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Research on Potential Training Effects Based on Wearable Embedded Wireless Communication Devices in Sports Training

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Abstract:

In recent years, sports culture has gradually come closer to life. It has become a top priority to improve the effectiveness of sports from teenagers and reserve power for the Olympic Games. Wearable embedded wireless communication equipment can effectively analyze sports training from a scientific point of view. The idea of "digital sports" is gradually introduced into sports training, and with the increasingly mature information technology and network technology, the posture information is monitored by sensors, so that training and material selection parameters are scientific and digital. A wearable embedded digital sports training system is designed, and a solutions is put forward aiming at the accuracy of training actions, scientific training methods and early warning analysis of joint injuries. The experimental results show that the system can achieve the purpose of providing training schemes for athletes.

Keywords: Wearable; Embedded; Wireless communication device; Sports training; Digital

1 INTRODUCTION

Since the twentieth century, information and information technology has developed rapidly and the information age has officially arrived. People cannot live without information and information technology in all aspects of their working life, clothing, food, housing, transportation, fitness and medical care. The traditional information dissemination method has developed into a modern information dissemination method that integrates computer technology, software technology, network technology, data management technology and communication technology. With the rapid development of network technology, the content of information processed, produced and disseminated by the network as a carrier includes: current affairs, electronic publications, images and texts, video and audio, etc. It is the trend of development, and the advantages are very obvious compared with the traditional communication methods. Therefore, digitization of the information resources expected to be disseminated is a prerequisite for achieving the development of communication relying on network technologies.

On January 30, 2018, the National Sports Bureau held a seminar on "Digital Sports Training". Participating coaches and researchers, while understanding the forms and trends of UCI internationalized training, advocated the implementation of the idea of "science and technology for the Olympics", opened new ideas to improve key technologies, and gained a deeper understanding of effective digital scientific training, which also reflects the trend of digital sports booming in China [1]. [On February 25, 2018, the first match of the 2017-2018 National Youth Campus Football League (University Group) Regional Tournament, jointly founded by the China University Sports Association (CUSSA) of the Ministry of Education and the Chinese Football Association (CFA) and exclusively operated by Ali Sports, was held, and this kind of corporate-run "digital sports" tournament will become a trend in the future. In 2018, Ali Sports, the University Sports Association and the Chinese Sports Association announced a 10-year contract to jointly operate campus sports events, with CUFA being the first event to be operated after the partnership was established. Ali Sports will guide the leapfrog development of the university league through commercial operation of the tournament, extensive passive and active communication, and technology-assisted sports, expecting to bring changes to this traditional event. This is an important proposition to be accomplished by Ali Sports, reflecting the fact that leading domestic Internet companies and major universities in China have also made efforts to start developing "digital sports" technology.

Sports posture monitoring technology based on wearable embedded wireless communication devices is the key technology of "digital sports training", which is the basis for the study of human-related sports, medical health, virtual reality technology and other disciplines. . Therefore, suitable posture monitoring methods are needed to ensure the accuracy, real-time and scientific nature of the measurements [7-10], especially for athletes, where monitoring methods should avoid interfering with normal training movements. There are many methods of sports posture monitoring, and whether their size, accuracy and power consumption, combined with the development of sensor technology, can be used as a tool for athletes and coaches to provide match analysis and assist training, and whether they are practical, are all factors that need to be considered in the development of digital sports training. The potential training effects of athletes in sports training can be effectively improved by embedded equipment, and this paper provides an in-depth study from this perspective.

2 DIGITAL SPORTS TRAINING TECHNOLOGY AND THEORETICAL FOUNDATION

2.1 JOINT ANISOTROPIC FORCE BOUNDARY CALIBRATION AND JUDGMENT

The joint anisotropic force boundary is the limit angle that the athlete's anti-joints and tendons are subjected to during movement. The athlete under test wears the device and measures the prescribed movements by fixing two wearable inertial sensors s1, s2 on the external surface of the upstream and downstream limbs of a joint joint linkage of the athlete doing the limit position about the flexion/extension, forward/backward rotation and circular rotation movements. The acceleration, angular acceleration and geomagnetic parameters output by the embedded processor measurement unit are calculated by Kalman filtering and normalization to calculate the posture quaternion, and the quaternion of the two wearable inertial sensors are recorded.

If the parameters measured by real-time calculation and analysis are $(\omega_t, \theta_t, \varphi_t)$ taking the elbow joint as an example, φ is the rotation angle, $\varphi_t < \varphi_{min}$ means the prerotation movement exceeds the limit, $\varphi_t > \varphi_{max}$ means the postrotation movement exceeds the limit. The flexion and extension angle of the elbow joint is indicated by θ .

