SIMULATION MODEL FOR THE ASSESSMENT OF DIRECT AND INDIRECT GEOREFERENCING TECHNIQUES IN ANALYTICAL PHOTOGRAMMETRY

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ABSTRACT

This paper compares between the direct and indirect georeferencing techniques in Photogrammetry bases on a simulation model. A flight plan is designed which consists of three strips with nine overlapped images for each strip by a (Canon 500D) digital camera with a resolution of 15 Mega Pixels.

The triangulation computations are carried out by using (ERDAS LPS) software, and the direct measurements are taken directly on the simulated model to substitute using GPS/INS in real case. Two computational tests have been implemented to evaluate the positional accuracy for the whole model and the Root Mean Square Error (RMSE) relating to (30) check points show that the indirect georeferencing is more accurate than the direct georeferencing. The computed RMSE of indirect georeferencing technique are (±0.0686 m., ± 0.0402 m.±, 0.3583 m.) in (X, Y, Z) respectively, while by direct georeferencing technique are (±0.1274 m., ± 0.1220 m., ± 0.5132 m.) in (X, Y, Z) respectively. Finally, the aim of this paper can be summarized as investigating the possibilities of using a simulation model to evaluate the applicability of direct and indirect georeferencing and analyzing the accuracy of both techniques.

الخلاصـة

يقارن البحث بين تقنيتي الإرجاع الأرضي (georeferencing) المباشر وغير المباشر في المسح التصويري اعتمادا على موديل محاكاة، حيث صممت خطة الطيران لتضم ثلاثة خطوط طيران بواقع تسع صور في كل خط وبتداخل أمامي وجانبي بين الصور الملتقطة باستخدام كاميرا رقمية نوع (Canon 500D) ذات دقة تمييز صورية (15 Mega Pixels) . إن حسابات التثليث أجريت باستخدام برنامج (ERDAS LPS) في حين أخذت القياسات على نموذج المحاكاة مباشرة للتعويض عن استخدام (GPS/INS) في الحالة الواقعية. لتثمين الدقة الموقعية لكل النموذج تم حساب جذر معدل مربع الخطأ (RMSE) اعتمادا على (٣٠) نقطة تدقيق وبتطبيق اختبارين حسابيين ، وجد أن تقنية الإرجاع الأرضي غير المباشر أدق من تقنية الإرجاع الأرضي المباشر. لأن نتائج جذر معدل مربع الخطأ في التقنية غير المباشرة كانت (±0.0686 m., ± 0.0402 m. , ± 0.3583 m.) في (X, Y, Z) على التوالي ، بينما كانت النتائج في التقنية المباشرة (±0.1274 m., ± 0.1220 m., ± 0.5132 m.) في (X, Y, Z) على التوالي أيضاً.
وبذلك يتلخص الهدف من البحث في إمكانية استخدام نموذج المحاكاة لتقييم تقنيتي الإرجاع الأرضي المباشر وغير المباشر عن طريق حساب جذر معدل مربع الخطأ(RMSE) بكلا التقنيتين ومقارنة دقتيهما.

KEY WORDS: Bundle Adjustment, Direct Georeferencing (DG), GPS/ INS, Indirect Georeferencing.

1. INTRODUCTION

Photogrammetry may involve rigorous mathematical calculations of ground coordinates by computer [Wolf, 2000], these computations require georeferencing: which occupy scaling, rotating, and translating processes to match a particular size of image with a position on ground area [Wing, 2005].

To carry out that, two quantities must be known: the coordinates of the camera lens perspective centers (Xo, Yo, Zo) "the position of exposure point" and the orientation elements (ω, φ, κ) of the image "the rotation matrix", as shown in **Fig.1**

Where (Xo, Yo, Zo) and (ω, φ, κ) are called the Exterior Orientation Parameters (EOP).

The georeferencing methods can perform by two different ways to derive (EOP) of an image:

- Indirect georeferencing
- Direct georeferencing

It is obvious that the camera orientation is a basic geometric problem that leads to determine the (EOP).

