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DESIGN AND SIMULATION OF JUMPING ROBOT

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Abstract

To explore rough, inaccessible terrain or to aid in search and rescue operations, the tiny machines could be fitted out with sensors to explore rough, inaccessible terrain or to aid in search and rescue operations. The form of jumping is unique because it allows robots to travel over many types of rough terrain where no other walking or wheeled robot could go. The jumping robot is designed by using Solid work software and the possible jumping is simulated by Cosmos motion software. The spring force is analyzed and the jumping displacement versus with time from spring energy is simulated. The Cosmos software is used to simulate the possible movement and jumping of the robot. Also, the pneumatic circuit is designed and simulated. The results from simulations are given in spring forces, which are accumulated and change to jumping power. This result is given in displacement of vertical jumping. The idea of this jumping robot is the energy associated with the vertical motion is transferred from the kinetic energy of falling into potential energy of elastic deformation and back. It is practicable to set up simple control.

1. Introduction

The example of jump robot is a tiny robot that leaps like a grasshopper as shown in Figure 1. Researchers suggest they could be deployed to explore other planets or warzones. Weighing just seven grams, the mechanical can jump 1.4 meters, ten

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times further for its weight and size than any existing robot. A small battery allows the prototype it to jump 320 times at three second intervals. It works by using half-gram motor to slowly charge two torsion springs, which are released by a click mechanism.

Figure 1. The robot, created by Swiss researchers from the Laboratory of Intelligent Systems at the Federal Polytechnic School of Lausanne.

This store-and-release mechanism differs from most other jumping robots which hop continuously. This is similar to the way fleas and grasshoppers store elastic energy in their legs, releasing it via a hooked tendon catch when they are ready to jump. Fleas can jump about 100 times their body length in a single leap. Tiny jumping robots could be fitted with solar cells to recharge between jumps and deployed in swarms for extended exploration of remote areas on Earth or on other planets. Other applications include carrying small cameras or sensors, such as chemical sensors to detect sources or leakage of chemicals in industrial plants, or find people after natural calamities. Jumping robots have been around for decades, with a variety of leaping styles based on different animals. At University of Bath, a new robot has been created and is capable of both rolling and jumping, which allows for greater mobility over the widest variety of terrain types. The robot is a small, flexible spherical cage weighing less than a kilogram. The frame slowly stores energy from electric motors between jumps. By bypassing legs entirely, the rolling robot avoids much of the navigational and control complexity inherent in walking robots and the damage such devices take during frequent falls (Poulakakis [3]). A good leg design is crucial for a legged system, determining many aspects of its overall performance.

2. Hopping Principle

The simplest hopping mechanism is a bouncing ball. If the ball is dropped, then it will fall to the ground, compress, and spring upward again. If the ball is moving forward, then it will remain moving forward. This can be said that the kinetic energy related with its forward velocity is unchanged. The main features of this hopping machine are that the vertical velocity reverses direction at collision. The energy associated with the vertical motion is transferred from the kinetic energy of falling into potential energy of elastic deformation and back. It is practicable to set up simple control laws to make the ideal hopper hop. One idea is that these control laws could be used for the articulated leg by considering the center of mass. Analysis of data available in the literature also showed that the energetic and dynamics of running and hopping in animals can be approximated using the virtual leg (Birch et al. [1]; Lee and Raibert [2]). The model consists of a point-mass on a linearly springy leg and represents the dynamics of the center of mass of a running animal and the virtual springy leg from the center of mass to the foot point on the ground. The center of mass of an animal is considered, so even the masses of legs are counted in the center of mass of the whole body. As a result, the leg of the model is not a physical leg but a conceptual leg with the distance between the center of mass from location of the body and the location of the foot. The bouncing monopod with the compression of its spring can be easily calculated from the total energy of the center of mass as

$$E_{total} = E_{potential} + E_{kinetic,X} + E_{kinetic,Y} + E_{kinetic,Z}, \tag{1}$$

where

$E_{potential}$ is the change in potential energy,

$E_{kinetic,X}$ is the kinetic energy in horizontal,

$E_{kinetic,Y}$ is the kinetic energy in vertical,

$E_{kinetic,Z}$ is the lateral directions, respectively.

