Topographic Survey with Analytical Close Range Photogrammetry

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ABSTRACT

Topographic survey uses to determine the relative locations of points (coordinates) on the earth's surface by measuring horizontal distances, differences in elevations and directions. Generally speaking the production of large scale topographic maps requires precise topographic survey with land surveying instrument such as (Total Station) which is costly and time consumed. The objective of this research is to produce topographic maps using an unconventional means through application analytical close range photogrammetry. The analytical close range photogrammetric method is characterized by low efforts and cost, the speed of topographic survey works, as well as the possibility of measuring and / or assessing places inaccessible. Photos strip was selected at University of Technology as a case study with area (400 m^2). The fieldwork started with generation of ground control points around the area. A theodolite (wild T2) was used to measure the ground (X, Y, and Z) coordinates for GCPs within the study area. The strip consists of eight overlapped images, overlap more than 60% were captured using a single non metric digital camera (Canon EOS D500) (with a resolution of 15.10 mega pixels). After capturing images for study area two steps were used for processing data. The first step was used to process these images for producing 3D coordinates from 2D images with different methods by using two software. The first software using Matlab2014b dealing with different methods Sequential (R-I) and bundle adjustment (BA) methods, and another software ERDAS IMAGINE (LPS) using block bundle adjustment. The second step was used GIS software to producing large scale topographical map. The computed Root Mean Square Error (RMSE) for three methods (Resection – Intersection, Bundle Adjustment and Bundle Adjustment Block) and it was found that the RMSE in R-I method is (2.917cm) , RMSE in B-A method is (2.882cm) and RMSE in Bundle Block Adjustment method is (3.112cm). The final result was a topographic map with scale (1:100 and 1:200).
Keywords: Sequential (R-I), bundle adjustment (BA), block bundle adjustment, ERDAS IMAGINE (LPS) software, Matlab2014b software, GIS software

INTRODUCTION

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographs. In many instances, the use of photogrammetry can be more efficient, less labor-intensive, and more cost-effective

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than other types of field survey [1]. Photogrammetry is concerned with deriving measurements of the size, shape, position and texture of objects from measurements made on photographs. In its simplest method, a pair of overlapping photographs is used to create a three-dimensional model with the use of appropriate instrumentation can yield quantifiable dimensions of object. Traditionally these dimensions were represented on maps and plans, either as elevations, facades and/or contours [2]. Photogrammetry divided into two basic categories: aerial and close-range [3]. Close-range photogrammetry is all descriptive terms that refer to photos taken with an object-to-camera distance of less than 300 m in addition to measurement technology that can be used for the extraction of 3D points from the photographs [4]. Photogrammetry has been used in preparing a topographic map. Cameras and other photogrammetric instruments and techniques have been improved continually, so that spatial data collected by photogrammetry today meets very high accuracy standards. Photogrammetry is now the principle method employed in topographic mapping and compiling other forms of spatial data. It is characterized by the speed of collecting spatial data in an area, relatively low cost, ease of obtaining topographic details, especially in inaccessible areas, and reduced likelihood of omitting details in spatial data collection [5]. A topographic survey is shown to determine the planimetric location and topographic release of features in three dimensions. The topographic survey is utilized to define natural and man-made features on a particular parcel of land. It usually contains any man-made underground features, like beneficial lines and shows above ground improvements like buildings and retaining walls. A topographic survey aims at describing the land topography. A topographic survey should always be carried out for the preparation of a contour map [6]. The problem producing topographic maps using land survey require a number of many workers, costly, time consumed, and sometimes there are areas difficult to access. The significance of this study is to produce topographic maps using analytical close range photogrammetry. The analytical close range photogrammetry method is characterized by low effort and cost, the speed of topographic survey works, as well as the possibility of measuring and assessing inaccessible places.