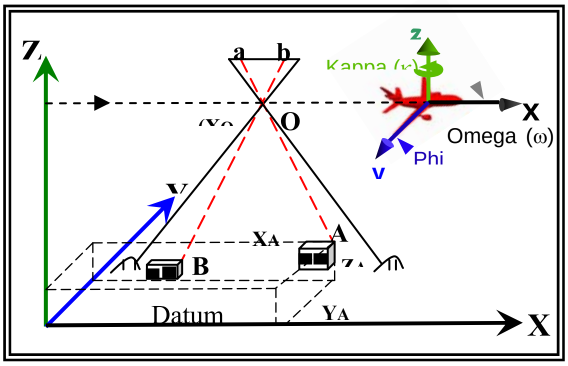

Fig. 1: the Exterior Orientation Parameters[Salama, 1980]

2. INDIRECT GEOREFERENCING

The **indirect** georeferencing approach uses conventional Aerial Triangulation (AT) that used a block of images with well-distributed sufficient number of (GCPs) for estimating the (EOP) and applying geometric constraint such as collinearity equations between the image points and object points. [Ebadi, 2006]

The Aerial triangulation is applied to the process of determining (X, Y, Z) ground coordinates of individual points based on measurements from photos, as shown in **Fig.2**

When the Image orientation is known, it is the key elements in any photogrammetric project to determine the three-dimensional coordinates of all points from images.

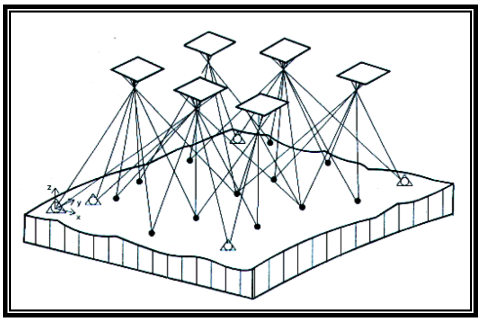

Fig. 2: Aerial Block Triangulation

3. DIRECT GEOREFERENCING

For **direct** georeferencing, EOP of an image can be determined directly by Differential Global Position System (DGPS) integrated with an Inertial Navigation System (INS).This allows the mapping to move from traditional aerial triangulation (AT) to direct georeferencing (DG) techniques.

Direct georeferencing is certainly one of the most significant applications of new technology in the mapping area. This approach combines the technologies of airborne GPS for determining the position of the plane and the camera. In addition, the velocity, with the abilities of (INS) for provides attitude, or orientation of the sensor with respect to the ground. Thus, the system that used in direct georeferencing contains the following:-

- Differential Global Position System Receiver (DGPS).
- Inertial Navigation System (INS).
- Camera.

As illustrated in **Fig. 3**

Fig. 3: Flight System (clockwise from upper left: aircraft, sensor head with camera and INS, data

logger with display and keyboard, data logger) [David, 2001]

4. COMPARISON BETWEEN DIRECT & INDIRECT GEOREFERENCING

As presented in earlier sections, the indirect georeferencing approach uses (AT) requires GCPs. When the availability of ground control points is in question, such as within forests, snow-covered grounds, desert, or along a coast line, the ability to resolve the EOP indirectly is limited. [Wing, 2005]

Also the time consuming ground control points have been reduced when using a block adjustment assisted by relative kinematics GPS derived coordinates of projection center.

In addition, some projects only require a single strip or single photo orientation. For instance, in the case where there are an existing Digital Elevation Models (DEM), the use of traditional AT to determine the EOP is unpractical because it requires excessive GCPs and additional overlapping photos.

Hence in many applications DG georeferencing is either the only practical solution, or the most cost effective solution [Schwarz and El- Sheimy, 2004].

The DG provides substantial benefits over AT. However, the accuracy achieved when using DG is limited by the accuracy achievable by DGPS, INS, and any remaining residual camera calibration error, which is not sufficient for some large scale mapping applications. At the same time, the stable geometry provided by direct EOP can reduce the number of required GCPs and tie points to a minimum.

5. EXPERIMENTAL WORK

To evaluate direct and indirect georeferencing, a simulation model is used to investigate the possibilities, then evaluating the accuracy of both techniques by analyzing the Root Mean Square Error (RMSE). The experiment consists of the following steps:-

- Establishing a lab simulation model.
- Preparing the suitable flight plan.
- Manufacturing a metal structure of flight plan.
- Establish and measure control and check points.
- Photo exposure stage.
- Block triangulation by ERDAS LPS 9.2.
- Comparison between the results of RMSE for the check points.

