3D RECONSTRUCTION OF BUILDING MODEL USING UAV POINT CLOUDS

Nor Hanani Sani[1], Khairul Nizam Tahar[1]*, Gyanu Raja Maharjan[2], Jose C. Matos[3], Muizzuddin Muhammad[4]

[1]Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor Darul Ehsan, MALAYSIA.
[2]Central Department of Geography, Tribhuvan University, P.O.Box 8613, Kirtipur, Kathmandu, NEPAL
[3]ISISE, Institute of Science and Innovation for Bio-Sustainability (IB-S), Department of Civil Engineering, University of Minho, Guimarães, Portugal
[4]Konsultan Jurutera Melombong Yeow Sdn Bhd, No. 61-1, 1st Floor, , Petaling Utama Avenue, Jalan PJS 1/50, 46150 Petaling Jaya, Selangor Darul Ehsan, Malaysia

Commission II, WG II/4

KEY WORDS: UAV, 3D Model, Point Cloud, Precision

ABSTRACT:

Photo-realistic 3D model of object cannot be created by using conventional Total Station method. The aim of this study is to generate 3D building model using UAV's dense point clouds. In this research, the ability of remotely detected information for the construction of 3D building models is found to be as specific as UAV datasets, Tacheometry Survey and Traverse Survey. Pix4D and MeshLab software were used in this study to perform image processing of 3D building. The building was built up upon using the information needed from capturing UAV images. This procedure requires the height of building to be measured through conventional method such that of UAV and the height is then compared with a 3D building model. At the end of the process, the comparison of height of building, also known as RMSE, was conducted. The images of building were then processed in Photogrammetry which is the Pix4D software. Using Pix4D, this study proceeded with several processing stages such as camera calibration, photo uploading, building of dense cloud, mesh generation, and model texturing. Those processes were done automatically by using Pix4D tools. High quality of photo-realistic 3D model of building was then successfully constructed. The accuracy assessment was done by comparing the measurement of 3D model of building. Direct measuring of building by using total station had taken place to compare the measurements between 3D model details with actual measurements. The measurement of 3D model of building was done in Pix4D software. The RMSE achieved in this study is 0.015 m which is under reasonable accuracy limit. This study proves that UAV point cloud is capable to produce a very fine 3D model.

1. INTRODUCTION

In this modern century, new technology of drones which involves every aspect needed by engineers for the development of infrastructure is becoming rapidly progressive. These trends are so important nowadays to maintain the balance between humans and technology needs in their daily activities, work, and socioeconomic. To make the Three-Dimensional (3D) mapping development a success at the end of the project, preparation and planning during and at the completed stage needed to be more emphasised as it is relating to its own context (Filip Biljecki, 2017). It has no significant cause other than the purpose of choosing a sufficient model to complete the required tasks while balancing computing, economic and cognitive limits (Biljecki, 2017; Haala et al., 2015; Xiong et al., 2016).
Today, the use of large-scale urban 3D mapping has become ubiquitous among many application domains. For example, exponents of the mapping industry are striving to augment their data sets with detailed 3D models and mapping in reflecting the real world. Unmanned Aerial Vehicle (UAV) navigation requires techniques that allow for the accurate mapping of unstructured 3D environments such as stairwells, tunnels, and caves. As a step towards that goal, this paper presents a system to build three-dimensional maps (Alidoost & Arefi, 2015; Chen et al., 2018; Rouhani et al., 2017). 3D building models can be generated with different levels of detail. Models like this will serve as either a representation of rough buildings or consist of explicit geometry with more details (Harinish et al., 2019; Mwangangim 2019; Verdie et al., 2015). Automatic building change detection at different periods is extremely important for city monitoring, disaster assessment, map updating, etc. Some existing data sources might be used in this task such as 3D geometry model (e.g., Digital Surface Model and Geographic Information System) and radiometric images from satellites or special aircrafts. However, it is too expensive for timely change detection through the aforementioned methods. With the rapid development of UAV technique, capturing the city building images with high resolution camera at a low altitude becomes cheaper.
The technique that is often used to measure building is the conventional method. However, the conventional method is time-consuming and cannot be used to make photo-realistic three-dimensional (3D) model of an object (Malihi et al., 2016; Widyaningrum & Gorte, 2017). The problem centres on how to collect the 3D information of a building efficiently and quickly. This study discusses new methods that can reduce the time to build a model using the Unmanned Aerial Vehicle method. Current technique to measure the building is by using conventional Total Station. This method requires coordinate transfer from 3 good marks from any datum such as Cadastral Reference Mark. However, a problem of this method is that it requires more time and manpower. Furthermore, this conventional method is not suitable for tight space area such as Dewan Agong Tunku Canselor (DATC) building which is located at the top of the hill. The use of Total Station is not cost effective.
This paper discusses on building reconstruction from dense photogrammetric points clouds. The scope of this study is to

