International Journal for Housing Science and Its Applications
Publish August 10, 2025. Volume 46, Issue 4 Pages 499-509

https://doi.org/10.70517/ijhsa46445

Design and Practice of Sports Training Simulation System Based on Virtual Reality Technology

Xiaoming Yan[1,*]
[1] Physical Education Department of Nanyang Institute of Technology, Nanyang, Henan, 473004, China
Corresponding authors: (e-mail: 13598272752@163.com).

Abstract The standardization and personalization needs of sports training have driven the application of virtual reality technology in the field of sports. This study designs and implements an athletic training simulation system based on virtual reality technology, which uses 3D human motion simulation simulation technology for training simulation, creates an action database through motion capture, applies offset mapping technology to correct the design of training actions, checks the reasonableness of the actions by using the Newtonian Eulerian motion model, and arranges the standardized technical action sequences through the method of motion splicing. The system integrates the core functional modules of VR perception interaction, motion capture acquisition, training environment establishment and action reproduction. In the study, 100 athletes were experimentally selected to verify the training effect, and the results showed that the error of the system's action data acquisition was controlled within 0°15', the mastery of the training content reached 96%, the training cost was maintained at 10,000 yuan, and the error of the system's response speed was no more than 5%. The system in this paper can effectively improve the training effect of athletes, significantly reduce training costs, and provide an efficient and economical technical solution for sports training.

Index Terms Virtual reality technology, sports training, simulation system, motion capture, training effect, technical level

I. Introduction

Sports training method is the intermediary of mutual transformation between sports training theory and training practice, and occupies a very important position in sports training [1]. The reform and development of education and the progress of science and technology are always inextricably linked, with the development of the network era and the arrival of the information age, the rapid development of modern educational concepts and teaching facilities, sports training methods are also undergoing subtle changes [2], [3]. The traditional training methods that used to be monolithic and formulaic are changing to the modern training methods that are more interactive and visual [4]. All these changes have prompted us to put forward higher and newer requirements for sports training concepts and sports training models. Therefore, modern sports training must actively adopt emerging science and technology to reform sports training methods and innovate training methods, and virtual reality technology is one of the important means [5]-[7].

Virtual reality technology (VR), that is, the comprehensive application of a variety of interactive interface technology forms, multimedia technology forms, computer graphics, simulation technology, artificial intelligence, computer network technology, multi-functional sensing technology, etc., with the help of application software, hardware equipment, sensor equipment, etc., to achieve a specific form of operation [8]-[10]. At present, the key technology in computer virtual reality technology contains five aspects. First, the construction of virtual space modeling, computer technology can build a virtual environment space for the applicant, and corresponds to the physical space of the real world [11]. Second, sound localization, the applicant in the virtual environment also needs sound, which can be based on different sound sources, individual left and right ear differences, and phase difference, etc. for defense and accurate confirmation [12]. Third, visual and spatial tracking, i.e., the applicant can get the same sensory experience as in the real world in the virtual space, and can use video imaging equipment to track the specific location [13]. Fourth, sensory feedback, the applicant can use VR feedback devices such as gloves to feel the specific force and resistance, which in turn allows the applicant to have a sensory experience, and can know the size of the force and the direction from through the sense of force and touch [14]. Fifth, sound exchange, in the virtual environment can still hear other people's voices, language, etc., to achieve the effect of human-computer interaction [15].

At present, competitive sports are developing rapidly in the direction of high, difficult and precise, so it is necessary to use some advanced scientific and technological means in the training process to maximize the potential of athletes [16]. This process requires the comprehensive use of knowledge of disciplines related to human movement and the analysis of the intrinsic laws of sports. Sports training simulation system belongs to the science of experimental technology, is the use of computer simulation technology to reproduce the process of athletes' training actions, which helps to find the problems in the training process, to achieve the purpose of timely correction [17]-[20]. VR is a product of the development of the Internet, through the programming of simulation of the real environment, and therefore the VR technology has been widely used in the training of some sports [21].

