Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666

Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

JOURNAL OF INFORMATION SYSTEM AND TECHNOLOGY MANAGEMENT (JISTM)
www.jistm.com

GLOBAL ACADEMIC EXCELLENCE

POINT CLOUD REGISTRATION AND ACCURACY FOR 3D MODELLING - A REVIEW

Ahmad Firdaus Razali[1], Mohd Farid Mohd Ariff[2*], Zulkepli Majid[3*]

[1] Geoinformation Department, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
Email: afirdaus65@graduate.utm.my
[2] Geoinformation Department, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
Email: mfaridma@utm.my
[3] Geoinformation Department, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
Email: zulkeplimajid@utm.my
[*] Corresponding author

Article Info:

Article history:
Received date: 01.10.2021
Revised date: 01.11.2021
Accepted date: 20.11.2021
Published date: 01.12.2021

To cite this document:

Razali, A. F., Ariff, M. F. M., & Majid, Z. (2021). Point Cloud Registration and Accuracy For 3D Modelling - A Review. *Journal of Information System and Technology Management*, *6* (24), 131-138.

DOI: 10.35631/JISTM.624014

Abstract:

Geoinformation is a surveying and mapping field where topography and details on the ground are spatially mapped. The point cloud is one of the data types that is used for measurement and visualisation of Earth features mapping. Point cloud could come from a different source such as terrestrial laser scanned or photogrammetry. The concepts of terrestrial laser scanning and photogrammetry surveying are elaborated in this paper. This paper also presents the method used for point cloud registration; Iterative Closest Point (ICP) and Feature Extraction and Matching (FEM) and the accuracy of laser scanned, and photogrammetric point cloud based on the previous experiments. Experimental analysis conducted in the previous study shows an impressive result on laser scanned point cloud with very mínimum errors compared to photogrammetric point cloud.

Keywords:

Terrestrial Laser Scanning, Photogrammetry, 3D Modelling, Point Cloud

Introduction

Generally, the method of obtaining spatial information and geometry primitives are the advantage of point cloud. Point cloud is a spatial representation of geometry and surface that appear in digital visualisation.

Journal of Information System and Technology Management JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

This paper presents about the conceptual idea and advancement of geospatial technologies and 3D modelling to enhance 3D data acquisition assessment. Table 1 shows the 3D acquisition system involved in geoinformation field.

Table 1 3D Acquisition System

Acquisition system	3D acquisition and modelling
Range-based	Mobile Laser Scanning System
	Terrestrial Laser Scanning
Image-based	Close-range photogrammetry
	Spherical photogrammetry
Systems range or image-based	Remotely Piloted Aircraft Systems (RPAS)
	Unmanned ground vehicle (UGV) system

(Ancona et al., 2015)

Geoinformation Method

Terrestrial Laser Scanning

Terrestrial laser scanning is a method of capturing virtual reality of ground scene through laser emission. The equipment, known as terrestrial laser scanner (TLS) is actually a ground- based version of airborne light detection and ranging (LiDAR). LiDAR sensor, installed in an airborne is frequently used for topography and terrain mapping. Meanwhile TLS, is practically used for capturing as- built or structure on the ground such as roads, buildings, dams, bridges and many more. TLS works without additional personnel to hold a ranging pole or to place targets since it works as an active remote sensing system (Zakaria et al., 2019). This was also supported by (Mettenleiter, 2004).

This can be seen as an advantage for TLS if there is hazardous area such as landfall site becomes the site of interest (Zakaria et al., 2019). Figure 1 shows example of indoor point cloud model. Other than that, TLS has better accuracy and precision, no interference with operations and construction activities and the equipment operating and data processing are also simple (Thomson & Boehm, 2014). The emitted laser signal is received by the sensor system producing distance, triangulation and coordinate positioning of the targeted point. However, the signal emission can be refracted or interrupted if the scanned surface is wet or shiny. Figure 2 shows the transmission and receiving of pulse of light where the time-of-flight measurement takes place.

