THREE-DIMENSIONAL CINEMATOGRAPHIC ANALYSIS: ENLARGING A CALIBRATED VOLUME

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Doing research in open games requires a calibrating system as large as the size of the playing court. In this paper, a new reference structure, poles system, which could encompass the size of a playing court, is developed. Comparisons between the currently available frame and the poles systems are made. The results showed that the poles are comparable to those obtained using the Peak calibration frame, despite the difference in the dimensions of the structures, the location of the control points, as well as the physical characteristics of the structures.

KEY WORDS: calibration, calibration frame, poles system.

INTRODUCTION: Calibration is an important process in collecting data. Usually, in a laboratory experiment a subject performs a task within a prescribed area. For that the control object for calibration needs to cover the whole prescribed area or volume. This condition must be fulfilled because research has shown that extrapolation errors occurred outside the control point distribution (Wood and Marshall, 1986). Yet the size of the currently available calibration frame limits the research for motions taking place in a larger volume. For the past few years, there have been a number of researches focusing on this problem. Challis (1995) came out with a new multiphase calibration procedure. Hinrichs and McLean (1995) compared the non-linear transformation (NLT) and extrapolated direct linear transformation (DLT) methods and concluded that if the activity volume exceeded the size of available DLT control object, the NLT is superior. In a biomechanics research of open games carried out by the present authors, such as the studies on badminton during the Thomas/Uber Cup 2000, the motion took place in a very large volume (which was the size of the playing court) and the movements could take place anywhere in the playing court. Thus the calibration frame should be placed at all possible points in the court. To satisfy the condition mentioned above, the authors divided the playing court into nine equal parts (A, B, C and 1, 2, 3). The left side of the in front of the service line area is denoted as A1, the middle of that is denoted as B1 and the right side is C1. The left middle court is A2; the rear court is A3, and so on. The calibration frame was then recorded in one location after another. It took about an hour to complete the whole court. It has to be stressed that to increase the accuracy of the results, the calibrated location was done overlapping with its adjoining location. A total of 18 calibrated locations were recorded. During capturing and digitizing process a problem was identified whereby some of the movements occurred in two calibrated areas. For example, while a player was performing a backhand drive stroke he was in B2 location. Then in contact and follow through phases, parts of his body were in A2 location. Experiments were followed to solve the problem. For the specified movement, two trials were done on both calibration locations. The result indicated that location of calibration is to be chosen based on the occurrence of the movements in a location. Therefore, in the previous problem B2 was chosen. Unfortunately, the accuracy is still subjective. Thus the use of the calibration frame was found to be rather cumbersome and inaccurate for the study of movement in a large volume. This leads to a new innovative idea of a practical calibrating system, which could encompass a larger volume than that covered by the currently available frame. The first experiment was conducted at the Sports Center, University of Malaya using the currently available frame provided by the Peak Performance Technologies and a new reference structure, the survey poles (Rambely et al, submitted). The experiment was conducted to compare the result obtained using the two methods of calibration whereby the dimensions of both systems were about the same. They found that despite the difference in locating the control points, one distributed within the activity space and the other surrounding the activity space, the physical characteristics of the structures and the total number of control points, the results obtained were about the same. They concluded that it was possible for the new reference frame to be moved outside the activity space, thus to enlarge the calibrated volume. Therefore, the objective of the second experiment was to look at the accuracy of the reconstruction of points of the unknown coordinates for a large calibrated volume. The results will be compared with the result of Peak calibration frame.

METHODS: The currently available three-dimensional object space, the Peak calibration frame, is commercially available from the Peak Performance Technologies (Englewood, Colorado). It has dimensions of 2.2 m x 2.2 m x 1.6 m. The structure contains 25 known points, with 8 rods protruding from the core of the structure. The new structure, the poles system, was manufactured at the Mechanical Engineering Workshop, Faculty of Engineering, and University of Malaya. The structure, called UM4-20 provided a total of 20 control points, mimicking Frame B of Challis and Kerwin (1992). For a structure containing 25 control points, called UM5-25, another pole was located at the center of the prescribed area. The UM4-20 (or UM5-25) was constructed using four (or five) poles standing vertically with a square base of 0.15 m^2 for each pole. Each black-painted pole was made from 12 mm diameter mild steel onto which five centrally drilled white spheres, with 38 mm in diameter, were firmly fixed at 0.47 m intervals from center of one sphere to the other, vertically. The distance from the horizontal surface to the center of the first marker from the bottom is 0.22 m. The precise locations of the control points were determined by surveying the calibration frame. The dimensions of the structure, built by the four/five poles, are very flexible. It could encompass a larger volume than that of the Peak calibration frame. The structure was designed so that the control points surrounded the space in which an activity was to take place. The locations of the markers in the structure were flexible, but in the experiment, they were arranged as follows: markers A – E (on pole number 1) were fixed to one edge of the structure, with point A denoted the origin, markers F – J were fixed to the other edge on pole 2, while markers K – O on pole 3 and P – T on pole 4, Figure 1. The alphabetical labeling of the markers was done bottom to top, left to right, and front to back (clockwise). Hence marker A was always located at the left lower front (net) corner followed vertically up-wards by markers B – E. The other front edge began from the bottom with marker F, followed vertically up-wards by markers G – J, etc.

