RECONSTRUCT 3D BUILDING MODEL BY USING MULTI-SOURCE POINT CLOUDS

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Abstract

Nowadays, there are many sources of point clouds which are no longer restricted in airborne LiDAR (Light Detection and Ranging). Multi-source point clouds can provide abundant information for reconstructing a 3D building model. One can use Photosynth, the free software provided by Microsoft, to get point clouds through images taken by digital camera; even they were taken in different time or by different cameras. It's more convenient and faster. This research tries to integrate the point clouds from ground-based LiDAR and Photosynth by using some control points. Experimental results show that point clouds generated by Photosynth could increase the amount of points of ground-based LiDAR. On the other hand, the latter could provide accurate coordinates to the former. The efficiency of 3D building model reconstruction can be improved by combining multi-source point clouds.

Keywords: *Point clouds, Reconstruction, 3D building model, LiDAR*

1 INTRODUCTION

Compared with traditional field survey method, LiDAR system can collect large number of points with high accuracy three-dimensional coordinates in a short period. However, if one want to acquire entire data of an object, multi-station scanning was required. Some places might be inconvenient to set up instruments. Therefore, this research tried to use another way to obtain point clouds. One could simply get point clouds by taking pictures. Actually, the software, Photosynth developed by Microsoft can produce these point clouds. Through Photosynth, one could obtain point clouds in any field of view. Nevertheless, the accuracy of these point clouds was uncertainly. The purpose of this research is to combine point clouds obtained from ground-based LiDAR and Photosynth, and estimate the accuracy of a 3D building model reconstructed by the point clouds.

Photosynth was developed by University of Washington Animation Research Labs and Microsoft in 2006, and then opened to public access in 2008. There were 20 GB free spaces for users to upload their own images. Camera parameters, positions, and 3D relative geometry of a sequence of images were recovered to create three dimensional models (N. Snaevely *et. al*, 2006). A scene by synthesizing input images shown as Figure 1 can then be established. For acquiring accurate information, this software may be used to find feature points in each image. SIFT (Scale Invariant Factor Transformation) detector (Lowe, 2004) was used because of the characteristic of invariance to image transformation.

