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ANALYSIS OF THE POSSIBILITIES FOR APPLYING THE ASG-EUPOS SYSTEM SERVICES FOR ESTABLISHING THE DETAILED CONTROL NETWORKS

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K e y w o r d s: ASG-EUPOS, NAWGEO, POZGEO, POZGEO_D, RTK, GPS, GLONASS.

A b s t r a c t

The paper presents analyses and comparisons of coordinates' determination accuracy using ASG-EUPOS system real time (NAWGEO) and post-processing (POZGEO and POZGEO_D) services in the context of establishing detailed control networks. The survey of the detailed land survey network was conducted during construction of the national road S22 in its section Elbląg-Chruściel. At the first stage of the research static GNSS surveys were conducted using four Topcon HiPer Pro receivers. Almost all the points of the land survey network were stabilized in location with good availability to satellites. Only in the vicinity of some points, at the distance of around 10 meters, trees were situated. Processing of the observations was conducted by post-processing using the Topcon Tools software for 30–40 minute sessions using the observations from the network of fixed reference stations of POZGEO_D service. Additional static sessions were also processed using the POZGEO service. At the second stage of the study, RTK surveys using the ASG-EUPOS system NAWGEO service by applying two Topcon HiPer Pro receivers where one of them determined the position on the base of the single physical reference station while the other used the VRS network observations were conducted on the same points of the detailed network. The paper contains comparative analyses of the coordinates obtained and of their accuracy.

ANALIZA MOŻLIWOŚCI WYKORZYSTANIA SERWISÓW SYSTEMU ASG-EUPOS DO ZAKŁADANIA SZCZEGÓŁOWYCH OSNÓW GEODEZYJNYCH

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S ł o w a k l u c z o w e: NAWGEO, POZGEO, POZGEO_D, ASG-EUPOS, RTK, GPS, GLONASS.

Abstrakt

W pracy przedstawiono analizy i porównania dokładności wyznaczeń współrzędnych z wykorzystaniem serwisów czasu rzeczywistego (NAWGEO) i postprocessingu (POZGEO i POZGEO_D) systemu ASG-EUPOS w kontekście zakładania szczegółowych osnów geodezyjnych. Pomiar szczegółowej osnowy geodezyjnej wykonano podczas budowy drogi krajowej S22, na odcinku Elbląg – Chruściel. W pierwszym etapie badań wykonano pomiary statyczne GNSS z wykorzystaniem 4 odbiorników Topcon HiperPro. Prawie wszystkie punkty osnowy geodezyjnej były stabilizowane w miejscach o dobrym dostępie do satelitów. Tylko w pobliżu niektórych punktów w odległościach około 10 metrów znajdowały się drzewa. Obserwacje opracowano w procesie postprocessinu z wykorzystaniem oprogramowania firmowego Topcon Tools, dla sesji 30–40-minutowych, z wykorzystaniem obserwacji sieci stacji referencyjnych serwisu POZGEO_D. Dodatkowo sesje statyczne opracowano także z wykorzystaniem serwisu POZGEO. W drugim etapie badań, na tych samych punktach osnowy szczegółowej, przeprowadzono pomiary RTK z wykorzystaniem serwisu NAWGEO systemu ASG-EUPOS dwoma odbiornikami Topcon HiperPro – jeden z nich wyznaczał pozycję na podstawie pojedynczej fizycznej stacji referencyjnej, natomiast drugi z wykorzystaniem sieciowych obserwacji VRS. Praca zawiera analizy porównawcze otrzymanych współrzędnych i ich dokładności.

