Computer Fraud and Security
ISSN (online): 1873-7056

Design and Implementation of Sports Safety Mechanics Signal Monitoring System in Sports Training

Liu Siyuan[1], Qiu Yunan[1,*], Li Jiaze[1], Bao Jiuzhi[1], Zhang Hetong[2]
[1] *Jilin Medical University,Jilin,China*
[2] *Southwest University,Chongqing,China*

Abstract:

Human movement is closely related to human health and has been widely concerned. With the development of sports biomechanics and anthropometry, people's research on human motion is becoming more and more in-depth. The complexity of human physiological structure determines that human motion research needs the intersection of many disciplines, and its application range is very wide. This paper studies the relationship between sports biomechanical parameters. Through the measurement and analysis of sports biomechanical parameters, this paper analyzes the law of human movement. Based on the performance test of the system, this paper carries out the experiment of motion measurement, and applies it to the control of computer games for reliability test. The research results can provide theoretical guidance for human posture recognition and sports training.

Keywords: Sports Health, Sports Biomechanics, Sports Parameter Measurement, Reliability Test.

1. INTRODUCTION

The driving force of human movement research is also changing [1-2]. With the in-depth study of human motion, human motion measurement, human sports biomechanics and other disciplines have also been strongly developed. The complexity of human physiological structure determines that human motion research needs the intersection of many disciplines, and its application range is very wide. The most important step in the research of human motion is pattern regularization.

In the research of human motion, we must first measure all kinds of human motion, obtain the relevant data and parameters of human motion, and then explore the motion characteristics and analysis mechanism of human body on the basis of statistical analysis [4-7]. Only on the basis of accurately obtaining human motion information can the research have practical significance.

2. METHODS OF HUMAN MOTION INFORMATION COLLECTION AND ANALYSIS

2.1. METHOD FOR COLLECTING HUMAN MOTION INFORMATION

SOM is often used in the clustering analysis and qualitative research of big data in the field of Informatics because of its intuitive, visual and visual performance characteristics.In the research of SOM data pattern recognition and visualization, there are usually two methods to classify and analyze the data [8]:

(1) cluster analysis first, then carry out visual image calibration and projection, after projection, the same category of data for new image visualization expression;

(2) according to the mapping structure of the data itself for clustering and image visualization expression.For physical health data, the second method is often used because of the discreteness of its variables.

SOM has obvious advantages in dealing with multi-dimensional big data. Its method has unique visualization ability, which can directly reflect the change pattern of each parameter. By generating self-organization chart of each parameter, it can intuitively and qualitatively express the distribution characteristics of each parameter in a specific interval. In SOM analysis of this study, the Euclidean distance calculation, classification and visual expression of physical data characteristics are carried out based on U-matrix and K-means methods.

2.2. MOTION INFORMATION ACQUISITION AND ANALYSIS BASED ON ACCELERATION SENSOR

Combined with the comparison results, motion environment and motion characteristics, inertial sensor is selected to complete the design. It has strong adaptability to environmental factors, low cost and is suitable for dynamic environment. Because it is less dependent on environmental factors, its robustness is also relatively stable. Therefore, the sensor is used to complete the design. Among inertial sensors, MEMS sensors have been widely used because of their wireless transmission, low cost, good acquisition effect and convenient operation. Therefore, in this design, MEMS inertial sensor is used to complete the design. When the sensor is relatively stationary, the included angles between each sensitive axis and the gravity direction are θ、φ、γ [9-10]:

$$\begin{cases} v_x = kgcos\theta + v_0 \\ v_y = kgcos\varphi + v_0 \\ v_z = kgcos\gamma + v_0 \end{cases} \tag{1}$$

Where: v_x, v_y and v_z represent the voltage signals output by the X, Y and Z axes of the accelerometer;

k is the sensitivity of accelerometer;

g represents gravitational acceleration, generally 9.8m/s^2;

v_0 represents the voltage output by the accelerometer when the acceleration is 0.

The inverse function can be obtained:

$$\begin{cases} \theta = arccos\left(\dfrac{v_x - v_0}{kg}\right) \\ \varphi = arccos\left(\dfrac{v_y - v_0}{kg}\right) \\ \gamma = arccos\left(\dfrac{v_z - v_0}{kg}\right) \end{cases} \tag{2}$$

Blender can run on different platforms and takes up little space after installation. Although it often does not support documentation or sample release, it has a wealth of functions, and most of them are high-end module shaping software. Its characteristics are: (1) Support different geometric entities, including polygon, mesh, fast surface molding, curve and vector characters. (2) Multipurpose internal rendering and integration of YAF ray, an open source ray tracing package. (3) Animation tools include reverse action components, which can set backbone, structural deformation, key frames, timeline, nonlinear animation, system specified parameters, vertex weight and softened momentum components, including mesh collision reconnaissance and a particle system with reconnaissance collision. (4) Use Python language to create and make game and work automation scripts. (5) Basic nonlinear image editing and production functions.

