Research on the Design of Motion-control Robot based on Microsoft Kinect

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Abstract: The development of Microsoft Kinect provides an important premise for the human-computer interaction and enriches users' experience. It supports the design and research of motion-sensing robot. This paper, based on Microsoft Kinect, studies the design of motion-control robot and discusses bone identification. Space vector method and filtering algorithm are proposed for the identification and calculation of bone key points, to provide certain reference for the design of motion-control robot.

1. Introduction

The interaction research based on motion-sensing recognition is gradually applied to all walks of life. Modern computers show more and more appearances and functions. In the process of updating camera technology, computational algorithm becomes stronger. Based on Microsoft Kinect, the scientific design and research of motion-control robot can better capture bogy action, realize human-computer interaction, provide convenience for users' individualized operations and form new experience.

2. Research Development

The research on motion-sensing technology began in June 1948 and was first carried out by the Argonne laboratory in the United States. It mainly studied the handling of radioactive materials remotely controlled by robot and opened up the research in countries around the world. In 1990, based on the purpose of obstacle removing by remote sensing robots, Japan designed a remote sensing robot equipped with a feedforward stereo camera and a mechanical feedback joystick, but its efficiency is less than 50% of manual work. In 1994, the University of Western Australia connected industrial robots to the front end of public access, adopting Internet-controlled methods for the first time. Subsequently, the motion-sensing technology achieved great development results and was gradually applied to the game industry. In 2009, Microsoft announced Kinect for the first time, which was also developed to meet the needs of the game. In the actual selling, Kinect is added with the RGB camera. At present, there are more and more people in the design and research of motion-sensing human-computer interaction using the sensor Kinect, such as 3D reconstruction technology, 3D virtual fitting room, environmental monitoring technology and virtual remote control operation.

3. Theoretical Foundation

3.1 Motion-sensing technology

Motion-sensing technology is a human-computer interaction technology that directly interacts with the surrounding environment or equipment by human voice and action, and recognizes, analyzes, and provides feedback on user actions. This technology is mainly to actively promote the human body's voice, body movements to interact with computers to avoid relying on physical manipulation, such as keyboards and mice, to ensure more natural human-computer interaction [1]. In the motion-sensing interaction, the goal of motion-control is achieved by actively using a variety of motion-sensing hardware devices and software control systems. Hardware device is mainly used to identify the actions of the controller and to transmit the information data. The software control

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system is mainly responsible for processing various data information, and actively doing feedback work [2].

After analysis and research, the principles of motion-sensing technology is mainly divided into: (1) inertial sensing motion-control. It plays the role of the inertial sensor, senses the physical parameters of users' mody movements, and accurately calculates users' motion based on the received physical parameters. (2) Optical sensing motion-control. In the process of acquiring the space human body image, it plays the role of the optical sensor, analyzes the human body image condition, and thus acquires the body movement of human body. (3) Inertial and optical combined sensing motion-sensing. It fully combines the above two sensing technologies, and rationally uses various sensors and cameras to detect the movement and position of human hand [3].

3.2 Introduction to Kinect

Kinect is a sensor developed by Microsoft. It is essentially a motion-sensing 3D camera that achieves good control of the game by capturing the player's body movements. Kinect itself has three cameras, namely infrared emitting device, infrared camera and RGB color camera, which can directly recognize the face, movement and voice of the target person [4].

(1) Hardware structure. Kinect sensor contains many hardware structures, such as infrared emitting device, infrared cameras, RGB color cameras, PS1080 running chips, motors, and microphone arrays.

