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Analysis of Systems Ensuring the Acquisition of Real-Time Cartographic Navigation Information

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***Abstract* – Electronic Chart Display and Information Systems (ECDIS), which are used on vessels and can replace paper charts, allow to obtain and display on electronic charts information from basic and additional data sources. For the certified use of ECDIS instead of paper charts, it is necessary to ensure constant updating of Electronic Navigation Chart (ENC) data provided to vessels for use. The known visual and satellite observation systems intended for cartographic information update are costly, have low accuracy and do not allow to quickly update navigational charts in real-time mode. The stand-alone use of remotely piloted aircraft (RPA) will make it possible not only to substantially reduce costs and increase the accuracy of monitoring, but also to provide information in real-time mode.**

***Keywords* – Cartographic information, remotely piloted aircraft, satellite systems.**

I. Introduction

The digital revolution, which started in the 80s of the last century along with the transition from analogue technologies to digital ones, has gradually transformed into a computer revolution that has made computers cheaper and promoted their wide use. This resulted in the appearance of a global network, the development of which created the possibility to instantly transfer practically any type of information (data, voice and video). It gave the opportunity to both create new systems, algorithms and models and integrate already existing ones with new functionality [1]. Global changes that now can be quite clearly visible when compared to the situation 20–30 years ago have occurred everywhere – from medical industry to usual city traffic control, from nuclear power station control to personal communication systems.

The maritime field, in particular the field of maritime navigation, has not become an exception. There appeared satellite positioning systems, Automatic vessel Identification Systems and Electronic Chart Display and Information Systems. In accordance with the requirements of the International Convention for the Safety of Life at Sea (SOLAS) [2], Electronic Chart Display and Information Systems, which are used on vessels and can replace paper charts, allow to obtain and display on electronic charts information from basic and additional data sources. These can be both sensors providing information about the vessel itself (position, course, speed, depth) and data channels from other systems. For example, the radar and Automatic Identification System (AIS) provide real-time information about other nearby objects such as vessels, shorelines, buoys, lighthouses, etc. Navigational Telex (Navtex) system can transfer to ECDIS navigation and meteorological information that will be displayed on the chart with reference to the area where this information will be relevant. At the moment, all passenger ships, tankers and cargo ships (the latter with a gross registered tonnage of above 10 000 gross tons) have to be equipped with a certified ECDIS [3].

For the certified use of ECDIS instead of paper charts, it is necessary to ensure constant updating of Electronic Navigation Chart's (ENC) data provided to vessels for use. Otherwise, instead of a navigation system, one will receive a Garbage In Garbage Out system, which will lead to emergency situations ending in multi-million material losses in the maritime field and, in the worst case, in human losses. Thus, for example, on 29 May 2015, passenger motor ship "Lotos" ran aground in the

Stark Strait, Russia, 300 m away from the shore. There were 132 people on-board. The situation was resolved without human losses; however, the investigation carried out to uncover the cause of the incident concluded that “the navigation buoy marking the safe navigation channel was carried 128 m away from its installation point by an abnormally strong underwater current due to seasonal climate changes” [7]. It means that the error could be measured not in metres, nor even in tens of metres. Moreover, it did not appear instantly. Installation of navigation marks in the sea and supervision of their operation as well as the accuracy and timeliness of ENC updating are among the responsibilities of the National Hydrographic Organization. Real-time cartographic navigation information has to correspond to the latest edition published by the National Hydrographic Organization and comply with the requirements of IMO. For instance, in Latvia, the Hydrographic Service of the Maritime Administration of Latvia is a national coordinator – a competent government body authorized to obtain and collect information about changes in the status, parameters and coordinates of navigation objects [8].

II. International Regulation of the Procedure of Updating Electronic Charts

There exists a list of requirements of such international organizations as International Maritime Organization (IMO), International Hydrographic Organization (IHO) and International Electrotechnical Commission (IEC) both for ECDIS as a whole and separately for the update of internationally certified Electronic Navigation Charts (ENC).

Basic documents regulating the updating of ECDIS electronic charts are IHO S-57 standard – “A data format for digital hydrographic data transfer” and IHO S-52 standard – “A standard used by ECDIS manufacturers that determines how ENC data is displayed on an ECDIS screen”. The requirements of these two documents are presented in IMO Resolution A.817 (19) – ECDIS Performance Standards [4].

In compliance with S-57 standard, all navigation information is to be kept in a vector form, which can effectively save storage space when saving the card. Besides, the minimum time for restoring or refreshing the chart on the screen is required. In addition to that, this method allows to update parameters of any object on the chart (coordinates, type and so on) without affecting other objects and the global parameters of the chart. S-57 standard describes the control mechanisms allowing to adjust separate data components [5].

