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The method of using remote sensing high-resolution imagery data in cartographical study of seaports

Metoda wykorzystania wysokorozdzielczych teledetekcyjnych danych obrazowych w kartograficznym opracowaniu portów morskich

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Key words: remote sensing, satellite imagery, high-resolution data, cartographical study

Abstract
The article presents the author's method of scale determining of cartographical chart. The worked out method permits on scale defining on the base on resolution of source imagery, precision of location and internal geometry of situational details as well as the defining of interpretation aim. In present study authors introduce a new attitude to cartographical study of seaports. It relies on very high resolution imageries using to create a orthophotomap and regards it as a final product instead of product attending to updating other maps.

Słowa kluczowe: teledetekcja, zobrazowanie satelitarne, dane wysokorozdzielcze, opracowanie kartograficzne

Abstrakt
W artykule przedstawiono autorską metodę wyznaczania skali opracowania kartograficznego. Opracowana metoda pozwala na określenie skali w oparciu o rozdzielczość materiału źródłowego, dokładność lokalizacji i geometrii wewnętrznej szczegółów sytuacyjnych oraz zdefiniowanie celu interpretacyjnego opracowania. W niniejszym opracowaniu autorzy przedstawiają nowe podejście w kartograficznym opracowaniu portów morskich. Polega ono na wykorzystaniu wysokorozdzielczych obrazów satelitarnych do tworzenia ortofotomapy satelitarnej i potraktowanie jej jako produktu końcowego zamiast materiału służącego do aktualizacji innych map.

Introduction

Currently, creating maps of seaports is holding mainly in support of existing maps, plans, surveys and aerial photograph. Existing studies and analysis concentrate mostly on using aerial and radar photograph as source materials, in which exists well defined relationship between a pixel size and a scale of cartographical study [1, 2]. Practical generally method bases on calculation of accuracy of field checkpoints location and adjustment points GCP (General Control Point) measured in terrain and on an imagery. The results of mathematical analysis define the accuracy of object localization on an imagery and are referred to 0.3 mm (0.2 mm) value on cartographical study. On that basis the usefulness of particular imageries in cartographical studies is determined (the scale is limited) [1]. In this classic depiction the possibility of using of the aerial (satellite) photograph is limited in first order by potential accuracy of object location [3]. This caused, that satellite imageries which presents usually low quality in object location accuracy (several or over ten meters), are not in used in cartographical studies of traditional maps [1, 2].

Simultaneously, in many centers, scientific and military institutions all over the world, oriented on collating information for intelligence and reconnaissance analyses needs, researches about interpretation possibilities of satellite imageries are conduced. There is lack of this type of studies focused on cartographical using of imagery data. Some of data distributors (e.g. GEOSYSTEMS Polska) introduce into use the concept of scale for interpretative aims, which in case of satellite orthofotomaps studies is about twice larger than scales of traditional cartographical studies, which are determined by terrain object location precision on the map [3, 4]. So far direct using of satellite imagery in creating maps process has found application in warfare zone in Iraq and Afghanistan, where applied scales of maps in relation to resolution of imageries has also not confirmed traditional attitude to scale of study [1, 5].

Simultaneously using satellite imageries in study of terrain about special meaning for the reason of defences, safety and economic, based on treating satellite orthophotomap as a final product, not only as a material for updating aims.

In the publication, the method of determination of a satellite orthopphotomap cartographical is proposed. This method based on using new methods and experiences as well as on a possible adaptation of a researches schema for needs of cartographical study of a seaport terrain.

The algorithm of using high-resolution satellite imageries in cartographical study of seaports

In present study authors designed and realized the algorithm introduced below (Fig. 1).

The algorithm assumes such a proceeding, in which the definite interpretative aim of study, possibility of detection, identification and description of objects as well as the analysis of terrain (the character of infrastructure, range of cartographical study), become first. The next stage is selection of input imageries and verification of their usefulness. The verification is carried out on the terrain measurements basis (use standards comparative schemes) as well as in laboratory. Received results defined the legitimacy of imageries using and showed general ranges of their usage. On that basis following parameters of cartographical study are calculated:

- optimum scale (scale series) of study in relationship with kind of satellite imagery and its resolution (a relationship: scale of study-resolution);
- admissible resolution of satellite images for cartographical studies in set scale;
- required accuracy level of location and geometry of objects, on the orthophotomap of the seaport.

