International Journal of
Applied Mathematics,
Electronics and Computers
IJAMEC
ISSN:2147-8228 www.atscience.org/IJAMEC
Advanced Technology and Science
Original Research Paper

Laser Scanning and Photogrammetric Evaluation of Uzuncaburç Monumental Entrance#

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Accepted 15th August 2014

Abstract: This studied in Ayaş, Erdemli the town of Mersin. In this study it is aimed 3D modeling of Historical Uzuncaburç monumental entrance by the using of both methods; Terrestrial Laser scanning, Terrestrial photogrammetric methods. At first, it is coordinated with the targets which are studied on the historical gate. These coordinates are approved as the the reference coordinates. The coordinates of these targets are obtained with help of both terrestrial laser scanning and terrestrial photogrammetric method. These coordinates are compared with the accurate coordinates and made a sensibility research. In this project Optech laser scanner is used to obtain 3D point datas. These point clouds are combined by Polyworks software and the terrestrial photogrammetric drawings are done by Photomodeler software.

Keywords: *Laser Scanning, Terrestrial Photogrammetry, 3D model, Point Cloud*

1. Introduction

In recent years ,the use usage of laser scanning systems on 3D modeling works is increasing. In this system the modeling of the objects are done with the help of point cluster. All points which are in the point clouds, have 3D coordinates. In a few minutes thousands of 3D points can be obtained about the mentioned object. Terrestrial object has been used for this used for this purpose for years. Terrestrial laser scanning is a quite new method for 3D modeling. Although terrestrial laser scanning has some disadvantages, it has important advantages. These advantage scan be listed below; directly obtaining the 3D points, quite effective on defining the formless structures, and obtaining the results in a short time. Limited distance, high imaging expenditure and not obtaining the attribution of the object, are the primary disadvantages [1].

2. Terrestrial Laser Scanning Technology

Terrestrial laser scanning technology is a new developing technology which is used for 3D modeling of the objects. Today, the most popular measuring system for laser scanners is "Time of flight". This technique enables to measure the identified distance for several 100 meters. Besides, phase measuring principle is another partner technique. At this technique distance is limited in 100 meters. Accuracy of measured distance is just a few mm. Some terrestrial laser scanners can measure up to several m. Those are used in more industrialized applications. Optic triangulation is the kind of distance measuring principle which is used in this kind of terrestrial laser scanners. The accuracy of these measures are at micron levels. Terrestrial laser scanners can be group according to their technical features below [2-5].

Table 1. The classification of terrestrial laser scanner

MEASURING SYSTEM	DISTANCE(m)	ACCURACY (mm)
Time Of Flight	< 100	< 10
	< 1000	< 20
Phase Measuring	< 100	< 10
Optic Triangulation	< 5	< 1

2.2.The differences that differs the terrestrial laser scanners from traditional measuring techniques

The most effective way of terrestrial laser scanners is capturing the 3D geometry of the objects directly, fast and detailed.
Other advantages in order: [3]

1- The impressive decrease of expenditures

2- Complenting the Project much faster. The Project can be completed in a few days.

3- It can measure at complex, in accessible, dangerous objects and areas where the traditional techniques failed.

4- As the scanning process does not depend on the lighting. It is possible to scan even at night.

5- Completeness and comprehensiveness at scanning: It can capture everything at one time. Thus, if any information is needed, it is not necessary to go back to the scaning area. this also rises the trust of the user fort the result.

6- From now on, multiple purposed data usage.

3. Study Area

This work is done in Uzuncaburç, Silifke the town of Mersin. The gate is, through the North-South direction on the second pillar road and on the North of the Zeus temple, which has three entrance; one is in the middle and big and the others are on the

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 # This paper has been presented at the International Conference on Advanced Technology&Sciences (ICAT'14) held in Antalya (Turkey), August 12-15, 2014.

both sides of the middle one. The coordinates are 36° 34' 53,8"north, 33° 55' 25,60" east (Figure 1). The 3 arched structure has 31 meters length and 12 meter high. The gate is dated in 2nd century AD. This gate is one of the most important structures of the historical city because there is a tablet on it which is written the name of the city, "Diokaesareia". By this tablet, we are able to learn that this gare was restored the roman imsikketor Arcadius (AD 395- 408) and Honorius (AD 395- 423).

