



Accuracy Assessment of 3D Model Based on Laser Scan and Photogrammetry Data

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Abstract

A three-dimensional (3D) model extraction represents the best way to reflect the reality in all details. This explains the trends and tendency of many scientific disciplines towards making measurements, calculations and monitoring in various fields using such model. Although there are many ways to produce the 3D model like as images, integration techniques, and laser scanning, however, the quality of their products is not the same in terms of accuracy and detail. This article aims to assess the 3D point clouds model accuracy results from close range images and laser scan data based on Agi soft photoscan and cloud compare software to determine the compatibility of both datasets for several applications. College of Science, Departments of Mathematics and Computer in the University of Baghdad campus were exploited to create the proposed 3D model as this area location, which is one of the distinctive features of the university, allows making measurements freely from all sides. Results of this study supported by statistical analysis including 2 sample T-test and RMSE calculation in addition to visual comparison. Through this research, we note that the laser3D model provides many points in a short time, so it will reduce the field work and also its data is faster in processing to produce a reliable model of the scanned area compared with data derived from photogrammetry, then the difference were computed for all the reference points.

Keywords: 3D model, laser scanner, Agi photoscan, cloud compare, image processing, point cloud.

تقييم دقة النموذج ثلاثي الابعاد بناء على بيانات المسح الليزري والمسح التصويري

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المساحة، الهندسة، بغداد، بغداد، العراق

الخلاصة

D3 يمثل انشاء نموذج ثلاثي الابعاد كأفضل طريقة لمحاكاة الواقع في جميع تفاصيله وهذا ما يفسر مساق العديد من التخصصات العلمية نحو ذلك لإجراء القياسات والحسابات والمراقبة في مختلف المجالات. وعلى الرغم من وجود العديد من الطرائق لإنتاج النموذج ثلاثي الأبعاد مثل الصور وخوارزميات التكامل وأخيراً المسح بالليزر ، إلا أن جودة النموذج المنتج ليست هي نفسها من حيث الدقة والتفاصيل. هذه المقالة تهدف إلى تقييم دقة النموذج ثلاثي الأبعاد الناتج عن كل من الصور القريبة المدى ومسح الليزري حيث استخدم لذلك كل من برنامج Agi photoscan وبرنامج Cloud compare لتحديد مدى ملائمة كل منها للعديد من

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التطبيقات. كما تم اختيار المكتبة المركزية في جامعة بغداد كمنطق دراسة لإنشاء نموذج ثلاثي الأبعاد وذلك كونها إحدى المعالم المميزة للجامعة إضافة إلى موقعها الميداني الذي يعطي حرية لأجراء القياسات من جميع الجهات. وعليه فقد أظهرت نتائج هذه الدراسة المدعمة بالتحليل الإحصائي (بما في ذلك اختبار الفرضية T-test) بالإضافة إلى المقارنة المرئية (أن النموذج الثلاثي الناتج من بيانات الليزر يمكن الاعتماد عليه، وأكثر دقة وأقل تشويهاً مقارنة ببيانات نموذج الصورة.

1. Introduction

The virtual three-dimensional (3D) city model generation is a very novel research topic for engineering and non-engineering scientist. Photogrammetry describes abroad array of techniques used to derive physical measurement from 2D images and digital photogrammetry [1]. The quality of the 3D reconstruction is heavily dependent on the competent and accuracy of dense cloud generator. In photogrammetry, there are many techniques that deal with images to obtain 3D information for models [2]. Close range photogrammetry represents one of the most key tasks to create 3D model. Recently, 3D models were not only generated depending on images in the present of other techniques that utilize laser scanner to create such model. This can be achieved by four different types of laser scanners (Aerial, terrestrial, mobile and space laser scanner). Furthermore, 3D building model is gaining more scientific attention in recent times due to its application in various fields such as vehicle autonomous navigation, urban planning, heritage building documentation, gaming visualisation, agriculture, monitoring and tourism. The quality of the Level of Detail (LoD) of building models relies on the high-resolution data sets obtained for the building. As an alternative to laser scanners, Unmanned Aerial Vehicles (UAV) are efficient in collecting good quality images and generate reliable LoD3 of buildings (i.e. to model both roof and facades of a building) with relatively lower cost and time [3]. Recent studies have shown the usefulness of TLS in quickly measuring field dense point cloud, Such laser scanner use laser light to deliver digital information about objects and stored as point cloud and this technology is widely used in a number of applications as stated earlier [4]. [2]. structure from motion (SFM) is one of the commonest methods used in photogrammetry to derive 3D measurement. This procedure deals with the principle of parallax based on different photographs that captured from different station point and explain the shafts in features images. Gatzolis *et al* [5] proposed a method for monitoring forests especially trees images delivered from a portable camera in UAV and described how the developed technology could represent the natural object also show high performance to provide tree dimensional data for accurate assessment. [6] presented a tool to 3D model of building by combining the Google earth and GIS environment to visualization 3D model for making decision in elevation they applied this tool on Batom city in Indonesia. [7] proposed to use the Aid of loops shooting technology to process the lack in 3D model which delivered from (UAV) that caused by distortion and airflow and they enhanced the accuracy of 3D reconstruction by using the proposed method. 3D reconstruction was examined by Boboc *et al.* [8] to compare models delivered from two different softwares: Tango construction and Agi phoscan software, The results from their examination showed that the data delivered from Tango application provided morphometric data marked by time saving and quickly way to obtain 3D model reconstruction compared with other methods. Additionally, Bori and Hussein [9] also examined a 3D model delivered from different devices. They used smartphone and digital camera with AGI phoscan software to show how could the smartphone to generate 3D model and reported the capability of smartphone to derive a reliable model and the ease of handing with images from smartphone. Additionally, they used the images from Google earth to integrate them with the delivered model to obtain building roofs information. Taking the advantage of the available advanced technology and terrestrial laser scanner, the present research was set to examine a

created 3D model using different data source and processed data with different software to compare model visually and statistically along with explaining the potential benefit for each technology.

