Trimble Laserace 1000 Accuracy Evaluation for Indoor Data Acquisition

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KEYWORD: Indoor surveying, 3D data acquisition, Laser scanning, Accuracy evaluation

SUMMARY

Surveying includes several techniques for outdoor and indoor data acquisition like photogrammetry, land surveying, remote sensing, Global Positioning System (GPS) and laser scanning. Electronic Distance Measurement (EDM) is reliable and frequently used technique. Photogrammetry can be defined as data acquisition technique for a large area from a fixed and pre-planned distance. Remote sensing uses satellites to capture data from space and laser scanning is the most reliable and precise data acquisition technique which is costly and time consuming compared to the other mentioned techniques. Currently GPS is one of the most used techniques to measure coordinates, distance and angles between points in outdoor environments which have some drawbacks in indoor environment (signal penetration). Currently for indoor surveying, EDM and Terrestrial Laser Scanner (TLS) are mostly used. In this paper, several techniques for indoor 3D building data acquisition have been researched and compared. A new technique of indoor building data acquisition is proposed. This technique is efficient and rapid which acquire shorter time as compared to others, however results show inconsistency in horizontal angle for short distance below than 20 meter in indoor environment which was improved by least square adjustment algorithm. Next phase is to investigate object reconstruction algorithms to optimize measurements.
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1. INTRODUCTION

Traditional land surveying, photogrammetry, remote sensing, GPS and laser scanning are some well-known techniques in the field of surveying engineering which can be used for indoor and outdoor data acquisition. These techniques are explained in this section.

Land surveying

Land surveying can be defined as art of measuring and locating angels, lines and elevation of the surface of the earth, underground working and on the beds of water bodies (U.S. Department of the Interior, 1973). In 1960s first EDM came into existence which was too expensive. High demands for EDM decreased the device price which made it affordable for most professions. EDM is one of the most reliable and used techniques in the field of land surveying which can be used for precise distance measurement and coordinates of any point. New EDM equipment is highly accurate and with the current speed of technology development in surveying engineering more advanced functions for EDM is expected.

Photogrammetry

Photogrammetry can be defined as science of capturing reliable information of the surface of the earth which is non-contact technique. Photogrammetry can be grouped to two parts: measuring and interpretation of captured information (Schenk, 2005). Data acquisition can be divided into four groups: geometric, physical, semantic and temporal information. Digital Terrain Model (DTM), Digital Surface Model (DSM), 2D/3D reconstruction and classification of objects for mapping and visualization are products of photogrammetry (Baltsavias, 1999).

GPS

GPS is a space based satellite navigation system which can provide time and location anywhere on the surface of the earth. GPS is one of the most used data acquisition technique in recent years with high accurate results. GPS is used in outdoor environment in surveying projects and other services such as Location Based Services (LBS). GPS has several drawbacks in indoor environment (penetration problem) (Razavi and Moselhi, 2012).

Remote sensing

Remote sensing is information acquisition from an object without physical contact. Remote sensing can be passive or active. Passive remote sensing uses natural reflection or emission radiation. Sun reflection is the most common source for passive remote sensing. Active remote sensing uses its own sensor radiation. DTM and DSM can be captured by using ALS (LiDAR); this technology (ALS/LiDAR) emits or
captures signals returned from surface of earth. Internal Measuring Unit (IMU), GPS and laser scanning system are three main parts of an ALS system (Tse et al., 2008). Recently, there has been more interest for 3D building modeling based on the LiDAR data but extracting building from huge data is difficult and time consuming which requires experienced technicians.

Laser scanning
Laser scanning includes three types of data acquisition: Terrestrial Laser scanning (TLS), Mobile Laser Scanning (MLS) and Airborne Laser Scanning (ALS).

Focus of this paper is put on indoor surveying and for this project three devices were used: Leica scanstation C10 (laser scanner), Leica 307 TCR (total station) and Trimble LaserAce 1000 (rangefinder). This experiment was done to validate the use of the rangefinder in indoor environment. Model reconstructed from laser scanner was a benchmark.

2. 3D DATA ACQUISITION

Indoor positioning has become an important factor in many different applications but a lack of standard is feeling and there are more challenges encountered in this field (Deak et al., 2012). According to Donath and Thurow (2007), considering various fields of applications for building surveying and various demands, geometry representation of a building is the most crucial aspect of a building survey. Laser scanning technology started in the 1990s (Amato et al., 2003) and it can measure a 3D object surface with high speed of pulse. This technology is considered as a tool for remote and rapid data collection and it can be used in many different applications from regional urban planning to architectural field. A scanner directly can measure distance and reflection intensity of 3D objects surface and store collected data in a database automatically (Dongzhen et al., 2009). Recent TLS technology can collect more than 500,000 points in a second with the accuracy of ±6 mm and in some cases much better high accuracy surveying. The full scanning collects a range of 3D points which is called point clouds. Point clouds consist of 3D coordinates (X, Y and Z) and reflection intensity which can be used in accuracy estimation in post-processes. Point cloud is normally in an unordered list but they can be processed and ordered into a 2D array of point coordinates (range image). Nowadays, most of scanners can export collected point clouds in the range image format directly. An important issue of TLS is that scanners can only acquire points with line of sight. As a result, in order to acquire full data from a given scene, multiple scans from different viewpoints have to be done and then they have to be registered accurately in a common coordinate system. For this project Leica scanstation C10 (laser scanner), Leica 307 TCR (total station) and Trimble LaserAce 1000 (rangefinder) was used (see Figure 1).
This paper describes comparison of 3D building reconstruction from data collected by laser scanner, total station and rangefinder.

