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Charting of the shoreline of inland waters using digital remote sensing images

Kartowanie linii brzegowej wód śródlądowych z wykorzystaniem zobrazowań teledetekcyjnych

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Abstract

Orthophotomaps are now an irreplaceable source of topographic data acquisition, which also can be used in the preparation of navigational charts. As they are maps for special applications, they shall have a specified charting accuracy. The aim of this study is to evaluate the accuracy of the shoreline mapping using aerial photographs and satellite images. This evaluation was based on the statistical analysis related to the accuracy of the vectorization of the inland waters shoreline.

Słowa kluczowe: mapy elektroniczne, zobrazowania teledetekcyjne, nawigacja, IENC, linia brzegowa

Abstrakt

Ortofotomapy stanowią dziś niezastąpione źródło pozyskiwania danych topograficznych, które również można wykorzystać w opracowaniu map nawigacyjnych. W związku z faktem, że są to mapy do zastosowań specjalnych, muszą cechować się określoną dokładnością sytuacyjną. Celem pracy jest ocena dokładności kartowania linii brzegowej z wykorzystaniem zdjęć lotniczych i obrazów satelitarnych. Oceny tej dokonano na podstawie analizy statystycznej związanej z określeniem dokładności wektoryzacji linii brzegowej akwenów śródlądowych.

Introduction

Polish River Information Services should assure an access to electronic charts elaborated for the water region from the place Ognica to Szczecin including Dąbie Lake. Presently, the coverage of inland waters by cells of electronic charts is only partial, and specifically applies to the area of joint of internal marine and inland waters. This is ensured by the marine cells of electronic charts, which enclose a small extent the adjacent inland waters. However, given their purpose, part of inland cells have no resource of information relevant to IENC. Such a state formally excludes the use of these materials for inland waterways, as separate standards for mapping are applicable in this case. The remaining inland waterways are without the coverage of both standardized electronic and paper maps.

Currently in production process of electronic charts high resolution remote sensing imagery is increasingly used. In the case of mapping the coastline and other elements of topographical maps, a crucial task is to evaluate the remote sensing imagery in terms of the accuracy of vector data. So far, this problem was unrecognizable due to the creation of charts by digitizing navigational paper or topographical maps, and appeared with the popularization of high resolution remote sensing images, which due to their information potential are increasingly being used in the development of electronic charts [1].

The coastline in electronic navigational charts

The navigation chart is the primary source of information for the navigator. Currently, analog charts are increasingly giving way to digital maps [2], which in better way ensure the safety of navigation of the vessel. Thanks to them, among other things, the navigator can quickly access the interesting information, to assess the situation based on constant display the vessel's position and to control and monitor the way of the vessel. In inland navigation can be used standardized or non-standardized electronic charts. In the first case, they are part of an Inland Electronic Chart Display and Information System (Inland ECDIS), while in the second of electronic chart of others systems (ECS).

Information to be included on an Inland Electronic Navigational Charts (IENC) are defined in the hydrographic standards issued by the International Hydrographic Organization [3, 4]. In accordance to the aforementioned standards, electronic map should include all necessary information relating to safe navigation. It may also contain additional information that would assist in navigation. For this reason, three levels of information that are available on the index of standardized systems of electronic charts are identified. Coastline must be included in the basic information resource, defined as the minimum amount of ENC information that is presented and which can not be reduced by the operator, consisting of information that is required at all times in all geographic areas and under all circumstances. Display should include at least:

- shoreline (at mean water level);
- shoreline constructions (breakwater, dam);
- boundaries of the fairway;
- beacons, buoys, lights, notice marks;
- waterway axis with kilometre and hectometre indications;
- isolated danger spots in the fairway below and above water level, such as subways, bridges, overhead wires;
- official aids-to-navigation (e.g. buoys, lights and beacons).

According to S-57 standard, the coastline is the contact line between shore and water. General characteristics of the coastline as an object and the principle of the encoding is shown in figure 1.

