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Estimation of Horizontal Accuracy of the Large-Scale Digital Maps***

1. Introduction

In line with global trends, domestic government and self-government institutions as well as businesses deploy spatial information in the broadly defined concept of management [2, 9]. Searching and academic sector in the geodesist and cartographer community collaborate with the national economy in the development of spatial information systems. Research and development efforts are made to acquire, gather and release spatial data [8]. The academic community should actively participate in theoretical and practical efforts supporting the development and updating of digital map databases [14] and their effective and rational (preceded by an analysis of their quality) application for execution of economic tasks [4, 18].

The authors have presented the results of research of the accuracy of digital data acquired by various methods for the development of databases of large-scale maps. The discussed issue is not a local issue that occurs in Poland only, of course. The digital data quality assurance may be specified as a set of features connected with the data ability to meet the current and future demands of users. The basic features that describe the digital data quality include: genealogy, accuracy, completeness, compliance and timeliness [11]. It is commonly understood that data should be complete, compliant and updated to the maximum possible level. The accuracy of the digital map database is too the key aspect to integration of geographic data and their interoperability in the base of spatial data infrastructure [16].

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Accuracy of digital data has already been investigated by numerous researchers who were presented by López and Gordo [13]. The investigations are also performed with the use of statistical analysis [19, 20], as well as other, modern research methods [1, 3, 5, 6]. They concern mainly in agricultural or cadastral issues and maps produced at medium and small scales available in particular countries. In Poland, the large-scale maps exist for the entire country in the form of the base map (this map may be so called as "technical map"); the investigations were thus focused main on that technical map.

This paper considers the case of estimation of horizontal accuracy of the base digital maps with accordance polish mapping agency standards [12]. The presented results characterize the accuracy of horizontal data entered into the databases of digital maps of the cities of Olsztyn and Zielona Góra. The accuracy of digital map data was estimated in selected parts of the investigated cities (on so-called control sub-objects) which characterize the probable range of real accuracy of the analyzed digital maps.

2. Formal Aspects of Estimation of Horizontal Accuracy of Digital Maps in Poland

The aim of the research of horizontal accuracy of digital maps was to determine the real accuracy of topographic details of the 1st accuracy group (so-called well defined points or control points), expressed in terms of their plane co-ordinates (X, Y) in the databases of digital maps. Based on the determined errors of position of 1st group planimetric features, the researchers attempted to estimate the usefulness of the gathered digital data and determine the accuracy of the analyzed maps. The accuracy of digital maps was estimated based with accord of obligate in Poland Technical Instruction O-2 and Technical Guidelines K-1.2 [12], in view of which an error of position of a planimetric point in 1st accuracy group in an analogue map (identical to the plotted graphic presentation of a digital map) should not exceed ± 0.3 mm on the map's scale.

The accuracy of digital map data was analyzed through a comparison of several types of features (not altered in the surveyed area) – co-ordinates of 1st group planimetric features – recorded during initial acquiring with the relevant co-ordinates obtained from a direct control measurement. Main three types of features were investigated during the analysis, including apex points of building contours (marked with letter B), boundary points (G) and aboveground utility points (U). Control measurements were conducted with the use of an electronic tachymeter in reference to class III horizontal restorable geodetic control network (www.osnowy.pl) with error of position of a point at m_P < 0.03 m. The model co-ordinates of control points were determined from field surveys containing redundant observations for the rigorous adjustment of measurement results and an estimation of measurement accuracy (results were adjusted in SIEĆ'95 application developed by Professor Gajderowicz). The authors found that control points in Olsztyn had been determined with error of $m_P < 0.02$ m, and in Zielona Góra – $m_P < 0.03$ m.

