Digital Terrain Modeling by Real Time Kinematic GPS

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Abstract

Digital Terrain Model (DTM) nowadays is invaluable aid for the engineering community. Nevertheless, the time and cost associated with DTM data acquisition have often been prohibitive. This is due to the process of data collection, which is costly and time consuming. DTM is based on topographical information which is commonly obtained by photogrammetry, remote sensing, laser scanning, radar interferometry, and other classical terrestrial or Global Positioning System (GPS) survey. Photogrammetry, remote sensing and radar interferometry are commonly applied on the generation of medium to low-resolution DTM covering large area. Meanwhile, laser scanning, classical terrestrial survey and GPS are employed for high-resolution DTM generation.

Most of civil engineering projects are in large scale applications which need high-resolution DTM. Laser scanning furnishes latest technology for medium to high resolution DTM generation but it is still relatively expensive. Classical terrestrial survey is relatively cheaper but requires intervisibility between stations. Real Time Kinematic GPS (RTK GPS), compared to both previously mentioned techniques, provides an easy, quick, and comparatively cheap alternative where less surveyor needed for the survey and no intervisibility between stations required. The paper is focused on the experiment aiming to derive a high-resolution DTM by RTK GPS by comparing it to classical terrestrial survey using Total Station. The analysis of this research covers the accuracy and efficiency assessment of the digital terrain modeling using RTK GPS.

Keywords
DTM, RTK GPS, topographical information, resolution, intervisibility

1. Introduction

Terrain representation of topographic data is essential for many engineering project, including civil engineering. Topographic data are currently obtainable from land surveying, aerial photogrammetry (Mikhail et al., 2001), optical (Toutin, 2001) and radiometer images (Hirano et al., 2003), synthetic aperture radar (Rabus et al., 2003; Toutin and Gray, 2000), and light detecting and ranging technique (Wehr and Lohr, 1999).

DTM is an integral part of every aerial photogrammetry workflows. Photogrammetry is one of the most popular techniques to acquire DTM. This technique is still in use in many engineering projects especially for topographical mapping of medium to large sized projects. Nevertheless, the cost of DTM data acquisition using this technique is considered to be prohibitive, especially for engineering application. Radiometer and optical images offer a seamless raster Digital Elevation Model with a variety of spatial resolution. The USGS provides Digital Elevation Model (DEM) with a spatial gridding ranging from 10 to 30m and elevation units standardized to decimal meters (Gesch et al., 2002). The processing of data acquired in the C band (radar wavelength λ=5 cm) by the SRTM interferometric radar on board of the Endeavor Shuttle provides a nominal 30m DEM of over 80% of the Earth landmass surface with an estimated vertical accuracy of 15m and a discretization to the nearest meter (Nico et al., 2004). This spatial resolution is reduced to 90m pixels for area outside USA (Farr and Kobrick, 2000). Stereo optical images acquired by IKONOS and QuickBird furnish another means to acquire a DEM with planimetric and vertical accuracy of 1m and 0.6m respectively. The successful processing of these images depends on the sun illumination and cloud covering conditions (Toutin and Cheng, 2000). Light detecting and ranging (LIDAR), the latest technology, also offers another means to acquire high resolution DTM.

All the above space mapping techniques can be used to acquire DEM and DTM. DEM are different compare to DTM. It does not refer only to topography but also including vegetation and buildings, bridges etc. However, often users need a high-resolution Digital Terrain Model (DTM) of a small area of interest where topography is the biggest concern (Nico et al., 2005). A high resolution DTM enables easy derivation of subsequent information for many applications such as landslide prone areas monitoring, terrain and drainage mapping for run-off modeling and flood risk assessment, urban planning and etc.

The use of DTM within the entire civil engineering community has to be assessed from the technical and financial point of view. These reasons specifically deal with the data capture phase of the DTM, which is where the greatest cost and time is recognized. Criteria that must be considered when evaluating acquisitions methods and systems are; cost effectivity, accuracy, usability, repeatability, and ease of use. GPS technology, in particular real-time kinematics GPS, has been developed to the stage where it has become another tool for professional surveyors. Commercial products offer user-friendly hardware/software and suggest techniques that can improve productivity at a high accuracy (Roberts, 2005). GPS survey technique compare to other data acquisition methods provides an easy, quick, and comparatively cheap tool to extract accurate and high resolution topographic information. This paper concerns the generation of high-resolution digital terrain model. This paper is focused on the experiment aiming to derive a high-resolution DTM by RTK GPS by comparing it to classical terrestrial survey using Total Station. The analysis of this research covers the accuracy and efficiency assessment of the digital terrain modeling using RTK GPS.

