Positional Accuracy assessment of features using LiDAR point cloud

Leena Dhruwa [a,*], Pradeep Kumar Garg [b]

[a] Ph.D. Scholar, Department of Civil Engineering, IIT Roorkee, Uttarakhand, India-247667 -leena_d@ce.iitr.ac.in
[b] Department of Civil Engineering, IIT Roorkee, Uttarakhand, India-247667 - p.garg@ce.iitr.ac.in

KEYWORDS: Positional accuracy, Large-scale, Lidar point cloud, Terrestrial Laser Scanner

ABSTRACT:

Nowadays, Light Detection and Ranging (LiDAR) data acquisition technology is gaining popularity due to its accuracy, precision, and rapid data collection. In recent years, many applications have demanded 3-D models and 3-D mapping for fly-through views of cities. LiDAR data is used to map topographic features as well as the height and density of high-rise objects, such as trees and buildings, on the earth's surface. Although there are numerous traditional surveying and space-based technologies existing to determine the elevation or height of any object are time-consuming, inaccurate, and require additional effort. Therefore, the present study focused on developing a large-scale 3D map and accuracy assessment for existing high-rise features in the study area using a Terrestrial Laser Scanner (TLS). Further, LiDAR point cloud data has been used to estimate the position and elevation of the building. It can acquire data anytime, i.e., day and night, and collects more than 1.5 million points per second. The FARO Scene software has been used to process the data, and the processed data is then automatically registered and verified. The point cloud data's overall registration RMSE error is 36 mm. This file with an extension *.LAS format contains the positional coordinates of the features.
The approach provided here for positional accuracy of features with improved accuracy will be helpful for identifying and monitoring the shift and deformations in the buildings and other features. It may also be used for site analysis, planning, and building information modeling.

1. Introduction

Accurate geospatial data is crucial for a wide range of applications, such as urban planning, forestry, infrastructure management, and disaster response. Also, High-quality urban development is vital for regional and global sustainable development (Chen, 2021). LiDAR technology has emerged as an essential tool for acquiring precise and in-depth geographic information due to its ability to capture high-density point clouds of data (Benedek, 2021).

To assure the truthfulness of subsequent analyses and applications, it is essential to evaluate the accuracy of features obtained from LiDAR point clouds (Kim, 2020). This study intends to present an overview of the approaches used for LiDAR point cloud data-based positional accuracy assessment of features.

Many evaluation techniques and standards have been developed to measure the positional accuracy of features retrieved from LiDAR point clouds. The root means square error (RMSE), which assesses the difference between the known ground truth coordinates and the corresponding coordinates generated from LiDAR data, is one frequently used statistic. RMSE provides a numerical assessment of the point cloud's overall positional accuracy (Saba, 2021).

Point cloud registration is another essential aspect of positional accuracy evaluation. In order to create a composite image of the scanned area, point cloud registration involves lining up many point clouds that were taken from various locations or at multiple times. By reducing the differences between overlapping points in several scans, registration techniques strive to increase the accuracy of the fused point cloud.

Furthermore, feature extraction from LiDAR point clouds is a key step in many applications. Features such as buildings, trees, roads, and hydrological networks can be automatically extracted from point clouds using advanced algorithms.[1] With the use of advanced algorithms, point clouds can automatically extract features like structures, trees, roadways, and hydrological networks (Zhu, 2011). As a primary parameter of three-dimensional (3-D) urban form (Sun et al., 2021), the building height is helpful for accurate estimation of the concentration, which is essential in understanding the impacts of the vertical characteristics of urban areas on the environment and human wellbeing (Li, 2020). However, the accuracy of these extracted features is influenced by various factors, that includes the point density, noise, occlusions, the complexity of the objects, how the scans were taken, and the spheres placed were at the appropriate range. Insights on the reliability of the feature extraction process can be gained by evaluating the positional correctness of extracted features (Elkhrachy, 2017).

LiDAR technology offers a number of advantages, while challenges exist in achieving optimal positional accuracy. Certain factors, such as vegetation cover, buildings, and terrain characteristics, can impact the accuracy of LiDAR measurements (Pramod, 2022). Additionally, the data pre-processing steps, such as selecting filters and removing outliers, can affect the accuracy of feature extraction and subsequent accuracy assessment.

