C1-4 ID18

3D IMAGE ANALYSIS WITH PAN/TILT/ZOOM AND ITS ASSESSMENT OF ACCURACY

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The purpose of this study is to realize 3D Image Analysis with Pan/Tilt/Zoom function using SIMI Motion system and to evaluate the accuracy of 3D coordinate data. The results show that in the same Cartesian reference system, the change of the spatial absolute coordinates measured by laser theodolite and 3D image analysis is averaged over 24 points 0.018 m ± 0.003 m, and the relative error of 3D image tracking analysis could be controlled under 1.0%, this accuracy of measurement can meet the need of sport technique analysis. In addition, this study introduces the whole procedure to realize 3D Image Analysis with Pan/Tilt/Zoom function, to analyze the factors influencing the accuracy of measurement, and to suggest what should be done to reduce the measurement error.

KEY WORDS: 3D coordinate, image analysis, Pan/Tilt/Zoom, accuracy.

INTRODUCTION: Obtaining 3D data via video-analysis is a common procedure in sports biomechanics, and the data outside of the calibration frame can cause significant inaccuracy using two or more fixed cameras. In order to overcome the restriction of the limited movement space, 3-D reconstructions with Pan-Tilt-Zoom technique was developed that allow cameras to be rotated around their vertical and horizontal axes. Some motion analysis systems (e.g. SIMI Motion) have Pan-Tilt-Zoom function and use the algorithm developed by Volker Drenk. This algorithm requires additional points (or reference points) in the movement space, and their 3-D coordinates have to be measured according to the system of coordinates which is defined by the calibration frame. When recording the images of moving object, two or more reference points must be visible at any time during the movement. Using Pan/Tilt/Zoom functions increase the methodological complexity.
The aim of this work is to introduce how to obtain 3D data using Pan/Tilt/Zoom cameras, to evaluate measuring error, and to discuss the factors influencing on data accuracy.

METHODS: Under the condition of laboratory, 14 reference points were distributed in the movement space, 24 fixed points (balls from A to X , in the middle of Fig.1) and the poles (shaped as L-frame, the length of each pole is 1.20 m) held by a student walking from one side of volume surrounded by reference points to other side (Fig.2) were recorded by two Pan-Tilt-Zoom DV cameras at the rate of 50 Hz. For the fixed points, their 3-D coordinates were measured and calculated with the laser theodolite (Topcon GPT-3002N) and SIMI motion system respectively, the data measured by above methods were compared to verify the reliability of data from Pan/Tilt/Zoom method. For the moving poles, their length were calculated by Pan-Tilt-Zoom method and compared with actual length to estimate the measurement accuracy.
In order to verify the relationship between the image size of object and measurement error, 2-D coordinates of L-Frame on image P'1(x1i, y1i), P'2(x2i, y2i) and P'3(x3i, y3i), i=1,2,3…..962, for digitizing points P1, P2 and P3 of Camera A and B were exported as raw data, according to the following formula:

$$Ai = \frac{1}{2}\left[x_1 i\left(y_2 i - y_3 i\right) + x_2 i\left(y_3 i - y_1 i\right) + x_3 i\left(y_1 i - y_2 i\right)\right]$$

The areas of triangles formed by L-Frame (P'1(x1i, y1i), P'2(x2i, y2i) and P'3(x3i, y3i)) were calculated, and regarded as the index to indicate the image size of objects. These areas for Camera A and B were expressed by A_L and A_R. The arrangement of test is shown in Fig. 1

