

## Research Article

# Design and Optimization of Motion Training System Assisted by Human Posture Estimation Algorithm

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With the rapid development of computer technology and electronic information technology, the sports training system no longer depends on the traditional algorithm for operation support, and various advanced posture algorithms are emerging. At the same time, it also further optimizes the intelligence and accuracy of the sports training algorithm. As an advanced algorithm combined with virtual reality technology, human posture estimation algorithm plays an obvious role in optimizing the effect of sports training. This paper will design a motion training system based on the optimized and improved human posture trajectory algorithm, use the depth image correlation theory to solve the problem of non-Gaussian noise crosstalk in the depth image of the traditional human posture algorithm in principle, improve the accurate feature extraction of the depth image by the algorithm, and solve the problem of human feature redundancy, so as to further improve the accuracy of the establishment of a single human model; on the problem of multi-person posture estimation algorithm, this paper proposes a high-resolution multi-person posture high-precision network model and adds the focus mechanism. Based on this, this paper realizes the high-precision and high-speed modeling of multi-person posture, so as to provide an accurate model for the multi-person function of sports training system and improve the efficiency of the algorithm. In the experimental part, this paper takes tennis as a typical case to design the sports training system and experiments based on the system designed in this paper. The experimental results show that the system under the proposed algorithm has obvious advantages in accuracy and training effect.

## 1. Introduction

With the continuous development of information technology and the continuous progress of sports rehabilitation medicine, the relationship between it and sports training medicine is becoming closer and closer. The traditional sports training system mainly adopts physical methods such as observation method. This method is intuitive, but has obvious subjectivity, so its effect is not satisfactory [1, 2]. With the introduction of computer vision technology, relevant institutions and researchers began to use cameras to capture, track, and analyze athletes' movements [3, 4]. When athletes train or exercise, such image capture equipment based on cameras can realize the acquisition of motion images, the capture of motion features, and the real-time tracking of motion forms, so as to realize the fine processing

of athletes' motion state through real-time quantitative scientific analysis. For the processed sports data, combined with the corresponding basic theories such as human mechanism and human kinematics, it can assist athletes in sports, so as to further improve their sports level [5–7]. At the level of the corresponding game entertainment field, through conventional cameras and other sensors, we can continuously extract and analyze the relevant motion data of limbs, joints, and so on when the human body is moving, conduct three-dimensional modeling processing on such analysis information, and establish a huge and complex database system through a large amount of data extraction, storage, and analysis. Based on this database system, a sports training system is established to give more realistic and coordinated body language to the characters in games or movies [8]. In the corresponding field of sports medical

rehabilitation, analyze the injury of patients through medical gait, and design the corresponding sports training rehabilitation plan based on medical gait, so as to realize the rehabilitation treatment of patients, without providing certain treatment means and rehabilitation support [9].

As a key research algorithm in sports training system in recent years, human posture estimation algorithm is mainly an algorithm to obtain the information between each joint of moving human body based on image or video information. By obtaining the information between human joints, the position can provide key elements for the sports training system [10, 11]. Traditional human pose estimation algorithms are widely used in human behavior recognition, which also combines various depth neural algorithms such as convolutional neural network. In the field of human-computer interaction, the rapid capture of human actions is realized based on various sensors, which realizes the friendliness of human-computer interaction to a certain extent. With the further development of technology, the combination of human posture estimation algorithm and depth image is becoming closer and closer. However, the depth image of traditional human posture estimation algorithm is generally nonlinear data, which have a large amount of redundant information, which will lead to huge problems in the data reliability of human motion model [12, 13]. The sports training system is mainly developed under the action of multi-disciplinary integration. At the level of system research and development, it is mainly developed to the integration of sports competition. The sports training system includes sports training, sports material selection, and sports competition. The corresponding subjects are athletes. These disciplines have a certain correlation and intersection, which together constitute the theory of competitive sports. The research of sports training system, like other disciplines, is a developing and constantly improving theoretical system, which is maturing with the continuous development of competitive sports. Therefore, how to better fuse the depth image in the human posture estimation algorithm, maintain the feature structure of high-dimensional data and the corresponding effective information, so as to fully extract the effective features of the data, and then reasonably select and analyze the features is very important and meaningful [14].

Based on the above situation, this paper will design the motion training system based on the optimized and improved human posture trajectory algorithm, use the depth image correlation theory to solve the non-Gaussian noise crosstalk problem in the depth image of the traditional human posture algorithm in principle, improve the accurate feature extraction of the depth image by the algorithm, and solve the problem of human feature redundancy, so as to further improve the accuracy of the establishment of a single human model. On the problem of multi-person posture estimation algorithm, this paper proposes a high-resolution multi-person posture high-precision network model and adds the focus mechanism. Based on this, this paper realizes the high-precision and high-speed modeling of multi-person posture, so as to provide an accurate model for the multi-person function of sports training system and improve the

efficiency of the algorithm. In the experimental part, this paper takes tennis as a typical case to design the sports training system and experiments based on the system designed in this paper. The experimental results show that the system under the proposed algorithm has obvious advantages in accuracy and training effect.

The main structure of the article is as follows: the second section of the article will focus on the current research status of sports training system based on human posture estimation algorithm. The third section will focus on the analysis and research of human posture estimation algorithm based on depth image depth data fusion, solve the problem of human feature redundancy, and establish a human motion training system based on tennis. In the fourth section, the experimental research and data analysis will be carried out based on the above designed system. Finally, this paper will summarize.