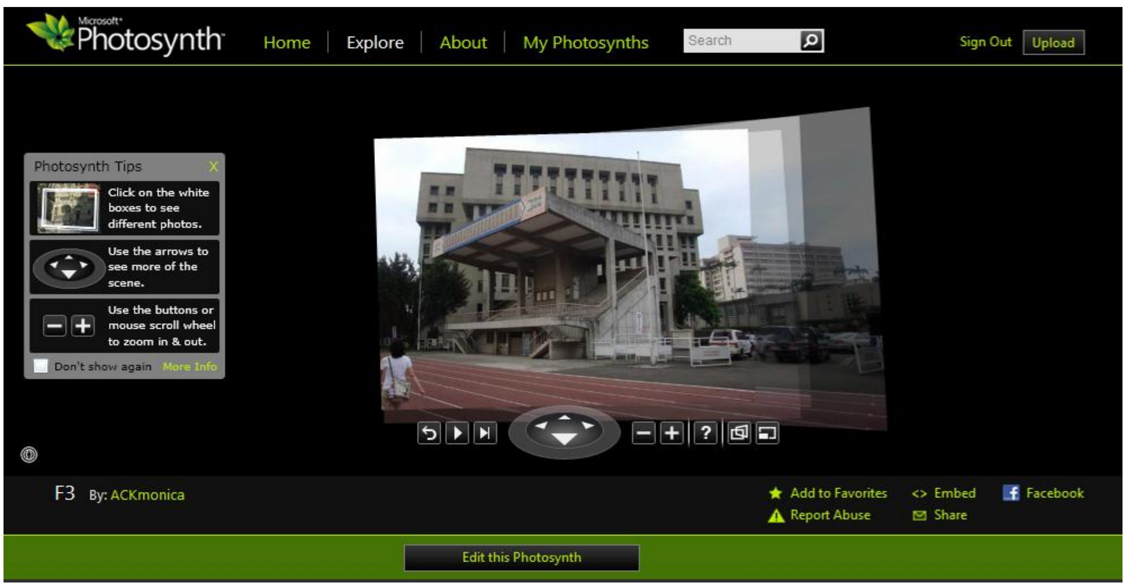


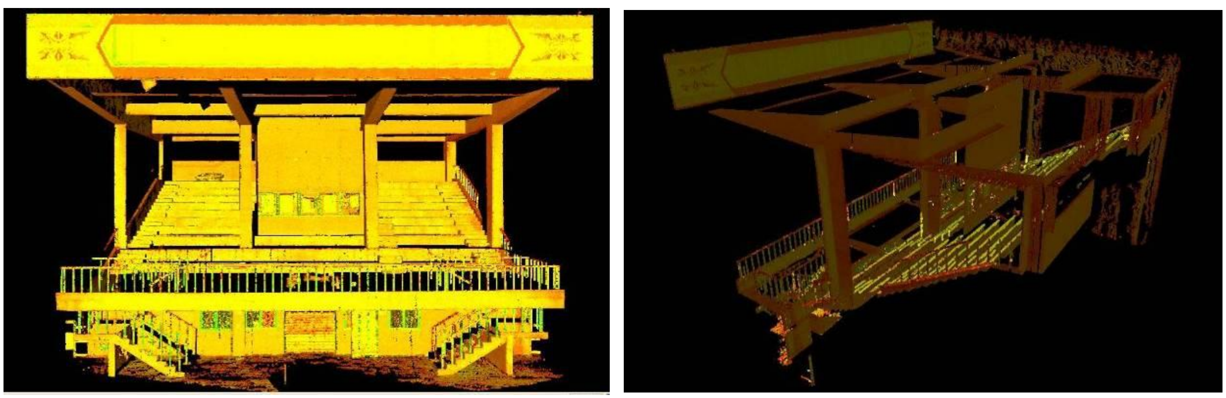
Figure 1: The scene synthesized by Photosynth

2 RESEARCH DATA

The test object is a grandstand of playground shown as Figure 2. In the research, this grandstand was taken by combining two sets of point clouds. One was acquired by ground-based LiDAR, the other was produced by Photosynth. Firstly, this research used ground-based LiDAR to scan the grandstand. This research setup the density of point clouds to be 1 mm between points in the distance of 100 m and there were about 4 millions points acquired. The result was shown as Figure 3. Because there was only one station scanning, no point could be seen in the backside (Figure 3(b)). Secondly, pictures of the grandstand were taken for generating point clouds by Photosynth. 194 pictures were taken for obtaining 40,464 points shown as Figure 4.

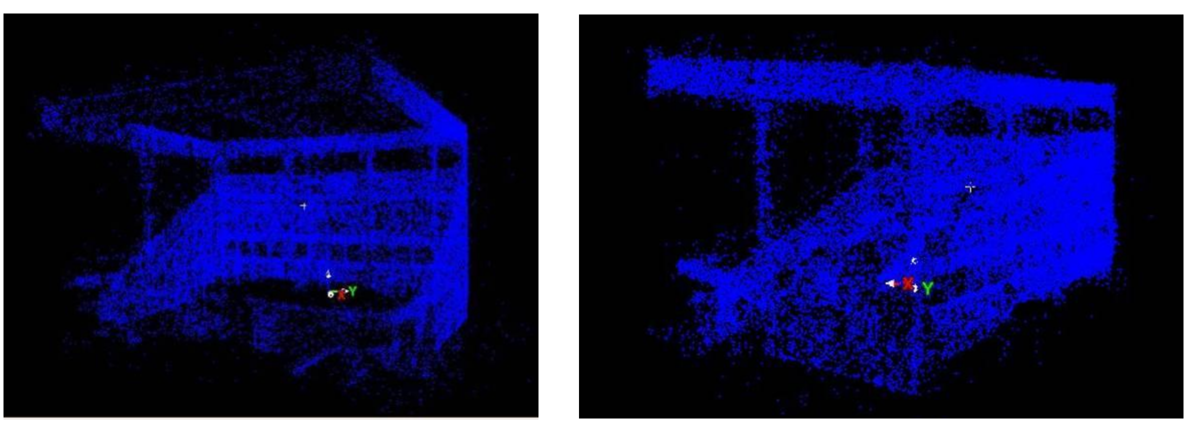
(a) Front (b) Back

Figure 2: The object to be measured.



