EVALUATE OF TWO DIFFERENT METHODS IN CLOSE RANGE PHOTOGRAMMETRY FOR DETERMINATION 3-D COORDINATE APPLIED TO VERTICALITY CHECKING

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ABSTRACT

There are many ways to construct object -space coordinates, each is designed for a certain purpose. In this research, a comparison between two different methods, in close range photogrammetry was carried out, in order to find, the more accurate, simpler and more economic method. The accuracy in each method was determined by comparing its coordinates with the coordinates of the test field, which were calculated from the intersection method.

1.INTRODUCTION

Engineering surveyors are often required to monitor the inclination and the direction of tilt of structures. The plum bob and spirit level are considered to be the easiest and most efficient instrument used in most cases. However, when the structure is inaccessible, it is not possible to utilize these methods. For determining the three dimensional coordinates of points, which are difficult or impossible to access, there are many different methods, which can be used for these purposes. This paper presents, discusses and compares between two different methods. The first method, is the pseudo image, it is a different technique for the geodetic coordination of object-space controls in close-range photogrammetry method. The second method is an alternative approach for solving the space intersection problem in close range photogrammetry.

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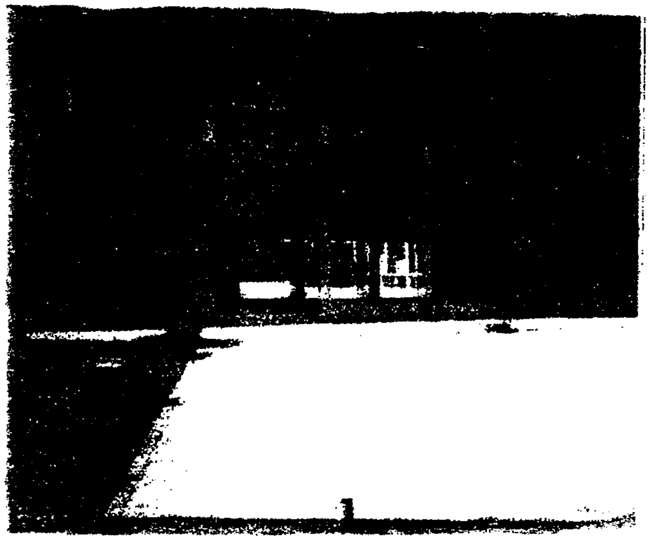
2.TEST FIELD

At the faculty of Engineering Shebin El-Kom, there is one reference point network, this reference point is a vertical plane forming the test wall. The dimensions are 15*11 meters (Fig. 1).



Fig(1) The test field and the reference points network
by using the metric camera UMK10/1318

The wall is constructed for an object distance of the range of about 6 to 25 metros. The reference point network consists of 36-fixed black-and white circular shaped targets (Fig.2). The intersection method by two theodolite stations was used to compute the coordinates of the control and check points, which are needed for the orientation of the photographed object and for evaluation of the accuracy of the two different methods. In this research, the intersection method is used as a comparable method to compare between the results obtained from two different methods (the pseudo image and the proposed technique).
The above mentioned test field, using the intersection method, has been characterized by the following RMS errors: 0.23 mm for the X-axis; o.28 ; o.23 mm for the Y-axis and 0.21 mm for the Z-axis.
In this method two observation stations (A and B) are fastened in the front of the test field. Fig. (2) shows the targets, which are fixed on the vertical wall in the front of the two observation stations (A and B). Line AB was taken as a base line, where horizontal angles between that line and rays to the intersected targets on the test field were measured. One-second theodolite (Theo-10-A) from Zeis Jena was used for the angles measurement. The length of the base line AB was measured by a steel tape with an accuracy of ±0.5mm. The horizontal and vertical angles were measured twice with the theodolite face left and face right with the zero reading being changed each time and the mean values of the measured angles were computed. Rays to the targets were determined using the base line (AB) and the obtained

horizontal angles. The coordinates of all targets of the test field were calculated.

