

Using 360-Degree Panoramic Photogrammetry and Laser Scanning Techniques to Create Point Cloud Data: A Comparative Pilot Study

Praseedha Subramanian, M.Sc. and Masoud Gheisari, Ph.D.
University of Florida
Gainesville, Florida

Obtaining information from a volumetric data is possible from a set of data points in space, called a 'point cloud' and this paper aims at comparing the point cloud data generated from 360 Panoramic Photogrammetry technique as an alternative to common Laser Scanning techniques. 360-degree panoramas capture all directions and efficiently cover a full sphere around the capture point creating a large field of view, unlike the 2D capture which provides a still image at a given direction. The objective is to compare these two techniques and extend our understanding of their differences regarding time, cost, and quality. The results of the pilot study show that 360 Panoramic Photogrammetry technique is significantly faster and cheaper compared to the Laser scanning technique and might be an appropriate technique in applications where less level of accuracy would be sufficient.

Keywords: Panoramas, Point Clouds, 360-degree Photogrammetry, Laser Scanning

Introduction

Reality capture is the process of delivering spatial information (i.e., size, shape, position) of a body in its real or as-built state. Construction industry demands as-built information or detailed 3D model for its use in activities such as project documentation (Lerma et al., 2010), quantity take-off (El-Omari & Moselhi, 2008), quality control (Dai & Weibing, 2013), and progress monitoring (Kim et al. 2011). Successful delivery of a construction project involves accurate details and on time capture of as-built information of the site conditions. Laser Scanning and Photogrammetry are two of the primary reality capturing techniques in the construction industry that is being widely used in the present days.

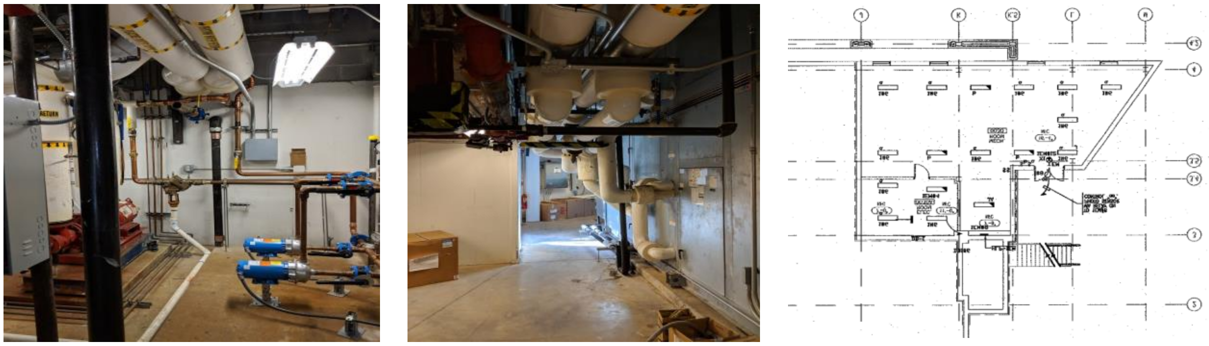
Over the last decade, Laser Scanning has become the dominant technology for reality capture. LiDAR (Light Detection and Ranging) is a surveying method that analyses the real-world scenario by using pulsed laser light to map physical features with high resolution to acquire reliable data. LiDAR is used by shooting laser beams followed by distance measurement at every pointing direction. A LASER (Light Amplification by Stimulated Emission of Radiation) scanner is a device that works by emitting a laser beam to the projected direction and receives it back. It then uses the beam to measure distances from the sensor to the targeted object (Pfeifer & Briese, 2007). The collected data can then be used to construct 3D models. The Laser Scanner market for the forecast period from 2017-2022 is expected to be valued at 5.06 billion U.S. Dollars from the year 2022 (Zion Market Research, 2017). Laser Scanning has been established as a valuable technique in documenting accurate construction data of buildings and prevailing conditions to control their impacts on surrounding systems. The foremost application for such documentation is to evaluate existing as-built settings of old buildings that lack a proper or accurate drawing (Klien et al., 2012). Due to labor-intensive and time-consuming process to perform progress monitoring, Laser Scanning is also widely being used for construction progress documentation in relatively newer projects (Su et al., 2006). The point-cloud data generated by a Laser Scanning technique provide a large quantity of spatial information that is either usually lacking in existing drawings or hard-to-create through manual processes. The rapid improvement of camera systems, software, and computer capabilities have increased the competitiveness of Photogrammetry as another reality capturing technique (Dai & Weibing, 2013). Photogrammetry is the art of obtaining dimensions from photographs, specifically for recovering the exact positions of surface points on-site through Triangulation process. The collected data can then be used to construct three-dimensional digital models and extend its applications henceforward for construction activities.

