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Accuracy Assessment of Stonex X-300 Laser Scanner Cameras

Luma Khalid Jasim
College Of Engineering, University of Baghdad
E-mail:j.lumakhalid@yahoo.com

ABSTRACT

Assessment the actual accuracy of laboratory devices prior to first use is very important to know the capabilities of such devices and employ them in multiple domains. As the manual of the device provides information and values in laboratory conditions for the accuracy of these devices, thus the actual evaluation process is necessary.

In this paper, the accuracy of laser scanner (stonex X-300) cameras were evaluated, so that those cameras attached to the device and lead supporting role in it. This is particularly because the device manual did not contain sufficient information about those cameras.

To know the accuracy when using these cameras in close range photogrammetry, laser scanning (stonex X-300) device is used to obtain photos of a board including (23) ground control points on it, those observed from two stations and adjusted by using equations of the 3D adjusted triangulation networks by lengths and angles (hybrid routine). (10) GCPs and (13) checkpoints were used to compare the Root Mean Square Error (RMSE) of checkpoints that result from using laser scan cameras with (RMSE) of the same checkpoints that result from using digital photos (Nikon 5200D).

The result of (RMSE) comparison was(58.9 mm.) in the X direction, (10.5 mm.) in the Y direction and(0.09 mm.) in the Z direction.

Key Words: Laser scanner, Digital camera, Close Range Photogrammetry, Bundle Adjustment, 3D triangulation network.

تقيم دقة كاميرات جهاز المسح الليزري Stonex X-300

لمى خالد جاسم
جامعة بغداد-كلية الهندسة

الخلاصة

إن تقيم الدقة الفعلية (الحقيقية) للاجهزة المختبرية قبل الاستخدام الاول امر في غاية الاهمية وذلك لمعرفة قدرات مثل هذه الاجهزة و توظيفها في مجالات متعددة . حيث ان كتيب الجهاز يوفر معلومات وقيم في ضروف مختبرية لدقة تلك الاجهزة , وبالتالي فان عملية التقيم الفعلية ضرورية .

في هذا البحث تم تقيم الدقة لكاميرات جهاز المسح الليزري (Stonex X-300) , وذلك لكون تلك الكاميرات ملحقة بالجهاز وتؤدي دوراً داعماً فيه, وهذا على وجه الخصوص لان كتيب الجهاز لايحتوي على معلومات كافية عن تلك الكاميرات.

*Corresponding author
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لمعرفة الدقة عند استخدام تلك الكاميرات في اعمال المسح التصويري ذو المدى القريب تم استخدام جهاز المسح الليزري (Stonex X-300) للحصول على صور للوح يضم (23) نقطة ضبط ارضي, والتي رصدت من محطتان و مصححة باستخدام معادلات تصحيح شبكات التثليث ثلاثية الابعاد المركبة بالاطوال والزوايا الهجينة , (10) نقاط ضبط ارضي و(13) نقطة تحقق (check points) استخدمت لمقارنة معدل متوسط مربعات الاخطاء لنقاط التحقق االناتج من استخدام صور كاميرات جهاز المسح الليزري مع معدل متوسط مربعات الاخطاء الناتج باستخدام كاميرا رقمية (NIKON 5200D) .

الناتج من مقارنة (RMSE) (58.9 mm.) باتجاه الشرق , (10.5 mm.) باتجاه الشمال و(0.09 mm.) في ارتفاعات النقاط.

الكلمات الرئيسية: جهاز المسح الليزري, الكاميرا الرقمية, المسح التصويري ذو المدى القريب, التصحيح بالاحزمة الشعاعية, شبكات التثليث ثلاثية الابعاد.

1. INTRODUCTION

Generally speaking in the close range photogrammetry 3D model of the number of certain points are determined based on two approaches:

- Approach A: plane surveying can be made through the use of field surveying instruments such as Total Station for the purpose of determining the 3D coordinates of certain points through the use of land surveying instruments requires a number of well-defined and precise (3D)[horizontal and vertical ground control points (GCPs)].
- Approach B: can be done through the use of close-range photogrammetric technique simply by taking a minimum of two photos from two stations.

The precision of processing in this approach depends on the number and distribution of the ground control points. This research is using approach A to provide ground control points for approach B, used two data resource and compare between them.

