PORT SAID ENGINEERING RESEARCH JOURNAL
Faculty of Engineering – Port Said University
Volume 21 No. 1 March 2017 pp. 17:24

Assessment the Accuracy of Data Acquisition by Close Range Photogrammetry Technique in The Restoration of Historical Buildings

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Abstract

Monuments and historical sites usually exposed to changes in color, material and shape due to several environmental and human factors. Therefore, continuous repair and maintenance for these valuable monuments and sites are usually needed. Preparing permanent precise records and documents for these monuments is the optimum way for their preservation. The purpose of this paper is to study, and assess the factors affecting the accuracy when using Close Range Photogrammetry (CRP) technique to reconstruct 3D objects. The façade of Coptic Museum and the AMR IBN AL-AAS Gate were chosen in this study. The results indicated that flatbed scanner with metric camera was acceptable in such cases when the photographed facades have no coarse details. whereas, nonmetric camera cannot be used in precise measurement. Also, it was concluded that using photogrammetry scanner with metric camera in close-range photogrammetry technique were acceptable for precise 3D restoration applications.

Keywords: *Close Range Photogrammetry; Multi-Image Orientation; metric camera; non-metric camera.*

1. Introduction

Egypt is the richest country all over the world in terms of Archeological sites where more than one third of the world's historical sites exist in Egypt. Preserving these historical places in good conditions is a national goal. It is important to produce precise 3D records for these ancient places so that they can be used to reconstruct them to the original shape in case they are subjected to any kind of damage or destruction by natural disasters such earthquakes or floods. A variety of cameras are used in terrestrial photography. All of them may be classifications as either metric or non-metric [1,2]. The purpose of this research was to study the accuracy of using flatbed scanner instead of photogrammetric scanner. Also, evaluating the accuracy of using non-metric camera instead of metric camera. Other purpose was to study the effect of increasing the number of images and/or number of ground control points in CRP technique [3].

2. Practical Work

2.1. Study Area

There is a lot of monuments in Egypt, which need to be documented. These monuments are scattered all over the country. In this paper the Coptic museum façade and AMR IBN AL-AAS Gate in Babylon Fortress were selected to be studied for documentation. Figure 1 displays the flowchart of the practical work.

2.2. Total Station Measurements

To study both façades of The Coptic Museum and AMR IBN AL-AAS Gate, it is required to observe number of points using total station instrument. Some of these points were used as Ground Control Points (GCPs) and the rest were used as check points (CHPs) to evaluate the used equipment and processing technique.

As mentioned above, some control points were selected on the façades under consideration. The coordinates (X, Y, and Z) of these points were observed using (SET-X Sokkia) total station and the measurements were made using reflectorless technique instead of sheet reflector to avoid touching the facades considering the sensitivity of these monuments.

For the Coptic Museum, a set of points were selected on the monumental façade according to its extent and geometry. Twenty-eight points were selected to be observed; six of these points were used as GCPs (point's numbers 2, 11, 12, 19, 22, and 28) and the rest were used as CHPs. Figure 2 shows the location of GCPs and CHPs in the Coptic museum façade.

Regarding, AMR IBN AL-AAS Gate facade, fourteen points were selected to be observed; six of these points were used as GCPs (point's numbers 2, 5, 6, 8, 10, and 13) and the rest were used as CHPs. Figure 3 shows the location of GCPs and CHPs in the AMR IBN AL-AAS Gate.

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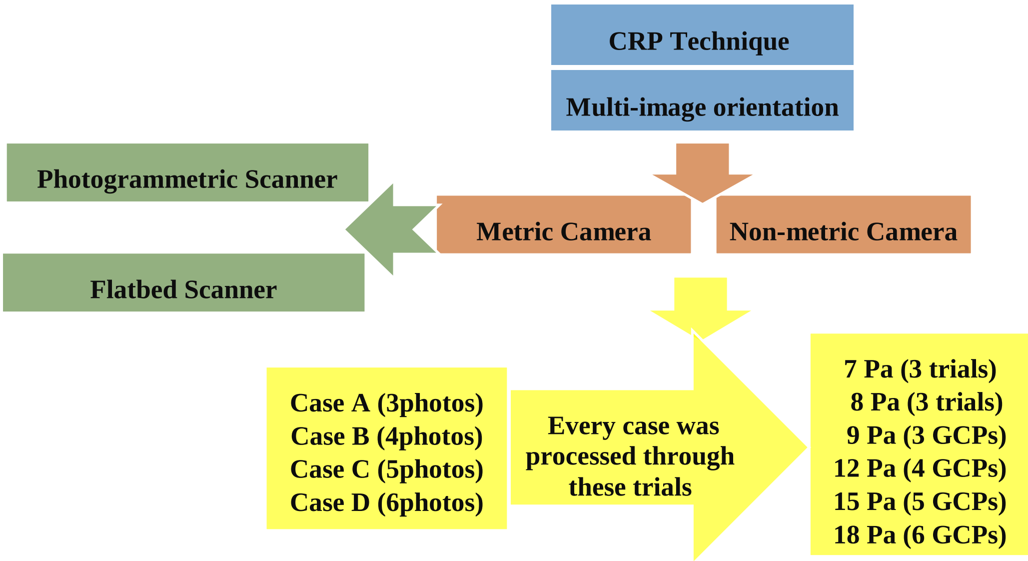


