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[1] Qingfeng Shi
[1,*] Yunkun Cui

Research on Motion Capture System of Motor Skill Based on Computer Vision Technology

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Abstract: - Compared with the existing motion capture system, the inertial conduction based motion capture method proposed in this project can effectively overcome the shortcomings of the current motion capture, such as limited communication distance, low accuracy of data acquisition, low visualization degree of model display software, narrow application range, etc., and improve the practical application value of the method. A method of motion capture and motion control based on wireless network is proposed. Since most of the skeleton of the human body is rigid, the complete expression of the human movement is realized through the study of 17 important joints, and all the movement information of the athlete can be obtained by placing sensors on the corresponding nodes. Through wireless network transmission technology, the player's action information is transmitted to the 3D modeling software to achieve real-time control of the action. When measuring each sensor, strapdown inertial navigation technology is used to improve the accuracy of acquisition. The 3D modeling software is based on a professional motion capture software, and through the forward and inverse kinematics of its motion, the 3D modeling is highly consistent with the wearable device.

Keywords:Nine-Axis Sensor; Motion Capture; Visual Technology; Kinematics Algorithm; 3D Modeling Software.

I. INTRODUCTION

Motion capture is a method to collect and reproduce the motion information of human or other objects by mechanical, optical or sensor means, and reproduce its motion state. In the daily life of this paper, it is most commonly used in anime movies and motion-sensing games. Usually, athletes wear devices that can collect motion data, and then model them through software and integrate them with previously obtained motion data, so as to build a model that moves with athletes at the same time or presents their previous movements [1]. With the continuous improvement of people's material living standards, the verisimilitude of motion forms of virtual characters in animation, film, and motion-sensing games is getting higher and higher, and the huge market demand also drives the rapid development of motion capture technology. In the process of scientific and technological development, people will also notice that this technology has more applications, for example, In this way, the athlete's body position can be obtained to assist the athlete in training, and by using the data captured by the movement, the robot can be remotely controlled to perform certain high-risk and high-risk operations [2]. The need to drive scientific and technological progress, and scientific and technological progress can adapt to new needs, the two complement each other, determining that the future of motion capture will be a very broad field.

Different motion capture techniques have their own advantages and disadvantages. Take the current popular optical motion capture as an example, this method can not only achieve very high accuracy, but also achieve what other technologies can not achieve - the capture of the athlete's face [3]. However, this technology also has certain limitations, first, it must have a certain competition environment, but also must have enough speed to shoot, which makes the application of motion capture technology is greatly limited. Secondly, in the process of multi-person motion capture, the luminous points on the surface of the athlete's body will interfere with each other, resulting in the failure of motion capture [4]. There is also a more common motion capture technology, that is, inertial conduction motion capture, this technology has gradually developed in recent years, because of the limitations of the volume of the instrument, can not capture the face and other small parts of the movement, but low cost, no site restrictions, real-time, capture accuracy and optical motion capture equivalent, so the development potential is great. The purpose of this design is to develop a simple, inexpensive, universal motion capture and control system in the context of the current popularity of virtual reality and motion capture technology [5]. In recent years, with the development of science and technology, inertial transfer motion capture technology has gradually emerged, but in China, in inertial motion capture research investment is still very little, a relatively mature equipment, its cost is also high, and has a very low universality. Some of the previous designs were also based on six-axis sensors, and most of the motion data obtained had to be corrected in order to achieve

[1]School of Taishan University, Taian 271000, China
*Corresponding author: Yunkun Cui

more accurate results. Therefore, the design uses the nine-axis sensor MPU9250 for the movement test of the body. First, the data obtained in this way is more accurate without too much correction; The second is to use the magnetometer in the nine-axis sensor for calibration fusion, thus improving the accuracy of the data [6]. In addition, the design also uses WiFi for data transmission, increasing the range of communication, thus improving the application range of the system. Finally, this paper adopts the method of secondary development of MotionBuilder, its purpose is to use the powerful performance of MotionBuilder, good human-computer interaction experience, real modeling effect, and compared with the self-developed graphics display software, save a lot of time and improve the efficiency of work [7]. After the mannequin software obtains the movement data of the performers, it can control the virtual human body to perform the same movement as the real performers through a series of fusion calculations.

II. Overall system design scheme

A perfect motion capture system can be divided into three important components, one is data acquisition, which is the basis of motion capture, and every link behind it should be used, otherwise it will affect the final result [8]. After obtaining this information, the next thing to face is how to transmit this information to other places, once this information is lost, then this information will seriously affect the accuracy of motion capture. After obtaining all the information, people must first build a complete human skeleton, and then connect the information of these skeletons with the various joints of the athletes, and then simulate the real action through positive and negative movements.

A. Design Framework

According to the specific implementation of the system, the system architecture can be divided into two modules: software and hardware architecture. Figure 1 shows the overall architecture of the system (images referenced from VIRTUAL AND AUGMENTED REALITY).

