



Smartphone Photogrammetry: A modern technique to create 3D Models of a Building

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Abstract – Smartphone is an omnipresent device for data acquisition that assist in image capturing. Image as rich source of data are suited for generating point clouds and 3D models. This research intend to investigate the potential use of Smartphones for cheap and rapid generation of point clouds and 3D models. It uses two smartphones (TECNO W3 and AFRI-ONE) for multiples images capturing and PhotoModeler UAS software trial version is used to process these images from both phones separately. The results obtained for TECNO W3 gave maximum and minimum pixels of point marking residuals as 2.1 and 0.000389 pixels respectively; maximum and minimum pixels of point marking RMS residuals as 1.93 and 0.000309 pixels respectively; and maximum, minimum and overall RMS point of precision as approximately 0.52m, 0.52m and 0.52m respectively while that of AfriOne 2in 1(3.50) gave maximum and minimum pixels of point marking residuals as 2.89 and 0.0000421 pixels respectively; maximum and minimum pixels of point marking RMS residuals as 2.08 and 0.0000401 pixels respectively; and maximum, minimum and overall RMS point of precision as approximately 0.52m, 0.52m and 0.52m respectively. The 3D model will not only be used for visualisation purposes but will also serve as a detailed information source in helping technical staff to maintain any historical buildings as well as providing documentation for other projects in built environment. The resulted outputs can be integrated in the GIS and in addition, the panoramic images can processed to generate interactive spherical views used for the creation of a virtual tour for Tourists.

Keywords: *Models, MVS, Photogrammetry, PhotoModeler, Smartphone*

1. Introduction

Smartphone is a mobile phone or cellular telephone with an integrated computer and other features not originally associated with telephone such as an operating system, web browsing and the ability to run software applications (TechTarget, 2018). This device have several features such as connection to an App store, internet connectivity, a mobile browser, a digital camera with video capacity, GPS-global positioning system among others. Some of these features play a vital roles in photogrammetry, for instance, a digital camera with video capacity do provide the means of capturing digital images. Hence, it could serve as data acquisition device for photogrammetry projects.

Photogrammetry is the science of making measurements from photographs, especially for recovering the exact positions of surface points (Wikipedia, 2018). In other words, it is simply the science, art, and technology of obtaining reliable information from Photographs (engineering.purdue.edu). Therefore, it is simply a 3-dimensional coordinate measuring technique that uses photographs as the fundamental medium for metrology or measurement (Pillai, 2015). According to Pillai (2015), the fundamental principle used by Photogrammetry is triangulation and this is achieved by taking photographs from at least two different locations, so called "lines of sight" can be developed from each camera to points on the object. These lines of sight are often referred to as rays, are mathematically intersected to produce the 3-dimensional coordinates of the points of interest and 3D models. This technique has been employed in topographic services but in recent years it is widely applied in the field of architecture, industry, engineering, Archaeology, historic documentation (Çabuk., Deveci , Erginçan , 2007), forensic, underwater, medicine, Building design and renovation, geology and many others for the production of precise 3D data (Remondino, 2003).

Therefore, Smartphone Photogrammetry is a science and technology of obtaining reliable information from multiple digital images acquired with smartphone using Photogrammetry software like PhotoScan, PhotoModeler, Pix4D Mapper, among others. Smartphone is an omnipresent device for data acquisition that assist in image capturing and captured Images are rich source of data which are suited for generating point clouds and 3D models. The benefits of this technique are low cost of data acquisition, rapid gathering of digital images and easy to obtain/access information from terrestrial

1.1 Aim and Objectives

The main aim of the research is to create 3D model of a Building from multiple images captured with two Smartphones. To achieve the aim of this project, the following objectives will be follows:

- i. Create a calibrated or approximate camera description,
- ii. Plan the Measurement Project,
- iii. Take photographs of the object or scene,
- iv. Import the photographs into PhotoModeler,
- v. Mark features (e.g. points, shapes etc.) on the photographs,
- vi. Identify which points are the same, and
- vii. Process the data

2. Literature Review

2.1 Photogrammetry

This technique is the science, art, and technology of obtaining reliable information from photographs or images. It can be classify into Metrical and Interpretative Photogrammetry (Pillai, 2015). The former is the surveying applications used to determine distances, elevation, areas, volumes, and cross-sections to compile topographic measurements. Thus, it primarily uses aerial and sometimes terrestrial photos. Therefore, the later involves recognizing objects from photographic images created from satellite imagery which senses energy wavelengths which is called remote sensing (i.e it is art or science of gathering information about an object or image without actually coming into physical contact). Several professions like Surveying, Geology, archaeology, Military, Agriculture, deformation studies, among others can use this technique in their various field and it is employed since cover area quickly, Low costs and easy to obtain or access information from air or Terrestrial (Pillai, 2015).

