Research Article

Research and Implementation of the Sports Analysis System Based on 3D Image Technology

Hongwei Wang,1 Jie Gao,2 and Jingjing Liu3

1Capital University of Physical Education and Sports, Beijing 100191, China
2Beijing Sport University, Beijing 100084, China
3Capital Normal University High School, Beijing 100084, China

Correspondence should be addressed to Jingjing Liu; liujj524@163.com

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On the basis of existing research, this paper analyzes the algorithms and technologies of 3D image-based sports models in depth and proposes a fusion depth map in view of some of the shortcomings of the current hot spot sports model methods based on 3D images. We use the 3D space to collect the depth image, remove the background from the depth map, recover the 3D motion model from it, and then build the 3D model database. In this paper, based on the characteristics of continuity in space and smoothness in time of a rigid body moving target, a reasonable rigid body target motion hypothesis is proposed, and a three-dimensional motion model of a rigid body target based on the center of rotation of the moving target and corresponding motion is designed to solve the equation with parameters. In the case of unknown motion law, shape, structure, and size of the moving target, this algorithm can achieve accurate measurement of the three-dimensional rigid body motion target’s self-rotation center and related motion parameters. In the process of motion parameter calculation, the least square algorithm is used to process the feature point data, thereby reducing the influence of noise interference on the motion detection result and correctly completing the motion detection task. The paper gives the measurement uncertainty of the stereo vision motion measurement system through simulated and real experiments. We extract the human body motion trajectory according to the depth map and establish a motion trajectory database. For using the recognition algorithm of the sports model based on the 3D image, we input a set of depth map action sequences. After the above process, the 3D motion model is obtained and matched with the model in the 3D motion model database, and the sequence with the smallest distance is calculated. The corresponding motion trajectory is taken as the result of motion capture, and the efficiency of this system is verified through experiments.

1. Introduction

The technology that senses the motion of the human body through some sensors and can more accurately store and record it is computer sports capture [1]. The research fields of sports analysis technology based on 3D images include pattern recognition, computer image processing, computer vision, and computer graphics [2]. The application prospect of sports model technology based on three-dimensional images is very wide. It can be used as material in film, animation, game, and other systems. It can also save intangible cultural heritage in the form of sports for protection and has real-time effects. The 3D image-based sports model technology can also be used in the real-time motion recognition field, such as somatosensory interaction [3]. Human body sports models based on three-dimensional images can be divided into two types: broad sense and narrow sense. The broad sense of motion capture generally includes the capture of facial expressions, gestures, and human bone joints, while the narrowly defined human body sports model based on three-dimensional images only refers to the capture of human bone joint motion [4]. With the gradual maturity of the development of sports model technology based on 3D images, there are already many methods to capture...
motion, many of which have also been applied to actual projects (such as games, film and television animation, new generation of human-computer interaction, and action recognition) [5].

However, the currently widely used 3D image-based sports model system has many shortcomings. For example, the capture system has various hardware devices that need to be worn by athletes. These devices are expensive and complicated and require higher environmental requirements for the athletes. The accuracy is not high, and the user experience is not good. These shortcomings restrict the application of this technology in some fields to a certain extent [6]. In recent years, the depth camera has been developed rapidly, which provides a new method for the capture of motion. The 3D image-based sports model fused with the depth map is obtained because it avoids many shortcomings of the traditional capture system [7]. Under unstable lighting conditions, the sense of movement can be established by matching the obvious corresponding features in the space; that is, the visual moving target can be tracked in a long-distance space. Therefore, similarly, the method of tracking and analyzing specific markers in the image sequence can be used to detect motion [8]. The feature-based discrete measurement method is proposed based on this principle. It is suitable for measuring the motion parameters of long-term, large-volume moving targets, and the algorithm is relatively simple to implement. There are some effective linear algorithms, which require the measurement environment. It is also relatively low and is more suitable for field applications in industrial production and national life [9]. Because several traditional 3D image-based sports model technologies require the athletes to wear hardware devices or stick markers on their bodies and some also require athletes to wear special clothing, it is very inconvenient to recognize or interact with actions. In addition, these systems are often more expensive and require a special site, so it is difficult to achieve in general applications [10].