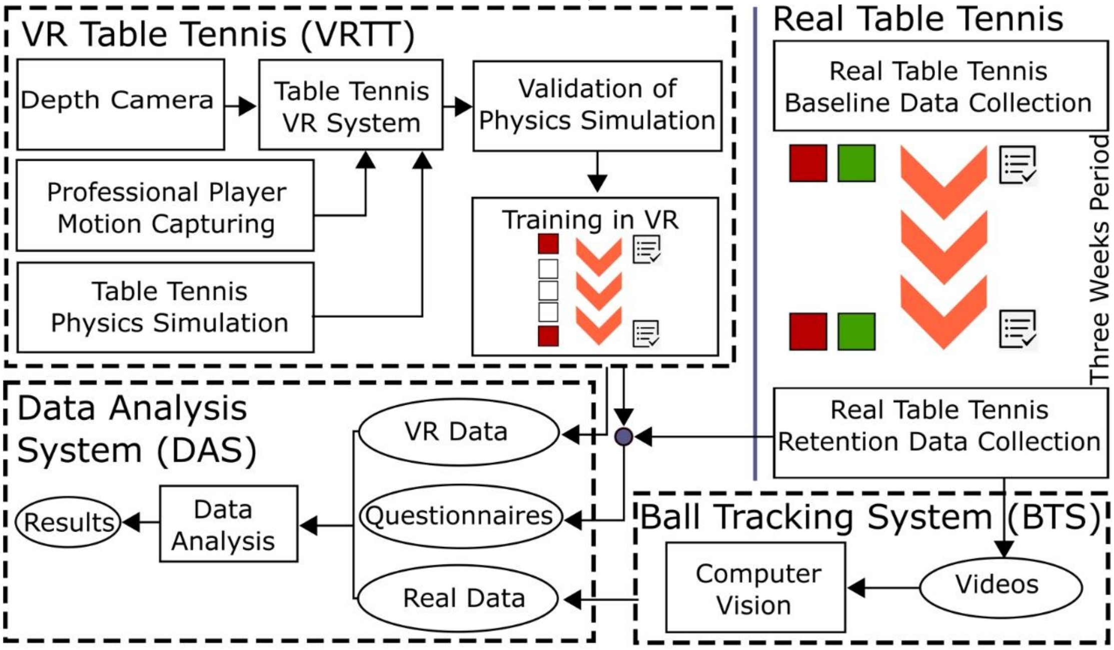

Fig.1 Motion capture system architecture

The main body structure of the human body is composed of the body, the left right upper limb, the right lower limb and the head and neck, so to get the complete human movement data, it is necessary to put the appropriate number of sensors in these positions, so that the complete human movement information can be obtained. Because most of the human bones are hard and cannot be bent, as long as the sensor is placed on the joint connected with it, 17 joints can be extracted through the simplified extraction of the human skeleton, and the information of 17 joints can be used to complete all the actions of a person, and transmitted to the PC through the wireless network [9]. By processing the collected data on the PC, the posture data that drives the model to move can be obtained, and then the virtual model can be controlled to make similar actions. At the same time, it can also store human movement data for other applications.

B. System hardware design

The hardware structure of this design is composed of three blocks, the first is the hardware of the sensing equipment, which completes the task of collecting information; The second link is the information summary and transmission link, which is responsible for the information summary of the previous nodes, and then the packet transmission; The third module is to provide energy to each chip to ensure that the entire system can run smoothly. In general the software hardware structure diagram in figure 2 (image references from https://github.com/xianfei/SysMocap) are presented. First, all he has to do is build all 17 sensors. Each sensor adopts JY901 to obtain the motion information, and sends it to STM32 through serial communication, and communicates with SP3485 through serial communication interface [10]. Each SP3485 is then connected and the previous data is transmitted via SP3485 to the serial /WiFi transmission module. In the diagram, in order to simplify the structure, 1-17 sensors are connected together. If too many devices are installed on one line, it will be impossible to receive any information. Therefore, a total of five lines are divided into four, four, four, three and two sensors are suspended on each line. The sensor will be installed on 17 key nodes that are important for human activities. After collecting and transmitting all the information received by the module, the wireless network module compresses the information and then transmits it to the PC through the router. The 3D modeling software on the PC can obtain this information through the program, and then bind this information with the corresponding nodes in the 3D model, and through a series of fusion operations, the information can be converted into the driving data for the operation of the 3D model. After the match, the data of each action can be stored for data backup and can be used in other CG software.

