metric. Its values range from 0.2 (dark green dots) to 1 ship per hour (bright green dots). It is seen that in general, the intensity of movement in the strait is low.

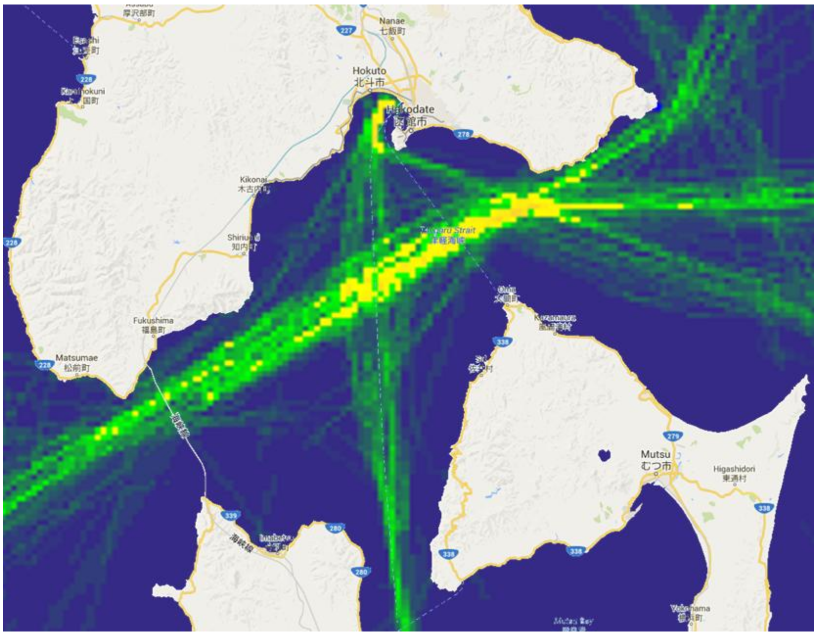

Figure 2. The results of the calculation of the “velocity of vessels” metric in the Tsugaru Strait.

Figure 2 shows the “velocity of vessels” metric. One can see areas where high-speed vessels are moving (yellow dots, metric values in the range from 1 to 3 “high-speed” vessels per hour). There are no areas in the selected water area where the metric would assume “extremely” high values.

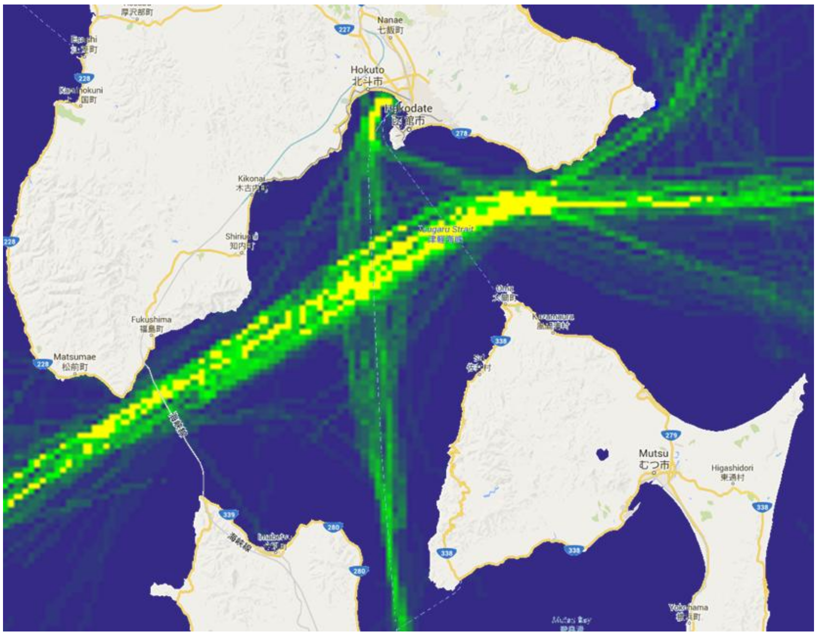

Figure 3. The results of the calculation of the metric “size of vessels” in the Tsugaru Strait.

Figure 4. The results of the calculation of the metric "“number of vessels” in Tokyo Bay.

