OPEN ACCESS
Saudi Journal of Civil Engineering
Abbreviated Key Title: Saudi J Civ Eng
ISSN 2523-2657 (Print) |ISSN 2523-2231 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Create a 3D Model for University of Baghdad Based on Aerial Photos

Ahmed Kareem Jebur[1*]

[1]Department of Surveying Techniques, Kut Technical Institute, Middle Technical University, Kut, Iraq

DOI: 10.36348/sjce.2021.v05i06.002 | **Received:** 08.06.2021 | **Accepted:** 10.07.2021 | **Published:** 27.07.2021

***Corresponding author:** Ahmed Kareem Jebur

Abstract

This paper includes the use of aerial images captured by a metric camera to build digital 3D models because these models have evolved greatly and increased the demands to meet the requirements of many applications. The reliability of these models depends mainly on the data processing methods, the approved tools for the solution, and the data quality. Where the automatic method was used in this research to process data, determine the three-dimensional coordinates and extract the three-dimensional model. Several programs can be used to process data and determine 3D coordinates such as Agisoft Photoscan. The results were evaluated on the basis of statistical methods in order to assess the accuracy and reliability of the results of the Agisoft Photoscan software for exact 3D modeling applications. To that aim, the study was carried out by an airborne metric camera with a height of 457 m at the University of Baghdad in Baghdad City. The evaluation was carried out based on the height of several buildings in the study area to assess the accuracy of the final 3D digital model. Whereas the overall accuracy of the 3D model dependent on the RMSE was (0.3014 m).

Keywords: 3D Model, demands, applications, programs, Agisoft Photoscan.

INTRODUCTION

Nowadays 3D city modeling and visualization of large cities have become more and more popular, and the requirements for 3D city models are developing and growing quickly in different fields incorporated. Therefore, there are many solutions to make the process of generating the 3D model cheaper and faster. The reason behind their increasing popularity is being these models can be used not only in urban planning and design, but also in other applications such as energy facility management, demand estimation and visualization for navigation, visualization of cultural heritage, and many others in addition to being used in computer games, filmmaking and the art of creating virtual reality [1].

The 3D city models are essentially digital models for the city that contain a visual representation of buildings and other objects with 2.5 or 3D [2]. The 2.5 D expression is used to describe models that only have a unique Z-value defined by XY-coordinates [3]. However, some types of objects, for example, solid models or CAD models can be represented as 3D. The three-dimensional city model is the basis for many applications, and it is also a platform for integrating city information from various sources [4]. The 3D model makes it easier for people to understand the spatial relationships of urban objects. Because the real world we live in is three-dimensional, it is natural that the human mind interprets and understands these models at high speed. Many companies use 3D scenes to attract users by enhancing and simplifying their application processes. Research and work on 3D models have become a more widespread and hot topic in both academic and business domains. Many algorithms and methods have been developed to deal with 3D models and make them more easy and accurate.

Three techniques are used for the 3D city models: automatic, semiautomatic and manual. [5]. Thus, the 2D and 2.5D maps are considered as the basis for semi-automatic and manual approaches for creating a 3D city model. In this research, an automatic approach was used to create a 3D city modeling for three levels of details LOD0, LOD1, and LOD2 as illustrated in Figure (1). The LOD is the degree and scale of work in terms of accuracy and type of work. The 3D city models created by many methods can be later transferred into the geographic information system (GIS) easily and used as a base for GIS data. Further, these 3D models can be published online for many users [6].