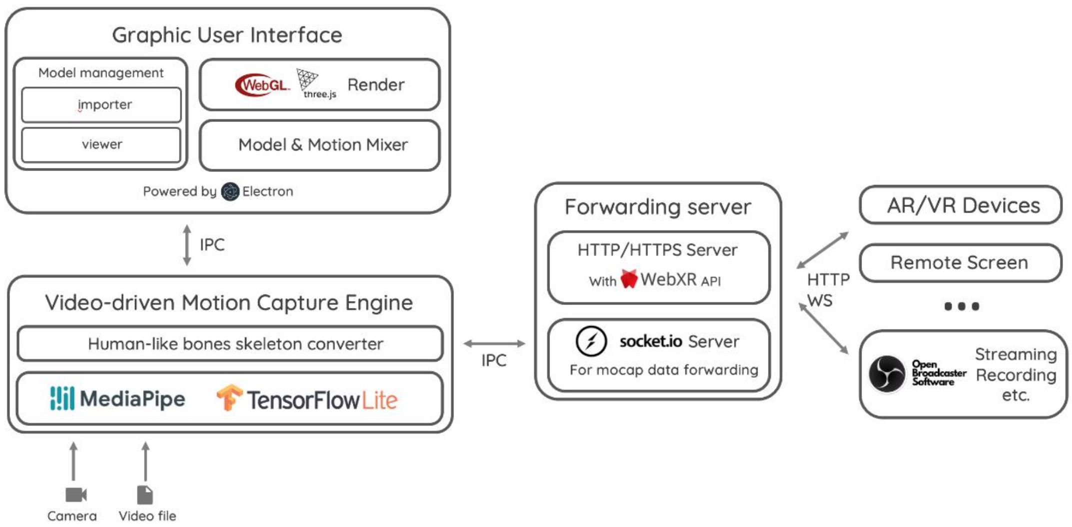

Fig.2 Hardware framework of motion capture and control system

The data acquisition system is mainly composed of power module, 17 sensor modules, data collection and transmission module, three main modules. In the system, the power unit is mainly lithium battery and power management module, and the inertia test unit is mainly lithium battery, and the power management module is responsible for charging and discharging, power off, voltage reduction and voltage regulation operations [11]. The nine-axis sensing unit JY901 is connected to the STM32 in serial mode and then transmits data through the STM32 to the SP3485, combining the individual sensor nodes and the data summary transmission module via the RS-485 communication interface. After collecting all the data, it is transmitted to the UART/WiFi module through SP3485. In this way, the data obtained by the nine-bit instrument can be transmitted wirelessly to the router and eventually to the PC. The system uses Socket technology to realize the communication between the sending unit and the PC, sends a position command to the PC through the PC, and feedbacks the corresponding data to the PC. In practical application, people should focus on the accuracy, volume, power consumption, battery life and cost of the sensor measurement unit. After completing the hardware architecture, the next step is to study the hardware architecture of the platform. The hardware architecture of the overall system is shown in Figure 3 (image cited in Hamlyn CRM: a compact master manipulator for surgical robot remote control).

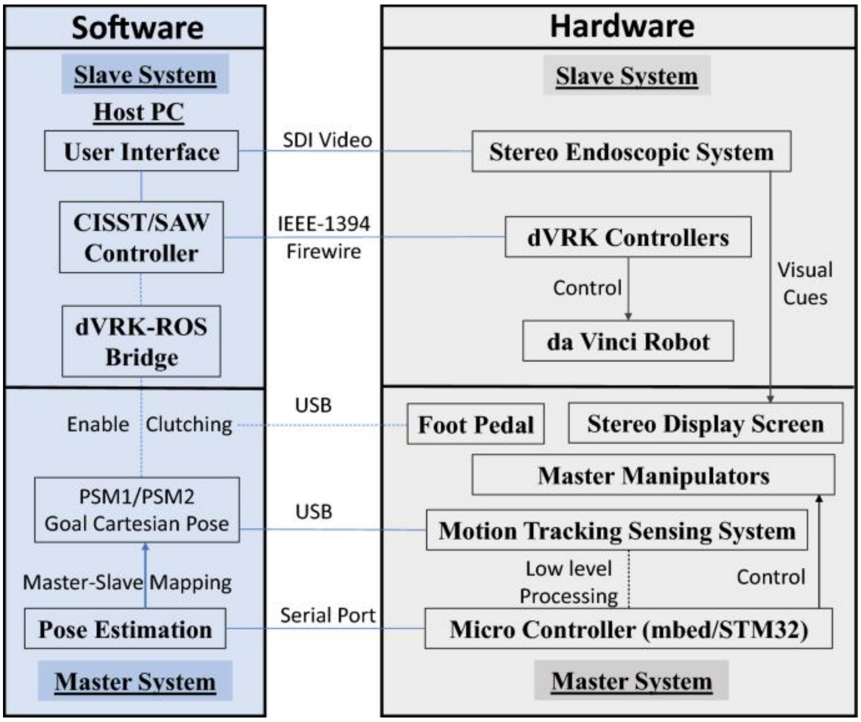

Fig.3 Software framework for motion capture and control system

The system adopts JY901 components as the design scheme. The MPU9250 is the core of the system. The MPU9250 is an excellent nine-axis digital sensor, which can convert 16-bit ADC three-axis acceleration signal, 16-bit ADC three-axis gyro signal and 16-bit ADC three-axis magnetic field signal, with high test accuracy and sampling frequency, and can be programmed to 100 HZ. The JY901 is the Lacrosse Precision Precision inertial navigation component that uses the MPU9250 as its core chip. On the one hand, this model is chosen because of its fast operation speed, on the other hand, because it uses Kalman filter to improve the accuracy of the system, and its cost is relatively low, easy to achieve low power consumption. The JY901 entity and pin diagrams are shown in Figure 4 (image quoted at www.raspberrypi.com) :

