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AN ANALYSIS OF THE ACCURACY OF THE TRANSFORMATION OF THE COORDINATORS OF MINING MAPS BY DISTINCT METHOD

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Abstract

The article presents the results of an analysis of the accuracy of the transformation of the coordinates of the boundary points of neighbouring mining areas in Silesia. The transformations were carried out independently for each mining area caused the equivalent boundary points of neighbouring mining areas in the local coordinate system to have different coordinates in the national PL-2000 system. In addition, analyses were carried out taking into account measurement accuracy confirming the sensitivity of the first order conformal transformation to measurement errors. The differences that occur indicate the need to look for a method that will reduce or eliminate them.

Keywords: coordinate transformation, first order conformal transformation, accuracy analysis, mining cartography, mining

ANALIZA DOKŁADNOŚCI TRANSFORMACJI WSPÓŁRZĘDNYCH MAP GÓRNICZYCH METODĄ ODRĘBNĄ

Abstrakt

W artykule przedstawiono wyniki analizy dokładności transformacji współrzędnych punktów granicznych sąsiednich obszarów górniczych na Śląsku. Transformacje przeprowadzono niezależnie dla każdego obszaru górniczego, co spowodowało, że równoważne punkty graniczne sąsiednich obszarów górniczych w lokalnym układzie współrzędnych mają inne współrzędne w krajowym układzie PL-2000. Dodatkowo przeprowadzono analizy uwzględniające dokładność pomiaru potwierdzające wrażliwość transformacji konforemnej pierwszego stopnia na błędy pomiarowe. Występujące różnice wskazują na konieczność poszukiwania metody, która je zmniejszy lub zniweluje.

Słowa kluczowe: transformacja współrzędnych, transformacja konforemna pierwszego stopnia, analiza dokładności, kartografia górnicza, górnictwo

1. INTRODUCTION

The basic legal regulations in the field of mining activities [1] and the management of surveying-geological documentation [2] clearly define the obligations of the entrepreneur regarding the documentation records they keep. Documents may be prepared in local coordinate systems only if there is a possibility of their transformation to the geodetic reference system, which is an element of the national spatial reference system [3, 4].

The issue of coordinate transformation between different coordinate systems has been addressed in the literature by many authors, including in the works of [5–7]. The problem of coordinating coordinates is an international problem and also occurs in Chinese mining [8].

In effect of the research conducted several years ago at the Silesian University of Technology [9] on the transformation accuracy of local coordinate systems, a new procedure for the realization of a transformation task (referred to as one-stage transformation) was de-

