A Proposal of image-based measurement instead of laser-based measurement for indoor application

To cite this article: J R Hartono and F J Oei 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **1007** 012026

IOP Conf. Series: Materials Science and Engineering 1007 (2020) 012026 doi:10.1088/1757-899X/1007/1/012026

A Proposal of image-based measurement instead of laser-based measurement for indoor application

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Abstract. Measuring dimensions of indoor environment have an important role in construction, whether for calculation of work, or documentation purposes. Humans may introduce errors and make measuring real objects less accurate. Several methods have been developed to reduce this error and one of them is a non-contact measurement that executes according to guideline can minimize this error. Measurement using image-based measurement can reduce human involvement, where Total Station Theodolite (TST) is very dependent on its operator skill and involvement. This study aims to show the differences between image-based and laser-based measurements using TST in measuring the dimension of the indoor environment. Image-based measurement was obtained by taking photos of a few rooms and processed with an open-source software to produce a 3D model. This 3D model then measured to provide measurement for differences comparison. Laser-based measurement was obtained by hiring professional surveyor to measure the rooms with TST. Results from this study can be used as a reference in developing a new method to measure dimension in indoor application. Without hiring professional to measure using photogrammetry in this research, measurement using photogrammetry can get average differences of 0,2593% from measurement using TST.

1. Introduction

Dimensions of room should documented accurately, whether it is for documentation, further work, or marketing purposes. A method that can accurately, easily, and cheaply measure in indoor environment is needed. With expensive equipment and skillful surveyor, measuring using TST could have good accuracy. Photogrammetry had been comparable to TST in accuracy for outdoor use, [1]. With range from camera to object as one that could affect accuracy, [1]. Bringing photogrammetry to indoor use will shorten this range, and hopefully can improve accuracy.

In recent years, the pace of development in mobile photography has raised significantly with every smartphone have multiple cameras in it. Besides that, in-device processing like computational photography also on the rise. This improvement even goes to low-end mobile phones and it makes an entry point for photogrammetry even lower. In software, many open-source photogrammetry programs are being developed. This further helps lowering the cost of photogrammetry which is its main advantage, [2]. Photogrammetry and laser-based have been compared before but this comparison is based on outdoor-used and photos taken from video footage by using drone, [1], [3], [4].

This study tries to find whether photogrammetry as image-based measurement can be used in measuring indoor dimensions, especially in fitting-out construction. To achieve that, this study aims to show the difference between photogrammetry against methods that have been used often in construction. Total Station Theodolite (TST) is selected because of its frequently used in construction. This can give similarity in the comparison and can help this study to be understood and accepted more easily.

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2. Method and materials

2.1. Data Acquisition

The measurement were taken from six newly finished rooms, all have been painted and were about to be fitted out. Room 1, and 2 have a cutout on one of the corner, Room 3 is rectangular, Room 4 is irregular, large and have a column in the center, Room 5, and 6 is narrow and short. Every wall in these rooms marked by A0 newspapers 3 meters apart. The test data for photogrammetry was taken in multiple rooms with a smartphone camera. Photos were taken by facing the wall, and in every 1.2 m distance apart, with a maximum of 3 meters away from the wall. Another set of photos were taken facing inside, perpendicular with the wall, in every 1.2 m distance apart along the wall, and a maximum of 20 cm away from the wall. The first set is taken to cover all walls, and the second set is taken to cover the center of the room, this illustrated in Figure 1. The laser-based measurement was taken by hiring a professional surveyor to measure the rooms with TST. TST measurements were taken with Nikon DTM 322. Both being timed.

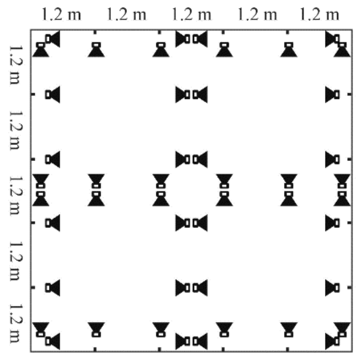

Figure 1. Illustration of camera placement

2.2. Method

All photos were processed by using Meshroom 2019.2 (open-source photogrammetry software) and the result (3D file) then opened in Blender (open-source 3D software) to be measured. Meanwhile, TST measurement data were plotted into AutoCAD file and measured. The measurement by TST was used as a reference and compared with the measurement from photogrammetry.