Figure 1: The flowchart of the practical work.

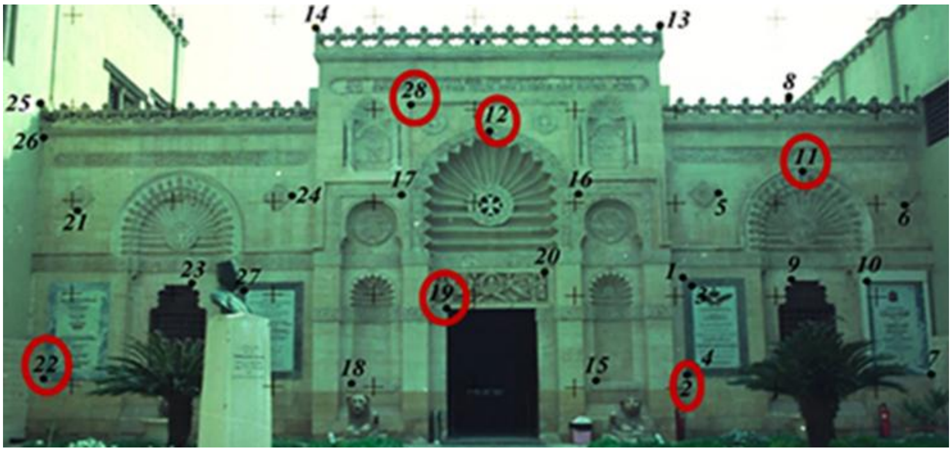


Figure 2: location of GCPs and CHPs in the Coptic Museum façade.

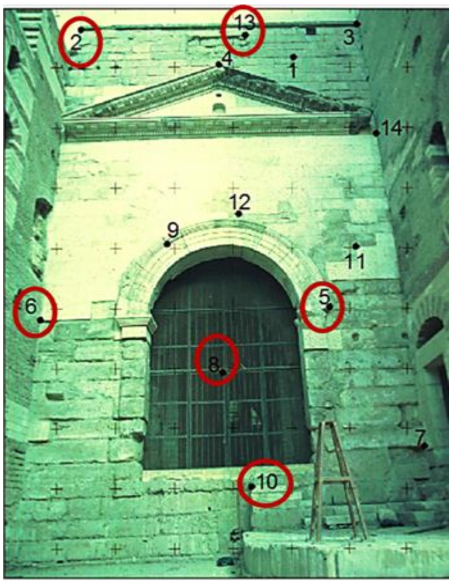


Figure 3: Location of GCPs and CHPs in AMR IBN AL-AAS Gate.

2.3. CRP Technique

In this research, the Multi-image orientation used as a method of recovering the photographic configuration of photo assembly. This method designed for determining camera stations and object points sequentially by intersection and resection model [4].

2.3.1. Images Capturing

A variety of cameras are used in terrestrial photography. All of them may be classifications as either metric or non-metric. The two camera types are used in this paper. Six camera exposure stations were set out in the front of the façade. These stations were distributed (left, middle, right) with variable distances from the facade.

For metric camera, a hand-held RolleiMetric 6008 normal camera was set up on the planned camera exposure station. The camera was oriented to the line of symmetry of the frontal with the help of the central reseau line. The reseau was directly placed in front of the film plane to allow the numerical corrections of the film deformation [5]. This correction is a decisive criterion for photogrammetric precision evaluation. The camera output was a hard copy format (negative of 60x60 mm), which was converted into a digital format for further processing. The scanner is an essential part of soft copy photogrammetric systems. In this paper, digital image data were derived from the frame images of photographic film by using two methods. In the first method, the captured images were scanned by using high-precision photogrammetric scanner (AGFA DUE SCAN scanner with resolution 4000 dpi). In the second method, the captured images were scanned by using normal-precision flatbed scanner (HP Scanjet scanner with resolution 600 dpi).

