COMPARISONS OF THE THREE-DIMENSIONAL MODEL RECONSTRUCTED USING MICMAC, PIX4D MAPPER AND PHOTOSCAN PRO

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ABSTRACT: Three-dimensional models derived from digital survey techniques are growing and focusing on many areas of application. The three-dimensional model has high geometric accuracy with rich spatial and spectral information. In this study, we will utilize three software for three-dimensional models reconstruction, they are commercial software packages and open source tools. Their advantages and disadvantages will be investigated. The suggested commercial suites are PhotoscanPro and Pix4DMapper, whereas the open source one is the MicMac tools developed by IGN France. The images are taken by a Sony Alpha 6000 digital camera with 20 mm focal length. In general, there are four steps to reconstruction a 3D model from 2D digital images. The first step is the initial processing for photo triangulation with camera self-calibration. After initial processing we can obtain the exterior and interior orientation parameters for all images. We setup a scale bar during image acquisition. Thus, after dense image matching, i.e. the second step, we can obtain dense point cloud with real dimension. For accuracy evaluation, we utilize Riegl VZ400 terrestrial laser scanner to collect reference point cloud. Then, we can compare their 3D discrepancy. The third and fourth steps are mesh and texture generation, respectively. The performance comparisons will consider geometric accuracy, completeness and point density. After experiments, all three software provide satisfying results and we conclude that PhotoScanPro and Pix4DMapper are more straightforward to use with user friendly interface. While the MicMac is recommended for experienced users, particularly it support push-broom sensors, such as high-resolution satellite image.

1. INTRODUCTION

Three dimensional models have become an essential tool for experts in various domains. They are used in urban and environmental planning, in cultural heritage documentation, in building and infrastructure inspection, in industrial measurement and reverse engineering applications, in film industry, video games and virtual reality applications. Various methods are used in order to produce these models such as photogrammetry, laser scanning and traditional surveying (Georgantas, 2012). Three dimensional reconstruction for object has great significance for the protection and documentation of object. In order to document small cultural assets, adapted image-based 3D reconstruction are suggested. The increase in performance of the digital camera and the development in calibration technology, close-range photogrammetry is more easily used to recover 3D model of the object with high accuracy (Samaan, 2013).

The construction process based on close-range photogrammetry can be divided mainly into several steps: image acquisition, orientation, and dense image matching. So, automating the construction depends on automating these procedures. In close-range photogrammetry, there are more complex scenes, occlusion, distortion, and the object has various shapes to be taken into account (Samaan, 2013).

In this paper, we are presenting an accuracy assessment of 3D point clouds of complex interiors produced with a fully automated open source photogrammetric software MicMac developed by the IGN (Institut Geographique National), Pix4D Mapper and Agisoft PhotoscanPro. MicMac, as a photogrammetric tool, stresses the aspects of accuracy, reliability, and provides tools typically unavailable in existing software alternatives (Rupnik, 2017). And than, PhotoscanPro is an advanced image-based solution produced by the Russian-based company AgiSoft LLC for creating professional quality three-dimensional (3D) content from still images. This program has a simple interface and it enables the generation of sparse, dense point cloud, accurate three-dimensional textured meshes and other representations such as DSMs and orthophotos (Chiabrando, 2015). Pix4D is professional processing software, developed at Computer Vision Lab in Switzerland and can be applied for converting thousands of images. As well as, Pix4D introduces a new software package Pix4Dmapper with included the rayCloud, a new concept extending the stereo view triangulation and increasing the accuracy of 3D modelling results (Ruzgiene, 2015).

We are also interested in defining the error sources in the different phases of a photogrammetric acquisition and the reliability of a photogrammetric acquisition in terms of field and office time compared to those with a laser scanner. We have chosen a stone statue as study target. The stone statue dataset was acquired with a Sony Alpha 6000 and a 20 mm focal length. In order to be able to compare the metric quality of our photogrammetric point cloud, we have used a Riegl VZ400 terrestrial laser scanner which provided us with a 3D point cloud of known measurement that can be used as a reference.

