The Integration between CAD and Digital Closerange Photogrammetriy for Accuracy Studies

Mostafa Abdel-BaryEBRAHIM[1], Farrag Ali FARRAG[2]

[1]Civil Engineering Department. Faculty of Engineering, Rabigh, King Abdul Aziz University. Kingdom of Saudi Arabia

[2]Civil Engineering Department. Faculty of Engineering, Al-Jouf University, Kingdom of Saudi Arabia

Abstract: ***Accuracy studies in plane (2D) or in space (3D) have been carried out in digital close range photogrammetry in different ways and by different methods.Basically, the accuracy studies in digital close range photogrammetry depend on the field measurements of the object. CAD environment has a wide incorporation in digital close range photogrammetric works. These fieldwork measurements have a certain accuracy, which depends on the measuring tools and the used method. This accuracy can affect the accuracy of the results obtained by digital close range photogrammetry. Such effect can be easily obtained theoretically, but it is hard to be obtained practically. To avoid the effect of the field measurement accuracy on the digital close range photogrammetric accuracy, a new technique is applied in this study to obtain a test field that has a very accurate dimension. In the same time, by using this technique the camera orientation elements can be fixed with a certain values, which have free errors. This paper will discuss the details of this new technique based on CAD (3D Studio software) as an excellent environment for accuracy studies in digital close range photogrammetry. The effect of camera configuration on the accuracy of close range photogrammetry is also analysed.***

Keywords: Close-range; Photogrammetry; Accuracy; CAD; 3D-Studio

1. Introduction

There is no doubt that CAD environment has an importantrole in the photogrammetric works. It is involving mainly in reconstruction of 3D models of the objectsandis playing a big role in the visualisation of these models. Kraus K. [1] mentioned, “A representation of the object surface based on edges and points is indeed possible and usable in CAD-system”. Many researches involved in using the CAD system in photogrammetry. For example, Coppola, F. et al [2] has used both AutoCAD and 3D Studio as a CAD environment to display volumes as solids, rendering, and animation of the object. In addition, Vogtle, Th. and Steinle, E. [3] used CAD environment to visualise objects in 3D city models. In the worldwide webs we can find huge number of sites have mentioned the relation between the CAD and photogrammetry. In fact, the use of CAD system in photogrammetry is at end stages. In this paper, CAD system will be used at the beginning of the photogrammetric operation. In other word, it will be used as a photograph acquiring system.

The procedures of evaluating accuracy in digital close range photogrammetry are common and well known. To evaluate the accuracy in digital close range photogrammetry we must have field measurements that can be compared with those measurements obtained from the photogrammetric application. The field measurements usually are accurate (up to a certain limit). This accuracy depends on the used instruments and on the mathematical models used to calculate the 2D or 3D co-ordinates. Brief definitions of the accuracy and how it can be achieved in the photogrammetric works have been mentioned by Ebrahim[4]. In general, the accuracy can be obtained from the field measurements as follows:

- Choose a suitable test field to be used in the study (natural or artificial).
- Take some field measurements for the object to obtain the 2D or 3D co-ordinates for some chosen points (targets).
- Choose cameras configuration based on the factors that will be studied.
- Choose the suitable camera to be used.
- Take the photographs.
- Manage if the digital method or the traditional method will be used.
- Measure the photo co-ordinates of the targets.
- Calculate the object co-ordinates based on the photogrammetric solution.
- Compare the surveying co-ordinates with that obtained from the photogrammetric solution and make the required statistics.

With the great progress of the computer science, we have additional tools that enable us to make such studies easier and more efficient. CAD environment is a very suitable tool for such studies. Using such kind of software enables us to obtain an accurate 3D model without any field measurements. In this case, point’s co-ordinates can be obtained directly from the model because we have the object with its accurate 3D dimension in the computer.

1.1 3D-Studio

In fact, 3D Studio software is designed to enable numerous creative professionals to work on specific aspects of the same project while easily combining discrete elements into complex shots, animations, or game levels. The software also boasts a redesigned renderer that retains the speed of its predecessor while delivering superior results and simplifying the process of creating stunningly realistic images, scenes, and special effects. Other key enhancements include nestable external references, application-wide scripting and macro recording, a customisable work environment, powerful organic modelling capabilities, and a host of other new features that accelerate the creation of digital content. 3D Studio uses also, a very useful feature for the photogrammetrist. This feature is the cameras. It uses two different types of cameras, free and target. The most used camera is the target type that enables us to position the camera in a certain position and direct it to a certain direction and a target. This enables us to fix the camera orientation elements.

