Research on New Macro-Moving 3D Mouse Based on 3-UPS Space Parallel Mechanism

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Abstract. This paper describes a new macro-moving 3D mouse with STC89C52 chip as the control core, combined with A/D conversion chip, sensors, USB interface and using 3-UPS space parallel mechanism. The 3D mouse has obvious motion perception, good real-time performance, high reliability, excellent technical performance, convenient operation, low cost and excellent performance, which meets people's needs and has a broad application prospect.

1. Introduction
With the rapid development of 3D technology, 3D operating system emerged at the right moment, so it is necessary to develop a multi-dimensional mouse with space operation ability to match it. The main problems are complex operation, low control accuracy and lack of operation reality for the most existing six-dimensional input devices on the market[1]. In order to overcome the above problems, this paper designs a macro-moving 3D mouse with space six-dimensional operation ability, which enables the operator to have a more real sense of movement/rotation within the macro-moving range[2-3]. New type macro dynamic 3D mouse has spatial three-dimensional displacement variables and three dimensional angle of synchronous detection function, and it is applied broadly in the industrial multi-dimensional virtual assembly, robotics, computer-aided design, 3D games and the future of 3D operating system in high technologies. besides the research achievements of our country with independent intellectual property rights of the macro dynamic type 3D mouse transition and the marketization process also will have a great role in promoting.

Figure 1.

Figure 1 and figure 2 show the schematic diagram of aircraft simulation and simulated flight. The user can freely use the 3D space mouse. The movement of the flight simulator in the control system is realized by using virtual reality technology to realize the three-dimensional movement and rotation of the aircraft in the virtual terrain environment, so that the operator can truly feel as if he controls the aircraft in flight, and thus realize the simulation of the aircraft movement in the real world[4].

Figure 2.
2. Hardware design

2.1 Circuit design

The 3D mouse is mainly composed of three modules, namely SCM control module, communication interface and computer module. MCU control module uses low power consumption, high-performance 8-bit microcontroller STC89C52 chip, and it has 8K in the system programmable flash memory, which can directly use serial port download, greatly saving program debugging time; Sensors use potentiometer which converse the resistance change into A voltage change, then through A/D transformation chip send to the single chip microcomputer, due to the angle of the potentiometer value or displacement and voltage one-to-one correspondence, so without direction of the rotation of the potentiometer, and the A/D conversion chip is multi-channel acquisition, high resolution, so the circuit design is simple, low cost, and the mouse is high resolution; It chooses CH375 as USB communication chip, in the local end it has 8-bit data bus and read, write, chip selection control line and interrupt output function, which can be easily connected to the SCM/DSP/MCU/MPU controller system bus; It selects TLC2543 of 12 bit output as A/D chip.

2.2 Structural design

2.2.1 Multi-dimensional parallel mechanism design. The mechanical body of the new macro moving 3D mouse adopts a spatial parallel mechanism. By collecting the relevant displacement signals of each guide rail in real time, the kinematic solution of the parallel mechanism calculates its real spatial six-dimensional input, and divides the working area into three parts. As shown in figure 3, the parallel mechanism of the six-dimensional position and attitude sensor is composed of a moving platform, a base, and multiple branches connected to the moving platform and the base. The moving platform can move or rotate relative to the base. By changing the number of branchlets and the structural form of the branchlets themselves, the moving platform can have motion characteristics of different dimensions. Therefore, it is necessary to study the construction method of parallel mechanism with a given motion dimension (such as 2-6 dimensions). According to the multidimensional space mouse with six degrees of freedom of movement in the space, choose 3 UPS (3 represents the movable platform and base with three identical branch chains, U represents the hook hinge, P represents the moving pair, and S represents the ball joint) parallel mechanism, the motion platform as a ball head operation, to ensure that the appearance of multidimensional space mouse is compact, small, the advantages of easy operation[5-6]. This paper mainly studies the parallel mechanism with 6D motion, based on 3UPS parallel mechanism, to meet the needs of different applications, different degrees of freedom, different dexterity. Therefore, "six-dimensional position and attitude sensor” is taken as the core mechanism, the kinematics model between the moving platform and the base is established, the dexterity of the mechanism and the minimum appearance volume are taken as the comprehensive optimization objectives, and the key parameters of the mechanism are determined through multi-objective optimization[7].
2.2.2 **Optimization design of key parameters of multidimensional parallel structure.** The main structure of the six-dimensional position and attitude sensor shown in figure 4 is a 3-UPS parallel mechanism, which is composed of a moving platform, a static platform and three identical UPS branches. Hooke hinge U is composed of two rotating pairs whose axes are respectively perpendicular to and parallel to the plane of the static platform, and the two axes intersect at a point[8].

