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Data extraction from an electronic S-57 standard chart for navigational decision systems

Ekstrakcja danych z mapy elektronicznej w standardzie S-57 na potrzeby nawigacyjnych systemów decyzyjnych

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Key words: electronic chart, navigational decision support system, area discretization

Abstract
The problem of using data from an electronic navigational chart meeting the S-57 standard for applications in the navigational decision support systems is dealt with. The authors consider problems of the selection and transformation of data used in the process of navigational situation analysis. The method of data acquisition and selection along with some methods of data presentation are described and compared. The operation of developed algorithms is discussed in relation to a selected fragment of an electronic chart. Advantages and disadvantages of various solutions are indicated.

Słowa kluczowe: mapa elektroniczna, nawigacyjny system wspomagania decyzji, dyskretyzacja obszaru

Abstrakt
W artykule przedstawiono zagadnienie wykorzystania danych zawartych na elektronicznej mapie nawigacyjnej w standardzie S-57 dla potrzeb nawigacyjnych systemów decyzyjnych. Rozpatrzono problemy selekcji oraz transformacji danych wykorzystywanych w procesie analizy sytuacji nawigacyjnej. Przedstawiono metodę pozyskiwania i selekcji danych oraz wybrane metody ich prezentacji. Porównano prezentowane metody. Omówiono działanie opracowanych algorytmów na przykładzie wybranego fragmentu mapy elektronicznej. Przedstawiono wady i zalety poszczególnych rozwiązań.

Introduction

During voyage planning, navigational situation analysis and ship conduct one has to use a navigational chart. Apart from a printed chart, navigators increasingly use an electronic navigational chart (ENC). At present, the most frequently used in ECDIS systems is the S-57 standard. Hydrographic data from selected areas are presented on such charts in the form of symbols, points, lines, polygons and text.

This information may be used in navigational decision systems to, *inter alia*, indicate dangers, analyze a present situation, work out a safe trajectory of ship movement.

The article presents two alternative methods of data extraction from an ENC made in the S-57 standard. The information may be transformed, processed and recorded by using regular and irregular meshes. The choice of data processing method depends on the required accuracy of computing, time limit for developing a solution and area configuration. Due to the efficiency of algorithms used in decision systems and the degree of complexity of an analyzed situation, a relevant fragment of the whole area has to be chosen for computations.

Data selection

The S-57 ENC, in geometric terms, is an ordered set of elements on a plane, i.e. points, lines and polygons (Fig. 1). These are described by geographical coordinates and attributes of objects these coordinates represent. The displayed chart is

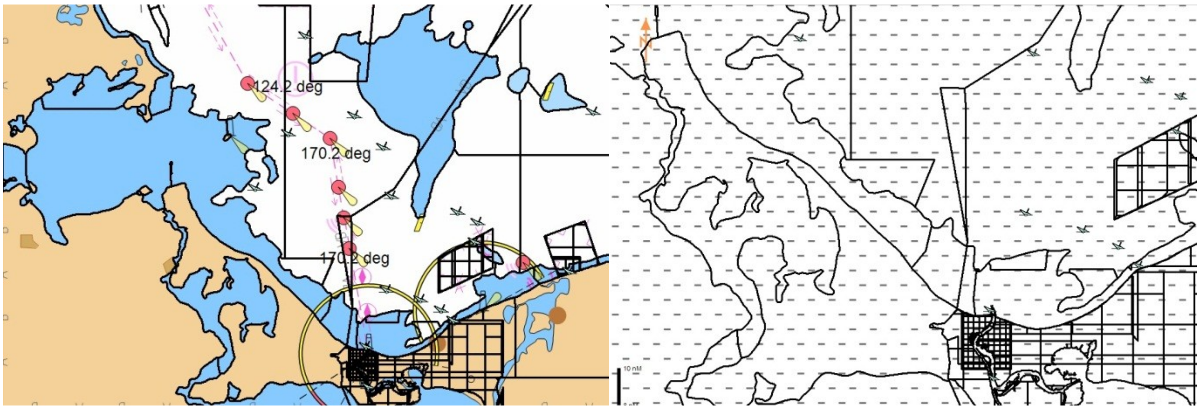

Fig. 1. A navigational chart and its vector representation
Rys. 1. Mapa nawigacyjna i jej reprezentacja wektorowa

created by superimposition of many elementary charts (cells) and a choice of displayed elements of these charts depends on the scale and configuration settings (day or night vision, selection of the displayed elements: base, standard, others) [1].

Based on the information contained in files including charts, it is possible to read out area-related data, the user is interested in and to use it in a navigational decision support system [2].

The following data are mainly needed for a situation analysis:

1. Coastline;
2. Depths (contours);
3. Areas temporarily prohibited for navigation;
4. Traffic separation schemes;
5. Dangerous points and prohibited for navigation (wrecks etc.).

