Applications of Camera Total Station System (CTSS) in the Construction Surveying

Abbas Zedan Khalaf*[1] , Muntaha kassim Haidir[1], Luma Khalid Jasim[2]
[1]Department of Building And Construction Engineering, University of Technology, [2]Department of Surveying Engineering, University of Baghdad, Baghdad, Iraq

Abstract:
Engineering structures in general require at implementation conducting engineering surveys of the implementation stages of work to keep up with identical implementation of the technical specifications, on the other hand most of the facilities task (large structures, towers, dams, bridges, etc…) require the conducting of periodic monitoring to determine any change could happen with time in the three-dimension(X,Y,Z).
The traditional approach in this proposal for this business is by conducting a field survey using ground surveying devices in addition to the photogrammetry survey, regardless of the manner of the work requires the provision of a number of well distributed ground control points for the purpose of the above required survey work.
This research includes the application of(CTSS)system for a structural survey above as well as monitoring facilities **disregarding the control points** to provide cost, time and effort. The results using this technique(CTSS)are very promising (RMS in X= ±1.7 mm, Y= ±1.7 mm, Z= ±0.9 mm).which gives an overall precision of (RMS= ±2.6 mm).

KEYWORDS: Digital close range photogrammetry; camera TotalStation; control system.

تطبيقات نظام كاميرا–جهاز المحطة الكاملة (CTSS) في المسح الانشائي

عباس زيدان خلف[1*]، منتهى قاسم حيدر[1]، لمى خالد جاسم[2]
[1]قسم البناء والإنشاءات، الجامعة التكنلوجيا، [2]قسم هندسة المساحة، جامعة بغداد، بغداد، العراق

الخلاصة
المنشآت الهندسية بشكل عام تتطلب عند التنفيذ إجراء أعمال المسح الهندسي لمراحل تنفيذ العمل لمواكبه مطابقه تنفيذ للمواصفات الفنية, هذا من ناحية ومن ناحية أخرى معظم المنشآت الهندسية المهمة (المنشآت الضخمة, الأبراج, السدود, الجسور... الخ). تتطلب فيها إجراء أعمال مراقبة دورية لتحديد أي تغير قد يحصل في شكل منشأ مع الوقت في البعد الثلاثي .(X,Y,Z)
الأسلوب التقليدي المتبع في هذا المقترح لهذه الأعمال يتم من خلال إجراء مسح ميداني باستخدام أجهزة المسح الأرضي إضافة إلى المسح التصويري وبغض النظر عن الأسلوب المتبع يتطلب العمل توفير عدد لابأس به من نقاط الضبط الأرضي control points لغرض إجراء أعمال المسح المطلوبة أعلاه.
هذا البحث يتضمن تطبيق منظومة (CTSS) لإجراء المسح الإنشائي أعلاه وكذلك مراقبة المنشآت **بالاستغناء عن نقاط السيطرة لتوفير** الكلفة والوقت والجهد.أظهرت النتائج لهذه المنظومة دقه عالية للنقاط المحسوبة. وكانت النتائج واعدة جداً (Z=±0.9 mm, Y=±1.7 mm,X=±1.7 mm).

1. INTRODUCTION

Generally speaking in the construction survey 3D coordinates of a number of certain points are determined which are generally made by two approaches:

- approach one: construction survey can be made through the use of land surveying instruments such as Level, Theodolite and Total Station for the purpose of determining the 3D coordinates of a certain construction points through the use of land surveying instruments requires a number of well-defined and precise (3D)[horizontal and vertical ground control points(GCP)].
- approach two: construction survey can be done through the use of close range photogrammetric technique simply by taking a minimum of two photos to the construction from two stations.

The precision of processing in this approach depend on the number and distribution of the ground control points.

The advantage of approach two as compared with approach one is time and effort.

This research represent using an approach of Camera Total Station System(CTSS) which represent an integration between approach one and approach two above without the need of specific ground control points in the object space.

