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ASSESSMENT OF TECHNICAL QUALITY OF MODULAR HYBRID NETWORKS

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Introduction

The method of modular networks that was devised in Poland in the 1970's, initially did not meet with a significant interest from surveyors. One of the reasons was the limited access to electro-optic rangefinder as well as to computer technology. The problem was probably also lying in the polish technical rules (regulations) G-4.1 [GUGiK 1986], that are formulated not too clearly, especially in the area of numeric processing. However, at the present stage of surveying technology development, nothing stands on the way to make an attempt to renewed implementation this method with some necessary modifications.

An effect of the research made up by the author (in the 1990's) was e.g. a proposal of amendment the current technical rules [Gargula 1998]. At present there are being conducted researches concerning the question of strengthening the modular networks with GPS measurements [Gargula 2007].

The concept of combination (integration) of the classical and GPS methods appeared in the early period of satellite technology development for geodetic applications (the turn of the 1980's and the 1990's). Initially it was connected with modernization or establishing new geodetic networks. The classical methods were supported by GPS vectors (static or pseudo-static methods) in order either to raise the measurement quality, or to improve the "network geometry". The other reason of using the additional GPS measurements was either the impossibility of connection the survey net with the control one, or the lack of good aiming directions between surveying stations. However, the satellite methods of network realization met often with the field limitations (e.g. the lack of open horizon) and then the classical surveying technique was necessary in order to make a supplement measurement. The issues of integration of these two different surveying technologies was an object of researches being made up by many authors, mainly in the 1990's [Bałut i Gocał 1997; Welsch 1986; Asteriadis i Schwan 1998]. An important stage in this integration process was the creation by surveying equipment producers, the standards of integrated (hybrid) measurements. The hybrid surveying sets consist not only in combination of the electronic tachymeter and GPS receiver, but they need to creation the common calculating platforms, so common changing data formats are necessary [Filipek 2006].

The concept of hybrid network will be here understood as the set of geodetic points (stations), which spatial or plane positions have been determined on the basis on both classical (angular-linear) measurements and the GPS observations. We assume that there is possibility of use the integrated surveying instruments (*total station* + GPS receiver) type *smart station* as well as the integrated sets type "GPS receiver + reflector prism 360°". Receiving the survey data of these two types has to take place simultaneously, because the stations in modular networks are originally the temporary points (without marking on the field).

Preliminary accuracy analysis on network models

Preliminary accuracy analysis allows to predict the network accuracy before making survey, when the geometrical set of observations is known and the observation accuracy m_0 is assumed [Hausbrandt 1971]. However, information about value of the observations is of course not necessary. The coordinate mean errors m_x, m_y and the positional error m_P are usually the quantities wanted. As known from the theory of adjusting calculus, the mean error m_X of any function (e.g. mean error of a point coordinate) is being determined based on the known variance-covariance matrix $\mathbf{Q_X}$ of a parameters (coordinates) vector:

$$m_x = \pm m_0 \sqrt{Q_{ii}} \qquad (1)$$

where Q_{ii} denotes the appropriate diagonal element of matrix $\mathbf{Q_X}$.

The average positional error $\overline{m}_P$ is an often used criterion for total accuracy of network. Its value can be indirectly calculated from the variance-covariance matrix $\mathbf{Q_X}$:

$$\overline{m}_P = \pm m_0 \sqrt{\frac{1}{p} Tr(\mathbf{Q_X})} \qquad (2)$$

where: m_0 – unit mean error of observations; p – number of network points; $Tr(\mathbf{Q_X})$ – trace of matrix $\mathbf{Q_X}$.

The main goal of the tests carried out in this work was the studying of the influence of additional GPS observations on modular network accuracy. Preliminary accuracy analyses were performed using one of the modules of geodetic computer system known in as GEONET [Kadaj 2001]. The tests were carried out with following network models:

a) version A–classical modular network (Fig.1),

b) version B–modular network with GPS observation without anyone, given reference point (Fig. 2),

c) version C–modular network with GPS observation with one, given reference point (Fig.3).