Close range photogrammetry provides the possibility of getting the three-dimensional (3D) coordinates of an object from two-dimensional (2D) digital images in a fast, precise, reliable, flexible and economical way. This makes it an ideal tool for accurate industrial measurement, **Aguilar, et al. 2005, Fraser, 1993.**

2. DIGITAL CLOSE RANGE PHOTOGRAMMETRY

Digital close range photogrammetry is a technique for precisely measuring objects directly from photos or digital images captured with a camera at close range to the object. Multiple, overlapping images capturing from different stations, produces measurements that used to create accurate 3D models of targets. **Atkinson, 1996, Easa, 1988, and Slama, 1980.**

The digital close range photogrammetric projects are generally done through the use of a digital nonmetric camera through the implantation of the well- known collinearity equations **Cooper, and Robson, 2001.**

Each point has two collinearity equations, one for the(x) photo coordinate and the other for the (y) photo coordinate **Ghoch, 1979.**

The general form of the collinearity equation for (x,y)in close range photogrammetry having the following general forms: **Wolf, and Dewitt, 2000.**

$$x - x_o = -c\,\frac{[m_{11}(X-X_L)+m_{12}(Y-Y_L)+m_{13}(Z-Z_L)]}{[m_{31}(X-X_L)+m_{32}(Y-Y_L)+m_{33}(Z-Z_L)]} = -c\,\frac{U}{W} \quad (1)$$

$$y - y_o = -c\,\frac{[m_{21}(X-X_L)+m_{22}(Y-Y_L)+m_{23}(Z-Z_L)]}{[m_{31}(X-X_L)+m_{32}(Y-Y_L)+m_{33}(Z-Z_L)]} = -c\,\frac{V}{W} \qquad (2)$$

Where:

(x ,y), photo coordinates of the point.

(x_o, y_o, c), interior orientation parameters(I. O. P).

(m11, m12, m13…m3), elements of the matrix of rotation that are the rotation's function angles (ω, φ, κ)as shown in **Fig. 2**.

(XL, YL, ZL), three-dimensional coordinates of the camera station.

(X, Y, Z), the 3D coordinates of the object points as shown in **Fig.1**.

The parameters involved in the collinearity Eq. (1&2) above are shown geometrically in **Fig. 1&2**.

3. METHODOLOGY

3.1 Establishing Ground Control Points (GCPs)

(23) Ground control points were established on a whiteboard, (10) GCPs and (13) checkpoints to use for triangulation and compute the error and as shown in **Fig. 3**.

3.2 Observed Coordinates, distance, the horizontal and vertical angle of the control and the checkpoints

The coordinates of points were observed by using Total station (Topcon (ES)) from two stations (A, C) as shown in sketch and **Fig. 4**

3.3 Adjusted triangulation networks by lengths and angles (hybrid) using Matlab code.

The adjustment code was used to adjust distances and angles to compute the corrected coordinate. The reference observation values that was observed by the total station was used as approximate value and use as input data to the Matlab code**, Shanwer, 2017,** to compute the adjusted coordinates and apply the assessment.

3.4 Capturing photos

- Two photos were taken to the board from stations (A, C) using a digital nonmetric camera (Nikon 5200D) as shown in **Fig.5**.
- Six photos were taken to the board from one station (B) using cameras of laser scanning (Stonex X-300) device as shown in **Fig.6**.

3.5 Data processing

Use of Leica Photogrammetry Suite 9.2 software, which is mainly consisting of camera calibration, resection and the computation of the adjusted 3D, coordinates of the required construction points **Easa, 1988,** as shown in **Fig. 7&8**.

4. RESULTS AND DISCUSSION

The results of the data processing using photos of Nikon camera by (LPS) software (RMSE) were computed as shown in **Fig. 9**.

The results of the data processing using two photos cameras' laser scan X-300 by (LPS) software (RMSE) was computed as shown in **Fig. 10**.

The result of (RMSE) comparison is (58.9 mm.) in the X direction, (10.5 mm.) in the Y direction and (0.09 mm.) in the Z direction as shown as in **Fig. 11**.

5. CONCLUSION

1. The end-lab of the photos delivered from Stonex X-300 cameras is approximately 25%, therefore the accuracy of the outputs was less than those delivered from the photos of Nikon camera.
2. The results obtained from X-300 laser scan cameras deliver a low accuracy of 20.4 mm. in X direction 3.4 mm. in the Y direction and 0.4 mm. in the Z direction. This kind of accuracy can be used in photogrammetry applications those need low precision requirements.
3. The coordinate (X, Y) could get from a single photo of cameras' laser scan X-300 with an accuracy of$\pm 5\ mm.$.
4. Photos of cameras' laser scan X-300 can be used for visualization with laser data and measurements that need less accuracy for photogrammetry.
5. The result of the comparison test with Nikon camera was (58.9 mm.) in the X direction, (10.5 mm.) in the Y direction and (0. 09 mm.) in the Z direction.