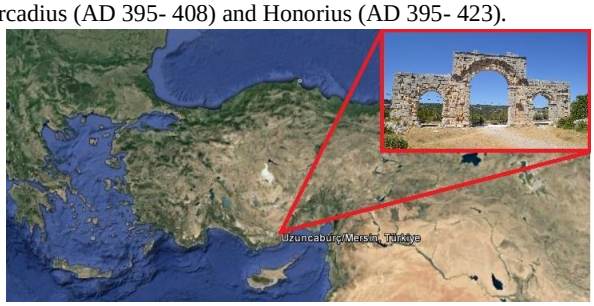
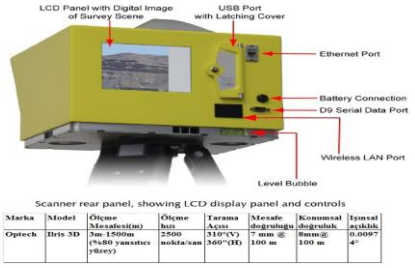


Figure1. The position of the Uzuncaburç gate on the earth

4- Material- Method

Two different technique is used to complete the work at filed. First one is terrestirial laser scanning, the other one is photogrammetric. During the pre-study process of modeling , the Uzuncaburç gate, laser scanning tool and electronic total station (Figure 2 and 3), the target papers which are stuck on the walls, are provided**(Figure 4)**



Scanner rear panel, showing LCD display panel and controls

Marka	Model	Ölçme Mesafesi(m)	Ölçme hızı	Tarama Açısı	Mesafe doğruluğu	Konumsal doğruluk	Işınsal açıklık
Optech	Ilris 3D	3m-1500m (%80 yansıtıcı yüzey)	2500 nokta/san	310°(V) 360°(H)	7 mm @ 100 m	8mm@ 100 m	0.0097 4°

Figure 2. Optech Ilris 3D laser scanner

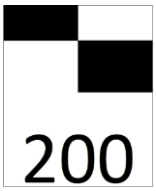


Figure3. Total Station GPT 3007 **Figure 4.**A4 photocopy paper shaped target sheet

After the preparations had finished at the field, the measurement of the control points at the study started. Angles and distances are measured by Total Station GPT 3007 laser and vertical, horizontal and oblique distances are measured by laser Total Station (Figure 5). And also coordinates are obtained with these devices.

Figure 5. The coordination of the control points with total station

4.1 The application of terrestrial laser scanning at Uzuncaburç Gate

The study which we applied has two process. One is at the area, the other one is at the office. The area work includes scanning the area with laser scanning devices. Office work includes the transferring of data to computers or to suitable applying devices which is obtained during the area work. The area work takes 1 day and Office work takes 3 days long. The scanning of the castel gate with terrestrial laser scanning is applied on six different scanning station. Each scanning is applied at the partner points with in at least 4 link points. The scanning process is applied Optech Ilris 3D laser scanning device with in 1 cm points density. The scanning process is controlled by its own controller programme of the scanner "controller" (Figure 6 and 7).

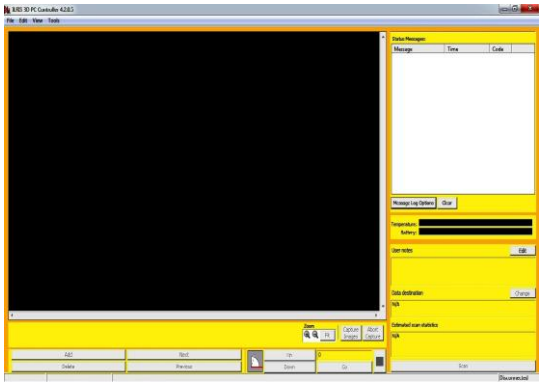


Figure 6. The interface of the controller programme

Figure 7. The terrestrial laser scanning process at the field

At first, the datas which are collected during the field work, are transformed into PIF, XYZ, RAV,IXF extensions etc. by Parser programme (Figure 8).

