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Applying Remotely Piloted Aircraft Systems for Correcting Electronic Chart Data and Ensuring Safe Navigation

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Abstract

The article proposes a solution to the problem of operative data collection for correcting electronic chart data and ensuring safe navigation. A subsystem for obtaining cartographic data with the help of the Remotely Piloted Aircraft Systems **(**RPAS) has been developed.
On the basis of data received from RPAs, it is possible to create a draw layer for an electronic chart with new coordinates of objects. Creation of such layers will make it possible to objectively evaluate the situation taking into account possible parameter changes for selected key objects. In case of continuous parameter change, for example, the change of shoreline coordinates, this layer is sent to a hydrographic service for introducing changes to the official electronic chart. When using the RPAS, the system will allow to track changes in real time, which at present is possible only with the help of space satellites.
KEY WORDS: *electronic chart data, ensuring safe navigation, electronic chart data correction, remotely piloted aircraft systems*

1. Introduction

Navigation of vessels, as the most important component of navigation, is governed by instruments issued by the International Maritime Organization (IMO) and by national regulations developed by the Maritime Administration. The main commercial navigation aids have to be certified to comply with international operational standards. Safety requirements applicable to the building, equipment and operation of vessels are reflected in particular in the SOLAS (Safety of Life At Sea) Convention [1].

At present, the main means of officially approved electronic navigational cartography is ECDIS or Electronic Chart Display and Information System that complies with both national and international requirements.

In 2009, the IMO adopted requirements on the mandatory installation of ECDIS systems on all merchant ships over 3000 GT and passenger ships over 500 GT (Fig.1). At present, all new cargo ships and tankers with a capacity of over 3000 gross tons and all passenger ships over 500 gross tons have to be equipped with electronic chart systems in compliance with the requirements of the SOLAS Convention [1].

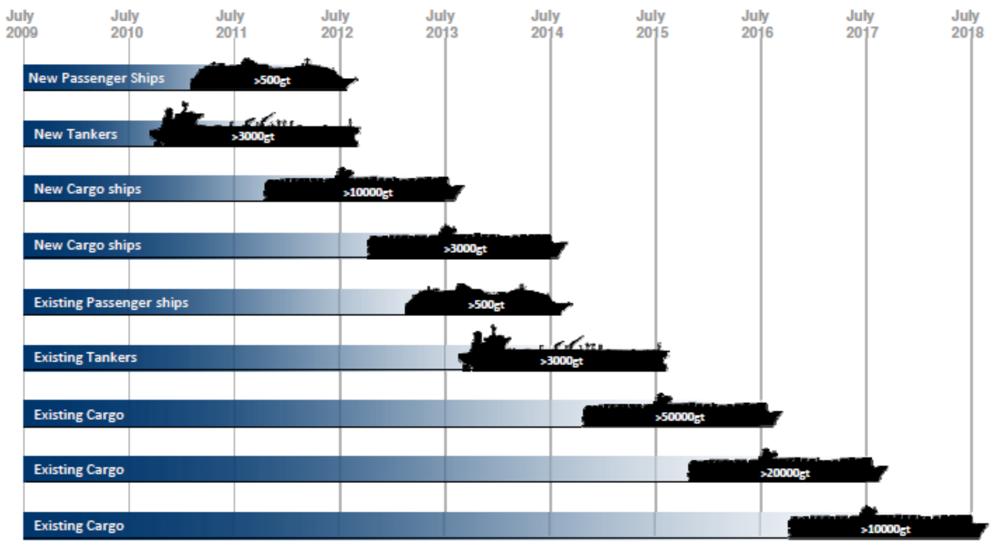

Fig. 1 Cargo carrying capacity of modern sea vessels

In accordance with the SOLAS Convention (1974), since 2002 the ECDIS has been included in the list of marine navigation equipment (Rule 19) and can be used for executive plotting. It was first officially announced in the IMO Resolution of 1995. This resolution states that if there is ECDIS with a collection of official ENC (Electronic Navigation