In blender, objects are separated from data, which makes it possible to mold quickly. You can combine multiple scenes into a single file (a file called ". Blend"). All ". Blend" files generated by blender have perfect compatibility with forward and backward versions, and also have complete cross platform support. Automatically and regularly store ". Blend" to avoid data loss due to crash. It can be obtained:

$$\begin{cases} \bar{a}_y + \bar{a}_z = \bar{g}_y + \bar{g}_z + \bar{a} \\ \bar{g}_y + \bar{g}_z = \bar{g} \end{cases} \Rightarrow \bar{a} = \bar{a}_y + \bar{a}_z - \bar{g} \tag{3}$$

Since the actual acceleration a of the measured point forms an included angle of 90 degrees with the Y-axis, it will not affect the output of the Y-axis of the sensor, and the output of the Y-axis of the sensor still meets the following formula:

$$a_y = g\cos\theta \Rightarrow \theta = \arccos\frac{a_y}{g} \tag{4}$$

Therefore, the calculation method of instantaneous attitude in the process of arm motion is relative to that in static state, but the instantaneous acceleration, velocity, force and other parameters need to be analyzed in the motion state.

Instantaneous acceleration:

$$a = a_y\cos\theta + a_z\sin\theta - g \tag{5}$$

When the calculation result of the above formula is positive, it means that the acceleration direction is the same as the positive direction of Z axis, otherwise it is opposite.

Instantaneous speed:

$$v = v_y + \int a dt \qquad (6)$$

Where: v_0 represents the measured initial speed. In engineering calculation, time is generally differentiated into several small intervals. In each small time interval, it is considered that the acceleration of particles is constant for convenience of calculation. Then the above formula can be simplified to:

$$v_i = v_{i-2} + a_{i-1}\Delta t\left(i \geq 0\right) \qquad (7)$$

Instantaneous force:

$$F_i = mv_i \qquad (8)$$

Where: m represents the mass of particles. For the mass of different particles of human body, many scholars and experts at home and abroad have measured it by various means, which can be queried according to the information published by the World Health Organization

3. DESIGN AND DEBUGGING OF MOTION INFORMATION ACQUISITION SYSTEM

3.1. OVERALL SYSTEM DESIGN

The motion information acquisition system consists of two parts: signal acquisition unit and data processing unit. The signal acquisition unit consists of a sensor network composed of a master and five slaves. The slaves are the nodes of the sensor network, and the triaxial acceleration sensor ADXL330 is the core device. The circuit of signal conditioning is designed. AVR microcontroller is used as the controller, and five slaves are installed at the monitoring points of human body according to the measurement requirements. The host of the signal acquisition unit controls the five slaves to collect acceleration signals through I^2C bus. And collect the data collected by each slave and transmit it to the data processing unit by wireless communication.

The data processing unit takes the ARM7 chip STR7l0F-Z2T6 of EMBET company as the core, completes the analysis and processing of the acceleration data sent by the signal acquisition unit, and finally obtains the human motion information needed for research.

3.2. System hardware design

The function of the signal acquisition unit is to synchronously collect the three-dimensional acceleration information of the measured point in real time, and upload the collected acceleration information to the data processing unit of the system. The signal acquisition unit is a master-slave sensor network composed of a host and multiple slaves. During measurement, the slave will be installed on the measured point of the human body, and all slaves of the signal acquisition unit are controlled by the host through I^2C bus.

Because the main purpose of designing this system is to collect the acceleration signal of human motion, it is necessary to select a suitable acceleration sensor as the acquisition element of acceleration signal. The selection of sensor should be based on the characteristics of acceleration signal generated during human motion. According to the characteristics of acceleration parameters during human motion, the frequency range of accelerometer used to measure human motion can meet the requirements in the range of 0Hz ~ 20Hz, and the measurement amplitude range is – 3g ~ + 3g.

In order to facilitate the installation on the human body and minimize the impact of the acceleration sensor itself on the movement, in addition to considering its performance, we should also consider the products with as small volume, high integration and low cost as possible. The development of MEMS technology makes the acceleration sensor develop towards miniaturization and integration. It is also more and more used in motion acquisition and measurement in various fields, such as inertial navigation, tilt sensing, earthquake monitoring and automobile insurance. Acceleration is an important parameter reflecting human motion, and the acceleration sensor can directly reflect the human acceleration. Therefore, the acceleration sensor based on MEMS technology has also been widely used in human motion measurement.