2. Methodology

3D-reconstruction of object delivered from images required several steps that must be accomplished to get the 3D model; this will be summarized in this methodology and flowchart (Figure 6). The first step is to configure the Ground Control Points (GCPs) around the study area. This achieved using geodesy receivers (Topcon GR5) based on the static GNSS positioning technique with two hours periodic time which is a step necessary for each technique. Then the captured data from the two different sources collected and processed. The proposed methodology divided in two sections (field and office work) as given below:

2.1 Field work

2.1.1. Generate ground control point

In this stage, the ground control points (GCP) were generated (for georeferenced and check points) in all of the investigated buildings using two device: the first one was Topcon GR5 to generate the base line near the selected building and the other one is Topcon total station to measure all points on the building. A hundred points were measured in field on all sides of the building. Some of these points were used in two steps as as marker in the process step and for the georeferenced step; while other points were used for assessment as check points (Figure 1 explain these points).

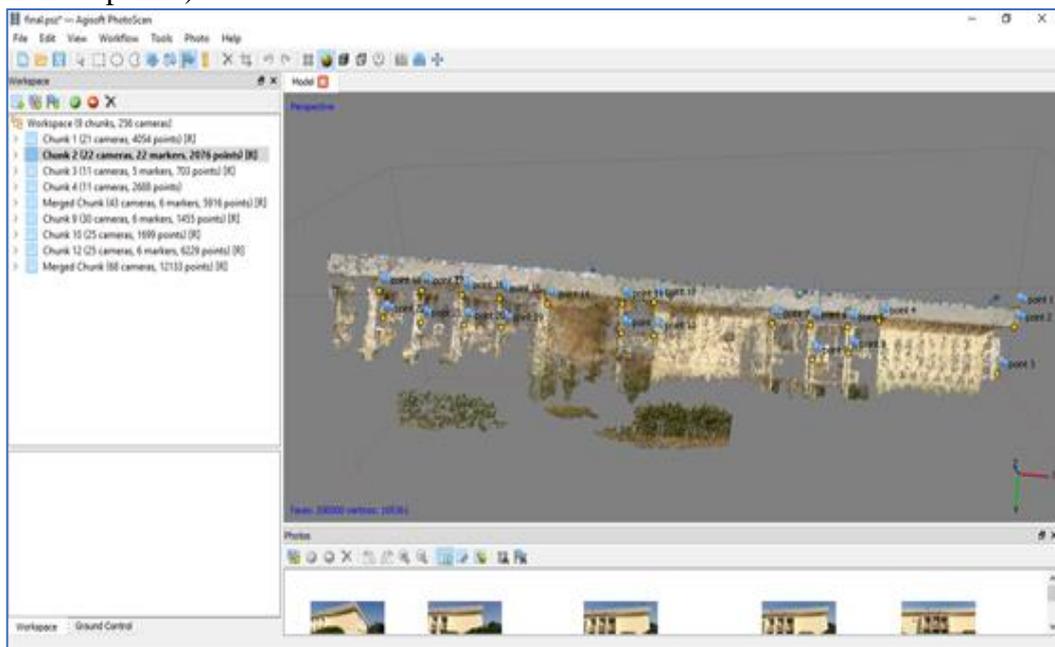


Figure 1-The control points.

2.1.2. Collect images

After measuring all of the generated GCP in the studied building (the building was scanned by 86 images). The images were captured by using Digital Single Lens Reflex camera (DSLR). Then the collected images were used to determine the distance from the building to the user (H) also determine the distance between stations (B)(when the image was captured from different points or stations) to get the best overlap. This setting must be considered before collecting data (images or point cloud), therefore these distances are determined before work begins.

2.1.3. Laser scanner data

To generate 3D model of the building from point cloud, terrestrial laser scanner (Stonex300) was used for this purpose. This device can be controlled using mobile or laptop via Wi-Fi connection. Before the scan starts, several settings should be made afterwards such as, bubble calibration, job name, scan angle, and camera capture. The building was scanned from 16 stations around it to obtain optimum coverage of building and dense point cloud (Figure 2 shows all devices used in field work).



Figure 2-Devises used in the field part of the present study. b- Total station b- Topcon GR5 c- DSLR camera d- Stonexx300 laser scanner.

2.2 Office work

In this part of the study, all data collected in the previous stage were processed using the following steps:

2.2.1. Images processing

The collected images were processed to obtain 3D model using Agi soft photoscan software which is an advanced image based 3D modeling solution to create quality 3D model from still camera. After images added to the software, the markers were distributed on the points which measured in the field. In this regard, several steps must be applied on images loaded in this software: the first one was align images, in this process the camera position at the time of image capture was defined by the interior and exterior orientation parameters. While the second stage involves the generation of dense point cloud. At this stage the points will detected, and the match between photos will achieved. To obtain more detailed PhotoScan could and produce extra dense point cloud the PhotoScan environment from workflow menu is provided with such options. Following markers creation on the points that measured by total station device (not all the points because some points used as a check points for the accuracy assessment), the next step was the software creation of the three -dimensional mesh based on dense point cloud. After that the surface of the building was generated by mesh option. While the final stage from this process involves the built texture (relevant on the mesh). All this process can be found in the Agi photoscan in workflow menu as it illustrated in Figure 3.

