

The kinematics and dynamics simulation of spider robots based on ADAMS

Fu Mengyu

North China Electric Power University

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Abstract: In the nature, the spider's unique physiological structure and crawling mechanism give it strong adaptability to the rugged irregular terrain. Bionic research on spider is of significance on the development of multipied robots that need to go to some unconventional walking locations. This paper has taken a simple eight-legged spider biomimetic robot as an example. A simulation has been carried out on the movement mechanism that spiders maintain stability with one group of legs and look for optimum supporting point on the ground with another group of legs at the same time. This paper also enumerates and analyzes results that may get by simulation.

Background introduction

With the continuous progress of robot technology, the working environment of the robot tends more and more complicated, which requires the robot to have higher flexibility and adaptability to unknown environments. In this case, there is no doubt that bionic technology is one of the most effective way to solve the problems of robot development. Bionics is to learn from the nature of animals and replicate their outstanding performance in a certain aspect through the imitation of their physiological structure and movement mechanism.

In the nature and human society, there are some places where human beings can't reach and some special occasions that may endanger human life, such as the surface of planets, the mine disaster, disaster prevention and rescue and the fight against terrorism etc. Irregular and rugged terrain is the common feature of these environments. This feature limits the application of wheeled robots and tracked robots. However, walking robots have a unique excellent performance on this terrain compared with the wheeled mobile robot. Moreover, walking robots' advantages will become more apparent with the further study of bionic multi-legged walking robots.

At present, the domestic and foreign researches on multipied bionic robot have achieved some results such as the six-legged bionic crawling robot developed by America, Biobot, which is based on the research of insect gait. In the future, not only will be a large number of multi-legged bionic robots used in military operations and space exploration, but also come into people's life more widely to be used in production, entertainment and service industries.

Bionic Principle

Leg is the locomotive organ of insects. Generally speaking, an insect has 3 pairs of legs. Each leg consists of coxa, trochanter, femur, tibia, tarsus and pretarsus. The hexapod usually walks on three legs as a group. That being said, the front and rear foot of one side and the middle foot of the other side are regarded as a group. A triangular support structure is formed in this way. When the three legs are placed on the ground and backward, the other three legs are raised to prepare for

replacement. The front foot is used to pull hexapod's body forward by pawing something. The middle foot is used to support and lift the body on this side. As for the rear foot, it can push hexapod's body forward and turn the body. This type of movement allows insects to stop at any time and place, because the center of gravity is always in the triangular support structure.

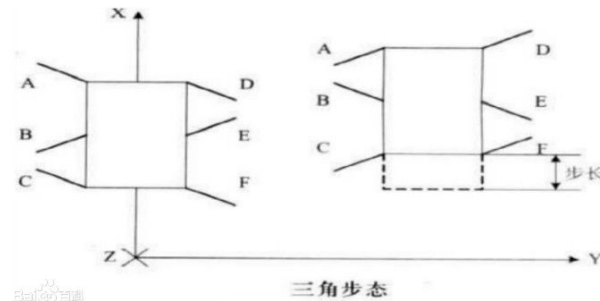


Fig.1 Schematic diagram of six-legged insects' triangle gait

Similarly, the eight-legged insects represented by spiders are also divided into two groups to crawl. Which is distinguished from the six-legged insect is that it forms the triangular support structure using four legs in the process of moving. That's to say, the ipsilateral toes almost coincide. When it is still, it can remain stable by a parallelogram structure formed by four legs.

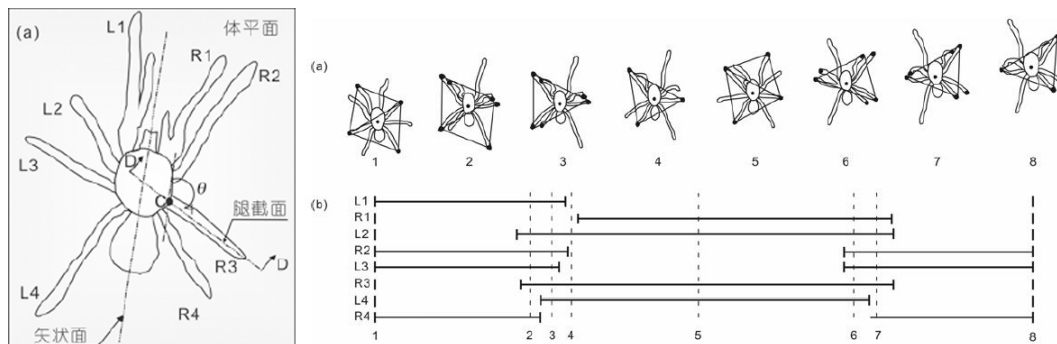


Fig.2 Schematic diagram of spider's gait

The spider robot in this paper is relatively simple. A joint on the insect's leg has been abolished. So the robot can only achieve lateral movement. At the same time, the rectangular support is substituted for the triangle support. Although the stability is reduced, but it still has a certain adaptability to the ground undulating in only one direction.