*Corresponding Author: Khairul Nizam Tahar
khairul0127@uitm.edu.my

develop 3D mapping using UAV dataset. This study reviews the reconstruction of the 3D building model using UAV. DATC in UiTM Shah Alam (Figure 1) was chosen as the area of research. This study focused on DATC building which is located near the Perindu College and Stadium of UiTM Shah Alam. This area was chosen as the best research area because the building is one of the biggest buildings located in UiTM. This building was selected because the surrounding features have a large open space and less obstacles for UAV flight missions. A thorough planning was established to achieve the objective of the project.

Figure 1. Dewan Agong Tunku Canselor in UiTM Shah Alam

2. METHODOLOGY

Several processes were performed to develop the final product to this study, which is a 3D model of DATC of UiTM Shah Alam. The 3D model was constructed by using UAV as a platform. DJI Phantom 3 Standard was used in this study. The methodology of this study as shown in Figure 2.

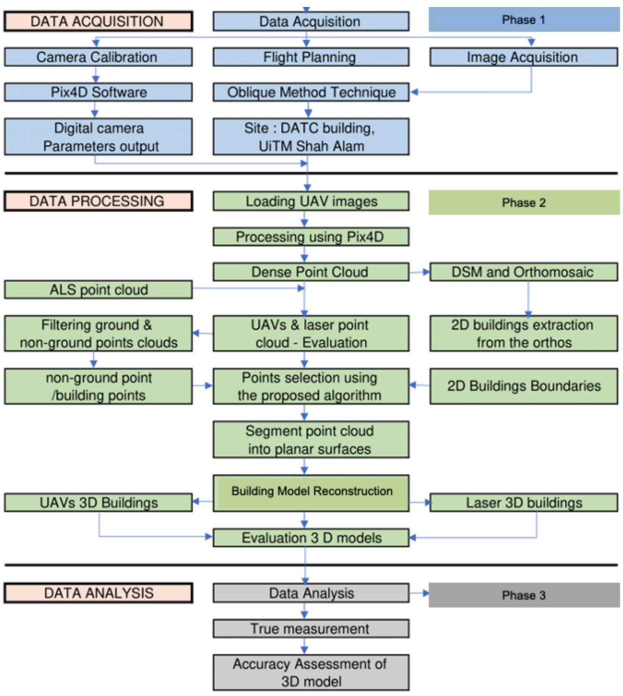

Figure 2. The detail of methodology

Data was needed to produce the final output. The images of DATC building were acquired from DJI Phantom. Several methods were conducted to obtain the data. Flight planning was important for autonomous flight mission and manual flight mission. The camera also needed to perform calibration whereby the Pix4D software was utilised. Image acquisition was done by using UAV camera. Since DATC building surrounded area is covered by high trees and have limited space, manual technique was used for image capturing. Data acquisition for this research study were divided into two approaches for 3D modelling and the 3D model of Dewan Agong Tunku Canselor building based on true measurement was validated. Nonetheless, there was a different path to acquire the data for both objectives.

The process is through knowing the real dimension of the building captured as it is the most important aspect for this project because from the data it captures, an easier plan could be devised for the next stage. To get good images, there are some criteria need to be followed and more time spared during the planning for this project is recommendable. It can save much more time instead of making any mistakes during the processing data acquisition. During the image capturing using a drone, good lighting must be considered the most as it can help to get better quality results with less shadow appearances.