## **2. Related Research: Research Status of Motion Training System Design Assisted by Human Posture Estimation Algorithm**

As for the design and optimization of sports training system, a large number of researchers and research institutions have studied and analyzed it. The conventional methods mainly include image method, graph analysis method, portable sensor algorithm, and so on [15–19]. For the human target detection level, a large number of algorithms are also emerging and improve the effect of sports training system at different levels. The human target detection algorithms commonly used by relevant research institutions in Europe include algorithms based on relevant image segmentation and detection, detection algorithms based on relevant image gradient, detection algorithms based on relevant statistical learning, etc. [20, 21]. At the research level of the combination of human posture estimation algorithm and sports training system, a large number of optimization algorithms are emerging. 2D single person human pose estimation algorithm is a typical human body estimation algorithm, which is mainly proposed by relevant researchers in the USA. Its corresponding optimization algorithm includes random decision tree algorithm, sparse probability regression algorithm, image structure model algorithm, and other optimization algorithms [22, 23]. With the continuous in-depth research of deep learning algorithm, relevant research institutions in Europe combine it with human body estimation algorithm, and relevant researchers in the USA fully combine human body estimation algorithm with convolutional neural network, which adopts multi-stage cascade mode, and each corresponding stage includes corresponding supervision system [24, 25]. A Chinese mainland researcher has proposed combining structural feature learning algorithm to solve single person pose estimation problem. The algorithm uses bidirectional tree model to solve the related problems [26]. Similarly, Chinese mainland research institutes introduce the focus mechanism in the traditional human pose estimation algorithm, which is mainly used to solve the problem of precision and performance of the corresponding system [27, 28]. In the field of multi-person attitude estimation

algorithm, the current main algorithm is still combined with convolutional neural network. Relevant Japanese researchers have proposed cascade pyramid network as multi-person attitude estimation algorithm, in which a variety of networks are added to realize the estimation of multi-person human attitude [29, 30]. At the corresponding 3D human pose estimation level, the main algorithms are the extension of 2D human pose estimation algorithm. The corresponding mainstream algorithms include pose estimation algorithm, linear model, compound pose estimation regression algorithm, and other algorithms [31–33].

### 3. Design and Optimization of Sports Training System Assisted by Human Posture Estimation Algorithm

This section will mainly analyze and study the optimization algorithm of human posture estimation algorithm and build a set of sports training system based on this optimization algorithm. The main system framework is shown in Figure 1. It can be seen from the figure that the human posture estimation algorithm corresponding to the core algorithm mainly includes three levels: human body depth image processing and analysis, depth feature extraction and analysis of depth image, and selection and processing of human pose estimation algorithm and information feedback processing. It can be seen from the corresponding motion estimation algorithm of the human body in the running process of the system. It can be seen from the figure that at the software algorithm level, first, the depth data acquisition of motion information are realized based on the human posture estimation algorithm, and the depth image is fully analyzed. Then, the depth image extracted in this paper is deeply preprocessed and analyzed. The corresponding preprocessing includes the steps of feature image denoising, median filtering, and Gaussian filtering. The feature extraction operation based on the processed image mainly includes depth feature extraction processing, depth comparison feature extraction processing, human part feature extraction processing, and other related steps. Then, the extracted features are modeled and processed, and fed back to the sports training system for adjustment. Finally, it acts on the athletes for training. In the aspect of hardware design of sports training system, it mainly includes human motion sensing system module, human motion system power supply and management module, acquisition data processing module (mainly image and data filtering module), system CPU module, and its auxiliary circuit module. At the corresponding software architecture level, it mainly includes data acquisition architecture, wireless transmission architecture, human-computer interaction architecture, etc.

### 4. Analysis and Research of Human Pose Estimation Algorithm Based on Depth Image Depth Data Fusion

The traditional human body pose estimation algorithm has serious disadvantages. Based on this, this paper proposes a

human body optimization estimation algorithm based on depth image, which adopts depth comparison features, combined with directional gradient features and other factors to optimize the algorithm. The corresponding core architecture of the algorithm is shown in Figure 2. It can be seen from the figure that the corresponding algorithm architecture has more feature capture links and focus factor introduction compared with the traditional algorithm. The main modules include human depth image denoising processing module, human posture image enhancement module, human posture feature extraction module, focus factor module, feature fusion module, decision-maker module, and human posture output module.

The corresponding human posture image preprocessing module mainly includes two algorithms: human posture image enhancement and foreground extraction. The corresponding image enhancement part mainly uses the histogram equalization strategy to process the extracted depth image and realizes the balanced distribution of the corresponding irregular distribution, so as to enhance the dynamic interval corresponding to the pixel value difference in the depth image, so as to improve the pixel contrast of the depth image. The corresponding comparison example is shown in Figure 3. The corresponding Figure 3 is the comparison diagram of image gray value before posture enhancement and posture enhancement. From the figure, it can be seen that the corresponding image histogram is evenly distributed in each interval after human posture image enhancement, so that the details between each area are more obvious and the depth image is more clearly visible.

The edge of the processed depth image is extracted, so as to highlight the edge of the human body, and then extract and strengthen the human body from the depth image. In feature extraction, the main extracted features include depth image comparison features and binary pure phase filter features and gradient features of optimization direction.

The corresponding depth image comparison features and its corresponding core calculation formula are shown in formula (1), where the corresponding  $d(x)$  represents a pixel in the depth image and the corresponding  $a$  represents the corresponding offset. The corresponding depth image comparison feature extraction process is as follows:

$$F(i, x) = d_i(x) - d_j(x) + d\left(\frac{w}{d_i(x)}\right) - d\left(\frac{w}{d_j(x)}\right). \quad (1)$$

Step 1: capture and record the response of different positions of the corresponding human body in the depth image.

Step 2: compare the vertical depth information, extract and operate the depth value between the known pixel and the pixel directly above a certain distance, and perform subtraction calculation.

Step 3: compare the depth of character pixels and scene pixels.

Step 4: analyze the corresponding features and depth values extracted above.

