Research Article

Perception and Recognition of Upper Limb Movement Trajectory of Aerobics Based on Multi-Intelligent Sensors

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Aerobics is an indispensable part of school teaching. Aerobics can exercise the human body’s flexibility, muscle extension, and cardiopulmonary function. However, there are many details in the aerobics movements that need attention, so this article mainly studies the perception and recognition of the upper limb movement trajectory of aerobics. This article is mainly based on multi-intelligent sensors to perform motion capture and recognition of upper limb movements in aerobics. Therefore, in order to design a multismart sensor-based aerobics upper limb movement perception recognition system, this paper proposes to combine the VM-i three-axis magnetic sensor and MEMS smart sensor to capture the upper limb movement trajectory. Then, the aerobics upper limb movement trajectory and posture mathematical description method to obtain the model of the action perception recognition system are written. In order to verify the system, this paper also designed the actual effect of attitude calculation and A-RRM algorithm verification experiment. Finally, it is optimized with the data obtained from the experiment, and the accuracy and efficiency comparison experiment with the traditional motion perception recognition system is carried out. Experimental results show that the motion recognition accuracy of the aerobics upper limb movement trajectory recognition system based on multismart sensors is improved by 13%-23% compared with the traditional motion recognition system. The recognition efficiency of the action perception recognition system based on multismart sensors is 9%-15% higher than that of the traditional action recognition system.

1. Introduction

With the development of sensor networks, the large-scale and universal networked development of information perception in the transportation field has received strong technical support. With the development of embedded systems, communication technology, and microelectronics technology, sensor networks are composed of nodes with sensing functions, communication functions, and computing functions [1–4]. With intelligence, diversity, heterogeneity, and self-organization, it can autonomously complete tasks based on sensing and organize distributed network perception systems. After 2000, due to the reduction of the manufacturing cost of the sensor node, the reduction of the size, and the highly unified function, the sensor network technology was deeply studied and applied in many occasions.

Real-time tracking and capturing of human motion is an important scientific research topic in the fields of inertial navigation, biomedicine, virtual reality, human-machine control, and sports. Current motion capture systems mainly include optical motion capture systems, magnetic motion capture systems, mechanical motion capture systems, and inertial motion capture systems. Inertial sensing equipment can overcome the jitter, delay interference, low-speed drift, and restricted movement of other sensing equipment.

In order to study the application of smart sensors, Garcia et al. designed a smart sensor to predict the established sensory fish quality index. The sensor dynamically correlates the microbial count and TVB-N with the quality index [5]. The intelligent sensor designed by it is mainly used in fish quality detection and has some shortcomings in motion capture. It is still a difficult task to achieve selective detection of target analytes in aqueous media. Here, Naha et al. reported the conceptualization and synthesis of a new customized molecular probe R based on 1,8-naphthalimide, which can be used as a trifunctional molecular sensor for CN, Fe, and...
H2S [6]. The molecular sensor that Naha et al. chose to use may be lacking in motion capture. It would be better if multiple smart sensors were used. Privacy issues have become part of the daily lives of most people, especially in large cities and densely populated areas. But a new type of smart sensor designed by Malone hopes to improve the security of these personal spaces while maintaining privacy [7]. The smart sensor researched by him is used to protect privacy, and its data protection ability is very strong, but it is insufficient in motion capture. In the process of large-scale application of aerobics to the public, many large companies will organize such popular aerobics competitions and performances to celebrate. Ma expresses the characteristics in the design of the action to achieve better results. His research found that the current aerobics combines the knowledge of dance and music, with various forms of expression [8]. Optical motion capture is based on estimating the three-dimensional position of the marker through triangulation from multiple cameras. Rahimian and Kearney introduced and compared two camera placement methods. The first method is based on a metric, and the second method is based on the view distribution of the target point [9]. His research is based on the camera’s triangulation to capture; this kind of capture method can refer to adding multismart sensors. In the field of sports performance, the goal of motion capture is to track and record the athlete’s human movement, analyze its physical condition, performance, technique, and the origin of injury, prevention, and rehabilitation. Pueo et al. reviewed the latest developments in motion capture systems for sports performance analysis. Although the optical system is the reference system for its accuracy, the cost of the equipment and the time invested in capture and post-processing are more [10]. The focus of Pueo et al.’s research is motion capture, and the results of his research can be applied to multismart sensor motion capture. Cross-modal face matching between the thermal spectrum and the visible spectrum is a very required function for night surveillance and security applications. Sarfraz and Stiefelhagen proposed a method to bridge this modal gap. Their method uses deep neural networks to capture the highly nonlinear relationship between the two modes [11]. The spectrum-based recognition they studied is insufficient in the application of multismart sensors. Traffic sign recognition plays an important role in autonomous vehicles and advanced driver assistance systems. Based on the research on the effect of color space on the representation learning of convolutional neural networks, Zeng et al. proposed a new traffic sign recognition method called DP-KELM, which uses the kernel-based extreme learning machine (KELM) classifier and deep perception features [12]. His research is based on the method of convolutional neural network to identify traffic signs, which has a little reference value in motion capture, but it is not very relevant to multismart sensors.