For the purpose of analyzing, a present navigational situation on board a ship and planning necessary manoeuvres the area concerned is that covering not more than 20 miles around that ship. Therefore, it has to separate relevant information

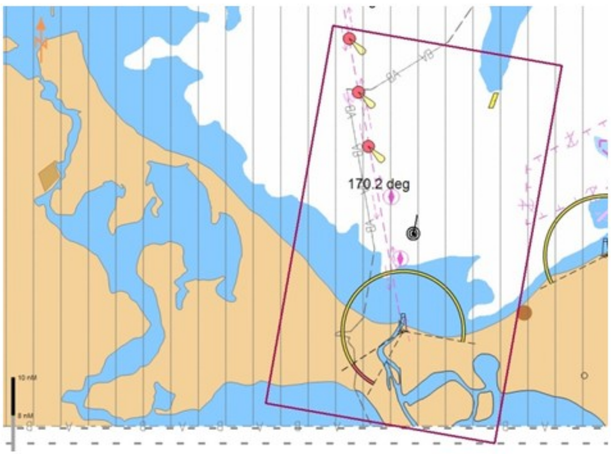

Fig. 2. A selected ENC fragment
Rys. 2. Wybrany fragment nawigacyjnej mapy elektronicznej

from the whole set of chart data. Besides, algorithms for situation analysis and route (path) optimization often require that the examined area should be defined as a rectangle whose vertical sides are parallel to the vector of own ship movement (Fig. 2). Then, it is necessary to transform the point coordinates of an analyzed chart fragment.

Due to a substantial number of lines determining areas available within a given chart, it needs to limit the number of lines, points and polygons to those only that cross the selected area (Fig. 3). Next, lines outlining all selected objects should be analyzed and cut, so that they will be contained in the defined area. This process refers only to elements important from the navigator's viewpoint, e.g. only those depth contours are analyzed that mark depths less than own ship's draft, while other contours are neglected.

	Obiekty	Glebokosci			Lad			Restricted		
		Linie	Faces	Punkty	Linie	Faces	Punkty	Linie	Faces	Punkty
DE316003	1338	38	331	27804	60	94	6027	60	94	6027
DE316004	1131	94	254	14014	21	64	3517	21	64	3517
PL3A0000	245	18	78	1664	3	9	273	3	9	273
PL3B3000	303	30	157	3205	1	28	212	1	28	212
PL3C0000	155	20	83	2294	1	12	198	1	12	198
PL4MAP36	178	47	168	4805	1	1	24	1	1	24
PL4MAP37	1764	184	420	24723	38	121	6314	38	121	6314
PL4MAP38	1872	289	484	26919	34	159	6445	34	159	6445
DE516650	88	8	53	891	3	22	319	3	22	319
PL5SWINO	884	148	332	14714	7	118	1854	7	118	1854
PL5SZCZE	1302	214	411	17770	15	139	3334	15	139	3334

Fig. 3. The geometric complexity of some navigational charts
Rys. 3. Złożoność geometrii wybranych map nawigacyjnych

Methods of data extraction

After transformations, a chart fragment is obtained that will then be overlapped with a regular or irregular mesh with quadrilateral elements. The choice of a discretizing algorithm depends on analyses that are currently carried out and the method used for optimization.

The result of optimization computations must then be transformed into the original coordinate system.

Regular meshes, with regular quadrangle elements, defined by points determining the angles of subsequent elements, are the simplest form of area discretization (Fig. 4) [3]. Their basic advantages are a simple discretizing algorithm and easy computation / searching for node positions. The only data required are the position and number of one node and the mesh resolution in the directions of x and y or φ, λ, depending on the currently used coordinate system. Regular meshes require a high resolution in order to obtain a sufficiently accurate representation of an area. As a result, a large number of elements is obtained. An increased number of points and possible transitions between them leads to a longer computing time. A decreased number of nodes, in turn, will reduce the accuracy of area representation. As a result, various computation results will be obtained for the same navigational situation.

