Absolute & Relative GPS Orthometric Heights using Regional Fitted Geoid

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SUMMARY

Establishment of vertical datum for land related surveying works using conventional levelling technique is a tedious process. With the advent of GPS (Global Positioning System) technology, determination of heights value for vertical datum in engineering works and alike seems feasible. In this study, two approaches in height determination using GPS are explored. The two technique involve are the absolute and relative GPS heighting. In the absolute technique, the ellipsoidal heights obtained through GPS observation for the observed points are transformed to the orthometric heights (H) by applying the respective geoidal separation value (N). In this technique, only one GPS is needed for the observation. However, for the determination of horizontal position (x,y), the processing will integrate the MyRTKnet (Malaysian Real Time Kinematic Network) as base station. As for the relative approached, two GPS receiver are needed. One of the GPS receivers will be placed at a known point with known height value and the other receiver at an unknown point. In this study, it is found that for 14 tested points, the Root Mean Square Error (RMSE) for the corresponding heights obtained using the absolute and relative techniques proposed are ±0.115m and ±0.046m respectively. In this study, it is found that for height determination using the two GPS observation technique, the relative GPS heighting approached seems to be more reliable.

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1. INTRODUCTION

Traditionally, height is transferred from a point of known height to another unknown point using fly levelling method (Ceylan, Inal, & Sanlioglu, 2005). This process is very costly, labour intensive and time consuming. The levelling process need to be done by at least two personnel. In certain situations like a place that hard to reach,as for example forest, hills, and mines areas, levelling methods can be highly dangerous and tedious (Xiang-hui & Hong-juan, 2012).

With the development of GPS technology and processing techniques, GPS is now commonly used as a tool for horizontal positioning among surveyors. It is also known that, GPS could also be used in height determination (Saiful Aman & Helmi Zulhaidi, 2009; Xiang-hui & Hong-juan, 2012). Direct height measurement using GPS derived ellipsoidal heights (h) which refer to ellipsoid surface could be carried out with ease. However, transforming the ellipsoidal height (h) to orthometric height (H), a high accuracy geoidal seperation value (N) at the observed point is needed (Hofmann-Wellenhof & Moritz, 2005) .

In Malaysia, MyGeoid (DSMM, 2005) model established by the Department of Surveying and Mapping, Malaysia (DSMM) could provide the geoid separation value (N). It is known that, for the Peninsular Malaysia, Sabah and Sarawak, the MyGeoid model with an accuracy of ±5 cm (Nordin, Abu, Hua, & Nordin, 2005) was established using various derived height values which include airborne gravity measurements.

Two concepts of GPS heighting is applied in this study which are the absolute and relative GPS heighting. Both concept use static method of observation. Absolute GPS heighting only needs one GPS receiver during measurement meanwhile in relative GPS heighting, more than one GPS receiver used during measurement. For relative GPS heighting, GPS measurements need to be done simultaneously for both GPS receivers.

2. ABSOLUTE AND RELATIVE GPS HEIGHT

In this section, GPS heighting concept will be discussed briefly. In general, there are 2 main concepts in the determination of orthometric height using GPS, known as absolute and relative technique. In general, the orthometric height can be computed based on Equation (1). The illustration on the relationship between ellipsoid, geoid and orthometric height is shown in Figure 1.

$$H = h - N \quad (1)$$

where H is the orthometric height, h is the ellipsoid height observed by GPS and N is geoid height.

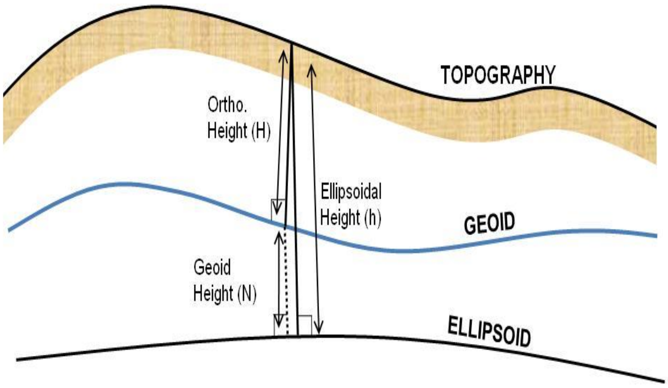

Figure 1. Relationship between ellipsoid, geoid and orthometric height.