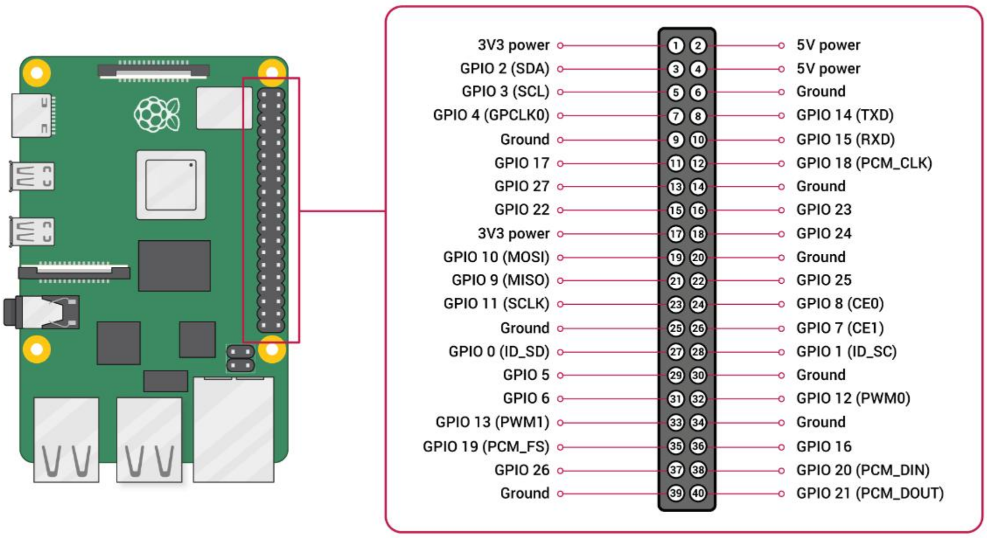

Fig.4 Sensor hardware diagram and main pin description

The data collection part was selected, and then the whole sensor network was designed with JY901 as the core. Each sensor in the previous section is collected by JY901, then transmitted to STM32 via serial interface, then connected to SP3485 via serial interface, and then SP3485 sends the resulting data. The circuit block diagram of the JY901 with STM32 is shown in Figure 5 (image quoted in STM32 PCB DESIGN).

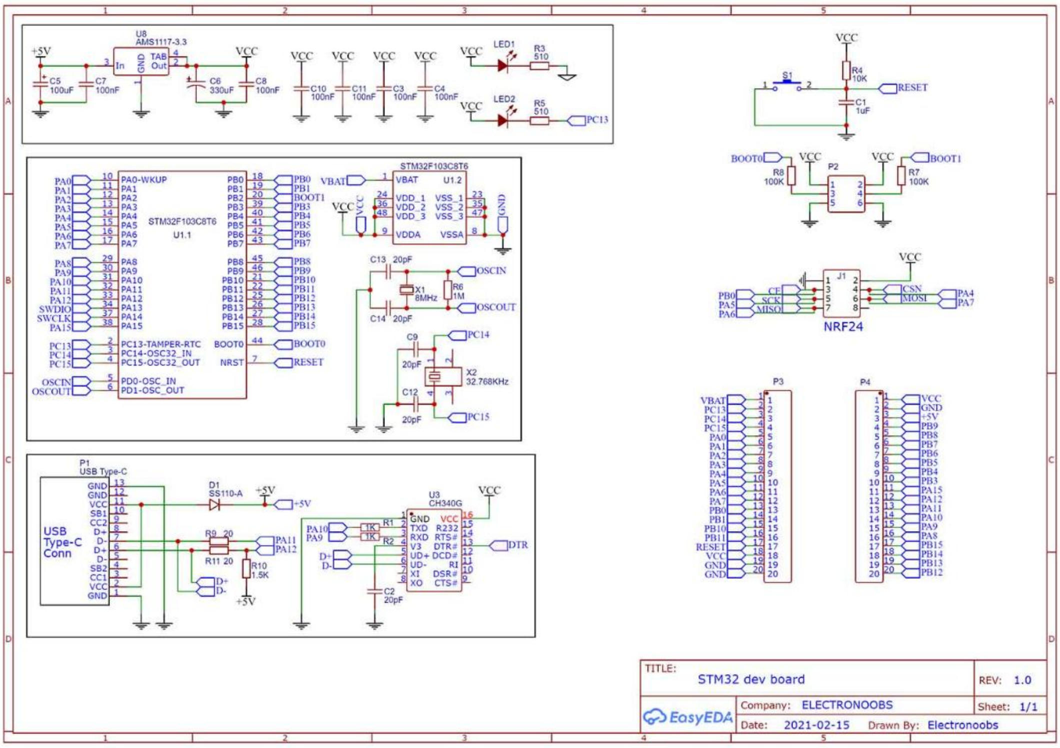

Fig.5 Schematic diagram of the connection between STM32 and JY901

The SP3485 is a half-duplex transceiver with "half-duplex" characteristics, that is, in the case of transmit or receive, the transmission cannot be synchronized. As can be seen from the figure, pin R in this design is connected to the U1RX of STM32, pin D is combined with the U1TX of STM32, and the two jointly complete the transmission of data, and pin DE/RE indicates that this chip is used for sending and receiving data. In addition, the JY901 operating voltage is 5 V, while the SP3485 and STM32 operating voltage is 3.3V, so also need a 5 V to 3.3V circuit, in this case, this paper chose a low voltage drop regulator AMS1117. First of all, STM32 reads the sensor JY901, and uses programming to transmit all the collected data to SP3485, SP3485 is a RS-485 serial communication specification, there can be 32 nodes on a serial bus at the same time, and this article is 18, so it well meets this requirement [12]. After the SP3485 of the data aggregation component is sent to the UART/WiFi component to the UART/WiFi component, the component encapsulates the data, transmits it to the 3D modeling program on the PC through the router, receives it through the Socket communication mode, and completes the data transmission.

