Multi-Body Dynamics in Whole-Body Locomotion: Dynamics of Elastically Suspended Loads

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1 Motivation

There is increasing need to understand the role multiple bodies or flexible (non-rigid) bodies play in the dynamics and control of legged locomotion. This is an area of interest to biologists as well as roboticists. Robots can potentially benefit because multiple or flexible bodies, if designed properly, can potentially enhance the dynamics and adaptive capabilities of legged robots. In particular, robots using elastically suspended loads have been shown to have several benefits including reduced energetic cost of locomotion. However, approaches to understanding this aspect of biology or assist in the design of such robotic systems requires greater theoretical development.

2 State of the Art

There have been recent articles published on the suspended load backpack [5, 6] and the modern horse jockey riding style [4]. Before that, Kram published work on suspending mass on elastic poles [3]. Further, work on tail-righting maneuvers and active back bending in lizards have caused many to wonder what role these multi-body dynamics play. In some cases, these mechanisms have been shown to enhance locomotion. There may still be additional areas where such complex mechanisms exist. If they do enhance locomotion, how can we quantitatively and qualitatively predict their affects? In other words, how do we model these phenomena to understand them from first principles? We focus here on elastically suspended loads in locomotion.

Currently the majority of work investigating elastically suspended loads is experimental in nature and has discovered some benefits to reducing forces and energetic cost of locomotion. The underlying mechanism responsible for these improvements is still not well understood. There appears to be some required coupling between the suspended load and the dynamics of legged locomotion to produce a net benefit such as reduced metabolic cost. While some numerical simulations of suspended load backpacks exist, there are very few activities to model the fundamental dynamics of this behavior mathematically. Further, no physical robot models currently exist to test basic hypotheses about elastically-suspended loads.

3 Approach

Our approach is to first mathematically model simplified versions of legged locomotion with a suspended load. These models include SLIP-like models with am additional mass that is coupled through some load suspension mechanism and double-mass hopper models [1]. This approach leads to predictions and theoretical development of the dynamics of locomotion with a suspended load. Second, we test these predictions using a simplified robotic model of elastically suspended loads [2].

The authors have several current studies in progress using this approach, and will present new data, models, and experimental designs.

4 Discussion

During a talk or poster presentation, we intend to address the following questions regarding multi-body locomotion, especially concerning elastically suspended loads:

Why can elastically-suspended loads enhance locomotion?

What is the origin of such mechanisms in biology?

Are these complex mechanisms essential to fully capable locomotion, a nuisance based on biological history, or simply an additional benefit to take advantage of?

Are there other applications of elastically-suspended loads in legged locomotion systems?

If these provide additional benefit to locomotion, what kind of benefit can be achieved?

How do we model these phenomena?

These questions are important to developing a theory of legged locomotion with elastically-suspended loads. The answers to these questions can help explain the phenomenon of elastically-suspended loads in biology and provide new testable hypotheses for the implementation of elastically-suspended loads for human and robot applications. The full potential of elastically-suspended loads has yet to be fully explored and realized.

5 Preferred Format

15 minute talk, 5 minute talk, or poster.

References

[1] J Ackerman and J Seipel. Coupled-oscillator model of locomotion stability with elastically-suspended loads. to appear at the 2011 ASME IDETC, 2011.

[2] J Ackerman and J Seipel. Energetics of bio-inspired legged robot locomotion with elastically-suspended loads. to appear at the 2011 IEEE IROS conference, 2011.

[3] R Kram. Carrying loads with springy poles. *Journal of Applied Physiology*, 71(3):1119, 1991.

[4] T Pfau, A Spence, S Starke, M Ferrari, and A Wilson. Modern riding style improves horse racing times. *Science*, 325(5938):289, 2009.

[5] LC Rome, L Flynn, EM Goldman, and TD Yoo. Generating electricity while walking with loads. *Science*, 309(5741):1725, 2005.

[6] LC Rome, L Flynn, and TD Yoo. Biomechanics: Rubber bands reduce the cost of carrying loads. *Nature*, 444(7122):1023–1024, 2006.