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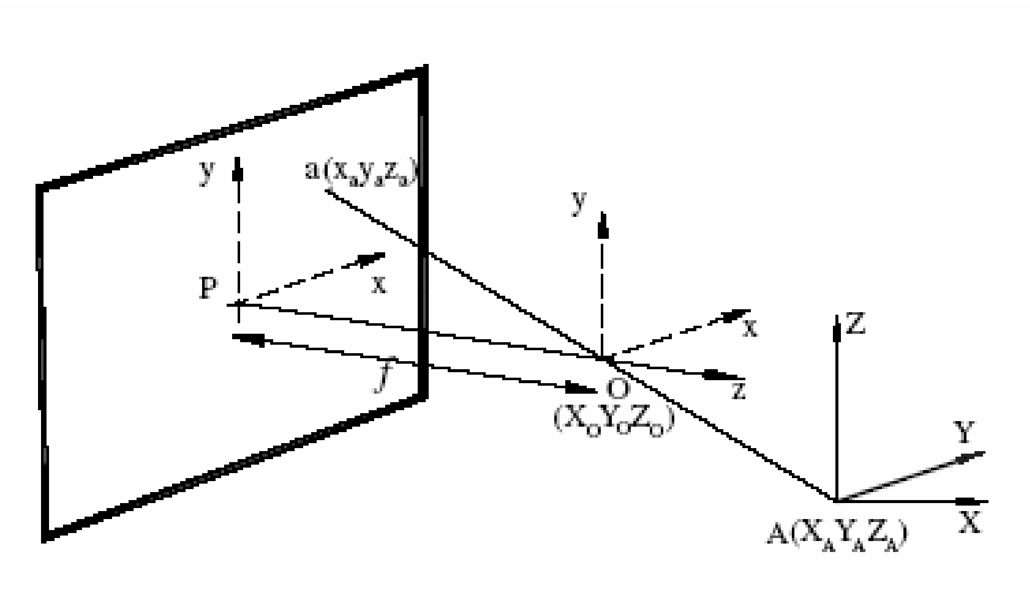

Figure 1. Central perspective of point A in close range photogrammetry**, Arias, et al., 2005.**

