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GNSS Processing Data Result with Sequential Adjustment Method to Estimate the Monitoring Control Point Coordinate at Sermo Dam

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Abstract. Monitoring a structure building like a dam needs to detect any movement. The movement can be measured by adding control point to measure it. Geodynamic movement, expansion of area monitoring, and detection of ground cracks require by adding the new of control points. The addition of control points in a measurement requires specific data processing strategy. Therefore, it used the sequential adjustment method. This research aims to identify 3D coordinate values and the difference precision of the control points from the sequential adjustment method. The first step of sequential adjustment used five control points with one point considered fixed. The second step was added with five control points. The difference of coordinate precision analysis using sequential adjustment method indicates that there are increased precision in five control points which are processed in the first step. The addition of the coordinate precision ranges from 0,193 to 5,450 cm. Based on the comparative of two variants sample test shows that the precision of coordinates resulted for the first step is significant different from the second step. The results of the comparison between two variants test indicate that the precision of the result in first step does significantly different to the second step.

1. Introduction

Sermo Dam is a structure building that functions as a reservoir for clean water, irrigation, and flooding prevention in Kulon Progo Regency. Remember of the vital function of the Sermo Dam for the people of Kulon Progo Regency, supervision and maintenance are needed to avoid any damage of the dam. One form of this effort is to monitor the deformation dam. Previous research used terrestrial methods for monitoring deformation control points. In this study GNSS survey method was used. The advantage of using the GNSS method is the monitoring control points do not need to be seen with each other and point coordinates are specified in a particular reference frame [1].

Based on the research of [2], there is an active fault of Parangtritis-Kulon Progo which passes through the Sermo Dam. The existence of these faults is possible cause the geodynamic movements which result in the resistance of the dam structure building. Therefore, in this research a measurement control point was added to detect movements that occur due to the presence of the fault. In addition to the presence



of geodynamic movements, the expansion of the monitoring area and crack detection can also cause an addition in the number of monitoring control points.

The addition of control points in a measurement requires a special data processing strategy to determine the difference in precision generated. Therefore, it used sequential adjustment method [3]. Processing with the sequential adjustment method cannot use existing GNSS data processing software. Therefore GAMIT software was used to process GNSS data from RINEX raw data into baseline data and its precision. Baseline data and its precision were used as inputs in sequential adjustment so that the coordinates and its precision are generated. Addition of monitoring control point was done by adding five new control points so that the overall control points are 10 points. GNSS observation was carried out on the 2014 in day of year (doy) 250 on five old control points (BMS1, BMS2, BMS5, BMB1, and BMB2) and doy 129 in 2015 on five new points (MAK1, MAK2, MAK3, MAK4, and MAK5). The results of the processing were tested by comparing two sample variants to determine whether the significantly differences in the results of the coordinates and its precision with sequential adjustment.

2. Methods

The data were used in this research are:

1. Data on 10 IGS points (CNMR, COCO, DARW, DGAR, KARR, PARK, PBR2, PIMO, TOW2, and XMIS) for the 2014 250 year and doy 129 in 2015 for global binding.
2. Data on six CORS BIG stations (CBTL, CMGL, CPBL, CPWD, CSEM, and CSLO) doy 250 in 2014 and doy 129 in 2015 for local binding.
3. Data on five old control points (BMS1, BMS2, BMS5, BMB1, and BMB2) doy 250 in 2014.
4. Six point control data (MAK1, MAK2, MAK3, MAK4, MAK5 and BMS1) doy 129 in 2015.
5. Supporting data for processing GAMIT/GLOBK.

The software were used in this research are GAMIT/GLOBK and Matlab. Before estimation using the sequential adjustment method, GNSS data was processed using GAMIT software first so that the baseline length between the monitoring control points and their precision is generated.

2.1. Baseline Length Estimation with GAMIT

The baseline length estimation of the monitoring control point was carried out using a local binding reference. Local binding was intended to get the position and its precision of the observation points relative to the local tie point [4]. In this research, the object of this research is a structure building that falls into a small scale category so that local processing was used for processing data. The steps for estimating the baseline with local binding are:

1. Data from six CORS stations on the 250 year 2014 doy 129 and 2015 processed with GAMIT/GLOBK was bound to 10 IGS stations (global binding) so that the coordinate file and the precision of the points processed are obtained. The file was used as an apriori file for local binding.
2. The 2014 doy 250 GNSS observation data and 2015 doy 129 processed with GAMIT was bound to six CORS BIG stations using apriori file as a result of step 1 (local binding) so that the baseline length and its precision was generated.