III. PROCESSING OF MOTION POSTURE DATA

In this paper, SINS combined with Kalman filter is used to analyze the attitude information of the robot, which makes the obtained data more accurate. The Kalman filter is introduced in JY901 software, so it will not be introduced here. The strapdown solution method is embedded in the 3D modeling software, but its core lies in the analysis of the collected data, and has a close relationship with the sensing equipment, so this chapter will introduce its design and implementation in detail. This paper mainly introduces the basic principle and realization method of strapdown inertial navigation system. By converting the acceleration data on the axis of each sensor into an "absolute acceleration" in a geographic coordinate system, the position of the location is obtained by quadratic integration. Secondly, by comparing the angular rate measured by gyroscope with the relative position in the earth coordinate system, the angular rate of the system at different positions can be obtained [13]. There are three main methods of coordinate transformation, one is the direction cosine method, one is the Euler Angle method, and one is the quaternion method. These three aspects can be translated into each other. In order to make the connection between these three aspects more clear, it is assumed that a_m, b_m, c_m is used in this paper to represent the unit vector along the axis of the geographical coordinate system, $a_\beta, b_\beta, c_\beta$ is used to represent the unit vector along the axis of the body coordinate system, and the orientation of a_β in the geographical coordinate system can be determined by the cosine of its corresponding three directions, whose expression is

$$a_\beta = (a_\beta \cdot a_m)a_m + (a_\beta \cdot b_m)b_m + (a_\beta \cdot c_m)c_m \quad (1)$$

In the same way, there are

$$b_\beta = (b_\beta \cdot a_m)a_m + (b_\beta \cdot b_m)b_m + (b_\beta \cdot c_m)c_m \quad (2)$$

$$c_\beta = (c_\beta \cdot a_m)a_m + (c_\beta \cdot b_m)b_m + (c_\beta \cdot c_m)c_m \quad (3)$$

As a matrix

$$\begin{bmatrix} a_\beta \\ b_\beta \\ c_\beta \end{bmatrix} = \begin{bmatrix} a_\beta \cdot a_m & a_\beta \cdot b_m & a_\beta \cdot c_m \\ b_\beta \cdot a_m & b_\beta \cdot b_m & b_\beta \cdot c_m \\ c_\beta \cdot a_m & c_\beta \cdot b_m & c_\beta \cdot c_m \end{bmatrix} \begin{bmatrix} a_m \\ b_m \\ c_m \end{bmatrix} \quad (4)$$

The

$$D_m^\beta = \begin{bmatrix} a_\beta \cdot a_m & a_\beta \cdot b_m & a_\beta \cdot c_m \\ b_\beta \cdot a_m & b_\beta \cdot b_m & b_\beta \cdot c_m \\ c_\beta \cdot a_m & c_\beta \cdot b_m & c_\beta \cdot c_m \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} \\ S_{21} & S_{22} & S_{23} \\ S_{31} & S_{32} & S_{33} \end{bmatrix} \quad (5)$$

The above formula is a pose matrix expressed by direction cosine. Quaternions were first invented by Hamilton, an Irish mathematician and physicist [14]. The aim of this paper is to study a space geometry that deals with a plane problem in complex form. However, after the advent of strapdown inertial navigation technology, this inertial navigation technology has been widely paid attention to and widely used. In this paper, some basic properties of quaternion and its relation with cosine matrix are briefly explained. a, b, c quaternion is a number with four elements consisting of the real number 1 and the imaginary number a, namely

$$W = (w_0, w_1, w_2, w_3) = w_0 + w_1 a + w_2 b + w_3 c \quad (6)$$

And the quaternions used in fixed point rotation of rigid bodies are "normalized", that is

$$|W| = \sqrt{w_0^2 + w_1^2 + w_2^2 + w_3^2} = 1 \quad (7)$$

As mentioned above, a quaternion is a real three-imaginary number, so any vector in 3 dimensions can be considered a quaternion with a real part of 0. In other words, quaternions can be obtained from a 3-dimensional vector to a 4-dimensional mapping. Therefore, this paper can apply these properties and operation rules of quaternion in three-dimensional space [15]. The last three pose data RotX, RotY, and RotZ can represent the Angle of each node. Because the Euler Angle is an absolute value, the Euler Angle can be defined as the pose Angle, that is, RotX for Pitch pitch (-90,90), RotY for Roll roll (-180), and RotZ for Yaw direction (0,360). Next, this paper can use the basic knowledge of SINS to solve it. Its working block diagram is shown in Figure 6 (image cited in Bionic Integrated Positioning Mechanism Based on Bioinspired Polarization Compass and Inertial) Navigation System):