Practical issues related to ENC updating are mostly considered in S-52 standard that includes Appendix 1 – “Guidance on Updating the Electronic Navigational Chart” [6]. The main requirements for official ENC updating for the marine ECDIS are set out in IMO Resolution A.817 (19).

III. Application of Visual Observation for Updating Cartographic Information

This method requires the use of real sea vessels belonging to the Hydrographic Service or sea vessels owned by other departments and services. For example, in Latvia, visual observation is carried out with the help of a vessel called “Kristians Dals” owned by the Hydrographic Organization (Fig. 1). This method is not optimal neither from the point of view of time nor from that of budget. The necessity of using real sea vessels and specially trained personnel as well as maintenance and repair expenses require substantial finance.

Fig. 1. The vessel “Kristians Dals” owned by the Latvian Hydrographic Organization.

In addition to that, in this case, it is impossible to talk about the real-time mode. The Latvian coast extends for approximately 10 000 km^2 (Fig. 2). Thus, the time spent on obtaining complete information about all objects can be measured in weeks and months.

Consequently, if the number of sea vessels is small, it is impossible to collect visual information in such a vast area within a reasonable period of time. Increasing the number of vessels for data acquisition would lead to the proportional growth of expenditures.

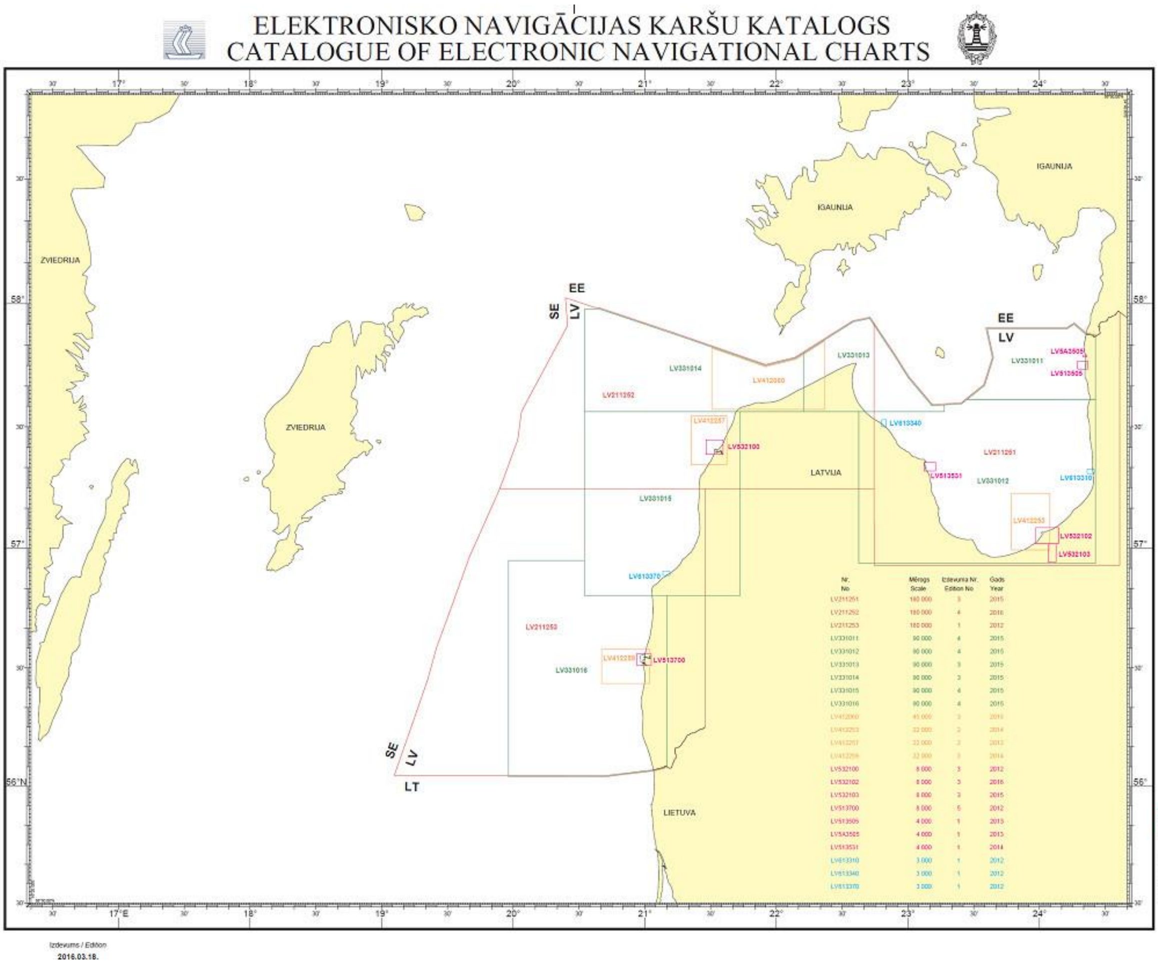

Fig. 2. Area of responsibility of Latvian Hydrographic Service [10].