The BMS1 point which is an old point and has been included in the processing of GAMIT doy 250 in 2014 was included again in the processing of GAMIT doy 129 in 2015. This is because in the GNSS measurements, the coordinates are estimated using the GNSS net method. The formation of GNSS nets on GAMIT software was carried out by observation day (by doy) so that with a single point observed in two doys, the baseline can be generated from the combining of two adjustment. The result of GAMIT software is *q-file* which contains of the baseline length and standard deviation. Baseline length and standard deviation are used as inputs in sequential adjustment processing.

2.2. Estimation of sequential adjustment

The sequential adjustment estimation which used in this research is the parameter method. The sequential parameter adjustment method was used to calculate the parameter solutions of a project that has been completed, and then it was added with new data [5]. The estimation with sequential parameter adjustment, the data was grouped into the first and second data. The residual function in the equation can be written in a matrix [5] such as equations 1 and 2:

$$V_1 = A_1 X + L_1 \quad (1)$$

$$V_2 = A_2 X + L_2 \quad (2)$$

In this case, V_1 , V_2 are the residual matrix for the first and second data groups, A_1 , A_2 are the design matrix for the first and second data groups, X is the parameter matrix, and L_1 , L_2 was the remaining matrix. The parameter values are estimated by equation 3.

$$X_2 = X_1 + \Delta X \quad (3)$$

$$X_1 = -(A_1^T P_1 A_1)^{-1} A_1^T P_1 L_1 \quad (4)$$

$$\Delta X = -(A_1^T P_1 A_1)^{-1} A_2^T T (A_2 X_1 + L_2) \quad (5)$$

$$T = (P_2^{-1} + A_2 (A_1^T P_1 A_1)^{-1} A_2^T)^{-1} \quad (6)$$

In this case, X_2 is the parameter (coordinate) of the results of the second stage of adjustment, ΔX is the contribution of new measurements to the adjustment parameters of the first step, and X_1 is the parameter (coordinates) of the first step result. The value of parameter precision can be estimated from the parameter cofactor matrix. The second step cofactor matrix (Q_{x_2}) can be searched using equation 7.

$$Q_{x_2} = Q_{x_1} + \Delta Q \quad (7)$$

$$Q_{x_1} = (A_1^T P_1 A_1)^{-1} \quad (8)$$

$$\Delta Q = (A_1^T P_1 A_1)^{-1} A_2^T T A_2 (A_1^T P_1 A_1)^{-1} \quad (9)$$

In this case, Q_{x_2} is the second step parameter cofactor matrix, ΔQ_x is the contribution of a new measurement to the parameter cofactor, and Q_{x_1} is the first step parameter cofactor matrix. The precision value of each corresponding parameter was obtained from the root of the matrix Q_{x_2} diagonal element then multiplied by the variant aposteori.

2.3. The Comparison of Two Sample Variants Test

A comparison of two sample variants test was carried out to test the variants of two different samples. The test aims to evaluate the differences in the first and second samples. A comparison of two sample variants test was carried out in sequential adjustment. The F-count distribution value was accepted if the comparison of the aposteori variants in the interval according to equation 10 [6]:

$$\frac{\hat{\sigma}_1^2}{\hat{\sigma}_2^2} \frac{1}{F_{\frac{\alpha}{2}, f_1, f_2}} < \frac{\sigma_1^2}{\sigma_2^2} < \frac{\hat{\sigma}_1^2}{\hat{\sigma}_2^2} F_{\frac{\alpha}{2}, f_2, f_1} \quad (10)$$

In this case, f_1 , f_2 are the degree of freedom, α is the degree of trust, $\hat{\sigma}_1^2$, $\hat{\sigma}_2^2$ are the first and second aposteori variant, and F is the distribution value *Fisher* table.

3. Result and Discussion

The results of this research are the coordinates and its precision of the monitoring control points at Sermo Dam using sequential parameter adjustment. The coordinates obtained are the coordinates of 10 monitoring control points and five precision coordinates of old monitoring control point. Precision can

be seen from the amount of standard deviation generated. Differences in precision only seen in five old control points because the five points involved in the first and second step of sequential adjustment.

In the first step of sequential adjustment there are four coordinate control points. The BMB1 point is used as a fixed point with coordinates -2174072,399 m; 5933543,933 m; -862689,652 m. The coordinate system used is the 3D Cartesian coordinate system. The coordinates of thesequential adjustment results was presented in Table 1.