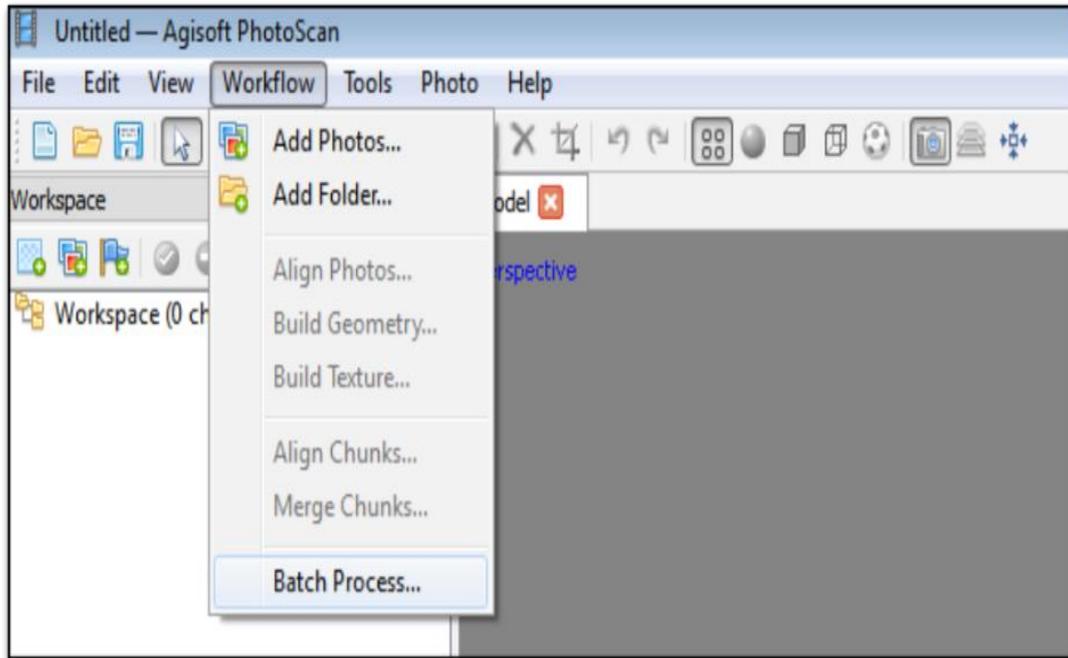


Figure 3-The workflow menu in the Agi photoscan.

2.2.2 Laser data processing

Laser scanner Stonexx300 provided the raw data (x3a) after scanned the selected objects. Thus a file manager is needed to convert the raw data to data have extension that can deal with other software. File manager converts data from x3a into .las data to import it in cloud compare software, is a 3D point cloud be editing and processing software. There are several steps to process data for getting 3D model; the first one is the alignment for each two scan from align option which available in tool menu. (Figure) shows the interface and tool menu of this program).

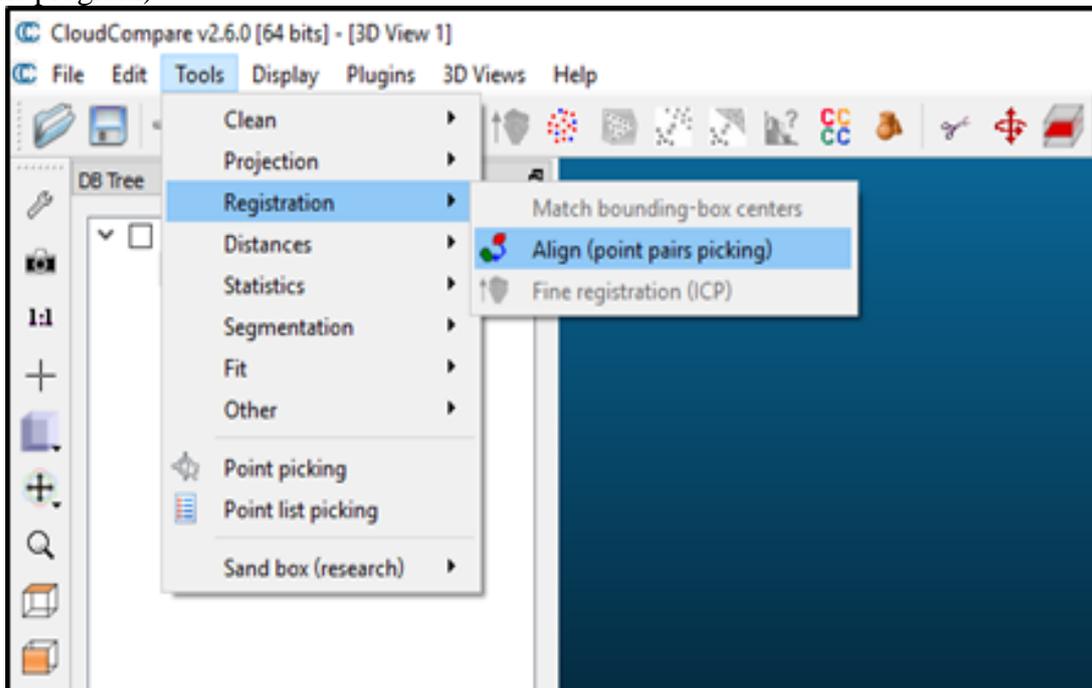


Figure 4-The interface of cloud compares

The software asks the user to pick several pairs of points to register them (manual pick) and give the report about this step for RMSE. In this case the user must make decision about accept or refuse this step according to RMSE and the required accuracy from 3D model. If the user refused it must repeat this process else the final registration step will applied to the data delivered from previous step(Figure 5 explain the selected point for registration).

