ISSN : 0974 - 7435 Volume 10 Issue 22

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(22), 2014 [13739-13744]

Study on the movement posture measurement system based on traction parallel

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ABSTRACT

The key of traction parallel is to make the posture get a more accurate measurement process during the human body movement by carrying out the cable measurement between the moving platform and the static platform, so as to provide a strong foundation for the posture accuracy during the human body movement. In the research and exploration of this area, first, it carries out an in-depth exploration for the layout and basic unit of the measurement system. Through the establishment of appropriate mathematical model, it makes the human movement measurement process become a relatively simple process from a complex process. In this process, this study researches from the aspects of basic configuration of the pose measurement unit and the definition the measurement unit movement parameter to ensure the basic structural of the measurement unit maintain highly unambiguous and confirm the movement parameter of the measurement unit effectively. After that, it explores the relationship between the three point layout of the moving platform and the segment parameters of human body specifically. The main aspects are the explorations to the selection of motor control mode, the working principle of DC motor and location working mode to make the system work process maintain a high degree of accuracy and lay a solid foundation for the construction of the system and the accurately and efficiently operation. Finally, this study discusses the position measuring workspace derivation of the measurement system and the analysis of error sources of the measurement system to improve the effectiveness of the system construction. This is the main idea of the research process, which fully reflects the specific purpose and content of the study.

KEYWORDS

Traction parallel; Movement posture; Measurement system; Exploration research.

INTRODUCTION

From the perspective of the accuracy of human movement posture, the significance of the construction of the movement posture measurement system is to enhance the accuracy of the movement posture, so as to produce the promoting effect. Also, it is the secured condition to ensure the human movement process to achieve the scientific and effective purpose. In the research process of this field, the study researches the layout and basic unit of the measurement system, the relationship between the three point layout of the moving platform and the segment parameters of human body, the position measurement spatial derivation of the measurement system and the analysis error sources of the measurement systems to make the research process have the strong Meticulous and scientificalness.

THE LAYOUT AND BASIC UNIT OF THE MEASUREMENT SYSTEM

Actually, the body movement is a more complex limb movement process, which has a corresponding movement law during the limb movement. At the same time, it can repeat a particular action with the complete action to show the strong regularity of it. During the design process of the movement posture measurement system, it is needed to construct the mathematical model effectively; so as to make the more complex human movement process can be transformed into a unit body which has a more convenient measurement process.

The basic configuration of the pose measurement

The cable pose measurement unit is a new measurement means for the measurement of human body movement. Its characteristics are that the structure of the measurement process is relatively simple, the inertia it generates is relatively small and the cost needed for measurement is relatively low. The measurement unit is mainly composed of three important components which are static platform, moving platform and cable. Among them, the static platform is a fixed part, the cable is elicited by the fix of the static platform and the moving platform is a part of the human body. In the simple analysis and calculation process for the measurement results, it is needed to simplify the measurement unit effectively, which is shown in Figure 1. In the whole measurement unit, A1-A6 represents the static platform and cylindrical bodies B1-B3 represent the moving platform respectively. The two platforms are connected by six cables[1].

During the relevant literature collection and sorting process, it can be concluded that the calculation method can use the tetrahedron method. In the whole calculation process, if the length of the six cables and the focus A1-A6 can be calculated effectively, the space position of the three points B1-B3 in the moving platform of the cylindrical bodies can be determined. Based on this, the method can calculate each of the kinematic parameters in the movement process of human bodies.

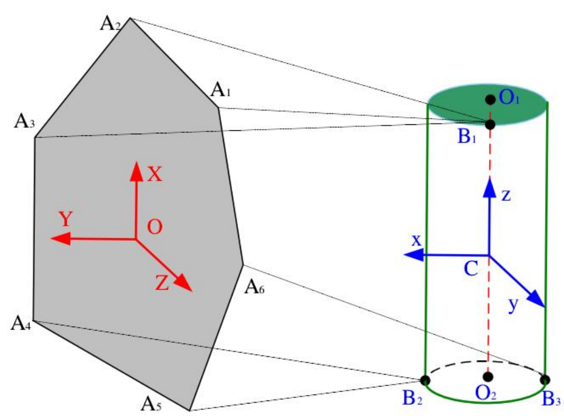

Figure 1 : The basic configuration of the measurement unit

Definition of the measurement unit movement parameter

In movement parameter calculation process of the measurement unit, it needs to give the corresponding analysis of its moving platform, which needs to make the appropriate description to the accurate parameter of the moving platform. In this process, the moving platform moves freely within its space. At this time, the moving platform has six free degrees. And, the corresponding six parameters can be applied effectively to describe its position and posture specifically. In this process, it is needed to establish three position coordinates and three orientation coordinates. However, the position coordinates are used to determine the location of the moving platform reference point in the static coordinate. Its location can be fully reflected by a simple rectangular coordinate. The position coordinates are used to judge the specific location of the moving platform in the work space, where the Euler angles is usually used. After the calculation to the Euler angles, the intrinsic link among the Euler angles in moving platform, the angular velocity and angular acceleration of the moving platform can be conducted by specific geometric relationship. It can establish the specific relationship among the three aspects[2].