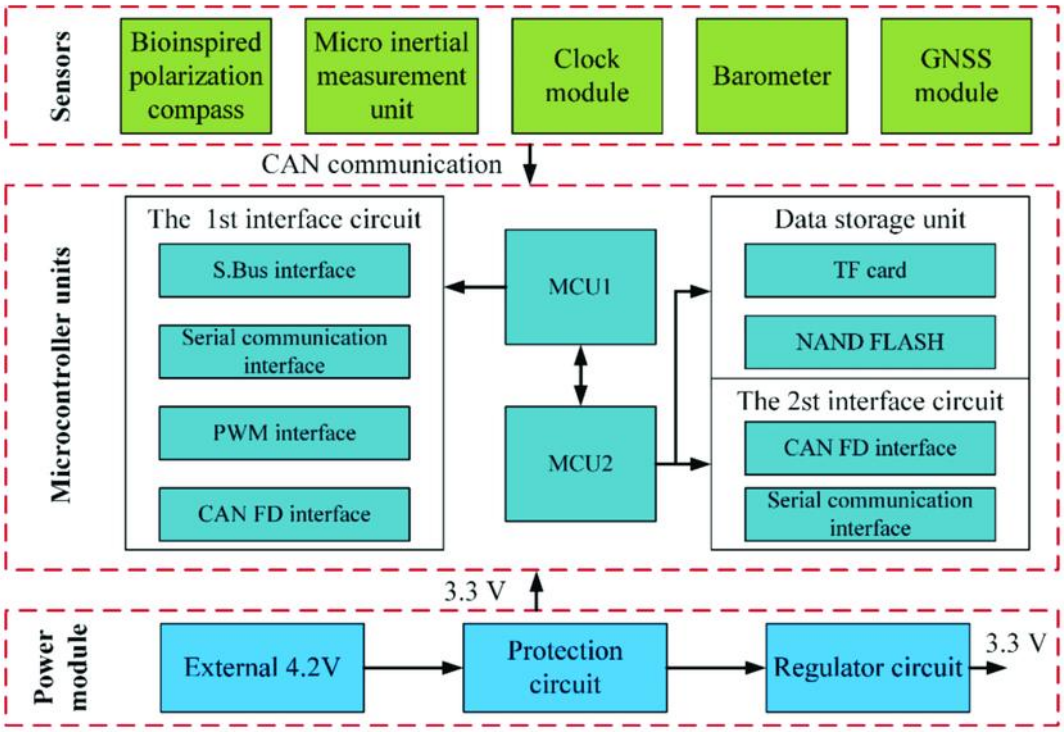

Fig.6 Strapdown inertial navigation diagram used in this system

According to the original data of the accelerometer and gyroscope components, quaternion can be obtained after error compensation and correction, and then from the quaternion upward can be converted into the direction cosine matrix of the sensor coordinate system to the geographical coordinate system, and absolute acceleration can be obtained, and then the relevant position information can be obtained through quadratic integration [16]. Combined with 3D modeling software and kinematics calculation, the human motion is simplified.

IV. Software implementation of data transmission

After the data transfer on the hardware, the next step is to study the software of this part. First of all, STM32 analyzed the test results of JY901. In the third chapter, the hardware implementation of the system is described, and the serial communication between the two modules is proposed. In addition, if you want to write a program in the single chip computer, you must also have a SWD download interface, the design of this interface is relatively simple, here will not go into details [17]. After the STM32 initialization program is deleted, the core content of the entire software includes the program for reading JY901 data and transmission, and the following will be a specific description of this part of the programming. First, the design flow of the main program is shown in Figure 7 (the image is quoted in the Development of AI Algorithm for Weight Training Using Inertial Measurement Units):