On the basis of the current mainstream 3D image acquisition method research, this paper proposes a method of using mode to acquire 3D images. At the same time, an iterative threshold method based on the depth value is proposed using mode to acquire 3D images. At the same time, an iterative threshold method based on the depth value is proposed using mode to acquire 3D images. On the basis of this technology in some fields to a certain extent [6]. In recent years, the depth camera has been developed rapidly, which provides a new method for the capture of motion. The 3D image-based sports model fused with the depth map is obtained because it avoids many shortcomings of the traditional capture system [7]. Under unstable lighting conditions, the sense of movement can be established by matching the obvious corresponding features in the space; that is, the visual moving target can be tracked in a long-distance space. Therefore, similarly, the method of tracking and analyzing specific markers in the image sequence can be used to detect motion [8]. The feature-based discrete measurement method is proposed based on this principle. It is suitable for measuring the motion parameters of long-term, large-volume moving targets, and the algorithm is relatively simple to implement. There are some effective linear algorithms, which require the measurement environment. It is also relatively low and is more suitable for field applications in industrial production and national life [9]. Because several traditional 3D image-based sports model technologies require the athletes to wear hardware devices or stick markers on their bodies and some also require athletes to wear special clothing, it is very inconvenient to recognize or interact with actions. In addition, these systems are often more expensive and require a special site, so it is difficult to achieve in general applications [10].

On the basis of the current mainstream 3D image acquisition method research, this paper proposes a method of using mode to acquire 3D images. At the same time, an iterative threshold method based on the depth value is proposed to remove the background of the depth image. Based on the characteristics of the existing 3D motion model reconstruction methods, a depth image-based 3D motion model reconstruction method is proposed. Through the use of the three-dimensional information in the depth image, the three-dimensional motion model can be easily restored. Based on the existing motion trajectory extraction technology, a method of first finding the joint points of the motion trajectory and then connecting the joint points with simple lines is proposed for a motion trajectory extraction algorithm. First, we calculate the distance between the corresponding components of the two sequences and traverse the generated matrix from to to get a path with the shortest distance. According to the process of this algorithm, we must first calculate the distance between the components in the sequence to measure the similarity of the sequence. For the measurement process and detection characteristics of the stereo vision three-dimensional motion measurement system, the paper proposes an optimized design of feature marker rods as features. Each rod is composed of 5 features with strong reflective characteristics, which greatly improves the quality of feature imaging and the feature antinoise and background interference ability; it can simplify the algorithm of corresponding feature recognition and feature matching and ensure the accuracy of feature detection, feature extraction, and feature matching.

2. Related Work

The process of extracting the contour under the premise of the known image background will be simple and easy, but the environmental background is usually difficult to accurately determine, so there are many methods to propose a probabilistic model modeling method to estimate the probability of the background and the foreground to separate the contour [11]. In order to ensure the integrity of the contour, Li and Yang [12] used local features to encode the contour information and abandoned the use of the global features of the contour. A similarity measurement relationship can be established between them, so that the meaning of different human motion images can be recognized. In addition, Lu et al. [13] used device context to measure the similarity between images. The method has also better effect. When calculating the motion data, the two-dimensional information often cannot meet the requirements. Li et al. [14] considered restoring the two-dimensional information into three-dimensional information. For ordinary optical cameras, multiple cameras were required to shoot athletes from different angles to reconstruct the three-dimensional motion model of the human body. There are many methods based on this theory to conduct research, among which the method of three-dimensional object difference based on visual hull is different. The image sequence of the viewpoint was used to intercept the spatial cube, so that the real 3D motion model can be approached visually from the camera. Later, the method of Zhang [15] improved the three-dimensional object difference method, so that the camera cannot shoot the athletes at the same time. In addition, there is a method of reconstructing a three-dimensional motion model using depth values. This method is based on the principle of computer binocular vision. Two cameras are calibrated in advance to shoot the same athlete. The parallax of the two cameras is calculated to calculate the point on the image for depth value and then use the depth value to recover the three-dimensional motion model. In addition, some algorithms also take into account the timing relationship of the original image and combine the timing relationship for research. For example, Miyoshi et al. [16] measured the importance of each image edge in a moving image sequence which is the optical flow method.