2.2 Dense Surface Modeling

This is a set of tools for extracting and manipulating a dense pattern of points from photographs or images (PhotoModeler UAS 2018 help). The surfaces in the photographs should have a visible random and/or natural texture and the photographs should ideally be taken in a paired stereo configuration (Remondino, Spera, Nocerino, Menna, & NEX, 2014). It can be thought of as a camera-based 3D ‘laser-scanner’ which can obtain detailed surface measurements and models that would not be practical otherwise with point-based photogrammetry.

This is available in the Photogrammetry software like PhotoModeler Scanner, PhotoModeler UAS, PhotoScan, Pix4D Mapper, among others. These have the ability to do Dense Surface Modeling from photographs or images. There are two methods to choose from when generating DSM’s (PhotoModeler UAS 2018 help). By default the MVS (Multi-View Stereo) method is selected. The main difference between the two methods is that MVS uses multiple photos to extract and match features to build up a dense point cloud, while the Paired Photo method works on pairs of photos only. With Paired Photo’s one generates a complete model by picking multiple pairs and then merging the point clouds. With MVS all photos are considered at once.

i. MVS approach

In many cases the MVS approach is more automated and usually requires no parameter adjustment, no extents / trims, and no selection of photos to process. The MVS method works best when there are a large number of overlapping photos. DSM processing will create a single PointMesh based on the photos in the project.

You can set the Meshing steps to triangulate the point cloud, either as a step immediately after DSM creation using the Meshing tab of the DSM dialog, or you can run the Meshing steps separately using the Modify PointMesh tool after the PointMesh point cloud is generated (Schwind, 2018)

ii. Paired Photos approach

The Paired Photos approach (which was generally replaced by MVS in v2013) can be selected for projects with a smaller number of photos taken in stereo pair configurations, with less overlap between pairs. The Paired Photo method can sometimes produce more uniform grids of points as well. For the Paired Photo method you will need to pick appropriate photo pairs when running the DSM process. Choose the pairs that meet the requirements as described in DSM Photo Requirements. These can be run all at once or one at a time. The Select Best Photo Pairs Dialog can be used to select one or more photo pairs based on certain criteria. The processing will create a PointMesh per pair and the meshing steps will register and merge these, then triangulate.

Therefore, Dense Surface Modeling is a search algorithm that uses an existing pre-oriented project and photos from that project to search for image patches that 'look' alike (Lemmens, 2018). The MVS method uses multiple photos, while the Paired Photos method works in photo pairs. When a good match is found between photos, the orientation and camera data allows the program to compute the correct 3D location of the surface point corresponding to the image patch. The basic steps of the DSM process are (PhotoModeler UAS 2018 help):

- i. Start with an oriented and high-quality PhotoModeler project with low residuals and at least two or more camera stations with suitable base-to-height ratios. Define the extents of the search using DSM Trims (a trim can include the defined area or optionally exclude it), using the entire photo boundary (PhotoModeler will define the combined area of the selected images), or using one or more approximate surfaces (these surfaces can be path surfaces, NURBS surfaces, surface draw connected surfaces, or even cylinders, see DSM Approximate Surfaces). If using MVS, it usually not necessary to define extents, though it will use DSM Trims if they have been defined.
- ii. Run the DSM process with appropriate settings. Steps (iv) though (xi) are carried out by the program automatically.
- iii. The DSM algorithm first collects the photographs to be processed.
- iv. Depending on the DSM method, small features in images are matched between photos to build up a point cloud.
- v. All the matches are then optimized for the best overall fit, throwing out bad and weak matches, plus handling occlusions and large depth changes, etc.
- vi. A subpixel refinement is carried out for the matches.
- vii. The matched positions are used to create 3D points using camera station information.
- viii. If more than one pair of photographs is being run, the results of each point cloud are then registered and merged into one cohesive point cloud.
- ix. The data clean up and meshing steps then convert the point cloud into a triangulated mesh surface.
- x. In some projects noise is inevitable (noise is 3D points solved off the correct surface). High quality projects minimize this but there may be background imagery that gets in the way to create noise. In these cases, the point meshes can be created by DSM without a meshing step. Then using the manual point edit mode you delete the unwanted points. Then you run the registration, meshing and smoothing as a separate step.

Finally, the mesh is then texture from the photos using the best resolution from various photos used in this process (John, 2017).

2.3 3D Model

A 3D model is a set of connected 3D points, edges, curves and cylinders or shapes which represent an object. Three dimensional points have coordinate values for each of the Cartesian axes (X, Y, and Z). The points and edges in the 3D model can be connected by lines and/or by patches, called Surfaces. These connections help the user to visualize the three dimensions when the model is projected onto a flat surface such as a computer monitor or a printed page.