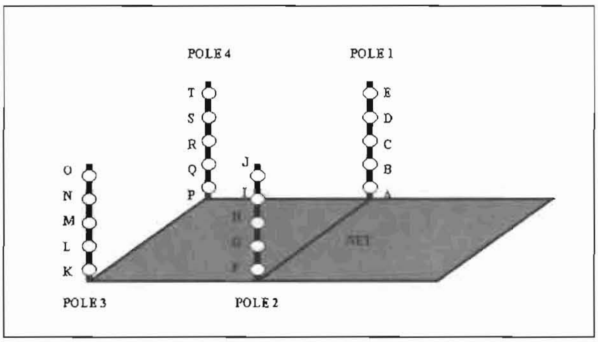

Figure 1. Location of the markers corresponding to the poles.

The experiment was done at the Sports Center, University of Malaya, to study two different dimensions of calibrated volume. The dimensions are 3.35 m x 6.1 m x 1.88 m and 6.7 m x 6.1 m x 1.88 m, which are the dimensions of the half-court and the full court of the half badminton court, as shown in Figure 2, respectively. To facilitate a direct comparison between the control Peak calibration frame and the poles calibration structure for each dimension, the position of the Peak calibration structure was recorded at the center of the half- and full-courts, points P6 and P5 respectively. Three gen-locked Panasonic WV-CP450/WV-CP454 CCTV video cameras with 8 mm lenses, color S-video and 6x zoom capabilities were used to capture the images of all points used in the experiment. The cameras were 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 was set so that the total volume to be calibrated was visible. Three Fumiyama CA688 portable color television monitors enabled the field of view of the camera to be adjusted and observed. Video data were recorded on three Panasonic NV-SD570AM Peaks–computerized and controlled videocassette recorder.

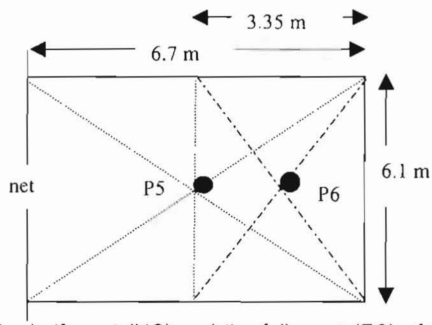

Figure 2. The dimensions of the half-court (HC) and the full court (FC) of the half badminton court, with P6 and P5 are points at the center of the respective dimension.

The videotapes were edited using an industrial standard NTSC Panasonic AG-7350 videocassette recorder and an IBM-compatible personal computer with 256 MB RAM. Included in the computer set-up were the miroVIDEO DC30 Plus Video Capture Card, On board SCSI-2 Controller and network interface connector, and a 15-in. SVGA monitor. The Peak Motus 2000 software was used to digitize the trials. Subsequent to digitizing, the raw data were smoothened using the Butterworth digital filter with the cut-off frequency of three. For the 3D space reconstruction, the DLT technique was employed. The three cameras were mounted so that the reference calibration frame position was central to the field of view. One camera (C1) was positioned with its optical axis nearly parallel to the court to obtain the front view of the calibration frame and another (C3) was placed with its optical axis approximately perpendicular to the court. The other camera (C2) was placed approximately 45° to the court. The position of the calibration frame and the poles system were recorded at 50 Hz on videotapes. For each camera position, a frame was chosen for the digitization of the control points. Each point was digitized twice and the mean was used in the analysis to reduce the influence of random errors. To assess the calibration errors of the structures, the recording of a subject holding a badminton racket performing five repetitive strokes at each point was taken. The parameter used for the comparison was the velocity of top of the racket. The average of the trials was calculated and the result of the reconstruction of points of the unknown coordinates was presented in Table 1.

RESULTS AND DISCUSSION: The result of the second experiment is presented in Table 1. From the table, it can be inferred that calibration structures of the UM5-25 and UM4-20 produced results that are about the same as that of the Peak calibration frame. However, the dimensions covered by the three calibration structures are different, as well as the physical characteristics of the systems. At points P5 and P6, the Peak calibration frame was located at exactly on the points with its specified dimensions, whereas the UM5-25 and UM4-20 covered the whole half- and full-court. At point P1, only the values obtained from UM5-25 and UM4-20 were calculated to assess other points beside the center point. Hence, it might suggest the possibility of expanding the control volume using the poles system. However, the accuracy of the reconstruction of known points has to further analyze to confirm the success of the poles system.

CONCLUSION: The results showed that the poles systems are comparable to those obtained using the Peak calibration frame, despite the difference in the dimensions of the control region, the location of the control points, as well as the physical characteristics of the structures. Furthermore the results might suggest the possibility of enlarging control volume using the poles system. However, further research has to be done to assess a true comparison between the Peak calibration frame and UM4-20 and UM5-25 systems. By using the poles system, the calibration process takes about 20 minutes to complete the whole court. This time saving factor is important in open games research as the schedule of competition are usually tight.

Table 1. The calibration result of three different calibration structures and dimensions.

	Object Space	**Maximum Velocities (m/s)**		
	Percentage Error	**P1**	**P5**	**P6**
Peak FC	1.28	-	12.53	12.14
UM5-25 FC	0.25	10.34	12.42	10.54
UM4-20 FC	0.11	10.85	12.48	10.55
Peak HC	0.70	-	12.53	12.14
UM5-25 HC	0.23	11.39	11.97	11.15
UM4-20 HC	0.16	10.55	11.72	11.85

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