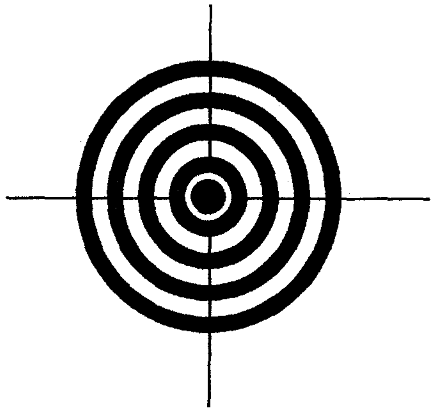


Fig. 2 The Target

3.THE PSEUDO IMAGE METHOD

A different method for the geodetic coordination of object space controls in close - range photogrammetry has been proposed by Abdel Aziz and Karara (1974) . In the pseudo image method the theodolite is used instead of the camera for taking the photograph and also is used instead of the comparator for image coordinate measurements.

The advantages of the pseudo image method are that:

- -One needs only a theodolite for measurements and a simple calculator for data reduction.
- -The resulting accuracy is better than that obtained by using the proposed technique and is comparable with the accuracy of the intersection method.
- -No need for development and processing.
- -No need for a comparator to measure the image coordinates.
- -One can reach the required accuracy for measuring the image coordinates by using small scale.
- -In the pseudo image there is no limitations on the format size, the depth of field and the intensity of light.

The principal of the pseudo image method consists of three successive steps:

a- Recording from two (or more) stations the perspective bundles with a theodolite used as a camera in the test area .

b- Relative orientation of the images and computation of the model coordinates of the points.

c- Scaling the model is necessary if the computed coordinates are to be used as an object-space control for data reduction.

For more detail, the reader is referred to Abdel Aziz and Karara (1974). To verify the pseudo image method, two observation stations (A and B) in front of the test field were used as a theodolite station. The horizontal and vertical directions to all targets from the two theodolite stations (A and B) were observed by one -second theodolite Theo 10- A from Jena). In this work, the test field (Fig.1) consists of 36 points and three different calibrated distances were observed. In this technique, the theodolite images are formed analytically from theodolite measurements. The pseudo - image coordinates in a convergent imaging configuration ($\omega_1 = \omega_2 = 0.0$ & $\kappa_1 = \kappa_2 = 0.0$& $\varphi_1 = \varphi_1 = 42^\circ$) of all targets in the pseudo image plane of the horizontal circle can be calculated as follows :

$$x = C_k \tan(90 - \alpha_0 + \alpha)$$
$$z = C_k \tan\beta / \cos(90 - \alpha_0 + \alpha)$$

where :

α_0 is the horizontal direction of the other station;
x and z are the theodolite image coordinates;
C_k is the camera constant;
β is the vertical direction of the target.

The theodolite observations and the virtual image coordinates are listed in tables1 and 2. The object space coordinates can be obtained with an origin at the perspective center of the left station, the X axis parallel to the given X axis, and the Z axis a vertical line parallel to the plump bob direction at the origin. The object space coordinates can be obtained by using the values of the relative orientation parameters and the exact values of B_X and B_Z. The object space coordinates of the test field targets are listed in table 3.

TABLE (1) THEODOLITE OBSERVATIONS AND VIRTUAL IMAGE COORDINATES AT THE LEFT STATION (A).

α_0 136° 05' 35"			Image coordinate	
Pt. N.o	Horizontal directions (α)	Vertical directions (β)	xl mm	zl mm
1	38° 04' 40"	71° 35' 30"	-14.081	33.610
2	38 16 20	75 29 20	-13.735	26.125
3	38 13 30	82 33 20	-13.819	13.191
4	52 04 55	71 06 50	10.491	34.398
5	52 02 20	75 45 35	10.415	25.516
6	51 52 10	83 07 00	10.116	12.133
7	66 01 30	72 01 10	36.263	34.522
8	66 00 20	76 28 20	36.224	25.589
9	65 54 05	83 27 40	36.019	12.183
10	77 53 05	73 40 15	61.983	34.469
11	77 56 15	77 43 10	62.110	25.625
12	77 39 40	84 20 40	61.444	11.623
13	50 27 40	84 35 20	7.639	9.499
14	49 37 20	85 14 10	6.167	8.350
15	60 29 20	84 48 15	25.668	9.388
16	59 24 30	85 21 50	23.667	8.333
17	24 25 20	52 06 05	-39.736	83.764
18	23 16 25	71 50 30	-42.076	35.583