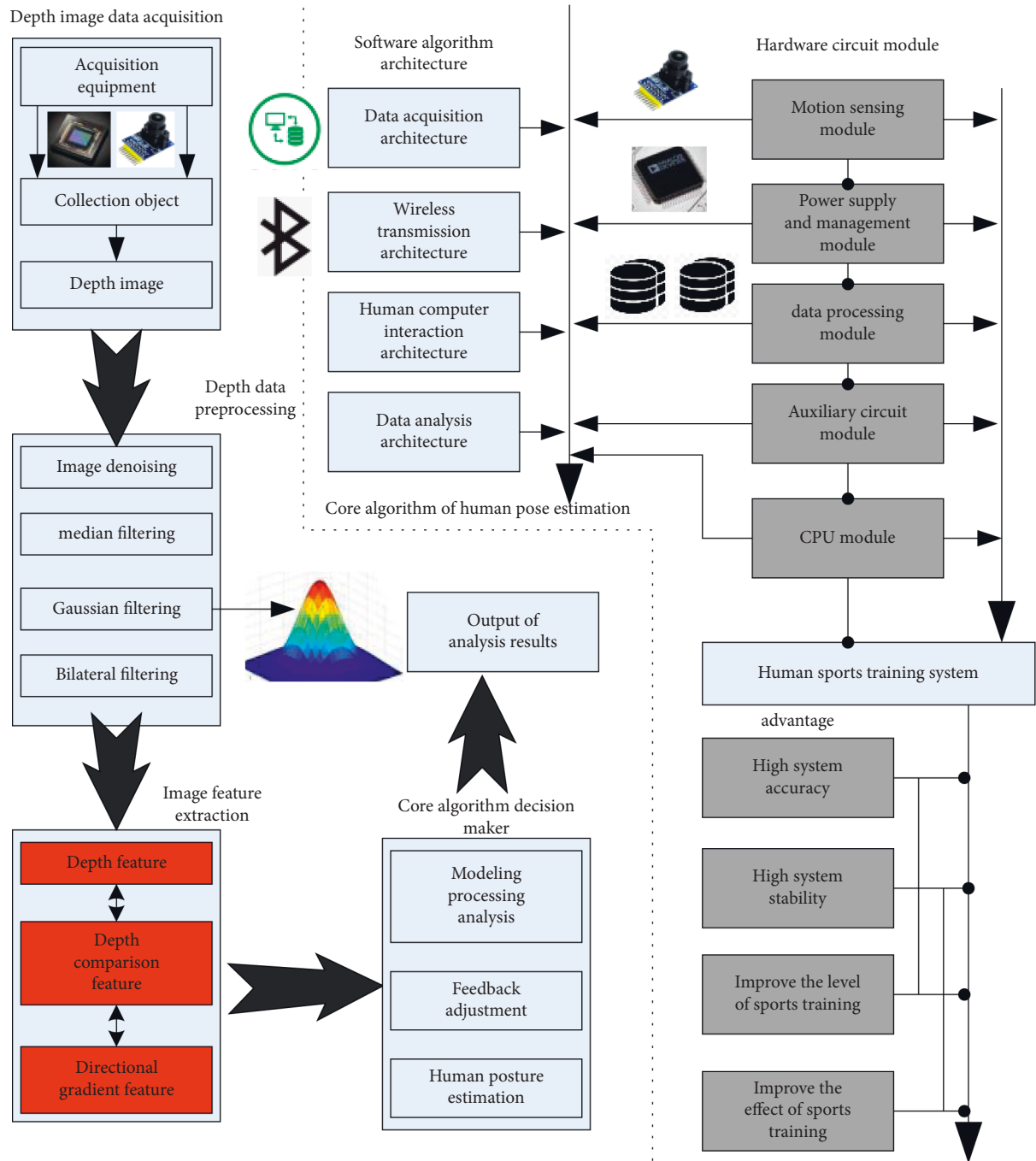


FIGURE 1: Software and hardware framework of motion training system assisted by human posture estimation algorithm.

At the feature extraction level of binary phase only filter, it is mainly processed based on the following formula (2), core formula. The corresponding extraction steps are as follows:

$$\begin{aligned} K(a, b) &= \{1\}, Q(a, b) \langle \alpha - \Pi, \alpha \rangle, \\ K(a, b) &= \{-1\}, Q(a, b) \langle \alpha, \alpha + \Pi \rangle. \end{aligned} \quad (2)$$

Step 1: Select a pixel in the image, scan in 8 directions based on the pixel, find the jump point in each direction based on different pixels and analyze it.

Step 2: Calculate and record the distance between the pixel point and the jump point in 8 directions.

Step 3: Obtain and record the characteristic values of corresponding pixels based on the above formula.

Step 4: Calculate the characteristic values of all pixels and record the analysis according to steps 1 to 3 above. In the gradient feature extraction layer of the optimization direction, the feature extraction of pixels is mainly realized by arc tangent operation. The corresponding gradient feature extraction core formula is

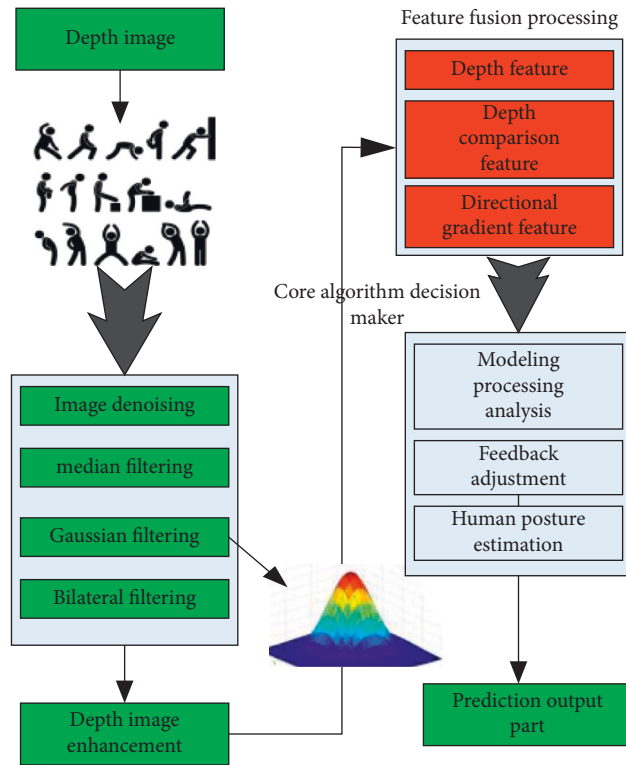


FIGURE 2: Architecture of human posture optimization estimation algorithm based on depth image.