2. Real-Time Kinematic GPS

Real-time kinematic GPS (RTK GPS) is a differential positioning technique that uses known coordinates of a reference station occupied by one receiver to determine coordinates of unknown point visited by a rover receiver (Mowafy 2000). This technique employs L1 and L2 carrier phase measurement. The processing is carried out in real time, providing instant information of the computed coordinates with an accuracy of a few cm levels. The phase of the GPS satellite can be measured to a few millimeters by almost all commercially available GPS receiver. The use of data link, to transfer the measurements gathered at the reference receiver, allows the calculation of the rover coordinate at the time of measurement (Lemmon et al., 1999). This real time capability enables surveyor to check on the collected data to be performed at the field. The data link requirements are a function of: amount of data to be transmitted (number of satellites, data type and format), reliability and integrity requirements, operating conditions, and distance between the reference and rover stations (Mowafy, 2000). The types of data links that are commonly used are radio modem, GSM or UMTS modem, and internet protocol. Radio modem can be used for distance less than 15 km. GSM and UMTS modem or transfer via internet protocol is an alternative means and can be used for baseline more than 15 km. However, these techniques depend on the availability of GSM, UMTS and internet network itself, and also suffer of data latency. Data latency is the main consideration on the application of RTK GPS technique. It is the time needed for transmitting the data from the reference to the rover stations, decoding and software handling. Latency time could range between 0.1 to a few seconds, depending on the type of the data link used, the distance between reference to rover stations, and the condition at the time of the measurement (Mowafy, 2000). Data latency degrades the quality of RTK GPS data.

Nowadays, commercial RTK GPS is capable of giving high accuracy positioning. Single frequency receivers (L1 only) can be used as well as dual frequency (L1 and L2). Single frequency receivers are commonly less expensive than dual frequency ones. Nevertheless, dual frequency receivers are recommended for medium and long baseline measurement due to the capability of providing faster phase ambiguity fixing solution. The use of dual frequency receivers are also suggested for area with moderate obstructions (buildings, vegetation, etc). This is due to the availability of L1 and L2 and the combination of those two data that allow better ambiguity fixing.

3. Practical Considerations on the adoption of RTK GPS for DTM Data acquisition

In practice, many practitioners are still reluctant to adopt the application of RTK GPS for large scale mapping in general, and for DTM data acquisition tools particularly. This is due to a number of reasons such as a lapsed understanding on the technology, confusion about GPS surveying capabilities and best practice techniques, uncertainty over how to best utilize existing GPS service and infrastructure, lack of time/resources to invest in the technology, and also prohibitive cost (Roberts, 2005). RTK GPS surveying offers many benefits for engineering projects, including civil engineering. Firstly, RTK GPS can provide adequate accuracy for large scale mapping. Most of all modern RTK GPS, especially dual frequency receivers furnish precise positioning with accuracy range of 1-2 cm (Roberts, 2005). This accuracy is sufficient for large scale mapping (scale 1:500 – 1:2000) or even for civil works in construction sites and utility setting out which require higher scale. Referring to the National Mapping Accuracy Standards (NMAS), this accuracy is also suitable for DTM data acquisition since many engineering projects use 60 or 30 cm contour interval. Secondly, RTK GPS offers ease of use and repeatability of the survey. Traversing and intervisibility is not a necessity as it is an obligation for classical survey using total station, the common technique that has been use for years by civil engineer. RTK GPS survey also offers efficiency since fewer surveyors needed to conduct the survey as it can be performed by one surveyor. All the above reasons allow RTK GPS survey to achieve higher productivity surveying compared to total station survey.