19	30 23 10	71 26 05	-28.122	34.889
20	44 48 10	70 50 10	-2.252	34.762
21	59 09 20	71 18 05	23.202	34.744
22	72 08 40	72 41 25	48.884	34.690
23	103 01 15	89 02 25	153.562	3.070

TABLE (2) THEODOLITE OBSERVATIONS AND VIRTUAL IMAGE COORDINATES AT THE RIGHT STATION (B).

α_0 145° 26' 05"			Image coordinate	
Pt. N.o	Horizontal directions (α)	Vertical directions (β)	xr mm	zr mm
1	97° 55' 45"	76° 10' 40"	-91.615	33.368
2	98 00 25	97 12 35	-91.865	25.880
3	98 03 05	84 33 30	-92.008	12.945
4	89 11 40	74 08 50	-66.842	34.156
5	89 28 10	78 10 20	-67.539	25.271
6	89 19 40	84 21 45	-67.180	11.892
7	77 41 35	72 23 40	-40.928	34.287
8	77 59 55	76 49 35	-41.552	25.385
9	77 46 30	83 17 55	-41.095	11.939
10	63 57 50	71 17 55	-14.997	34.229
11	64 15 00	75 55 05	-15.508	25.385
12	64 12 10	83 14 10	-15.424	12.001
13	81 04 35	85 11 50	-48.001	9.32
14	78 51 30	85 42 05	-43.323	8.192
15	72 03 00	84 75 25	-29.840	9.209
16	69 51 10	85 28 20	-25.709	8.177
17	105 04 10	62 09 35	-117.644	81.546
18	105 37 05	77 15 40	-119.953	35.306
19	101 56 35	76 35 10	-105.409	34.652
20	93 45 10	74 50 55	-79.026	34.513
21	83 34 30	73 04 35	-53.485	34.506
22	70 52 20	71 38 00	-27.615	34.444
23	126 45 55	89 45 20	-295.957	1.333

TABLE (3) COORDINATES OF THE TARGETS OBTAINED BY USING THE VIRTUAL IMAGE.

Pt NO	Coordinates		
	X	Y	Z
1	-2.1744	15.4421	6.8421
2	-2.1048	15.3243	5.6556
3	-2.1161	15.3127	3.6718
4	1.6242	15.4822	6.9776
5	1.5996	15.3589	5.5709
6	1.5669	15.4897	3.5314
7	5.6246	15.5108	7.0067
8	5.5763	15.3940	5.5911
9	5.5923	15.5262	3.5435
10	9.6403	15.5533	7.0130

11	9.5807	15.4253	5.6047
12	9.5704	15.5760	3.4624
13	1.6436	21.5185	3.6962
14	1.49204	24.1924	3.6719
15	5.5364	21.5695	3.6769
16	5.7388	24.2482	3.6726
17	-6.1065	15.3679	14.5248
18	-6.4688	15.3741	7.1225
19	-4.3564	15.4915	7.0568
20	-0.3521	15.5949	7.0731
21	3.6224	15.6126	7.0765
22	7.6508	15.6509	7.0812
23	4.0901	2.6634	1.7337

4.THE PROPOSED TECHNIQUE

4.1THE THEORETICAL ASPECTS

Rahil [2000]proposed an alternative approach for the problem of the space intersection in close range photogrammetry. When compared with the conventional close-range photogrammetry technique, the proposed method is more accurate ,simpler and economic [18] .

The advantages of this approach are as follows:

-Using single camera instead of stereo metric camera, to obtain stereo pairs, by exposing single photos at the ends of a measured base line.

-Choosing the suitable base-depth ratio, which gives geometric strength;

-There is no geometric problem, when the photographed object lies in one plane;

-The expected accuracy of the object space coordinates is better than that obtained by using the conventional analytical photogrammetric technique;

-Saving the required time for linear measurements and for control points establishments.