For non-metric camera, a hand-held Olympus digital camera with 8 Megapixel resolution was set up on the planned camera exposure stations. The camera output was a soft copy format.

2.3.2. Data Processing

Close Range Digital Workstation (CDW) was used for data processing [6]. In loading images to the project, four cases were conducted, in case A three images were loaded, in case B four images were loaded, in case C five images were loaded and in case D six images were loaded.

In fixing System, RolleiMetric CDW makes it possible to compute all results directly in a final user coordinate system. The minimum information that is needed for system definition is six coordinates of three points -not on a straight line- plus one distance (seven Parameters). The input data was only used for computing the multi-image orientation. Many trials in fixing system were conducted in every case. These trials were three trials for 7 Pa (seven parameters from coordinates of three GCPs), three trials for 8 Pa (eight parameters from coordinates of three GCPs), one trial for 9 Pa (coordinates of three GCPs), one trial for 12 Pa (coordinates of four GCPs), one trial for 15 Pa (coordinates of five GCPs), and one trial for 18 Pa (coordinates of six GCPs).

When getting the report, the coordinates (X, Y, and Z) of the CHPs were obtained. These coordinates were compared by the corresponding coordinates obtained by using total station. Then the residual error of coordinates was calculated. Therefore, RMSE and max residual error of the coordinates were computed.

$$E_X = X_{TS} - X_{CRP} \quad (1)$$

$$E_Y = Y_{TS} - Y_{CRP} \quad (2)$$

$$E_z = Z_{TS} - Z_{CRP} \quad (3)$$

$$E_R = \sqrt{[(E_X)^2 + (E_Y)^2 + (E_Z)^2]} \quad (4)$$

$$RMS_E = \sqrt{\frac{\sum E^2}{n}} \quad (5)$$

Where (X_{CRP}, Y_{CRP}, and Z_{CRP}) are the coordinates of CHPs from CRP technique, (X_{TS}, Y_{TS}, and Z_{TS}) are the coordinates of CHPs from Total Station, (E_X, E_Y, and E_Z) are residual error of the coordinates, E_R is the resultant residual error, and n is the number of CHPs.

3. Results and Analysis

3.1. Coptic Museum Façade

3.1.1. Metric Camera Using Photogrammetric Scanner

For Case (A), the number of images taken in the process was three images and the number of Parameters for fixing system was varied from 7 Pa to 18 Pa. It could be noted from Figure 4 that the RMS resultant residual error changed from 14.78 mm to 15.99 mm. The best accuracy obtained when using four GCPs (12 Pa) in the fixing system.

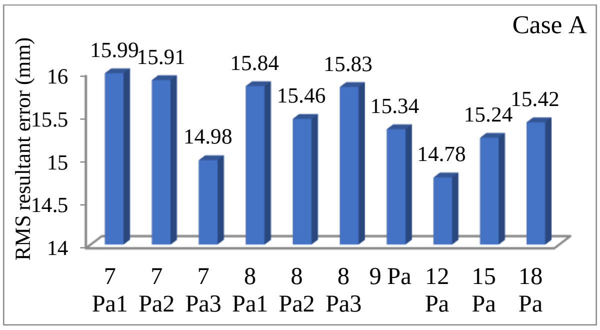


Figure 4: RMS resultant residual error for Case A.

For Case (B), the number of images taken in the process was four images and the number of Parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 5 that the RMS resultant residual error changed from 14.26 mm to 15.09 mm. The higher accuracy obtained when using four GCPs (12 Pa) in the fixing system.

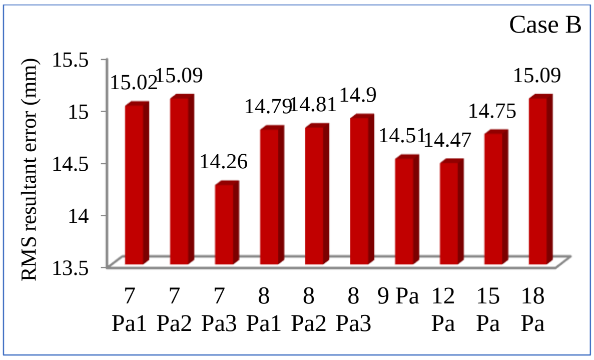


Figure 5: RMS resultant residual error for Case B.

For Case (C), the number of images taken in the process was five images and the number of Parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 6 that the RMS resultant residual error changed from 14.34 mm to 15.02 mm. The best accuracy obtained when using four GCPs (12 Pa) in the fixing system.

