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THREE DIMENSIONAL CURVE HALL RECONSTRUCTION USING SEMI-AUTOMATIC UAV

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ABSTRACT

Nowadays, photogrammetry is up against the problem of how to collect the 3D information of a city building efficiently and quickly. In the recent years, the Unmanned Aerial Vehicle (UAV) has been getting more attentions from the photogrammetry industry. The UAV has many good characteristics which can be implemented in many tasks that manned aircraft was unable to fulfil. The aim of this study is to reconstruct a 3D model of the Dewan Agung Tunku Canselor (DATC) building by applying the concept of the UAV Close Range Photogrammetry. The control points were established using the basic angular measurement method which consists of 26 control points at the DATC building. The data from angular intersection were processed using the StarNET software to obtain the coordinates of the control points at the building. The 3D DATC model was successfully developed and the qualities of the 3D model were assessed. The analysis was based on the length measurement from the 3D model and actual length. The residual mean square equation was used to determine the accuracy of the 3D point coordinates of the 3D DATC model. In conclusion, UAV can be used for a 3D model reconstruction in the condition it follows the correct technique and procedure.

Keywords: three dimensional, building, close range, photogrammetry, UAV.

INTRODUCTION

Nowadays, photogrammetry is up against the problem of how to collect the 3D information of a city building efficiently and quickly. 3D simulation and virtual reality are forms of the digital city in which the building forms are needed for establishing the 3D model. The 3D building method can be divided in two ways which are fast construct and high precision for many buildings and fine construct for a building to update the building area. Researchers have distributed the 3D building method all around the world to give forward different methods towards their own applications [1, 5]. However, there is still a shortage of approach which can meet the most and highest demands of various users.

High-resolution photogrammetry images are the most important things for the 3D information acquisition [2, 6]. The general photogrammetry techniques by satellites and aircraft can acquire the geographical information of the large area. However, there are some limitations on the detail acquisition of a city building. The satellite is affected by the height, running cycle, cloud and some other factors. The aircraft is also restricted by many things such as airspace limit and weather. Therefore, these techniques cannot completely meet the requirement of subtle 3D information acquisition in a city building. In the recent years, Unmanned Aerial Vehicle known by the acronym of UAV is a new platform of photogrammetry.
UAV system is a low altitude aerial photogrammetry and getting more and more attentions in the photogrammetry industry in expanding the practical application scope4. The UAV can capture the earth surface images from a different altitude [3]. There is no man in a UAV during flight mission and it is navigated by a remote device. UAV offers several new possibilities in a wide range of applications. The UAV has many good characteristics such as low cost, simple manipulation, high resolution and flexibility. The UAV can be used in many tasks where manned aircraft is unable to complete, for example the acquisition of a building texture and building pattern. A lot of practices proved that the UAV is an ideal tool for a high-resolution photo collection for city building, especially the 3D reconstruction of city buildings. It is important due to its potential for the usage of 3D models in city planning, damage assessment, monument conservation, architecture and digital tourism.

This study applied the concept of UAV Close Range Photogrammetry approach to introduce another option to reconstruct a 3D model of the Dewan Agung Tunku Canselor (DATC) building. The process of the 3D model reconstruction using LIDAR and UltraCam is very costly and has a limitation based on the height of the building and its location that should be suitable to place the camera to get accurate photos [6]. On the other hand, the detail reconstruction of the building also becomes more important for future conservation. In many critical situations, building models that are only enhanced by textures are not sufficient. Semantics such as the attribution of the window or door are important for many scenarios such as rescue operations or the calculation of energy balances. These two problems could be solved using the 3D reconstruction technique based on the 2D pictures taken by UAVs. UAVs have been used to survey buildings of various heights without interfering with any obstacle and can reach any position required to take the suitable angle for capturing photos. In addition, the UAV ability to collect the data makes data sets of measurement becomes easier [4].

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MATERIALS AND METHODS

There are several steps and methods implemented in this study in order to achieve the objectives. The methodology consists of four phases. Phase 1 was the preliminary study, which is important to give an idea and knowledge of future planning. Phase 2 started from camera calibration and followed by data collection. In the data collection, two methods were carried out to create a central point on the building and image captured by using the UAV. Phase 3 was data processing using the PhotoModeler Scanner software to create the 3D building models. The last phase was about result and analysis. Based on the 3D building output, the accuracy assessment of the 3D building model was being conducted.