Introduction

Appropriate determination of the ambiguity of phase surveys is necessary for precise determination of the GPS baseline coordinates from satellite observations (MISRA, ENGE 2006). This is the necessary condition, but in case of the limited access of the GPS receiver antenna to the satellites the determinations of ambiguities may be incorrect for a given pair of satellites, which results in appearance of gross errors (BAKUŁA et al. 2009). Erroneous determination of the baseline coordinates can be detected in the process of GPS baselines adjustment in case of the appropriate number of redundant observations and appropriate tying to the network of reference points (BAKUŁA et al. 2007, 2008). The possibility of obtaining high accuracy of the satellite survey results is influenced by numerous factors related not only to the type of equipment used but, first of all, the methodology of planning and performance of satellite observations. The GPS observations processing method, i.e. the choice of the appropriate methodology for processing the GPS baselines and next conducting the detailed analysis of their correct determination has also a significant influence on the obtained accuracies and reliability of the coordinates determined. Only in case of the appropriately planned network of GNSS baselines and redundant observations, we can obtain reliable analysis of accuracies in the process of GPS baselines adjustment (HOFMANN-WELLENHOF et al. 1997) and that is why, at actually every stage of survey and processing of satellite observations independent control should be applied and redundant observations should be used. The paper presents the accuracy analysis of coordinates obtained from processing the GPS/GLONASS network using the

POZGEO_D service as well as using GPS observations and the POZGEO service only. Additionally, at each point two independent RTK/GPS sessions were conducted using the ASG-EUPOS system NAWGEO service (BOSY et al. 2008). The detailed land survey network developed fulfilled the additional function of the implementation network with the required internal accuracy of horizontal coordinates at the level of 10 mm. Achievement of such accuracy is difficult, particularly when the survey is conducted where the access to satellites is limited.

Description of field survey

The land survey network along the road S22 in the section Elbląg – Chruściel was the test object during the experimental survey works. Within the frameworks of the experiment survey was conducted on 35 points (Fig. 1) where on the majority of points good survey conditions for satellite observations were available. The field experiments were divided into two stages. Stage one involving survey on the determined points by static method was conducted on October 5, 2010. Four land survey Topcon HiPer Pro GNSS receivers were used for static survey.

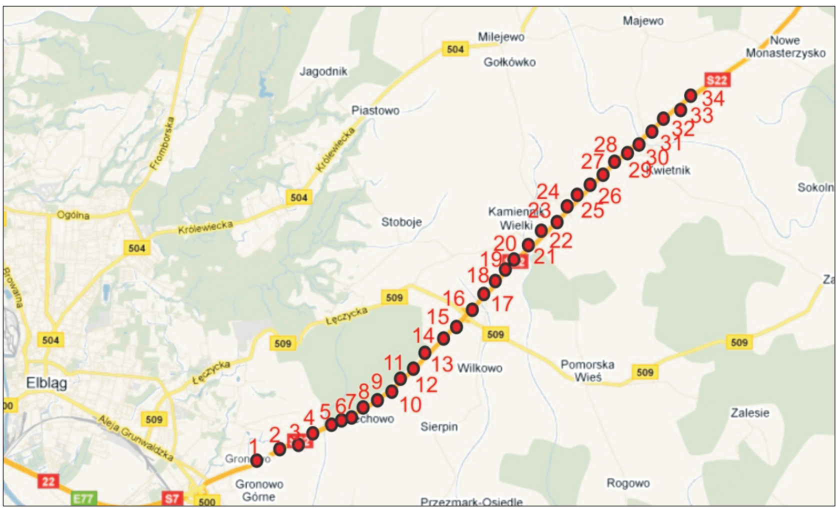

Fig. 1. Location of the control points on the object surveyed

The survey sessions duration depended on observation conditions on the point and ranged from 30 to 45 minutes. Table 1 presents the distribution of points for measurement into individual survey sessions.

Table 1

Distribution of the surveyed detailed network points according to the survey session

Session	Point No.	Point No.	Point No.	Point No.
1	1	2	4	–
2	3	5	6	7
3	8	9	10	11
4	12	13	14	15
5	16	17	18	19
6	20	21	22	23
7	24	25	26	27
8	28	29	30	Kon_168
9	31	32	33	34

Raw observations recorded by Topcon receivers were converted to the standard RINEX (*Receiver Independent Exchange*) data exchange format using the JPS2RIN.EXE software. The observations obtained from the static survey were processed in two ways. The first one involved post-processing and network adjustment using the commercial Topcon Tools software. For the purpose of tying the network the observation data from the station in Elbląg (ELBL), and two virtual stations (Vir5, Vir6) was downloaded from the POZGEO-D service (Fig. 2).

