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Accuracy Assessment of LiDAR Data Using Longitudinal Profile of a Road

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ABSTRACT

LiDAR data gives accurate elevation therefore; we can obtain 3D modelling from LiDAR data which can be used for many applications such as civil engineering and surveying engineering, etc.

For accuracy assessment of LiDAR elevation data, a longitudinal profile are done from field survey using laser level instrument type (Leica Sprinter 100) of a road having about (350m) length, adjacent to the Building and Construction Engineering Department, which locates inside study area, then compares it with longitudinal profile, which drowns from LiDAR elevation data using (ArcGIS9.3) program. 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, Profile, Accuracy assessment, ArcGIS.

تقيم الدقة لبيانات الليدار باستخدام مقطع طولي لطريق

الخلاصة

بيانات الليدر تعطي بيانات دقيقة للارتفاع، وبذلك يمكننا الحصول على نماذج ثلاثية الابعاد 3D من بيانات الليدر الذي يمكن استخدامه في العديد من التطبيقات مثل تطبيقات الهندسة المدنية وهندسة المساحة، ....الخ.

لتقييم دقة بيانات الارتفاع الليدر، تم القيام بمسح طولي (مقطع طولي) من خلال المسح الميداني باستخدام جهاز تسوية ليزري نوع (Leica Sprinter 100) لطريق موجود في الجامعة التكنولوجية طوله حوالي (350 متر) ، متاخم الى قسم هندسة البناء و الانشاءات ، والذي يقع داخل منطقة الدراسة ، ثم تم مقارنة بيانات المسح الحقلية للمقطع الطولي للطريق مع بيانات الليدر من خلال استخدام برنامج (ArcGIS9.3).و طبقاً لنتائج التقيم توصلنا الى انه قيم الارتفاع لبيانات الليدر ذات دقة عالية تتراوح ما بين 3-10 سم من الممكن الحصول عليها.

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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 [1, 2, and 3]. Consequently, used elevations of station for a longitudinal profile obtained from LiDAR data. And then analysis of results obtained from field surveying using level instrument and compatible the results with the accuracy of LiDAR data for accuracy assessment 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 [6]:

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

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 will be used synonymously in this book.
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. [6]

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. 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, laserscanning depends on knowing the speed of light, approximately 0.3 m/ns. Using that constant, we can calculate how far a returning light photon has travelled to and from an object [7]:

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

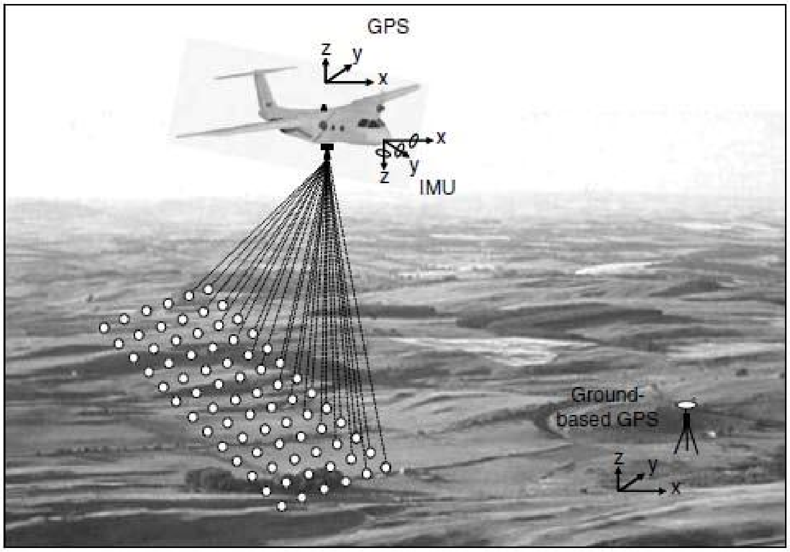


Figure (1). Typical operation of an airborne LiDAR survey. The sensor operates in swaths across the terrain surface (shown by small open circles in this diagram), and is Georeferenced by an inertial navigation unit (INU) in the aircraft and a ground-based differential GPS. [7].

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. [6]

ROAD PROFILE /METHOD of STATEMENT

University's main road (350m) is divided the road path to eight main stations (eight segments) by (50m) between the station and other along the central line of the road are shown in figure (2). Where the distances are measured using laser device with level instrument.