Besides, this method requires time and resources not only for data acquisition but also for further works – data processing, making decisions about the necessity of correcting and sending corrections to vessels. The method becomes even more costly when using manned aircraft for continuous monitoring.

IV. Application of Satellite Observation for Updating Cartographic Information

This method includes the possibility of permanent or periodic (in certain periods of time) visual observation of navigation objects from satellites located over the area in question for further processing of obtained photographic images with the aim of deciding about the necessity of updating. However, in this case, the resolution of satellite photography constitutes the biggest problem.

Before 2014 it was forbidden by the United States Department of Commerce and Department of Defence to commercially sell images with a resolution exceeding 50 cm per pixel to third parties. For example, Digital Globe – the commercial operator of several civilian satellites for remote Earth sensing and major supplier of satellite photography results (in particular for Google Maps/Earth and Virtual Earth) was able to offer satellites with a resolution exceeding 50 cm per pixel only in 2014, after being granted special permission by the United States Department of Commerce [11]. However, the restriction – 25 cm per pixel – is currently in force. And it is rather difficult to obtain for satellite observations. The practical implementation of the latest generation of Digital Globe's satellites (WorldView-3) provides a maximum panchromatic camera resolution of up to 31 cm per pixel under perfect conditions.

It is necessary to take into account that patterns for stable object (buoys, lighthouses, vessels) recognition in a photo by using software include areas of several tens of pixels in both horizontal and vertical directions rather than a 3×3-pixel matrix. Otherwise, it is extremely difficult to identify an object. However, with account of the above-mentioned restrictions, even under optimum conditions (for example, at 31 cm per pixel image resolution and a 10-pixel square recognition matrix) objects with a diameter of less than 3 m are impossible to recognize. If the conditions are not optimum, it will be challenging to recognize an object of 5 or 10 m.

In addition to that, it must be considered that in most cases conditions will not be perfect. Light refraction on atmospheric inhomogeneity imposes limitations on the maximum possible resolution when observing Earth from space. This limitation depends on the state of the atmosphere and under favourable conditions (the morning orbit) is about half a meter per pixel. Under especially favourable conditions (calm air), it reduces up to 30 cm. If at this moment a satellite with an optical resolution exceeding this restriction will appear over the area being observed and take a photo, the photo will anyway have a resolution of not less than 30 cm per pixel. It is also necessary to take into account that such a coincidence, i.e. when a satellite appears at a certain place, is possible only by accident, because it is impossible to predict where and when such conditions will exist.

It is practically impossible to achieve a better resolution than 30 cm per pixel – even very calm air refracts light anyway.

A resolution of up to 50 cm per pixel can be achieved by improving the quality of optical systems. However, this is a limit. Any improvements will not be able to overcome atmospheric refraction. Thus, recognizing objects less than 5–10 m in size in a satellite photograph will always be related to high probability of error even when using advanced optics.

V. Application of Satellite Positioning Systems with Further Transfer of Information

This method implies the creation of a system that allows to transfer coordinates for each object. The system includes a subsystem using satellite positioning for determining the location of an object and a transfer subsystem intended for the transfer of determined coordinates. The transfer is possible both in real-time mode and in operator query response mode. This is the direction in which systems intended for determining the necessity of updating navigation information are presently developing.

Such systems are being developed independently in different countries. For instance, some information about the creation of such a system was published on 18 October 2018 in Russia. There is an innovative technical solution for the remote monitoring of floating marks – STAB® NaviLamp navigation lamp equipped with a function for satellite monitoring and control of buoys, which makes it possible to receive information about the condition of equipment in real-time mode [12]. McMurdo company offers Oceania Marine Tracking Buoy System with similar functionality [13]. There are separate units intended for installation on any navigation objects, for example, autonomous satellite GLONASS/GPS tracker NAVISET SEAPOINT IRIDIUM [14].

