PERFORMANCE OF REAL-TIME KINEMATIC GLOBAL POSITIONING SYSTEM AND AUTOMATIC LEVEL SURVEYING FOR HEIGHT DETERMINATION: A COMPARISON

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Abstract—The purpose of the research was to determine vertical accuracy of RTK-GPS in comparing with automatic level surveying procedure as has been applied in the vicinity of the University Putra Malaysia campus. A comparison of the differences between the two methods indicates 95% confidence accuracy. The results obtained by this experiment indicated an accuracy of 0-10 centimeters in the measurement of elevation by RTK-GPS system. The result of the present work also indicated that the RTK-GPS system might be very useful in surveying work as carried out by topographers, engineers, and surveyors etc.

Keywords-Global Positioning System, Real-Time Kinematic, Automatic level Surveying, Geometric, Satellite.

I. INTRODUCTION

Positioning in a short time and high precision is an importance issue in surveying [1]. Prior to 1990, the dominant technique to determine the height of points on the ground surface was geometric leveling [2]. Traditional leveling is cost effective but provides good accuracies only in small study areas [3, 4]. After 1990, many effort were implemented in developing of technologies and methods for geod determination in sub centimeter level of accuracy [2, 5].

Positioning and navigation were revolutionized by development of Global Positioning System (GPS)[6]. This system was alternative technique to geometric leveling that provides rapid and reliable information [2, 5]. Today, GPS plays an important role in geodesy, land surveying, earth science, cadastral surveying, etc.

Positional information can be obtained from two or more stations in three-dimensional space. Components of positional information (include North, East, and up) are calculated in a geocentric Cartesian coordinate system (dX, dY, and dZ) or in the local geodetic horizon system (LGHS) from which longitude, latitude, and elevation can be obtained [7]. Development in GPS technologies helps to collect data in different field of study such as surveying application, Global Information System (GIS) etc. [1].

The most important sources of error in GPS navigation and precise positioning are categorized in two group: non-dispersive (include error of satellite orbit and troposphere delay) and dispersive (include ionosphere delay) [8, 9]. Errors can be compensated through Real-Time Kinematic (RTK) which increases the accuracy to the centimeter level [10] since GPS, on its own, can not measure the elevation with such accuracy. Performance of RTK-GPS depends on the three issues: (1) reliability, (2) Speed, and (3) accuracy [11]. Man made or natural blockage such as wall, tree, etc. cause limitation in measurements or may make it impossible [12, 13].

RTK satellite navigation is a technique that is employed in surveying. It uses dual frequency systems and provides accuracy of 1 centimeter ± 2 parts per million (ppm) horizontally and 2 centimeters ± 2 ppm vertically of accuracy provide by dual frequency systems[8, 10]. This process includes measurement of corrections by reference to the station of RTK networks [5], and the sub meter precision in cadastral surveying by Bluetooth wireless connection to receive Global System for Mobile communication (GSM) correction [1]. Langley detailed the process of estimating the phase measurement correction [14].

RTK-GPS as the dynamic type of GPS positioning technique provides accurate result (some millimeters error) in real time [1, 12, 15]. Clark and Lee reported 4 to 9 cm errors in elevation to assess the topography in their studies by RTK-GPS in 1998 [12]. A study was conducted in Australia to find if the vertical accuracy is satisfactory. In compare with 60-point control it has been indicated 53
millimeters (95% confidence) accuracy by RTK-GPS [16]. Borgelt et al. (1996) reported the results of comparing RTK-GPS systems to geometric leveling. The elevation errors were limited to 12 centimeters. Featherstone and Stewart (2001) expressed that GPS positioning is weaker in elevation measurement due to the situation of satellites in the sky.

The two case studies highlighted the weakness of RTK-GPS due to blockage of satellite signals near the buildings and/or under the tree canopy. Therefore, the usage of RTK-GPS will be dependent on the applications, the error tolerance of the applications, and the size of fields [17].

Comparison between RTK-GPS and geometric leveling techniques shows statistically compatible results [16]. Also, RTK-GPS techniques saves the cost up 50% [5, 18] due to minimization of number of staff and obtaining consistent coordinates [5]. It also reduces the mapping process by 30% in normal condition [19]. Another advantage of RTK-GPS opposed to geometric methods is determination of coordinate of points in high precision without line of sight [20] and obtaining greater flexibility, efficiency, and productivity [21].

According to the literature, longitude and latitude of points when RTK-GPS is used, is trustable and equal to specification of equipment while the elevation obtained through RTK-GPS is doubtful. In the light of this discussion, purpose of present work is verifying the accuracy of elevation by RTK-GPS system in compare with automatic leveling.

II. METHODOLOGY

A 16-ha survey area was chosen inside University Putra Malaysia for the study. It is located in 101º 43' 10" E - 101º 43' 23" E longitude and 3º 00' 17" N - 3º 00' 32" N latitude. A SOKKIA C4 automatic level with accuracy of ± 2.5 millimeters was used to measure the height of points. In this part, heights were compared and water level of pond in survey area was assumed as a temporary benchmark. To collect information by RTK-GPS, Trimble 5800 (Trimble Navigation Ltd.) dual-frequency GPS receivers were used. It includes antenna, and TSC2 controller. The manufacturer’s specification for Trimble 5800 in March 2007 for vertical component was ± 20 millimeters. The minimum distances between the survey points were 50 m while the maximum was 130 m.