Before proceeding to the next steps, camera calibration is the most important process. The aim of the camera calibration is to determine the characteristics of a camera that are taken out from the user's photographs. In this project, integrated camera mounting on DJI Phantom 3 Standard UAV was used for the calibration process. The lists of parameters were focal length, format size and principal point. Specifically, to execute this process, the value of focal length of the lens, the digitising scale, and, the principal point need to be known. The calibration is required to ensure the images captured are flat and all the distortion on the images are eliminated.

2.1 Ground Control Point (GCP) Marking

Ground controls are known as a targeted or picked control points in photo to be identifiable. They are also known as horizontal control and vertical control for photos in photogrammetry surveying scope. Vertical and horizontal require a different configuration value to ensure they serve as an intended purpose. To perform an accurate photo processing, GCP is the most important data that needs to be included in the photogrammetry process to know the exact value of the ground coordinates system where the value of each point represents horizontal position and altitude of the coordinates. These points are necessary during the photogrammetry process for the georeferencing and building a 3D model including the process of point cloud and Digital Surface Model (DSM) plan at the end of the process.

In performing a control point, ground survey needs to be carried out to establish checkpoints within the survey area. There are two techniques to be utilised in gathering the control points which are Global Positioning System (GPS) and conventional survey (Tacheometry Survey). To determine that the checkpoints are in good condition, two sets of well-defined datum were observed using total station to act as a survey datum in serving as performing checkpoints. The accuracy of the building was determined by evaluating the comparison of height of building derived from ground survey point and the height from the digital model constructed by DSM from UAV datasets. The control points were then used to validate the digital models after constructing both in value of the horizontal and vertical with RMSE results. Vertical assessment was based on the height of the digital model of the building at every known point with respective to survey height from ground survey at the same point from ground survey. Furthermore, the accuracy for horizontal (RMSExy) assessment can be identified from the difference at a known point through the survey (x,y) for the

building edges and other points that can be seen during the UAV datasets processing.
In the making of 3D mapping, the next step was to capture the dimension of every perspective of building by using Point of Interest System which is available in DJI Phantom as the circle motion continuously surrounds the building or location of project by concentrating and ensuring that the drone gimbal and camera overlook the position of drone during flying process. There is also a flight option included and it can get a 360° view of the surrounding clearly.

2.2 Data Processing

The Pix4Dmapper photogrammetry software reconstructed every feature present in the image set. In this case, the only way to acquire images of each surface requires moving the object to obtain various perspectives of the object. It is, therefore, necessary to blank out the background around the object by placing the object in a space with no features that could be picked up as automatic tie points.
The main data in this study are the images taken from the UAV to create the 3D model. The images underwent a calibration stage where the images need to be flattened. Only then, the 3D modelling process can be started. It is necessary to select good photos for 3D model construction before starting any operation. Only good photos were loaded in Pix4D software. Double photos, blurred, or any unwanted photos were eliminated. There is the "Add Photos" button where the photos can be uploaded in a bundle. Pix4D accepts several image formats such as JPEG, TIFF, PNG, BMP and JPEG. Automatic Tie Points were created during this step. These are the bases for the next steps of processing.
Following the workflows in Pix4D, the next step after photo aligning is building the dense point cloud from the images. Pix4D allows the generation and visualisation of a dense point cloud model. The camera positions are estimated, and then the program calculates the depth information for each camera angle. Next, that depth information is combined in a single dense point cloud.
This software is considered as one of the good technologies for UAV users as it can create accurate measurements from photographs and high-quality 3D models. Results from the 3D model process are already creating the dense point cloud or also known as dense surface modelling and DSM from the photographs of texture surfaces itself in virtually any sizes have all capabilities to create whatever the user wants such as dense surface modelling and many more. The processing to generate dense surface modelling is the same process as to create a dense point of cloud when there is large number of 3D points of cloud in one result.
MeshLab is a free, open-sourced photogrammetry software in providing a set of tools for editing, cleaning, healing, inspecting, rendering, and converting these kinds of meshes. This software can export a 3D mesh and only work with the dense point cloud, or the viewport. To clean up and refine the 3D mesh, we need to work with other programs like MeshLab. Point clouds can be opened by double-clicking on an OBJ/FLY data format. The MeshLab software can speed up the process of creating 3D model. This software can measure the length of the building, several areas of the building were captured as sample to compare the accuracy with the 3D model (Figure 3).