The principal of the proposed technique consists of the following steps:

a)Construction of two or more photos of the test area;

b)Relative oriention of the images and computation of the model coordinates of the points;

c) Scaling the model is necessary if computed coordinates are to be used as an object –space control.

In this study, we will be dealing with the symmetric convergent case ($\Phi_L = \Phi_R = \Phi$). For the simplicity and convenience work, photos would be arranged so, that the horizontal fiducial line in each photo stays horizontal while the vertical fiducial line in each photo remains vertical.

By investigating the relative orientation parameters which are required to orient the right photo with respect to the left photo one finds that:

-Two orientation parameters of the two photos are known, having zero values; because:

a) The Z- axes of the two photos, which is parallel to the plumb line are parallel ($\kappa_1 = \kappa_2 = 0.0$).

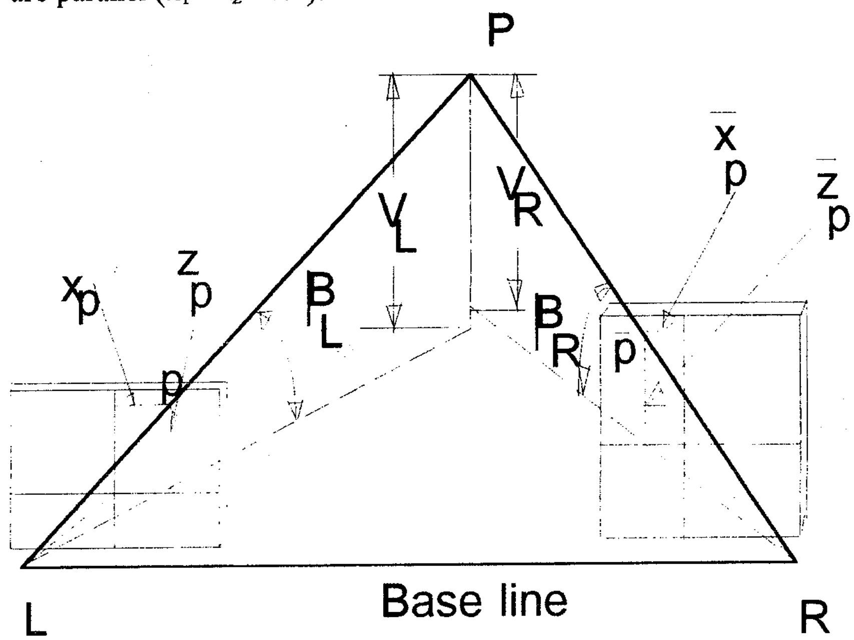


Fig. (3.a) Elevation of points from two horizontal photos.

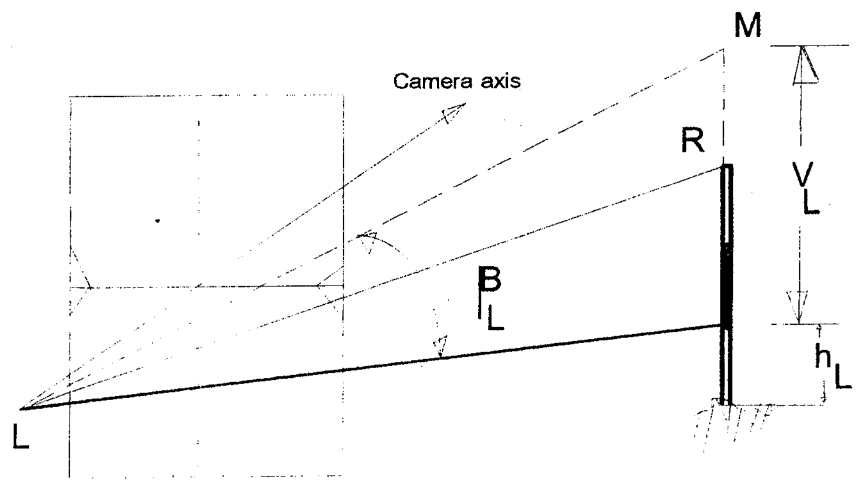


Fig. (3.b) Elevation of points at the left exposure stations.