Haralabidis et al. [17] described the structure of the human body with simple shapes and searched for the closest human body region in the input image to determine the body region. This process is the process of energy equation optimization. At present, there are many methods of using machine learning to recognize body parts. The recognition of various parts of the human body uses the machine
learning method based on AdaBoost. According to the image of human body movement, they find out the most easily recognized part according to the results of the previous human body part training and then find other parts step by step according to the inherent sequence of the connection of the human body. Modenese and Kohout [18] used a support vector machine to identify each part of the human target in the image and used a random decision forest method for marking body parts, which uses pixels instead of body parts for identification and analysis. The data set is trained to obtain a random decision tree, which is used to judge the attribution of pixels on the contour, and then, the pixels of each part are clustered to obtain the joint points of the human body. This method can quickly capture the movement of the human body, and Microsoft’s latest somatosensory interactive device mode also uses this set of technical solutions. This type of discrete pose estimation method is based on body part recognition. Its advantage is that the motion recognition speed is faster and the algorithm efficiency is relatively high. However, because the joint points are estimated through the body part, there are errors and it is difficult to achieve the accuracy requirements for higher motion capture.

There are two main ways to optimize the model. One is optimization in a two-dimensional space. Some scholars use particle filters to optimize the created models. Particle filters have many and effective constraints on human motion. First, prescribing the athlete’s initial posture (T-pose) is the action to be done at the beginning. The purpose of this is to make the local model and the athlete model easier to align and then use the current frame image to transform the local model and identify that particle filters are used to determine other parts of the body [19]; the other way is to optimize in a three-dimensional space, and the local model established by scholars is represented by a three-dimensional point set. The depth data is transformed into a spatial point set. The matching is implemented between the spatial point sets, and the local model is further optimized. This matching process uses the nearest point matching method. The optimization of the local model is also iterative matching. The final result is to make the local model and the athlete’s three-dimensional sports model similar [20]. The action captured by this fusion model method is smooth, and the quality is relatively good, but the algorithm has high complexity, and the real-time effect is difficult to achieve [21].

3. Construction of the Sports Analysis System Based on 3D Image Technology

3.1. Hierarchical Distribution of 3D Image Technology. Ordinary color images only contain data information such as the texture and color of objects, and the imaging principle of color images is projection imaging, so color images have no distance information of objects; that is to say, color images are two-dimensional, and it is difficult to form a three-dimensional space. The depth image has three-dimensional information. The pixel coordinates of the depth image represent the distance between the object and the camera (or depth sensor), which means that each pixel not only represents the plane information of each point \((x, y)\) of the object. It shows the distance information perpendicular to the \((x, y)\) plane, that is, the data information of the \(z\)-axis. Figure 1 shows the hierarchical distribution of 3D image technology.
Compared with the traditional process of extracting three-dimensional data from ordinary color images, the use of depth images is much simpler. The three-dimensional information of the depth maps can be used directly, which greatly simplifies the problems of three-dimensional reconstruction.

\[
P(A, B) = P(A | B) \times P(B) = P(B | A) \times P(A). \tag{1}
\]

Image data has a discontinuous characteristic, which is reflected by the edges of the image. For depth images, at the edges of the image, the depth values corresponding to pixels have changed. The edge information usually marks the end and the beginning of the area, and the area and the edge represent the basic image features, and many other features of the image can be obtained by deriving the basic features.

\[
\begin{aligned}
A(i) \cap A(j) &= \emptyset, \\
A &= \cup A(i). 
\end{aligned} \tag{2}
\]

Sequence image motion detection technology based on the principle of stereo vision is a noncontact 3D measurement technology based on the principle of stereo vision and optical imaging, because of its noncontact, fast measurement speed, convenient and flexible measurement methods, and relatively high measurement accuracy. Higher advantages have been more and more widely used. The stereo vision motion detection system can generally be divided into the following modules: image acquisition module, feature extraction, recognition module, stereo matching module, camera parameter calibration module, spatial point positioning module, and motion parameter calculation module.

\[
\text{cov} (X) = E \left[ X \times X^T - \left( E(X) \times E(X)^T \right) \right]. \tag{3}
\]