Kinematic analysis of 3-UPS parallel mechanism includes two aspects: on the one hand, the kinematic positive solution of 3-UPS parallel mechanism is to solve the position and attitude of the moving platform relative to the reference coordinate system under the condition that the geometric parameters and joint variables of the mechanism are known. On the other hand, when the geometric parameters of the mechanism and the position and attitude of the moving platform relative to the reference coordinate system are known, the joint variables needed to reach the position and attitude are solved, which is called the inverse kinematic solution of the 3-UPS parallel mechanism. The position of the moving platform solution is relatively simple, and the attitude to solve more complex, the commonly used methods such as rotation matrix and a twisted angle and euler angle, because of the moving platform adopts the rotation matrix to describe attitude when need nine parameters, and a twisted horn and euler Angle only need three parameters, at the same time all euler angle of rotation is relative to the moving coordinate system to describe, in the computer programming to realize 3D virtual control when the mouse is very convenient, so this design uses the euler angle relative to the moving platform to describe the attitude of the reference frame.

Shown in diagram as shown in fig.4 institutions, including A, B, C for hook hinged U two axis of rotation center point, C, D, E as the center of the ball joint S, and their respective triangle is an equilateral triangle formed by two equilateral triangle center respectively O1 and O2, Dx, Ex, Fx,D, E, F respectively in A, B, C to determine the plane projection, h1, h2, h3 to AD, BE, CF distance between two points, α1, α2 and α3 are the acute angles between the projection of AD, BE and CF on the plane determined by A, B and C and AO1, BO1 and CO1; β1, β2 and β3 are the angles between AD, BE and CF and the plane determined by A, B and C. In order to facilitate analysis and calculation, the static coordinate system O1X1Y1Z1 and the moving coordinate system O2X2Y2Z2 as shown in fig.4 are respectively established. O1 and O2 are the origin of the static and moving coordinate systems respectively.

Since the joint variables of the six-dimension controller are obtained through the sensors installed at the two rotating pairs of hooke hinge U and the moving pair P, the inverse kinematics solution of the 3-ups parallel mechanism is selected in this paper. The coordinates of the center points of the moving platform (x, y, z) and alpha, beta, and gamma are known variables, while the institutional joint variables α1, α2, α3, β1, β2, β3, h1, h2 and h3 are unknown. According to the coordinate transformation formula, the midpoints O1D, O1E and O1F of the stationary coordinate system O1X1Y1Z1 have the following relations with the midpoints O2D, O2E, O2F and 02O2 of the moving coordinate system

\[ O2X2Y2Z2; \gamma (D, E, F) = \text{Euler}(\alpha, \beta, \lambda) \gamma (D, E, F) + \gamma O2 \]  

If the length of side ABC of equilateral triangle is a and the length of side DEF is b, the coordinates of D, E and F in the moving coordinate system are:(b/2,-b/6,0), (b/2,-b/6,0), (0,b/3,0). By substituting the coordinates into equation (1), the coordinates of D, E and F in the static coordinate system O1X1Y1Z1 (xi, yi, zi) (i=1, 2,3) can be obtained.