Modern competitive sports have put forward higher requirements for the accuracy of athletes' technical movements and maximization of training effects, and the traditional sports training model faces many challenges in terms of personalized guidance, standardized implementation and effect evaluation. It is difficult for coaches to accurately capture the technical details of athletes in real time, and athletes are unable to intuitively compare the differences between their own movements and the standard movements, which, to a certain extent, limits the improvement of training quality. At the same time, the traditional training method often relies on the subjective judgment and experience of coaches, and lacks objective data support, making it difficult to realize accurate technical guidance. In addition, high-level sports training on the venue, equipment and staffing requirements are high, training costs continue to rise, and the risk of sports injuries in the training process can not be ignored. Virtual reality technology, as an emerging digital technology, has the unique advantages of immersive experience, real-time interaction and precise feedback, which provides a new way of thinking to solve the pain points in traditional sports training. The technology can build a realistic virtual training environment, realize the accurate capture and analysis of athletes' movements, and provide a scientific basis for the development of personalized training programs. Foreign countries started earlier in the field of virtual reality sports training, and have formed a relatively mature technology system and application mode, while the domestic related research is still in the exploratory stage, and the depth and breadth of the application of the technology need to be further expanded. Based on this background, it is particularly important to construct a complete set of virtual reality sports training simulation system. Starting from the system design concept, this study analyzes the core elements of the sports training simulation system, including key features such as personalized customization capability, efficient data processing function and user-friendly interface. A 3D action database is established by motion capture technology, offset mapping technology is used to realize action correction and optimization design, and Newtonian Eulerian motion model is used to verify the reasonableness and scientificity of the actions. The system integrates multiple functional modules such as VR perception interaction, motion capture acquisition, virtual environment construction and action reproduction to form a complete technical solution. The training effect, cost control and response performance of the system are verified through comparative experiments to provide empirical support for the popularization and application of virtual reality technology in the field of sports training, and to promote the development of sports training in the direction of intelligence and digitalization.

II. Sports training simulation system

II. A. Design elements of an athletic training simulation system

II. A. 1) Personalization

Intelligent sports training systems need to take into account the unique needs and training characteristics of individual athletes, rather than adopting a single fixed model to design training programs for all. With this in mind, the system needs to have the ability to collect the athletes' various physical indicators so that it can more accurately meet the athletes' individual needs through high-quality data feedback and well-designed training programs.

II. A. 2) Efficient data-processing capabilities

A leading sports training simulation system must deeply integrate powerful big data processing capabilities to accurately process massive amounts of data to generate more realistic and reliable training feedback results. In this process, the system must make full use of highly efficient intelligent algorithms and cutting-edge machine learning technologies to further optimize the use of data and in-depth analysis, thereby significantly improving the performance level and credibility of data analysis. For example, when performing training analysis, the use of a refined data matrix not only significantly reduces the data processing time, but also allows the feedback results to be presented to the athletes/coaches at a much faster rate.

II. A. 3) User-friendly interface

Athletic training simulation system needs to be equipped with a very humanized and simple and convenient user interaction interface, so that athletes and coaches can realize various functions without any obstacles. Through its built-in sophisticated algorithms for in-depth analysis and interpretation of various performance data of athletes, the communication between coaches and athletes will be smoother and more efficient, which will not only help to enhance the coaching team's ability to respond quickly to problems that arise in the training process, but also facilitate the athletes' deep understanding of their own state of play.

II. B.Athletic training simulation with virtual reality technology

In the paper, the simulation of exercise training is carried out by 3D human movement simulation technology. Firstly, we create a database of athletic training movements by motion capture, then correct and design the athletic training movements in the database by offset mapping technology [22], and check the reasonableness of the corrected and designed movements by motion and kinetic analysis, and then use the motion splicing method to arrange the single standard technical movements after simulation and inspection, so as to obtain a new sequence of standard movements, and then compare the obtained simulated standard movement sequences and athlete training movement videos by the same-screen comparison. On this basis, the simulated standard movement sequences and athletes' training videos are analyzed to improve the quality of sports training and the level of athletes' technical movements.

II. B. 1) Athletic training movement modification and design

Motion capture provides an ideal way to create a three-dimensional database of athletic training movements. The basic principle is to accomplish the recording of motion data of the sports training target using sensor tracking equipment. It is characterized by the successful capture of actual human motion data, and at the same time, the captured motion information has temporal information, which can improve the simulation fidelity of human motion state change. The motion data of the human body surface marking points are recorded by optical principle, and the record is used as the initial 3D motion data. In order to successfully extract the 3D human skeleton from this data, it is necessary to filter and reduce the noise of this data.

By selecting the original frames to create a system that can match the virtual marker points and skeleton of the motion capture target, the skeletal motion of the motion capture data is optimized based on the minimum spacing criterion between the actual marker points and the virtual marker points. The motion data obtained from the optimization algorithm is noise reduced by smoothing and filtered by a quaternionic linear time-invariant filtering system to obtain a smooth skeletal motion. The Euler angle data are converted into corresponding quaternions by logarithmic operation and mapped into the tangent space, filtered by filtering the tangent space, and mapped into the quaternion space by exponential operation to convert the filtered result into the Euler angle data. After completing the creation of the realistic movement database for sports training, each realistic movement is presented in the form of virtual human synthesis software package VHSDK5.0 in three-dimensional form, and at the same time, the visualization method is used to correct and interactively design the realistic movements, and the Newtonian Eulerian movement model is used to complete the examination of the rationality degree of the new movements obtained after the correction and design, so as to obtain the personalized standard technical movements for sports training.