4. Testing of the RTK GPS Technique

The performance of RTK GPS should be tested to assure that GPS-derived coordinate are a uniformly high quality and fitting the accuracy claimed by the manufacturer. RTK GPS measurement over a short baseline connecting two known points is a simple way to test the performance of the receiver. Accuracy test of the RTK GPS receiver was performed by comparing the coordinates of the measurement to the true value of the known points coordinates. The test was carried out to measure a 10 m baseline on an open area inside Universiti Teknologi Petronas (UTP). The equipment used for the experiment is Topcon Hiper dual frequency equipped with PDL radio modem for data link. The rover receiver was set to collect coordinates continuously with an interval of 15 seconds. The observation was conducted at June 06 2007. The duration of the measurement is approximately 6 hours and 1345 points was successfully collected. The result of the test is given in figure 1 and figure 2.

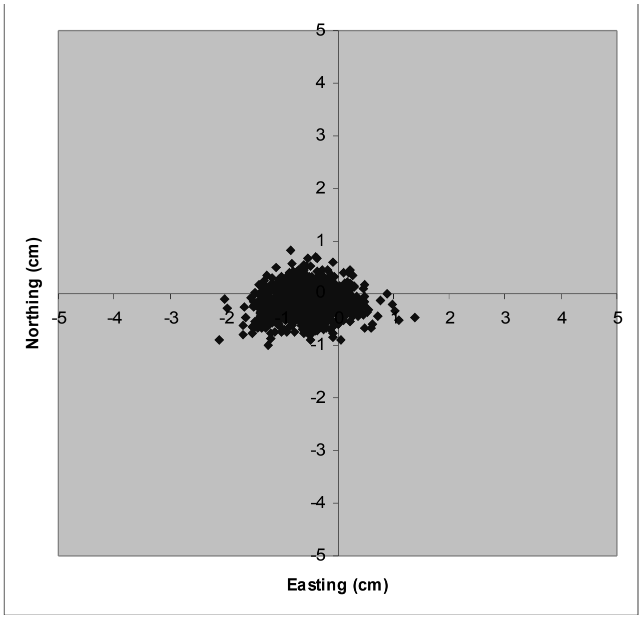


Figure 1. Scatter plot of horizontal position drift

As shown in the figure1, the maximum value of horizontal position drift is 2.11 cm for easting and 0.84 cm for northing. The trend of the horizontal position drift of the easting is leaning to the negative value, this phenomena is still under discussion with the manufacturer.

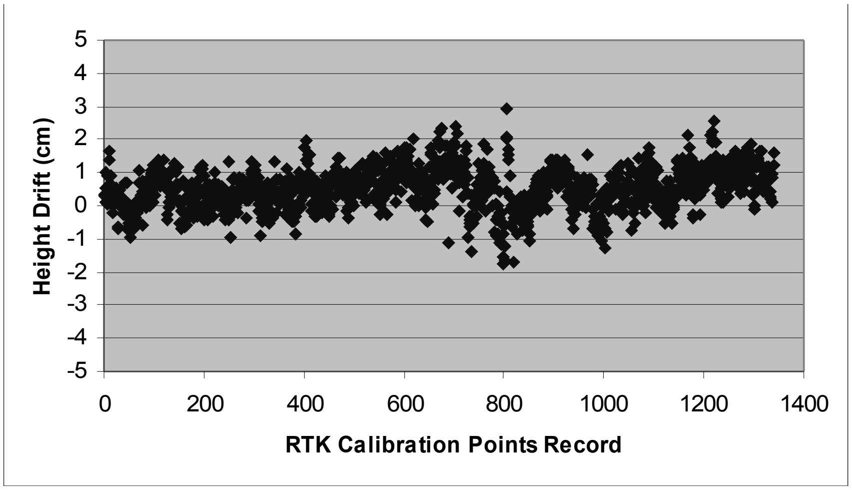


Figure 2. Scatter plot of height drift

As shown on figure.2, most of the drifts values are lower than 2.5 cm, except for record number 805 and 1219 that is 2.92 cm and 2.53. Overall result shows that the height drift is higher than the horizontal position drift. This drift signs the well accepted facts that the height accuracy of GPS is lower than the horizontal accuracy. The statistic of the test is shown on table.1

