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Computer-Aided Design AND APPLICATIONS

Exploring the Potential of Virtual Reality in Table Tennis Training through Hybrid Motion Capture

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Abstract: According to the opinions of The General Office of the State Council on strengthening school physical education to promote the comprehensive development of students' physical and mental health. For deepening teaching reform, strengthening physical exercise, and extensively carrying out table tennis sports advantages have become the key content of school sports development. In order to improve the effect of table tennis training system, improve the traditional teaching, and realize the scientific and intelligent teaching requirements, this paper proposes the design and development of table tennis basic technical action evaluation system based on mixed motion capture technology. At the same time, in view of the lack of professional technical guidance in the current public fitness problems, the design and research of this system can realize the technical movements of table tennis trainers to a certain extent The function of guidance and evaluation, assist the use of table tennis trainers in independent learning and table tennis technical action evaluation, and strengthen its auxiliary system. This paper studies the table tennis sports training auxiliary system, using mixed motion capture technology, to improve the training technical guidance and table tennis action guidance, mainly using hardware equipment using Microsoft Kinect2.0 hybrid motion capture technology, by calling color data flow, depth information data flow, bone data flow and other related data interfaces, obtain the original depth data information capture, as the system input data, test and evaluation module program design and development. Using Kinect2.0 motion capture equipment has greatly reduced the depth of information collection system this, and the data processing is relatively simple, real-time good, easy to promote the public application. It also confirms the utility of Kinect2.0 hybrid sports capture technology in table tennis sports training. This paper can further expand and develop the characteristics of table tennis and other sports, which is conducive to the interdisciplinary integration of sports and computer theory and technology, and promote the development of sports. Moreover, compared with high-precision motion capture equipment, Kinect hardware equipment is low. On the basis of this hardware equipment, the data and information acquired by the system are designed and developed, which is easy to be widely promoted and has high practicability and feasibility.

Keywords: Mixed sports capture; table tennis sports training; auxiliary system; Kinect2.0; Virtual Reality
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1 INTRODUCTION

Auxiliary sports system is an important research field, with Virtual Reality (VR) mainly using computer vision, computer graphics and motion capture technology combined with sports characteristics, according to the user demand design and development auxiliary system, to improve the sports learning entertainment and scientific, arouse public enthusiasm for sports participation, learning to master sports skills have important practical significance and application value.

Table tennis as a national ball in our country has a good mass base, the audience range, but for the public fitness table tennis beginners or amateurs, due to the lack of professional technical guidance, only rely on books, teaching video methods to learn table tennis skills, to continuously improve the level of table tennis technology has more difficult, sometimes easy to form wrong technical habits, itself is not easy to find and correct in time, accumulated sports damage, therefore, the lack of professional technical guidance to a certain extent hindered the development of table tennis in the public fitness. Therefore, along with the modern science and technology in the With the rapid development and application of the field of sports, it is urgent to explore the scientific and intelligent training auxiliary system to Virtual Reality (VR) improve the deficiency of the traditional teaching mode. The use of Virtual Reality (VR) in training also helps users avoid incorrect technical habits, thereby reducing the risk of sports injuries.

This paper builds a system development platform, collects human movement information through Kinect2.0 hardware equipment as the input data of the system, and designs data acquisition control to realize the action data acquisition module of the system. After data acquisition, the raw data should be smoothed and jitter eliminated, and the human motion information data after filtering and noise reduction should be saved by calling the relevant interface, and wait for the system to evaluate and analyze the user data.

At present, Kinect hybrid motion capture technology has been well applied in physical education teaching and training. Some scholars have taken advantage of the convenience and efficiency of Kinect to design and develop teaching assistance systems for golf, Taijiquan and other sports, and have certain practical application value. Because the table tennis playground is relatively small and flexible, it meets the field test requirements of the best capture range of Kinect hardware equipment, and collects human sports data without wearable devices, which is cheap and easy to promote and apply. Therefore, this paper proposes to design and develop table tennis sports training based on hybrid action subsidy technology. The auxiliary system has certain necessity and feasibility.

This paper by studying the relevant literature to understand the current situation and trend of table tennis sports training research, the table tennis glue, teachers and trainers, obtain its demand in training, and then build a hybrid motion capture system, using Kinect to collect the human movement information of trainers, in the information data machine processing, after the system analysis of the user action guidance, to achieve the effect of auxiliary training.