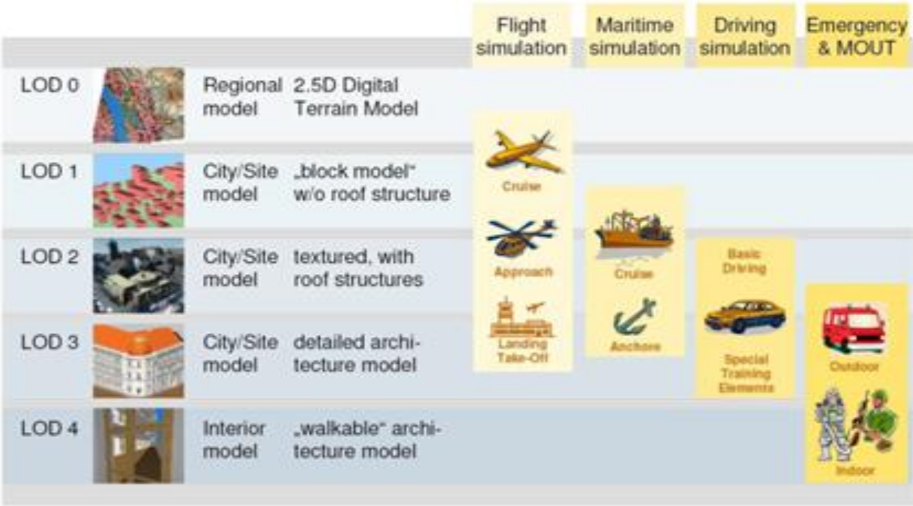

Figure-1: LOD definition for city models

Background and Motivation

In the past, virtual 3D models are being built using primary materials, (e.g. wood), because of the flexibility and easy handling of this material, where the measurements are taken in traditional methods so that the work is done in direct contact with the target [2]. However, with the advancement and development of technologies, virtual 3D models are produced utilizing computer-aided design and by using additional software such as AutoCAD but with manual measurements [8]. To overcome these difficulties, many techniques and remote sensing devices have been developed. These techniques are considered as the leaders in this respect and are commonly used in extracting 3D models nowadays such as photogrammetry and Light detection and ranging (Lidar).

These techniques provide lots of information with high accuracy standards and reliability without direct contact with the real world (except for assessment and validation purposes). Further, these techniques are importantly decreasing time and efforts exerted by users in comparison with the traditional techniques. This is the main motivation behind the creation of 3D city models by adopting these technologies to meet the requirements of 3D digital models in a wide range of technical applications.

Photogrammetry

Photogrammetry is the earliest technique of remote sensing. It is the process used to determine geometric information, including the three-dimensional position (3D coordinates), orientation, size, and shape of any objects, from images without touching the objects but by applying the measurement process directly to the images [9]. This process is usually referred to as 3D reconstruction. Photogrammetry is essentially an information extraction technology of different objects or phenomena that can be obtained from their photographs or images. The photogrammetric technique is more important for many applications such as industrial design, architecture, accident investigation, medicine, and 3D modeling, etc [9].

The photogrammetric technique can be divided according to the location of the camera during data acquisition into three types:

1. Aerial photogrammetry: This type deals with images captured by a camera mounted on airborne platforms.
2. Terrestrial photogrammetry: In this type, images are acquired by a fixed sensor (camera) installed on the ground and take images of objects facing and away from the camera within a certain distance. In case the distance between the camera and the object is less than 300m, it will turn to be a special case from terrestrial photogrammetry called close-range photogrammetry [10]. Space photogrammetry: This type deals with images captured to the earth or any other planet by a sensor mounted on satellites.

Case Study and Dataset

It was the College of Engineering at the University of Baghdad. The case study was chosen to study the various characteristics and objects of a city that are available in urban sites. The dataset consists of eight aerial photographs as shown in Figure-2 and two flight lines with four photos for each flight line. The block of the images for the University campus has 20% side lap overlap and 60% end lap. These images are taken with a flying height equals to 457 m above mean sea level (MSL) and focal length of the camera equals 152.16 mm. This area of study covers around 1.333 km^2 area on the ground. The study area is restricted to latitudes between (33º 16′ 00″ - 33º16′30″ N), and longitudes of (44º 22′30″- 44º23′00″ E) as shown in Figure-3.

