Biped Walking Robot Control System Design

Jian Fang

Abstract

For biped walking robot posture instability problems presented this paper, ZMP gait planning algorithm and a time division multiplexing servo control method are used to achieve self-controlled walking robot gait. Experimental results show that the methods described herein can be used to achieve stable operation of the walking robot. With a PC using labview robot control interface, the software is simple, straightforward, and easy to operate to control movement of the robot.

Keywords: bipedal walking robot, ZMP gait planning algorithm, Labview

1. Introduction

Robot invention is a milestone in the history of human technology. Especially biped robot technology is hot in recent years, and many theory and technology of intelligent robotics research. Compared with conventional wheeled and crawler crawling robot, higher technical requirements are needed for a bipedal robot with stronger intelligence and better environmental adaptability. Biped robot used to to carry out research for the promotion of the development of humanoid robots is of great significance.

**CorrespondingAuthor:Jian Fang*
(*E-mail:757314739@QQ.COM*)
School of Electrical Engineering Jilin Engineering and Technical Teachers College Changchun,130052,China

In this article bipedal robot body structure first proposed has been studied on the basis of determining the distribution of the degrees of freedom of the robot, robot control system hardware circuit design, and then under the zero moment point ZMP theoretical guidance for the robot gait planning.

2. Biped Robot Hardware Design

2.1 Biped Robot Body Structure Design

By contrast analysis of human leg movement and joint degrees of freedom, and with reference to the degree of freedom at home and abroad, a biped robot was assigned to determine the six degrees of freedom bipedal walking robot lower limbs agency. Where the number of degrees of freedom for each leg has lower extremity 3 (a hip, a knee, a ankle), multiple degrees of freedom of the rotation axis of the cross was made of a type of space, so that the biped robot's joints were used to simplify and control the intended person. Range of motion of each joint is shown in Table 1.

Table 1: Range of motion of the joints

Joint	Articulation range (degrees)	Joint form
Hip	-30~30	Two-DOF planar parallel mechanism and linkage
	-45~45	
	-45~45	
Knee	-90~90	Planar Linkage Mechanism
Ankle	-30~30	Two-DOF parallel mechanism
	-45~45	

Biped robot and a side elevation view of Figures 1 and 2.

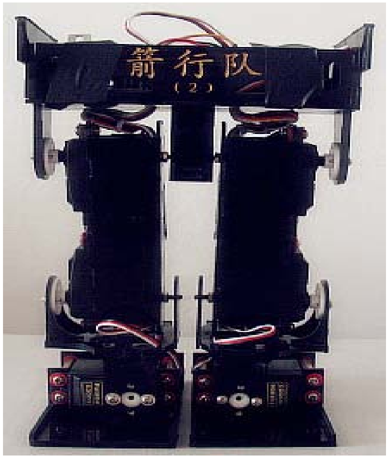


Figure 1: biped robot front view

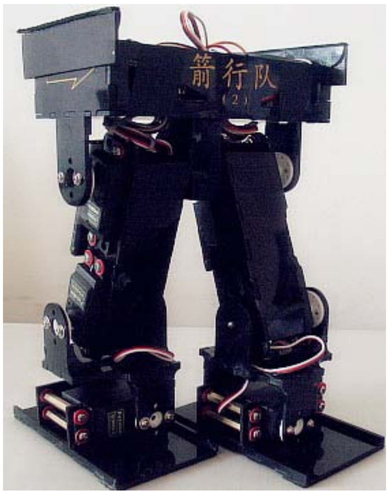


Figure 2: biped robot side view

2.2 Biped Robot Hardware Circuit Design

Biped robot hardware consists of a DC servo motor, reduction gear, and a control circuit. The control circuit board used AT89S52 MCU control. AT89S52 has the following standard features: 8K in-system programmable Flash with memory. 8K bytes of Flash, 256 bytes of RAM, 32 I / O lines, Watchdog Timer.Two data pointers, three 16-bit timer / counters, a six-vector two interrupt structure, full-duplex serial port, on-chip oscillator and clock circuitry.

The design selected the servo motor FUTABA S3003 Servo paperback edition (excluding rudder package) by the input pulse width controlling its rotation angle.