5-1. Establishing a lab Simulation Model

Building a model that used in the practical experience, which is an urban area, contains structures and features, varying in height like buildings, trees and river.

This is designed within a scale of (1/1000) with the dimensions of (156.5 cm. * 115 cm.) as shown in **Fig. 4**

Fig. 4: the simulation model

5-2. Prepared Flight Plan

The flight plan was designed on a scale of 1/25000, overlap 65%, and side lap 35%. After the transformation of the model values to the actual values in meters (m.), the air base become (B =140 m.), and spacing between adjacent flight lines (W = 390 m.). The simulated covered area dimensions are (1565*1150) m., which results in a block that contains three flight lines, and each one contains **nine** photos. The plan of flight is shown in **Fig. 5**

5-3. Manufacturing a Metal Structure for the Simulation Flight Plan

A metal structure is designed according to the flight plan to expose the photos.

The structure consists of an iron table with dimensions (120 * 160 cm.) and height (120 cm.) and equipped with iron carriers moveable on cushions fixed with screws to the table. This movable carrier is for the purpose of control the required flying height as shown in **Fig.6**. This designed metal stand can accommodate and modified for different flight plans.

The adjacent flight paths positions were determined on the cushion with a space of (39 cm.) according to the designed (W) measurement and exposure stations established on the moveable carriers every (14 cm.) according to the designed air base (B) measurement.

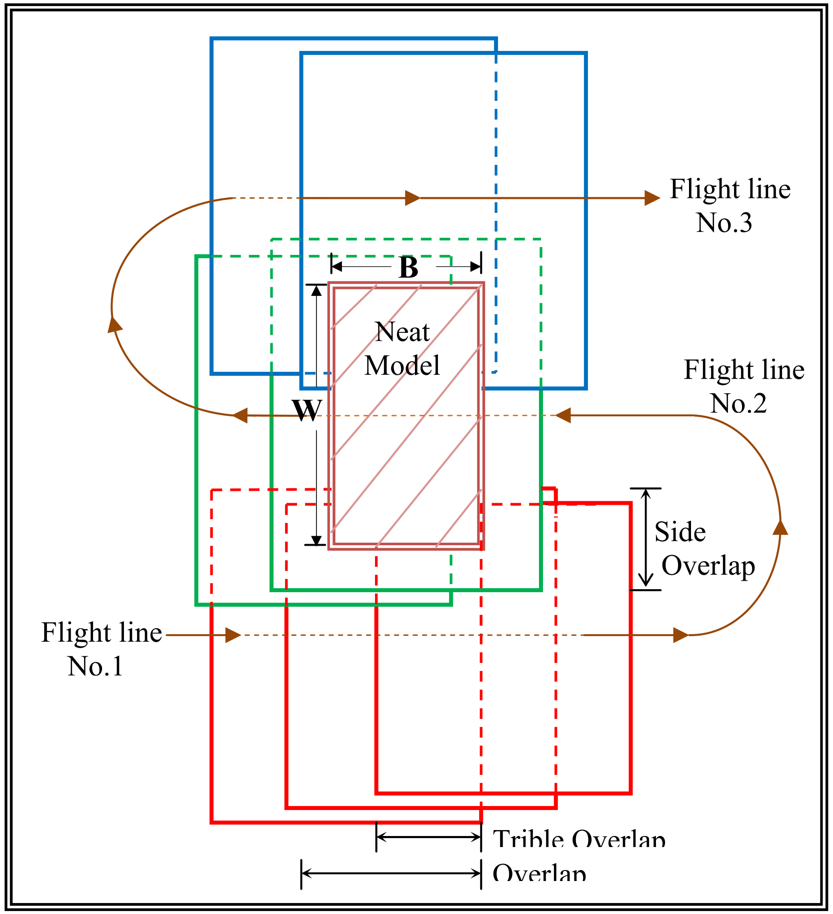

Fig. 5: details of flight plan [Wolf, 2000]

Fig. 6: metal structure of flight plan

5-4. Measured Control Points

The selection of points, which are suited to represent the ground control and check points need a careful procedure. Several artificial points were fixed to represent the full ground control points. The coordinates are measured by utilizing the sliding ruler in the metal framework as shown in **Fig. 7** and **Fig. 8.** The origin of the coordinate system was chosen at the lower left corner of the model, and the x-axis represents the edge of the horizontal model and the y-axis represents the vertical edge of the model while the z axis represents the direction of the plumb line. The measurement results listed in the **Tables (1) and (2)**.

