The adjustment of regional levelling network using in-house developed software.

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ABSTRACT

Precise levelling albeit it's laborious and slowness is still serving as backbone in the establishment of height network. A regional levelling network naturally consists of several hundreds of BM points hence its adjustment is becoming a cumbersome tasks. In practice such adjustment is performed using commercial software. This paper is aim to discuss the least squares adjustment of a height network of regional coverage by using an in-house developed computer routine instead of commercial software.

This paper exemplified the work done to adjust the levelling network covering the region of Sabah and Sarawak which involved quite a large number of unknown parameters with a total of about 300 BM's in Sabah and more than 500 BM's in Sarawak. The adjustment task has become interesting to report because it was done using as self developed in-house software. One good thing about the software is that user will find it easy to use, requires a very simple file of input data and yet manage to solve a large number of unknowns.

The results indicate that the in-house software is capable in handling the adjustment of regional levelling network. Comparison of the results obtained with another adjustment results for the same data performed by commercial software (Delfy) shows that both results were very much identical.

1. INTRODUCTION

Precise leveling albeit it's laborious and slowness is still serving as backbone in the establishment of height network. Being simple to operate precise leveling has served well to facilitate the establishment and densification of regional coverage of height network. The establishment of height network is very crucial to meet the user technical demands for surveying and engineering purposes especially in region like Sabah and Sarawak.

A regional levelling network naturally consists of several hundreds of BM points hence its adjustment is becoming a cumbersome tasks. In practice such adjustment is performed using commercial software. This paper is aim to discuss the least squares adjustment of a height network of regional coverage by using an in-house developed computer routine instead of commercial software.

2. REGIONAL LEVELLING NETWORK OF SABAH AND SARAWAK

The setting up of height network in the region of Sabah and Sarawak has a history which dated back to British colonial era. The earliest height network record was the result of Borneo Primary Triangulation established in 1948 (BT48) by the British Directorate of Colonial Survey. The work then was continued by the respective agencies (i.e., Sarawak Department of Land and Surveys and Sabah Department of Land and Surveys) by putting up precise leveling surveys in parts of Sarawak and Sabah.

In the late 80's the Department of Survey and Mapping Malaysia (JUPEM) was given the responsibility regarding the geodetic infrastructures covering Sarawak and Sabah. Since then the establishment of height network by precise leveling has become one of Jupem's main effort in the region. A more elaborate discussion on height network in Sarawak can be obtained in Mohamad Asrul (2005) while Anual Aziz (2005) has provided more for Sabah.

2.1 JUPEM's precise leveling network in Sarawak

The establishment of precise leveling network in Sarawak by JUPEM's was initiated in the late 90's. The work by Jupem is a continuation and also a re-surveyed of leveling route which was previously laid out by Sarawak Department of Land and Surveys. The latter has conducted a first order precise leveling work from a tide gauge station at Pulau Lakei to Kuching and then to Miri and it was done between 1958 to 1970.

Since then there were many BMs destroyed or lost due to rapid development and road infrastructure works. The replacement of destroyed BMs couples with the need of height network densification has certainly made the effort of establishing a new leveling network by Jupem in Sarawak becomes very crucial.

By 2002, two important precise leveling projects covering Kuching region and a levelling route extending from Miri to Sibu was completed by Jupem. This levelling line is slightly over 800 km in total and provide interconnection to three tide gauge stations which were located near Kuching, Bintulu and Miri (Mohamad Asrul, 2005).