The innovation of this article is that this article uses a combination of VM-1 three-axis magnetic sensor and MEMS smart sensor to capture the motion trajectory of the upper limbs of aerobics. Then, combined with the characteristics of the upper limb movement trajectory of aerobics and the mathematical description method of posture, the model of the aerobics upper limb movement trajectory recognition system based on multi-intelligent sensors is designed.

2. Multismart Sensor-Based Aerobics Upper Limb Motion Capture Method

2.1. Motion Capture Method of Smart Sensor. The motion capture system [13] is shown in Figure 1. Continuous monitoring of patient information provided by the motion capture device is indispensable for timely detection of patient health problems. Moreover, the actions and places of elderly patients can also be tracked in real time, so that they can be treated in time when an emergency occurs. In a motion capture system, sensors that monitor the physiological characteristics of patients such as electric current scanners, sensors that monitor movement characteristics such as accelerometers, gyroscopes, and magnetic flux sensors, can include various types of wearable sensor devices [14]. With the rapid development of MEMS sensing technology, the somatosensory network is composed of small and lightweight sensing devices such as speedometers, gyroscopes, magnetic flux sensors, and wireless sensor networks, which can avoid restricting human movements through wired transmission.

The movement of the human body can be regarded as a series of complex and regular movements. In order to complete the action, each action can be completely decomposed into the action of each hand and foot, and the actions between the hands and feet are independent of each other. The various movements of the human body are composed of multiple degrees of freedom. Due to its complexity, there are still many difficulties and problems when computers simulate the movements of hands and feet.

At present, the most representative motion capture devices are the MVN system of Xsens in the Netherlands and the 3DSuit product of Innalabs in the United States, but there are currently no commercial products in this field. Foreign products are expensive and do not support secondary development. The purpose of this article is to realize the basic functions of the research and analysis of the motion capture system and to develop its own motion capture system.

2.1.1. MEMS Smart Sensor. As the posture measurement unit of the motion capture system, MEMS inertial sensor [15] is an indispensable part of the motion capture system for motion information collection. Its main function is to use the built-in sensor unit of the sensor to collect real-time motion posture information of the motion capture object.

The IEEE1451.5 substandard in the IEEE1451 standard family [16] constructs the wireless smart sensor system structure; wireless smart sensors have the advantages of interchangeability and scalability to meet the needs of different fields and industrial fields. The IEEE1451.5 wireless smart sensor is mainly composed of WTIM [17] and NCAP [18]. The two are connected and communicated wirelessly; the system architecture is shown in Figure 2.

It can be seen from Figure 2 that the networked smart sensor system complies with the basic hardware and
software model of the IEEE1451 standard family and has the basic topology of a wireless sensor network. With wireless sensor network as the development platform, the IEEE1451 standard family is applied to wireless sensor network data collection, which can not only realize the automatic identification function of smart sensors but also connect the sensors to the network conveniently and have network communication functions.

In the networked smart sensor system, users send data requests to the smart sensor network according to their personal needs, and NCAP receives the data requests, analyzes and processes them, and queries whether the network has this type of sensor service interface. If the service request can be provided in the network, the service response waiting signal will be sent back to the user, and the data request command will be sent to the corresponding WTIM at the same time, and the service data will be provided to the user after receiving the data sent back by the WTIM. If there is no corresponding service in the network, the user is informed that this network does not provide the service.

When WTIM receives the command sent by NCAP, after analyzing and processing the command, it sends the corresponding operation instruction to the sensor module. For example, read the TEDS table of the sensor module, or read the sensor data of a certain channel, and send the data returned by the sensor module to NCAP.

The built-in EEPROM [19] in the sensor module is used to store TEDS, which covers the sensor information and parameters of all channels of this module. The module has simple command analysis and response functions, covering all functional modules in the IEEE1451.5 standard.