Charts) with correction on board of the vessel, the system can be regarded as a legal equivalent to paper charts [2]. ENC has to include all cartographic information necessary for ensuring navigational safety; besides, ENC may include additional data, which are not usually shown on marine maps and contained in pilots and other navigational aids, and which are necessary for maritime navigational safety. Official ENCs are charts developed by a state's hydrographic organization to be used in ECDIS by applying S-57 – a basic electronic chart format defined by the International Hydrographic Organization (IHO) and intended for data exchange among hydrographic services, agencies and manufacturers of cartographic products and systems [3].

Ensuring the accuracy and timeliness of ENC correction is a responsibility of national hydrographic organizations. Cartographic information has to correspond to the data from the latest edition published by a state's national Hydrographic Service, as well as to the relevant IMO requirements. For example, in Latvia, the Hydrographic Service of the Maritime Administration of Latvia is a national coordinator: this is an institution authorized by the government to collect and receive information about changes in the condition, parameters and coordinates of navigational objects. The collected information including electronic chart corrections has to be analysed and sent to vessels and coastal services. Unmanned aerial vehicles (RPA) can serve as an effective tool for the quick collection of accurate information for correcting charts [4-6]. Paper [7] describes the functioning of the cartographic information collection system for navigation by using the RPA. This work analyses the operation algorithms of the separate subsystems of the above mentioned system.

2. Practical Implementation of the Cartographic Information System

To identify monitor objects (buoys, lighthouses, etc.), an image recognition subsystem is used (Phase 1 [7]). The subsystem allows to identify the presence of certain objects in the image as well as to calculate the relative coordinates of the centres of these images. The results of recognition are reflected in a table containing the location coordinates of key monitor objects (Figs. 2 and 3).

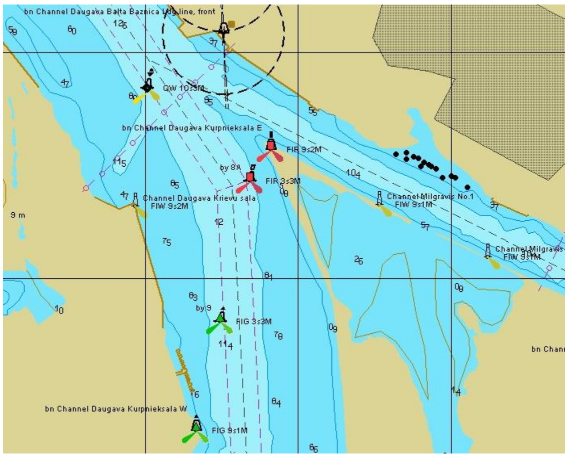

Fig. 2 Original electronic chart for a specified area

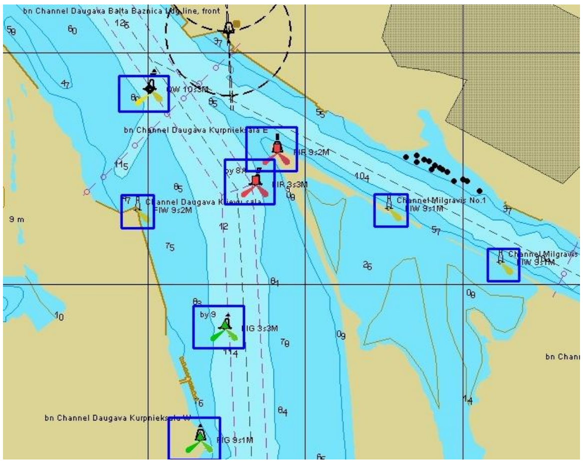

Fig. 3 A processed chart after determining the location of monitor objects (rectangles)

After identifying monitor objects, it is necessary to make an RPA flight plan and determine flight parameters (flight range, speed, altitude), as well as the quality of photography, intensity of framing photography, etc.