Objective of the Study

The aim of this research is using analytical close range photogrammetry to generate a precise topographic map. This study deals with close range photogrammetry to determine the three dimensional ground coordinates from two dimensional coordinate (photo coordinates). This can be done using non metric digital camera. In this research, the selected study area is a part of University of Technology. Two major aspects will be studied in this research. Firstly, data acquisition and 3D model generation using photogrammetric software (MATLAB and ERDAS IMAGIN (LPS)) will be are investigated with different methods (Resection-Intersection, Bundle adjustment and Bundle Block Adjustment). The accuracy of these techniques is determined in terms of root mean square error (RMSE). Secondly, a topographic map will be produced using GIS software.

Methodology

The methodology has been divided into following steps:

1-Placing (18) targets representing the control point on the study area (the University of Technology).

2- Measuring the 3D coordinate system (X, Y, Z) of the targets by using Theodolite (wild T2).
3- Photographing the study area by using a high resolution digital camera. (Canon EOS D500).
4- Computing the 3D coordinates of selected objects in study area by using different photogrammetric methods (Resection–intersection, Bundle adjustment and Bundle block adjustment).
5- Producing a topographic map for the extracted coordinate from the analytical Close Range Photogrammetry.

Photogrammetric System

Essentially there are two phases for close range photogrammetry process: the field work and photogrammetric processing. All photogrammetric field work began with the establishing of well distributed ground control points in the study area (selected part from University of Technology used as case study with area (400 m2)). Control points were represented with the small targets with three dimensional coordinates (X, Y, Z) measured in the field with theodolite (T2). Then, strip of stereo-images collected at specific locations were recorded. During the processing phase, 3D coordinates computed using photogrammetric software. The photogrammetric system is made up of three steps:
(a) Establishment of 3D controls for photogrammetric work.
(b) Image data acquisition.
(c) Photogrammetric data processing.

Establishment of 3D control for Photogrammetric work

- **Survey measurements**

Theodolite (wild T2) as shown in the figure (1) is ideally suited for almost every type of survey task. In addition to its high accuracy (1" second), it is simple to handle, has a well-illuminated optical and reading system and can be used with a large variety of accessories and attachments [7].

Figure (1) Theodolite (wild T2)

- **The principle work of Theodolite (wild T2)**

The theodolite set up in the 3rd floor of the department of building and construction. The first set up at station (1) and observing station (2) the horizontal circle reading

(H.C.R) and vertical circle reading (V.C, R), were measured to (18) target points (control point) from each station as shown in figure (2). The distance between the two stations where measured precisely with steel tape.

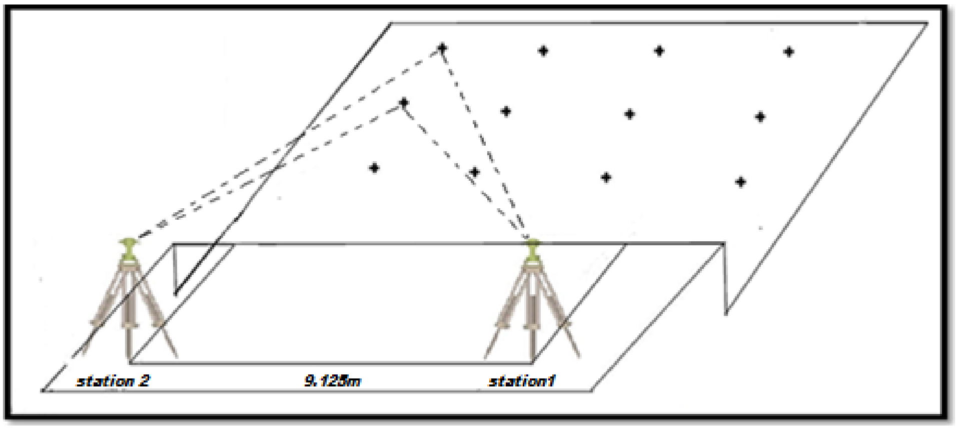

Figure (2) field survey

- **Artificial Targets**

Artificial Targets to identify control points are placed on the ground as to be ground control in the absence of natural control points, distributing these point proximally to forma grid to covered whole area, those points were represented with targets installed in ground using a metal wedge as shown in the figure(3)

Figure (3) Artificial Targets

Image Data Acquisition

The step of capturing photo is important for photogrammetric project, in this work capturing photo by using Canon EOS D500. This type of high resolution digital cameras named non-metric because it is un calibrated. In other words its interior orientation parameters were unknown. This type of camera is shown in figure (4), and its main characteristics are illustrated in table (1).

