ACCURACY ASSESSMENT OF MDL LASER ACE®300 FOR POINT POSITIONING AND 3D MODELING IN FORESTRY APPLICATION

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Abstract

The process of automation towards gathering of tree inventory and the creation of a 3D model for forestry applications are highly demanded. In the present study, a MDL LaserAce®300 was the main equipment used in acquiring three dimensional (3D) surface data of points and tree feature in a forested environment. The results from the field observations conducted, was assessed based on the accuracy attained of the horizontal positions and the constructed 3D model of the forest floor. The planimetric assessment will be based on the standard traversing and tacheometric surveying data sets respectively. In the tree inventory exercise, tree positions are gathered from a known coordinated point. The points are part of a traverse survey station. In this study, the accuracy of the traverse points is evaluated based on the coordinates of eight survey stations forming a closed traverse. The survey stations coordinates are established using MDL LaserAce®300 and a total station (Topcon GTS 235N) respectively. The coordinate for the first survey station was assumed to be N1000, E1000 and the respective coordinates forming the traverse were then computed. The linear misclosure (accuracy) for the traverses are 1: 107 and 1:55017 for MDL LaserAce®300 and total station respectively. On the other hand, the RMSE (Root Mean Square Error) for the computed coordinates established using MDL LaserAce®300 and total station is found to be 1.131 m. With this accuracy, traversing using MDL LaserAce®300 is obviously adequate for forestry application. For the vertical accuracy assessment, an area of approximately 200 x 200 meter within a forest reserve compartment with varying topography of 95 to 102 m above MSL (Mean Sea Level) was chosen. Two sets of DEMs (Digital Elevation Models) were constructed using 235 and 250 points gathered using MDL LaserAce®300 and total station respectively. The targeted 235 points using MDL LaserAce®300 was directed at the middle of a tree trunk at approximately 1.5 m above ground level, which represent the position of observation during the tree inventory exercise. For the observed 250 points using total station, the points are represented by the position of the prism pole, randomly placed to capture the surrounding topography of the study area. In this study, it was found that the accuracy of the constructed MDL LaserAce®300 DEM is ±1.95 m. With these accuracies (planimetric and constructed DEM) obtained, the usage of the MDL LaserAce®300 to support various forest mapping activities such as gathering of tree inventory data, and the construction of the 3D model is justifiable.

Keywords: Measuring Laser, Tree Inventory, 3D model

INTRODUCTION

The rainforest is the world's greatest natural resource and needs to be preserved and managed sustainably. Malaysia, being a tropical rainforest the conservation programme is understood as being part of the activities under the jurisdiction of the Forestry Department, and one of their challenging tasks is to obtain a tree inventory data on selected trees, such as the trees' geo-location with respect to a local reference coordinate system, tree height, diameter breast height (dbh), species type and other associated tree attributes for the development of the Geographic Information System (GIS) database. The process is tedious, time consuming, costly and labour intensive. The identification of individual trees plus tree count is one of the important agendas for inputs to the GIS database.

No doubt, with the advent of GPS (Global Positioning System), positioning of Earth's surface features could be carried out with ease; however, in a forested environment, the effect of tree canopy cover will usually result in blockage of the satellite signal and certainly, would give some restrictions for a good observational record, which ultimately could degrade the accuracy of the position obtained. Furthermore, the height component obtained from handheld GPS is of low accuracy to support the creation of a reliable 3D model. The normal surveying method of gathering tree inventory variables, which involved sophisticated surveying equipments such as the total station and other surveying accessories need trained personnel to execute the task. With the advent of handheld laser equipments such as the MDL LaserAce®300, acquisition of tree position using this equipment seems appealing. MDL LaserAce®300 is equipped with a fluxgate compass that could determine the direction of a sight with respect to the magnetic North. Horizontal and slope distance between the observer and target could also be measured with ease using the MDL LaserAce®300. With this information, spatial information such as, positions of respective points and difference in height between observed and targeted points can be computed using the direction and height information obtained from the MDL LaserAce®300.

