# Structure Design and Movement Simulation of Bipedal Robot

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**Abstract.** Biped walking robot is designed based on the principle of bionicswhich can walk like a human.The biped robot can replace the prosthesis for the disabled, and it can also make the robot better to complete the dangerous or high-intensity work. This robot not only has characteristics of simple structure, multiple functions, and steady movement,  but also can easily stand, squat, walk before and after , run and twist.The robot's movements are controlled by the hip joint, the knee joint, the ankle joint, and the lumbar vertebrae.The drive motor adopts MG996R servo with accurate motion, stable rotation and maximum torque of 15kg/cm. Finally the structure of robot is designed according to the theory of zero moment point. in the UG software, the parts are modeled and assembled, and then the biped walking simulation is realized. And then, the motion law of each particle is obtained.

## Introduction

Biped robot involves the  fields of kinematics, mechanical structure, electronic machinery, bionics, sensing and control etc.. In the study of the double foot robot, it is needed to combine the knowledge in many fields to form a new and effective research theory.The main research significance is to find the ideal replacement prosthesis. With the study of the biped robot, the mechanical foot can replace the traditional wheelchair and the walking foot in the future, so that the amputation patients canfind substitutes in the form and function more closed to the legs of the person.The main contents of this paper are kinematic scheme, structure design, strength checking, complex parts machining, robot gait balance and dynamic simulation.

## Develop action plan

The subject of the biped robot can make actions,such as standing, twist the waist, heels, normal walking and running. According to the action, the distribution of the degree of freedom is shown in Fig.1.

## Structure design

The shape and size of the legs are design in this paper, and  the actual legs of man is the design basis. The waist, thighs, legs and feet are assembled to determine the overall height of the robot. Double structure is adopted, and the inner structure consists of different mechanical parts, such as bearings, motors, metal plates, screws, bolts, etc., the outer structure is close to  the human legs as far as possible in appearance.
After a lot of Surveying and mapping on the leg, the data is been exchanged. modeling and rendering are completed  in UG.  Inner structure is shown in Fig. 2, outer structure is shown in Fig.3, and whole assembly is shown in Fig.4.

## Parts processing

FDM technology is used for the processing method of parts, the full name of  FDM is fuse accumulation forming technology,which is a kind of rapid prototyping technology. Outer structure of

robot are processed by FDM technology and the process flow is as shown in Fig.5.

Lumbar vertebral joint

Left hip joint

Right hip joint

Left knee joint

Right knee joint

Left ankle joint

Right ankle joint

◯——— Pitch freedom

△——— Deflection freedom
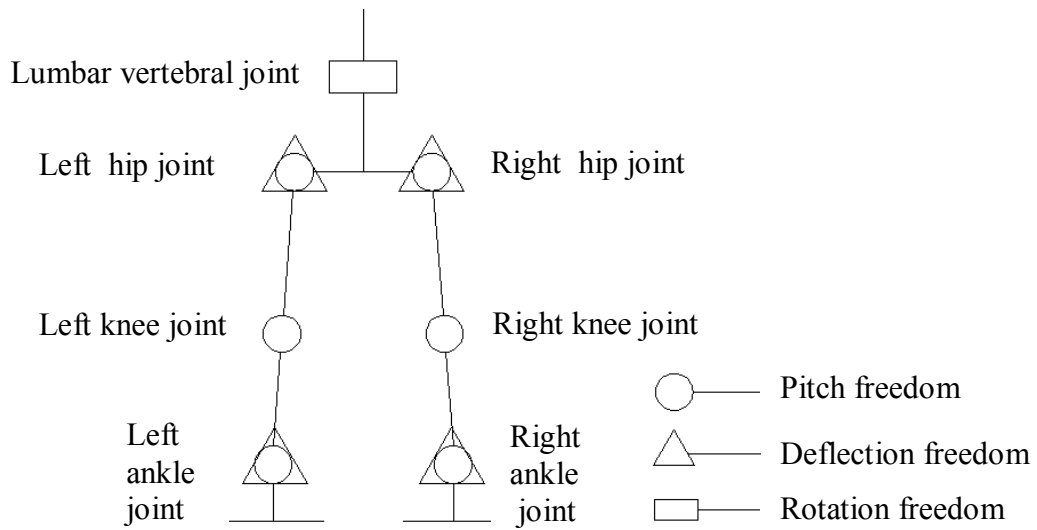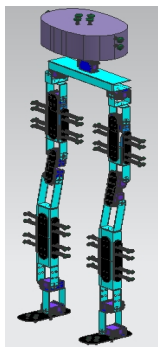
▭——— Rotation freedom