The early processing content in the field of image processing included edge detection. The characteristics of edge information include amplitude and direction. Along the trend of the edge curve, the pixels change smoothly, while when the trend of the vertical edge curve is vertical, the pixels change drastically, and this drastic change may be a slope shape or a step shape.

\[
P(S(i), S(j), \cdots, S(k) \mid T(t)) = P(S(i) \mid T(t))P(S(j), \cdots, S(k) \mid T(t)). \tag{4}
\]

In actual processing, the edge detection operator is often used to detect the presence or absence of an edge and its direction. The main operators for detecting the edge of the depth image are the Robert operator, Prewitt operator, and Sobel operator.

\[
E(f(x)) = \frac{\sum_{i=1}^{n} w(t) \times f(x(t))}{\sum_{i=1}^{n} w(t)}. \tag{5}
\]

Generally speaking, the computer vision motion detection method based on discrete features mainly includes three steps: the first step is to find the corresponding features in the image sequence, and these features should have a certain uniqueness in order to distinguish and detect. The second step is to find the position of the corresponding feature in the next frame of a feature in the previous frame of the same image sequence, so as to complete the matching and correspondence.

\[
E(f(x)) = \frac{\sum_{i=1}^{n} w(t) \times f(x(t))}{\sum_{i=1}^{n} w(t)}. \tag{6}
\]

The third step is to design and give the motion model of the moving target, adopt an appropriate motion solution algorithm, and use the corresponding characteristic three-dimensional coordinates of each time point obtained by matching to calculate and solve the motion parameters and structural parameters of the moving target.

\[
P(x) = \int P(B \mid A(x)) \times P(A(x)) dA(x), \tag{7}
\]

\[
\int f(x)p(x \mid t)dx = 1/n \times \int f(x)p(t \mid x)p(x)dx = 0.
\]

The electromagnetic technology is mature, low cost, fast, and good real-time, and the calibration of the device is relatively simple. However, it has very high requirements on the environment. In order not to cause distortion of the electromagnetic field, metal objects cannot appear in the performance venue and nearby; otherwise, the accuracy will be affected.

The 3D motion model is first processed with other software tools before importing into Java3D, which is divided into the following three steps. The graphics simulation system requires a very precise shape, but it is not necessary for invisible internal features. The existing Pro/E model is used for design and processing, so it contains all the features of the part. Unnecessary internal features will cause the output file to be very large to directly output nearly three hundred files without making any changes. The files are about 17 MB and cannot be opened by the browser. Of course, they cannot be imported into Java3D. Therefore, the Pro/E model must be simplified. According to the virtual body, each object in the above picture can be extracted, and then, a meaningful name is given to each object, and the link is carried out according to the link relationship in the above
For the object that needs to be rotated, set the rotation axis, and you can easily move the rotation axis to a suitable position. There are mainly two ways to simplify: one is to remove the invisible parts and the other is to remove the invisible features of the visible parts. Invisible parts refer to the internal parts of the athlete and have no effect on the appearance. The invisible features of a part refer to the internal features of the part, such as some features such as holes inside the part. Figure 3 shows the three-dimensional image file size histogram of different motion processes. In the process of modification, we pay attention to the sequence of feature creation; otherwise, the error of not being able to find the benchmark will occur when opening it again. After simplifying the file size reduced to 4 MB, the file has been reduced by three-quarters. Then, based on the simplified model file, it is applied to Java3D after some sorting.

The classic methods of three-dimensional distance measurement, such as Euclidean distance, can only be used to measure between a single frame, while a motion sequence is composed of actions in multiple frames, and the length between sequences may be different, so the distance measurement method is not suitable for the measurement between sequences. By placing two or more predesigned feature marker rods composed of five feature marker balls with high reflective characteristics on the tested moving target, they will move with the moving target. The speed CCD camera is placed near the measured moving target, so that its field of view covers the entire range of movement of the feature marker rod and shoots the motion sequence image of the reflective feature marker ball to perform edge detection, center extraction, and center extraction on the feature target in the image. For feature matching and spatial point coordinate calculation, we design the target motion model, establish the motion parameter solving equation, and accurately solve its relevant 3D motion parameters and spin center. When the shooting rate of the camera is high enough, the trajectory of the spatial point can be obtained from the image sequence. Firstly, the system is calibrated, and then,
the camera continuously photographs the athletes’ movements and saves the image sequence. Then, the image sequence is processed and analyzed. The marker points are identified, and then, the spatial position of the marker points at each moment is calculated. If we want to get an accurate motion trajectory, the camera’s shooting rate is required to be relatively high, at least 60 frames per second.