Although the concept of the shoreline and the shore is often confused, the shore and the coastline are generally used as synonyms. By contrast, a waterside structure is a permanently installed (not floating) artificial structure at the interface between water and land, that is a coastline made by human hand. Hence, sections of natural shoreline and banks of lakes and rivers should be coded as an object of the COALNE acronym, while the artificial parts of the shoreline and banks of lakes and rivers and canals, with their borders, should be coded as an object of the SLCONS acronym. Each class of objects on the electronic navigational charts has a certain descriptive attributes. S-57 standard for the shoreline specifies the attributes listed in table 1.

D.2 Topography

D.2.5 Shoreline (M)

The line where shore and water meet. Although the terminology of coasts and shores is rather confused, shoreline and coastline are generally used as synonyms. (IHO Dictionary, S-32, 5th Edition, 858, 4695)

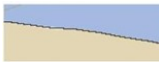
Graphics	Encoding instructions	Object Encoding
Chart Symbol  *IENC Symbolization* 	A) EU: Shoreline should be extracted from data collected at mean water conditions, if possible. B) US: Shoreline is project specific: in pool areas, project pool is used; in open water areas, shoreline should be extracted at low water conditions.	<u>Object Encoding</u> Object Class = COALNE(L) (M) SCAMIN = [EU: 45000; US: 300000] (C) SORDAT = [YYYYMMDD (C) SORIND = (Refer to Section B, General Guidance)

Fig. 1. Definition of coastline and method of its coding in the Inland ENC [5]
Rys. 1. Definicja linii brzegowej oraz sposób jej kodowania na śródlądowych mapach elektronicznych [5]

Table 1. Acronym of attributes of COALNE object [6]
Tabela 1. Akronimy atrybutów obiektu COALNE [6]

Acronym	Attribute	Acronym	Attribute
CATCOA	category of coastline	NINFOM	information in national language
COLOUR	colour	NTXTDS	textual description in national language
CONRAD	conspicuous, radar	PICREP	pictorial representation
CONVIS	conspicuous, visually	SCAMAX	scale maximum
ELEVAT	elevation	SCAMIN	scale minimum
NOBJNM	object name in national language	TXTDSC	textual description
OBJNAM	object name	RECDAT	recording date
VERACC	vertical accuracy	RECIND	recording indication
VERDAT	vertical datum	SORDAT	source date
INFORM	information	SORIND	source indication

For example, the coastline has an attribute specifying its category, that is CATCOA:

- steep coast – a coast backed by rock or earth cliffs, gives a good radar return and is useful for visual identification from a considerable distance off, where cliffs alternate with low lying coast along the shoreline;

- flat coast – a level coast with no obvious topographic features;
- sandy shore – a shoreline area made up of sand, i.e. loose material consisting of small but easily distinguishable, separate grains, between 0.0625 and 2.000 millimetres in diameter;
- stony shore – a shoreline area made up of rock and rock fragments ranging in size from pebbles and gravel to boulders or large rock masses;
- shingly shore – a shoreline area made up of rounded, often flat water worn rock fragments larger than approximately 16 millimetres,
- glacier, seaward end – projecting seaward extension of glacier, usually afloat; also called glacier tongue;
- mangrove – one of several genera of tropical trees or shrubs which produce many prop roots and grow along low lying coasts into shallow water;
- marshy shore – a shoreline area made up of spongy land saturated with water. It may have a shallow covering of water, usually with a considerable amount of vegetation appearing above the surface;
- coral reef – a reef, often of large extent, composed chiefly of coral and its derivatives;
- ice coast – a vertical cliff forming the seaward edge of an ice shelf, ranging in height from 2 m to 50 m or more above sea level;
- shelly shore – a shoreline is made up of shells i.e. made up of the hard outside covering of marine animals.

The accuracy of mapping situational elements of navigation charts

Traditionally, in studies of land-based maps, the situational accuracies of objects are defined in the geodesic technical standards [7]. According to the technical instructions they are specified by the average position errors of points on the map and its scale. In the case of navigation charts the situation is different. According to the adopted recommendations, eleven standard cell compilation scales were adopted, which correspond to the scales of range radar image. In the electronic inland charts radar picture is an additional, important information layer. Taking into account the different scales of source materials, both analog maps as well as remote sensing images, compilation scale of charts should have a value near the bigger scale. For example, data derived from maps of scale 1:25 000, situated in the range of standard scales of 1:45 000 and 1:22 000 must be compiled in the scale 1:22 000. In addition, exceptions to this rule are applied, which allow for greater migration between source materials and compilation scales. Setting the compilation scales for all cells of the electronic charts should be based on the standard ranges of radar coverage as specified in table 2.