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

Figure 1 Example of Indoor Point Cloud

Source: (Lachat, Landes, & Grussenmeyer, 2019)

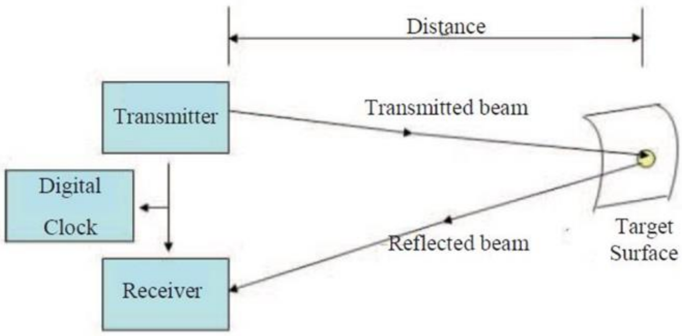

Figure 2 Laser Scanner Principle

Source: (Saptari, Hendriatiningsih, Bagaskara, & Apriani, 2019)

Photogrammetry

Point cloud data captured by camera in photogrammetry surveying is applicable for 3D modelling that is practical for presenting as-built details. The use of SfM software provide an advantage of developing 3D geospatial information of a scene or object as shown in Figure 5. The output from SfM is more than just orthophotos, where point cloud and meshes are the benefit for 3D geometry and 3D data extraction.

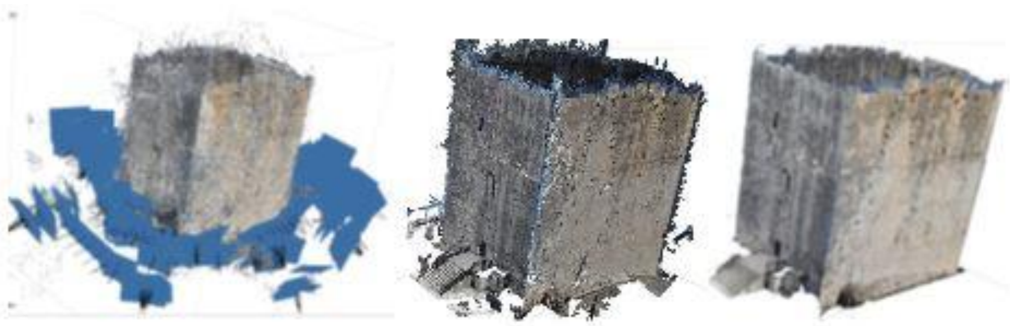

Figure 3 Photogrammetric Point Clouds; from Left, Spare Cloud, Dense Cloud, And Photorealistic Cloud

Source: (Al Khalil, 2020)

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

Phtogrammetry has geometry and spatial primitives which leads to safe, fast and accurate for elaborative detailing (Ahmet & Yakar, 2018). In addition, 3D reconstruction representing shapes and 3D geometry of architecture details can be generated by photogrammetry with the combination of other geodetic tools (Croce, Caroti, Piemonte, & Bevilacqua, 2019).

3D Data Presentation

Laser scanning technology offers relevant and reliable data representation of Earth features and infrastructures on the ground. Table 2 shows the impact of using laser scanning for spatial modelling. The practice of laser scanning for as built infrastructure is compatibly well functioning if this technique is optimized for cleaned and well- defined 3D model Figure 4 shows wireframe 3D model before translated into semantic model.