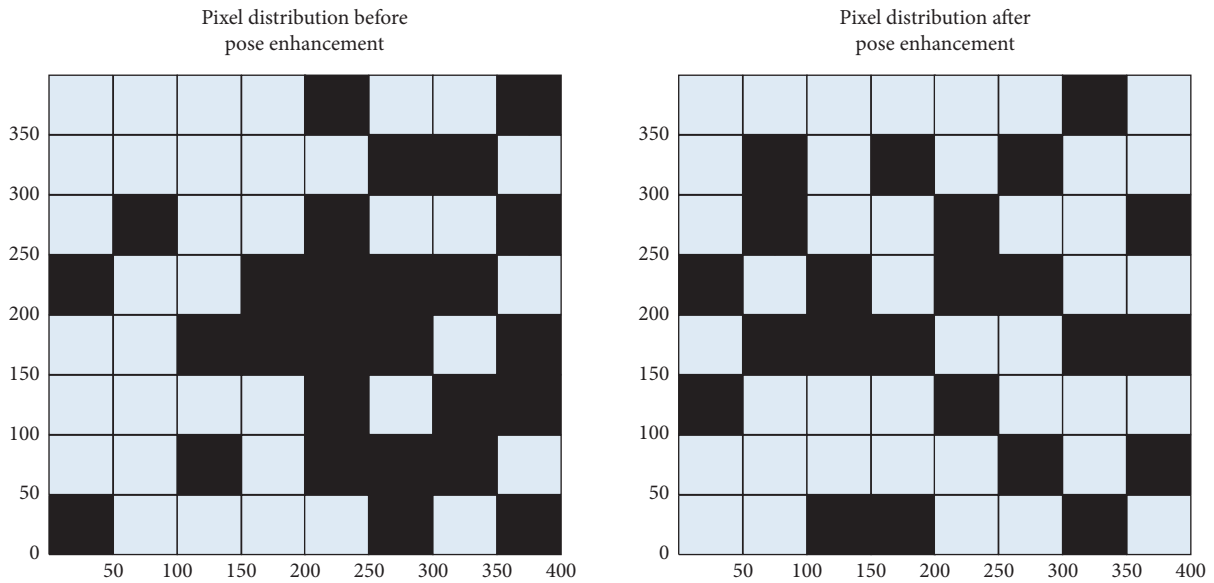


FIGURE 3: Comparison diagram of image gray value before attitude enhancement.

shown in formula (3), where the corresponding  $P(x, y)$  represents the depth value of the corresponding pixel and the corresponding reverse gradient phase angle is selected between zero and 360 degrees. The calculation process of the corresponding directional gradient is shown in Figure 4. As can be seen from Figure 4, the main calculation flow is as follows: first set the

corresponding initial value, then read in the depth value of the corresponding pixel, so as to calculate the directional gradient eigenvalue of the pixel, then judge the phase of the corresponding eigenvalue and enter different phase intervals for processing according to the judgment, and finally obtain the gradient eigenvalue of the optimized direction and output it.

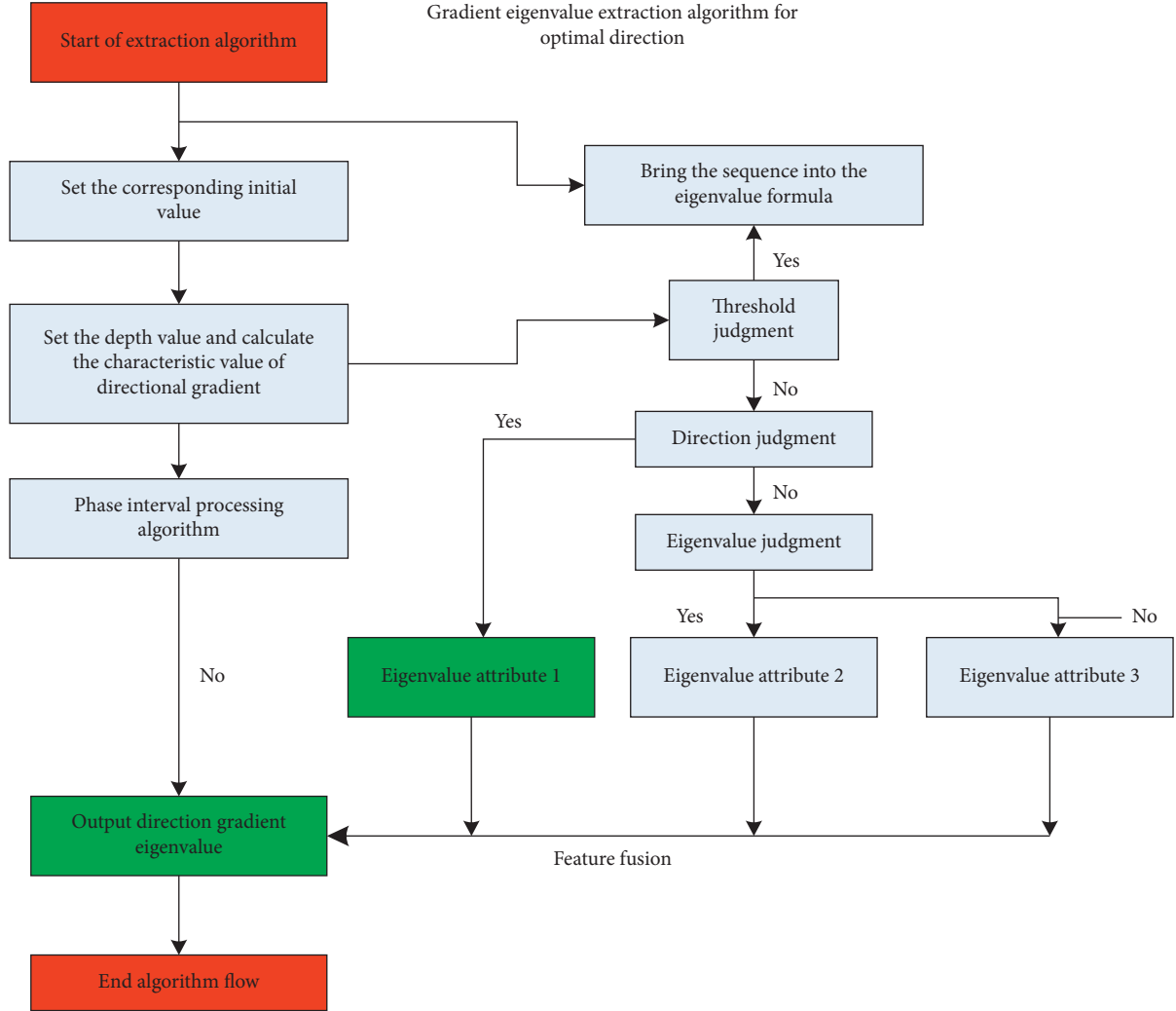


FIGURE 4: Framework of gradient eigenvalue extraction algorithm in optimization direction.