In a bouncing monopod, E_{total} remains constant during the aerial phase. During ground contact, the total energy decreases due to the simultaneous reduction of potential and kinetic energy. The decrease in total energy is equal to the work done on the monopod (ΔW) during each ground contact which in turn is equal to the product of force (F) times one half the compression (Δl) of the leg of the virtual monopod as

$$\Delta E_{total} = \Delta W = \frac{F * \Delta l}{2}. \tag{2}$$

Here a linear relationship between force and displacement has been assumed which is in good agreement with experimental findings. The decrease in total energy at each bounce (ΔE_{total}) can be estimated from the sum of the positive fluctuations in total power of the center of mass.

3. Mechanical Design

The methodology can be separated mainly into three parts, designing the mechanism of the robot, electronic and power system, and controlling the robot by programming through the embedded microcontroller. The mechanism design is intended to get insight on how the robot can jump (Zeglin and Brown [6]; Zeglin [7]).

For this design, a pneumatic cylinder is used to simplify the mechanical part and controller. The model is a mechanical prototype of an air spring with pneumatic system. As shown in Figure 2, the mechanism parts of the jumping robot consist of four links, two springs and one pneumatic cylinder.

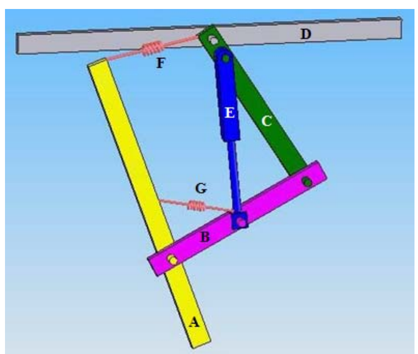

Figure 2. The model of jumping robot.

Link **A** is the important part working as jumping leg. Pneumatic cylinder **E** is the power of jumping robot. The mechanism system starts by contraction of the cylinder **E** by pneumatic power. The spring **F** and **G** will accumulate the energy for jumping. After the cylinder is drawn at maximum point, the pneumatic power will down suddenly by software. The two springs will change the accumulated energy to jumping power and link **A** will jump from the ground. This is one cycle for jumping and then the system will start with contraction of cylinder **E** again.

Pneumatic circuit. A pneumatic actuator is used as a simple solution to make the robot jump. Pneumatic systems use air as a source of energy (Wolfram [5]). The piston rod of a single acting cylinder is operated by the input of compressed air at the front end position. When the compressed air is shut off, the piston returns to its starting position via a return spring. The 3/2-way solenoid valve normally closed. The solenoid valve is controlled by applying a voltage signal at the solenoid coil. By stopping the signal, the valve is set back to its starting position through the use of a return spring. If no signal is applied to the valve, then it can be manually operated. The pneumatic circuits to control are shown in Figure 3 and Figure 4. In Figure 3, the pneumatic circuit is in the stop state. In this state, no signal from micro controller enables the solenoid valve to work the cylinder.

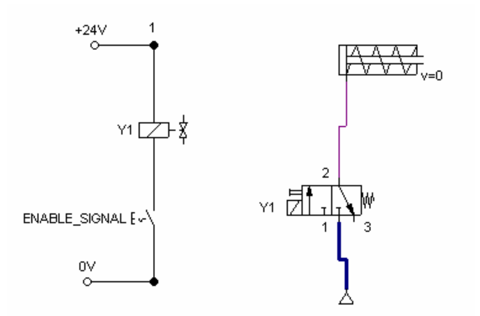

Figure 3. The pneumatic circuit in stop state.

In Figure 4, the pneumatic circuit is in the work state. In this state, signal from micro controller is sent to enable the solenoid valve to work the cylinder.

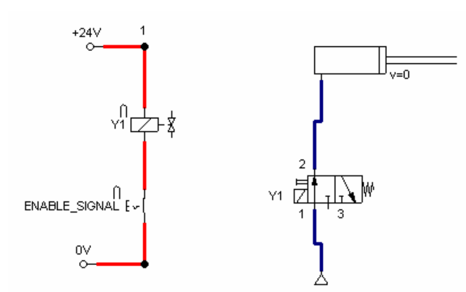

Figure 4. The pneumatic circuit in work state.