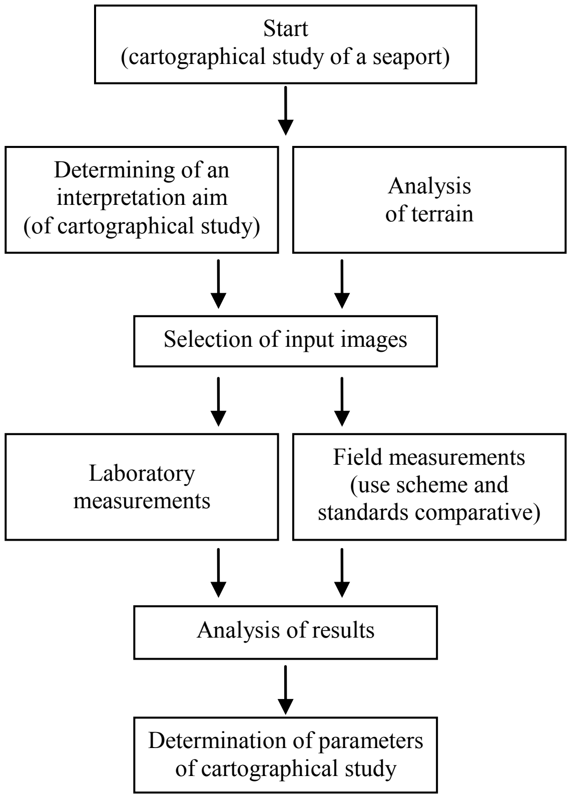

Fig. 1. The algorithm of using high-resolution satellite imageries in cartographical study of seaports
Rys. 1. Algorytm wykorzystania wysokorozdzielczych obrazów satelitarnych w kartograficznym opracowaniu portów morskich

Setting of interpretation aim – detection and identification of objects

Determining of an interpretative aim of map study has two dimensions. Firstly, it defines what kind of object should be possible to identify on an image. Secondly, on what accuracy level (detection, identification, precise identification, technical analysis)?

In recent years the American Intelligence conducted the sequence of analyses of accessible images, on the basis of which they introduced the interpretative possibilities of objects from images in resolution function (Table 1).

Considering the data shown below "half meter" resolution of image (pixel size) seems to be sufficient for precise identification e.g. ships, boats as well as harbours and their infrastructure. To circumstantiation and technical analysis, images with resolution 0.3 m or higher would be indispensable. Therefore it is necessary to qualify what kind of aims cartographical study will be using. In case of seaports to general identification of ships and objects of infrastructure – 5 m resolution is sufficient. The table 1 shown also that 0.6 m resolution is required for the precise technical analysis.

Table 1. Target identification in ground resolution (meters) according to STANAG 3769 (Standarization Agreement)
Tabela 1. Zestawienie wymiarów terenowych piksela w celach wykrycia, identyfikacji, opisu i analizy technicznej obiektu (rozdzielczość podana w metrach). Dane i definicje wg Polskiej Normy Obronnej NO-02-A046 (STANAG 3769)

Object	Detection	Identification		Description	Technical analysis
		general	precise		
Bridges	6	4.5	1.5	1	0.3
Nuclear Weapons Components	2.5	1.5	0.3	0.03	0.0015
Vehicles	1.5	0.6	0.3	0.06	0.0045
Minefields	3–9	6	1	0.03	n/a
Ports and Harbors	30	15	6	3	0.3
Railroads Yards & Shops	15–30	15	6	1.5	0.4
Roads	10–20	5	1	0.6	0.4
Urban Areas	60	30	3–5	1	0.75
Terrain	90+	30–90	4.5	1.5	0.75

Definitions used in table 1 according to STANAG 3769 means:

- *Detection*: the discovering of the existence of an object but without recognition of the object;
- *Identification* (*general*): the ability to fix the identity of a feature or object on imagery within a group type, i.e.: tank, aircraft;
- *Identification* (precise): the ability to place the identity of a feature or object on imagery as a precise type, i.e.: T-54 tank, MIG-21J;
- *Description* (*technical analysis*): the ability to describe precisely a feature, object or component imaged on film.

The analysis of the terrain and input images (comparative standards and interpretative keys)

The analysis of terrain connection to qualification of interpretative study aim has task to choice suitable resolution imageries [2, 6]. After the choice of images follows the assessment of possibility recognition and identifying watercrafts as well as infrastructure of seaports. The reconnaissance of specific watercraft permits on qualification of the harbor rank automatically as well as his possibility of similar watercrafts (tonnage, draught, dimensions) mooring and also the possibility of placing and supplying watercrafts with necessary products. Correct recognition of watercrafts takes the opportunity to reliability assessment of possibility making ports by various military and non-military watercrafts. Across realization of measurements on orthophotomap of specific harbour it is possible to confirm the kind of watercraft being in this area, with definite accuracy of measurements (e.g. to harbour master's office, to distributor of fuels, or to the heads of mole). This information presents essential value in a case of quick action about precision aims planning [7]. It permits on enemy's surprise in situation when he can not use battle formation or with safety considerations he can not use own fire.