Although both techniques are used for reality capture, Laser scanning data is comprehensive and provides 3D data from even one scan location whereas in photogrammetry at least two locations are necessary to obtain relatable data (Kolecka, 2011). The primary advantage that Photogrammetry has over laser scanning is the lower cost of the equipment. The cost of a high-quality camera is relatively lower than a commercial laser scanner. On the other hand, Photogrammetry requires prior planning for data acquisition as compared to laser scanning which is spontaneous and provides accurate, fast results (Valenca et al., 2008).

In Photogrammetry technique, a significant amount of time needs to be spent on site to capture many images of objects or environments. The main part of this limitation is because regular high-quality cameras that are being used to capture images are usually limited in their field of view and users are required to capture many 2D images to get the full view of the targeted area or object. In this study, we are proposing the use of 360 panoramic cameras with a large field of view to reduce the time spent on site to capture and decrease the number of image captures on site. A 360 panorama captures everything visible from different positions and can create highly realistic and detailed representations of the environment with an almost full field of view (Bourke, 2014).

Methodology

The primary purpose of the research is to generate the point cloud data using 360 Panoramic Photogrammetry technique and comparing it with Laser Scanning technique, considering factors such as workflows, cost, quality and time. To investigate the proposed study, a pilot study was conducted. A mechanical room of an actual educational building was selected as the pilot study testbed due to its complexity and a considerable number of objects (e.g., pipes and HVAC-related equipment) present in it (Figure 1). Often, Laser Scanning techniques are preferred over conventional tape measures in such complex areas of buildings. Laser Scanning techniques have been in use for more than a decade owing it to its reliability and accuracy. This pilot study is to test the point cloud generated from 360-degree panoramic images and compare it against the point cloud obtained from the Laser Scanning technique thereby considering it as an accepted standard.



a: Interior of the mechanical room b: Floor plan view

Figure 1. Pilot study location; a mechanical room

Hardware Specifications

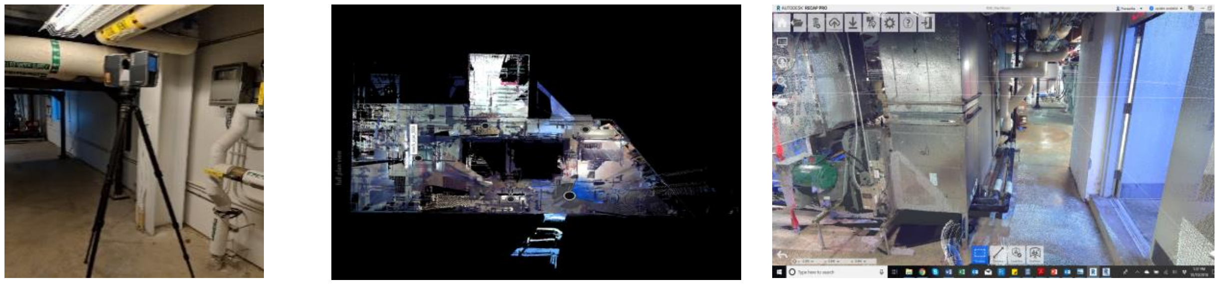
FARO Focus 3D 120 Laser Scanner was used to capture the study location. The scanner was set on ¼ resolution and 4x Indoor HDR quality as read from the specific laser scanner. Insta 360 ONE camera was also used to capture the 360 panoramic images along with an iPad. 360 camera was set on HDR/Indoors resolution/exposure and 24 MP quality. Both Laser Scanner and 360 cameras were mounted on a tripod for capturing purposes. The data processing and point cloud generation were performed on a Dell Inspiron laptop with 1.70 GHz processing speed and 8 GB RAM and Intel ® Core™ i5 – 4210U CPU processor.

Data Capture, Processing and Registration, and Extraction

The general workflow of the pilot study through both 360 Panoramic Photogrammetry and Laser Scanning techniques included the following steps: (a) Data Capture, (b) Processing and Registration, and (c) Data Extraction. This section will further discuss these steps for each reality capturing technique.