Close range photogrammetry offers the possibility of obtaining the three-dimensional (3D) coordinates of an object from two-dimensional (2D) digital images in a rapid, accurate, reliable, flexible and economical way. This makes it an ideal tool for precise industrial measurement [1], [10].

2. Digital Close Range photogrammetry

Digital close range photogrammetry is a technique for accurately measuring objects directly from photographs or digital images captured with a camera at close range. Multiple, overlapping images taken from different stations, produces measurements that can be used to create accurate 3D models of objects. [5],[9],[3].

Know a day digital analytical close range photogrammetric projects are generally done through the use of a digital non metric camera through the implantation of the well known collinearity equations [7].

Each point having two collinearity equation, one for the(x) photo coordinate and the other for the (y) photo coordinate [2].

The general form of the collinearity equation for (x,y)in close range photogrammetry having the following general forms: [4].

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

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

(x,y)….photo coordinates of the point

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

(m11,m12,m13,……..m33)…elements of the rotation matrix which are a function of rotation angles(ω, φ, κ)as shown in figure(2)

(X_L , Y_L , Z_L)….three dimensional coordinates of the camera station

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

The parameters involved in the collinearity equation (1&2)above are shown geometrically in figures (1&2): [6].

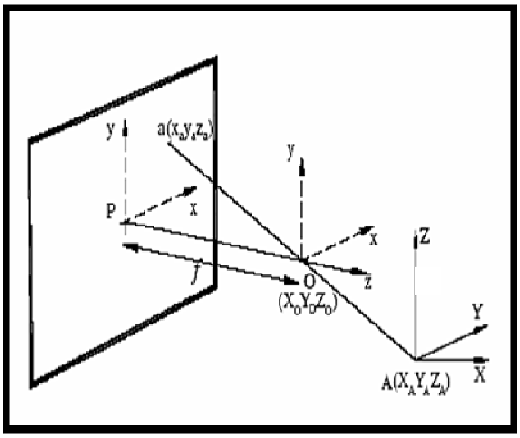

Figure 1- Central Perspective Of Point A In Close Range Photogrammetry [1].

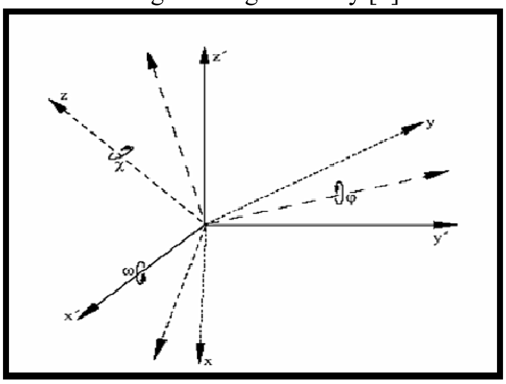

Figure 2- Rotation Angles On The Three Axes (X,Y,Z) [1].

3. Data Processing

In (CTSS)approach the data processing were done through the use of Leica Photogrammetry Suite (LPS) software, which is mainly consist of camera calibration, resection and the computation of the adjusted 3D coordinates of the required construction points[8].

Furthermore the data processing using the(LPS)software used in this research will be demonstrated numerically in the case study presented in the next section.

4. Case study

In this research one story building at the University of Technology are chosen at which a number of well defined points were selected thirteen check points.

Four close range photogrammetric photos were taken to the building from different stations using a digital no metric camera (cannon EOS500D)with 15mega pixel resolution and zoom (18-200)mm as shown below: [11].

Figure 3- Cannon EOS 500D.

4.1 Case One: for Calibrating the System

The 3D coordinates of the camera station as well as the control system were determined through the use of the Total Station which connected with the camera as shown in figures below:

Figure 4- Leica Total Station System With Cannon Camera.

