Experiment of accuracy of DLT method

Experiment of the accuracy of space points reconstruction using DLT method.

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Abstract— *This study compares the input values of area coordinates with the results of space point reconstruction. We used changes of area coordinates and evaluated the changes to DLT coefficients. We tried to find the distances between calibrated and reconstructed points in the space. To find the minimum of this space distance is the main problem of the reconstruction. We tried to take control of input area coordinates and evaluate the space position of the point of reconstruction.*

Keywords-DLT method, 3D reconstruction, stereo photogrammetric system, stereo cameras.

I. INTRODUCTION

DLT method is one of the classical procedures which apply space points calculation from image coordinates. The method is based on corresponding points which are visible from two or more cameras with area coordinates $[x_1, y_1]$; $[x_2, y_2]$; $[x_n, y_n]$. The reconstruction is based on procedure when the 3D point's coordinates in space are known. We can calculate coefficients of transformation by these area coordinates. The coefficients of transformation are called DLT coefficients (Direct Linear Transformation). By using these transformation coefficients we can calculate space coordinates of the arbitrary point which is visible in the calibrated space. The calibration of space is the first step of the procedure. We have to register area coordinates of calibrating points from every camera view. $[x_1, y_1]$; $[x_2, y_2]$; $[x_n, y_n]$. These values are the input parameters for the DLT coefficients calculation. We can calculate the space coordinates [x,y,z] of every visible point by the registration of the area coordinates of this point and by help of DLT transformation coefficients. There are two critical registrations of the area coordinates in this procedure. The first one is during the space calibration and the second one is as the input for the space coordinates calculation. Both of these registrations are very important and our priority is maximum precision during these steps.

II. METHOD

We selected DLT algorithm with 11 transformation coefficients. We selected MATLAB software as the programming environment and tool for the calculations. The picture from every camera was digitalized to frame 720 x 576 pixels. Digital zoom was applied to every frame and the area coordinates were formatted with four positions behind the decimal separator.

III. RESULTS

A. Experiment 1: Relationship between changes of the area coordinates point's position and changes of the coefficients DLT.

The first step of this experiment was the area coordinates registration of the calibrating points. We calculated the DLT coefficients from these coordinates in the next step. We introduced noise artificially to represent managed changes of the area coordinates. According to the changes of the area coordinates we can observe the changes of DLT coefficients. The area coordinates from every view and the DLT coefficients are the input values for calculation of the space coordination of the reconstructed point. There are real distances between the original space position and the new position which we calculated by help of DLT coefficients. These controlled changes of input values show how the quality of registration of the area coordinates depends on the precision space point reconstruction.

TABLE I. CHANGES OF 11 DLT COEFFICIENTS WITH CONSTANT CHANGES OF AREA COORDINATES

	Change of camera coordinates [absolute value]				
DLT coefficient	***0***	***0.01***	***0.05***	***0.1***	***0.5***
1	1.0795	1.0795	1.0794	1.0795	1.0789
2	-0.0049	-0.0049	-0.0049	-0.0049	-0.0050
3	1.2938	1.2938	1.2939	1.2939	1.2944
4	73.5994	73.6094	73.6494	73.6964	74.0994
5	-0.0131	-0.0132	-0.0132	-0.0133	-0.0137
6	-1.6567	-1.6567	-1.6567	-1.6567	-1.6568
7	-0.0591	-0.0591	-0.0590	-0.0590	-0.0585
8	235.0576	235.0676	235.1076	235.1576	235.5676
9	-0.0012	-0.0012	-0.0012	-0.0012	-0.0012
10	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
11	0.0013	0.0013	0.0013	0.0013	0.0013

	Change of camera coordinates [absolute value]				
DLT coefficient	***1***	***2***	***3***	***4***	***5***
1	1.0783	1.0772	1.0760	1.0749	1.0737
2	-0.0050	-0.0051	-0.0052	-0.0053	-0.0054

3	1.2951	1.2963	1.2976	1.2989	1.3002
4	74.5954	75.5994	76.5994	77.5994	78.5994
5	-0.0143	-0.0155	-0.0166	-0.0178	-0.0189
6	-1.6568	-1.6569	-1.6570	-1.6571	-1.6572
7	-0.0578	-0.0565	-0.0563	-0.0540	-0.0527
8	236.0576	237.0576	238.0576	239.0576	240.0576
9	-0.0012	-0.0012	-0.0012	-0.0012	-0.0012
10	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
11	0.0013	0.0013	0.0013	0.0013	0.0013

In Table 1 there are counted values of DLT coefficients with constant changes of area coordinates from two cameras C1 and C2. We implemented these changes from basic calculated value with steps 0.01; 0.1; 1 unit of area coordinate. We applied the noise for every camera separately due to the fact that simultaneous change of area coordinates in both views could partially disguise each change. The area coordinate is composed of two elements [x; y]. We implemented noise separately to the x – coordinate and y – coordinate from every camera view. Consequently we observed the distances between calibrated point and reconstructed point in the space.

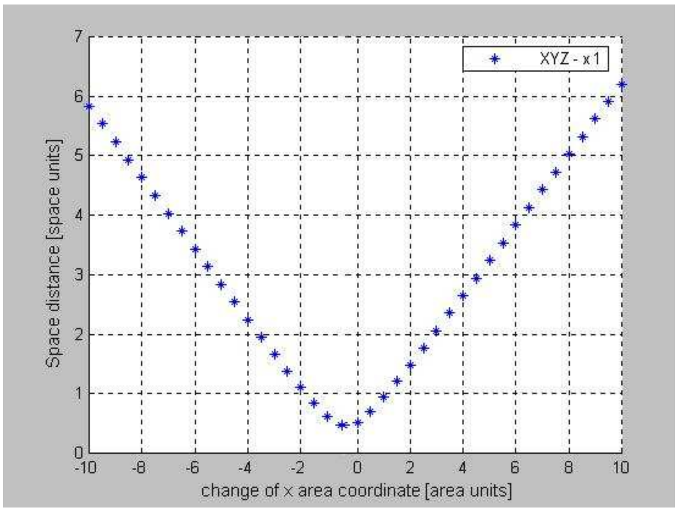

Figure 1. The changes of space distance in reference to changes of area coordinates. (View 1 – x coordinate: x1=62.42256 - 82.42256).