Table 2. Radar range and standard scale list [8]
Tabela 2. Wykaz zasięgów radarowych oraz standardowej skali [8]

Radar range [NM]	Standard scale	Radar range [NM]	Standard scale
200	1:3 000 000	3	1:45 000
96	1:1 500 000	1.5	1:22 000
48	1:700 000	0.75	1:12 000
24	1:350 000	0.5	1:8000
12	1:180 000	0.25	1:4000
6	1:90 000	–	–

Electronic charts, because of its use include topographic information useful for the navigation. In the case of topographic data the rules do not

Table 3. Required accuracy according to S-44 [9]
Tabela 3. Wymagane dokładności według S-44 [9]

Order	Special	1a	1b	2
Description of areas	Areas where under keel clearance is critical	Areas shallower than 100 metres where under keel clearance is less critical but features of concern to surface shipping may exist	Areas shallower than 100 metres where under keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate
Positioning of fixed aids to navigation and topography significant to navigation (95% confidence level)	2 m	2 m	2 m	5 m
Positioning of the Coastline and topography less significant to navigation (95% confidence level)	10 m	20 m	20 m	20 m
Mean position of floating aids to navigation (95% confidence level)	10 m	10 m	10 m	20 m

include methods for data acquisition, but only determine the generalized situational accuracy at confidence level of 0.95. Such information can be found in the standards of IHO S-44 [9], where the accuracy of topographic data is dependent on its significance in navigation and classification to the water region category (Table 3). Coastline by the following table may be regarded as an topographical facility important for navigation and directly as the coastline. In the special category, the required accuracy may reach 2 or 10 m, while in the remaining additional 5 and 20 m.

The use of remote sensing images for map elaboration

Currently, topographic measurements can be carried out by direct measurement (field measurements) and by the use of remote sensing methods. Of particular importance are high resolution aerial photographs and satellite images that allow to obtain detailed information for an extensive and often not easily accessible area adjacent to the navigation waters. In particular, this applies to mapping the coastline and the topography of coastal zone of rivers.

This paper presents an analysis of available remote sensed digital imagery in terms of charting shoreline for usage in electronic charts. The studies used remote sensing images with different field resolution. In the creation of electronic charts for the cell area of the port of Szczecin two types of digital color orthophotomaps were used. The former were made on the basis of satellite imagery (IKONOS) on a scale of 1:5000 with the terrain size of a pixel equals to 1 m. The latter are orthophotomaps based on aerial photographs taken with analogue or digital camera in the scale 1:5000 with pixel size of 0.5 m.

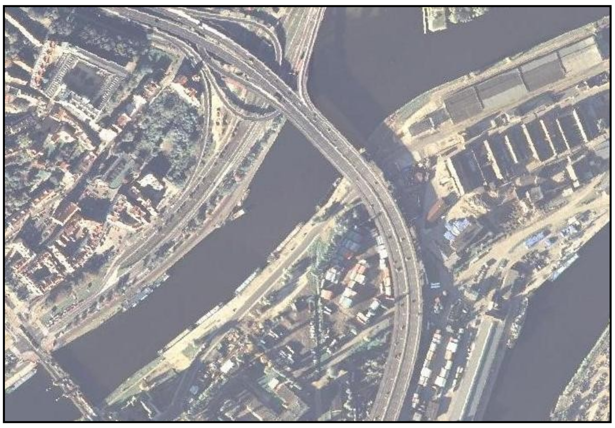


Fig. 2. Aerial photograph of part of the Odra River in Szczecin
Rys. 2. Zdjęcie lotnicze odcinka rzeki Odry w Szczecinie