There are three main reasons for the development of networked smart sensors using 6LoWPAN wireless sensor network [20]: first, the 6LoWPAN wireless sensor network is the mainstream of the future wireless sensor network, and it is an open protocol system, unlike ZigBee, which is a proprietary protocol stack, access to the Internet also requires gateway support. Second, with the widespread application and popularization of IPv6 technology, the use of the 6LoWPAN network is more easily accepted. Third, the 6LoWPAN protocol stack occupies a small storage space, only a few KB to tens of KB of code space, which can not only reduce hardware expenses but also reduce the area of the CPU to meet the low-cost requirements of the Internet of Things. The overall design scheme of the networked intelligent sensor based on 6LoWPAN is shown in Figure 3.

In the 6LoWPAN networked intelligent sensor system, the NCAP node is mainly responsible for the establishment and maintenance of the 6LoWPAN network, the discovery and management of WTIM node sensor services, and the management of data communication with the Internet.

2.1.2. VM-3 Three-Axis Magnetic Sensor. The VM-3 axis magnetic sensor [21] has multiple bridges made of magnetically sensitive materials. These bridges can sense the magnetic field strength of different axes and convert it into a differential voltage, so that the voltage can obtain the omnidirectional magnetic field strength. The frame is shown in Figure 4.

The relevant characteristics are as follows: working voltage is 2.7 V ~ 5.25 V, working current is 0.55 mA, sensitivity is 512LSB/Gauss, and sampling frequency is 50 Hz/s.
VM-i integrates a 3-axis gyroscope, a 3-axis accelerometer, and a 3-axis magnetic sensor. If the measurement ranges of the original sensors exceed their respective limits, the measurement accuracy will decrease, and malfunctions may occur depending on the situation. The large temperature difference when using the VM-i sensor will also affect the measurement accuracy. The operating temperature of each sensor is -40 to +80°C.

The system uses the accelerometer, gyroscope, magnetic sensor, and temperature sensor integrated micromechanical
sensor VM-i as an inertial measurement unit to detect the sensor’s acceleration, angular velocity, magnetic field strength, and ambient temperature. Using the direction of the earth’s gravity measured by the accelerometer, the direction of the earth’s magnetic field is measured by the magnetic sensor to correct the acceleration information of the hands and feet measured by the gyroscope. Using Kalman filter Fusion to calculate the algorithm of human body three-dimensional posture data (3-axis acceleration, 3-axis angular velocity, 3-axis magnetic field strength), the posture information in the form of Euler angle, quota power, or rotation matrix was the output. Figure 5 is a flow chart of VM-i sensor data collection.

2.2. Aerobics. Aerobics [23] is a kind of physical exercise based on aerobic exercise, characterized by health, strength, and beauty, designed to promote physical and mental health and happiness. Aerobics is the product of the development of the times, and there are different understandings in different periods. From the earliest definition as a branch of gymnastics, to the development of music, gymnastics, dance, and other sports, to the fields of mass entertainment and competitive sports, the definition of the concept of aerobics has gradually become clear. Figure 6 shows the classification of aerobics.

2.2.1. The Connotation of Aerobics. Aerobics is usually done with bare hands or light machines. Supplying enough oxygen to supply energy is a form of exercise for the body to perform aerobic energy activities. It mainly affects the cardiopulmonary function of active people. As the basis of aerobic endurance, it is given characteristics during low-intensity to medium-intensity exercise.

From the perspective of human health, aerobics training has good effects, especially in weight control, weight loss, improvement of body shape, and improvement of coordination and rhythm. At present, aerobics has become one of the main courses of physical education in Chinese schools and is deeply loved by the majority of students. In the junior high school, bodybuilding operation is listed as a elective as an optional subitem for students, which not only forms a reserve force for the development and growth of aerobics in the future but also provides talents for the development and popularization of the school in the future. Not only that, in the opening ceremony of the school sports meeting and various performances, aerobics has also become one of the essential items, and it also brightens the school culture. A well-organized aerobics team will also become the exclusive feature of the school and an exclusive advantage against various competitions.

Modern aerobic exercise originated in the United States. In the former Soviet Union, Poland, and other countries, aerobic exercise has been incorporated into the physical education syllabus of universities, junior high schools, and elementary schools. In Japan, adolescents, adult women, babies, and pregnant women all do aerobic exercises. After aerobics was introduced into China, Chinese people integrated Chinese qigong, martial arts, folk dance, etc. into aerobics, which made it have typical Chinese characteristics. Aerobics is an ideal aerobic exercise; its main purpose is to improve health, balance the body shape, and enjoy the body and mind. Fitness aerobics exercise time is generally longer, the music speed is moderate, and the exercise intensity is moderate, suitable for all kinds of people with fitness as the goal. Aerobics can be further classified and named according to different classifications.

