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Action Planning and Design of Humanoid Robot Based on Sports Analysis in Digital Economy Era

Yu Han*

Shenyang Jinbei Vehicle Manufacturing Co., LTD, Shenyang, Liaoning, China

84869006@qq.com

**corresponding author*

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Abstract: With the rapid development of digital economy era, robot will become an important part of the future social development. At present, many researchers at home and abroad are also engaged in the field of robotics. Humanoid robot is one of the most active research hotspots in the field of intelligent robot because of its unique walking mode. Based on the above background, the purpose of this paper is to study the motion planning and design of humanoid robot based on sports analysis. In this study, the motion mode of the robot is generated based on the analysis of human sports movement, and the stability of its gait is controlled based on the ZMP control strategy, and the stable walking of the robot is realized. Firstly, the stable walking conditions of humanoid robot are analyzed, and the ZMP position of multi particle and single particle humanoid robot model is solved; secondly, the real-time ZMP measurement of robot is completed based on the pressure sensor of robot sole, and the algorithm optimization solution of robot hip joint angle is carried out based on ZMP control strategy, The dynamic simulation experiments in webots show that the ZMP point of the robot is always in the stable region during the walking process, which proves the validity of the gait pattern generated based on ZMP. Finally, the humanoid evaluation of the robot walking process is completed. The results of similarity function show that the gait similarity between robot and human body is more than 70% in most of the time, It can meet the human requirements of robot gait.

1. Introduction

In the 1980s, more and more universities and research institutions began to get involved in robot research. Many famous robot research laboratories and experimental platforms were established in that period. Nowadays, with the advent of the digital economy era, the processing capacity of computer chips has been greatly improved, while the volume and power consumption have decreased significantly, which provides the material basis for manufacturing robots with real-time processing ability of complex tasks. Recently released robots have more diverse working environments, more intelligent to deal with problems, and many of them have multi task processing ability. Humanoid robot is the closest robot to human in robot field. Not only is his appearance similar to that of human beings, but his thinking method and behavior ability are also closer and closer to human beings. Humanoid robot has a high self-adaptive ability, which can constantly obtain new information from the outside world and update it. Humanoid robots can accomplish tasks in ways that robot designers have never thought of. So in the future, robots may be out of human control and smarter than humans, so some humanoid robot researchers have such concerns.

Due to the importance of humanoid robot research, many research teams began to study humanoid robot, and achieved good results. He made model identification and adaptive control design for the devanit hartenberg model of humanoid robot. For the six degree of freedom upper limb of the robot, the recursive Newton Euler (rne) formula is used to model each joint coordinate system. In addition, the estimated inertia parameters are taken as the initial values of the rne based adaptive control design to improve the tracking performance. The simulation results show that the identification algorithm is effective. In order to apply the knowledge obtained from highly specialized autism treatment field to robot based interactive training platform, an innovative design method is needed. Barakova presents a process of content creation and co design for Lego's treatment of autism spectrum disorders in children by performing a humanoid robot. This co creation takes place in various disciplines of autism therapy and behavioral robotics, and applies design and human-computer interaction methods to connect the latest developments in these disciplines [1-2]. Koolen proposed a momentum based floating robot control framework and applied it to the humanoid atlas. The core of the control framework is a quadratic programming, which represents the motion task as the constraint on the joint acceleration vector and the constraint caused by unilateral ground contact and limited grasp. They described in detail the necessary adjustments needed from simulation to actual hardware, and gave the results of walking on rough terrain, basic operation and multi-point contact balancing on inclined surfaces (the latter is only in simulation) [3].

In order to improve the reliability of existing human motion tracking algorithms, Xu proposes a method to impose restrictions on the underlying hierarchical joint structure, which is real. Unlike most existing methods, they explicitly express the dependence between different degrees of freedom, and derive these limitations from the actual experimental data. The experimental results show that when trying to track complex and fuzzy upper body motion from low-quality stereo data, this can significantly improve the performance of the existing system [4]. Motion capture system is an effective tool to generate realistic trajectory contour for humanoid robot. For example, traffic police and aircraft police spend a lot of time directing car and aircraft traffic and are vulnerable to pollution and mental and physical fatigue. These tasks can be automated by using robots that mimic the movement of the upper body of the human body. In order to develop this kind of robot system, it is necessary to study the natural motion of human body. The naeemabadi study compared the joint tracking capabilities of Kinect and vicon nexus. For several planar and nonplanar motions, Kinect is an effective tool to track upper body motion, and the measurement error of joint angle frequency and amplitude is small. The limitations of Kinect tracking are discussed through rotation test and weighted test [5].

