Video Based Distance Measurement for Jump Events

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Abstract: In this paper, a novel video distance measurement system was developed to measure performance in jump events. The system contains camera calibration, video recording, distance measurement and results management. It's based on a video recording system comprised of two high resolution cameras. The cameras are specially calibrated by the markers fixed alongside the landing area. The performance of each jump can be measured immediately after landing of the athletes by placing a cursor line on the leading edge of the break made by the athlete. Distance data, landing pictures as well as landing sequence can be exported. After tested the proposed technique and device in many national events and paralleled the results with electronic distance measuring apparatus, satisfactory results have been obtained. The designed device gains considerable advantages in measuring accuracy, efficiency and re-judgment compared with traditional equipments using spike such as steel measuring tapes and electronic distance measuring apparatus.

1. Introduction

Distance measurement is one of the most important tasks for judges in jump events. The methods to measure jump performance are developed with advanced science and technology. The devices covered by these methods include steel measuring tapes and electronic distance measuring apparatus (EDM) [1]. Nowadays, due to the low cost and simple operation, steel measuring tapes are still used for measuring distance or checking the accuracy of fibreglass tapes and subsidiary measuring devices in the field events. Meanwhile, the unavoidable deformation of the steel ruler and linear ship while pulling magnify the error of steel measuring tapes. Afterwards, the application of EDM or laser rangefinder improved the accuracy of distance measurement which uses a laser beam to determine the distance to an object. The most common form of laser rangefinder operates on the time of flight principle by sending a laser pulse in a narrow beam towards the object and measuring the time taken by the pulse to be reflected off the target and returned to the sender, where triangulation or other techniques are often used.

In order to obtain the linear performance for each jump trail, a spike must be placed at the nearest break left by the athletes while traditional measuring devices are employed. First, the spike inserted into the sand may destroy the line of the break for which the judge normally put the spike behind the border of the break. In this way, it is possible to have a radius' difference of spike. In the actual measurement, the difference may reach 2 cm when the spike inserted into the sand is inclined, especially while the spike tilt towards the jump direction, the distance difference may be:

$$\Delta D = L sin\ \alpha \qquad (1)$$

Where L is the length between measuring point (the centre of prism or the attaching position of steel) and the inserted point if the break on sand. a is the inclined angle between spike and vertical line. Another flaw of traditional devices is it may be difficult to judge while argument happen as the break on the sand was destroyed and the break may be levelled.

As the technology of machine vision developed, we might retrieve the information of 3 dimension (3D) object from 2D graph by using the computer. This information includes shape, location, feature

and movement by which reconstruction and recognition can be employed, such as obstacle avoidance in robot navigation [2] and visual inspection for quality control [3]. The research demonstrated that the measuring accuracy has reached 0.02 pixels [4]. Therefore, to develop a novel video distance measurement system (VDM) based on the machine vision technology may solve the problem of classical devices.

The paper is divided into the following sections: section 2 describes the algorithm for camera calibration procedure and is composed of pinhole model and nonlinear model; Section 3 explains the hardware components and pre-work of the VDM; Section 4 is composed of four sub-section dealing with distance measurement procedure; Section 5 presents the comparison between VDM and EDM measuring results.

2. Camera Calibration

Camera calibration is the process to determine the internal camera geometric and optical characteristics (intrinsic parameters) and/or the 3D position and orientation of the camera frame relative to the real world coordinate system (extrinsic parameters). The purpose of the calibration is to establish a relationship between 3D points from the real world and 2D points from the image in computer [5]. Calibration is essential when metric information is required. Precise calibration is the first step towards the measurement of distance in the real world from its projections on the image plane.
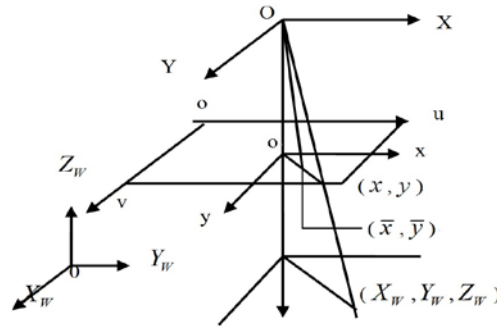

Fig. 1. Pinhole model with perspective projection and radial lens distortion.