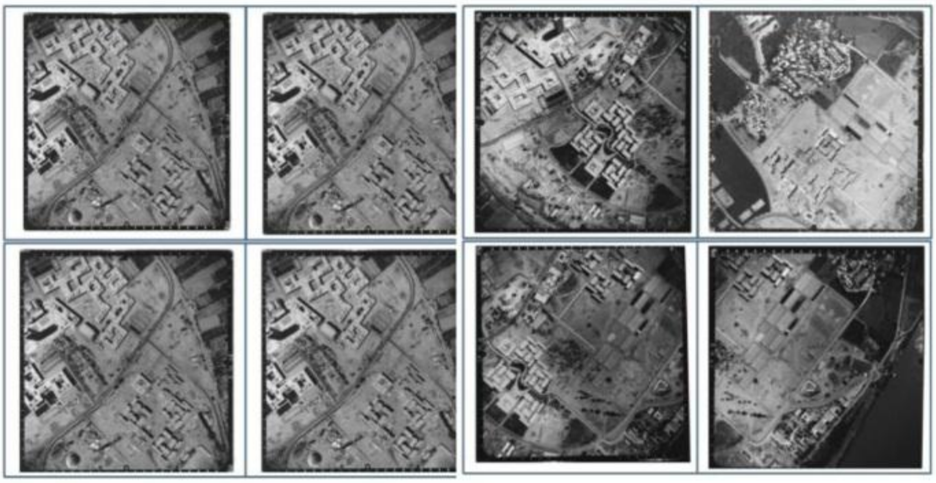

Figure-2: Illustrate the block of photos of the dataset consist flight lines 1 and 2

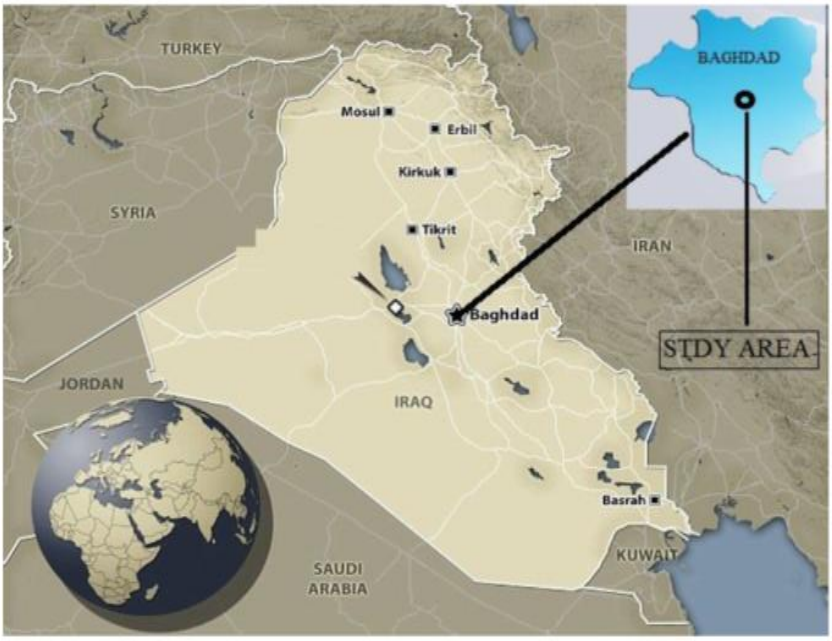

Figure-3: Site of study areas.

RESULTS AND CONCLUSION

Field Surveying Results

Field survey is an essential and important part to obtain control data for processing and analyzing aerial triangulation. The data listed in Table-1, represent the observations of the ground coordinates (X, Y, and Z) which were collected using differential global positioning system (DGPS), Topcon GR-5.

Table-1: Represent the ground coordinates (X, Y, and Z) which were collected using DGPS

Point No	Point ID	X m	Y m	Z m	Type
1	**P8**	441821.021	3681853.522	35.123	Control
2	**Point 21**	442058.735	3681720.710	36.628	Control
3	**Point 61**	442123.9722	3681831.032	35.600	Control
4	**C2**	442385.342	3681976.243	36.054	Control
5	**P12**	442427.573	3681817.943	34.542	Control
6	**P3**	442168.903	3681466.58	35.782	Control
7	**Point 15**	442169.1312	3681279.722	36.920	Control
8	**P5**	442401.082	3681335.272	35.003	Control
9	**1200**	442023.995	3681030.632	36.713	Check
10	**C7**	442019.143	3681038.843	34.715	Control
11	**C9**	441835.532	3681596.123	35.903	Check

