

ABSTRACT

Bipedal robots navigating dynamic environments must avoid collisions while maintaining stable and efficient locomotion. While both model-based and learning-based approaches have enabled impressive locomotion capabilities, the challenge of intelligently adjusting stepping strategies for different environments remains underexplored. In particular, stepping mode (contact sequence) and stepping frequency are critical factors in shaping walking performance.

This thesis presents a control framework that advances bipedal locomotion in the following ways: (1) We develop a real-time Model Predictive Control (MPC) framework that enables bipedal robots to autonomously switch between standing and stepping avoidance modes, enhancing maneuverability where the problem is formulated as a convex Quadratic Programming (QP) problem for computational efficiency. (2) We introduce a novel step-timing adjustment strategy based on the MPC solution to improve responsiveness to dynamic, fast-moving obstacles. (3) To handle ground-level obstacles, we decompose the nonconvex foot-level safe regions into several convex candidates and determine optimal footholds using Mixed-Integer Quadratic Programming (MIQP). A minimum travel-distance constraint is also incorporated to enable selection between stepping over or around obstacles. (4) An A* global planner is integrated to generate a valid global-level path, providing guidance to the MPC. (5) The proposed framework is validated through simulations and hardware experiments on two 3D bipedal robot platforms, Cassie and Digit, demonstrating effective real-time obstacle avoidance and adaptive stepping behavior.