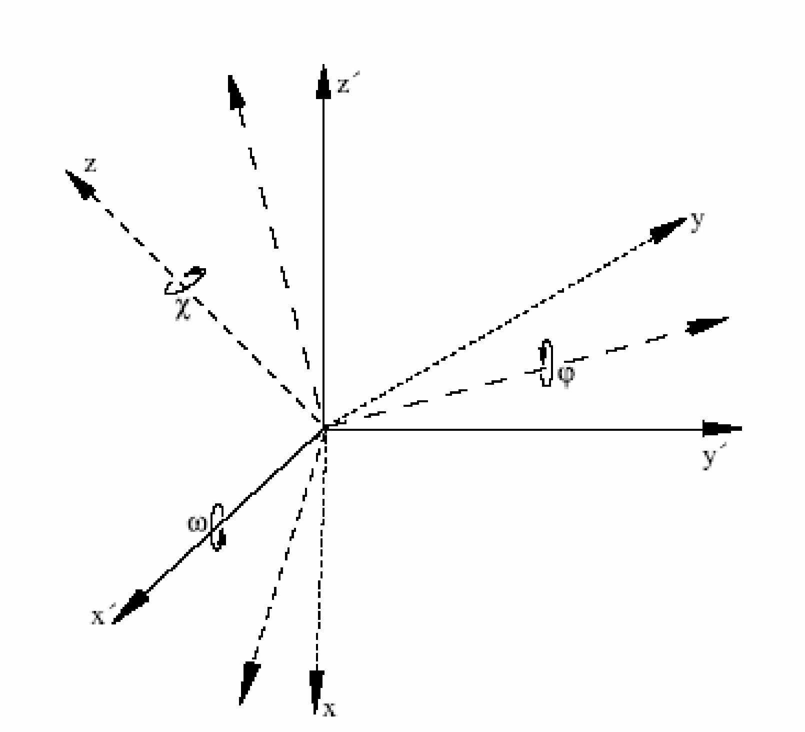

Figure 6. Rotation angles on the three axes (X, Y, Z), **Arias, et al., 2005.**

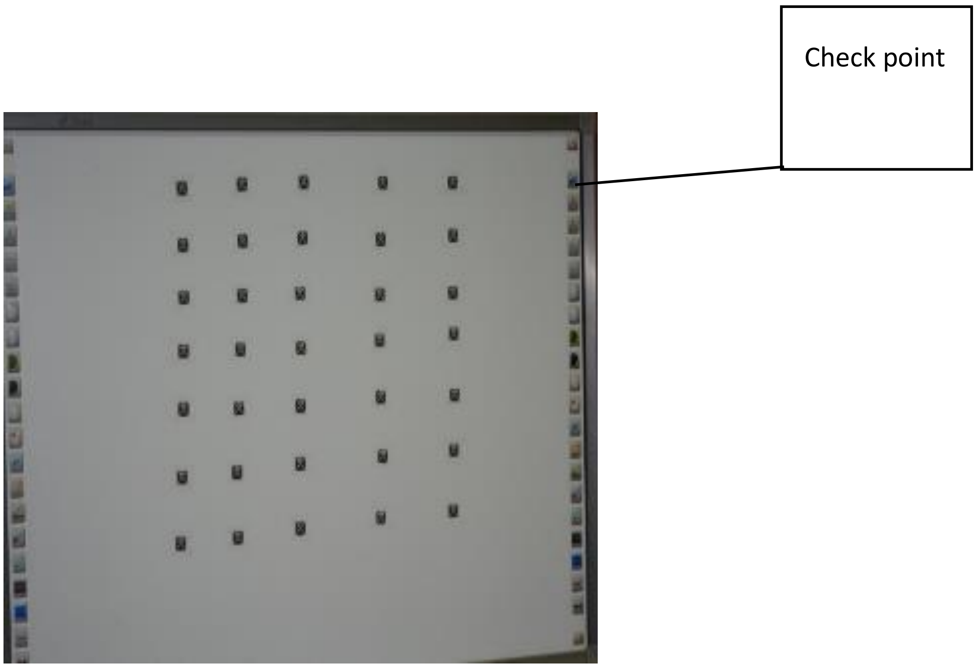

Figure 3. Distribution of (GCPS) and checkpoints.

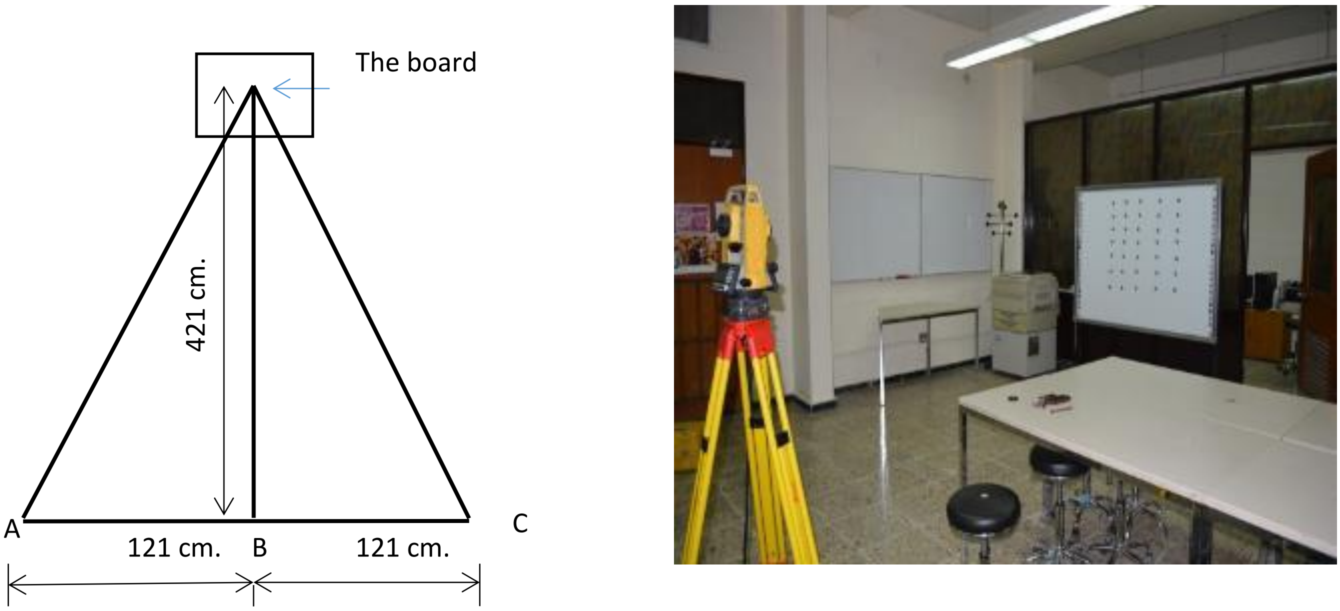

Figure 4. Sketch for stations.