(2) Kinect SDK. Currently, Kinect's drive program is gradually deepening, which are mainly divided into two types. First of all, Microsoft SDK drive platform. It is a driver platform developed by Microsoft to enhance the effect of Kinect and connect it perfectly with Windows system computers. In the platform, Kinect is divided into three layers of architecture, from top to bottom, the application interface layer, the device connection driver layer and the hardware structure layer. Secondly, b: OpenNI of PrimeSense. It refers to open-ended natural interaction, and it is a more mainstream open source driver platform besides SDK. The difference is that it can support multiple operating systems such as Windows system. This platform was developed to implement universal natural interaction application API, mainly to ensure the use of cross-platform and cross-device, and to bridge the information transmission of visual, audio sensor, visual and audio-aware middleware. The overall architecture of OpenNI is consistent with the SDK platform [5].

(3) Data acquisition. Kinect is designed to capture and process image data and save it as an image data stream. The image data stream contains information such as image type, resolution, etc., and is a collection of consecutive still image frames. In the operation of Kinect, three types of data streams can be collected according to the internal settings of the system, namely color, depth and audio image data, and the corresponding functions are identification, bone tracking and voice recognition [6].

(4) Data processing. The image data stream collected by Kinect needs to be treated separately according to different data streams. The depth image needs to be filtered and binarized to achieve separation between the target object and the background. Bone joint point image information is processed by smoothing to ensure the authenticity and accuracy of the bones. The other two image data streams do not need to be processed [7].

4. The Design of Motion-control Robot based on Microsoft Kinect

Based on Microsoft Kinect, the design of motion-control robot is feasible, which can create new customer experience and meet users' requirements [8].

4.1 Image acquisition and bone recognition

Linux is a free and freely distributed Unix-like operating system based on POSIX and UNIX that can support multi-user, multi-task, multi-thread and multi-CPU operation requirements [9]. Taking the Linux platform as the premise of motion-sensing robot design, and setting the drive program of Kinect in advance requires Microsoft Kinect operation platform, the OpenNI program library, for deep acquisition and processing of human images. It fully collect image information of human bone joint points and transmit them to the information system, and compare them with the bone algorithm library provided by OpenNI to accurately identify each bone joint point of the human body, so as to scientifically and effectively extract each space coordinate point.

4.2 Filtering algorithm

By virtue of Kinect sensor, the human body image data collection work is carried out. There is a certain disturbance in these data, which causes the instability of robot control. Therefore, the identified bone points must be filtered to make the robot always run in a consistent and normal state. To scientifically and effectively, accurately and quickly collect and identify human body images and bone joint points, it is required to choose the appropriate algorithm, focusing on anti-interference, calculation speed, accuracy, etc., by considering a variety of algorithms, the filtering algorithm can achieve good effect. The detailed steps of filtering algorithm is shown in Figure 1.

The operation of robot requires that the control data is sent to the robot as quickly as possible to increase the response speed of robot. In the process of actual application, the filtering algorithm can directly transmit the corresponding data in a timely manner, and the reaction speed is fast. On the basis of OpenNI, the bone joint points are collected, formed into space coordinates, and detailed analysis work is carried out. It can be found that the data disturbance situation occurs mostly around the actual joint coordinates of the human body, and the fluctuation range is small, plus the presence of the identification dead zone, resulting in inaccurate detection of joint points. Therefore, the filtering algorithm can provide a certain premise for ensuring the stable operation of the robot, and correspondingly deal with some unrecognized joint points.