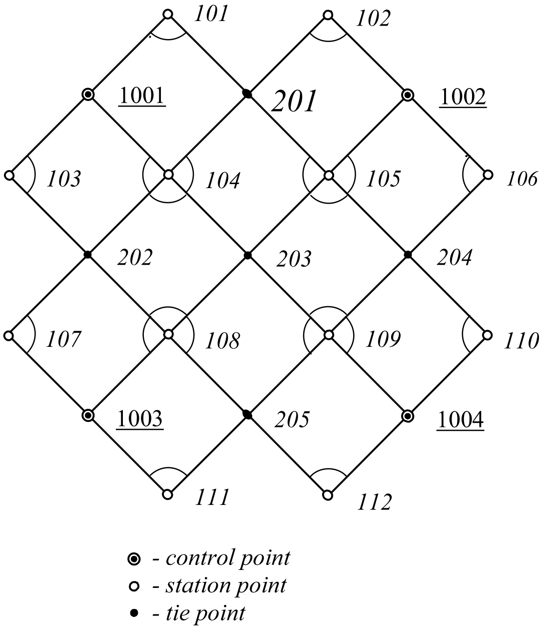

Fig.1. Classical modular network (version A)

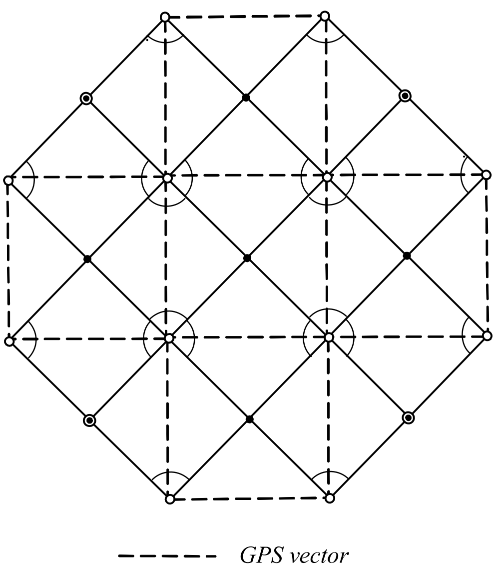

Fig. 2. A hybrid modular network with any number of reference GPS points (version B)

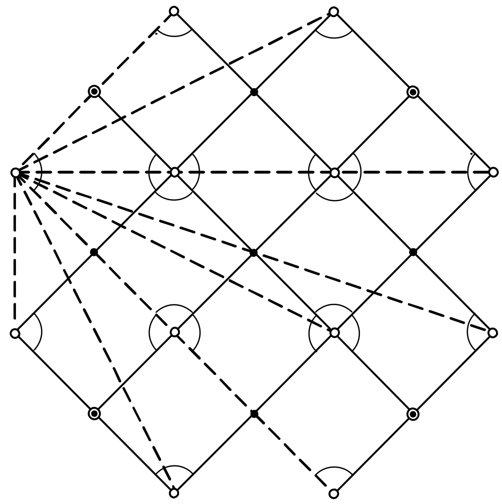

Fig. 3. A hybrid modular network with one reference GPS point (version C)

In the adjustment task of hybrid observation sets, instead of the components ΔX, ΔY of GPS vector, there are very often used so called pseudo-observations, that is a function of the original observations [Kadaj 2001]. In the case of the plane observation adjustment, there will be e.g. horizontal distance d' and azimuth A:

$$\left(\Delta X_{ij}, \Delta Y_{ij}\right) \rightarrow \left(d'_{ij}, A_{ij}\right) \tag{3}$$

where:

$$d'_{ij} = \sqrt{\left(\Delta X_{ij}\right)^2 + \left(\Delta Y_{ij}\right)^2} \tag{4}$$

$$A_{ij} = tg\frac{\Delta Y_{ij}}{\Delta X_{ij}} \tag{5}$$

In order to carry out the accuracy analysis of the network models in versions B and C, the GPS observations were converted in similar manner (3). The determination of pseudo-observation mean errors (*a priori* values) was the next preparatory task. Assuming that accuracy of observations (vectors) GPS is constant and equal $m_{\Delta X} = m_{\Delta Y} = \pm 0{,}005$m, we can receive formulas for calculation the mean errors of quantities (4) and (5):

$$m'_d = \pm\sqrt{m^2_{\Delta X}\left(\frac{\left(\Delta X\right)^2 + \left(\Delta Y\right)^2}{\left(\Delta X\right)^2 + \left(\Delta Y\right)^2}\right)} = \pm m_{\Delta X} \tag{6}$$

$$m_A = \pm m_{\Delta X}\frac{\rho^{cc}}{\sqrt{\left(\Delta X\right)^2 + \left(\Delta Y\right)^2}} \tag{7}$$

The values of observation mean errors for all three network versions are compared in Table 1. Since vector distance in version C is not constant (as it was in version B), so the values of mean error will be also various: $m_A \approx \pm(5^{cc} \div 16^{cc})$. However, in order to standardize the accuracy, the average value of $m_A \approx \pm 10^{cc}$ was assumed in this case. The results of preliminary accuracy analysis are compared in Table 2.