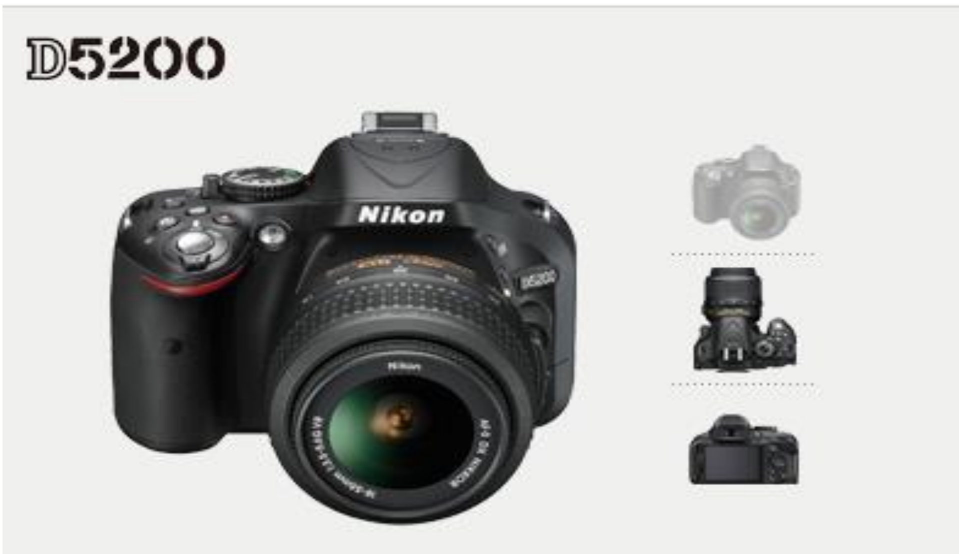

Figure 5. Nikon 5200D.

