Series Elastic versus Parallel Elastic Actuators in Hopping Robots

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Introduction

For hopping robots in the 3kg range, high hop-to-hop energy restitution has not been reported [1], [2]. We built several hopping robots based around elastic energy storage in high coefficient of restitution spring steel leaf springs to explore means of improving energy efficiency in a hopping gait. We present lessons learned from hopping robot design when using both series elastic and parallel elastic actuators. With series elastic actuation our best restitution was 11.2%; with parallel actuation using the same springs and motors gave 49±5%

Methods

We collected data at 100Hz using a reflective-marker-based motion tracking system (Qualisys). Markers associated with the rigid robot “torso” marked height above ground.

We computed restitution by dropping the robot and calculating the ratio between drop height and the height of the following bounce. We zeroed measured heights by subtracting the height of the robot at rest on the ground. We measured this reference height at the start of every trial.

We performed three different types of trial: first with the spring legs unbent, second with the motors holding a motor position of 10 degrees, third with the motors holding a motor position of 20 degrees.

Results

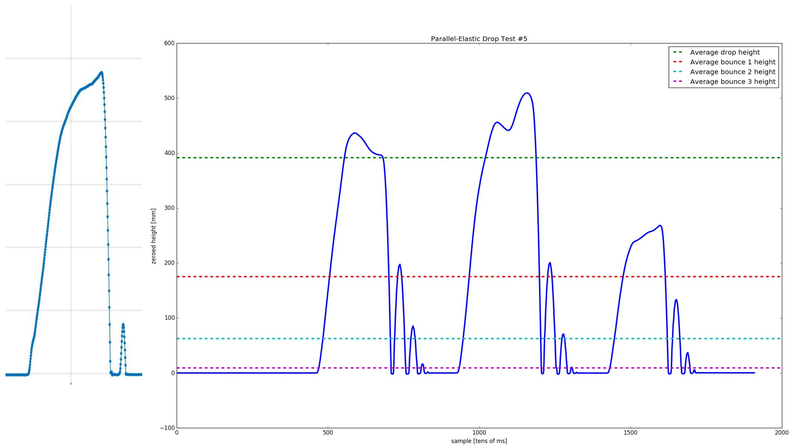

Fig. 1. A comparison of series elastic actuator restitution (left) versus parallel elastic actuator restitution (right) on our hopper.

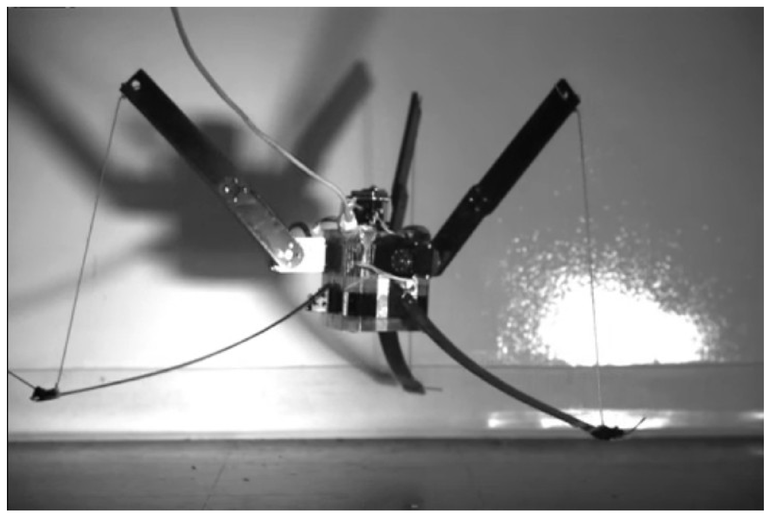

Fig 2. Image of hopping robot.

Discussion

Despite the ability to develop arbitrary control laws that mimic conservative systems using techniques like passivity-based control or inverse dynamics, most commercial motor controllers operate in specific modes, e.g. position or torque control. In these modes, ground collisions tend to be treated as disturbances, which damps out any stored energy. To build hopping robots using commercial controllers with significant energy restitution, a parallel path for energy storage, such as a parallel elastic element, is needed.

References

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Acknowledgments

Our current and recent funding is from the following projects:

- ARO W911NF-14-1-0573
- ARO W911NF-17-1-0243
- ARO MURI W911NF-17-1-0306
- NSF CMMI 182591