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INTEGRATION OF AERIAL AND CLOSE-RANGE PHOTOGRAMMETRIC METHODS FOR 3D CITY MODELING GENERATION

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Abstract

Aerial photogrammetric method is currently used to generate the 3D city model at level of detail two (LOD2). However, the method faced with the problem of mapping the small buildings due to scaling factor. Therefore, this research aim to produce 3D building model of small building by using Close-Range Photogrammetric (CRP) method. The generated 3D model were than integrate with the 3D city model generated from aerial images for simple visualization and applications.

Keywords : 3D City Model, 3D Building, Aerial Photogrammetry, Close-range Photogrammetry, PhotoModeler, Visualisation

1.0 INTRODUCTION

In 3D city model development, it is important to choose appropriate data and suitable method (Kobayashi, 2007). Aerial photogrammetry data mainly used in 3D city model development compared to the airborne laser scanning data. Aerial photogrammetry performs semi-automatic process in developing 3D city model; manual digitizing on aerial images and performs automatic process in height determination.

The 3D city models consist of fundamental component such as Digital Terrain Model (DTM), building models, street space models, and green space models (Jurgen et al., 2006). Recently, the reconstruction of 3D building model in 3D city model development has attracted public interest to improved 3D building model in terms geometry and textures. In the earlier production of 3D city model by using aerial photogrammetry, Vermeij and Zlatanova (2001) had reconstructed the building model as a block model. The block model is extracted from digitizing the building shape from the roof view. Textures and roof is not visualized in the block model. In 2003, Flamanc et.al, has improved the 3D building model by adding roof on top of the block model without textures. Then it follows by Kobayashi (2007), which make an improvement on the building model textures and geometry.

However, there still has constraint to develop building model from aerial images such as the recognition of the small building in aerial images. Aerial photogrammetry is used for small-scale mapping and the images are taken from high position by airplane. The aerial images gives an advantage to covers wide area on the ground but lack in recognition of small building due to the resolution of aerial images. **Figure 1** shows the small building in aerial images.

Figure 1 The difficulties to recognize small building in aerial image

In addition, the facade and geometry of the building from aerial images is visible from the air. The architectural instalments such as windows, door or balconies are not visible in aerial images.

Therefore, due to the circumstances of aerial images in the reconstruction of 3D building model, this research objectives are to improve the current photogrammetric technique in the reconstruction of 3D building model towards of 3D city model development by using Close-Range Photogrammetric (CRP) technique and to verify the limitation of Close-Range photogrammetric technique in the reconstruction of 3D building model due to the geometry and textures of the building facade.

2.0 CLOSE-RANGE PHOTOGRAMMERY

Close-range photogrammetry methods are fundamental for aerial photogrammetry (Hallert, 1960). In general, close-range photogrammetry is a technique of representing and measuring 3D objects using data stored on 2D photographs, which are the base for rectification (Vesna, 2008). In order to obtain 3D information, the two photographs of the same objects are necessary. Close-range photogrammetry is a part of terrestrial photogrammetry but has dissimilarity in camera-to-object distance. In the close-range photogrammetry, the limitation of camera-to-object distance is less than 100m (Cooper and Robson, 2000).

Close-range photogrammetry is mostly used for deformation measurement of structures, architectural mapping, modelling buildings, documentation of artefacts, reverse engineering purposes, or remodelling traffics accidents and crime investigation. Architectural and archaeological photogrammetry is the example of close-range photogrammetry application that is widely been used since 1960s (Dallas, 1996). In architectural and archaeological, the close-range photogrammetry is used as data capture to provide 3D CAD drawing for structures of the buildings or monument. The accuracy of close-range photogrammetry in producing 3D model for architectural and archaeological gives the promising result and it is proven by Hanke and Ebrahem (1997).

Due to the capabilities of close-range photogrammetry in 3D measurement of architectural, an experiment has been conducted to create 3D building model for 3D city model application. Low cost close-range photogrammetry technique is the aims to create 3D building model.

