Show the Potential of Agisoft Photoscan Software to Create a 3D Model for Salhiyah Residential Complex in Baghdad Based on Aerial Photos

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Abstract
This research includes the use of aerial photos that taken by metric camera for the constructing 3D digital models, because of these models have developed significantly and increase demands to meet the requirements of several applications. The credibility of these models is essentially depending on the methods of data processing, tools that adopted for solution and quality of data. Whereas in this research automatic method was utilized for data processing, the 3D coordinates identification and extraction of the 3D model. Several software's can be utilized for data processing and the 3D coordinates identification such as Agisoft Photoscan software. To examine the accuracy and the reliability of the results of this software for precise 3D modeling applications, the results were evaluated based on statistical methods. To achieve this aim, The study was done in Baghdad / Salhiyah Residential Complex using data collected by an airborne metric camera with 911.82 m height of flying. To evaluating the final accuracy of a 3D digital model, an evaluation process were done based on the height of some different buildings distributed in the study area was implemented. Whereas the final accuracy of the 3D model based on the root mean square error (RMSE) was equal to (0.277m).

1. Introduction
In the last years, increased the demand and development of 3D models of the city have been very rapid, especially in the field of rebuilding man-made objects, obtaining 3D data and structuring 3D data. The generation of 3D model of the city is task-related and challenging in practice scientific perspective [1]. Recently, many approaches have been proposed to build a construction model. Due to complexity of the buildings, especially the building’s roof, the researchers pay care to the data model and structure. On the other hand, opportunities to utilize 3D modeling of the city and visualization are increasing quickly as more cities conversion from 2D to 3D GIS (Geographic Information Systems). Luckily, if the 3D models are constructed in such a way that new data can be added as it be available, the usefulness of the 3D models will continue to increase as additional applications and workflows are developed. Now days, can be categorized the most common applications into a simulation, transportation, urban planning, real estate, and census. Also, these models can be used not only in transportation and real estate but also in many other applications such as estimation of energy demand, management of the facility, navigation, movie industry and many others [2]. So, the 3D models of the city are digital models for the city that contain a
visual representation of buildings [3]. Also, some type of objects can be represented as 3D, for example, solid models or CAD models. The 3D model of the city is considered as the basis for different applications and it is also a podium for merging information of the city from different sources [4].

Normally the 3D models of a city are created using different approaches: manual, semi-automatic and automatic approaches [5]. The automatic approach was used in this research to create 3D model of the city using Photoscan software. Also, this research examines the potential of utilizing Agisoft software to deliver credible data for precise 3D Modelling applications. Moreover, evaluate the obtained results from the Photoscan.

2. Dataset and Study Site
Study site includes the boundaries of Salhiyah residential complex which equals to (0.347 km²). It is located in Baghdad city, Iraq within (44° 22′49.80″ - 44°23′29.72″ E) longitude and (33° 19′ 09″ - 33°19′28.32″ N) latitude as show in Figure (1).

Figure 1. Study site [7].

The dataset of this study area entails of four aerial photos taken by a metric camera and they have a format of (23 x 23) cm. This dataset was the first project of photogrammetry to cover the bulk of Salhiyah residential complex. The panchromatic images involved one flight line with 60% end lap. In addition, these photos were taken from a height of flying equals to 911.82 m above the ground and focal length equals to 303.94 mm as shown in Figure (2).
3. Methodologies
This study was executed with basic four steps. The first step involves data collections which include collecting of (Ground control points) GCPs and adjusting them. The second step consists of processing of photos and operation of triangulation using least squares solution. The third step involved the statistical analysis and validation of results of the processing Photoscan software. However, the last step contains the implementing photogrammetric procedures to create 3D model based on the results of triangulation operation and compute the accuracy of a final 3D model.

3.1. Collection of Ground Control Points
The GCPs were acquired utilizing the technique of differential global positioning system (DGPS) and later adjusted accurately using robust least squares method. To collect the data of GCPs, Topcon GPS device (GR-5) was utilized and the mode of working was the real time kinematic (RTK). The coordinates of 24 points were collected; these points are located on clear features with good distribution over the study site. Also, these coordinates are measured according to the Universal Traverse Mercator (UTM) projection reference. From all observed points, just 14 points were used as control points and the remained 10 points were used as checkpoints as shown in Figure (3).
In this research high number of checkpoints were used due to the reliability of accuracy which depends on the number of the checkpoints and their distribution of these points [6]. Later a 3D coordinates network are delivered, however they cannot be post-processed for accurate later stages without adjustment. Therefore, to adjust the GCPs, a 3D network of adjustment was applied using non-linear solution (model of coordinates variation). Least squares method was adopted for accurate final derivable. Later for the next stage of processing used the adjusted the GCPs coordinates.