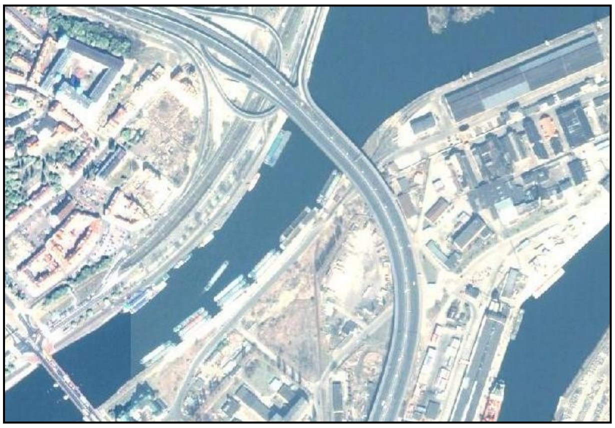


Fig. 3. Satellite image of part of the Odra River in Szczecin
Rys. 3. Obraz satelitarny odcinka rzeki Odry w Szczecinie

Assessment of the situational accuracy

As previously mentioned, the navigational charts scale does not necessarily have links with the situational-accuracy requirements of mapping field details, as is the case of land studies (base map, topographic maps for commercial purposes). Requirements contained in the hydrographic standards are specified by the requirements for the situational accuracy of objects depending on the belonging of the body of water to one of four categories of areas of navigation and relevance to navigation. Given the nature of inland navigation reservoir in the water junction within the range and neighborhood of port of Szczecin, the area should have a special category (Table 3). This is the most rigorous of the orders and its use is intended only for those areas where under keel clearance is critical. Hence, the topography data of relevance in navigation, should have a situational accuracy of 2 m. The coastline and topographical data of lesser importance for navigation should have an accuracy of 10 m. These values are given at a confidence level of 0.95 [10].

In order to determine the compliance requirements of the situational accuracy of mapped objects with the hydrographic requirements, the vectorization accuracy of the topographic objects was examined on the example of the shoreline. The situational accuracy of the objects has been verified by direct measurements by using Trimble R6 measuring set operating in network RTK ASG-EUPOS mode. Natural coastline, due to the presence of tall trees, lack of access to the shore itself (marshy land, overgrown with common reed) has not been verified by direct measurements, and thus not taken into account in this study.

Analysis

For the purposes of analysis errors were calculated, whose values determine the distances from the points measured by the RTK receiver to the vectorized line. In the case of rectilinear sections of coast, errors are represented geometrically by the line forming a right angle with a line, in the case of corners these sections link the actual coordinates with the corresponding point of the collapse. Vectorization error (e_v) was calculated by the formula:

$$e_V = \pm\sqrt{\left(x_{\mathrm{RTK}} - x_V\right)^2 + \left(y_{\mathrm{RTK}} - y_V\right)^2} \qquad (1)$$

where: x_{RTK}, y_{RTK} – the coordinates of the point measured by RTK technique, x_v, y_v – the coordinates of a point on the vectorized line.

For the analysis only fragments of lines were used, which can be obtained without a doubt of interpretation nature. In the case of aerial photographs, the sample size (n) consisted of 391 samples, while for the satellite image its value amounted to 417. The analysis was conducted separately for the straight sections and the corners of the quays. Measurements were carried out at various quays lying inside the port and the city of Szczecin, within the area of approximately 14 km^2. Studies included coastline of the total length of 9.8 km. Exemplary measurement by RTK kit is shown in figure 4.

Fig. 4. Measuring of shoreline points on the West Odra River
Rys. 4. Pomiar punktów linii brzegowej na Odrze Zachodniej

Unfortunately, the histograms did not have a normal distribution in all cases. Hence, statistical analysis was performed for an average m in the population of an unknown distribution [11]. Confidence intervals were determined for the mean m with standard deviation of the sample S defined as:

$$P\left\{\overline{X} - z_\alpha \frac{S}{\sqrt{n}} < m < \overline{X} + z_\alpha \frac{S}{\sqrt{n}}\right\} \approx 1 - \alpha \qquad (2)$$

In the case of corners only average value was calculated, because the statistical sample was less than 120. Coefficient of confidence, in accordance with the requirements of the IHO, was adopted at the level of 0.95. Histograms for sample sets taken from aerial photographs are summarized in figure 5.