Fig. 7: measurement of points coordinates

Fig. 8: fixing the GCPs coordinates

Table 1: the control points coordinate

No	Point ID	X (m.)	Y (m.)	Z (m.)
١	2	406.000	281.900	87.000
٢	11	737.600	384.800	100.900
٣	29	1219.000	147.500	110.500
٤	56	892.000	1029.000	92.000
٥	69	1307.000	590.000	87.800
٦	78	1431.000	931.400	92.000
٧	110	511.000	853.000	92.000
٨	112	410.000	525.000	92.000

Table 2: the coordinate of thirty checkpoints

No	Point ID	X (m.)	Y (m.)	Z (m.)
١	57	893.200	750.300	96.000
٢	61	946.200	712.500	96.200
٣	62	1057.900	601.600	96.700
٤	3	449.000	140.800	91.200
٥	70	1292.200	632.500	89.200
٦	71	1197.500	604.000	96.100
٧	43	406.800	868.400	82.600
٨	91	1372.500	206.600	88.500
٩	92	680.000	553.700	129.700
١٠	95	444.000	335.600	90.700
١١	98	1058.000	553.000	97.200
١٢	73	585.800	217.000	92.000
١٣	104	1198.600	549.500	94.700
١٤	106	459.100	281.100	90.200
١٥	107	603.000	495.500	115.600
١٦	108	444.000	413.000	91.900
١٧	94	1008.200	130.500	113.200
١٨	96	1090.900	136.200	111.300
١٩	109	1193.400	226.000	112.500
٢٠	50	738.000	769.400	98.000
٢١	111	567.100	873.200	89.500
٢٢	20	978.800	75.700	88.500
٢٣	116	449.100	191.000	94.100
٢٤	117	449.000	174.500	93.400
٢٥	118	448.800	169.300	93.200
٢٦	119	496.900	190.700	93.700
٢٧	27	651.200	671.600	99.200
٢٨	35	651.400	481.400	101.500
٢٩	36	548.000	464.200	97.200
٣٠	93	460.800	909.000	82.700

The distribution of the full ground control points, checkpoints, and photos in the simulated block is shown in **Fig. 9.**

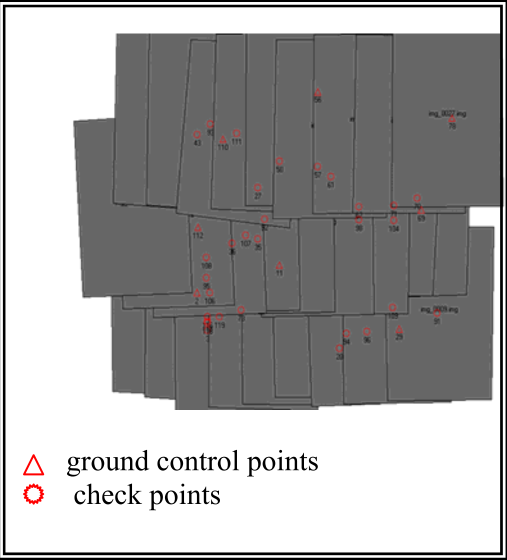

Fig. 9: distribution of ground control points and checkpoints in the simulated aerial block

5-5. Photo Exposure

Exposure was done by a digital camera of type (Cannon EOS 500D EF-S 18-55 mm)) as shown in **Fig. 10.** The pre-calibration of the camera was done by using Photo Modeler software; **Table 3** illustrates the calibration results.