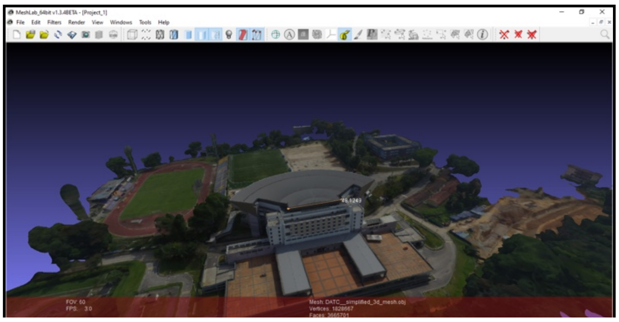

Figure 3. Measuring the length of the building.

3. RESULT AND ANALYSIS

Topographic survey is one of methods on defining the exact location and heights of building or any number of verities of point features on the building to be collected. To gain the information of the points on building, Total Station was used to capture points information (Table 1).

Point	Easting (m)	Northing (m)	Height (m)
B01	777721.633	339065.000	77.063
B02	777733.368	338994.200	79.426
B03	777752.173	338994.200	51.705
B04	777787.215	338994.200	52.593
B05	777806.003	338994.200	50.299
B06	777836.275	339075.200	50.683
B07	777817.450	339065.000	80.972
B08	777748.115	339048.200	81.149
B09	777790.920	339048.300	81.180
B10	777697.610	339039.400	81.617
B11	777730.860	339039.400	53.239
B12	777808.333	339039.300	73.164
B13	777841.499	339039.100	70.671
B14	777730.681	339039.200	53.028
B15	777808.767	339039.000	54.330
B16	777721.633	339065.000	52.163

Table 1. Results of Control Points using Conventional method

UAV method is one method on how to define the height of building. To gain information of point of building, it needs to capture point information from the process by using the Pix4D software (Table 2).

Point	Easting (m)	Northing (m)	Height (m)
B01	777703.001	339074.972	78.074
B02	777721.583	339064.965	78.422
B03	777733.328	338994.146	51.294
B04	777752.103	338994.154	51.374
B05	777787.150	338994.122	51.511
B06	777805.941	338994.098	51.727
B07	777836.212	339075.099	79.110
B08	777817.386	339065.003	78.952

B09	777748.050	339048.124	79.699
B10	777790.854	339048.224	79.999
B11	777697.543	339039.299	53.572
B12	777730.792	339039.323	71.852
B13	777808.264	339039.242	72.388
B14	777841.429	339039.074	54.598
B15	777730.610	339039.128	53.702
B16	777808.695	339038.987	54.331

Table 2. Results of Control Points using UAV method.

3.1 Analysis on the Differences between Height taken by Conventional Method and UAV Method

Table 3 shows the comparison measurements. From the results shown below, there are some differences between height of building taken from UAV method and conventional method (Figure 4).

Point	Height		Differences (z) m – (z') m = (z") m
	Conventional Method (z) m	UAV method (z') m	
B01	77.063	78.074	-1.011
B02	79.426	78.422	1.004
B03	51.705	51.294	0.411
B04	52.593	51.374	1.219
B05	50.299	51.511	-1.212
B06	50.683	51.727	-1.044
B07	80.972	79.110	1.862
B08	81.149	78.952	2.197
B09	81.18	79.699	1.481
B10	81.617	79.999	1.618
B11	53.239	53.572	-0.333
B12	73.164	71.852	1.312
B13	70.671	72.388	-1.717
B14	53.028	54.598	-1.57
B15	54.33	53.702	0.628
B16	52.163	54.331	-2.168
RMSE			1.407

