From Running Birds to Walking Robots: Optimization as a Unifying Framework for Dynamic Bipedal Locomotion

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Abstract
Bipedal locomotion is a complex phenomenon to understand and control, making it difficult for legged robots to achieve the speed, agility, efficiency, and robustness of their animal counterparts. To close this gap in performance and understanding, this thesis argues for using numerical optimization to investigate and implement bipedal control as it applies to biology, dynamical models, and robots alike. This work uses trajectory optimization as its primary tool for analyzing and synthesizing bipedal locomotion control in its arguably most dynamic domains: aerial running in cursorial birds and underactuated walking and running in robots. We present 1) an investigation uncovering the task-level control objectives of ground-running birds from quail to ostrich, 2) modeling investigations into control strategies that optimize these objectives, and 3) the design of a highly dynamic robot and the optimal walking control thereof. As a general conclusion, we posit that dynamic and biologically bipedal locomotion can be achieved by optimizing energy costs while strictly avoiding injurious forces and satisfying practical locomotion task constraints.

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