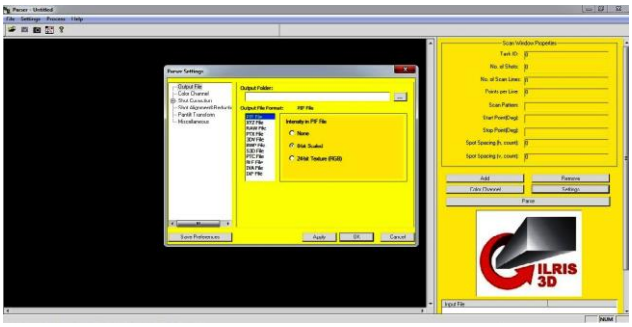


Figure 8. The interface of parser programme

The files, whose extension are transformed, then opened with polyworks programme and combined with it. The combination process is applied while two different point clouds partner point is is defined. At the end of this process, the point clouds of the castle gate is obtained (Figure 9 and 10).

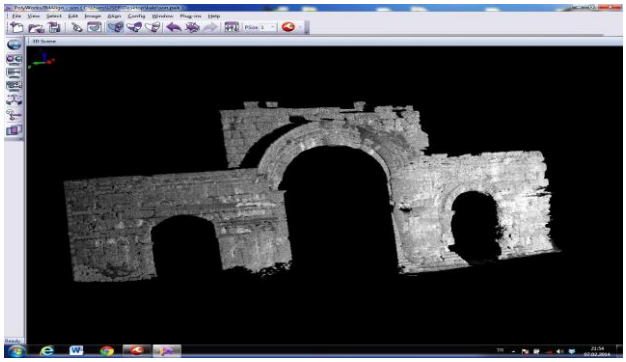


Figure 9. The point clouds of the front side of the castle gate

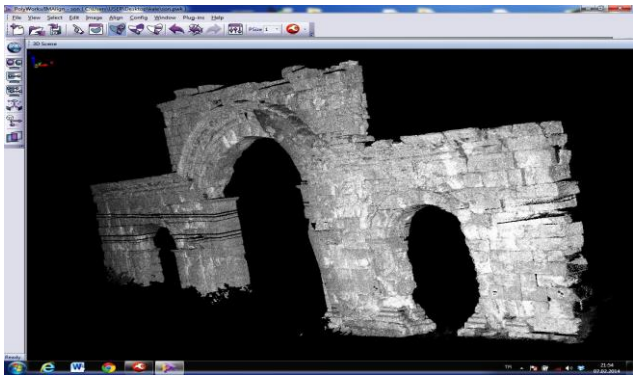


Figure 10. The point clouds of the front side of the castle gate

4.2.The application of the terrestrial photogrammetric method at Uzuncaburç gate

First of all photography work is completed in terrestrial photogrammetric study. Photographing was made by Nikon camera D3100 (Figure 11 and 12).

Figure 11. The photo taking of castle gate

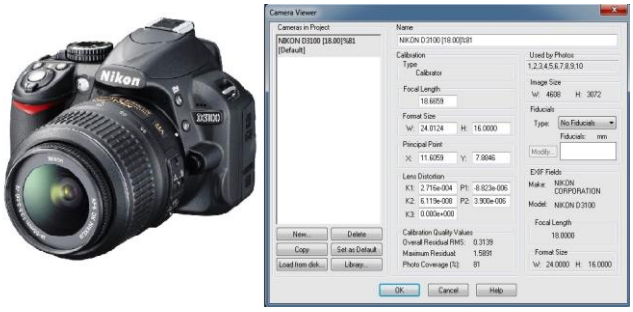


Figure 12. The calibration rates of Nikon D3100 camera

After completing the photo taking process, the taken photos are balanced, drawn (Figure 13), and illustrated (Figure 14) Photomodeler Scanner programme.

