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Research on Tripod Gait of Bionic Hexapod Robot

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Abstract

Based on the bionic theory and the analyzed of movement mechanism for six-legged insect, the principle of tripod gait movement for walking robot was analyzed in this paper, and basic parameters and the principle of relative movement theory on gait research were discussed. Then the hexapod walking robot was assembled by using the component of Fischertechnik. With the characters of simple connective structure, unique design, this robot can walk forward and backward and can avoid mini-barrier. The experiment showed that this robot has good mobility and stability.

Keywords*: bionic hexapod robot, tripod gait, mechanism with four connecting rod*

1. Introduction

Bionic (bionic technology) is synthesized by two words, Biology (Biology) and Technology (technical). Research is usually based on the nature science. In the past few years, research area has touched upon walking or running. Thus, the robots with legs have invented. Such a walking machine can walk on bumpy or soft earth, even cross obstacles, stairs, ditches, and do a series of difficult movements that wheels can't do. This robot can be used in dangerous place such as nuclear power plants, coal mines for rescue [1].

With the big degrees of freedom for the foot, the bionic hexapod walking robot is more flexible and adaptable on uneven ground. The touch area to the ground for the hexapod walking robot is discrete compared with the wheel robots or track robots. Small contact area with the ground, you can choose the best supporting point on the ground. Even under the condition of the surface is very irregular, Robot is also able to walk freely through strict selection of supporting point. Walking robot research has become one of the most attractive areas in robotics. The study for multi-legged walking robot with independently driven system is more focused on the gait design [2] [3].

Walking gait is the way the system to move, that is the order for walking system to lift feet or put down feet. Due to the development needs of walking robot, McGhee, father of robots, summarizing the results on previous research on animal gait, systematically presents a series of strict mathematical definition of description and analysis of gait. After that, researchers of various countries have got many results in the stable gait cycle rules for four feet, six feet, eight feet and other multi-legged walking machine research. These results include a variety of gait characteristics and classification, such as triangular gait, wave gait, free gait, tracking gait, gait parameters and their relationships. However these studies are limited in theory of gait analyses; take no account of specific implementation. Based on the principle of bionics and the component of Fischer, a walking Robot with six feet is assembled to implement the theory of tripod gait.

2. Theory and Design of Tripod Gait for Hexapod Bionic Robot

2.1. Movement Principle of Triangle Gait

While "Class Hexapods" insects (cockroaches and ants, etc.) walking, generally not six feet go forward at same time, but go forward alternately in form of three pairs of feet divided into two groups and form triangular supporting structures. The front and rear foot in left side and the middle foot in right side are in a group. The front and rear foot in right side and the middle foot in left side are in another group. They composed two triangular supporting structures separately. When all the feet in one triangular supporting structure lifted simultaneously, the feet in another triangular supporting structure keep still. The middle feet in two sides are the supporting point to

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support the weight of insect body. The front tibia muscle contraction, pull the body forward, at the same time, the rear tibia muscle contraction, push the body forward. So the body slightly rotates around the middle feet, letting the center of insect weight shift from three feet in a triangular supporting structure to another three feet. And then repeat the move periodically. Because of weight center always within triangular frame, this walking style easy let the insect stop at anytime. This is a typical triangle gait. The waveform of the gait is $\beta=\frac{1}{2}$. Its walking path is not straight line but a zigzag curve to move forward.

Movement diagram for Hexapod robot using tripod gait is shown in Figure 1. Feet that touch the ground (see the black box) forms a stable triangular structure. Such kind of robot would remain stable walking posture, not easy to fell [4].

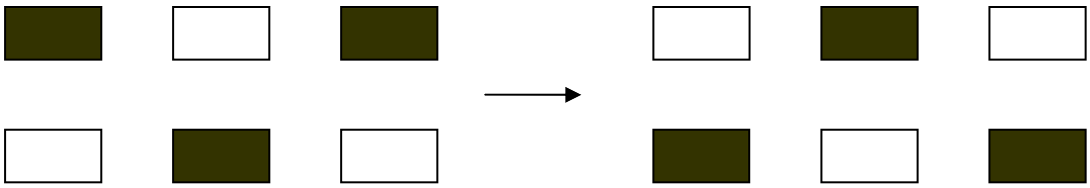

Figure 1. Tripod Gait of Robot

2.2. Assembled for Hexapod Robot Mike

Crank-and-rocker mechanism is set as six feet for Hexapod robot Mike. And smart interface board 31002 is set for controller. The driving element consists of two small DC motor with reducer. Lwin3.0 software which developed by company fischertechnik is programmed and controlled.