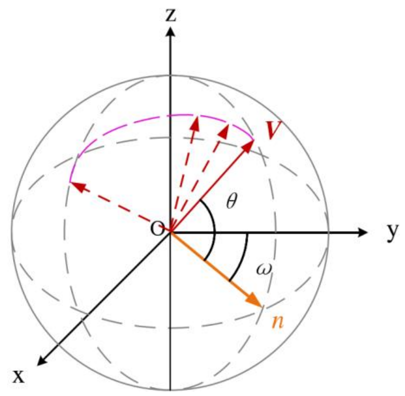

Figure 1 The figure of extract points on circle motions

During the circular rotation motion of the upper arm around the upward limit position of the shoulder joint, n discrete points are uniformly drawn and the curve fitting is completed by the least squares method, assuming that the curve equation is described by the following equation.

$$\theta(\omega) = a_0 + a_1\omega + a_2\omega^2 + \cdots + a_k\omega^k, \omega \in (\omega_1, \cdots \omega_n)(k \geq 3)$$

$$\theta(\omega) = b_0 + b_1\omega + b_2\omega^2 + \cdots + b_k\omega^k, \omega \in (\omega_{n+1}, \cdots \omega_{2n})(k \geq 3)$$

Can obtain fitting parameters：

$$\begin{pmatrix} a_0 \\ a_1 \\ \vdots \\ a_n \end{pmatrix} = \begin{pmatrix} 1 & \omega_1 & \cdots & \omega_1^k \\ 1 & \omega_2 & \cdots & \omega_2^k \\ \vdots & \vdots & \ddots & \vdots \\ 1 & \omega_n & \cdots & \omega_n^k \end{pmatrix}^{-1} \begin{pmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_n \end{pmatrix}, \quad \begin{pmatrix} b_0 \\ b_1 \\ \vdots \\ b_n \end{pmatrix} = \begin{pmatrix} 1 & \omega_{n+1} & \cdots & \omega_{n+1}^k \\ 1 & \omega_{n+2} & \cdots & \omega_{n+2}^k \\ \vdots & \vdots & \ddots & \vdots \\ 1 & \omega_{2n} & \cdots & \omega_{2n}^k \end{pmatrix}^{-1} \begin{pmatrix} \theta_{n+1} \\ \theta_{n+2} \\ \vdots \\ \theta_{2n} \end{pmatrix}$$

2.2 MOVEMENT NORMALITY ANALYSIS

In many sports, skill is more important than strength. Analyzing the direction of force transmission, better performance can only be achieved when all tendons produce force that is superimposed in the same direction. Different sports have different movements and directions. Through the above joint model, we can analyze and compare the data in the process of movement, determine the differences between limb and joint movements and the normative movements, and determine the causes of wrong movements.

The quadratic number and triaxial acceleration at the moment of landing are measured by inertial sensors to determine the normality of the athletes' movements. The purpose of the first jump is to obtain the best distance and initial speed, the first and second jump landing single foot stomp, should pay attention to control the body center of gravity, if the center of gravity behind the landing foot will produce "poke" action, reduce the initial speed. After the jump, the hip, knee and ankle joints should be actively extended, and the lower leg of the swing leg should be properly extended forward to increase the gliding distance, but not too far, otherwise it will also produce "poking" action [3]. If the two landing-jumping movements are not standardized will have a great impact on the long jump performance.

(1) The angle of the athlete's posture: In the figure, the line segment represents the calf and thigh, and the rectangle represents the hip, instead of the center of the body. The direction of force is transmitted to the human torso through the calves and thighs, and a slight deviation in the angle of the stirrups may reduce the speed of the athlete already. According to the technical elements of the long jump, the body's center of gravity should be kept above the landing foot when landing, not too far ahead and not too far behind, in order to be the standard technical action. The movement process of landing on one foot is shown in the following figure.

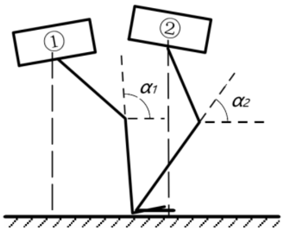

Figure 2 The diagram of landing movement

(2) Athletes' movement trajectory

During the long jump, the body's aerial posture, extension degree, and soaring height all affect the athlete's performance. Although there are no standardized parameters or standards for many detailed movements, it is possible to analyze which movements are deficient through the movement trajectory curve. If the angle or direction of the error, should be corrected in time, if it is a lack of tendon strength, you can also find the targeted training methods.

