Accuracy Assessment of Lidar Data Using Geomatic Approaches

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Received on: 10/1/2012 & Accepted on: 4/10/2012

ABSTRACT

The fast development in Remote Sensing technology with various sources of data especially LiDAR (Light Detection And Ranging) images promote the ability of using data , but the accuracy of produce Maps issue always need to be evaluate.

So the main aim of this research is to evaluate the accuracy of using elevation data for various techniques, such as Photogrammetry and remote sensing techniques then comparison with traditional filed surveying using DGPS total station and level instrument.

LiDAR data gives accurate elevation therefore; 3D model can be obtained from LiDAR data which can be used in many applications such as civil engineering and surveying engineering, etc.

In this research University of Technology has been chosen as case study area, and many Geomatic approaches executed such as extracted height of features from field surveys using Total Station and comparison with the heights extracted from LiDAR data. According to the results analysis it can be stated that the elevations from the LiDAR data within accuracy of (3-10) cm can be obtained.

Keywords: LiDAR, Accuracy Assessment, Remote Sensing Data

تقيم الدقة لبيانات الليدر باستخدام الطرق الجيوماتيكية

الخلاصة

التطور السريع في تكنولوجيا الاستشعار عن بعد مع تعدد مصادر البيانات و خصوصاً منها مخيلة الليدر زاد من قدرة استخدام هذه البيانات المتاحة في انتاج الخرائط ، ولكن تظل مسالة دقة الخرائط المنتجة تحتاج دائما إلى تقيم . وبالتالي فإن الهدف الرئيسي من هذا البحث هو تقييم الدقة للارتفاعات باستخدام بيانات ارتفاع لتقنيات مختلفة، مثل المسح التصويري وتقنيات الاستشعار عن بعد ثم مقارنتها مع الطرق التقليدية للمسح باستخدام منظومة DGPS و المحطة الكاملة (Total Station) و جهاز التسوية (Leveling instrument). بيانات الليدر تعطي

بيانات دقيقة لذلك الارتفاع، وبذلك يمكن الحصول على نموذج ثلاثي الابعاد 3D من بيانات الليدر التي يمكن استخدامها في العديد من التطبيقات مثل الهندسة المدنية وهندسة المساحة، الخ. في هذا البحث تم اختيار موقع الجامعة التكنولوجية كحالة دراسية، واستخدامت العديد من الطرق الجيوماتيكية منها استخراج ارتفاع العوارض من المسح الحقلي باستخدام المحطة الكاملة (Total Station) و مقارنتها مع الارتفاعات المستخرجة من بيانات الليدر و طبقاً لنتائج التحليل تبين ان ارتفاعات المستخرجة من بيانات الليدر ذات دقة تتراوح ما بين (٣-١٠) سم.

INTRODUCTION

Three measurement components make up the LiDAR system: GPS for horizontal and vertical position, Inertial Measurement Unit for angular attitude, and laser scanner for ranging to points on the ground. The raw LiDAR data are combined with GPS positional data to georeference the data sets. Once the flight data is recorded, appropriate software processes the data that can be displayed on the computer monitor. This data can then be edited and processed to generate surface models, elevation models and contours.

Consequently, in this research the LiDAR data image for the area of study UOT camp Bounded by the coordinates (from 448219.7 to 448673.4) easting and (from 3685708.9 to 3686036.7) northing in zone 38N according to UTM – WGS1984 coordinate system used for observed elevations of twenty check points by using Quick terrain reader V.6.1.2 program and then analysis the results that obtained from Geomatic approaches for accuracy assessment of LiDAR data and compatible the results with the accuracy of LiDAR data.

THE LiDAR RETURN SIGNAL AND LiDAR EQUATION

If the speed of light is denoted by c, then the delay t between the transmitted and backscattered pulses from an object at distance x is given by [16]:

$$t = 2\frac{x}{c} \ldots\ldots(1)$$

If only the direct path is considered, that is, multiple scattering is excluded for the time being. Equation (1) relates the return time with the distance of the scatterer. Time and distance can thus be, and used synonymously in this research. Differentiated, Equation (1) also shows that the smallest discernable depth interval

$$\Delta x \geq \frac{c}{2}\,\Delta t \ldots\ldots(2)$$

And, thus, depth resolution is limited by the laser pulse length, detection system time constant, or digitizer or photon- counting time-bin width, whichever is the longest.