Fig.1 DOF distribution of Biped Robot

Fig.2 Inner structure  Fig.3 Outer structure   Fig.4 Whole assembly
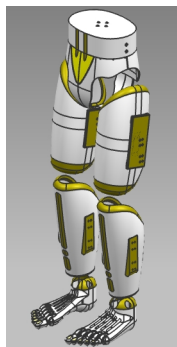
Layered structure     Interface

Slicing process → Set surpport → Set path

↑ *.STL file

Import STL file

↑ *.prt file

Modeling

Set parameters

↓

Machining model

↓ Stop and pickup

Post processing
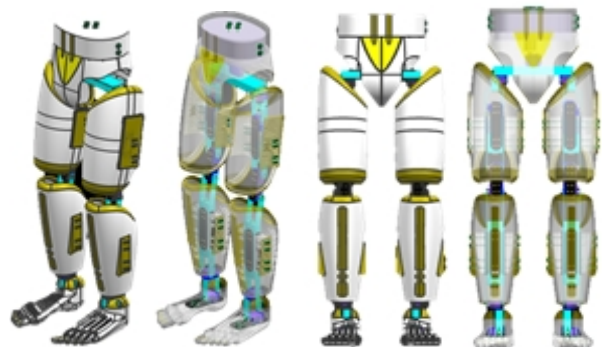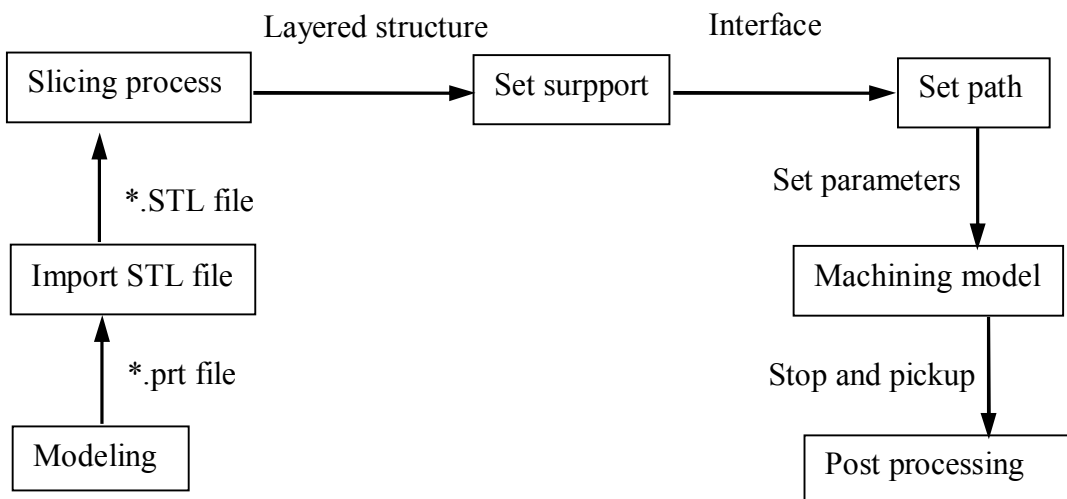
Fig.5 Process flow

After machining each part, the appearance structure of the biped robot is formed according to the assembly relationship, as shown in Fig.6.
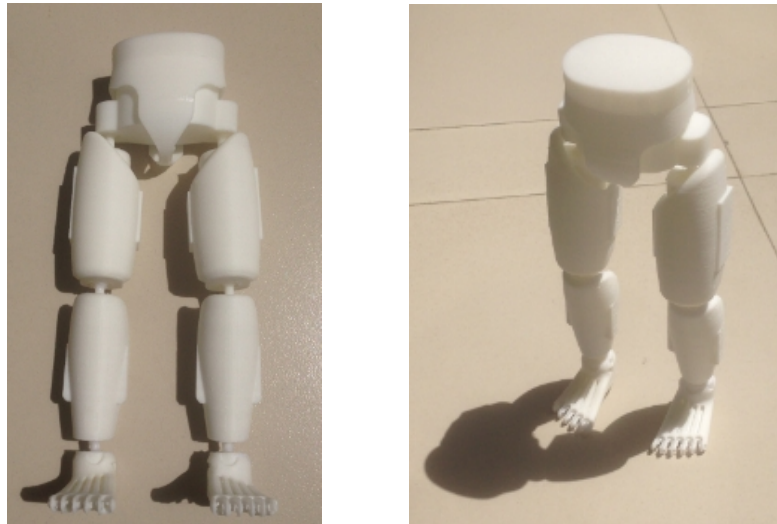
Fig.6   Reverse structure assembly appearance