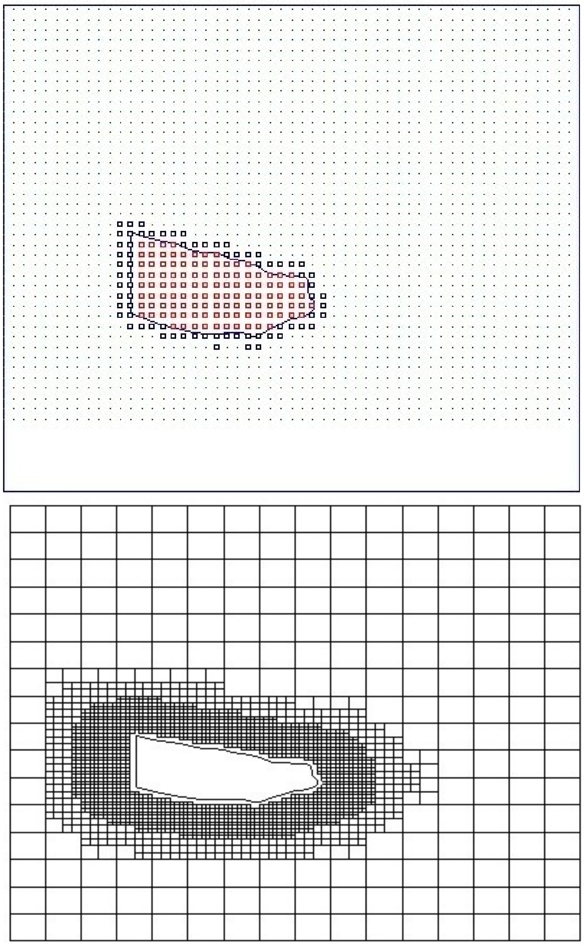

Fig. 4. A regular and an irregular mesh
Rys. 4. Siatka regularna i nieregularna

It may also turn out that part of the analyzed area should be covered with a high resolution mesh, while for other fragments of the same area, it is not needed, i.e. elements of bigger surface area could be used. There is no such possibility if a regularmesh is applied. It is possible, however, to set various mesh resolutions in the directions x and y depending on the present situation, geometric complexity of the area and the dynamics of moving objects.

Irregular meshes ensure more accurate representation of the analyzed area and adjustment of the number of mesh elements to area structure (Fig. 4) [4]. A disadvantage of the method is a much more developed discretization algorithm and the need to increase the number of mesh parameters, which results from the necessity of determining each element size, the number and size of neighboring elements, balancing of the structure etc. The amount of necessary extra computations varies and depends on the structure of the currently analyzed chart fragment. This lengthens the time of mesh creation compared to a regular mesh.

As a result, we get a structure of mesh nodes and elements, a discrete representation of the analyzed area, described by means of two-dimensional tables that contain:

1) coordinates and parameters of points (mesh nodes);
2) data on successive mesh elements.

The contents and size of tables depend on the currently used method of discretization and the structure of the analyzed chart fragment. If the area was covered by a regular mesh, the number of nodes and elements is proportional to the resolution of the mesh defined by the user or determined by the algorithm from an analysis of chart structure. In case of an irregular mesh, the distribution of elements is chosen by the algorithm and depends on the position of all analyzed objects. The user only defines a minimum and maximum size of a single element and a maximum allowed number of mesh elements.

The obtained structure of mesh nodes and elements are a basis for an analysis of a current navigational situation. At this stage, dangers and restrictions resulting from the location of all stationary objects are considered. These are, *inter alia*, coast lines, shallow waters, areas temporarily or permanently prohibited for navigation, traffic separation schemes, wrecks etc. Geometrically, these objects are divided into three categories:

- points – wrecks, buoys;
- lines – quays;
- areas – land, areas prohibited for navigation, depth contours etc.

Another criterion for classification is the qualification of objects as prohibited / dangerous or imposing restrictions in navigation depending on, e.g. safe depth required for own ship, or time, e.g. areas temporarily inaccessible.

In case of dangerous areas, the mesh nodes and elements encompassing a given object or its part and lying at a distance shorter than the user-defined safe distance are marked as prohibited (Fig. 5). If there are dangerous points, the nodes and elements lying within a circle with a radius equal to the defined safe distance centered on the dangerous point are marked as prohibited.

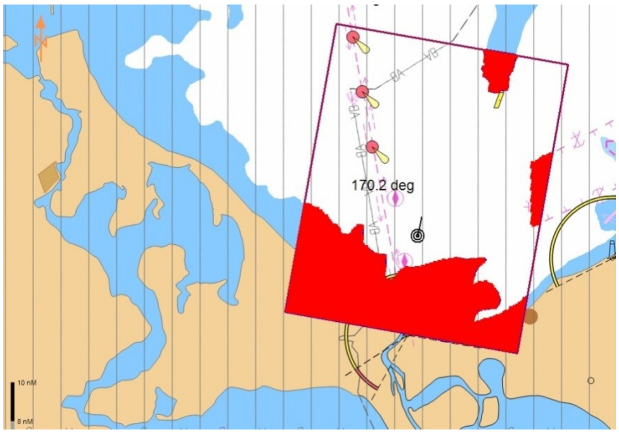

Fig. 5. A fragment of a navigational chart with marked prohibited areas
Rys. 5. Fragment mapy nawigacyjnej, zaznaczone obszary zabronione

In case of points and objects qualified as restricting navigation in the analyzed area and the mesh is irregular, the mesh is made denser within an area encompassing the analyzed object and some distance beyond it. For a regular mesh, its density depends on the structure of the whole currently analyzed chart fragment and on the qualification of objects lying within this fragment.