The main part of Fischer creative model is made of high quality nylon plastic, which with the quality of size precision, not easy to wear, repeated setup and disassembly but does not affect the accuracy of the model. The patented design for parts is dovetail groove which can achieve part joint in six-side. This unique design can achieve free combination or expanded.

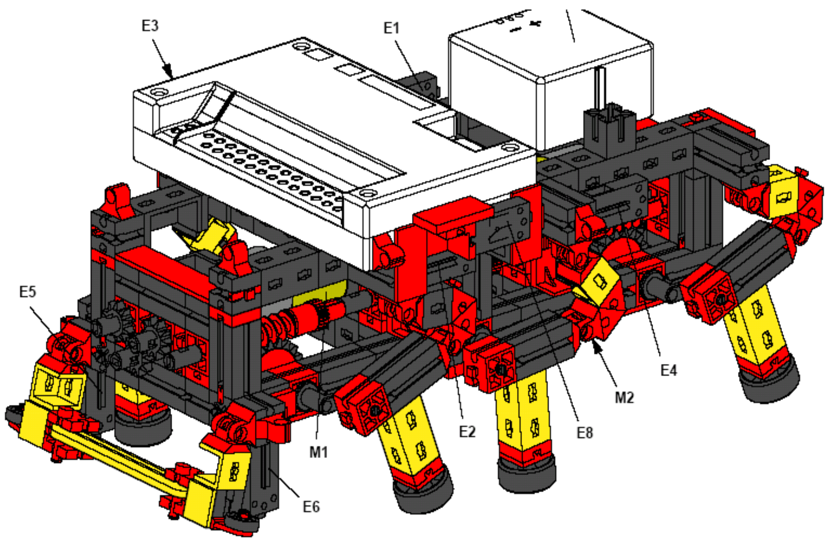

Figure 2. The Figure of robot Mike

The robot Mike with six feet is assembled by the parts of Fischer as shown in Figure 2. The whole structure for the robot includes three parts: the mechanical part, the sensor part and control part. Mechanical parts are mainly composed of the frame, two dc motors, gear and worm drive, six sets of four-bar link structure. When the DC motor is working, the spur gear which linked on the motor shaft will drive the worm-shaft rotation. Rotation of worm-shaft will drive the three worm-wheels in one side to rotate. Then drive the three feet to move, thus the robot Mike goes forward.

The foot of robot was designed according to the theory of four-bar link structure which called crank-and-rocker mechanism. Under the action of the crank, the gear can swing back and forth. Adjust the distance from the frame to the bottom of feet, in order that the move path of feet of robot was ellipse when crank rotate. Six cranks were assembled for six feet. When three feet touch the earth, the crank of another three feet rotated 180-degree. Then Mike went step by step, and form stable tripod gait.

2.3. Tripod Gait Analysis for Hexapod Robot

For the robot Mike, use tripod gait to achieve static walking. As shown in Figure 3. The 1, 4, 5 feet is a group. The 2, 3, 6 feet is another group. The two groups did coordinated motion. The weight shifted from the reset state of 2, 3, 6 feet to initial state of 1, 4, 5 feet (a). The first motion is the swinging feet lifted and move forward “one step” (b).Then it became the supporting feet and supported the body to move one step(c).After that, another group of swinging feet went forward (d), then became supporting feet to move body (e). From the diagram we see that the locus of the feet on x y plane is almost irregular. The locus of the feet should be a curve because the knee joint is fixed when hip joint is swing. But it’s not contradictory to Figure 1.Because in process of moving, the triangle gait is not deformation and weight center always within supporting triangular frame and therefore it’s also stable.