Point No	Point ID	X m	Y m	Z m	Type
12	**C11**	441847.084	3681860.012	36.153	Check
13	**Point 10**	441748.753	3682057.298	34.823	Control
14	**P09**	442105.399	3682100.201	34.013	Check
15	**C15**	442104.985	3682050.102	34.200	Check
16	**C13**	441841.134	3682078.143	34.743	Control
17	**P13**	441618.083	3681623.603	35.790	Control
18	**Point 3**	442551.1623	3681362.103	34.940	Control
19	**1000**	441757.128	3681297.503	35.992	Check
20	**C31**	442175.516	3681615.743	35.513	Control
21	**C14**	441985.105	3682113.085	34.591	Control
22	**C11**	442182.335	3681836.569	35.892	Check
23	**C12**	441743.5235	3681857.886	35.423	Control
24	**Point 4**	441899.898	3681589.465	36.627	Control
25	**P7**	441777.151	3681631.710	34.412	Control
26	**C41**	442098.563	3681258.323	34.253	Control
27	**C51**	442336.646	3681241.005	34.392	Check
28	**C18**	442325.723	3681319.421	34.693	Control
29	**C16**	442481.303	3681348.865	34.098	Check

Aerial Triangulation Results

Triangulation was applied using Agisoft Photoscan software for the study areaA minimum of 3 GCPs for each stereo pair must be defined in single overlapping areas, and several tie points were calculated in individual stereo images. In stereo models, triangulation is carried out to estimate the 3D ground positions of tie points. The external orientation parameters (EOPs) are also determined for each image. The results of the triangulation process are shown in Figures-4. The number of 3D point clouds generated was equal to 7519294 points generated by Agisoft photoscan for the study area.

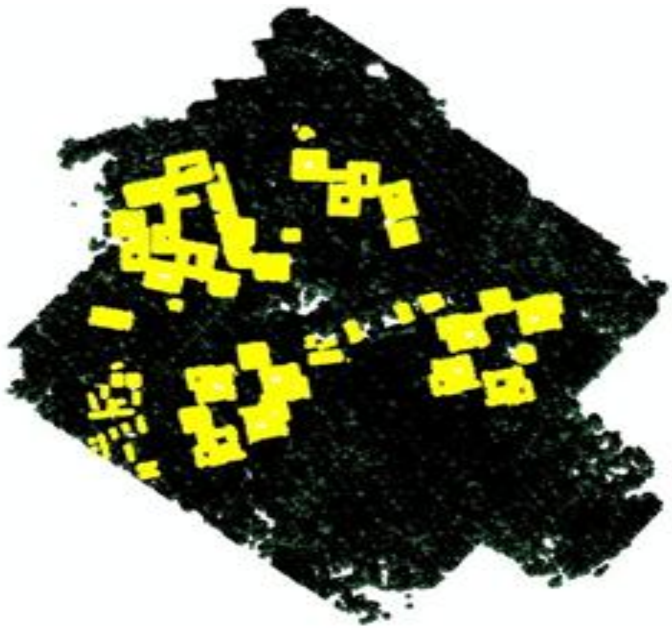

Figure-4: The 3D point clouds for the study area

Raster Surface Generation Results

After following the automatic classification process to groups the 3D data into three different classes, GIS was used to generate the 3D surface (raster surface) using the Kriging method. The results are shown in Figure-5 and Figure-6 are showing the raster surfaces of the building classes. Bear in mind that the output cell size for all surfaces was equal to 0.2 m^2.