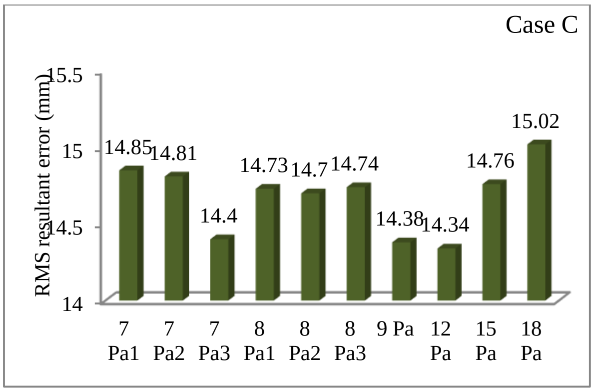


Figure 6: RMS resultant residual error for Case C.

For Case (D), the number of images taken in the process was six images and the number of Parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 7 that the RMS resultant residual error changed from 14.17 mm to 15.09 mm. The best accuracy obtained when using four GCPs (12 Pa) in the fixing system.

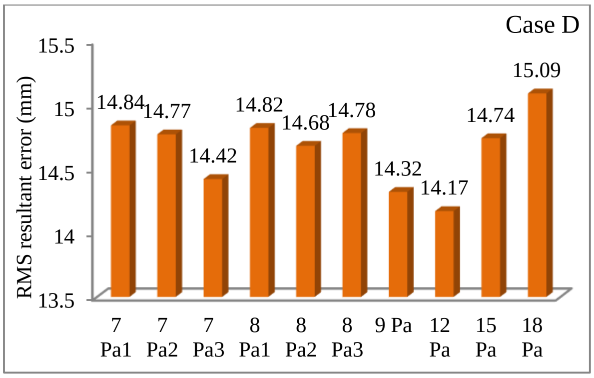


Figure 7: RMS resultant residual error for Case D.

In general, it could be concluded that the best accuracy results obtained when using four GCPs (12 Pa) in the fixing system with regard to RMS resultant residual error. Whereas, no significant change in the RMS result occurred when number of parameters changed from 12 PA. These results can be explained by the directions and the values of the residual errors which were found to be the same. Therefore, the algebraic differences between these directions were very small as shown in Figure 8.

Figure 8: The vector error of all CHPs in case D.

The results of increasing the number of images–taking into consideration the use of four GCPs in the fixing system - are shown in Figure 9. The RMS resultant residual error changed from 14.17 mm to 14.78 mm, which considered small. It can be concluded that the increase of images had no significant impact on the results accuracy, but it required more processing time. Therefore, the use of three images was found to be sufficient.

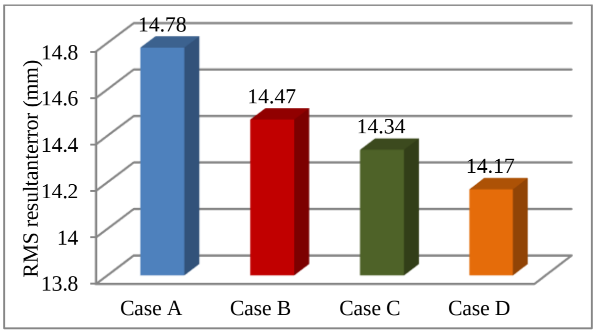


Figure 9: RMS resultant residual error when using four GCPS in the fixing system for all cases.

3.1.2. Metric Camera Using Flatbed Scanner

For Case (A), the number of images taken in the process was three images and the number of parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 10 that the RMS resultant residual error changed from 31.45 mm to 34.73 mm. The best accuracy obtained when using five GCPs (15Pa) in the fixing system.

For Case (B), the number of images taken in the process was four images and the number of parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 11 that the RMS resultant residual error changed from 31.5 mm to 34.73 mm. The best accuracy obtained when using five GCPs (15Pa) in the fixing system.

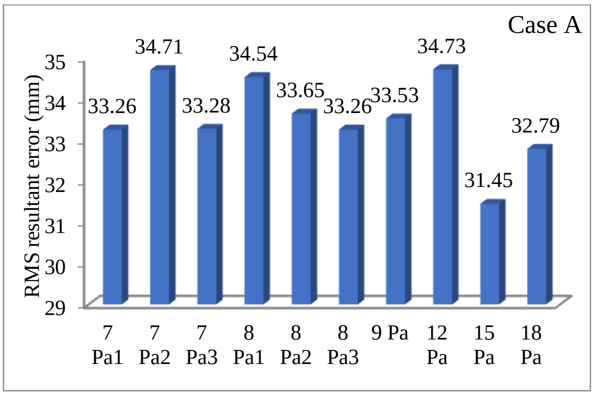


Figure 10: RMS resultant residual error for Case A.