3.2. Photo Processing using Simultaneous Solution
The processing of photo with aerotriangulation workflow is also called as the technique of bundle block adjustment (BBA), because this technique is based on the idea of many rays of light (bundle rays of light) those come from a source of light (sensor of the camera) are making a bundle of rays that intersect to generate the spatial positions. BBA was applied in this research to generate the 3D point clouds following the triangulation geometry process using Photoscan software. The equations of collinearity are the formula utilized as a mathematical model to adjust these bundles based on least squares method. Nevertheless, these equations are not linear and therefore they need to be linearized for the best solution. This can be obtained mathematically based on the first order terms of Taylor's theorem and for the unknowns using initial values [7]. From this step, 3D dense clouds are generated then input for further steps. In this respect, it is worth to mention that all the conventional survey data in this research were measured with reference to the UTM projection. Therefore, all photogrammetric data are transformed from the image coordinate system into a common reference system [8].

3.3. Accuracy Assessment
To determine the accuracy and the reliability of the results of Photoscan software for accurate 3D modeling applications, it has been applied a statistical analysis based on RMSE and based on the Minitab software for the evaluation of the results. Whereas the RMSE was applied to the results of the triangulation process through the RMSE as an index referring to the accuracy of the triangulation process.
in the Photoscan software based on the referenced checkpoints, and the Minitab software was applied based on the point clouds that generated through of triangulation process.

4. Result

4.1. GCPs Adjustment

Table (1) shows the adjusted coordinates of the control points based on the method of least squares after applying the adjustment of 3D network. The accuracies of the GCPs (RMSx, RMSy, RMSz) equal to (0.087,0.098,0.23).

| NO  | X             | Y             | Z            | Type |
|-----|---------------|---------------|--------------|------|
| 1   | 443074.7956   | 3687258.441   | 38.953       | Check |
| 2   | 443379.3667   | 3686878.278   | 39.235       | Check |
| 3   | 443379.4809   | 3687162.56    | 40.185       | Control |
| 4   | 443251.0484   | 3686951.333   | 39.125       | Control |
| 5   | 443246.2106   | 3687138.73    | 38.953       | Check |
| 6   | 443258.8149   | 3687275.902   | 46.369       | Check |
| 7   | 443267.5086   | 3687402.426   | 38.458       | Control |
| 8   | 443414.4624   | 3687367.807   | 39.786       | Check |
| 9   | 443400.9261   | 3686990.869   | 37.837       | Control |
| 10  | 443262.0058   | 3686857.209   | 38.495       | Control |
| 11  | 443079.1539   | 3686862.217   | 39.468       | Control |
| 12  | 443063.5144   | 3686987.856   | 40.356       | Check |
| 13  | 443067.6035   | 3687143.56    | 40.874       | Control |
| 14  | 443397.617    | 3687264.629   | 46.892       | Control |
| 15  | 443075.5876   | 3687387.241   | 39.682       | Control |
| 16  | 443064.7621   | 3687487.595   | 38.002       | Control |
| 17  | 443272.2374   | 3687489.432   | 38.226       | Check |
| 18  | 443399.3312   | 3687483.886   | 39.336       | Control |
| 19  | 443241.3667   | 3687026.336   | 40.965       | Control |
| 20  | 443153.4515   | 3687485.816   | 47.635       | Control |
| 21  | 443150.0659   | 3687393.959   | 39.685       | Check |
| 22  | 443154.1033   | 3687258.368   | 40.288       | Control |
| 23  | 443393.0777   | 3687070.025   | 38.695       | Check |
| 24  | 443034.8952   | 3687562.959   | 38.644       | Check |

4.2. Result and Analysis of the BBA

Triangulation process was applied using software of Agisoft. Three GCPs at least must be specified for every stereo pair and measured several tie points on stereo image. A method of triangulation is performed to estimate the locations for ground coordinates (X, Y, Z) of tie points in stereo models. It also determines the values of parameters of exterior orientation (EOP) of each image. Figure (4) explains the GCPs distribution, tie and checkpoints in the adjusted stereo model. The triangulation results are 3D point clouds as shown in Figure (5). The number of point clouds that generated was equal to 4266365 points.
4.3. Result of Accuracy Assessment

4.3.1. Based on RMSE

Statistical analysis was performed based on RMSE that computed during and after completing the process of triangulation. To compare the coordinates that measured by DGPS and adjusted later with coordinates triangulated from photogrammetry, 10 checkpoints were utilized. The results are listed in Table (2).
Table 2. RMSE delivered from Photoscan Software.

