Multi-Step Planning for Robotic Manipulation

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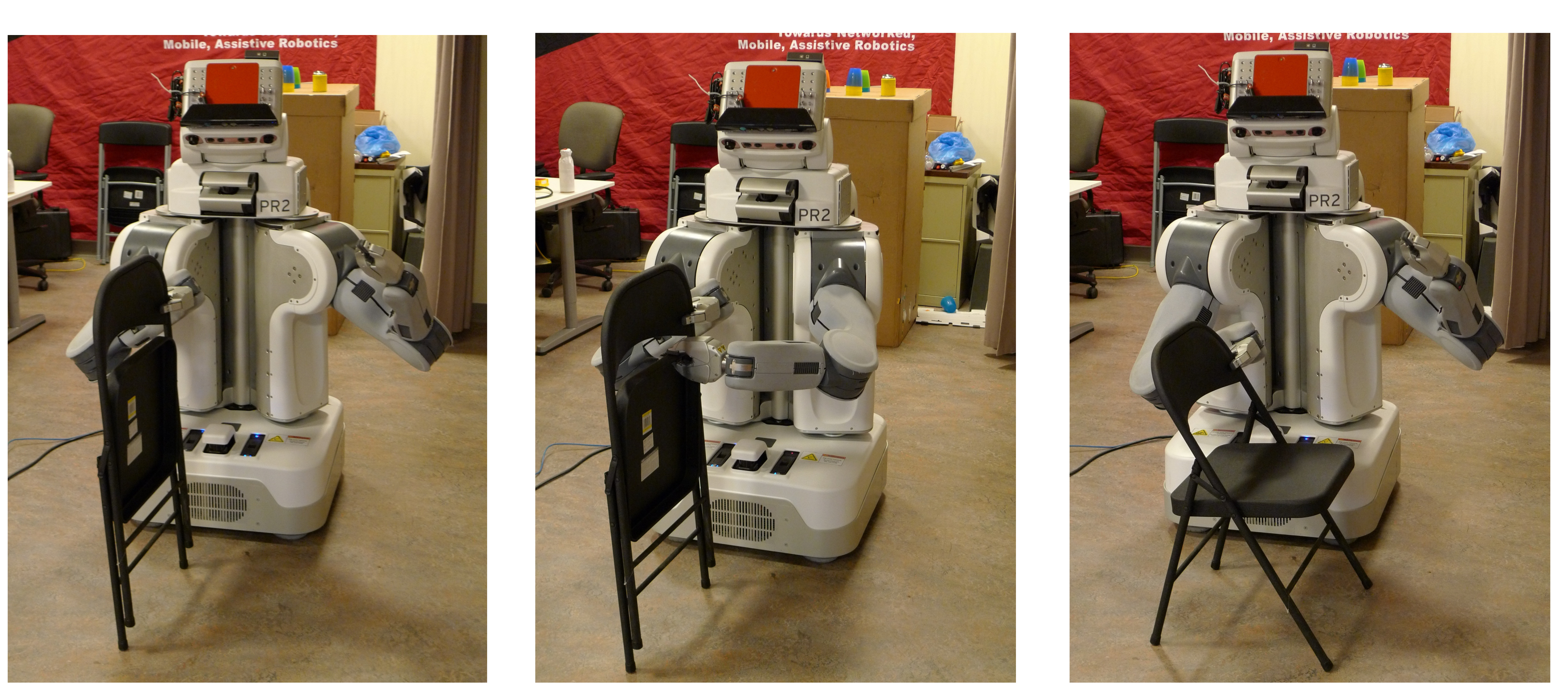
Problem Statement
We are developing a planning approach for complex robotic manipulation tasks. We are specifically interested in problems where there is a large state space involving interacting and uncontrolled elements. To solve these problems we are using a multi-step planning approach that combines continuous and discrete planners.

Terminology

configuration: the full combined state of the robot and object

stance: a state in the unactuated dimensions of the configuration space, plus the state of the robot grippers

transition: a configuration that is valid in multiple grasp stances (such as where one gripper can be open or closed), such that the robot can move from one grasp stance to another by opening or closing a gripper in this configuration



Left: An initial configuration
Center: An example of a grasp stance with one gripper on the back and the other on the seat of the chair
Right: A potential goal configuration

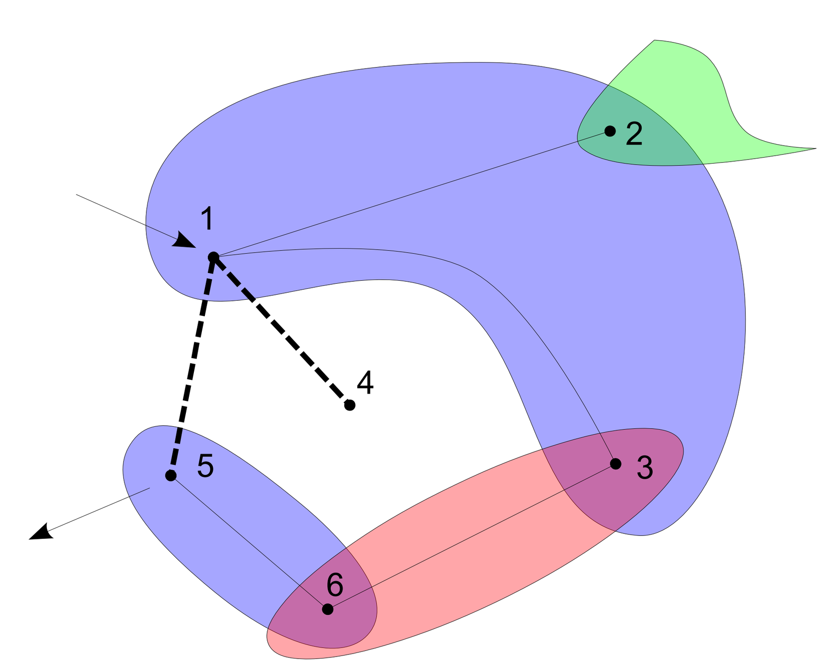
The Folding Chair
We are working to demonstrate this planning approach by implementing a planner that will decide how to grasp and move to unfold a standard folding chair. This is non-trivial manipulation that will test the kinematic limits of the robot and require the planner to make decisions about grasps and re-grasps.