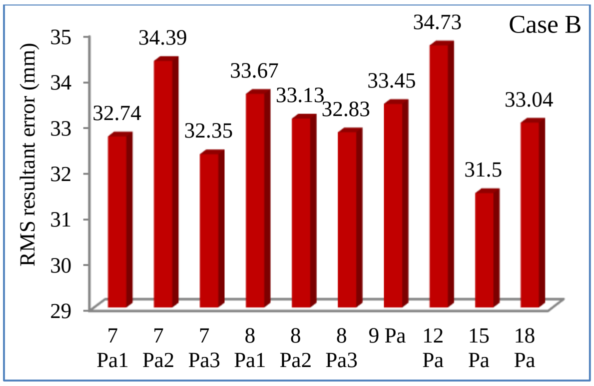


Figure 11: RMS resultant residual error for Case B.

For Case (C), the number of images taken in the process was five images and the number of parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 12 that the RMS resultant residual error changed from 31.18 mm to 35.49 mm. The best accuracy obtained when using five GCPs (15Pa) in the fixing system.

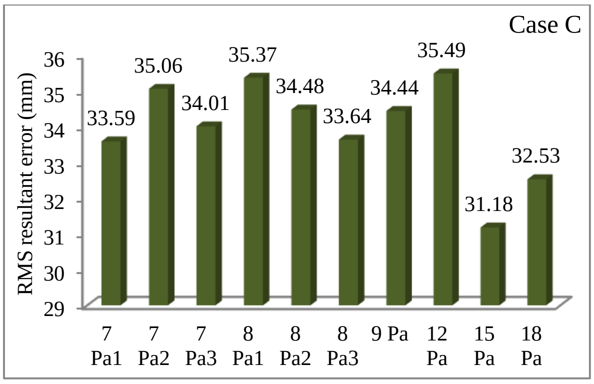


Figure 12: RMS resultant residual error for Case C.

For Case (D), the number of images taken in the process was six images and the number of parameters for fixing system was varied from 7 PA to 18 PA. It could be noted from Figure 13 that the RMS resultant residual error changed from 30.49 mm to 36.05 mm. The best accuracy obtained when using five GCPs (15Pa) in the fixing system.

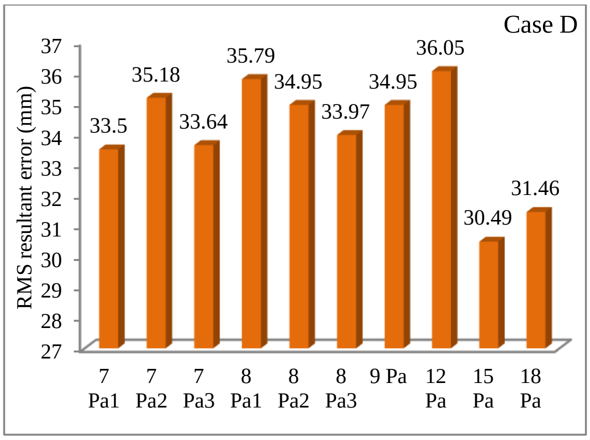


Figure 13: RMS resultant residual error for Case D.

In general, it could be concluded that the best accuracy results obtained when using five GCPs (15Pa) in the fixing system with regard to RMS resultant residual error. Whereas, no significant change in the RMS result occurred when number of parameters changed from 15PA. These results can be explained by the directions and the values of the residual errors which were found to be the same. Therefore, the algebraic differences between these directions were very small.

The results of increasing the number of images -taking into consideration the use of five GCPs in the fixing system- are shown in Figure14. The RMS resultant residual error changed from 30.19 mm to 31.5 mm, which considered small. It can be concluded that the increase of images has no significant impact on the results accuracy, but it required more processing time. Therefore, the use of three images was found to be sufficient.

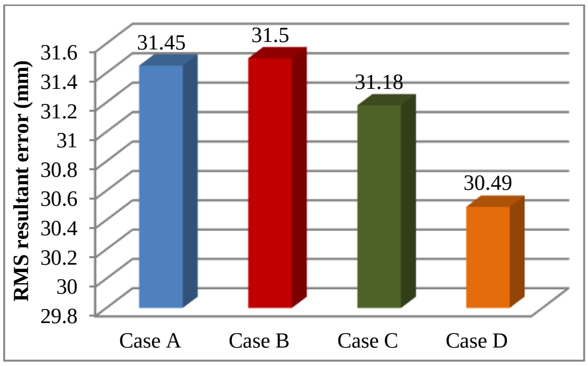


Figure 14: RMS resultant residual error when using five GCPS in the fixing system for all cases.