| point | Actual value X | Actual value Y | Actual value Z | Calculated value X | Calculated value Y | Calculated value Z |
|-------|----------------|----------------|----------------|--------------------|--------------------|--------------------|
| 1     | 443074.795     | 3687258.441    | 38.953         | 443074.9           | 3687258.6          | 38.672             |
| 2     | 443379.366     | 3686878.278    | 39.235         | 443379.3           | 3686878.2          | 39.425             |
| 5     | 443246.21      | 3687138.73     | 38.953         | 443246.11          | 3687138.7          | 38.723             |
| 6     | 443258.814     | 3687275.902    | 46.369         | 443258.72          | 3687275.7          | 46.179             |
| 8     | 443414.462     | 3687367.806    | 39.786         | 443414.43          | 3687367.7          | 39.649             |
| 12    | 443063.514     | 3686987.856    | 40.356         | 443063.46          | 3686987.8          | 40.125             |
| 17    | 443272.237     | 3687489.432    | 38.226         | 443272.21          | 3687489.4          | 38.489             |
| 21    | 443150.065     | 3687393.958    | 39.685         | 443150.11          | 3687393.9          | 39.256             |
| 23    | 443393.077     | 3687070.025    | 38.695         | 443393.19          | 3687070.1          | 38.809             |
| 24    | 443034.895     | 3687562.958    | 38.644         | 443034.78          | 3687562.9          | 38.864             |

RMSE X =0.0817 m  RMSE Y =0.0921 m  RMSE Z=0.243 m

4.3.2. Based on Minitab software
Statistical analysis that carries out by using Minitab software based on one-sample T-test to find error values. The simple size equal to 4265635 points. In this research, there is a one value used for this mission that called a p-value. P-value is referring level of significance, it is used as a gauge for rejecting or accepting the null hypothesis whereas P-value is 0.05. Figure (6) shows the results of the statistical analysis.

![Summary of statistical analysis for point clouds](image)

Figure 6. Summary result of statistical analysis for Photoscan data.

5. 3-D Model Extraction
Photoscan software has the ability to extract the 3D model as shown in Figure (7) with a high quality for the texture and the reliability of the results. Also, it can export the results into different formats which can
be submitted to Google earth for different applications such as tourism, in addition, creating a digital elevation model (DEM) as shown in Figure (8).

![Figure 7. 3D model for study area.](image1)

![Figure 8. DEM (digital elevation model).](image2)

6. Assessment of final model
A comparison was made between the actual heights of selected buildings with those generated from the 3D model to compute the final vertical accuracy of the 3D model. The actual height were computed using total station. Table (3) represents the results of the vertical.
Table 3. Vertical accuracy assessment of the 3D model.

| Building | Actual height (m) | Computed height (m) | Difference (m) |
|----------|-------------------|---------------------|----------------|
| Building 1 | 35.13             | 35.45               | 0.32          |
| Building 2 | 35.13             | 35.37               | 0.24          |
| Building 3 | 35.13             | 35.43               | 0.3           |
| Building 4 | 35.13             | 34.98               | 0.15          |
| RMSE     |                   |                     | 0.277 m       |

7. Discussion and Conclusions
In this study, the performance of the software of Photoscan to derive accurate data from aerial photos was assessed and analysed to show the possibility of this software for reliable 3D modelling. In addition, creating a 3D model from these images. To investigate this, a study was done in Baghdad / Salhiyah Residential Complex using data collected from an airborne metric sensor with 911.82 m height of flying. The results of Photoscan show potential according to the objective of study and quality of the dataset following statistical. Different variables effect on the reliable of the data delivered, such as the image quality, orientation of the image, adopted scenario, distribution of the GCPs and availability, etc. The delivered results indicate the accuracy of the triangulation process in Photoscan software is highly accurate through the RMSE outputs. Also, the number of points that intensified by Photoscan is a lot, due to the ability of Photoscan to intensify points through the triangulation process to millions of points, however, these points are effect on the accuracy of the final model. Moreover, the results of statistical analysis indicate the reliability of data extracted using Photoscan software. In addition, the ability of Photoscan to create a 3D model is very high with good quality whereas the final accuracy of the 3D model is equal to 0.268 m in the vertical distance of the buildings.

Thus, the following conclusions can be extracted from the results of this case study:
- Results show the reliability of Photoscan software in the triangulation process and thus in 3D modelling applications.
- The great potential of Photoscan to intensify points through triangulation process.
- The Photoscan software can be used easily. It doesn't need approximate values for unknowns, including the parameters of exterior orientation and control points.

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