3.3. Model Data Clustering Optimization. Kinematics is a science that does not consider the forces and moments that produce motion in the research and specializes in the study of the laws of motion of objects. It involves the high-order derivatives of the position, velocity, acceleration, and position variables of a moving object with respect to time (or other variables). Athlete kinematics mainly analyzes the athlete’s movement relative to a fixed reference frame as a function of time, especially the relationship between the joint variable space and the position and posture of the athlete’s end effector. It includes the following two basic problems: (1) knowing the amount of motion of each joint (the angular displacement of the rotating joint, the linear displacement of the moving joint), where it is required to determine the position and posture of the end effector, which is the so-called positive problem of athlete kinematics (direct problem), and (2) determining the amount of motion of each joint according to the position and posture requirements of the end effector, that is, to solve the problem of how to make the end effector achieve the desired position and posture. This type of problem is called the kinematics of athletes’ inverse problem (indirect location problem). Table 1 shows the cluster analysis of sports trajectory model data.

For trajectory planning in a three-dimensional space, it is necessary to specify the joint vectors of the athlete’s starting point and ending point and then interpolate the joints to obtain the joint trajectory. The joint trajectory needs to meet a set of constraint conditions, such as the pose, velocity, and acceleration requirements of each node (start point, drop point, and end point), so that the joint position, speed, and acceleration are continuous in the entire time interval. VRML (Virtual Reality Modeling Language) files describe the abstract functional behavior of time-based interactive 3D multimedia information. The time-based 3D space described by the VRML file is called virtual world or realm for short. The graphic objects and auditory objects contained in it can be dynamically modified through a variety of mechanisms. The objects and their attributes in the realm are described by nodes, which form a scene graph according to certain rules. The first type of nodes in the scene graph is used to represent objects from the visual and auditory perspectives. The client program applies for a connection, and the server monitors all ports to determine whether there is a service request from the client program. When the client program requests to connect to a certain port, the server program connects the “socket” to the port. At this time, the server and the client establish a dedicated virtual connection. The client program can write the request like a socket, and the server program processes the request and sends the processing result back through the socket. They are organized in a hierarchical system and reflect the spatial structure of the realm. Figure 4 shows the hierarchical architecture of 3D motion image features. Another type of node participates in the event generation, and a routing mechanism is to form a route graph to determine how the realm changes dynamically over time.

Therefore, the feature-based motion measurement method can be summarized as extracting a set of discrete, sparse, highly discriminative two-dimensional features from the image, which correspond to the three-dimensional features of the moving target in the scene, such as points, lines, and surfaces. Then, based on the characteristics, the corresponding relationship between the sequence image frames at different moments is established. Under the necessary constraints such as rigidity assumptions, a set of targets containing targets are established according to the knowledge of motion dynamics, projective geometry theory, and the prior knowledge of related moving targets. The equations of motion parameters and structural parameters use the image coordinates (single-machine case) or space coordinates (dual-machine case) of the corresponding features between frames at different times to calculate and solve the equations containing the target motion parameters and structural parameters.