Table 1

Comparison of observational mean errors

Network version	Classical observations		GPS observations and pseudo-observations		
	m_d [m]	m_β [^{cc}]	$m_{\Delta X}=m_{\Delta Y}$ [m]	m'_d [m]	m_A [^{cc}]
A	0,005	10	-	-	-
B	0,005	10	0,005	0,005	16
C	0,005	10	0,005	0,005	10

Table 2

Results of preliminary accuracy analyses

No of point	Local coordinates		Mean errors of coordinates and position(*10^{-3})								
			Version A			Version B			Version C		
	X	Y	m_x	m_Y	m_P	m_x	m_Y	m_P	m_x	m_Y	m_P
101	600,0	200,0	3,0	6,0	7,0	2,0	3,0	4,0	2,0	4,0	4,0
102	600,0	400,0	3,0	6,0	7,0	2,0	3,0	4,0	2,0	4,0	4,0
103	400,0	0,0	6,0	3,0	7,0	3,0	2,0	4,0	2,0	2,0	3,0
104	400,0	200,0	3,0	3,0	4,0	2,0	2,0	3,0	2,0	2,0	3,0
105	400,0	400,0	3,0	3,0	4,0	2,0	2,0	3,0	2,0	2,0	3,0
106	400,0	600,0	6,0	3,0	7,0	3,0	2,0	4,0	5,0	2,0	5,0
107	200,0	0,0	6,0	3,0	7,0	3,0	2,0	4,0	4,0	2,0	4,0
108	200,0	200,0	3,0	3,0	4,0	2,0	2,0	3,0	2,0	2,0	3,0
109	200,0	400,0	3,0	3,0	4,0	2,0	2,0	3,0	2,0	2,0	3,0
110	200,0	600,0	6,0	3,0	7,0	3,0	2,0	4,0	5,0	2,0	5,0
111	0,0	200,0	3,0	6,0	7,0	2,0	3,0	4,0	2,0	4,0	4,0
112	0,0	400,0	3,0	6,0	7,0	2,0	3,0	4,0	2,0	4,0	4,0
201	500,0	300,0	4,0	2,0	4,0	3,0	2,0	4,0	4,0	2,0	4,0
202	300,0	100,0	2,0	4,0	4,0	2,0	3,0	4,0	2,0	3,0	4,0
203	300,0	300,0	4,0	4,0	6,0	3,0	3,0	4,0	3,0	3,0	4,0
204	300,0	500,0	2,0	4,0	4,0	2,0	3,0	4,0	2,0	4,0	4,0
205	100,0	300,0	4,0	2,0	4,0	3,0	2,0	4,0	4,0	2,0	4,0
1001	500,0	100,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1002	500,0	500,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1003	100,0	100,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
1004	100,0	500,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Average error					4,3	-		3,1	-		3,4
Maximum error					6,3	-		4,1	-		5,3

Comparing the obtained mean errors (average and maximum) one can conclude that the use of GPS vectors causes an improvement of the quality of modular network. The net in version B (Fig. 2) compare the most favorably, where the neighbouring stations of classic survey are connected (tied) with additional GPS vectors. In version C (Fig. 3) there are all stations connected by GPS measurements, but only with reference to one control point. In this case there is the smaller number of observations, but the mean errors of net points are greater. The accuracy differences between the three net versions (Table 2) are not large, however they can be significant in many special geodetic tasks, for instance when displacement or deformation determining.

The growth of network reliability in versions B and C (with reference to version A) is also great of importance. This is probably caused by the growth of observation number, but with no increasing of the unknown parameter number. It is worth noting that one plane vector give two additional observations. For comparison we will calculate the Otrębski's parameter *O*, which is one of the known reliability indexes [Prószyński 1992]:

$$O = \frac{k}{n}$$

where: n – total number of observations, k – number of indispensable observations.