Figure 3: robot control board

Figure 4: servos S3003 physical map

FUTABA S3003 servo motor parameters is shown in Table 2

Table 2: FUTABA S3003 parameters

Product Name	FUTABA S3003
Supplier Code	S3003
Size	40.4×19.8×36.0mm
Working speed	0.23sec/60 （4.8V）0.19sec/60 （6.0V）
Output Power	3.2kg/cm（4.8V）4.1kg/cm（6.0V）

High time periodic pulse signal input is usually between 1ms and 2ms, and high and low times around 20ms. The control line input is a periodic square wave pulse width adjustable cycle square wave pulse signal, 20 ms (ie, a frequency of 50 Hz). When the pulse width of the square wave changes, the steering angle of the shaft changes; the angle change is proportional to the pulse width change. Relationship between pulse width of FUTABA S3003,and steering angle of the output shaft between the input signals is represented in Figure 5.

Enter the positive pulse width (period of 20ms) Servo motor output arm position

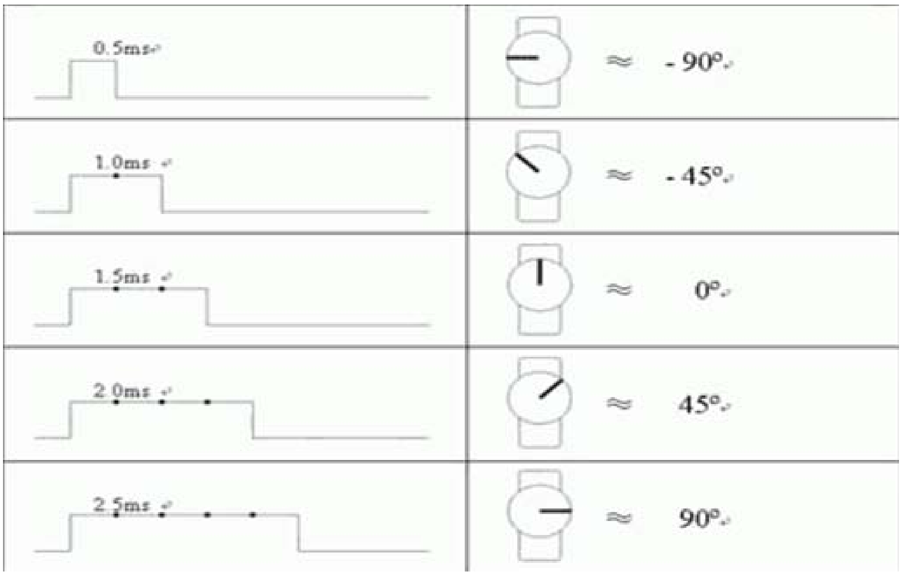


Figure 5: Servo output pulse width corresponding to the position location map

3. Biped Robot's Gait Planning ZMP

3.1 ZMP Principle of a Gait Planning

ZMP (Zero Moment Point) suffered a bipedal walking robot gravity, and 'the intersection of inertial force and ground reaction force vector of the three extension cords are together with the ground. When one foot of the robot grounds, ZMP must fall within the scope of the sole; two feet touch the ground, located within the boundary of the convex polygon formed by the feet area; this area is called stable region. In ZMP place, the robot suffered zero lateral forces and moments, and gait planning ZMP is calculated as follows:

$$Y_{ZMP}(t) = \frac{\sum_{i=0}^{n} m_i\left(\dot{Z}_i(\dot{t}) + gz\right)Y_i(t) - \sum_{i=1}^{n} m_i\left(\dot{Y}_i(\dot{t}) + gY\right)Z}{\sum_{i=0}^{n} m_i\left(\dot{Z}_i(\dot{t}) + gz\right)} \tag{1}$$

$$X_{ZMP}(t) = \frac{\sum m_i(\dot{Z}(\dot{t}) + gz)X_i(t) - \sum_{i=0}^{n} m_i(\dot{X}_i(\dot{t}) - + g_x)Z_i(t)}{\sum_{i=0}^{n} m_i(Z_i(\dot{t}) + g_z)} \tag{2}$$

$$Z_{zmp}(t) = \frac{\sum_{i=0}^{n} m_i(\dot{Z}_i(t) + g_z)Z_i(t)}{\sum_{i=0}^{n} m_i(\ddot{Z}_i(t) + g_z)} \tag{3}$$

Where : t - time;

$X_{ZMP}(t)$, $Y_{ZMP}(t)$ ——during the robot to the X and Y coordinates of the ZMP, respectively;

$Z_{ZMP}(t)$ ——Z coordinating the movement of the center of gravity of the state;

m_i ——The quality of the i-th component;

$X_i(t)$, $Y_i(t)$, $Z_i(t)$ ——The i-th coordinates of the center of gravity means, respectively;

g_X, g_Y, g_Z ——gravity components of the coordinate system.