(a) Front (b) Back

Figure 3: The point clouds generated from ground-based LiDAR



(a) Front (b) Back

Figure 4: The point clouds from Photosynth

3 RESEARCH METHOD

Two sets of point clouds were then combined by coordinate transformation. The ground-based LiDAR was the primary one, and then transformed the other one to match up the ground-based LiDAR coordinates. There were at least three conjugate control points to be picked. First of all, a three-dimensional conformal transformation (see equation 1) was used. It was also known as seven-parameter similarity transformation. Seven parameters include three rotations, three translations (T_x, T_y, and T_z), and one scale factor (S). Three rotations could develop a single matrix. A three-dimensional affine transformation was then adopted for considering the scale factors for three axes might be different. Therefore, scale factor, S, would be divided to S_x, S_y and S_z. It was also called nine-parameter transformation. The results were depended on the distribution of control points. This research tried to find out the combination that makes the operation converged. In the end, the model would be reconstructed.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = S \begin{bmatrix} r_{11} & r_{21} & r_{31} \\ r_{12} & r_{22} & r_{23} \\ r_{13} & r_{23} & r_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} \quad (1)$$

Based on aforementioned description, the flow chart is drawn in Figure 5.

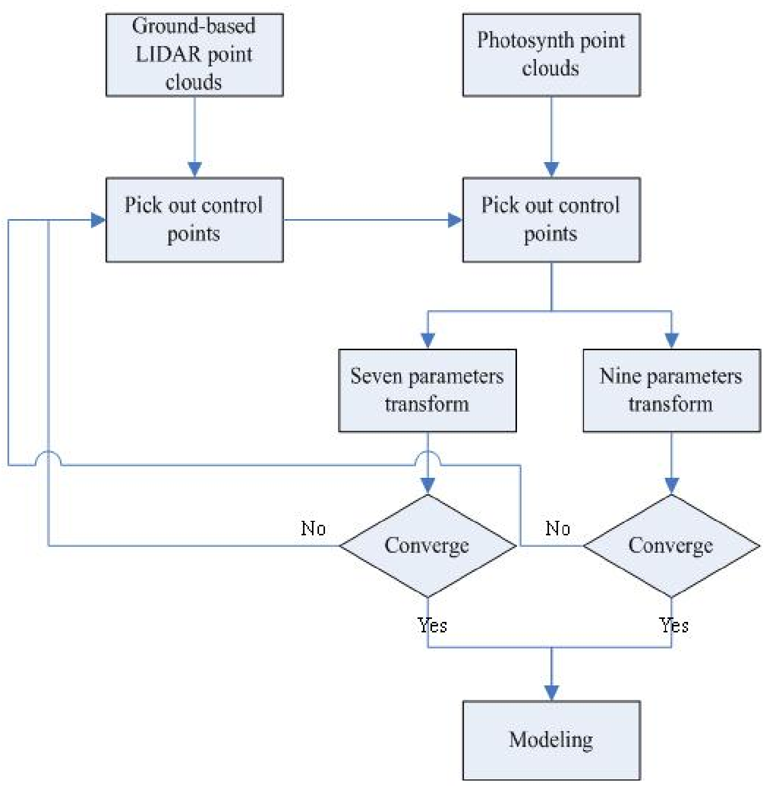


Figure 5: The research flow chart

4 RESULTS AND ANALYSIS

4.1 Results

Eight control points were picked out for executing transformation. The control points were shown in Figure 6, and indicated with letter A to H. They need to disperse in three axes equally, and the conjugate points had to be found in ground-based LiDAR data. For decreasing the number of the control points, the research tried to delete points gradually based on the variance of them. That is, the point which had biggest variance would be deleted first, and so on. In the end, there were only three points (A, E, and G) could be reserved in seven-parameter transform. Furthermore, there were four points (A, E, G, and H) which were retained in nine-parameter transform, because of redundant was necessary. The operation results were shown in Table 1.