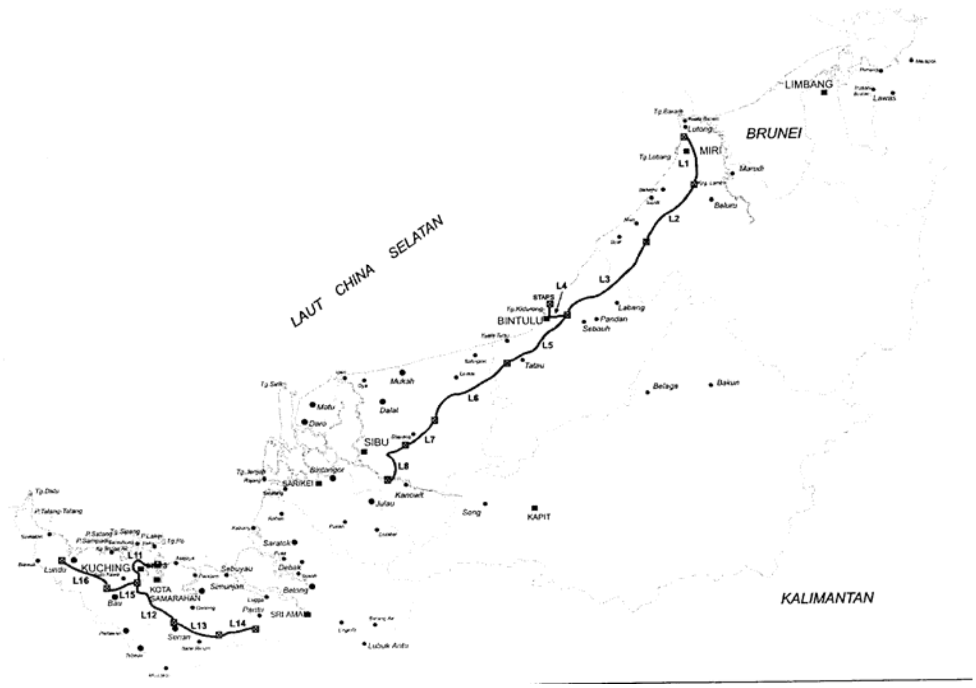


Figure 1: JUPEM's leveling route in Sarawak

2.1 JUPEM's precise leveling network in Sarawak

In Sabah, the Jupem's precise leveling project was initiated in 1986 and then re-surveyed in late1996. Among its main aim is to provide interconnection to five tide gauge stations, which were respectively located at Kota Kinabalu, Kudat, Sandakan, Lahad Datu and Tawau (Anual Aziz, 2005).

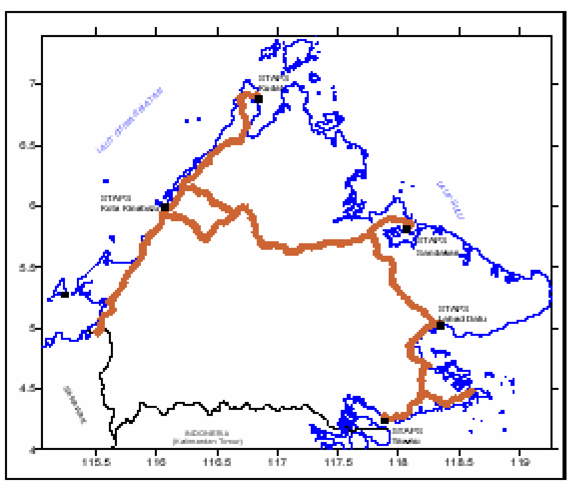
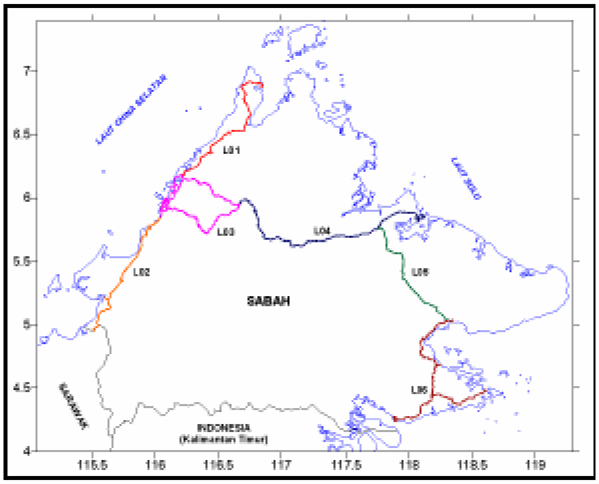


Figure 2: Sabah Precise Levelling Network (up to 2002)

All the field works were carried out using Leica NA 3000 and NA 3003 automatic digital precise level instruments. By late 2002, the precise leveling network in Sabah has covered a total of 1418 km leveling route with 1283 BMs planted. These leveling route were divided into six different sectors identified as L01 to L06 as shown in Fig 3.