Calculate the space angle of right foot, right calf, right thigh and hip respectively, and combine with the static parameters of the athletes, including the data of calf length and thigh length, draw the movement change trajectory curve graph through the 3D model. By analyzing the similarity with the normative action to or, the action normative or those detailed actions are not done properly.

And the angle of each part of the limb is calculated by the human joint model, which needs to analyze whether the athlete's action of stomping on the ground during jumping is standardized.

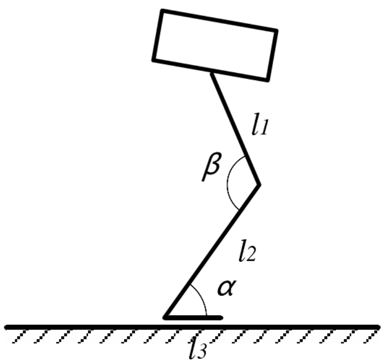

Figure 3 The angle diagram of landing movement

3 DATA ACQUISITION AND ANALYSIS BASED ON WEARABLE WIRELESS COMMUNICATION DEVICES

3.1 GENERAL HARDWARE FRAMEWORK

The hardware of this monitoring system has two communication methods, one is 4G communication method and the other is WiFi communication method. 4G communication method means that the node transmits the data to the relay base station through the wireless module, and then the 4G module of the base station uploads to the server, and WiFi communication method means that the data is transmitted to the client through WiFi method within the local area network. Both methods can ensure real-time and are not limited by the site environment.

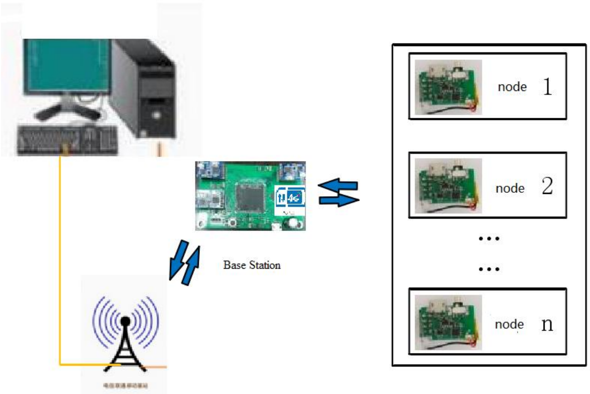

Figure 4 Topology diagram of hardware communication mode (a) 4G mode

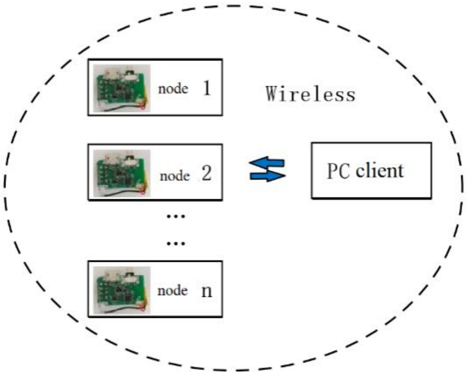

Figure 5 Topology diagram of hardware communication mode (b) WiFi mode

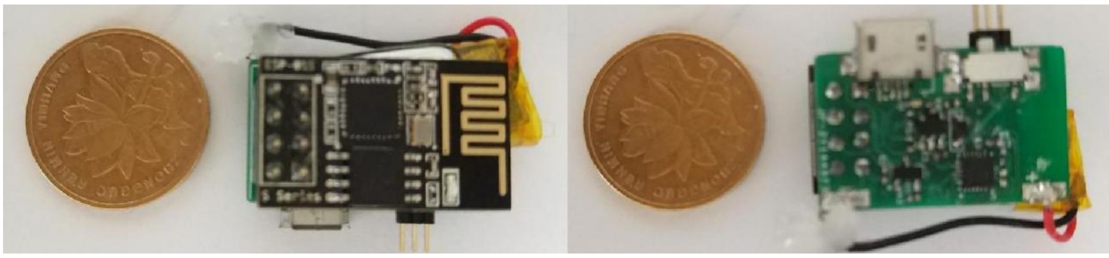

Figure 6 The physical picture of node (a)the front of node(wireless circuit) (b)the back of node(sense measurement circuit)

3.2 BASE STATION HARDWARE COMPONENTS

The transmission base station consists of a power management unit, a wireless communication unit, a master control unit, a data upload unit, and a base station configuration unit. The main function of the base station is to receive the data sent by the nodes using the wireless communication unit, aggregate and process them, and then transfer them to the PC via USB. The physical diagram of the base station is shown in the following figure.