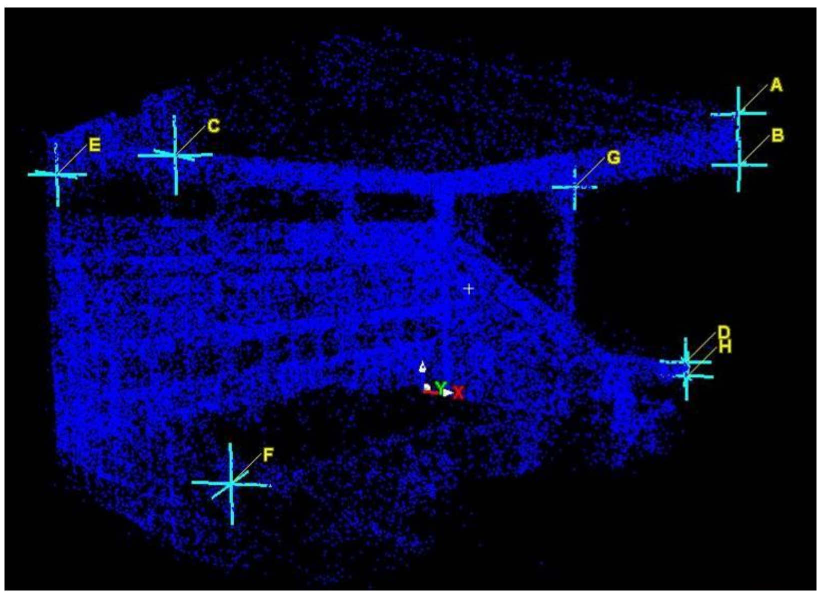


Figure 6: The distribution of control points

Table 1: The results of two transformations

	Seven-parameter		Nine-parameter	
Number of control points	8	3	8	4
Standard deviation of unit weight (m)	0.130	0.067	0.127	0.048
Degree of freedom	17	2	15	3

Table 2 showed the variances of ultimate control points, and the symbol, V_P, was computed by equation 2.

$$V_P = \sqrt{{V_x}^2 + {V_y}^2 + {V_z}^2} \qquad (2)$$

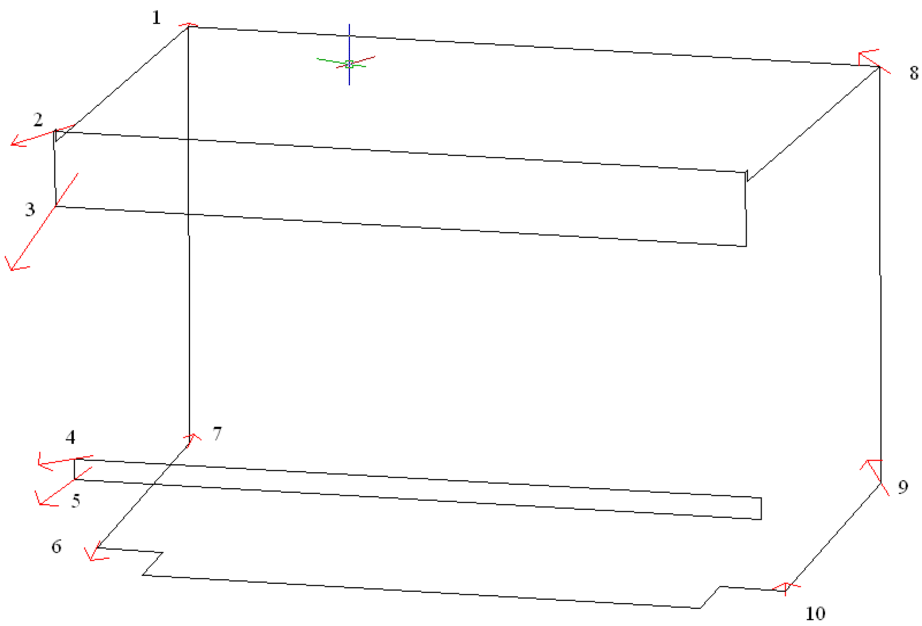
Table 2: The variances of control points (Unit: m)

	Seven-parameter				Nine-parameter			
	V_x	V_y	V_z	V_P	V_x	V_y	V_z	V_P
A	0.007	0.054	0.035	0.065	-0.019	0.039	0.004	0.044
E	0.000	-0.034	-0.054	0.064	0.014	-0.036	-0.036	0.053
G	-0.007	-0.019	0.019	0.028	0.000	0.019	-0.004	0.019
H					0.006	-0.022	0.036	0.043