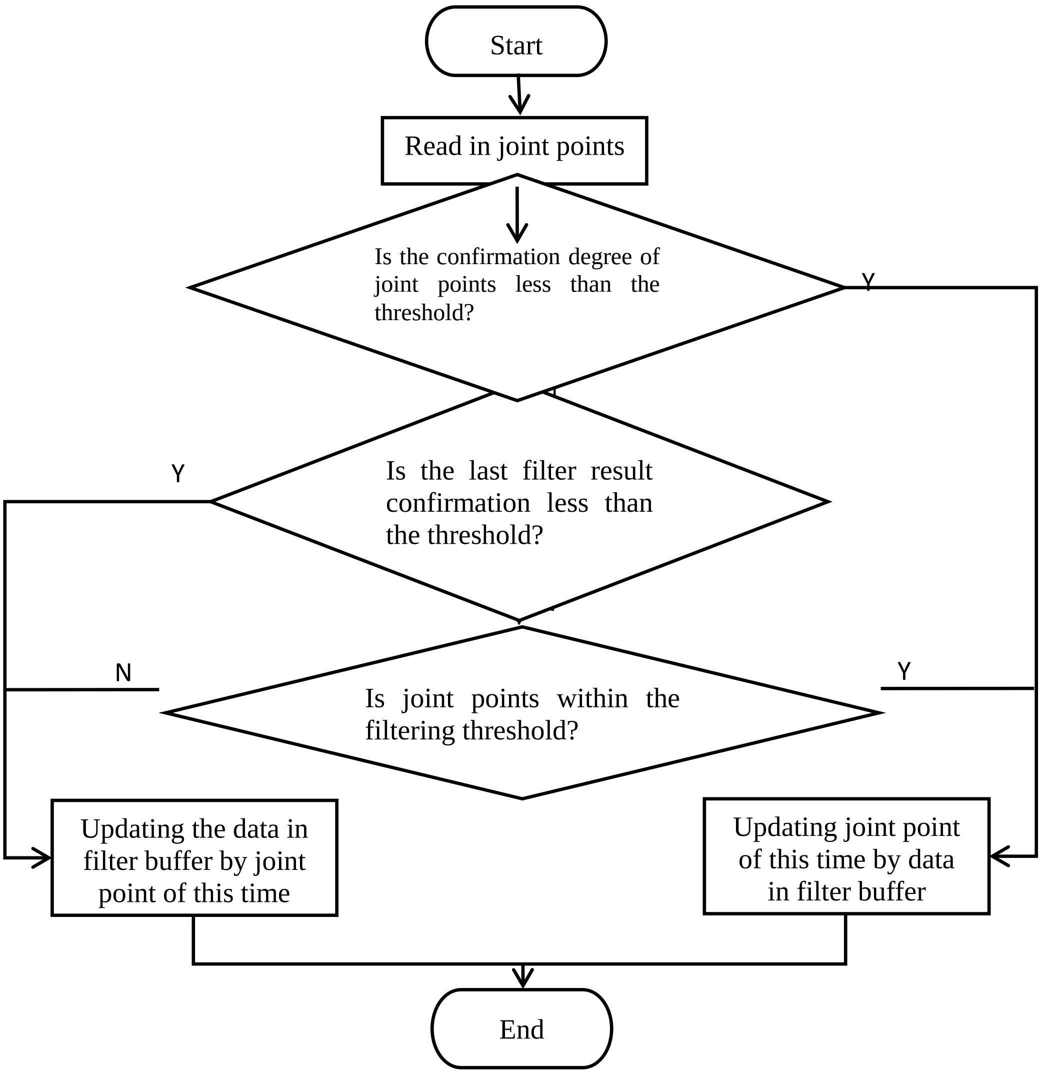

Figure 1 Detailed steps of filtering algorithm

It can be seen that in this study, in order to enhance the recognition accuracy of motion-control robot, the filtering algorithm used is improved and belongs to the amplitude-limiting filtering algorithm. This method reflects the idea of dynamic programming. The data collected, analyzed and processed under this algorithm is the optimal solution after each filtering process, and the overall optimal solution of the data is obtained.

4.3 The calculation of joint angle by space vector method

4.3.1 Space vector method

On the basis of identifying the human bone points, it is also necessary to calculate each angle. The methods commonly used in the past are mostly analytical geometric methods, but it cannot be ignored that there are an unavoidable problem in the specific calculation links, that is boundary conditions. Specifically, the analytical geometry calculation method needs to consider multiple special cases of parallel, overlap, vertical, and intersection, which not only makes the code volume explode, but also increases the bug of the code, bringing great difficulty to coding and debugging. At the same time, it should be noted that the existence of a large number of boundary conditions needs to be calculated and verified in calculation links in time. However, in the process of collecting images, Kinect cannot perform online debugging under the breakpoint, so that the correctness of the algorithm cannot be verified.

