Dynamic Scaling of a Dog Robot

Portland State UNIVERSITY

Joseph Sammartino[1] , Fletcher Young [2] , Roger Quinn [2] , Alexander J. Hunt [1]

[1] Department of Mechanical and Materials Engineering, Portland State University, Portland, OR [2]Department of Mechanical and Aerospace Engineering, Case Western Reserve University, Cleveland, OH

NSF National Science Foundation

C3NS NeuroNex Communication, Coordination, and Control in Neuromechanical Systems

Abstract:

Animals perform locomotion over different timescales and different limb lengths. These limb lengths and time scales play an important role in determining if forces during motion are dominated by visco-elastic properties, inertial properties, or damping properties. To explore how these properties may affect neural control of motion, we plan to test the effects of changing the dynamic properties of an existing robot dog at Portland State University named Muscle Mutt. Muscle Mutt uses braided pneumatic actuators as muscles and a neural controller to achieve locomotion. We will scale the damping ratio and natural frequency of the hind leg of the dog to match that of a rat or mouse by adding springs and dampers at each joint. The spring and damping constants will be set by optimizing parameters to match free-hanging experiments of live animals. We will then test theories of neural control stability for balance and walking by adjusting dynamic properties and speed of movement. We will compare results between different neural controllers at different dynamic scales to validate our hypothesis that physical dynamics play a crucial role in determining neural structure.

Forces During Motion:

There are three main regions in the mechanics space of motion. Limbs that are dominated by inertial forces have active control and active damping during motion. For limbs that are dominated by visco-elastic properties, compensatory control and active damping are unnecessary. In the third region is limbs that are dominated by elastic forces, the joint viscosity acts to damp movements, resulting in stable movements. (1)

Muscle Mutt:

Muscle mutt is quadruped robot that has three degrees of freedom on each leg. Each leg segment has a pair of antagonistic pair of braided pneumatic actuators. It achieves locomotion through a neural controller. We can use this framework to test out how the dynamics of an animal's legs affect the neural controller. (2) We can do this by building a set of modular legs that are dynamically scaled so that the damping ratio and natural frequency matches that of a rat.

Matlab Model:

We created a Matlab model of Muscle Mutt legs. The equations of motion are derived using the Lagrange method. The next part of the model that is added is theoretical components into the model. To find the theoretical visco-elastic components needed to match the joint angles of a rat, we built an optimizer in matlab.

Optimization:

We built an optimizer that optimizes nine different coefficients, damping and spring coefficients and theta bias angles, at each joint. The optimizer tries to minimize a least squares cost function of the joint angles of the input and the joint angles of the model. We have optimized the coefficients for the Muscle Mutt Matlab model. The next optimization will be optimizing for the rat legs.

Future work:

Incorperating into the Robot:

We will add springs and dampers to each joint of the hind leg, with the coefficients equal to those calculated in the simulation.

Neural Controller Test:

More future work to be done. We will compare two different neural controllers. One for the dog robot with the original legs, one for the rat legs, and then switch them to see how the controller performs with different dynamics.

Conclusion:

Having the optimization procedure finalized, optimizing the model with animal data will calculate the leg parameters. We are going to work on designing the legs with these parameters as visco-elastic components. Then we will compare the results between the two controllers.

References:

(1) G. Sutton, N. Szczecinski, H. CHiel, R. Quinn. **"Neural control of rhythmic limb motion is shaped by size and speed" Pre-draft**

(2) C. Scharzenburger "Design of a Canine Inspired Quadruped Robot as a Platform for Synthetic Neural Network Control" Masters Thesis