A STUDY ON THE ACCURACY OF THREE-DIMENSIONAL SPACE RECONSTRUCTION FOR POLES SYSTEM ON A 6 x 6 m2 FIELD.

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An investigation on space reconstruction error for the poles system, which covers an area of 6 x 6 m2 field, is carried out using a three video camera system. Two sets of location for the poles are tested. The result of the RMS error shows a superiority of the positioning the control points at the corners of the court, compared to that of the sides of the court.

KEY WORDS: calibration, poles system, sports biomechanics.

INTRODUCTION: Games like badminton, sepak takraw (which is very popular in Asian countries), tennis, and volleyball, which demand the object to fall or the striking object to hit within the boundaries of a court are hard to conduct a biomechanical research. This is due to problems related to a calibration process including precise location for each camera and intersection of the optical axes of the cameras, as well as the size of the control object. There is a sturdy control object but smaller in size compare to the dimension of the court, or a large calibration structures that are difficult to carry, construct and erect. Thus a good choice of a control object is preferred, which is simple, flexible, and easy to carry around but can encompass the size of the playing court as well as needs a short time for calibration, considering the break between games is tight. Therefore, in order to perform a biomechanical analysis of such games, it needs (1) great flexibility in camera set-up for the camera positions have to accommodate the layout of the stadium, (2) a large control object with fewer control points that can encompass the size of a playing court, and (3) a short calibration process, if possible the control points should be placed at the easiest and known measured positions, for example at the corners of the court.

The most popular methods used in doing research in biomechanical analysis was introduced by Abdel-Aziz and Karara (1971). The direct linear transformation (DLT) method offered great advantages for reconstructing the location of points in three-dimensional space, especially for open games purposes. The advantages of the method are positions of the cameras are arbitrary and do not need to be measured, the optical axes of the cameras do not need to intersect, and minimum only images from two cameras are required. Meanwhile, the control object can be constructed in any form, small or large. van Gheluwe came out with a configuration that has been known as a 'Christmas tree' (Challis and Kerwin, 1992). Wood and Marshall (1986) constructed a wedge-shaped structure, Hatze (1988) built a rectangular-shaped frame, Walton (Challis and Kerwin, 1992), Chen et al. (1994) and Hinrichs and McLean (1995) used hung spheres, and Challis and Kerwin (1992) combined the work of van Gheluwe and Hatze. Yet the size of all of these structures was small compared to the dimension of the mentioned playing court. To enlarge a calibrated volume, Challis (1995) proposed a new multiphase DLT procedure using a rectangular calibration frame with a volume of 0.6 m3 to calibrate a volume six times greater, by placing the frame in eight different positions. Hinrichs and McLean (1995) suggested using the non-linear transformation (NLT) method using a single pole to build any size of control volume. They reported that the NLT approach was revealed only in comparison with the extrapolated DLT.

Numerous authors have discussed the issue of using an appropriate number of control points, in the investigation of the accuracy in space reconstructions (Challis and Kerwin, 1992; Chen et al., 1994; Wood and Marshall, 1986; Hatze, 1988; Hinrichs and McLean, 1995). Wood and Marshall (1986) found that the best result is achieved when using 30 control points (mean RMS error was 5.7 mm) as compared to 11 and 7 control points (mean RMS error were 6.1 mm and 5.7 mm, respectively). Furthermore, they reported 11 DLT parameter solutions and the right-left camera set-up produced superior result than 12 DLT parameter solutions and right-center camera set-up. Challis and Kerwin (1992) found that results from reconstruction of control points confirmed that using fewer control points produced better results. When the control points are arranged at the corners of a cuboid shape with 8 control points, the result was comparable to those arranged on the outer cuboid with 36 control points. In addition, by increasing the number of control points (8, 20, 36), the accuracy increased by a smaller amount (2.4 mm, 2.2 mm, 2.1 mm and 2.2 mm, 2.0 mm, 2.0 mm for frame A and D respectively). This was corroborated by Chen et al. (1994), who compared the configurations that occupied the whole calibration frame of 16, 20 and 24 control point groups and demonstrated that each group produced much similar results. They recommended on using 16-20 control points for better calibration accuracy by the DLT method. On the other hand, Hinrichs and McLean (1995) stated that using 40-60 control points gave the most accurate result and additional improvement beyond 60 control points may be possible.

Discussing about time constraint, which is a very significant factor in conducting open games research, none of the method mentioned above provides this advantage. Thus in this paper we propose a method using poles system which considers all the three requirements mentioned above. Therefore, the objective of this paper is to study the accuracy of poles system using the DLT method by means of three dimensional space reconstructions. Two configurations are used to effectively determine the location of control points.

METHOD: The use of a control object would provide a group of points whose x, y and z coordinates are known through the process of calibration. Thus the control object, the poles system called UM4-20, is manufactured at the Mechanical Engineering Workshop, Faculty of Engineering, University of Malaya (Rambely et al, 2002). The poles system provides a total of 20 control points, following the findings of Challis and Kerwin (1992) and Chen et al. (1994).