3.0 METHODOLOGY, INSTRUMENTATION AND RESULTS

In this research, aerial photogrammetry data is still used in order to produce DTM or base of the 3D city model while the close-range photogrammetry is to perform the 3D building reconstruction. In addition, the others objects or entities that can be placed in 3D city model such as streets, trees, and parking lot can be extract from aerial photogrammetry. **Figure 2** shows the flow of aerial photogrammetry task and close range photogrammetry task. Close-range photogrammetry is the main task that highlighted in this research where it is used to improve the method of 3D building reconstruction by aerial photogrammetry.

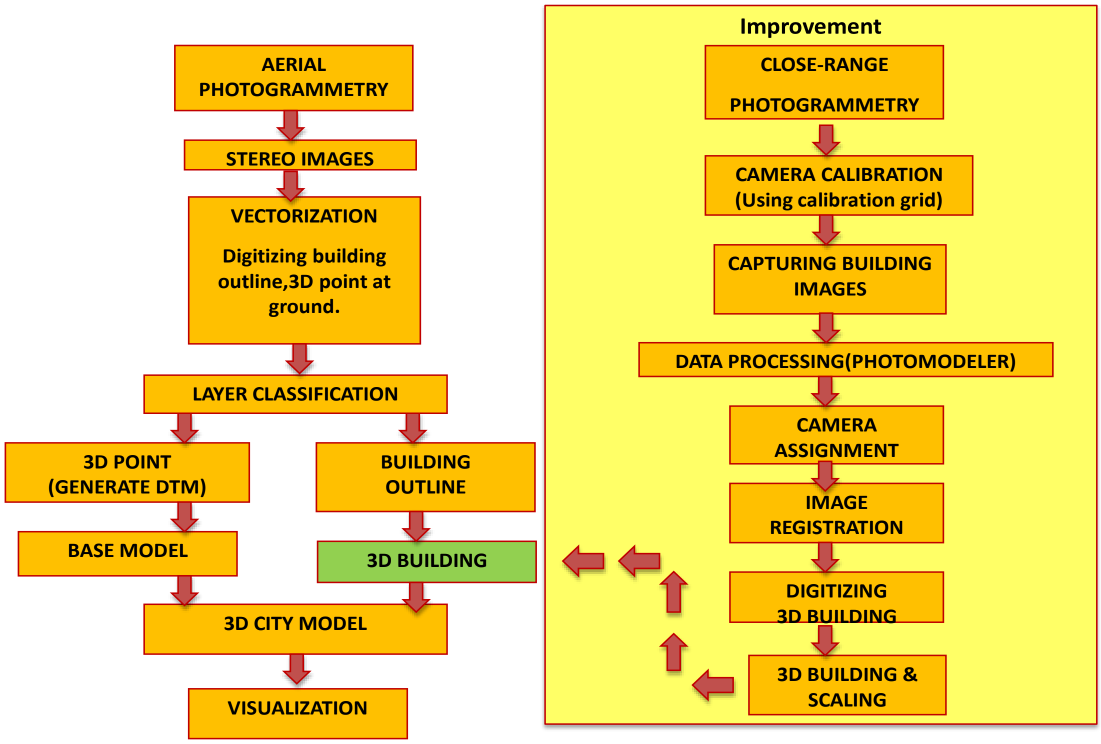

Figure 2 Flow of Aerial Photogrammetry and Close Range Photogrammetry Task

3.1 Aerial Photogrammetry Processing

The aerial images processing are including stereo model processing, vectorization, layer classification and development of base model. Stereo model processing is the process to

orient two aerial images and it is performs by using DVP software and the stereo model produces stereo images. The stereo images are used in vectorization stages which it involves the digitizing the building outline and extracted the 3D points in the stereo images. The 3D points consists of local coordinate information (x,y) and height information (z). Then, layer classification is performing to separate the 3D point and building outline layer for base model development.
In order to complete the base model for 3D city model, the DTM are generated from 3D points and the buildings outline are drape onto the DTM. **Figure 3** shows the process of DTM generation and **Figure 4** shows the building outline on DTM. Both of these processes are perform by using ArcScene Software

