Research on the Standing Long Jump Performance Evaluation System for Key Points of Human Skeletons

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ABSTRACT

The standing long jump is a commonly employed measure for assessing the strength, velocity, and coordination of teenagers. It is crucial in conducting physical fitness evaluations in numerous countries. Nevertheless, the precision and cost-efficiency of conventional assessment techniques have posed challenges. Existing methods frequently lack accuracy and might be expensive, which restricts their wider use. This work presents a mirror vision algorithm specifically developed to enhance the assessment of standing long jumps by concentrating on crucial anatomical landmarks such as the human trunk, legs, and foot. Through the examination of these critical domains, the algorithm is capable of providing enhanced precision and reliability in performance evaluations. The main aim of this research is to tackle the limitations of conventional approaches, including the problems of imprecise assessments and exorbitant expenses. The study aims to provide a more dependable and cost-effective method for assessing the athletic performance of adolescents. This approach has the potential to improve the efficacy of physical fitness evaluations, rendering them more accessible and accurate, hence enabling the formulation of better-informed training and development plans for young athletes. In conclusion, this innovation has the potential to greatly enhance the methods used for worldwide physical education and sports assessments.

***Keywords**: Standing long jump,mirror system algorithm, assessment system, investigation, performance judgement*

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INTRODUCTION

In recent years, with the continuous development and application of computer technology and artificial intelligence technology, vision-based human motion analysis technology has received rapid development and widespread attention. In the measurement of standing long jumps, domestic and foreign researchers have conducted extensive research. Among them, a representative one is the reliability and validity study of standing long jump measurement based on RGB-D cameras proposed by Li Guomin et al., which explores the feasibility of technology application from the perspective of image acquisition. Wang Ke et al. used Kinect depth cameras to map the obtained depth data to bone images, using the minimum value of bone point

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data to the depth of the takeoff position as the long jump distance. Zhao Fengshen et al. and Shi Xiaohua et al. determine whether athletes have completed takeoff and landing by sensing whether infrared rays are obstructed and determining the landing point and long jump results.

In the field of visual computing, relevant scholars have also conducted certain research. For example, Tang Xinyu and others use human pose estimation to evaluate the rehabilitation effect of rehabilitation training. Shi Jue uses human pose estimation to detect falls in elderly people. In sports, tracking athlete postures through videos and judging athlete movements is beneficial for quantitatively analyzing the characteristics of athlete movements. A multi-person posture detector is used to estimate the athlete's posture, preventing background characters from influencing the standing long jump results.

The current research results indicate that most scholars are still making corresponding improvements in the field of infrared equipment for this project, with technological breakthroughs occurring at a relatively slow pace. However, few scholars have conducted research combining artificial intelligence and computer vision technology. Simultaneously, the imprecise recognition of background interference by infrared devices and their high cost significantly reduced the scientific nature of punishment and the economic feasibility of technical application in this sports event.

Therefore, based on previous research, this project simulates the principle of human brain visual imaging from the perspective of the brain and scientific technology and uses key points of human bones as judgment information points to design a visual recognition system for standing long jump movements. Automatically measure and generate athletic results. This study has high application value in solving physical fitness monitoring and sports competition evaluation techniques, reducing manual intervention, and improving the reliability and validity of the evaluation.

METHODOLOGY

This study is a standing long jump performance measurement method based on human posture and visual judgment. Initially, the standing long jump technique is analyzed to identify the key performance points. Firstly, by analyzing the process of standing long jump technique, identify the key points for performance evaluation. Secondly, based on the three stages of takeoff, takeoff, and landing, the system identifies five stages for data extraction, forms a closed loop for system data extraction, and ultimately generates athlete results. These 5 stages should include facial recognition, testing area, long jump status judgment, landing point edge localization, and score measurement. As shown in Figure 1.

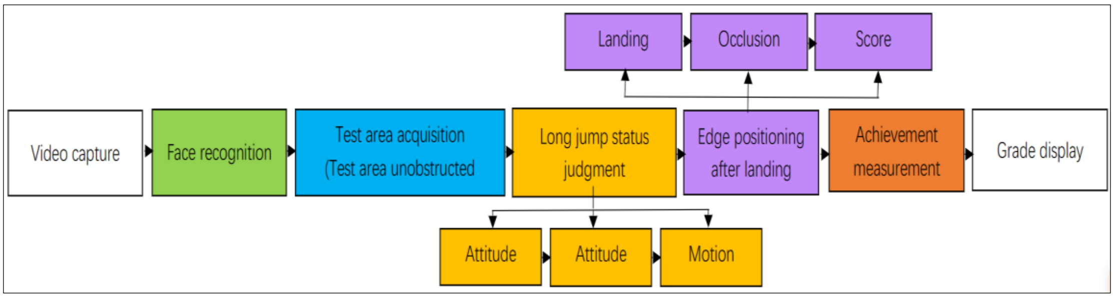

Figure 1. Design Principal Diagram

Facial recognition: Convert the original video data stream into images, then perform facial recognition on the images in chronological order. If the facial recognition is successful, proceed to the next process.