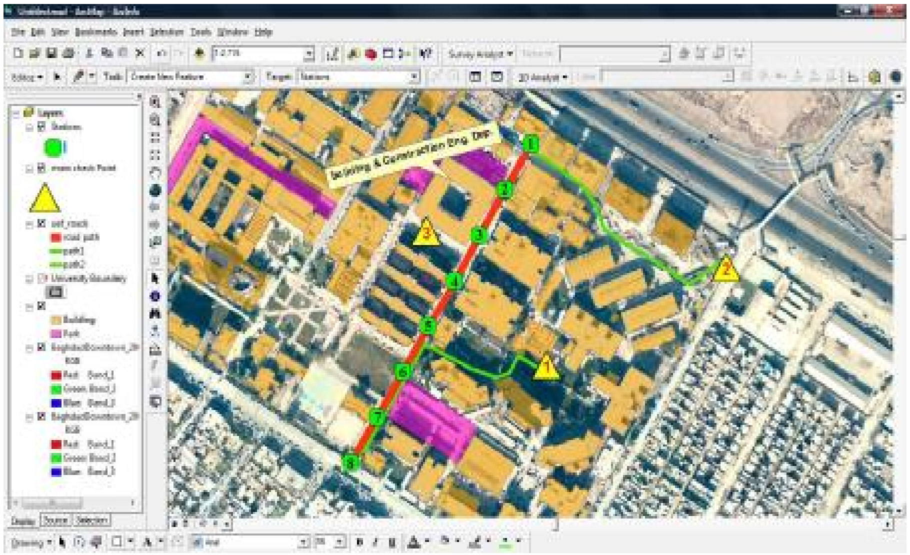


Figure (2). Location of Road Stations.

Road profile survey begins from GCP No.2, which has ellipsoid height 31.246 m relative to WGS 84using Laser Level .And observes main eight stations along the route, finally closed on the GCP No. 1, which has ellipsoid height 31.551 m relative to WGS 84, the elevations of these stations are calculated depending on the elevation of GCP No.2.

Table(1) results of profile levelling using level survey .

Sta.	B.S	E.L.S	F.S	I.F.S	Elevation	Rem.
GCP No. 2	1.o470	32.2930			31.246	
A				1.2284	31.0646	
B	1.5639	32.2689	1.5880		30.7050	
C	1.6735	32.3820	1.5604		30.7085	
D	1.6757	32.6046	1.4531		30.9289	
E	1.5550	32.6596	1.5000		31.1046	
F	1.7644	32.8830	1.5410		31.1186	

Sta.	B.S	E.L.S	F.S	I.F.S	Elevation	Rem.
0+00	1.5797	32.9092	1.5535		31.3295	on road
0+50	1.5440	32.8933	1.5599		31.3493	on road
1+00	1.5580	32.9046	1.5467		31.3466	on road
1+50	1.5492	32.8282	1.6256		31.2790	on road
2+00	1.5232	32.8350	1.5164		31.3118	on road
2+50	1.5584	32.9301	1.4633		31.3717	on road
3+00	1.4927	32.8213	1.6015		31.3286	on road
3+50	1.6762	32.9057	1.5918		31.2295	on road
G	1.5511	32.8152	1.6416		31.2641	
H	1.5370	32.1623	1.1899		31.6253	Main Entrance.
I	1.5001	32.5202	1.1422		31.0201	
J	1.5121	32.8820	1.1503		31.3699	
GCP No.1			1.3288		31.5532 31.5510	C.E. 0.0022

The close error at the GCP No. 1 was 0.0022m as shown in table (1) A longitudinal road profile has been draw through the final results of the elevations of the stations values in the table (1) using ArcGIS Desktop 9.3 program (3D analyst extension), as shown in the Figure (3).