Clearly, the delay between successive pulses must be longer than 2/c times the distance from which no return signal can be detected any more. This is usually quite a bit longer than the LiDAR range, or maximum distance out of which meaningful data can be collected. [16]

In the in-flight direction, point spacing is determined by aircraft speed and altitude, whereas in the cross-flight direction (normal to the angle of flight

direction), point spacing is defined by scan angle and altitude. In terms of what is actually emitted, each pulse has a diameter, or 'footprint' (typically between 0.5 and 1 m) and a length defined by the time between the laser pulse being switched on and off. In essence therefore, each pulse is a cylinder of light. On their own, these reflected pulses are not enough to construct a terrain surface; accurate x-y-z position using differential GPS is needed relative to ground-based GPS base stations, the roll, pitch and yaw of the aircraft needs to be measured by an inertial measuring unit (IMU), which in turn allows the angular orientation of each laser pulse to be determined as shown in figure (1). Finally, the times taken for each laser pulse to reflect off the ground (or whatever surface) and return to the sensor is measured. This is termed the 'return'. In essence then, laser scanning depends on knowing the speed of light, approximately 0.3 m/ns. Using that constant, how far a returning light photon has travelled to and from an object can be calculated [17]:

$$Distance = \frac{Speed\ of\ light \times Time\ of\ flight}{2} \quad \ldots\ldots(3)$$

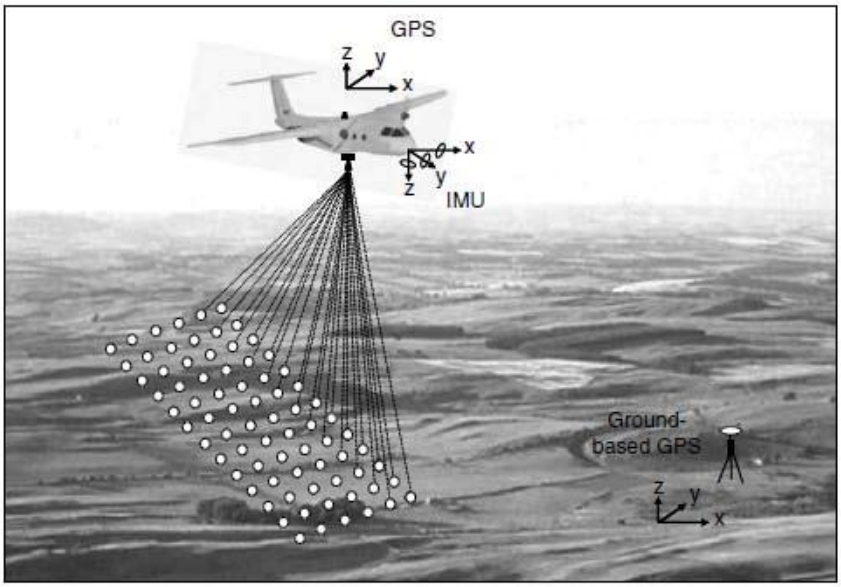

Figure (1) Typical operation of an airborne LiDAR survey [17].

The calculation of the detector output or LiDAR signal can be carried out rigorously, although hardly ever in closed form, if the spectral, temporal, and spatial properties of the laser light and the optical properties of the LiDAR receiver are to be taken into account in full detail. Unless chirped beams are used (which were hard to avoid in the early, ruby laser- dominated times of LiDAR), the spectral and spatial–temporal properties can be treated separately. The ways the atmosphere interacts with the spectral properties of the laser light differ very much for the different types [16].

EXTRACTION FEATURES HEIGHT FROM LiDAR IMAGE

After compute final elevations of five GCP of the ellipsoid height relative to WGS 84 from data of different field surveys such as DGPS, Total Station and Laser level instruments .These five GCP become as a reference for other field works such as extraction features height and ground elevations that are located inside study area. Twenty check points (markers) are selected in different locations inside the study area; they can be easily recognized in the aerial photo and LiDAR Image for the purpose of evaluating the features height accuracy for the LiDAR data image. As shown in Figure (2).