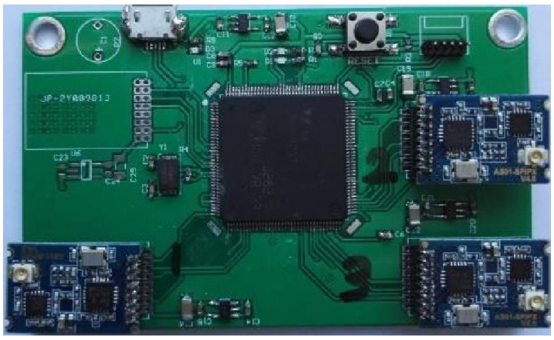

Figure 7 The physical picture of hub

The main control unit is mainly used to read the data received by the wireless communication unit, process it and send it to the PC via USB. The core part of the microcontroller includes DSP, FPU, 1Mbytes FLASH, 256Kbytes SRAM, and the main frequency of the core can reach 180MHz; the peripherals of the microcontroller include SPI communication interface and complete USB2.0 full speed controller. In the base station, the SPI communication interface communicates with the wireless communication unit, and the USB2.0 full-speed slave serves as the communication interface for the base station configuration unit and the data upload unit.

In addition to using on-chip peripheral resources to establish communication connections with other units of the base station, the MCU also uses its kernel computing power to receive data for initial processing. In the MCU initialization, the system clock configuration and peripheral operating state configuration are completed. The system clock is configured to operate at a maximum frequency of 180MHz, and the SPI interface and GPIOs used are configured to the corresponding operating modes.

The USB communication interface initialization mainly configures the USB of the microcontroller as the virtual serial port (VCP) in the USB CDC communication class, and creates 512bytes receive buffer and transmit buffer respectively, the receive buffer is used to receive the configuration information sent by the base station configuration software, and the transmit buffer is used to cache the processed node data.

The FLASH memory initialization of the base station configuration parameters is to create a storage space for the base station configuration parameters in the on-chip FLASH in the MCU to ensure the long-term validity of the configuration parameters by using the power-down data non-loss feature of FLASH.

In the initialization of the wireless communication module NRF24L01, the chip's operating mode is configured to receive mode, and the node's receive address, receive channel and over-the-air rate are configured according to the configuration parameters in the MCU's on-chip FLASH. Updating the node configuration parameters is to write the configuration parameters in the USB receive buffer to the MCU on-chip FLASH, overwriting the original configuration parameters. To ensure that the data is received in time, the wireless communication module uses interrupts to trigger the MCU to receive the data, which is further processed in the main loop after being received in the buffer.

4 EXPERIMENT AND ANALYSIS

4.1 GENERAL FRAMEWORK FOR SOFTWARE DESIGN OF WEARABLE WIRELESS COMMUNICATION DEVICES

The core idea of this research is to "digitize" sports training, proposing a sports training system based on hardware devices, and more importantly, analyzing the collected posture data and applying the analysis results to real sports training.

Currently, there are two common software platform architectures for information management mode in Internet technology, namely Client/Server (C/S) mode and Browser/Server (B/S) mode [4]. Browser is the browser, as long as the device can use WEB browser can interact with the server through the domain name or URL; Server is the server, refers to the user to provide data services of the back-end server, the function is more complex, need to achieve multiple concurrency (multi-threaded) and a large amount of data processing.

This paper needs to collect a large amount of data and do data processing, and also needs to embed 3D scenes, which requires high running speed of PC, and the user group of this system is also fixed. In summary, from the advantages and disadvantages of both C/S and B/S modes, this system is more suitable to use the framework of C/S mode, and the overall architecture diagram of the software platform design is shown in the following figure.