The results according to the designed flight plan were twenty-seven photos which are illustrated in **Fig. 11.**

Table 3: the camera calibration report

Camera Parameter	Value (mm.)
Focal Length	26.075762
Xp - principal point x	11.278399
Yp - principal point y	7.565733
Fw - format width	22.590848
Fh - format height	15.0622
K1 - radial distortion 1	1.584e-004
K2 - radial distortion 2	-2.480e-006
P1 - decentering distortion 1	4.339e-006
P2 - decentering distortion 2	-3.129e-005
Pixel size	0.00475
Principal point shift xo	-0.1284
Principal point shift yo	-0.1157

5-6. Block Triangulation by ERDAS-LPS

The block triangulation computations were done by using ERDAS LPS 9.2. The direct georeferencing has done without the need for ground control points (the exterior orientation parameters supposed to be known) as illustrated in **Table 4** from the direct measurements on simulated model, substitution there from the GPS and INS measurements.

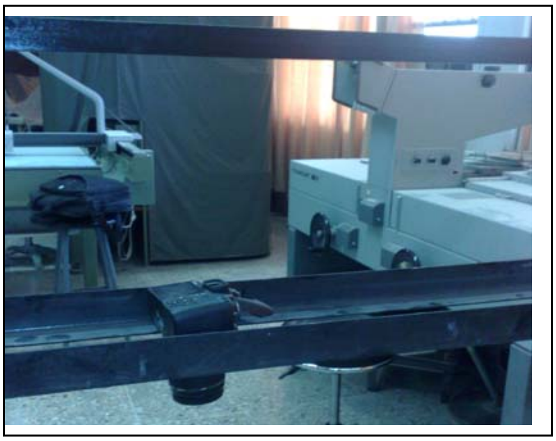

Fig. 10: photos exposure

Fig. 11: the simulated aerial block

The results of adjusted Aerial Block by direct and indirect georeferencing and their residuals are listed in the following **Tables 4 to 8**

Table 4: the fixed exterior orientation parameter

Strip No.	Image ID	Xo (m.)	Yo (m.)	Zo (m.)	Omega (degree)	Phi (degree)	Kappa (degree)
Strip 1	1	181.700	174.200	845.400	4.103	-6.999	-89.85
	2	333.000	166.000	857.300	3.265	-5.950	-91.043
	3	481.000	155.500	859.600	1.305	-3.776	-89.832
	4	630.200	156.600	864.300	1.846	-2.948	-90.330
	5	779.200	161.500	867.100	2.580	-1.804	-90.028
	6	929.600	168.700	868.300	3.898	-0.134	-89.781
	7	1088.400	165.400	862.700	2.190	1.273	-88.528
	8	244.0٠٠	166.100	862.600	2.489	2.419	-90.285
	9	1391.800	152.300	844.100	3.679	1.111	-89.808
Strip 2	10	1384.400	563.500	852.700	2.229	7.258	88.544
	11	1240.600	565.100	861.700	2.282	6.115	87.162
	12	1084.600	547.500	870.500	-0.914	3.066	88.962
	13	926.000	553.600	875.200	-1.612	2.159	90.311
	14	764.700	558.800	874.500	-1.387	1.882	90.280
	15	613.700	568.300	872.900	-1.586	1.315	90.959
	16	462.800	563.700	870.200	-2.141	0.688	91.775
	17	299.300	574.100	857.200	-1.032	-1.628	92.485
	18	135.100	585.800	843.600	0.924	-1.364	92.950
Strip 3	19	192.600	981.100	839.300	-3.079	-7.188	-90.826
	20	337.300	978.400	848.100	-3.168	-6.328	-90.479
	21	498.000	958.000	853.600	-4.582	-5.128	-94.526
	22	642.900	980.000	855.300	-3.867	-3.282	-90.932
	23	792.200	983.200	858.500	-2.826	-1.942	-89.649
	24	944.400	969.300	855.100	-4.746	0.622	-89.738
	25	1100.200	968.300	853.100	-3.322	0.625	-89.297
	26	1266.000	963.900	845.800	-3.263	0.618	-90.367
	27	1420.500	961.800	840.100	-1.555	0.808	-89.995

Table 5: the adjusted coordinate of checkpoints by direct georeferencing and their residuals