2.1 Pinhole Model

The pinhole model is the most common model for calibration procedure [6]. A perspective projection with pinhole camera geometry is used to give the relationship of 3D world points and 2D image points. Three coordinates are established: world coordinates (X_W,Y_W,Z_W); camera coordinates(X,Y); image coordinates(x,y), in the image coordinate, pixels coordinates(u,v), as show in *Fig.1*.

The relation between a point $p(X_W,Y_W,Z_W)$ in the world coordinate and its projection point(u,v) in the image coordinate is described as:

$$Z_c\begin{bmatrix}u\\v\\1\end{bmatrix}=\begin{bmatrix}\alpha_x & 0 & u_0 & 0\\0 & \alpha_y & v_0 & 0\\0 & & 1 & 0\end{bmatrix}\begin{bmatrix}R & T\\0^T & 1\end{bmatrix}\begin{bmatrix}X_W\\Y_W\\Z_W\\1\end{bmatrix}=M_1M_2X_W=MX_W=\begin{bmatrix}m_{11} & m_{12} & m_{13} & m_{14}\\m_{21} & m_{22} & m_{23} & m_{24}\\m_{31} & m_{32} & m_{33} & m_{34}\end{bmatrix}\begin{bmatrix}X_W\\Y_W\\Z_W\\1\end{bmatrix}$$

(2)

The parameters before coordinate are metric transformation parameters. The R and T are calibration parameters rotation matrix and transform vector respectively. Through this transform, world coordinates is explained in image coordinates.

2.2 Nonlinear Model

Take into account the intrinsic camera parameters and modelling lens distortion. Three types of distortion are considered (radial distortion, decent distortion and thin prism distortion.)[7,8]. The

coordinate must be replaced as:

$$\overline{x} = x + \sigma_x(x, y); \overline{y} = y + \sigma_y(x, y) \tag{3}$$

σ_x and σ_y are the distortion errors in the x and y direction respectively with detailed form:

$$\sigma_x(x, y) = k_1 x(x^2 + y^2) + [p_1(3x^2 + y^2 + 2p_2 xy)] + s_1(x^2 + y^2)$$
$$\sigma_y(x, y) = k_2 x(x^2 + y^2) + [p_2(3x^2 + y^2 + 2p_1 xy)] + s_2(x^2 + y^2) \tag{4}$$

The distortion errors comprised of radial distortion, decent distortion and thin prism distortion as presented in the formula. k1, k2, p1, p2, s1, s2 are the nonlinear parameters. In the proposed calibration procedure, only the radial distortion is considered as it is the most relevant distortion generated by the lens.

3. Components and Pre-Work

3.1 Markers for Calibration

Some markers are put alongside the landing area before calibration (10-12 markers in total, 5-6 for left side and 5-6 for right side, *Fig.2*). The markers are fixed to the ground so that they can stay at the same place from the calibration to the end of the events. The position where markers located is near the sandpit by which the camera can take all the markers. Additionally, points on the markers for calibrating must be clean and clear. The coordinates of the markers in three dimensions are measured by the EDM and recorded for VDM calibration. After identifying the calibrating points of markers with two cameras respectively, the VDM calculates the intrinsic parameters and extrinsic parameters of the cameras automatically.
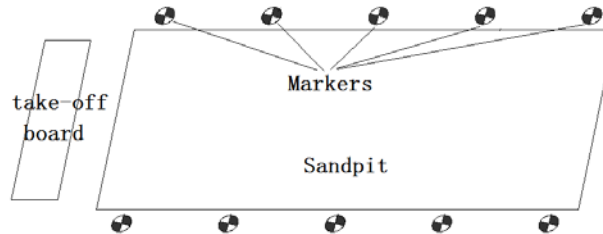

Fig. 2. Markers positioning.