In the experiment, a dimension of a badminton or sepak takraw court is used, which is 6.7 m x 6.1 m x 2.1 m. For the location of the non-control points, the court is divided into nine parts with distances of 1.676 m (5.5 ft) and 1.524 m (5.0 ft) in x and y directions, respectively. The non-control points provide the unknown points in space to check the calibration accuracy.The new structure is designed so that the control points surround the space in which an activity is to take place, as recommended by Challis and Kerwin (1992). The locations of the markers in the structure are flexible, but in the experiment, they are arranged as follows: markers A - E (on pole number 1) are fixed to one edge of the structure, with point A denotes the origin, markers F - J are fixed to the other edge on pole 2, while markers K - O on pole 3 and P - T on pole 4 (Rambely et al, 2002).

Three gen-locked Panasonic WV-CP450/WV-CP454 CCTV video cameras with 8 mm lenses, color S-video and 6x zoom capabilities are used to capture the images of all points used in the experiment. The cameras are directly gen-locked using three Norita SR-50 time-code generators for video to provide shutter synchronization and identical frame rates. For each camera, the zoom lens is set so that the total volume to be calibrated is visible. Three Fumiyama CA688 portable color television monitors enable the field of view of the camera to be adjusted and observed. Video data are recorded on three Panasonic NV-SD570AM Peak-computerized and controlled videocassette recorder. The videotapes are edited using an industrial standard NTSC Panasonic AG-7350 videocassette recorder and an IBM-compatible personal computer with 256 MB RAM. The Peak Motus 2000 software is used to digitize the trials.

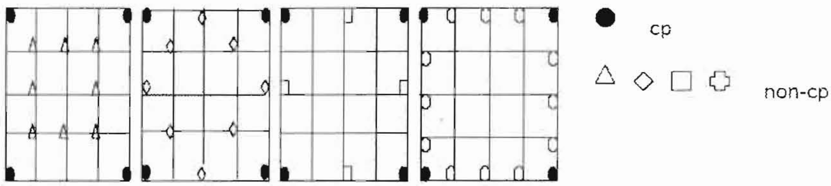
The three cameras are mounted so that the reference calibration frame position is central to the field of view. One camera (C1) was positioned with its optical axis nearly perpendicular to the court and another (C3) was placed with its optical axis approximately parallel to the court. The other camera (C2) was placed approximately 45 to the court. The position of the calibration frame was recorded at 50 Hz on videotapes. For each camera position, two subsequent frames are chosen for the digitization of the 20 control points. Each non-control point was digitized four times and the mean is used in the analysis to reduce the influence of random errors. The control points is categorized into two groups, with each group contains the same number of control points. These are as follows:

SC - standing corner, where the poles are placed at each corner of the court.
SS - standing side, where a pole is placed in the middle of two corners.

For each group of control points, additional points with known coordinates are distributed throughout the calibration space and the root mean square (RMS) error is computed from them. The RMS error is calculated from

$$RMS = \left[\sum_{i=1}^{N} \frac{(E_i - R_i)^2}{N} \right]^{1/2}$$

where Ei is the estimated value of the reconstructed of points, Ri is the known coordinates and is N the total number of reconstruction of points. For each group of control points, a group of reconstruction of points, the non-control points, is further divided into several configurations, which are as follows; A - the 40 non-control points are distributed within the calibration space, where eight poles are placed inside the court; B - the 40 non-control points are placed within and around the perimeter of the calibration space, where four poles are inside and the other four are on the sides of the court; C - the 20 non-control points are distributed only around the perimeter of the calibration space; D - same configuration as C but the number of control points is increased to 60. These configurations are shown in Figure 1.



A B C D

Figure 1: Configuration used in the experiments.

RESULTS AND DISCUSSION: The results are presented in Table 1. The RMS error shows a superiority of the positioning the control points at the corners of the court. By spreading the non-control points through out the space produces the best mean of RMS error, 2.5 mm. The accuracy of the space reconstructions decreases as the additional group of known points is moved towards the perimeter of the court. The mean RMS errors for both configuration shows that by positioning the control points at the sides of the court does not provide any advantages for the poles system. Furthermore it is easier to place the poles at the corners than the sides of the court.

Table 1 RMS errors in the spatial coordinates (values in mm).

Configurations	X	Y	Z	Mean
SC-A	0.775	3.189	3.401	2.46
SC-B	2.624	2.674	2.196	2.50
SC-C	2.700	3.896	2.233	2.94
SC-D	1.932	2.668	2.985	2.53
SS-A	2.864	2.368	4.805	3.35
SS-B	2.537	3.280	2.982	2.93
SS-C	6.25	5.49	2.152	4.63
SS-D	2.48	3.437	3.804	3.24

CONCLUSION: The study proposes on using the poles system for calibrating a very large volume, which can cover as large as 6 x 6 m2 field. The poles are easy to carry and erect during a research project especially during the open games tournament. By placing the poles at the corners of the court will cut the time need for calibration process during the competition.

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