2 REVIEW OF RESEARCH AT HOME AND ABROAD

Motion capture system is based on the principle of computer graphics, through the specific sensor equipment of object motion information in space real-time tracking, using video capture device will track object motion trajectory[12], posture and other action information record, save, and after computer data processing to obtain the three-dimensional coordinates of object motion in space, for analysis, processing, application and reconstruct the state of motion in virtual space. Around 1970,

the psychologist Tohansson completed the basic prototype of the motion capture system in his MLD laboratory, and first proposed the concept of motion capture[5].By the early 1980s , Computer motion capture technology has begun to be widely paid attention to by relevant scholars. Literature [13] has carried out more in-depth research on this technology, which has promoted the further development of motion capture technology. Motion capture technology was first mainly used in the field of animation production [6]. This technology can reconstruct the 3 D virtual model and reproduce the action process by capturing the movements of the actors. After the improvement of the accuracy and function of motion capture technology in recent years[9], the motion capture system has been applied in various fields, and the application in the field of sports is also relatively in-depth [2]. The motion capture system can effectively and accurately capture the physiological and biochemical indicators of athletes for real-time monitoring and injuries Prevention, also applied to the characteristics of athletes technical movement law analysis, correction [8], to improve the technical level of athletes auxiliary coaches training teaching has great significance, and through the synchronization of athletes complex action data information preservation, reduction function, in competitive sports games for the naked eye is not easy to identify the complex, controversial problems, motion capture technology can be used as the referee auxiliary system to assist the referee accurate judgment [10].

Microsoft in 2010, Kinect1.0 motion device is the most representative monocular visual motion capture system in recent years [15], the device through a single infrared depth camera capture scene depth data information, the human object without wearing any sensing equipment, can effectively capture tracking 6 moving body frame image and 21 joint 3 d coordinate information [14],[11]target extraction and tracking target object clothing, body shape and external environment changes, can accurately match the human skeleton image information, the technology effectively promote the computer vision motion capture The development of technology makes the concept of "human-computer interaction" more thoroughly demonstrated. In 2014, Microsoft launched the second generation of Kinect for Windows product Kinect2.0. Compared with the first generation, Kinect2.0 has made great improvements in terms of hardware and software [3], effectively improving the human capture accuracy and the number of joint points, and obtaining more human posture information. Microsoft has also released Kinect SDK v2.0, a toolkit for academic research and application development, and many scholars and developers have also designed and achieved good applications Effects, such as "virtual fitting mirror", "intraoperative diagnosis" [6], "mechanical operation" and tai Chi teaching system designed and developed for sports projects [1], golf swing auxiliary training system and standing long jump test system, etc. Therefore, it is feasible and practical to develop an auxiliary training system for table tennis [17].

In conclusion, the application of Kinect hybrid motion capture technology in physical education teaching has been gradually developed. The research of motion capture based on deep information obtains human movement information in a natural and efficient way, and develops the rationality of technical action to assist the training of sports projects.

3 STUDY ON TABLE TENNIS SPORTS TRAINING AUXILIARY SYSTEM BASED ON MIXED SPORTS CAPTURE

3.1 Hybrid Motion Capture Principle

This paper studies the specific implementation path of motion capture based on Kinect2.0 device with RGB wide-angle color camera, depth camera and infrared transmitter (infrared projector), where infrared transmitter and depth camera constitute the depth sensor of Kinect2.0 device, which can obtain the depth data information of the target scene and output it in the form of depth image [16]. The structure of Kinect2.0 device is shown in Figure 1. The collection of depth information can accurately realize the segmentation of target object and scene, separate the front and rear scenes

of the test environment and obtain 3 D data Information is the technical basis of human body recognition, bone image mapping and other modules in Kinect motion capture.