Key biped walking robot trajectory control is determined according to the motion trajectory of the knee and hip joints of the ankle. Foot lift height is 0, the track is determined by only the knee stride, and the pace and tempo of the track can be uniquely identified in the hip.The gait cycle is shown in Figure 6.

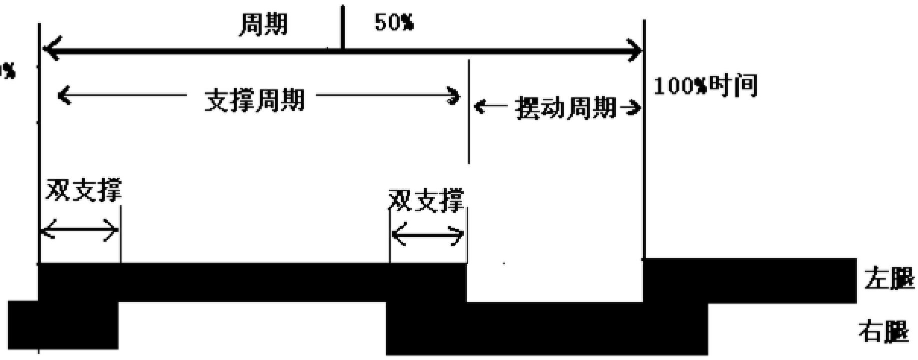


Figure 6: gait cycle diagram

Algorithm 2. ZMP gait planning

Based on the above analysis, ZMP can get biped robot gait planning flow chart shown in Figure 7.

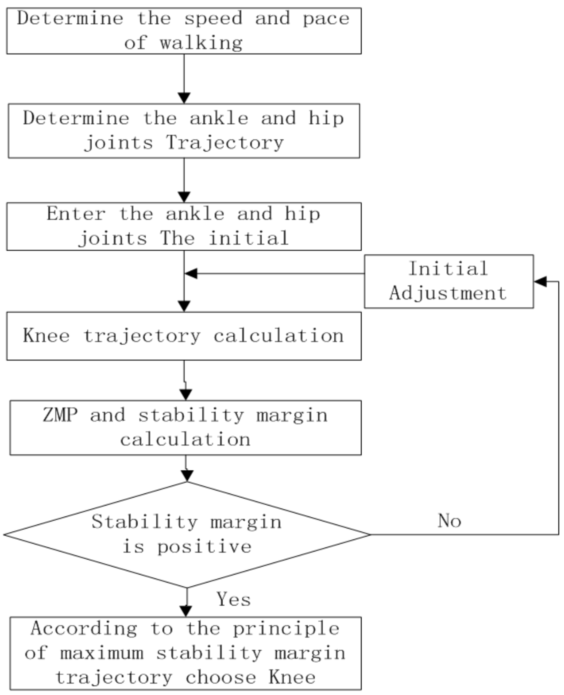


Figure 7: Biped robot gait planning flowchart

Bipedal walking robot complete process consists of three stages.

1). Infancy: the initial legs to walk side by side under stationary state changes, a distance of half a step is forward in the legs, and hips rate rises from zero to a constant value;

2). Full step stages: two legs alternately step forward in the distance, hip rate is unchanged;

3). Step off the stage: a half step is forward in the hind legs and landed parts in parallel with the other leg; hips rate is reduced to zero speed, and restored to the side by side legs resting state.

Focusing on the entire trajectory calculation steps,forward movement of the planning steps are as follows:

1). Determine the velocity and step length;

2). Set the initial parameters, calculate the trajectory of ankle and hip joints;

3). Knee trajectory is calculated according to the ankle and hip trajectories;

4). Calculate ZMP trajectory;

5). Change the parameter value, return to step 2;

6). Select the maximum stability of the track.

4. System Test

4.1 Test Environment

To facilitate debugging, we use Labview to design a PC debugging interface, The debug interface includes six degrees of freedom bipedal walking robot joint commissioning panel, using RS232 serial port debugging interface for data exchange with the control panel. The interface can slide through six PWM control, joint control of six movements, and the control interface is shown in Figure 8.