Tree counting using laser scanning technology and remotely sensed data sets is an active research agenda. However, inside a forested area, especially in a tropical forest setting consisting of trees of different tree species, the task is quite daunting and cumbersome. Although utilizing techniques that involved the integration of airborne remotely sensed datasets, such as the utilization of hyperspectral and LiDAR (Light Detection and Ranging) data sets could be giving reliable information of the tree attributes that could aid towards creating accurate GIS database of the tree inventory, for instance [1], they may not be so successful in the determination of tree species, *dbh* and height. This is due to the diversity of tree species in a heterogeneous environment which complicate the reflectance response and ultimately do not facilitate the tree identification process via image-based processing analysis techniques [2]. Hence, the success of identifying tree species using remotely sensed data sets is debatable. On the other hand, the construction of a Digital Surface Model (DSM), which depicts the surface and above-surface features for various forest applications, is highly demanded. By having surface models, the tree height component may be estimated accordingly. Laser scanning technology or commonly known as LiDAR seems to be the-state-of-the-art approached in the creation of the digital model, for instance [3]. The construction of Digital Elevation Model (DEM) of the forest floor in a rainforest environment using LiDAR is not an easy or straightforward task since one needs adequate and reliable samples of point-cloud LiDAR data that actually hit the ground or the forest floor. This was made difficult by the obstruction of the canopy cover against the travelling laser pulse signals, the acquisition of these data sets by no means, is cheap and easy. Thus, the development of tree inventory via field-based survey measurement of the tree parameters remains to be ever important for foresters in their daily routine activities.

The acquisition of tree inventory parameters by field-based survey methods is the common practice in Malaysia. The practice, however has some drawbacks, which include the need of more manpower and trained personnel. However, lack of control points, difficulties in determining line of sight coupled with rugged terrain conditions are among the obstacles often faced by foresters and land surveyors.

Among other, drawbacks include, acquisition of the information using conventional surveying techniques needs trained personnel, incurred high cost and time consuming. Field's automation in a tree inventory process seems to be the solution in need to speed up the process of tree inventory survey and data management. The advent of surveying technology such as, hand held laser, namely the MDL LaserAce®300 [4] that could measure distances, the difference in height and bearing automatically with reasonable accuracy. Integrating this equipment with computing technology towards automation in acquiring tree inventory seems feasible. In this study, the capability of the MDL LaserAce®300 towards acquiring tree inventory and Reduced Level (height) in an automated system is investigated. The accuracy of the horizontal and vertical position of points gathered will then be critically assessed with respect to forest application.

METHODOLOGY

In this study, an in-house software known as Automated Spatial Survey Information System (ASSIST) that automates the process of acquiring tree inventory is developed using Visual Basic and C++ high level programming language [5]. This system utilized MDL LaserAce®300 as main hardware. Figure 1.0 shows main menu for ASSIST. Among the main modules incorporated within ASSIST software are shown in Figure. 1.

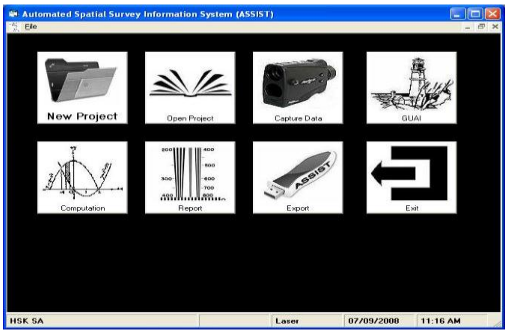


Fig 1. ASSIST Main Menu

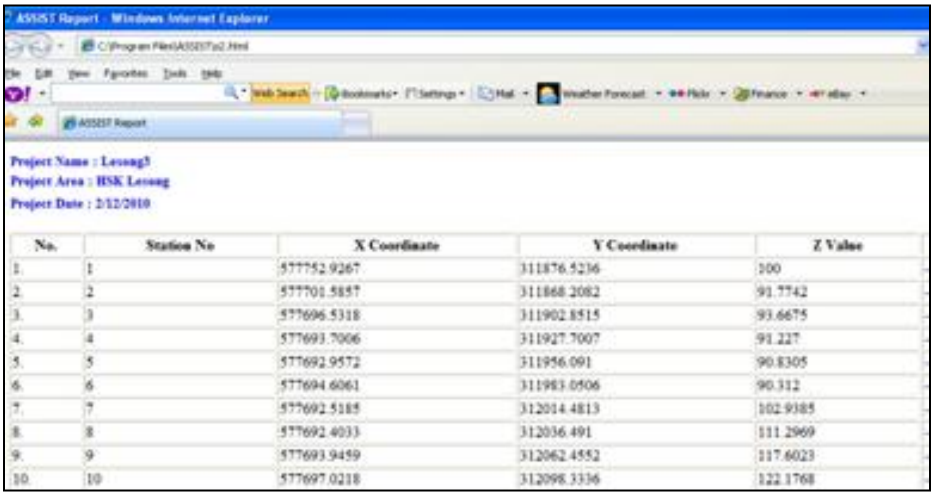
Table 1 gives brief explanation on the associated modules within the software. There are eight (8) main modules with dedicated functions to ensure the process of acquiring tree information will be carried out with ease.

