Geometric Insights for Data-Driven Gait Analysis

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Abstract

Energetically optimal gaits are of interest to both robotics and biology communities. Two respective goals are: (a) finding goal functions for learning robot gaits which produce stable and efficient motion [1], [2]; and (b) assessing biomechanical optimality of behaviors in organisms [3]. A common pitfall of the former goal is a cumbersome experimental requirement, as each candidate gait must be physically tested. The latter goal is challenging because it is difficult to assess the actual energetic cost organisms incur.

Our contribution to solving these problems is a novel approach for building gait-centered, local models from data. By using data-driven analysis tools for oscillators [4] to inspect geometric locomotion models of systems, we can predict system performance given small gait modifications. Our techniques are currently restricted to friction dominated regimes in which the mechanical connection and cost of developing kinetic energy govern the cost of transport (such as in [5], [6]). These local models eliminate the requirement for the empirical verification of small design modifications in (a) and provide a pathway for benchmarking biological gait optimalty in (b).

We applied our methods to learning a swimming / slithering gait for a simulated 9 link swimmer [7], initialized from a simple gait that used only two of the motors. Our algorithm converged to a gait that looks serpentine after a dozen trials of 30 cycles each, in an 88 parameter gait space. This is notable for two reasons: (a) a typical simplex gradient optimization, e.g. the Nelder-Mead algorithm, would require 89 trials just to initialize the search routine; (b) at each gait, we relied on the simulated system noise to produce enough variability to allow the gait parameter gradients to be identified.

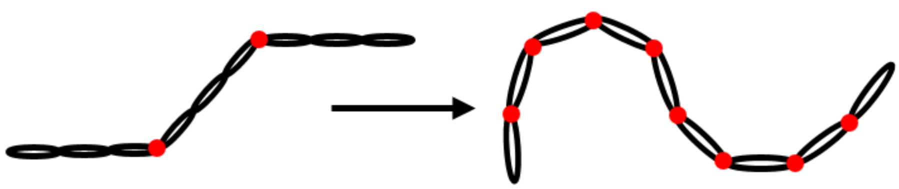

Fig. 1. A nine link swimmer converges quickly to a serpentine behavior, even though the initial strategy locks 75% of the joints. A key feature of this approach is that system noise is welcomed here. System noise directly informs the local models, providing a broader view of the system's dynamical landscape. This allows the swimmer to procedurally improve its performance with each physical test.

We are in the process of constructing a data-driven criterion for geometric gait optimality. Future plans include fitting models to biological motion-capture data, allowing us for the first time to address optimality of gaits without detailed mechanical locomotion models.

References

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