Table 1. Statistic of the RTK GPS testing

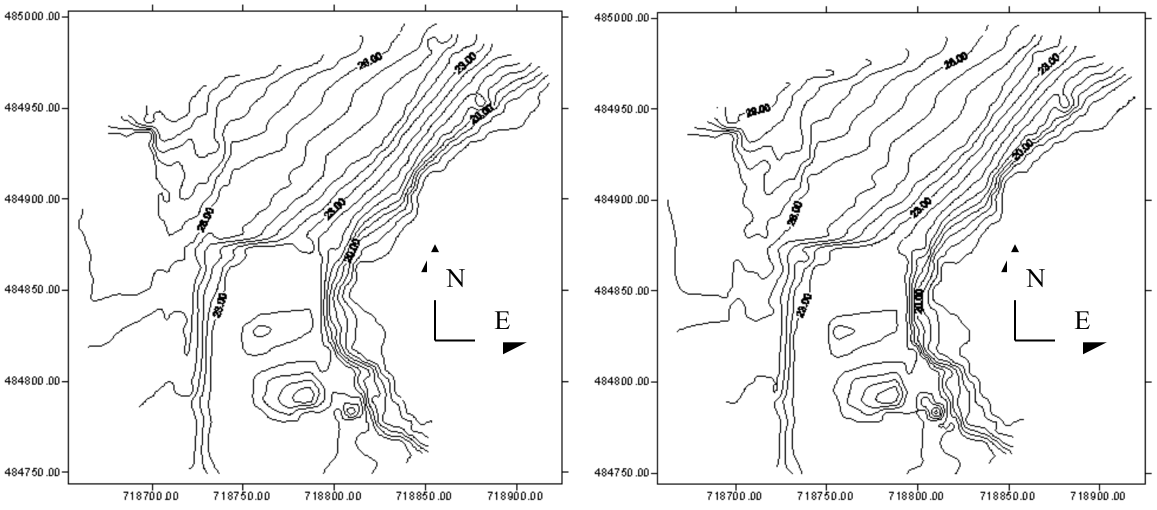
Drift	Minimum (cm)	Maximum (cm)	Average (cm)	RMS (cm)
Easting	0.11	2.11	1.17	0.88
Northing	0.10	0.84	0.48	0.36
Height	0.15	2.92	1.21	0.97

Referring to the test result as shown on the table.1 above, it is evident that the accuracy of the RTK GPS is very good and fitting the accuracy stated by the manufacturer (10mm + 1ppm). This means that the equipment is in a good condition and capable of giving appropriate accuracy for the application.

5. DTM Data Acquisition and Representation

The DTM data acquisition was performed in a part of area of Universiti Teknologi Petronas. The selected site is characterized by the presence of significant relief of the terrains. RTK GPS survey was conducted on 4 sessions at 4 different days. The duration of each session is approximately 4 hours. There are 2 benchmarks used on this experiment, PG01 and PP15. Base station was set on PG01 while PP15 was used as initial point. Initializations were performed on this initial point on the beginning of each session to check the drift and consistency between sessions. The receiver settings are; 10° cut of angle, minimum number of satellites in view is 6, and maximum PDOP is 6. The GPS was set to accept any solution either floats or fixed. The threshold of the RMS is 3 cm for horizontal position and 5 cm for height. The purpose of the setting is to check the performance of the RTK GPS when used under vegetation or closed to building. The rover receiver was mounted on a rod. Topographic height spots and features were collected point by point to ensure representative data acquisition. Classical survey using Total Station was also conducted in the same area with the same session duration. This is to compare the productivity of the RTK GPS to the classical survey.