Figure 2, shows an example of the acquired survey stations coordinates from a tree inventory exercise using ASSIST. The information that will be reported includes, the traverse station number and the three-dimensional rectangular coordinates of a survey station (X,Y and Z). It should be pointed out that, in a tree inventory exercise using ASSIST, the first coordinate (X,Y,Z) for the starting Survey Station (Station 1) of the traverse loop should be known.

By knowing the coordinate of Survey Station 1, the coordinate of the next Survey Station (i.e. Station 2) of the traverse can be computed based on the recorded bearing and distance measured by the MDL LaserAce®300. After establishing Survey Station 2, the tree inventory parameter is collected at Survey Station 1.

Table 1. System (modules) within ASSIST

No	Module	Purpose/Capability
1	New Project	Creation of a new project, initialisation for the project is carried out in this module.
2	Open Project	Open an existing project from the database.
3	Capture data	Integration with the MDL LaserAce® 300. Tree inventory database will be created in this module.
4	GUAI	Graphic User Advanced Interface (GUAI) for online viewing, help user to navigate in the rainforest and viewing of the tree inventory coverage.
5	Computation	Standard surveying adjustments on surveyed points and tree positions.
6	Report	Generation of survey report and tree inventory.
7	Export	Export to GIS ready format (shape file).
8	EXIT	Exit the software.



Project Name : Lesong3
Project Area : HSK Lesong
Project Date : 2/12/2010

No.	Station No	X Coordinate	Y Coordinate	Z Value
1.	1	577752.9267	311876.5236	100
2.	2	577701.5857	311868.2082	91.7742
3.	3	577696.5318	311902.8515	93.6675
4.	4	577693.7006	311927.7007	91.227
5.	5	577692.9572	311956.091	90.8305
6.	6	577694.6061	311983.0506	90.312
7.	7	577692.5185	312014.4813	102.9385
8.	8	577692.4033	312036.491	111.2969
9.	9	577693.9459	312062.4552	117.6023
10.	10	577697.0218	312098.3336	122.1768

Fig 2. Information for the traverse

This is done by measuring distances (horizontal, slope and difference in height) to the surrounding trees at a known height (Figure 3) using the MDL LaserAce®300 equipment. The diameter-at-breast height (*dbh*) is computed based on relaskop reading couple with the distance measured by MDL LaserAce®300 to the tree. The tree species are identified manually and chosen from the database, which is embedded within the ASSIST.

The procedure is then repeated on the next survey station until the survey process is completed. The process of traversing that forms a closed loop (start and end at the same survey station) is recommended.