Test area extraction: Collect an unobstructed image of the standing long jump test area, segment the image, extract the test area, and use it for subsequent stages.

Long jump status judgment: Image recognition of human body position to determine whether the tester has reached the designated testing area, and if so, start the test. The system automatically inputs the posture detection network module to obtain the key points of human posture and the two-dimensional spatial coordinates of the key points of human posture. Obtain the starting frame interval, landing frame interval, and landing frame based on the two-dimensional spatial coordinates of the key points of human posture.

Landing point rear edge positioning: Determine the final landing point by continuously positioning the rear edge of the landing point. Obtain the landing point coordinates based on the landing frame, calculate the long jump distance based on the landing point coordinates and the two-dimensional spatial coordinates of the test area, and use the long jump distance as the score.

Score measurement: Determine whether the score is valid based on the starting frame interval and landing frame interval. If it is invalid, return to the facial recognition step and continue to obtain the original video data stream.

Experimental methods

This study employs experimental reasoning and mathematical model measurement verification, and the specific experimental process is as follows.

Attitude detection

Using an open-pose human pose detector to detect human posture. Select 17 human keypoint positions detected by the open pose multi-person pose detector. The posture detection box is the smallest rectangular box that contains multiple important human skeletal key points, such as the head, torso, arms, and legs. When converting the original video data stream into an image, frame-by-frame extraction is used to obtain the image. Figure 2 illustrates this.

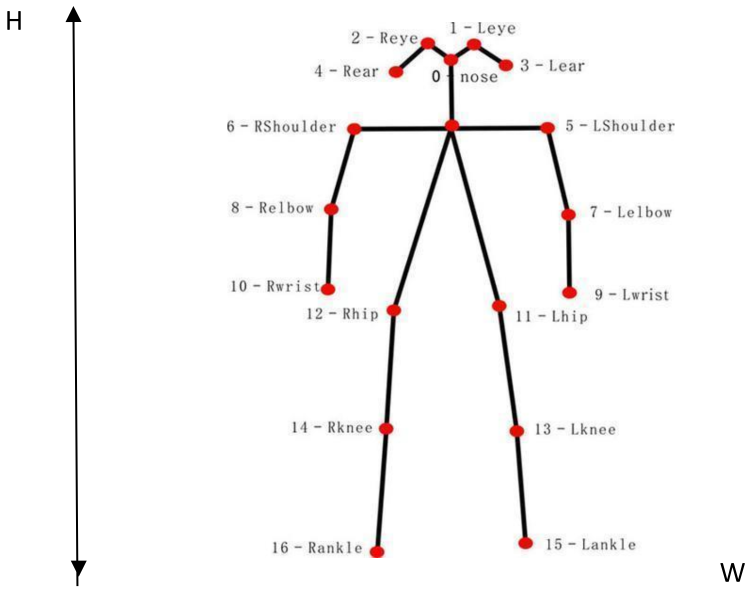

Figure 2 Example of Open Pose Key Points

Attitude Tracking and Action Judgment

Based on the coordinates of the toe key points in the posture data of the jump frame interval, determine whether the tester is behind the jump line. If so, determine whether the tester is taking off and save the d frames before taking off as the jump frame interval, recording the frame number of the jump frame. Obtain a first-level landing frame interval of length d based on the average frame difference between landing and takeoff.

Based on the trend of angle changes at key points of human posture, take the g-frame image with a decreasing trend of leg posture angle in the first level landing frame interval as the second level landing frame interval, and take the last frame of the second level landing frame interval as the landing frame. A long jump measurement method based on key points of human bones is used to determine the effectiveness of results.

In this process, if the tester falls, the vertical distance between the wrist key point coordinates and the heel key point coordinates in the posture data of the first level landing frame interval is used to determine whether they have fallen backward and to assess the effectiveness of the score. If the vertical distance between the wrist key point coordinate and the heel key point coordinate is less than the distance from the toe key point to the more critical point behind the foot, it is judged that the tester has fallen backward, and the score is invalid.

