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Research on Optimization Walking Robot Gait Planning Based on Human Bionics

Xuhui Sun

Luoyang Institute of Science and Technology Luoyang, 471003, China;
E-mail:lylgsxh@163.com

Abstract

This paper had analyzed the degree of freedom robot and then simulates the robots and humans similar to the lower limbs, to establish sports model of the robot. The analysis robot has 10 degrees of freedom, in which one leg has five degrees of freedom, namely, a degree of freedom of the knee, hip ankle is assigned two degrees of freedom. Depending on the needs of the kinematic model is divided into forward motion model and lateral movement model. Link by representatives' form various parts of the robot to simplify the model. Through the establishment of the geometry and the Cartesian coordinate system, analyze the relationship between the joint angle and joint use mathematical functions to represent the correspondence between swing foot and between each joint. By Zero Moment Point (ZMP) stability analysis, to ensure the stability of humanoid robot, obtained center of gravity and zero moment point formula, thus proving humanoid robot walking stability. Using of spline interpolation and polynomial fitting method for solving the hip, the equations of motion of the ankle joint, the knee. By setting the parameters, the use of MATLAB simulation software to obtain motion curve of each joint and humanoid robot designed to simulate obtain humanoid robot gait simulation video.

Keywords: *zero moment point; humanoid robot; fuzzy control; gait planning*

1. Introduction

In recent years, research has gradually become the mainstream of artificial intelligence research, and also one of the main directions of future development, one of the shows is its advanced humanoid robot platform, a collection of complex knowledge of many disciplines [1-3], such as artificial intelligence, computer technology control technology. Humanoid robot research has become a hot issue in the field of robotics. Shape and human humanoid robot of similar shape, and the ability to emulate some features of the human body, such as sensing function and physical function, and like humans, have a certain ability to converse and share experiences and humans have the ability to function. The biggest difference with other robots is that the performance of its functions and appearance on two aspects of the characteristics [4-5], specific performance: Compared with the wheeled robot humanoid robot, it has many advantages. In contrast, the humanoid robot can mimic the human gait, walking in a limited space.

Humanoid robot is a kind of human shape, and the ability to emulate some of the physical features of the human body, awareness and social skills and have some experience in the human part of the robot [6-7]. Humanoid robot is a mechanical and electrical, computer, sensors, control technology and materials, and many other subjects in one, is an important indicator of the level of a national high-tech development, therefore, the world's developed countries have invested heavily in research and development.

Study on the rapid development of humanoid robots, features and characteristics of human robot more alike, the reality of everyday life in humans similar to walking through form, and humans can get things done together, so imitation humanoid robot research is

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becoming the Key focus areas of research, not only in scientific research is an important academic research to make our lives more convenient, at the same time the important value has also been reflected in the robot. Humanoid robot has a wide working space, obstacle ability, small mobile blind spot, a wide range of activities, and low energy consumption [8]. The main issue is that of humanoid robot gait of visual design, one can achieve the most basic features humanoid robot gait.

2. Humanoid Robot Model

2.1. Freedom of Distribution

We design humanoid robots, the first to design its organization, institution is the overall framework, and we have to be realized before the next function in the framework set up under the premise. That is our priority in achieving the humanoid robot gait have to do is set up their freedom [9-10], and the carrier as a basis to achieve the desired function. Humanoid robot, their freedom and humanity should be similar, and a lot of freedom of human beings, to the freedom of the human body is fully implemented in the robot body is unrealistic, and therefore this function for gait for the design of humanoid robot for a reasonable degree of freedom.

This paper is to design a humanoid robot gait visual effects, and therefore the focus placed on the robot limb design [11-13]. Due to the complexity of the human skeleton and muscles, we cannot put all of the lower extremities of human freedom which are configured to the robot, so not only are technically considerable difficulty, but also in the control will be a great complexity, as This article draws on joint degrees of freedom to determine the allocation of domestic and international distribution and structure type freedom humanoid robot.

Numerous joint type robots, a large part comes from the body's structure, similar to the body's wrists, ankles and cervical joints, to achieve rotational kinetic energy, therefore robot has rotary joints. In addition there are linear joints, mainly to achieve human-like elbow function, called linear joints. Numerous joint type robots, if you want to control all the joints of difficulty is very large, very complex, so we'll make it possible to simplify the design process.