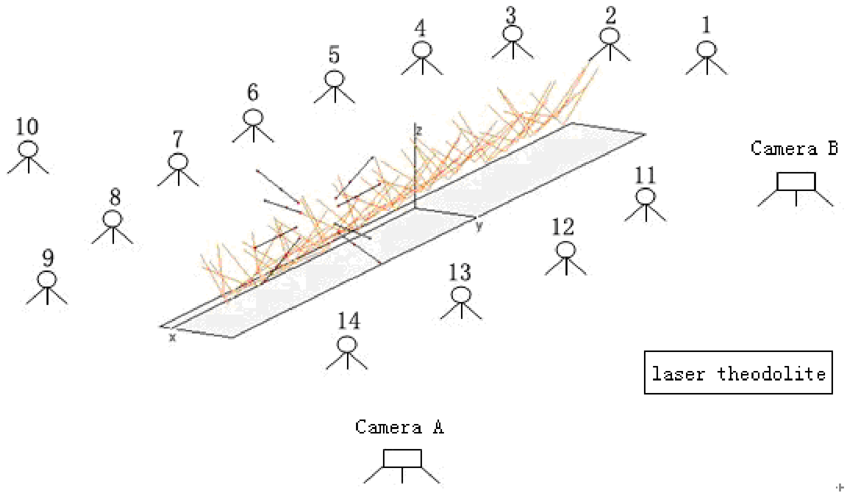

Fig.1 Diagram of the test arrangement

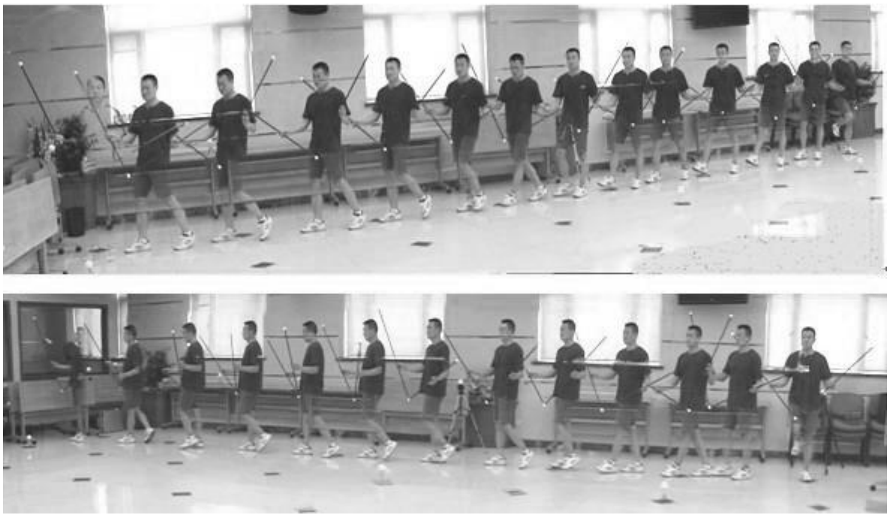

Fig.2 The images captured by camera A and B with PTZ

RESULTS: △XYZ represents the distances between the coordinates of fixed points by image analysis and that by laser theodolite. It could be known from Table 1 that the mean value of △XYZ for 24 fixed points is 0.0179 m , and the standard deviation is ±0.0028 m. It means that the accuracy of coordinates by image analysis could reach the centimeter level.

Table 1 The differences of the coordinates measured by image analysis and laser theodolite Unit: m

Name	△X	△Y	△Z	△XYZ
A	-0.0126	0.01	-0.0112	0.0196
B	-0.01	-0.0107	-0.0127	0.0194
C	-0.0105	-0.0075	-0.0098	0.0162
D	-0.0123	0.0119	-0.0116	0.0207
…	…	…	…	…
…	…	…	…	…
U	-0.0116	0.0051	-0.0134	0.0184
V	-0.0106	0.0071	-0.0081	0.0151

Name	△X	△Y	△Z	△XYZ
W	-0.009	-0.0026	-0.0117	0.0150
X	-0.0115	0.003	-0.0113	0.0164
Mean	-0.0112	0.0001	-0.0119	0.0179
Std	0.0019	0.0073	0.0023	0.0028

The lengths of the L-shaped poles, i.e. L_{12} and L_{23}, were calculated by the means of 3-D image analysis. As the actual lengths of poles are 1.2m, the measurement errors of L_{12} and L_{23} were shown in Table 2. L_{12} and L_{23} are 1.215 ± 0.011 m and 1.211 ± 0.008 m(N=962), and the average errors of L_{12} and L_{23} measured are 0.0154±0.0107 and 0.0105±0.0081 respectively.
The average errors ±1.96SE for L_{12} and L_{23} are 0.0154 ± 0.0007 m and 0.0105 ±0.0005 m, so according to statistics, it means that the absolute values of errors for over 95% measured data with a significance level of 5% are smaller than 0.0161 m and 0.0110 m, and the relative errors for L_{12} and L_{23} are 1.36% and 0.92% respectively.

Table 2 The measurement errors of L_{12} and L_{23}（N=962）

	Actual length (m)	Measured data (m)	average error± Std(m)	average errors± 1.96SE	relative Errors (%)
L_{12}	1.2	1.215 ± 0.011	0.0154 ± 0.0107	0.0154 ± 0.0007	1.36
L_{23}	1.2	1.211 ± 0.008	0.0105 ± 0.0081	0.0105 ±0.0005	0.92

The correlations between area index and measurement errors were given in Table 3.

Table 3 Correlations between A_L, A_R and measurement errors (N=962)

Correlations	*L12 Errors*	*L23 Errors*
A_L	-0.318*	-0.054
A_R	-0.522*	-0.334*

* significant, at the level p＜0.001

DISCUSSION: In this study, it was assumed that the spatial coordinates measured by laser theodolite were more accurate than the data obtained by image analysis. For the 24 points placed randomly in movement volume, their 3-D data by image analysis were closed to the data by laser theodolite, this indicates that 3-D image analysis with PTZ is reliable.
For the spatial distances, the results shows that the errors of L_{12} and L_{23} were increasing with regard to the sequence of images, as a result of it, it should be noticed that in this test Camera A kept the image size of L-shaped poles almost as same as beginning by zoomed lens, while Camera B was not so, as L-shaped poles moved far away from Camera B, the image size of L-shaped became smaller. This indicates that when capturing image with tow or more cameras, the image size captured by one camera can influence the results.
The changes of area index A_L and A_R indicates quantitatively that the image size of L-shaped poles remains almost same in the view of Camera A with PTZ, while the image size of L-shaped poles for Camera B was decreasing. As all correlation coefficients between measurement error and image size of captured object are negative, it indicated, that in positions where the object is biggest in the captured image, measurement error is the

smallest. This indicates that the videosetup needs to positioned in order to image the object of interest as big as possible in order to reduce measurement errors.
In sport, some events (e.g. high jump, triple jump) cover big movement volume, using image analysis with Pan/Tilt/Zoom 3-D kinematical data can be obtained to analyze the techniques of athletes in whole course.

CONCLUSION: Through comparing the 3-D coordinates of fixed points obtained by analysis and surveying & mapping, the data by 3-D image analysis with PTZ are reliable. In this test, the relative error could be controlled under 1.0 %. The image size of object taken by cameras is one of the important factors influencing the measurement accuracy. So in practice, the images should be filled with object filmed by cameras as much as possible, in order to improve the measurement accuracy.

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