The characteristics of the chair are fully specified a priori, and we are able to use simple inverse kinematics to sample transitions where stances overlap in configuration space.

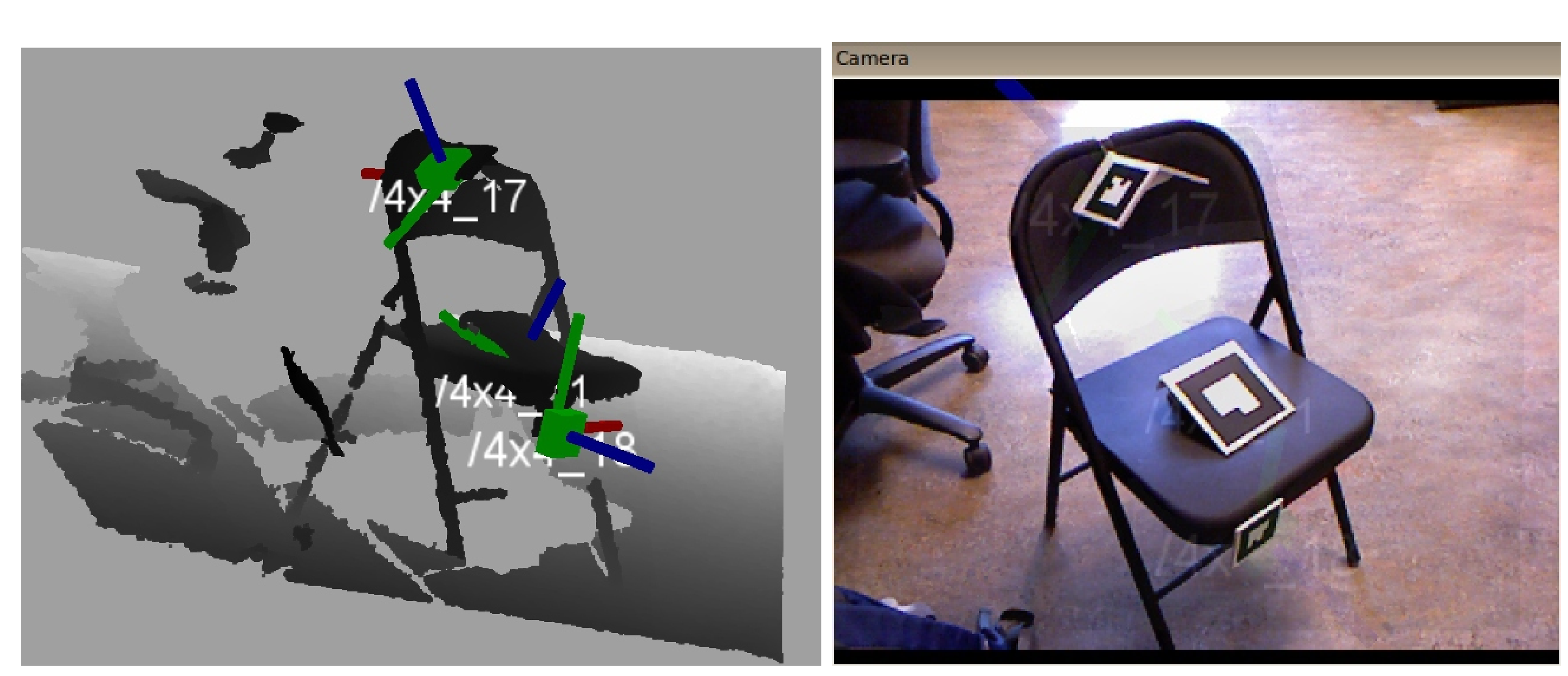
Approach
We structure the problem by breaking it into a discrete planning problem through the set of transitions. The discrete planner is allowed to step from one transition to another if two conditions are satisfied: the transitions have a stance in common, and a feasible trajectory exists (in continuous space) from one transition to the next through the common stance.

Thus, a completed plan forms a path with transitions as way-points, with a gripper state change at each way-point, and a continuous trajectory between way-points.

The diagram below shows a simplified example of a configuration space for a multi-step problem. The shaded regions represent the configurations which are valid for a particular stance. State 1 is the initial state and state 5 is the goal. State 1 and 5 are in the same stance, but there is no valid trajectory between them, but by exploring a path through stance 2, the planner is able to reach the goal.



Chair Detection
We use an array of AR Tag style markers affixed to the major parts of the chair to detect and track the pose of the chair. At left is a visualization of the point cloud of the chair with rendered markers shown where tags are detected. At right is the camera image the from which those markers were detected.



Future Work
We are interested to see how this approach will scale to problems of increasing difficulty. One of the key challenges here will be detecting the structure and constraints of the world in a form that is useful to the planner. Being able to specify manipulation goals in terms of world state instead of robot joint positions would be a significant enabling technology in robotics.

http://robotics.usc.edu/~max/