The design focus is to realize the visualization gait of humanoid robots, so the main analysis mainly in the lower limbs humanoid robot. Lower limb design robots and human lower limb highly similar, all with the three main joints are the hip, knee and ankle joints. Carefully observe the process of human walking, you will find human walking; swinging leg is the greatest feature of their walk, to walk must swing his legs. In the swinging leg in the process, when the body to lean forward to move forward or backward in the process to be kept in balance, and in the process, is to play a major role in the hip joint. People in the process of walking leg swing forward or backward, the position of the center of gravity must be changed, the body's own center of gravity height above the ground must change accordingly, in the course of these changes, the main center of gravity height adjustment rely knee to keep body balance. The main role of the ankle is in the process of human walking, the main role to play with, with the hip so that the body and the legs can be moved up, and can adjust the foot and ankle from the ground.

2.2. Kinematic Modeling Analysis

Humanoid robot kinematics analysis is the basis for the subsequent gait analysis, but also to analyze and verify the use of a degree of freedom to the configuration. Kinematic modeling to analyze the state of motion of each joint in the model, and can be expressed by a mathematical expression. In kinematics modeling contains forward kinematics modeling and inverse kinematics modeling, forward kinematics modeling is mainly determined forward motion of each joint state, the state of motion contains the distance and angle of its movement through these motions obtains humanoid robot during movement of each joint and limb pose. Inverse kinematics and forward kinematics is just the opposite, by humanoid robot when in motion, showing a different location so as to solve the status of the movement, also known as the movement in the joints between the distance and angle problems. If the positive result is obtained and inverse kinematics can be mutual conversion, it indicates that humanoid robot model created is correct, and the next step can be performed in-depth research and design.

Robot kinematics modeling process, the main robot movement is time to resolve the reference coordinate system related functions; especially each joint has a different function, combined with the positional relationship between the robot actuator terminals. Method of robot kinematics, for the present there are many, such as graphical method, DH matrix method and the like. And on the momentum of development of the robot, we can study robot kinematics methods are continuously enriched, and like singularity theory, robotics has been introduced to them. The DH matrix method has a very mature theoretical and more practical experience has been. But each method has its advantages and disadvantages, DH matrix method, although widely used, but the modeling process is complex, computationally intensive, and difficult to solve the inverse kinematics, so this article to find a more convenient way to achieve the appropriate Kinematic analysis.

At home and abroad through the study found, set certain assumptions based on this design, and set the conditions related to the shackles to restrain, then humanoid robot in the process of movement, and no relevant connection between the forward and lateral plane Therefore there was no situation of mutual influence. To facilitate further research and design, to build a relatively simple mathematical model, we put before the humanoid robot during walking to the plane and the lateral plane is divided into two parts were modeled, and create a different link model, at this end of the support leg to establish Cartesian kinematic analysis, combined with the geometric relationships and links established model coordinates of each link, so can this geometric relationship between the swing feet and other joints The relationship expressed by mathematical expressions. This is a relatively simple and intuitive model, compared to DH matrix method, greatly reducing the amount of computation. This article is to adopt this approach to model the humanoid robot kinematics. After splitting up in front of the plane and the lateral plane, link robot model for the establishment of the forward plane shown in Figure 1.