$$D_p(a, b) = \tan^{-1} \left( \frac{[p(a, b+1) - p(a, b-1)]}{[p(a+1, b) - p(a-1, b)]} \right). \quad (3)$$

Based on the above eigenvalues, the main fusion algorithm used in this paper is the minimum redundancy maximum correlation feature fusion algorithm. By continuously selecting subsets in the system, measuring the correlation between features and corresponding feature subsets, the feature selection of depth image is carried out, so as to maximize the feature correlation and minimize the feature redundancy to realize the feature selection and analysis of relevant pixels. The mutual information of pixels is mainly expressed by information entropy. The corresponding information entropy determines the stability between corresponding variables. The corresponding mutual information represents the similarity between different variables. The corresponding core calculation formula of mutual information is shown in formula (4). The corresponding  $h(x)$  in the formula represents the entropy information of random variables.

$$\begin{aligned} I(a, b) &= h(a) - h\left(\frac{a}{b}\right) \\ &= p(ab) \log \frac{p(ab)}{[p(a) * p(b)]}. \end{aligned} \quad (4)$$

At the level of the corresponding focus mechanism, it is mainly processed by imitating the observation mechanism of the human body. Its main idea is to add the focus judgment mechanism to the depth image sequence, so as to obtain the focus weight value between different positions of the depth image sequence and different positions of the input text, it is weighted and summed based on the weight value, and the corresponding focus vector is transmitted to the corresponding decoding module for decoding. The corresponding schematic diagram is shown in Figure 5. As can be seen from Figure 5, the connection between the hidden state sequence and the hidden state sequence of the depth image can be established through the introduction of the focus mechanism, so as to improve the performance of the original model and fully extract the eigenvalues of the hidden state sequence.



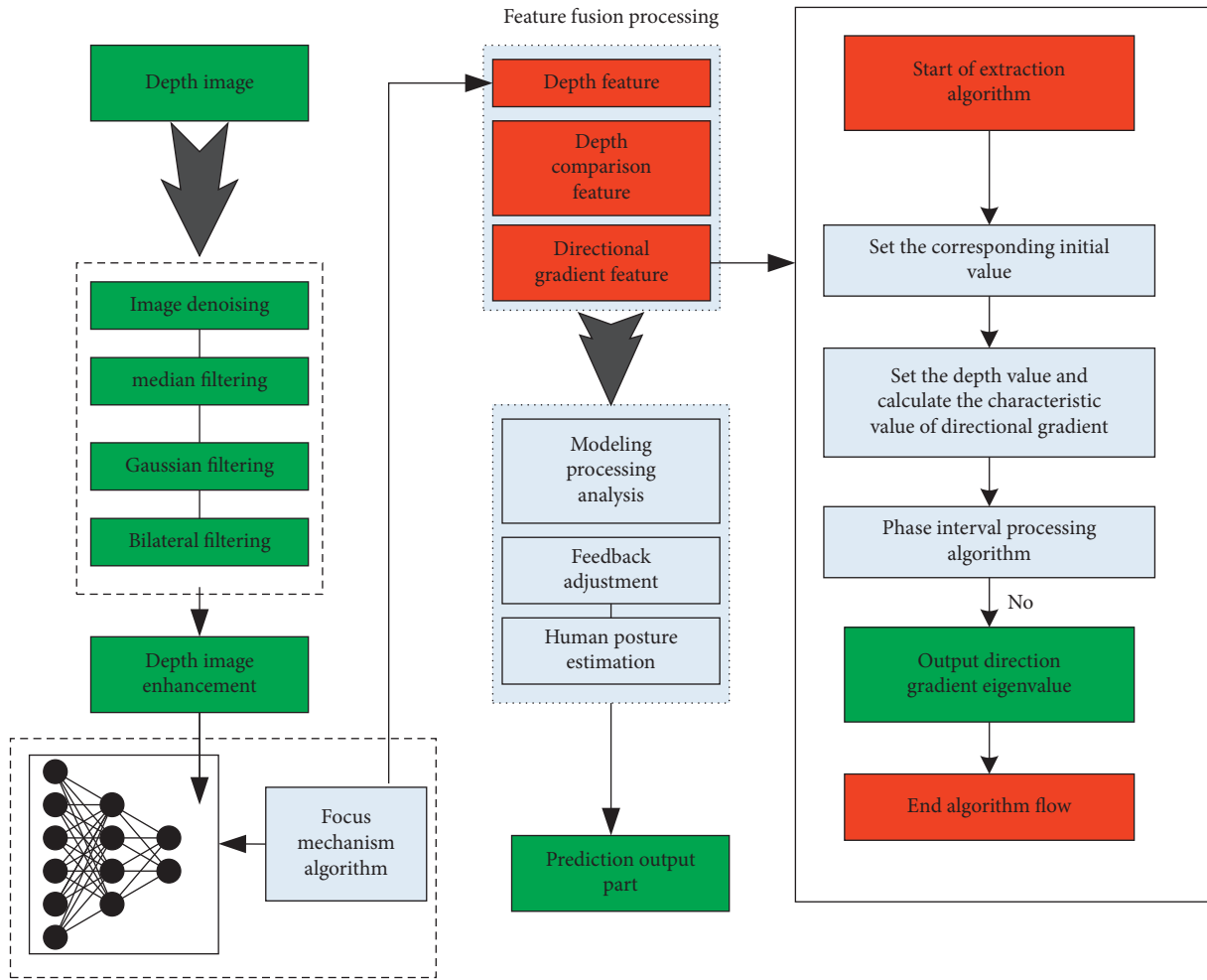


FIGURE 5: Operation flowchart of focus mechanism.

The optimization of human posture estimation algorithm based on the above can further solve the disadvantages of traditional algorithms, improve the performance of human posture estimation algorithm, and better provide support for sports training system.