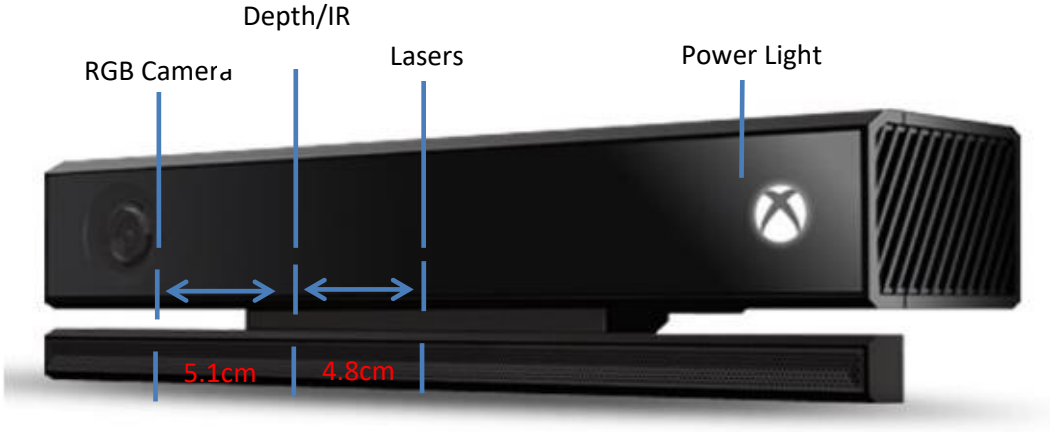

Figure 1: Overall structure diagram of Kinect2.0 equipment.

Kinect2.0 uses TOF (Time of Flight) photon time-of-flight technology to obtain depth information, that is, the infrared transmitter actively emits a strong periodic sine or cosine light pulse wave, the depth camera receives the light pulse reflection signal, and the actual depth value R of the target object can be calculated according to the phase difference.
TOF obtains the distance d between the measured object and the focal plane of the infrared emitter. The calculation formula is:

$$d = \frac{1}{2} c \cdot t = \frac{1}{2} c \cdot \frac{\Delta\varphi}{2\pi f} \tag{1}$$

In the formula (3-1), C is the propagation speed of light in the atmosphere, i.e. C ~ 3 x 10m/s, f is the frequency of modulated light emitted by the infrared transmitter, and $\Delta\varphi$ is the phase difference between the transmitted light signal and the reflected light signal. The propagation time of the optical pulse can be calculated and expressed by the phase difference between the two signals. For the unknown quantity $\Delta\varphi$, according to the cross-correlation function between the transmitted signal and the reflected signal, four equal interval specific phase samples are selected for the reflected optical signal in one modulation cycle, and the $t = ft\left(t_0 = 0, t_1 = \frac{1}{4}T, t_2 = \frac{1}{2}T, t_3 = \frac{3}{4}T\right)$ is used to calculate the optical signal strength respectively, so as to calculate the $\Delta\varphi$ value.
The light wave signal emitted at the set modulation frequency f is:

$$S(t) = A \cdot \cos(ft) \tag{2}$$

The reflected light wave signal after propagation is:

$$r(t) = kA \cdot \cos(ft + \Delta\varphi) + B \tag{3}$$

Cross-correlation function of light wave signal and reflected light signal emitted by infrared emitter:

$$C_i = C(t_i) = \frac{1}{2} kA \cdot \cos(t_i + \Delta\varphi) = B \tag{4}$$

In the above expression, A is the amplitude of the emitted cosine wave signal, f is the modulation frequency of the emitted light signal, k is the decay coefficient of light waves generated during the propagation and reflection process, and B is the signal bias caused by the addition of background light. The phase difference is calculated according to the optical signal intensity of the selected four sampling points as;

$$\Delta\varphi = \arctan \frac{C_3 - C_1}{C_2 - C_0} \tag{5}$$

The above calculation process finally obtains the depth value of the measured environment space, and the 3 D position information of the measured environment can be obtained in real time. The motion capture technology has strong resistance to external light interference, high hybrid capture accuracy and relatively stability.

3.2 Hybrid Motion-Capture Recognition

Deep image and RGB image compared by external environment light less, can measure the environment 3 d position information, therefore, in the hybrid motion capture technology acquisition depth image separation strategy, segmentation before and after the image, determine the contour area, through the middle layer, the pixel classification, identify the isolated human parts information, using machine learning algorithm, finally complete the body of human object 3 d information tracking, acquisition, Kinect based on depth image of human bone information tracking recognition process is shown in Figure 2.