It is assumed that, relative to the human body movement $movement(t)$, the correction of the movement posture $attitude(t_i)$ to obtain a new movement posture $attitude^{'}(t_i)$ can be selected by the mouse in the $X \times Y$ -size user window, and the corresponding rigid body is pulled to realize the correction process, so as to improve the convenience of visual interaction action design. Let $\Delta x, \Delta y$ be the amount of change in the x, y direction when the mouse is pulled, and based on Euler's theorem [23], let the Euler's angle of a certain action b that can pass through the zyx direction be expressed as $\langle \varepsilon, \phi, \varphi \rangle$:

$$\begin{aligned} \sin\varepsilon &= \frac{c\Delta x}{X} = \frac{(1-c)\Delta y}{Y} \\ \sin\phi &= \frac{d\Delta x}{X} = \frac{(1-d)\Delta y}{Y} \\ \sin\varphi &= \frac{a\Delta x}{X} = \frac{(1-a)\Delta y}{Y} \end{aligned} \quad (1)$$

where the influence factor is denoted by c, d, a. The influence factor can be used to express the influence condition of $\Delta x, \Delta y$ on the Euler angle $\langle \varepsilon, \phi, \varphi \rangle$ in x, y, z each coordinate direction, which can be obtained by solving Eq. (1):

$$\varepsilon = \arcsin \frac{c\Delta x + (1-c)\Delta y}{X+Y}$$
$$\phi = \arcsin \frac{d\Delta x + (1-d)\Delta y}{X+Y} \tag{2}$$
$$\varphi = \arcsin \frac{a\Delta x + (1-a)\Delta y}{X+Y}$$

Based on this, the setting of the new motion attitude $attitude'(t_i)$ is realized. The new motion $movement'(t)$ is obtained through the offset mapping technique. The operational equation for the t_i moment offset is:

$$\begin{aligned} b(t_i) &= attitude'(t_i) - attitude(t_i) \\ &= \langle h_0'(t_i) - h_0(t_i), g_0'(t_i) - g_0(t_i), \cdots, g_m'(t_i) - g_m(t_i) \rangle \end{aligned} \tag{3}$$

where b denotes a motion, h and g denote the points corresponding to the current frame and the neighboring frames, respectively. The offsets of the remaining moments are operated in the same way to obtain the motion offset $b(t) = \langle b_{-1}(t), b_0(t), \cdots, b_m(t) \rangle$ corresponding to $movement(t)$. By superimposing the motion offset $b(t)$ to the initial motion $movement(t)$, a new motion $movement'(t)$ can be obtained as:

$$\begin{aligned} movement'(t) &= movement(t) \oplus b(t) \\ &= \langle h_0^n(t) + b_{-1}(t), g_0^n(t), \cdots, g_m^n(t) + b_m(t) \rangle \end{aligned} \tag{4}$$

Based on the characteristics of the athlete's physical parameters of the human body inertia parameters to achieve the prediction, and through the establishment of the Newtonian Eulerian motion model [24] within the required moment of inertia and other parameters to achieve personalization, based on this equation to the new movement $movement'(t)$ to be the degree of reasonableness to be tested, to achieve the visualization of the interactive design, movement testing and feedback of the interactive process, to achieve the purpose of correcting and designing the athletic training movements.

II. B. 2) Athletic Training Movement Choreography Simulation

By modifying and designing sports training movements to obtain a standard number of individual technical movements, a fixed number of movements are selected and connected in a specific order to realize the simulation of a set of standard technical movements. In order to significantly reduce the risk of athletic training and to help coaches to determine the method of athletic training movements, the results of the simulation of a set of standardized technical movements can be presented in advance through three-dimensional graphics. Therefore, a graphical interface was designed to allow the selection, pulling, and deletion of athletic training movements, and only the connection between two movements was emphasized in the choreography simulation of standardized technical movements. The two kinematic training movement segments are represented as $n_1(t), n_2(t)$, which is connected to a new standardized technical movement sequence by motion transition and motion mirroring techniques. The final stance $attitude_1(t_1)$ of movement segment $n_1(t)$ and the first stance $attitude_2(t_2)$ of movement segment $n_2(t)$ are represented in turn:

$$\begin{aligned} attitude_1(t_1) &= \langle h_0^1(t_1), g_0^1(t_1), \cdots, g_m^1(t_1) \rangle \\ attitude_2(t_2) &= \langle h_0^2(t_2), g_0^2(t_2), \cdots, g_m^2(t_2) \rangle \end{aligned} \tag{5}$$