The establishment of the coordinate system

During the calculation process of the measurement unit, for convenient, two coordinate systems are set. The two coordinate systems are the static coordinate and the body-fixed coordinate respectively. The static coordinate is fixed on the corresponding static platform, while the body-fixed coordinate is required to fix on the moving platform. The two coordinates are connected with six cables and connection points between the static platform and the cables are replaced by A1-A6, and the connection points of the three cables on the moving platform are represented by $B_1 - B_3$. In the moving platform, $\|B_1B_2\|$ is known as S_1, while $\| B_1B_3 \|$ is represented by S_2 and $\| B_2B_3 \|$ is represented by S_3. The length of the six cables connected with the static platform is represented by $l_1 - l_6$.

In the static coordinate system, a_i represents the position vector of the connection point of the defined vector in the coordinate system, and vector $^{B}b_i$ represents the vector of $B_i\left(i\ =\ 1-3\right)$ in the body-fixed coordinate system. At the same time, this vector also represents the vector of CB_i in the static coordinate[3]. And, the specific location of the body-fixed coordinate in the static coordinate can be calculated by the rotation matrix. The rotation matrix can be usually represented by $^{A}R_B = (r_1, r_2, r_3)^T$, in which r_1, r_2, r_3 respectively represent the direction vector of the static coordinate and the body-fixed coordinate.

Definition of euler angles

For the Euler angles, the main scope of its application is the description to the dynamics of rigid body and kinematics posture (φ, θ, ψ). In the research and discussion of this field, through the effective application of Euler angles, the rigid position is described in the process[4]. As for the moving platform, usually through the corresponding rotation of the body-fixed coordinates, it can reach a designated and effective position. During the process of rotation, these rotations can effectively determine the position of a rigid body, which is shown in Figure 2 specifically.

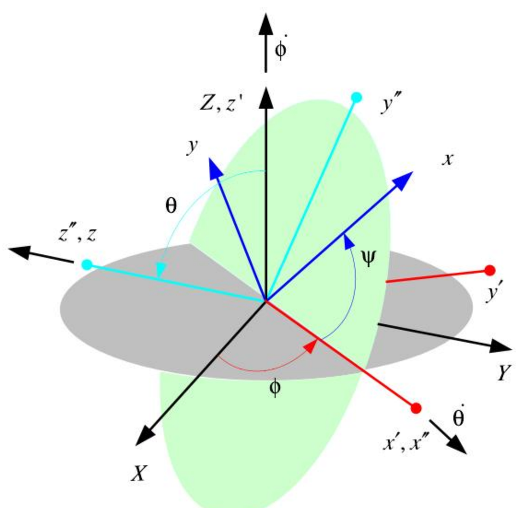

Figure 2 : Euler angles $Z - X - Z$

It can be seen from Figure 2, O-XYZ is the static coordinate and C-XYZ is the body-fixed coordinate. In the coordinate system x', y', z' and x'', y'', z'' are the transition coordinates. Compared with the expression process of the static coordinate, the body-fixed coordinate can be effectively expressed in accordance with its position vector, which is $c = (X, Y, Z)^T$. This expression process can show that the body-fixed coordinate can effectively determine the position of the static coordinate and it can be specifically expressed by a rotation matrix, which is shown as $^{A}R_B = (r^1, r^2, r^3)^T$. In this, r^1, r^2, r^3 represents the position vector of the unit direction of the static coordinate respectively. However, in the rotation matrix, $^{A}R_B$ can express the specific positions of the three Euler angles effectively.

$$^{A}R_B = \begin{bmatrix} \cos\psi\cos\phi - \cos\theta\sin\phi\sin\psi & -\sin\psi\cos\phi-\cos\theta\sin\phi\cos\psi & \sin\theta\sin\phi \\ \cos\psi\sin\phi + \cos\theta\cos\phi\sin\psi & -\sin\psi\sin\phi+\cos\theta\cos\phi\cos\psi & -\sin\theta\cos\phi \\ \sin\psi\sin\theta & \cos\ \psi\sin\theta & \cos\theta \end{bmatrix} \quad (1)$$