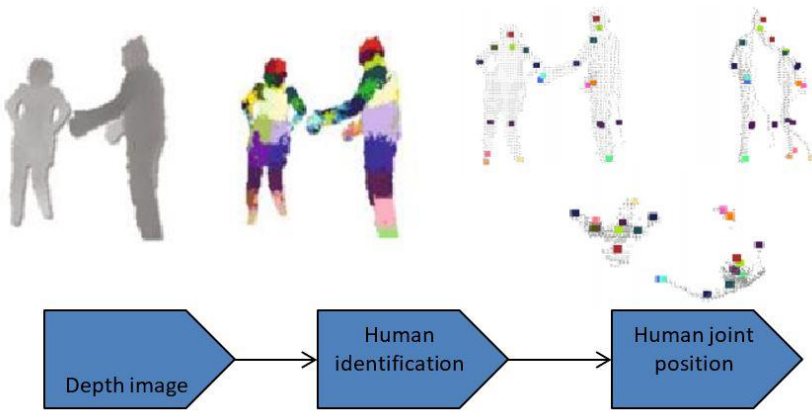

Figure 2: Flow chart of hybrid motion capture for human bone recognition.

Human object in the construction of the layer, namely figure 3 depth image segmentation after the middle of the human body, the stage is the different body parts of separate object recognition

classification process, object data information input system training model, extract the depth of the parts of the human body information and used to train 32 different parts of the classifier, distinguish the human body characteristics formula is:

$$f_\theta(I,x)=d_l\left[x+\frac{\mu}{d_l(x)}\right]-d_l\left[x+\frac{v}{d_l(x)}\right] \tag{6}$$

Where, x is the pixel value of the depth map pixel, dl (x) is the depth value of x pixel value in the depth image l, 0= (u, v) is the lens offset vector, 1 / dl (x) is the human size scale, normalize the offset, I is used as a marker image. The calculation formula reflects the difference between the 3 D shape of the measured pixel and its surrounding area. For example, if the offset pixel is the pixel in the background image, the dl (x) tends to be positive infinity, so the parts of the body can be effectively distinguished according to the different influence characteristics.
According to the collected data model training decision tree forest classifier, specify the pixels in the image distribution probability of various parts of the body, through the decision tree separation node characteristics and threshold, the depth of pixel classification, and for each branch node repeatedly calculated by the machine learning the human area distribution probability, compared with the threshold to determine the classification of pixels. The decision tree classifier is not affected by human clothing, body shape, action posture and other factors, and can accurately divide the pixels of each part to the region with the maximum probability, and has robustness. Thus, based on the

3.3 Table Tennis Technical Action Extraction

3.3.1. Table Tennis Sports Movements

There are many types of table tennis technology, such as forehand attack, backhand technology, forehand and backhand loop technology, platform technology and due to the different way of grip push block technology, straight horizontal technology, formed by the way of cutting technology, etc., [4]but no matter use any technical type, if you want to achieve effective hitting, contains the following technical links:

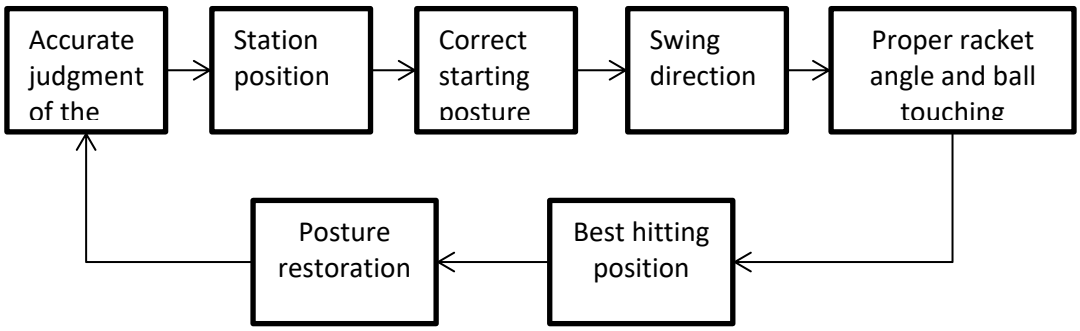

Figure 3: Table tennis technical link.

As can be seen from the figure above, the accuracy and rationality of technical movements can have an impact on each technical link. Therefore, for beginners, mastering the correct and reasonable basic table tennis technical movements can effectively reduce the error rate and be conducive to the learning of other combination technologies.