The difference that exists between directions $g_0^1(t_1)$ and $g_0^2(t_2)$ can be expressed as follows:

$$dist(g_0^1(t_1), (g_0^2 t_2)) = \| \log(g_0^1(t_1))^{-1} \times (g_0^2(t_2)) \| \tag{6}$$

Whether or not motion mirroring should be performed on motion segment $n_2(t)$ is determined by equation (6). The result can still be denoted as $n_2(t)$. Mapping $g_i^1(t)$, $g_i^2(t)$, $q_i^1(t)$ and $q_i^2(t)$ after logarithmic change to Q^3. Connecting $g_i^1(t)$ and $g_i^2(t)$, $h_0^1(t)$ and $h_0^2(t)$ by curve splicing, assuming that w_d, w_c is the tangent rate at the beginning and the end of the two plane curves $x^1(t)$ and $x^2(t)$ in turn, the cubic ergodic curves of w_d, w_c are the tangent rates defined at the left and right endpoints of $[h_c, h_d]$, which can be represented by cubic Bessel curves as follows:

$$x(t)=\sum_{i=0}^{3} h_i \phi_i(t) \tag{7}$$

where $\phi_i(t)=\binom{3}{i}(1-t)^{3-i}t_i, h_0=h_c, h_1=h_c+\frac{w_c}{3}, h_2=h_d-\frac{w_d}{3}, h_3=h_d$.

Based on this, the spatial curve $q_i(t)$ connecting $q_i^1(t)$ and $q_i^2(t)$ can be obtained by curve splicing, and after the exponential change of the spatial curve, it is mapped to the unit quaternion space to obtain the quaternion curve $g_i(t)$ connecting $g_i^1(t)$ and $g_i^2(t)$, and then obtain the brand new standard action sequence $n(t)$ connecting the sports training action clips $n_1(t)$ and $n_2(t)$, and then compare and analyze the sequence and the athletes' training video with the same screen, so as to realize the purpose of improving the training instruction level of the coach and the technical standard of the athletes' action. The sequence is compared and analyzed with the athlete's training video on the same screen to improve the coach's training instruction and the athlete's technical standard.

II. C.Athletic training simulation system structure design

II. C. 1) System functions

The system functions in this paper are as follows:

(1) The functional structure of the VR perception interaction system is shown in Figure 1:

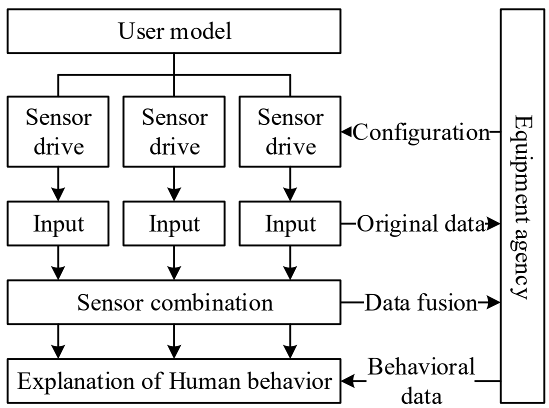

Figure 1: Schematic diagram of the VR perception interaction model

The sports training simulation system designed in this paper is able to simulate the scenes in the training process of the athletes and record some action data, so as to determine whether the athletes' movements meet the standards. Therefore, the combination of the simulation system and VR technology must comply with the data output and input functions to ensure that the maximum degree of simulation of the athlete's movements on the basis of virtual reality, to create a realistic and reliable simulation environment.

(2) Motion capture and acquisition function

There are many ways to capture the movement source training action, this paper through the inertial sensor to capture. The information captured through the node is transported to the PC using a wireless network, and the data is saved to build a human action database.

(3) Establishment of training environment and equipment

Combined with the characteristics of different sports to establish a virtual sports scene, the system can use sensors to collect on-site information, the use of mathematical models to drive the three-dimensional vision, the establishment of realistic training environment, in which the scene can not only complete the training task, but also to the virtual training equipment and simulation of human modeling. This technology can be used not only in the training process, but also in the pre-competition adjustment phase, which helps athletes to play the real level.

(4) Action Reproduction

Action reproduction is a key function of the sports training simulation system. Some training videos usually can not achieve satisfactory results, through the system can be easily realized. Its three-dimensional form of virtual athletes to realistically reproduce a variety of actions to help athletes improve their technical level, but also the use of visualization to make athletes easily grasp the technical aspects of reducing injuries.

Combined with the main functions of the system, the main architecture of this simulation system is shown in Figure 2.