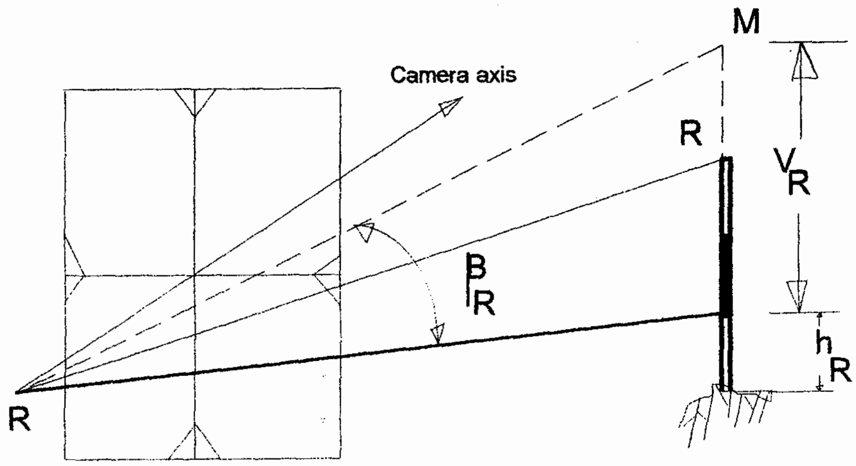


Fig. (3.c) Elevation of points at the right exposure station.

b) Both of the two photo lie on a vertical plane ($\omega_1 = \omega_2 = 0.0$)
The translation element along the Y-direction B_Y has a zero value; because the two exposure stations lie on the X- axis.

The elevation of the two exposure stations (left and right) can be calculated by using the following technique :

The philosophy of this technique is based upon photographing of one or more precise levelling staff or special constructed marker poles, (see Collins and Madge 1981) which are fixed at the appropriate places relative to the two exposures stations.

Care is taken in fixing a leveling staff, such that the base plate is at ground, and the staff should be verticaly ensured. The effect of photographing leveling is illustrated in Fig.(3.a-3.c) . The photo coordinates (x, z) from the center of the photography to the bottom of the staff image are recorded. Consider β_L and β_R being the vertical angles of inclination between the horizontal plane and the ray from the camera to the object point P, on the left and right photos respectively.

Then $$\beta_L = \tan^{-1} [z /(x^2 + c^2)^{0.5}] \qquad (1)$$

And

$$\beta_R = \tan^{-1} [z' / (x'^2 + c^2)^{0.5}] \qquad (2)$$

where:

- x is the measured x-dimension (coordinate) from the center of the photo to the image of the staff at the left station
- z is the measured z-dimension (coordinate) from the center of the photo to the image of the staff at the left station
- x' is the measured x-dimension (coordinate) from the center of the photo to the image of the staff at the right station
- z' is the measured z-dimension (coordinate) from the center of the photo to the image of the staff at the right station

According to Figure. (3.b) and Figure. (3.c), one can determine the difference in elevation between the camera axis at the left and right camera stations (V_L and V_R) respectively. From the photo coordinate of the lower part of the staff (x, z) together with the calculated horizontal distance between the exposure stations and the vertical staff, the difference in elevation (V_L and V_R) between the camera axis (left and right respectively), and the lower edge of the staff graduation, can be calculated using the following equations:

$$V_L = D_L \tan(\beta_L) \quad (3)$$
$$V_R = D_R \tan(\beta_R) \quad (4)$$

Where:

V_L: is the difference in elevation between the left exposure station and the lower edge of the staff graduation

V_R: is the difference in elevation between the right exposure station and the lower edge of the staff graduation

D_L is the horizontal distance from the left camera St. to the levelling staff.

D_R is the horizontal distance from the right camera St. to the levelling staff.

The exposure stations elevation can be obtained using the following equations:

$$E_L = V_L + h \quad (5)$$
$$E_R = V_R + h \quad (6)$$

Where

E_L is the elevation of the exposure station at the left station

E_R is the elevation of the exposure station at the right station

h is the elevation of the lower edge of the staff graduation.