Table 3. Differences between conventional and UAV height

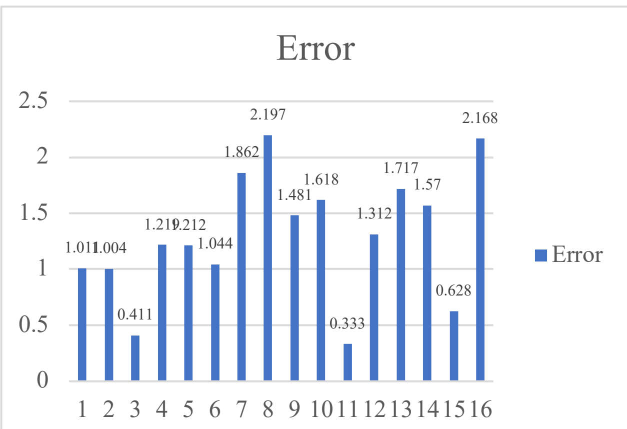

Figure 4. Value of the differences height between Conventional and UAV method.

3.2 Analysis on the Differences between Length of Building taken by Conventional and 3D Model

The image of building where the measurement was taken to determine the value of length of building and investigate the differences between conventional method using total station and calculation have shown the differences between practical measurement and 3D model output obtained from the completion of point cloud until texture model (Table 4 and Figure 5).

No	Building Detail	Error (m)		
		Point Cloud	Meshes	Texture Model
1	Wall 1	0.142	0.032	0.011
2	Wall 2	0.123	0.041	0.008
3	Wall 3	-0.114	0.046	0.015
4	Wall 4	0.045	0.064	0.028
5	Wall 5	-0.147	0.057	-0.038
6	Wall 6	0.146	-0.062	0.047
7	Wall 7	0.157	-0.032	-0.008
8	Wall 8	-0.132	-0.043	-0.01

Table 4. Comparison error between point cloud, meshes and texture model.

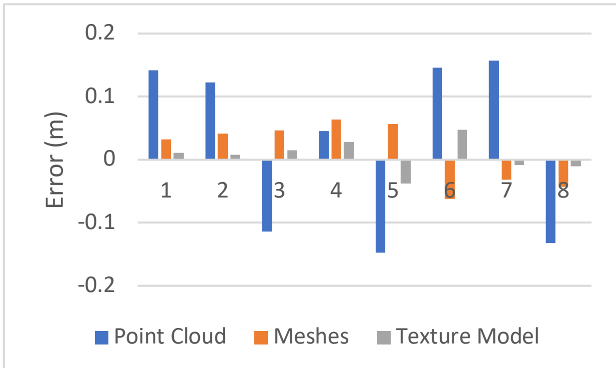

Figure 5. Pattern error between point cloud, meshes and texture mode.

The study has concluded this experimental analysis and review as the outcome of the study. It is shown that there are differences in the error (in meter) between point clouds until texture model. Thus, it can be analysed that the value of that comparison is x-axis represents the number of sample and y-axis is the error for each output (Figure 6).