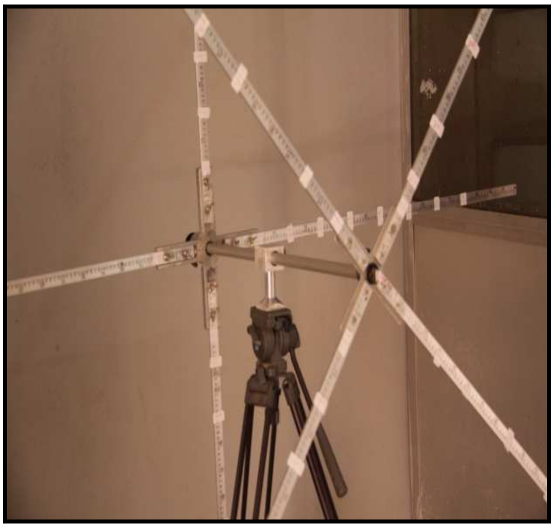

Figure 5- The Control System.

Figure 6- The Photos Of The Building With Control System.

The following table represent the 3D coordinates of the control system as well as the check points measured through the use of the Total Station for calibration .

Table 1- Measured 3Dcoordinates Of The Control System And The Check Points

ID	Type	X(m)	Y(m)	Z(m)
1	Check	102.4852	108.0957	101.7926
2	Check	101.3487	109.5817	102.5134
3	Check	101.4696	109.4134	102.9297
4	Check	102.8511	107.6112	103.8689
5	Check	103.2129	107.9433	103.3214
6	Check	102.8652	107.6395	100.4823
7	Check	105.0911	109.6803	101.4708
8	Check	107.7078	112.0898	103.9858
9	Check	110.6674	114.7596	103.4264
10	Check	111.5775	115.0368	104.5444
11	Check	110.6326	114.7418	100.8666
12	Check	99.815	111.656	100.5181
13	Check	99.8062	111.6634	103.9554
14	Control	103.423242	107.085129	101.453525
15	Control	102.914932	107.161046	101.929101
16	Control	103.635818	107.036951	101.462857
17	Control	104.174457	106.893632	102.038123
18	Control	103.543919	107.900951	101.387297
19	Control	102.864873	108.058776	101.451273
20	Control	103.753258	107.84023	102.188619
21	Control	104.559073	107.590201	101.357445

The results of the data processing using (LPS) software are shown in table below:

Table 2-The Computed 3Dcoordinates Of The Selected Points Resulted From(LPS)

ID	X(m)	Y(m)	Z(m)
1	104.21114223365	109.151308195175	103.26087670337
2	104.315297702779	109.186608203556	102.173981359476
3	105.380047311624	109.94239784386	103.362611980108
4	105.368592326922	109.940431981399	102.125878344034
5	106.733271320095	111.519909673156	101.546300638295
6	107.65846863455	112.058731909384	100.626824393022
7	107.516223186048	112.218683727495	101.523443269619
8	110.266944445103	114.779671857025	102.25611738405
9	106.070067583538	110.569010098737	103.924783864559
10	107.521703490458	112.242662672646	104.000085398541
11	109.421684526557	113.637020470316	100.838551392426
12	102.826472913634	107.021701787786	104.310747524577
13	106.044416311092	110.58333745959	100.639432763663
14	107.989372649165	112.338509048788	102.159242418453
15	105.222633171609	110.035629960211	102.186735984646
16	105.214923652913	110.022068539685	103.288111746162

Table 3-the root mean square error(RMSE) of the check points shown in table below:

RMSE X mm	RMSE Y mm	RMSE Z mm
±0.9	±0.9	±0.0

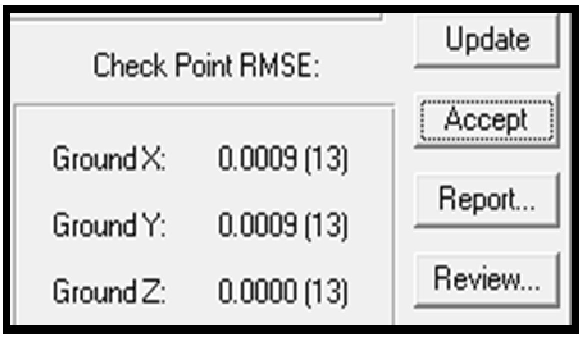

Figure 6-The RMSE From LPS Software.