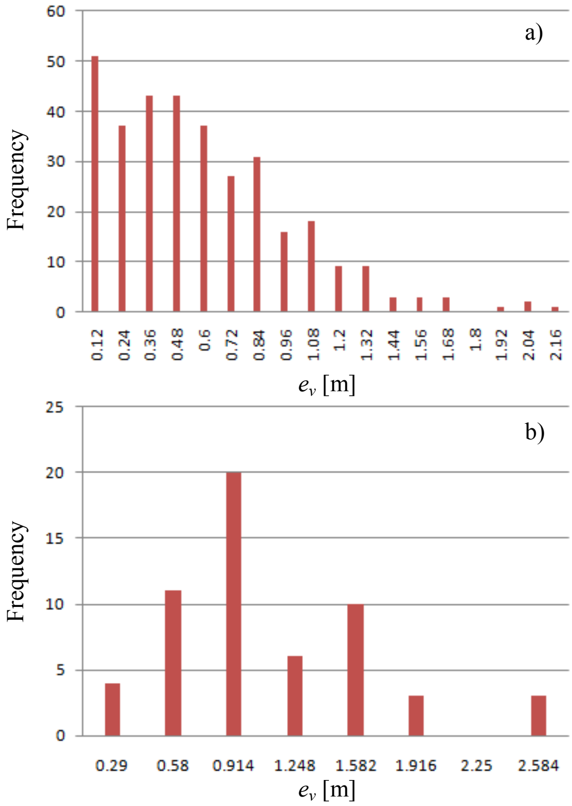


Fig. 5. Histograms of analyzed errors: a) straight section, $n = 334$, b) corners, $n = 57$
Rys. 5. Histogramy analizowanych błędów; a) odcinek prosty, $n = 334$, b) narożniki, $n = 57$

Calculated confidence intervals are summarized in table 4.

Table 4. Statistics for the sample of aerial photographs
Tabela 4. Statystyki dla próby ze zdjęć lotniczych

The geometry of the shoreline	Confidence interval	Mean m	Standard deviation S
Straight section	$0.50 < m < 0.58$	0.54	0.40
Corner	–	0.94	–

Histograms for sample sets taken from satellite images are summarized in figure 6.

Calculated confidence intervals are summarized in table 5.

Given these results, it can be concluded that both the analyzed data derived from aerial photographs and images meet the quality requirements including the RTK measurement error; average error of RTK measurement was 2.2 cm, maximum 6.3 cm. In the analysis one should pay attention to the maximum errors, which are summarized in

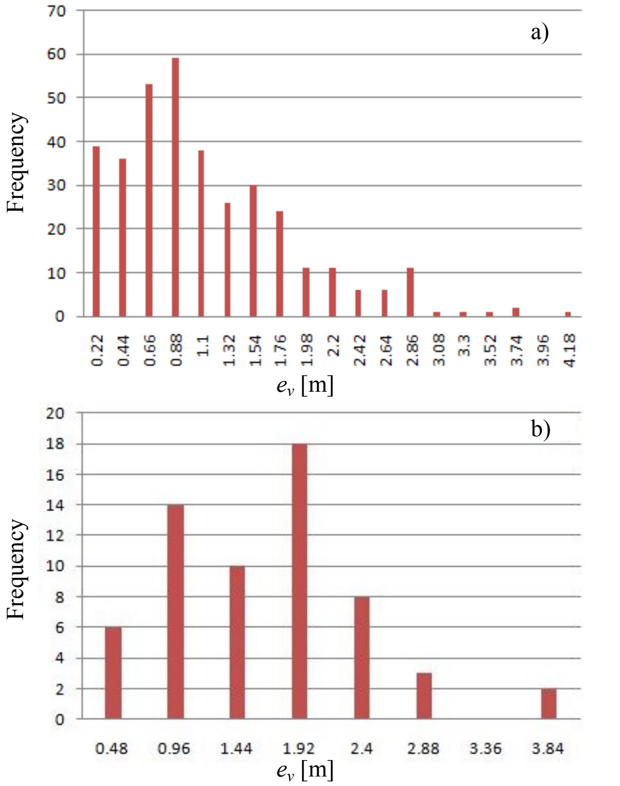


Fig. 6. Histograms of analyzed errors: a) straight section, $n = 356$, b) corners, $n = 61$
Rys. 6. Histogramy analizowanych błędów: a) odcinek prosty, $n = 356$, b) narożniki, $n = 61$