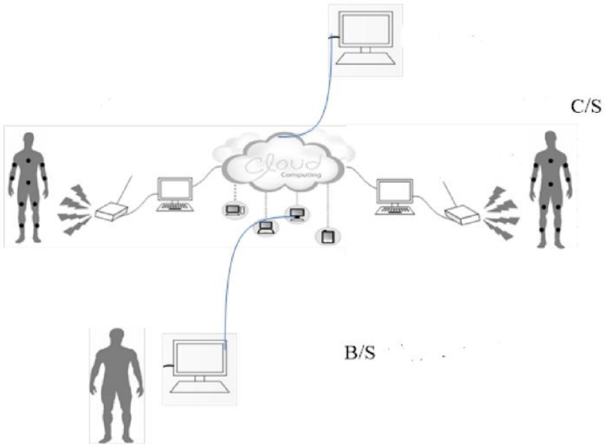

Figure 8 The design architecture of software platform

The above figure depicts the composition of this software platform, which mainly consists of a cloud server and a PC client.The C/S platform model distributes data and data analysis between the client and the server, and this distributed system has the advantage of being highly cohesive and transparent. Cohesion is reflected in the fact that each client is highly autonomous in terms of data and has a local database management system [5, 6]. Transparency is reflected in the user experience in that when using the client software it is not known whether the data is sourced locally or remotely, and the system does not feel distributed. In this system, the data measured by the sensing devices are stored on the PC, and some of the valid data are uploaded to the server, where they can be accessed by other clients. There are several major functions: first, collecting data of motion posture with hardware devices, second, storing and querying data, third, embedding 3D scene plug-in to display and playback scenes of motion, and fourth, analysis and processing of key parameters. The function of the cloud server is mainly to provide data services for the client, and to analyze the data of multiple users in general, while ensuring data security and network security.

Figure 9 The practical photos of software with senses

Functions of real-time acquisition: Firstly, connect to the sensing device, calibrate the sensor parameters, and other hardware related operations. Secondly, realize the communication with the sensors and store the data sent by the sensors. Finally, embedding the 3D scene control to show the athlete's pose movement in real time.

3D scene: the embedded Unity3D control. Firstly, it builds a personalized 3D model of the human body and can change the model parameters according to the athlete's physical information. Secondly, it can reproduce the trajectory of human movement, and can slide to change the perspective and rotation, and can also realize the functions of playback, slow playback, intercepting data clips, and action comparison.

Data analysis and processing: Multi-angle analysis is carried out for the collected data. Firstly, the trend of data change is analyzed to judge the change of a certain athlete's movement of a unified item, and the athlete's movement is affected by the degree of fatigue; secondly, the analysis of force direction and joint angle is carried out for key movements to judge the anti-joint force situation to prevent sports injury; thirdly, the direction of force transmission is analyzed to judge whether the athlete's movement is standardized.

User information management: Personal files are designed for each athlete and coach, including personal information, body type parameters, records of athlete training and data analysis results, etc. The database is established locally in the client, providing operations such as adding, deleting, changing and checking, and the management of data and information is an important manifestation of the "digitalization" of sports training.

Background server: mainly includes two functions, one is to communicate with the client, receive the data sent by the client, and also to realize multi-user and concurrent access; the second is to analyze the data uploaded by the client, and ensure data security and network security.

4.2 ATHLETE 3D SCENE IMPLEMENTATION

The steps to implement the 3D scene and human model in this software platform are as follows.

(1) BIPED bone model: As in Figure 4.9, set the hip as the parent bone of all limbs, radiate to the limbs step by step according to the 17 rigid body model, and add connection points between adjacent bones according to the way human bones are connected. Adjust the coordinate system of each bone to match the world coordinate system.

(2) Add a skin to the skeleton model: As in Figure 4.10, bind the skin to the skeleton so that the skin can move with the skeleton. Adjust the skin parameters to prevent the phenomenon of skin splitting, such as the twisting action of the small arm, the skin should be connected to the upstream limb, otherwise it will turn like "screwing the bottle cap".

(3) Export the fbx file of the skeleton and skin model to Unity engine: adjust the coordinate system and model parameters again to be consistent with the parameters in Unity engine.

(4) Write script code in JavaScript: receive quaternion data from the program and assign values to the corresponding joints according to the function relationship.

(5) Export the webplayer control, embed it in the developed software, and use the sendMessage() method to pass quaternions to the control to drive the model, etc.

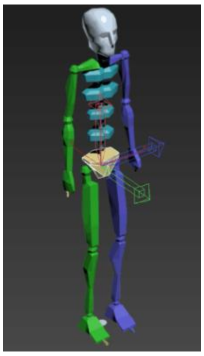

Figure 10 The diagram of BIPED skeletal model

Figure 11 The diagram of 3Dmax skinning model

The software platform uses MySQL to build the local database, which mainly contains user information and data information. The specific table structure and field information are as follows: Table is the user information table, users are divided into athletes and coaches, and the user Id is used to distinguish the user type and the user Id is the primary key of the data table, which is used to query, modify and delete the user information. The foreign key is used to connect the athlete information and the coach information table, which indicates the relationship between coaches and athletes and facilitates the management of athlete information by coaches.