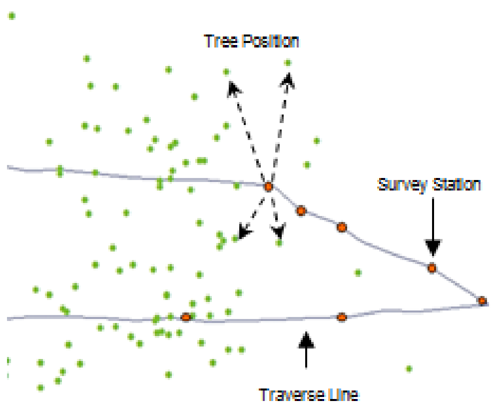
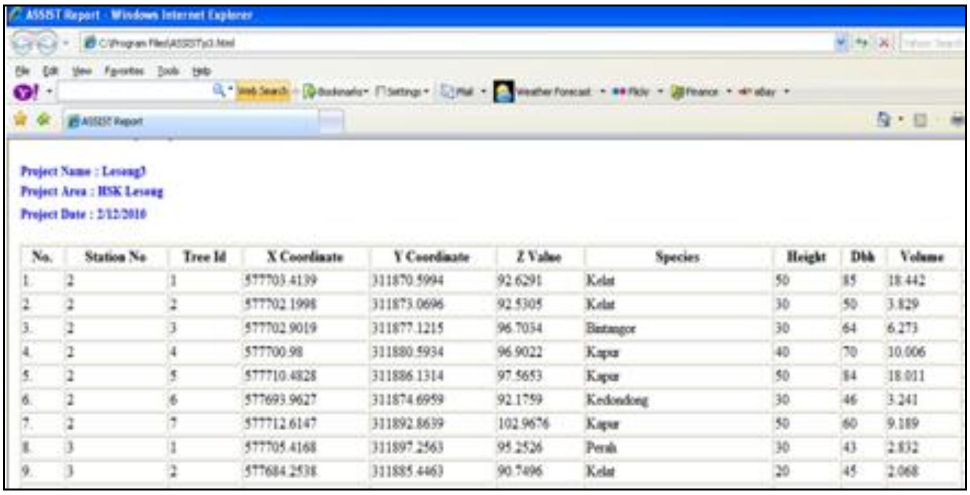


Fig 3. Acquisition of tree inventory from an established survey station

Figure 4, depicts the attribute data for the tree inventory acquired using ASSIST and they include, the Survey Station (from which the coordinates of the tree is acquired), the computed coordinates for the tree position (X-Coordinate, Y-Coordinate), the Reduced Level of the tree position (Z-Value), the tree species, height, *dbh* and Volume (computed).

Referring to Figure 4, based on the computed reduced level (Z Value) of points collected during the tree inventory exercise, Digital Elevation Model for the area could be easily constructed. Fig 5 shows an example of a DEM constructed using the reduced level (Z Value) with the aid of ArcGIS software [6].



Project Name : Lesong3
Project Area : HSK Lesong
Project Date : 2/12/2010

No.	Station No	Tree Id	X Coordinate	Y Coordinate	Z Value	Species	Height	Dbh	Volume
1.	2	1	577703.4139	311870.5994	92.6291	Kelat	50	85	18.442
2.	2	2	577702.1998	311873.0696	92.5305	Kelat	30	50	3.829
3.	2	3	577702.9019	311877.1215	96.7034	Bintangor	30	64	6.273
4.	2	4	577700.98	311880.5934	96.9022	Kapur	40	70	10.006
5.	2	5	577710.4828	311886.1314	97.5653	Kapur	50	84	18.011
6.	2	6	577693.9627	311874.6959	92.1759	Kedondong	30	46	3.241
7.	2	7	577712.6147	311892.8639	102.9676	Kapur	50	60	9.189
8.	3	1	577705.4168	311897.2563	95.2526	Perah	30	43	2.832
9.	3	2	577684.2538	311885.4463	90.7496	Kelat	20	45	2.068

Fig 4. Tree Inventory

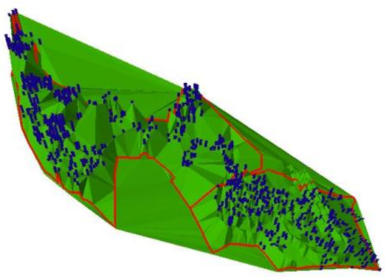


Fig 5. Constructed DEM using Reduced Level information

Instrument and Data

Table 2, shows the equipments used in this study, among the equipments used are Total Station (Topcon GTS 235N) and its accessories, which include tripod and reflector. The Total Station is used to acquire survey points with high accuracy and the points collected will act as the control during the assessment process. Apart from Total Station, the MDL LaserAce®300 (with pole and prism) was also used. MDL LaserAce®300 is the main equipment used in the tree inventory exercise where the points gathered using this equipment will be critically assessed compared to the point's collected using Total Station.

As mentioned, the coordinates of related points can be acquired via measurement made by MDL LaserAce®300. The accuracy of the observed coordinates (X,Y,Z) in supporting forest application need to be checked and determined. In this study, the datasets derived are evaluated based on two components, namely;

i) Horizontal Accuracy, and

ii) Vertical Accuracy

The datasets used to evaluate the horizontal accuracy is based on a closed traverse consisting of eight (8) survey station. The first set (control) survey is carried out using accurate surveying equipment consisting of a Total Station.