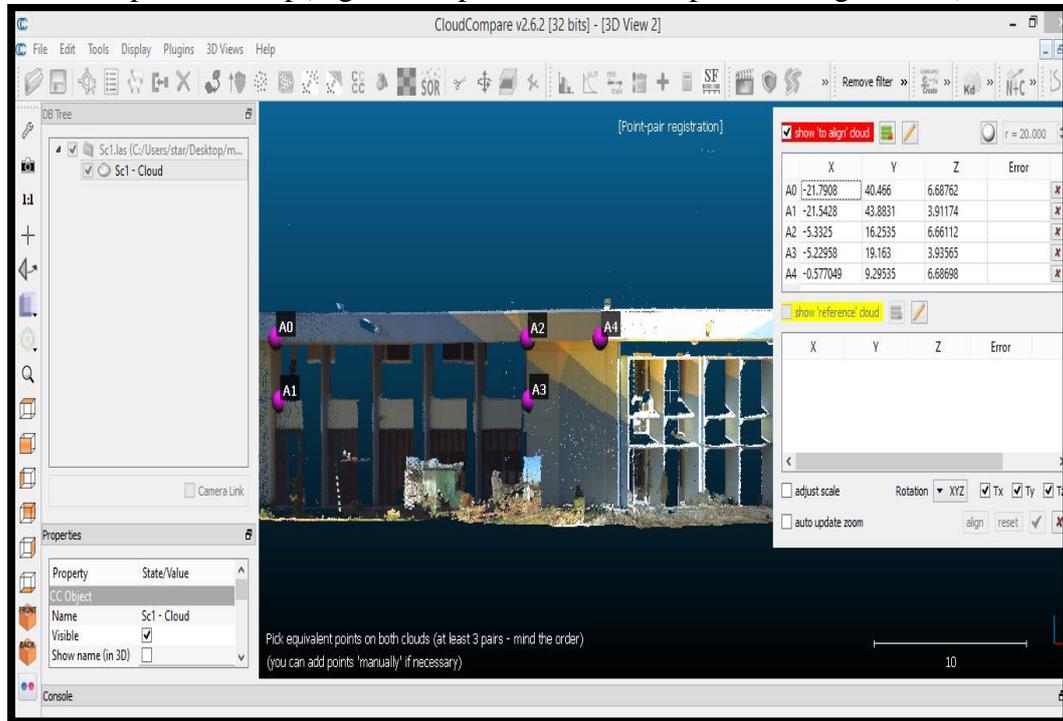


Figure 5-The align (registration) step.

The next step is final registration, which is included the Iterative Closet point algorithm (ICP). This step was automatically occurs after identifying the reference and moved scans. At the end of this stage the 3D model was generated from 16 scans(the final model shown in results section). To obtain model with a real coordinate, the georeferenced step was applied on the generated model using registration tools in the cloud compare software. This required identifying GCPs which have the real coordinate in software and input coordinate for each point to transformation all points to the real coordinate (Figure 6 show all steps of methodology in flowchart).

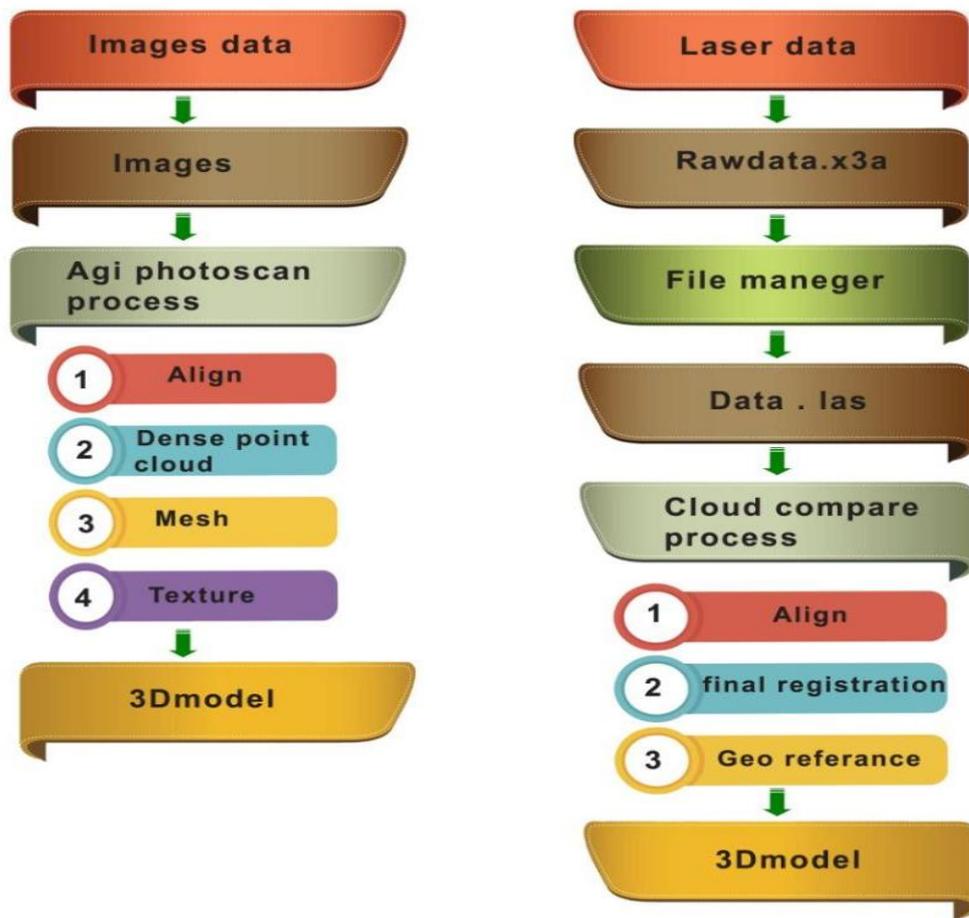


Figure 6-Flow chart of the methodology.

3. Results and discussion

In this research the 3D model was compared by using two different data after applying all steps which explained in the methodology. The obtained results from each step are given in the below sections:

3.1 Results from image data

Agi soft photoscan software was used to process images to create 3D model. Figure 7 explains the model delivered from the first steps in this software (adding photos and align these photos to generate 3D points cloud from 2D images).