2. METHODOLOGY

Utilize three types of software for three-dimensional models reconstruction, they are commercial software packages and open source tools. The suggested commercial suites are PhotoscanPro and Pix4DMapper, whereas the open source one is the MicMac tools developed by IGN France (Apero/MicMac, 2012).

In general, there are four steps to reconstruction a 3D model from 2D digital images. The first step is the initial processing for photo triangulation with camera self-calibration. After initial processing we can obtain the exterior and interior orientation parameters for all images. We setup a scale bar during image acquisition with a length of 1.000104 meters. Thus, after dense image matching, i.e. the second step, we can obtain dense point cloud with real dimension. For accuracy evaluation, we utilize Riegl VZ400 terrestrial laser scanner to collect reference point cloud. Then, we can compare their 3D discrepancy. The third and fourth steps are mesh and texture generation, respectively. Figure 1 is a research workflow that describes the steps of the research process.

All the images have been acquired with Sony A6000 camera, its focal length is fixed with 20mm (no zooms). Table 1 lists the specifications of the camera that were used in the experiments. These lenses were mounted on a Sony Alpha 6000.

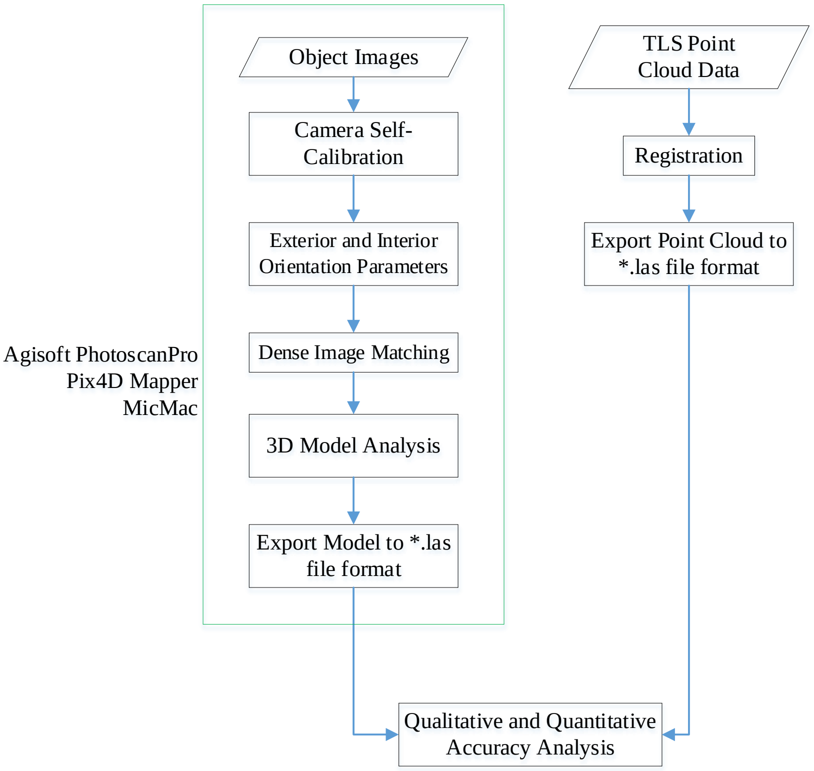


Figure 1. Research Workflow

Table 1. Specification of camera

Camera	Sony Alpha 6000
Focal length	20 mm
Pixel Size	3.92 µm
Sensor Size	23.5 x 15.6 mm
Image Size	6000 x 4000 pixels
Sensor Type	CMOS
Effective pixels	24 megapixel
Average photo-object distance	2 M
Approximate GSD	0.392 mm/pixel

3. EXPERIMENTAL SECTION

3.1 Data Acquisition

The total number of images used in this project is 103. We took the pictures from different locations and directions to cover the whole statue. Figure 2 is the target object used in this research located at the National Cheng Kung University campus Tainan, Taiwan. The stone statue was built in 1998 with size about 1.5m x 1.5m x 3m. In some detail areas such as concave or complex area, more pictures should be taken to avoid occlusion effect.