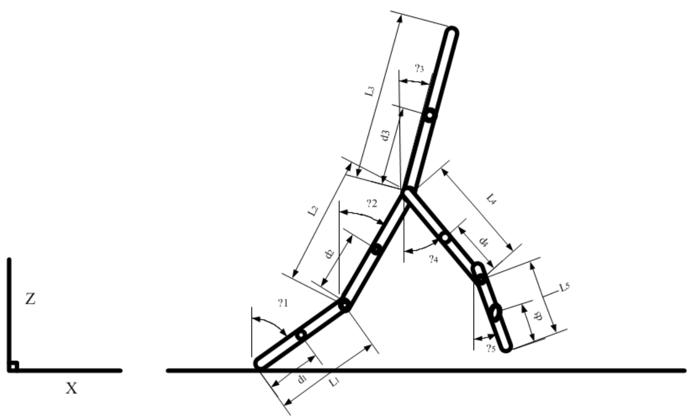

Figure 1. Five-Link Robot Model

Left foot of humanoid robot was supporting foot, then O(0,0) to establish the origin of the reference coordinate system in the ankle joint. Let each joint coordinates in the Cartesian coordinate system established for (x_i,z_i), i=(1,2,3,4,5,6); each joint with respect to the Z axis of the corner of θ_i, i=(1,2,3,4,5,6); the joints of their actual angle is α_i, i=(1,2,3,4,5,6); the length of each link is l_i, i=(1,2,3,4,5,6); quality of each link is m_i,

i=(1,2,3,4,5,6); each rod centroid coordinate of a Cartesian coordinate system for ($x_{\alpha i}$,$z_{\alpha i}$), i=(1,2,3,4,5,6); each rod centroid distance below the joint shaft for d_i, i=(1,2,3,4,5,6).

$$\begin{cases} x_2 = l_1 \sin\theta_1 \\ z_2 = l_1 \cos\theta_1 \end{cases} \tag{1}$$

$$\begin{cases} x_3 = l_1 \sin\theta_1 + l_2 \sin\theta_2 \\ z_3 = l_1 \cos\theta_1 + l_2 \cos\theta_2 \end{cases} \tag{2}$$

$$\begin{cases} x_4 = x_3 \\ z_4 = z_3 \end{cases} \tag{3}$$

$$\begin{cases} x_5 = l_1 \sin\theta_1 + l_2 \sin\theta_2 + l_4 \sin\theta_4 \\ z_5 = l_1 \cos\theta_1 + l_2 \cos\theta_2 - l_4 \cos\theta_4 \end{cases} \tag{4}$$

$$\begin{cases} x_6 = l_1 \sin\theta_1 + l_2 \sin\theta_2 + l_4 \sin\theta_4 + l_5 \sin\theta_5 \\ z_6 = l_1 \cos\theta_1 + l_2 \cos\theta_2 - l_4 \cos\theta_4 - l_5 \cos\theta_5 \end{cases} \tag{5}$$

θ_j corner is provided at the forward left side of the Z-axis positive direction, the right side is a negative direction, by the geometric relationship between the rotations angles of each joint can be obtained after the change with respect to its angle is:

$$\begin{cases} x_{a1} = d_1 \sin\theta_1 \\ z_{a1} = d_1 \cos\theta_1 \end{cases} \tag{6}$$

$$\begin{cases} x_{a2} = l_1 \sin\theta_1 + d_2 \sin\theta_2 \\ z_{a2} = l_1 \cos\theta_1 + d_2 \cos\theta_2 \end{cases} \tag{7}$$

$$\begin{cases} x_{a3} = l_1 \sin\theta_1 + l_2 \sin\theta_2 + d_3 \sin\theta_3 \\ z_{a3} = l_1 \cos\theta_1 + l_2 \cos\theta_2 + d_3 \cos\theta_3 \end{cases} \tag{8}$$

$$\begin{cases} x_{a4} = l_1 \sin\theta_1 + l_2 \sin\theta_2 + \left(l_4 - d_4\right) \sin\theta_4 \\ z_{a4} = l_1 \cos\theta_1 + l_2 \cos\theta_2 + \left(l_4 - d_4\right) \cos\theta_4 \end{cases} \tag{9}$$

$$\begin{cases} x_{a5} = l_1 \sin\theta_1 + l_2 \sin\theta_2 + l_4 \sin\theta_4 + l_5 \sin\theta_5 \\ z_{a5} = l_1 \cos\theta_1 + l_2 \cos\theta_2 - l_4 \cos\theta_4 - l_5 \cos\theta_5 \end{cases} \tag{10}$$