The configuration of absolute GPS heighting concept is shown in Figure 2. In this concept, GPS Observation (GPS Point) is located at any point on the earth's surface where the orthometric heights need to be determined. The GPS point should be connected to at least one nearest reference station (base). In this case, MyRTKnet is used as the base station. It should be pointed out that, the function of the base station is to provide a correction in order to determined the accurate position of GPS point (Latitude, Longitude and Ellipsoidal height). It also assist the transformation of the observed GPS coordinates to local coordinate system.

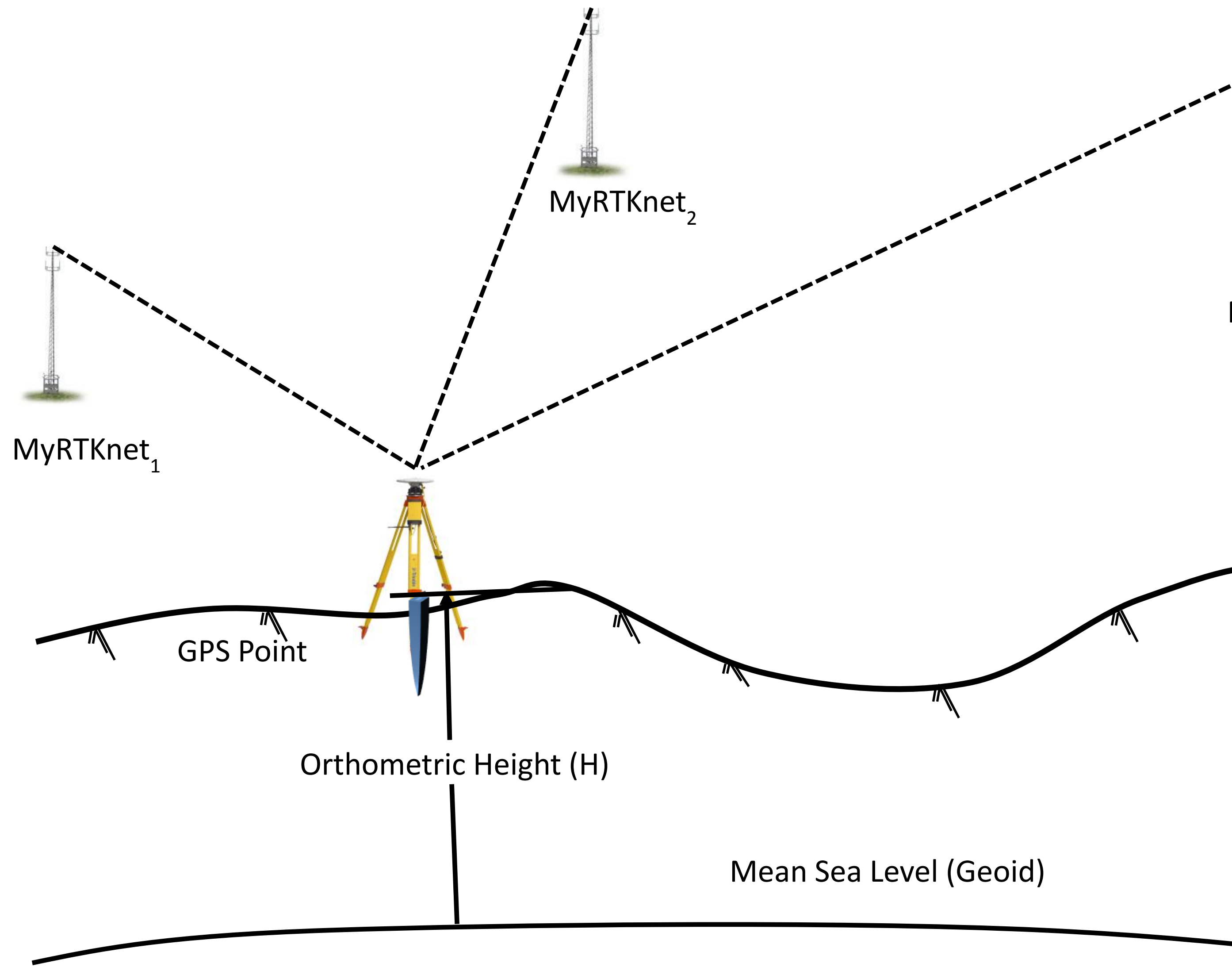

Figure 2. Absolute GPS heighting observation for the determination of orthometric height

Referring to Figure 2, by using MyGEOID model, the geoid height can be extracted according to the corrected horizontal position of the observed GPS point. Finally, the orthometric height can be computed by using Equation (1).