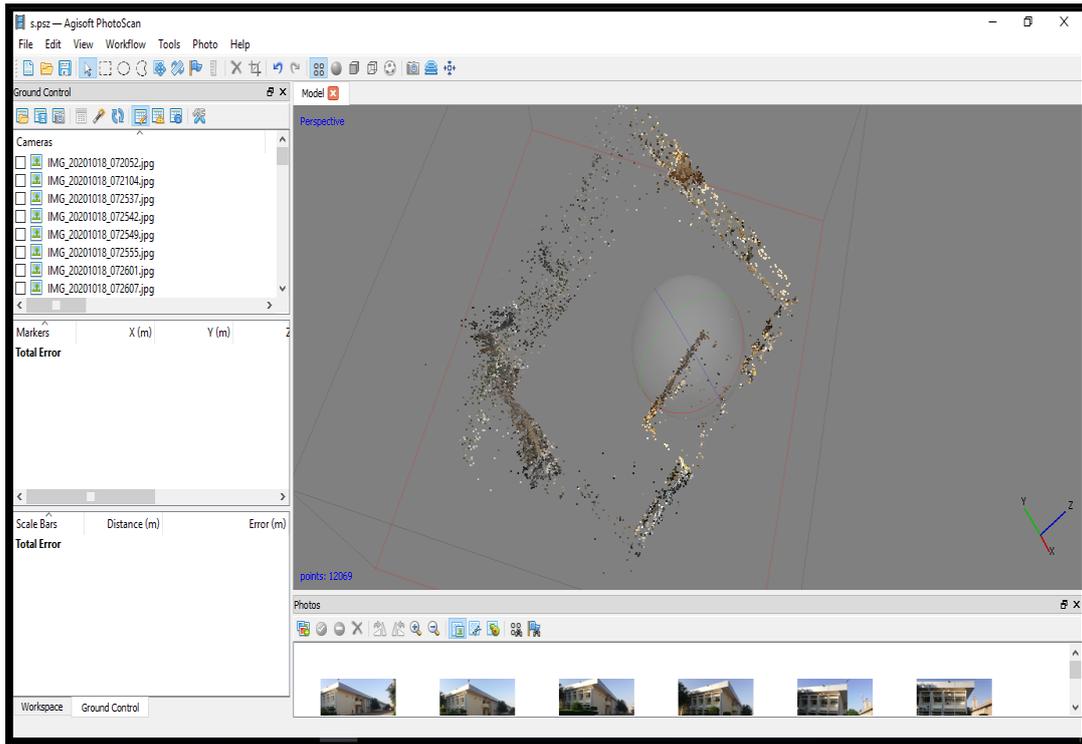


Figure 7-Points cloud from images.

The other steps involving the dense point and texture generation to obtain the final model from selected building (Figure 8 explain the results from these steps).

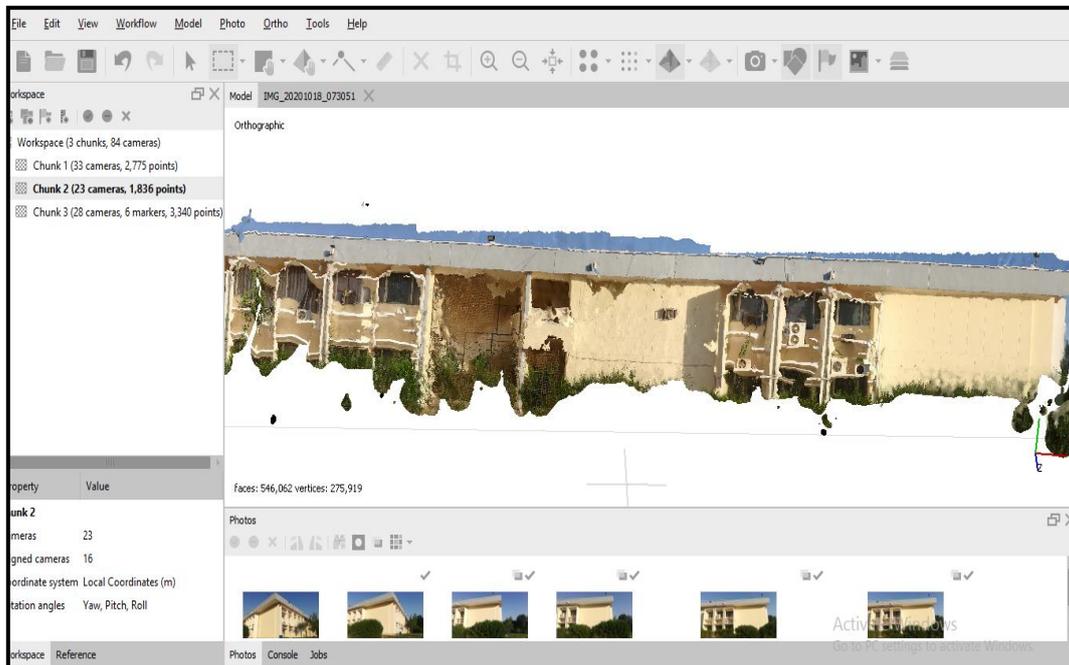


Figure 8-The surface from images.

The process of images handling using Agi photoscan required high performance computer which it insulted in. Models generated from 2D images were influenced by several factors such as the weather and shadow when the images were captured. In addition to the barrier around the building such as the tree and another buildings. These barriers make obstruction

when images were processed in this software (Figure 9 shows the final model for the building delivered by images with some blocking caused by tree).



Figure 9-The final model for the selected object.

3.2 Results from laser data

Cloud compare software was used to process the laser data and generate 3D point cloud for the selected building. Figure 10 shows the data loaded and aligned in this software. In the beginning of the process, the software requires to identify which scan is reference also which scan can be aligned.