2.3. Inverse Kinematics Modeling Analysis

Use inverse kinematics parameters of each joint can be change, these parameters include corner joints. In gait when planning, in order to be more conducive to our calculations, we require one of the constraints is that the upper body perpendicular to the ground, in conjunction with Figure 1, there are θ_3=0. Let the hip coordinates (x_h,y_h), swinging leg ankle coordinates of (x_k,y_k), the forward kinematics modeling available in front of solving the x_h=x_3,z_h=z_3,x_k=x_6,z_k=z_6, namely:

$$\begin{cases} x_h = l_1 \sin\theta_1 + l_2 \sin\theta_2 \\ z_h = l_1 \cos\theta_1 + l_2 \cos\theta_2 \end{cases} \tag{11}$$

$$\begin{cases} x_k = x_h + l_5 \sin\theta_5 + l_4 \sin\theta_4 \\ z_k = z_h - l_5 \cos\theta_5 - l_4 \cos\theta_4 \end{cases} \tag{12}$$

Because of multiple solutions of inverse kinematics, joint angle range constraint is that we needed to get in the way of joint angles. For θ_1 and θ_5 are bound scope [0,90], θ_2 and θ_4 for the constraint range is [-90,90], can be obtained by calculation

$$\theta_1 = \arccos\frac{x_h^2 + z_h^2 + l_1^2 - l_2^2}{2l_1\sqrt{x_h^2 + z_h^2}} + \arctan\frac{x_h}{z_h} \tag{13}$$

$$\theta_2 = \arctan\frac{x_h - l_1 \sin\theta_1}{z_h - l_1 \cos\theta_1} \tag{14}$$

$$\theta_4 = \arctan\frac{x_k - x_h - l_5 \sin\theta_5}{z_h - z_k - l_5 \cos\theta_5} \tag{15}$$

$$\theta_5 = \arccos\frac{(x_k - x_h)^2 + (z_h - z_k)^2 + l_5^2 - l_4^2}{2l_5\sqrt{(x_k - x_h)^2 + (z_h - z_k)^2}} + \arctan\frac{x_k - x_h}{z_h - z_k} \tag{16}$$

3. Stability Analysis

To make biped robot can walk, we need to get the coordinates of each joint relationship and time. Since the contact area of the biped robot is relatively small, there is no fixed base, so the robot during walking gait design plan relates to the stability of the entire system, is planning the most important factor.

Stability of the robot is divided into two kinds of static stability and dynamic stability. Static stability, dynamic stability is a special case of ignoring some of the parameters in a particular condition. Static and dynamic velocity walk walking speed compared to static when they went, each rod robot velocity and acceleration are relatively small, so we can simply ignore the inertial force of each bar member brought. At the same time the instantaneous speed of foot had contacted with the ground when not considered, so the center of gravity as a standard robot stability during walking. It can be seen, the static stability can only walk slowly when the robot in order to use this method. However, the dynamic of the walk way, since the walking speed, so the front and side of the robot produce inertial force, so before the homeostasis cannot be maintained. Dynamic stability with the zero moment had seed as a criterion of stability. Within the scope of the process of walking humanoid robot, the position of the point ZMP has been the sole component, shown in Figure 2, during walking robots, if it is in the single support time, ZMP has been within the scope of the support leg, or located within the scope of the support legs, ZMP falls within this range will not find dumping situation, so that stability can be maintained. If the ZMP position is located just off the edge of the line when the support leg or foot edge line support, then the robot is located in a critical state, there will be two states, one for the dump will occur, and the other is to remain stable. If the support foot ZMP located outside the area, the robot will not remain stable.

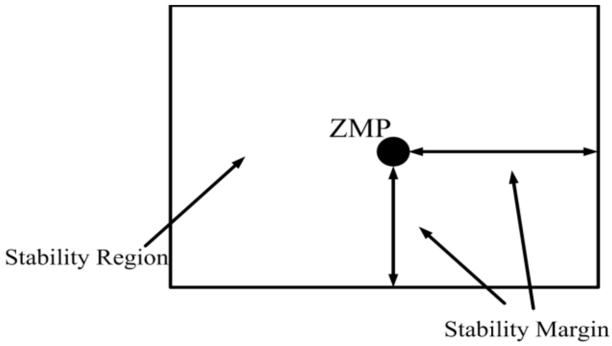

Figure 2. Dynamic Stability with Zero Moment Point

Let gravity point support frame as the origin of the reference coordinate system, and the reference plane and the supporting surface XOY coordinate system is in the same plane. The quality of each link provided in the coordinate system of the humanoid robot as m_i, center link coordinates (x_{ci},y_{ci},z_{ci}). Combined with the reference coordinate system and according to D'Alembert theorem, put all the forces and moments during walking robot suffered simplified, you can get X, Y, Z direction of force