In the process of designing motion-control robot, after research and practice, it has been found that boundary conditions can be effectively avoided by the calculation of the space vector.

4.3.2 Coordinate mapping

There is a certain difference between Kinect coordinate system and general mathematical one, which is shown in Figure 2.

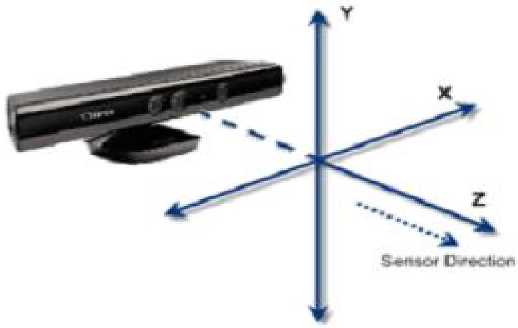

Figure 2 Kinect coordinate system

In the process of calculating human joint points, the use of space vector requires the processing of various coordinate data. Scientifically process the coordinate system of Kinect and map it to the mathematical coordinate system. The specific method used is relatively simple. Firstly, according to the translatability and directionality of the vector, Kinect coordinate system is deduced, and any two non-coincident coordinate points in the coordinate system can be set, such as A(x1, y1, z1) and B(x2, y2, z2). Secondly, the coordinates need to be transformed so that they can meet the requirements of the mathematical coordinate system. Furthermore, the vector AB is composed according to the mathematical coordinate system, which can be considered to be drawn from the zero point of the coordinate axis. The actual conversion equation is given.

$$A\vec{B} = \left(x_2 - x_1, y_2 - y_1, z_2 - z_1\right)$$

By means of coordinate mapping, the surface can simplify the calculation of the joint angle of the human body to the calculation of the angle between the space vectors.

4.3.3 Specific calculations

In this research, there are many limitations on the steering engine of motion-control robot joint, including the distance between the big arm and the forearm, and the inaccurate position recognition. If the big arm is in a natural static state, in order to accurately identify the rotation of the big arm and the forearm, it is impossible to achieve the goal with Kinect motion-sensing device. It is necessary to achieve the goal of joint adjustment by means of the steering engine on the shoulder of the robot. This part puts forward higher requirements for the joint angle calculation work. It is not enough to calculate the angle between the two space vectors. Thus, carefully identify and calculate the various action angles recognized during the control of the robot movement can reach better results. The progressive algorithm is introduced into the calculation process, to accurately calculate the angle between the spatial plane xOz and the plane formed by the shoulder, elbow joint and hand, and obtain the final result, so as to obtain accurate data, and adjust the speed of the steering engine on the shoulder according to the angle.

