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Title: Manipulation Planning for Humanoids: Finding Constrained Goal Configurations and Planning Low-Cost Feasible Paths

Abstract: This talk addresses to key problems in motion planning for humanoids: 1) Finding a feasible goal configuration for cluttered environments that obeys humanoid constraints (e.g. balance, closed-chain kinematics, etc), and 2) Planning with soft constraints, which can enable a wide range of humanoid behavior. I will present our work in these two areas and discuss prospects for future exploration.

Planning motion for humanoid robots requires obeying simultaneous constraints on balance, collision-avoidance, and end-effector pose, among others. Several algorithms are able to generate configurations that satisfy these constraints given a good initial guess, i.e. a configuration which is already close to satisfying the constraints. However, when selecting goals for a planner a close initial guess is rarely available. Methods that attempt to satisfy all constraints through direct projection from a distant initial guess often fail due to opposing gradients for the various constraints, joint-limits, or singularities. We approach the problem of generating a constrained goal by searching for a configuration in the intersection of all constraint manifolds in configuration space (C-space). Starting with an initial guess, our algorithm, Constellation, builds a graph in C-space whose nodes are configurations that satisfy one or more constraints and whose cycles determine where the algorithm explores next. We compare the performance of our approach to direct projection and a previously-proposed cyclic projection method on reaching tasks for a humanoid robot with 33 DOF. We find that Constellation performs the best in terms of the number of solved queries across a wide range of problem difficulty. However, this success comes at higher computational cost.

Once a goal configuration is found, we would also like to plan a path to that configuration that is not only feasible, but has a low-cost in terms of criteria like path length, distance from obstacles, etc. However, finding paths in high-dimensional spaces becomes difficult when we wish to optimize the cost of a path in addition to obeying feasibility constraints. Existing algorithms for this problem have difficulty navigating *cost-space chasms*–-narrow low-cost regions surrounded by increasing cost. Such chasms are particularly common in planning for manipulators because many useful cost functions induce narrow or lower-dimensional low-cost areas. I will present the Gradient-RRT algorithm, which combines C-space sampling with a local gradient method to bias the search toward lower-cost regions. Gradient-RRT is effective at navigating chasms because it explores low-cost regions that are too narrow to explore by sampling alone. I will show examples of this algorithm finding low-cost paths with several different types of cost functions, one of which encodes planning-with-uncertainty.