Laser Scanning

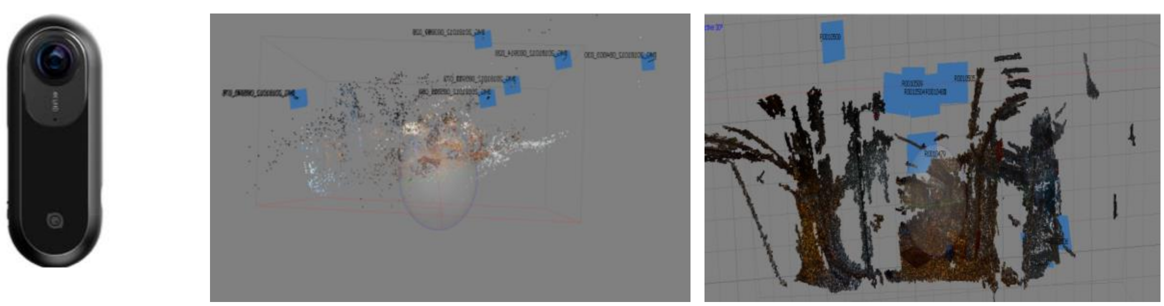
The Laser Scanning equipment was calibrated for its initial settings. The time taken to perform five captures of the site was approximately 75 minutes including setting up and capturing on each location (Figure 1-a). Five locations were selected considering the line of sight and maximum overlap between the current and the successive scans. The scans obtained is in .fls format which is then transferred from the SD card to the computer to begin processing in Recap Pro (version 5.0). As the point clouds comprised of only five scans, the scans were merged by the “auto-registration” feature (Figure 2-b) due to maximum overlap. Also, targets were not used to make the data collection process very similar to 360 data captures. Figure 2-b illustrates the extracted point cloud of the mechanical room from one of the scan locations using Recap Pro software.



(a) Data Capture (b) Processing and Registration (c) Data Extraction
Figure 2. General workflow using Laser Scanning technique

360-Degree Panoramic Photogrammetry

For the 360 Panoramic Photogrammetry technique, Insta 360 ONE camera (Figure 3-a) was leveled and placed at around 20 locations. Several attempts were conducted to find an optimal number of images. Since it was performed under artificial light, no issues were noticed concerning lighting. To secure 80-90% overlap between images the camera was moved to around 20 spots in the mechanical room to capture the 360 images. The total time taken for capturing those 20 captures was around 10 minutes which included the time to set up the camera and capture one image on each spot. Unlike laser scanning technique that required around 12 minutes to do the capture on each scene, the capture time for the 360 images was significantly lower and around 10 seconds for each capture. Then data processing and registration were conducted using Agisoft Photo Scan, a high-quality reliable image processing software package. The workflow involved the standard parameters available in the Agisoft that begins with aligning photos followed by building dense point cloud, building the mesh, and build the texture. The dense point cloud data was built in Agisoft after optimization of the alignment (Figure 3-b). At any phase of the data processing method, point cloud data can be exported in different formats such as OBJ, FBX. After the mesh is built, data extraction is possible by exporting the model produced (Figure 3-c).



(a) Data Capture (b) Processing and Registration (c) Data Extraction
Figure 3. General workflow using 360-Degree Panoramic Photogrammetry technique

Results and Discussion

The pilot study comparing two data capturing techniques of Laser scanning and 360-degree Panoramic Photogrammetry was conducted, and the point cloud results were analyzed considering the factors of time, cost, and quality. The results have been discussed in this section.

Time

One of the main comparisons was the time involved in conducting the pilot study using both techniques and producing the point cloud data. It is noted that although data processing time is not significantly different between two techniques (60 minutes for Laser Scanning vs. 40 minutes for 360 Panoramic Photogrammetry), data capturing time in Laser Scanning was more than seven times slower than capturing 360 panoramas on site. 360 Panoramic Photogrammetry might be a better option when there is a time limit on capturing the data onsite, or there is an active construction zone, where work cannot be put to hold for a long time to do the captures.