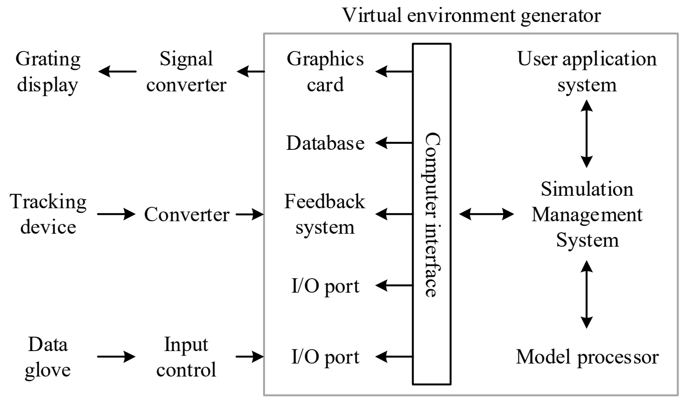

Figure 2: shows the overall architecture diagram of the simulation system

II. C. 2) System hardware modules

(1) Database

To realize the acquisition of athletes' movements, the data must be stored effectively. However, inertial sensors are an emerging field and do not constitute a universal database. In order to realize continuous motion capture, the capture device configuration needs to be improved. To this end, this paper utilizes MongoDB database, which can not only realize massive data storage, but also achieve the purpose of data sharing.

Compared with the traditional relational database, it has the following advantages: easy scalability: there is no connection between the databases, which improves the performance of the application expansion, can be combined with the data requirements, add more data tables about the training action, the same in the real architecture to show the scalability, flexible data processing capabilities: such a database can be flexible to store the data format, there is no need to realize the stored data. Flexible data handling: this database can store data in a flexible format, without the need to realize the construction of fields on the stored data, eliminating some complexity.

(2) Graphics device interface

Windows application pages can provide different types of function sets for applications. There are various types of services, the most important of which are graphics and multimedia services. Among them, GDI belongs to a subset of graphics and multimedia services, providing interfaces for programs, including monitors, printers and fax machines and other devices. Among the hundreds of programs provided by GDI, the functions that can be called are divided into 17 fields, most of which are exported from the Win32 subsystem.

(3) Image capture card

Image acquisition card refers to the microcomputer structure on the basis of the external card for the acquisition of a variety of image tasks. The use of digital decoding form, the input PAL system, NTSC system and other signals for digital processing, after decoding and transforming into RGB-24bits format digital information, Ran the use of PCI bus sent to the PC system.

Capture card can better realize the image real-time decoding and front-end processing, and microcomputer inherent resources to generate a more complete image acquisition system. Image acquisition card using the bus control mode, realize the camera to the computer internal reliable transmission. Image acquisition point array is square, image size and location can be selected, and the use of interrupt form, the image transmission and user programs cleverly connected.

II. C. 3) System software modules

In this paper, the simulation simulation system software is built on the basis of joint programming of LabVIEW and MATLAB. The LabVIEW program is divided into three modules: data fetch and read, calculation output and control output. Before the module starts the work task, a queue needs to be created to set the work order of each module. The system creates a total of two queues, one for reading and calculating data, and the other for outputting calculation results. Among them, the main task of the fetch and read module is to use LabVIEW program to read the electromyographic signal information acquired by the sensor. This module is divided into three sub-modules, which are used for obtaining data address, converting data form and data operation respectively. After completing the data fetching and reading tasks, the calculation module turns on the working mode and outputs the EMG signal automatically.

III. Training results and analysis based on athletic training simulation system

Experiments to verify the effectiveness of the practical application of the sports training simulation system based on virtual reality technology designed in this paper, an athlete training hall was selected as the object of study, in which 100 athletes involved in different sports training programs were selected to simulate training using the system in this paper, and the results are as follows.

III. A. Data Acquisition Tests

In this paper, the system utilizes the position and direction sensors etc. to collect the athletes' action data. In this paper, the collection data of ten athletes are randomly selected, and the collection error of the system movement data is shown in Table 1. In this paper, the system collects the athletes' movement error is basically controlled within 0°15', which indicates that this paper's system is able to collect the athletes' movement training data more accurately, which is conducive to the enhancement of the effect of the system's movement training in this paper.

Table 1: Data acquisition error

Athlete number	Upper arm		Waist bending	
	Athlete's action	System display action	Athlete's action	System display action
1	45°00'	45°12'	46°00'	46°09'
2	41°05'	41°11'	65°13'	65°11'
3	24°15'	24°19'	45°13'	45°18'
4	25°00'	25°05'	49°02'	49°05'
5	15°22'	15°31'	78°05'	78°09'
6	70°44'	70°43'	79°12'	79°10'
7	81°09'	81°01'	84°23'	84°22'
8	50°85'	50°80'	15°22'	15°21'
9	77°08'	77°17'	74°10'	74°15'
10	46°78'	46°82'	56°08'	56°04'