Although the technical movements of table tennis will have some differences in everyone's technical movements because of individual forms such as height, arm length and other reasons, from the form and content of the movements, the technical action structure of each technical type is consistent. By summarizing relevant theoretical textbooks and biomechanical research related to table tennis technology, table tennis technical movements are generally divided into four action stages: lead stage, swing stage, swing stage and reduction stage, as a complete action cycle of table tennis technology. Due to space and time constraints, this paper will include the swing stage, from the perspective of action recognition, as the player is completing In the process of technical movement, the displacement change of each joint point and the arm swing speed and joint Angle divide a complete table tennis technical action into lead stage, swing stage and reduction stage. Here to take the right-handed forehand attack as an example for the action stage description.

Lead stage: judge to the ball, holding the racket by the preparation action to the right rear, by capture the joint point 3 d position information and the joint speed change, in the racket stage athletes from preparation posture to the end, the racket speed increases and decrease, theoretically in the first time, with the camera frame as the reference coordinate system, but to the x axis positive direction And reach the maximum value moment.

Swing stage: by the end of the minimum moment the racket to the racket speed again reach minimum and close to 0 all remember the swing action stage, this stage includes the touch with swing process, but because the touch stage time is short to capture, and for good players technical action, the maximum swing speed does not always appear in the touch moment, so the maximum speed to judge the touch moment and as the action contrast, there will be large error. Therefore, the minimum point of the elbow angle is the end point of the swing phase, During this process, the joint points of the upper limb move towards the y-axis and reach the maximum value.

Figure 4: Forehand attack ball posture process.

3.3.2. Table Tennis Action Information

This paper extracts the action characteristics of outstanding athletes, and as the standard of evaluation and analysis, therefore, the selection, judged by experts, 20 secondary players, 20 outstanding players each complete 40020 complete data collection, and by adjusting the light and equipment location, and finally selected 400 stable and small system error smooth data storage, as action characteristics The data sample is taken, and the basic information of excellent athletes is shown in Table 1.

sex	*number of people*	*Age (age)*	*stature (cm)*	*Years of training (years)*	*Rank grip*	*Type of play*	*Pier type*	*Sports level*

man	*10*	*20 ± 2*	*174+0.06*	*12 ± 2*	*Horizontal grip (9) straight shot (1)*	*Fast break combined arc (10)*	*Double adhesive (10)*	*Level 1 (8) Level 2 (2)*
woman	*10*	*21 ± 2*	*167 ± 0.03*	*12 ± 3*	*Horizontal grip (10)*	*Fast break combined arc (10)*	*Double adhesive (10)*	*Level 1 (4) Level 2 (6)*

Table 1: Basic information table of excellent athletes/persons.

Test environment as shown in Figure 4, action data acquisition by service machine fixed service, to ensure the same initial position, reduce the initial position and the impact of the racket and table tennis touch stage cannot capture, therefore, requires players hit uniform fixed area range, to reduce the action error, ensure the consistency of external parameters of the system.

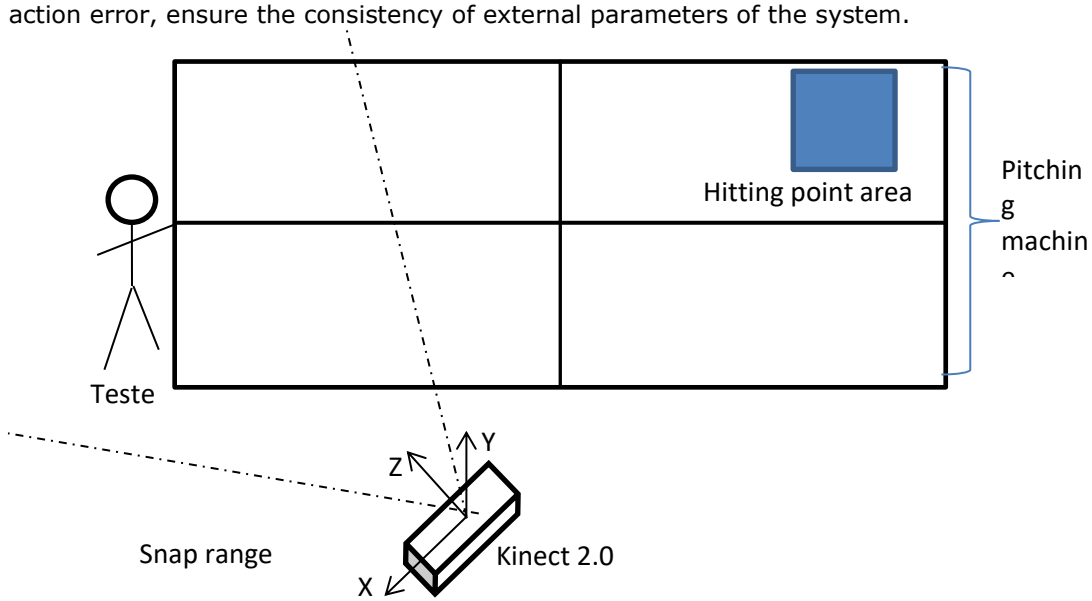

Figure 5: Test site schematic diagram.