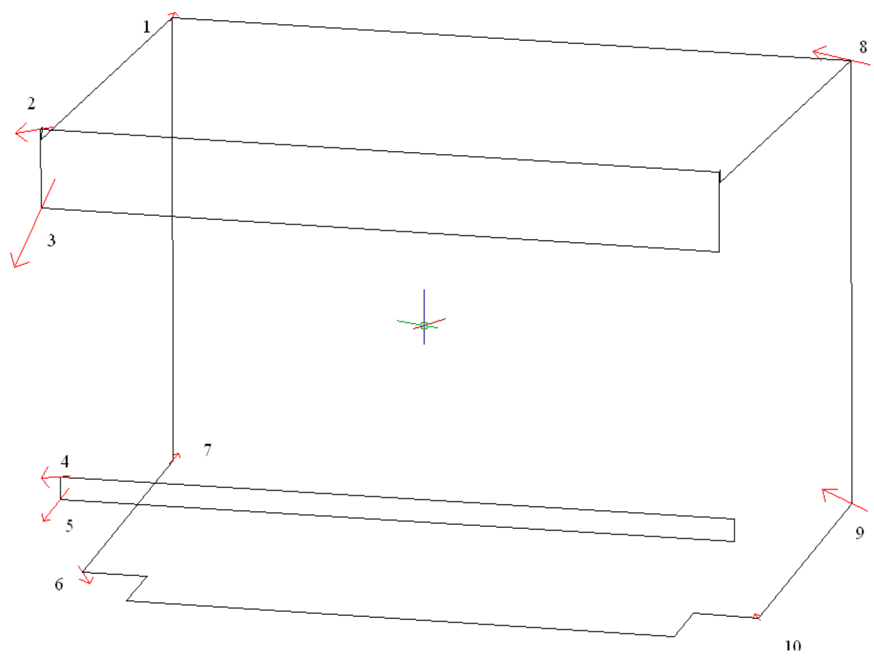
To verify the accuracy, the research chosen ten check points to calculate RMSE (Root Mean Square Error) of these two transform methods with different amount of control points. These check points were surveyed in field, and the computation results were shown in Table 3. The letter, ΔP stands for the difference between field survey data and seven-parameter or nine-parameter transformation data. The distribution and errors of two methods (ΔP) were shown in Figure 7. For the clear reorganization, this research enlarged the errors three times. The head of each arrow stood for the correct direction of each check point.

Table 3: Calculation results of check points (Unit: m)

	Seven-parameter								Nine-parameter							
	8 control points				3 control points				8 control points				4 control points			
	ΔX	ΔY	ΔZ	ΔP	ΔX	ΔY	ΔZ	ΔP	ΔX	ΔY	ΔZ	ΔP	ΔX	ΔY	ΔZ	ΔP
1	-0.051	0.082	-0.145	0.174	-0.024	0.002	-0.039	0.046	-0.094	0.140	-0.195	0.258	0.003	0.044	-0.069	0.082
2	0.743	0.033	0.011	0.744	0.770	-0.024	-0.003	0.770	0.790	0.061	-0.078	0.796	0.379	-0.073	-0.021	0.387
3	0.677	-0.049	0.654	0.943	0.715	-0.102	0.642	0.966	0.726	-0.021	0.587	0.934	0.322	-0.151	0.631	0.724
4	0.533	-0.001	-0.075	0.538	0.634	-0.035	-0.061	0.638	0.582	0.032	-0.006	0.583	0.279	-0.072	-0.034	0.290
5	0.462	-0.030	0.178	0.496	0.565	-0.064	0.191	0.600	0.512	0.002	0.252	0.571	0.208	-0.101	0.221	0.320
6	0.190	0.179	0.030	0.263	0.312	0.148	0.067	0.352	0.229	0.217	0.151	0.350	0.014	0.126	0.106	0.165
7	-0.193	0.074	-0.225	0.306	-0.044	0.039	-0.106	0.121	-0.204	0.140	-0.089	0.263	-0.053	0.074	-0.076	0.119
8	0.398	0.062	-0.377	0.552	0.392	-0.004	-0.252	0.466	0.308	0.060	-0.416	0.521	0.834	0.081	-0.295	0.888
9	0.083	-0.049	-0.446	0.456	0.167	-0.084	-0.306	0.359	0.006	-0.050	-0.297	0.301	0.583	0.001	-0.291	0.652
10	0.056	0.128	-0.199	0.243	0.147	0.112	-0.150	0.238	0.051	0.106	-0.067	0.135	0.233	0.127	-0.122	0.292
RMSE	±0.524				±0.533				±0.530				±0.470			