Table 2. Major Equipments used in the study

No	Instrument	General Description	Comments
1	 Total Station (Topcon)	Angular Accuracy 1" Distance Accuracy .001m	Acquisition of survey points for traverse and tacheometric points to act as control for assessment
2	 EDM Prism & Tripod	Mount the Total Station (Tripod) and for EDM reflector (Prism)	Part of Total Station accessories
3	 LaserAce® 300	Angular Accuracy 0.1degree Distance Accuracy 0.1m	Acquisition of survey points for traverse and tacheometric points to be accessed its accuracy
4	 Prism With Pole	Adjustable heights, act as LaserAce®300 reflector.	Reflector for MDL LaserAce®300

The second dataset for the closed traverse was measured using the MDL LaserAce®300. Table 3, shows the dataset gathered using Total Station and MDL LaserAce®300.

Table 3. Bearing and distance between total survey station and MDL LaserAce®300

Total Station				MDL Laser			
Station		Bearing	Distance	Station		Bearing	Distance
From	To	(Degree, Min & Sec)		From	To	(Degree, Min & Sec)	
1	2	176 59 26	40.489	1	2	178 00 00	38.2
2	3	258 19 23	58.729	2	3	260 06 00	57.0
3	4	311 36 01	80.215	3	4	312 30 00	79.8
4	5	307 29 00	100.168	4	5	306 00 00	99.5
5	6	354 55 05	120.256	5	6	356 00 00	119.1
6	7	87 00 13	150.990	6	7	85 30 00	152.0
7	8	81 05 03	38.768	7	8	83 06 00	37.8
8	1	175 11 58	196.252	8	1	174 12 00	197.5

For the vertical accuracy assessment, an undulating area of approximately 200 x 200 meters with elevation varying from 95 to 102 meters above Mean Sea Level (MSL) inside a forest reserve compartment is chosen. The selected area represents a natural condition where tree inventory tasking was undertaken. Altogether 250 points were taken as samples and their coordinates (X,Y,Z) were measured and recorded using a Total Station instrument utilizing the Tacheometric Survey technique (act as control) [7]. Whilst another 235 points were gathered using the MDL LaserAce®30, by observing the tree trunk (middle) at approximately 1.5 meters above ground level. Fig 6 shows the distribution of those points across the study area with the point samples representing the Tacheometric and MDL LaserAce@300 respectively. Based on these 3-D point samples, the digital elevation models (DEMs) were generated for both acquired survey techniques using TIN Interpolation method. The digital elevation models are constructed based on the 3D coordinates gathered.

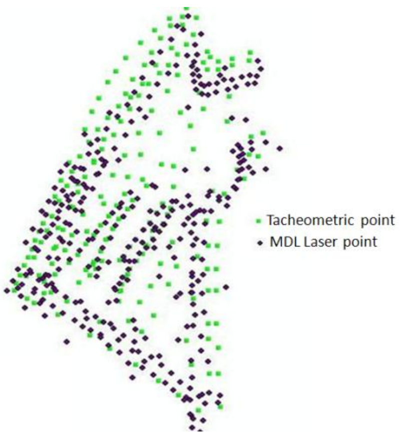


Fig 6. Points distribution acquired using total station and and MDL LaserAce@300

RESULTS AND DISCUSSION

The horizontal and vertical accuracy for the datasets gathered is analyzed quantitatively under the following headings;

Horizontal Accuracy

The accuracy (Linear Misclosed) [7] for both traverse, namely using the Total Station and MDL LaserAce@300 are first determined. Referring to Table 4, the accuracy (Linear Misclosed) for the traverse are 1: 55017 and 1:107 representing standard traversing using Total Station and MDL LaserAce®300 respectively. Since the accuracy for the standard traverse using Total Station exceed

1:8000 for the first class survey [7], the standard traverse will then act as a control in the assessment process.