In this study, the motion mode of the robot is generated based on the analysis of human sports movement, and the stability of its gait is controlled based on the ZMP control strategy, and the stable walking of the robot is realized.

2. Kinematics and Stability Criterion of Humanoid Robot

2.1. Kinematics and Dynamics

Due to the differences in body shape, joint number, limb proportion and motion environment between the demo human body and the humanoid robot, the captured and extracted human motion data cannot be directly used in robot motion design [6-8]. The structure of human skeleton is complex, and there are more than 200 joints. However, restricted by its own mechanical structure, there are only dozens of joints [9]. Human kinematics research shows that the realization of motion forms including walking, running, jumping and falling to the ground is mainly restricted by dozens of main joints [10-11]. Therefore, the human motion model can be simplified based on the characteristics and distribution of robot joints, and the mapping relationship of key joint movement data between human and robot, i.e. motion redirection processing, can be used for kinematic and dynamic constraint processing [12].

The purpose of kinematic constraints is to map the key motion data of the demo human body to a humanoid robot with specific motion patterns [13]. For example, when the robot is in a fixed standing state and the upper limbs move without collision with the environment, the kinematic constraints need to consider the mapping of human robot joint parameters, the stability control of biped touchdown, and the range of motion angle of whole body joints, When the robot limb collides with the environment, it is necessary to consider the balance control while standing and the protection posture constraint when falling down; the purpose of dynamic constraint is to match the stability of the data processed by kinematics through the dynamic equation analysis [14-15].

In order to make the motion data after kinematics and dynamics constraints reappear on the robot, it is necessary to consider the degree of consistency between human motion and robot motion, that is, similarity. For example, in the design of biped walking based on angular motion trajectory similarity, the lower limb joint angle of human biped movement is represented by the angle values of hip joint, knee joint, ankle joint and toe joint, and the walking speed is controlled by the angular velocity and angular acceleration of relevant joints [16]. Therefore, when the process is reproduced on the humanoid robot, the human robot motion joint model mapping should be established, The motion is controlled by angle, angular velocity and angular acceleration, and the similarity is judged by comparing the above indexes on the human robot motion model [17].

2.2. Forward Kinematics and Inverse Kinematics Solution

Kinematics mainly analyzes the space-time characteristics of motion from spatial position, motion trajectory, angle, angular velocity, angular acceleration and so on[18-19]. According to the way of motion data processing, it can be divided into forward kinematics and inverse kinematics. Among them, forward kinematics is to solve the spatial posture of limbs by demonstrating the joint angle of human body, It is suitable for calculating the position of the center of gravity and judging the collision of the body environment; the reverse kinematics process is opposite to the forward kinematics, and the joint angle is solved by the position and posture of the end effector, which is suitable for processing and demonstrating the captured images of human motion [20-22].

(1) Forward kinematics

The forward kinematics calculation is solved by the chain multiplication rule of homogeneous transformation. Let the origin of the world coordinate of the robot be its initial standing position, the world coordinate system is Σ_W, and the local coordinate system of the i joint is Σ_i. with the change of motion posture, the unit rotation matrix is $r_i = [e_{ix}\ e_{iy}\ e_{iz}]$, where $e_{ix}\ e_{iy}\ e_{iz}$ is the unit vector and parallel to the x, y and z axes respectively [23],

$$r_j = R_i r_i \tag{1}$$

The conversion from i to j satisfies the following conditions:

$$p_W = p_i + R_i^i p_W \tag{2}$$

Where p_W and $^i p_W$ are the spatial pose in i and j coordinate systems respectively, then the homogeneous transformation matrix is:

$$T_i = \begin{bmatrix} R_i & p_i \\ 000 & 1 \end{bmatrix} \tag{3}$$

From formula (1) ~ (3), the chain multiplication rule of homogeneous transformation is as follows:

$$T_N = T_1 {}^1T_2 {}^2T_3 ... {}^{N-1}T_N \tag{4}$$

TN is the homogeneous transformation matrix of the position and posture of the nth joint.