3. Results and discussion

3.1. Result of photogrammetry measurement

Photos were taken and grouped by room, and processed accordingly. Because photos taken every 1,2m, number of photos taken in every room will be different, longer perimeter of the room means, more photos being taken. This ensure every wall is equally covered in the photos. Figure 2 shown sample photo taken in data acquisition. Figure 3 shown 3D model from photogrammetry which retained the room's shape and texture. Figure 4 shown measurement results taken from Room 1 to Room 4

Figure 2. Sample photos taken in data acquisition

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Figure 3. 3D model from outside (left) and inside (right).

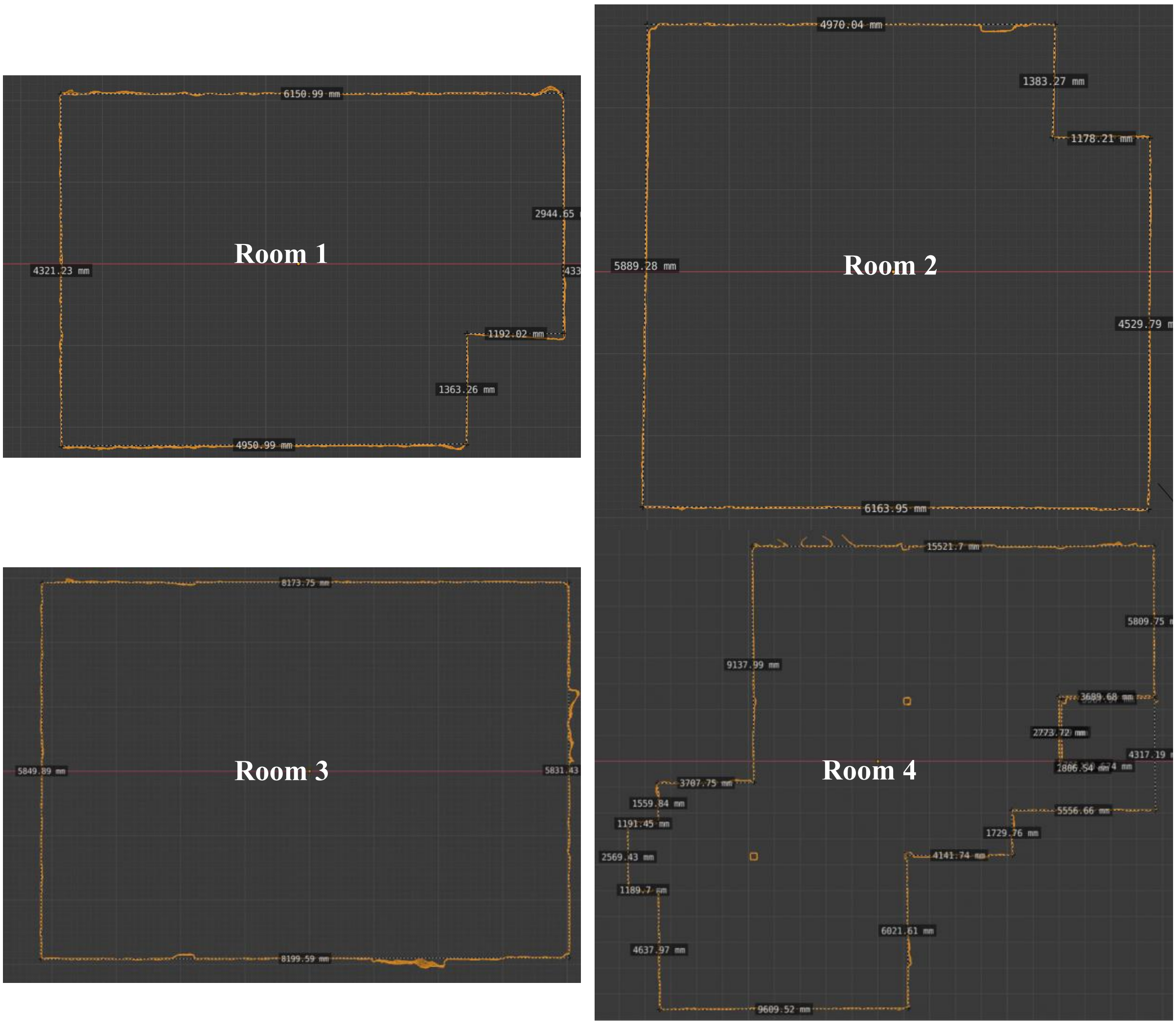


Figure 4. The measurements from 3D model in Blender.