2.2.2. Current Status of Aerobics Teaching. Since the founding of New China, the educational concept of the old Soviet Union has always influenced China’s school sports. School physical education is basically centered on technical sports guidance, teaching materials, and teachers as the center, focusing on the formation of physical skills and the changing laws of physiology, the “four-part structural model” of organizational education and sports technology and sports performances. Students are concerned about the scores of the exam, and the teacher teaches the content and methods of the exam. This kind of educational thought overemphasizes teacher education, overemphasizes teacher’s protagonist, ignores students’ subjectivity, and ignores students’ active and active “learning”, ignore students’ learning content, learning methods, learning choices, ignore and reject the active situation of the learning environment and other aspects of students’ interest, enthusiasm, initiative, creativity, and creative cultivation. In particular, it ignores the important position of the cultivation of learning ability, self-learning ability, and innovation ability. Treating students as mass-produced products, eliminate their own initiative and differences, and place students in a subordinate position of education, thereby affecting their overall, coordinated and positive growth. Since the introduction of aerobics in China in the 1980s and entering the university, the aerobics education model has inevitably been influenced by the educational concept of the former Soviet Union. In addition, judging from the characteristics of aerobic exercise, the guidance mode of this project is easier to use the traditional guidance mode of “complete demonstration-explanation-decomposition demonstration-exercise” than other sports. In the guidance, the teacher is always a subject, students always “copy” passively and mechanically, which limits the cultivation of students’ personality and overall quality. This kind of students trained under the traditional sports model not only lacks the necessary scientific sports knowledge but also lacks independence, self-discipline, and innovative spirit and lacks sports ability.

With the advent of the new century, we must follow correct educational thoughts, formulate scientific and reasonable courses, and cultivate high-quality, social, physical and mental health talents. Aerobics is a unique sports activity with high fitness effects. Since its inception, it has caused a sensation all over the world, setting off a wave of bodybuilding all over the world. After that, aerobics was quickly adopted by the university’s physical education class. China is one of the most popular and interesting sports for college students. Today, it is very popular to offer gymnastics courses in universities. However, completing aerobic exercise courses, making full use of aerobic exercise education, implementing innovative education, enriching its meaning,
and expanding its space will become a topic of new development for university teachers. Therefore, it is very important to explore the university’s aerobic exercise education model in theory and practice. Updating the concept of education, we continue to explore and create a university aerobics education model that helps to cultivate the talent of the century.

Because aerobics is a body movement displayed under the accompaniment of music, it is ornamental and entertaining and can show the beauty of people. Therefore, it is loved by the majority of students and is one of the first choices for college students in the elective courses of physical education colleges. The national new curriculum reform marks the school curriculum reform. Many scholars have questioned the current teaching model after inheriting the research results of predecessors and pointed out that in the teaching process, full attention should be paid to the student’s main body status. Putting students’ “learning” at the top of teaching, and at the same time, teachers’ “teaching” should not be neglected. However, in teaching, teachers play a role as the leader, and students play as a “professor.” In traditional teaching methods, most teachers teach students to imitate learning, and students only pay attention to their own

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**Figure 5: VM-i sensor data collection flow chart.**

**Figure 6: Types of aerobics.**
learning results, only limited to the teacher’s guidance, there is no mutual guidance among students, because the phenomenon of neglecting the "teaching" of students is widespread. In the long term, it only favors the teaching of systematic knowledge and theory, which encourages students’ learning dependence, inhibits students’ learning initiative, and hinders the cultivation of students’ innovative talents, and it is difficult to achieve all-round development of students and improve students’ comprehensive quality. Therefore, the two should complement each other in the teaching process to complete the teaching task goal.

Aerobics is a difficult-to-beauty course in the event group theory. There is a certain degree of difficulty in the operation of the movement. It requires the help of students to master the movement. Therefore, the members of the cooperative group must cooperate to complete the teaching task, must practice the basic skills of the movement many times to master the movement, and the help and guidance between the peers can realize the smooth progress of the cooperative learning teaching mode. Only through the above implementation process can the purpose of cooperation and the purpose of mastering the skills of students be achieved.

2.3. Mathematics Description Method of Posture. Euler angle method, quaternion method, etc. express the carrier’s posture in the specified coordinate system [24]. There is a mutual conversion relationship between them.

2.3.1. Euler Angle Method. The Euler angle method is also one of the commonly used mathematical expression methods. There are 3 parameters in the coordinate system to describe the posture of the carrier. Euler angle can represent the relative deviation angle between two coordinate systems. The target coordinate system can be reached through 3 different rotations. For the first time, it can select any axis in ABC, and for the second time, it can select any of the following two other axes. For the third time, one other than the second axis is selected. There are two typical two types of expressions as follows.