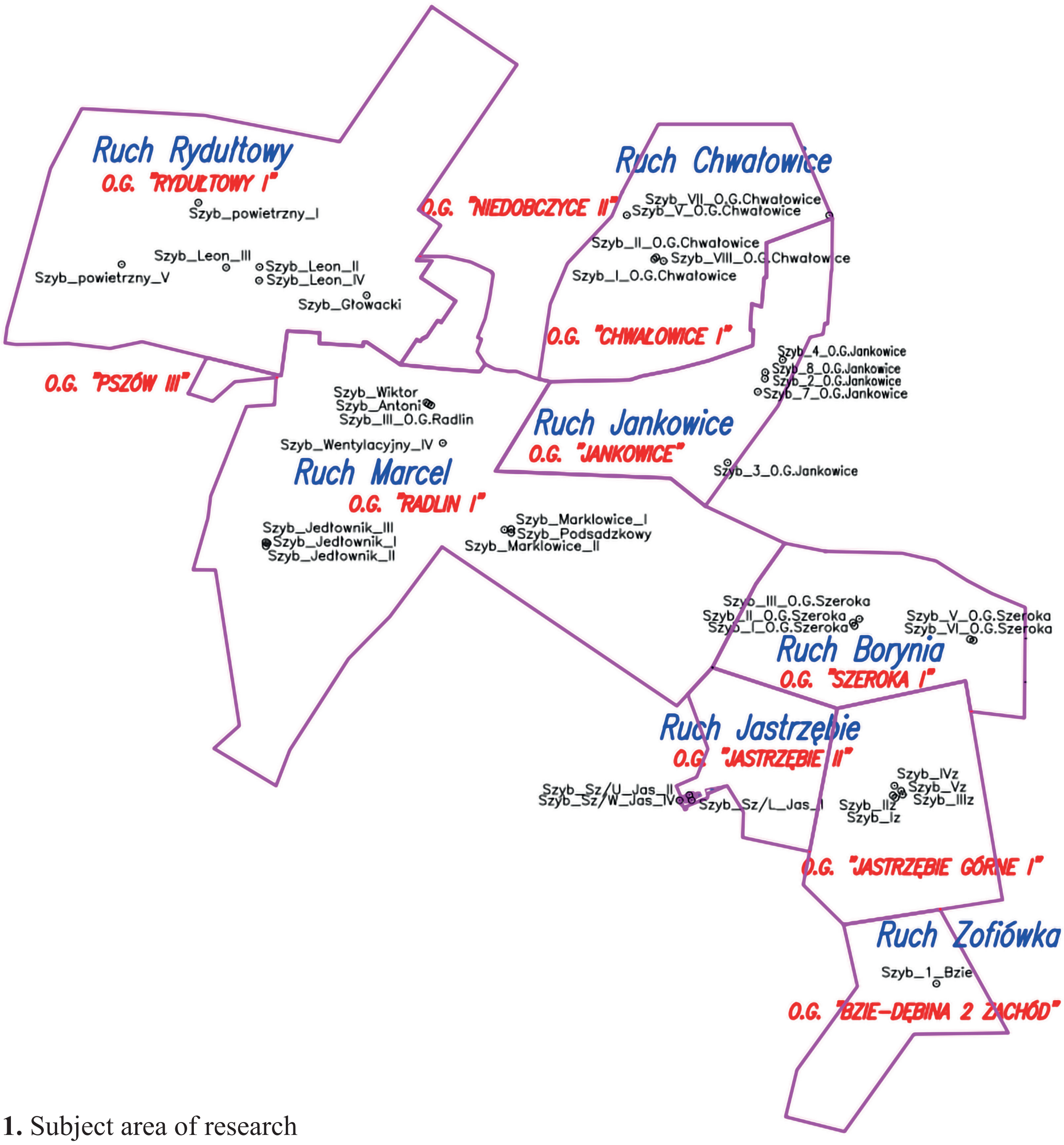

Fig. 1. Subject area of research
Ryc. 1. Przedmiotowy obszar badań

veloped, allowing for the transformation of coordinates directly from the local system to the national system with the required accuracy level.

Unfortunately, a significant problem of transformation carried out independently for each mining area lies in the fact that different coordinates of equivalent points in the PL-2000 national system are obtained as a result of this transformation. Between the boundaries of the areas are formed areas not belonging to any mine. This is a significant problem, primarily due to the fact that these data should feed the resource collected, among others, in the WUG archives (used after the decommissioning of mines), or in databases created as part of the implementation of the INSPIRE Directive [10]. Krawczyk A. in his work [11] points precisely to the great importance of finding a single consistent coordinate system for mining sites.

The article presents the research results involving the differences in the coordinates of equivalent boundary points before and after the transformation task, independently for each of the analyzed areas. Also the analysis of transformation accuracy was carried out.

2. INPUT DATA

The research covered 10 mining areas of two neighboring coal mines (Fig. 1) from the Upper Silesian Coal Basin (as of January 1, 2019). Table 1 summarizes the information on the analyzed mining areas of KWK ROW and KWK Borynia-Zofiówka-Jastrzębie.

Prior to transformation task, the coordinates of equivalent boundary points obtained from the mines were compared using a separate method.

The analysis of the obtained materials attested to the occurrence of boundary points present only in the definition of one of the neighboring mining areas. Accordingly, no equivalent point was found. This involved the need to introduce it by perpendicular projection of the boundary point present in the definition of one of the areas onto the boundary line of the neighboring area which did not have such a point (Fig. 2).