III. B. Comparison of training effects

In the process of comparing the effect of athletes' sports training, the degree of mastery of training content was selected as a comparison index. Among the selected 100 athletes, 21 athletes with similar age and basically the same physical quality were selected and arbitrarily divided into three groups of 7 each, the first group used the traditional training system based on artificial neural network to conduct sports training, the second group used the training system based on mechanical motion device to conduct sports training, and the third group used the system of this paper to conduct sports training. The three groups of athletes were trained with different sports training systems for 10 weeks, and the effects of sports training of each group were analyzed and recorded every week, and the results were shown in Table 2. After the first week of training, the athletes using this system (the third group of athletes) had a significantly better mastery of the training content than the athletes using the other two systems (the first group of athletes and the second group of athletes), with a mastery of the training content of up to 78%. As the duration of athletic training increased, the mastery of the training content increased in all groups of athletes. After 10 weeks of training, the mastery of the training content of the athletes using this system reached 96%, while the mastery of the training content of the athletes using the other two systems was 76% and 74%, which was much lower than the mastery of the training content of the athletes using this system. It can be seen that the system in this paper is more effective for athletes' training and more suitable for athletes' sports training.

Table 2: Training content mastery

Time	Training content mastery/%		
	This system	Traditional training system based on artificial neural network	Training system based on mechanical sports installation
Week1	78	45	48
Week2	81	49	49
Week3	84	56	52
Week4	85	64	55
Week5	87	68	59
Week6	88	70	65

Week7	89	71	67
Week8	91	74	59
Week9	93	75	70
Week10	96	76	74

III. C. Cost comparison

Comparison of the cost spent on the athletic training process of each group of athletes during the eight weeks of training during the training effect test experiment, the results are shown in Table 3. When conducting the first week of training, the cost spent by this paper's system was 0.6 million and 0.2 million yuan lower compared to the other two systems, respectively. With the extension of the exercise training time, the cost of training using this paper's system has been maintained at the same cost as the cost of the first week of training, i.e., the cost of exercise training using this paper's system has always been 10,000 RMB after 8 weeks of training. On the other hand, the cost of training using the conventional training system based on artificial neural networks and the training system based on mechanical locomotion devices increased at a rate of 0.3 million yuan per week and 1.0 million yuan per week, respectively, i.e., after 10 weeks of training, the cost of exercise training using the other two systems amounted to 43,000 yuan and 102,000 yuan, respectively. This suggests that utilizing the system in this paper for athletic training is less expensive and more practical to apply.

Table 3: Training cost (RMB 10,000)

Time	Training content mastery/%		
	Training system based on mechanical sports installation	Traditional training system based on artificial neural network	This system
Week1	1.6	1.2	1.0
Week2	1.9	2.2	1.0
Week3	2.2	3.2	1.0
Week4	2.5	4.2	1.0
Week5	2.8	5.2	1.0
Week6	3.1	6.2	1.0
Week7	3.4	7.2	1.0
Week8	3.7	8.2	1.0
Week9	4.0	9.2	1.0
Week10	4.3	10.2	1.0

III. D. System responsiveness

Comparing the response speed of this paper's system during the training effect test experiment, the results are shown in Figure 3. The response speed of the observation data calculation of this paper's system basically meets the real-time requirements of the simulation and analysis of virtual reality technology, and the response speed error does not exceed 5%, which proves that the response speed of this paper's system is guaranteed.

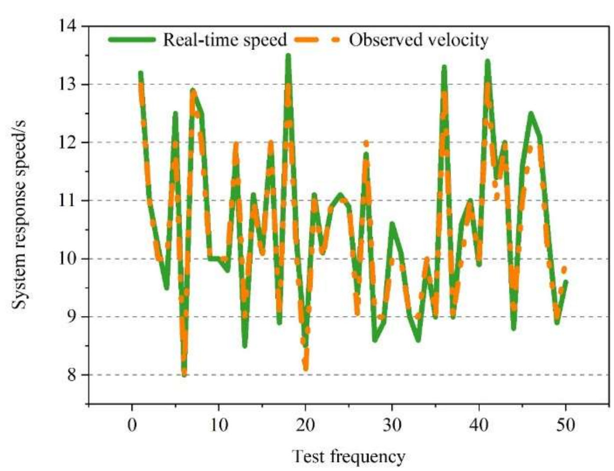

Figure 3: System response speed test results

III. E. Evaluation of the effectiveness of system applications

Since the number of athletes participating in the training was only 100, the mean values of cognitive anxiety, somatic anxiety and state confidence indicators and heart rate and heart rate variability were mainly counted for the athletes in the four training scenarios before and after the training. Among them, the scores of cognitive anxiety, somatic anxiety and state self-confidence indicators, the subjective state anxiety level of the participants were measured by using the Mental Readiness Scale (MRF-L), which has 3 entries and 11-point Likert scores to measure state anxiety (worry, nervousness, and level of self-confidence) from the dimensions of cognitive anxiety, somatic anxiety, and state self-confidence, respectively, and the higher the scores of cognitive and somatic anxiety indicate that the state anxiety The higher the cognitive and somatic anxiety scores, the higher the level of state anxiety. Heart rate variability is evaluated by RMSSD, the rapid change component of heart rate variability reflects the tension of the vagus nerve and its role in regulating the heart rate. The larger the RMSSD, the stronger the vagus nerve tension. Table 4 shows the descriptive results of the effectiveness of the contextual settings of the virtual reality-based sports training simulation system in this paper.Overall, the trend of the data suggests that all four training scenarios may be more successful in inducing stressful states in athletes.

