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GPS – PSEUDOKINEMATIC SURVEY METHOD

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Abstract

The article describes the measurement and calculation of points' coordinates for photogrammetric control points gained by the GPS pseudokinematic survey method. Further, the pseudokinematic observation method and a 12 points measurement example on the Pivka territory is described. Calculated are coordinates of points in the GK system and the accuracy analysis.
Keywords: *accuracy, control points, Global Positioning System, photogrammetry, GPS pseudokinematic survey method, Slovenia*

INTRODUCTION

For a research in photogrammertry in December 1992 in the Pivka territory a network of 12 points was calculated by the GPS pseudokinematic survey method. The Pivka example was chosen due to the fact that in 1991 in this area CAS was carried out and connective network calculated. The coordinates of points were calculated at the Surveying Institute of the Republic Slovenia whereas topography is stored at the Surveying and Mapping Administration in Postojna. For the measurement ground control points were used.

CONTROL POINTS COORDINATES DETERMINATION BY THE GPS

To determine photogrammetric control points 12 points were calculated by the GPS pseudokinematic survey method. (Table 1)

The points were divided into two groups. The first group is formed by points of the given GK coordinates (5 points). In the group there are trigonometric points of the fourth order: 113z, 106z, and 175z; trigonometric point of the third supplementary order, point 104z and connective point 86. Eight control points (f1, f2, f3, f4, f5, f6, f7 and f8) form the second group of points. These were calculated by the GPS measurements. The f2 point is identical with the point 106. All points are approachable by car. The control points had to be determined coordinates in the GK coordinate system.

PSEUDOKINEMATIC METHOD – OBSERVATION

The required accuracy of control points determination was given as to the accuracy of photogrammetry, namely $m_x = m_y = \pm 0{,}05$ m and $m_z = \pm 0{,}10$ m. According to the required accuracy, relatively short distances (to 5 km) and good reachability of points, the GPS pseudokinematic method, which is satisfactory as to the given requirements, was used to determine new points by GPS measurements (King 1987). The GPS pseudokinematic survey method resembles the kinematic method as to the observation method (data collection) and the statistical method in data processing. The method is known also as the method with intervals or statistic method with interruptions. To execute GPS pseudokinematic survey at least two receivers with antennas are needed. By a typical GPS pseudokinematic survey one of the receivers is located at a known point, with the other one we move from point to point and at each we register data for 5 to 10 minutes. After approximately one hour we return with the mobile receiver to each point once more and observe it again for 5 to 10 minutes. Thus for each point approximately one hour observation without data in the middle is made (Table 2). The importance lies in each receiver visiting the same point twice. The one hour time-lag between the first and the second visit of the point is needed for the arrangement of the satellites in the sky to be changed in such an extent as to allow integer ambiguity determination. The time-lag between observation of the same point is not to be shorter than 50 minutes and not longer than 120 minutes (Ewing 1990).

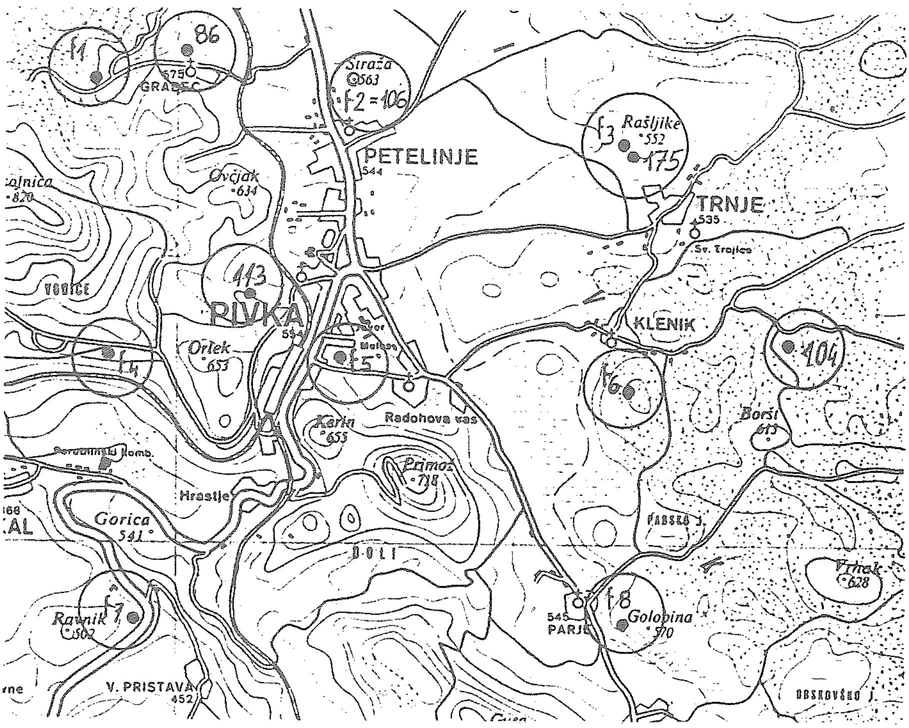

Fig. 1: Points on which observations were carried out (section from a map 1:50 000)

By planning the GPS pseudokinematic survey at least 3 (better 4 or more) satellites of the same kind have to be available to be in the sky for the whole observation period of one group of points (two visits of all points). When on road between the points there is no need to receive a satellite signal. In case we have more mobile receivers simultaneously collecting data, and the operators in radio connection, we can determine also vectors among them. The pseudokinematic method does not require one of the receivers to be on a permanent point but all the receivers may be mobile. This procedure is more productive especially in the case when there is a lesser number of receivers available. In this way we gain less independent vectors.