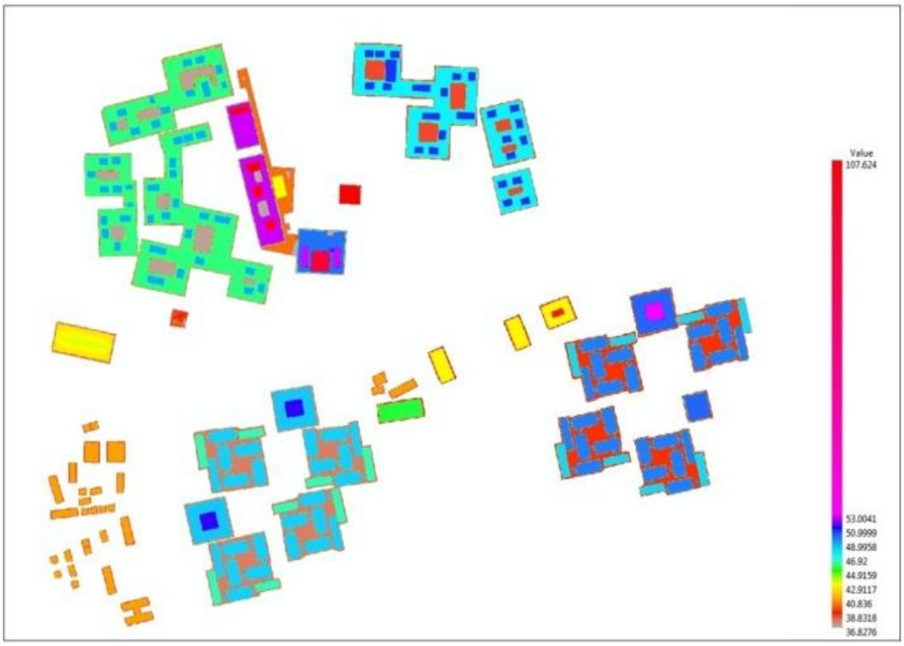

Figure-5: Raster surface of building class in the study area

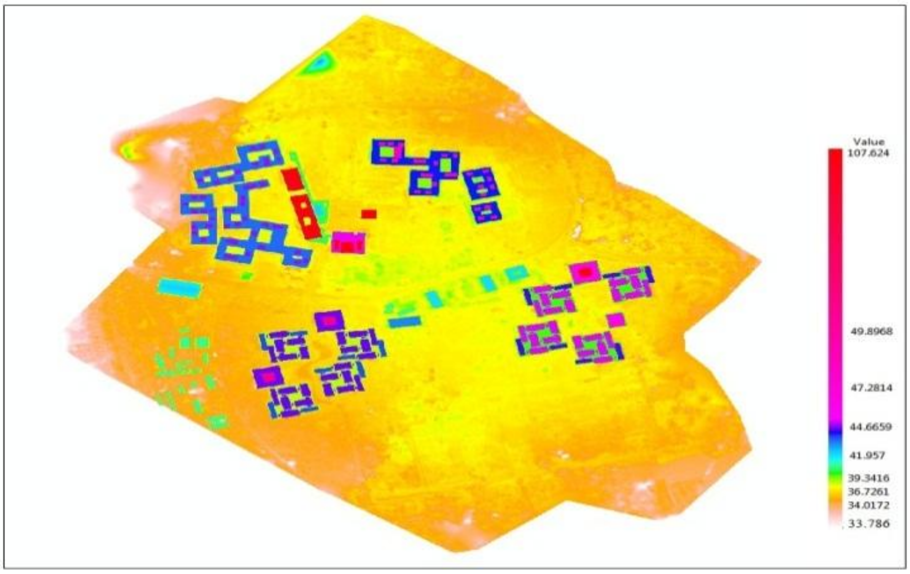

Figure-6: Raster surface for all classes in the study area.

The raster surface in Figures-5 shows only buildings that have been constructed based on building points, whereas the raster surface in Figure-6 shows all objects. It is also possible to notice that the difference in the elevation in the earth layer is rather limited and this indicates that the level of the Earth's surface is fairly classified correctly because the study areas are urban areas.

TIN Surface Generation Results

For this part of the work, the ARC Scene software ver. 10.4.1 was used to generate the surface model (vector surface) based on the raster surface for all classes, with tolerance for a Z value equal to 0.2m. The result is shown in Figure-7 are representing the TIN (Triangulated Irregular Network) surfaces generated in case studies.