Table 4. Linear Misclosed

Total Station

Station		Bearing	Distance	Latit	Depart
From	To	(Degree, Min & Sec)			
1	2	176 59 26	40.489	-40.433	2.126
2	3	258 19 23	58.729	-11.886	-57.514
3	4	311 36 01	80.215	53.257	-59.984
4	5	307 29 00	100.168	60.955	-79.486
5	6	354 55 05	120.256	119.783	-10.652
6	7	87 00 13	150.990	7.893	150.784
7	8	81 05 03	38.768	6.008	38.300
8	1	175 11 58	196.252	-195.564	16.424
		Total	785.867	0.014	-0.004
		Linear Misclosed	1: 55017		

MDL Laser

Station		Bearing	Distance	Latit	Depart
From	To	(Degree, Min & Sec)			
1	2	178 00 00	38.2	-38.177	1.333
2	3	260 06 00	57.0	-9.800	-56.151
3	4	312 30 00	79.8	53.912	-58.835
4	5	306 00 00	99.5	58.485	-80.497
5	6	356 00 00	119.1	118.810	-8.308
6	7	85 30 00	152.0	11.926	151.531
7	8	83 06 00	37.8	4.541	37.526
8	1	174 12 00	197.5	-196.489	19.959
		Total	785.9	3.208	6.558
		Linear Misclosed	1: 107		

Referring to Table 4, the *Latit* and *Depart* [7,8] component are computed based on Equation 1 and 2.

Figure 7 shows an example for the position of *Latit* and *Depart* on a surveyed line.

$$Latit = Distance * Cos\ (Bearing) \quad [1]$$

$$Depart = Distance * Sin\ (Bearing) \quad [2]$$

Referring to Fig 7, the *Latit* and *Depart* component for the surveyed line is in the North (+ve) and East (+ve) direction. Bearing is referred to the horizontal angle measured from reference North to the line of sight. In Fig 7, the line of sight is from Station 1 to Station 2.

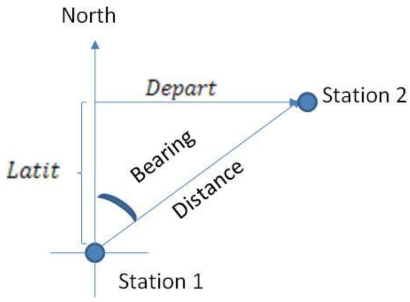


Fig 7. *Latit* and *Depart* for a survey line

Adjustment on the *Latit* and *Depart* obtained (Table 5) was then carried out using the Bowditch Method [7,8] The coordinates for the traverse are then computed by assuming the first point coordinate as N1000, E1000 (Northing, Easting).The different in coordinates between established using Total Station and MDL LaserAce®300 in Northing and Easting are computed (Table 5). The Root Mean Square Error for the different in coordinate is then computed based on Equation 3.

$$RMSE = \sqrt{\left[\frac{1}{n}\sum_{i=1}^{n}(\nabla)^2\right]} \quad [3]$$

$RMSE$ = Root Mean Square Error

n is the total number of points and *i* is the point number

∇ is the different in Northing (dN) or Easting (dE)

Table 5. Difference in established coordinates

Point	Coord Total Station		Coord MDL Laser		dN	dE
	Northing	Easting	Northing	Easting		
1	1000	1000	1000	1000		
2	959.566	1002.126	961.667	1001.012	-2.101	1.114
3	947.679	944.613	951.633	944.383	-3.954	0.230
4	1000.934	884.629	1005.218	884.877	-4.284	-0.248
5	1061.888	805.143	1063.295	803.545	-1.407	1.598
6	1181.669	794.491	1181.609	794.237	0.060	0.254
7	1189.559	945.275	1192.912	944.491	-3.353	0.784
8	1195.567	983.575	1197.298	981.7	-1.731	1.875
				RMSE	2.793	1.076
				$RMSE_{dNdE}$	1.131	

Referring to Table 5, it is shown that using MDL LaserAce®300 for forest mapping seems feasible, the accuracy of the laser in establishing horizontal points is ±1.131m ($RMSE_{dNdE}$). For tree inventory purposes, where the position of the tree should be established with less than ±5 meter [9] of accuracy, MDL LaserAce®300 could play an important role towards forest inventory mapping.

Vertical Accuracy

The vertical accuracy is based on the different in height between the constructed DEMs (Grid size 2m) as shown on the Residual Surface (Figure 8) [10]. In this study, the error seems to occur in step slopes areas, and this might due to the uncertainty in the creation of the model due to the position and number of points gathered to represent the surface. However, further studies on the effect will be an ongoing research agenda.