3. Characterization of the Investigated Objects and an Estimation of Their Accuracy

Five digital maps (objects) for the cities of Olsztyn and Zielona Góra were the subject of our research. **The object A** is the digital technical map in the scale 1:500, produced on the basis of direct survey performed at the university campus in Olsztyn in 1995–1996 by student teams with use of an electronic tachymeter (total station surveys). The survey ware based on the restorable 3rd class geodetic control network. The investigations was based on 481 control points. **The object B** is the digital base map of the City of Zielona Góra. The digital map has been produced basing on existing results of surveys, performed in the period of 1974–1999 (basing on technical traversing of the 2nd order from 1973–1974, developed in accordance with the B-III Instruction), by means of the method of orthogonal measurements, and, in the recent period, by means of the polar method, using an electronic tachymeter (in relation to the restorable 3rd class network). The investigations was based on 1619 control points. **The object C-I** is the digital orthophotomap of the City of Olsztyn. The digital orthophotomap was produced basing on 1:5000 aerial photographs taken within the Phare Programme in 1995. Aerial photographs were processed to the digital form using a matrix scanner with the resolution of 1000 dpi; then the orthophotomap was developed at the scale of 1:2000. The investigations was based on 311 control points. **The object C-II** is the digital orthophotomap of the City of Zielona Góra developed at the scale of 1:2000. The orthophotomap was generated based on aerial photographs (taken in March 2002) on a 1:6000 scale. In the applied processing technology, field dimensions of one pixel were equal to 0.20 m. The investigations was based on 462 control points. **The object D** is the digital base map of the City of Olsztyn. The digital map was produced using the method of graphical-and-digital processing of the analogue base map at the scale of 1:500 with the layers of utilities, at the scales of 1:500 and 1:1000. The base map was produced basing on technical traversing of the 2nd order from 1974. Survey of details was performed by means of a photogrammetric method, for initial conditions of October 1977. The map was updated by means of direct surveys, connected to the control network of 1974, and, after 1986 – to the newly established restorable geodetic control network of the 3rd class. The investigations was based on 2282 control points.

3.1. Determination of the Accuracy of Maps Produced by Means of Direct Measurements

Digital data gathered in object A and object B are most often classified jointly as data obtained from direct measurements. It should be noted, however, that as regards direct measurements, the process of entering topographic details into the database of a digital map comprises two stages: measurement and the following after it analytical and computational processing of the measurement whose results are entered into the database. In view of the differences in completing the above stages in objects A and B (i.e. the transfer of the physical location of topographic details to be entered in the database of a digital maps with the use of co-ordinates), the accuracy of digital map data was estimated with the use of separate mathematical formulae.

Estimation of the Accuracy of the Object A

Measurements performed with an electronic tachymeter (upon the observance of fundamental measurement principles) produce uniform and highly accurate observation material, and when fully automated, the stage of analytical and computational processing (in the total station) takes place practically without the operator's direct involvement. In the technology of producing a digital map database from topographic data acquired by total station surveys, measurements are performed with control elements recommended by Instruction G-4. Therefore a some number (481 points) of topographic details of 1st accuracy group were surveyed twice. The estimation of the accuracy of the object A relied on the assumption that the differences (ΔX, ΔY) in the co-ordinates of twice obtained control points represent their true errors. According to the theory of measurements in pairs, a formula was then indicated to calculate the error of position of a point entered in the database of a map produced from direct measurements with an electronic tachymeter

$$m_p = \sqrt{\frac{[\Delta L^2]}{2N}} \tag{1}$$

where:

m_p – error of position of a point in a digital map produced by means of surveys with an electronic tachymeter,
$\Delta L = \sqrt{\Delta X^2 + \Delta Y^2}$ – length of vector of shift of control point,
N – number of control points.

In the research disposed of a set of 481 control points which included majority of observed details in 1st accuracy group. After a preliminary analysis, three points in respect of which the length of vector of shift of point differed significantly from the remaining lengths of vectors were discarded (vector lengths of: 0.37 m, 0.54 m and 0.87 m, where $\Delta L < 0.10$ m in 93% of control points). At next stage, based on the formula (1), the accuracy of position of type B and U topographic details and other topographic points was estimated, and the accuracy of digital technical map data in object A was estimated together in view of the entire set of 478 control points.