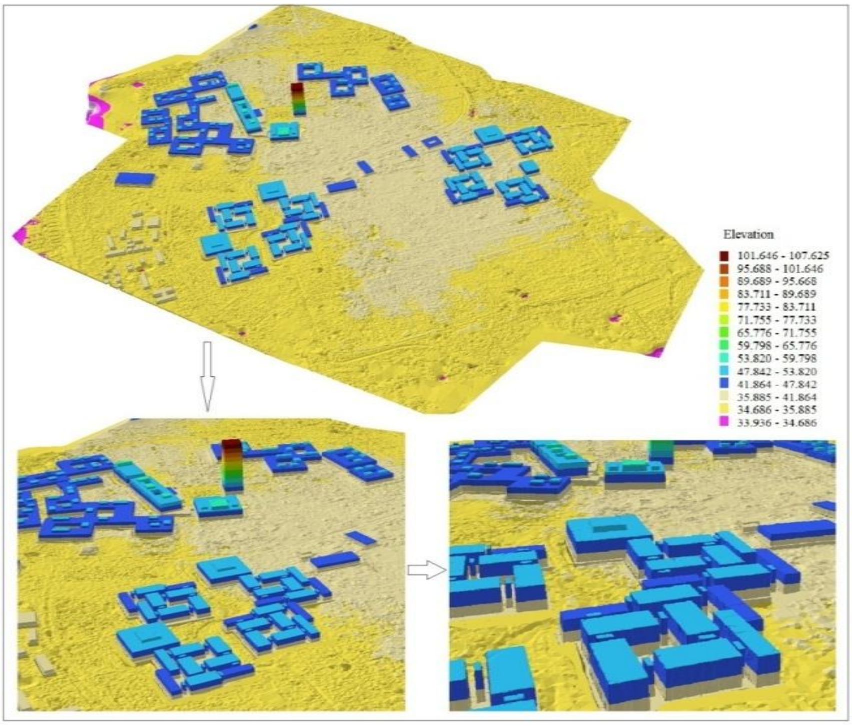

Figure-7: TIN surface for all classes in the study area

Through the results of the TIN generated from Arc Scene software above, it can be noticed that the edges of the buildings are fairly generated and this is due to the accuracy and the efficiency of the Arc Scene software in the vector surfaces extraction. The other explanation is the efficiency of the Agisoft photoscan software in the triangulation process, which affects on the number of the generated points. It is also noticed that the color gradient, which indicates differences in height, can be used for distinguishing between the existing objects.

3D City Model Extraction Results

Due to the simple interface of Google SketchUp software, this software was used to deliver the final 3D city models in addition to the products from Arc Scene. Further, this software was very helpful to publish the 3D model online on Google earth for different applications such as tourism. Results of Google SketchUp that been published on Google earth are shown in Figure-8.

However, the final products from Arc Scene software are presented in Figures 9 and 10. The results below show the difference between the 3D model of the study area in terms of the area of the study area and the number of objects for which a 3D model was created, which affect the time period required to create this 3D model.

Figure-8: The final 3D city model created by Google SketchUp and displayed in Google Earth

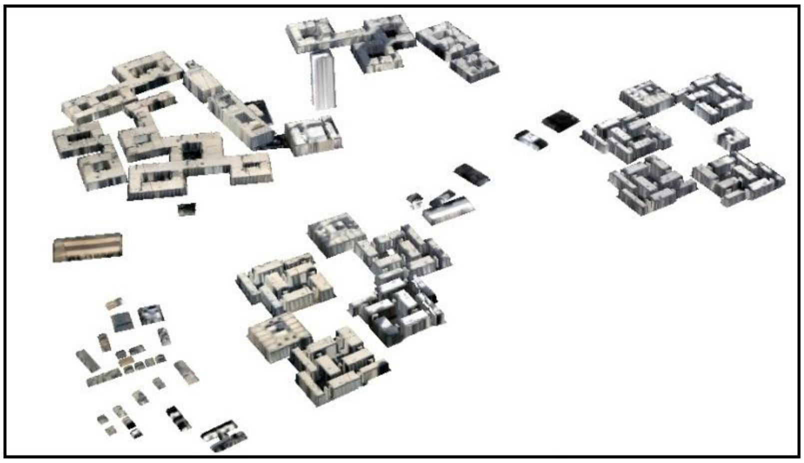

Figure-9: The final 3D city model of buildings in the study area created by ARC Scene