Site study

The preliminary study was about the review of the reconstruction of the 3D building model using UAV. The selected study area was the Dewan Agong Tuanku Canselor in UiTM Shah Alam. This building was chosen because the location has a large open space area and fewer obstacles for the UAV flight mission. Figure-1 shows the location of DATC. Reconnaissance is important to recognize and locate the position of the proposed control point. Control stations were established near the building.

Figure-1. The location and view of Dewan Tuanku Agung Canselor (DATC).

Camera calibration

In this study, the non-metric camera was used. The Nikon-Coolpix camera is a non-metric camera used in this study. There are some reasons why this camera was chosen. The first reason is the camera is light and easy to be carried by the UAV. Besides that, it is installed with Global Positioning System (GPS) and Wi-Fi application which can be connected to the drone control and able to remotely control the camera during a flight mission. Then, the photograph data can be directly transferred to the computer. The camera calibration results were used for the UAV data acquisition, which is following the requirement of the study. The camera calibration must be done to get the actual camera configuration. Camera configuration was performed to determine the principle points of x and y, focal length (f) and lens distortion coefficients. This process was conducted by using a standard grid calibration image.

Establishment of control point

The establishment of the control points of the DATC building was conducted using the survey technique. The control point was established using the traverse method and angular method. The purpose of this survey is to obtain the position of northing, easting and height for all the control points. The selection of the control point criteria was marked at the upper, edge and outer corner of the window frame as the target points. The target points at the building must be seen at least from three control stations. The input for angular intersection such as back bearing, horizontal angles on the face left and face right, vertical angles on the face left and face right, and height of the instrument. The measurement of the control points started with the first set, which was at the Ground Control Point (GCP) 1 and the reference object was GCP2 while the angle set was 0^{o}. Then, the horizontal and vertical angles to the control points were measured. Figure-2 shows the location of the control point. The process of the control point coordination was determined using the StarNET software in order to obtain the coordinate for each control point.

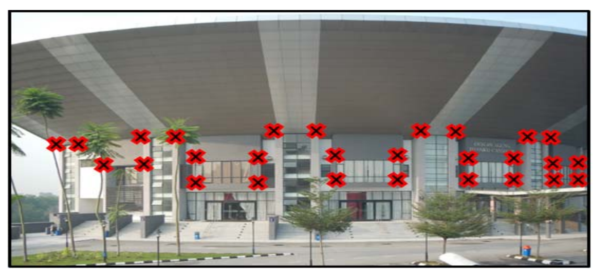

Figure-2. Establishment of control points on the building.

The angle measurement data of each target point was processed by using the StarNET software. This software provides the Least Square Adjustment calculation, so it is very suitable to be used in this study. All points were measured redundantly from all three GCPs. From the 26 control points marked, only 14 points could be used as the good control points at the building because they have small residual and the lower bound result after the process in the StarNETwas compared to the unselected control point. Therefore, to pass the StarNET process, these 14 points were used to process in the StarNET. The report produced by the software indicates that the 14 measurements were good where the 5% Chi-square test was passed. The 5% Chi-Square test passed means that the Chi-square statistical value falls between 95% of the probability which means that the null hypothesis is accepted. Therefore, it means that only 14 control points had no systematic error, blunders or incorrect standard deviation in the measurement and data processing. The only error in the measurement was a random error which could not be avoided.

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Image acquisition

Image acquisition for this study was done using a hexacopter. The calibrate camera Nikon-Coolpix was used to capture the images. This camera was attached to the bottom of the hexacopter (Figure-3). The complete set of the drone was used to capture the images of the building, which also consist of the target points. Before the flight mission was conducted, the mission planner software was used. The mission planner software was one of the drone planning missions. The waypoints were created by using the point-and-click waypoint entry using the Google Maps. Figure-4 shows the waypoint entry which was planned for the flight mission. After all the waypoints in the mission planner were set up, they were sent to the hexacopter input control.

Figure-3. The complete set of hexacopter with camera Nikon-Coolpix.

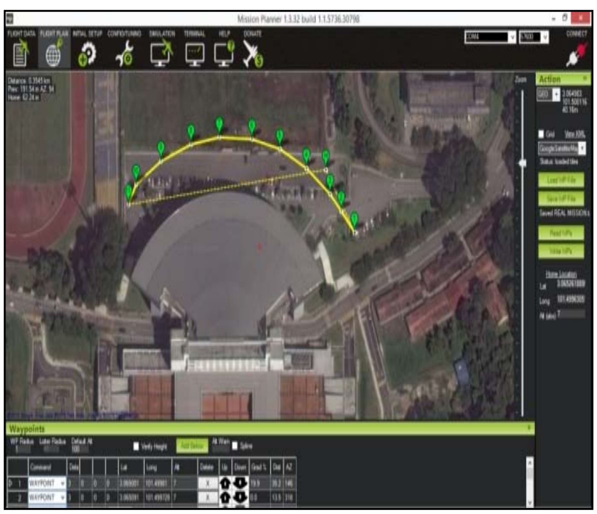

Figure-4. The waypoint entry in the mission planner software.