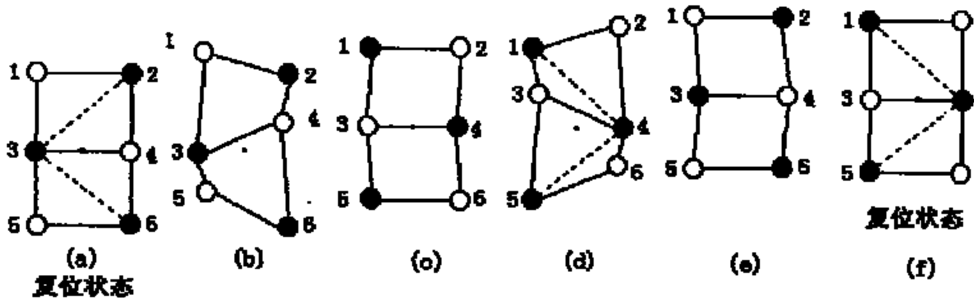

Figure 3. Triangle gait of robot Mike

Supposed weight supporting triangle is A′(xa,ya), B′(xb,yb), C′(xc,yc) in coordinate system. The weight center of robot Mike located at origin of the coordinate. When Mike moves one step to the left, the weight center will move along x-axis, also within the triangle. So it’s a stable tripod gait. The Mike’s moving is also coordinated because weight supporting triangle is not deformed when moving [5].

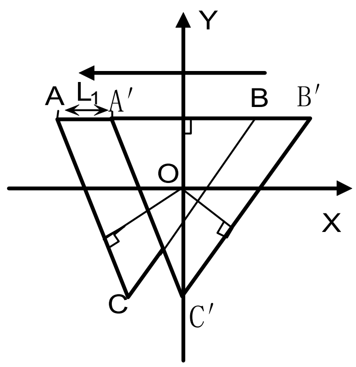

Figure 4. Coordinate analyze for triangle gait

2.4. Kinematics Analysis

When the walking robot we designed used tripod gait, the three legs in the same group did the same movement at anytime. Then the three legs can be equivalent to one leg. The model is analyzed as figure below:

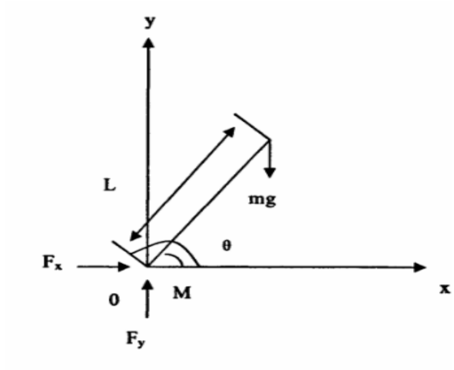

Figure 5. Kinematics analysis for model

In order to facilitate the analysis, it assumes that the body quality of the robot focus on one side of the leg, and the mass of leg is negligible. M is the drive torque which acted on the walking robot. F_x and F_y are the reactive force which acted by the ground. G is the acceleration of gravity. L is the length of one leg. θ is the angle formed by the supporting leg and horizontal direction. Formulation can be written as [6]-[8]:

$$\begin{cases} m\ddot{x} = F_x \\ m\ddot{y} = F_y - mg \\ L\ddot{\theta} = F_x \sin\theta - F_y L\cos\theta + M \end{cases}$$

Where

$$\begin{cases} x = L\cos\theta \\ y = L\sin\theta \end{cases}$$

Substitute x and y then simplify, mathematics expression for motion model of robot can be get [7]:

$$\begin{bmatrix} 1 & -L\sin\theta & L\cos\theta \\ mL\sin\theta & 1 & 0 \\ -mL\cos\theta & 0 & 1 \end{bmatrix} \begin{bmatrix} \ddot{\theta} \\ Fx \\ Fy \end{bmatrix} = \begin{bmatrix} M \\ -mL\cos\theta\dot{\theta}^2 \\ -mL\sin\theta\dot{\theta}^2 + mg \end{bmatrix}$$

2.5. Control Program of Hexapod Robot

Robot should be programmed in order to move. LLWin3.0 of Fischer is the graphical programming software, can achieve real-time control and easy to use. The ladder program was used when intelligent interface board 31002 was applied.18 kinds of function modules were in the software package, can be programmed in any combination. It is graphical display and automatic connection in computer. We use the digital control model E1 and E2 to control the feet to walk. Limit switch E8 was used as a reset switch. Power of motor E2 was supplied by VAR2.The motor M1 would stop while limited switch switched on. Motor M2 would stop when switch E2 switched on. The program was shown as Figure 6 [9].