Because ADXL330 has the characteristics of small volume, light weight, stable performance and low cost, and all indexes can meet the basic requirements for human motion acceleration signal acquisition, this chip is selected as the sensing element of the system.

In the process of human movement, in addition to the effective acceleration signal, there are other interference signals from the outside. If the output of the sensor is directly analyzed and applied without any processing, it is obviously impossible to obtain accurate results. Therefore, the corresponding noise reduction processing must be carried out on the signal output of the sensor to obtain the correct acceleration information. Since the frequency of human motion acceleration is generally 0-20hz, the acceleration signal higher than 20Hz can be regarded as interference. In order to reduce the influence of interference signal, a low-pass filter with a cut-off frequency of 20Hz is designed at the output end of the sensor to remove high-frequency noise.

3.3. SYSTEM SOFTWARE DESIGN

In the system performance requirements analysis, the operating environment requirements of the system is an important aspect. The operating environment requirements we refer to refer to the software and hardware requirements required for the operation of the system. For different software systems, the hardware environment is different. Similarly, the software environment of the system is also an important link. For example, some systems can only run under the windows environment, while some systems can only run under the Linux environment, and some cross platform systems can run on platforms that cannot. For this system, the hardware running environment is our x86 machine. For the software environment, our system supports windows and Linux environment.

The client of the system mainly runs in Windows environment, while the server of the system. For security reasons, our system web server is Ubuntu 10.04 server or above operating system, and the database is my SQL.

The data processing unit mainly completes the following functions: after receiving the acceleration data, the signal acquisition unit digitally filters it, analyzes and processes the data with a reasonable algorithm, and obtains relevant conclusions; Communication with host computer, etc. The system initialization link is mainly to initialize the ARM7 chip itself and related peripheral devices to ensure that all links are in normal working state. After the initialization of the system is completed, query and wait for the signal acquisition unit to upload the ready signal. If the system waiting time is exceeded, the system will try to communicate with the acquisition unit again. If the communication fails, the system will enter the standby state.

After the initialization of the system is completed, the functions and parameters should be set according to the demand in two ways: real-time reading and batch reading. At present, there are many mature and advanced digital filtering methods, and the filtering method of program judgment is used in this system. Engineering practice shows that the change of many physical quantities takes a certain time, and the change between two adjacent sampling values has a certain limit. Program judgment filtering is to determine the maximum deviation △y that may occur between two adjacent sampling signals according to practical experience. If it exceeds this deviation value, it indicates that the input signal is an interference signal and should be removed; If it is less than this deviation value, 'the signal can be taken as the sampling value.

4. EXPERIMENT AND APPLICATION OF MOTION INFORMATION ACQUISITION SYSTEM

The displacement measurement experiment mainly uses a slave to collect the acceleration signal when the object is moving. After digital filtering, the collected data are analyzed and processed to obtain the displacement data of the object movement. The measurement error of the system can be obtained by comparing the system calculation results with the actual measured displacement values.

In order to facilitate the calculation of acceleration, velocity, displacement and other parameters by using the program, the whole displacement process is differentiated into several small time periods △t. in each time period △t, it is considered to be processed according to the uniform acceleration motion, which can greatly reduce the calculation process. Since the frequency of acceleration signal acquisition on each axis is 100Hz, let △t = 10ms, and the specific calculation method is as follows:

$$a_i = \frac{N-128}{26} \times 9.8\left(m/s^2\right) \quad (9)$$

Where: a_i is the calculated value of acceleration in the ith time period;

N is the digital output of the system.

$$v_i = v_{i-1} + a_i \Delta t\left(m/s\right) \quad (10)$$

Where: v_i is the average speed in the ith time period (when i = 0, vi = 0);

△t=10ms.

$$s_i = v_i \Delta t\left(m\right) \quad (11)$$

Where:s_i is the displacement of each time period.

$$s = \sum_{i=0}^{n} s_i \quad (12)$$

Where: s is the total displacement, which is the sum of displacement of each section.

The complexity of human motion is high. In order to measure conveniently, the human structure must be simplified and a human motion model conducive to calculation must be established. By accurately measuring the motion of limbs, that is, links, and then according to the constraint relationship between each link and joints, the comprehensive information of human motion is finally obtained.

Since the elbow joint remains stationary during the curved arm action, which is equivalent to the two-dimensional plane movement of the wrist joint, and the movement direction of the wrist forms an angle of 90 ° with the X axis of the slave sensor, the acceleration acting on the X axis is always 0. Therefore, only the acceleration data of Z axis and Y axis need to be analyzed in the experimental process.