Let Σ_i be the female connecting rod coordinate system, b_j be the origin of Σ_j in the current connecting rod coordinate system, a_j is the rotation axis vector, and φ_j is the joint angle:

$${}^iT_j = \begin{bmatrix} e^{a_j \varphi_j} & b_j \\ 000 & 1 \end{bmatrix} \tag{5}$$

According to formula (4) and (5), the posture (p_j, r_j) is as follows:

$$p_j = p_i + R_i b_j \tag{6}$$

$$R_j = R_i e^{a_j \varphi_j} \tag{7}$$

(2) Inverse kinematics

There are two methods to solve inverse kinematics, one is numerical method and the other is analytical method [24-25]. The analytic method is limited by the mechanical structure of the specific robot. It describes the relationship between the joint angle and the position and posture of the connecting rod by high-order multivariable nonlinear equations, which has a large amount of calculation and complex solving process, and its value is difficult to obtain. The numerical method is based on forward kinematics, using trial and error and correction error method to solve, the solution method is intuitive, the calculation speed is fast, and it is often used in practice. The basic principle of numerical method is shown in Figure 1.

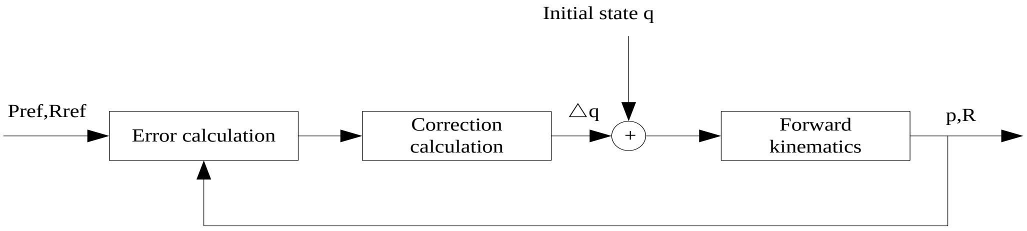

Figure 1. Basic principles of numerical method

The algorithm steps are:

Step1 Determine the desired target posture of the connecting rod $\left(p^{ref}, R^{ref}\right)$;

Step2 Set the joint angle vector q for the torso-target link;

Step3 solve the current link posture (p, R) through forward kinematics;

Step4 solve the distance $(\Delta p, \Delta R) = \left(p^{ref} - p, R^{T} R^{ref}\right)$ between the current link and the target link;

Step5 When the distance is 0, that is, $d(\Delta p, \Delta R) = \|\Delta p\|^{2} + \|\ln \Delta\omega\|^{2} \to 0$ is met, the calculation is stopped;

Step6 When the distance is greater than the specified threshold, that is, $(\Delta p, \Delta R) > (p_T, E_T)$ is met, the modified value △q is solved;

Step7 modify the joint angle vector to q=q+△q and go to Step3.

When the robot is in a certain posture, such as walking with straight legs, the inverse of the Jacobian matrix does not exist. At this time, the robot posture is called a singular posture, the joint torque cannot be controlled, and uncontrollable motion patterns may occur. At present, there is no effective method to solve the singular posture trap. Generally, the design should avoid possible singular postures, such as slightly bending the knee joints of the robot legs when walking.

2.3. Criteria for Walking Stability of Humanoid Robots

At present, the stability criteria of humanoid robot motion mainly include: COP (Center of Pressure), ZMP (Zero Moment Point), FRI (Foot Rotation Indicator) point, angular momentum change rate HG (Rate of Change of Angular Momentum) and limit Ring stability criterion.

(1) ZMP stability criterion

The ZMP criterion is not essentially different from the FRI and COP criteria, and it is currently the most widely used humanoid robot stability criterion. ZMP, or Zero Moment Point (Zero Moment Point), is defined as: a point where the robot supports the contact surface of the sole of the foot with the ground, at which point the horizontal component of the effective moment such as the reaction force of the ground is zero. As can be seen from the above definition, ZMP is not actually a zero torque, but the flip torque is zero at this point.

The ZMP stability criterion is defined as: when the robot is walking, if the ZMP point is always within the support polygon formed by the contact surface of the support foot and the ground, the robot is stable, otherwise it is unstable. The so-called support polygon is defined mathematically as the minimum convex set or convex hull of the contact point set. During the one-leg support period, it is the area where the supporting feet are in contact with the ground, and during the two-leg support period, it is the support polygon area.