RIEGL VZ-400 Terrestrial Laser Scanner (TLS) is used to scan the object for collecting reference point cloud. RIEGL VZ-400 is a terrestrial laser scanner that has a 1.5 m minimum scan range, its laser wavelength is near infrared, together with 5 mm measurement accuracy and 3 mm measurement precision. Point cloud data generated from TLS is stitched from four stations around the statue. For completeness purpose, the TLS position for scanning should include all the sections on the object of the statue. Figure 2 is the object of this research to be tested.

Figure 2. Stone statue

3.2 Photo Alignment and Dense Point Cloud Generation

Before tie-point matching, a feature (key) point extraction step is performed. Most of them adopt Scale Invariant Feature Transform (SIFT) - like feature descriptor for key point extraction together with RANSAC filtering for tie-point matching. As a first result the images have been automatically aligned through structure-from-motion (SfM) technique. In order to accelerate the process of tie point generation we have to consider that an image can overlap with the other 3 images before and after it.

This process generates sparse 3D point cloud that include all the portions of the object acquired during the image acquisition, as shown in Figure 3. During this step, the alignment accuracy parameter used in PhotoscanPro is “High” accuracy together with “Medium” quality dense point cloud generation. While in Pix4D Mapper, the keypoints image scale used is “Full” while the point cloud densification is set as “Multiscale with half image size”.

In MicMac the first step has been the computation of tie-points (TPs) and maching from all pairs of images using the command called “Tapioca”. Than, the second step has been bundle adjustment (calibration and orientation) on the recognized matching points using the command called “Tapas”. At this point it’s possible to generate a sparse point cloud to check the result using the command called “AperiCloud”. Finally the automatic dense matching is computed using a command called “C3DC” (MicMac, 2017).

a b c

Figure 3. The calculated tie-points in (a) PhotoscanPro, (b) Pix4D Mapper, and (c) MicMac

Figure 4 shows the 3D view after photo alignment in the used three software. It includes the positions, orientation and footprints of all images together with colorized sparse tie-points. From the figure, we can see more camera position is located in the middle of the object surrounding it and no camera was located on top of the object because the stone statue is too tall to take picture from above. The top area is reconstructed using tilt images taken from lower position so surround the top of the object will cause missing information and introduce large error. If we want to create more complete result on the top area, we need to take image from its above too. By taking pictures with farther distance from the object will decrease the object detail.

a b c

Figure 4. Calculated Tie Points with camera location in (a)Photoscan Pro, (b)Pix4D Mapper, and (c)MicMac

After initial processing we can setup a scale bar. The scale bar can be introduced by measuring two points of known distance that can be seen in all images. Thus, after dense image matching, i.e. the second step, we can obtain dense point cloud with real dimension.

3.3 Result and Discussion

3.3.1 Visual Comparison of Points Clouds: The next process after obtaining the internal and external orientation, we can generate dense point cloud in every software used. Figure 5 shows the generated dense point cloud including the TLS one. From the figures, we can see that there are some outlier points appear at the boundary of object due to larger surface curvature and discontinuity.