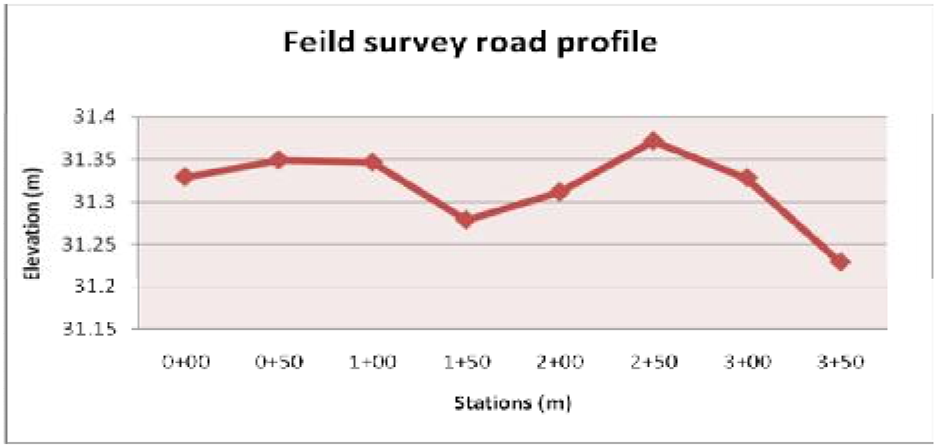


Figure (3) Longitudinal profile from field survey.

From LiDAR data of the study, area Longitudinal road profile drawing of the road using the ArcGIS Desktop 9.3 program through LiDAR image added into ArcMap window, interpolated icon in 3D analyst bar is clicked , then graphic line is drew along the road stations as figure (4). [4, 5]

Profile Graph through 3D analyst bar is used; the profile graph of the road is appeared on ArcMap windows as shown in Figure (5).

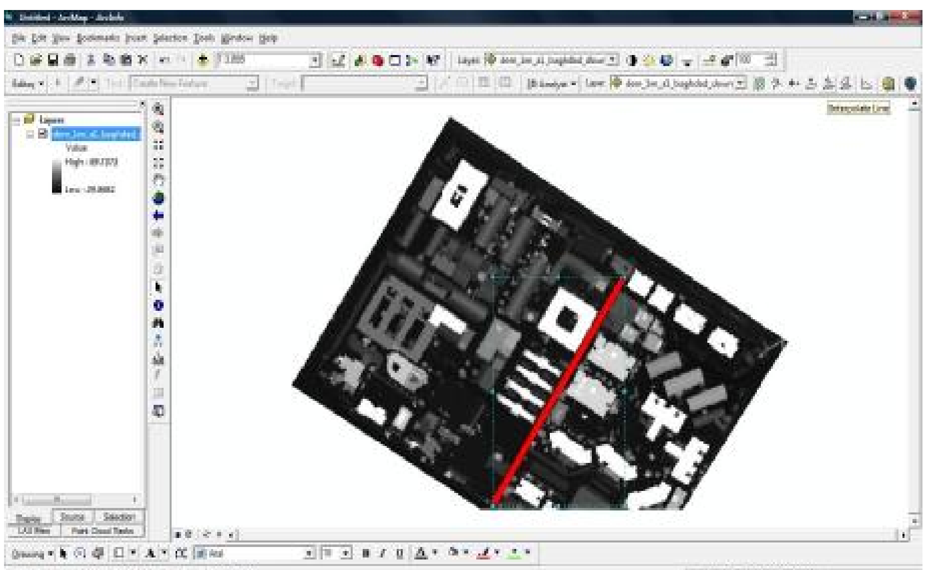
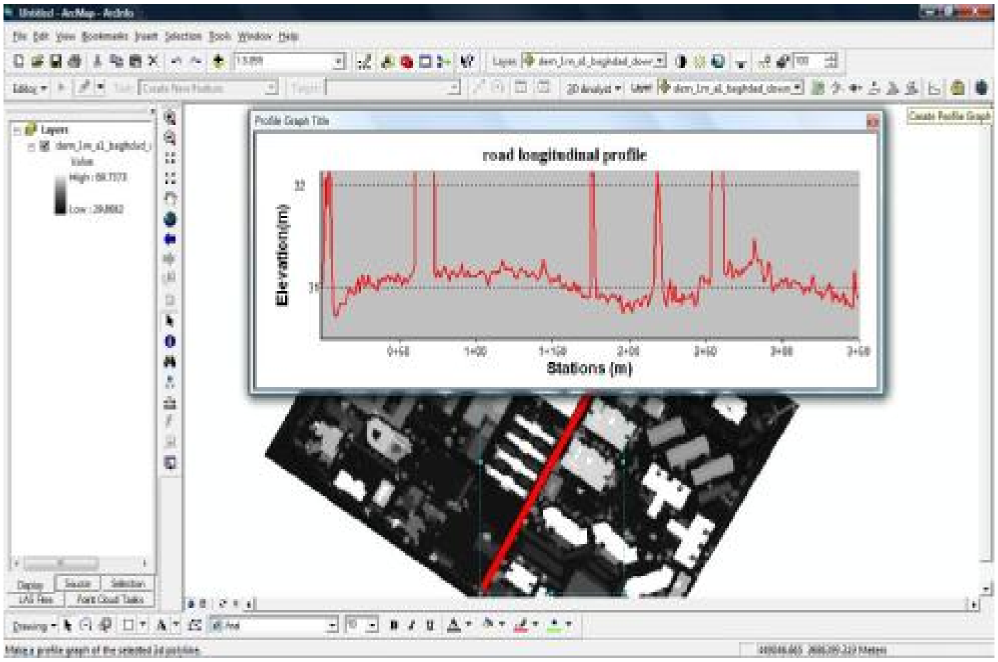