By using the UAV, the images were captured around the building where the altitude was about ±5 meter. The distance between the drone and object was approximately similar to control the quality of the required images. The images were captured about ±25 meter from the object in order to get clear and sharp images. Many referenced point-across photographs were needed as they are required in the PhotoModeler scanner image processing. Based on the close range photogrammetry concept, the object must be captured in at least three images at different angles. As mentioned previously, the control point must be marked first before data capture. This mark was used for the image matching process. The importance in image acquisition is to ensure that all images have the constant overlap percentage. 20 images were captured totally to complete the front area of the DATC building

Data processing and analysis

There are two important aspects of this study, which are the instrument and working system. The instrument used in this system was a set of computer and camera. The working system consisted of PhotoModeler software used to analyse the acquired images. In this study, the PhotoModeler software was used to produce a digital image of the 3D model so that the image measurements can be carried out. In this phase, it can be divided into eight levels of the process using the PhotoModeler software. After the processing phase was completed, the next phase was an analysis of the model. The analysis depends on the result obtained from this technique. After all the photographs were processed, image measurement can be carried out. This study focused on the comparison between the result from the 3D DATC building model using a photomodeler and actual drawing of the DATC building in AutoCAD software. The accuracy (RMSE) of northing, easting, and height of 3D model were determined based on the result and actual building. Measurement analysis was carried out based on the different features in the PhotoModeler software and feature measurement at the actual building.

RESULTS AND DISCUSSIONS

The result and analysis present the 3D formation and analysis. As mentioned in the previous section, data acquisition such as an image captured is the most important part of any project in the close range photogrammetry. The camera calibration is also the important step before the data processing. The final output is the 3D model of DATC and the accuracy assessment is based on the actual building measurement. Based on the results, the comparison between the 3D DATC building model and an actual 3D model was assessed. The result can be analysed based on the 3D model in photomodeler, multi-photograph images of DATC and drawing DATC in the AutoCAD software. The analysis also included the RMSE calculation for the northing, easting, and height of the 3D models. The measurement was carried out in the different texture by using the PhotoModeler software coordinates and feature measurement of the building.

Comparison between 3D building model and actual building model

Based on this study, the results were assessed between the 3D building models and actual building model. The quality of the 3D model result was measured

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using the photomodeler software. Figure-5 shows the structure of the DATC building in 3D model using the photomodeler scanner software. The result can be viewed and rotated from any angle as the user's wish. The high qualities of the 3D-texture model took a longer time to create but gave a good quality representation of the 3D building structure. The result of the DATC 3D model was free from any distortion. The 3D model had almost exactly the same features and texture as the real building as shown in Figure-5. The structure of the 3D-texture model was not completed due to fewer images captured because there was an active construction in the study area that made it difficult to fly the UAV in the area.

In general, the structural of the drawing can be seen exactly the same with the results given by the photomodeler scanner software. However, the 3D model showed only the 3D structure without any 3D-texture. The actual length information was taken from the existing information at the layout plan. It was also measured at the real features of the DATC building by using tape. Based on the 3D model result, the comparison between the length measurements was approximately the same. The difference of length measurement between the 3D model result and actual length measurement was 0.3 m for maximum length and 1 mm for minimum length.