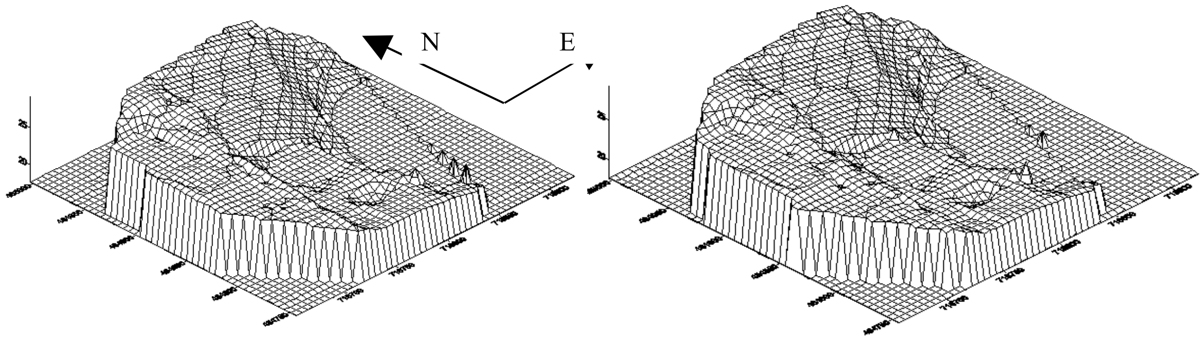
The RTK GPS was performed by one surveyor and successfully collected 2269 points. Meanwhile, in the same time of duration the classical survey successfully collected 1701 points. The classical survey was performed by two surveyors, one surveyor as the total station operator and the other one holding prism pole. Comparing the number of the collected points, it is clear that the RTK GPS gives higher productivity and almost 1.5 times faster than the classical survey. The classical survey needed 3 instrument setups to cover the area. The result of the survey is viewed in 2D representation of contour lines on figure.3 and 3D view of the DTM is shown on figure.6 below.



RTK GPS

Total Station

Figure 3. Contour lines generated from DTM acquisition data



RTK GPS

Total Station

Figure 4. DTM generated from DTM acquisition data

Visually, the result given by the two techniques is almost similar. Profile measurement along the survey area was carried out to verify the result. This survey was performed using both RTK GPS and Total Station. The purpose of the survey is to validate the results given by RTK GPS compare to the total station survey. The result is given in table.2 below.

Table.2 Height of profile points

North - South Profile				West - East Profile			
Point No.	RTK GPS (m)	TS (m)	Different (m)	Point No.	RTK GPS (m)	TS (m)	Different (m)
1	19.9102	19.941	0.0308	1	29.0897	29.125	0.0353
2	21.2585	21.292	0.0335	2	27.8698	27.885	0.0152
3	21.2799	21.333	0.0531	3	26.9092	26.922	0.0128
4	21.8983	21.928	0.0297	4	26.5409	26.533	-0.0079
5	22.7371	22.746	0.0089	5	26.6915	26.678	-0.0135
6	23.1959	23.202	0.0061	6	25.5952	25.599	0.0038
7	23.5779	23.575	-0.0029	7	25.5009	25.503	0.0021
8	23.7615	23.762	0.0005	8	24.5233	24.516	-0.0073
9	23.9574	23.973	0.0156	9	23.6445	23.644	-0.0005
10	23.8732	23.912	0.0388	10	22.5459	22.555	0.0091
11	23.7636	23.786	0.0224	11	22.582	22.607	0.025
12	22.5432	22.555	0.0118	12	20.3977	20.405	0.0073
13	23.6219	23.644	0.0221	13	19.0279	19.045	0.0171
14	24.4735	24.516	0.0425	14	18.5881	18.615	0.0269
15	25.4744	25.503	0.0286	15	18.744	18.772	0.028
16	25.5898	25.599	0.0092	16	18.8171	18.839	0.0219
17	26.6901	26.678	-0.0121	17	19.4374	19.477	0.0396
18	26.1628	26.149	-0.0138	18	21.7293	21.752	0.0227
19	25.992	25.993	0.001				
20	25.6133	25.604	-0.0093				

As shown on table 2, the minimum difference between RTK GPS and total station on the north-south profile and west-east is 0.05 cm. Meanwhile, the maximum difference for north-south profile is 4.31 cm and for west-east profile is 3.96. The contour line of the DTM representation used is 60 cm. Having the maximum difference is 4.31, it is evident that the value of the result is within the common accepted threshold of 1/3 contour line interval.

6. Conclusion

The aim of this paper was to asses the adoption of RTK GPS as a means of DTM data acquisition. The result of the experiment indicated that RTK GPS can provide sufficient accuracy for DTM data acquisition tool. The speed of the RTK GPS survey was almost 1.5 faster than total station survey. It is obvious that the technique has a good efficiency compared to classical survey using total station since it can be performed by one surveyor. Further research in varying environments and conditions is required to give a better assessment on the application of the technique.

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