A Bio-Inspired Quadruped Robot with a Global Compliant Spine

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1 Motivation

Spine is often neglected during the design of a quadruped robot, even though we all know it plays important roles in animal's body formation and motion coordination. Traditionally, a quadruped robot has rigid trunk. Without the spine, the body of a quadruped robot does not have compliancy and flexibility necessary for generating high-speed and complex motions. A rigid-trunk robot has many disadvantages, such as uncoordinated motions among legs, swaying trunk, and difficulty to increase speed and to keep balance when walking on rough terrains. To overcome the disadvantages of rigid spine, we plan to design a quadruped robot with a global compliant spine.

2 State of the Art

Most legged robots, even the so-called most advanced quadruped robot, BigDog, are designed with a rigid spine now. Some quadruped robots were designed with one or two DOFs in the trunk, namely waist joint. But this kind of trunk is not same as animals' spine, which consists of many vertebras nested each other, so that the whole spine has flexibility, can rotate in yaw, pitch and roll. The main barriers to design a compliant spine like animals' are how to design the shape and structure of the spine and how to determine the parameter of stiffness. Solving this problem involves elastic mechanics and multi-body kinematics. But for legged robot with multiple DOFs, there has not been an effective method.

3 Own Approach

In our work, a compliant spine of one-piece elastic material is designed to replace the rigid trunk of a quadruped robot to improve motion coordination among the four legs and postural stability of the trunk. Firstly, the biologically-inspired central pattern generator is modeled to produce position trajectories for the active joints of the quadruped robot to walk in trot. Based on the motion trajectories, we assumed a 10deg deformation in yaw of the spine. Then, we employed the deformation mechanism of elastic material and discretized pseudo rigid body to design the shape and dimensions of the compliant spine. We propose three types of spine shape, and analyze the stress-strain distributions of each spine comparatively then the best one is chosen. At last the postural stability of the body during walking of the quadruped robot with the best spine is evaluated quantitatively via dynamic simulations. And the coordination among the four legs is investigated qualitatively by conducting physical experiments.

4 Current Results

We have conducted the stress-strain distributions analysis and the dynamic walking simulations. The results show the stress and strain distribution is uniform and cannot cause damage to the spine. And the spine center of the quadruped robot swing less when it walks in trot. That means the compliant spine can improve postural stability positively.

5 Best Possible Outcome

We expect to construct a physical prototype, which can walk more compliantly and naturally with more stable posture of its body, more coordinated among the four legs just like their counterpart in the nature. We expect the quadruped robot can interact with rough terrains more naturally and compliantly.

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