Estimation of the Accuracy of the Object B

Topographic data acquired through the recalculation of the results of direct measurements conducted in the course of 30 years (recorded in technical reports) cannot be regarded as highly uniform due to the variety of the applied topographic survey methods and differences in the applied control networks. For this reason, the accuracy of the object B was estimated by comparing the coordinates of 1st group topographic details (type B, G and U) which have been entered into the database of the analyzed map with their model co-ordinates determined in the direct control survey. The error of position of control point was computed based on a simplified formula (2)

$$m_{P_{\mathrm{II}}} = \sqrt{\frac{[\Delta L^2]}{N}} \tag{2}$$

where:

$m_{P_{II}}$ – error of position of a point in the estimated digital map,

$\Delta L = \sqrt{(X_{\mathrm{II}} - X_{\mathrm{I}})^2 + (Y_{\mathrm{II}} - Y_{\mathrm{I}})^2}$ – length of vector of shift of control point,

$X_{\mathrm{II}}, Y_{\mathrm{II}}$ – co-ordinates of the control point obtained from the database of the estimated map,

$X_{\mathrm{I}}, Y_{\mathrm{I}}$ – model co-ordinates of the control point,

N – number of control points.

3.2. Determination of the Accuracy of Maps Produced by Means of Graphical-and-Digital Processing

In case of object C and object D, topographic data were acquired with the use of the graphical-and-digital processing technology. This technology is an advanced process, and in the case of object D it is even more complex and susceptible to a larger number of sources of potential errors. The problem of estimating the accuracy of each stages of graphical-and-digital processing has been discussed by other authors, among others by Gościewski [10]. This paper presents estimation the accuracy of digital map data produced in the graphical-and-digital processing technology through vectorisation of raster maps.

Estimation of the Accuracy of the Object C

To investigate the accuracy of topographic data acquired by manual vectorisation of a raster orthophotomap image (so-called as "monoplotting" in the literature [15]) was realized an experiment in which selected topographic details were vectorised twice. In the process of monoplotting of the orthophotomap of Olsztyn (object C-I), the co-ordinates (*X*, *Y*) of aboveground utility points (wells) were determined (i.e. co-ordinates of the centre of circular or rectangular geometric figures). The investigated topographic details were selected due to their clear identification in the raster orthophotomap image. The co-ordinates of 311 topographic points were obtained (twice) from the orthophotomap by manual vectorisation, whose accuracy was estimated (where the differences in the twice obtained co-ordinates were regarded as true errors) in accordance with the theory of measurements in pairs. Accuracy of vectorisation was 0.06 m. The maximum absolute value of discrepancies between co-ordinates acquired in double vectorisation was: 0.18 m for *X* and 0.17 m for *Y*. The average results of the double vectorisation process were adopted as the ultimate co-ordinates of aboveground utility points obtained from the digital orthophotomap, and they were compared against the co-ordinates of the same topographic details acquired by means of survey with an electronic tachymeter. The resulting differences produced a set of 311 vectors of shift of topographic points, and none of the vectors were longer than 0.60 m. The co-ordinates (*X*, *Y*) of topographic details of (nearly exclusively) 1st accuracy group were obtained through vectorisation of the raster image of orthophotomap of Zielona Góra (object C-II). They were: I – elements of fence (other than pillars); II – corners of concrete structures; III – apex points of building contours; IV – apex points of curb lines; V – other pillars; VI – pillars of fence; VII – wells. The co-ordinates of 501 topographic points were obtained on the orthophotomap by manual vectorisation whose accuracy was estimated in accordance with the theory of measurements in pairs. In the course of manual vectorisation, 39 topographic points were found to be unsuitable for analysis, mainly because their plane co-ordinates could not be reliably read from the raster orthophotomap image. Due to the above, the analysis was performed based on a set of 462 twice vectorised points. The average vectorisation error was 0.05 m. The maximum absolute value of discrepancies between coordinates from double vectorisation reached 0.20 m for *X* and 0.18 m for *Y*. The average results of the double vectorisation process were adopted as the ultimate co-ordinates of the analyzed topographic points obtained from the digital orthophotomap, and they were compared against the co-ordinates of the same topographic details determined in a total station survey. The resulting differences produced a set of 462 vectors of shift of topographic points (ΔL). The analysis of the entire set lengths of ΔL showed that a vector of shift had an average length of 0.28 m, and the vast majority of vectors (95%) did not exceed double the average vector length ($\Delta L \leq 0.56$ m), while several (6) vectors of shift of control point had the length of $\Delta L = 1.0$ m ± 0.2 m. The accuracy of topographic data acquired from digital orthophotomaps was estimated in view of the formula (2).