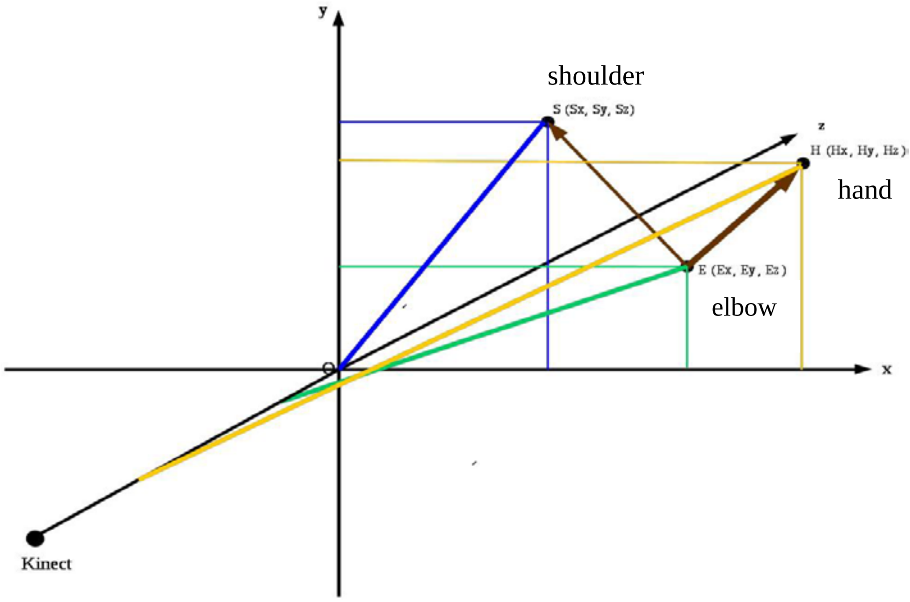

Figure 3 The vector of joint point in left arm in Kinect critical coordinate system

From Figure 3, it can be seen that the joint points (shoulder, elbow, hand) of the motion-control robot are in the spatial plane, and the corresponding z-axis from the inside to the outside are: shoulder, elbow, hand, and the three points are in the z-axis negative semi-axis in the vector diagram.

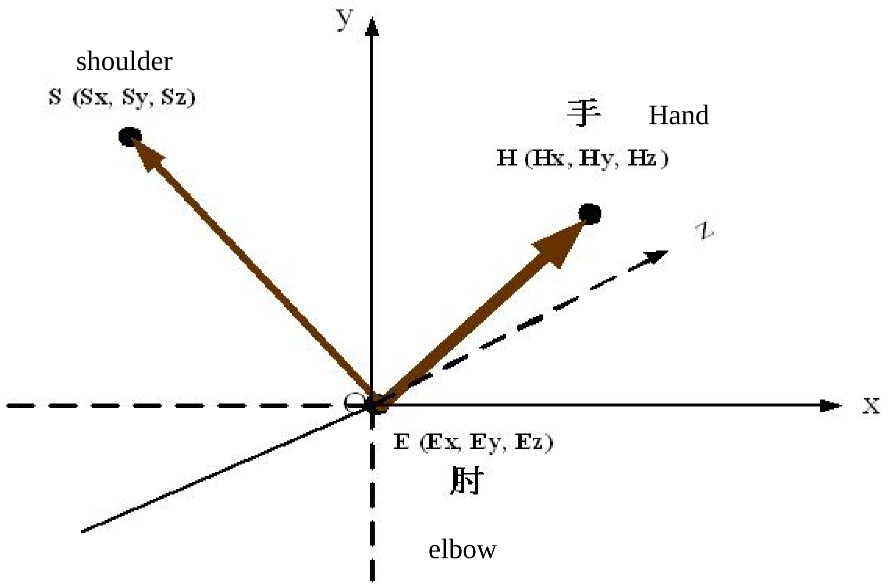

Figure 4 The vector transformed to mathematical coordinate system

When calculating the angle of the elbow joint, the angle between the space vector ES and EH can be directly used. The calculation process is presented.

$$\vec{ES} = \left(S_x - E_x, S_y - E_y, E_z - E_z\right)$$

$$\vec{EH} = \left(H_x - E_x, H_y - E_y, H_z - E_z\right)$$

$$\cos\theta = \frac{\vec{ES} \bullet \vec{EH}}{\left|\vec{ES}\right|\left|\vec{EH}\right|}$$

The space vector algorithm can completely get rid of the cumbersome boundary conditions (for the overlap of the bone points, it can be solved by filtering). In the process of this algorithm, the identified data can be incorporated into the general formula, and the obtained result is fast and accurate.

Calculate the angle of the up and down swing of the big arm, and calculate the angle data directly according to the calculation process of the elbow joint angle. Specifically, first, the vector ES is subjected to projection processing so as to be in the xOy plane; secondly, the angle between the vector ES and the y coordinate axis is calculated, and the result is obtained.

Calculating the angle of the shoulder steering engine that assists the rotation of the forearm, it is also necessary to project its data in the mathematical coordinate system and convert it into a vector. The specific conversion relationship is shown in Figure 5.