### 5. Design of Human Sports Training System

Based on the above related theories, this paper designs the relevant human sports training system based on tennis, and the corresponding design framework is shown in Figure 6. As can be seen from Figure 6, the training system is mainly composed of hardware sensor part and software algorithm part. The corresponding hardware and software parts realize communication connection through wireless sensor network. At the software algorithm level, firstly, the depth data acquisition of motion information is realized based on the human posture estimation algorithm, and the depth image is fully analyzed. Then, the depth image extracted in this paper is deeply preprocessed and analyzed. The corresponding preprocessing includes the steps of feature image denoising, median filtering, and Gaussian filtering. The feature extraction operation based on the processed image mainly includes depth feature extraction processing, depth

comparison feature extraction processing, human part feature extraction processing, and other related steps. Then, the extracted features are modeled and processed, and fed back to the sports training system for adjustment. Finally, it acts on the athletes for training. At the hardware level of the system, it can be seen that it mainly includes motion sensing module, power supply and management module, data processing module (mainly filter module), CPU module, and its auxiliary circuit module. At the corresponding software architecture level, it mainly includes data acquisition architecture, wireless transmission architecture, human-computer interaction architecture, etc.

In the corresponding hardware design details, the corresponding hardware part is mainly composed of sensor design part, power supply management part, data processing and analysis unit part, data acquisition, and storage part. The corresponding sensor hardware design level mainly includes the speed signal acquisition sensor, the programmable speed adjustment sensor part, and the programmable motion sensing trigger interrupt hardware part, and the corresponding main processor part also includes the filter part, the wireless RF part of the main processor, and the wireless circuit design part. The corresponding power supply and management part is mainly to supply power to the sensor

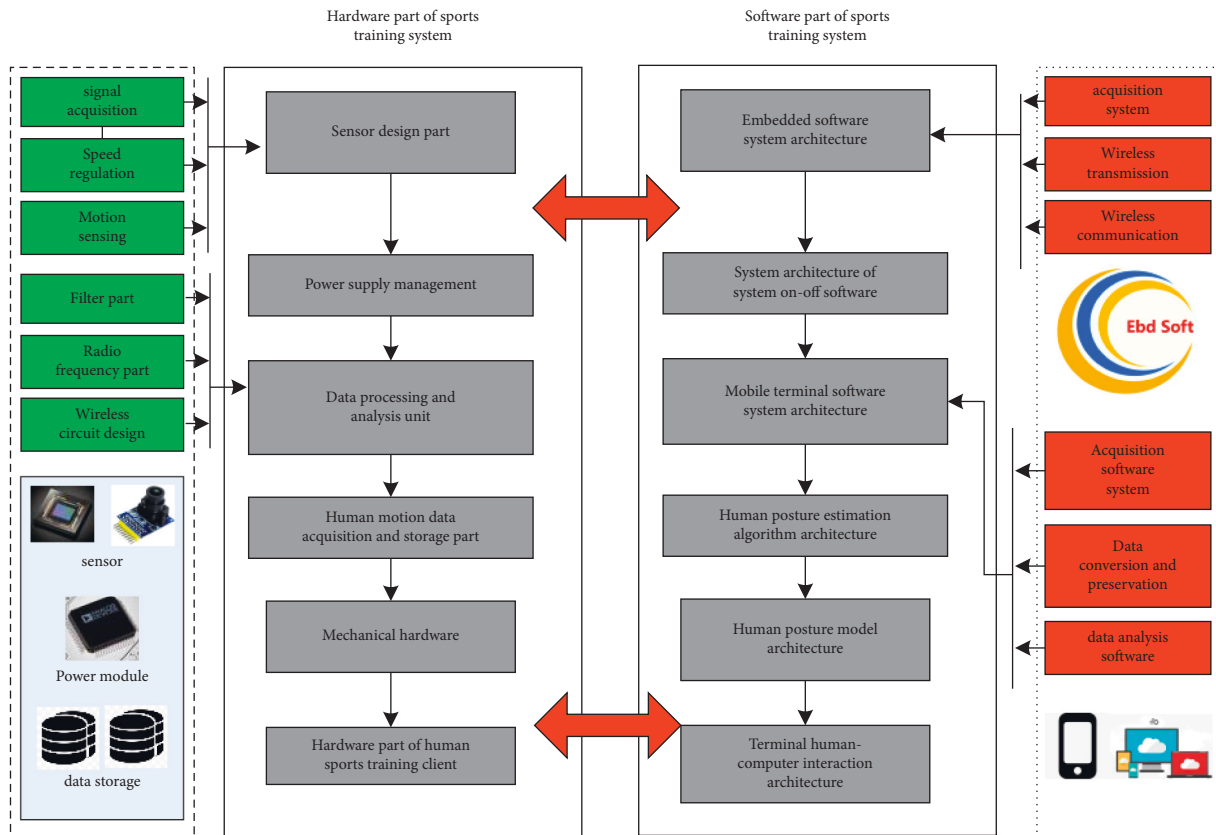


FIGURE 6: Design framework of human training system.

and the corresponding data processing and acquisition module. At the same time, it also needs to realize the health management of the battery. The corresponding power chip includes conventional power modules such as lt4644, lt4620, and lt8056. In the selection of sensor module, the particularity, power consumption, performance, and volume of tennis training system need to be considered. The sensor module selected in this paper is mpu6050 series. The corresponding wireless circuit design part needs to fully consider the RF-related knowledge, such as impedance matching and transmission line theory.

In the corresponding software design detail level, the corresponding software level mainly includes embedded software system architecture, system on-off software system architecture, mobile terminal software system architecture, etc. At the corresponding embedded software system architecture level, it mainly includes data acquisition system design and wireless transmission network software design. The corresponding system switching software system architecture mainly includes switching system configuration design. The corresponding mobile terminal software system architecture mainly includes data real-time acquisition software system architecture, data conversion, and storage software system architecture and data analysis software system architecture. At the corresponding wireless transmission network architecture level, the relationship between the corresponding host manager interface, data link layer, and corresponding physical layer should be fully considered. In the corresponding system on-off software design level, we

need to pay attention to the reasonable configuration of the sleep time of the main chip and the corresponding power consumption, as well as the reasonable configuration of the motion interrupt response corresponding to the sensor chip.

## 6. Experiment and Data Analysis

Under the framework of the above tennis training system, the experiment is carried out and the experimental data are analyzed. The corresponding experimental conditions are as follows: all the software codes in this paper are realized under win7 \* 86 + VS2008 + MATLAB. The object of this paper is the human motion training system under the traditional human posture estimation algorithm. The corresponding experimental steps are as follows:

Step 1: Collect the corresponding human tennis training images through the sensor as the input part of the sports training system.