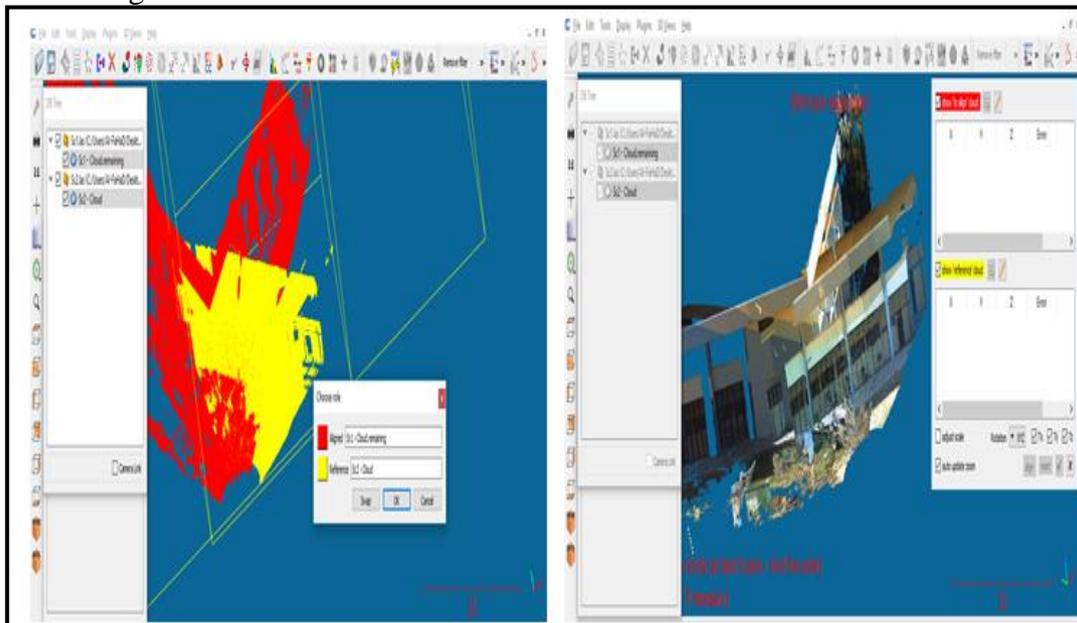


Figure 10-The align process

To obtain model with a real coordinate for any measurement, the final registration was applied on model delivered from previous step (Figure 11 shows the steps).

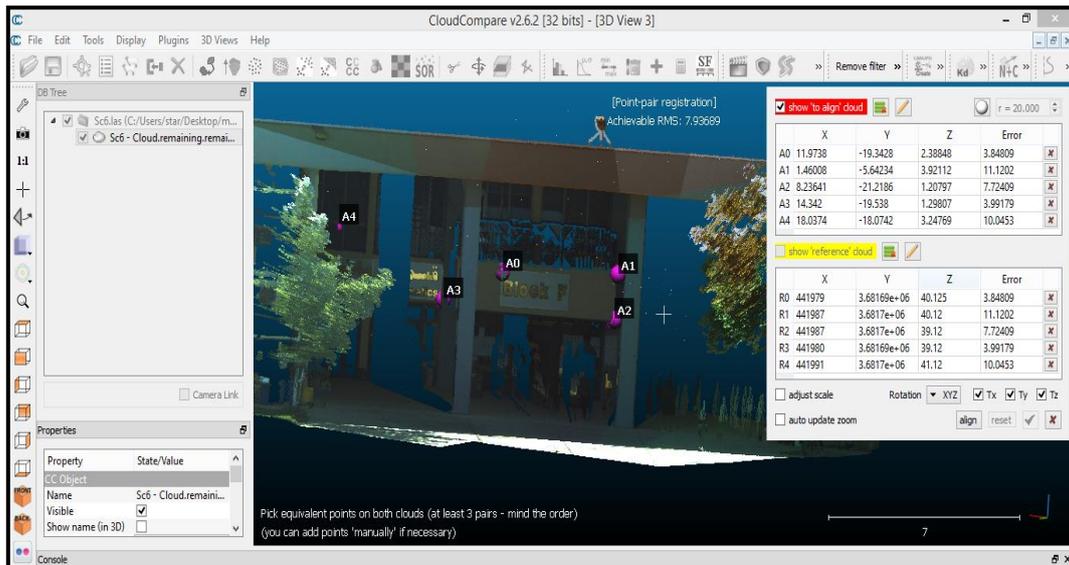
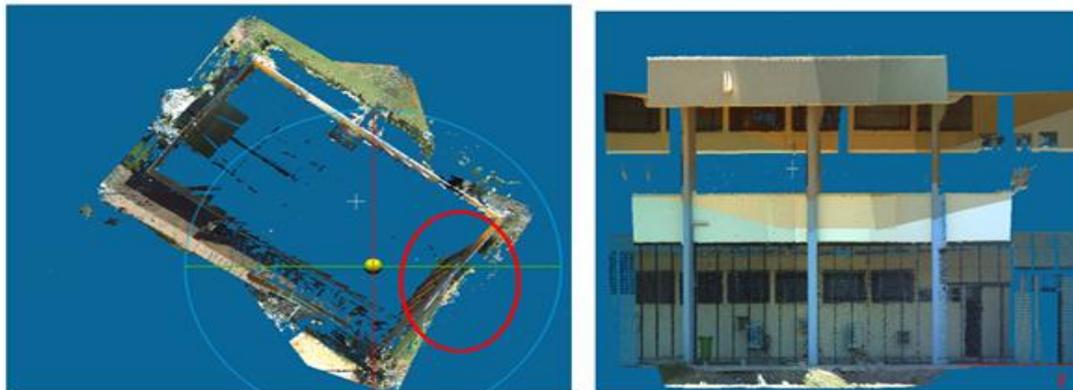
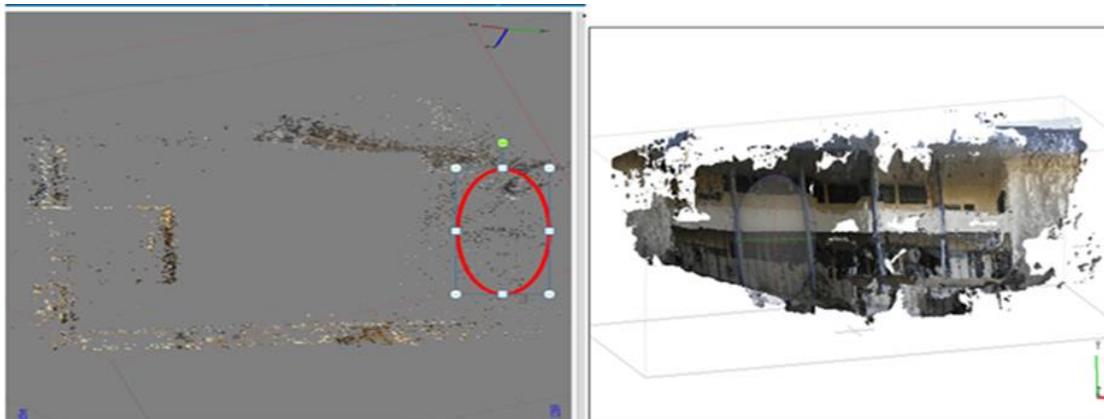


Figure 11-The georeferenced step

From the above explained steps, the results delivered from different sensors exhibited that model delivered from laser scanner have extra point (millions point) in a short time with more details explained in model and less occlusion (leads to reduce the cost and processing which shown in the final model. Figure 12 presents two model delivered from images and laser. It is also explain how the laser data overcome in shadow and barrier caused by tree these which is a problem that is appeared in the model delivered by images.