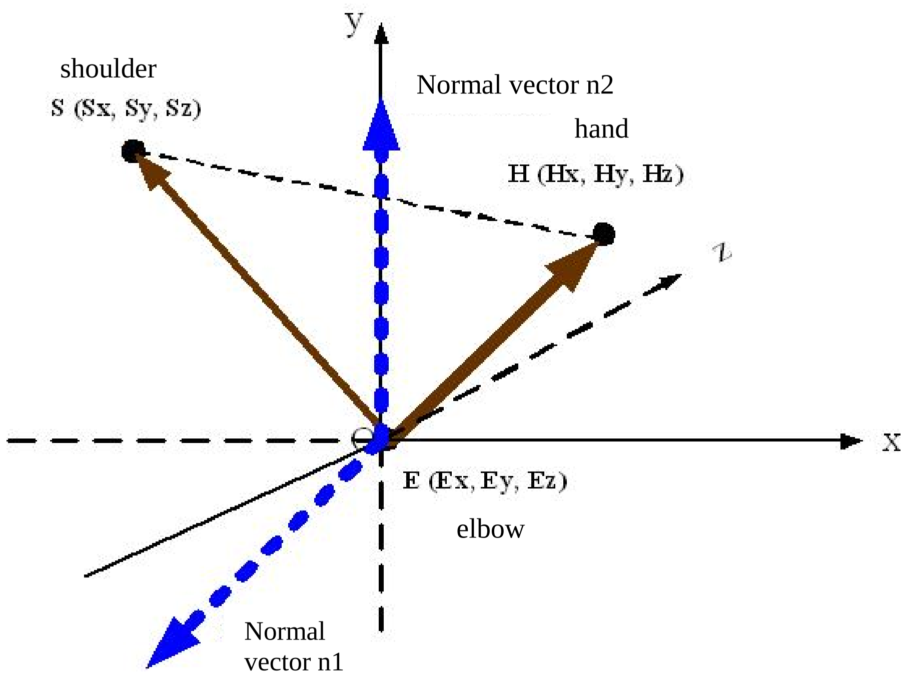

Figure 5 The angle vector conversion of shoulder steering engine assisting the rotating of forearm

In order to obtain the angle of the plane of the shoulder steering engine assisting the rotation of the forearm, first, the normal vector of the two planes is required, and secondly, the angle between the two planes is calculated according to the normal vector. The calculation is shown in Equation (1)-(5).

$$\vec{ES} = \left(S_x - E_x, S_y - E_y, E_z - E_z\right) \quad (1)$$

$$\vec{EH} = \left(H_x - E_x, H_y - E_y, H_z - E_z\right) \quad (2)$$

$$\vec{n}_1 = \vec{EH} \times \vec{ES} \quad (3)$$

$$\vec{n}_2 = \left(0,1,0\right)\ 0 \quad (4)$$

$$\cos\theta = \frac{\vec{n}_1 \bullet \vec{n}_2}{|\vec{n}_1||\vec{n}_2|} \quad (5)$$

First of all, according to Equation (1) and (2), calculate vector ES (the vector of elbow joint to shoulder) and vector EH (the vector of elbow joint to wrist; with Equation (3), calculate the normal n1 of space place composed by shoulder, elbow and hand, which requires the cross product; the normal vector of space plane xOz is shown by Equation (4), and calculate the angle between normal vector n1 and normal vector n2 according to Equation (5); the angle of shoulder steering engine assisting the rotation of forearm can be calculated and the data recognition and processing goal of bone joint points of human body can be achieved.

5. Conclusion

This paper, starting from the research development of Microsoft Kinect, introduces the theoretical foundation for the design of motion-control robot and proposes some feasible strategies. In the bone recognition and processing, it is necessary to conduct analysis and research based on the operation of Microsoft Kinect and achieve better effects through space vector and filtering algorithm.

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