Route No	Levelling Route
L01	Tuaran - Kota Belud - Kudat
L02	Kota Kinabalu - Beaufort - Sipitang - Sindumin
L03	Kota Kinabalu - Ranau - Tambunan - Kota Kinabalu
L04	Ranau - Telupid - C.P Sandakan - Sandakan
L05	C.P Sandakan - Lahad Datu
L06	Lahad Datu - Tawau - Semporna

Figure 3: Precise Levelling Route in Sabah

3. IN-HOUSE LEVELLING ADJUSTMENT SOFTWARE

A software for the purpose of levelling adjustment has been written using Fortran source codes. The software employed parametric least squares adjustment model. The software is easy to use and requires a simple form of input file. A sample of an input data file is shown in Figure 4 which is extracted from the input file for Kuching levelling route.

The information for levelling networks normally include basic observation records such as stations name or BMs number, height difference and leveling line distance between two BMs. As exemplified by Figure 4 the input file is begin with a job title (i.e., Levelling Sarawak – Kuching). This is followed by a number which is representing the total number of BMs available for the job (i.e., 259 for Kuching leveling route). Then the BMs identification no and names is listed accordingly.

The input data is continued with the information regarding datum for the adjustment. As for Kuching leveling route a Bench Mark identifies as TA1258 was chosen as datum with height value of 3.405m. The input file is ended by information on total number of observation available and the observation data for each leveling line (i.e., identification the two BMs, the height difference and distance). There were 518 observation data used in the adjustment of Kuching levelling job and 258 unknowns BMs height to be solved.

```
Levelling Sarawak - Kuching
259
1       BM1068
2       BM1069
3       BM1264
4       BM1266
5       BM1275
-
-
256     TBM641
257     TBM649
258     TBM651
259     TBM656
1
125     TA1258      3.405
518
1       BM596       TA1311      0.59394      0.06
2       TA1311      BM596       -0.59316     0.06
3       BM596       TA1312      3.86093      1.21
4       TA1312      BM596       -3.8604      1.21
-
-
511     TA1175      TA1174      12.89015     1.15
512     TA1174      TA1175      -12.89088    1.15
513     TA1068      TA1069      3.0999       0.99
514     TA1069      TA1068      -3.09848     0.99
515     TA1145      TA1144      1.77563      0.67
516     TA1144      TA1145      -1.77478     0.67
517     BM1284      TA1149      2.92405      0.55
518     TA1149      BM1284      -2.92423     0.55
```

Figure 4: Sample of input data file

The solution seeks in parametric least squares adjustment is in the form of x = $(atpa)^{-1}$ atpl. In the case of leveling network, the adjustment will ultimately furnish the reduced height for all the BMs. For the adjustment of regional leveling network, one of the main challenge is in dealing with the inversion of matrix $(atpa)^{-1}$ in large dimension.

The standard deviation of the observed height difference for each leveling line with distance S_i, is computed as $\sigma_i = 1/S_i^{-1}$. Next, the covariance matrix is adopted in the form of $\Sigma = 1/\sigma_i^2$ and then the weight matrix is computed as $P = \sigma_0^2\, \Sigma^{-1}$.

The method of weight matrix computation as discussed above is been used by Jupem in it's leveling adjustment work and as such is implemented in the working of the current software. Additionally, there is another alternative method of weight matrix computation included in the software. The technique employed is based on MINQE methodology and its implementation has been shown in Zainal Abidin (2005).

As for future work, the software described above will be expand to enable it to handle the adjustment of leveling network in a more integrated mode. The main emphasis of such computation is to integrate various height data type (i.e, levelling, GPS and geoid heights information) into a single combined adjustment. Of late, with the increasing use of GPS in levelling, the practice of having a combined adjustment involving heterogeneous height data is becoming further indispensable. The practical examples of such work were described in Fotopoulous (2005) and Danila (2006).

4. THE SABAH & SARAWAK LEVELLING ADJUSTMENT RESULTS

This paper illustrates the work done to adjust the levelling network of regional coverage which involved quite a large number of unknown parameters. The adjustment of Sabah precise leveling network involved a total of 368 BMs. As for Sarawak the adjustment was split into two – the first cover the area of Kuching region with 258 BMs and the second is Sibu-Miri route with 525 BMs. The adjustment for Sarawak was done separately since inter-connection between the two leveling lines is not exist.

The adjustments were implemented using the minimum constraint approach with one BM point was selected as datum. Information about the datum point used in each adjustment is shown in the following table. Such datum point were chosen as there were used as well in the adjustment done by Jupem as reported in Anual (2005) and Mohd Asrul (2005).

