Planning quadrupedal gaits in granular media with geometric mechanics

Julian Whitman[1], Baxi Chong[1], Yasemin O. Aydin[2], Chaohui Gong[1], Jennifer M. Rieser[2], Guillaume Sartoretti[1], Daniel I. Goldman[2], and Howie Choset[1]

[1] The Robotics Institute
Carnegie Mellon University
Pittsburgh, PA, USA
jwhitman@cmu.edu

[2] School of Physics
Georgia Institute of Technology
Atlanta, GA, USA

In both biological and robotic articulated legged systems, coordination among the limbs and body contributes to effective locomotion. In this work, we use geometric and robophysical models to examine salamanders' leg-body coordination as they crawl through granular substrates. We use a simplified model with nine degrees of freedom, one in its spine and two in each of its four legs. We use geometric mechanics tools to plan full-body gaits that maximize body displacement in the two-dimensional space of spine bend and gait cycle phase over a range of leg swing timings. The coordination patterns we find are comparable to those observed in biological salamanders. Next, we validate these gaits on a nine degree-of-freedom robot model in a bed of granular media, and find that the trends in coordination and displacement match between the robotic experiments and geometric analysis. Our results provide insight into the necessary changes in coordination between body and limb movements as the system adapts its gait for speed and terrain changes.