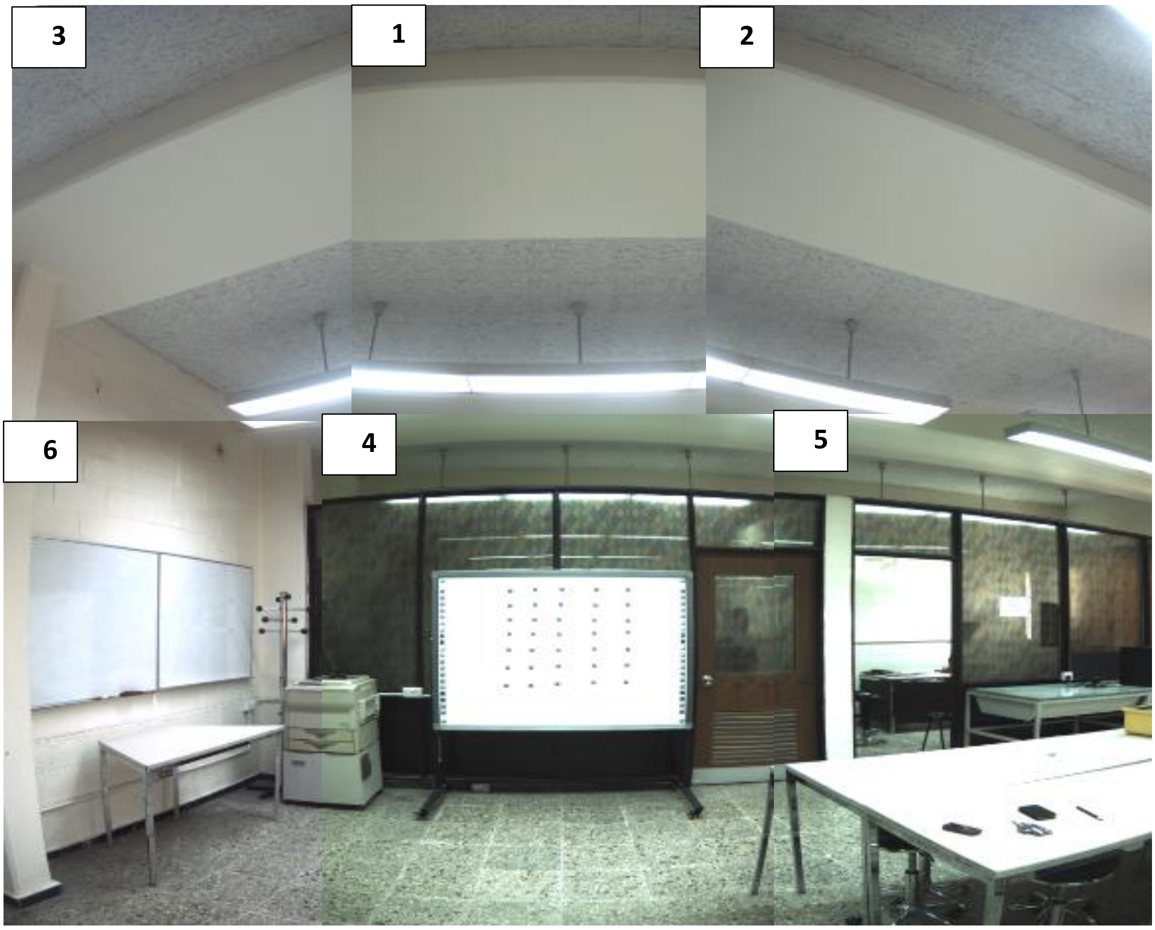

Figure 6. Photos from laser scan cameras.

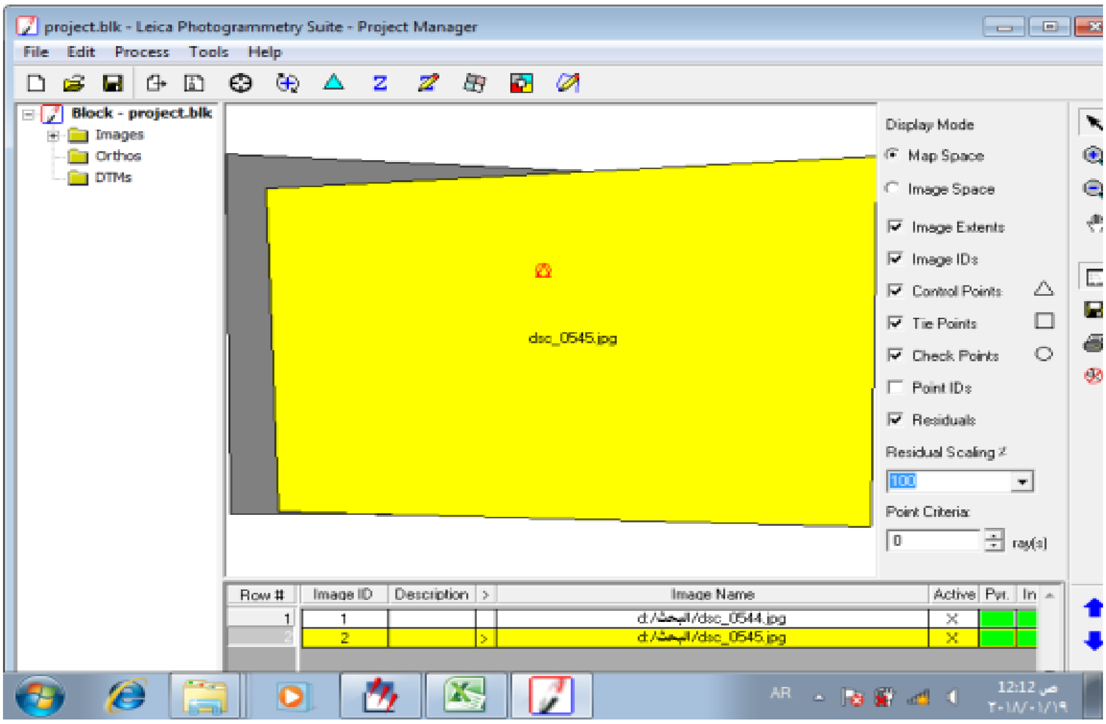

Figure 7. Windows of processing with LPS**.**

Figure 8. The window of processing with LPS.