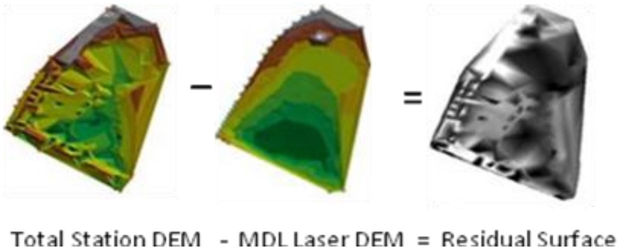


Fig 8. Residual surface

Table 6, shows the computed mean error for the residual surface. The mean is computed based on the total summation of the error with respect to grid count (occurrence) for the surveyed area.

Table 6. Error Count of the Residual surface

Number of Grid Count	Error (Different) in meter	Total Error (Meter)
38	0.5	19
68	1.7	115.6
43	2.2	94.6
18	3.3	59.4
8	4.3	34.4
5	5.5	27.5
Total = 180		(350.5/180) *Mean Error* = 1.95 m

It was known that, Digital Elevation Model (DEM) depicting the forest environment is of high value to a variety of forestry applications, such as designing of logging routes, biomass study and the simulation of flood plain studies. In this study, it was shown that, using MDL LaserAce®300, heights of points can be gathered with reasonable accuracy of less than ±2 meter [9]. In forestry applications, DEM constructed with less than ±5 meter accuracy is sufficient to support a diversity of forestry applications [9].

CONCLUSION

Tree inventory is of high importance in managing forest activities. This study has depicted the capability of MDL LaserAce®300 for tree inventory exercise. It should be pointed out that, during a tree inventory exercise, the position of the tree needs to be determined, therefore, the accuracy of the instrument in used need to be assessed. It was found that the accuracy of the horizontal points (survey station) and the constructed DEM is less than ±2 meters by utilizing the MDL LaserAce®300. The findings from this study are adequate to support data collection for tree inventory and other forestry applications.

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REFERENCES

[1] Abdul Hamid, J. R., Mather, P. M. and Hill, R. A., (2003). Mapping of conifer forest plantations using airborne hyperspectral and Lidar data, (Ed.). *Proceedings of the 23rd Symposium of the European Association of Remote Sensing Laboratories, Ghent, Belgium*, 2-5 June, Millpress.

[2] Nafisah Khalid, Juazer Rizal Abdul Hamid, Abdul Malek Mohd Noor & Zulkiflee Abd Latif. (2011). Synergistic Utilization of Multispectral and LiDAR Data for Tree Crown Delineation. *Proceeding of the 10th International Symposium & Exhibition on Geoinformation 2011 (ISG & ISPRS 2011)*. Shah Alam, Selangor, Malaysia.

[3] Roslina, I., Zulkiflee A. L., and Jasmee, J.,(2011), Accuracy Assessment of Elevation Models Derived from LiDAR, *International Symposium & Exhibition on Geoinformation 2011 (ISG & ISPRS 2011)*. Shah Alam, Selangor, Malaysia.

[4] MDL, (2011), Measurement Device Ltd., http://www.mdl.co.uk/,25 November 2011.

[5] Azman Ali, (2010), Tree Mapping System, *Unpublished MSc thesis*, (University Teknologi MARA, Shah Alam, Malaysia).

[6] ESRI, (1997), *Using ArcView 3D Analyst*, ESRI Inc, California, USA.

[7] Uren, J. and Price, W. F, (1994), *Surveying for Engineers*, (London: The Macmillan Press Ltd).

[8] Irvine, William, (1995), *Surveying for Construction,* McGraw-Hill International (UK) Limited. 4th Edition.

[9] KHALI, A., IBRAHIM, S. and NORIZAN, A. P., (2001), Tree mapping using DGPS as part of precision forestry practices, *Conference on Remote Sensing Technology & GIS in Forestry Application*, Malaysian Centre for Remote Sensing (MACRES), Kuala Lumpur, Malaysia.

[10] Jaafar, J.,(2000), An evaluation of the generation and potential applications of digital surface models, *Unpublished PhD thesis*, (The University of Nottingham, Nottingham, UK).