Figure (4). Graphic line draw along the rod path.



Figure(5). Profile Graph of the road.

RESULTS ANALYSIS OF LONGITUDINAL ROAD PROFILES APPROACH

When comparison between the two Longitudinal road profiles as in Figure (6) to evaluate the accuracy of LiDAR elevation data .The different in elevation of eight stations which construct from field survey and LiDAR data as seen in table (2)are arranged from 0.0092m to 0.1128m .

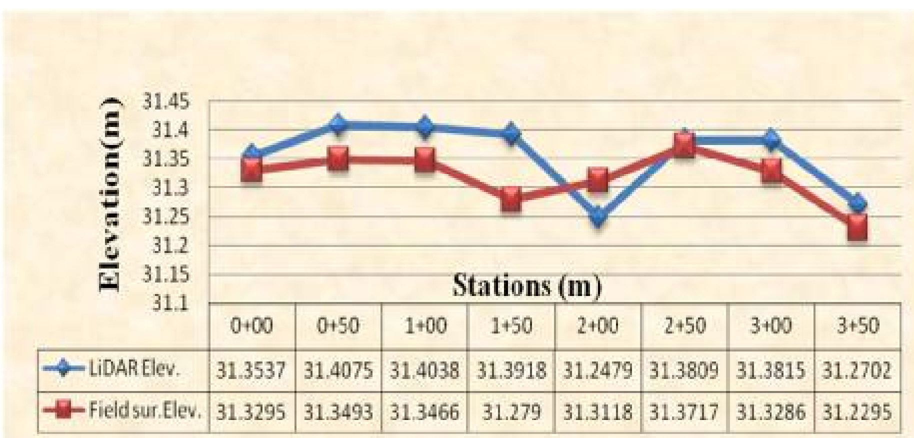


Figure (6) Longitudinal profiles extracted from LiDAR and Level survey.

The ΔH value at station 1+50 is (0.1128m) ;Table (2), the ΔH value is bias out of accuracy of LiDAR data as shown in figure (7),therefore this station is checked by using aerial image (resolution 10 cm) which is taken at the same time with the LiDAR image , the identification appear that something placed on the road exactly at station 1+50, as shown in figure (8) .
For this reason the elevation of this station (31.3918m) relates with this something nor road elevation , hereupon the other ΔH values of stations except station 1+50 are lying within LiDAR accuracy (3cm-10cm).

Table(2) ΔH between LiDAR and Level elevations for station of Longitudinal Profiles.

Station	(LiDAR) Elevation (m)	(Level) Elevation (m)	ΔH (m)
0+00	**31.3537**	**31.3295**	**0.0242**
0+50	**31.4075**	**31.3493**	**0.0582**
1+00	**31.4038**	**31.3466**	**0.0572**
1+50	**31.3918**	**31.2790**	**0.1128**
2+00	**31.2479**	**31.3118**	**0.0639**
2+50	**31.3809**	**31.3717**	**0.0092**
3+00	**31.3815**	**31.3286**	**0.0529**
3+50	**31.2702**	**31.2295**	**0.0407**