(1) Description of action judgment parameters

In the process of action feature extraction, should first according to the characteristics of each stage technical action selection parameters, make the movement between stage, with 20 excellent players 20 forehand attack technology data information as sample data to estimate the overall mean interval, action judgment parameters set as table 2 (right hand forehand attack as an example).

Action stage	*Action characteristics*	*parameter setting*
Tapping stage	*Turn the waist while holding the pat from the initial preparation position* *Take your hand to the right back of the body*	*Participation of all bone joints* *Time interval of the action stage* *X-axis offset*
The swing hit stage	*By lead end moment posture,*	*Participation of all bone joints*

Restore stage	*Turn your belt, move your arm, and swing the ball* *Attitude at the end of the swing* *Restore to ready action posture*	*Time interval of the action stage* *Y-axis offset* *Participation of all bone joints* *Time interval of the action stage* *Y-axis offset*

Table 2: Action characteristics describe the parameter setting.

2）Bone joint point extraction

Through the euler distance to calculate the initial action posture and end posture joint point movement distance, according to the change degree of each joint participation, the bone joint participation represents the influence on movement, therefore, in each action stage to choose a group of higher influence of joint point and participation as excellent athletes technical action features.

The Euler distance calculated by the bone joint point of the 3 D position information is as follows:

$$d\left(X_{joint}, X_{joint,j}\right)=\sqrt{\left(x_{joint,i}-x_{joint,j}\right)^2+\left(y_{joint,i}-y_{joint,j}\right)^2+\left(z_{joint,i}-z_{joint,j}\right)^2} \tag{7}$$

$d\left(X_{joint}, X_{joint,j}\right)$ is the Euler distance between the joint point. The coordinate position of X_{joint} in frame i and the joint coordinate position of frame j in 3 D space, and the 3 D space coordinates of X_{joint} are (x, y, z).

According to the Euler distance, the proportion of the spatial change of each joint point from the initial posture to the end of the overall change of the movement is the joint point participation. The calculation formula is as follows:

$$P_i=\frac{d_i}{\sum d_j}, j=0,1,2,\ldots,25, i=0,1,2,\ldots,25 \tag{8}$$

The di is the European distance between the initial action moment and the end action moment of the i th joint point, and the Pi is the action participation of the i th joint point.

In the process of doing technical movements, athletes will form partial occlusion of the finger joint points, foot joint points and left elbow joint points (due to the table and clapping), resulting in inaccurate data capture.Also considering the finger joint, foot and left elbow for right hand holding point of table tennis forehand attack technique change effect is small, therefore, in the joint point data information collection, no longer for fingers, feet, left elbow and other joint information data collection and analysis, only track for HandRight, WristRight, ElbowRigh t,ShoulderRight,SpineShoulder,SpineBase,HipRight,KneeRight,SpineMid,ShoulderLeft,HipLef t,AnkleRight,KneeLeft,AnkleLeft,Neck,Head et al 16 human bone joint point data information to improve the system computational capture efficiency.Collect the 20 forehand attack technical action data of 20 outstanding players (right hand holding) to get each joint The Euler distance of point movement changes, and the arithmetic mean of the Euler distance of each joint with 20 forehand shots for each player, indicating the overall movement characteristics of the player, and the lead stage as an example is shown in Table 3.