Step 2: Based on different human posture estimation algorithms, the motion state and corresponding posture data of players swinging and playing are obtained and stored.

Step 3: Feature value extraction and similarity analysis based on depth image.

The corresponding experimental part, experimental principle, experimental conditions, and corresponding experimental indicators are as follows:



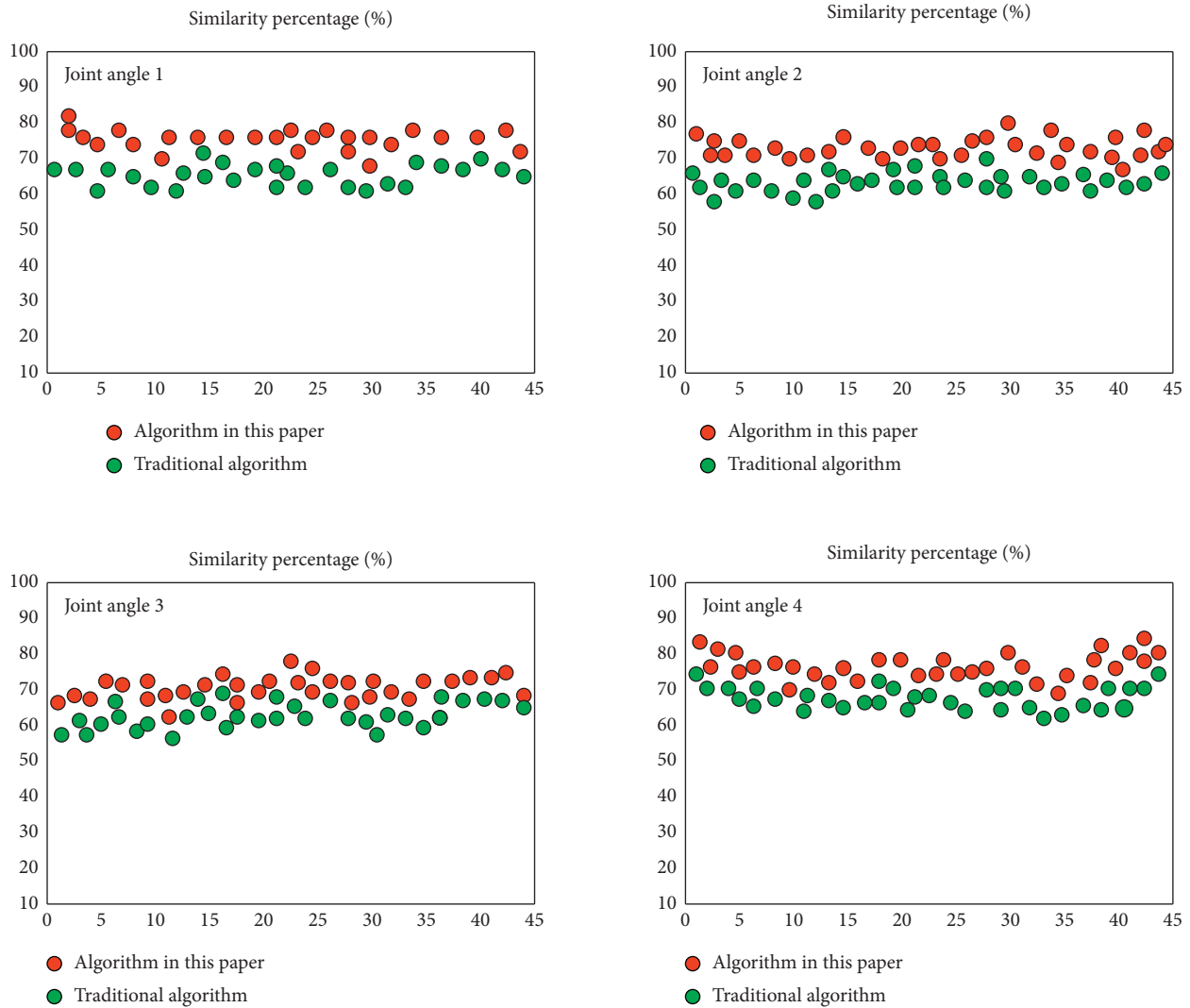


FIGURE 7: Comparison of similarity curves between different joints of sports training system under different algorithms.

Experimental principle: Based on the above frame diagram of human sports training system (this paper takes tennis as an example).

Experimental conditions: Variable control based on human joint similarity index, long-term similarity index of different joints, and stability index of sports training system, and comparative analysis and research are carried out at the same time.

Experimental index analysis: There are three main indexes in this paper, which correspond to the similarity index of human joints, the similarity index of different joints in long term, and the stability index of sports training system. These indexes all reflect the performance of the system.

In practice, four joint angles are selected for comparative experiment, and the corresponding experimental results are shown in Figure 7. As can be seen from the figure, based on the sports training system under the algorithm in this paper, the corresponding athletes can better perform the training results during training, so their corresponding action

similarity is higher than that of the traditional algorithm. From the experimental data, the similarity of the motion training system under the optimized human posture estimation algorithm in this paper is about 10% higher than that under the traditional algorithm.

In order to further verify the corresponding algorithm advantages of this algorithm in a long time period, this paper also carries out similarity comparison experiments based on the above four joints, and the corresponding comparison experiment results are shown in Figure 8. It can be seen from the figure that the corresponding similarity of the sports training system under the algorithm in this paper is more obvious than that under the traditional algorithm over time. From the long-time experimental data, the similarity of the motion training system under the optimized human posture estimation algorithm in this paper is about 12% higher than that under the traditional algorithm, and the corresponding performance gap becomes more and more obvious with the passage of time.