The error in coordinates when using satellite positioning systems without any additional algorithms or correction systems is more than 10 m. The use of correction requires the installation of additional equipment units, which will increase the cost and reduce the reliability of the equipment. 10 m is a substantial error from the point of view of positioning key navigation objects. For example, a fairway buoy actually carried 15–20 m away will be marked on the chart with a displacement of up to 2 m, which will lead to an emergency. If the number of objects is increased to several tens or, in case of ports and port territories, to several hundreds, the probability of an error will increase dramatically.

Selecting satellite positioning systems, it is also necessary to take into consideration the price factor. All the above-mentioned implementations use IRIDIUM satellite system for information transfer. Each observed object has to be equipped with such a module. However, this system is not free. It means that when the number of observed objects is large (from tens to hundreds), substantial user charge is to be paid. The use of common mobile communication is impossible even in the inner port territory (due to rather low position of transmitting antennas, for instance, in case of buoys), not to mention remote navigation objects. The cost of the module including the development of the required protection model against certain weather conditions (high humidity, vibration) is also very considerable. In addition to that, taking into consideration the necessity of testing, maintaining and repairing each component of the system, additional expenditures will be required.

VI. Application of Remotely Piloted Aircraft (RPA) for Determining the Necessity of Navigation Updates

Working with small objects (for example, in the field of maritime navigation – buoys, life rafts, people overboard; in case of pollution – for determining the source of pollution), the above-mentioned methods are accompanied by aerial photography with the aim to increase the accuracy. Aerial photography allows to achieve higher spatial resolution of a photo in-situ yet has higher unit cost expressed in monetary units spent on the unit of the area being observed. Photography made with the help of remotely piloted aircraft instead of manned aircraft can be used as an additional source of information allowing to significantly reduce the costs.

At the same time, the stand-alone use of RPA will make it possible not only to substantially reduce costs and increase the accuracy but also to provide real-time information [16, 17].

The cartographic information collecting system (CICS) acquire data with the help of RPA calculates the theoretical coordinates of monitor objects before the flight and draws up an optimum flight plan with account of RPA number. During the monitoring, the system compares the actual parameters of the objects with the parameters on the electronic chart being used, and in case of mismatch it can make a decision on the necessity of making changes based on the allowable values of coordinate change (for example, the change of coordinates by a distance of $\geq$ 10 m makes it necessary to update the charts). The allowable values for each type of objects can be set by the operator. Then all the information about the necessary update is transferred in real-time mode to the National Hydrographic Service for further processing.

The coastal segment of the system includes several software modules responsible for:

- flight plan drawn up on the basis of the electronic chart of the area to be monitored;
- reception and processing of photography data received during the RPA flight;
- determining the real location of objects;
- making a decision about notifying the operator when it is necessary to update the parameters of navigation objects [18].

The servicing of several RPA is less time-consuming and costly in comparison with the servicing of a sea vessel, a manned aircraft or a system of satellite data communication channels.

In the process of research, new object identification subsystem methodology was created and implemented, which allows to determine the coordinates of objects on electronic chart or (after additional image processing) on photographs obtained from real area with RPV. The subsystem uses consistent colour filtering as well as mathematical morphology functions. Further, methodology for actual location of cartographic objects subsystem was created and implemented. Subsystem is able to overlay image from RPV photo to electronic ECDIS chart, recalculating scale and direction. The program's realization of this subsystem was able to calculate and change the scale and angle of the photograph in order to obtain an image matching to ECDIS electronic chart for same area. Moreover, methodology for object's real coordinate calculation subsystem in the World Geodetic System 1984 (WGS84) was created and subsystem realized. Was researched and proved algorithm for calculations of real object's coordinates, which allows to calculate the real coordinates of mobile object (such as a buoy) from pixel photography using stationary objects (such as lighthouses or coastlines) with certain coordinates [18].

VII. Conclusion

1. The known visual and satellite observation systems intended for cartographic information update are costly, have low accuracy and do not allow to quickly update navigational charts in real-time mode.
2. The stand-alone use of RPA will make it possible not only to substantially reduce costs and increase accuracy but also to provide information in real-time mode.
3. During further research, it is necessary to develop a specialized RPA complying with the following requirements:
   – equipment with the devices of cartographic information acquisition and transfer system;
   – the possibility of ensuring flights above the water surface at the allowed altitudes;
   – the possibility of ensuring a long-lasting flight which is long enough to cover the required monitoring area;
   – the possibility of equipping with a photo-taking device ensuring the quality which is good enough for object recognition;
   – the possibility of equipping with a transmitting device that can transfer all data to the coast for further processing.
4. Using realizations of the above-mentioned methodologies were carried out practical experiments as for separate use of each subsystem, as well as the use of cartographic information collection system with RPA vehicles complex for maritime vessels' control as whole system. The results of applying CICS realization allow obtaining information without the need for constant supervision by the operator, with minimal error for positions and fast reaction's time.