Figure (2) Twenty check points (markers) location .

FEATURES HEIGHT / METHOD OF STATEMENT

The Quick Terrain Reader program which is one of the many programs that specialist in LiDAR data processing was used to extract the height of the selected twenty checkpoints from LiDAR date as shown in Figure (3).

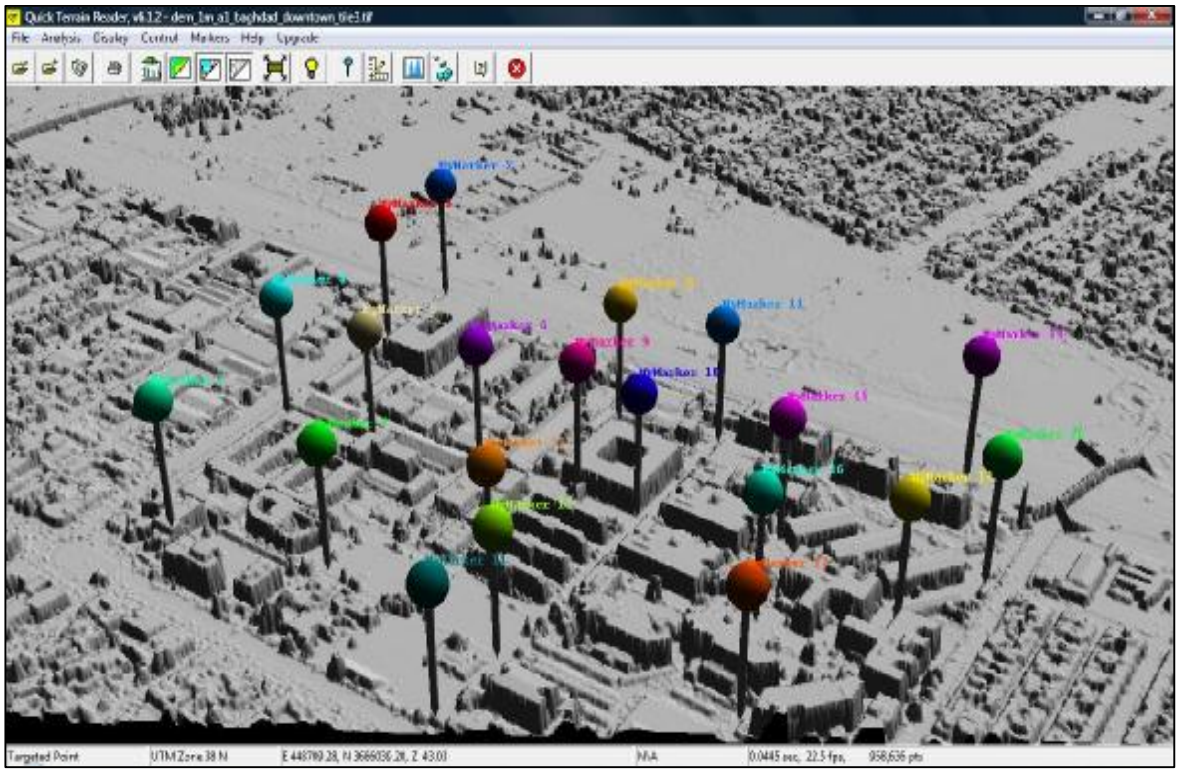

Figure (3) 3D-Area of study shown twenty check points (markers) location in Quick Terrain Reader program .

LiDAR data Image was loaded in Quick Terrain Reader program window ,and from the place marker pin button , marker ,were placed on locations of check points (markers) in the LiDAR data Image see Figure(3), then from markers Tab in menus bar Edit Marker was selected , Edit Marker window appeared that Contain information for this marker , including the (Altitude)ellipsoid height relative to WGS 84 Figure(4).