A



B

Figure 12-A- Final model from laser data B- Point cloud model from images data.

3.3. Statistical results

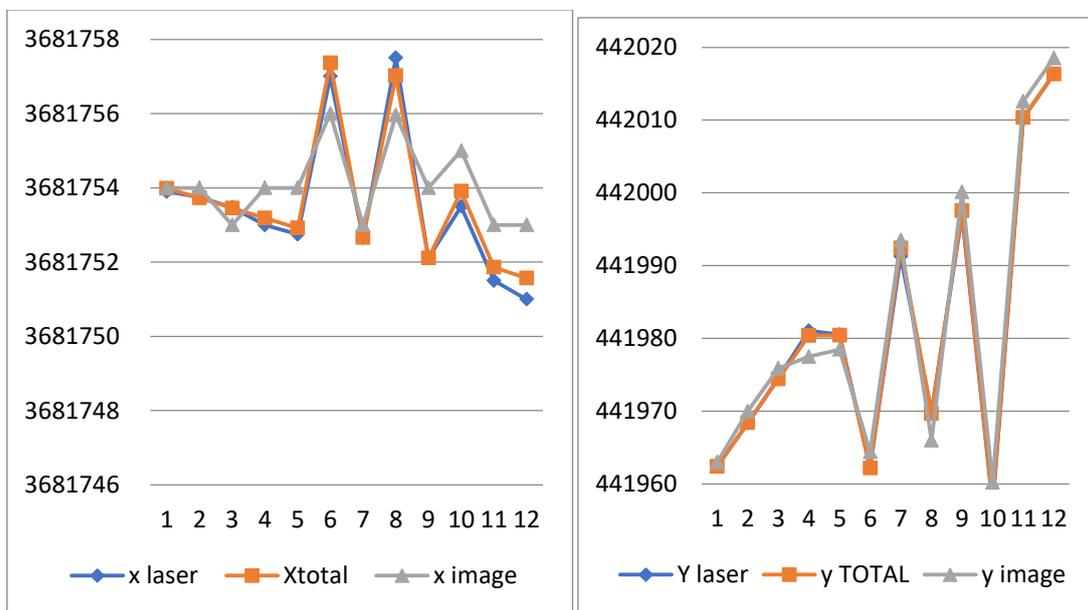
The 2-sample T-test was applied to compare points cloud derived from two different software (Agi photostan and cloud compare) with different sources of data (images and laser data); each data with the reference points measured by total station.

In this test, the confidence level of 95% was adopted and the results were discussed based on the delivered P-value; if the P-value is less than (0.05) this means that the mean between the two compared samples are significantly different. Before applying this test, the F-test must be applied. This F-test is designed to compare the variances between two sample datasets and checks if the samples have equal variance or not which is one of the input requirements of the T-test [10]. Before applying all these steps, the normality test was applied to check data distribution at first instance. The normality test is designed to check whether the data are normally distributed and following normal distribution curve hypothesis or not. Table 1 shows the results obtained from this test.

Table 1- Results from statistical test

Data	P-value		
	X coordinate	Y coordinate	Z coordinate
Laser data	0.746	0.997	0.978
Images data	0.644	0.881	0.779

From above table noticed that the obtained coordinate delivered from laser data seem to be more convergence with the reference coordinates measured by total station in comparison with coordinate delivered from images data. This could be due to the coordinates delivered from laser data is more closer to the reference coordinate than those delivered from images data. Also, the histogram graph was used to show the approximation of the coordinate with the reference (Figure 13 explains the histogram graph).



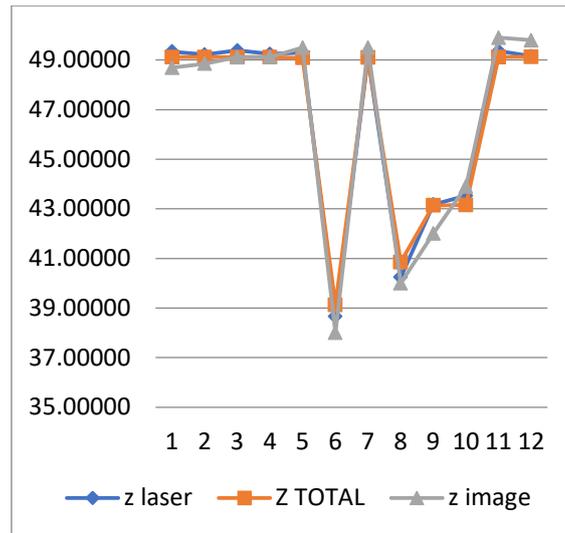


Figure 13-The histogram graph.

The histogram above explains the less difference between laser coordinate with reference coordinate (coordinate measured by total station) compared with the difference between the coordinate delivered from images with the reference coordinate. Also, the RMSE was calculated (by using 12 check points) for each coordinate delivered from image and laser with the reference coordinate measured by total station. The RMSE values delivered from laser data were 0.642, 0.478, and 0.300 while those delivered from image were 1.101, 1.594, 1.428 in xyz, respectively; this difference is shown in Figure 14.