Structural design

In this paper, the spider robot's leg used for simulation is four-bar linkage with one degree of freedom. This mechanism can simulate the spider legs' lifting, falling and pedaling.

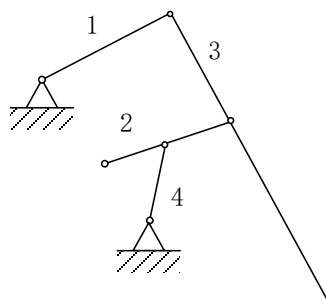


Fig.3 Schematic diagram of leg mechanism

Among this picture, bar 1 and bar 4 are articulated in the main body of the robot (the frame). Bar

2 is the drive of the four-bar linkage. The floating end of the figure is actually hinged on the cross hole of a transmission gear.

Every leg have different condition with its neighboring leg in moving, and if one rise, another will fall. Simulation of the spider's self-stabilization and movement mechanism is based on it. The regular movement of legs mostly rely on bar 2 of four-bar linkage whose one end hings on one of the two opposite cross hole in transmission gear.

By the match of gear system and linkage mechanism, the overall structure of the robot is compact, and it can achieve regular movement of eight legs with only a driving motor.

In order to easy adjustment of size and overall assembly, we can set up and assemble the spider robot model applicable for ADAMS in Pro/E.

The Establishment of Virtual Prototype

ADAMS, Automatic Dynamic Analysis of Mechanical Systems, is the virtual prototype analysis software developed by U.S. Mechanical Dynamics Inc. So far, ADAMS, which is one of the most authoritative mechanical system dynamics simulation software, has been adopted by hundreds of major manufacturers all over the world.

Because of the modeling function of ADAMS is not particularly well, it has good compatibility to the generated file of the current mainstream modeling software, such as Pro/E, SolidWorks, Inventor etc. In this paper, the Pro/E model is introduced to replace the geometric modeling steps in ADAMS.

The main steps of virtual Prototyping are as follows:

(1) Import model.

(2) Initial settings according to the model. These settings are conducive to model observation and subsequent operations, including the abolition of the grid display, modify the size of the icon, and so on.

(3) Add joints. Joints in virtual prototype mainly comprise rotary joints and coupling joints. Rotary joints is used to simulate all joints on spiders' legs, and hing the gears on the machine frame. Coupling joints can build the gear drive transmission system.

(4) Add the drive. Through the use of the match of the gears and linkages, the spider robot structure is greatly simplified. A motion on the middle gear is able to keep the normal operation of the prototype.

(5) The establishment of terrain. Flat ground is the most basic terrain. In theory, the robot has the ability to find the best support points in one direction, that is, to achieve a horizontal barrier. So we can also set the lateral-undulated terrain.

(6) Add contact force. Contact force between the terrain and the robot's eight leg need to be set. Fiction ensures walking and collision damping makes the robot not bounce off the ground.

(7) Simulation analysis.

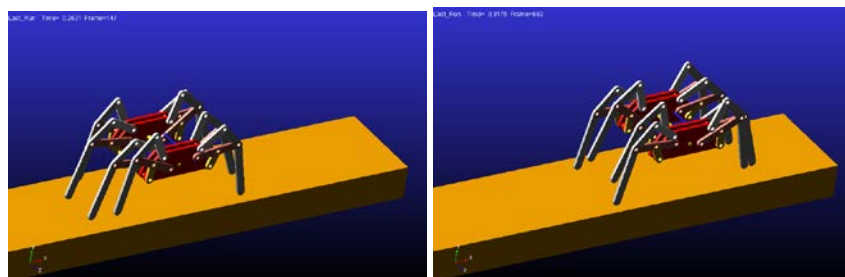


Fig.4 Virtual prototype and simulation in ADAMS

Conclusion

This paper takes the kinematics simulation of the robot walking on the flat for example. ADAMS can directly output the displacement, velocity, acceleration and other kinematic parameters. Combined with forces such as the friction between the hinges, the contact force and gravity, dynamic analysis will become easier.

The frame can be analyzed from the Y direction of displacement. For example, in this paper, each motion cycle of the robot will appear a slight pause, which is due to the inappropriate size of the component. This way will be helpful to adjusting the movement of the frame. Or we can directly observe the trajectory of some points, wherever they are on the rack or on the bar.

Simulation on the rugged terrain and to leap over an obstacle also has important practical significance. In theory, this kind of robots can cross the barrier which have the same height with the highest height that its legs can arrive.

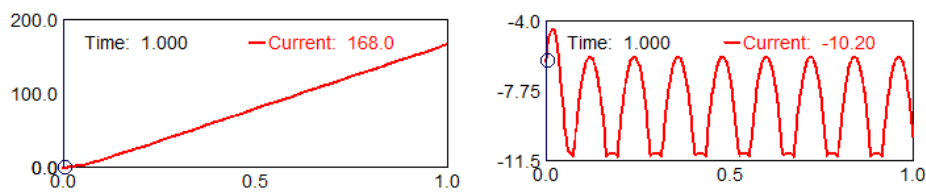


Fig.5 Displacement maps in X and Y directions

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