Table 5. Statistics for the sample of satellite images
Tabela 5. Statystyki dla próby z obrazów satelitarnych

The geometry of the shoreline	Confidence interval	Mean m	Standard deviation S
Straight section	$0.96 < m < 1.10$	1.03	0.74
Corner	–	1.51	–

table 6. These errors exceed the usual spatial resolution of orthophotomaps determined at the level of 2–3 pixels and reach the level of 4–5 pixels for aerial photographs and 4 pixels for satellite images.

Table 6. Maximum errors
Tabela 6. Błędy maksymalne

Orthophotomaps	Aerial	Satellite
Straight section	2.14 m	3.99 m
Corner	2.49 m	3.81 m

Summary and conclusions

Based on the conducted analysis, it can be ascertained that more accurate mapping of coastline is in the straight sections than the corners. The average value of the error of straight sections is set at approximately 1 pixel of orthophotomaps, while for the corners it is a value of approximately 1.5–2 pixels. These values are smaller, especially in the case of straight sections, than commonly values of orthophotomaps accuracy assumed at the level of 2–3 pixels. However, in both cases, these results meet the quality requirements for a special area – all are equaled or lesser than allowed error of 2 m.

Results of this work also show that for charting coastlines by using orthophotomaps can be used products with bigger terrain dimension of pixel and lesser accuracy, which can be determined by rule 2–3 pixels. An example is satellite IKONOS image with spatial dimension of pixel equaled 1 m, which accuracy may be determined at the level of 2–3 metres. Theoretically, this range of values exceeds permitted 2 m error for significant objects in the special area. Obtained real accuracy, according S-44 standard guidelines, was in the range of 0.96 and 1.06 meter for straight sections of coastline and 1.51 m for corners, what was much better result than required 2 m.

An important observation in the aspect of navigational chart creations is that the orthophotomaps itself may have greater errors. For the analyzed cases it reached the level of 4–5 pixels (2.14–2.49 m) for aerial photos and 4 pixels (3.99–3.81 m) for satellite image. For more precise map elaborations or charting some important objects like bridges, direct measurements will certainly be invaluable.

References

1. Espey M.: Remote Sensing Division, NGS, NOS, NOAA, Using Commercial Satellite Imagery and GIS to Update NOAA ENCs, ESRI International User Conference Proceeding, 2005.
2. Yogendran S.: ECDIS Approach for Paperless Navigation. Hydro International, GITC Publication, 1999, 5, 8.
3. IHO S-57, Transfer Standard for Digital Hydrographic Data, Special Publication No. 57, Edition 3.1, 2009.
4. IHO S-52, Specification for Chart Content and Display Aspects of ECDIS, Edition 5.0, 1996.
5. Inland ENC Harmonization Group, Inland Electronic Navigational Chart Encoding Guide, Edition 1, version 3.1.1, 2008.
6. Inland ENC Harmonization Group, Inland ENC Feature Catalogue, Edition 2.1, 2008.
7. Rozporządzenie Ministra Spraw Wewnętrznych i Administracji z dnia 24 marca 1999 r. w sprawie standardów technicznych dotyczących geodezji, kartografii oraz krajowego systemu informacji o terenie. Dz.U. 1999, nr 30, poz. 297.
8. IHO, Annex A to Circular Letter 108/2007, IHB File No. S3/8151/CHRIS.
9. IHO, Standards for Hydrographic Surveys S-44, 5th Edition, February 2008.
10. IHO, Standards for Hydrographic Surveys, 5th Edition, February 2008, Special Publication No. 4.
11. Sobczyk M.: Statystyka. Wydawnictwo Naukowe PWN, Warszawa 2001.

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