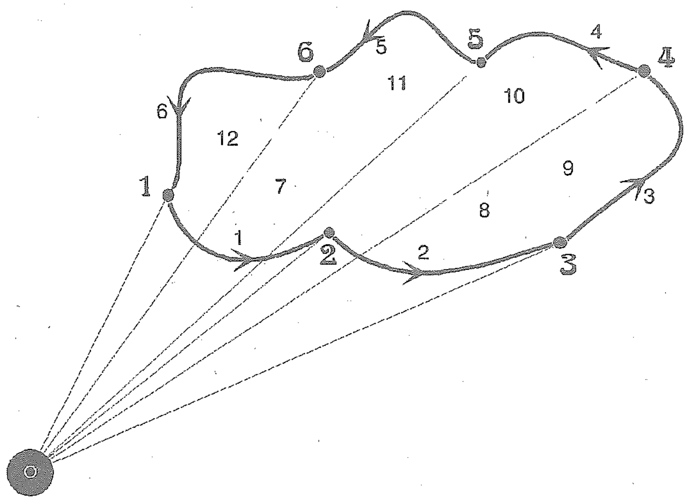

Fig. 2: Pseudokinematic survey method (one permanent, one mobile receiver)

In our case the measurements of points was executed by three two frequency GPS Ashtech XII receivers. The observations were made on December 16, 1992. According to method, satellites arrangement, and number of receivers an observation planning was made which is crucial for effectiveness. The satellites arrangement (20 launched satellites till now) enabled observations between 10.15 and 12.15 and from 12.45 on by local time. The needed observation time together with travels among points with 2 receivers would encompass 8 hours, and four hours with 3 receivers. The observations were carried out in two sections. In both sections one of the receivers was on a permanent place and two mobile. The observations with the mobile receivers were executed simultaneously (radio connection) in such a manner, that a calculation of 18 vectors was possible.

The course of measurements according to sections was as follows:

1st Section

Begin	*End*	*Receiver 1*	*Receiver 2*	*Receiver 3*
10.15	10.23	104	f3	f1
10.33	10.41	104	175	86
10.52	11.02	104	f6	f2
11.12	11.20	104	f3	f1
11.30	11.38	104	175	86
11.48	11.57	104	f6	f2

2^{rd} Section

Begin	*End*	*Receiver 1*	*Receiver 2*	*Receiver 3*
12.50	13.03	86	104	113
13.18	13.26	86	f8	f4
13.45	13.55	86	f5	f7
14.10	14.18	86	104	113
14.32	14.41	86	f8	f4
14.53	15.05	86	f5	f7

The real observation time is evident form tables of the section 1 and 2.

PSEUDOKINEMATIC METHOD – CALCULATIONS

By GPS observation processing programme 18 spatial vectors (Table 3) and their accuracy were calculated. Then by Columbus programme the vectors were adjusted in the net. The net was first adjusted as a free net on ellipsoid so that we adopted for the given coordinates of one point (φ, λ, H). By the adjustment of a free net we can estimate the quality of observations. We found out there were no faults in the net. Then, the net was adjusted so that we adopted as a given point the point 113 with coordinates (φ, λ, H) and four points with altitudes (113, 86, 175 and 104) the hypothesis beeing that locally the geoid is not changing (ellipsoid altitude differences correspond to altitude differences). By such net adjustment we acquire the coordinates φ, λ, H, where the H is the altitude, for all three points. From the three coordinates φ, λ and H we remove the element of height and transform the φ and λ into GK coordinates. The coordinates, acquired by this method, are local and burdened by absolute inaccuracy of GPS measurements. With GPS measurements relative relations in the net are well determined whereas the absolute net position on ellipsoid is worse determined (some 10 to 100 meters).

So acquired coordinates have to be transformed into the state GK system. To get coordinates of control points in the state coordinate GK system the GK coordinates of a local net were transformed into the state system on the basis of four points, given (presented) in both systems. The points used for transformation were 86, 104, 113 and 175. The Table 3a shows results of the transformation of GK coordinates into the state GK system. Given are the coordinates of points, residual errors at control points after the transformation and mean errors of transformation (M) in each axis.