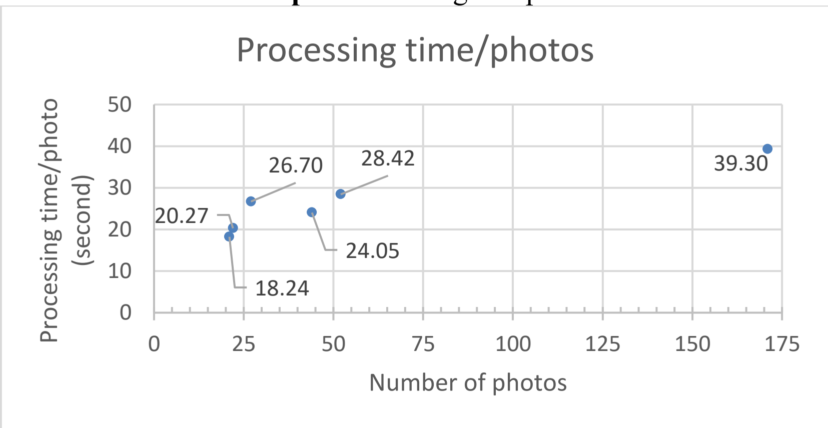
Six rooms were processed but 2 rooms can not be measured because the 3D model that produced, did not have a straight wall. Some of the walls failed to be reproduced in software and the result showed a wavy plane.

Table 1. Photogrammetry process summary

Room	Time		Number of photos taken
	Take photos	3D Processing	
Room I	0:02:15	0:12:01	27
Room II	0:03:37	0:17:38	44
Room III	0:04:19	0:24:38	52
Room IV	0:14:12	1:52:00	171
Room V	0:01:45	0:06:23	21
Room VI	0:01:47	0:07:26	22

Table 1 shows that the processing time increased when the number of the input photos also increased This seems normal, but processing time per photos is increased too with the increase in the number of photos processed. This is shown in the following graph.

Graph 1. Processing time/photo



When processing Room 5 and 6 with 21 and 22 photos respectively, processing time per photos for Room 5 is 18,24 and for Room 6 is 20,27. This trend continue with increasing phtotos that being use Processing time per photos for Room 4 (171 photos) is 39,30s. Increasing number of photos processed also increasing proccessing time for individual photos, becase every feature that extracted from each photos, need to be compared to all features extracted from ohther photos.

This is an important consideration when take photos of an object, more photos will increase processing time per photos. This is because more photos means more features to be compared, and these features need to be compared to all features available to find a matching feature.

3.2. Result of TST measurement

Surveyor measured room on-location took 1 hour 57 minutes and 24 seconds, after that surveyor drew rough estimate of room shape. The next day surveyor sent 2D layout AutoCAD file, this file then checked and there was some mistakes in measurement file. This file then revised and being sent a few hours later. The following is the result from the said file.