Athletes only have the right to modify their own user information, while coaches can view the information and sports data records of the athletes they take. Only with administrator privileges can access all information and make necessary changes at will to ensure data security and prevent data loss.

Table 1 The table of coach info

Fields	Definition	Data Type	Allow NULL values
Id	Instructor Number	INT(11)	No
name	Instructor's name	VARCHAR(32)	No
password	Password	VARCHAR(16)	No
item	Sport	VARCHAR(32)	Yes

Table 2 The table of player info

Fields	Definition	Data Type	Allow NULL values
Id	User Number	INT(11)	No
name	User Name	VARCHAR(32)	No
phone	Contact Number	VARCHAR(16)	No
password	Password	VARCHAR(16)	No
height	Height	FLOAT	No
weight	Weight	FLOAT	No
gender	Sex	INT(1)	No
age	Age	INT(3)	No
Address	Address	VARCHAR(128)	Yes
bodysize	Body Type	INT(11)	Yes
coachId	Trainer number	INT(11)	Yes

4.3 ANALYSIS OF KEY PARAMETERS TO PROMOTE TRAINING EFFECTIVENESS

The wireless communication network in this paper is based on the Netty framework, which treats all client requests as "events" and the processing flow is similar, mainly handled by the MessageHandler class, MessageDecoder class and MessageEncoder class. The "upstream" means the client sends data to the server, and vice versa, the "downstream" means the server sends data to the client. A summary table of communication protocols between the cloud server and multiple clients is as follows.

Table 3 The communication protocol between Client and Server

Events	Content	Format	Remarks	Mode
Client 1 Go Live	Send client 1 id	A string of length 4 (eg:abcd)	Ready to receive data from Client 1 Data	Upstream/
Client 2 Go Live	Sending client 2 id	A string of length 4 (eg:abcd)	Ready to forward to client 2 ctx=Map.get(abcd)	Downstream
…	…	…	…	…

4.3.1 Joint injury warning analysis

When measuring the pre/post rotation range, care should be taken to tie the sensor node to a fixed position of the small arm, as the rotation angle should be different in different positions. The measured normal range of motion curve of the elbow joint is shown in the figure.

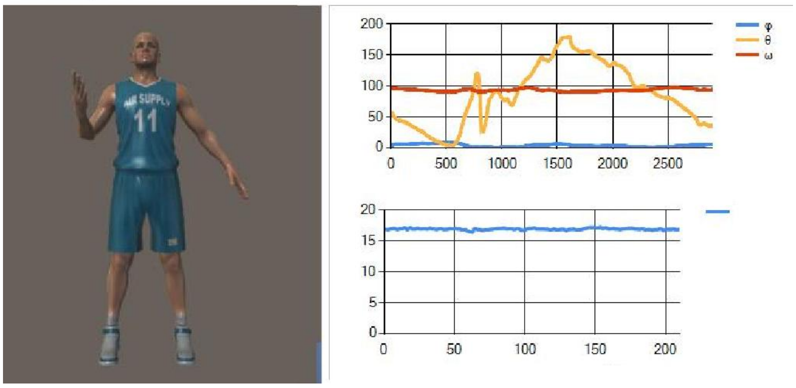

Figure 12 The page of the elbow normal range calibration（a）Flexion and extension

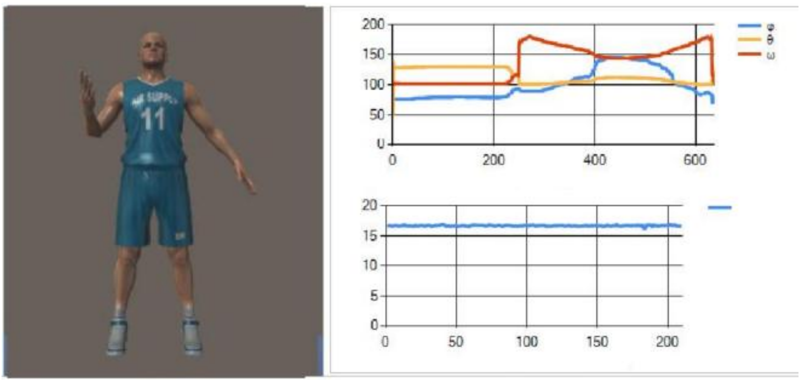

Figure 13 (continued) The page of the elbow normal range calibration (b)Pronation movement

For the experiments, the plane near the wrist joint, where the ulnar and radial bones form, was chosen as the measurement point, and the range of forward/backward rotation relative to the initial position of the body was about -50°-90° as shown in (a) above. The flexion/extension motion should remove the effect of the initial position of the wearing device, as shown in Fig. (b) The range of elbow flexion/extension angles can be obtained as approximately 0°-163°, and the curves of the other two angles are almost smooth.