Table 4: Descriptive results of situational setting effectiveness

Status anxiety indicator	Scene1	Scene2	Scene3	Scene4
Cognitive anxiety preanxiety	3.15	2.88	2.56	3.36
Cognitive anxiety	7.45	6.15	5.54	7.85
Preanxiety measurement	4.88	2.56	2.38	3.44
After somatic anxiety	6.65	6.34	5.67	7.86
Preconfidence	8.97	4.55	3.89	5.56
After confidence	9.02	5.89	5.89	6.38
Pre-heart rate/min-1)	70.56	78.45	69.45	78.56
After heart rate test/(min-1)	86.45	86.56	81.46	89.45
RMSSD pre-measurement/ms	20.55	11.26	10.78	13.56
RMSSD after measurement/ms	9.45	9.18	8.05	11.42

In the system testing phase, 10 athletes were selected to experience all the training modules in accordance with the training process, and to make retrospective subjective evaluation of the effectiveness of training based on their own experience, including 2 questions, which are the evaluation of the athletes on their own stress coping ability and anti-jamming ability, with a 5-point scale from 1 to 5, with 5 representing complete agreement and 1 representing complete disagreement. Table 5 shows the descriptive results of the effectiveness of the training module of this paper's system to enhance the anti-stress and anti-interference ability. Overall, the training module related to this paper's virtual reality technology-based sports training simulation system can better improve the anti-stress ability of athletes, and the subjective evaluation scores of the 10 athletes in the two questions are all over 4. The training module of this paper's system has a positive the training module of this paper's system has a positive effect on improving the anti-interference ability of athletes. This paper is based on the application of virtual reality technology to evaluate the sports training simulation system After the training, review the performance of the athletes in each training scenario, combined with the athlete's views and feedback on the system, to make a summary and evaluation of its application.

The system realizes the simultaneous interaction of psychological, physiological and behavioral evaluation indexes through VR simulation training software. At the same time, the increase of visual elements, the actual training of athletes training with psychological regulation guidance, can be used by the athletes before and after the usual training, which is conducive to the athletes in the face of the actual competition, the enhancement of psychological quality and stress resistance.

Table 5: Descriptive results of the effectiveness of different training modules

Athlete number	Through system training, I think I'm pressing in the game Ability to respond	Through system training, my psychological response in the game Anti-interference ability has improved
1	4.2	4.6
2	4.6	4.7
3	4.8	4.6
4	4.5	4.8

5	4.3	4.9
6	4.6	4.6
7	4.7	4.5
8	4.1	4.7
9	4.3	4.6
10	4.7	4.8

IV. Conclusion

The sports training simulation system based on virtual reality technology shows significant advantages in practical application. The system has successfully constructed a complete training system containing motion capture, motion correction, motion choreography and effect evaluation through three-dimensional human motion simulation technology.

The experimental data show that the athletes trained with this system have outstanding performance in terms of training content mastery, reaching 96% after 10 weeks of training, which is significantly higher than the 76% of the traditional training system and the 74% of the mechanical motion device training system. The system has obvious advantages in cost control, and the cost of the whole training cycle is always maintained at 10,000 RMB, while the cost of the other two training systems reaches 43,000 RMB and 102,000 RMB respectively, which is a significant cost saving effect.

The data acquisition accuracy test shows that the system is able to control the athletes' movement acquisition error within 0°15', which meets the technical requirements of precise training. The system response speed test results show that the response speed error is no more than 5%, which can meet the real-time requirements of simulation and analysis of virtual reality technology.

The evaluation of psychological training effect shows that the subjective evaluation of 10 test athletes on the system to improve the anti-stress ability and anti-interference ability are all above 4 points, indicating that the system has a positive effect on the cultivation of psychological quality.

The deep integration of virtual reality technology and sports training provides an effective path for the innovation of sports training mode, which has a broad application prospect and promotion value.

References

[1] Putra, C. A., Permadi, A. S., & Setiawan, M. A. (2024). Information technology innovation in sports learning: understanding global trends and challenges. Retos: nuevas tendencias en educación física, deporte y recreación, (58), 844-854.