4. Application and Analysis of the Sports Analysis System Based on 3D Image Technology

4.1. Feature Extraction of 3D Image Data. We use the German SIMI Twiner software to find the synchronization point of the left and right cameras in the same process and then determine the starting point and ending point to be analyzed. The body and link center of gravity calculations are based on the Hanavan model which performs digital low-pass filtering and smoothing on the original data, and the filtering frequency is 6 Hz. In the process of shooting, we shake the camera left and right to track the athletes. On the basis of ensuring that there are at least three control points in the background of each screen, try to make the images of the athletes large and clear, so as to facilitate subsequent video analysis and ensure the accuracy of analysis. In this experiment, assuming that the camera size is 256 × 256 pixels, the illumination intensity function \( i(x, y) \) is based on the CCD camera imaging formula, and the camera coefficients are set to \( a = 0.5 \) and \( b = 15 \); the left half of the image is the reflected rate LR which is set to 0.1, and the reflectivity RR of the right half of the image is set to 0.15. The coordinate system of the image frame does not
represent the actual position coordinates of the visual field environment but represents the corresponding coordinates on the sensor, which are determined by the resolution of the sensor. From the above analysis, it can be seen that in order to restore the three-dimensional model from the depth image, the pixel coordinates of the depth image need to be converted into space coordinates, and the depth data is dimensioned, and the depth data needs to be normalized first. Subsequently, white Gaussian noise with $t = 3$ is added to the image to synthesize a nonuniform weakly illuminated image for edge detection methods to detect the step edges in the image.

Figure 5 shows a comparison chart of the three-dimensional image signal-to-noise ratio broken line. The larger the signal-to-noise ratio is, the better the edge detection performance of the edge detection algorithm is. It can be seen that both methods have significantly larger signal-to-noise ratios because they both adopt the design idea of independent lighting. It can also be seen that in the low-grayscale and low-contrast noise-containing image area, the method fully considers the imaging model of the CCD camera and the illumination reflection image formation model, which overcomes the unevenness in the imaging process. As a result of the influence of lighting factors, it shows better edge detection and antinoise capabilities. We shoot the three-dimensional frame and determine the three-dimensional coordinates of the marker ball. The two cameras shoot the frame for about 2 seconds, pause, and then use the total station to measure the origin point $a$ of the three-dimensional frame coordinates, point $v$ in the $x$-axis.
direction, and point \( j \) in the \( y \)-axis direction. For the coordinates of the additional control points, we use the software on the computer to collect the data observed by the total station and convert the coordinates of the additional control points into coordinates in the rectangular coordinate system defined by the three-dimensional calibration frame.

### 4.2. Sports Sequence Simulation

The main experiment in this paper uses two cameras to take pictures of the whole process of the three test jumps of the research object (the shooting frequency is 25 Hz), uses a total station to calibrate the peak frame and the additional control ball in a wide range of three-dimensional space, and uses the German belt Pan/Tilt/Zoom module function SIMI-Motion video analysis system for video analysis. In the analysis process, the human body digital model is used to perform digital low-pass filtering and smoothing on all the analyzed data, and the cutoff frequency is 6 Hz. The three-dimensional image analysis of human motion is realized by converting the two-dimensional image coordinates recorded on the film and video tape into the three-dimensional coordinates of the actual space. The direct linear transformation (DLT) algorithm directly establishes the relationship between the coordinates of the coordinate system and the coordinates of the object space. This linear transformation is achieved by taking a picture of the calibration frame and then calculating the photographic coefficient. The collected motion images are sorted, Zazziolski’s human body model is selected, and the software is used for analysis. The data obtained by the analysis is smoothed by low-pass filtering, and the smoothed data obtained is analyzed, filtered, and sorted. The main points of this shooting method are to prepare a high-precision calibration frame. There must be at least 6 calibration points with known coordinates on the frame. The least squares method can be used to obtain the 10-element linear equations, which can be solved to obtain 10 photography and then find the three-dimensional coordinates of the point.

Figure 6 shows the statistical error distribution of the 3D image positioning accuracy. These data prove that the method has higher edge positioning accuracy than other methods. The blue data line represents the control group, which is the accuracy of the model obtained according to the literature algorithm; the red data line represents the experimental group, which is the accuracy of the model obtained according to the algorithm proposed in this article. It can be seen from the comparison that the red data line is more stable and the displayed value is higher, which shows the superiority of the algorithm in this paper. This is because the improved wavelet multiscale multiplication edge detection technology and the fuzzy edge enhancement technology based on pixel gradient direction information are used in this paper, which greatly improves the antinoise ability and positioning accuracy of edge detection. In order to form the required trajectory in the three-dimensional space, the end pose is first converted to the joint vector angle through the inverse kinematics solution, and then, a smooth function is fitted to each joint, starting from the starting point and passing through all the path points in turn, finally reaching the target point. For each section of the path, each joint moves at the same time, which ensures that all joints reach the path point and end point at the same time. The three-dimensional space method describes the athlete’s trajectory as a function of joint angles and performs trajectory planning. Table 2 shows the distribution of the calibration coordinate system of the 3D moving image. The three-dimensional space method does not need to describe the path shape between two path points in a rectangular coordinate system, and the calculation is simple and easy. And because the three-dimensional space and the rectangular coordinate space are not continuous.