Fig. 2. Identification of infrastructure objects and watercrafts
Rys. 2. Identyfikacja elementów infrastruktury portu morskiego oraz jednostek pływających

The situation looks similarly with port infrastructure (Fig. 3), which made possible the refuge for ships and fuel supplement.

Possessing schematic arrangement of port infrastructure objects as well as imageries it is possible to precise establish location of the most important port objects, beginning from harbour master's office and finishing on individual elements using to fuel supplement of watercraft. Correct identification of these elements permits on quick paralyzing their possibility or suitable saving before purposeful destruction. Using high-resolution imagery data and standards comparative in port infrastructure, it is possible to distinguish basic elements indispensable to watercrafts service providing them suitable supplement, which is possible to find in typical harbours all over the world. Therefore taking into account mentioned above in present publication taking interpretation keys and comparison standards into assessment of usefulness of imagery is postulated [7], what include also table 1.

This analysis shows that satellite imagery with pixel size as 0.6 m choosing to cartographical study of a harbor is sufficient. The additional verifications of an image is possible across realization of field measurements or with (well-known) dimensions of real objects (e.g. ships), measurement of these objects on the image and comparison of received in that ways results [4, 6].

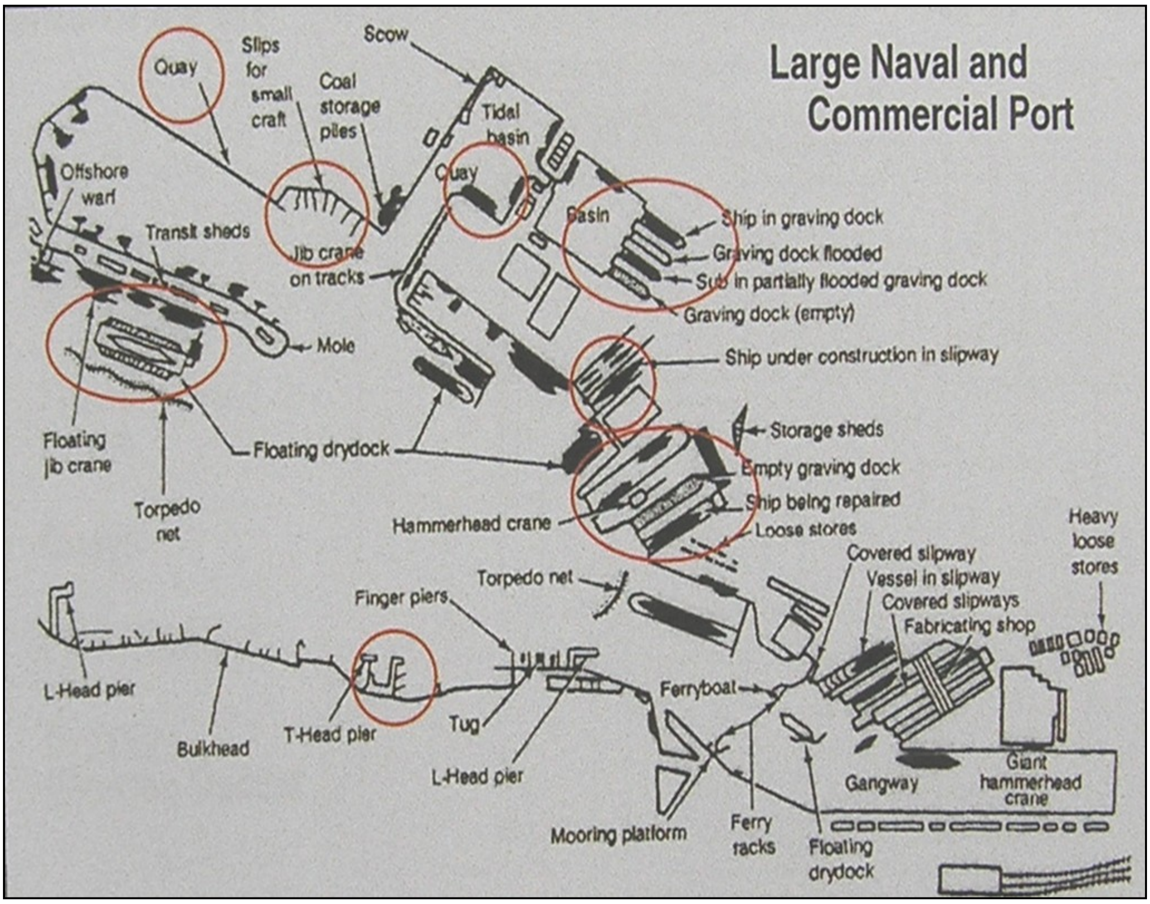

Fig. 3. Main objects of port infrastructure: piers, mooring platforms, dry and wet docks, accommodation-ladders, cranes of Hammerhead type, hangars
Rys. 3. Główne obiekty infrastruktury portowej: pomosty, platformy cumownicze, przegrody, suche i mokre doki, trapy, dźwigi typu Hammerhead, pochylnie kryte, hangary, mola, baseny pływowe

Terrain and laboratory measurements (accuracy assessment)

Terrain and laboratory measurements have the task to characterize an accuracy of imagery internal geometry. In present study satellite imageries are not use for updating aims, therefore accuracy of objects location better than few meters has a minor meaning. From this point of view more important is properly projection of objects geometry e.g. length of ship than the fact that a ship is located 3 m inaccurately related to the center of the Earth (location in WGS-84).

The next step after qualification of interpretative aim is the decision about required accuracy level of objects location in global co-ordinate system. In case of satellite imageries (according to some data producers and distributors as well as authors of some publications) [1, 2] accuracy oscillate in few pixels range, therefore as assumed above for 0.6 m resolution data (and better) it is in few meters range. Therefore (from this point of view) the dimensions of objects, not their global location, are subjects to measurements.

