Robustness and Efficiency of Planar Biped Walking Robots

Abstract

by

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Legged robots are desirable for many applications, especially in man-made environments where having legs is a distinct advantage over having wheels. The legged robots in these applications must be both robust to disturbances and energetically efficient, and achieving these characteristics represents two of the most pressing challenges within the field. This work seeks to experimentally demonstrate that the use of curved feet under hybrid zero dynamics (HZD) -based control offers efficiency benefits and to make HZD-based controllers more robust to velocity disturbances. These aims were investigated using the biped robot ERNIE, which was transitioned from treadmill walking to continuous overground walking.

Efficiency improvements of curved feet over point feet were demonstrated by improving a previous model to appropriately account for curved foot impacts. Curved foot gaits, in general, had decreased specific resistance, a measure of energy consumption per distance traveled, and smaller joint errors compared point-foot gaits at similar speeds. Robustness improvements were made by developing new controllers to reject velocity disturbances in experiment. An orbit-stabilizing control approach was successful at rejecting impulsive angular velocity disturbances applied to a simplified system in simulation, but the approach was too complex to implement in hardware. However, heuristic rules for disturbance rejection in hardware were developed from implementing the dominant control responses to disturbance
from the orbit-stabilizing controller. These control actions modify the trajectories of the torso and swing leg in response to a deviation from desired forward hip velocity. The heuristic-based control had increased efficiency (lower specific resistance) compared to the HZD-based control, smoothing the average step velocity around the room by reducing the accelerations and decelerations present with the original controller. Additionally, in response to both acceleration and deceleration disturbances, the heuristic-based controller returned to within 10% of the desired average step velocity in at least half the steps as with the HZD-based controller.