The elevations recorded for each survey points by the above mentioned methods were undergone the T-test by SAS software version 9.1. The results of GPS-RTK testing were compared against the results from automatic level surveying as a further quality check.

III. RESULTS AND DISCUSSION

12 points were selected for height checking in the research area. The position of points and elevation of ground surface from Mean Sea Level are illustration in Fig. 1.

<table>
<thead>
<tr>
<th>Point</th>
<th>Elevation from MSL by RTK-GPS (m)</th>
<th>Height from Ground Surface by Automatic level (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond</td>
<td>38.746</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>38.426</td>
<td>-37</td>
</tr>
<tr>
<td>2</td>
<td>39.290</td>
<td>52</td>
</tr>
<tr>
<td>3</td>
<td>38.501</td>
<td>-28</td>
</tr>
<tr>
<td>4</td>
<td>38.346</td>
<td>-38</td>
</tr>
<tr>
<td>5</td>
<td>37.791</td>
<td>-95</td>
</tr>
<tr>
<td>6</td>
<td>39.189</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>39.205</td>
<td>44</td>
</tr>
<tr>
<td>8</td>
<td>39.043</td>
<td>66</td>
</tr>
<tr>
<td>9</td>
<td>40.204</td>
<td>152</td>
</tr>
<tr>
<td>10</td>
<td>39.629</td>
<td>78</td>
</tr>
<tr>
<td>11</td>
<td>39.628</td>
<td>95</td>
</tr>
</tbody>
</table>
In case of RTK-GPS, elevations of points were recorded in meter. The number of tracked GPS satellites being observed was between 6 to 9 satellites.

To investigate the accuracy of the GPS-RTK results, heights determined from this method were compared with automatic leveling. Table II shows the height of points by both RTK-GPS, and automatic leveling.

The results clearly showed that GPS-RTK provides the elevation with accuracy at the centimeter level. It has been found that accuracy of 0-10 centimeters is improved. Regarding to the overlap line that is appeared in Fig. 2, it can be expressed that the two sets of data are quite close to each other. Large differences between RTK-GPS and automatic leveling surveying occurred at stations 6 and 10 (10.0 cm), 11 (6.8 cm), and 1 (5 cm). It could be attributed to the limited number of satellites being tracked at that moment and the interference of satellite signal due to tree canopy.

The relative deviation of T-test is 5% that is an input for the software. If obtained T-value is less than 0.05, there is a significant difference between two sets of data [22, 23]. Based on the result of statistical tests, the T-value is equal to 0.09 thus there is not significant difference between two sets of data.

**TABLE II. Comparison results of two sets of data**

<table>
<thead>
<tr>
<th>Point</th>
<th>Automatic leveling method which referred to lake surface (m)</th>
<th>RTK-GPS method which is submission of the lake at sea level (m)</th>
<th>Differentiate between two methods of measurement (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond</td>
<td>0</td>
<td>38.746</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>-0.370</td>
<td>-0.320</td>
<td>0.050</td>
</tr>
<tr>
<td>2</td>
<td>0.520</td>
<td>0.544</td>
<td>0.024</td>
</tr>
<tr>
<td>3</td>
<td>-0.280</td>
<td>-0.245</td>
<td>0.035</td>
</tr>
<tr>
<td>4</td>
<td>-0.380</td>
<td>-0.400</td>
<td>0.020</td>
</tr>
<tr>
<td>5</td>
<td>-0.955</td>
<td>-0.955</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0.330</td>
<td>0.443</td>
<td>0.113</td>
</tr>
<tr>
<td>7</td>
<td>0.440</td>
<td>0.459</td>
<td>0.019</td>
</tr>
<tr>
<td>8</td>
<td>0.660</td>
<td>0.684</td>
<td>0.024</td>
</tr>
<tr>
<td>9</td>
<td>1.520</td>
<td>1.559</td>
<td>0.028</td>
</tr>
<tr>
<td>10</td>
<td>0.780</td>
<td>0.883</td>
<td>0.103</td>
</tr>
<tr>
<td>11</td>
<td>0.950</td>
<td>0.882</td>
<td>0.068</td>
</tr>
</tbody>
</table>

IV. CONCLUDING REMARKS

This study shows that the RTK-GPS surveying can provided an accuracy of 0-10 centimeters in the measurement of elevation. The terrain correction was not crucial due to small difference between the elevations of points but it could be necessary in mountainous regions. The overall reliability of RTK-GPS in case of elevation is more than 95%. Such accuracy is adequate for landscaping, installing utilities like power-lines, power cables, pipe lines, etc. It was also found that the size of study area is an important parameter in precision of elevation. The results indicate that integrating RTK-GPS system with automatic level is proper for surveying in urban environments.

A study on RTK-GPS surveying in vertical direction is recommended as a further research to assess the precision, accuracy, and reliability of the method. The data gathered in RTK-GPS surveying has different precision than what was estimated and expressed by manufacture’s documentation.

ACKNOWLEDGMENT

The authors would like to thanks to Eeman Norae and Ehasn Saghatforoush from University Putra Malaysia who provided valuable and constructive comment on the paper. Authors are also thankful to UPM: Institute of Advance Technology for Assistance.

REFERENCES


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