The first method assumes that the initial position of the carrier coordinate system and the reference coordinate system \( o - a_b c_z \) is the same at the beginning, and the carrier coordinate system becomes \( o - a_y b_z c_y \) after three rotations. The first time is to turn the \( \theta \) angle around the \( c_z \) axis to reach the \( o - a_y b_z c_y (o - a_y b_z c_y) \) position; the second time is to rotate the \( \sigma \) angle around the \( b_z \) axis to the \( o - a_y b_z c_y \) (\( o - a_y b_z c_y \)) position, and the third time is to rotate the \( \beta \) angle around the \( c_z \) axis to the \( o - a_y b_z c_y \) position.

Denoting \( o - a_y b_z c_y, o - a_z b_z c_z, o - a_y b_z c_y \) and each coordinate system as the \( x, I, II, \) and \( y \) systems. The coordinate transformation relationship between the \( x \) system and the \( I \) system is

\[
\begin{bmatrix}
a_1 \\
b_1 \\
c_1
\end{bmatrix} = Z_{x}^{I} \begin{bmatrix}
a_x \\
b_x \\
c_x
\end{bmatrix}.
\]  

(1)

Among

\[
Z_{x}^{I} = \begin{bmatrix}
\cos \theta & \sin \theta & 0 \\
-\sin \theta & \cos \theta & 0 \\
0 & 0 & 1
\end{bmatrix}.
\]

(2)

The coordinate transformation relationship between the \( I \) system and \( II \) system is:

\[
\begin{bmatrix}
a_2 \\
b_2 \\
c_2
\end{bmatrix} = Z_{I}^{II} \begin{bmatrix}
a_1 \\
b_1 \\
c_1
\end{bmatrix}.
\]

(3)

Among

\[
Z_{I}^{II} = \begin{bmatrix}
\cos \sigma & 0 & -\sin \sigma \\
0 & 1 & 0 \\
\sin \sigma & 0 & \cos \sigma
\end{bmatrix}.
\]

(4)

The coordinate transformation relationship between the \( II \) system and the \( y \) system is

\[
\begin{bmatrix}
a_y \\
b_y \\
c_y
\end{bmatrix} = Z_{II}^{y} \begin{bmatrix}
a_2 \\
b_2 \\
c_2
\end{bmatrix}.
\]

(5)

Among

\[
Z_{II}^{y} = \begin{bmatrix}
\cos \gamma & \sin \gamma & 0 \\
-\sin \gamma & \cos \gamma & 0 \\
0 & 0 & 1
\end{bmatrix}.
\]

(6)

From this, the coordinate transformation relationship between the \( x \) system and the \( y \) system can be obtained

\[
\begin{bmatrix}
a_y \\
b_y \\
c_y
\end{bmatrix} = Z_{II}^{y} Z_{x}^{I} Z_{x}^{II} \begin{bmatrix}
a_x \\
b_x \\
c_x
\end{bmatrix} = Z_{x}^{y} \begin{bmatrix}
a_x \\
b_x \\
c_x
\end{bmatrix}.
\]

(7)

It is very inconvenient to use this method to describe the position change of the rotating object, so other Euler angle definition methods are used.

Another method assumes that the initial position of the carrier coordinate system and the reference coordinate system \( o - a_y b_z c_z \) is the same at the beginning, and the carrier coordinate system becomes \( o - a_y b_z c_y \) after three rotations. The first time is to turn the \( \alpha \) angle around the \( c_z \) axis to reach the \( o - a_y b_z c_y (o - a_y b_z c_y) \) position; the second time is to rotate the \( \beta \) angle around the \( b_z \) axis to the \( o - a_y b_z c_y \) (\( o - a_y b_z c_y \)) position, and the third time is to rotate the \( \delta \) angle around the \( c_z \) axis to the \( o - a_y b_y c_y \) position.
Among them, the abovementioned coordinate systems are still denoted as $x$, I, II, and $y$ systems, and the coordinate transformation relationship between the $x$ system and the I system is

$$
\begin{bmatrix}
a_1 \\
b_1 \\
c_1
\end{bmatrix}
= Z_x^I
\begin{bmatrix}
a_x \\
b_x \\
c_x
\end{bmatrix}.
$$

(8)

Among

$$
Z_x^I
= \begin{bmatrix}
1 & 0 & 0 \\
0 & \cos \alpha & \sin \alpha \\
0 & -\sin \alpha & \cos \alpha
\end{bmatrix}.
$$

(9)

The coordinate transformation relationship between I system and II system is

$$
\begin{bmatrix}
a_2 \\
b_2 \\
c_2
\end{bmatrix}
= Z_{II}^I
\begin{bmatrix}
a_1 \\
b_1 \\
c_1
\end{bmatrix}.
$$