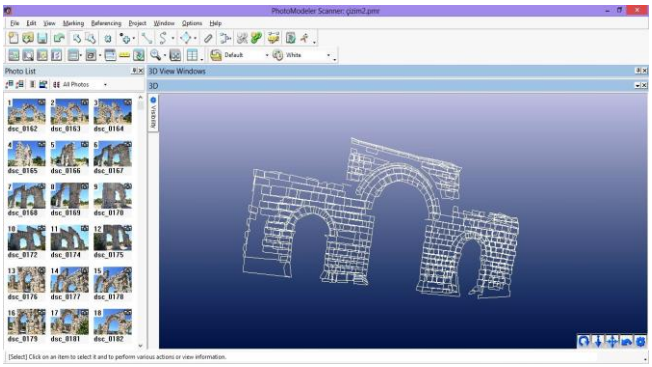


Figure 13. Drawing the castle gate on Photomodeler programme

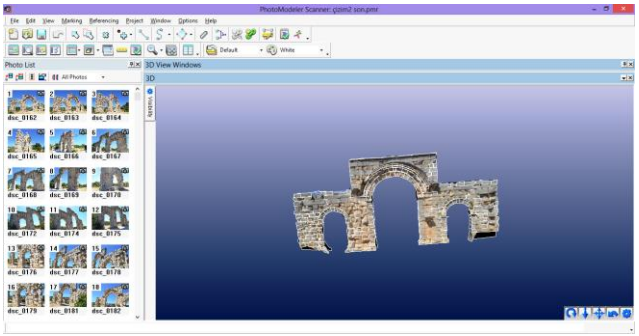


Figure 14. The illustration of image match process

5. Findings

The 20 paper points (Figure 15) which are stuck on castle walls, are coordinated by total station. The coordinates are confirmed as the exact coordinates.

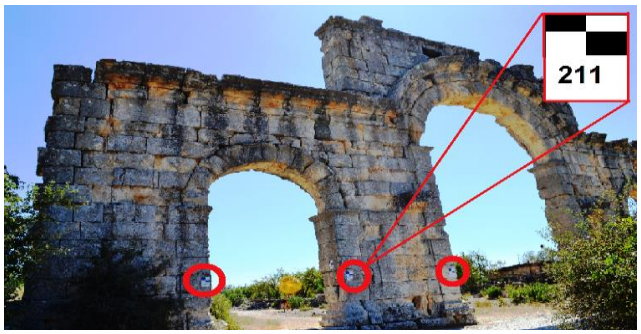


Figure 15. Sticking the paper target on the object

The coordinates of the 20 points are calculated by both using the results of laser scanning and the terrestrial photogrammetric

techniques. These coordinates are given in the Table-1.

Table-1. The exact coordinates, the coordinates which are calculated by using the laser scanning and terrestrial photogrammetric techniques

EXACT COORDINATES				LASER SCANNING COORDINATES			TERRESTRIAL PHOTOGRAMMETRIC COORDINATES		
N.N	Y	X	Z	Y	X	Z	Y	X	Z
211	730.384	1081.278	1010.255	730.376	1081.273	1010.251	730.38	1081.276	1010.252
212	733.439	1081.957	1009.717	733.436	1081.959	1009.719	733.435	1081.959	1009.712
213	737.692	1082.928	1009.04	737.698	1082.922	1009.045	737.696	1082.926	1009.043
214	740.911	1083.687	1009.745	740.916	1083.691	1009.748	740.914	1083.686	1009.745
215	748.05	1085.398	1009.799	748.057	1085.403	1009.796	748.053	1085.396	1009.794
216	751.52	1086.207	1010.29	751.522	1086.203	1010.296	751.521	1086.205	1010.296
217	755.438	1087.143	1010.71	755.435	1087.148	1010.711	755.435	1087.147	1010.713
218	757.759	1087.619	1011.314	757.756	1087.615	1011.317	757.757	1087.615	1011.312
219	755.1	1087.655	1010.736	755.097	1087.655	1010.738	755.102	1087.657	1010.733
220	733.885	1082.701	1009.603	733.885	1082.704	1009.607	733.881	1082.703	1009.609
221	738.039	1084.254	1010.151	738.035	1084.258	1010.155	738.035	1084.256	1010.158
223	730.175	1082.406	1010.274	730.179	1082.409	1010.272	730.178	1082.402	1010.274
224	732.685	1082.988	1010.227	732.688	1082.983	1010.223	732.682	1082.985	1010.222
225	737.108	1083.912	1009.011	737.102	1083.91	1009.014	737.105	1083.915	1009.012
226	751.646	1087.014	1010.725	751.641	1087.018	1010.728	751.641	1087.019	1010.729
227	747.707	1085.939	1009.813	747.709	1085.936	1009.819	747.709	1085.932	1009.819
228	741.19	1084.873	1009.831	741.194	1084.878	1009.834	741.194	1084.875	1009.839
229	740.753	1084.921	1010.286	740.758	1084.924	1010.282	740.758	1084.924	1010.282
230	747.754	1086.568	1010.211	747.75	1086.563	1010.208	747.759	1086.565	1010.21
232	755.12	1088.3	1010.233	755.126	1088.301	1010.231	755.122	1088.304	1010.239

With the help of using the differences of characteristic point coordinates at castle gate (Table-2), for each coordinate component sensibility standards are identified.