This section provides an overview of the process of creating a 3D model with PhotoModeler, from start to finish. There are basically steps of producing a 3D model with Photogrammetry software like PhotoModeler UAS 2018. According to PhotoModeler UAS 2018 help, the steps are given as follows:

- i. Create a calibrated or approximate camera description,
- ii. Plan the Measurement Project,
- iii. Take photographs of the object or scene,
- iv. Import the photographs into PhotoModeler,
- v. Mark features (e.g. points, shapes etc.) on the photographs,
- vi. Identify which points are the same,
- vii. Process the data, and
- viii. Export the resulting 3D data to a CAD or graphics program.

The nature of the steps changes based on the type of project such as an automated SmartPoint project, an automated Coded Target project, a manual project, Time-based Measurement / Motion Projects, or a UAV / drone project (PhotoModeler UAS 2018 help). The basic theory and process is similar in all project types but some details are changed - based on the level of automation.

3. Methodology

The process of creating a 3D model or point cloud starts by taking photographs of the object or scene (My Apartment in Olowobida, Ede) using two Smartphone (TECNO W3 and AfriOne 2in 1). The multiples images acquired with these devices were added and processed separately in Photogrammetry software called PhotoModeler.

In order to process the captured images acquired with both Smartphones, click on create new project and automatically generates Point Cloud and Meshes (Smart Points). This is achieved through Feature detection processes, twenty six (26) images and one hundred forty eight images (148) were detected while processing the images acquired by both Smartphone separately; matching and marking were done for devices; orientation of images from both devices were done as well and Smart Matched were carried out for both captured images by both Smartphones separately.

Thereafter, the images from both devices are automatically aerotriangulated through both process of image comparison (pairing of images) and Multi-View Stereo (MVS). This process automatically extract tie points, matches pairs and determines orientation and positioning of the block images. It is achieved entirely through the use of camera positions and the resulted aerotriangulated block were then processed into a 3D model, and clean up the point cloud to produces a triangulated mesh with high geometric precision.

Finally, the mesh is then texture from the photos using the best resolution from various photos used in this process.



Figure 1 My Apartment in Olowobida, Ede

4. Results and Analysis

Figure 2 below shows that out of the twenty six (26) photos or digital images captured by TECNO W3 only fourteen (14) were oriented and that a total of one thousand, four hundred and eight (1408) SmartPoints were obtained with a maximum residual and overall RSM residual of 2.1 and 0.696 respectively while Figure 3 shows that out of the one hundred and forty eight (148) photos or digital images captured by AfriOne 2in 1 ninety (90) were oriented and that a total of thirteen thousand, six hundred and seventy one (13671) SmartPoints were obtained with a maximum residual and overall RSM residual of 2.89 and 0.928 respectively.

The results obtained for TECNO W3 in figure 4 gave maximum and minimum pixels of point marking residuals as 2.1 and 0.000389 pixels respectively; maximum and minimum pixels of point marking RMS residuals as 1.93 and 0.000309 pixels respectively; and maximum, minimum and overall RMS point of precision as approximately 0.52m, 0.52m and 0.52m respectively while that of AfriOne 2in 1(3.50) in figure 5 gave maximum and minimum pixels of point marking residuals as 2.89 and 0.000421 pixels respectively; maximum and minimum pixels of point marking RMS residuals as 2.08 and 0.000401 pixels respectively; and maximum, minimum and overall RMS point of precision as approximately 0.52m, 0.52m and 0.52m respectively.

The end result of this research is a 3D models created from the images or photos captured for TECNO W3 and AfriOne 2in 1 are in Figure 6 and Figure 7 respectively.

Summary			
Last Processing			
Software Version: PhotoModeler UAS 2018.0.0.2235, demo (64-bit)			
Date: Sun Jun 17 18:27:26 2018			
Photo Summary			
	Total	Oriented	Not Oriented
Photos	26	14	12
Point Summary			
	Count	Maximum Residual	Overall RMS Residual
Manually marked	0	n/a	0
Sub-pixel	0	n/a	0
SmartPoints	1408	2.1	0.696
PointMesh Summary			
284223 points in 2 point cloud PointMeshes			
101643 triangles in 2 triangulated PointMeshes			

Figure 2

Quality			
Photographs			
Total Number: 26		Number Oriented: 14	
Cameras			
Calibrated	Auto Calibrated	Field Calibrated	Inverse Other
0	0	0	2
Photo coverage (percent)			
Minimum: 18.8	Maximum: 72.3	Average: 62.5	
Point Marking Residuals (pixels)			
Minimum: 0.000389	Maximum: 2.1	Point ID of Max: 5077	
Point Marking RMS Residuals (...)			
Minimum: 0.000309 (pt:3966)	Maximum: 1.93 (pt:3310)	Overall: 0.863	
Point Angle (degrees)			
Minimum: 3 (pt:5009)	Maximum: 23.3 (pt:5677)	Average: 6.13	
Point Precisions (m)			
Minimum: 0.52 (pt:3073)	Maximum: 0.52 (pt:6474)	Overall RMS: 0.52	