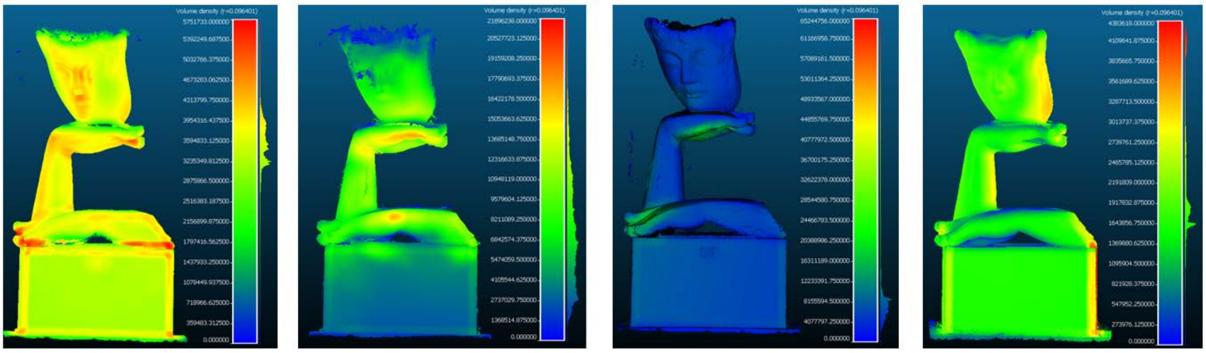
The result of points clouds was influenced by some factors. The light or environmental condition around the object. We know that in generating points clouds, we need to capture the object images using digital camera. Digital camera is a passive sensor that only receive the visible light from the object in front of it. If we capture the object image in bad or less light condition, then the 3D result can be bad in visibility or the texture color will be looked so dark. Furthermore, the image taking technique including the object to camera position distance and image overlap. In taking the picture, we need to consider the distance to object. If we take the picture too far from the object, then the result of 3D model will not good because some of object details will be lost or cannot be recognized.

a b c d

Figure 5. Dense point cloud generated by (a) Photoscan Pro, (b)Pix4D Mapper, (c) MicMac, and (d) TLS

3.3.2 Point Cloud Density Assessment: Here we analyze the qualitative and quantitative performance of the generated point clouds. First we input all four point cloud data into Cloud Compare software (CloudCompare, 2017). We conduct the registration process to align all point clouds with the same location and orientation.

We calculate the volume density of point cloud using Cloud Compare software by setting the radius of 0.1 meters. In Figure 6 and Table 2, it summary the volume density of point cloud in pseudo color and numerical statistics. The color legend shows that blue with lower density, while red denotes higher density. It demonstrates that PhotoscanPro result is evenly distributed that has an average volume density of 3,482,020.29 points/m^3. On the other hand, the volume density of point cloud from Pix4D Mapper results is uneven, the volume density is higher in the middle portion of the object. For MicMac, we can find out that the distribution of point cloud is almost even that has an average volume of 12,338,213.94 points/m^3. From Table 3, it also shows that MicMac has the highest volume density because in MicMac we have setup a higher image scale for dense image matching. In the meantime, observing the volume density of TLS, we can find out its distribution is also uniform, except for surface with higher curvature.



a b c d

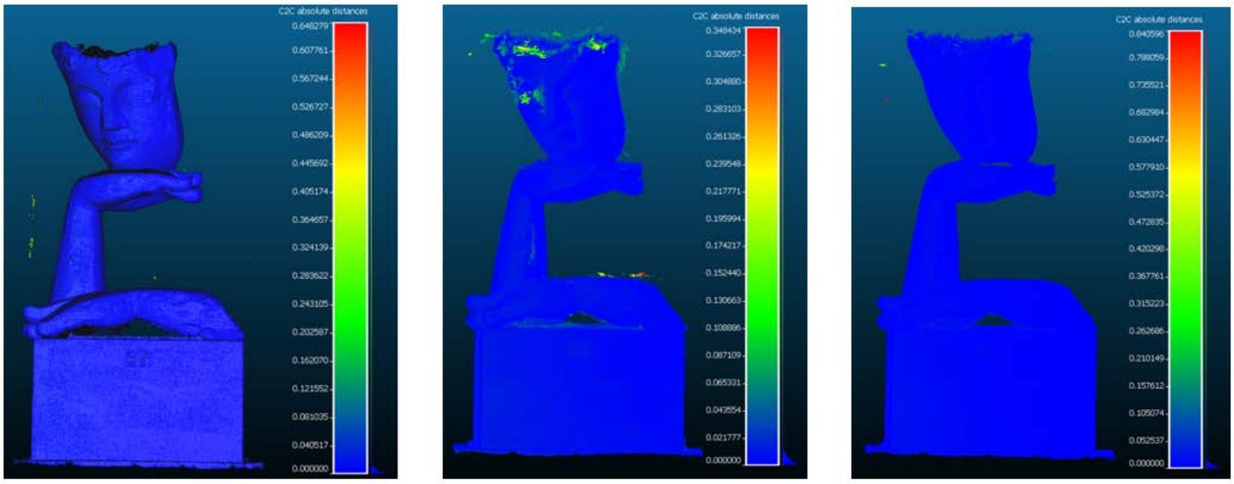
Figure 6. Volume density of point cloud (a) PhotoscanPro, (b) Pix4D Mapper, (c) MicMac, and (d) TLS.