Fig. 3. Two camera positioning.

3.2 Camera Positioning

The landing area is scanned with high horizontal and vertical resolution by two cameras located outside of the in-field in the position where they have an uninterrupted view of the landing areas (show in *Fig.3*). The cameras covered completely both the landing area and the calibrating markers. Normally, the distance between cameras and the landing area is about 5～50m. Cameras should be

positioned stable as any shake on the camera might influence the calibration results directly. As the focal length is fixed, the size of the landing picture on the screen is determined by the height of the camera and its shooting angle. The higher the distance of the camera to the landing zone, the lower the optic distortion generated by the lens and camera.

Fig. 4. EDM measurements of markers.

4. Distance Measurement

A series of precise calibration processes before the event ensure the equipment is operating and measuring correctly. Check measuring difference before and after each competition by comparing against currently used EDM equipment or steel measuring tape. After placing the spike, the VDM and EDM may perform the measurements with both systems. To have a thorough comparison between the two system, it is important to read the data without conversion, that is in 1/1000 m. The reference point for checking in the VDM system is the point passing by the central axis of the spike.

4.1 Data Recording

For each attempt, the cameras take a series of images of the athletes' jump and landing points. The time to record the picture of a jump trial is different since the spike may be used or removed. In case of spike inserting, the record procedure may start immediately after the spike placed. Because of the invasive role of the spike, the judge in the landing area inclined to put the spike further from the take-off line to avoid the modify of the breaks left by athletes, it may bring 5mm distance from the centre of the spike not considering the inclined error. Since the jump sequence is recorded in video mode and displayed on a computer screen, The VDM can distinguish the edge of the breaks easily without using spike, therefore recording of the jump trial may start immediately after take-off.

4.2 Distance Measurement

To complete the measurement, it is needed to identify the picture that shows the break left by the athlete after the jump. It is essential to record all the frames after landing to have a detailed recognition of the breaks as the measurement is done from the nearest break in the landing area made by any part of the body to the take-off line or take-off line extended.
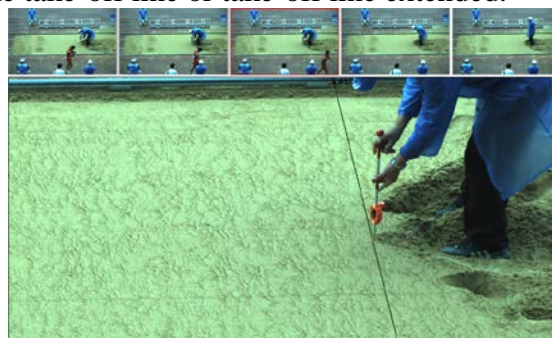

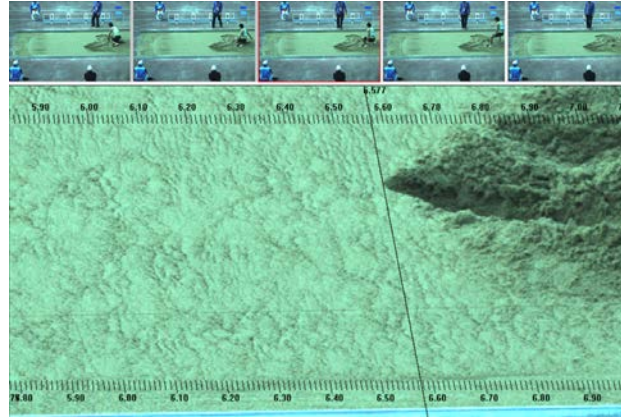Fig. 5. Operating interface of VDM with the spike

Fig. 6. Operating interface of VDM without spike.