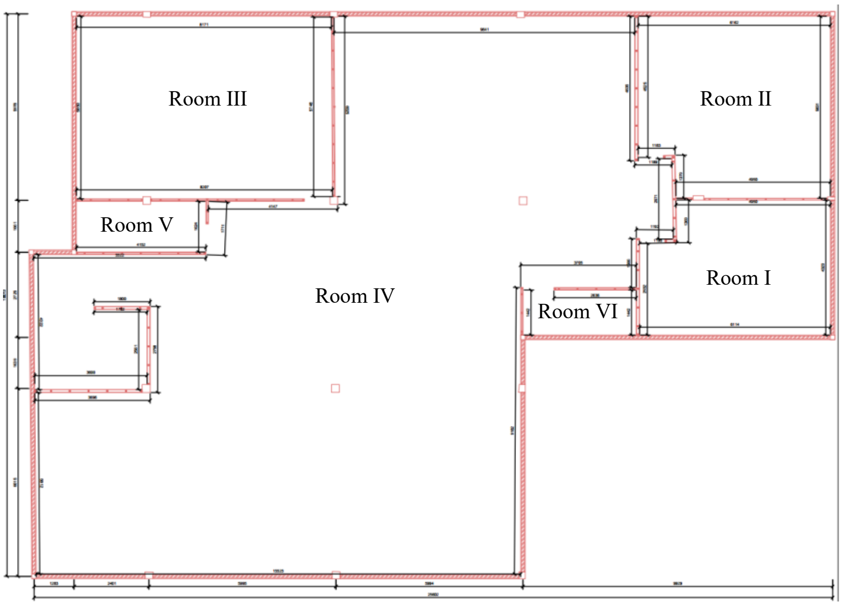


Figure 5. TST measurement result.

3.3. Comparison

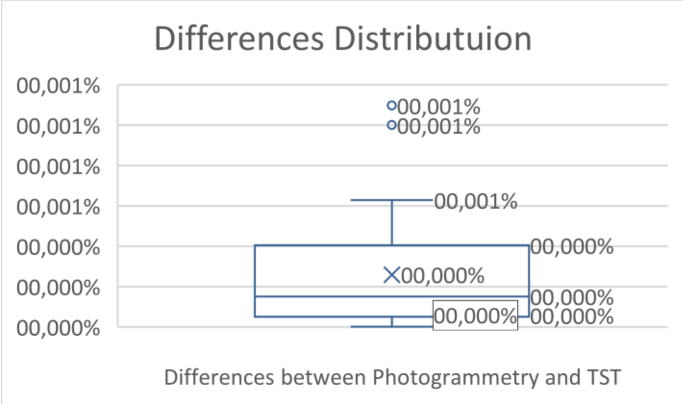
All measurement from Figure 4 being compared with measurement using TST from Figure 5. This comparison is shown in Table 2 below. The difference between measurement using photogrammetry and TST then shown as percentage in Table 2 with TST as reference. This comparison then used for calculating value of χ^2, interquartile range (IQR), and average of the difference between photogrammetry and TST.

Table 2. Comparison of TST and photogrammetry measurement.

Room I			Room IV		
TST	Photogrammetry	Diff (%)	TST	Photogrammetry	Diff (%)
4950 mm	4950,99 mm	0,0200%	15525 mm	15521,7 mm	0,0213%
4323 mm	4321,93 mm	0,0248%	5812 mm	5809,75 mm	0,0387%
6114 mm	6151,28 mm	0,6097%	3696 mm	3689,68 mm	0,1710%
2932 mm	2944,6 mm 5	0,4314%	2758 mm	2773,72 mm	0,5700%
1193 mm	1192,02 mm	0,0821%	1800 mm	1806,54 mm	0,3633%
1369 mm	1363,26 mm	0,4193%	1702 mm	1706,58 mm	0,2691%
Room II			2561 mm	2557,89 mm	0,1214%
TST	Photogrammetry	Diff (%)	3600 mm	3587,97 mm	0,3342%
4950 mm	4970,04 mm	0,4048%	4322 mm	4317,19 mm	0,1113%
5831 mm	5889,28 mm	0,9995%	5522 mm	5556,66 mm	0,6277%
6162 mm	6163,95 mm	0,0316%	1710 mm	1729,76 mm	1,1556%
4525 mm	4529,79 mm	0,1059%	4148 mm	4141,74 mm	0,1509%
1183 mm	1178,21 mm	0,4049%	6025 mm	6021,61 mm	0,0563%
1377 mm	1380,36 mm	0,2440%	9641 mm	9609,52 mm	0,3265%
Room III			4635 mm	4637,97 mm	0,0641%
TST	Photogrammetry	Diff (%)	1189 mm	1189,7 mm	0,0589%
5848 mm	5831,43 mm	0,2833%	2571 mm	2569,43 mm	0,0611%
8171 mm	8173,75 mm	0,0337%	1192 mm	1191,45 mm	0,0461%
5850 mm	5849,89 mm	0,0019%	1566 mm	1559,84 mm	0,3934%
8207 mm	8199,59 mm	0,0903%	3705 mm	3707,75 mm	0,0742%
			9182 mm	9137,99 mm	0,4793%

Graph 2 shows the distribution of differences between TST and photogrammetry in percentage from Table 2.

