From Ostrich to Quail: A Simple Unified Model of Ground-Bird Running

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1 Motivation

Ground birds exemplify robust and agile bipedal locomotion, dexterously running over both hidden and visible obstacles. Birds also span the largest size range of all extant bipeds. Through trajectory optimization of simple hypothesized models derived from broad cross-species running experiments, we aim to reveal an underlying model and set of control objectives for the dynamic running of birds.

2 State of the Art

Work-optimal control predicts general features of animal locomotion [1] and reduced-order bird models to date have generally been energy conservative [2]. Approaches have been proposed to discover biological models or control objectives through hybrid-zero dynamics [3] and trajectory optimization [4] respectively. Instead, by targeting a specific hypothesis, we aim to reveal both.

3 Own Approach

We hypothesize that a simple spring-mass model with damping and actuation (Fig 1a) can explain key data features. In particular, we seek to explain kinematic and ground-reaction force (GRF) data collected for level running of five bird species, spanning a 540-fold mass range. By using trajectory optimization and nonlinear regression in tandem, we identify the spring stiffness and damping coefficient for which work-optimal control best matches bird force data.

4 Current Results

Our model produces tight correlations to the force data across all observed species (Fig 1b). Particularly, we observed a notable asymmetry in the GRF across all species (similarly observed in humans [5]), an inexplicable feature for conservative models. We explain this "tail" phenomenon as a work-optimal control response to inherent leg dissipation, a novel insight. This being only a two-parameter fit suggests 1) birds of all sizes prioritize minimum-work actuation and 2) the actuated model is a valid approximation of steady-running birds of all sizes.

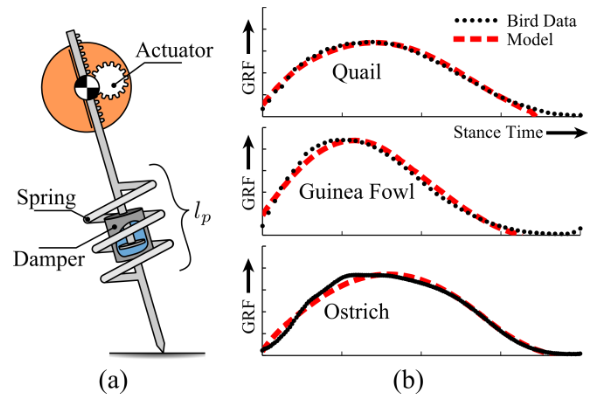

Figure 1: (a) Spring mass model with actuation and damping (b) Preliminary fitting of work-optimal control and bird GRF

5 Best Possible Outcome

We believe discovering strong model predictions within this broad data set represents insight into the fundamental objectives and features of dynamic legged locomotion, in birds or otherwise. Such codified principles could be applied directly to running robots.

Acknowledgement

This work is supported by Human Frontier Science Program (RGY0062/2010).

References

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