Table-2. The differences between the exact coordinates and, the coordinates obtained from laser scanning and photogrammetric

LASER SCANNING DIFFERENCE(mm)			TERRESTRIAL PHOTOGRAMMETRIC DIFFERENCE(mm)		
Vy(mm)	Vx(mm)	Vz(mm)	Vy(mm)	Vx(mm)	Vz(mm)
4	5	4	4	2	3
3	-2	-2	4	-2	5
-6	6	-5	-4	2	-3
-5	-4	-3	-3	1	0
-7	-5	3	-3	2	5
-2	4	-6	-1	2	-6
3	-5	-1	3	-4	-3
3	4	-3	2	4	2
3	0	-2	-2	-2	3
0	-3	-4	4	-2	-6
4	-4	-4	4	-2	-7
-4	-3	2	-3	4	0
-3	5	4	3	3	5
6	2	-3	3	-3	-1
5	-4	-3	5	-5	-4
-2	3	-6	-2	7	-6
-4	-5	-3	-4	-2	-8
-5	-3	4	-5	-3	4
4	5	3	-5	3	1
-6	-1	2	-2	-4	-6

At this grade, the sensibility standards are calculated weightily. S_o=20m unit distance is chosen as the average distance between total station and the object points, weight Pi= 20/si equality is determined for each point (Table-3).

Table-3. weights and distances from the total Station points

N.N	Distance(Si=m)	Weight (So=20 m) Pi=20/Si
211	14.12	1.416
212	15.79	1.267
213	18.76	1.066
214	21.35	0.937
215	27.67	0.723
216	30.88	0.648
217	34.61	0.578
218	36.81	0.543
219	25.02	0.799
220	9.81	2.039
221	10.77	1.857
223	9.49	2.107
224	9.18	2.179
225	10.4	1.923
226	21.76	0.919
227	18.26	1.095
228	12.84	1.558
229	12.45	1.606
230	18.11	1.104
232	24.94	0.802

With the help of weightedly found results point cloud changes is tried to be identified.3D location accuracy is calculated as in formula(1). [4].

(1)

Weighted $Sx_0 = \sqrt{\frac{[PVxVx]}{n-1}}$ $Sy_0 = \sqrt{\frac{[PVxVx]}{n-1}}$ $Sz_0 = \sqrt{\frac{[PVxVx]}{n-1}}$

(2,3)

3D location accuracy $S_{3B} = \sqrt{Sx_0^2 + Sy_0^2 + Sz_0^2}$

$$Sx_i = \frac{Sx_0}{\sqrt{Pi}} \qquad Sy_i = \frac{Sy_0}{\sqrt{Pi}} \qquad Sz_i = \frac{Sz_0}{\sqrt{Pi}}$$

3D location accuracy $S_{3B_i} = \sqrt{Sx_i^2 + Sy_i^2 + Sz_i^2}$

As a result of weighted evaluation location accuries which are calculated for each point,are calculated according to formula (2) and the results are given at Table-4.

Table-4. Weight (Different sensibility) found values standart deviation

Laser Scanning			Terrestrial Photogrammetry		
4.825	4.478	4.135	4.152	3.619	5.332
SY0	SX0	SZ0	SY0	SX0	SZ0

Table-5. Weightedly found 3D location accuracies (For each points)