Long Jump Distance Measurement

Input each frame image of the second-level landing frame interval into the shoe target detection network model to determine whether there are shoes in the image. If so, obtain the boundary information of the shoe position box (x, y, h, w) and proceed to step 1. If not, proceed to step 2. (x, y) is the center point of the shoe position box, and h and w are the height and width of the shoe position box.

Step 1: Determine the landing point coordinates based on the y-axis coordinates of the boundary of the shoe position box and the key point on the heel.

Step 2: Determine the coordinates of the landing point based on the average heel coordinates (Xmean, Ymean) and foot length (foot_len); The average heel coordinates (Xmean, Ymean) are the average heel coordinates of all images in the second-level landing frame interval. Foot length foot_len=dist (point1, point2); Points 1 and 2 represent the coordinates of the toes and heels.

Step 3: Calculate the distance deviation and calculate the long jump distance based on the distance deviation. The long jump measurement method based on the key points of human bones is characterized by calculating the distance deviation and obtaining the long jump distance based on the distance deviation. The specific process is as follows:

(1) The parallel line that records the coordinates of the landing point and the lower boundary line of the test area is line 1, the intersection points of parallel line 1 and the starting line are p_start, the intersection point of parallel line line1, and the endpoint line is p_end.

(2) Record the intersection point between the line connecting the deviation coordinate point pair and the parallel line line 1 and use it as the deviation calculation point, $p = 0.75$. The deviation coordinate points include the coordinates of the deviation detection points located on the upper and lower edges of the testing area.

(3) Update the deviation coordinate point pairs and repeat the process (2) to obtain the deviation calculation point p1.5 and the deviation calculation point p2.25.

(4) Calculate the pixel distance dist_p0.75 from the deviation calculation point p0.75 to the intersection point p_start, dist_p1.5 from the deviation calculation point p1.5 to the intersection point p_start, and dist_p2.25 from the deviation calculation point p2.25 to the intersection point p_start.

(4) Calculate the pixel distance dist_p0.75 from the deviation calculation point p0.75 to the intersection point p_start, dist_p1.5 from the deviation calculation point p1.5 to the intersection point p_start, and dist_p2.25 from the deviation calculation point p2.25 to the intersection point p_start.

(5) Calculate the pixel distance (dist'line) from the intersection point p_start to the intersection point p_end.

Calculate the deviation and the actual distance of the error at point p=0.75. Bias=0.75=0.75 distp p p<0.75/dist'line 3.

Calculate the actual distance of the error at the deviation calculation point p1.5, bias1.5=1.5 dist_p_1.5/dist_line 3.

Calculate the actual distance of the error at the deviation calculation point p2.25, bias2.25=2.25-dist_p_2.25/dist_line 3.

(6) Calculate the pixel distance (dist.result) from the landing point to the intersection point (p_start).

Determine the range in which the pixel's distance dist_result is located. If the pixel's distance dist_result is within the range [0, dist_p-0.75], proceed to process (7).

If the pixel distance dist_result is within the range of [dist_p-0.75, dist_p-1.5], then it enters the process (8).

If the pixel distance dist_result is within the range of [dist_p1.5, dist_p2.25], then it enters the process (9).

If the pixel distance dist_result is within the interval [dist_p_2.25, dist_line], then it enters the process (10).

(7) Calculate the distance deviation, i.e.,

$$bias = (dist\_result)/(dist\_p\_0.75) * bias\_0.75$$

(8) Calculate the distance deviation, i.e.,

$$bias = (dist\_result - dist\_p\_0.75)/(dist\_p\_1.5 - dist\_p\_0.75) * bias\_1.5$$

(9) Calculate the distance deviation, i.e.,

$$bias = (dist\_result - dist\_p\_1.5)/(dist\_p\_2.25 - dist\_p\_1.5) * bias\_2.25$$

(10) Calculate the distance deviation, i.e.,

$$bias = (dist\_result - dist\_p\_2.25)/(dist\_line - dist\_p\_2.25) * bias\_line$$

(11) Determine the outcome of the long jump distance, as follows:

Result=(dist_result/dist_line) * 3-bias

The coordinates of the deviation detection points on the testing area's boundary, as well as the testing area's two-dimensional spatial coordinates, are manually demarcated using the OpenCV library. The key points of human posture include hand key points and heel key points.