Table 1. The coordinate from sequential adjustment

Point	Component	Coordinate (m)	σ (cm)
BMS1	X	-2173994.722	1,265
	Y	5933592.585	2,843
	Z	-862625.3933	0,615
BMS2	X	-2174236.963	0,983
	Y	5933501.312	2,055
	Z	-862561.5899	0,502
BMS5	X	-2174219.433	7,921
	Y	5933435.029	10,086
	Z	-862704.217	2,369
BMB2	X	-2174225.656	1,012
	Y	5933530.935	2,102
	Z	-862459.54	0,527

Based on Table 1, the BMS5 has the worst precision. This is influenced by the location of the BMS5 point located at the valley of the Sermo Dam, so that the satellite viewing space is limited. In addition, there are high plants around the point, so there are a lot of obstructions.

In the second step of the adjustment, five new control points of deformation monitoring were added, measured in the 129 day of 2015. The new five points are MAK1, MAK2, MAK3, MAK4 and MAK5. However, the standard deviation result from this adjustment is the standard deviation of the monitoring control point that used in the first step. This is because in sequential adjustment only the increasing precision effect value was generated due to the addition of points in the second step. The standard deviation of the second step of sequential adjustment results was presented in Table 2.

Table 2. Standard deviation of second step from GAMIT data processing

Point	σX (cm)	σY (cm)	σZ (cm)
BMS1	0,678	1,525	0,345
BMS2	0,603	1,264	0,309
BMS5	3,578	4,636	1,089
BMB2	0,617	1,287	0,321

Based on Table 1 and 2 there is an increase precision in each component of the monitoring control point. This is because in the adjustment processing of the second step, the increases of monitoring control points cause increase the number of equations. It made the error value of a point distributed to another. Therefore, there was an increase in precision at another four monitoring control points.

Table 3. The difference of precision in the first and second step of sequential adjustment

No.	Point	First step	Second step	Difference
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		σ_X (cm)	σ_Y (cm)	σ_Z (cm)	σ_X (cm)	σ_Y (cm)	σ_Z (cm)	σ_X (cm)	σ_Y (cm)	σ_Z (cm)
1	BMS1	1,265	2,843	0,615	0,678	1,525	0,345	0,578	1,318	0,270
2	BMS2	0,983	2,055	0,502	0,603	1,264	0,309	0,380	0,791	0,193
3	BMS5	7,921	10,086	2,369	3,578	4,636	1,089	4,343	5,450	1,280
4	BMB2	1,012	2,102	0,527	0,617	1,287	0,321	0,395	0,815	0,206

Based on Table 3, it can be seen that there is a difference of precision between first and second step. The difference ranges from 0.193 cm to 5.450 cm. The visualization of the differences in precision was presented in Figure 1.

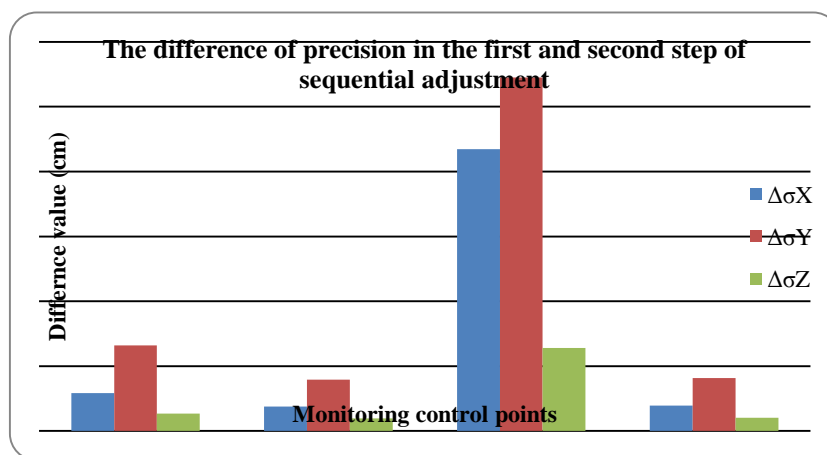


Figure 1. Visualization of the difference of precision in the first and second step of sequential adjustment

Based on Figure 1, there are differences in precision generated from both step. The biggest difference was found in BMS5 for X, Y, and Z components are 4.343 cm, 5.450 cm and 1.280 cm. The Y component becomes the highest precision difference component because the Y component as a vertical component. This is because the location of the Sermo Dam is around the equator and in the eastern longitude [7]. The vertical component of GNSS observation has 2,5 times precision lower than the horizontal component [8], [9], and [10].

In the results of the estimation of the sequential adjustment precision, a statistical test was performed, namely a comparison of two sample variants test. The statistical test aims to evaluate whether the precision of the first step sequential adjustment estimation is significantly different from the second stage statistically or not. This test used the first and second stage aposteriori variants. Variants are obtained from the square of the standard deviation value (precision). This estimation used equation 10.