Estimation of the Accuracy of the Object D

The accuracy of digital map data acquired through manual vectorisation of raster maps was researched at several stages covering different fragments (sub--objects) of the City of Olsztyn. The obtained results were a full presentation in dissertation [7]. The estimation of the accuracy of the object D involved a comparison of the co-ordinates of 1st group topographic details (type B and U) entered into the database of the analyzed map against the co-ordinates of the same points determined by an electronic tachymeter. The error of position of topographic point was computed with the use of formula (2).

4. Discussion of the Results

The computed errors of position of topographic details of 1st accuracy group made an overview of the usefulness of digital map data acquired by various methods and supported the estimation of real accuracy of the analyzed large-scale maps. The determined accuracy of digital map data is presented in table 1.

The accuracy of topographic data acquired from surveys performed with an electronic tachymeter (object A) was within the 0.04–0.05 m range. The resulting database may be released in the form of a 1:250 analogue map presentation. The accuracy of topographic data collected in the digital map database developed from the results of previous direct measurements (object B) generally ranged from 0.10 m to 0.30 m. Smaller accuracy of position of details was determined in control sub-object B-3 and in sheet 1(2) of control sub-object B-7. According to the information provided by the Office of the City of Zielona Góra, the less accurate map fragments had already been updated with the results of new direct surveys. In view of the above, it should be noted that the database of object B may be released on a graphic presentation scale of 1:500 or 1:1000.

Table 1. The accuracy of digital map data produced by different methods

Investigated object and method of acquiring the co-ordinates of topographic points	Base scale of the map	Control object or sub-object		Type and number of control points	Determined mean error of position of a point [m]	The conventional allow scale of the map presentation (denominator answering the polish accuracy standard)
A New survey performed with an electronic tachymeter	1:500	A		B – 139	0.04	1:250 (133)
				U – 128	0.05	1:250 (166)
				Other – 211	0.04	1:250 (133)
				Total – 478	0.04	1:250 (133)
B Co-ordinates computed from the results of previous direct measurements	1:500	B-1		B – 200	0.14	1:500 (466)
				G – 57	0.19	1:1000 (633)
				Total – 257	0.15	1:500 (500)
		B-2		B – 93	0.21	1:1000 (700)
				G – 124	0.21	1:1000 (700)
				Total – 217	0.21	1:1000 (700)
		B-3		B – 192	0.34	1:2000 (1133)
				G – 17	0.20	1:1000 (666)
				Total – 209	0.33	1:2000 (1100)
		B-4		B – 193	0.22	1:1000 (733)
				G – 48	0.20	1:1000 (666)
				Total – 241	0.22	1:1000 (733)
		B-5		B – 131	0.10	1:500 (333)
				G – 66	0.23	1:1000 (766)
				U – 121	0.24	1:1000 (800)
				Total – 318	0.20	1:1000 (666)
		B-6		B – 150	0.16	1:500 (533)
				G – 67	0.07	1:250 (233)
				U – 47	0.14	1:500 (466)
				Total – 264	0.14	1:500 (466)
		B-7	sheet 1(2)	B – 20	0.77	1:5000 (2566)
				G – 1	0.87	1:5000 (2900)
				Total – 21	0.77	1:5000 (2566)
			sheet 2(2)	B – 67	0.20	1:1000 (666)
				G – 5	0.28	1:1000 (933)
				Total – 72	0.21	1:1000 (700)

Table 1. cont.

C Manual vectorisation of the raster orthophotomap image (monoplotting)	1:2000	C-I	U – 311	0.21	1:1000 (700)
		C-II	I – 15	0.43	1:2000 (1433)
			II – 36	0.42	1:2000 (1400)
			III – 28	0.33	1:1000 (1100)
			IV – 172	0.33	1:1000 (1100)
			V – 130	0.29	1:1000 (966)
			VI – 40	0.30	1:1000 (1000)
			VII – 41	0.31	1:1000 (1033)
			Total – 462	0.33	1:1000 (1100)
D Graphical-and-digital processing (manual vectorisation of raster maps)	1:500	D-1	B – 487	0.36	1:2000 (1200)
			U – 514	0.40	1:2000 (1333)
			Total – 1001	0.38	1:2000 (1266)
		D-2	B – 330	0.43	1:2000 (1433)
			U – 219	0.48	1:2000 (1600)
			Total – 549	0.45	1:2000 (1500)
		D-3	B – 163	0.45	1:2000 (1500)
			U – 77	0.49	1:2000 (1633)
			Total – 240	0.46	1:2000 (1533)
		D-4	B – 105	0.23	1:1000 (766)
			U – 131	0.40	1:2000 (1333)
			Total – 236	0.33	1:2000 (1100)
		D-5	B – 73	0.31	1:1000 (1033)
			U – 61	0.29	1:1000 (966)
			Total – 134	0.30	1:1000 (1000)
		D-6	B – 49	0.44	1:2000 (1466)
			U – 66	0.34	1:2000 (1133)
			Total – 115	0.39	1:2000 (1300)