Let the gravity acting on the center of mass of the humanoid robot be mg and the inertial force be ma_G, and its moment about any point Q on the supporting surface is:

$$M_Q = QG \times mg - QG \times ma_G - \dot{H}_G \tag{8}$$

Where m is the mass of the robot, a_G is the acceleration of the center of mass, and $\dot{H}_G$ is the rate of change of the angular momentum about the center of mass. Then there is a certain point D, which has the following relationship:

$$M_D = DG \times mg - DG \times ma_G - \dot{H}_G, M_D \times n = 0 \tag{9}$$

Where n is the normal vector of the support surface. In the calculation, based on the dynamic model of humanoid robot, the coordinates of point D are calculated by formula (2), and the ZMP position is obtained.

In order to ensure the stable motion of humanoid robot, ZMP points should always be located in the support polygon and have a certain distance from the support polygon in the actual gait planning process, so as to provide a stability margin.

The pursuit of ZMP stability improves the stability of the robot system, but ZMP theory requires that the stable point should always be kept in the stable region, and the dynamic stability should be maintained at any time during the walking process. This condition is too conservative and harsh, which makes the gait energy consumption of humanoid robot is large, the walking speed is low, and the environmental adaptability is poor.

(2) Stability criterion of angular momentum rate of change

By observing the movement process of human beings, researchers found that: when standing, walking or running, people always try to maintain the stability of angular momentum of mass center, and when people are suddenly hit in standing state, they always try to restore balance by swinging their trunk. Through the statistical analysis of human walking data, it is found that the angular momentum of mass center has nothing to do with walking speed, and it is maintained in a very small range. The dimensionless component of the angular momentum of mass center is less than 0.02. So many researchers have defined the stability of the robot from the angle of momentum.

CMP point is the intersection point of the straight line passing through the center of mass parallel to the ground reaction force and the supporting surface. When the ground reaction acts on the CMP point, the horizontal component of angular momentum remains unchanged. When the ground reaction force passes through the center of mass, CMP and ZMP coincide, and the angular momentum of the center of mass is conserved and the robot is stable; when the ground reaction force does not cross the center of mass, the two do not coincide, and the angular momentum of the center of mass is not conserved, and the robot is unstable.

The defect of the stability criterion of the rate of change of angular momentum is that there is no necessary relationship between the stability of angular momentum and the stability of angular momentum. For example, a person can maintain stability while constantly swinging his trunk.

(3) Stability criterion of limit cycle

The stability criterion of limit cycle defines the stability of the system from the motion process of the robot. Because the bipedal walking is a periodic motion in the stable state, the robot state repeats every other walking cycle, and it shows periodic orbit (limit cycle) in state space. Researchers often use Poincare return map PRM (Poincare return map PRM) to analyze the stability of limit cycles. The core is to transform the stability of limit cycles into the stability of fixed points of PRM. The limitation of the limit cycle stability criterion is that it is the determination of the stability of periodic motion. The biped walking is a kind of periodic motion, which meets the requirements of limit cycle determination. However, the biped robot is not only in the motion state, when the robot is in the static standing state, the limit cycle criterion is no longer applicable. Although the definitions of the above three stability criteria are different, they share the following basic properties:

1) Necessity: when the stability condition is not satisfied, the robot will fall down.

2) Sufficiency: when the stability condition is satisfied, there is always a path to prevent the robot from falling.

3) Comparability: it has the concept of quantity and can compare the stability of robots in different states.

4) Measurability and computability: the stability margin of the current state can be calculated online by measuring the relevant state variables.

5) Interpretability: the stability criterion has a certain physical significance, which can explain the instability degree of the robot, and can be used as the decision-making basis of stability control.

Due to the significant difference in limb structure and proportion between humanoid robot and demonstrator, when the captured sports trajectory is applied to the corresponding joint of humanoid robot, it is easy to cause the robot to lose stability and fall to the ground. Therefore, the motion stability constraint should be applied to the robot. ZMP criterion is a commonly used method for robot stability control. When ZMP is always in the polygon formed by the sole of the robot supporting the ground, the robot is in a stable state.

Let (x^{zmp}, y^{wmp}) be the ZMP coordinates of the robot. If the sole of the robot fully contacts the ground, the corresponding ZMP coordinates can be calculated by the following formula:

$$\begin{cases} x^{zmp} = \dfrac{Mgx + p_z \dot{P}_x - \dot{L}_y}{Mg + \dot{P} z}, y^{zmp} = \dfrac{Mgy + p_z \dot{P}_y - \dot{L}_x}{Mg + \dot{P}_z} \end{cases} \tag{10}$$

In the formula, the robot mass is M, the ground force is f, the gravity acceleration is g, P=Mg+f is the relationship between momentum and ground force, and L=c×Mg+τ is the relationship between angular momentum and force, ground the height is pz.