Figure (4) camera canon EOS D500

Table (1) main characteristics for canon EOS D500 camera [8]

Type	Digital single-lens reflex AF / AE camera	
Effective pixels	Approx. 15.10 mega pixels	
Image sensor size	22.3x 14.9 mm	
Lens mount	Canon EF mount	
Recording pixels	(1)large :	Approx. 15.10 mega pixels (4752 x 3168)
	(2)medium:	Approx. 8.00 mega pixels (3456 x 2304)
	(3)small:	Approx. 3.70 mega pixels (2352 x 1568)
	(4)RAW:	Approx. 15.10 mega pixels (4752 x 3168)
Focusing modes	One-shot AF,AL Servo AF,AL focus AF, Manual focusing	
Shutter speeds	1/4000sec.to 30secs.bulb (total shutter speed range available range varies by shooting mode.)X-sync at 1/200sec.	
Depth-of-field	Enable with depth-of-field preview button	
Image type	JPEG ,RAW (14-bit canon original) RAW + JPEG simultaneous recording possible MOV	

Photogrammetric data Processing

After capturing images for study area, two steps were applied for data processing as follows:

1. The first step was to process the images for producing 3D model using two software.

- Matlab software with different methods:

1) Sequential (R-I)

2) Simultaneous (BA)

- LPS software using block bundle adjustment

2. The second step was used to produce topographical map using GIS software

Resection –intersection (R-I)

(R-I) is a set of functions that implement the sequential data processing in case of close range photogrammetry , selected points for each pair of photo and then analysis these photo by using this method for computing 3D for each model, and then calculate the RMS depending on other control point

Bundle Adjustment (BA)

(BA) is a set of functions that implement the simultaneous data processing in case of close range photogrammetry, selected points for each pair of photo and then analysis these photo by using this method for computing 3D for each model, and then calculate the RMS depending on other control point

Bundle Block Adjustment

Using Bundle block adjustment method for the purpose of getting the 3D coordinates model for study area where using LPS program (bundle adjustment method) depending on less number of control points in the block (the block consists from eight photos with overlap more than 60%) depending on manual or automatic selecting points

Results

- **Resection –intersection method**

Table (2) Check points and RMSE for 1st model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	X m	Y m	Z m	X m	Y m	Z m
1	512.523	564.924	489.610	512.529	564.9188	489.614
2	511.551	565.008	490.607	511.549	564.992	490.596
3	506.187	567.000	489.156	506.195	567.027	489.152
Mean Square Error in check points (cm)						
RMSE x=0.5405		RMSE y=1.8259			RMSE z=0.7052	
Total RMSE= 2.0306						

Table (3) Check points and RMSE for 2nd model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	X m	Y m	Z m	X m	Y m	Z m
1	506.187	567.000	489.156	506.183	567.025	489.150
2	499.685	566.842	489.176	499.686	566.882	489.174
3	499.484	566.995	489.366	499.471	567.054	489.330
Mean Square Error in check points (cm)						
RMSE x=0.8014		RMSE y=4.3881			RMSE z=2.1291	
Total RMSE=4.9428						

Table (4) Check points and RMSE for 3rd model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	X m	Y m	Z m	X m	Y m	Z m
1	499.685	566.842	489.176	499.676	566.830	489.178
2	490.610	566.643	489.187	490.615	566.641	489.202
3	499.484	566.995	489.366	499.459	567.008	489.335
Mean Square Error in check points (cm)						
RMSE x=1.5873		RMSE y=1.0347			RMSE z=1.9781	
Total RMSE=2.7392						