As for the relative GPS heighting concept, apart from the base station (MyRTKnet), a GPS observtion on a selected Standard Benchmark (SBM) is also needed. Figure 3 shows the configuration of the relative GPS heighting technique.

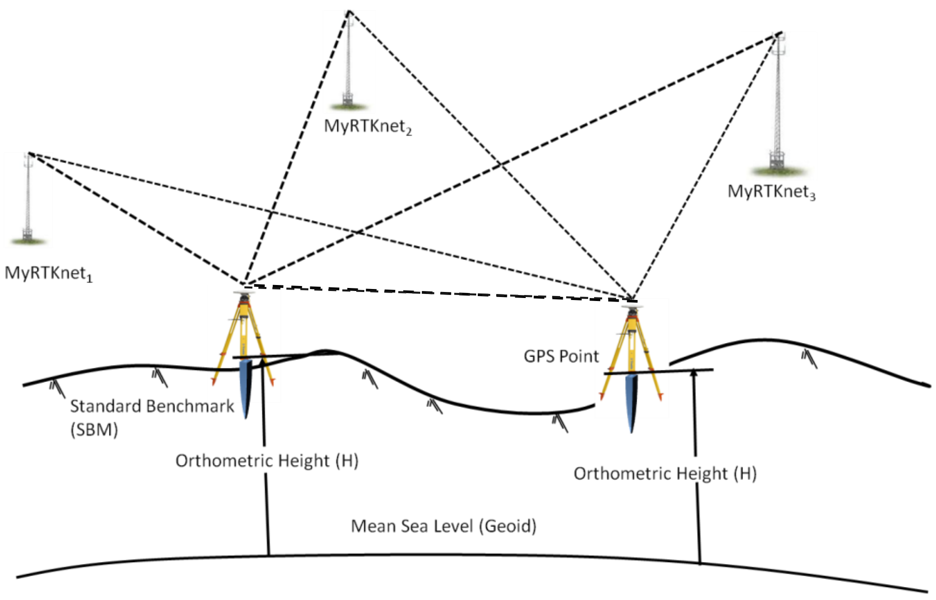

Figure 3. Relative GPS heighting observation for the determination of orthometric height

In this concept, the GPS observation on the SBM and GPS point is carried out simultaneously and linked to a MyRTKnet (base station). Based on Figure 3, the orthometric height for the GPS point can be computed based on the Equation 2.

$$H_A = h_A - N_A \pm \varepsilon \qquad (2)$$

Where, H_A is the computed orthometric height at point A, h_A is the corrected ellipsoidal height at point A, N_A is the geoid height and ε is the orthometric error. This error (ε) is determined using Equation 3.

$$\varepsilon = H_{SBM(GPS)} - H_{SBM(Levelling)} \qquad (3)$$

Where $H_{SBM(GPS)}$ the orthometric height is computed from GPS by using Equation 1 at the SBM and $H_{SBM(Levelling)}$ is the known benchmark height value.

3. STUDY AREA AND DATASET

The study area comprises of 8000 square kilometres situated in the state of Melaka and Negeri Sembilan, Malaysia. It is situated in the southern region of Peninsular Malaysia. The distribution of MyRTKnet base station and the 14 randomly selected Standard Benchmark (SBM) position is shown in Figure 4. It should be pointed out that, in this study the benchmark height values are established by the Department of Surveying and Mapping, Malaysia (DSMM). The SBM height values are determined through precise levelling referring to the National Geodetic Vertical Datum (NGVD) . In this study, GPS observation is carried out using Trimble R8.