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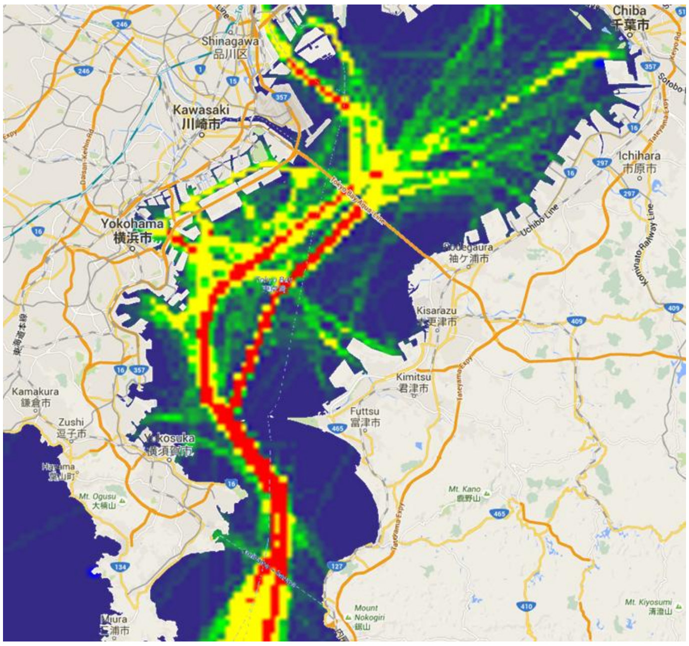

Figure 5. The results of the calculation of the metric “velocity of vessels” in Tokyo Bay.

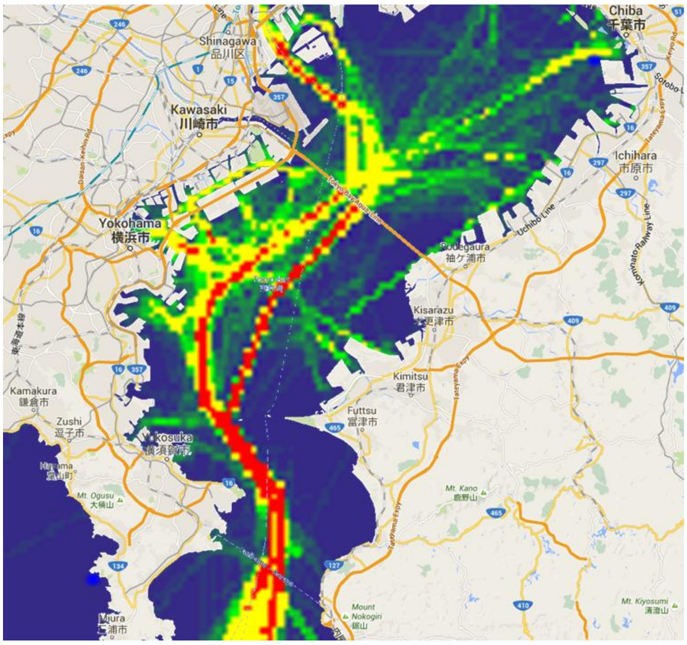

Figure 6. The results of the calculation of the metric “size of vessels” in Tokyo Bay.

Figure 3 shows the “size of vessels” metric. The areas where the largest vessels move are visible (the yellow dots correspond to the values of the metric in the range from 1 to 3 "large" vessels per hour). As in the case with the “size of vessels” metric in the selected water area, there are no areas where the “size of vessels” metric is excessively high. Comparing figures 1, 2 and 3, we can conclude that the largest ships are usually the fastest.

In general, one can see the feature of the water area traffic: intersecting north-south and west-east ship-flows.

Figures 4-6 show the results of calculations of the traffic intensity in the Tokyo Bay. Data on traffic for 24 hours was processed, containing about 1,200,000 records of type (1). The water area was divided into square sections with a side of 500 m.

Figure 4 shows the “number of vessels” metric for Tokyo Bay. Its values range from 0.2 (dark green dots) to 3 ships per hour (yellow dots). The greatest intensity of movement is observed in the southern part of the bay.

Figure 5 shows the “velocity of vessels” metric for Tokyo Bay. On this marine area there are areas that are distinguished by high speed (red dots, metric values in the range of more than 3 “high-speed” vessels per hour).

Figure 6 presents the “size of vessels” metric for Tokyo Bay. There are areas where the largest vessels are moving (red dots, metric values of more than 3 "large" ships per hour). As well as for the Tsugaru Strait, there is a correlation between the velocity and size of the vessels, which, apparently, is an invariant property of the marine areas.

4. Conclusion

1. Retrospective data on the movement of vessels in the waters provided by resources like [9] allow solving the problem of estimating the intensity of the movement of vessels.

2. Different model interpretation of the concept of “intensity of movement” is possible. The paper proposes metrics for estimating the intensity based on data on the number, velocity and size of vessels.

3. Data was obtained on the traffic intensity of vessels in specific areas with different traffic patterns (Tsugaru Strait, Tokyo Bay, etc.). The results of calculations indicate the informativeness of the proposed traffic intensity metrics.

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