A METHOD TO OBTAIN 3D KINEMATICS DATA OF WHOLE HIGH JUMP MOVEMENT

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The purpose of this study was to introduce how to use 3D image analysis with Pan/Tilt/Zoom cameras to obtain the 3D kinematical data in the event of high jump. The attempts by a chinese elite female highjumper were filmed with two cameras. In addition to control frame, the 3D coordinates of additional control points were measured by a theodolite and transformed into the same reference system. Then these parameters were used in the Motion Analysis System and in the software to level the reference system. Finally, the 3D kinematical data of whole high jump movement could be obtained for further analyzing techniques. This method can be used to analyze other sport events.

KEY WORDS: 3D kinematics data, Pan/Tilt/Zoom cameras, high jump.

INTRODUCTION: 3D image analysis was usually used to diagnose the techniques of high jump. There are some papers published using this method, but there are the following two limitations. Firstly, most of the papers only focus on the analysis and research on take-off of high hump or on the movement of the last 3 steps in run-up phase (Li, Wang & Xu, 2002; Shi,Liu & Li, 2009), that means that only some phases of high hump were researched. Secondly, another limitation was 3D image analysis without Pan/Tilt/Zoom, if the whole movement of high jump, including run-up, take-off and clearing the bar phases, were photographed, the image of athletes would be very small, and it was difficulty to digitize the images, so that the error of results through data analysis could be large. The method discussed in this paper will overcome these limitations.

METHODS: In addition to setting up the calibration frame in front of the jumping stand, 16 additional control balls were placed in the practice field, in order to ensure the whole movement of high jumper being in the calibrated area. The reference system was defined by the calibration frame, the X direction of frame coordinate system is perpendicular to the jumping stand and point to the direction of foam bag. Y direction parallels the rail and Z direction is vertical to the ground. (Fig.1).

Using a theodolite (Topco GPT-3002N) station, laptop computer and "Control Point Measurement and Coordinate Transformation Software System (CPMCTSS)" (Ai & Gui, 2011), 3D coordinates for 16 additional control balls were measured and transformed to the coordinate reference system (Tab. 1).

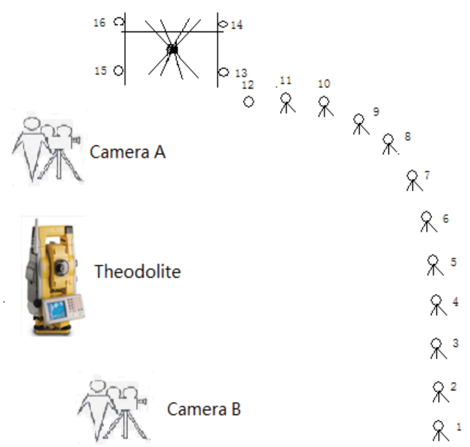

Figure 1: Diagram of the test

Table 1
The Coordinates of Control Balls in the Referecne System defined by Calibration Frame

Control Point No,	X/m	Y/m	Z/m
1	-14.042	-7.072	-0.798
2	-11.887	-7.100	-0.741
3	-9.891	-7.238	-0.692
4	-7.812	-7.262	-0.647
5	-5.650	-7.345	-0.600
6	-3.722	-7.181	-0.556
7	-1.734	-6.819	-0.509
8	-0.080	-6.010	-0.461
9	1.064	-5.057	-0.418
10	1.692	-3.644	-0.385
11	2.092	-2.442	-0.355
12	2.234	-1.443	-0.437
13	2.071	-0.432	-0.020
14	2.085	-0.445	1.712
15	2.151	3.675	0.501
16	2.168	3.660	1.764

Two Pan/Tilt/Zoom cameras (25 FPS) were used to film two attempts of bar height 1.85m (one succeed and one failed) by Chinese woman high jumper ZHENG Xingjuan, and at least 2 among 16 additional control balls were visible in each image taken by two cameras. The motion images were digitized by SIMI° Motion 3D system with the function of Pan/Tilt/Zoom. The data were smoothed by the low-pass filter with cut-off frequency 6Hz, and the Hanavan model was used to calculate the center of gravity (COG) .

It was obviously from the data in Tab.1 that the XOY plane of the reference system did not parallel to the horizontal plane, Using "Control Point Measurement and Coordinate Transformation Software System" the parameter of leveling was calculated, by rotating 0.962° clockwise around the Y Axis of the XOY plane of reference system, the XOY plane of reference system could be made parallel to the horizontal plane.

RESULTS AND DISCUSSION: The 3D data obtained were the coordinates in the reference system defined by the calibration frame, it was needed that the reference system should be translated or rotated properly to describe the movement of high jumper actually.
In this test, the coordinates of the center of the control ball (12) put on the ground in the frame coordinate system are (2.234 , -1.443 , -0.437) (refer to Tab. 1) and the radius of the ball is 0.035m. The coordinate of base in the right jumping stand in XOY plane is (2.15 , -0.31), so the original point of reference system was translated to (2.15,-0.31,-0.47), and then a new coordinate reference system with respect to the right base of jumping stand was created.

Fig. 2 represents the height changes of the athlete COG to the ground during her movement before and after (the solid and dashed lines) the leveling the reference system respectively. It was clear that the curve of COG after leveling could describe the actual movement of high jumper, so it reminds us that when making 3D motion analysis in large range, the leveling of the reference system is the necessary step to carry out, otherwise the data obtained could not describe the movement objectively.