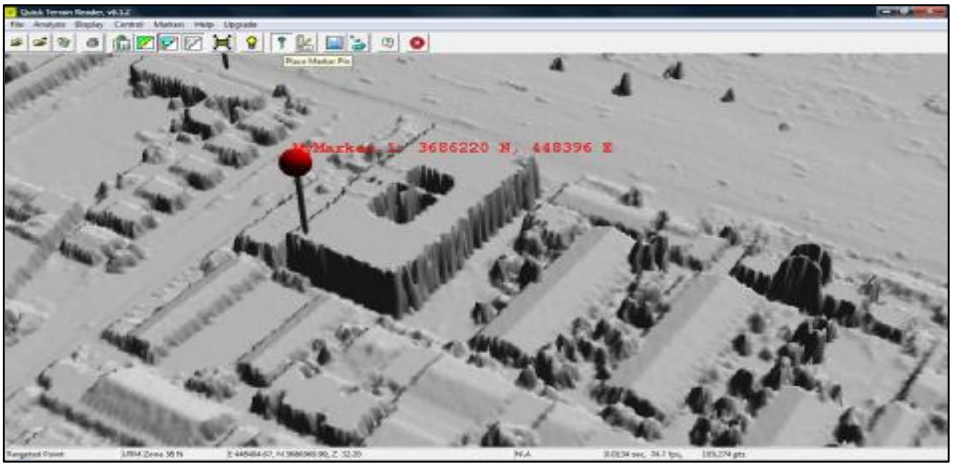

Figure (4) Placed check point (marker) location on LiDAR Image.

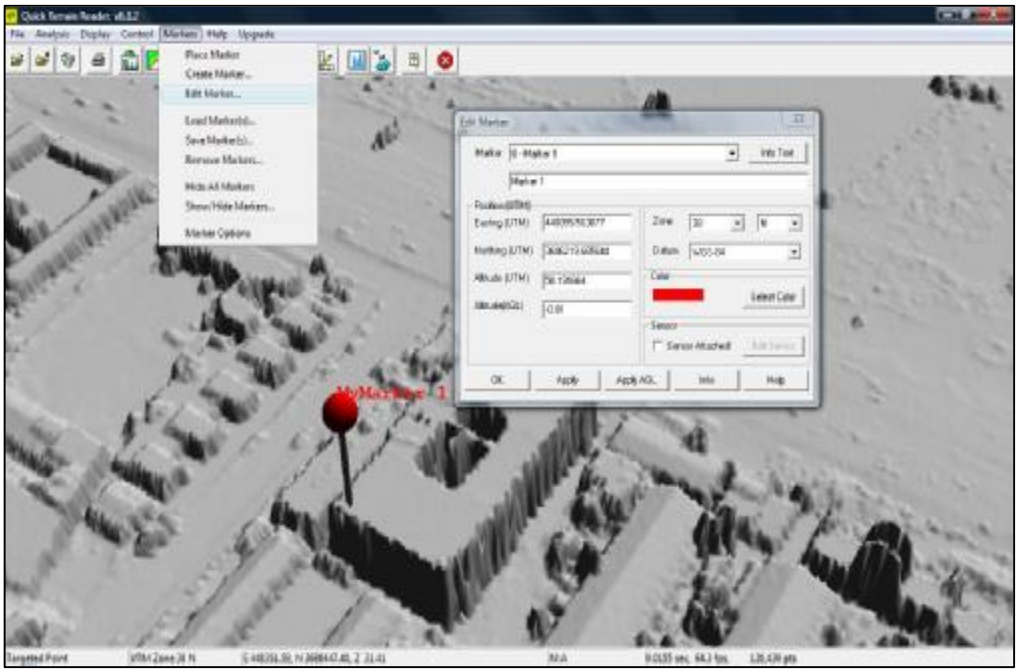

Figure (5) Data of the marker, including the Altitude.

The same approach was used for extracting the ellipsoid height relative to WGS 84 for twenty check points (markers) from LiDAR elevation data as shown in Table(1).

Table (1) Ellipse Height of the twenty check points (markers) extracted from LiDAR.