Table 2 Laser Scanning for 3D Modelling

	Acquisition system	3D acquisition and modelling
1	Data presentation	3D data consists of 3D coordinates positioning and/or spatial data. (Cantoni & Vassena, 2019; Sethuramasamyraja & Mangalapallil, 2014)
2	Data storage	Digital (Maietti, Ferrari, Medici, & Balzani, 2016)
3	Attribute	Dimensional measurement with geometrical primitives scanned data. (Stančić, Roić, Mađer, & Vidović, 2014a)
4	Details monitoring	Improve decision making (Volk, Stengel, & Schultmann, 2014)
5	Location	Scanned data can be overlaid on a map with local coordinate system. (Sethuramasamyraja & Mangalapallil, 2014)
6	Filing system	Asset data are stored and presented in GIS or database (Maietti et al., 2016)

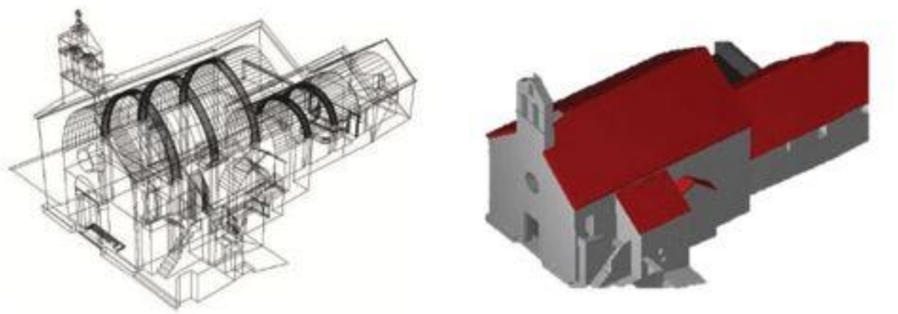

Figure 4 Wireframe 3D Model (Left) and Rendered 3D Model (Right)
Source:(Stančić, Roić, Mađer, & Vidović, 2014b)

Point Cloud Registration

Point cloud registration is the process of points alignment through a rigid body transformation algorithm. Equation 1 shows the basic alignment formula that ICP uses to find rigid body transformation (Stachniss, 2021).

$$\sum_{(i,j)\in C} \left\| y_i - Rx_j - t \right\|^2 \rightarrow min$$

Journal of Information System and Technology Management JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

where,
Y = Point cloud (source)
X = Point cloud (target)
R = Rotation matrix
T = Translation vector

Assuming coordinates of P and Q:
Y = $\{y_i \mid 1 = 1,2,3 \ ...\}$
X = $\{x_i \mid 1 = 1,2,3 \ ...\}$
with correspondences $C = \{(i,j)\}$

ICP uses two sets of data to iteratively refine the transform by repeatedly constructing pairs of related points on the surface and minimizing an error metric (Fujimoto, Kimura, Beniyama, Moriya, & Nakayama, 2009). Meanwhile, Li, Wang, Wang, and Tao (2020) define ICP as the creation of rigorous transformation matrix by iteratively aligning two datasets and searches for point-to-point correspondence.

There is one modern method of point cloud registration known as feature extraction and matching method (FEM). FEM is an improvement method of ICP where it eliminates noise error during the registration process as demonstrated by Liu, Kong, Zhao, Gong, and Han (2018). From a point cloud collection, FEM finds concave or convex points. Any surface with convex or concave points is considered a feature point. Equation 2 shows the determination of concave and convex point (Liu et al., 2018).

Let a point cloud dataset, P;

$$S(p) = \frac{1}{2} - \frac{1}{\pi}\arctan\frac{k_1(p) + k_2(p)}{k_1(p) - k_2(p)}$$

which,

p_i is a local convex point: $S(p_i) > \max\ (S(p_{i1}), S(p_{i2}), \ ..., S(p_{ik}))$
p_i is a local concave point: $S(p_i) < min\ (S(p_{i1}), S(p_{i2}), .., S(p_{ik}))$
$S(p_{i1}), S(p_{i2}), \ ..., S(p_{ik})$ = $S(p)$ value of the point p_i neighbourhood points.

Measurement and Accuracy
Koivumäki, Steinböck, and Haneda (2021) demonstrate an experiment for point cloud accuracy analysis, identifying the effect of processed point cloud and raw point cloud in defining measurement. They discovered that processed point cloud with de-noising processing is accurate compared to raw point cloud which it incapable to reproduce corrected multipath in the measurement, creating spurious reflection that does not exist in the reality. Figure 5 shows the processed point cloud and the raw point clouds.