This research paper aims to provide the positional accuracy of the features using a Terrestrial Laser Scanner. A comparative analysis with different tool-based assessments has been conducted for positional accuracy assessment. The research will address the challenges associated with LiDAR data processing and provide recommendations for improving accuracy. The findings of this study will contribute to enhancing the reliability and precision of LiDAR-based applications across various domains.

* Corresponding author

2. Study Area

Roorkee is a municipal corporation in the Haridwar district of the Uttarakhand state. Sir Proby Cautly founded Roorkee Municipal Corporation in the year 1868. Indian Institute of Technology (IIT) Roorkee campus, shown in Figure 1, has been chosen as a study area in the Haridwar district. IIT Roorkee, the oldest technical institute in Asia, was formerly known as the University of Roorkee (1949-2001) and Thomason College of Civil Engineering (1847-1949), established by Sir James Thomason in 1847.

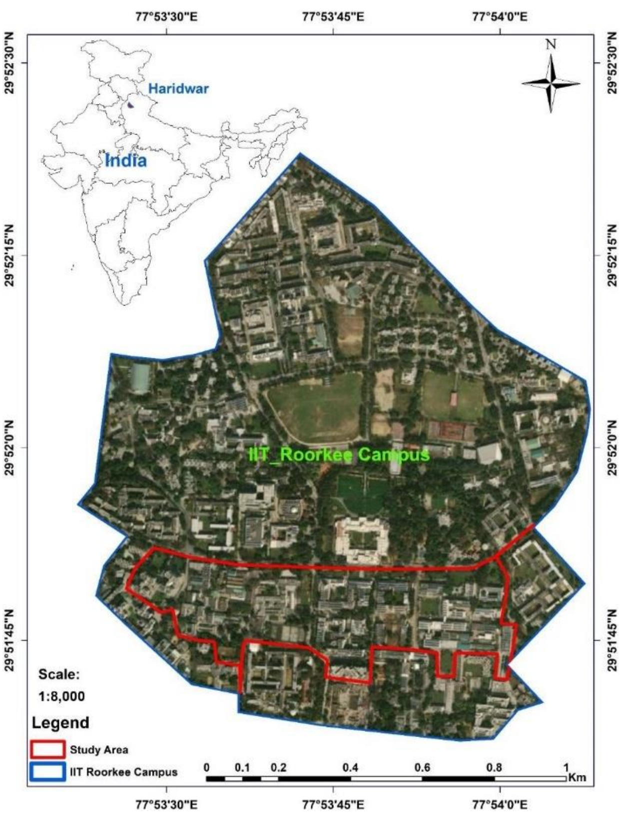

Figure 1- Location map of the study area (IIT Roorkee campus)

The center geographical coordinates of the IIT Roorkee campus are 77°35'45.24" E and 29°51'58.67" N. The total area of the campus is 358.5 acres (1.48 km^2) as per the 2011 census; the total population of Roorkee is 238422, where 35.17% population lives in urban. Roorkee has an average elevation of 268 m. The climatic condition of Roorkee is warm and temperate. Moreover, Roorkee is well connected to India's capital and other important cities of India by road and rail network.

3. Data Used

A building (polygon) feature has been chosen for the purpose of this study.

- The coordinates of all four building corners have been acquired using Differential Global Positioning System (DGPS). The base and receiver of the Sokkia GRX2 have been used in the field for data collection. The instrument's mapping accuracy ranges from 2-3 cm.
- Terrestrial Laser Scanner (TLS) with an accuracy of +-0.0001 (instrumental accuracy) has also been used for acquiring LiDAR point cloud data of the same features.
- Ground control points must be established first to start the survey with a Terrestrial laser scanner; therefore, RTK-GPS and checkerboards have been used to obtain the GCPs. The accuracy of the GCPs survey was found to increase asymptotically with more GCPs (Gindraux, 2017). Further. Table 2. Show the latitude, longitude, and elevation of each GCP acquired before the scans.