4. Results and Simulation

After the jumping robot is designed by using Solid work software, the possible jumping is simulated by Cosmos motion software. The spring force is analyzed and the result of spring *F* is shown in Figure 5 and spring *G* is shown in Figure 6 versus with time. Also, the jumping displacement versus with time from spring energy is shown in Figure 7.

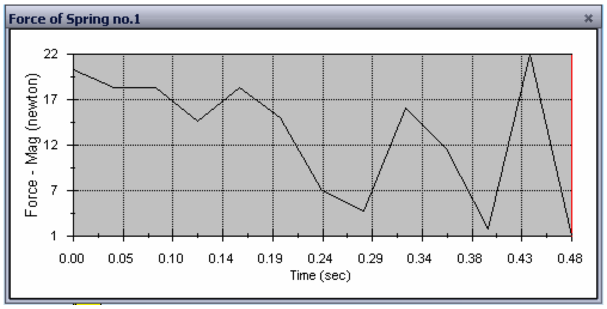

Figure 5. The output of force of spring *F*.

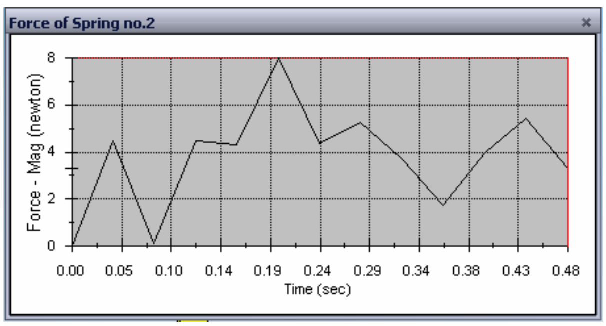

Figure 6. The output of force of spring *G*.

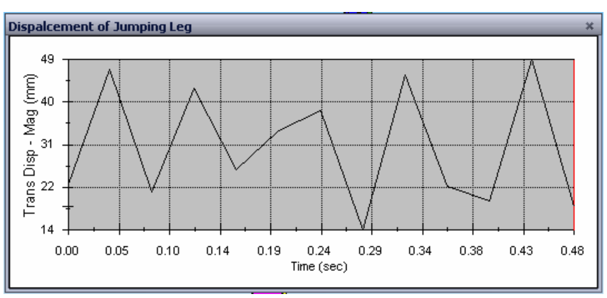

Figure 7. The jumping displacement.

5. Conclusion

The main point of this paper is to design and simulate a simple mechanical model of jumping robot. The idea of this jumping robot is the energy associated with the vertical motion is transferred from the kinetic energy of falling into potential energy of elastic deformation and back. It is practicable to set up simple control. For mechanic part, we design the jumping robot with linkages, springs and pneumatic cylinder. Then we use the Cosmos software to simulate the possible movement and jumping of the robot. The pneumatic circuit is designed and simulated too. The results from simulations are given in spring forces, which are accumulated and change to jumping power. This result is given in displacement of vertical jumping.

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References

[1] M. C. Birch, R. D. Quinn, G. Hahm, S. M. Phillips, B. Drennan, A. Fife, et al., Design of a cricket microrobot, Proceedings of International Conference on Robotics and Automation, 2000, pp. 1109-1114.

[2] W. Lee and M. H. Raibert, Control of hoof rolling in an articulated leg, Proceedings of International Conference on Robotics and Automation, 1991, pp. 1386-1391.

[3] I. Poulakakis, On the passive dynamics of quadrupedal running, Master Thesis, McGill University, Montreal, Canada, 2002.

[4] R. D. Satya, Robotics Technology and Flexible Automation, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1994.

[5] S. Wolfram, Analytical Robotics and Mechatronics, Electrical Engineering Series, McGraw-Hill, Inc., New York, 1995.

[6] G. Zeglin and B. Brown, Control of a bow leg hopping robot, Proceedings of International Conference on Robotics and Automation, 1998, pp. 793-798.

[7] G. Zeglin, The bow leg hopping robot, Doctoral dissertation No. CMU-RITR-99-33, the Robotics Institute Carnegie Mellon University Pittsburgh, Pennsylvania, 1999.