Stability Analysis of Biped Robots

by

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Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

April 2024

Abstract

This thesis primarily focuses on the stability of biped robots under different circumstances. In the last six decades of biped research, the goal has been to make them capable enough to live with humans in the real world and be used in applications, namely, disaster management and extra-terrestrial locomotion, where the employment of human life is risky. To achieve this goal, the stability of bipeds in different environmental conditions needs to be investigated. While there have been many advancements in biped research, the limitations of surrounding environmental conditions, e.g., the terrain geometry, stance scenario, and magnitude of external disturbance, still exist on stable locomotion and stance stability.

At the beginning of this thesis, the dynamic modelling of a biped was performed in the dual algebra framework. Apart from conventional equations of motion, this formulation yielded analytical expressions for reaction forces along joint axes that had not been explored before. The equations of motion were used to model stable underactuated locomotions on various geometrical surfaces. A methodology was proposed to achieve stable locomotion on various surfaces,i.e., level ground, 2^o and 4^o inclined grounds, and a circular surface with radius of curvature 8m by altering the controller gains.

Further, the stance stability of bipeds against external disturbances was analyzed. If the external disturbance does not cause significant changes in the system's states, stability can be achieved by proper Centre of Mass (CoM) or Centre of Gravity (CG) placements without using any controller. An exact theory was developed to study the static stability of a planar biped in Euclidean space. The contact geometries were considered generic, unlike the special cases of line and point contact geometries in the recent literature.

If the external disturbance causes significant changes in the system's states such that the CoM placement is not sufficient for stability, controller action is required. It is also known as push recovery. In the present work, a novel control and optimization methodology has been developed and implemented on a 12-DoF biped for push recovery from different stance scenarios, i.e., double leg stance on a level ground, double leg stance on two level grounds offset by a height and single leg stance. Using newly introduced terms, 'Effective Disturbance Ratio' (EDR), and 'Effective Disturbance Support Ratio' (EDSR), it was shown that our proposed methodology performed better than the existing methodologies for push recovery across different contact conditions. A real prototype was developed to test the simulation results.

Keywords: Biped, Dynamics, Stability, Locomotion, Stance, Contact, Push Recovery.