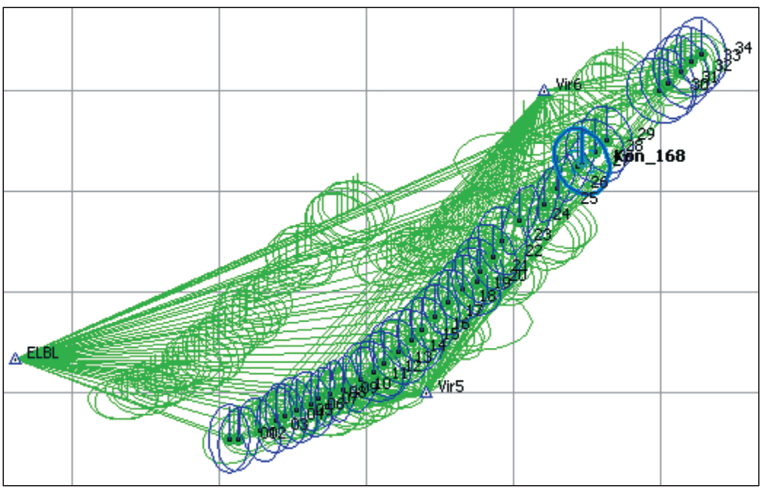

Fig. 2. Network of the adjusted baselines from post-processed static GNSS sessions

The adjustment process was conducted using the least squares method in relation to all three reference stations. The mean errors of coordinates of the points after adjustment did not exceed 5 mm while the values of the residues for the GPS/GLONASS baselines did not exceed 29 mm.

Determination of the coordination of points by POZGEO service was the second method for processing the static survey results. In this case, at the first stage of the analysis the observations from complete survey sessions (further referred to as the long sessions) were sent to the ASG-EUPOS system while in the second stage the observation files shortened to 15 minutes (with one second survey interval) were sent. The TEQC (The Toolkit for GPS/GLONASS/Galileo/SBAS Data) software was used for dividing the files.

Stage two of the survey was conducted on November 24, 2010. It involved measurement of all the determined points by means of the RTK method using two Topcon HiPer Pro receivers and the ASG-EUPOS system NAWGEO service. One of the receivers determined the position on the base of a single reference station situated in Elbląg (ELBL station) while the other receiver used observations from the virtual reference stations (VRS) selected automatically by the mobile receiver software.

Fig. 3. Survey of points by means of the RTK method

Analysis of processing of the points using the ASG-EUPOS system post-processing services: POZGEO_D and POZGEO

Stage one of the analysis involved comparison of the coordinates of points obtained from the POZGEO service for two different durations of sessions: 15 minutes (i.e. 900 survey epochs) and 30–40 minutes (full lengths of sessions carried out on individual points). The largest differences of coordinates occurred on point number 1 amounting to 2,891 m for the x coordinate, 1,192 for the y coordinate and 3,728 for the h coordinate. Presence of such gross errors was probably caused by obstructions at that point (Fig. 4a); the analyses of accuracies for the computed coordinates obtained from the POZGEO service for the above points did not indicate any problems with their determination

(Tab. 2), i.e. estimated accuracies were very small at the level of 1–3 cm. Point 25 situated in the vicinity of the middle voltage power line (Fig. 4b) was the second point in which large differences of coordinates, exceeding significantly the service accuracy characteristics, occurred. The differences of coordinates obtained for the remaining points oscillated within the 10 cm range (Fig. 5).