In order to further verify the advantages of the motion training system under the optimized human posture

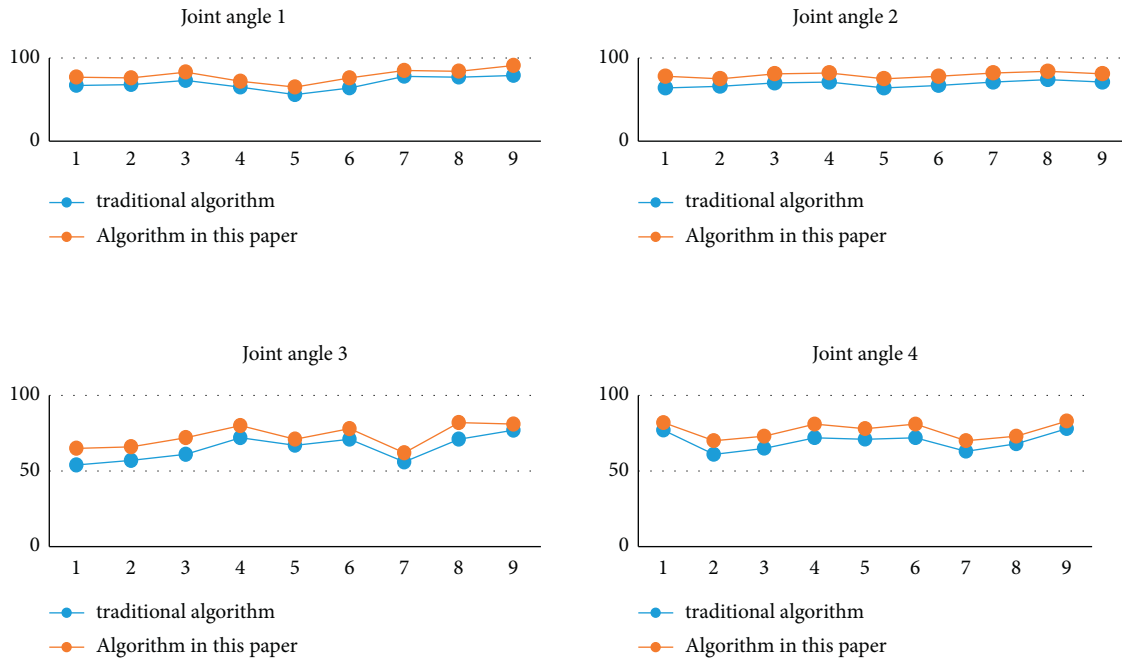


FIGURE 8: Comparison of similarity curves between different joints of sports training system under different algorithms in long period.

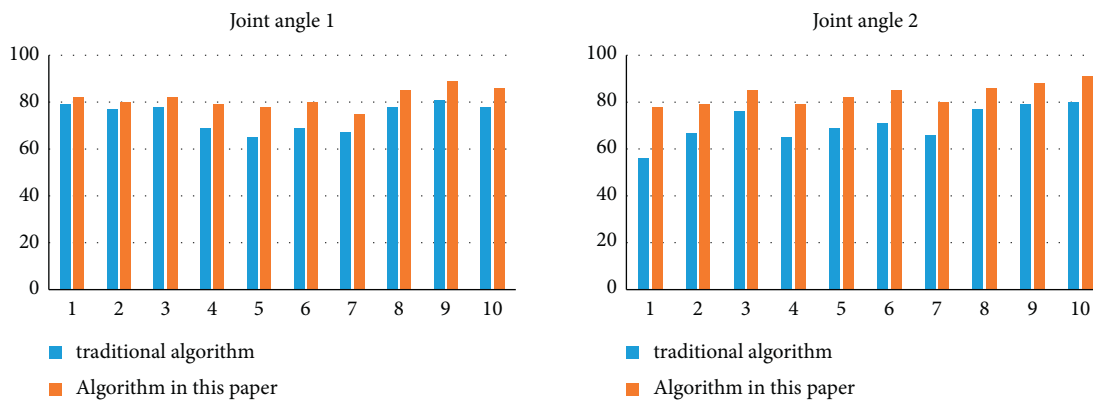


FIGURE 9: Stability comparison curve of sports training system.

estimation algorithm in system stability compared with the traditional algorithm, the stability test is carried out in this paper. The main experimental content is to design a set of complex tennis training actions, which are trained by athletes under different algorithms. At the same time of training, grasp and analyze their sports characteristics based on different algorithms and feed them back to the sports training system for optimization training. Therefore, the accuracy of athletes under complex actions is judged and recorded through the number of experiments. The stability experimental results of the corresponding system are shown in Figure 9. From Figure 9, it can be seen that the sports training system under the algorithm in this paper has obvious advantages, and it has obvious value for the long-term training and level improvement of athletes.

Based on the above experimental results and analysis, the motion training system under the optimized human posture estimation algorithm proposed in this paper has obvious advantages compared with the traditional system. It not only

theoretically solves the disadvantages of the sports training system under the traditional algorithm, but also further verifies the enforceability and superiority of the algorithm at the experimental level. Therefore, based on the above correlation analysis and the final experimental results, it can be concluded that the sports training system under this algorithm has an obvious effect on promoting athletes' sports training recovery and sports-level improvement.

## 7. Conclusion

This paper mainly analyzes and studies the research status and existing problems of sports training system design under human posture estimation algorithm. Aiming at the existing problems, this paper makes a systematic analysis and research, and puts forward the optimization algorithm. Specifically, this paper designs a motion training system based on the optimized and improved human posture trajectory

algorithm, uses the depth image-related theory to solve the problem of non-Gaussian noise crosstalk in the depth image of the traditional human posture algorithm in principle, improves the accurate feature extraction of the depth image by the algorithm, and solves the problem of human feature redundancy, so as to further improve the accuracy of the establishment of a single human model. On the problem of multi-person posture estimation algorithm, this paper proposes a high-resolution multi-person posture high-precision network model and adds the focus mechanism. Based on this, this paper realizes the high-precision and high-speed modeling of multi-person posture, so as to provide an accurate model for the multi-person function of sports training system and improve the efficiency of the algorithm. In the experimental part, this paper takes tennis as a typical case to design the sports training system and experiments based on the system designed in this paper. The experimental results show that the system under the proposed algorithm has obvious advantages in accuracy and training effect. This paper will focus on the research and analysis of multi-person pose estimation algorithm in the following research and further optimize the 3D single person pose estimation algorithm, so as to further improve the advanced and accuracy of the sports training system. In this paper, the research on the motion training system based on human posture estimation algorithm mainly analyzes the optimization of its software and hardware architecture in the later stage and further reduces the energy consumption of the algorithm. For the extraction of dynamic human features, this paper will further analyze how to improve the stability of the corresponding algorithm and the accuracy of feature extraction [34].

## Data Availability

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

## Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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