The mesh nodes and elements marked as prohibited are not taken into account in further analyses aimed at e.g. route choice and optimization (objects may move only in allowed areas), which permits to reduce the number of possible combinations and shortens computing time of optimizing algorithms. This is of particular importance in probabilistic methods, in which a great number of feasible solutions is considered.

Computing experiment

To verify the proposed methods of data extraction, a computing experiment was performed based on two variants of an encounter situation of two ships:

1) in an open sea area;
2) in a restricted area.

According to the Collision Regulations, own ship is obliged to make a manoeuvre to safely pass the other vessel.

The extracted data covered a selected area with elements of an electronic chart lying up to 10 Nm ahead and 2 Nm astern of own ship. Besides, the area reached as far as 6 Nm to the sides – 3 Nm on port and starboard side. The results are given in figures 6 and 7.

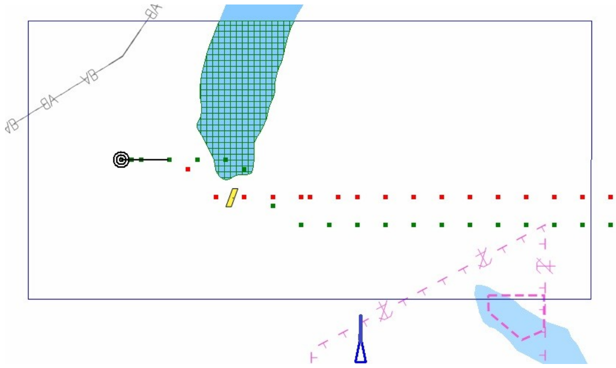

Fig. 6. A solution to a navigational situation, encounter of two ships, using a regular mesh
Rys. 6. Rozwiązanie sytuacji nawigacyjnej spotkania dwóch statków z wykorzystaniem siatki regularnej

For an open (unrestricted) area, the optimal trajectory does not account for the insufficiently deep water region (green points in Fig. 6). When the depth is taken into account, the trajectory is changed to bypass the prohibited area and, simultaneously, pass the target at a preset distance (red points in Fig. 6).

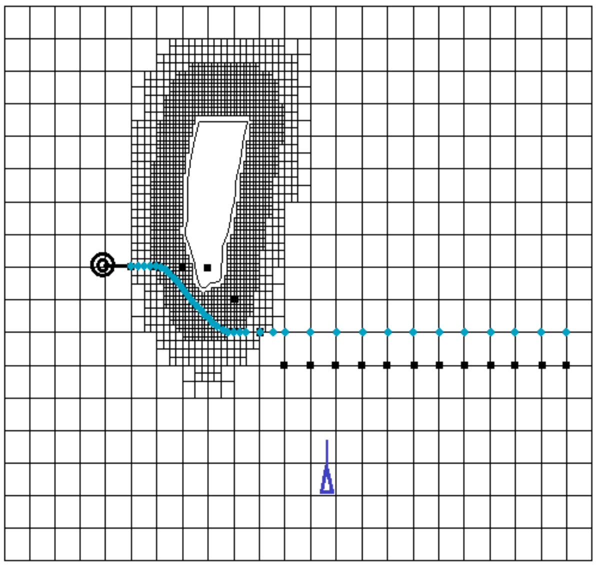

Fig. 7. A solution to a navigational situation, encounter of two ships, using an irregular mesh
Rys. 7. Rozwiązanie sytuacji nawigacyjnej spotkania dwóch statków z wykorzystaniem siatki nieregularnej

Conclusions

The methods presented in this article allow to effectively extract and select data contained on an electronic navigational chart of S-57 standard. Selected data may be used for information purposes, in the process of a current navigational situation analysis and the determination of safe trajectory in a restricted area in navigational systems, particularly in a navigational decision support system.

Procedures of creating regular meshes have a significantly less complex structure, thus allowing to simplify many computations, e.g. while an optimal trajectory is being determined. Consequently, the implementation of other, e.g. optimization algorithms, is made easier.

In case of irregular meshes, the process of their creation is much more complex, but is allows to adjust the mesh structure to the contents of a selected chart fragment. Areas recognized as dangerous are in this case represented more accurately. As a result, trajectories of ship movement in particularly dangerous areas can be planned more precisely.

The method makes it possible to additionally reduce the number of points by taking into account the ship manoeuvrability.

The obtained results make up a basis for further research aimed at shortening the time of algorithm operation, enhancing the accuracy of area representation, and application of proposed methods for data extraction from navigational charts in the new S-100 standard giving access to larger quantity of hydrographic data, consequently enabling a more accurate area description.

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