Skeletal joint point	*Euler distance (μ±SD) (m)*	*degree of participation (μ±SD)*
HandRight	*0.800+0.03*	*0.327 ± 0.064*

WristRight	*0.615±0.082*	*0.247±0.013*
ElbowRight	*0.286±0.080*	*0.113+0.014*
ShoulderRight	*0.112±0.024*	*0.045±0.004*
SpineShoulder	*0.066±0.036*	*0.025±0.012*
SpineBase	*0.030+0.014*	*0.012+0.004*
HipRight	*0.053±0.008*	*0.020±0.002*
KneeRight	*0.026±0.017*	*0.011±0.010*
SpineMid	*0.043±0.019*	*0.017±0.006*
ShoulderLeft	*0.082±0.057*	*0.031±0.020*
HipLeft	*0.006±0.015*	*0.026±0.011*
AnkleRight	*0.014±0.012*	*0.006±0.006*
KneeLeft	*0.071±0.060*	*0.026±0.021*
AnkleLeft	*0.033±0.015*	*0.014±0.009*
Neck	*0.070±0.053*	*0.026±0.019*
Head	*0.141± 0.07*	*0.054±0.021*

Table 2: Bone and joint characteristics information during the racket introduction action stage of the forehand attack.

4 EXPERIMENTAL ANALYSIS

In order to verify the feasibility of the algorithm and the realization of the system evaluation and analysis function, the data of the forehand attack technology (right hand holding), analyzed Structure, sequence and excellent athletes movement is consistency, therefore, the user technical action characteristics with the extraction of technical action characteristics of excellent athletes, the user technical action evaluation, by calling the matlab program interface, the calculated evaluation results in the form of charts, the test results are shown in figure 5, 6 and 7.

Figures 5, 6 and 7 show the comparison of the technical action characteristics of the user in the three technical action stages. The abscissa is the sequence of skeletal joint points, the ordinate is the corresponding joint point participation of each bone point, the red broken line is the movement characteristics of excellent athletes, and the blue is the movement characteristic data information of the tester.As can be seen from the analysis results of the excellent athletes in a forehand complete technical action cycle, three technical action stage of bone joint participation, are right hand, right wrist, elbow initial and end movement range is larger, other parts of the participation is small, and relatively gentle, shows that many other parts of the body More than shaking, there is a good center of gravity shift, so that the participation of a joint point is almost equal.According to the analysis of Figure 5, in the stage, the user technical action and excellent athletes have certain similarity, although some joint point participation slightly higher some differences, but through the analysis of the calculation results, the difference range in the range of excellent athletes, and the correlation coefficient r = 0.950, correlation is very high, therefore, the user in the technical action stage, reasonable action.According to Figure 6, the user is abnormal in the technical movement of the swing stage, showing the participation of the hand and wrist joints Compared with the movement characteristics of the joint points corresponding to the movements of excellent athletes, the participation is low and obvious, and the movement range of the right waist joint point is too large. Through the analysis, it can be considered that the common elbow lifting phenomenon occurs in the swing stage, and the movement correlation coefficient is r = 0.686, and the movement difference is obvious.Therefore, the movement in the reduction stage is also unstable. From Figure 7, the overall trend of the feature contrast is obviously different.

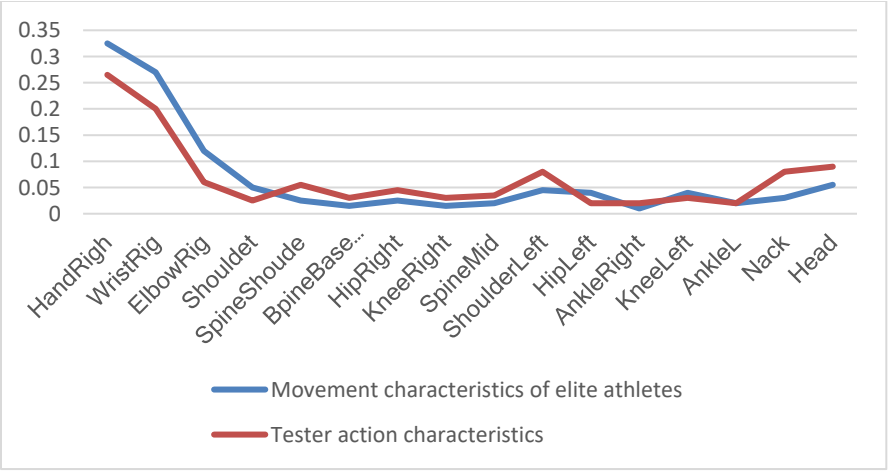

Figure 6: Comparison of technical action characteristics of right hand forehand attack in the lead stage.