For versions considered this parameter takes the following values:

$$O_A = \frac{34}{52} \cong 0{,}65; \quad O_B = \frac{34}{84} \cong 0{,}40;$$

$$O_C = \frac{34}{74} \cong 0{,}46 .$$

Numeric example

For hypothetical nets (Fig.4, Fig.5) there were carried out the adjustment of observation sets by parametric method. The first step was to create of the functional model and the stochastic model for each of the nets.

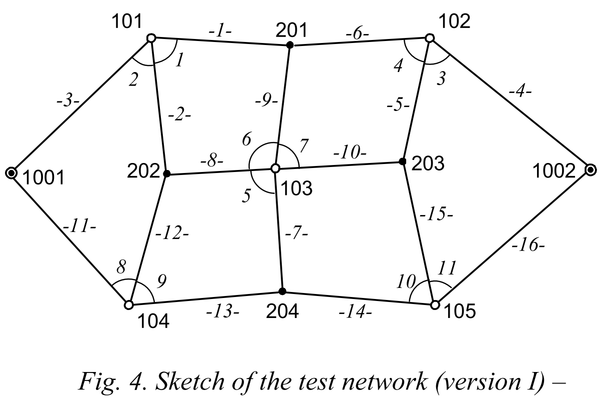

Fig. 4. Sketch of the test network (version I) – classical modular network

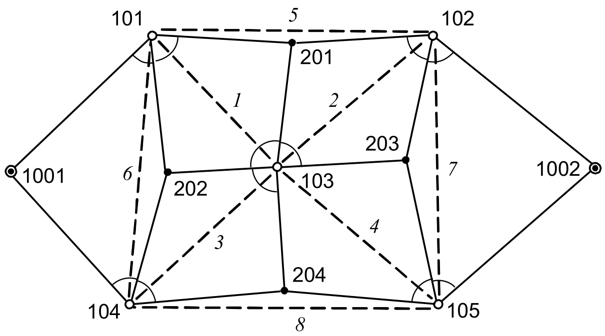

Fig. 5. Sketch of the test network (version II) – modular hybrid network

The formulas type (8), (9), (10) are the basis to create the set of correction equations in linear form. It was assumed that all of the observations are expressed in local coordinate set *xy* (it also concerns to GPS vectors). The problems of transformation of the vectors from geocentric set to the ellipsoid WGS84 and the projection of them to the plane are not the object of this work.

Horizontal length

$$v_{ij}^{(d)} = \frac{\Delta x_{ij}^{(0)}}{d_{ij}}\left(dx_j - dx_i\right) + \frac{\Delta y_{ij}^{(0)}}{d_{ij}}\left(dy_j - dy_i\right) + l_{ij}^{(d)} \tag{8}$$

where:

$$l_{ij}^{(d)} = d_{ij}^{(0)} - d_{ij}; \quad d_{ij}^{(0)} = \sqrt{\left(\Delta x_{ij}^{(0)}\right)^2 + \left(\Delta y_{ij}^{(0)}\right)^2},$$

$$\Delta x_{ij}^{(0)} = x_j^{(0)} - x_i^{(0)}; \quad \Delta y_{ij}^{(0)} = y_j^{(0)} - y_i^{(0)},$$

$v^{(d)}$ – correction to horizontal length; d – horizontal length observed; $d^{(0)}$ – approximate horizontal length; (δx, δy) – coordinates corrections; $l^{(d)}$ – deviation of observation (free term); ($x^{(0)}$, $y^{(0)}$) – approximate coordinates; ($\Delta x^{(0)}$, $\Delta y^{(0)}$) – increments of approximate coordinates.

Horizontal angle

$$v_{jik}^{(b)} = -\frac{\Delta y_{ik}^{(0)}}{\left(d_{ik}^{(0)}\right)^2}\left(dx_k - dx_i\right) + \frac{\Delta x_{ik}^{(0)}}{\left(d_{ik}^{(0)}\right)^2}\left(dy_k - dy_i\right) + \frac{\Delta y_{ij}^{(0)}}{\left(d_{ij}^{(0)}\right)^2}\left(dx_j - dx_i\right) - \frac{\Delta x_{ij}^{(0)}}{\left(d_{ij}^{(0)}\right)^2}\left(dy_j - dy_i\right) + l_{jik}^{(b)}$$

where:

$$l_{jik}^{(\beta)} = \beta_{jik}^{(0)} - \beta_{jik};$$

$$\beta_{jik}^{(0)} = arctg\left(\frac{\Delta y_{ik}^{(0)}}{\Delta x_{ik}^{(0)}}\right) - arctg\left(\frac{\Delta y_{ij}^{(0)}}{\Delta x_{ij}^{(0)}}\right),$$

$v^{(\beta)}$ – correction for the horizontal angle; β – observed horizontal angle; $\beta^{(0)}$ – approximate horizontal angle; $l^{(\beta)}$ – free term.