Table 2
Point determination accuracy analysis performed in the ASG-EUPOS system obtained from the system report

Point number	Long session					15-minute session				
	System 1992 X	System 1992 Y	mx	my	mp	System 1992 X	System 1992 Y	mx	my	mp
1	697662.165	530108.769	0.012	0.000	0.012	697659.274	530107.577	0.029	0.001	0.029
25	702021.596	535882.734	0.006	0.009	0.011	702021.865	535882.010	0.010	0.020	0.022

Fig. 4. Obstructions from the northern side on point 1 (Fig. 4a) and medium voltage transmission line near the point 25 (Fig. 4b)

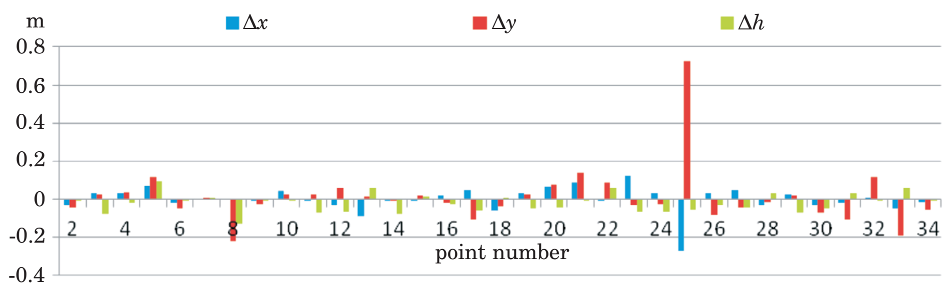

Fig. 5. Differences of coordinates obtained from processing the long and the 15 minute sessions in the POZGEO service

For transparency of the above figure, point one for which the analysis of the results obtained showed major differences in the coordinates was omitted. Analysis of the minimum and maximum values of the coordinates' differences (obtained from the POZGEO service for long and for 15-minute sessions) for the remaining points determined are presented in Table 3, except for points 1 and 25 in case of which gross errors in computations using the POZGEO service were observed in case of short static sessions.

Table 3
Minimum and maximum values from comparison between two computations

Specification	Δ x [m]	Δ y [m]	Δ h [m]
Min.	-0,086	-0,220	-0,128
Max	0,124	0,137	0,092

Comparison of the coordinates originating from the POZGEO service with the coordinates obtained from the post-processing using the POZGEO_D service showed again the largest differences in coordinates for points 1 and 25. The differences of coordinates for point 1 are presented in Table 4.

Analyses of the comparison of points' coordinates obtained from the POZGEO service (long and 15-minute session) with own computations made using the Topcon Tools software are presented in Figure 6. Point 1 was not included in Figure 6 for which the differences were expressed in meters (Table 4).

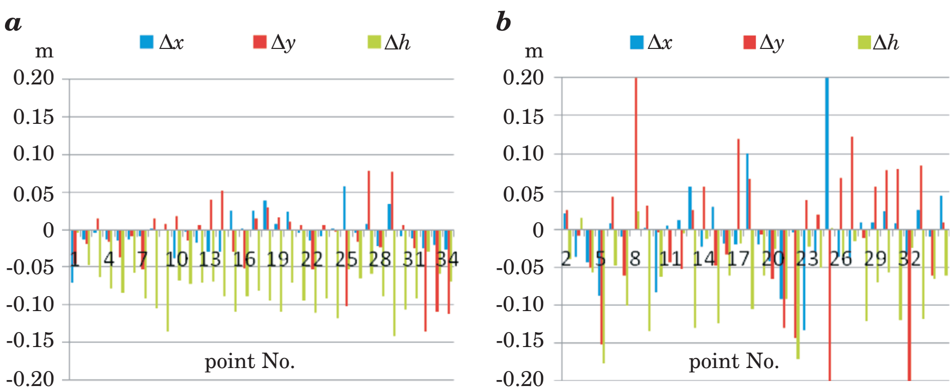

Fig. 6. Differences of coordinates obtained from the POZGEO service from a long session (*a*) and 15-minute session (*b*) and the coordinates obtained from the post-processing (Topcon Tools software)

Table 4

Differences in the coordinates for the first point in case of different computation variants