From the above formula, it can be seen that the Euler angles can effectively calculate the cosine matrix direction of the body-fixed coordinate as opposed to the direction of the static coordinate. If the rigid Euler angles can be reflected in a straight condition, then through the formula above, its direction cosine matrix can be calculated effectively[5]. However, from the opposite point of view, if the direction cosine matrix ${}^{A}R_{B}$ of the rigid body is known, the expression of the Euler angles can be further determined by the above formula. These expressions are shown as follows:

$$\begin{cases} \cos\theta = r_{33} \quad \sin\theta = \pm\sqrt{1-r_{33}^2} \\ \cos\phi = -\dfrac{r_{23}}{\sin\theta} \quad \sin\phi = -\dfrac{r_{13}}{\sin\theta} \\ \cos\psi = -\dfrac{r_{32}}{\sin\theta} \quad \sin = \psi \dfrac{r_{31}}{\sin\theta} \end{cases} \tag{2}$$

In the above formula, r_{ij} represents the element of the i-th row and j-th column in the cosine matrix ${}^{A}R_{B}$.

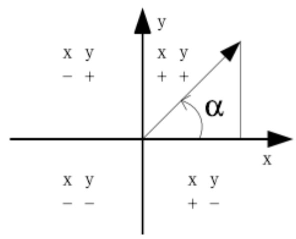

Figure 3 : Inverse tangent function atan2

RELATIONSHIP BETWEEN THE THREE POINT LAYOUT OF THE MOVING PLATFORM AND THE SEGMENT PARAMETERS OF HUMAN BODY

The basic configuration of human movement measurement unit is shown in Figure 1. Using the tetrahedron method described in the literature, the coordinate B_3、B_1、B_2 can be calculated in the static coordinate system. In this study, the three point layout of platform under the human movement measurement unit adopts the first layout scheme described in the literature, which is to simply the hands or legs into the cylinders or the cones. In this section, the human body is analyzed by simplifying them into the cylinders and this kind of layout program is shown in Figure 4. The cylinder radius is R; the length $\|O_1O_2\|$ is the known parameter; B_1 is disposed at one end of the cylinder; B_2 and B_3 are arranged at the other end of the cylinder symmetrically. By the derivation of the following formula, the direction of the cylinder axis O_1O_2 can be determined, and the line O_1O_2 is perpendicular to line B_2B_3; O_1O_2 and O1B1 form the γ angle and form the π / 2-γ angle with the normal vector n_2 of the plane $B_1B_2B_3$. The coordinate of O_2 can be obtained by three formulas, which is denoted by $\gamma = \tan^{-1}(R/\|o_1o_2\|)$.

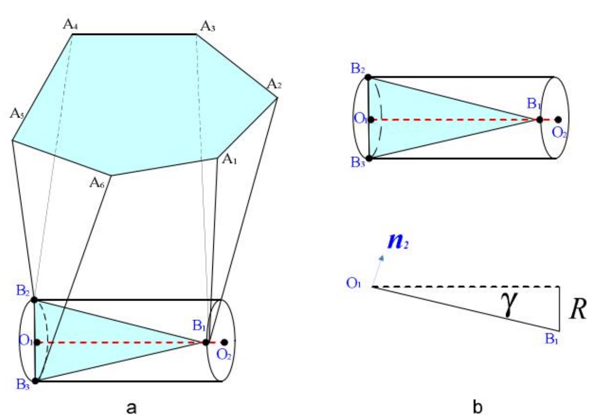

Figure 4 : The layout of cables on the moving platform

The selection of motor control mode

In the construction of the measurement system mentioned in this part, the core hardware is the servo motor. Therefore, to make a further research for the work principles and characteristics of the servo motor is particularly important.

However, there are some differences between the control systems, which mainly reflect the different nature of the work. And, in the prime mover, there are three control modes can achieve the purpose of this section. These three control modes are the torque mode, location mode and speed mode. In the research process of this aspect, the first two are chosen.

When the human body movement measurement system is in the proper working condition, the work mode of servo motor in the process is the torque mode mainly. But in the course of human body movement, the body is in movement, which would lead to the torque of the cable larger or smaller than the specified torque of the servo motor. However, the servo motor has the same movement process with human body, and installing the corresponding sensors on the servo motor can explain the movement parameters effectively to transfer these movement parameters into the controller. After that, through the relevant network, the sports parameters are uploaded to the host computer to calculate and analyze the parameters by every operation system of the host computer, making the six free degree parameters in the moving platform can be determined to achieve the ultimate goal that is to carry out the real-time measurement for human movement[6].

However, when the system is in the opposite direction process, the servo motor needs to determine the mode of operation based on the actual situation, such as the position mode, speed mode, and so on. The host computer is required to carry out the trajectory instruction to transfer the corresponding signal instruction by the servo motor to get into the controller ultimately. And the control signal needs to be transferred into the servo motor through the bus to achieve the goal that the servo motor can work in the track which is specified.