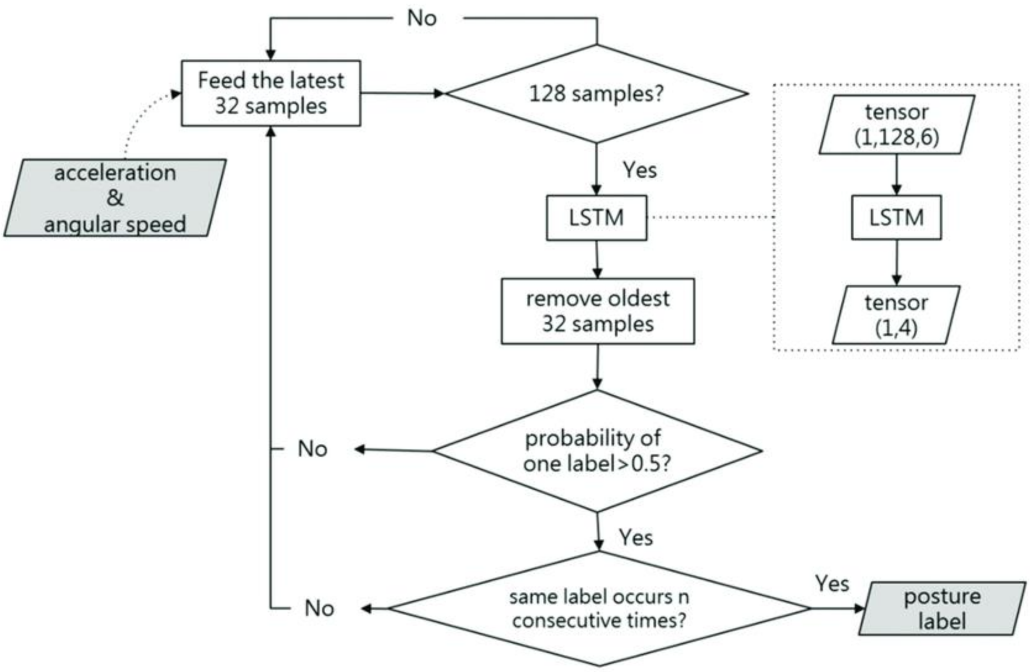

Fig.7 Main program flow chart

The main function of this system is to initialize STM32 MCU, and add a delay function related to the sampling rate of the sensor. Because the serial communication mode is used, it is necessary to initialize the serial communication. In this scheme, two two-way serial communication are used, USART1 is the serial communication between STM32 and JY901, and USART1 is the serial communication transmitted by STM32 to SP3485. Then set a priority for interrupts [18]. In addition, in order to determine the working condition of STM32, an LED is added to help determine the working condition of STM32, so the initialization of the LED is also required in the program. The next thing to do is to enter the whlie cycle, if user 1 rxflag=0x01, that is, when the transport flag is turned on, to transmit data to SP3485. Refer to the JY901 instruction manual, the data transmitted is a total of 28 bytes, starting with *-01-6*4=24-#, that is, starting with *, followed by the induction address, followed by 24 bytes of data, including acceleration, angular velocity, Angle, magnetic field strength, each of which takes up 6 bytes [19]. That is, the XYZ axis of each data takes up 2 bytes, ending in #. In order to transmit the information of the UART/WiFi module to the 3D model program, it is necessary to use socket programming, which is an interface, its working principle is to first initialize the socket on the Sever side, and then bind and listen to the corresponding port. If the client has also started the socket interface and established a link, it is ready to transfer data. The detailed architecture is shown in Figure 8 (image cited from Internals overview):

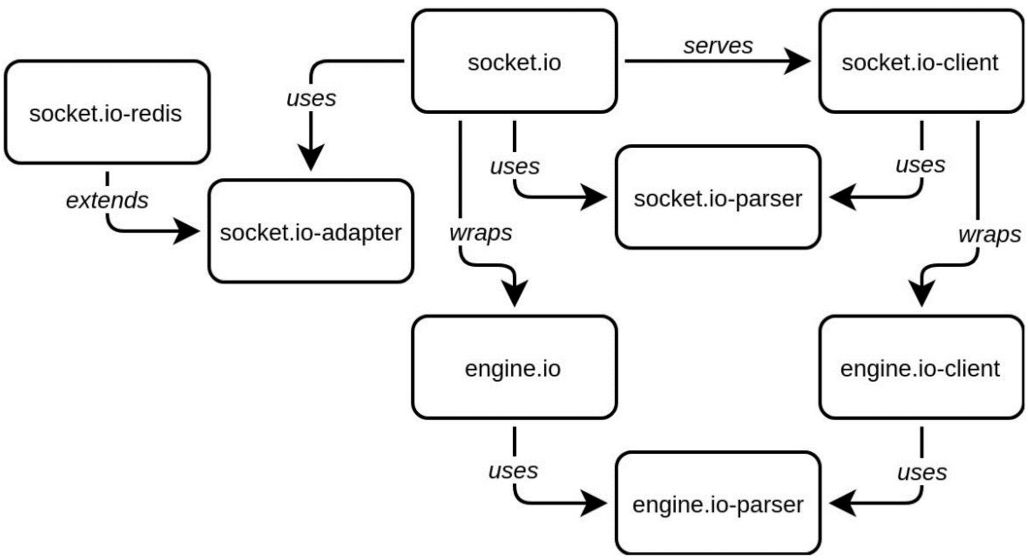

Fig.8 Socket implementation framework

V. TEST AND RESULT DISPLAY

A. *Data Testing*

This section starts with some data tests, followed by some node tests. After setting up the IP and the corresponding port, set up a server, boot it, and if connected, have a client interface [20]. All things are ready, and then you can issue a command, such as 2A0123,01 is an address, that is, the sensor number, after issuing this command, if there is no problem, you will receive a hexadecimal return data 2A-01-XXX-23, here, XXX is the acceleration and magnetic field strength of the original data, Here, the data on each axis takes up 2 bytes, as an example, 0699 is the acceleration data on the X-axis.

B. *Detection of local nodes*

After confirming that the data can be transmitted, it's time to perform some critical tests using the graphics card. The key point of the test is whether the test results can be accurately calculated by the graphical software, and to check its sensitivity and accuracy. In the course of the test, the obtained data is transmitted wirelessly to the image display program through the strapdown inertial navigation technology to obtain more accurate position and Angle information; By constructing a skeleton, FK/IK technology is used to fuse the above data to realize the cooperative movement of the robot control system based on attitude measurement [21]. The detection results of local nodes in motion acquisition and control system are given. As can be seen from Figure 9, the athlete's local movement posture is consistent with the 3D modeling movement (the picture is quoted in World Electr.Veh.J. 2024, 15(3), 85).