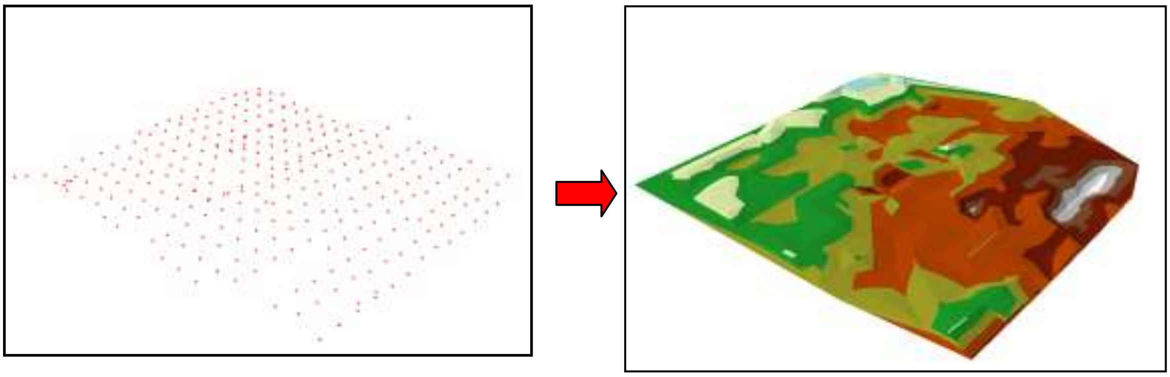

Figure 3 Digital Terrain Model (DTM) generation from 3D point height.

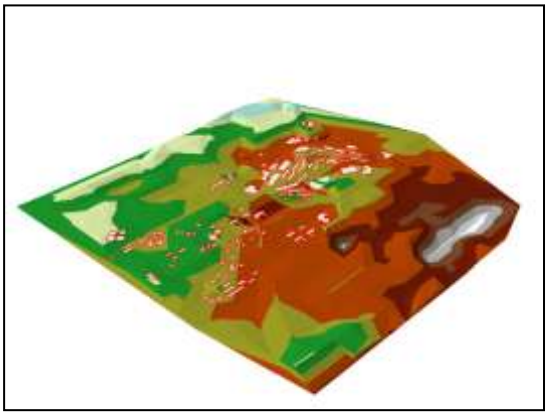

Figure 4 Building outline drape onto the DTM

Since the buildings are important component in the creation of 3D city model, the temporary buildings model can be placed to the base model. The temporary buildings model are modelled by extruded the buildings outline. The geometry and the height of the buildings are based on the buildings outlines.

At this stage, landscape effect can be added to the model to make the model more realistic. The material that used as the visual effect is orthophoto image. Orthphoto image are produced from the aerial images and it is overlay onto the DTM. **Figure 5** shows the extruded buildings with the landscape effect from orthophoto images.