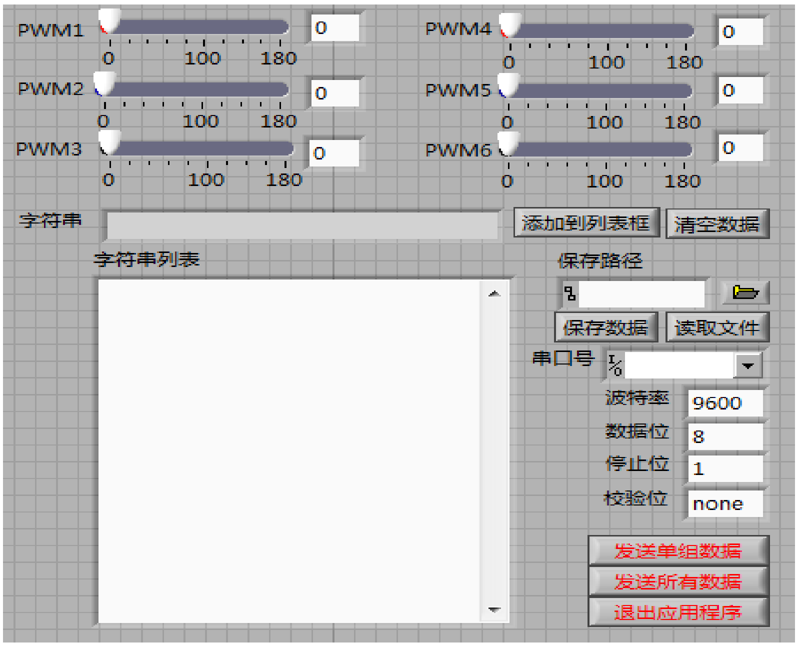


Figure 8: Servo parameter adjustment interface

4.2 Joint Independent Testing

Labview PC data debugging knee was through the serial port to the next crew pulse for debugging, The corresponding angle, the angle of the pulse, is according to the equation: y = 500 +11.11 x (pulse y, the angle x), Obtaining an angle corresponding to the number of pulses is shown in the following table, corresponding to the knee joint action:

Testing times	Pulse	Expected angle	Measured angle
1	500	0	0
2	833	30	30.2
3	1000	45	43.2
4	1167	60	61.2
5	1333	75	76
6	1500	90	90.5
7	1667	105	105.6
8	1833	120	121
9	2167	150	152.5
10	2500	180	180.1

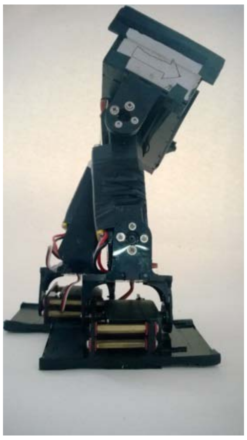
4.3 Gait Planning Test

Setting the upper body while walking is always perpendicular to the ground, feet parallel to each other, and always parallel to the ground. Robot with a step frequency walking can have walking speed of 60mm / s. Reference to characteristics of human walking, walking robot under planning the projection of the center of gravity on the ground sine curve always falls on the ground within feet range. Test swinging feet in the air gives the robot trajectory sampling points as shown in Figure 9.

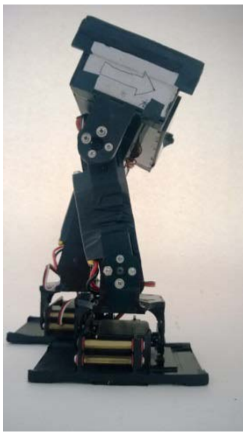
0 degrees to test the left ankle

The left hip 30 degrees test

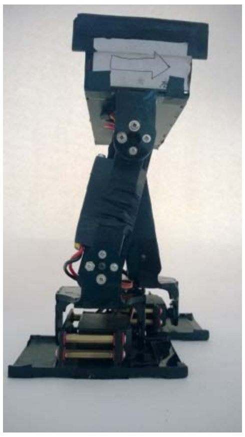
The left knee 15 degrees test



The left knee 15 degrees test



0 degrees to the right ankle test



Right hip 30 degrees test

15 degrees to the right knee test

15 degrees to the right knee test

Figure 9: robot gait planning picture

5.Conclusion

Biped robot body design with a total of six degrees of freedom can be used as a platform of scientific research, and also be used for robot competition. For further expansion of robot reserved space, ZMP results were verified by using mathematical modeling methods for the design of static walking robot planning and physical planning.

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Jian Fang received the B.S.degrees in Automation from Jilin Institute of Technology in 1998 , M.S. degree in control engineering from Jilin University in 2007.In 1998,he joined the Jilin Teachers' Institute of Engineering &Technology in 2000,where he is cuttentlya Associate Professor and associate dean in electric work academy.His current research interests are Motion control of a mobile robot, path planning, intelligent controland their applications.