Specification	Own computations – POZGEO computations for long session [m]			Own computations – POZGEO computations for 15-minute session [m]			15-minute session from POZGEO – own computations [m]			15-minute session from POZGEO – RTK (344-0419 receiver) [m]			15-minute session from POZGEO – RTK (344-0391 receiver) [m]			15-minute session from POZGEO – RTK from 2 receivers [m]		
Point	Δ *x*	Δ *y*	Δ *h*	Δ *x*	Δ *y*	Δ *h*	Δ *x*	Δ *y*	Δ *h*	Δ *x*	Δ *y*	Δ *h*	Δ *x*	Δ *y*	Δ *h*	Δ *x*	Δ *y*	Δ *h*
1	-0,071	-0,046	-0,004	2,891	1,192	-3,728	-2,962	-1,238	3,724	-2,956	-1,232	3,747	-2,966	-1,229	3,776	-2,961	-1,230	3,745

Comparative analyses of network points processing using the POZGEO_D and NAWGEO services

For the purpose of verification of the results obtained, on the determined points the additional survey using two GNSS Topcon HiPer Pro receivers by means of the RTK method and applying the ASG-EUPOS system NAWGEO service was conducted. In the first receiver the network solution of VRS (RTCM 3.1) service was applied while in the second receiver the data from a single reference station (ELBL station in Elbląg) was used. The mobile telephone set Motorola V547 and IGTS-R (mobile GSM/GPRS/EDGE module) were used as modems assuring the GPRS connection. For each point 120 survey epochs with the 1-second interval were recorded. On the base of the data obtained the mean coordinates for each point were determined. The comparison of the coordinates obtained from two GNSS receivers showed similar results to the real time NAVGEO service that oscillated within the range of 2–3 centimeters in case of both using the observations from one reference station and from the virtual reference station (Table 5, Fig. 7).

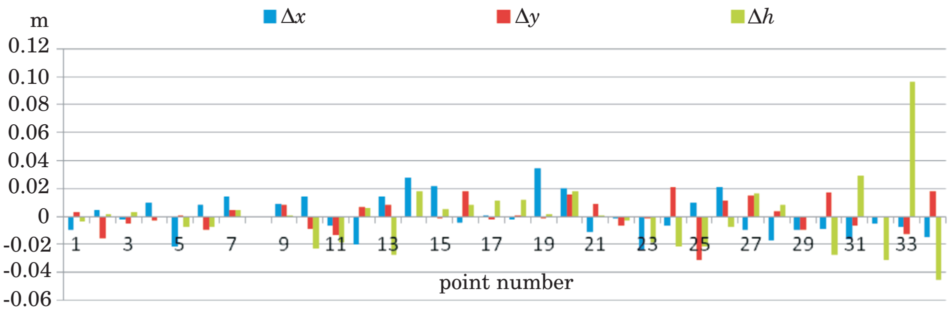

Fig. 7. Differences of the averaged coordinates from surveys conducted using two RTK receivers

Table 5

Minimum and maximum values of the results obtained

Specification	Δ *x* [m]	Δ *y* [m]	Δ *h* [m]
Min.	-0,024	-0,031	-0,046
Max	0,034	0,021	0,096

Point 8 was not included in the comparisons because of the construction works that were in progress during the RTK survey. The differences of horizontal coordinates from RTK survey between two receivers oscillated within the range of 2–3 centimeters, which is within the accuracy ranges of the ASG-EUPOS system RTK services.

The mean coordinates from survey (by means of two receivers) using the RTK method were compared with the results obtained from static sessions post-processed using the POZGEO_D service (Fig. 8) and POZGEO service (Fig. 9), using all the GNSS observations, i.e. the long sessions. The coordinates of baselines between points determined were determined using the GPS and GLONASS observations.