$$F=\begin{bmatrix}F_x\\F_y\\F_z\end{bmatrix}=-\sum_{i=1}^{n}m_i\begin{bmatrix}x_{ci}\\y_{ci}\\z_{ci}+g\end{bmatrix} \tag{17}$$

$$M=\begin{bmatrix}M_x\\M_y\\M_z\end{bmatrix}=-\sum_{i=1}^{n}m_i\begin{bmatrix}(z_{ci}+g)y_{ci}-y_{ci}z_{ci}\\x_{ci}z_{ci}-(z_{ci}+g)x_{ci}\\y_{ci}x_{ci}-x_{ci}y_{ci}\end{bmatrix} \tag{18}$$

$$\begin{cases}x_{ZMP}=-\dfrac{M_y}{F_z}=\dfrac{\sum_{i=1}^{n}m_i(z_i+g)x_i-\sum_{i=1}^{n}m_ix_iz_i}{\sum_{i=1}^{n}m_i(z_i+g)}\\[2ex] y_{ZMP}=\dfrac{M_x}{F_z}=\dfrac{\sum_{i=1}^{n}m_i(z_i+g)y_i-\sum_{i=1}^{n}m_iy_iz_i}{\sum_{i=1}^{n}m_i(z_i+g)}\end{cases} \tag{19}$$

$$\begin{cases}x_{COG}=-\dfrac{M_y}{F_z}=\dfrac{\sum_{i=1}^{n}m_igx_i}{\sum_{i=1}^{n}m_ig}\\[2ex] y_{ZMP}=\dfrac{M_x}{F_z}=\dfrac{\sum_{i=1}^{n}m_igy_i}{\sum_{i=1}^{n}m_ig}\end{cases} \tag{20}$$

When establishing routes model humanoid robot, the first to observe the human dynamic during walking can itself as the object of study, was observed in the process of walking and do not pose the joints at different time points. Through its own observations and a model of the human body as a data analysis, we found that human walking is actually the process kept repeating the process in motion a cycle. Instant is walking into two distinct phases, one phase for the single foot support the entire body in motion, describing the generalization is to the foot as a support surface, the heel of the other foot off the ground to the front of the support leg falls process on the ground, this process is divided into a stage; and his feet propped stage is two feet from the ground to start, step one foot, the other foot as a support leg until taken to the dog feet stage toes touching the ground, concrete stage analysis shown in Figure3.

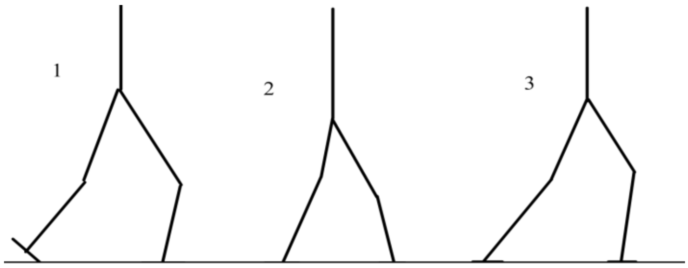

Figure 3. Support Phase Model

In Figure 3, 1 → 2 is the single support phase, 2 → 3 phase support for the feet. In fact, people in the walking process, is an ongoing cycle, which is the anchor point and the center of gravity constantly changing. In this paper, the main research is in a bipedal walking cycle support phase trajectory. Suppose feet propped stage walking time and length of each step, and these two values to plan joint support faze trajectory feet as assumed values. Figure4 is a combination of the provisions of this article a person walking gait cycle.