Table 2 presents the summary of points between which discrepancies occurred as well as the resulting coordinate differences calculated for them. Additionally, also additional points are included in the summary. The differences in the location of equivalent boundary points of neighboring areas range from 0.01 m to 1.00 m.

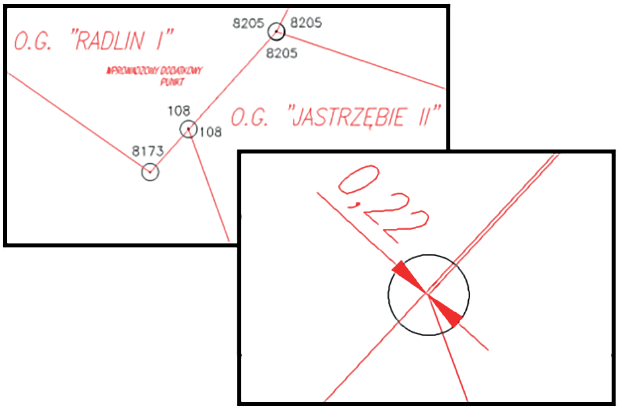

Fig. 2. Example of the calculated distance between the boundary point and the boundary line of two adjacent areas
Ryc. 2. Przykład obliczonej odległości pomiędzy punktem granicznym a linią graniczną dwóch sąsiadujących obszarów

3. REALIZATION OF THE TRANSFORMATION TASK

The transformation task was performed independently for each of the analyzed mining areas using a single-stage transformation. The first order conformal transformation was adopted in the conducted research. It was referred to as distinct transformation.

The Geolisp program by M. Poniewiera [12] and the GEONET software package [13] were used to carry out the task.

Shafts (their geometric center on the surface) were adopted as adjustment points, and boundary points were used as binding points.

The transformation parameters were determined on the basis of the coordinates of the adjustment points (known in both systems), obtained directly from the

Table 1. Summary of the analyzed areas
Tabela 1. Zestawienie analizowanych obszarów

No.	Name of Coal Mine Company	Name of Ruch (unit)	Name of Mining Area (O.G.)
1	KWK ROW	Ruch Chwałowice	O.G. Chwałowice I
2	KWK ROW	Ruch Jankowice	O.G. Jankowice
3	KWK ROW	Ruch Marcel	O.G. Radlin I
4	KWK ROW	Ruch Rydułtowy	O.G. Pszów III
5	KWK ROW	Ruch Rydułtowy	O.G. Rydułtowy I
6	KWK ROW	–	O.G. Niedobczyce II
7	KWK Borynia-Zofiówka-Jastrzębie	Ruch Borynia	O.G. Szeroka I
8	KWK Borynia-Zofiówka-Jastrzębie	Ruch Jastrzębie	O.G. Jastrzębie II
9	KWK Borynia-Zofiówka-Jastrzębie	Ruch Zofiówka	O.G. Bzie-Dębina 2 Zachód
10	KWK Borynia-Zofiówka-Jastrzębie	Ruch Zofiówka	O.G. Jastrzębie Górne I

Table 2. Resultant differences in the coordinates of equivalent boundary points for selected mining areas
Tabela 2. Wypadkowe różnice współrzędnych tożsamych punktów granicznych dla wybranych obszarów górniczych