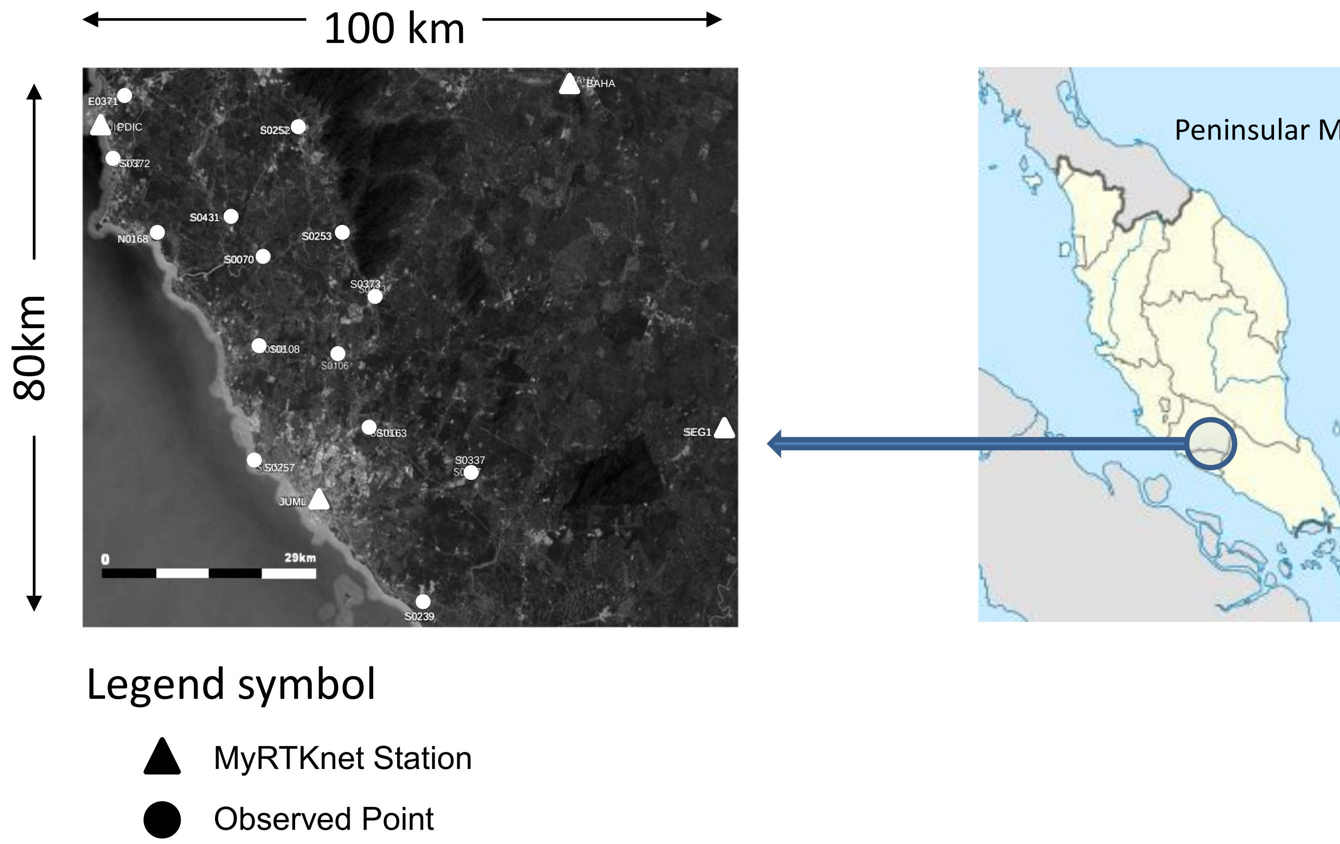

Figure 4. Distribution of MyRTKnet and SBM for the study area

4. FIELD OBSERVATIONS AND PROCESSING

Static GPS observation method is used in the absolute and relative GPS heighting technique proposed. GPS observations are carried out using Trimble R8 geodetic-quality receiver and it is mounted on fixed-height 2 meter range pole. The field observation procedure was conducted in accordance to the regulation prescribed by the Department of Survey and Mapping Malaysia (DSMM, 2005). In this study, 3 Continuously Operating Reference Station (CORS) from MyRTKnet is used as a control to establish the connection to the Geocentric Datum Malaysia 2000 (DSMM, 2005).