Table 2 - Acquired Coordinates of Ground Control Points (GCPs)

S. No	GCPs	Latitude	Longitude	Elevation (m)
1	GCP 1	3307134.6198	780073.6586	221.0125
2	GCP 2	3307129.9839	780070.5256	221.2599
3	GCP 3	3307132.7404	780076.4080	220.6451

4. Methodology

Figure 3 shows the proposed overall methodology flow diagram to obtain the objectives. It comprises four steps: data collection, pre-processing, post-processing of collected data, and result analysis. Further, each module of methodology has been discussed in detail. The adapted methodology for finding the positional accuracy of the features using the LiDAR point cloud is outlined in the following steps:

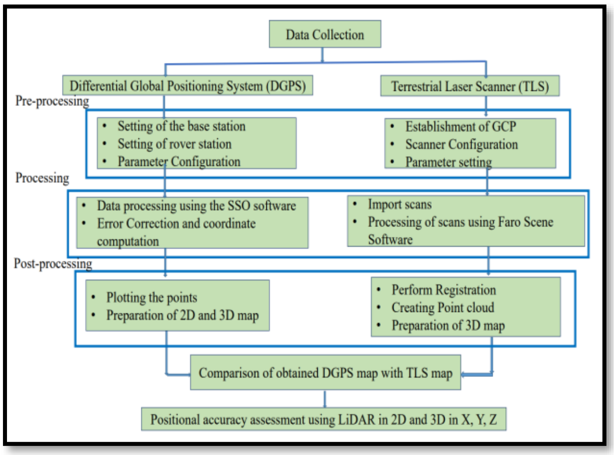

Figure 3- Flow diagram of the methodology

4.1 Data collection

Data collection has been carried out based on the field survey. A differential Global Positioning System (DGPS) via Sokkia GRX2 has been used for the field data collection of the study area. A base station is set static at a point, and the rover is moved to the desired positions. Also, a Terrestrial Laser Scanner (TLS) has been used to collect data in the field. Some parameter setting has been done while using DGPS, such as creating projects, providing the projection system, providing single/dual frequency, elevation mask, height, etc. Similarly, while using TLS, scanner configuration has been done viz, profile setting, i.e., indoor or outdoor, sensor selection resolution/quality setting, and some advanced setting scan point filters, i.e., clear sky, clear contour. All these settings need to be done before starting the scans.

4.2 Ground Control Points (GCPs)

Three Ground Control Points (GCPs) using RTK-GPS and checkerboards placed on the ground have been established in the area of interest for georeferencing of the LiDAR data collected using the Terrestrial Laser Scanner shown in Table 2.

4.3 Data processing

Processing of the data can be done under the following sections:

4.3.1 Preprocessing: It involves all the steps, such as parameter setting and scanner configuration, done for the collection of data. It also consists in importing the raw data to the software for processing.

4.3.2 Processing: Imported data of DGPS has been processed in Spectrum Survey Office software, where all the error correction has been done, and the coordinates are computed. With TLS data, Faro scene software is being used to process all the scans, which need to be imported first then some process configuration setting is done. After that, certain filters were to be applied, and all the scans were processed.

4.3.3 Post-processing: Processed DGPS has been used to plot the data in Arc GIS. But with TLS-processed data, checkerboards and spheres placed during data acquisition were checked for georeferencing or registration, which is to be done for common tie points to recognize features. Then the final result was imported as a .las file and has been further analyzed. Finally, a point cloud has been created.

4.3.4 Positional accuracy assessment: After processing both the tool's data, positional accuracy has been assessed wherein the

DGPS data has been used as a base map to compare the positional shift. Geographic Information System (GIS)is used to find the shifting value between the points taken by the DGPA and the TLS after creating the vector shapefile.

5. Result and Discussion

In this study, two different tools were used to obtain the correct coordinates for a specific area and to show the difference between them based on a map obtained from DGPS data. The result obtained with the two has been compared, and the positional shift in the vertical and horizontal direction has been evaluated. Table 4 shows the shift analysis of the point coordinates of a building feature obtained using TLS compared with the DGPS coordinates. The last column of the table, i.e., the horizontal and vertical shifts, show the RMSE change (Δ) in the planimetric (x, y) accuracy and height z accuracy. The result indicates that the change in the horizontal, i.e., x, y direction is in submeter accuracy except for the two values, which are not in the acceptable limit. The result with vertical shifts shows that the change in the vertical, i.e., z-direction is in meters. Here in that table, the two highlighted values have very high inaccuracy. The result also concluded that the data are more accurate in a 2-