3. 3D BUILDING MODELLING AND REPRESENTATION

In a surveying project, data acquisition, processing and modelling will be done separately which is time consuming and costly. This research is an attempt to overcome all procedures of surveying at once. Time and accuracy were considered as two important factors presented by this paper. Rangefinder was connected to a personal laptop via Bluetooth and data capturing and modelling was done simultaneously. For validation of Trimble LaserAce 1000, Leica 307 TCR and Leica scanstation C10 were used. Number of stations and time required for data capturing and modelling for each device has been considered (see Table 1).

<table>
<thead>
<tr>
<th>Surveying Equipment</th>
<th>Time</th>
<th>Number of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leica scanstation C10</td>
<td>600 (Minutes)</td>
<td>4</td>
</tr>
<tr>
<td>Leica 307 TCR</td>
<td>120 (Minutes)</td>
<td>3</td>
</tr>
<tr>
<td>LaserAce 1000</td>
<td>15 (Minutes)</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Time and number of stations for each surveying equipment.

Data collection, processing (pre-processing and post-processing), modelling and representation of laser scanner are considered to as a difficult task to deal which is a drawback of this system and significantly increases time and cost of a project. All laser scanning procedures requires experts.
3D building captured by Leica 307 TCR and Leica scanstation C10 were precise and they showed almost the same results. Trimble LaserAce 1000 showed inconsistent behaviour in distance of below 20 meter in indoor environment with errors in horizontal angle which causes overlapped and rotated models (see Figure 2).

4. RANGEFINDER CALIBRATION

Coordinates measured by rangefinder is not as precise as laser scanner or total station measurement. According to a provided specification accuracy of Leica scanstation C10, Trimble LaserAce 1000 and Leica 307 TCR is shown in Table 2.

<table>
<thead>
<tr>
<th>Surveying Equipment</th>
<th>Distance Accuracy</th>
<th>Horizontal Angle Accuracy</th>
<th>Vertical Angle Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leica scanstation C10</td>
<td>±4 (Millimeter)</td>
<td>12 (Second)</td>
<td>12 (Second)</td>
</tr>
<tr>
<td>Leica 307 TCR</td>
<td>±3 (Millimeter) ±2ppm (Parts per million)</td>
<td>7 (Second)</td>
<td>7 (Second)</td>
</tr>
<tr>
<td>Trimble LaserAce 1000</td>
<td>±100 (Millimeter)</td>
<td>120 (Second)</td>
<td>12 (Second)</td>
</tr>
</tbody>
</table>

Table 2. Accuracy of Leica scanstation C10, Leica 307 TCR and Trimble LaserAce 1000.
3D building measured by LaserAce 1000 can be calibrated and reconstructed from Leica scanstation C10 or Leica 307 TCR based on the least square adjustment algorithm. Least square adjustment is a well-known algorithm in surveying engineering which is used widely by engineers to improve observation data. Least square adjustment for linear (Equation (1)) and non-linear (Equation (2)) systems was used to reconstruct 3D objects.

\[
X = (A^TWA)^{-1}A^TWL = N^{-1}A^TWL \tag{1}
\]

\[
X = (J^TWJ)^{-1}J^TWK = N^{-1}J^TWK \tag{2}
\]

Where \( L \) and \( K \) = observation
\( J \) =Jacobian matrix
\( W \) = observation weights
\( X \) = unknowns
\( A \) = coefficient of unknowns.

Results from calibrating LaserAce 1000 based on the least square adjustment using Leica scanstation C10 data were calculated (see Table 3).