If more than one vertical staff is available, the average value of exposure stations elevation (left and right respectively) can be obtained.

4.3 THE OBJECT SPACE COORDINATE

A point (P) on object is defined in terms of 3-D coordinates, X, Y, Z while the corresponding points in the photos are in terms of their photo-coordinates, x, z for point p on the left photos and x^{-}, z^{-} for point p^{-} on the right photos. Referring to Fig. (4), consider the horizontal distance of a ground point P from the left exposure station, LP= D_L. The horizontal distance of the ground point P from the right exposure station, RP= D_R.

Consider α_p and α_p^{-} being the horizontal angle between the optical axis (CA_L & CA_R) and the ray from the camera to object point P on the left and right photos respectively.

Furthermore, $\alpha_p = \arctan(x/c)$ and $\alpha_p^{-} = \arctan(x^{-}/c)$

$$\delta_L = 90 - \Phi_L \quad \& \quad \delta_R = 90 - \Phi_R$$
$$\theta_L = \delta_L - \alpha_L \quad \& \quad \theta_R = \delta_R - \alpha_R$$
$$\theta_L = 90 - \Phi_L - \alpha_L \quad \& \quad \theta_R = 90 - \Phi_R - \alpha_R$$
$$\theta_M = 180 - (\theta_L + \theta_R)$$

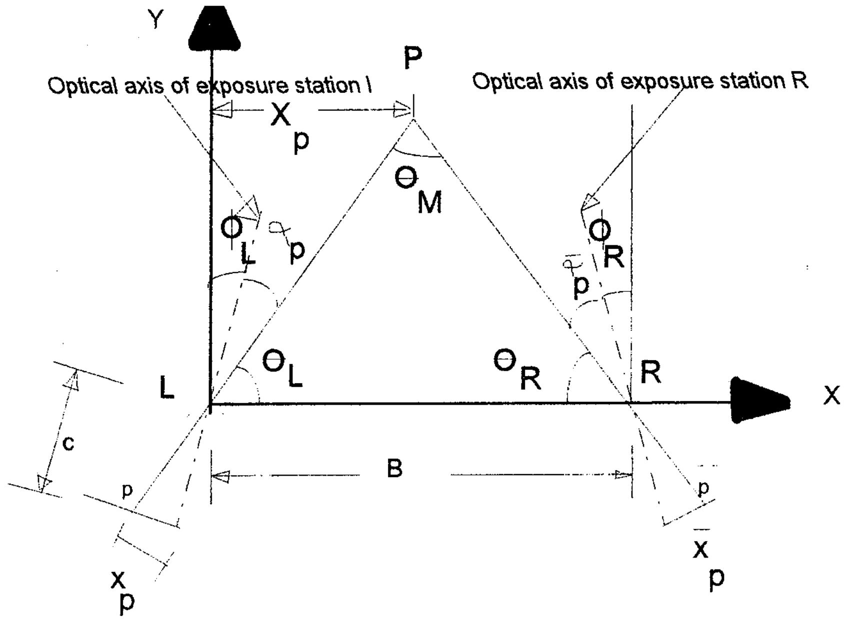


Fig. (4) Horizontal position of points from two horizontaly photos.

Consider θ_L and θ_R being the horizontal angles between the target (P) and the base line at the left and right exposure stations respectively,

$$\theta_L = \Phi_L - \alpha_L \quad \& \quad \theta_R = \Phi_R - \alpha_R$$

Then

$$\theta_M = 180 - (\theta_L + \theta_R)$$

Also, from sine rules in triangle L P R,

$$\frac{D_L}{Sin\theta_R} = \frac{B}{Sin\theta_M} \quad (7)$$

$$i.e.\ D_L = \frac{B\ Sin\theta_R}{Sin\theta_M} \quad (8)$$

$$and\ also\ \frac{D_R}{Sin\theta_L} = \frac{B}{Sin\theta_M} \quad (9)$$

$$i.e.\ D_R = \frac{B\ Sin\theta_L}{Sin\theta_M} \quad (10)$$

These give the object space coordinates:

$$X_P = D_L * COs\ \theta_L \quad (11)$$

$$Y_P = D_L * Sin\ \theta_L \quad (12)$$

$$Z_P = E_{L\ (average)} + D_L * \tan\beta_L \quad (13)$$

4.4 THE DETERMINTION OF THE BASE LINE (B)

The length of the base line can be obtained as follows:

-Determine the ground coordinate of the two ends of the known line (L) by using any assumption value for (B) such as $\bar{B}$

-Compute the ratio (R) between the true length of the known line (L) and the calculated length of the same known line ($\bar{L}$), which was calculated from the ground coordinates.