References

[1] A. Vaivads, J. Tereščenko, V. Šestakovs, "A Model of Interconnection Between Aircraft Equipment Failures and Aircraft "States" in Flight", *Transport and Aerospace Engineering*, RTU, vol. 6, no. 1, pp. 30–36, 2018. https://doi.org/10.2478/tae-2018-0004

[2] International Maritime Organization. International Convention for the Safety of Life at Sea, 1974, SOLAS amendments entering into force 1 July 2014. United Kingdom, 2014.

[3] International Maritime Organization. Adoption of amendments to the international convention for the Safety of Life at Sea, 1974, as amended, IMO Resolution MSC.282(86) (adopted on 5 June 2009). United Kingdom, 2009.

[4] *Performance standards for electronic cart display and information systems (ECDIS).* IMO Resolution A.817 (19). United Kingdom, International Maritime Organization, 1995.

[5] *IHO Transfer Standard for Digital Hydrographic Data*. IMO S-57 standard, International Maritime Organization, 2000.

[6] *Specifications for Chart Content and Display Aspects Of ECDIS*. IMO S-52 standard, International Hydrographic Organization, 2014.
[7] VestiRegion, "Smeshhenie navigacionnogo buja stalo prichinoj posadki na mel' teplohoda «Lotos»." [Online]. Available: http://vestiregion.ru/2015/06/01/smeshhenie-navigacionnogo-buya-stalo-prichinoj-posadki-na-mel-teploxoda-lotos/ [Accessed 23 October 2018].
[8] Maritime Administration and Marine Safety Law. The Saeima, Latvia, 2002. [Online]. Available: https://likumi.lv/ta/en/en/id/68491-maritime-administration-and-marine-safety-law [Accessed 20 May 2019].
[9] State Border Law of the Republic of Latvia. The Saeima, Latvia, 2009. [Online]. Available: https://likumi.lv/ta/id/57676-latvijas-republikas-valsts-robezas-likums [Accessed 20 May 2019].
[10] Pricelist of Hydrographic Service. Maritime Administration of Latvia. [Online]. Available: https://www.lja.lv/node/231 [Accessed 21 December, 2015].
[11] DigitalGlobe, "U.S. Department of Commerce Relaxes Resolution Restrictions DigitalGlobe Extends Lead in Image Quality." [Online]. Available: https://web.archive.org/web/20140714215709/http://media.digitalglobe.com/press-releases/u-s-department-of-commerce-relaxes-resolution-restrictions-digitalglobe-extends--nyse-dgi-1122861/ [Accessed 23 October 2018].
[12] Spaceteam, "SpejsTim predstavil novoe reshenie dlja monitoringa sredstv navigacionnogo oborudovanija na vnutrennih vodnyh putjah." [Online]. Available: http://space-team.com/pressa/detail/new_fleet_managenent_system_for_waterway/ [Accessed 23 October 2018].
[13] McMurdo, "McMurdo Oceania Marine Tracking Buoy System". [Online]. Available: https://shopcdn.textalk.se/shop/35145/art15/24593215-731da0-Oceania_datasheet_A4_LR_FINAL_iss1.pdf [Accessed 22 May 2018].
[14] Discovery Telecom, "Naviset Seapoint Iridium," user manual. [Online]. Available: https://www.discoverytelecom.eu/upload/iblock/480/seapoint_engl1.pdf [Accessed 23 October 2018].
[15] Discovery Telecom, "Naviset Seapoint Iridium," tech, specs. [Online]. Available: https://www.discoverytelecom.eu/catalog/5010.html [Accessed 23 October 2018].
[16] A. Urbahs and V. Žavtkēvičs, "Remotely Piloted Aircraft route optimization when performing oil pollution monitoring of the sea aquatorium", *Aviation*, vol. 21, no. 2, pp. 70–74, 2018. https://doi.org/10.3846/16487788.2017.1344139
[17] A. Urbahs and I. Jonaite, "Features of the use of unmanned aerial vehicles for agriculture applications," *Aviation*, vol. 17, no. 4, 2013, pp 170–175. https://doi.org/10.3846/16487788.2013.861224
[18] A. Urbahs and D. Goreļikovs, "Applying remotely piloted aircraft systems for correcting electronic chart data and ensuring safe navigation", *Proceedings of the International Conference Transport Means* 2018, Lithuania, KTU, 2018.

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