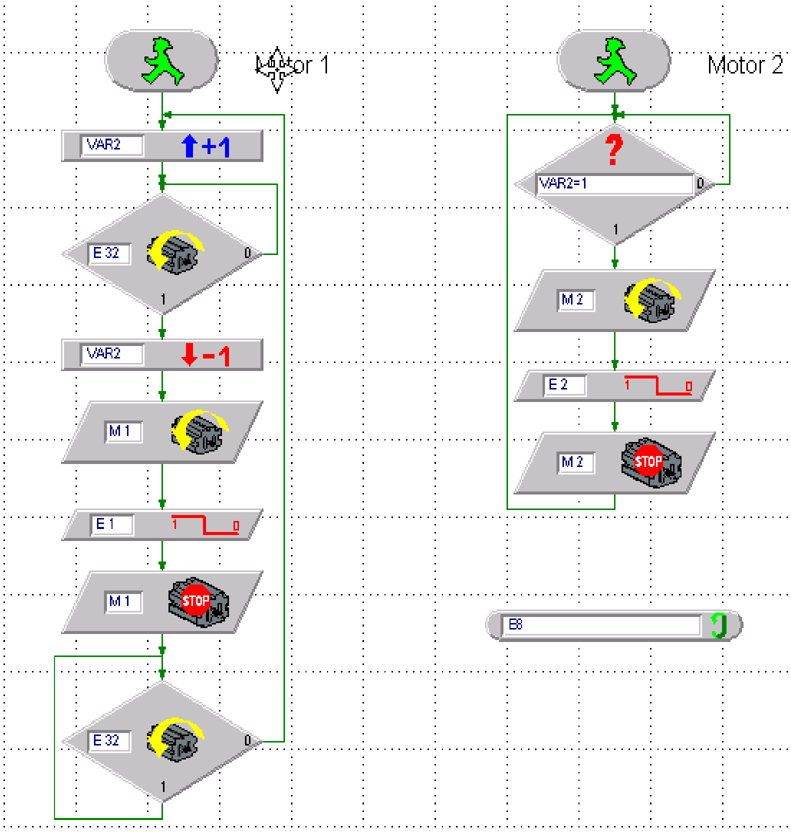

Figure 6. Controlling programmed of Robot Mike [9].

3. Parameter Descriptions for Gait of Hexapod Robot

McGhee, who is the father of robot, defines the parameter in the motion such as step length supporting factor and the phase initially, supposed that any gait can be described by lag in phase of each foot's motion and weight supporting factor of each foot, which provide the math foundation for gait research. Hexapod robot gait is the sequence of feet's up and down in the working system. The feet of walking robot can be seen as two state components. The transfer phase of the feet is the period of leaving the ground, which programmed as 1. The support phase of the feet is the period of touching the ground and compelling the body forward, which programmed as 0. The period gait T is time for one foot finish all the motion in one cycle. The period gait means all feet spent the same time in the motion cycle and each foot's motion period does not change as time is changing. Duty factor is the time proportion that one feet supporting weight on the ground in whole motion period [9]-[14].

4. Experimental Results and Analysis

The functions of hexapod robot for go forward, go backward, turn to left; turn to right and avoid the obstacle had been tested. The result shows that the robot walks smoothly and can cross the small barrier. When the shield in the front of the robot touch the big obstacle, the limited switch turn on, give the robot a control signal then robot will avoid the obstacle. In order to prevent the trip when the model turn left, the left foot of the robot step small pace then the right foot step a big pace. Then the robot would turn and the tripod gait was controlled well by program.

But if the robot walks for a long distance, it will emerge the uncoordinated gait. This phenomenon is due to the motion was realized by linkage mechanism, which have mechanic and electric differences, can't maintain the walking phase of left and right foot same in whole process. When the differences accumulate up to some degree, the uncoordinated gait will emerge [10].

5. Conclusion

On the basis of the bionics principle, the tripod gait principle of the hexapod robot and stability was analyzed in this thesis. The hexapod robot was assembled by Fischer package and programmed on computer. After that the experiment was done. The relationship between the gait parameter and the robot was described in theory. The result shows that the robot can walk in strict accordance with tripod gait, realize the function of moving straight, turning, avoiding barrier, and have good mobility and stability.

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