No	Point ID	X (m.)	Y (m.)	Z (m.)	Vx (m.)	Vy (m.)	Vz (m.)
١	3	449.040	140.885	90.781	0.040	0.085	-0.419
٢	20	978.924	75.791	88.646	0.124	0.091	0.146
٣	43	406.891	868.500	83.593	0.091	0.099	0.993
٤	50	738.031	769.541	99.058	0.031	0.141	1.058
٥	57	893.296	750.344	96.918	0.096	0.044	0.918
٦	61	946.238	712.583	97.008	0.038	0.083	0.808
٧	62	1057.954	601.742	97.239	0.055	0.142	0.539
٨	70	1292.315	632.637	89.500	0.115	0.137	0.300
٩	71	1197.638	604.086	96.414	0.138	0.086	0.314
١٠	91	1372.653	206.691	88.214	0.153	0.091	-0.286
١١	92	680.030	553.918	130.131	0.030	0.218	0.431
١٢	95	444.100	335.769	90.631	0.101	0.169	-0.069
١٣	98	1058.326	553.117	97.680	0.326	0.117	0.480
١٤	73	585.849	217.208	92.026	0.049	0.208	0.026
١٥	104	1198.704	549.585	94.966	0.104	0.085	0.266
١٦	106	459.279	281.139	90.291	0.179	0.039	0.091
١٧	107	603.069	495.635	115.721	0.069	0.135	0.121
١٨	108	444.179	413.241	91.900	0.179	0.241	0.0
١٩	94	1008.359	130.644	113.469	0.159	0.144	0.269
٢٠	96	1091.066	136.321	111.654	0.166	0.121	0.354
٢١	109	1193.522	226.047	112.593	0.122	0.047	0.093
٢٢	111	567.216	873.301	90.641	0.116	0.101	1.141
٢٣	116	449.229	191.037	93.785	0.129	0.037	-0.315
٢٤	117	449.061	174.546	93.094	0.061	0.046	-0.306
٢٥	118	448.953	169.347	92.941	0.153	0.047	-0.259
٢٦	119	496.921	190.808	93.747	0.021	0.108	0.047
٢٧	27	651.177	671.604	99.702	-0.023	0.004	0.502
٢٨	35	651.544	481.612	101.919	0.144	0.212	0.419
٢٩	36	548.167	464.208	97.777	0.167	0.008	0.577
٣٠	93	460.931	909.101	83.405	0.131	0.101	0.705

Table 6: adjusted exterior orientation parameters by indirect georeferencing

Strip No.	Image ID	δ Xo (m.)	δ Yo (m.)	δ Zo (m.)	δ Omega (degree)	δ phi (degree)	δ kappa (degree)
Strip 1	1	3.025	3.037	1.049	0.2238	0.2223	0.0455
	2	1.571	2.858	0.774	0.2128	0.1158	0.0253
	3	1.473	2.802	0.744	0.2095	0.1061	0.0207
	4	1.425	2.858	0.858	0.2131	0.1030	0.0215
	5	1.411	2.470	0.757	0.1831	0.1009	0.0195
	6	1.797	2.369	0.792	0.1753	0.1290	0.0187
	7	1.892	2.325	0.897	0.1740	0.1377	0.0188
	8	3.178	2.885	1.316	0.2169	0.2403	0.0335
	9	6.990	6.704	3.686	0.5228	0.5109	0.1255
Strip 2	10	1.963	2.853	0.651	0.2146	0.1470	0.0303
	11	1.714	2.450	0.528	0.1834	0.1258	0.0189
	12	1.497	2.316	0.440	0.1713	0.1083	0.0136
	13	1.387	2.416	0.497	0.1777	0.0999	0.0136
	14	1.192	2.396	0.602	0.1762	0.0864	0.0135
	15	1.187	2.427	0.737	0.1783	0.0860	0.0147
	16	1.561	2.485	0.873	0.1820	0.1136	0.0184
	17	2.529	2.533	1.131	0.1869	0.1879	0.0260
	18	4.715	3.336	1.628	0.2422	0.3485	0.0520
Strip 3	19	3.817	3.862	2.635	0.2848	0.2726	0.0745
	20	1.937	3.102	2.374	0.2331	0.1414	0.0355
	21	1.608	2.830	2.102	0.2138	0.1171	0.0254
	22	1.746	2.902	2.041	0.2191	0.1247	0.0280
	23	2.201	3.037	1.988	0.2288	0.1587	0.0286
	24	1.484	2.755	1.759	0.2086	0.1053	0.0227
	25	1.728	2.865	1.641	0.2165	0.1238	0.0238
	26	1.963	2.857	1.500	0.2164	0.1424	0.0290
	27	2.771	3.084	1.469	0.2313	0.2034	0.0419