1.2 The Idea of Using 3D Studio

3D Studio, is a CAD environment, enables us to create an accurate 3D model. It is a very suitable environment to have a model that can be used as a test field for photogrammetric works. By creating a 3D model in this environment and have some photographs for this model from different points of view, we can use the photogrammetric techniques to obtain the 3D co-ordinates of this model. As mentioned before, 3D-Studio software has its great features that it offers the use of cameras, so we can use these cameras to obtain photographs of the model. The photogrammetric solution can be used to obtain the model co-ordinates. By comparing these co-ordinates with that of the original model, the accuracy of photogrammetric solution can be estimated.

2. Practical Test

To prove that the CAD environment can be a useful tool for accuracy investigation in digital close range photogrammetry, a study is carried out using this tool. The chosen subject, to be studied, is the camera configuration and its effect on the accuracy of digital close range photogrammetry. To be able to carry out this study, the following works must be done:

- Taking the photographs and obtaining the test field points' co-ordinates through the 3D Studio.
- Calculating the photogrammetric test field points' co-ordinates.
- Comparing the obtained co-ordinates with that obtained from 3D Studio.
- Analyse the results.

2.1 3D Studio Works

There are some works through 3D Studio software must be done to have the photographs that will be used in this study. These works are:

- Create a test field model.
- Define a camera.
- Configure the cameras.
- Render the scene each time using a camera position.

2.2 Creating the Test Field Model

In 3D-Studio software, a test field model has been created. The test field models consists of 35 posts with 10 x 10 cm cross section and with different heights vary from 10 to 80 cm. These posts have been fixed to a plan board as zero datum. The posts arranged in horizontal rows and vertical columns with 50 cm distances centre line to centre line. To have a good photo contrast for marking the target points through the digital photogrammetric software, different materials for the posts and the baseboard have been assigned. Also, a target spotlight in the front of the test field has been used to illuminate the posts' top. Figure (1) shows the test field.

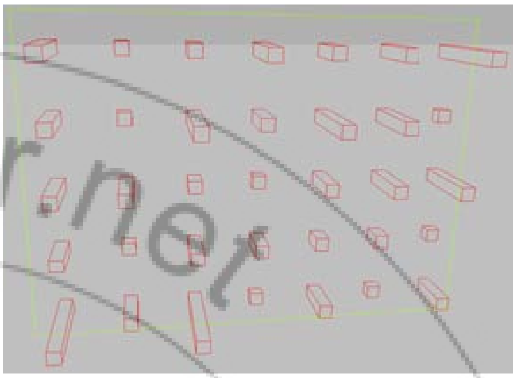

Figure 1: The test field

2.3 Define the Camera

A camera through 3D Studio has been defined with 35 mm focal length, 36 X 24 mm format and 63 degree angle of convergent.

2.4 Configure the Cameras

12 cameras have been arranged in front of the object in row and columns, 4 m away from the object. The cameras' axes have been directed to the object centre. Figure (2) shows the test field with the cameras configuration in 3D Studio.

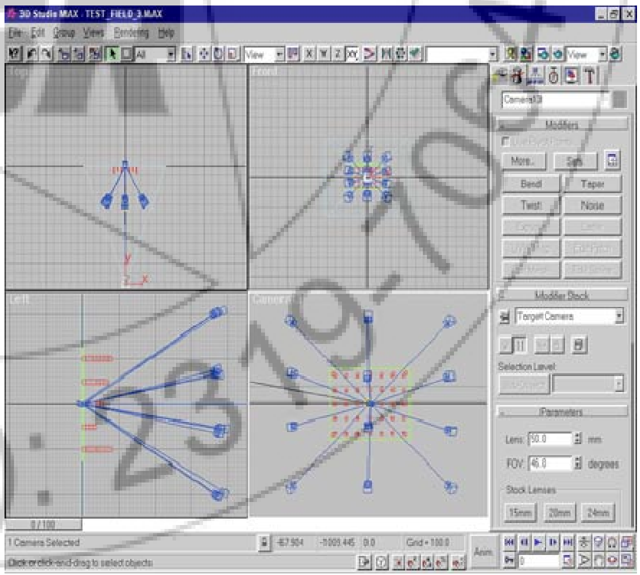

Figure 2: Cameras configuration

2.5 Rendering the Scene

To have the photograph from each camera position, the view port must be assigned to view the appropriate camera scene. Then rendering the camera scene with fixing the rendering option to the desired resolution and saving under the desired file name. Figure (3) shows one of the obtained test field photograph (rendered scene).