**Equilibrium analysis**

Zero torque point must be at the bottom of the foot to achieve a stable movement for the robot, if not, then the robot will occur jitter, distortion, and even fell. The position of zero moment point is the intersection between the extension of resultant force and the foot , so that the robot can walk or stand stably, and the equilibrium point is analyzed below.
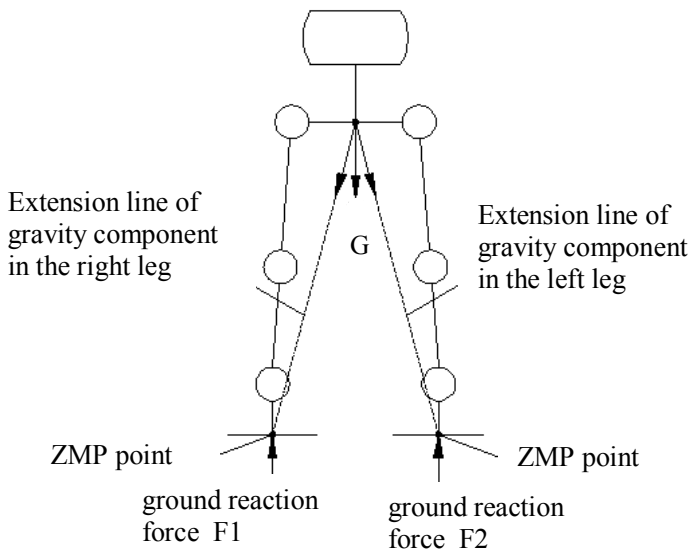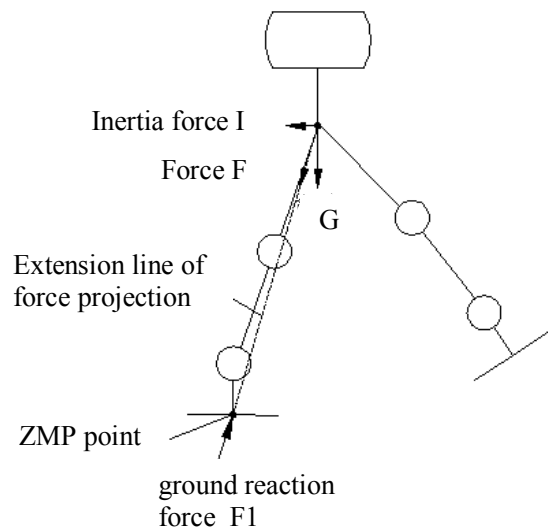


Fig.7 Equilibrium point when standing          Fig.8 Equilibrium point at single foot supporting

   **Equilibrium point when standing.** When Biped robot is standing, a certain angle exits between two feet. At this point, the robot is subjected to gravity G, the ground reaction force F. They are balance force, equal to and opposite each other. The ground reaction force is symmetrically on the feet of the robot, so the gravity projection is in the robot's legs and falls within the range of the feet. Stress analysis is shown in Fig.7

   **Equilibrium point when dynamic walking.** The robot walking process can be divided into two periods -- feet support and single foot support.The period of feet support  can be regarded as the start or end of dynamic walking,Similar to standing. The difference is that the legs support period is a momentary concept. At this point, the stress analysis is the same as when standing.Single foot support phase is the period of biped robot walking, the robot's feet alternately walking, relying on the center of gravity transfer, leg-raising etc.. In the process, each time only one foot landing, and the other foot left floating.Single leg support when walking, all the powers of the force extension line should fall on

the sole of the foot, so the robot walking stable. The stress in the single leg support phase is shown in Fig.8.