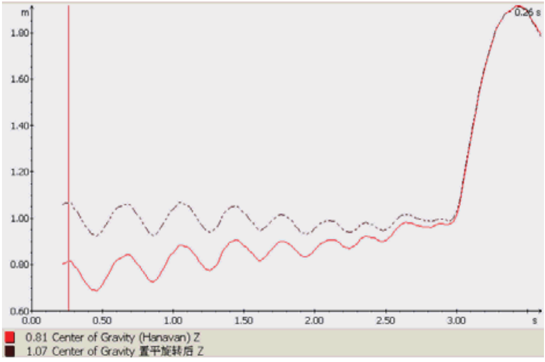

Figure 2: The comparison of COG heights before and after levelling the reference system

After the translation and leveling of reference system, the 3D kinematic data (such as step lengths, height and velocities of COG, angles of body segments) could be calculated to analyze the techniques of high jumper. Fig.3 is the stick figures of the successful trial jump of ZHENG Xingjuan using 3D image analysis with Pan/Tilt/Zoom, it covers the whole course from the beginning of run-up to the clearance of the bar.

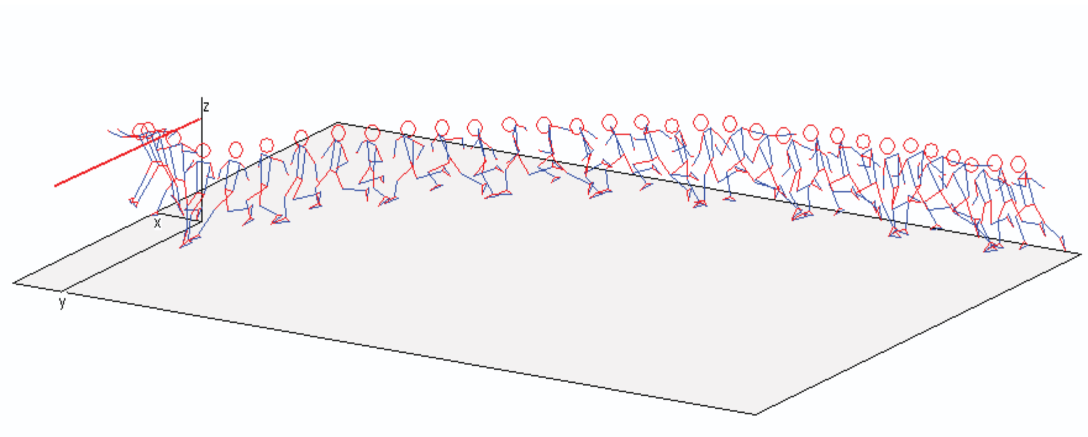

Figure 3: The stick figures of high jumper

In this study, the 3D data of the whole high jump movements (run-up, take-off and clearing the bar) were obtained, and then based on them, other kinematical parameters, such as distances, velocities and angles of joints or segments could be calculated for further research.

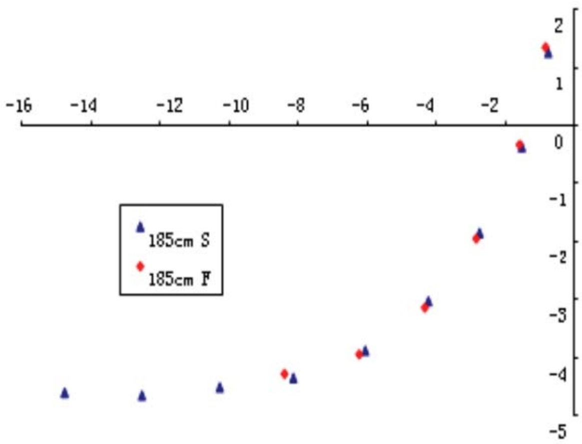

Figure 4: The locations of each step in run-up phase (Unit: m)

As a example, Fig. 4 is the topview of the locations of each step in the run-up phase for the 8 steps of the succeed trial and the 5 steps of the failed trial (185cm). Under the new reference system, the data shown in Fig. 4 are relative to the jumping stand, so that the radius of run-up curve could be calculated, and it is easy for coaches to evaluate the techniques of high jumper.

3D Image Analysis with Pan/Tilt/Zoom cameras is one of the methods to capture movements in large space, its relative error of 3D image tracking analysis could be controlled under 1.0% (Ai, 2013). The reference system normally is defined by the calibration frame , which is set up manually, so that the directions of X,Y and Z axis are not as expected . In practice, it is important to make use of transformation of coordinate translation and rotation, otherwise the coordinates in such reference system could not describ the actual movement. For this purpose, CPMCTSS was designed and developed for adjustment of reference system. The method mentioned in this paper can also used in other sport events, like triplejump and pole vault mainly in horizental motion or like diving and trampolin mainly in vertical motion, in order to get the 3D date of the whole mevements for these events.

CONCLUSION: As a research method discussed in this paper, 3D image analysis with Pan/Tilt/Zoom cameras could be used to record and analyze the movements of sport in the large range, and kinematic data covering the complete motion process could be obtained. The leveling of reference system is the key procedure in 3D image analysis with Pan/Tilt/Zoom, it can ensure that the 3D kinematic data can describe the motion process objectively. The parameters, such as step length and frequency, the locations of each step, and others deduced from 3D data could be used in the later research of high jump techniques.

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