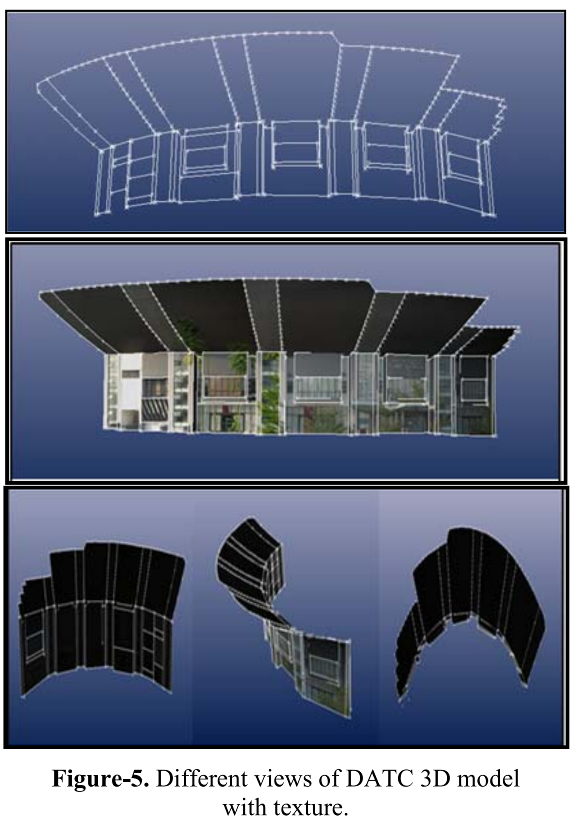

Figure-5. Different views of DATC 3D model with texture.

Quality of 3D model

The quality of the 3D model was determined by the residuals between the image coordinates marked on the image and actual coordinates based on the camera calibration. The 3D model was formed with the northing, easting, and height information after the control point representation of the building model. As stated in the PhotoModeler scanner software guideline, the final total errors of the 3D model formation project must be less than 5.0 to indicate the good 3D formation project.

The final total error was calculated by using the assumption precision value in the bundle adjustment. The value set in the Photomodeler software was 5.0. The value of the final total error influenced the standard deviation of the sub-pixel marked points which were set by the users. Therefore, if all input in the 3D model met the assumption set by the Photomodeler, the final total error value of the last iteration mode should be 5.0. If the final total error is more than 5.0, it means that the assumptions being made by Photomodeler are incorrect or there are gross errors in the 3D models processing. If the final total error value is less than 5.0, it means that the marking process to build the 3D model is more precise than the assumptions. The result shows that the final error of the 3D models was less than 5.0, which indicates that the 3D models were under tolerance. This means that the formation of those 3D models was done precisely. The 3D models looked like the same but the dimensions of each 3D model formed were less different from the actual building model.

The result stated that the largest difference for the easting coordinates was ±0.072 m and the smallest was ±0.000 m. The RMSE for easting was ±0.291 m. The accuracy of the coordinates also depends on the residual of the processing. If there are many mistakes or error during the observation and digitizing stage, it would affect the accuracy of the results. The result stated that the largest difference for the northing coordinates was ±0.8 m and the smallest was ±0.1 m. The RMSE for northing was ±0.550 m. The coordinates between the two methods were quite similar and showed not much different. However, due to a large error at the northing point, the points were outliers and could not be used. The result stated that the largest difference in height was ±0.875 m and the smallest was ±0.025 m. The RMSE for height was ±0.577 m. The result can be stated that the accuracy assessment of the 3D building model was approximately similar to the actual building model because it was under tolerance. The accuracy of coordinates depends on the residual during the processing. The error of 3D model can increase due to many aspects such as poor in camera calibration, the establishment of the control point and process of image matching.

Analysis of length measurement of 3D model

The final analysis was done through the length measurement of the 3D model. The measurements were calculated between the result (measured length) and real building (actual length). The measurement was carried out based on different features such as window and wall. The result stated that the maximum residual was 0.345 m and the minimum was 0.001 m. The RMSE for length measurement was ±0.140 m. The accuracy of length measurement for the 3D model depends on the quality of the control point establishment of the building. The error can increase if the upper mark is at the wrong point during image processing.

CONCLUSIONS

Based on this study, it shows that the UAV in Photogrammetry has become one of the latest technologies used in mapping and the 3D application. The aim of this study is to model a 3D building using the UAV images of the Dewan Agung Tuanku Canselor Shah Alam Selangor as the study area. Based on this study, the results were assessed between the 3D building models and actual building model. The high quality of the 3D model result was measured using the Photomodeler software. The result of the 3D model was almost exactly similar to the features and texture of the real building. Next, the 3D model was formed with the northing, easting,] and heighting information after the control point representation of the building model. As stated in the PhotoModeler scanner software guideline, the final 3D model formation project was good. The result can also be analysed in RMSE of the northing, easting, and heighting. The result stated that the accuracy assessment of the 3D building model of the northing was ±0.7 m, easting ±0.2 m and heighting ±0.5 m. The accuracy assessment depends on the residual during the processing. Therefore, the error of the 3D model can increase due to many aspects such as poor in camera calibration, the establishment of the control point and process of image matching. The length measurement was also discussed in the accuracy assessment of the 3D model. The result stated that the measured and actual length were approximately similar where the measurement was carried out based on different features of the building. The concepts of the UAV technique applied in the close range photogrammetry can be introduced to reconstruct a Dewan Agung Tunku Canselor 3D building model.

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