-Compute the correct value of the base line (B) as follows:

$$\text{The correct value (B)} = \bar{B} * (R) \qquad (15)$$

$$Ratio(R) = \frac{True\ length\ of\ the\ known\ line\ (L)}{Computed\ length\ of\ the\ known\ line\ (\bar{L})} \qquad (14)$$

4.5 CHECK COMPUTATION OF THE OBJECT SPACE COORDINATES

According to figure (4), the object space coordinates can be determined as a check computation using the following equations:

$$X_P = B - (D_R * COs\ \theta_R) \qquad (16)$$

$$Y_P = D_R * Sin\ \theta_R \qquad (17)$$

$$Z_P = E_{R\ (average)} + D_R * tan\beta_R \qquad (18)$$

5. THE EXPERIMENTAL WORK

In this research, a test field has been successfully used for experimental work. The test field was photographed with the metric UMK 10/1318 from Zeis Jena. The elevation view of the test field is shown in figure (1).

Two stereo pairs were so arranged, that they were on the same base and also one base-to object distance ratio is used. The first stereo pair is performed horizontal in a symmetrical convergent imaging with 29° convergent angle, and the second stereo pair is established also horizontal in a symmetrical convergent imaging with 43° convergent angle. In the photography, two precise leveling staff in a vertical position and a subtence bar were used. The leveling staves and the subtence bar are 2 meters long and they were lying in front of the test field. All the photographs were measured with the stereo comparator, Techochart- D from Carl Zeis Jena. The photo coordinates were measured with a coordinates RMS of 5 μm. Image coordinates for each individual fiducial marks of the two photos were measured twice.

6. DATA REDUCTION

In this work, the data reductions have been done with two different analytical approaches to determine the ground coordinates of points of interest: the virtual image method and the suggested approach.

6.1 THE VIRTUAL IMAGE METHOD

In this method, the mathematical photogrammetric models (such as relative and absolute orientations)are applied to theodolite images which are formed analytically from theodolite measurements.

6.2 THE PROPOSED APPROACH

In this approach, no control points have been used. The data reduction procedure consists of:

a) The determination of the horizontal angles (α_L and α_R) between the optical axis and the ray from the camera to object point P, on the left and right photo respectively;
b) Determination of the vertical angles (β_L and β_R) between the horizontal plane and the ray from the camera to object point P, on the left and right photo respectively;
c) Computation of the horizontal angles (θ_L and θ_R) between the object point P and the base line at the left and right exposure stations respectively;
d) Calculation of the horizontal distances (D_L and D_R) between the object point P, and the left and right exposure station respectively ,and
e) Computation of the coordinates (X, Y and Z) of points of interest.

7.DISCUSSION OF THE RESULTS

The coordinates which are computed from the virtual image method and the suggested approach are compared by the RMS- values of the coordinate differences in the check points. The comparison of results between the suggested technique and the virtual image method is shown in table (1) in terms of X, Y, Z coordinates differences as well as their essentially statistical parameters (RMS)

From table(4), it can be seen that, the virtual image method gives more accurate results than the suggested approach, since the former yields a smaller RMS than the latter.

Regarding to the comparison between the virtual image method and the suggested approach, the following remarks can be stated .

The photographs contain a wealth of interpretable information; thus one can say that, the photogrammetric archives of the building assume an "intellectual conservation" of the building in its "effective shape", at a precise moment in its history, but The virtual image method takes no account of perspective but simply shows details and parts geometrically.