| Image index | Track position \( X \) | Track position \( Y \) | Track position \( Z \) |
|-------------|----------------|----------------|----------------|
| 1           | 0.12           | 0.04           | 0.04           |
| 2           | 0.07           | -0.05          | -0.08          |
| 3           | -0.06          | 0.09           | 0.05           |
| 4           | 0.13           | 0.08           | 0.06           |
| 5           | 0.09           | -0.07          | -0.05          |

**Figure 6**: Statistical error distribution of 3D image positioning accuracy.
corresponding relations, the singularity problem of the mechanism will not occur.

We use this system to observe the control points and additional control points on each rod of the three-dimensional calibration frame, obtain their precise coordinates, and convert them to the designated coordinate system to track and scan three-dimensional images for a larger range of sports. The height of the center of gravity at the moment of take-off from the ground, the vertical distance from the moment of lift-off to the highest point of the sky, the distance from the highest point of the center of gravity to the crossbar after the take-off, and the center of gravity energy are given. The maximum height reached is not much different; the maximum height of the center of gravity for a successful test and two test jumps is not much different, but the vertical distance and the distance from the highest point of the center of gravity to the crossbar after the take-off are relatively large. Under the same coordinate reference system, the average difference of the absolute coordinates of the 15 points in the three-dimensional space measured by the total station and the image analysis is 0.05 ± 0.03, and the relative error of the three-dimensional tracking scan image measurement can reach 1.97%. Such measurement accuracy can meet the requirements of sports technical analysis.

4.3. Example Application and Analysis. We install the three-dimensional coordinate frame and place 100 additional marker balls along the athlete’s approach route, each with a marker ball on the top left, bottom left, top right, and bottom right of the pole. According to the requirements of the SIMI Motion 3D scanning and tracking video analysis system, while the two cameras are scanning and tracking the moving target, it is necessary to ensure that there are more than two additional control points in the captured picture, so the additional control points placed in this experiment are confirmed by scanning and viewing by two cameras on the left and right, and there are at least two control points in the background of each screen. Although the method can accurately locate the edge pixels in some low-contrast areas, it cannot give better detection results for edges located in low-contrast and low-grayscale areas at the same time. This is because the method does not consider the complete CCD camera imaging model and the illumination reflection image formation model, and its detection accuracy is affected by the absence in the CCD camera imaging formula, especially in low-grayscale areas. This influence greatly damages the quality of edge detection and positioning accuracy. Figure 7 shows the deviation distribution of 3D image edge detection for different moving points.

We see that in the case of nonuniform weak illumination, the edge detection accuracy of this paper is not greatly affected, and it can still give better edge detection results. The edges in the image can be positioned correctly, which further proves that the edge detection method is capable of detecting moving targets under nonuniform weak illumination, by creating the connected joints of the model, adding kinematics to the model, and assigning the three-dimensional coordinates of each joint of the human body analyzed in the kinematics method to the three-dimensional human body model to reconstruct the human body posture, perform balance analysis, and then analyze the established three-dimensional model in reverse dynamics. The joint will record the changes in the joint angle and muscle length when the model moves under the control of the motion guide point. From the data, it can be seen that the maximum height that athletes can reach is quite different, and there is a big difference in performance; there is no vertical distance between foreign athletes’ body center of gravity from the moment of flying off the ground to the highest point of the sky. In terms of significant difference, the height of the center of gravity of the athletes before the flight is smaller than that of the world sports, and the difference is very significant; when the center of gravity reaches the highest after the take-off, the vertical distance between the center of gravity of the athletes and the horizontal bar is greater than that of the world athletes, and the difference is very significant.