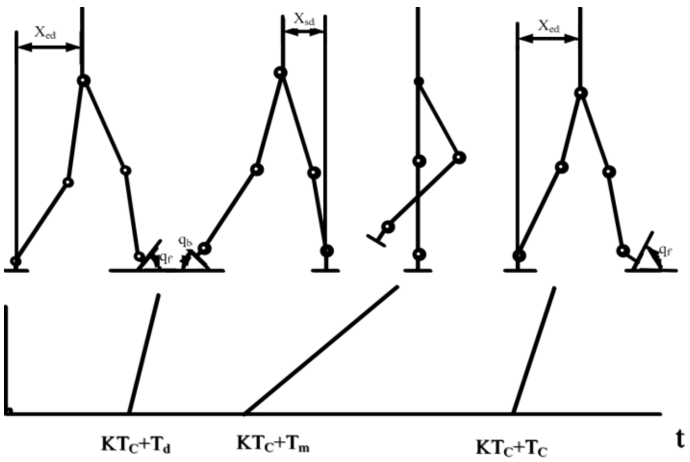

Figure 4. Walking Cycle

There robot model and some related parameters set in Figure5, it is assumed for the walking track (x_f,z_f) in the ankle a little, incorporated herein by reference coordinate left of Figure5, you can specify the ankle in the reference coordinate system the coordinates, the coordinates to describe the characteristics of humanoid robot motion in the ankle joint during walking in the direction and orientation. Meanwhile, the set point is hip (x_h,z_h) walking humanoid robot trajectory point, also incorporated herein by reference coordinates can be determined hip coordinate system coordinates. Walking can be obtained by calculating the trajectory of the ankle and hip joints humanoid robot; it can be determined to walk through knee trajectory of the coordinate transformation.

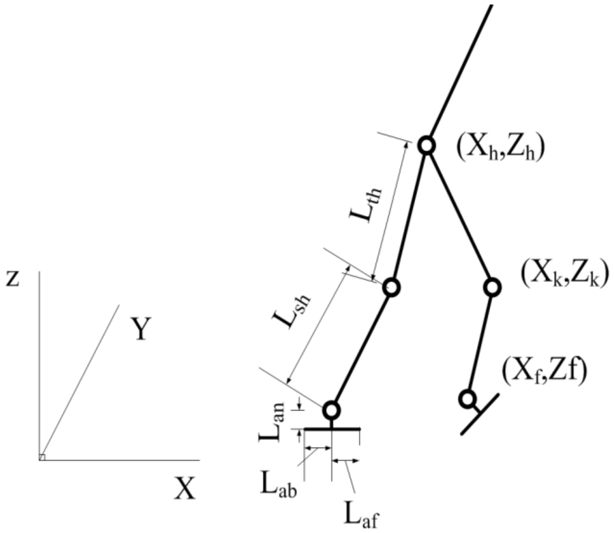

Figure 5. Robot Gait Planning

3. Simulation and Evaluation

Using MATLAB simulation, we according to the proportion of people in various parts of the height of the human body, in Figure6, Figure7 and Figure8, the parameter values involved once set after you can use MATLAB to calculate the ankle, hip and knee three walking tracks.