Graph 2. Distribution of differences between TST and photogrammetry in percentage



From Graph 2, it is shown that the average of differences is 0.2593%, Q1 is 0,0517%, Q3 is 0,4049%, and IQR is 0,3532%. Graph 2 also shown there is two outlier, using Tukey Fences. This can be used by the reader when considering photogrammetry from an accuracy perspective, whether this differences is still under their tolerance.

By using Chi-square analysis to check the goodness of fit, [5] that stated a closer value χ^2 to 0 means the smaller differences between data, the results of both photogrammetry and TST measurements provides χ^2=2,023018628. Value of $\chi^2_{0,05}$ with 36 degrees of freedom = 61.581, which means the photogrammetry measurement is still acceptable, [5].

Another differences between Photogrammetry and TST is the result that was being produced. Photogrammetry produces a 3D model and this 3D model (Figure 3) is comparable to photos that were taken (Figure 2). A 2D layout can also be pulled out from this 3D model, [6] and should there a need to measure the room again, this can be done digitally.

TST is point-to-point measurement only, the surveyor must able to guess how many points are needed, and once there is a point that was not being measured, the surveyor needs to revisit the site. So skillful and experienced surveyor is needed. When comparing the possibility of revisit, photogrammetry has a bigger possibility, because there is no standard in taking photos, this is shown in this research that photogrammetry failed to produce two rooms with the smallest dimension. Further research in photogrammetry limitation is needed for making proper guideline to avoid this.

Photogrammetry relies on registering features on photos and matching those features among the taken photos. The two said failed rooms are very narrow, taking photos in narrow rooms facing a wall, will only capture a small portion of the room. This has made the photos only have very few features that can be matched. This lack of features, hinders software to produced points that will be used to make the 3D model. Adding marker could help to produce a usable model, [6].

When comparing duration needed, photogrammetry took a total of 27 minutes and 55 seconds to take photos on-location and 3 hours and 6 seconds in processing on a 5-years old computer. This also includes the 2 failed rooms. The majority of time is on processing time that was done by computer with minimal human input. In contrast with TST measurement, after 1 hour 57 minutes and 24 seconds on-location measurement, the surveyor needs to draw a rough shape of the rooms to aid in drawing CAD files, the more points that are being measured, more complex this rough shape will be. After that, the surveyor processed the result in their office and the next day surveyor just submitted the measurement file. Some measurements in the drawing were wrong and revision ensued, this revision took a few hours. For those who need to outsource TST service, photogrammetry is more favorable. With an increase in CPU technology from a maximum of 4 cores 8 threads, 5 years ago to 16 cores 32 threads, in last year technology, a lot of time can be reduced.

Other than a higher-technology computer, a stereo-camera can be used to make a real-time 3D mapping, [7]. Stereo-camera with fixed distance also could improve accuracy. And with the decrease of processing time, this 3D model can be made periodically for monitoring, [8].

4. Conclusion

From the using Chi-square analysis to check the goodness of fit, with χ^2=2,023018628, and average differences is 0,2593%, it is concluded that photogrammetry is acceptable compare to TST. However, some factors need to be fulfilled, such as features availability on the measured object. A marker will be needed if there is no feature at all on the object.

Comparing time needed in location to measure length and width of every rooms. Photogrammetry need 27 minutes and 55 second, where TST need 1 hour 57 minutes and 24 seconds. Surveyor then needed 1 day to process and give final measurement, where photogrammetry need 3 hours and 6 second to produce 3d model of the rooms.

Final product that given by surveyor was a room layout with measurement. Photogrammetry produce 3D model that represent real life. This 3d model could be use in future, whether for re-measurement or to calculate the volume. This 3D model will be useful if the room is complex and will reduce the need for site revisit.

Photo acquisition and processing in photogrammetry do not need special skill, this is a major advantage of photogrammetry compared to TST. Almost all steps in photogrammetry can be automated.

This made photogrammetry can be used for periodical monitoring, either for static monitoring with multiple cameras, or single stereo camera, even moving monitoring with line follower and stereo camera for real-time 3D mapping.

Future research could include a comparison with a stereo camera, more markers, and modern equipment to improve time and accuracy or eliminate the need for a specialized worker.

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