Table 4 – Shift analysis using point coordinates collected by TLS compared to DGPS coordinates (Building feature)

S. No.	Point Code	DGPS			TLS			Horizontal Shift (m)	Vertical Shift (m)
		Latitude	Longitude	Ell. Height (m)	Latitude	Longitude	Ell. Height (m)		
1	C1 Bottom	29.86291693	77.89915733	214.521	29.86295467	77.89915374	224.810	0.000038	**10.289**
2	C1 TOP	29.86296192	77.88415843	231.873	29.86295025	77.89914979	235.330	**0.014991**	3.457
3	C2 Bottom	29.86293247	77.89909272	215.92	29.8631002	77.89796935	224.170	**0.001136**	8.250
4	C2 TOP	29.86280292	77.89799944	237.409	29.86308922	77.8979561	236.040	0.000290	-1.369
5	C3 Bottom	29.86277146	77.89798878	217.16	29.86291812	77.89794401	224.450	0.000153	7.290
6	C3 TOP	29.86303050	77.89913347	244.779	29.86292256	77.89794714	235.410	0.001191	-9.369
7	C4 Bottom	29.86278732	77.89910889	247.504	29.86277739	77.89911561	224.180	0.000012	**-23.324**
8	C4 TOP	29.86291817	77.89915248	245.556	29.86277282	77.89911806	236.000	0.000149	-9.556

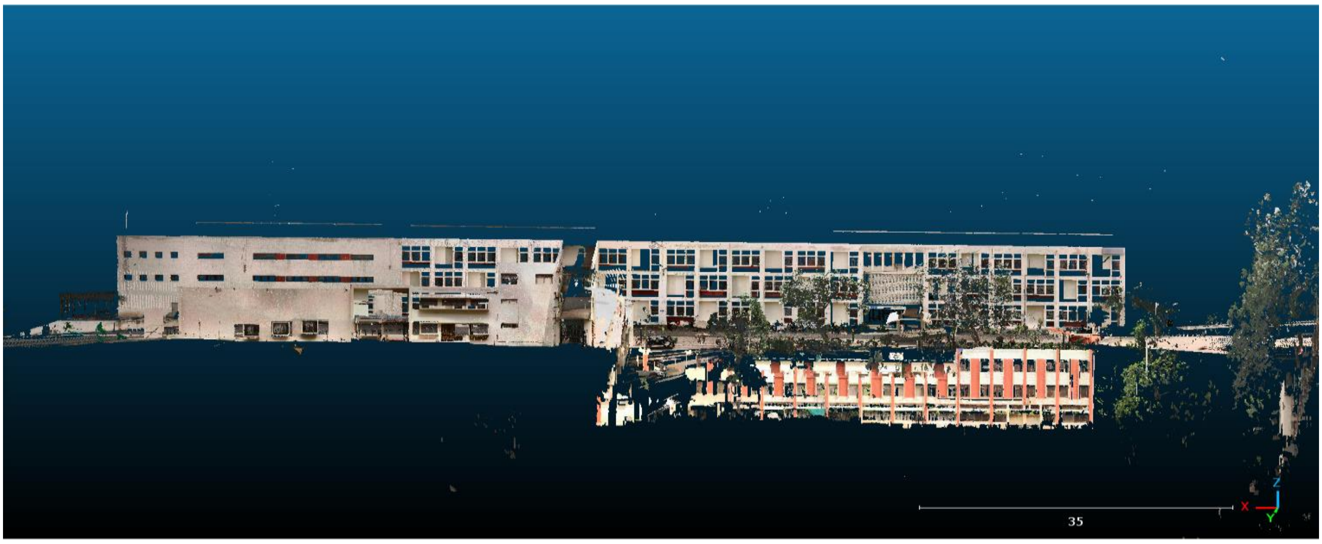

Figure 5 - 3D Map of Civil Engineering Department building using TLS

Dimensional (planimetric accuracy). However, it provides degraded accuracy in 3-Dimensional. The experimental error may occur due to an error in the GPS signal during data acquisition, mainly the multipath error. The result of the study also showed that the accuracy of the large-scale map varied depending on the tool used. The proposed technique may be used to determine the positional accuracy of building (polygon) features.