In GPS data porcessing, all the raw GPS observation were converted to RINEX format and processed using comercial software which is Total Busines Center 2.0 (TBC) (Trimble, 2010). In this study, Kuala Klawang, Port Dickson and Bahau from MyRTKnet stations were selected and used as the control reference station for the absolute and relative GPS heighting technique.

Table 1 shows the processing parameters followed in this study.

Table 1: Processing Parameters (Jamil, 2011)

Items	Parameter
General Procedure	Prescribed procedures as provided in manufacturer manual must be followed
Datum	GDM2000
Elevation Mask	15°
Ephemerides	Short baseline of less than 30 km: Broadcast Long baseline: Precise
Baseline Processing	RMSE less than 2 cm
Quality	Maximum data rejection - less than 10 % Ambiguity fixed solution
Adjustment	Least square adjustment should be used
Minimally Constrained Adjustment	One control station fixed in GDM2000 coordinates
Quality Indicator	Pass Chi-squares test at 95% confident region All baselines must pass the local test
Over-Constrained Adjustment	At least 2 control stations must be fixed in the final adjustment

The final stage of the study includes the computation of the accuracy estimates (RMSE). The RMSE is computed based on Equation 4 (Idris, Latif, Jaafar, Rani, & Yunus, 2012)

$$RMSE = \pm \sqrt{\sum_{i=1}^{i=n} \frac{\left(H_i^{GPS} - H_i^{SBM}\right)}{n}} \qquad (4)$$

where *n* is the number of the observed points, H_i^{GPS} is the orthometric heights derived at GPS point *i* and H_i^{SBM} is the SBM (Standard Benchmark) height at the same position on the ground.

5. RESULT AND ANALYSIS

The ellipsoidal height computed by using GPS technique were compared to the value of existing Standard Benchmark (SBM) established by precise levelling technique. Regional fitted geoid model (MyGEOID) is used in order to derive the orthometric height by using GPS. In this phase, results are converted into orthometric height by applying the geoid separation value for each height obtained using GPS.

Table 2 shows the result obtained and the RMSE computed.

Table 2. The different between Height Derived by GPS (Orthometric) and SBM Height (Levelling) and the RMSE computed

SBM No	Relative			Absolute		
	SBM Height	Orthometric Height	Different	SBM Height	Orthometric Height	Different
	(m)	(m)	(m)	(m)	(m)	(m)
1	5.569	5.534	0.035	5.569	5.679	-0.110
2	2.835	2.879	-0.044	2.835	2.881	-0.046
3	3.912	3.860	0.052	3.912	4.076	-0.164
4	14.834	14.827	0.008	14.834	14.948	-0.114
5	11.089	11.104	-0.015	11.089	11.21	-0.121
6	6.064	6.070	-0.006	6.064	6.156	-0.092
7	3.702	3.803	-0.101	3.702	3.707	-0.005
8	42.007	41.963	0.044	42.007	42.178	-0.171
9	31.188	31.141	0.047	31.188	31.39	-0.202
10	5.121	5.140	-0.019	5.121	5.178	-0.057
11	27.264	27.250	0.014	27.264	27.327	-0.063
12	2.993	3.082	-0.089	2.993	3.021	-0.028
13	41.776	41.747	0.029	41.776	41.895	-0.119
14	9.195	9.177	0.019	9.195	9.314	-0.119
		RMSE	**0.046**		**RMSE**	**0.115**

From Table 2, the RMSE computed for the absolute GPS heighting and the relative technique are ±0.115m and ±0.046m respectively. Referring to Table 2, for the relative GPS heighting technique, it is clearly shown that the different obtained between the derived orthometric height and SBM value had both positive and negative component. This might be due to the GPS observation error and hence only a small different is observed compared to the absolute technique. It could be concluded that, a more reliable height could be obtained by using the relative technique without incorporating the effect of error in the MyGEOID model.

6. CONCLUSION

From the study, it can be concluded that both concept of GPS heighting can be applied to determine height at reasonable accuracy for various engineering work. However, the accuracy anticipated is highly related to the proposed technique to be adopted. Further studies to confirmed the findings involving a greater number of points will be an ongoing research agenda.

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