Journal of Information System and Technology Management JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

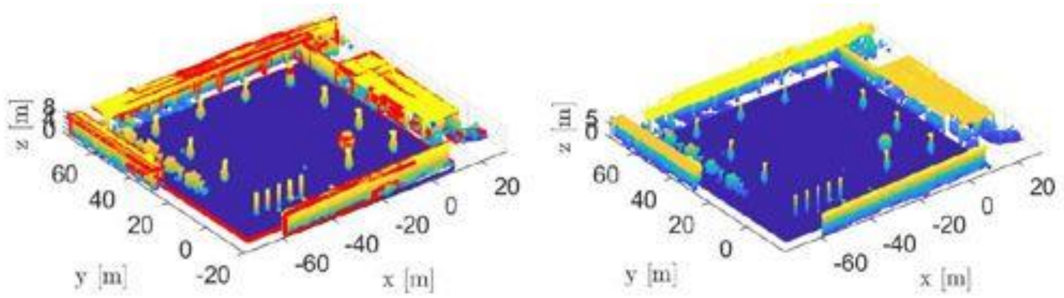

Figure 5 Denoised and Bing Cluster Populated Point Clouds (left) and Pre-Processed Raw Point Clouds

Source: (Koivumäki et al., 2021)

Petschnigg, Spitzner, Weitzendorf, and Pilz (2021) emphasize that integration of scanning method improves point cloud accuracy where number of holes can be reduced and increases the point cloud density. They presented the effect of different point cloud data source; laser scanning and photogrammetry in car factory details representation. The result was surprising where photogrammetry with wide-angle imaging produced 854-point density, the highest number compared to six-scans laser scanning dataset which was only 146.7-point density. However, in terms of accuracy, it was found that the six-scans laser scanning achieved the highest accuracy with ±4.8 mm compared photogrammetry with around ±6 to ±8 mm.

Conclusion

As conclusión, spatial information together with accurate model and mapping can be digitally recorded through point cloud scanning by using several geoinformation method such as terrestrial laser scanning and photogrammetry. The assessment of point cloud registration shall be focused on which method would be the most accurate to solve the rigid body transformation. Experimental analysis conducted in the previous study demonstrated in earlier section shows an impressive result on laser scanned point cloud with very mínimum errors compared to photogrammetric point cloud.

Acknowledgement

The authors highly acknowledge to Universiti Teknologi Malaysia for supporting this study under research grant Vot No. 21H09, 05G12

References

Ahmet, Ş., & Yakar, M. (2018). Photogrammetric modelling of hasbey dar'ülhuffaz (masjid) using an unmanned aerial vehicle. *International Journal of Engineering and Geosciences, 3*(1), 6-11.

Al Khalil, O. (2020). Structure from motion (SfM) photogrammetry as alternative to laser scanning for 3D modelling of historical monuments. *Open Science Journal, 5*(2).

Ancona, M., Clini, P., Dellacasa, A., Falzone, P., La Camera, A., Quattrini, R., . . . Stephens, J. (2015). Extending a mobile device with low-cost 3d modeling and building-scale mapping capabilities, for application in architecture and archaeology. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40*(5), 453.

Cantoni, S., & Vassena, G. (2019). Fast Indoor Mapping To Feed An Indoor Db For Building And Facility Management. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*.

Journal of Information System and Technology Management
JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014
Croce, V., Caroti, G., Piemonte, A., & Bevilacqua, M. G. (2019). *Geomatics for Cultural Heritage conservation: integrated survey and 3D modeling.* Paper presented at the 2019 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage.