Table 7: The accuracy of exterior orientation parameters by indirect georeferencing

Strip No.	Image ID	Xo (m.)	Yo (m.)	Zo (m.)	Omega (degree)	Phi (degree)	Kappa (degree)
Strip 1	1	181.638	174.122	845.292	4.1006	-6.9966	-89.8390
	2	332.908	165.915	857.134	3.2626	-5.9478	-91.0320
	3	480.893	155.419	859.329	1.3023	-3.7737	-89.8215
	4	630.116	156.464	864.103	1.8437	-2.9456	-90.3197
	5	779.122	161.350	866.998	2.5779	-1.8013	-90.0177
	6	929.492	168.621	868.117	3.8957	-0.1312	-89.7701
	7	1088.292	165.262	862.547	2.1875	1.2701	-88.5177
	8	1243.873	165.912	862.415	2.4869	2.4160	-90.2747
	9	1391.655	152.189	843.998	3.6766	1.1089	-89.7977
Strip 2	10	1384.269	563.491	852.515	2.2266	7.2552	88.5336
	11	1240.484	564.964	861.550	2.2794	6.1121	87.1519
	12	1084.503	547.404	870.387	-0.9112	3.0632	88.9512
	13	925.915	553.503	875.039	-1.6092	2.1561	90.3005
	14	764.628	558.702	874.327	-1.3849	1.8792	90.2692
	15	613.639	568.160	872.796	-1.5831	1.3126	90.9482
	16	462.691	563.619	870.052	-2.1387	0.6856	91.7646
	17	299.151	573.974	857.022	-1.0297	-1.6259	92.4746
	18	134.984	585.654	843.450	0.9218	-1.3613	92.9396
Strip 3	19	192.484	981.014	839.151	-3.0764	-7.1858	-90.8157
	20	337.163	978.273	847.972	-3.1653	-6.3260	-90.4688
	21	497.944	957.907	853.492	-4.5799	-5.1259	-94.5155
	22	642.839	979.945	855.136	-3.8643	-3.2795	-90.9214
	23	792.111	983.090	858.303	-2.8240	-1.9398	-89.6385
	24	944.336	969.196	855.103	-4.7435	0.6198	-89.7276
	25	1100.176	968.212	852.948	-3.3197	0.6224	-89.2870
	26	1265.893	963.761	845.603	-3.2609	0.6160	-90.3565
	27	192.484	981.014	839.151	-3.0764	-7.1858	-90.8157

Table 8: the adjusted coordinates of the check points and their residuals by the indirect georeferencing

No	Point ID	X (m.)	Y (m.)	Z (m.)	Vx (m.)	Vy (m.)	Vz (m.)
١	3	448.914	140.784	90.785	0.086	-0.016	-0.415
٢	20	978.846	75.635	88.403	0.046	-0.065	-0.097
٣	43	406.811	868.390	83.189	0.011	-0.006	0.589
٤	50	738.000	769.406	98.742	0.000	0.006	0.742
٥	57	893.274	750.282	96.717	0.074	-0.018	0.717
٦	61	946.219	712.499	96.835	0.019	-0.001	0.635
٧	62	1057.945	601.669	97.154	0.045	0.069	0.454
٨	70	1292.296	632.538	89.303	0.096	0.038	0.103
٩	71	1197.608	604.003	96.270	0.108	0.003	0.170
١٠	91	1372.539	206.570	88.176	0.039	-0.031	-0.324
١١	92	680.010	553.717	130.072	0.010	0.017	0.372
١٢	95	443.955	335.613	90.568	-0.045	0.013	-0.132
١٣	98	1058.226	553.041	97.457	0.226	0.041	0.257
١٤	73	585.728	217.044	91.923	-0.072	0.044	-0.077
١٥	104	1198.634	549.489	94.930	0.034	-0.011	0.230
١٦	106	459.133	281.091	89.969	0.033	-0.009	-0.231
١٧	107	602.940	495.451	115.596	-0.060	-0.049	-0.004
١٨	108	444.034	413.074	91.824	0.034	0.074	-0.076
١٩	94	1008.273	130.499	113.239	0.073	-0.001	0.039
٢٠	96	1090.979	136.188	111.335	0.079	-0.012	0.035
٢١	109	1193.418	225.910	112.415	0.018	-0.090	-0.085
٢٢	111	567.165	873.190	90.133	0.065	-0.010	0.633
٢٣	116	449.094	190.925	93.784	-0.006	-0.075	-0.316
٢٤	117	448.929	174.437	93.094	-0.071	-0.063	-0.306
٢٥	118	448.822	169.240	92.941	0.022	-0.061	-0.259
٢٦	119	496.801	190.682	93.650	-0.098	-0.018	-0.050
٢٧	27	651.150	671.614	99.646	-0.050	0.014	0.446
٢٨	35	651.411	481.426	101.815	0.011	0.026	0.315
٢٩	36	548.035	464.128	97.369	0.035	-0.032	0.169
٣٠	93	460.825	909.023	83.104	0.025	0.023	0.404