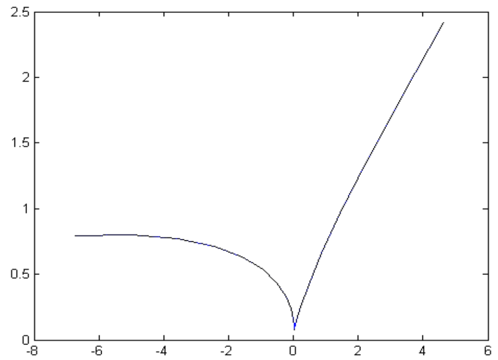

Figure 6. Trajectory of Ankle

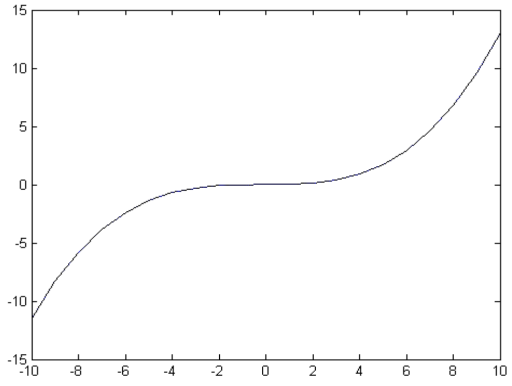

Figure 7. Trajectory of Hip

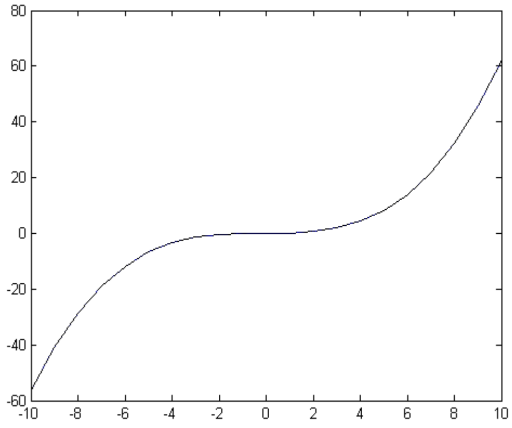

Figure 8. Trajectory of Knee

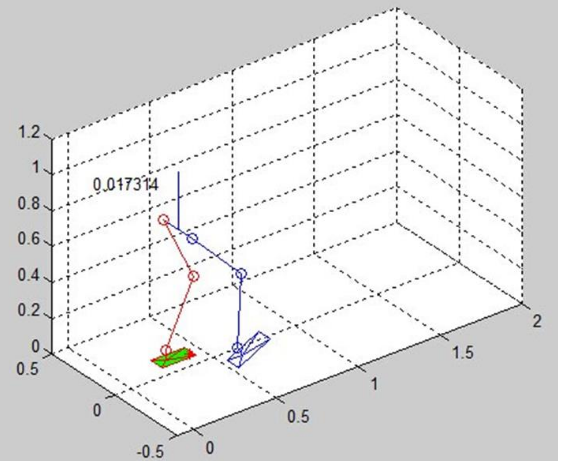

Figure 9. Screenshot Walking Robot Dynamic Graph (a)

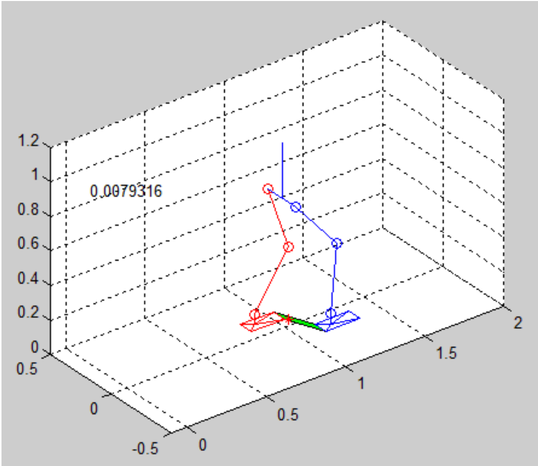

Figure 10. Screenshot Walking Robot Dynamic Graph (b)

When the hip joint angle changes continuously in a small area, but the knee to maintain a certain Angle, from the graph in Figure 6 can be seen, when the robot motion pace consistent with human leg walking posture. After several simulations also found between the rotation about the X axis joints J4 and J5 corner complementary obvious. Go around the Y axis of the joint complementary obvious, but the J3 and J7 the pace of the curve when hip change map generally the origin of the neighborhood of small angular rotation was realistic. Rotation around the Z axis body and J2 also show complementary trends. And the theory and program verification, relative order the parent link, the link pose and censored link has nothing to do with the previous only conjoin transformation matrix and joint related. On the basis of these experiments on the accumulation, through simulation constantly revised joint angle, after several exploratory corrections, you can get more group than in the optimization of joint angles. Since this method avoids linking multiple simulation software accumulation of errors due to data exchange and co-simulation result, the resulting joint angles gifted data can be stored in joint angle database, call it when the robot walks these optimized joint angle data can survive any joint angle values for the robot motion provide reliable data source. These data sources can be sent directly to the next bit machine connection port of walking biped robot motion control prototype.