3. Humanoid Robot Motion Experiment

3.1. Walking Model of Humanoid Robot

In order to verify the correctness and reliability of the robot gait mode, it is necessary to rely on the robot walking model based on the robot degree of freedom configuration. The walking model of the robot should not only reflect the structural characteristics of the humanoid robot, but also be consistent with the actual physical conditions, so as to reduce the difference between the actual physical bodies and improve the reliability of gait simulation experiment. Based on the degree of freedom configuration of humanoid robot, the walking model of humanoid robot is built in webots software, and the kinematics and dynamics simulation of humanoid robot are carried out in webots software.

VRML (virtual reality language) programming is used to build robot simulation model in webots, which is a modeling language used to build fictitious three-dimensional scene. VRML uses the data structure of scene graph to establish 3D environment. All objects in the scene graph are described in the form of node, and the nested "parent-child" structure can be realized between nodes. The attributes of the object can be set in the node, including the physical parameters such as position, posture, collision boundary, elastic coefficient and friction coefficient; the motion mode of the object can be realized by calling the program written by the controller node.

Following the logical structure of VRML, the data structure relationship between the joints of humanoid robot is as shown in Figure 2: the root node is the root node, and there are three "sub nodes", which are upper body, lhip and rhip, representing upper limb, left hip and right hip; lhip's "sub node" is lknee, representing the left knee, "Sun Tzu node" is lankle, representing the left ankle; the "child node" of rhip is rknee, representing the right knee, The "grandson node" is rankle, representing the right ankle. The logical structure determines the overall configuration of humanoid robot.

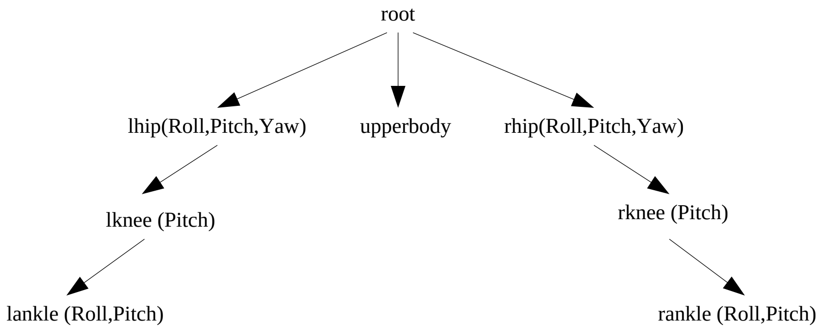

Figure 2. Topology diagram of humanoid robot joint structure

3.2. Motion Planning of Humanoid Robot

Motion planning is the main purpose of humanoid robot research. It mainly involves three aspects: path planning, gait planning and task operation planning.

Path planning: in the global environment, humanoid robot some discrete footprint planning. General steps of path planning:

1) The current environment of humanoid robot is described in space;
2) An evaluation system for path planning of humanoid robot is defined;
3) In all the generated path selection, the optimal path is calculated;
4) Smooth the selected optimal path.

The first step is crucial. The spatial description of the environment is closely related to the algorithm. Some algorithms are only suitable for specific environments;

In the second step, when evaluating the path planning of humanoid robot, the simple shortest path is not the optimal path. For example, sometimes the shortest path calculated is inaccessible to the humanoid robot. Therefore, the problem of finding the optimal path of humanoid robot becomes the problem of minimizing the cost function of humanoid robot;

The third step, the selection of the optimal path, need a core algorithm to calculate; when according to the path planning algorithm, in the third step to get the most effective path, the path needs to be smoothed, that is, the fourth step.

Gait planning: it is located at the bottom of humanoid robot's motion planning, which is mainly manifested in the change of all angles of humanoid robot's limbs. Representation is the trajectory of humanoid robot. Its main purpose is to plan the task of humanoid robot.

4. Simulation Analysis of Humanoid Robot Motion Planning and Design

4.1. Freedom Configuration of Humanoid Walking Model

In order to verify the correctness and reliability of the robot gait pattern, it is necessary to rely on the robot walking model based on the robot degree of freedom configuration. The walking model of the robot should not only reflect the structural characteristics of the humanoid robot, but also should be consistent with the actual physical conditions, reduce the difference between the actual physical body as much as possible, and increase the credibility of the gait simulation experiment. This subject selects Webots software as the research platform, based on the humanoid robot's degree of freedom configuration, builds a walking model of the humanoid robot in the Webots software, and simultaneously performs kinematics and dynamics simulation of the humanoid robot in the Webots software.