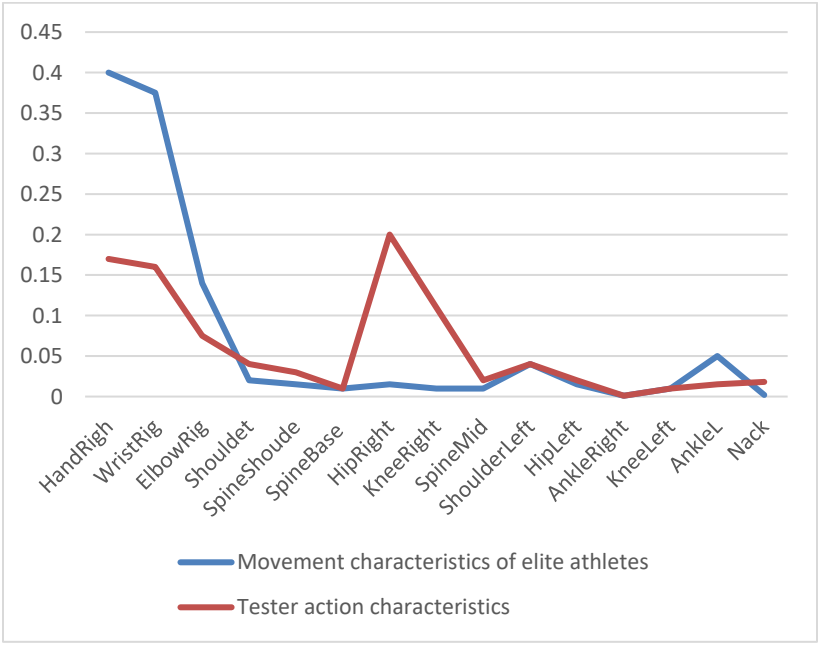

Figure 7: Comparison of technical action characteristics of right hand forehand attack in the lead stage.

The implementation of the test evaluation function and analysis results by table tennis experts and the system, the tester evaluation analysis, analysis results has the basic consistency, implements the evaluation function and the evaluation algorithm, but still need to interface display and analysis results intuitive to facilitate the user to understand and further consider the design.

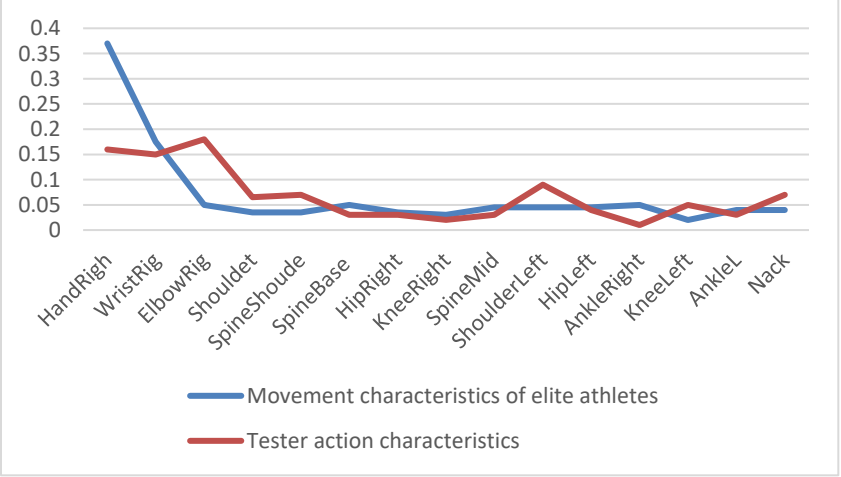

Figure 8: Comparison of the technical action characteristics of the right-hand forehand attack technique in the reduction stage.

5 CONCLUSION

This paper takes table tennis sports training as the research object, through the mixed motion capture technology and virtual reality in table tennis sports training, basically realizes the system function in the system framework, using Kinect2.0 for targeted system development, as a technical guidance and auxiliary training system for the public fitness or table tennis teaching courses in the widespread application is possible.

Through a large number of excellent athletes technical process of data acquisition, the characteristics of posture change, movement trajectory information extraction, as the user technical action test evaluation criteria, comparative analysis, display in the user graphical interface can show the user overall technical action stability three-dimensional surface diagram, the evaluation analysis results for real-time and intuitive test information feedback.At the same time, the system can identify and judge the wrong movements by extracting the movement gesture characteristic model of excellent athletes, and has a high recognition rate.

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