Fig. 4. Conteners measurements in Surabaya harbour
Rys. 4. Pomiary kontenerów w porcie Surabaya (Indonezja)

It the publication were measured dimensions of sea containers about real values: width 2.35 m, length 12.03 m. For measurements was used imagery from QuickBird satellite with 0.6 m resolution and multispectral composition (Pan–Sharpened – PSM – R, G, B, NIR), characterizing oneself the dimension of pixel size like panchromatic image and contents colorful composition like multispectral image. Measurements were carried out in software environment of ERDAS Imagine. Field measurements were not executed because the real dimensions of containers are well-known. Received errors scheduled below (Table 2) were calculated using formula:

$$m_0 = \sqrt{\frac{[VV]}{n-1}} \tag{1}$$

where: m_0 – mean error, V – apparent error, n – number of observations.

Table 2. Results of conteners measurements. Values with added sign – "*" care about column – Length
Tabela 2. Wyniki pomiarów kontenerów. Wartości z gwiazdką „*" dotyczą kolumny długość

Contener				
Measure-ments	Width [m]	Length* [m]	mean error – real	mean error – apparent
mean value	2.39	11.96	0.21 0.18*	0.08 0.10*
real value [m]	2.35 [± 5 cm]	12.03 [± 5 cm]	–	–

According to the table 2 the mean error (real) is in the frames of half value of pixel size. It is similar with mean error of an individual observation calculated for a value of apparent errors. These values are even smaller, which proves the accuracy of measurements, meaning that deviation between measured values and average measurement value (small dispersion of measurements values) is small.

The measurements were executed without special care, in scale (zoom) approximately 1:500. Therefore it could be expected, that during determination of characteristics (sizes) of objects an error for linear object measuring is the half of length (width) of pixel. It is true for surface objects with a surface of at least (a dozen or so) pixels. Taking it into consideration, measuring e.g. length of ships using 0.6 m resolution imagery, error should be not bigger than 0.3 m.

The definition of the cartographical study scale – the example

Task: the cartographical study of seaport;

Data:

- one meter imagery – pixel surface 1 m^2;
- interpretative aim – interpretation on level of precise identification (Table 1);
- global accuracy – 3–5 m, relative 0.5 pixels in scale of study;
- output resolution on printout – 150 dpi (270 dpi) or 120 dpi [2, 5];
- quantity of pixels per mm – about 6, allowable value – 2–3 pixels per mm.

Using formula (2) on denominator of a scale:

$$M = P_t / P_{op} \tag{2}$$

where: M – the nominative of a scale, P_t – field dimension of a pixel [m], P_{op} – pixel size on cartographical study [m] – for 6 pixels per mm – 0.00016 m.