The construction of the walking model of humanoid robot includes the process of freedom configuration, mechanical structure design and so on. Among them, the degree of freedom configuration is not only related to the flexibility and beauty of humanoid robot walking, but also related to the energy consumption and controllability of the robot. From the perspective of the robot, the schematic diagrams of these three planes are shown in Figure 3.The three rotation axes of Roll, Pitch, and Yaw are defined as the roll axis, pitch axis, and yaw axis. The positive direction of rotation is in accordance with the right-hand rule:

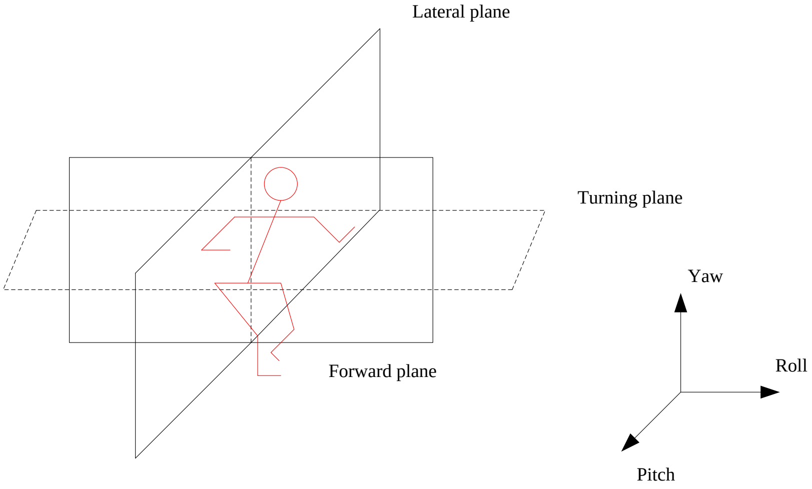

Figure 3. Schematic diagram of the robot walking plane

(1) Forward plane: used to realize the pitching motion of the robot, its rotation axis is the pitch axis;

(2) Lateral plane: used to realize the roll motion of the robot, which can allow the robot to complete the side swing and other actions and its rotation axis is the Roll axis;

(3) Turning plane: used to realize the turning movement of the robot, its rotation axis is the Yaw axis.

Imitating the joint settings of the human body, it is defined that there are three joints in the lower limbs of the humanoid robot, namely the hip joint, the knee joint and the ankle joint. The humanoid hip joint is an important joint connecting the trunk and the lower extremity. Since this subject pays more attention to the movement of the lower extremity of the humanoid robot, the upper extremity is simplified into a mass. In order to achieve the purpose of compensating the movement of the lower limbs through the adjustment of the robot's upper limb posture, the hip joint of the humanoid robot must have two degrees of freedom, pitch and roll, to adjust the position of the robot's center of gravity in the two-dimensional plane, and at the same time to achieve complexities such as turning Action, the hip joint needs to add another yaw degree of freedom; the knee joint of the robot is mostly used to achieve the buffer function, so the knee joint is set to a pitch freedom; because the ankle joint is the closest joint of the robot to the ground contact point, so the ankle joint Posture is very important for controlling the stability of the robot. Like the hip joint, in order to facilitate the adjustment of the position of the robot's center of gravity in the two-dimensional plane, the robot's ankle joint is set to two degrees of freedom of pitch and roll. The specific degrees of freedom configuration is shown in Table 1:

Table 1. Motion and simplification of the joints of the humanoid robot

Robot joint	Action	Axis of rotation
Hip joint	Roll	Roll axis
	Pitch	Pitch axis
	Yaw	Yaw axis
Knee joint	Pitch	Pitch axis
Ankle joint	Pitch	Pitch axis
	Roll	Roll axis

4.2. Humanoid Robot Straight Walking Experiment

Webots is simulation software that combines dynamics and kinematics. It can install a variety of sensors on the humanoid robot to detect the real-time status of the robot, including GPS, gyroscope, pressure sensor, accelerometer, etc., through its provided API can realize the reading of data. Webots software can also perform dynamics simulation based on Open Dynamics Engine (ODE), including functions such as collision detection.

Webots software includes Scene Tree, World, Console, and Program. The scene graph is used to display the structure of the robot model, the world is used to display the model entity of the robot, the program frame is used to write the algorithm program for the robot to call, and the console can output the program result.