4. Conclusions

By analyzing the results of field research at home and abroad within the humanoid robot, freedom of distribution, functional characteristics, combined with bionics human lower limb joints physiological analysis to simulate the human-like limb lower limb humanoid robot, while building a humanoid robot limb model and kinematics model, according to the different needs of the former model into forward motion and lateral motion model, and simplified humanoid robot into different forms of linkage, through the establishment of geometric models and coordinate systems and the angular relationships between each joint, obtained the equations of motion of the robot. By ZMP stability analysis, to ensure the stability of humanoid robot while walking, obtained center of gravity point and zero moment point formula to prove the design of humanoid robot can walk stably. Get hip to set the parameters of the equations of motion and knee and ankle joints; we use MATLAB simulation software to obtain the curve of each joint movement and for the design of humanoid robot simulation to simulation in MATLAB. MATLAB simulation results through observation available, able to basically achieve the former humanoid robot gait of walking exercise to visualize, but throughout the design did not consider other direction of movement obstacle and is more deficiencies designs place.

Acknowledgments

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References

[1] M. F. Silva and J. A. Machado, "A Historical Perspective of Legged Robots", Journal of Vibration and Control, vol. 13, no. 10, **(2007)**, pp. 1447-1486.

[2] J. Rummel, Y. Blum and H. M. Maus, "Stable and Robust Walking with Compliant Legs", IEEE International Conference on Robotics and Automation, Anchorage USA, **(2010)**, pp. 5250-5255.

[3] N. G. Tsagarakis, S. Morfey and G. M. Cerda, "Compliant Humanoid Coman: Optimal Joint Stiffness Tuning for Model Frequency Control", IEEE International Conference on Robotics and Automation, Karlsruhe, Germany, **(2013)**, pp. 673-678.

[4] S. Czarnetzki, S. Kerner and O. Urbann, "Observer-based Dynamic Working Control for biped Robots", IEEE International Conference on Robotics and Automation. Seoul, Korea, **(2001)**, pp. 692-698.

[5] B. Vanderborght, B. Verrelst and R. Ham, "Development of a Compliance Controller to Reduce Energy Consumption for Bipedal Robots", Autonomous Robots, vol. 24, no. 4, **(2008)**, pp. 419-434.

[6] T. L. Han, X. S. Wang and X. Luo, "Study of Stabilization Walking Pattern for Biped Robot", Journal of Southeast University, vol. 39, no. 2, **(2009)**, pp. 238-244.

[7] S. Guo, Y. F Fang and H. B. Qu, "Type Synthesis of 4-DOF Non-over constrained Parallel Mechanisms Based on Screw Theory", Robotica, vol. 30, no. 1, **(2012)**, pp. 31-37.

[8] K. J. Kim, B. So and O. Kwon, "The Energy minimization Algorithm Using Foot Rotation for Hydraulic Actuated Quadruped Walking Robot with Redundancy", IEEE 6th German Conference on Robotics, Munich, Germany, **(2010)**, pp. 786-791.

[9] C. Semini, N. G. Tsagarakis and E. Guglielmino, "Design of HyQ-a Hydraulically and Electrically Actuated Quadruped Robot", Journal of Systems and Control Engineering, vol. 225, no. 6, **(2011)**, pp. 831-849.

[10] S. Seok, A. Wang and M. Y. Chuah, "Design Principles for Highly Efficient Quadrupeds and Implementation on the Mit Cheetah Robot", the 2013 IEEE International Conference on Robotics and Automation. Karlsruhe, Germany, **(2013)**, pp. 3307-3312.

[11] L. H. Ding, R. X. Wang and H. S. Feng, "Brief Analysis of a BigDog Quadruped Robot", China Mechanical Engineering, vol. 23, no. 5, **(2012)**, pp. 505-514.

[12] S. Hirose, Y. Fukuda and K. Yoneda, "Quadruped Walking Robots at Tokyo Institute of Technology", IEEE Robotics & Automation Magazine, vol. 16, no. 2, **(2009)**, pp. 104-114.

[13] B. Ugurlu and A. Kawamura, "ZMP-based Online jumping Pattern Generation for a One-legged Robot", IEEE Transaction on Industrial Electronics, vol. 57, no. 5, **(2010)**, pp. 1701-1709.

Author

Xuhui Sun, was born in 1978 in Luoyang city, Henan province, in 2008 graduated from Xinan University, Master of Science; He is a lecturer in Luoyang Institute of Science and Technology, The main research interest is in human Bionics or motion simulation.