Design and Implementation of a Quadruped Bionic Robot Based on Virtual Prototype Technology

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Abstract. Design out a quadruped bionic robot with nine degrees of freedom. Conduct virtual assembly and trotting gait simulation on the robot by using NX software. Present the angular velocity and angular displacement curves of the diagonal two legs’ hip joints and knee joints, thus to instruct the practical assemble and control of the robot. The fact that the movement effect of the physical model is consistent with the simulation verifies the validity and practicability of virtual assembly and motion simulation both.

1. Introduction
The wheel type robot and the tracked robot are able to exhibit good athleticism on flat ground [1], but they are difficult to walk on complex irregular terrain, and even can’t get across at all. In the process of biological evolution, creatures have formed structural characteristics and material properties adapt to their living environment[2]. The bionic creeping robot realizes its motion with the crawling mechanism similar to biology. Because its foothold is discrete, it can choose the optimum supporting point on the ground it can reach. This makes the robot have better adhesion with the contact surface and better obstacle climbing ability. This kind of robot has very wide application potential in the field of military reconnaissance and the cleaning of high-rise building external wall and etc[3]. Research on foot-type walking robot has become one of the hottest spots of robotics now[4]. In this paper, a quadruped bionic robot with nine degrees of freedom is designed. First, UG NX software is used to build a virtual model. Then the trotting gait imitating quadruped insect in the nature is adopted to establish the virtual simulation. Finally, an experiment with a physical robot is carried out. The realize process of the quadruped bionic robot is introduced from the following aspects, such as body structure, gait planning, virtual prototype simulation analysis and results, experimental result and its analysis and so on.

2. Body Structure
Each leg of the quadruped bionic robot has two degrees of freedom. They are the swing of the hip joint and the knee joint. With these degrees of freedom, the robot can walk straight and turn a corner. There are a total of 9 degrees of freedom including a swing degrees of freedom of the head. Figure 1 is the structure sketch of the quadruped bionic robot’s legs. All of the robot’s legs, head and body in the physical model are plastic components of PC material. This kind of material not only has a certain strength, but also can reduce the quality of the robot. Each degrees of freedom of the robot is controlled by a MG995 steering gear with a quality of 55g, the maximum torque of which is 1.2NM. The quadruped bionic robot is directly driven by installing the steering gear directly in the robot joint. This kind of drive model can reduce the intermediate transmission links and the structure is compact.
The MultiFLEX 1.0 control card made in Beijing Bochuang company is adopted as the hardware control system of the robot.

The Virtual Prototype can replace the physical model, it also can Shorten the product design cycle and reduce the design cost. In this paper, build a quadruped bionic robot simulation model by using UG NX software, as shown in figure 2.

![Virtual prototype of the quadruped bionic robot](image)

**Figure 2**: virtual prototype of the quadruped bionic robot

1.knee joint 2.hip joint 3.crus 4.thigh 5.body 6.control system

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**Figure 1**: structure sketch of the quadruped bionic robot’s legs

### 3. Gait Planning

The stability of the foot-type robot is mainly determined by the gait[5]. The plan and control of the gait is critical to coordinated motion between the legs. Gait refers to the leg and leg placing sequence of the walking system. The swing-support sequence is used to control the robot’s walking in the working circumstance. Robot with uniform velocity walking changes periodically, so it is called gait period. The moving distance of the walking robot body’s barycenter in one gait period is defined as a step length. In the nature, the gait of the quadruped animal can be summarized as crawling, trotting, unilateral trotting, double foot jumping, jogging, race and four foot jumping and etc. In all of the basic gaits, crawling is the most common static gait for the crawl of general mammalian animal; while trotting, unilateral trotting and double foot jumping are belong to dynamic gait with two legs swing together. Among them, trotting gait is a gait with diagonal two legs swing together.

Trotting gait was adopted in this paper for the quadruped bionic robot. That is to say, four legs are at the standing phase in the initial state, as shown in figure 3(a); then the hind leg1 and fore leg 2 leap forward. During this process, thigh swings slightly around the hip joint 01, crus swings outwards around the knee joint 02, and the other two legs keep standing phase, as shown in figure 3(b); when the hind leg1 and fore leg 2 have leaped and balanced, the fore leg 1 and hind leg2 begin to leap forward, as shown in figure 3(c). The robot moves forward with four legs repeating the action.

### 4. Virtual Prototype Simulation Analysis and Results

Although the sketch map of the gait can clearly reflect whether each leg is at the support phase or at the free phase, it is much more complex to realize the gait transition and control the movements of the legs. Despite the theoretical analysis in the country has achieved certain development and has lay a foundation for robot, its operability remains to be verified and improved. So, by using the UG NX software, build a virtual prototype, establish simulation scheme, shown in Fig.4, simulate each leg joint motion, check the movement interference, simulate the trotting gait. The results conclude that the robot structure is feasible and the motion is stable. This can provide theoretical basis for the following design and control of the physical model.
5. Experimental Result and Its Analysis
According to the virtual prototype of UG NX, implement harmonious control of a physical quadruped bionic robot, as shown in figure 6. The movement screenshots of the experimental process are shown in Figure 11.

Figure 3: the sketch map of the quadruped bionic robot’s trotting gait
Figure 4: simulation connecting rod and joints
Figure 5 Motion simulation screenshot
Figure 6 the photo of the quadruped bionic robot
Figure 7 The angular velocity and angular displacement curve of left fore leg’s knee joint
Figure 8 The angular velocity and angular displacement curve of left fore leg’s hip joint
In the experiment, because of the small contact area between the foot end and the ground and small friction, the quadruped bionic robot has a slippery motion. So its actual move velocity is slower than the simulation. But on the whole, the robot crawls according to the trotting gait simulated in the virtual prototype. It moves stabled and basically agrees with the simulation result.

6. Conclusions
In this paper, design a quadruped bionic robot adapt to walking on complex irregular terrain. First build a virtual prototype, then simulate and finally do physical experiment. The virtual prototype technology’s instruction to productive practice and its superiority have been fully reflected. The results of the simulation indicate that the quadruped bionic robot can walk smoothly with the trotting gait. The results provide theoretical basis for the following design and experiment of the physical prototyping. The physical experiment movement agrees well with the simulation results. The virtual assemble and simulation are verified to be effective and practical.
7. References

[1] Yin XL, Zhang H, Zhao J, Liu YB and Zhao LH 2013(10) Gait control of hexapod robot based on local rules, J. HrbCU (Natural Sciences Edition) pp 565-70

[2] Lu YX 2004(1) Significance and progress of bionics, J. Bionic Eng pp 1-3

[3] Xiao Y, Wang JP, Jiang XK, Li XF and Liu ZG 2006(6) Design and Implementation of a Robot that is Imitative of Spider with Eight Legs, J. Mechatronics pp 79-82

[4] Zhang ZhY, Liu YF, Feng M and Yang YF 2007(10) The new hexapod robot design and simulate based on suppositional model machine technology, J. Equip Manu Tec pp 35-43

[5] Ma DX, Wang YH and Yue L, 2008 Rev. 37 (3) Gait Simulation and Implementation of a New Quadruped Robot, J. Mech Manu and Res pp 21-4