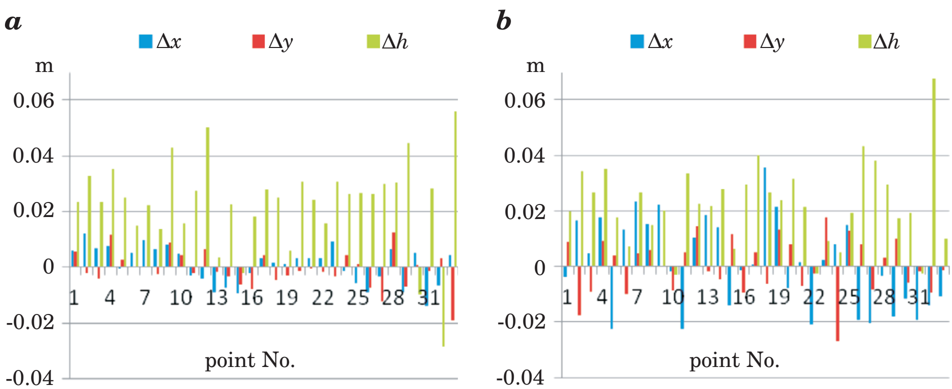

Fig. 8. Differences in coordinates obtained from the post-processing and from RTK survey

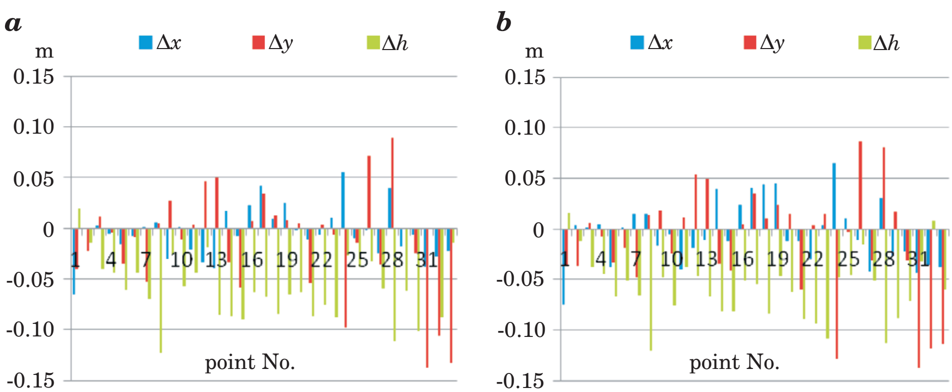

Fig. 9. Differences in coordinates obtained from the POZGEO service (long session) and from RTK survey

Analyzing all the comparisons of the surveys made using the RTK method with the results obtained from static observations it may be concluded that the RTK surveys obtained centimeter agreement with the coordinates obtained from static results for long sessions. This means that RTK surveys may represent excellent control for the results originating from rapid static surveys where any obstructions exist. This allows identification of possible gross errors. In such cases, however, application of synchronic static sessions and adjustment of satellite observations as networks and not as an individual point would be recommended. In case of the results processed using the POZGEO service (for 15-minute sessions with one second survey interval) the coordinates obtained by means of the RTK method are more reliable and are characterized by significantly higher accuracy.

Summary and conclusions

The comparative analyses conducted for the different survey methods and data processing methods indicated that the highest accuracy of coordinates; determination for the position can be assured by conducting the computations in post-processing. The possibility of generating observations for any virtual (VRS) stations from the POZGEO_D service is highly useful as a tool in post-processing. It offers the possibility of optimal network configuration. In case of computations that are conducted for the user by the POZGEO service the results obtained are satisfactory in case of long survey sessions only. Using the POZGEO service, each time we determine the coordinates for one point only. Each of the consecutive determined points is not tied to any network points and as a consequence the differences and jumps in the values of coordinates are difficult to control. The results of determination of coordinates using the POZGEO_D and POZGEO services are similar for points with the unobstructed horizon. Problems appear in case of short sessions and points with obstructions. In the above analyses such problem appeared in case of points 1 and 25 where obstructions in the form of trees and medium voltage power line existed. Determination of the coordinates of points by means of the RTK method was a very good method for verification and elimination of gross errors. The differences of coordinates between the computations in post-processing and the RTK surveys were within the accuracy limits assumed for the RTK services of the ASG-EUPOS system. They oscillated within 2 cm horizontally and 4 cm vertically. In case of 15-minute sessions (with one second survey interval) processed in the POZGEO service the differences oscillated within the limits of 20 centimeters horizontally and vertically. The RTK technique can guarantee accuracies of 1–3 cm horizontally in open area, but for control points independent RTK surveys are required to provide reliability.

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