Carnegie Mellon University

THE ROBOTICS INSTITUTE

THESIS PROPOSAL

Stability-Centric Mechanics for Rigid Body Manipulation

Tuesday, February 25, 2020

4305 Newell Simon Hall

3:00 p.m.

Thesis Committee:

Matthew T. Mason
Chair

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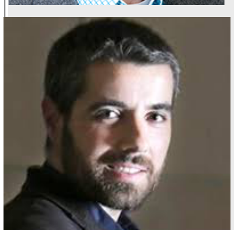

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Abstract

The repertoire of human manipulation is filled with creative use of contacts to move the object about the hand and the environment. It's the combination of these skills that makes human manipulation dexterous. However, in most robotic applications the robot just fix all contact points on the object and do grasping. Reliable robot manipulation beyond grasping is still rarely seen.

The difficulty comes from the multiple possible contact modes in a manipulation system. Failure or even physical damage could happen to a motion plan or controller if the system falls into an unexpected contact mode, which could be the result of the inevitable modeling uncertainties and disturbances. Most of existing approaches do not consider how to avoid unexpected mode switching, or only design heuristics for a specific system. To this end, a mechanical analysis method that evaluates not only feasibility but also contact mode stability is essential for reliable real world robotic manipulation.

This thesis provides such a mechanical analysis method for quasi-static rigid body manipulation problems. We address three aspects of the problem. First we study how contact mode breaks and transits to another, and provide criteria to measure the stability of a contact mode against different failure types. Second, we provide a robust control strategy to reliably execute manipulation under modeling uncertainties and disturbances. Finally, we propose a new view to single object manipulation problems called shared grasping, and provide a geometrical analysis method that directly evaluate the magnitude of disturbance wrenches the system can tolerate for any mode, so that we can select the most stable mode and pick robust control easily. We adopt a realistic expectation of robot hardware abilities and demonstrate reliable manipulation in a variety of settings.