[2] Han, L. (2024). Training of Future Physical Education and Sports Teachers in Higher Education Institutions: Modern Trends. Pedagogical Discourse, (35), 86-91.

[3] Mileva, E. (2016). Theoretical approaches to modern interpretation of pedagogy of physical education and sports. Faculty of Educational Sciences, 210-214.

[4] França, E. F., Antunes, A., Da Silva, A. C., Guerra, M. L. M., Cossote, D. F., & Bonfim, J. C. O. (2022). Concepts and principles of sports training: A narrative review based on the classic literature of reference. Int. J. Phys. Educ. Sports Health, 9, 214-217.

[5] Putranto, J. S., Heriyanto, J., Achmad, S., & Kurniawan, A. (2023). Implementation of virtual reality technology for sports education and training: Systematic literature review. Procedia Computer Science, 216, 293-300.

[6] Ting, L. (2015, August). Application of virtual reality technology to sports. In 2015 AASRI International Conference on Circuits and Systems (CAS 2015) (pp. 311-313). Atlantis Press.

[7] Zhang, Y., & Tsai, S. B. (2021). Application of Adaptive Virtual Reality with AI‐Enabled Techniques in Modern Sports Training. Mobile Information Systems, 2021(1), 6067678.

[8] Soltani, P., & Morice, A. H. (2020). Augmented reality tools for sports education and training. Computers & Education, 155, 103923.

[9] Qingtao, Z. (2020, April). Analysis and research on the combination of virtual reality technology (VR) and college sports training. In Journal of physics: Conference series (Vol. 1486, No. 5, p. 052011). IOP Publishing.

[10] Li, C., & Li, Y. (2020). Feasibility analysis of VR technology in physical education and sports training. IEEE Access.

[11] Wu, J. (2018). A Space Design Teaching Model Using Virtual Simulation Technology. International Journal of Emerging Technologies in Learning, 13(6).

[12] Rajguru, C., Brianza, G., & Memoli, G. (2022). Sound localization in web-based 3D environments. Scientific Reports, 12(1), 12107.

[13] Waller, D., & Hodgson, E. (2013). Sensory contributions to spatial knowledge of real and virtual environments. In Human walking in virtual environments: Perception, technology, and applications (pp. 3-26). New York, NY: Springer New York.

[14] Cooper, N., Milella, F., Pinto, C., Cant, I., White, M., & Meyer, G. (2018). The effects of substitute multisensory feedback on task performance and the sense of presence in a virtual reality environment. PloS one, 13(2), e0191846.

[15] Serafin, S., Geronazzo, M., Erkut, C., Nilsson, N. C., & Nordahl, R. (2018). Sonic interactions in virtual reality: State of the art, current challenges, and future directions. IEEE computer graphics and applications, 38(2), 31-43.

[16] Kos, A., Wei, Y., Tomažič, S., & Umek, A. (2018). The role of science and technology in sport. Procedia Computer Science, 129, 489-495.

[17] Yunchao, M., Mengyao, R., & Xingman, L. (2023). Application of virtual simulation technology in sports decision training: a systematic review. Frontiers in psychology, 14, 1164117.

[18] Hu, Z. (2021, December). Application of computer simulation technology in sports field. In International Conference on Electronic Information Engineering and Computer Technology (EIECT 2021) (Vol. 12087, pp. 484-489). SPIE.

[19] Hsu, C. Y., Huang, B. R., Wang, M. Y., & Yun-Jie, F. (2023). Exploring competitive sports technology development: using a MCDM model. Journal of Physical Education & Sport, 23(8).

[20] Talha, M. (2022). Research on the use of 3D modeling and motion capture technologies for making sports training easier. Revista de Psicología del Deporte (Journal of Sport Psychology), 31(3), 1-10.

[21] Ahir, K., Govani, K., Gajera, R., & Shah, M. (2020). Application on virtual reality for enhanced education learning, military training and sports. Augmented Human Research, 5, 1-9.

[22] Naiara Rodríguez Peña. (2025). Mapping migration capabilities worldwide. Comparative Migration Studies,13(1),31-31.

[23] Departamento de Matematica Aplicada y Estadistica Universidad Politecnica de Cartagena Murcia,Departamento de Matematica Aplicada y Estadistica Universidad Politecnica de Cartagena Murcia & Departamento de Matematica Aplicada y Estadistica Universidad Politecnica de Cartagena Murcia. (2019). Conformable Euler's theorem on homogeneous functions. Computational and Mathematical Methods,1(5),n/a-n/a.

[24] Luca Bascetta,Gianni Ferretti & Bruno Scaglioni. (2015). Closed form Newton–Euler dynamic model of flexible manipulators. Robotica,35(5),1006-1030.