(10)

Among

$$
Z_{II}^I
= \begin{bmatrix}
\cos \beta & 0 & -\sin \beta \\
0 & 1 & 0 \\
\sin \beta & 0 & \cos \beta
\end{bmatrix}.
$$

(11)

The coordinate transformation relationship between the II system and the $y$ system is

$$
\begin{bmatrix}
a_y \\
b_y \\
c_y
\end{bmatrix}
= Z_{II}^y
\begin{bmatrix}
a_x \\
b_x \\
c_x
\end{bmatrix}.
$$

(12)

Among

$$
Z_{II}^y
= \begin{bmatrix}
\cos \delta & \sin \delta & 0 \\
-\sin \delta & \cos \delta & 0 \\
0 & 0 & 1
\end{bmatrix}.
$$

(13)

From this, the coordinate transformation relationship between the $x$ system and the $y$ system can be obtained

$$
\begin{bmatrix}
a_y \\
b_y \\
c_y
\end{bmatrix}
= Z_{II}^y Z_{II}^I Z_x^I
\begin{bmatrix}
a_x \\
b_x \\
c_x
\end{bmatrix}.
$$

(14)

It can be seen from the above that as long as a clear Euler angle set is given, the position of the deviation of the target coordinate system relative to the reference coordinate system can be uniquely determined.

2.3.2. Quaternion Method. The quaternion method is a mathematical concept proposed by Irish mathematicians. This is a simple supercomplex number composed of 4 elements, composed of real numbers and 3 imaginary numbers $o, p,$ and $q$. It can be expressed as $x + yo + zp + sq$. With the development of inertial navigation systems, more and more quotas are used to describe the posture of the carrier, which can make up for the shortcomings of Euler angles when describing the posture. As we all know, the above-defined values of simple supercomplexes have the following rules:

$$
\begin{align*}
{\circ \circ} \ast {\circ \circ} &= {\circ \circ} \ast {\circ \circ} = {\circ \circ} \ast {\circ \circ} = -1, \\
{\circ \circ} \ast {\circ \circ} &= q, \\
{\circ \circ} \ast q &= o, \\
q \ast o &= p.
\end{align*}
$$

(15)

If $y, z, s$ are all 0, the abovementioned quaternion will degenerate into a real number, and when $z$ and $s$ are 0,
it will degenerate into a complex number, so it is called a supercomplex number.

(1) Quaternion Addition. Taking any two quaternions $a$ and $b$,

$$
\begin{align*}
    a &= a_0 + a_1 q + a_2 p + a_3 q,
    b &= b_0 + b_1 q + b_2 p + b_3 q,
    a + b &= (a_0 + b_0) + (a_1 + b_1) q + (a_2 + b_2) p + (a_3 + b_3) q.
\end{align*}
$$

(16)

It can be seen that the addition of any two quaternions is still a quaternion.

(2) Quaternion Multiplication.

$$
\begin{align*}
    a &= a_0 + a_1 q + a_2 p + a_3 q,
    b &= b_0 + b_1 q + b_2 p + b_3 q,
    a \otimes b &= (a_0 + a_1 p + a_2 q)(b_0 + b_1 q + b_2 p + b_3 q) \\
    &= [a_0 b_0 - (a_1 b_1 + a_2 b_2 + a_3 b_3)] + [a_0 b_1 + a_1 b_0 + (a_2 b_3 - a_3 b_2)] q \\
    &\quad + [a_0 b_2 + a_2 b_0 + (a_1 b_3 - a_3 b_1)] p \\
    &\quad + [a_0 b_3 + a_3 b_0 + (a_1 b_2 - a_2 b_1)] q.
\end{align*}
$$

(17)

(3) Matrix Representation of Quaternion. The quaternion can be written as a four-dimensional vector:

$$
\begin{align*}
\begin{pmatrix}
    a_0 \\
    a_1 \\
    a_2 \\
    a_3 
\end{pmatrix} =
\begin{pmatrix}
    b_0 \\
    b_1 \\
    b_2 \\
    b_3 
\end{pmatrix}.
\end{align*}
$$

(18)

3. Test Experiment of Aerobics Upper Limb Movement Trajectory Perception System Based on Multi-Intelligent Sensors

3.1. The Actual Effect of Posture Calculation. In order to test the effectiveness of vector observation method, angular velocity integral method, and complementary filtering algorithm, this paper analyzes the actual effect of attitude calculation. The specific analysis methods are as follows: (1) adjust the posture of the sensor node and compare the sensor node posture calculated by the vector observation method with the real posture under static conditions and (2) make the sensor node move at a higher frequency and output the calculation results of the two attitude algorithms in real time and compare the sensor node attitude calculated by the vector observation method and the angular velocity integral method. If the attitude difference between the above two comparisons is not large, it is considered that both the vector observation method and the angular velocity integral method are effective. First of all, this paper
analyzes the results of the pitch angle and roll angle calculated by the vector observation method in the range of 0 to 90 degrees. The experimental results and analysis are shown in Tables 1 and 2.