The working principle of DC motor

In order to analyze the later content effectively, here first discuss the working principle of the DC motor, and the final conclusion shows the specific relationship between speed, output torque and the output voltage. However, during the analysis process, in order to achieve an effective gradation purpose, the specific assumption process is required. The first, it assumes that the magnetic circuit of the motor does not reach the saturation situation, in which it is no need to carry out the further thought for the affect the nonlinear of magnetization curve. The second, it assumes that the motor reaches the load, so the effect on the reflecting of the armature would be rounded down. In Figure 5, in accordance with Ohm's law, the voltage balance equation of the armature circuit can be drawn.

$$U_a = E_a + I_a r_a \quad \textbf{(3)}$$

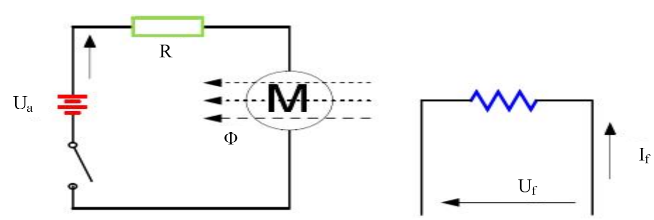

Figure 5 : The working principle of DC motor

The position working mode

The position working mode of the servo motor is applied mainly by the positioning devices and the specific working principle lies in the specific control of the frequency of the input pulse for the rotational speed. In this, the rotational angular displacement can be determined by the specific number of the pulse. Of course, the angular displacement can be determined appropriately by the assignment to the speed and the displacement of the drive.

Usually, the position loop of the motor is used to detect the control instruction which is putout for the controller. After the output instruction is issued, the position loop detects the whether the servo motor can achieve the position specified by the instruction. When the detection value has a certain deviation, the position loop is able to control the servo motor effectively to make it move onto the deviation position, so that it can carry out the accurate localization[7]. The main work flow of position loop can be fully shown in Figure 6.

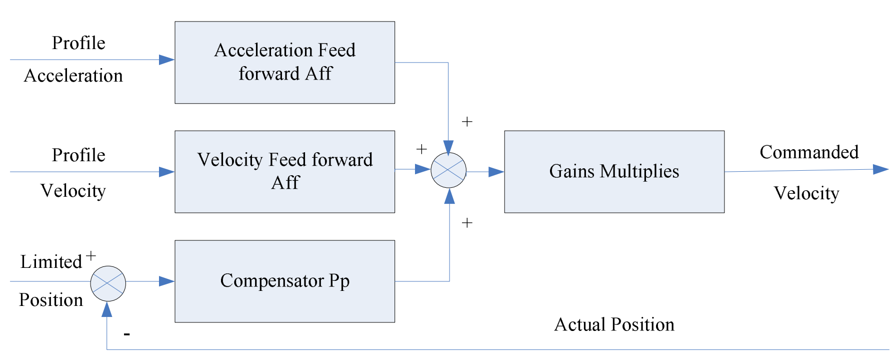

Figure 6 : The position loop signal flow diagram

THE POSITION MEASURING WORKSPACE DERIVATION OF THE MEASUREMENT SYSTEM

Position Measuring Workspace is defined as: when the moving platform maintains a constant stance, the coordinate origin which is fixed to moving platform in the static coordinate system can reach the position measuring workspace, which is also called the direction measuring workspace. In this paper, the numerical method is used to calculate the position measuring workspace. in order to calculate the effective measurement space, the ideal work areas are divided into a number of small cubes, and then checking each point whether meet the above four defining conditions and verifying whether the moving platform can reach the central location of these small cubes.

THE ANALYSIS OF ERROR SOURCES OF THE MEASUREMENT SYSTEM

It can be seen from the previous research and discussion process, the solution process for the measurement unit lies in the calculation for the length of the cable, so as to get the three-dimensional pose of the corresponding moving platform. During the measurement process, the variation existed in the cable length has an important effect on the accuracy of the whole pose calculation. However, in the exploration process to avoid the errors, the factors which cause the errors should be analyzed specifically to promote the factors which cause the errors efficiently. Through the previous discovery process, it can be summed up that the specific reasons that cause the low accuracy of the cable length measurement of body measurement unit are the position error of point A_i, the position error of point B_i and the measurement error of cable length.

CONCLUSIONS

Above is the relative exploration and discussion of this study combined with the construction of the movement posture measurement system based on traction parallel. In this study, the layout and the basic unit of the measurement system and the relationship between the three point layouts of moving platform and human body segment parameters are the focuses of the research. The core element of this study is the construction of the pose measurement unit, which makes the basic principle and the theme of the construction of the movement posture measurement system maintain the high specificity. At the same time, it hopes that the study can lay a solid theoretical and data foundation for the effective development of the future research and can strengthen the scientific and hierarchical depth of the researches in this field significantly.

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