Figure 4

Summary			
Last Processing			
Software Version: PhotoModeler UAS 2018.0.0.2235, demo (64-bit)			
Date: Sun Jun 24 17:33:01 2018			
Photo Summary			
	Total	Oriented	Not Oriented
Photos	148	90	58
Point Summary			
	Count	Maximum Residual	Overall RMS Residual
Manually marked	0	n/a	0
Sub-pixel	0	n/a	0
SmartPoints	13671	2.89	0.928
PointMesh Summary			
1561351 points in 1 point cloud PointMeshes			
269178 triangles in 1 triangulated PointMeshes			
Coordinate system Summary			
Units: meters			
No coordinate system defined.			
External check Summary			
0 check distances (average delta: 0 m, 0%)			
0 check points (average delta: 0 m)			
Description / Notes			
3D RECONSTRUCTION WITH AFRI-ONE			

Figure 3

Quality			
Photographs			
Total Number: 148		Number Oriented: 90	
Cameras			
Calibrated	Auto Calibrated	Field Calibrated	Inverse Other
0	1	0	0
Photo coverage (percent)			
Minimum: 20.8	Maximum: 86	Average: 68.3	
Point Marking Residuals (pixels)			
Minimum: 4.21e-005	Maximum: 2.89	Point ID of Max: 31205	
Point Marking RMS Residuals (...)			
Minimum: 4.01e-005 (pt:64199)	Maximum: 2.08 (pt:11919)	Overall: 1.08	
Point Angle (degrees)			
Minimum: 3 (pt:14763)	Maximum: 89.9 (pt:27365)	Average: 12.5	
Point Precisions (m)			
Minimum: 0.52 (pt:877)	Maximum: 0.52 (pt:68208)	Overall RMS: 0.52	

Figure 5



Figure 6a TECNO W3 3D MODEL



Figure 6b TECNO W3 3D Model



Figure 7a AfriOne 2in 1 3D Model



Figure 7b AfriOne 2in 1 3D Model



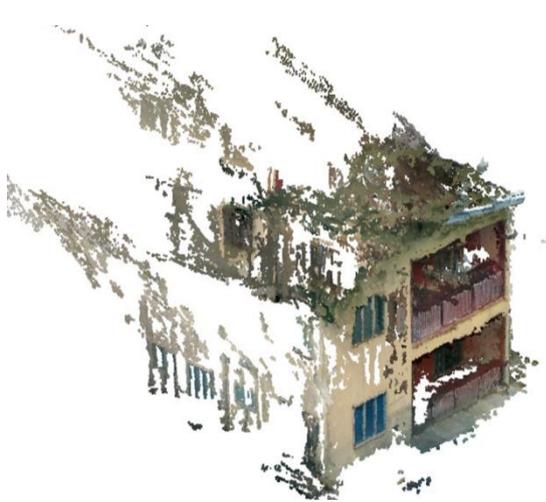
Figure 7c AfriOne 2in 1 3D Model



Figure 7d AfriOne 2in 1 3D Model



Figure 7e AfriOne 2in 1 3D Model



Conclusion and Recommendations

5.1 Conclusion

It is clear from this research that the higher the point density of point clouds is, better the 3D models created. The end products of this work will not only be used for visualisation purposes but will also serve as a detailed information source in helping technical staff to maintain any historical buildings as well as providing documentation for other projects in built environment. The resulted outputs can be integrated in the GIS and in addition, the panoramic images can be processed to generate interactive spherical views used for the creation of a virtual tour for Tourists. Therefore, accurate 3D models are core element of modern urban mapping and thus represent an important source of information to support various applications, such as space management, energy assessment, 3D cadastre, noise and pollution propagation or disaster management.

5.2 Recommendations

Based on the findings from this research, the following recommendations are made:

- The government should provide enough fund for procurement of photogrammetry software and hardware in order train students in this new trend of modelling.
- Licensed software should be employ subsequently since the accuracy of any work carry out will be display and store for further processing which is not possible in the PhotoModeler UAS 2018 trial version used for this modelling.
- The Smartphone Photogrammetry can be use to research into several fields of studies.
- The same photos quality should be use in subsequent work since this will enhance better output.
- Other photogrammetry software can be use in subsequent work in other to compare the results with that obtain using PhotoModeler UAS 2018

Acknowledgements

The study was made possible by downloading of free trial version of PhotoModeler UAS 2018 a product of Eos Systems. We really appreciated it kind gesture for allowing us access to it trial version in carrying out this work.

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