From the experimental results in Tables 1 and 2, we can see that the pitch angle and roll angle calculated by the vector observation method have a certain error, and the error increases with the increase of the pitch angle or the roll angle. When the pitch angle or roll angle is close to 90 degrees, the accurate angle value cannot be calculated by the vector observation method.

Then, this article analyzes the result of calculating the heading angle by the magnetic vector observation method in the inclined state. The experimental results are shown in Table 3. Comparing the heading angle measurement results in Table 3, it can be seen that the heading angle accuracy in the inclined state will be reduced, which is caused by the superposition of the error of the acceleration sensor and the error of the magnetoresistive sensor. Next, this article compares the calculation results of the vector observation method and the angular velocity integral method. In this paper, we try to make the sensor node produce higher frequency motion and record the change process of the roll angle obtained by the two calculation methods. The experimental results are shown in Figure 7.

Described in Figure 7 is the same movement process; this movement process includes two low-frequency movements and one high-frequency movement (5.5 seconds to 10 seconds). It can be seen intuitively from Figure 7 that the two algorithms do not have much difference in the recording of low-frequency motion, but there is a big difference in the recording of high-frequency motion. During the period from 5.5 seconds to 10 seconds, the high-frequency components recorded by the vector observation method are far less abundant than those recorded by the angular velocity integral method. In addition, this article can also find that the pitch angle recorded by the angular velocity integral method has a significant “drift” in the period from 5.5 seconds to 10 seconds. The above phenomena are consistent with the theory; they reflect the characteristics of the two algorithms and at the same time prove the necessity of complementary filtering.

3.2. A-RRM Algorithm Verification. The verification of the A-RRM algorithm is carried out in the NS2 environment. Table 4 shows the change in bandwidth obtained by each business as the total bandwidth of the vehicle-to-ground communication system changes.

It can be seen from Table 4 that when the bandwidth is small, the A-RRM algorithm can effectively allocate limited resources to more important services, which meets the requirements of designers. With the increase of bandwidth, the A-RRM algorithm gradually reduces the influence of service importance on the distribution method and satisfies the demand for fair distribution under the premise of ensuring transmission reliability.

The following compares the A-RRM algorithm with the traditional DCF algorithm and the rate allocation algorithm BRGF based on bankruptcy game theory. For the convenience of observation, select business 0 and business 1 as the observation objects for comparison. Figure 8 shows the results of the three algorithms for each service flow distribution.

As can be seen from Figure 8, BRGF is an algorithm that strictly refers to the business importance function in all intervals, so bandwidth will be wasted when the total bandwidth is large enough. As for the ordinary DCF algorithm, due to the large difference between the importance functions of the examples used in this article, the algorithm basically does not allocate bandwidth to the services of lower importance.

4. Multismart Sensor Motion Perception System in Aerobics Upper Limb Movement Capture Analysis

4.1. Investigation and Analysis of Aerobics Teaching. The pretest questionnaires and posttest questionnaires were compiled by consulting relevant materials and combining with the actual situation of school aerobics, for the
comparative analysis of results between the experimental group and the control group. 26 questionnaires were distributed in the pre-test, 26 were retrieved after filling out on-site, and 26 were effectively retrieved. The experimental group gave out 13 posttest questionnaires, and 13 were effectively recovered; the control group distributed 13 and effectively recovered 13 copies. The student’s learning experience of aerobics is shown in Table 5.

The students in the experimental group and the control group did not undergo a general aerobics course before the experiment. Combining the statistical results in Table 5, it can be seen that before the experiment, the two groups of students have similar experience in professional aerobics training, participating in school aerobics club training, obtaining sports grades, refereeing grades, etc., there is no obvious difference.

Physical fitness is a prerequisite for learning various sports skills. From the data in Table 6, it can be seen that the experimental group and the control group have the same level of body shape (height, weight) and basic physical fitness, and the $P$ value is greater than 0.05.