No.	Levelling Route	Datum Point (BM No)	Height (m)
1	Sabah	TG2018	3.682
2	Kuching	TA1258	3.405
3	Sibu - Miri	FBM1640	8.559

Table 1: Datum point used in the adjustment

Comparison between Jupem's results and height computed by the in-house software for some of the BM's are shown in Table 2 (for Sarawak) and Table 3 (for Sabah).

No	Bench Marks	JUPEM's Results	Results obtained (in-house software)	Diff. (in mm)
1	FBM 1640	8.5559	8.5559	0
2	BM 1646	-0.33458	-0.33514	0.56
3	TAP 1628	13.64987	13.64931	0.56
4	GPS 4049	22.12128	22.12072	0.56
5	TAP 1527	36.73927	36.73871	0.56
6	TA 1888	15.5462	15.54579	0.41
7	TA 1898	7.60272	7.60231	0.41
8	TAP 2000	22.21048	22.21007	0.41
9	TA 30061	35.59883	35.59843	0.40
10	TA 1954	3.84508	3.84467	0.41

(a)

No	Bench Marks	JUPEM's Results	Results obtained (in-house software)	Diff. (in mm)
1	TA 1258	3.405	3.405	0
2	TA 1177	0.16091 (?)	17.78393	(n/a)
3	TAP 1065	24.67562	24.67562	0
4	TAP 1040	36.22444	36.22444	0
5	TAP 2194	12.67548	12.67548	0
6	TAP 2175	24.02509	24.02509	0
7	TA 3201	19.25667	19.25667	0
8	TA 30061	35.59883	35.59843	0.40

(b)

Table 2: Comparison of BM's adjusted reduced height – Sarawak
(a) Miri-Sibu route & (b) Kuching area

No	Bench Marks	JUPEM's Results	Results obtained (in-house software)	Diff. (in mm)
1	SBM051	641.4907	641.4713	1.94
2	SU0112	739.4147	739.39480	1.99
3	BM214016	759.3559	759.33588	2.00
4	SU0134	823.8117	823.79031	2.14
5	SU0117	1023.359	1023.33669	2.23
6	SU0124	1287.384	1287.36113	2.28
7	SA0543	1654.027	1654.00501	2.22
8	SBM0009	1513.266	1513.24345	2.26

Table 3: Comparison of BM's height along route L0309 (Sabah network)

Judging from the comparison shown by Table 2, it clearly indicates that the adjusted heights were in very good agreement for the case of Sarawak. While for the leveling work in Sabah, the difference obtained is in the range of 1 to 2 mm which is considered small and since the difference is constant then it could be due to systematic error.

5. CONCLUSIONS

This paper demonstrates the work done to adjust the levelling network covering the region of Sabah and Sarawak which involved quite a large number of unknown parameters with a total of about 370 BM's in Sabah and slightly more than 500 BM's in Sarawak. The adjustment task has become interesting to report because it was done using as self developed in-house software. One good thing about the software is that user will find it easy to use, requires a very simple file of input data and yet manage to solve a large number of unknowns.

The results indicate that the in-house software is capable in handling the adjustment of regional levelling network. Comparison of the results obtained with another adjustment results for the same data performed by commercial software (Delfy) shows that both results were very much identical.

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REFERENCES

Anual Aziz (2005). Kajian Ke Arah Merealisasikan Jaringan Rujukan Tegak Geodetik Baru Di Negeri Sabah. MSc Thesis, Fakulti Kejuruteraan & Sains Geoinformasi, UTM Skudai.

Danila, Uliana (2006). Corrective Surface for GPS-levelling in Moldova. MSc Thesis, Geodesy Department, Royal Institute of Technology, Stockholm, Sweden.

Fotopoulos, Georgia (2005). Calibration of geoid error models via a combined adjustment of ellipsoidal, orthometric and gravimetric geoid height data. Journal of Geodesy, Vol. 79, No. 1-3, pp. 111-123.

Mohamad Asrul Mustafar (2005). Kajian Jaringan Kawalan Pugak Bagi Negeri Sarawak. MSc Thesis, Fakulti Kejuruteraan & Sains Geoinformasi, UTM Skudai.

Zainal Abidin Md Som (2005). The implementation of variance component estimation (VCE) using MINQE Approach into an adjustment of height networks. Paper presented at the International Symposium & Exhibition on Geoinformation - ISG 2005, Grand Plaza Park Royal, Batu Feringghi, Penang.