Point No	Neighboring areas	Difference [m]
51	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Pszów III	0.06
8079	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Radlin I	0.15
8073	KWK ROW O.G. Rydułtowy I – KWK ROW Ruch Marcel O.G. Radlin I	0.10
8073	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Niedobczyce II	0.10
8072	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Niedobczyce II	0.04
8065	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Niedobczyce II	0,97
8063	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Niedobczyce II	1,00
8060	KWK ROW O.G. Rydułtowy I – KWK ROW O.G. Niedobczyce II	1,00
64	KWK ROW O.G. Radlin I – KWK ROW O.G. Pszów III	0,07
108	KWK ROW O.G. Radlin I – KWK Bor.Zof.Jas O.G. Jastrzębie II	0,22
8205	KWK ROW O.G. Radlin I – KWK Bor.Zof.Jas O.G. Jastrzębie II	0,22
8205	KWK ROW O.G. Radlin I – KWK Bor.Zof.Jas. O.G. Szeroka I	0,04
8206	KWK ROW O.G. Radlin I – KWK Bor.Zof.Jas. O.G. Szeroka I	0,05
8207	KWK ROW O.G. Radlin I – KWK Bor.Zof.Jas. O.G. Szeroka I	0,06
8170	KWK ROW O.G. Radlin I – KWK ROW O.G. Jankowice	0,01
8123A	KWK ROW O.G. Radlin I – KWK ROW O.G. Chwałowice I	0,03
8147	KWK ROW O.G Chwałowice I – KWK ROW O.G. Jankowice	0,02
8205	KWK Bor.Zof.Jas O.G. Szeroka I – KWK Bor.Zof.Jas O.G. Jastrzębie II	0,25
8200	KWK Bor.Zof.Jas O.G. Szeroka I – KWK Bor.Zof.Jas O.G. Jastrzębie II	0,32
8200	KWK Bor.Zof.Jas O.G. Szeroka I – KWK Bor.Zof.Jas O.G. Jastrzębie Górne I	0,33
8201	KWK Bor.Zof.Jas O.G. Szeroka I – KWK Bor.Zof.Jas O.G. Jastrzębie Górne I	0,38
8239	KWK Bor.Zof.Jas O.G. Szeroka I – KWK Bor.Zof.Jas O.G. Jastrzębie Górne I	0,31
8200	KWK Bor.Zof.Jas O.G. Jastrzębie Górne I – KWK Bor.Zof.Jas O.G. Jastrzębie II	0,02
104	KWK Bor.Zof.Jas O.G. Jastrzębie Górne I – KWK Bor.Zof.Jas O.G. Jastrzębie II	0,27

mines. The procedure was analogous to the one developed in the research in 2017.

During the calculation of the transformation parameters by the program, also the values of deviations at the adjustment points, the values of the mean square deviations of the coordinates, the mean unit error and the maximum resultant deviation of the adjustment points were generated. A fragment of the protocol generated from Geonet 2006 is presented below (Fig. 3).

4. ANALYSIS OF COORDINATE DIFFERENCES OBTAINED BY THE TRANSFORMATION

After a single-stage transformation performed separately for individual mining areas of two neighboring mines, the obtained coordinates were analyzed. The differences between the coordinates of equivalent boundary points were calculated, which are listed in Table 3.

FLAT TRANSFORMATION in the system <GEONET 2006> (c)ALGORES-SOFT www.geonet.net.pl

DATE:

WORK OBJECT: c:\GEONET\Obiekty\2.ROW Ruch Rydultowy O.G.Rydultowy

CONTRACTOR:

MODEL: 1st order CONFORMAL TRANSFORMATION

INPUT DATA:

The number of given points of the origin set (xy1) = 45

Verified number of set points (xy1) = 45

Number of given secondary set points (xy2) = 6

Verified number of set points (xy2) = 6

Number of common points (xy1) and (xy2) = 6

GENERAL PARAMETERS:

Gravity centers of the sets of adjustment points:

Primary system (1): -37958.8633 -31944.7950 (xo, yo)

Secondary System (2): 5548148.3965 6530716.3925 (Xo, Yo)

Numerical scale = 3.55007483821082E-0004

ANALYSIS

Mean square deviations (sX,sY, resultant s):

sX = 0.0018 sY = 0.0011 s = 0.0022

Number of equations = 12

Number of unknowns = 4

System oversizing = 8

Mean unit error m0 = 0.0019

Maximum resultant deviation: 0.0035 for the point: Szyb_Leon_IV (Shaft Leon IV)

Fig. 3. Fragment of the transformation protocol for KWK ROW Company Ruch Rydułtowy O.G. Rydułtowy
Ryc. 3. Fragment protokołu transformacji dla KWK ROW Ruch Rydułtowy O.G. Rydułtowy

The obtained values range from 0.01 m to 0.45 m. The average difference between the coordinates is 0.19 m.