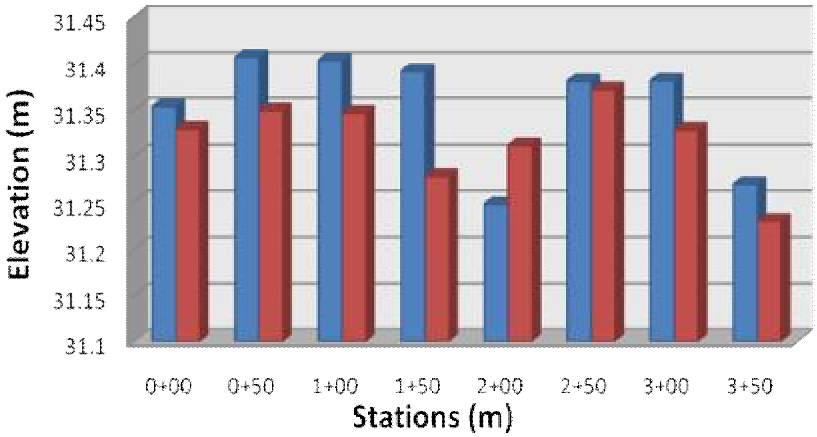


Figure (7) Comparison between Elevations of stations extracted from LiDAR and Level survey.

Figure (8). Location of station 1+50.

Additionally LiDAR data provide with details for topographic surface more than field survey as example in figure (9) shows topographic surface between two stations (1+00,1+50) along 50m obtain from field survey using Level instrument compared with the figure (10) which show more details topographic surface between same two stations.

For interpretation above situation, in field survey method observes only stations and calculates elevations of them and ignores points between stations. While the LiDAR scanning can obtain a dense 0.5-3 points per meter.

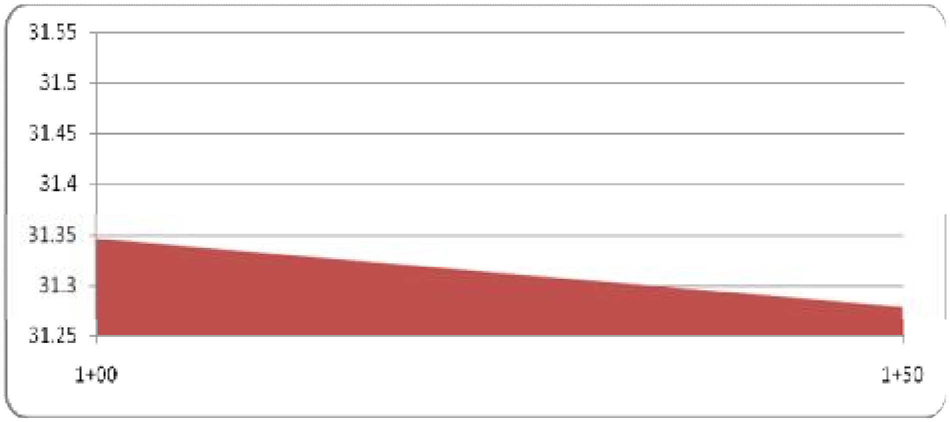


Figure (9). Topographic surface details between two stations obtained from field survey.

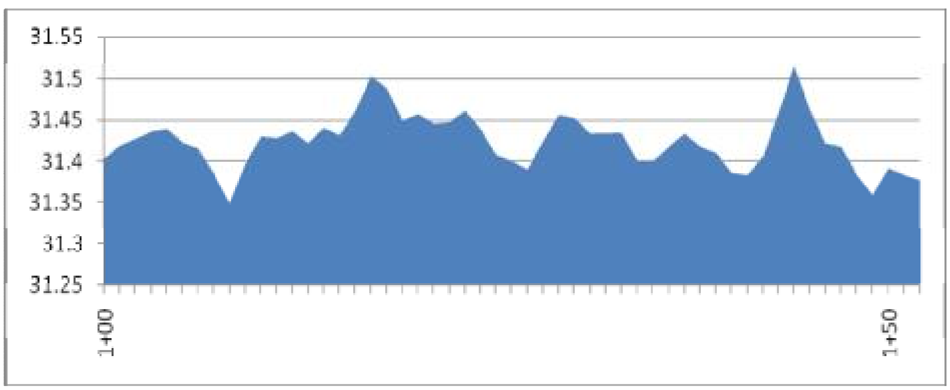


Figure (10). Topographic surface details between two stations obtained from LiDAR scanning.

CONCLUSTIONS

The accuracy assessment by comparing the elevation obtains from LiDAR data with that obtains from the land survey work the absolute vertical accuracy of the LiDAR data.

The study indicates the selection of a suitable method for obtaining the corresponding elevations of stations of road from the LiDAR data can be consider as criterion for the accuracy assessment of LiDAR data.

The elevation differences between the LiDAR data and the field work must be tested to see 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.

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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