## Motion simulation

The motion simulation in UG is based on mechanical linkage system and mathematical model of the system , by setting different types of connecting rod to determine stillness and movement of the structure, and on the computer the model added amount of physical motion, force, displacement, etc., to realize the model according to the specified movement requirements.The key frame of the two legged robot is intercepted by UG animation, as shown in Fig. 9.
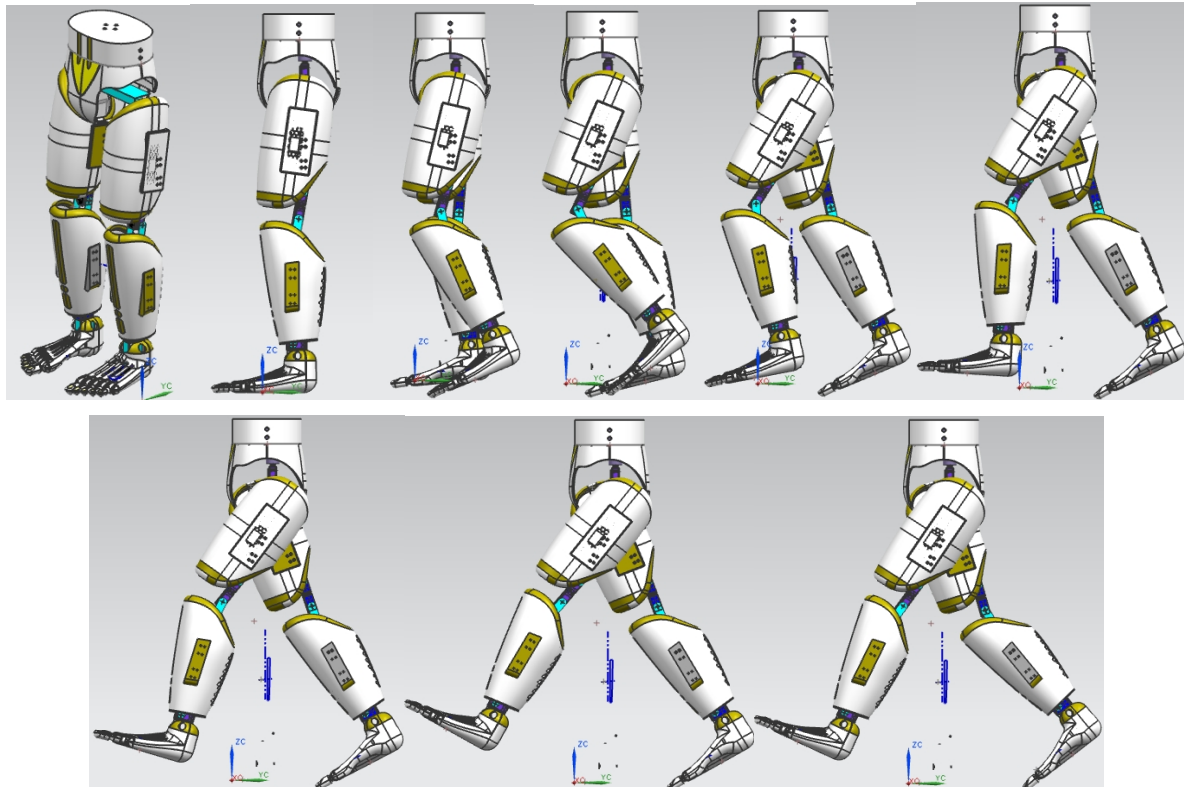