Weighted Values(mm) (Laser Scanning)					Weighted Values (mm) (Terrestrial Photogrammetry)				
N.N	Sy(i)	Sx(i)	Sz(i)	3B-Si	N.N	Sy(i)	Sx(i)	Sz(i)	3B-Si
211	4.054	3.762	3.474	6.127	211	3.489	3.041	4.48	6.442
212	4.288	3.979	3.674	6.447	212	3.69	3.216	4.738	6.812
213	4.673	4.337	4.004	6.976	213	4.022	3.505	5.164	7.425
214	4.986	4.627	4.272	7.403	214	4.29	3.739	5.509	7.921
215	5.676	5.267	4.863	8.348	215	4.884	4.257	6.272	9.018
216	5.996	5.564	5.138	8.786	216	5.16	4.497	6.626	9.526
217	6.348	5.891	5.439	9.267	217	5.462	4.761	7.015	10.085
218	6.546	6.075	5.609	9.538	218	5.633	4.91	7.234	10.401
219	5.397	5.008	4.624	7.966	219	4.644	4.048	5.964	8.575
220	3.38	3.136	2.896	5.201	220	2.908	2.535	3.735	5.369
221	3.541	3.286	3.034	5.423	221	3.047	2.656	3.913	5.626
223	3.324	3.085	2.848	5.124	223	2.86	2.493	3.673	5.281
224	3.269	3.034	2.801	5.049	224	2.813	2.452	3.613	5.194
225	3.48	3.229	2.981	5.338	225	2.994	2.61	3.845	5.528
226	5.033	4.671	4.313	7.468	226	4.331	3.775	5.562	7.997
227	4.611	4.279	3.951	6.89	227	3.968	3.458	5.095	7.325
228	3.866	3.588	3.313	5.869	228	3.327	2.9	4.273	6.143
229	3.807	3.533	3.262	5.788	229	3.276	2.856	4.207	6.049
230	4.592	4.261	3.934	6.864	230	3.951	3.444	5.074	7.295
232	5.388	5.000	4.617	7.954	232	4.637	4.042	5.955	8.561

Both standart deviation values of weighted standart and 3D location accuracies for each points are obtained from formula(3) (Table-5).

t-test is applied considering the coordinate differences and their standard deviation is known during the examining of whether the coordinate differences are meaning or not. Calculated test greatness is given in Table-6.These values are compared degrees of freedom (f=n-1) and error probability α=0.05 with in the limit value at t-chart.t-test limit value is (Considerin degrees of freedom f=20-1 and error probability α=0.05) 2.09.

Table-6 is examinated,it is seen that all the values are below the limiting values.

Laser Scanning				Terrestrial Photogrammetry			
N.N	Ty=Vi/Syi	Tx=Vi/Sxi	Tz=Vi/Szi	N.N	Ty=Vi/Syi	Tx=Vi/Sxi	Tz=Vi/Szi
211	0.987	1.329	1.151	211	1.146	0.658	0.670
212	0.700	-0.503	-0.544	212	1.084	-0.622	1.055
213	-1.284	1.383	-1.249	213	-0.995	0.571	-0.581
214	-1.003	-0.865	-0.702	214	-0.699	0.267	0.000
215	-1.233	-0.949	0.617	215	-0.614	0.470	0.797
216	-0.334	0.719	-1.168	216	-0.194	0.445	-0.906
217	0.473	-0.849	-0.184	217	0.549	-0.840	-0.428
218	0.458	0.658	-0.535	218	0.355	0.815	0.276
219	0.556	0.000	-0.432	219	-0.431	-0.494	0.503
220	0.000	-0.957	-1.381	220	1.375	-0.789	-1.607
221	1.130	-1.217	-1.318	221	1.313	-0.753	-1.789
223	-1.203	-0.973	0.702	223	-1.049	1.604	0.000
224	-0.918	1.648	1.428	224	1.066	1.223	1.384
225	1.724	0.619	-1.006	225	1.002	-1.149	-0.260
226	0.993	-0.856	-0.696	226	1.154	-1.324	-0.719
227	-0.434	0.701	-1.519	227	-0.504	2.024	-1.178
228	-1.035	-1.394	-0.906	228	-1.202	-0.690	-1.872
229	-1.313	-0.849	1.226	229	-1.526	-1.051	0.951
230	0.871	1.173	0.763	230	-1.265	0.871	0.197
232	-1.113	-0.200	0.433	232	-0.431	-0.990	-1.008

6. Results

Terrestrial laser scanning technology which boots the creation of 3D modeling studies, has been started to use widely day by day. It has been presenting an important role as it is faster and more practical on the studies of especially preserving historical and cultural heritages, relieve and documenting studies. The sensibilities ,obtained at both methods, reached us a conclusion with these techniques that they could be base for further restoration works. In conclusion of these documenting techniques. it is understood that by sending the documents to their appropriate usage opportunities ,there can be a data interaction between different disciplines ,and a decrease on expenditures. The usage of this system is getting wider ,especially in engineering, and it ensures advantages like time ,cost and labor decreasing. Considering that coordinate differences and their standard deviating are calculated-test is applied in order to understand whether the coordinates(obtained both total station and laser scanner) are meaningless or not. When t-test results are examined ,it is seen that all results are below the limited values.

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