The differences, even small ones, between the coordinates of the equivalent boundary points may indicate that the method used is not ideal.

5. TRANSFORMATION ACCURACY ANALYSIS

The transformation results were analyzed in terms of the accuracy of the transformation task. The analysis concerned deviations at the adjustment points.

As reference point for the accuracy assessment we applied the provisions contained in the G-2 Instruction – Detailed horizontal and altitude geodetic control network and coordinate conversions between systems [14] and technical guidelines G-1.10 [15]. For the purposes of the conducted analyses, the value of 0.05 m was adopted as the acceptable transformation error.

The values of deviations obtained in effect of the transformation between the local systems of Sucha Góra and the national PL-2000 system are listed in Table 4.

The obtained results indicate that all the analyzed transformations do not exceed the permissible trans-

Table 3. Differences between the coordinates of equivalent boundary points after the transformation
Tabela 3. Różnice pomiędzy współrzędnymi tożsamych punktów granicznych po wykonanej transformacji

Point No	Neighboring areas	Difference [m]
8073	KWK ROW O.G. Rydułtowy-KWK ROW Ruch Marcel (O.G. Radlin)	0,11
108	KWK ROW Ruch Marcel (O.G. Radlin)-KWK Bor.Zof.Jas Ruch Jastrzębie	0,27
8205	KWK ROW Ruch Marcel (O.G. Radlin)-KWK Bor.Zof.Jas Ruch Jastrzębie	0,29
8205	KWK ROW Ruch Marcel (O.G. Radlin)-KWK Bor.Zof.Jas. Ruch Borynia	0,03
8206	KWK ROW Ruch Marcel (O.G. Radlin)-KWK Bor.Zof.Jas. Ruch Borynia	0,02
8207	KWK ROW Ruch Marcel (O.G. Radlin)-KWK Bor.Zof.Jas. Ruch Borynia	0,02
8170	KWK ROW Ruch Marcel (O.G. Radlin)-KWK ROW Ruch Jankowice	0,02
8147	KWK ROW Ruch Chwałowice-KWK ROW Ruch Jankowice	0,01
8205	KWK Bor.Zof.Jas Ruch Borynia-KWK Bor.Zof.Jas Ruch Jastrzębie	0,31
8200	KWK Bor.Zof.Jas Ruch Borynia-KWK Bor.Zof.Jas Ruch Jastrzębie	0,45
8200	KWK Bor.Zof.Jas Ruch Borynia-KWK Bor.Zof.Jas Ruch Zofiówka (Jastrzębie Górne)	0,33
8201	KWK Bor.Zof.Jas Ruch Borynia-KWK Bor.Zof.Jas Ruch Zofiówka (Jastrzębie Górne)	0,37
8200	KWK Bor.Zof.Jas Ruch Zofiówka (O.G. Jastrzębie Górne) – KWK Bor.Zof.Jas Ruch Jastrzębie (O.G. Jastrzębie)	0,12
104	KWK Bor.Zof.Jas Ruch Zofiówka (O.G. Jastrzębie Górne) – KWK Bor.Zof.Jas Ruch Jastrzębie (O.G. Jastrzębie)	0,26
	average	0,19

Table 4. Deviations of the 1st order conformal transformation of flat coordinates of individual mining areas
Tabela 4. Odchyłki transformacji konforemnej stopnia 1 współrzędnych płaskich poszczególnych obszarów górniczych