6. Conclusion

The present article assesses the positional accuracy of features using a Terrestrial Laser Scanner (TLS) viz LiDAR data compared with the Differential Global Positioning System (DGPS) data. The result shows a shift in the positional accuracy in X, Y, and Z axis. Still, this shift is more in the vertical direction, i.e., height accuracy, than the horizontal direction, i.e., planimetric accuracy. The field survey strategy is very precise since all the calculations were performed in the field. In contrast, achieving the objective requires high-end computational facilities and extra human resources. Even though it has been noted that a 3-Dimensional shift is higher, it can still be used for various planning and construction tasks where 3-Dimensional data accuracy is not required. This study uses a 3D absolute accuracy assessment based on geometric features as a standard assessment practice.

A limitation of this 3D accuracy measurement using TLS was that the number of checkpoints was insufficient. Further, it is recommended that more checkpoints/tie-points are required to achieve greater positional accuracy, especially at the corners of the building, leading to more point clouds.

7. Future Work

LiDAR data can be used efficiently for 2-D/3-D mapping to achieve the desired accuracies. So, in the future, the present study may be extended to perform positional accuracy assessment for a few more features with the help of other geospatial tools. Also, the suitability analysis may be performed for the large-scale maps by comparing the accuracy obtained with various geospatial tools. TLS LiDAR data could potentially expedite ground truth surveys in the future, both in terms of the number of checkpoints collected and the speed of the data collection. It is also expected that as information technology advances, 3D laser scanning technology will expand, and the applications of 3D terrestrial scanners in structural analysis and building modeling will become increasingly sophisticated, in-depth, and widespread. Further, procured UAV data may be used for the positional comparative analysis of the features on the ground surface to prepare the large-scale maps.

Acknowledgment

I wish to thank the Indian Institute of Technology (IIT) Roorkee, India, for providing the required resources and infrastructure for the research and my supervisor Professor (Dr) P. K. Garg, for his constant support and guidance throughout the research work. In addition, I would like to express my gratitude to “ASPRS International Symposium 2023” for providing me the student support grant and an opportunity to attend the conference and express our ideas/work globally.

References

Benedek, C., Majdik, A., Nagy, B., Rozsa, Z., Sziranyi, T., 2021. Positioning and perception in LIDAR point clouds”. Digital Signal Processing, Volume 119, 2021,103193, ISSN 1051-2004.

Chen, R. S., Zhao, Z. Q., Xu. Du., Chen, Y., 2021. Progress of research on sustainable development index for cities and urban agglomerations Prog. Geogr., 40 (1), pp. 61-72.

Elkhrachy, I., 2017. Feature Extraction of Laser Scan Data Based on Geometric Properties. J Indian Soc Remote Sens 45, 1–10 (2017).

Gindraux, S., Boesch, R., and Farinotti, D., 2017. Accuracy assessment of digital surface models from unmanned aerial vehicles’ imagery on glaciers. Remote Sensing, 9(2), 186.

Kim, M., Park, S., Irwin, J., McCormick, C., Danielson, J., Stensaas, G., Sampath, A., Bauer, M., Burgess, M., 2020. Positional Accuracy Assessment of Lidar Point Cloud from NAIP/3DEP Pilot Project. *Remote Sens.* **2020**, *12*, 1974.

Li, X., Zhou, Y., Gong, P., Seto, K.C., Clinton N., 2020. Developing a method to estimate building height from Sentinel-1 data Remote Sens. Environ., 240 (2020), p. 111705, 10.1016/j.rse.2020.111705.

Pramod, K., Akshay, M, C., 2022. LIDAR Technology. International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653, Volume 10 Issue V May 2022.

Saba, N., 2021. Accuracy Assessment of Horizontal Measurements from LiDAR Available in Mobile Phones. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 10 Issue 11, November-2021.

Zhu, L., Shortridge, A., Lusch, D., Shi, R., 2011. Feature extraction from 3D lidar point clouds using image processing methods", Proc. SPIE 8159, Lidar Remote Sensing for Environmental Monitoring XII, 81590P (13 September 2011).