A comparison of two sample variants test using the Fisher distribution. This test was carried out with 95% confidence level and the first degrees of freedom (f_1) = 18, the second (f_2) = 63. The F-table value is 1.82. The null hypothesis was accepted if the F-count value was less than the F-table value, while the null hypothesis was rejected if the F-count value was greater than the F-table. The Fisher test results for the value of the standard deviation were presented in Table 4.

Table 4. The comparison test results of two sample variants of standard deviation values

Point	Component	$\hat{\sigma}_1^2$	$\hat{\sigma}_2^2$	F-count (F-table = 1,82)	Result
BMS1	X	1,601	0,460	3,477	Rejected

BMS2	Y	8,085	2,326	3,476	Rejected
	Z	0,379	0,119	3,181	Rejected
	X	0,966	0,364	2,652	Rejected
	Y	4,222	1,599	2,641	Rejected
	Z	0,252	0,096	2,642	Rejected
BMS5	X	62,744	12,801	4,901	Rejected
	Y	101,726	21,494	4,733	Rejected
	Z	5,611	1,187	4,729	Rejected
BMB2	X	1,023	0,381	2,686	Rejected
	Y	4,417	1,656	2,666	Rejected
	Z	0,278	0,103	2,702	Rejected

Table 4 shows that the test results comparing two sample variants are 100% rejected. This states that the coordinate variance value of the BMS1, BMS2, BMS5, and BMB2 in the first step is different from the second step. This can be happened because of the addition of monitoring control points at the Sermo Dam in the second step. The addition of control points for deformation monitoring made an increase of the measurement equations. This adds to the value of precision which obtained in the second stage of the adjustment.

4. Conclusion

The use of a sequential adjustment method is suitable to estimate the coordinates of the monitoring control points and its precision if additional control points occur and cannot be measured together. The addition of the precision of the five old monitoring control points in Sermo Dam ranged from 0.193 cm to 5,450 cm. In this research, it is considered that there is no shift value at the point, if the old point was shifted, this method cannot be used because it must be estimated using deformation analysis.

References

- [1] Hudnut, K.W. and Behr, J.A., 1998, Continuous GPS monitoring of Structural Deformation at Pacoima Dam, California, *Seismological Research Letter*, Vol. 09, No.4, U.S. Geological and the Southern California Earthquake Center, South Wilson Ave. Pasadena.
- [2] Waljiyanto, Widjajanti, N., Yulaikah, and Taftazani, M.I., 2015, Pengembangan Jaring Kontrol Geodesi Pemantau Waduk Sermo, *Jurnal Ilmiah Geometika*, Vol. 21, No.2, Badan Informasi Geospasial, Bogor.
- [3] Mikhail, E.W. and Ackermann, F., 1976, *Observations and Least Squares*, Dun-Donnelley Publisher, New York.
- [4] Lestari, D., 2015, Analisis Stabilitas Candi Borobudur Berdasar Integrasi Data Pengamatan GPS dan Terestris Jaring Pemantau Deformasi Candi, Desertasi, S3 Teknik Geomatika, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta.
- [5] Leick, A., 2004, *GPS Satellite Surveying*, John Wiley & Sons, Inc, New York.
- [6] Wolf, P.R. dan Ghilani C.D., 1997, *Adjustment Computations Statistics and Least Squares in Surveying and GIS*, John Wiley & Son Inc, New York.
- [7] Affriani, A.R., N. Widjajanti and Yulaikah, 2016, Pengaruh Bobot Pengukuran pada Perhitungan Perataan bertahap dari Data Hasil Pengamatan GNSS, presented in 2nd CGISE and FIT ISI at Yogyakarta, Yogyakarta.
- [8] Abidin, H. Z., 2007, Penentuan Posisi dengan GPS dan Aplikasinya, Pradnya Paramita, Jakarta.
- [9] Prasidya, A. S., 2015, Analisis Regangan 2D Lempeng Tektonik di Patahan Sumatra Berdasarkan Data Pengamatan GNSS Tahun 2010 sampai 2013, Tesis, Program Studi S-2 Teknik Geomatika,

Pascasarjana Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta.

- [10] Ulinuha, H., 2015, Analisis Deformasi Aspek Geometrik Segmen Mentawai Akibat Gempa Tektonik 10 Juli 2013, Tesis, Program Studi S-2 Teknik Geomatika, Pascasarjana Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta.
- [11] Affriani, A.R., 2016, Estimasi Koordinat Titik Kontrol Pemantauan Deformasi Bendungan Sermo dengan Metode Parameter Bertahap dari Data *Baseline* Hasil Pengolahan GAMIT, Tesis, S-2 Teknik Geomatika, Fakultas Teknik, Universitas Gadjah Mada.