GPS vector on a plane

$$\begin{cases} v_{jk}^{(\Delta X)} = dx_k - dx_j + l_{jk}^{(\Delta X)} \\ v_{jk}^{(\Delta Y)} = dy_k - dy_j + l_j^{(\Delta Y)} \end{cases} \tag{10}$$

where:

$$\begin{cases} l_{jk}^{(\Delta X)} = \Delta X_{jk}^{(0)} - \Delta X_{jk}; \quad \Delta X_{jk}^{(0)} = x_k^{(0)} - x_j^{(0)} \\ l_{jk}^{(\Delta Y)} = \Delta Y_{jk}^{(0)} - \Delta Y_{jk}; \quad \Delta y_{jk}^{(0)} = y_k^{(0)} - y_j^{(0)} \end{cases},$$

($v^{(\Delta X)}$, $v^{(\Delta Y)}$) – corrections for the increments of coordinates of a GPS vector; (ΔX, ΔY) – observed vector (vector's components); ($\Delta X^{(0)}$, $\Delta Y^{(0)}$) – approximate vector.

For the assumption about independence of observational set elements the stochastic model will be created by covariance matrix $\mathbf{Q_L}$ in diagonal form:

$$\mathbf{Q_L} = \mathbf{P}^{-1} = diag\begin{Bmatrix} \left(m_i^{(d)}, m_j^{(\beta)}, m_k^{(\Delta X)}, m_k^{(\Delta Y)}\right); \\ i = 1,2,\ldots,n_d;\ j = 1,2,\ldots,n_\beta;\ i = 1,2,\ldots,n_{\Delta X} \end{Bmatrix} \tag{11}$$

The initial data corresponding with test network in version *I* (Fig.4) and version *II* (Fig.5) are compared in Table 3.

On the basis of sketch (Fig.4), data (Table 3) and formulas (8), (9), the functional model (for the network in version *I*) has been created. It is composed of 27 equations (17 for lengths + 11 for angles). For the large dimensions of coefficient matrix, there is no possibility for showing here all the equation set. Below there are presented exemplifying equations for the length *-1-* and for the angle *1* (see Fig.4):

$$v_1^{(d)} = 0,250dx_{101} - 0,968dy_{101} + 0,250dx_{201} - 0,968dy_{201} + 0,003\,[m] \tag{12}$$

$$v_1^{(b)} = -0,440dx_{101} + 0,397dy_{101} + 0,573dx_{201} + 0,148dy_{201} - 0,134dx_{202} - 0,545dy_{202} + 0,0007\,[^g] \tag{13}$$

Functional model for the net in version *II* (Fig.5) is created by 27 equations type (12) and (13) as well as 16 equations for the eight GPS vectors (on the plane). Equations for GPS vectors are juxtaposed on the basis of formulas (10). For example, equations for the vector *1* (Fig.5) will take the following form:

$$\begin{cases} v_1^{(\Delta X)} = \delta x_{101} - \delta x_{103} + 0,003\,[m] \\ v_1^{(\Delta Y)} = \delta y_{101} - \delta y_{103} - 0,006\,[m] \end{cases} \qquad (14)$$

Putting the least square condition on these equations, we can obtain (on the basis of elementary formulas from adjusting calculus for parametric procedure, e.g. [Baran 1999]) the corrections to coordinates δx, δy, and next – the corrections to observations $v^{(d)}$, $v^{(\beta)}$ (also $v^{(\Delta X)}$, $v^{(\Delta Y)}$ for version *II*) – see Table 4. The accuracy of observations adjusted is characterized by mean error m_0. More detailed formulas for adjustment of modular hybrid network are presented in an earlier work of author [Gargula 2007].