3.1.3. Non-Metric Camera

As given in table (1), The RMS of resultant residual error was found to be in the range of 120 to 200 mm. the results were greater than the desired value, even with increasing the number of images and/or GCPs.

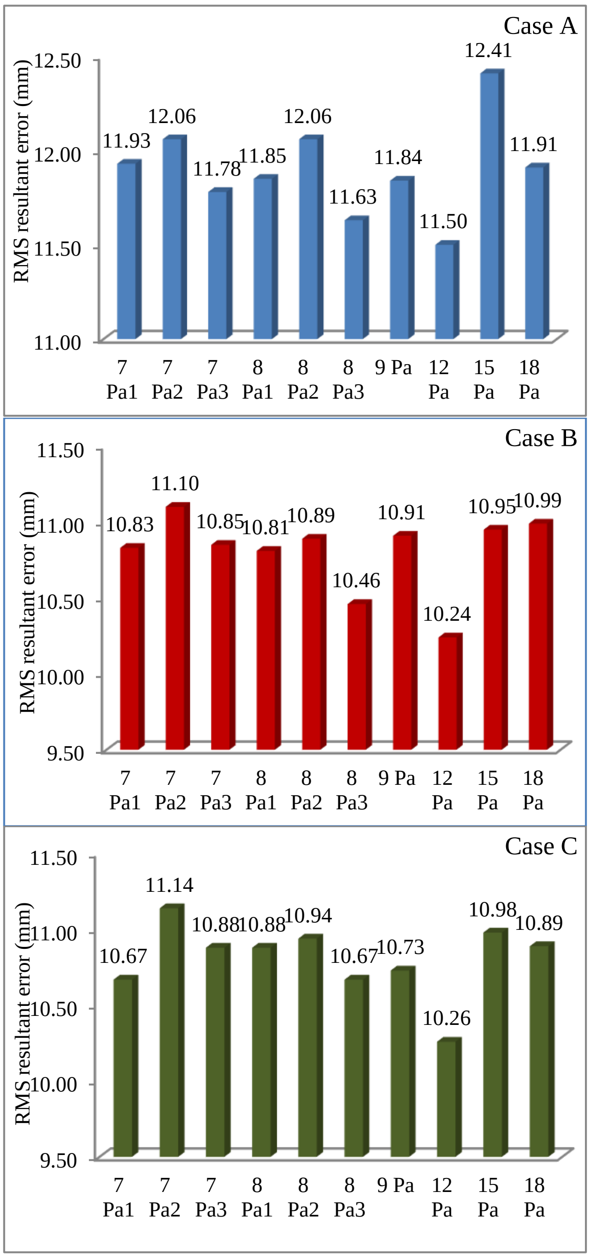
Table 1: The RMS residual error results when using nonmetric camera for all cases.

case	PA	RMS (mm)			
		E_X	E_Y	E_Z	E_R
Case (A)	7 PA_1	101.08	85.43	83.38	156.42
	7 PA_2	90.19	85.60	78.66	147.13
	7 PA_3	122.41	84.42	102.12	180.39
	8 PA_1	104.83	56.45	82.09	144.62
	8 PA_2	113.95	57.47	87.90	154.97
	8 PA_3	99.09	92.13	82.18	158.30
	9 PA	100.27	100.6	79.38	162.75
	12 PA	93.04	81.89	79.46	147.23
	15 PA	68.60	81.71	63.08	123.94
	18 PA	67.59	89.87	59.86	127.39
Case (B)	7 PA_1	95.55	112.2	80.89	168.11
	7 PA_2	104.58	111.2	89.91	177.19
	7 PA_3	130.62	110.3	109.43	203.03
	8 PA_1	105.80	76.97	84.92	155.98
	8 PA_2	121.24	68.22	90.93	166.19
	8 PA_3	103.75	90.24	87.27	162.86
	9 PA	104.70	89.60	83.85	161.31
	12 PA	97.17	61.54	84.38	142.65
	15 PA	75.45	85.86	71.17	134.65
	18 PA	73.67	91.96	66.81	135.45
Case (C)	7 PA_1	98.55	110.9	82.26	169.66
	7 PA_2	104.22	110.2	89.27	176.00
	7 PA_3	132.88	109.1	109.77	204.01
	8 PA_1	108.72	68.94	85.96	154.80
	8 PA_2	123.32	71.40	91.61	169.41
	8 PA_3	105.60	95.48	87.35	167.03
	9 PA	105.85	89.27	84.49	162.21
	12 PA	99.99	73.84	84.63	150.38
	15 PA	75.42	74.65	71.02	127.69
	18 PA	73.90	76.27	66.42	125.27
Case (D)	7 PA_1	99.07	105.9	81.92	166.55
	7 PA_2	104.63	105.1	89.64	173.32
	7 PA_3	132.83	104.2	109.92	201.47
	8 PA_1	107.43	67.16	84.73	152.42
	8 PA_2	123.34	64.86	90.83	166.34
	8 PA_3	106.33	88.90	86.43	163.34
	9 PA	103.38	93.29	82.43	161.82
	12 PA	95.71	80.26	82.40	149.64
	15 PA	75.01	81.00	67.89	129.61
	18 PA	74.10	86.74	63.91	130.76