The cursor line can be placed on the leading edge of the impression in the sand plane made by the athlete to measure the distance. The position of the cursor should be put on the exact point of the break nearer the take-off line. Zoom in the picture to obtain the detail of the break left by the athlete and compare the pictures pre and post landing to find any minimum changes of the sand plane.

Since the spike is not needed, the advantages of the VDM are presented as follows:

- the system is as accurate as the classical EDM system
- the points for measurement can be more precisely identified
- keep the shape of the breaks as no spike is used
- more faster for results issue and measurement
- the video or pictures are stored in computer in case of enquiry, protests and media share
- less people and equipment located around the landing area, better for the athletes and spectators

4.3 Accuracy Analysis

We tested the VDM in six national events and compared the measure performance with the classical EDM measure system. The results show that the record by VDM tends to be shorter than the record of EDM. Mainly, the difference between VDM and EDM is within ±3mm (>95% sample number). In many cases the large difference is due to the inclined of spike which may happen when the judge inserts the spike into the sand or releases his hand. Change the angle of the prism bar may also enlarge the difference of two systems.
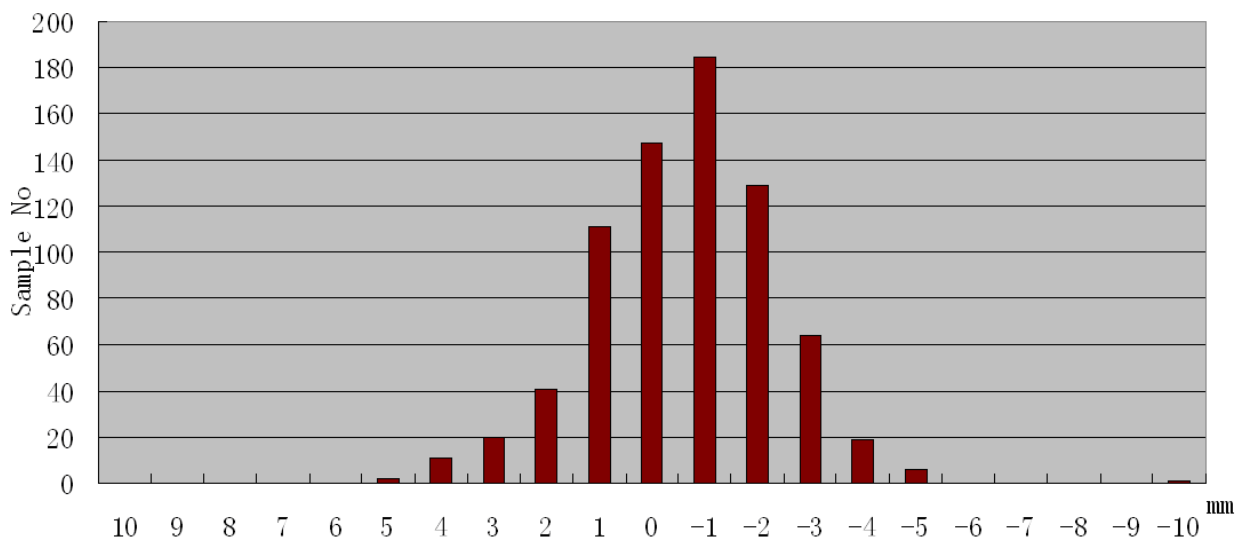

Fig. 7. Distribution of measurement difference (VDM-EDM mm) in six national events.

5. Conclusion

In this paper, we have developed a flexible new technique to measure performance in jump events. The system contains camera calibration, video recording, distance measurement and results management. Tested the proposed technique and device in many national events and compared its results with EDM, excellent results have been obtained. The designed device gains considerable advantages in measuring accuracy, efficiency and re-judgment compared with traditional equipments using spike such as steel measuring tapes and EDM apparatus.

Acknowledgment

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