We control the camera to perform 100 edge detections on the edge of the moving feature target at each movement speed at each exposure time, calculate the translation
distance of the target, and give the mean value of the abso-
lute error of the translation movement. Since the human
body model and connection have been described in mathe-
matical language and the computer system has been able
to recognize it, after the partial modification of the parameters
is input, the whole movement result will be changed to a cer-
tain extent, and then, it will be displayed in the computer for
easy observation. It can be seen that when the exposure time
is a constant of 40, 60, or 80 ms, initially when the moving
target moves at a lower speed, as the target moving speed
increases, the detection error does not decrease significantly.
This is because at this time, the impact of the target's motion
on the edge detection accuracy is not the main factor that
affects the edge detection accuracy.

Figure 8 shows the three-dimensional image detection
saliency error curve for different motion trajectory exposure
times. Through many experimental verifications, in this
motion detection test, when the motion speed of the moving
target changes within 10-80 mm/s, the Dalsa CA-D6 camera
produced by Dalsa in Canada and the reflective feature ball
produced by Qualisys in the United States are used. When
the target and the camera exposure time are controlled from
4 to 16 ms, the performance of edge detection is basically not
affected by the change of target movement speed, and it has
the best edge positioning accuracy. In general, in order to
illustrate the reliability of the measurement, the reliability
coefficient is usually calculated by mathematical statistics.
The closer the coefficient is to 1, the more reliable it is, and
the closer it is to 0, the less reliable it is. The reliability coef-
cient is slightly different due to different calculation
methods, but it is generally believed that the reliability coef-
cient of group measurement should be above 0.70. At the
same time, it is calculated that by increasing the number of
light sources, lighting intensity, and reducing the exposure
time of the CCD camera, the performance of edge detection
can be unaffected by changes in the speed of the target in a
larger range of target motion. With the further increase in
the moving speed of the moving target, the edge positioning
error caused by the target movement has gradually become
the main influencing factor that affects the edge detection
accuracy and the translational movement distance detection
accuracy. The accuracy of the edge detection gradually
increases with the increase in the moving target speed.

5. Conclusion

Based on the 3D motion model of the depth image, this
paper compares and analyzes the characteristics of the exist-
ing methods of 3D motion model reconstruction and then
proposes a method of 3D motion model reconstruction
based on the depth image. The depth image contains
three-dimensional information, and the three-dimensional
motion model can be easily restored by using the three-
dimensional information in the depth image. The algorithm
is used to realize the restoration of the 3D motion model,
and the point cloud data of the 3D motion model is
obtained. Through the introduction and analysis of the
existing motion trajectory extraction technology, a motion
trajectory extraction algorithm is proposed that first finds
the joint points of the motion trajectory and then connects
the joint points with simple lines. This algorithm avoids
the problems caused by body self-occlusion and boundary
noise and ensures the connectivity of the motion trajectory.
Through the introduction of the existing 3D image-based
sports model analysis methods, it is determined to use the
recognition method to carry out the 3D image-based sports
model simulation analysis of this article, and two one-to-
one corresponding databases of the 3D movement model
and the human body movement trajectory have been estab-
lished. On the basis of the existing 3D vision measurement
technology research, a stereo vision 3D rigid body move-
ment and self-rotation center measurement method based
on discrete feature marker rods is studied. For such a system,
the focus is on stereo vision-based three-dimensional rigid
body moving target motion modeling and motion parameter
calculation, feature target edge detection and extraction in
motion sequence images, corresponding feature matching
between stereo sequence images, and circular feature target
center extraction, and other key technical issues are consid-
ered. The motion parameters of the moving target's rotation,
translation, and spin center spatial positioning are measured, and the measurement uncertainty of the stereo vision motion measurement system is given, and the motion detection results of two groups of targets with different moving speeds are carried out. Through computer simulation, not only can the movement be analyzed according to the position, speed, angular velocity, and other kinematic parameters of the athlete when the movement is completed but also the movement can be adjusted according to the dynamic data such as the timing of the athlete’s joint force, the amount of force, and the continuous working time of the muscles. Through analysis and comparison, simulation and real motion test experiments have proven the correctness of the motion model and corresponding motion algorithm proposed in this paper.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

All the authors do not have any possible conflicts of interest.

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