From the result of the data processing using (LPS) software the shift between data required from total station and exposure station coordinate were compute as shown as in table below.

Table 4- The Shift Of Between Total Observation And Exterior Orientation Parameters.

Shift X m	**Shift Y m**	**Shift Z m**	**Shift Omega**	**Shift Phi**	**Shift Kappa**
0.00	0.00	0.30	5º	Horizontal angle	0.5º

4.2 Case two:

The second exposure station coordinates were measured by Total Station and computed shift from case one. Two photos expose and (13) check points measured by the system (CTSS) as shown in figures below:

Figure 7- The Photos Of The Building Without The Control System.

The following table represent the 3D coordinates of the check points measured for construction surveying of building .

Table 5- measured 3Dcoordinates of the check points

ID	Type	X (m)	Y (m)	Z (m)
1	Check	104.9086	108.2487	101.5586
2	Check	104.378	108.8047	101.6106
3	Check	101.6057	107.5104	102.4222
4	Check	101.6931	107.6887	102.7944
5	Check	102.6422	109.4811	101.8859
6	Check	102.878	109.8901	102.3126
7	Check	100.9019	105.7436	102.959
8	Check	100.9011	105.7466	101.1348
9	Check	103.1928	110.308	104.6151
10	Check	103.1705	110.2205	100.2304
11	Check	105.7449	106.4717	103.097
12	Check	106.1623	105.2575	102.4584
13	check	103.5703	110.0054	103.7844

The result of the data processing using (LPS) software are shown in table below:

Table 6-The Computed 3Dcoordinates Of The Selected Points Resulted From(LPS)

ID	X(m)	Y(m)	Z(m)
1	103.29387230678	111.283719492896	105.733623208594
2	104.307349781964	108.796626348102	103.29176263012
3	104.39292612196	108.762040242926	103.287042247046
4	104.281038229032	108.784224670308	101.299354215087
5	103.853821060845	109.256145751126	101.249005825567
6	104.385907311053	108.746310753714	102.225528288259
7	105.03265938595	108.00785939616	102.114385979773
8	104.887452928514	108.003577335613	102.163051250923
9	105.043538092916	108.004075626015	103.156803767107
10	104.884957538018	108.007962987168	103.082616086162
11	105.611194172734	106.516454720667	103.098090797487
12	106.334854952541	104.939299643423	102.841934318805
13	106.043420023736	105.394782081691	101.97504782046
14	106.02942	105.7165682	101.326013

	3772846	21766	255047
15	106.162294942565	105.280881317796	101.391065875987
16	106.18278848587	105.64912270016	101.18908643079
17	106.027623027917	105.71574920535	101.21537624653
18	106.077212434478	105.337203118624	101.522663351285
19	105.619116695993	106.53667974738	101.646097477778
20	105.426245040244	106.935838271886	101.644703735398
21	105.408613288571	106.967429176018	101.64291870607
22	105.734149601476	106.506497831168	101.614134886435
23	105.524823135685	106.741986321362	101.111111504918
24	105.518711727749	106.736175419536	101.358820723232
25	105.435649207992	106.950009809446	101.343344988798
26	105.434770837976	106.960168506304	101.078439859619
27	105.623378570501	106.538089785565	101.37544704734
28	105.73420990997	106.512930234922	101.112215426639
29	106.007683175119	106.837640123076	104.58724278863
30	101.192386293881	106.576499032107	102.61168940011
31	103.58848471049	110.00236326649	103.860725371573
32	106.192180343641	105.136482302258	102.654847456032
33	105.953460374996	105.734140500487	102.518372779424
34	105.878081009768	106.127335752586	102.667893369218
35	104.604341920423	108.406927283655	102.203405211325
36	104.631908696402	108.33963235013	103.175976515469