Result:

- received scale about 1:6200, for value 120 dpi about 1:4700;
- for imagery with 0.6 m resolution and 3 pixels per mm – received scale about 1:2000 (Fig. 5).

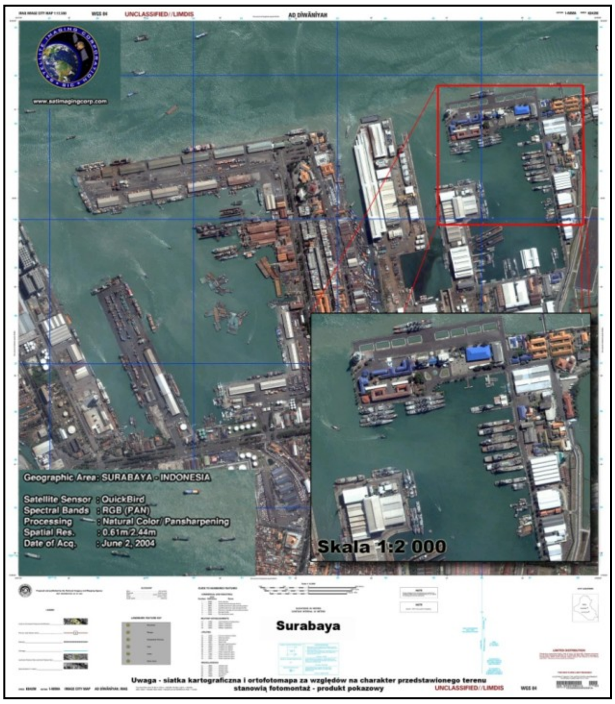

Fig. 5. The Example of cartographical study of a harbour (trick photograph)
Rys. 5. Przykład prezentacji kartograficznej portu morskiego (fotomontaż)

The interpretation of results: if we analyse one meter resolution imagery and put resolution 150 dpi (processed later on 270 dpi) we will receive in approximation 6 pixels per mm, which give a scale about 1:6200. For value 120 it will be about 1:4700. This scale is safe (optimum) about terrain zooming. For imagery with pixel dimension 0.6 m it is a value about 1:2500, what is in warfare area processing imagery similarly. In Iraq and in Afghanistan cartographical international support groups processed imageries even with value 2 pixels per mm, what for one meter resolution give a map scale 1:2000, and for half meter about 1:1200 and from this point of view it is a limited (maximum) scale.

The considering analysis mentioned above the result is that using satellite imageries in cartographical study (mapping) of a harbor area, for assumed and calculated in example data, is in range 1:1200–1:6200, simultaneously with indication optimum scale (for imagery with 0.6 m pixel size) as 1:2500.

Conclusions

Described method permits on determination of the scale of cartographical seaports' studies, in support of selection or independent calculation of input parameters. To achieve this aim it is necessary to determine: relative and absolute accuracy of object location, acceptance or determining of expected level of identification (detection) and analysis of objects, taking interpretation keys and comparative standards in object identification into consideration and also selection of imagery with suitable resolution.

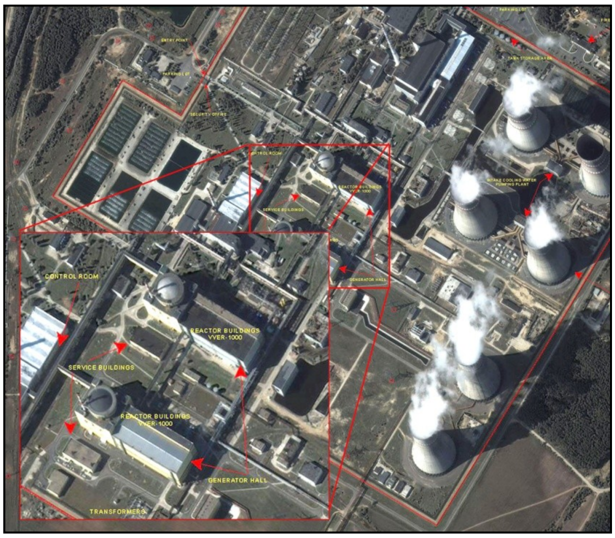

Fig. 6. Industrial area (QuickBird imagery)
Rys. 6. Obiekt przemysłowy w Iranie (zdjęcie z satelity QuickBird)

Additionally, described method, researches tools and scheme can be adopted on cartographical needs for aims:

– monitoring of activity state in seaports area,
– monitoring of state of atomic power stations (building),
– economic and military potential assessment (Fig. 6),
– monitoring of development of new technologies.

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