For the circumferential motion boundary of the shoulder joint, the curve fitted with $(\omega_1,\theta_1),(\omega_2,\theta_2)...(\omega_n,\theta_n)$ 15 discrete points taken during the motion is shown in the figure below.

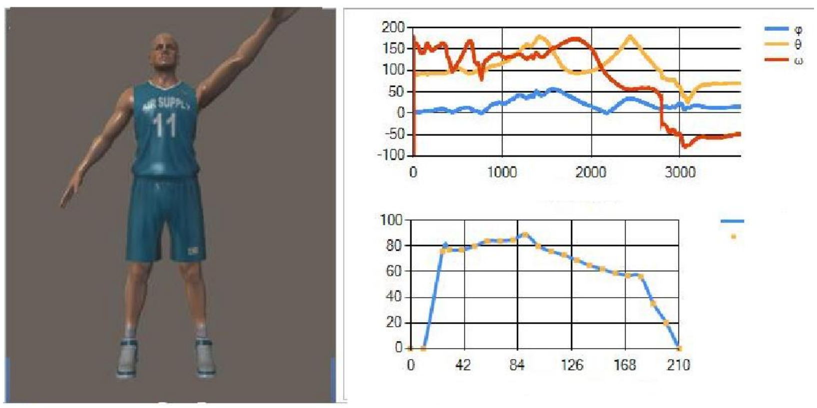

Figure 14 The fitting graph of shoulder circumduction movement

The fitting curve in the figure is when the shoulder joint does the circular rotation movement, θ changes with $\omega$the starting movement is the arm close from the chest, then wrapped around to the outside, \theta is the angle between the big arm and the horizontal plane, the angle change range is about 80°. After the database records the curve, calculate whether the real-time data exceeds the curve range, record the frequency of exceeding, and if the frequency exceeds the set threshold, the alarm page will pop up automatically.

4.3.2 Movement normality analysis

From the figure, the following conclusions can be drawn: it is difficult to observe the subtle differences in movements by visually observing the human body movements and animations, once the movement training data is quantified and processed, the differences between real-time movements and standard movements can be easily observed. From the spatial angle curve, it is possible to analyze which movement is not in place and further find the reason for the irregularity of the movement according to the physiological structure. For example, the process of jumping and landing movements monitored in the figure has a subtle difference in the angle of the leg at the time of landing. Limb 1 is the thigh action, limb 2 is the calf action, $(\omega_1, \theta_1, \varphi_1), (\omega_2, \theta_2, \varphi_2)$ represent the spatial angle curves of two data files, record 1 and record 2, respectively, where record 1 is the standard action. From the figure, it can be seen that the movement in record 2 landed with a larger angle between the lower leg and the ground, thus judging that the athlete's position of the center of gravity was not well adjusted when landing. The normative analysis page of one jump in the actual measured triple jump movement is shown in the figure below.

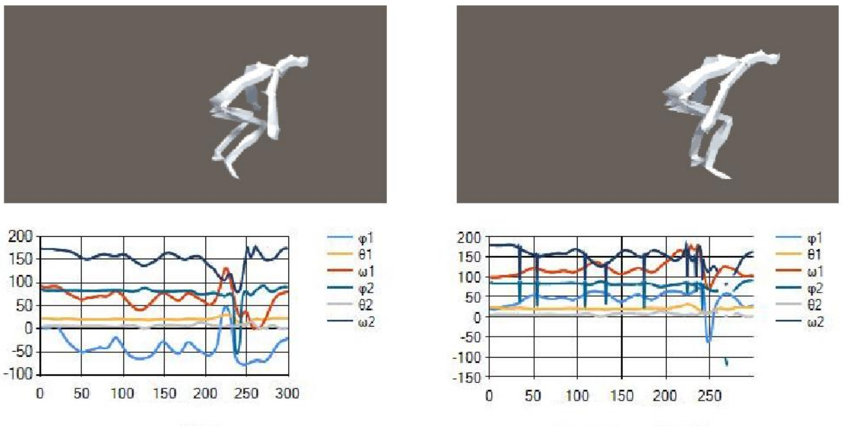

Figure 15 The page of movement normative analysis

4.3.3 Motion fatigue analysis

Multiple monitoring of the triple jump can be used to extract process parameters from it and monitor the process data of the athlete. For athletes, overload can exceed the muscular capacity. More importantly, fatigue can lead to a decrease in muscle strength, which can easily lead to injury.