Table 5: The aerobics learning experience of the two groups of students before the experiment.

| Project                                      | Test group |   | Control group |   |
|----------------------------------------------|------------|---|---------------|---|
| Number of people who have participated in professional aerobics training | 0          | 13| 0             | 13|
| Have participated in the school aerobics club | 6          | 7 | 7             | 6 |
| Number of aerobics                          | 0          | 13| 0             | 13|
| Number of referees in aerobics              | 0          | 13| 0             | 13|

Table 6: Comparison of the physical fitness of the groups of students before the experiment.

| Physical fitness   | Group               | $X$   | $T$    | $P$   |
|--------------------|---------------------|-------|--------|-------|
| Height             | Test group          | 175.66| 1.345  | 0.203 |
|                    | Control group       | 172.94|        |       |
| Weight             | Test group          | 69.12 | 1.573  | 0.166 |
|                    | Control group       | 95.64 |        |       |
| Skip rope in one minute | Test group | 141.33| -0.716 | 0.453 |
|                    | Control group       | 143.64|        |       |

Figure 9: Comparison of motivation and interest in learning aerobics between the two groups of students. (a) Comparison of the aerobics learning motivation of the two groups of students before the experiment. (b) After the experiment, the comparison of interest in aerobics learning between the experimental group and the control group.
In order to explore students’ motivation and interest in learning aerobics, this article conducted a survey. The results of the survey are shown in Figure 9.

According to Figure 9, in the experimental sample of 26 people, nearly 23% of the students in the experimental group and the control group chose bodybuilding operations as their special study for the pursuit of physical fitness. 23% of the students in the experimental group chose to learn aerobics out of the desire to master higher aerobics skills and tactics, and 31% of the students in the control group focused on improving aerobics skills. Nearly 39% of the students in the experimental group chose aerobics simply because of their interest in aerobics, while the control group also showed that 31% of the students chose aerobics because of their hobbies. 15% of the students in the experimental group believe that aerobics is a complex technical and difficult to learn project, so they participate in aerobics special class. In the control group, the same proportion of students chooses aerobics to challenge themselves. After a semester of study, 46% of the students in the experimental group thought that special learning aerobics was very interesting, while only 15% of the students in the control group held the same attitude. 39% of the students in the experimental group found aerobics special learning interesting and 31%
of the students in the control group. 15% of the students in the experimental group thought that after a semester of aerobics special courses, their degree of interest in aerobics became general and 39% of the students in the control group. No one in the experimental group thinks that aerobics learning is not very interesting, while 15% of the students in the control group still feel that aerobics learning is not very interesting. From the overall situation, the students in the experimental group are more interested in aerobics than the control group.

4.2. Comparative Analysis of Aerobics Upper Limb Movement Trajectory Recognition System Based on Multi-Intelligent Sensors and Traditional Motion Recognition.

Based on the above experiment, the data obtained in this paper is written into the aerobics upper limb movement perception recognition system based on multismart sensors. In order to verify its advantages with traditional motion perception systems, this paper designs a comparative experiment between the two. The two groups, respectively, performed action perception recognition on 10 aerobics upper limb movements. The comparison results of recognition accuracy and efficiency are shown in Figure 10.

It can be seen from Figure 10 that the motion recognition accuracy of the aerobics upper limb movement trajectory recognition system based on multismart sensors reaches 88%-95%, while the traditional motion recognition system is only 72%-75%. Compared with the traditional perceptual recognition system, the new perceptual recognition system designed in this paper is improved by 13%-23%. The motion recognition efficiency of the aerobics upper limb movement trajectory recognition system based on multismart sensors reaches 89%-92%, while the traditional motion recognition system is only 77%-80%. Compared with the traditional perceptual recognition system, the new perceptual recognition system designed in this paper is improved by 9%-15%. This shows that the aerobics upper limb movement trajectory perception system based on multi-intelligent sensors can effectively improve the accuracy and efficiency of aerobics upper limb movement trajectory perception and recognition.

5. Conclusions

This paper mainly studies the method of aerobics upper limb movement trajectory recognition and recognition based on multi-intelligent sensors. Therefore, this article uses the VM-i three-axis magnetic sensor and MEMS smart sensor to capture the motion trajectory of the upper limbs of aerobics by designing the motion capture technology of multiple smart sensors. Then, by understanding the trajectory and posture mathematical description method of aerobics upper limb movement, it is written into the perception and recognition of multismart sensors. In order to verify its actual effect on attitude calculation, this paper designs the actual effect experiment of attitude calculation and verifies the A-RRM algorithm; finally, the data obtained from the experiment will be proved. Then, in order to study the advantages of aerobics upper limb movement trajectory recognition system based on multi-intelligent sensors and traditional motion recognition, this paper also designed two sets of motion perception recognition systems to compare the recognition accuracy and efficiency of the experiment.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there is no conflict of interest with any financial organizations regarding the material reported in this manuscript.

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