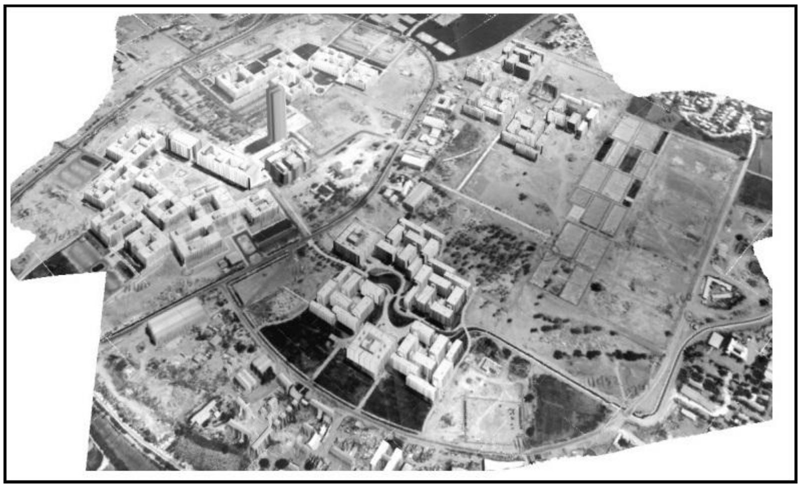

Figure-10: The final 3D city model of the study area created by ARC Scene

3D City Model Assessment

For a quality evaluation, assessment of any extracted 3D city model, an error diagnosis should be implemented. As horizontal feature assessment was applied in previous sections, vertical height-level assessments are still required and should be adopted. Field measurement was delivered and compared with those generated in the 3D model in the case study. Table-2 below represent the results of the vertical accuracy in the generated 3D city model based on 9 selected buildings in the study area. Figure-11 is showing the spatial positions of these buildings in the field.

Table-2: Vertical accuracy assessment of the 3D city model for nine buildings in the study area

Building	**Actual height (m)**	**Computed height (m)**	**Diff (m)**
Building 1	8.801	8.443	-0.358
Building 2	8.811	8.511	-0.3
Building 3	8.793	8.472	-0.321
Building 4	8.705	8.391	-0.314
Building 5	8.749	8.461	-0.288
Building 6	8.771	8.372	-0.399
Building 8	10.598	10.491	-0.107
Building 9	10.652	10.421	-0.231
		RMSE	**0.3014 m**

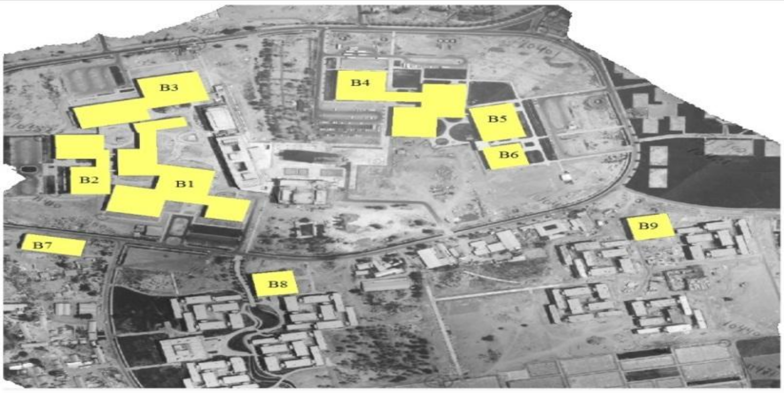

Figure-11: The buildings selected to assess the heights in the study area

CONCLUSIONS

Following a research overview and summary highlighted previously, the following conclusions have made upon the case study results:

- To produce 3D models, it is important to select an accurate and typical technique and data to derive 3D dense coordinates to the real-world surface including detailed objects in a short time and faster workflow. Digital photogrammetric software and aerial images are sufficient for this works because of their ability to a direct and accurate collection of 3D coordinates with high resolution and non-contact scenarios.
- The results demonstrate the reliability of Agisoft Photoscan in photogrammetric triangulation and accurate 3D modeling applications.
- Easy to use Agisoft photoscan, as it does not require any of the unknown approximate values that including control and points exterior orientation parameters.
- The results show that the precision and number of point clouds formed by a triangulation process influence the final 3D accuracy.

The Google Sketch Up has a strong ability to create a 3D model based on the results photogrammetric process.

ACKNOWLEDGMENTS

Partially the University of Baghdad supported this research. The authors thank their [Ali and Omer] colleagues for having insight and experience that has been of great assistance in the analysis.

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