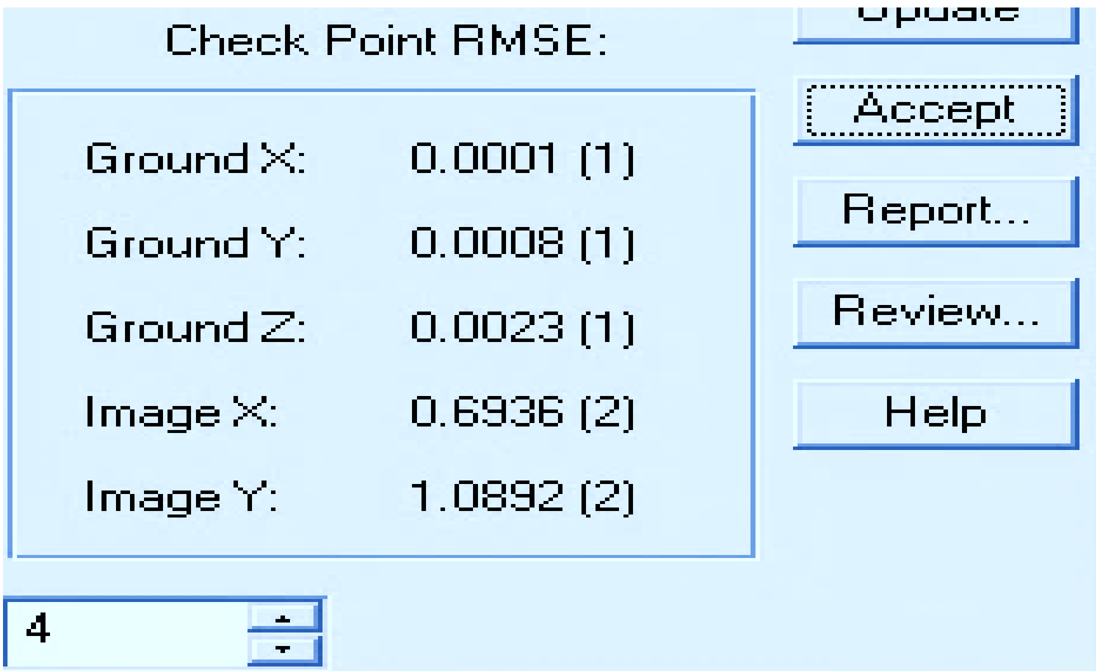

Figure 9. (RMSE) using photos of Nikon camera by (LPS).

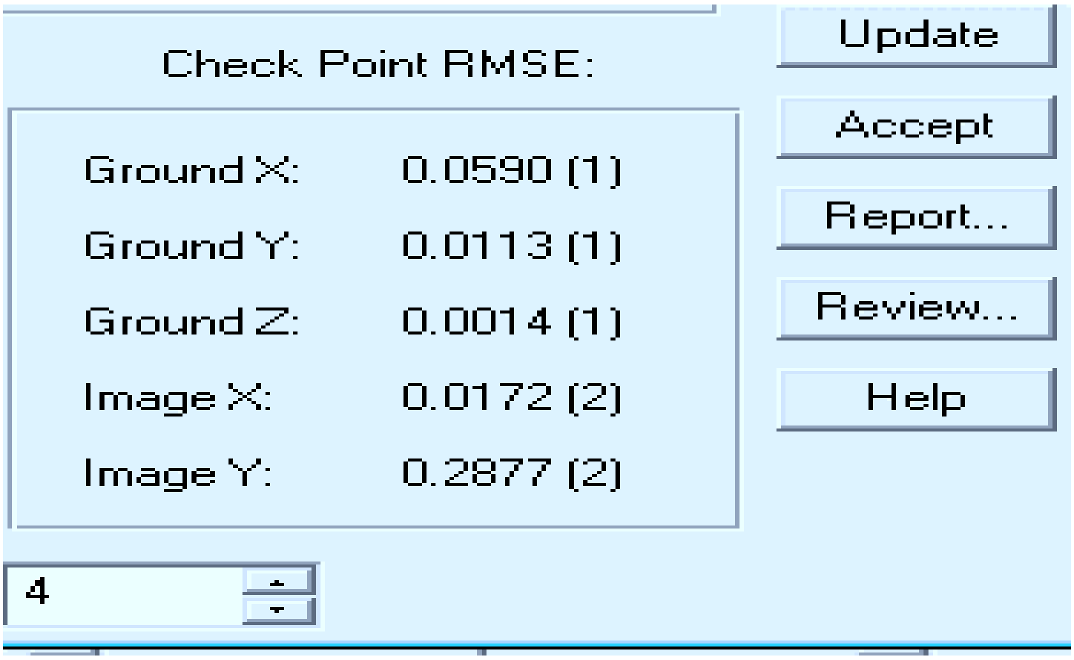

Figure 10. (RMSE) using photos of cameras' laser scan X-300 by (LPS).

