Course Description and Grading

Description: Robotic manipulation is the art and science of the mastery of contact to purposefully change the physical world. In this course, we will study what it takes to build autonomous systems that can bring about this change. To this end, we will cover the fundamentals of contact mechanics, perception, planning, and controls for manipulation. The course blends classical and modern methods and introduces a variety of open research problems.

The material presented focuses on applied robotic manipulation in unstructured environments such as kitchens and offices where uncertainty and decision-making play a pivotal role. We will make extensive use of simulation for homework problems and real-world implementation on hardware for the course project.

Topics covered include:

1. Mechanics of Manipulation – 7 sessions
    - Preliminaries of rigid-body contact mechanics
    - Grasp analysis and synthesis
    - Patch and surface contact models – context of planar pushing
    - Rigid-body dynamical systems undergoing Coulomb frictional interactions - complementarity formulation
2. Perception and State-estimation for Manipulation – 7 sessions
    - Cameras and tactile sensors
    - Object detection, segmentation, and localization
    - Multi-modal state-estimation
    - System identification, contact formation estimation, and constraint inference
3. Planning for Manipulation – 6 sessions
    - Grasp planning
    - Planar manipulation planning
    - Trajectory optimization through contact
    - Introduction to Task and Motion Planning with Push-Grasp Synergies
    - Introduction to Learning for Manipulation Planning
4. Controls for Manipulation – 6 sessions
    - Task-space controls and Dynamic Motion Primitives
    - Hybrid position-force control in fully actuated mechanisms
    - Hybrid systems control through mode schedules
    - Impedance control for contact
    - Model predictive control through contact
    - Reinforcement learning for manipulation

Grading 7 coding assignments: 55%. Open-ended project culminating in a 4-6 page paper: 25%. Quizes 15%. Class Participation: 5%. Assignments can be done in small groups, but each participant must submit an individual copy.

Recommended Prerequisites Linear algebra, probability theory, optimization. Homework assignments code is in Python – these requirements are generally not enforced but familiarity is strongly recommended.