Topographic data acquired from the raster orthophotomap image (developed on a 1:2000 scale) were highly accurate. As regards the analyzed topographic details, the error of position of a point ranged from 0.21 to 0.43 m. The co-ordinates of the analyzed points of 1st group guarantee accuracy on a 1:1000 scale of the map. The accuracy of a digital map data developed by graphical-and-digital processing (object D) was within the 0.30–0.50 m range. The resulting database may be released (in the form of an analogue map) in presentations whose scale does not exceed 1:2000.

5. The Summary and Conclusions

The analysis of the estimated maps produced by means different methods of digital data production indicates that digital map data acquired by direct survey with an electronic tachymeter (object A) is marked by the highest accuracy. High accuracy was also reported in respect of digital map data produced through the recalculation of the results of previous direct measurements (object B). Similar results were observed as regards topographic data (in particular well identified utility features) obtained through monoplotting, i.e. manual vectorisation of raster orthophotomap (object C). The least accurate data were produced through graphical-and-digital processing – by manual vectorisation of raster maps (object D).

As indicated by the results of this research, the accuracy of large-scale maps made with the use of topographic data produced by various methods is highly differentiated [7]. The above poses a significant obstacle to the use of large-scale maps for execution of economic tasks. The process of acquiring information from the database of a digital map is flawless, as regards the content of a large-scale map due to the clear obtain co-ordinates of objects. In practice, engineering applications of digital maps are limited to the use of analytical-and-digital methods. Correct and reliable results cannot be obtained by inputting incorrect data. Other authors have pointed out that the GIGO – Garbage In, Garbage Out – principle should be observed when considering the quality of digital data [17].

The results of the performed investigations and analyses have prompted the authors of this paper to formulate the following conclusions:

1) Digital map data produced by various methods do not always support the development of geodetic documentation at the required accuracy level.
2) The obtained results indicate that great caution should be exercised when selecting the methods of acquiring data for the generation of databases for large-scale maps.
3) In view of their experience, the authors postulate the need to estimate the accuracy of the databases of large-scale technical maps.
4) Digital map data accuracy should be verified to ensure the transparency of relations between map producers and map users, and to guarantee that national geodetic and cartographic resources meet the relevant quality standards.

References

[1] Bogaert P., Delincé J., Kay S.: *Assessing the error of polygonal area measurements: a general formulation with applications to agriculture*. Measurement Science and Technology, 16(5), 2005, pp. 1170–1178.

[2] Burmanje D.A.J.: *Spatial Data Infrastructures and Land Administration in Europe*. FIG Article of the Month July 2005, [on-line:] http://www.fig.net/pub/monthly_articles/july_2005/july_2005_burmanje.pdf.

[3] Croitoru A., Doytsher Y.: *Accounting for Discontinuities in Cadastral Data Accuracy: Toward a Patch Based Approach*. Paper of FIG Working Week in Paris, 2003, [on-line:] http://www.fig.net/pub/fig_2003/TS_15/TS15_4_Croitoru_Doytsher.pdf.

[4] Dąbrowski W., Doskocz A., Mrówczyński T.: *Miasto doceniło ortofoto* (The city appreciated ortophoto). Geodeta Magazyn Geoinformacyjny, 1(140), 2007, pp. 54–56.

[5] De Bruin, S.: *Modelling Positional Uncertainty of Line Features by Accounting for Stochastic Deviations from Straight Line Segments*. Transactions in GIS, 12(2), 2008, pp. 165–177.

[6] De Bruin S., Heuvelink G.B.M., Brown J.D.: *Propagation of positional measurement errors to agricultural field boundaries and associated costs*. Computers and Electronics in Agriculture, 63(2), 2008, pp. 245–256.