Check point (Marker)	Height (m)	Check point (Marker)	Ellipse Height (m)	Check point (Marker)	Ellipse Height (m)	Check point (Marker)	Ellipse Height (m)
1	50.191664	6	31.275412	11	31.302002	16	31.515332
2	50.214478	7	31.403799	12	31.007837	17	31.356279
3	43.798675	8	31.537108	13	31.412927	18	31.325596
4	31.288500	9	39.943124	14	31.270608	19	52.476883
5	31.181033	10	31.394545	15	31.134203	20	35.501537

Point's Height Accuracy Assessment using Total Station

For accuracy assessment of twenty check points height, these points observed by total station Leica type depending on values of the main GCP. Total Station installs at locations near GCP and the reflector was respectively installed on the locations of the twenty check points, then the height of check points were displayed on the digital screen of the Total Station after the height of the GCP is entered to the operation system in total Station instrument. Ten records are taken for each check point then the average of these records were computed to obtain the final ellipsoid height relative to WGS 84 of check points. The final ellipsoid height relative to WGS 84 of the twenty checks points shown in Table (2).

Table (2) Final results of Twenty Check Points using Total station survey

Check point	Ellipse Height (m)	Check point	Ellipse Height (m)	Check point	Ellipse Height (m)	Check point	Ellipse Height (m)
1	50.142	6	31.217	11	31.238	16	31.449
2	50.153	7	31.335	12	30.953	17	31.302
3	43.716	8	31.461	13	31.360	18	31.273
4	31.221	9	39.890	14	31.229	19	52.427
5	31.105	10	31.329	15	31.062	20	35.458

ANALYSIS FEATURES HEIGHT USING CHECK POINTS APPROACH:

The methodology of feature's height analysis was as shown in the Figure (6). After five GCP surveyed by Differential GPS (Topcon GR3) give credit for accuracy assessment of LiDAR data, twenty check points are selected inside study area, the height of these points calculated through two methods field survey using Total Station (Leica TPS400) and from LiDAR data.

Table (3) shows the comparison between the final results of heights .In this table the ΔH values are arranged from (0.049664 m to 0.080675 m). This range is located within accuracy of LiDAR data (3cm-10cm) in height depending on the selected features markers. Accordingly the accuracy of LiDAR data is inevitable in this approach.

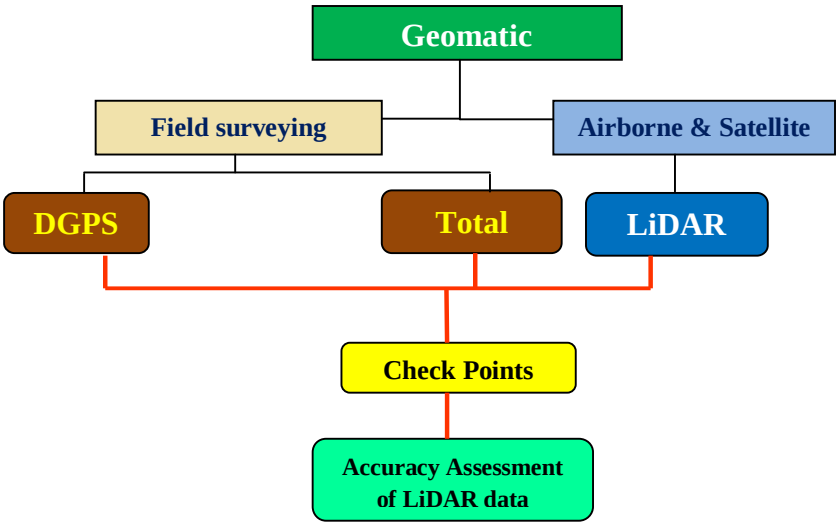

Figure (6) Methodology of Accuracy Assessment of LiDAR Data.

Also the comparison between the final results of twenty checkpoints (markers) are obtained from LiDAR elevation data using Quick Terrain Reader program method and traditional field survey using Total station method represented in the charts below (Figures 7.a and 7.b). These charts show LiDAR elevation data accuracy convergence with traditional field survey accuracy.Therefore these chartsand Table (3) give us un indication for accuracy assessment of LiDAR data for extraction features height.

Table (3) ΔH between LiDAR and Total station results.