The changes of space distance could be called linear on both sides at Figure 1. This relation is symmetrical but the minimum is not in zero value, which represents value of calibrated coordinate. The minimum is at the nearest point from the calibrated coordinate. The nearest point represents one picture unit step to the adjacent point in the neighborhood. We expected zero distance from calibrated point in an ideal situation. It is not possible in real situation and we found minimum of this distance. Three picture unit steps on both sides in x-coordinate represent 1 unit of space error. In this case it means less than 0,01m.

B. Relation between changes of the position of area coordinates points and the position of space coordinates points.

In this experiment we used calibrating points in the space, we counted DLT transformation coefficients and than we counted the space coordinates of the selected points. The main task was to evaluate the changes of space coordinates of known point position according to managed input changes of area coordinates. We applied changes of area coordinates in x-coordinate and in y-coordinate from two views. The basic value for the experiment was the area coordinates of the reconstructed point. To this basic value of area coordinates we added 10 area units in one direction and we subtracted 10 area units in the second direction. In every step of change of area coordinate we counted new position of space coordinate and we compared this result with the original space position. We chose 0.5 as the step of iteration. We wrote down the three components of space coordinate and we evaluated influence of every component to total reconstruction error.

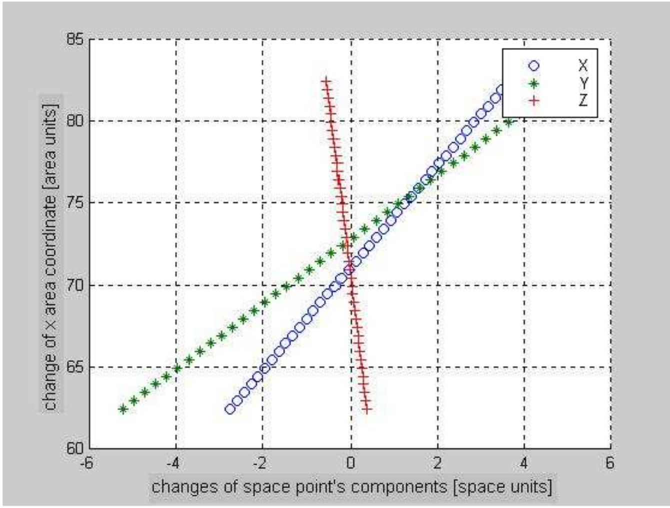

Figure 2. Changes of space point‘s components to changes of input area coordinates (View 1 – x coordinate)

There are three components of reconstructed space coordinates at Figure 2. All components cross the zero value of space coordinate, but in different value of input area coordinate. If we compare the parts of every component the dominant part has y-coordinate, minimal part has z-coordinate. Common changes of all area coordinates are at Figure 3. The most interesting part in the graph is in the neighborhood of zero value of space coordinate. The difference between minimum a maximum value of the space coordinate is 1.5 picture units in this part of the graph. On the border of the graph this difference is 0.5 picture unit only. Separately due to the fact that simultaneous change of area coordinates in both views could partially disguise each change. If we change both area coordinates simultaneously, depending on the direction of each change this will either increase or decrease the error.

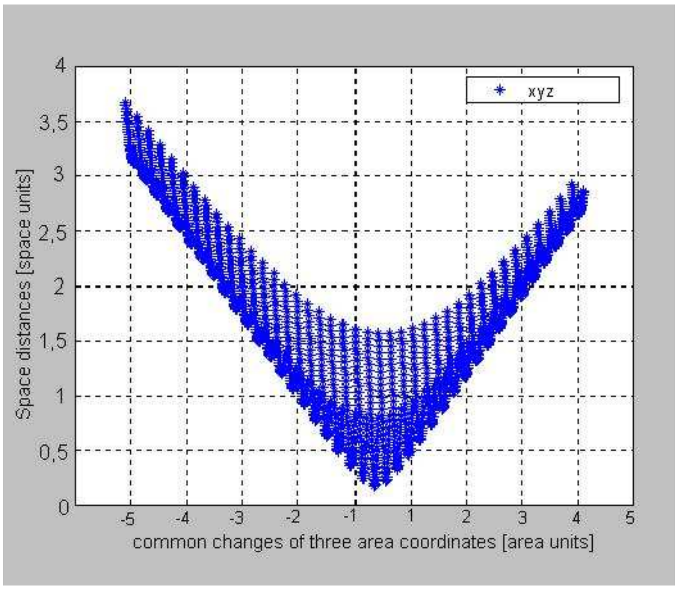

Figure 3. Common changes of all area coordinates and changes at distances between space coordinates.

CONCLUSION

Using this experiment we have shown how important is to register area coordinates with maximum accuracy $[x_1,y_1];[x_2,y_2]..[x_n,y_n]$ from every camera view. We have also shown that is possible to evaluate the accuracy of reconstruction using the difference between the area coordinates of the calibrated point and the reconstructed point. The managed introduction of artificial noise has demonstrated that this distance has in every case value above zero ($d > 0$). The main issue for interpretation is proportion between the space units as the global scale and real units in the space. It depends on large of view from every camera. For real image we have to compare the scale factor between one unit of area coordinate and space distance which we measure by help of units of calibrating space.

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