Table 1. Time Spent (in minutes)

	Laser Scanning	360 Panoramic Photogrammetry
Data Capturing Time:	75	10
Data Processing Time:	60	40
Total Time:	135	50

Cost

By the comparison between the equipment used for this study, it can be noticed that Photogrammetry techniques are significantly cheaper compared to Laser Scanning. FARO Focus 3D 120 Laser Scanner which was used in the pilot study was bought for $60,000 in 2009, but its price has dropped to $11,200 in 2017 (FARO's Website, 2018) due to very low demand for that old model. High-quality laser scanners currently cost around $65,000 to $185,000 for construction purposes (3D Laser Survey Website, 2018) and the average cost of onsite Laser Scanning service is around $1,500 per day depending on the nature and amount of scanning required (e.g., Arrival 3D Website, 2018). For the 360 Panoramic Photogrammetry, the cost of the equipment used was around $300, and the average cost of onsite captures and photogrammetry are around $600 (e.g. DroneDeploy Website, 2018)

Quality

The Percentage of Error from the actual site was calculated as a measure of the quality of the point cloud data generated through both Laser Scanning and 360 Panoramic Photogrammetry techniques. Percentage of Error can be determined through the following formula and using tape measures on site and point cloud measures from point clouds generated through Laser Scanning and 360 Panoramic Photogrammetry techniques (Figure 4).

$$\text{Percentage of Error} = \frac{\text{Point Cloud Measure Value} - \text{Onsite Tape Measure Value}}{\text{Onsite Tape Measure Value}} \times 100\%$$

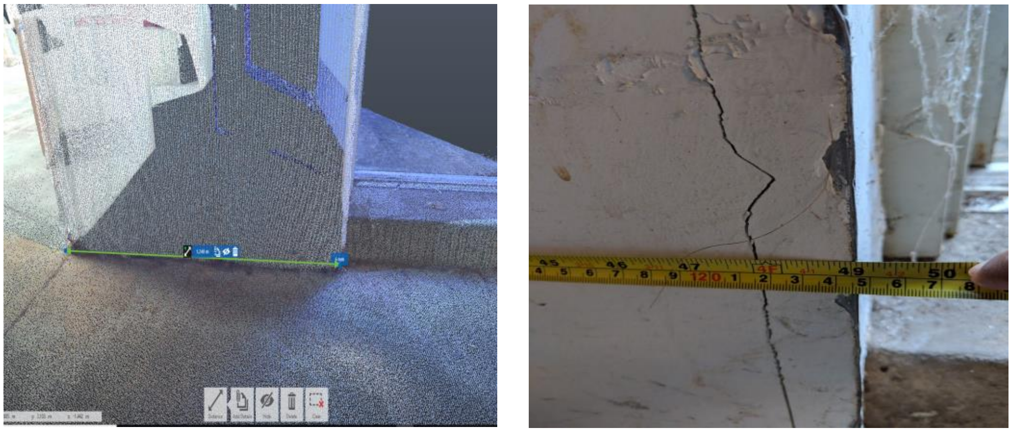


Figure 4. An example of Measurement from Recap Pro and onsite tape measure

To determine the percentage of error or level of accuracy from the point cloud information, ten random locations or objects were selected on site to take the tape measures and then the exact same locations or objects were measured in the point cloud data generated by both techniques. The sample size was selected based on common measurements that were visible in all three comparisons: tape measure, 360 photogrammetry and laser scanning point cloud. The average of the errors in Table 2 shows the quality of point cloud data generated through each technique. As shown in Table 2, 360 panoramic Photogrammetry has around 5-6 percent of error while laser scanning is more accurate with around 2% of error.

Table 2. Percentage of error for 360 photogrammetry and laser scanning techniques

		Value (Ft.)			% Error	
#	Description	Onsite Tape Measure	Point Cloud Measure (360 Photogrammetry)	Point Cloud Measure (Laser Scanning)	360 Photogrammetry	Laser Scanning
1	Wall (Width)	4.15	4.26	4.07	2.65	1.93
2	Column Flange	0.81	0.72	0.79	11.11	2.46
3	Column Web	1.00	0.89	0.96	11.00	4.0
4	Electrical Box (Length)	2.05	1.93	2.02	5.85	1.46
5	Mech Duct (Width)	2.50	2.46	2.49	1.60	0.40
6	Exit signage (Length)	1.40	1.50	1.34	7.14	4.28
7	Door (Width)	3.50	3.38	3.57	3.43	2.00
8	VFD Box (Width)	0.11	0.10	0.11	9.09	0.00
9	Pipe fitting	1.00	0.98	0.99	2.00	1.00
10	Air duct (Width)	2.4	2.35	2.4	2.08	0.00
				Average:	5.60	1.753