Table (5) Check points and RMSE for 4th model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	X m	Y m	Z m	X m	Y m	Z m
1	484.587	566.706	489.190	484.598	566.693	489.216
2	483.967	566.842	489.341	483.979	566.844	489.332
Mean Square Error in check points (cm)						
RMSE x=1.1689		RMSE y=0.9364			RMSE z=1.9430	
Total RMSE=2.4533						

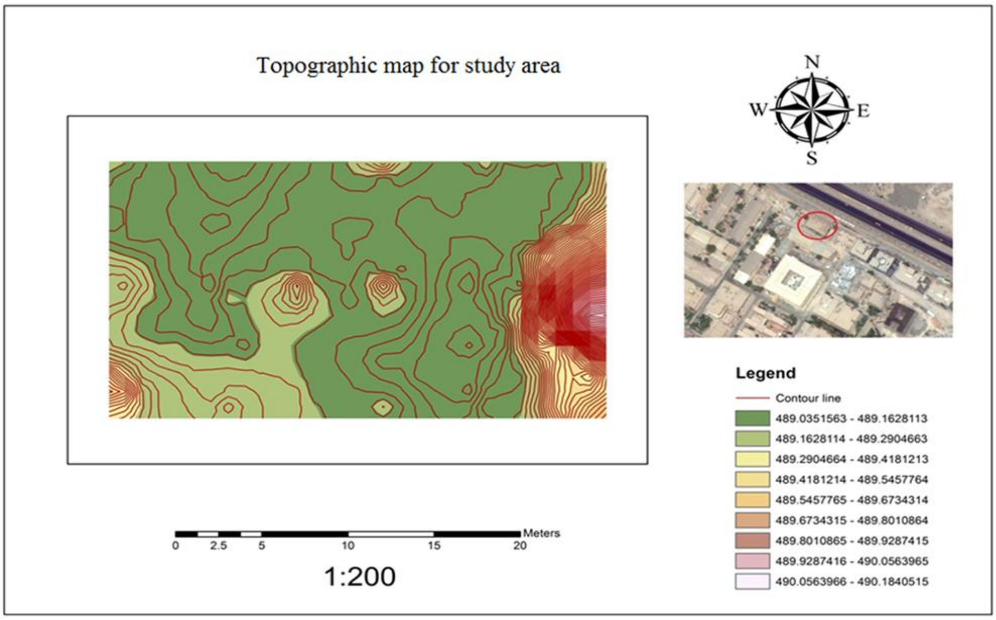

Figure (5) Topographic map for whole study area by 3D coordinates from (R-I) method

- **Bundle Adjustment (BA)**

Table (6) Check points and RMSE for 1st model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	**X m**	**Y m**	**Z m**	**X m**	**Y m**	**Z m**
1	512.523	564.924	489.610	512.529	564.925	489.613
2	511.551	565.008	490.607	511.549	564.996	490.595
3	506.187	567.000	489.156	506.195	567.021	489.153
Mean Square Error in check points (cm)						
RMSE x=0.5661		RMSE y=1.3905			RMSE z=0.7035	
Total RMSE= 1.6580						

Table (7) Check points and RMSE for 2nd model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	X m	Y m	Z m	X m	Y m	Z m
1	506.187	567.000	489.156	506.183	567.023	489.150
2	499.685	566.842	489.176	499.686	566.885	489.173
3	499.480	566.990	489.366	499.471	567.055	489.330
Mean Square Error in check points (cm)						
RMSE x=0.8082		RMSE y=4.4787			RMSE z=2.1358	
Total RMSE=5.0273						