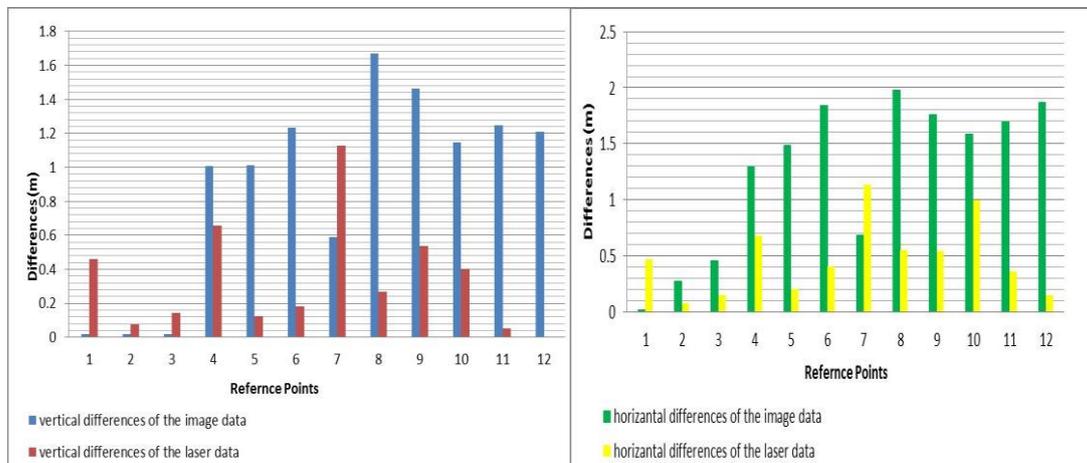


Figure 14-The difference chart

The purpose of the research is to accurately assess based on laser scan and photogrammetry data and whether one of them can be used without the others. From these results we can notice that the difference between coordinate delivered from laser compared to the reference coordinate is less than the difference delivered from image coordinate. The accuracy required in any project to determine which data is used. Some applications that do not need high accuracy thus images can be used for ease and low cost. While detailed-laser data is required in projects that require high accuracy, Additionally, images and laser data can be combined to investigate their utility for a number of future applications .

4. Conclusions

This research aims to assess the 3D point clouds model accuracy results from close range images and laser scan data based on Agi soft photoscan and cloud compare software to determine the compatibility of both datasets. Therefore the ability of stonxx300 data for generated 3D model was examined by comparison with another data (camera data) visually and statistically. The used methodology explained in this research and applied the selected building. The results produced by the suggested methodology indicated the clarity of the resulting model along with the speed and ease of dealing with the data obtained from the laser data. Also, showed the laser was not affected by the resulting shadow in the building and the existing obstacles, therefore we recommended to use laser data for obtain accurate models.

5. Disclosure and conflict of interest

The authors have declared no conflict of interests.

6. References

- [1] Forstner, W. *3-D City Models: Automatic and Semi-automatic Acquisition methods, Photogrammetric week, Wichmann, Karlsruhe*. 1999.
- [2] Jorge Chen and Keith C. Clarke . Rapid 3D modeling using photogrammetry applied to Google Earth. Conference: AutoCarto 2016, At Pittsburgh, Pennsylvania 2016. [https://www. Researchgate.net/publication/322603302](https://www.Researchgate.net/publication/322603302)
- [3] H.K. Palanirajan, B. Alsadik, F. Nex and S. Oude Elberink. “Efficient Flight Planning For Building Façade 3d Reconstruction” . *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLII-2/W13, 2019. <https://doi.org/10.5194/isprs-archives-XLII-2-W13-495-2019>
- [4] Xiao-Zhi Gao, Swarna Priya RM, Aarthy S L, Gunavathi C,Venkaatesh P, Srinivas Koppu. "3D Reconstruction of A Scene From Multiple 2d Images". *International Journal of Civil Engineering and Technology (IJCIET)* ,vol. 8, no. 12, pp. 324-331, December 2017.
- [5] Demetrios Gatzolis, Jean F. Lienard, Andre Vogs, and Nikolay S. Strigul . “3D Tree Dimensionality Assessment Using Photogrammetry and Small Unmanned Aerial Vehicles”. *PLOS one*. 2015. <https://doi:10.1371/journal.pone.0137765>.
- [6] Muhammad Zainuddin Lubis, Wenang Anurogo, Oktavianto Gustin, Andi, Aditya Hanafi, Dirgan Timbang, Fajar Rizki, Diaz Ariwinata Saragih, Indah Ira Kartini, Hana Cyintia Panjaitan, Marisa Tri Yanti and Herika Muhamad Taki . “Interactive modelling of buildings in Google Earth and GIS: A 3D tool for Urban Planning (Tunjuk Island, Indonesia)”. *Journal of Applied Geospatial Information*. 2017.
- [7] Jia Li , Yongxiang Yao, Ping Duan , Yun Chen , Shuang Li and Chi Zhang. “Studies on Three-Dimensional (3D) Modeling of UAVOblique Imagery with the Aid of Loop-Shooting”. *International Journal of Geo-Information*, 2018. <https://doi:10.3390/ijgi7090356>
- [8] Răzvan Gabriel Boboc, Florin Gîrbacia, Cristian Cezar Postelnicu, and Teodora Gîrbacia. “Evaluation of Using Mobile Devices for 3D Reconstruction of Cultural Heritage Artifacts”. M. Duguleană et al. (Eds.): VRTCH 2018, CCIS 904, pp. 46–59, 2019. https://doi.org/10.1007/978-3-030-05819-7_5.
- [9] Marwa Mohammed Bori , Zahraa Ezzulddin Hussein . “Integration the Low Cost Camera images with the Google Earth Dataset to create 3D Model using Close-range photogrammetry”. *Civil Engineering Journal*, vol. 6, no. 3, March, 2020. <http://dx.doi.org/10.28991/cej2020-0309142>
- [10] Montgomery, D. C. *'Design and analysis of experiments'*. Chichester, UK: Willy-BlackWell, 2005.