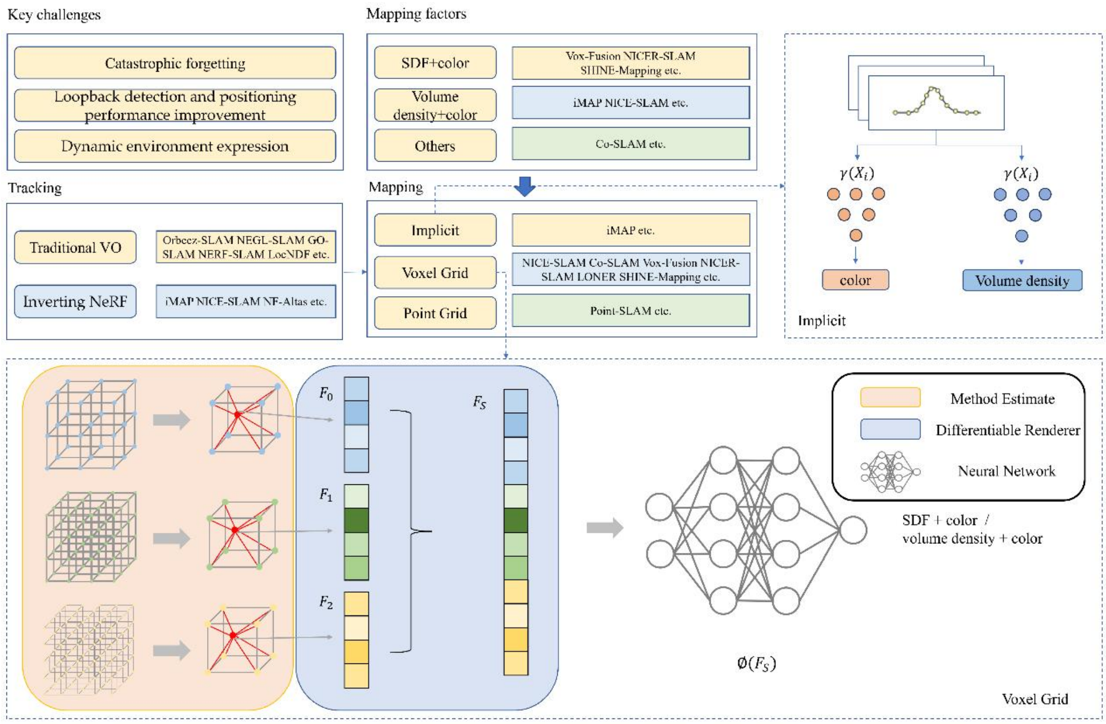

Fig.9 Effect diagram of single-node attitude detection

C. *Full-body node effect display*

Because the functions of node binding, port number and IP setting have been implemented in the program, so in the program, as long as the skeleton has been edited to join the view interface, and then the skeleton is personified, and then the skeleton is skinned and other operations. In addition, if the sensor is worn on the athlete's head, it should also be taken into account that because of the size and human body structure of the sensor, it cannot be worn on the wrist, elbow, knee, ankle, etc., but it should be placed 1-2 centimeters away from the front of the joint. In addition, to ensure that the athlete and the 3D model are in the same position in the initial state, the two sensors should be placed on the same line as much as possible [22]. By collecting the player's action information, the synchronization of 3D modeling action is realized. Figure 10 is a schematic diagram comparing the movements of the athlete and the virtual human in the working state of the system. When the athlete shows various movements, the generated model will immediately make the same movements. By "controlling" actual human movements that are "captured," the system's original goal is achieved. In order to make each joint play a role, they are respectively standing with flat hands, running, stepping and fighting, as shown in Figure 10:

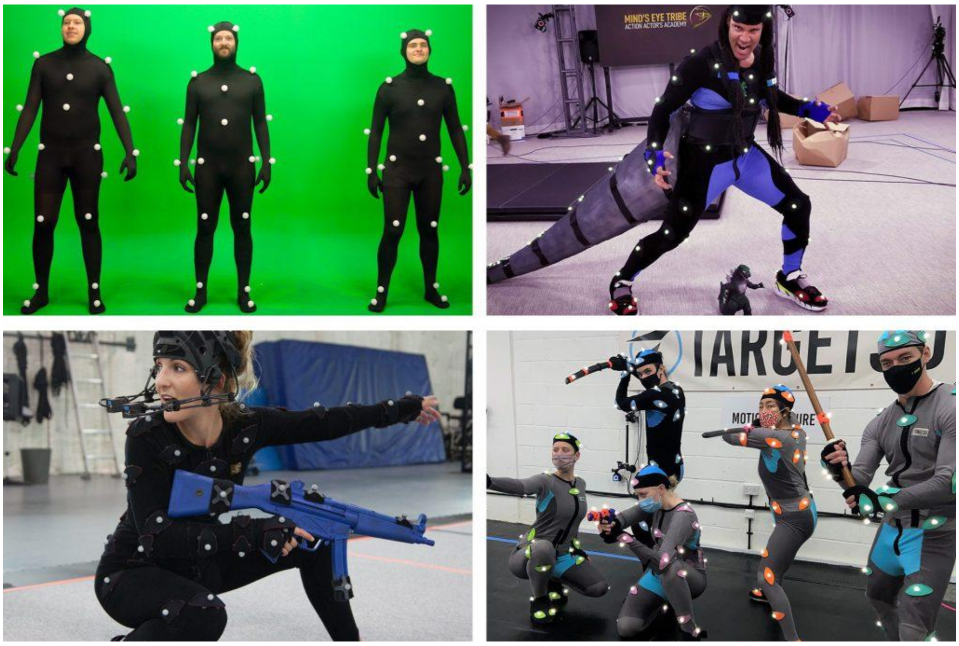

Fig.10 Comparison of athletes and simulated human movements

The motion trajectories of the virtual character and the athlete shown above are completely consistent, and can fully meet the user's requirements for the movement of the character, thus verifying that the scheme proposed in this paper is correct and effective.

VI. Conclusion

A method of motion capture and control is proposed, which has achieved good results in practical application. A new motion capture method based on inertial navigation is adopted. The system is based on C and C++, the hardware part is completed by AltiumDesigner, and the secondary development of SDK by MotionBuilder. In terms of acquisition and processing, JY901 is selected as the main acquisition unit. A single sensor node that can be collected, transmitted and received is realized. In this paper, the installation method of each sensor and the placement method of each sensor are introduced in detail. SINS method is used to process the initial data, and the coordinates, position, Angle and other related information of each sensor are obtained first.

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