Fig.9 Screenshot of robot walking process

After the completion of the simulation of the biped robot, the center of the ankle joint is set up, and the displacement time curve of the centroid point is generated by the UG simulation, as shown in Fig.10.  The curve of Fig.10 is treated by interpolation, and the curve of successive approximation is shown in Fig.11.
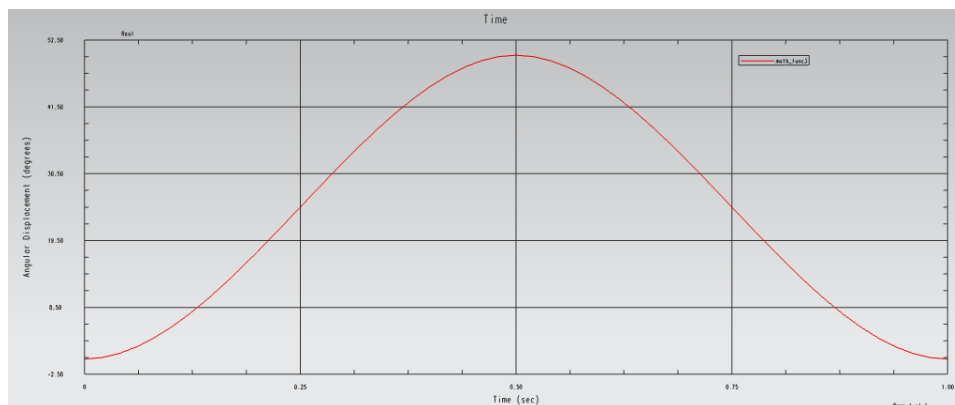


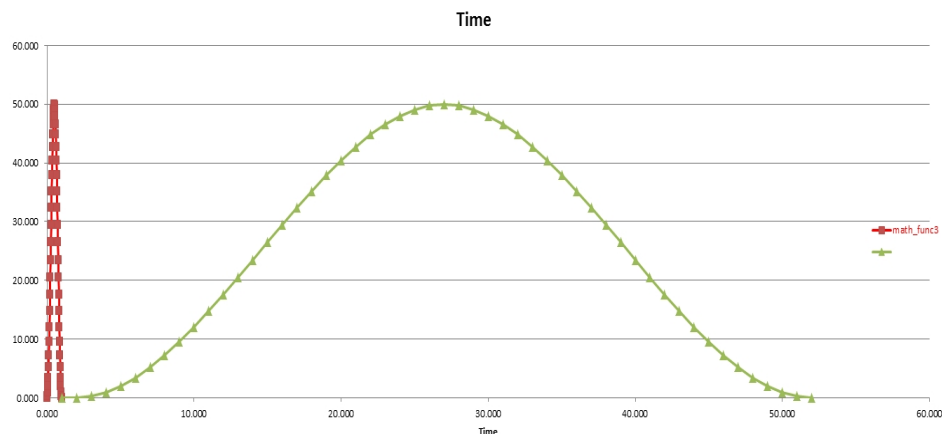Fig.10  Centroid displacement time curve of ankle joint

Fig.11 Sectional curve and ankle joint centroid

The curve of mass center of displacement and time is roughly in line with the ideal ZMP curve, but the centroid of the curve is changed slowly, and there is error in the wave degree.. Because when the movement, the robot feet and the ground is rigid collision, shock and vibration and energy loss exist in both contact, impact force affected the curve changes, part of the energy consumption, makes the curve tends to be gentle.

## Summary

The development of the biped robot continues, although it can not completely replace human, but can greatly reduce human's work and pressure,Liberate mankind from the multifarious labor. There are three points of the robot in the future,Wide application field, two development two and ideal material application.

## Acknowledgements

## References

[1]Liu Hongyi,song Weigang. Stability anayisis of combined wheeled and legged vehicle gaits.Proceedings of the 7th ICAR, 1995.

[2]Xiaohui xie,Lining Sun,Zhijiang Du.Predictor Display in Robot Teleoperation over Internet.Proceedings of the IEEE,2005.

[3]Paul RP.Robot Manipulators:Mathematics,Progranmming and control.Cambridge Mass:MIT Press, 1981.

[4]Gerry B Andeen.Robot Design Handbook.Newyork:McGraw-Hill Book Company.1988.

[5]Junjie Chen,Weiyi Huang,Aiguo Song.Design of New Research Plat for Telepresence Telerobot System.Proceedings of the IEEE,2005.

[6]Hurmuzlu Y.Genot F,and Brogliato B.Modeling,Stability and Control of Biped Robots:A General Framework.INRIA report,2001.

[7]Higashi Mita,Tama-ku,Kawasaki-shi.Development of a Human Interface Remote-controlled Robots Using an Eye-tracking System.Proceeding of IEEE,2005.

[8]S.Guo.T.Fukuda,Norihiko Kato,Keisuke Oguro.Development of Underwater Micro-robot Using ICPFA ctuattor,Proc.of IEEE Int.Conference on Robotics and Automation,Leuven,Belgium,1998.