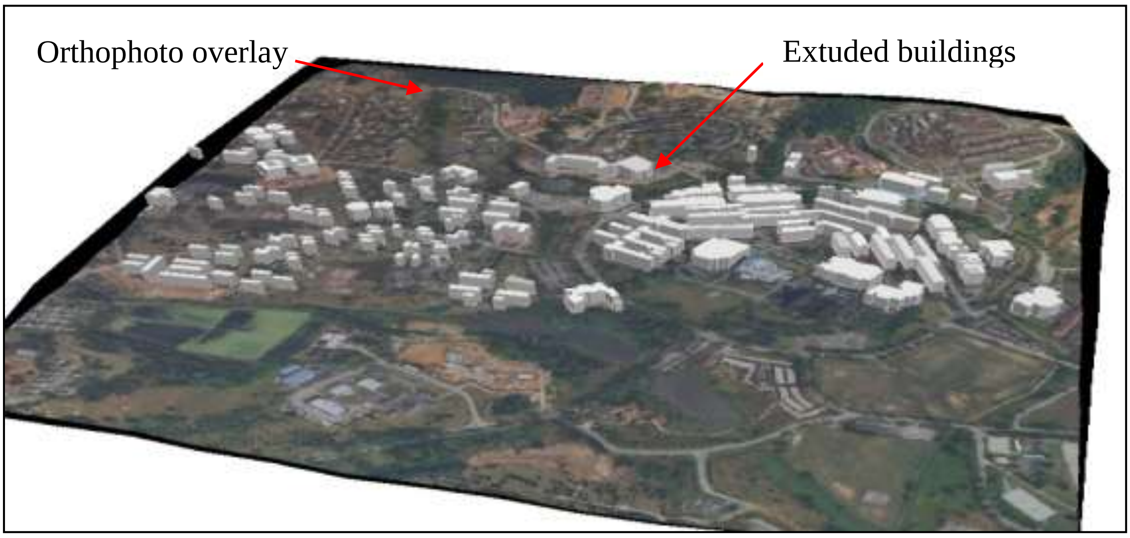

Figure 5 Extruded buildings with landscape effect from orthophoto images

3.2 Close-range Photogrammetry Data Capture and Processing

The SONY CYBERSHOT DSCF828 digital camera is used for CRP data collecting. Before capturing the image, the camera needs to be calibrated to define camera parameters in order to provide accurate measurement. The camera parameters are focal length, principal point, imaging scale, and lens distortion. In this study, the camera is calibrated by using calibration grid from PhotoModeler software. PhotoModeler is close-range photogrammetry software. The calibration grid is a pattern of dots and design for the Camera Calibrator in PhotoModeler. The calibration is started by captured eight calibration images with four camera position and one landscape and one portrait shot at each position.

While taking the images of the buildings, the camera position between two cameras must be in good angular separation which is close to 90º. The camera position is important in generate the correct position for the 3D point. The poor camera position occurs when the position between the two cameras is close to each other. In addition, the images must be overlap as much as possible in order to reference the points in the images. This is because, PhotoModeler needs points marked in two or more images and the images taken side by side should contain the same object features and points.

The images of the building are captured as many as well to covers the entire building facades. This work has captures 19 images to covers the building facades. When completed capture the images, the building image are processed using PhotoModeler 6.0.

3.2.1 PhotoModeler Processing

The building images that acquired are processed using PhotoModeler software to create the 3D building model. **Figure 6** shows the processing step to generate 3D building by using PhotoModeler 6.0.

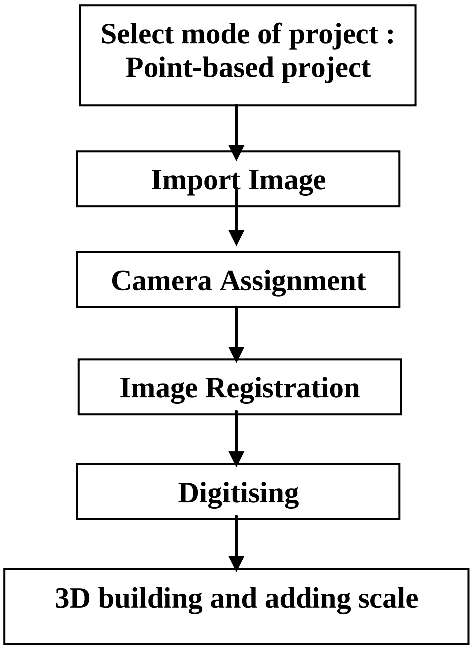

Figure 6 The Processing Step to Generate 3D Building by Using Photomodeler

PhotoModeler 6.0 consists of two modes of project; point-based project and shaped-based project. Point-based project is a process to marking the point on the photograph to create the 3D objects. The shaped-based model is a process to create the 3D objects by marking the edges of the shape into the photograph. In this study, the point-based mode is selected to process the data because this mode is basically used to create 3D for complicated object.

The next step is to import the building images that had been captured into the PhotoModeler 6.0. When starting the project, at least two or three photographs can be imported to the software because it helps to reduce the chance of failure in processing. The camera description has to be assigned into the software by importing the camera calibration file that had been made before capturing the image. PhotoModeler needs the camera description to create a geometrical relationship between points on the photograph and points in 3D space. The image registration process started after importing the calibration file. Image registration is the process to mark the point or edges of the objects on two or more different photograph and it is called as image referencing. The referencing must be mark on same position between the two photographs. **Figure 7** shows the referencing between the two images. At least six points has to be referenced on the photograph in order to register the images.