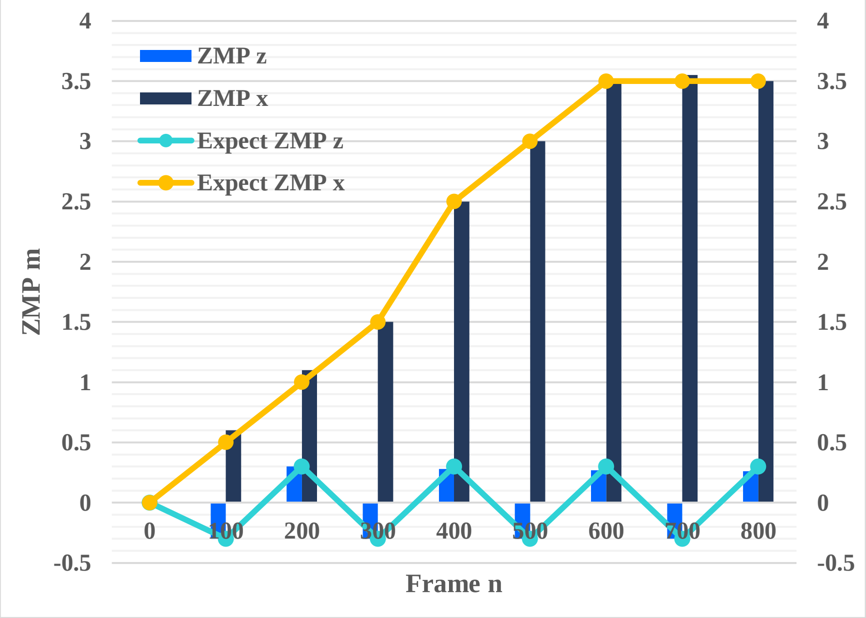

Figure 4. ZMP trajectory when the robot is walking

The real-time ZMP position can be measured by the pressure sensor on the foot of humanoid robot, as shown in Figure 4, in which the expected ZMP point position is in the center of the supporting polygon of the humanoid robot sole. It can be seen from the ZMP curve that when the humanoid robot first follows the ground with its left foot (about 100 frames), the control effect based on ZMP is not optimal, and the robot is unstable. The lateral position of ZMP has a large deviation, which is consistent with the simulation results. However, the stability of the humanoid robot is improved in the subsequent walking process; the actual ZMP point fluctuates around the center point of the support polygon and is in the stable range, which realizes the stable walking.

The simulation model adopts the mechanism parameters of "kdw-5". Taking the forward straight walking movement as an example, the segmented online planning algorithm is used to generate the gait data of 7 steps forward movement under the step length of 20cm and the complete step length period of 1s, and the obtained centroid trajectory is shown in Figure 5. It can be seen from Figure 3 that the planned ZMP trajectory is always in the support region, which ensures the stability of the robot's walking process.

Figure 5. Expected ZMP, CoG, CoC trajectories in the horizontal plane

The joint angle trajectory obtained by the segmented online planning method is shown in Fig. 5; in the starting stage, the left leg is the supporting leg and the right leg is the swinging leg. The maximum range of motion of the right leg knee joint is 13 degrees, the maximum range of motion of the right leg anterior ankle joint is 23 degrees, while the maximum range of motion of the right leg knee joint obtained by the non-segmented planning method is 19 degrees, The maximum range of motion of the right leg anterior ankle joint is 28 degrees; in the step in phase, the maximum range of motion of the right leg anterior hip joint is 27 degrees, the range of motion of the left leg knee joint is 11 degrees, and the range of motion of the left leg anterior hip joint is 15 degrees, while the maximum range of motion of the right leg anterior hip joint is 34 degrees, and the range of motion of the left leg knee joint is 14 degrees, The range of motion of the anterior hip joint of the left leg is 21 degrees; in the cycle walking phase, the range of motion of the right leg anterior hip joint is 33 degrees, the range of motion of the left leg anterior hip joint is 27 degrees, the range of motion of the right leg anterior hip joint is 35 degrees, and the range of motion of the left leg anterior hip joint is 35 degrees. Through comparison, it can be seen that the segmented online planning algorithm adopts different planning strategies according to the characteristics of different stages of walking process, effectively reduces the range of joint angle, and greatly improves the enforceability of gait. The details are shown in Figure 6.