Table 9: comparison between the RMSE of check points

Ground Coordinate	RMSE by Indirect Georeferencing	MSE by Direct Georeferencing
X	±0.0686	±0.1274
Y	±0.0402	±0.1220
Z	±0.3583	±0.5132

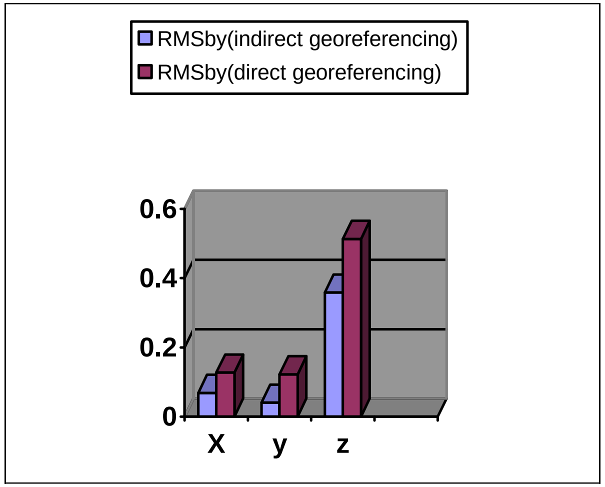

Fig. 12: the chart represented the statistical test

6- RESULTS DISCUSSION

By using ERDAS LPS and applying the direct and indirect georeferencing, the block triangulation leads to compute the coordinates of all points, which are tie points, check points, and other unknown points.

Then by computing the RMSE of each technique, the comparison results will be obvious that the indirect georeferencing gives a better positional accuracy when compared to the direct georeferencing technique as expected.

Table 9 represents the results that obtained from block triangulation in the two procedures. **Fig 12** explains the results from the statistical test.

7- CONCLUSION

From the experimental results obtained in this research the following conclusions are:-

1. The indirect georeferencing is more accurate than the direct georeferencing technique. The computed RMSE of indirect georeferencing are (±0.0686 m., ± 0.0402 m.±, 0.3583 m.) in (X, Y, Z) respectively, while by direct georeferencing are (±0.1274 m., ± 0.1220 m., ± 0.5132 m.) in (X, Y, Z) respectively.

2. The direct georeferencing gives an acceptable accuracy which is suitable for many engineering applications, like real time mapping and in the natural hazard conditions.

3. Simultaneous bundle adjustment using ERDAS LPS has sufficient accuracy level for large-scale mapping. Automatic tie point generation using exterior orientation parameters produced by GPS made dense and high accurate tie points and the block geometry were noticed to be better.

4. Direct georeferencing gives the exterior orientation parameters, projection center coordinates and attitude data, as the result of navigation process with GPS and INS observations without using control points in the navigation solution for airborne imagery and that will save the cost, time and efforts.

5. The Base/Height ratio of 0.25 is found to be sufficient when using digital cameras.

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9- LIST OF ABBREVIATION

AT: Aerial Triangulation.

B: the air base

DEM: Digital Elevation Models

DG: Direct Georeferencing.

DGPS: Differential Global Position System.

E.O.P: Exterior orientation Parameter.

GCPs: Ground control points.

INS: Inertial navigation system.

RMSE: Root mean square error