Check point	LiDAR Ellipse_ Height(m)	Total Station Ellipse_ Height (m)	ΔH (m)
1	50.191664	50.142	0.049664
2	50.214478	50.153	0.061478
3	43.798675	43.716	0.080675
4	31.288500	31.221	0.0675
5	31.181033	31.105	0.076033
6	31.275412	31.217	0.058412
7	31.403799	31.335	0.068799
8	31.537108	31.461	0.076108
9	39.943124	39.890	0.053124
10	31.394545	31.329	0.065545
11	31.302002	31.238	0.064002
12	31.007837	30.953	0.054837
13	31.412927	31.360	0.052927
14	31.270608	31.229	0.041608
15	31.134203	31.062	0.072203
16	31.515332	31.449	0.066332
17	31.356279	31.302	0.054279
18	31.325596	31.273	0.05596
19	52.476883	52.427	0.049883
20	35.501537	35.458	0.043537

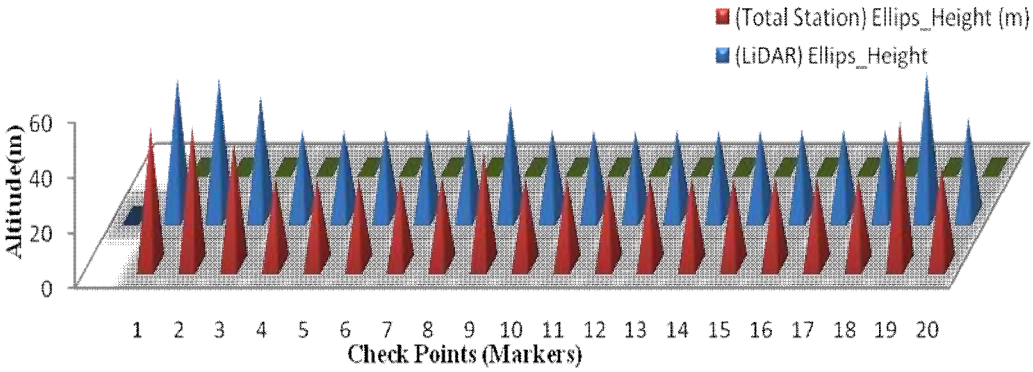

Figure (7.a) Comparison of check points height between LiDAR and Total Station.

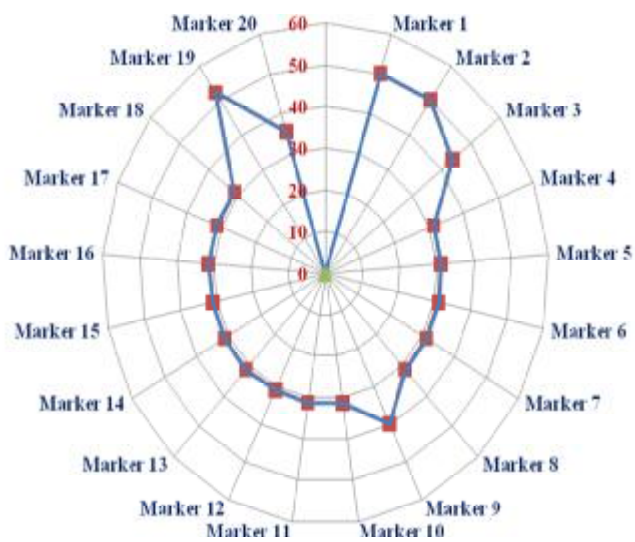

Figure (7.b): Accuracy of check points height.

CONCLUSIONS

The accuracy assessment by comparing the elevations obtained from LiDAR data with that obtained from the land survey work is considered as the absolute vertical accuracy of the LiDAR data.

This study indicates that selection of a suitable method for obtaining the corresponding elevations from the LiDAR data at the locations of the checkpoints might be effect on the accuracy assessment.

The elevation differences between the LiDAR data and the checkpoints must be tested to check if they are compatible in accuracy, so the appropriate measures can

be used for the vertical accuracy assessment of the LiDAR data for different applications.

The purpose of the vertical accuracy assessment, were only those LiDAR points that are around the checkpoints. There are needed to derive the elevation at the locations of the checkpoints others.

Finally, according to the results analysis it can be stated that the elevations from the LiDAR data within accuracy of (3-10) cm can be obtained.

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