Table (8) Check points and RMSE for 3rd model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	X m	Y m	Z m	X m	Y m	Z m
1	499.685	566.842	489.176	499.676	566.829	489.178
2	490.610	566.643	489.187	490.615	566.641	489.201
3	499.484	566.995	489.366	499.459	567.007	489.335
Mean Square Error in check points (cm)						
RMSE x=1.5865		RMSE y=1.0091			RMSE z=1.9688	
Total RMSE=2.7224						

Table (9) Check points and RMSE for 4th model

Actual Coordinates of Check points				Calculated Coordinates of Check points		
NO	**X m**	**Y m**	**Z m**	**X m**	**Y m**	**Z m**
1	484.587	566.706	489.190	484.598	566.692	489.216
2	483.967	566.842	489.341	483.979	566.844	489.332
Mean Square Error in check points (cm)						
RMSE x=1.1700		RMSE y=0.9814			RMSE z=1.9502	
Total RMSE=2.4770						

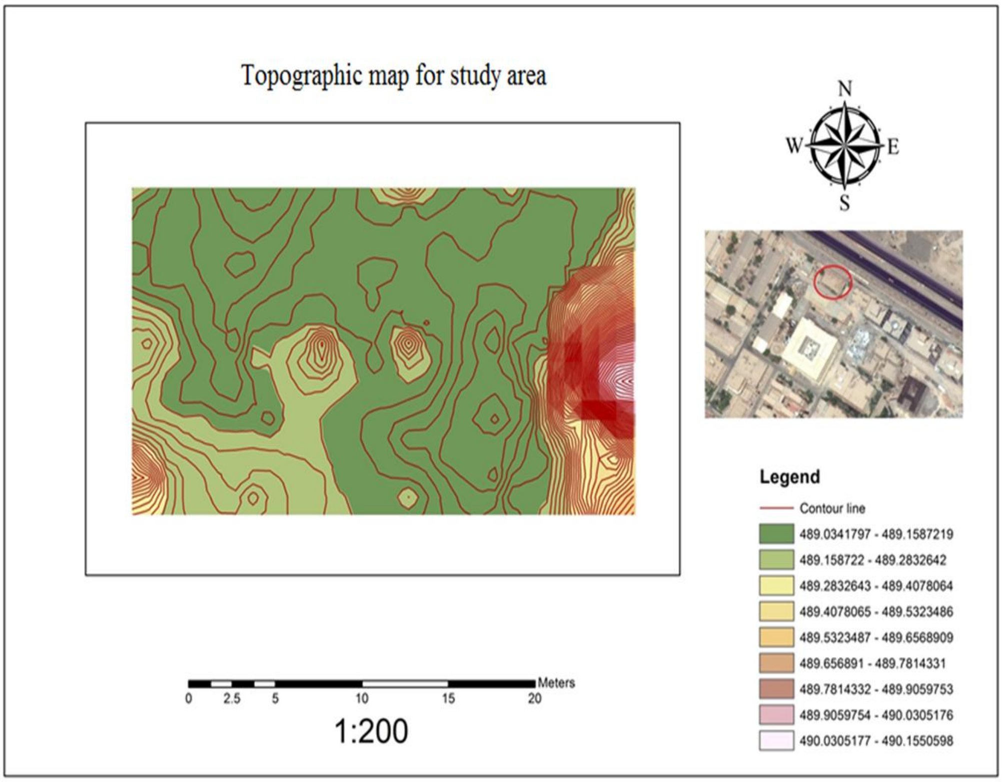

Figure (6) Topographic map for whole study area by 3D coordinates from (BA) method

- **Bundle Block Adjustment**

Table (10) Check Points Coordinates and RMSE by (LPS bundle block adjustment) method