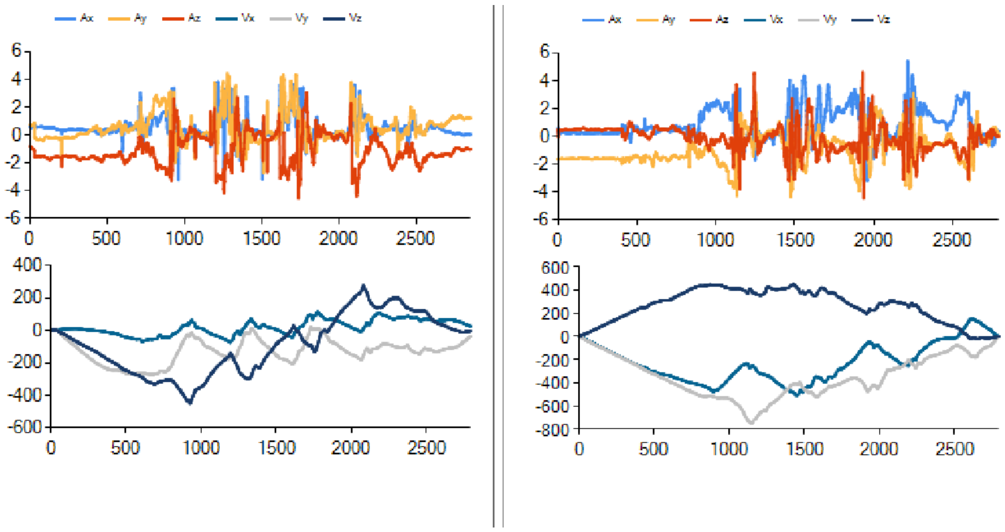

Figure 16 The screen of fatigue analysis

Through the measured acceleration change trend, the fatigue parameters of the athlete are evaluated, statistics on how long after the warm-up to reach the best state, easy to achieve good results, athletes in the case of tendon movement fatigue is easy to injury, should be timely rest or massage adjustment to reduce fatigue injury. The figure shows the change in acceleration of the left and right thighs during the triple jump, which can be analyzed according to the historical average data to show that the current warm-up state (A) is good and there is no trend of fatigue decline.

5 CONCLUSION

Aiming at the problems existing in current domestic sports training, such as unscientific teaching methods, unclear material selection standards, serious sports injuries, lack of digital resources, etc., this subject measures human posture data with the help of wearable sensor nodes and wireless communication base stations, and developed a software platform to help analyze the data and calculating the results. This paper focuses on the overall design framework and functions of the software platform. Secondly, it shows the completion of the client interface of the software platform, including the design and implementation of 3D scenes, etc. Then, it introduces the storage mode of data information, and briefly describes the performance of the background server framework and the process of building the server. Finally, the software platform is used to calculate and analyze the early warning of joint injury and the characteristic parameters of exercise normality. After many times of debugging and testing, the requirements of this digital sports training system are basically completed. It can provide solutions for sports training, reduce sports injuries, standardize athletes' movements, and help improve training results.

REFERENCES

[1] Lv Haiyan. A brief discussion on the utilization of digital technology in junior high school physical education. Art and Physical Training, 2017, 11-(32):181-182.
[2] Wang J. Research and design of motion capture system based on inertial sensors. Hefei: University of Science and Technology of China, 2015.
[3] Zhu L. Research on lower limb motion recognition for the elderly based on wearable sensors. Wuhan: Wuhan Textile University, 2017.
[4] Li Xiaoling. A comparison of C_S and B_S models in management information system development. Journal of Graphology, 2015, 36(2).
[5] Yang D. Research and Implementation of Distributed Database Technology. Electronic Science and Technology, 2015, 2(1):87-94.
[6] Pang Hui. On distributed databases. Computer Knowledge and Technology, 2011, 7(2):271-273.
[7] Abayomi Moradeyo Otebolaku M T A. User context recognition using smartphone sensors and classification models. Journal of Network and Computer Applications, 2016(66).
[8] H. V. Anupreethi S V. MSP430 Based Sign Language Recognizer for Dumb Patients. Procedia Engineering, 2012(38):1374-1380.
[9] Tomas B. Moeslund A H V K. A survey of advances in vision-based human motion apture and analysis. Computer Vision and Image Understanding, 2006,2(104):90-126.
[10] Reggie Bradford O. 8 Digital Trends Driving The Transformation Of Sports. Forbes Asia, 2016.