Table 2. Volume Density of Point Cloud

Unit: Point/m^3	**Agisoft PhotoscanPro**	**Pix4D Mapper**	**IGN MicMac**	**TLS**
Minimum	7,727.9	266.5	266.5	1,332.4
Maximum	5,751,733	21,896,238	65,244,756	4,383,618
Mean	3,482,020.3	7,474,799.6	12,338,213.9	2,255,204.2

3.3.3 Accuracy Assessment: To evaluate the geometric accuracy of all point clouds generated by three photogrammetric software, we calculate the distance discrepancy between the photogrammetric one with the TLS point cloud. To calculate the distance discrepancy, we set the TLS point cloud as the reference, then we can conduct cloud to cloud distance calculation in Cloud Compare software. Figure 7 illustrates the distance discrepancy in pseudo color. Table 3 tablet the statistics of cloud-to-cloud distance. Since the generated point has not been edited in advance, i.e. remove blunder points, the highest distance appears at PhotoscanPro vs. TLS with 0.821 meters.

However, more noise can be observed in the case of Pix4DMapper, as shown in Figure 7 (b), particularly those point cloud surrounding the top-area. By ignoring the blunder point and analyzing Table 3, we can find out the overall accuracies index (RMS and Standard deviation, etc.) for all three point clouds are all in mm level.



a b c

Figure 7. Distance computation towards to TLS (a) MicMac, (b) Pix4D Mapper, and (c) Agisoft PhotoscanPro

Table 3. Distance discrepancy statistics

Unit: meters	**Agisoft PhotoscanPro**	**Pix4D Mapper**	**IGN MicMac**
Max Distance	0.821547	0.356874	0.65142
Average Distance	0.002453	0.003193	0.00233
Max Error	0.013469	0.013566	0.01336
RMS	0.003036	0.002606	0.00802
Standard Deviation	0.005346	0.006432	0.00661

4. CONCLUSION

This study aims at comparing of the three-dimensional model reconstruction obtained with three image-based photogrammetric software packages, i.e. AgiSoft® PhotoscanPro, Pix4D Mapper, and MicMac. A stone statue is chosen as target and a Sony A6000 with 20mm fixed focal length camera is used to capture images. The nominal ground sampling distance is about 0.4 mm, which is very high for producing high volume density of point cloud. In all three software, they both have some parameters to control the output point cloud density. However, according to our experiment, we summarize the following finding below.

(1) Pix4D Mapper will produce more blunder points than the other two software.
(2) By using the default image scale setting for dense image matching, the MicMac will obtain highest number of point cloud.
(3) The uniformity of volume density for Agisoft PhotoscanPro appear the best.
(4) The overall geometric accuracy for all three software can obtain mm level of accuracy.
(5) MicMac is more difficult for non-expert users but is totally open and verifiable in each step. Whereas the Photoscan Pro and Pix4D Mapper are commercial software that are very easy to use for beginners.

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