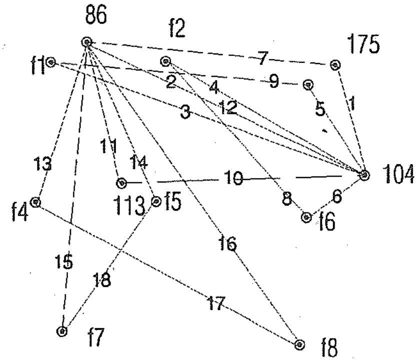

Fig. 3: Scheme of 18 observed vectors

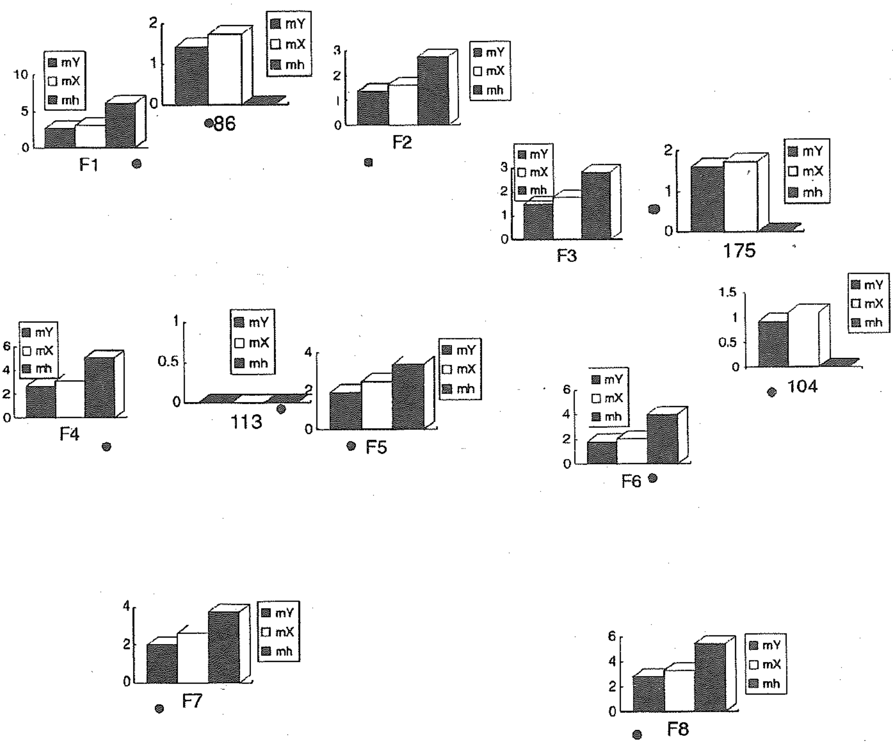

Fig. 4: Accuracy of points in the net, according to axis (calculated with Columbus programme – unit : centimeters)

Table 3a

Point	*Y*	*X*	*Z*	*dY*	*dX*	*dZ*
104	40527,854	59853,070	590,250	-,004	-,010	,000
113	37239,027	59751,440	628,530	,003	,020	,000
175	39758,049	61080,511	552,100	,011	,009	,000
86	36767,710	61658,828	589,740	-,010	-,018	,000
			M	±,008	±,015	±,000

Table 3b

Point	*Y*	*X*	*Z*
f1	36280,920	61385,209	582,256
f2	37831,818	61393,072	563,199
f3	39738,622	61077,366	551,608
f4	36071,325	59500,200	588,177
f5	37705,691	59503,454	575,612
f6	39729,547	59286,379	586,553
f7	36417,364	57752,429	473,504
f8	39623,740	57571,894	553,846

There are no residual errors at altitudes in the Table 3a since we connected the local net in altitude sense to points 104, 113, 175 and 86.

ANALYSES

From the observations at 12 points 18 spatial vectors were calculated. The observations of vectors are good, when the mean error of double phase difference determination (rms) is 0.09 and when the relation between the most probable values for the whole number of waves (ratio) is 3. At the Pivka observations it amounted to:

$$\text{rms:} \quad 0{,}003 < \text{rms} < 0{,}04,$$
$$\text{ratio:} \quad 25 < \text{ratio} < 284.$$

The mean errors of measured coordinate differences of vectors according to individual axes were from 3 to 61 millimeters. Before net adjustment the errors of closure of shapes (triangulars and quandrangulars) were calculated. The errors were within range of precision of mean errors of vectors. By the net calculation f rom spatial vectors also the accuracy of each point in the net is given (Fig. 4). The errors in the Y-axis are between 11 and 32 mm, in the X-axis between 9 and 28 mm, and in the Z-axis between 27 and 61 mm, which shows that the heights of points are twice worse determined as the position. This may result from bad heights of given points or else is the ellipsoid a bad approximation for a geoid. An independent verification was executed at the point 106 (one of the photogrammetric points), which had the given GK coordinates. The errors at the point 106 are: $\Delta Y = \Delta X = 0{,}01$ m and $\Delta Z = 0{,}07$ m.

CONCLUSION

The Pivka measurements stated that the pseudokinematic mensuration method in the GPS system is appropriate and effective at measurements in nets with distances not longer than a few kilometers. It is longed for the points be easy reachable. The GPS pseudokinematic method would be appropriate for new local nets, connective nets or nets of photogrammetric control points.

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