Table 7-The Root Mean Square Error(RMSE) Of The Check Points Shown In Table Below:

RMSE X(mm)	RMSE Y(mm)	RMSE Z (mm)
±1.7	±1.7	±0.9

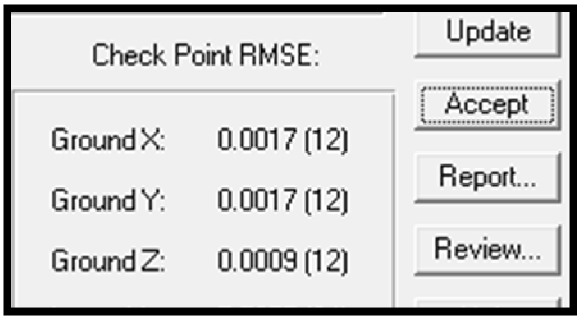

Figure 8-The RMSE From LPS Software.

5. Conclusion

- ❖ The results proved that were obtained through this research the possibility of dispensing provide control points through the use of the system.
- ❖ Reduction cost, effort and time when you use the Total Station with the camera and dispensing with the control points which usually installed constitute two-thirds of the cost of any engineering project.
- ❖ The use of photogrammetry substitute for the traditional methods used through the use of ground surveying devices.
- ❖ The ground coordinates of the building were obtained through photogrammetry and thus can be used in the production of 3D coordinates of the building.
- ❖ Through this research was to prove the possibility of re-formation of any missing pieces through images.
- ❖ The results of the program used in photogrammetry were accurate where RMSE was calculated for the (13) check points , Randomly distributed on the building was:

RMSE in X= ± 1.7 mm
Y= ± 1.7 mm
Z= ± 0.9 mm

And the total mean square [RMSE]= ±2.6 mm

6. Refrensces:

[1] Aguilar, M.A. Aguilar, F.J. Agüera, F. and Carvajal, F. **2005.** The Evaluation of Close-range Photogrammetry for the Modelling of Mouldboard Plough Surfaces, Biosystems Engineering , **90** (4):397–407.

[2] Ghoch, S. K. **1979**. Analytical Photogrammetry. Pergamon Press,New York.

[3] Slama, C. C. **1980**.The Manual of Photogrammetry. 4th Edn. American Society of Photogrammetrists, Falls Church ,VA.

[4] Wolf, P.R and Dewitt, B.A. **2000.** Elements of photogrammetry with applications in GIS. EEUU: McGraw-Hill.
[5] Atkinson, K.B. **1996** Close range Photogrammetry and machine vision. Caithness: Whittlesn Publishing.
[6] Arias, P. Herraez, J. Lorenzo, H. and Ordonez, C. **2005**.Control of structural problems in cultural heritage monuments using close-range photogrammetry and computer methods, Computers and Structures,83, 1754-1466.
[7] Cooper, M and Robson, S. **2001**.Theory of close range photogrammetry. In: Atkinson KB, editor. Close range photogrammetry and machine vision. Caithness, Scotland, UK: Whittles Publishing: pp.9-51.
[8] ERDAS, Inc. **1999.** ERDAS IMAGINE Version 8.4 OrthoBASE Tour Guide, Atlanta, Georgia USA.
[9] Easa, S.M. **1988**.Estimating Pit Excavation Volume Using Nonlinear Ground Profile Journal of Surveying Engineering, 114(2) 71-83.
[10] Fraser,C. S. **1993**. A resume of some industrial applications of photogrammetry. ISPRS Journal of Photogrammetry and Remote Sensing, 48(3): 12–23.
[11] Canon EOS 500D EF-S (18-55) mm, Instruction Manual.