Conclusion and Future Research

This study did a pilot test to compare 360 Panoramic Photogrammetry technique against Laser Scanning considering factors such as time consumed, the cost to use each technology, and the quality of generated point cloud data. 360 panoramic cameras with a large field of view would significantly reduce the time spent on site and decrease the number of image captures on site and can be an alternative to regular 2D images with a limited field of view for Photogrammetry purposes. The results show the efficiency of 360 Panoramic Photogrammetry with regards to time and cost as compared to a Laser scanning technique. Although the percentage of error for point cloud data generated by 360 Panoramic Photogrammetry was more than Laser Scanning, 360 Panoramic Photogrammetry might be an appropriate technique in applications where less level of accuracy would be sufficient. A future experiment should be conducted using both 360 Panoramic Photogrammetry and Laser Scanning techniques in a controlled environment to better evaluate their workflow, performance capabilities, challenges, and accuracy to benefit the industry.

Acknowledgements

Thanks, Prof. Raymond Issa, Ralph Tayeh, and Ricardo Eiris from Rinker School of Construction Management at the University of Florida for helping with data collection and review process. The presentation at the conference was also supported by UF DCP Travel Grant Initiative.

References

3D Laser Survey Website (2018). Laser Scanning Systems: To Buy or to Rent? Web. <http://3dlasersurveys.com/2011/laser-scanning-systems-to-buy-or-to-rent/>.

Arrival 3D Website (2018). 3d Scanning Services For Large and Small. Web. <https://arrival3d.com/3d-scanning-services/>.

DroneDeploy Website (2018). How to Price Your Drone Mapping Services. Web. <https://blog.dronedeploy.com/how-to-price-your-drone-mapping-services-b5fc31c86934/>.

El-Omari, S., & Moselhi, O. (2008). Integrating 3D laser scanning and photogrammetry for progress measurement of construction work. Automation in Construction, 18(1), 1-9.

FARO's Website (2018). Laser Scanner for Fast and Exact Indoor and Outdoor Measurements in Three Dimensions: Simply at Your Fingertips. Web. <https://www.faro.com/products/construction-bim-cim/faro-focus/>.

Fei Dai, & Weibing Peng. (2013). *Reality capture in construction engineering applications using close-range Photogrammetry* doi:10.4028/www.scientific.net/AMM.353-356.2795

Kim, C., Son, H., & Kim, C. (2011). The effective acquisition and processing of 3D photogrammetric data from digital Photogrammetry for construction progress measurement. *Computing in civil engineering (2011)* (pp. 178-185)

Klein, L., Li, N., & Becerik-Gerber, B. (2012). Imaged-based verification of as-built documentation of operational buildings. *Automation in Construction, 21*, 161-171.

Kolecka, N. (2012). Photo-based 3d Scanning vs. Laser Scanning - competitive data acquisition methods for digital terrain modelling of steep mountain slopes. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XXXVIII-4/W19*, 203-208. doi:10.5194/isprsarchives-XXXVIII-4-W19-203-2011

Lerma, J. L., Navarro, S., Cabrelles, M., & Villaverde, V. (2010). Terrestrial laser scanning and close-range photogrammetry for 3D archaeological documentation: The upper palaeolithic cave of parpalló as a case study. Journal of Archaeological Science, 37(3), 499-507.

Bourke, Paul. (2014) "The Panorama: Applications to Science and Heritage Visualisation." Lawrence Wilson Art Gallery, Web. <http://paulbourke.net/papers/lawrencewilson/>.

Pfeifer, N., & Briese, C. (2007). Laser Scanning–principles and applications. Paper presented at the *GeoSiberia 2007-International Exhibition and Scientific Congress,*

Su, Y. Y., Hashash, Y., & Liu, L. Y. (2006). Integration of construction as-built data via Laser Scanning with geotechnical monitoring of urban excavation. *Journal of Construction Engineering and Management, 132*(12), 1234-1241.

Valença, J., Júlio, E., & Araújo, H. (2008). Application of photogrammetry to bridge monitoring. Paper presented at the Structural Faults & Repair, 12th International Conference, 10-12.

Zion Market Research (2017). Global 3D Scanning Market Set for Rapid Growth, to Reach Around USD 5.06 Billion by 2022. Web. <https://www.zionmarketresearch.com/news/3d-scanning-market/>.