According to the follow formulas \( h_1 = ||AD||, h_2 = ||BE||, h_3 = ||CF|| \),then
\[
h_1 = \sqrt{(x_1 + \frac{a}{2})^2 + (y_1 + \frac{\sqrt{3}a}{6})^2 + z_1^2}
\]
\[
h_2 = \sqrt{(x_2 - \frac{a}{2})^2 + (y_2 + \frac{\sqrt{3}a}{6})^2 + z_2^2}
\]
\[
h_3 = \sqrt{x_3^2 + (y_3 - \frac{\sqrt{3}a}{3})^2 + z_3^2}
\]
Again by \( z_i = h_i \sin \beta_i \) conclusion, \( \beta_i = \arcsin \left( \frac{z_i}{h_i} \right) \) \( (i = 1, 2, 3) \) (5)

The Angle between ADx, BEx, CFx and the \( x_1 \) axis and its projection on the \( x_1 \) axis can be solved as follows:

\[
\alpha_1 = 30^\circ - \arccos \left( \frac{x_1 + a/2}{h_1 \cos \beta_1} \right) \\
\alpha_2 = 30^\circ - \arccos \left( \frac{a/2 - x_2}{h_2 \cos \beta_2} \right) \\
\alpha_3 = 90^\circ - \arccos \left( \frac{x_3}{h_3 \cos \beta_3} \right)
\]

(6) (7) (8)

Formula 2-8 is the inverse kinematic solution of 3-ups parallel mechanism. When the pose of the moving platform relative to the reference coordinate system is known, the variable size of each moving joint can be determined.

3. Software design

The upper computer program adopts MFC based interface display and control program to transmit the nine sensor signals collected by the single chip microcomputer to the upper computer program display to control the movement of space objects. The program flow chart is shown in figure 5. Firstly, CH375 is initialized in the specific workflow, if the upper computer does not send a signal, the workflow will be terminated. Otherwise, the MCU will close the interrupt, which call a function to collect the signal of the sensor, send buffer to write to the USB breakpoint, and send the number to the PC through CH375. After that, the PC will get the data of the MCU and send it to the interface for display.

![Start
CH375 initialization
The upper computer sends signals
No
Yes
MCU off interrupt
Call the function to collect nine sensor signals
Send buffer writes to USB breakpoint 2
Send numbers to PC through CH375
Obtain microcontroller data and send interface to display
End

Start
OpenGL related settings and initialization
Import 3D model
USB communication initialization
Set cycle clock
Change the corresponding graph variable according to the received data
Receive USB communication data
Update the picture
End

Figure 5. Upper computer flow chart

Figure 6. USB communication flow chart

The flow of USB communication program is shown in figure 6. OpenGL is initialized and is set up parameters in the specific process, then import 3D model, and then start to initialize USB communication, and set the cycle clock. After that, if CH375 device starts successfully, it will receive USB communication data, change corresponding variables according to the data, and finally update the screen. If the device fails to start, the program operation is terminated.

4. Simulation application analysis

The 3D mouse can be used to simulate the control of industrial commonly used parallel manipulator,
and the two are similar in principle because they have six degrees of freedom, so the 3D mouse is suitable for manual control parallel robot, under the control of the manipulator can realize up and down around six directions of translation, but also it can turn in space, the operator's hand movements accordingly reflected in the parallel mechanical hand.

The aircraft simulation program interface is shown in figure 7, which is divided into three areas: aircraft simulation area, 3D mouse movement comparison area and data display area. The user can observe the flight situation of the aircraft controlled by 3D mouse in the simulation area of the aircraft in the virtual environment, and the aircraft can realize various movements that can be realized by the real aircraft in space, such as forward, left and right turns, climb, dive, etc., giving people a more realistic feeling.

Figure 7. Aircraft simulation program interface

5. Concludes
The new macro moving 3D mouse designed in this paper uses the space parallel mechanism as the mechanical body. By collecting the relevant displacement signals of each guide rail in real time, the kinematic solution of the parallel mechanism can calculate its real space six-dimensional input, which can greatly simplify the complex operation of ordinary mouse and keyboard, and has strong practicability.

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