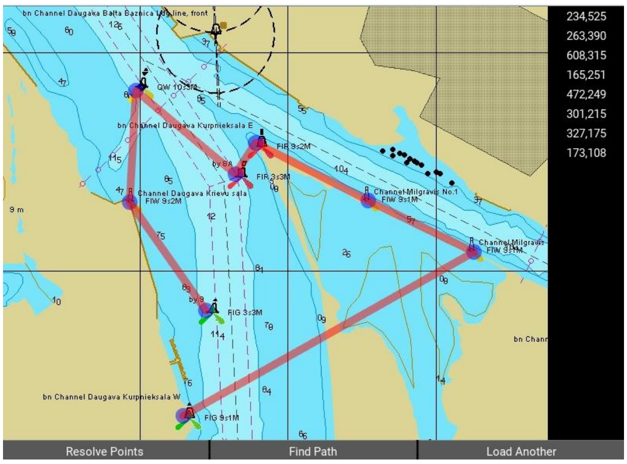

Fig. 4 The optimal flight plan for the monitoring of specified objects

To determine the flight plan, it is required to use an algorithm allowing to photograph a real layout of the specified number of objects in minimal time during the flight. For this purpose, a subsystem calculating an optimal flight plan for the identified objects is used. In the process of creating this subsystem, a comparison of various algorithms of optimal flight plan development was carried out by using graph theory from the point of view of calculation time optimality and the required resources. The subsystem uses the methods of dynamic programming [8] that make it possible to make the optimal flight plan based on object coordinates. An example of the result of subsystem implementation for a specified area (Fig. 1) is presented in Fig. 4.

For the comparison of a real and cartographic object locations, which have been received in the process of implementing Phase 1 and Phase 4 [7], a subsystem for transferring coordinates from bitmap image into World Geodetic System 1984 Datum (WGS84) is used. Such a transfer is mandatory for official charts used in ECDIS [9].

The algorithm we have developed for the created subsystem automatically recalculates object coordinates from the bitmap image (where coordinates are presented in pixels) into the geodetic coordinate system WGS84. Moreover, to calculate the coordinates of objects the coordinates of which may change (for example, buoys), it is possible to use the coordinates of key objects that cannot change their coordinates (for example, lighthouses). Key objects can be identified by their position on the shore, i.e. in an area with a colour gradient differing from the sea surface by colour. Besides, for manual correction, the key points of identified objects can be set by the operator who will enter their coordinates in WGS84. The operation of the subsystem for the automatic calculation of coordinates is presented in Figs. 5 and 6.

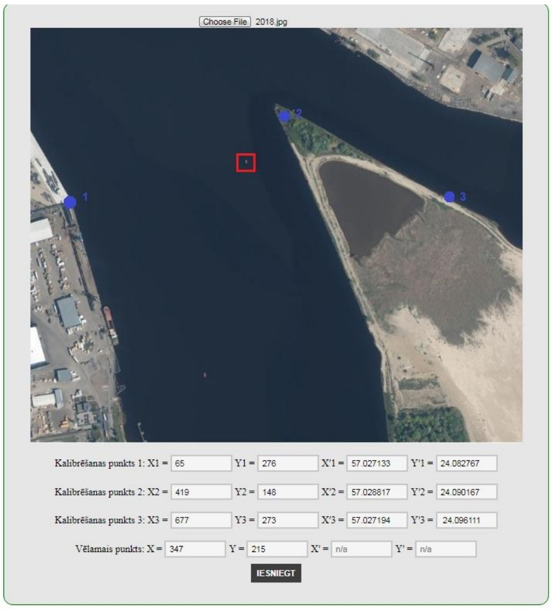

Fig. 5 Setting of key points (blue markers) with coordinates by the operator for the calculation of the WGS84 coordinates of the identified buoy (red marker)