Table 3

Data to be adjusted

Point No	*Fixed coordinates*		*Distances* [m]		*Angles* [g]		*GPS vectors* [m]	
No	X	Y	*1*	107,532	*1*	68,5909	*1*	103,179
1001	1000,000	1000,000	*2*	113,360	*2*	62,4838		-94,001
1002	995,420	1415,670	*3*	145,673	*3*	65,9656	*2*	107,734
			4	160,318	*4*	63,3353		113,281
Point	*Approximate coordin.*		*5*	112,652	*5*	102,7432	*3*	-107,914
No	X	Y	*6*	107,871	*6*	114,9371		-98,811
101	1107,451	1098,350	*7*	80,604	*7*	92,0259	*4*	-100,815
102	1112,006	1305,632	*8*	67,382	*8*	66,1487		106,694
103	1004,272	1192,351	*9*	76,924	*9*	64,7108	*5*	4,555
104	896,358	1093,540	*10*	82,189	*10*	70,8445		207,282
105	903,457	1299,045	*11*	139,611	*11*	72,7582	*6*	-211,093
201	1080,523	1202,459	*12*	105,872				-4,810
202	997,352	1125,323	*13*	114,063			*7*	208,549
203	1003,738	1274,531	*14*	97,281				6,587
204	924,520	1204,072	*15*	103,238			*8*	-7,099
			16	148,525				-205,505
			$m_d = \pm\,0{,}005$m		$m_\beta = \pm 0{,}0010^g$		$m_{\Delta X,\,\Delta Y} = \pm\,0{,}005$m	

Table 4

Results of observation adjustment (corrections and mean errors)

Version I (classical)				*Version I (classical + GPS)*					
v_d [m]		v_β [g]		v_d [m]		v_β [g]		$v_{\Delta X}$, $v_{\Delta Y}$ [m]	
1	-0,0009	*1*	0,00000	*1*	0,0006	*1*	0,00033	*1*	0,0026
2	-0,0026	*2*	-0,00096	*2*	-0,0062	*2*	-0,00137		0,0014
3	-0,0102	*3*	0,00024	*3*	-0,0091	*3*	0,00099	*2*	-0,0053
4	0,0035	*4*	0,00037	*4*	0,0000	*4*	0,00019		0,0012
5	0,0029	*5*	-0,00004	*5*	0,0019	*5*	0,00013	*3*	0,0019
6	0,0036	*6*	-0,00013	*6*	0,0037	*6*	-0,00008		-0,0009
7	0,0063	*7*	-0,00044	*7*	0,0039	*7*	-0,00024	*4*	0,0063
8	-0,0004	*8*	0,00070	*8*	0,0010	*8*	0,00132		-0,0015
9	-0,0036	*9*	-0,00020	*9*	-0,0058	*9*	-0,00044	*5*	-0,0058
10	-0,0064	*10*	-0,00031	*10*	-0,0057	*10*	0,00007		-0,0058
11	0,0065	*11*	-0,00056	*11*	0,0037	*11*	-0,00091	*6*	0,0071
12	0,0027			*12*	0,0027				0,0059
13	-0,0027			*13*	-0,0037			*7*	0,0009
14	-0,0021			*14*	-0,0023				-0,0011
15	-0,0065			*15*	-0,0099			*8*	-0,0037
16	-0,0061			*16*	-0,0059				0,0013
$m_0 = \pm 1{,}393$				$m_0 = \pm 1{,}127$					

Within accuracy analysis of the network points determination, mean errors of coordinates and positional errors have been calculated – formulas (1) and (2). The results of calculations for this step are compared in Table 5.