Fujimoto, K., Kimura, N., Beniyama, F., Moriya, T., & Nakayama, Y. (2009). Geometric alignment for large point cloud pairs using sparse overlap areas. *Proceedings of SPIE - The International Society for Optical Engineering*. doi:10.1117/12.805765

Koivumäki, P., Steinböck, G., & Haneda, K. (2021). Impacts of point cloud modeling on the accuracy of ray-based multipath propagation simulations. *IEEE Transactions on Antennas and Propagation*.

Lachat, E., Landes, T., & Grussenmeyer, P. (2019). *Comparison of point cloud registration algorithms for better result assessment–towards an open-source solution.* Paper presented at the ISPRS TC II Mid-term Symposium "Towards Photogrammetry 2020.

Li, P., Wang, R., Wang, Y., & Tao, W. (2020). Evaluation of the ICP Algorithm in 3D Point Cloud Registration. *IEEE Access, 8*, 68030-68048. doi:10.1109/ACCESS.2020.2986470

Liu, Y., Kong, D., Zhao, D., Gong, X., & Han, G. (2018). A Point Cloud Registration Algorithm Based on Feature Extraction and Matching. *Mathematical Problems in Engineering, 2018*.

Maietti, F., Ferrari, F., Medici, M., & Balzani, M. (2016). *3D integrated laser scanner survey and modelling for accessing and understanding European cultural assets.* Paper presented at the SBE Malta-Sustainable Built Environment.

Mettenleiter, C. (2004). Terrestrial Laser Scanning–New Perspectives In 3d Surveying.

Petschnigg, C., Spitzner, M., Weitzendorf, L., & Pilz, J. (2021). From a Point Cloud to a Simulation Model—Bayesian Segmentation and Entropy Based Uncertainty Estimation for 3D Modelling. *Entropy, 23*(3), 301. Retrieved from https://www.mdpi.com/1099-4300/23/3/301

Saptari, A. Y., Hendriatiningsih, S., Bagaskara, D., & Apriani, L. (2019). Implementation Of Government Asset Management Using Terrestrial Laser Scanner (Tls) As Part Of Building Information Modelling (BIM). *IIUM Engineering Journal, 20*(1), 49-69.

Sethuramasamyraja, B., & Mangalapallil, D. V. (2014). Infrastructure Asset Mapping Application of Three-Dimensional Laser and Geospatial Technology. *Journal of Multidisciplinary Studies Vol, 3*(2), 89-107.

Stachniss, C. (2021). ICP & Point Cloud Registration - Part 1: Known Data Association & SVD (Cyrill Stachniss, 2021). Retrieved from https://www.youtube.com/watch?v=dhzLQfDBx2Q&t=772s&ab_channel=CyrillStachniss

Stančić, B., Roić, M., Mađer, M., & Vidović, A. (2014a). *Building information management based on total station measurements and laser scanning.* Paper presented at the International Conference on Engineering Surveying INGEO 2014.

Stančić, B., Roić, M., Mađer, M., & Vidović, A. (2014b). *Building information management based on total station measurements and laser scanning.* Paper presented at the Proceedings of the 6th International Conference on Engineering Surveying INGEO 2014.

Thomson, C., & Boehm, J. (2014). *Indoor modelling benchmark for 3D geometry extraction.* Paper presented at the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences-ISPRS Archives.

Journal of Information System and Technology Management JISTM
EISSN: 0128-1666
Volume 6 Issue 24 (December 2021) PP. 131-138
DOI: 10.35631/JISTM.624014

Volk, R., Stengel, J., & Schultmann, F. (2014). Corrigendum to "Building Information Modeling (BIM) for existing buildings—Literature review and future needs"[Autom. Constr. 38 (March 2014) 109–127]. *Automation in Construction*(43), 204.

Zakaria, M., Idris, K., Majid, Z., Ariff, M., Darwin, N., Abbas, M., . . . Aziz, M. (2019). Practical Terrestrial Laser Scanning Field Procedure And Point Cloud Processing For Bim Applications–Tnb Control And Relay Room 132/22KV. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*.