Using Torque Redundancy for an Optimal Distribution of Contact forces: An Application to Legged Locomotion

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Abstract

The development of legged robots for complex environments requires controllers that guarantee both high tracking performance and compliance with the environment. More specifically the control of contact interaction with the environment is of crucial importance to ensure stable, robust and safe motions. Traditional model-based torque control approaches, such as inverse dynamics controllers, developed for fully actuated open-chain manipulators offer an appealing way for guaranteeing both high tracking performance and compliance with external contacts. However legged robots constitute a different class of control systems as they are inherently underactuated due to their floating base and subject to switching contact constraints. In particular when there are more contact constraints than degrees of under-actuation, there is an infinite number of torque choices that can achieve a desired motion. Usually torque redundancy is resolved by minimizing a quadratic cost in the commands under a given metric, which, for instance, can result in a minimization of the total command. In this presentation, we discuss how we can use torque redundancy to directly and explicitly minimize any quadratic cost in the contact constraints. Such a result is particularly relevant for legged robots as it allows to use torque redundancy to directly optimize contact interactions. For example, given a desired locomotion behavior, it can guarantee the minimization of contact forces to reduce slipping on difficult terrains while ensuring high tracking performance of the desired motion. The proposed controller is very simple and computationally efficient, and most importantly it can greatly improve the performance of legged locomotion on difficult terrains as can be seen in the experimental results.