<table>
<thead>
<tr>
<th>Point Number</th>
<th>( X ) LaserAce</th>
<th>( Y ) LaserAce</th>
<th>( Z ) LaserAce</th>
<th>( X ) Leica C10</th>
<th>( Y ) Leica C10</th>
<th>( Z ) Leica C10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-5.787</td>
<td>-16.084</td>
<td>2.695</td>
<td>-5.759</td>
<td>-16.253</td>
<td>2.711</td>
</tr>
<tr>
<td>2</td>
<td>3.171</td>
<td>-13.650</td>
<td>-0.03509</td>
<td>3.188</td>
<td>-13.339</td>
<td>0.002</td>
</tr>
<tr>
<td>3</td>
<td>0.377</td>
<td>-4.921</td>
<td>-0.074</td>
<td>0.378</td>
<td>-4.880</td>
<td>0.002</td>
</tr>
<tr>
<td>4</td>
<td>-8.629</td>
<td>-8.128</td>
<td>-0.035</td>
<td>-8.621</td>
<td>-7.807</td>
<td>0.001</td>
</tr>
<tr>
<td>5</td>
<td>-8.628</td>
<td>-7.965</td>
<td>2.724</td>
<td>-8.621</td>
<td>-7.807</td>
<td>2.713</td>
</tr>
<tr>
<td>6</td>
<td>-5.787</td>
<td>-16.08</td>
<td>2.695</td>
<td>-5.759</td>
<td>-16.253</td>
<td>2.711</td>
</tr>
<tr>
<td>8</td>
<td>0.352</td>
<td>-4.728</td>
<td>2.696</td>
<td>0.379</td>
<td>-4.880</td>
<td>2.711</td>
</tr>
</tbody>
</table>

Table 3. LaserAce 1000 calibration based on the least square adjustment.

Accuracy achieved by least square adjustment was calculated using Equations 3 to 6.

\[
\sigma_X = X_{\text{Laser Ace}} - X_{\text{Leica C10}} \tag{3}
\]

\[
\sigma_Y = Y_{\text{Laser Ace}} - Y_{\text{Leica C10}} \tag{4}
\]

\[
\sigma_Z = Z_{\text{Laser Ace}} - Z_{\text{Leica C10}} \tag{5}
\]

\[
\sigma_{XYZ} = (\sigma_X^2 + \sigma_Y^2 + \sigma_Z^2)^{1/2} \tag{6}
\]

Where \( \sigma_{XYZ} \) = accuracy of LaserAce 1000
\( \sigma_X \) = accuracy of LaserAce 1000 in X Axis
\( \sigma_Y \) = accuracy of LaserAce 1000 in Y Axis
\( \sigma_Z \) = accuracy of LaserAce 1000 in Z Axis

Table 4 shows accuracy of LaserAce 1000 achieved by calibration for selected eight points.
Table 4. Accuracy of LaserAce 1000 achieved by calibration for selected eight points.

Point number four has maximum error of ± 10 centimetres and there is minimum error of ± 0.005 centimetres for point number one (see Table 4). The 3D building calibrated and reconstructed is shown in Figure 3.

![Figure 3. 3D model calibrated and reconstructed based on the least square adjustment. (Trimble LaserAce 1000 (White) and Leica scanstation C10 (Black))](image)

Improved results of rangefinder data (see Figure 3) by least square adjustment is considered to be precise enough for indoor surveying purposes from author’s point of view.

5. CONCLUSION REMARKS

A rapid surveying technique for 3D indoor data acquisition has been proposed and presented. Main objective of this research was to propose a methodology for data capture and 3D modelling simultaneously. Rangefinder was compared to two high accurate surveying devices.
(Leica 307 TCR and Leica scanstation C10). In indoor environment, Trimble LaserAce 1000 showed inconsistency for distance below 20 meter in horizontal angle (see Figure 2). Rangefinder data was improved by least square adjustment which shows maximum error of ±10 centimetres and minimum error of ±0.005 centimetres (see Figure 3). Leica 307 TCR and Leica scanstation C10 had slightly the same results with consistent 3D models (see Figure 2). Authors of this paper intend to investigate object reconstruction algorithms in near future.

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REFERENCES


BIOGRAPHICAL NOTES

Ali Jamali holds an MSc degree in Geoinformatics from Universiti Teknologi Malaysia in Malaysia and a BSc degree in Civil engineering (Surveying engineering) from IAU in Iran. He is currently a PhD researcher with the 3D GIS group of the faculty of Geoinformation and Real Estate at the Universiti Teknologi Malaysia. His current research interest includes indoor surveying and 3D building modeling.

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François Anton is a Senior Lecturer at National Space Institute, Technical University of Denmark in Denmark. He completed his Ph. D. in Computer Science (at the interface of Scientific Computation, Computational Algebraic Geometry and Computational Geometry), at the University of British Columbia, Vancouver, British Columbia, Canada, with courses in Algebraic Geometry and Algebraic Topology from the Department of Mathematics at U.B.C.

Alias Abdul Rahman is a Professor at the Department of Geoinformatics, Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia (UTM), Skudai, Johor. He received a degree in Surveying and Mapping Sciences from North East London Polytechnic, England, UK in 1987, Postgraduate Diploma in GIS from ITC, Netherlands, and MSc in GIS also from ITC, Netherlands. In 2000, he received his PhD degree from the University of Glasgow, Scotland, U.K. He currently leads the 3D GIS research group in the Faculty.

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