Figure 7 The referencing between the two images

The digitising process is performed in order to create the 3D building model. The line mode is used to perform the digitising process. **Figure 8** shows the digitised images. The image registration and digitising step are repeated when importing the new image to the software.

Figure 8 The digitized images

Once the 3D building completed digitised, the model are scaled and oriented into coordinate system by using Three Point Rotation menu in PhotoModeler. Three known coordinates on the building are assigned into the model. In order to build up the photo-textures on 3D building model, the facades of the building was identified using surface path tool. This tool allows extract the textures from images into the model. Afterwards, the 3D building model are imported to 3D DXF (dxf) AutoCAD file as the building geometry and 3D Studio (3ds) file as the building textures to integrate with base model.

3.3 Integration Aerial and Close-Range Photogrammetry

The integration between aerial and close-range photogrammetry are execute in ArcScene. The 3D DXF file created in PhotoModeler are import into the base model as a building polygon while the 3ds cannot import directly into the base model. The 3ds file is needed to convert to Multipatch (mdb) file as a requirement in ArcScene to display 3D textures. Multipatch is a 3D geometry used to represent the outer surfaces of features that occupy a discrete area or volume in 3D surface (ESRI,2008). Google Sketch-up version 6 is used to help convert the 3ds file into mdb file so that the textures can import to the ArcScene. **Figure 9** shows the 3D building integrates with base model in ArcScene.

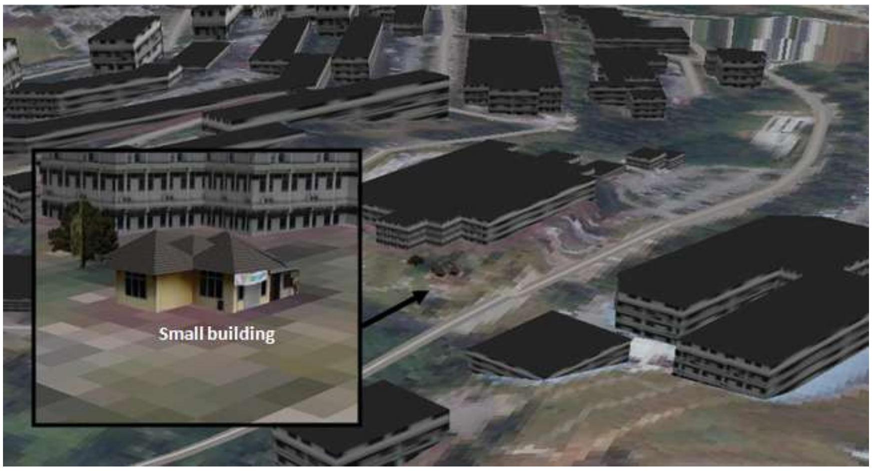

Figure 9 The 3D building integrates with Base Model in ArcScene

4.0 RESULT AND ANALYSIS

4.1 The 3D Building Model

The images of simple building had been captured to produce the 3D building model. In order to create the 3D building model, 19 images are taken but only 6 images are used to process and create the 3D model. **Figure 10** show the results of the 3D building model in wireframe and **Figure 11** shows the 3D building model with texture.

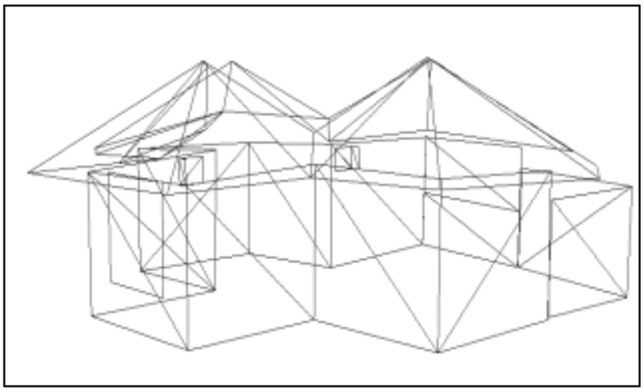

Figure 10 Wireframe 3D building model

Figure 11 3D Building Model with Texture

4.2 Visual Analysis

In this study, the LoD of 3D building model from close-range photogrammetry is categorising in LoD3. **Figure 12** shows the different LoD of building model between the base model and close-range photogrammetry.