Firstly, the attitude recognition is carried out when the arm remains stationary. The angle between the forearm and the desktop is calculated through the analysis of the data output from the machine. On the basis of completing the attitude recognition, the motion trajectory tracking experiment is carried out. In the recognition of arm posture, the direction of sensitive axis and the direction of elbow angle should be defined first, and the direction extending from elbow joint to wrist joint should be defined and the included angle between the forearm and the boom is defined as the elbow angle. In this way, when installing the accelerometer, it should be noted that the positive direction of its sensitive axis is consistent with the predefined direction.

In gesture recognition, the main task is to calculate the angle between the forearm and the desktop, and subtract the angle between the desktop and the forearm to get the angle between the forearm and the forearm. The main basis for judging the angle θ between the forearm and the desktop is the components of gravity acceleration on the X axis and Y axis of the sensor. According to the vector decomposition, we can know:

$$\begin{cases} g_y = gsin(\theta) \\ g_z = gcos(\theta) \end{cases} \Rightarrow \theta = arcsin\left(\frac{g_y}{g}\right) = arccos\left(\frac{g_z}{g}\right) \quad (13)$$

Where: g_y and g_z are the components of gravity acceleration on the Y axis and Z axis of the sensor respectively;

θ is the angle between the forearm and the desktop.

5. CONCLUSIONS

Combined with the development of sports biomechanics, on the basis of consulting a large number of relevant data, this paper analyzes the characteristics of human motion, summarizes and studies the measurement methods of human motion, and establishes the model of human motion and the spatial coordinate system of human motion combined with the physiological structure and motion characteristics of human body. The motion measurement method based on acceleration sensor is studied, and the related experiments and applications are carried out based on the self-developed acceleration sensor. For the collection of motion information, the commonly used methods are mainly based on image, video, electromagnetic, acceleration, EMG signal and so on. Various methods have their own advantages. However, there are also deficiencies, which are suitable for different occasions. If a variety of means are reasonably used and a variety of information are fused, it will play a key role in the collection of motion information.

REFERENCES

[1] 1.R. M. Palmieri, A. Weltman, J. A. Tom, J. E. Edwards and C. D. Ingersoll (2004) "An experimental knee joint effusion does not affect plasma catecholamine concentration". Neuroscience Letters, 366(1), 76-79

[2] 2.M. Tanaka, D. Vyas, G. Moloney, A. Bedi, A. D. Pearle and V. Musahl (2012) "What does it take to have a high-grade pivot shift?". Knee Surgery Sports Traumatology Arthroscopy, 20(4), 737-742

[3] 3.G. M. Thornton, J. C. Johnson, R. V. Maser, L. L. Marchuk, N. G. Shrive and C. B. Frank (2006) "Strength of medial structures of the knee joint are decreased by isolated injury to the medial collateral ligament and subsequent joint immobilization". Journal of Orthopaedic Research, 23(5), 1191-1198

[4] 4.E. A. Wikstrom, M. D. Tillman, T. L. Chmielewski and P. A. Borsa (2006) "Measurement and Evaluation of Dynamic Joint Stability of the Knee and Ankle After Injury". Sports Medicine, 36(5), 393-410

[5] 5.Mccosker, C., Renshaw, I., Greenwood, D., Davids, K., Gosden, E. (2019) “How Performance Analysis of Elite Long Jumping Can Inform Representative Training design Through Identification of key Constraints on Competitive Behaviours”, European Journal of Sport Science, pp.1-9.

[6] 6.Markovic, G. (2007) “Does Plyometric Training Improve Vertical Jump Height? A meta-analytical Review”, British Journal of Sports Medicine, 41(6), pp.349-355.

[7] 7.Hubert, M., Starzak, M., Sadowski, J. (2015) “Does Step Length Adjustment Determine take-off Accuracy and Approach Run Velocity in Long and Triple Jumps?”, Human Movement, 16(3), pp.124-129.

[8] 8.Bayraktar, I., Çilli, M. (2018) “Estimation of Jumping Distance using run-up Velocity for Male Long Jumpers”, Pedagogics, Psychology, Medical-biological Problems of Physical Training and Sports, 22(3), pp.124-129.

[9] 9.Rodríguez-Rosell, D., Torres-Torrelo, J., Franco-Márquez, F., González-Suárez, J. M., González-Badillo, J. J. (2017) “Effects of light-load Maximal Lifting Velocity Weight Training vs. Combined Weight Training and Plyometrics on Sprint, Vertical Jump and Strength Performance in adult Soccer Players”, Journal of Science and Medicine in Sport, 20(7), pp.695-699.

[10] 10.J. H. Che, Z. R. Zhang, G. Z. Li, W. H. Tan and F. J. Qu (2009) "Application of tissue-engineered cartilage with BMP-7 gene to repair knee joint cartilage injury in rabbits". Knee Surgery Sports Traumatology Arthroscopy, 18(4), 496-503