[7] Doskocz A.: *Badanie dokładności wielkoskalowych map numerycznych wykonanych różnymi metodami* (Examining of accuracy of large-scale digital maps made with different methods). Uniwersytet Warmińsko-Mazurski, Olsztyn, 2002 (Ph.D. Thesis).

[8] Faculty of Geodesy and Land Management (FGLM) UWM in Olsztyn: *Strategiczne obszary i problemy badawcze na Wydziale Geodezji i Gospodarki Przestrzennej* (Strategic research areas of the Faculty of Geodesy and Land Management for years 2006–2010). Home site of the FGLM, [on-line:] http://www.geo.kortowo.pl/ node/84.

[9] Gaździcki J., Linsenbarth A.: *GIS in Poland: development towards SDI*. Paper of 10th EC GI & GIS Workshop, Warsaw, 2004, [on-line:] http://www.ec-gis.org/Workshops/10ec-gis/papers/23june_gazdzicki.pdf.

[10] Gościewski D.: *Graficzna analiza błędów występujących w procesie przetwarzania* (Graphic analysis of errors occurring in graphic-numerical and numerical-graphic processing). Zeszyty Naukowe ART Olsztyn, 6, 1999, pp. 235–248.

[11] Guptill S.C., Morrison J.L. (Ed.).: *Elements of spatial data quality*. Published on behalf of the International Cartographic Association by Elsevier Science, 1995.

[12] Head Office of Geodesy and Cartography (HOGC): *Standardy techniczne w Polsce* (Technical standards in Poland). Home site of the HOGC, [on-line:] http://www.gugik.gov.pl/geodezja/standardy-i-wytyczne/instrukcje-i-wytyczne/instrukcje-i-wytyczne-techniczne-wykaz.

[13] López F.J.A., Gordo A.D.A.: *Analysis of Some Positional Accuracy Assessment Methodologies*. Journal of Surveying Engineering, 134(2), 2008, pp. 45–54.

[14] Pachelski W., Chojka A., Zwirowicz A., Sułkiewicz M., Parzyński Z.: *Teaching the basics of geomatics on the surveying faculties of University of Warmia and Mazury and Warsaw University of Technology*. Paper of Fifth European GIS Education Seminar EUGISES, Cracow 2006, [on-line:] http://www.eugises.eu/proceedings2006/Papers/Pachelski_full.pdf.

[15] Preuss R.: *Zakres zastosowań cyfrowej ortofotomapy w Polsce* (Scope of applications of digital orthophotomap in Poland). Archiwum Fotogrametrii, Kartografii i Teledetekcji, vol. 14, 2004, pp. 479–489, [on-line:] http://www.sgp.geodezja.org.pl/ptfit/wydawnictwa/bialobrzegi/Bialobrzegi2004/49-preuss.doc.

[16] Rönsdorf C.: *Positional integration of geodata*. EuroSDR Publication No. 48 – Related Papers, 2004, [on-line:] http://www.eurosdr.net/km_pub/no48/html/positional/related_papers.htm.

[17] Urbański J.: *Zrozumieć GIS – analiza informacji przestrzennej* (Understand GIS – analysis of spatial information). WN PWN, Warszawa 1997.

[18] Wrzołek A.: *Geograficzny System Informacyjny miasta Zielona Góra* (Geographic Information System of the City of Zielona Góra). Materials of Conference "Geodezja w Europie – wyzwania dla administracji i firm", 2004, [on-line:] http://www.geodezja-szczecin.org.pl/stara_strona/Konferencje/Konf2004/k10.html.

[19] Zakarevičius A., Jonauskienė I.: *Statistines kontroles taikymo galimybes vertinani žemes sklypu kadastro duomenu kokybe* (Opportunity to use statistical control for quality assessment of land parcels cadastral data). Geodesy and Cartography, 33(4), 2007, pp. 115–119, [on-line:] http://www.gc.vgtu.lt/en/lt/3/NR/PUB/12520 (in Lithuanian).

[20] Zandbergen P.A.: *Positional Accuracy of Spatial Data: Non-Normal Distributions and a Critique of the National Standard for Spatial Data Accuracy*. Transactions in GIS, 12(1), 2008, pp. 103–130.