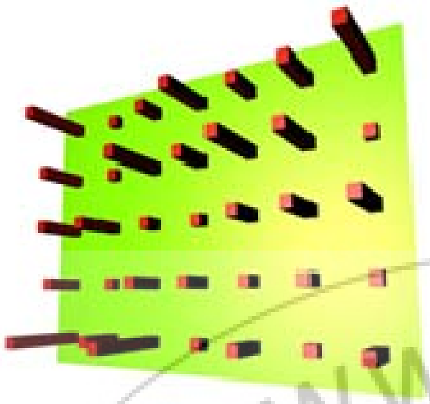

Figure 3: One of the test field photograph.

2.6 The Photogrammetric Technique

It is well known that the photogrammetric works concerning the steps to be done to obtain object co-ordinates or other desired results by using the photogrammetric technique. In this study the following steps have been photogrammetrically done:

- Importing the photographs into the used photogrammetric software.
- Marking the object points in the tested photographs (the upper-right corner of the post's top).
- Photogrammetrically solving for the chosen photographs.
- Marking the residual error for the obtained points' co-ordinates.
- Readjusting the marked points.
- Solving the photographs once again for final solution.
- Exporting the object points' co-ordinates in ASCII format.

The previous steps have been done for different camera's configuration. 25 cases have been studied to obtain the accuracy for each case. Figure (4) shows the camera positions and the identification numbers assigned to these positions. The configurations that have been used are listed in Table (1).

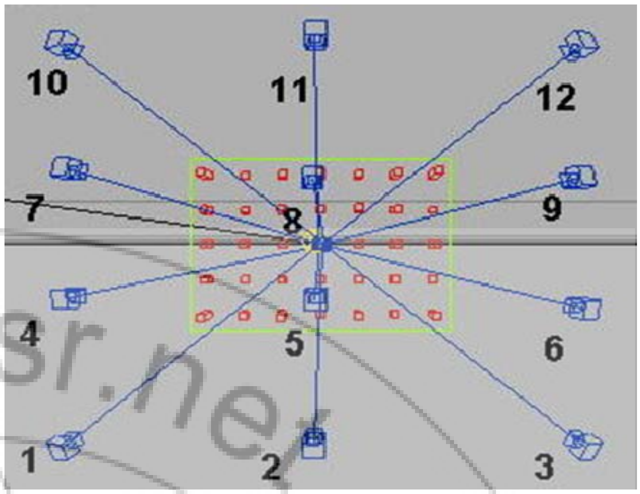

Figure 4: Camera positions and the identification numbers assigned to these positions

3. The Results

The space co-ordinates (X, Y, Z) for the object points (35 points) calculated from the photogrammetric solution using common digital close range photogrammetric software were obtained. In addition, the intersection angles at the points were obtained. These angles were expressed in three values, which are, the minimum, the maximum and the average intersection angles.

A comparison between the true points' co-ordinates from 3D Studio and the obtained points' co-ordinates from the photogrammetric solution has been carried out in the three directions (X, Y, and Z). The comparison has been done through statistical software, and the standard deviations for X, Y and Z co-ordinates, as an accuracy measurement (as stated by [5] and [6]) have been calculated. Table (2) shows the best and the worst relative accuracy (accuracy/object distance). All the comparison results have been tabulated as shown in Table (3). Figures (5), (6), and (7) show the relationships between the average intersection angle and the accuracy in X, Y and Z directions.

Table1: Positions of the used cameras

Case	*Used camera position*	*Number of photographs*
1	1-2-3-8	4
2	1-2-3-10-11-12	6
3	1-2-3-11	4
4	1-2-3-4-5-6	6
5	1-2-3-4-5-6-10-11-12	9
6	1-2-3-4-5-6-7-8-9	9
7	1-2-3-4-5-6-7-8-9-10-11-12	12
8	1-2-3-4-6-7-9-10-11-12	10
9	1-2-3-5	4
10	1-2-3-7-8-9	6
11	1-2-3	3
12	1-2-4-5-7-8-10-11	8
13	1-3-10-12	4
14	1-3-4-6-7-9-10-12	8
15	1-4-7-10	4
16	1-5-12	3

17	2-3-5-6-8-9-11-12	8
18	2-5-8-11	4
19	4-5-6	3
20	4-5-6-10-11-12	6
21	4-5-6-7-8-9	6
22	4-6-7-9	4
23	7-8-9-10-11-12	6
24	1-3-5-8-10-12	6
25	2-4-6-7-9-11	6

Table 2: The best and the worst relative accuracy

Co-ordinates	*X*	*Y*	*Z*
Best relative accuracy	1/10000	1/10811	1/9756
Worst relative accuracy	1/2439	1/3774	1/2235