RESULTS AND DISCUSSION

Experimental Conditions

According to simulation algorithms and combined with high-resolution cameras for score collection, the camera parameters are 3264 pixels x 2448 pixels, 15 frames/s. The camera is installed on a tripod on the ground with a height of 205cm. Using the nearest corner of the long jump test box as the reference, the horizontal direction is in the positive x direction with the long jump direction, and the direction perpendicular to x is in the y direction. The horizontal distance x from the standing long jump test area is 180cm, and the horizontal distance y is -5cm. Figure 3 depicts the experimental scenario.

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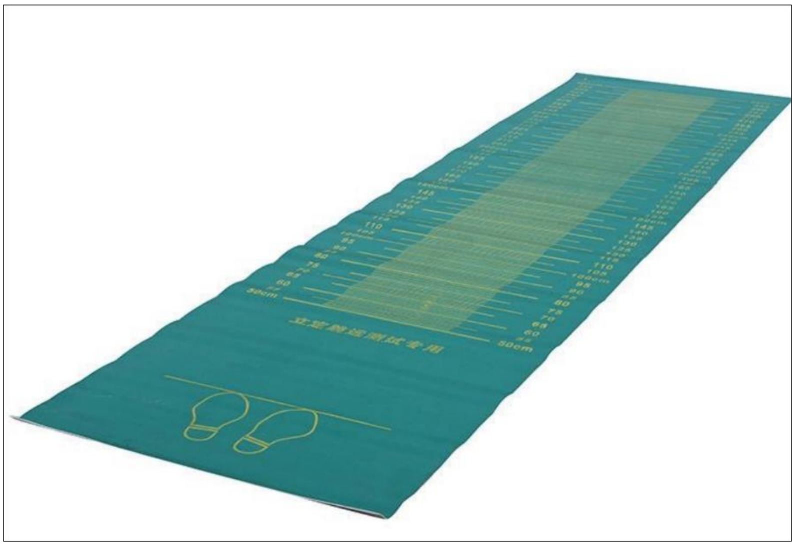

Figure 3 Standing Long Jump Floor Mat

Experimental Results

Select 50 testers for testing. For 50 testers with different heights and long jump habits, standing long jump results were measured, and 10 of them were selected as examples. The basic information is shown in Table 1.

Table 1.

Basic Information of Tested Personnel

Serial Number	Gender	Age/years	height / cm	Weight / kg
1	Male	20	176	72
2	Female	20	155	45
3	Male	22	175	70
4	Female	21	160	50
5	Female	23	162	52
6	Male	22	178	75
7	Female	22	172	59
8	Male	20	173	70
9	Male	21	176	65

10	Female	21	153	42

Table 2 displays the experimental results for the aforementioned 10 testers. The results showed that in the 50-person standing long jump test, 42 measurements had an error of less than 1cm, while the remaining 8 measurements had an error of less than 2cm, with an average absolute error of 0.501cm, which met the accuracy requirement for measuring 1cm in standing long jump exam results.

Table 2.

Measurement Results of Standing Long Jump Performance

Serial Number	Processing time / cm	Actual grades / cm	Measurement score / cm	Error / cm
1	6.08	183	182.325	-0.625
2	2.79	115	115.325	0.325
3	6.19	179	179.325	0.325
4	4.85	120	120325	0.325
5	7.68	142	141.825	-0.175
6	12.62	163	163.823	0.823
7	5.25	145	145.326	0.326
8	12.28	182	182.325	0.325
9	14.28	183	183.328	0.328
10	7.79	117	117.325	0.325

This experiment reveals that posture detection, posture tracking, and the assessment of takeoff and landing actions can achieve real-time performance. However, the landing point positioning part lacks real-time performance, and its processing time correlates with the athletes' time to stand or leave the landing point after landing. Normally, this research method can measure the final long jump result within 10 seconds after the subject completes the standing long jump.

CONCLUSIONS

Through experiments, the standing long jump performance measurement method based on human posture and visual judgment has high feasibility in actual standing long jump performance measurement. This study is more intelligent than traditional methods and can achieve unsupervised training. Compared to infrared measurement methods, this method has lower costs and is less prone to wear, meeting the requirements of practical applications. First, from a technical perspective, standing long jump tests can effectively utilize tracking strategies for key points in the human skeletal system. Secondly, the original video data stream is converted into images and facial recognition is performed on the images in chronological order, which can accurately identify the identities of the subjects and avoid confusion among them. Thirdly, the image is sent into the posture detection network module to obtain the key points of human posture and the two-dimensional spatial coordinates of the key points of human posture, achieving effective follow-up of the testing process. Fourthly, based on the human posture data in the jump frame interval, obtain the jump coordinate points, determine whether the tester is stepping on the line to jump, and determine whether the result is valid.

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