Table 5

Comparison of coordinates adjusted and mean errors

Version I					
No of point	*Adjusted coordinates*		*Mean errors*		
	X	*Y*	m_x	m_Y	m_P
101	1107,449	1098,348	0,0058	0,0066	0,0088
102	1112,013	1305,629	0,0060	0,0068	0,0091
103	1004,269	1192,349	0,0081	0,0042	0,0091
104	896,355	1093,545	0,0055	0,0066	0,0086
105	903,459	1299,046	0,0061	0,0061	0,0086
201	1080,523	1202,453	0,0092	0,0052	0,0105
202	997,348	1125,323	0,0085	0,0034	0,0091
203	1003,736	1274,529	0,0087	0,0036	0,0094
204	924,516	1204,074	0,0094	0,0051	0,0107
1001	1000.000	1000.000	-	-	-
1002	995.420	1415.670	-	-	-
Average error					0,0093
Maximum error					0,0107
Version II					
No of point	*Adjusted coordinates*		*Mean errors*		
	X	*Y*	m_x	m_Y	m_P
101	1107,449	1098,349	0,0028	0,0034	0,0044
102	1112,011	1305,632	0,0028	0,0034	0,0044
103	1004,271	1192,349	0,0035	0,0029	0,0045
104	896,358	1093,545	0,0027	0,0033	0,0043
105	903,461	1299,044	0,0027	0,0033	0,0043
201	1080,522	1202,455	0,0037	0,0036	0,0052
202	997,352	1125,322	0,0041	0,0024	0,0047
203	1003,736	1274,531	0,0042	0,0025	0,0049
204	924,520	1204,073	0,0038	0,0037	0,0053
1001	1000.000	1000.000	-	-	-
1002	995.420	1415.670	-	-	-
Average error					0,0047
Maximum error					0,0053

Comparing values of the unit mean error m_0 (Table 4) we can notice a drop of its value after including the GPS vectors to adjustment (version *II*). This entails decreasing coordinate mean errors and the positional error (Table 5).

Summary

The main goal of the performed tests and analyses was specifying an influence of additional observations (vectors) GPS on the accuracy of classical modular network. An essential assumption was hybrid survey, that is idea of using the same station points to receiving both classical observations as well as GPS observations. Justification for the use of such survey technology is the growth of accuracy and reliability of geodetic network without making the survey procedure significantly difficult.

Based on both preliminary accuracy analyses performed and the exemplifying network adjustment one can conclude that the proposed modular hybrid method meets expectations in the area of both accuracy (average positional error) as well as reliability (Otrębski's parameter). The values of these indexes are of course enough subjective, for they concern the specific case of network and the *a priori* observation mean errors assumed. However, it seems that the results allow to formulate the following general conclusion: Introduction of hybrid observational sets can be a sufficient way of improving the modular network construction. The method can be useful when realizing the tasks demanding high precision of determinations, e.g. for geodetic survey of displacements and deformations.

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Оцінка технічної якості модулярних гібридних мереж

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Модулярні мережі відзначаються великою еластичністю конструкцій та універсальністю застосування. У поєднанні із спостереженнями GPS можуть слугувати для визначення переміщень і деформацій. Метою цього дослідження є порівняння властивостей модулярної гібридної мережі із її класичним відповідником (без спостережень GPS). Як гібридну мережу прийнято конструкцію, яка дає можливість виконувати класичні і GPS вимірювання із спільних пунктів. Розглянуто проблеми цифрового опрацювання результатів вимірювань (створення функціональної моделі, метод урівноваження, аналіз точності).

Assessment of technical quality of modular hybrid networks

T.Gargula

Modular networks are characterized by some construction flexibility and the possibility of large scale of use of them. In connection with GPS observations (vectors) they can be useful as a method of determination (diagnostics) of ground displacements and deformations. The numeric tests carried out are aimed to compare some properties (accuracy, reliability) of modular hybrid network to its classical equivalent (without GPS observations). The hybrid network is here understood as a construction making possible the simultaneous classical and GPS survey at common stations. The questions of numeric processing of measurement results (creation of functional model, adjustment method, accuracy analysis etc.) are considered as well in the paper.

Ocena jakosci technicznej modularnych sieci hybrydowych

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Streszczenie. Sieci modularne cechują się dużą elastycznością konstrukcji i uniwersalnością zastosowania. W połączeniu z obserwacjami (wektorami) GPS mogą one służyć jako metoda wyznaczania (diagnozowania) przemieszczeń i odkształceń. Celem testów, przeprowadzonych w ramach niniejszego opracowania, jest porównanie własności (dokładność, niezawodność) modularnej sieci hybrydowej z jej odpowiednikiem klasycznym (bez obserwacji GPS). Sieć hybrydowa rozumiana jest tutaj jako konstrukcja umożliwiająca jednoczesny pomiar klasyczny i GPS ze wspólnych stanowisk. W pracy rozważane są również kwestie opracowania numerycznego wyników pomiarów (utworzenie modelu funkcjonalnego, sposób wyrównania, analiza dokładności itp.).