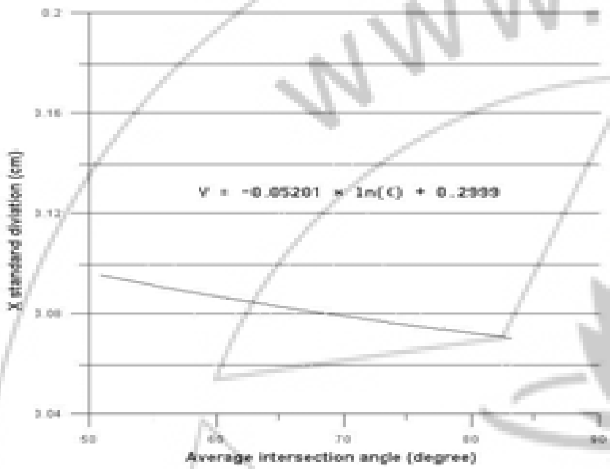

Figure 5: The relationship between the average intersection angle and the accuracy in X direction.

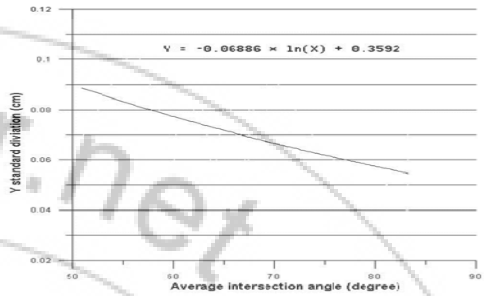

Figure 6: The relationships between the average intersection angle and the accuracy in Y direction.

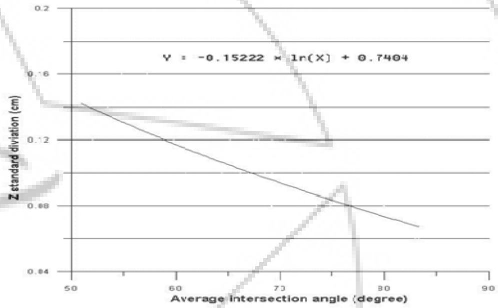

Figure 7: The relationships between the average intersection angle and the accuracy in Z direction.

Table 3: The results

No. of photographs	*Used cameras*	*Standard Deviation (cm)*			*Intersection angles (degrees)*		
		X	Y	Z	Min	Max	Aver.
4	1-2-3-8	0.068	0.069	0.106	40	74	60.1
6	1-2-3-10-11-12	0.04	0.047	0.076	74	89	83.3
4	1-2-3-11	0.073	0.083	0.138	52	74	67.5
6	1-2-3-4-5-6	0.069	0.067	0.095	56	79	66.5
9	1-2-3-4-5-6-10-11-12	0.078	0.07	0.078	74	89	83.3
9	1-2-3-4-5-6-7-8-9	0.097	0.064	0.063	64	86	74.9
12	1-2-3-4-5-6-7-8-9-10-11-12	0.042	0.037	0.041	74	89	83.3
10	1-2-3-4-6-7-9-10-11-12	0.065	0.064	0.055	74	89	83.3
4	1-2-3-5	0.047	0.06	0.104	30	74	60.1
6	1-2-3-7-8-9	0.084	0.062	0.089	64	86	74.9
3	3-7-6-5-3	0.057	0.064	0.115	24	74	60.1
8	1-2-4-5-7-8-10-11	0.091	0.085	0.085	52	72	62.8
4	1-3-10-12	0.052	0.04	0.068	74	89	83.3
8	1-3-4-6-7-9-10-12	0.074	0.054	0.053	74	89	83.3
4	1-4-7-10	0.082	0.069	0.104	16	63	50.9
3	4-1-0-3-0	0.059	0.047	0.075	34	89	82.7
8	2-3-5-6-8-9-11-12	0.061	0.052	0.089	52	73	64.0
4	2-5-8-11	0.108	0.106	0.179	48	62	56.1
3	3-8-8-4-1	0.13	0.088	0.12	55	75	65.2
6	4-5-6-10-11-12	0.08	0.067	0.07	64	84	74.3
6	4-5-6-7-8-9	0.149	0.093	0.127	60	77	69.2
4	4-6-7-9	0.164	0.097	0.138	60	77	69.2
6	7-8-9-10-11-12	0.046	0.056	0.104	31	77	67.4
6	1-3-5-8-10-12	0.065	0.043	0.069	74	89	83.3
6	2-4-6-7-9-11	0.084	0.071	0.077	60	77	69.2

4. Results Analysis

From Table (3), we can note that the accuracy is very high. It is about 0.4 mm (1/10000 relative accuracy) in the three directions (X, Y, and Z) in case using all the photos (12 photos). This happened because we are working with errorless ground co-ordinates. The photogrammetric co-ordinates accuracy has been studied in several researches. For example, [7] found that by using the same photogrammetric software, the relative accuracy is about 1/3000 for the non-metric camera and 1/8000 for the metric camera. In this study, the relative accuracy with the same software is much better than that obtained from the methods mentioned before. That means, the ground co-ordinates accuracy has a big influence in the obtained photogrammetric co-ordinates accuracy.