3.2. AMR IBN AL-AAS Gate

3.2.1. Metric Camera Using Photogrammetric Scanner

As seen in figure 15, The best accuracy was obtained when using four GCPs in the fixing system for all cases. These results were agreed with the Coptic museum façade results. Also, the increase of images has no significant impact on the results accuracy, but it required more processing time. Therefore, the use of three images was found to be sufficient.



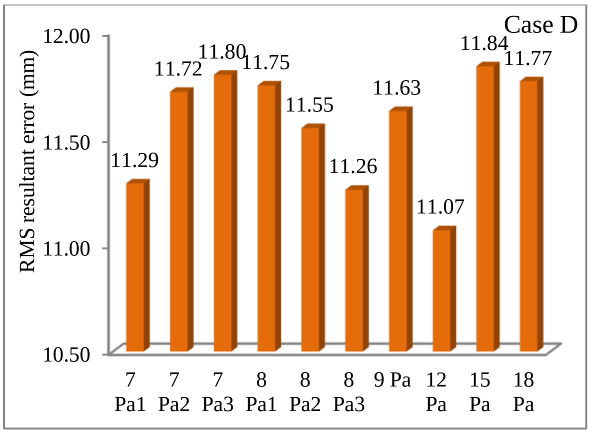
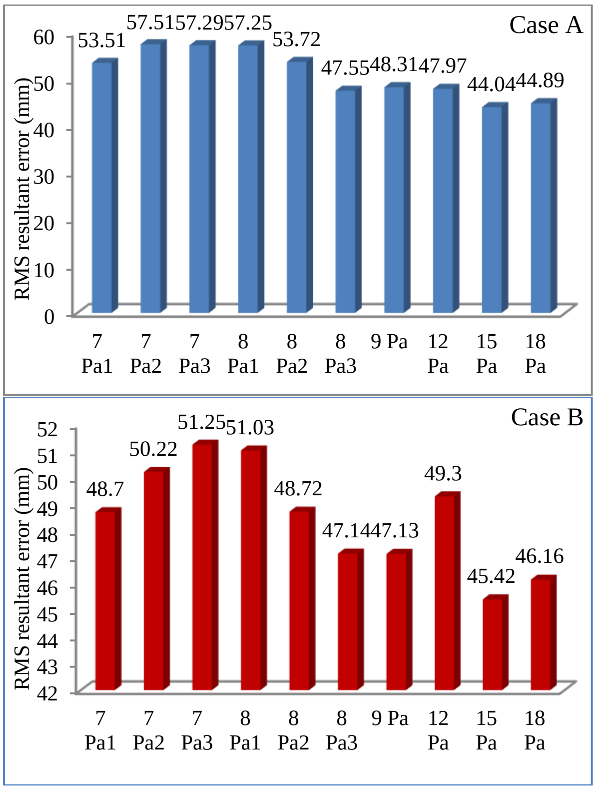


Figure 15: RMS resultant residual error for all Cases.

3.2.2. Metric Camera Using Flatbed Scanner

As seen in figure 16, The best accuracy obtained when using five GCPs (15 Pa) in the fixing system for all cases. These results were agreed with the Coptic museum façade results. Also, the use of three images was found to be sufficient.



