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Modeling adaptive locomotion behaviors using risk- aware optimal control

Locomotion in animals is plastic and adaptive to changing environments and physical capabilities. We present a computational framework for modeling locomotion behaviors that are both extemporaneous and shaped by prior experience. This modeling framework builds atop a trajectory optimization approach, which synthesizes behaviors for a math-modeled organism that minimizes a pre-defined cost. Traditionally, trajectory optimization is used to generate individual gaits for legged locomotors by minimizing energy costs. Our approach expands on existing methods by 1) continually re-optimizing behavior during simulation, 2) minimizing a probabilistic risk of failure (e.g. predation or energy loss), and 3) updating failure probability estimates from learned experiences. These extensions equip the framework with extemporaneous behavior, emergent prioritization, and acquired personality traits based on experience, respectively. As a primer, this presentation will introduce the foundations of continual trajectory optimization, called "model-predictive control" (MPC). Further, we will demonstrate how minimizing overall failure probability allows the framework to reprioritize behavior based on immediate need. For instance, a starving animal may put itself at greater risk of predation to forage for food. Lastly, we will show how varied experiences with stochastic risks (e.g. a chance injury) can create emergent "bold/shy" personalities in simulation. Example simulations range from simple double- integrator models to running bipeds. These proof-of- concept simulations are a steppingstone toward unifying behavior at the biomechanical level with larger environmental and ecological pressures.