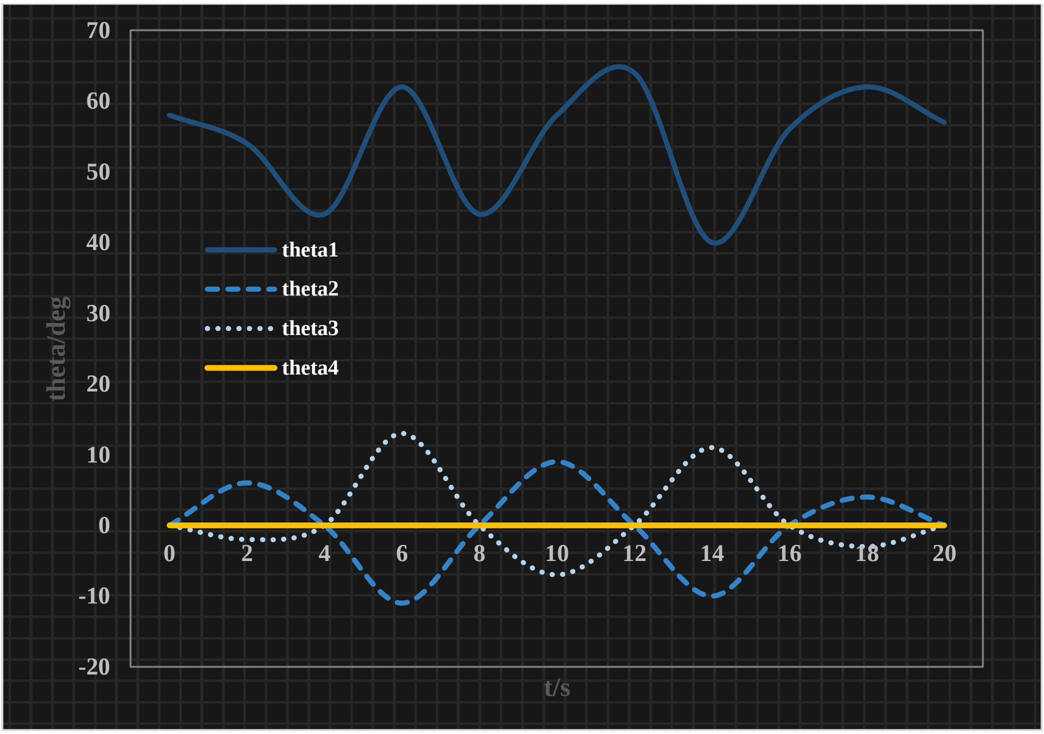

Figure 6. Segmental planning to get the joint angle trajectory of the legs

As shown in Figure 6, in order to achieve stable control, the range of joint motion of both legs of the robot is increased compared with that in the past, which indirectly leads to the increase of joint angular velocity. This speed change is most prominent in the motion of the front hip joint (blue solid line). This is consistent with the positive work done by external forces. However, after the swing foot landing and the support leg switching, the joint angle range and angular velocity of the two are basically the same, which shows that the stepping strategy effectively consumes the work done by the external force interference. This proves that the strategies and algorithms proposed in this section are effective.

5. Conclusion

As a research field with important academic value, application prospect and wide social benefits, humanoid robot has attracted more and more attention of countries and research institutions. This research takes the new generation humanoid robot kdw-5 of University of Defense Science and technology as the research object, and takes the humanoid robot based on sports analysis as the task background, and studies the gait planning and stability control of the humanoid robot, which mainly involves the stability detection and determination based on foot sensor, gait planning method, anti-interference stability control and so on.

In this study, the similarity motion system of humanoid robot is improved, which is divided into image capture and processing, similarity feature processing, similarity motion constraint and optimization, etc. the kinematics solution principle is elaborated, and the kinematics and dynamics constraints, the hierarchical structure of simplified human motion model and the motion redirection processing method are analyzed, The similarity of similar motion of humanoid robot is defined, and the control methods of key posture and basic sub phase extraction, coordination and synchronization, stability, collision free constraint and compensation, and joint rotation range constraint are proposed.

Through the research of this paper, although preliminary theoretical and practical research results have been achieved for gait planning and stability control of humanoid robot, due to the limited time, the robot model has been simplified in the research process, and the research on complex motion process and complex motion is not considered enough, and some theoretical problems have not been involved. Therefore, in the further research process, there are still some theoretical and engineering problems to be solved. The dynamic analysis of humanoid robot gait planning process is not enough. The stability control model of humanoid robot needs to be further improved. The stability control response strategy of humanoid robot under external force interference needs to be verified for complex actions.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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