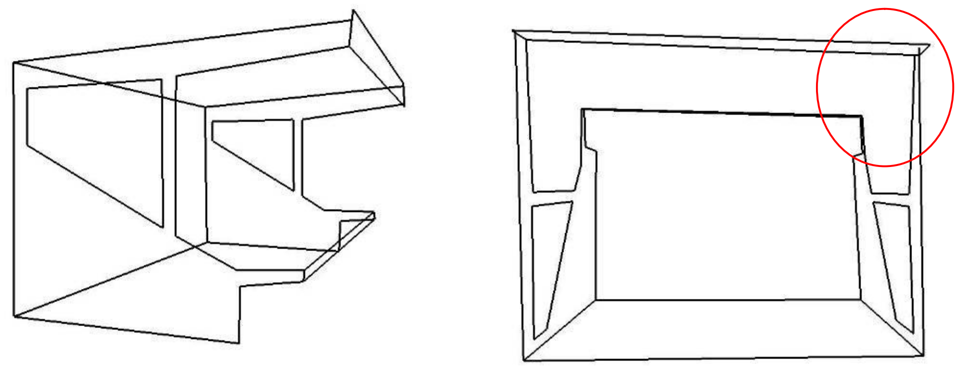
(a) Seven-parameter transformation



(b) Nine-parameter transformation

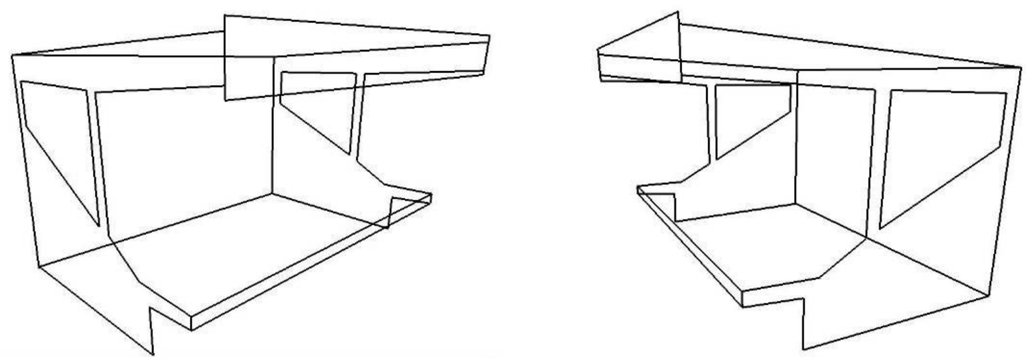
Figure 7: Distribution and errors of check points

In the end, this research tried to reconstruct a model of the grandstand. In order to show the difference, this research adopted Photosynth data first. Then, ground-based LiDAR data was added. The results of the former was shown in Figure 8, the other was shown in Figure 9.



(a) Left (b) Up

Figure 8: The model reconstructed by Photosynth data



(a) Left (b) Right

Figure 9: The model reconstructed by Photosynth and LiDAR data

4.2 Analysis

In Table 1, the results of standard deviation of unit weight show that nine-parameter transformation has higher accuracy than seven-parameter transformation has. In Table 2, the variances of control points in y-axis were higher than the others. Furthermore, in Table 3, when the control points were appropriate, nine-parameter transformation also showed higher accuracy than the other one. But the difference between these two methods wasn't obvious, that is, the accuracy of nine-parameter transformation didn't show significant improvement on this case.

In Table 3, check points which had higher error were in the left side. One could notice that the difference at point 3 was the highest (close to 1 m). That might because of the tree which was growing in the corner (shown as Figure 10) affect the results generated by Photosynth. For the same reason, the model reconstructed by the Photosynth data show a bias in the left side (shown as the red circle in Figure 8(b)). However, data generated by LiDAR could fix the situation. That's also the advantage of combining multi-source data.

Figure 10: The left corner of the grand stand

5 CONCLUSION AND RECOMMENDATION

Based on the experiment results, some conclusions and recommendations can be summarized as below.

A. Point clouds generated by Photosynth were good for reconstructing a three dimensional model. It could save much time than what field surveying can do.
B. 3 to 4 control points were enough to do a three coordinate transformation. Furthermore, improving the distribution of control points should increase the accuracy efficiently.
C. Although scales in different axes was disparity, but seven-parameter transformation was good enough in this case.
D. If Photosynth data had already registered by sufficient control points, and the error was acceptable, Photosynth data can be good enough for reconstruction.
E. Different view of photographs could offer more information of the object. For example, if there were images taken in a higher place, one could get some roof coordinates. So more pictures would be more helpful.
F. More check points should be used for evaluating the accuracy; it would be helpful to find out the precise distribution of errors.

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