Name of Coal Mine Company	Name of mining area (O.G.)	Deviation values in [mm]			
		S_x	S_y	S	S_{max}
KWK ROW	O.G. Rydułtowy I	1,8	1,1	2,2	3,5
KWK ROW	O.G. Radlin I	0,0	0,0	0,0	0,0
KWK ROW	O.G. Jankowice	0,4	1,9	2,0	3,8
KWK ROW	O.G. Chwałowice I	1,7	1,4	2,2	3,3
KWK Borynia-Zofiówka-Jastrzębie	O.G. Szeroka I	1,8	2,6	3,2	5,0
KWK Borynia-Zofiówka-Jastrzębie	O.G. Jastrzębie II	1,2	1,0	1,5	2,0
KWK Borynia-Zofiówka-Jastrzębie	O.G. Jastrzębie Górne I	0,0	0,0	0,0	0,0

where:
S_x, S_y – mean square deviation,
S – resultant deviation (transformation error),
S_{max} – maximum resultant deviation.

formation error adopted for the purposes of the research.

In addition, transformation analyses were carried out in terms of measurement accuracy. For this purpose, an additional transformation was carried out for one of the mining areas subjected to the research, taking into account the position error of one of the shafts. The measurement error was simulated by changing the X coordinate of one of the adjustment points by 0.25 m and 0.50 m.

A fragment of the table allowing for the differences in coordinates that were considered error-free (without introducing the measurement error) and the coordinates obtained as a result of transformation based on the adjustment point burdened with the position error are presented below (Table 5).

The simulated shaft measurement error of 25 cm causes differences in the range of 0.09 m – 1.00 m in the location of the boundary point. The differences resulting from the simulation of the measurement error of one of the adjustment points by 50 cm range from 0.23 m to 2.76 m. The differences in the position of the points in the second case are almost three times higher than those in the case of a 25 cm measurement error of one of the adjustment points.

We conclude from the analysis of the obtained differences that the one-stage first order conformal transformation is very sensitive to measurement errors.

Table 5. Differences between the coordinates considered error-free and the coordinates obtained as a result of a separate transformation, taking into account the error in the measurement of one of the adjustment points

Tabela 5. Różnice pomiędzy współrzędnymi, które uznano za bezbłędne i współrzędnymi uzyskanymi w wyniku transformacji odrębnej przy uwzględnieniu błędu na pomiarze jednego z punktów dostosowania

Point No	$\Delta XY_{Oi\,0,25}$ [m]	$\Delta XY_{Oi\,0,50}$ [m]
8152	0,471	1,306
8151	0,433	1,198
8141	0,583	1,512
8160	0,730	1,902
8161	0,557	1,433
8162	0,555	1,428
8163	0,388	0,976
8164	0,381	0,960
8165	0,348	0,869
8166	0,307	0,757
8167	0,086	0,227
8168	0,189	0,585
8169	0,437	1,260
8170	0,430	1,237
8124	1,000	2,764

6. SUMMARY

As part of the research, the 1st order conformal transformation was performed for 10 mining areas of 2 adjacent mines.

The analysis of the differences in the coordinates of the equivalent boundary points of the neighboring areas before the transformation showed that they ranged from 0.01 m to 1.00 m.

For the purposes of accuracy analyses, the obtained transformation results were analyzed in terms of the accuracy of the transformation task. The obtained values of maximum deviations ranged from 0 to 5 cm. Thus, we conclude that all performed transformations did not exceed the permissible transformation error assumed in the work.

The analysis of the differences in the coordinates of equivalent boundary points of neighboring areas after the completion of the transformation task independently for each analyzed area showed that they ranged from 0.01 m to 0.45 m. The average value for the analyzed points was 0.19 m.

The simulations of the measurement error of one of the adjustment points in the selected mining area by introducing the changes in coordinates by 25 cm and 50 cm allowed to conclude that the single-stage 1st order conformal transformation is sensitive to measurement errors.

The existing differences attested to the justified need to look for a method that would allow to reduce them or completely eliminate. The results of the analysis of transformation accuracy in terms of measurement errors confirmed such a necessity.

Preliminary proposals for solving the occurring problem by applying the method of independent models in the transformation task are presented in the article on the study of the accuracy of the transformation of border points of neighboring mines [16].

The presented issue was the basis for the research carried out as part of the doctoral dissertation on the application of the method of independent models for the transformation of local coordinate systems used in hard coal mines [17].

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