	Actual Coordinates of Check Points			Calculated Coordinates of Check points		
NO	**X m**	**Y m**	**Z m**	**X m**	**Y m**	**Z m**
1	512.529	564.918	489.614	512.518	564.939	489.623
2	511.549	564.992	490.596	511.568	564.973	490.587
3	506.195	567.027	489.152	506.185	567.056	489.163
4	499.686	566.882	489.174	499.695	566.897	489.185
5	499.471	567.054	489.330	499.481	567.082	489.351
6	490.615	566.641	489.202	490.625	566.621	489.223
7	509.950	562.772	489.299	509.969	562.798	489.299
8	504.710	563.386	489.029	504.725	563.398	489.048
9	501.715	571.574	489.102	501.734	571.595	489.121
Mean Square Error in check points (cm)						
RMSE x=1.4694			RMSE y=2.2491		RMSE z=1.5496	
Total RMSE= 3.1014						

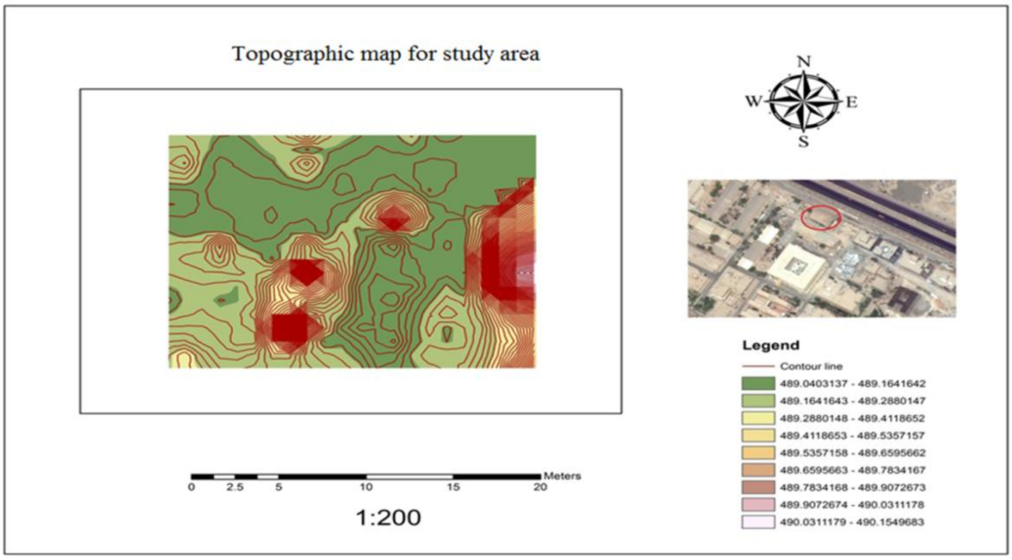

Figure (7) Topographic map for the whole study area using LPS bundle block adjustment method

Results analysis and discussion

After using the (R-I), (BA) and bundle block adjustment in three testing methods to compute the 3D coordinates of check points in the experiment, different results have been obtained through this operation. The standard to select the best method was done by determining the RMSE of each test. To analyze the results, a comparison between these accuracies was considered in order to select the best method.

- The obtained (RMSE) of the (R-I) method are illustrated in tables (2 - 5).
- The obtained (RMSE) of the (BA) method are addressed in tables (6 - 9).
- The obtained (RMSE) of the bundle block adjustment method are reviewed in table (10).

CONCLUSIONS

A topographic survey can be done with close range photogrammetry using Non metric digital cameras that available in the market (not expansive, easy for use and give a direct digital image data output). In this research, a good accuracy was obtained depending on the distribution a number of ground control point in the image. Theodolite (wild T2) was used to established 3D control point measurement of horizontal and vertical angles with high precision. A Bundle Block adjustment is the most practical method when compared it to other method because it needs fewer ground control point to resolve strip of overlapping photo. The root mean square error (RMSE) of three methods (resection intersection, bundle adjustment, and bundle adjustment block) to find:

- The obtained (RMSE) of the (R-I) method is (2.917cm)
- The obtained (RMSE) of the (BA) method is (2.882cm)
- The obtained (RMSE) of the bundle block adjustment method is (3.112cm)

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