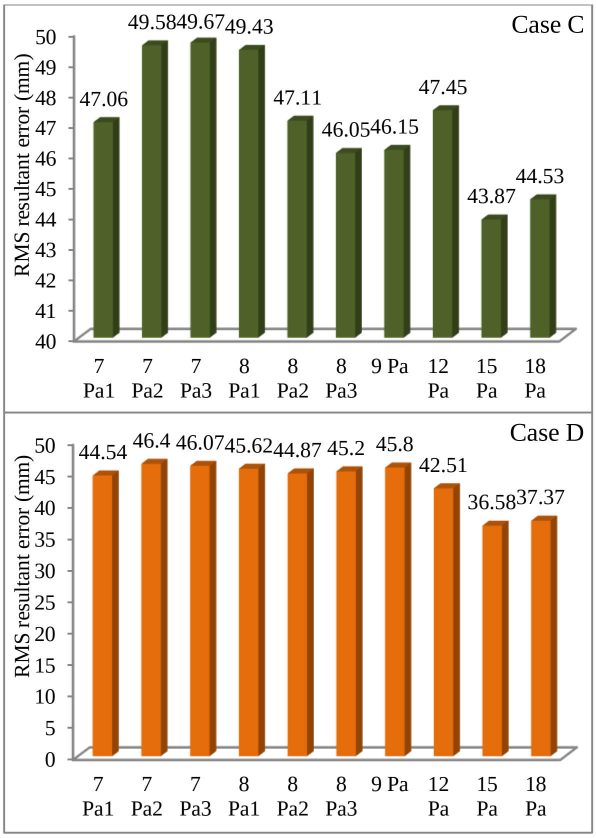


Figure 16: RMS resultant residual error for all Cases.

3.2.3. Non-Metric Camera

As given in table (2), The RMS of resultant residual error was found to be in the range of 100 to 300 mm. the results were greater than the desired value, even with increasing the number of images and/or GCPs as the results obtained from the previous façade.

Table 2: The RMS residual error results when using nonmetric camera for all cases.

case	PA	RMS (mm)			
		E_X	E_Y	E_Z	E_R
Case (A)	7 PA_1	80.40	52.44	163.56	189.65
	7 PA_2	112.67	51.27	119.28	171.91
	7 PA_3	50.99	51.11	84.65	111.25
	8 PA_1	49.97	63.96	73.51	109.51
	8 PA_2	73.92	52.49	167.16	190.16
	8 PA_3	53.89	162.27	80.42	188.95
	9 PA	43.05	165.31	78.98	188.20
	12 PA	52.71	244.60	73.66	260.83
	15 PA	52.42	195.92	68.47	214.06
	18 PA	45.15	174.03	63.49	190.68
Case (B)	7 PA1	76.51	48.06	164.82	187.96
	7 PA2	112.86	48.04	122.61	173.43
	7 PA3	54.65	48.30	86.70	113.30
	8 PA1	52.77	71.13	75.56	116.42
	8 PA2	72.11	49.22	165.51	187.13
	8 PA3	42.53	151.77	79.29	176.43
	9 PA	43.70	151.47	79.52	176.56

	12 PA	56.39	293.38	79.64	309.18
	15 PA	56.20	248.53	70.63	264.41
	18 PA	47.33	199.88	65.27	215.53
Case (C)	7 PA_1	66.14	47.74	158.46	178.23
	7 PA_2	105.39	48.35	123.55	169.44
	7 PA_3	53.24	48.79	82.98	110.01
	8 PA_1	51.91	59.16	74.81	108.59
	8 PA_2	69.80	48.52	157.78	179.22
	8 PA_3	35.95	147.51	77.35	170.39
	9 PA	41.32	145.86	78.67	170.79
	12 PA	54.19	282.20	79.80	298.23
	15 PA	55.66	235.49	70.91	252.15
	18 PA	45.81	190.80	64.67	206.61
Case (D)	7 PA_1	61.83	41.92	147.96	165.74
	7 PA_2	100.42	44.27	117.59	160.84
	7 PA_3	50.99	45.20	77.51	103.21
	8 PA_1	51.34	50.35	72.42	102.06
	8 PA_2	65.99	39.80	146.15	165.22
	8 PA_3	40.24	135.90	72.21	159.07
	9 PA	39.66	136.02	71.90	158.89
	12 PA	54.21	267.01	71.59	281.70
	15 PA	56.79	216.22	64.44	232.65
	18 PA	45.74	181.88	58.30	196.40

4. Conclusions

The following results may be concluded:

- When using Photogrammetry scanner with metric camera in CRP technique, the RMSE was found to be in the range of 10 to 15 mm. It was also found that the use of three images with four GCPs was sufficient to achieve the best results. Increasing the number of images will extend the processing time, with no significant changes on the results. The obtained results are acceptable for precise 3D restoration applications.
- When using flatbed scanner with metric camera in CRP technique, the RMSE was found to be in the range of 30 to 50 mm. Such results are acceptable in such cases when the photographed facades have no coarse details. It was also found that the use of three images with five GCPs was sufficient to achieve the best results.
- When using nonmetric camera in CRP technique, the RMSE was found to be in the range of 100 to 250 mm. Such results showed a large error which discard the possibility of using nonmetric camera for 3D restoration applications.

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