By sorting the results in relation to the X, Y and Z directions, it can be noted that the best accuracy always comes with the big average intersection angle but with a condition that the camera positions must be arranged in good positions. As example, the two cases, 1-2-3-10-11-12 and 4-5-6-7-8-9 are similar arrangements, but the first has big intersection angles, which improved the accuracy very much. Another example, the two cases, 2-4-6-7-9-11 and 4-5-6-7-8-9 have the same intersection angles, but the first case has better accuracy because it has better camera positions. The accuracy in Z direction depends mainly on the intersection angle, unless the camera positions are better in smaller intersection angle. The best camera positions for Z direction does not mean that it is the best for X and Y direction, but every direction has its camera arrangement, which gives the best accuracy.

Finally, from curve fitting shown in Figures (5), (6), and (7), it can be noted that, the curve's trends in the three directions are the same. The accuracy improved with increasing the intersection angle, but we must not forget to have good camera positions.

5. Conclusion

The results of this study demonstrate that the CAD environment (3D Studio software) could be an excellent tool for accuracy studies. The obtained influence of the studied factors in the accuracy is similar to the case of using natural or artificial test fields. Also, the achieved accuracy is very high because the results didn't affected by the accuracy of the ground measurements. In addition, we have the free choice to create any kind of computer models (test fields) with any shape and with any dimension. Such models can cost a lot of time and money if we tried to work with a natural or artificial test field. On contrary, using CAD environment in such studies, we have the ability to make changes in the test field or rearrange the camera position or change the internal elements of the used camera. This idea save the money and gives a wide range of studying the factors affecting the accuracy in digital close range photogrammetry that may be difficult to be achieved using real test fields.

References

[1] Kraus K., Photogrammetry: Advanced Methods and Applications, Vol. 2, 4th edition, Ferd. DuemmlersVerlag, Bonn, 1997.
[2] Coppola F., LO Brutto M., Midulla P., and VILLA B., "Urban 3-D Models For Planing Of Mobile Telephony Systems", International Archives of Photogrammetryand Remote Sensing. Vol. XXXIII, Part B3. Amsterdam 2000.
[3] Vogtle Th. and Steinle E., "3d Modelling Of Buildings Using Laser Scanning And Spectral Information", International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B3. Amsterdam 2000.
[4] Ebrahim M., "Determination of the Islamic Art Accuracy by Using Digital Digital Close Range Photogrammetry", the ISPRS archive of XIXthcongress, Vol. XXXIII, Amsterdam 2000.
[5] Hottier Ph., "Accuracy of Digital close Range Analytical Restitution : Practical experim-ental and Prediction", Photogra-mmetric Engineering and Remote sensing, 42(3), 1976.
[6] Fraser, C.S., "Film unflatness effects in analytical non-metric photogrammetry", ACSM-ASPRS Annual convention, Vol. 5, 1990.
[7] Hanke K. and Ebrahim M., " A Low Cost 3D-Measurement Tool for Architectural and Archaeo-logical Applications", Interna-tional CIPA Symposium, Goeteborg, Sweden, 1997.

Author Profile

Mostafa Abdel-BaryEbrahim received the B.Sc. and M.Sc. degrees in Civil Engineering from Faculty of Engineering, Assuit University in 1986 and 1992, respectively. During 1995-1998, he stayed in Institute of Geodesy, Innsbruck University, Austria to study the evaluation and application of digital close range photogrammetry for Ph.D. He has been awardedhis Ph.D. degree on 1998. He is now working as full professor at King AbdulAziz University, Kingdom of Saudi Arabia.

Farrag Ali Farrag received the B.Sc. and M.Sc. degrees in Civil Engineering from Faculty of Engineering, Assuit University in 1979 and 1984, respectively. During 1988-1991, he stayed in ITC, Netherlandto study applications of remote sensing for Ph.D. He has been awardedhis Ph.D. degree on 1991. He is now working as full professor at Al-Jouf University, Kingdom of Saudi Arabia.