University of Stuttgart
Institute for Nonlinear Mechanics

Master's thesis
Term paper

Impact Laws for Energetically Conservative Legged Systems

Topic Areas: Nonlinear (Hybrid) Dynamics, Geometry Numerics, Simulation

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Prerequisites/Prior Knowledge: Mechanical Engineering (Dynamik Mechanischer Systeme)

Identifying periodic motions (gaits) in legged models is essential for controller design and motion planning of robotic systems. Previous work [1] has shown that particular conservative legged systems, in which there is no energy dissipated, generate a connected set (Fig. 2) of a broad range of gaits. Hence, without any prior knowledge about locomotion characteristics, different gaits like skipping, running, and walking can be systematically found. However, legged models naturally dissipate energy when they undergo inelastic collisions, i.e., when feet make contact with the ground. Thus, to yield a conservative bipedal robot (Fig. 1), the foot masses which are involved in the kinetic energy loss at impacts, are scaled to zero [1]. This approach, however, results in singular mass matrices and is difficult to generalize for more complex models.

In this project, you are asked to contrast old and new impact laws (Chapter 4.2 & 6 in [2]) that do not require the scaling of masses and inertias to yield the desired conservative dynamics. Herein, you will investigate, implement and simulate different simplistic models like the biped in Fig. 1 and draw connections to Newton's law of impact which is commonly used in legged systems [1].
Furthermore, you will investigate how different projections (Fig. 3) could be superior to Newton's law in the presence of multiple simultaneous collisions.

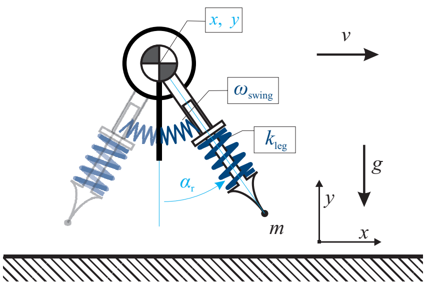

Figure 1: Model of a Planar Bipedal Robot

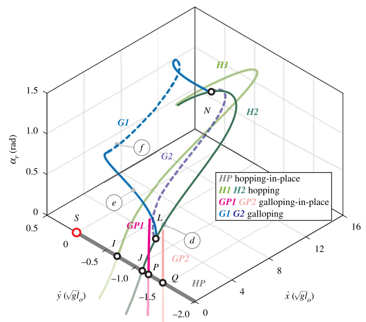

Figure 2: Connected (Conservative) Gaits

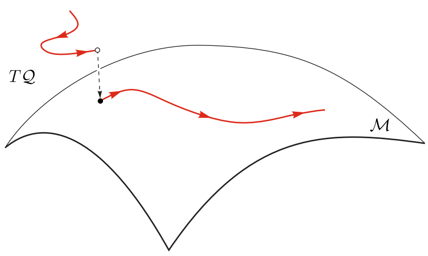

Figure 3: Projection onto Collision Space

[1] Gan, Zhenyu, et al. *All common bipedal gaits emerge from a single passive model.* Journal of The Royal Society Interface. (2018)
[2] Brogliato, Bernard. *Nonsmooth Mechanics: Models, Dynamics and Control.* Springer. (2016)