The proposed technique provides information for a very large number of points at a short time. This advantage is very essential, in case of structures, having rapid movements or deformations. This is the case, since the virtual image method takes more time to collect the necessary measurements at a certain time, during which the different monitoring defined targets could have gained a quite movement, not coinciding with the measurement instance.

The virtual image method provide information on movement at only a little number of targets on the object.

By using the proposed technique, a permanent record can be taken of a very large number of monitoring target points.

TABLE (4): STATISTICS OF OBTAINED COORDINATE DIFFERENCES FOR THE SECOND MODEL BETWEEN THE CONVENTIONAL AND THE PROPOSED TECHNIQUES AT THE USE CHECK POINTS (IN mm)

Pt. No	THE PROPOSED TECHNIQUE			the pseudo image		
	ΔX	ΔY	ΔZ	ΔX	ΔY	ΔZ
1	1.30	1.54	1.26	0.8	1.4	0.7
2	1.38	1.22	1.40	0.8	1.4	0.6
3	1.48	1. 14	1.29	0.8	1.4	0.8
4	1.18	1.17	1.08	0.7	1.4	0.5
5	1.24	1.21	1.36	0.7	1.4	0.7
6	1.27	1. 2	1.39	0.7	1.4	0.6
7	1.14	1.14	1.51	0.5	1.4	0.4
8	1.98	1.6	1.16	0.5	1.4	0.7
9	1.57	1.16	1.18	0.5	1.4	0.8
10	1.28	1.19	1.14	0.9	1.4	0.6
11	1.32	1.27	1.30	0.8	1.4	0.8
12	1.14	1.21	1.36	0.9	1.4	0.7
13	1.54	1.58	1.17	0.6	1.76	0.8
14	1.04	1.41	1.12	0.6	1.92	0.8
15	1.08	1.42	1.23	0.5	1.28	0.6
16	1.86	1.74	1.58	0.5	1.4	0.6
17	0.99	1.28	1.26	0.6	1.4	0.5
18	1.38	1.42	1.38	0.6	1.4	0.5
19	1.39	1.46	1.32	0.6	1.50	0.4
20	1.48	1.44	1.18	0.6	1.4	0.5
21	1.48	1.44	1.18	0.6	1.5	0.5
22	1.48	1.44	1.18	0.7	1.92	0.6
23	1.48	1.44	1.18	0.6	1.82	0.7
RMS2	1.36	1.35	1.27	0.570	1.57	0.378

8.CONCLUSIONS

The previous illustration for the virtual image method and the proposed technique shows that:

In matter of cost, the proposed technique permitted substantial savings in time and effort compared with the pseudo image.

The proposed technique has a large capacity and quite good accuracy. It is preferable to use the proposed technique when a great number of targets to be measured in a short space of time.

The pseudo image method can be used only when a little number of points has to be measured.

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تقييم طريقتين مختلفتين في التصوير عن قرب لتعيين الأبعاد الثلاثية كتطبيق للتحقق من الرأسية

فى هذا البحث تم مناقشة طريقتين مختلفتين كما تم أيضا المقارنة بين هاتين الطريقتين فى التصوير عن قرب (Close Range Photogrammetry) بهدف تحديد أى الطريقتين الأفضل من ناحية الدقة والأسهل فى التنفيذ والأكثر إقتصادية . وقد تمت المفاضلة من خلال مقارنة الإحداثيات فىكلا الطريقتين بالإحداثيات المعينة فى حقل الإختبار بالتقاطع الأمامى .وقد إقترحت إحدى هاتين الطريقتين فى هذا البحث أما الطريقة الثانية فتعرف بالصور الزائفة.

وقد تم فى هذا البحث التوصل الى النتائج الآتية :

- تعد الطريقة المقترحة فى هذا البحث الأقل فى التكلفة وفى الوقت والمجهود اللازم للتنفيذ بالمقارنة بطريقة الصور الزائفة.
- الطريقة المقترحة تؤدى إلى نتائج جيدة ويفضل إستخدامها فى حالة النقط الكثيرة والوقت القصير .
- يفضل إستخدام طريقة الصور الزائفة فى حالة النقط القليلة والوقت الطويل .