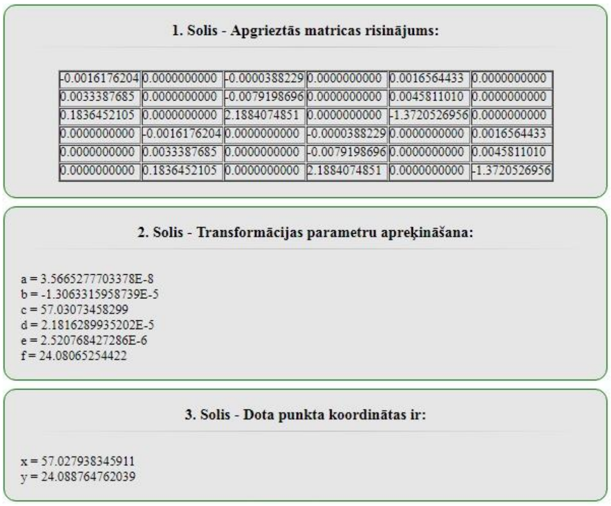

Fig. 6 The result of coordinate calculation in text format

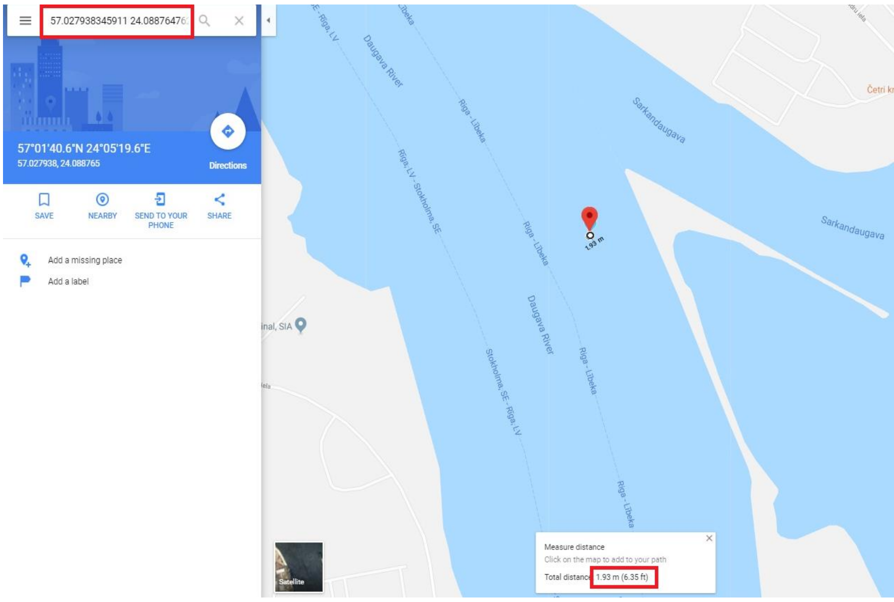

Fig. 7 Comparison of the obtained current coordinates of the object with the previous coordinates marked on the electronic chart

The calculated coordinates are compared with the object reference coordinates on the electronic chart. If the difference is greater than the value set by the operator, the system alerts of the position deviation for a certain object. An example of comparing the results of the previous calculation of object (buoy) position in the photo and its real coordinates is graphically shown (Google Map) in Fig. 7. The difference in coordinates is both visualized and represented numerically. The difference in object coordinate values in the considered example is less than 2 metres.

3. Conclusion

A system of collecting cartographic information for navigation with the help of RPA system has been developed. This system can simplify and cheapen the compulsory information acquisition procedure for government institutions responsible for providing cartographic data. Moreover, the response time is reduced to the time of inspection of key points by the RPA. Taking into consideration the inexpensive cost of this procedure, the frequency of information acquisition is determined by the operator and may reach several flights a day. When using several RPAs, the system will allow to track changes in real time for large geographical areas, which presently is possible only through satellite observation. In addition, the expenditures on satellite observation and the proposed RPA system may differ considerably.

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