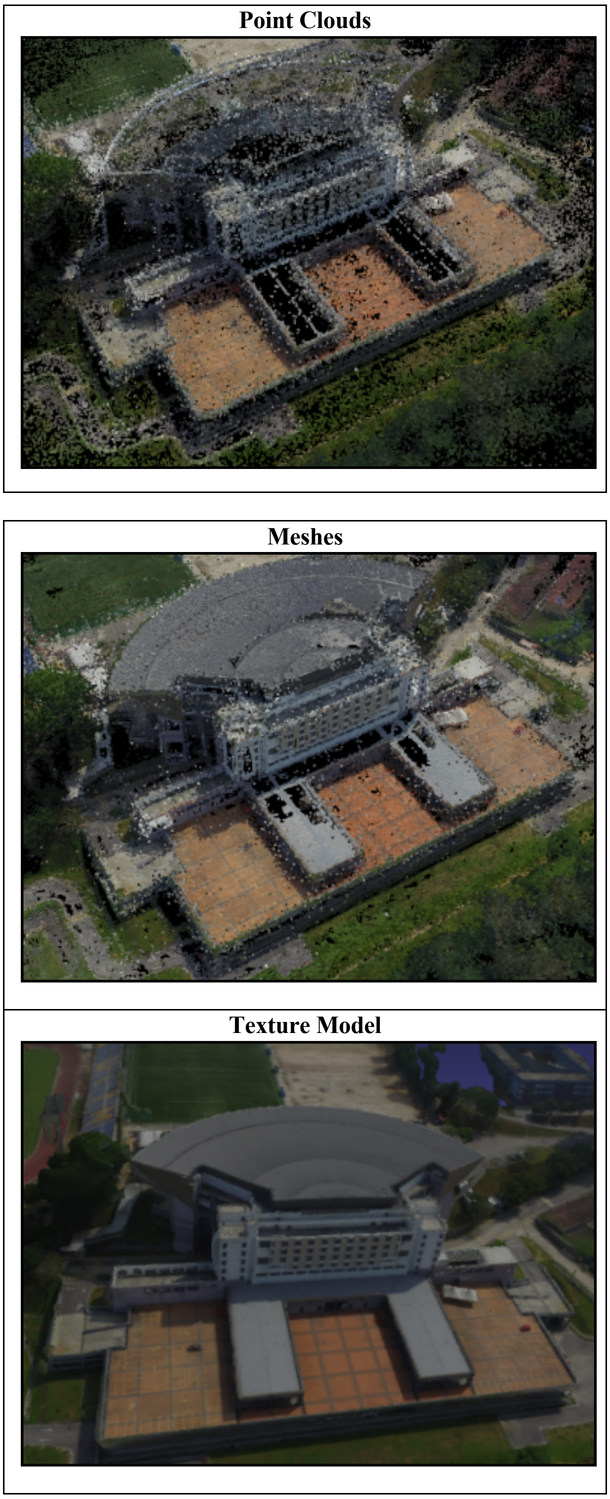

Figure 6. The visualisation of texture model of 3D building

4. CONCLUSION AND RECOMMENDATION

An oblique method with random position of UAV waypoint was used to acquire the images of DATC build. The images of DATC building were then processed in Photogrammetry which is the Pix4D software. This study went through several processing stages using Pix4D such as camera calibration, photos uploading, the building of dense cloud, mesh generation, and model texturing. Those processes were done automatically by using Pix4D tools. High quality of photo-realistic 3D model of DATC building is successfully constructed. The second objective of this study is to validate 3D model output based on point clouds, meshes and texture model with actual measurement. The accuracy assessment was done by comparing the measurement of 3D model of DATC Building. Through direct measuring of the DATC building by using total station, measurements were taken to compare the 3D model details with actual measurements. The measurement of 3D model of DATC building was done in Pix4D software.

There were few limitations when this study was carried out. The use of UAV was an advantage during the images acquisition process but the UAV itself has its own limit. The drone used during this study is DJI Phantom 3 Professional which is the medium spec level of consumer UAV. This is due to the limited cost in conducting this study. This UAV have higher quality of images with higher resolution which have longer range compared to DJI Phantom 3 Standard. Furthermore, finding a suitable position for camera is quite crucial part. There were obstacles such as trees and birds which had limited the coverage area of object in the images at some points of the camera's position.

Pix4D can overcome this problem by using the latest automatic images matching process which does not require the whole object in every single photo. DATC building is located at the top of the hill which had proven as a challenge as to find a good visual from UAV Photogrammetry. It requires not only a lot of experiences to create a 3D model of DATC building, but Pix4D software itself requires a lot of training and users must refer to its manual. If the setting of process is set to very high, the computer cannot process the data due to the lack of RAM and CPU power.
Camera calibration is vital at the start of the process which was done by using self-calibration in Pix4D software. The computer specification used to process the data must meet its requirements. This PC can only process the data for medium stage of accuracy and quality of 3D model. This is because 3D modeling process requires higher specs of computer to get the highest quality of image with better accuracy. Lack of budget limits the use of a suitable type of computer which requires two processors with 64GB of RAM.

ACKNOWLEDGEMENTS

Faculty of Architecture, Planning, and Surveying Universiti Teknologi MARA (UiTM), Research Management Centre (RMC) and Ministry of Higher Education (MOHE) are greatly acknowledged for providing the fund YTR 600-RMC/YTR/5/3 (004/2020) to enable this research to be carried out. The authors would also like to thank the people who were directly or indirectly involved in this research.

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