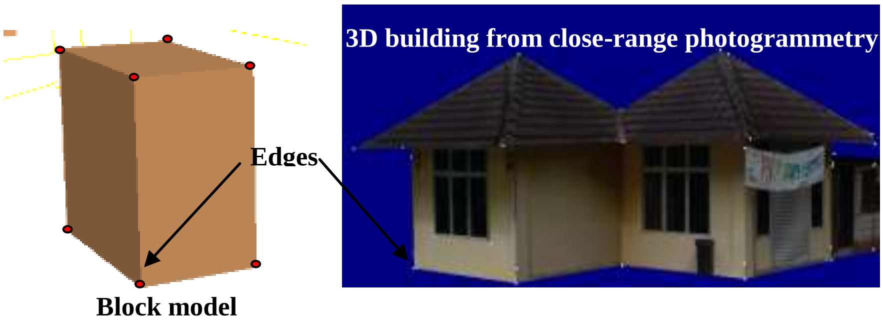

Figure 12 Different LOD of Building Model between The Base Model And Close-Range Photogrammetry

The results between the two models are compared in term of geometry and textures. The comparison is shown in **Table 1**.

Table 1 Comparison between block model and 3D building model from close range photogrammetry

3D model	Geometry	Textures
Block model	Consist of 8 edges No roof	No textures
3D Building model	Consist of 114 edges. With roof	Textures

The block model is a simple 3D model and it is shown such as a box. Block model consist of 8 edges, without roof and without textures. The edges are defined from the 3D block model in base model. The 3D building model as compared to close-range photogrammetry, the building model is produced same as the building from real world. The building model consists of 114 edges including the roof edges and the building model has textures. Therefore, the data from close-range photogrammetry is needed in order to develop photo-realistic 3D city model.

4.3 PhotoModeler Accuracy Assessment on 3D Building

The accuracy of photogrammetric measurement are depends on camera resolution, quality of camera calibration, geometry of the camera position, and the precision of marking location on the images (PhotoModeler, 2009). High camera resolution with good quality camera calibration is helps to achieve high accuracies in precision marking location on the images. This is the reason why the high camera calibration with good calibration results is used in this project.

The geometry of the camera position refers to angles between the camera stations. The low angle of the camera station gives low accuracy of the projects. The precision of marking location on the images shows the quality of measurement. Precision is determines by the number of residual value which the lower residual value shows the good marking precision. The geometry of the camera position and marks precision location is shown on **Table 2**.

Table 2 Accuracy Assessment of point location.

Id	X	Y	Z	X Precision	Y Precision	Z Precision	RMS	Angle
1	627182.6509	172769.4714	2.1349	0.0001	0.0001	0.0001	0.0003	64.1656
2	627186.0713	172769.3138	0.0150	0.0001	0.0001	0.0001	0.0013	81.7586
42	627180.9008	172778.7513	0.0491	0.0001	0.0001	0.0001	0.0036	88.8676
75	627179.0669	172776.5189	2.2998	0.0001	0.0001	0.0001	0.0049	89.4690
76	627178.9186	172771.7541	2.2551	0.0001	0.0001	0.0001	0.0077	86.2181

In **Table 2**, Id refers to the number identifying of marking points, XYZ value refers to the marking point coordinates, XYZ Precision shows marking point precision, RMS is refers to the Root Mean Square which shows the average marking precision of the point in pixels, and last column is shows the point angles between the photo. The overall RMS value of the building model that has been developed is 0.005 pixels and according to PhotoModeler (2009) the RMS value should be less than 3 pixels in order to have good photogrammetric project.

5.0 CONCLUSION

As a conclusion, the CRP method has capabilities to solve the constraint of aerial images in developing 3D model for small building in 3D city model development. In addition, the combination of aerial and close-range photogrammetric can be achieved into LOD3 which consist of details building geometry and textures.

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