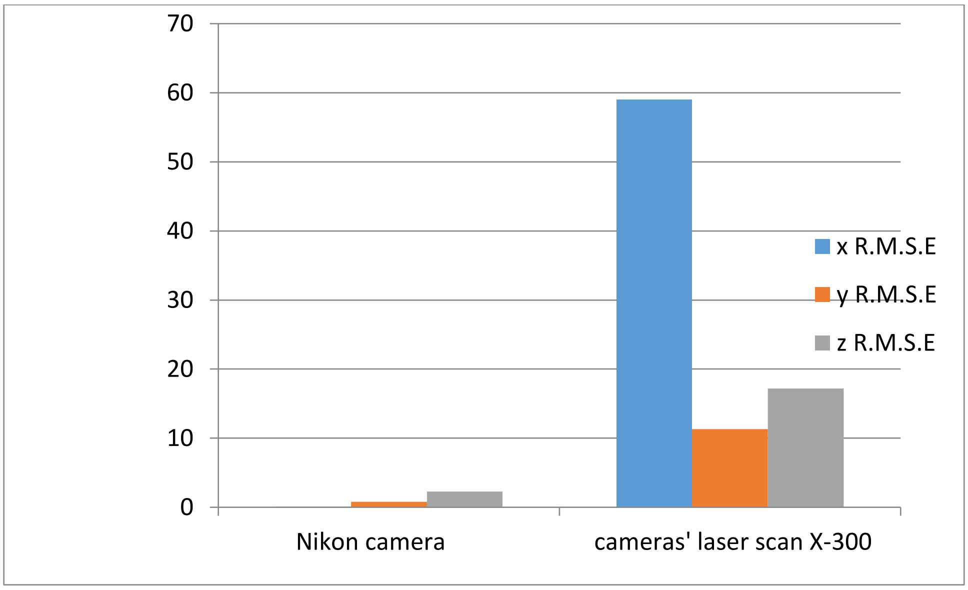

Figure 11. (RMSE) using photos of Nikon camera and photos of cameras' laser scan X-300 by (LPS) software.

Table 1. Measured coordinates, distance, the horizontal and vertical angle of sample control and checkpoints (from station A).

point	Distance m.	vertical angle	horizontal angle	X m.	Y m.	Z m.	type
36	4.4090	87°33’02”	11°22’25”	501.9491	504.2812	31.7745	control
37	4.4070	87°28’13”	11°21’10”	501.9386	504.2779	31.7512	check
38	4.4020	87°26’30”	11°36’44”	501.9432	504.2735	31.6592	check
39	4.4010	87°20’17”	11°23’22”	501.9331	504.2644	31.6451	check

Table 2. Measured coordinates, distance, the horizontal and vertical angle of sample control and checkpoints (from station C).

point	Distance m.	horizontal angle	vertical angle	X m.	Y m.	Z m.	type
36	4.5950	87°39’10”	340°00’18”	502.0091	504.3312	31.7245	control
37	4.5420	87°21’20”	340°58’14”	502.1085	504.3073	31.7512	check
38	4.5953	87°26’04”	340°05’50”	502.0132	504.3138	31.6592	check
39	4.5407	87°25’25”	340°58’20”	502.0532	504.3044	31.6651	check

Table 3. 3D coordinates for control and checkpoints after adjustment.

Point	X m.	Y m.	Z m.
36	501.9691	504.3012	31.7945
37	501.9585	504.2973	31.7212
38	501.9632	504.2938	31.6792
39	501.9532	504.2944	31.6551
40	501.9722	504.2908	31.6531
41	501.9633	504.2925	31.6182
42	501.9575	504.2886	31.5714
43	501.9542	504.2856	31.5218
44	501.968	504.2834	31.4583
45	501.9532	504.277	31.4089
46	501.9542	504.2736	31.3628
47	501.9521	504.2712	31.3146
48	501.9511	504.2697	31.2672
49	501.9419	504.2691	31.2296
50	501.9467	504.2655	31.1876
51	501.9302	504.265	31.1258
52	501.9228	504.2577	31.0864
53	501.9452	504.2584	31.0543
54	501.9241	504.2545	30.9897
55	501.9402	504.2521	30.9413
56	501.934	504.2464	30.8981
57	501.9146	504.2459	30.8588
58	501.9165	504.2467	30.8134