Constraint-Based Methods for Integrated Task and Motion Planning

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Robotic Planning

Planning – finding a sequence of actions to accomplish goals

Objective – develop generalizable planning system independent of domain, robot and environment

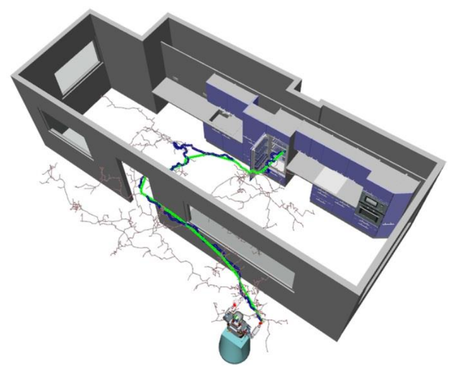
Applications – shipping, debris cleanup, household chores, search and rescue, …

Pick and Place Domain – grasp and transport objects to goal positions while avoiding colliding with obstacles [1]

[1] Wilfong, “Motion planning in the presence of movable obstacles,” 1988

Background

Motion Planning – finding motor specific actions to navigate between two robot configurations



Task Planning – abstract, symbolic planning through states described by propositional formulas

Combination of Task and Motion Planning reduces exponential dimensionality of planning [2]

Central Problem - committing to specific geometric choices early on can cause extensive backtracking [3]

Other Approaches and Problems

- Manipulation Graphs [4] – doesn’t scale with many objects
- Linear Programming [5] – only convex constraints

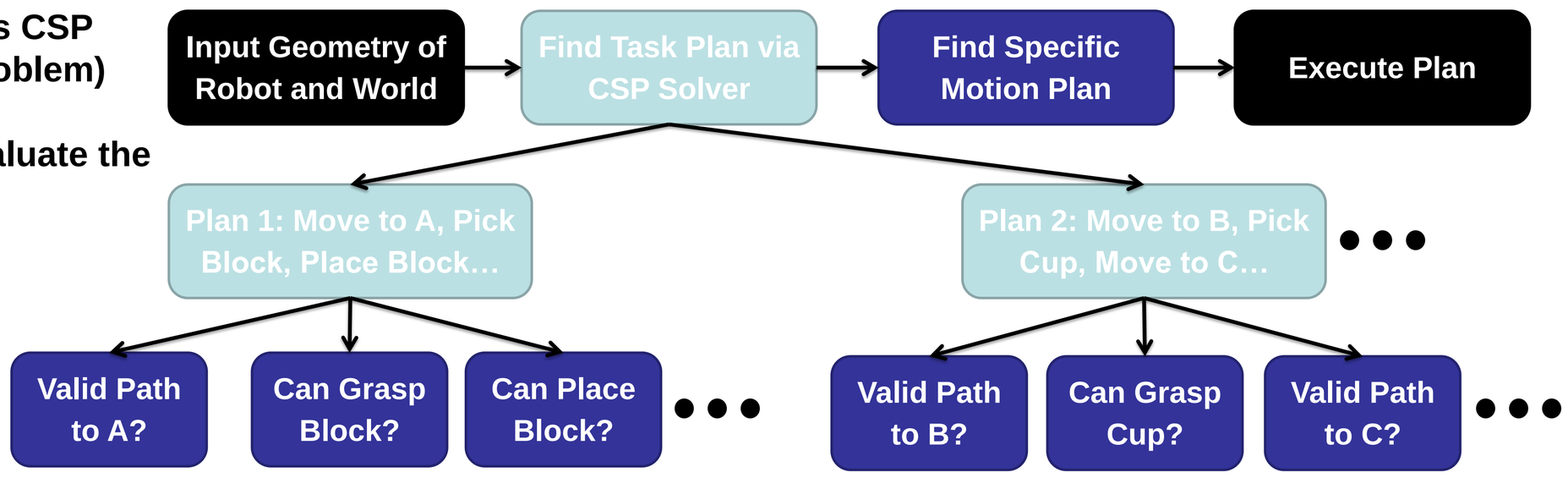
[2] Kaelbling et al. , “Hierarchical task and motion planning in the now,” 2011
[3] Lozano-Perez et al., “A constraint-based method for solving sequential manipulation planning problems,” 2013
[4]Simeon et al., “Manipulation planning with probabilistic roadmaps,” 2004
[5] Lagriffoul et al., “Constraint propagation on interval bounds for dealing with geometric backtracking,” 2004

Hierarchical Constraint Satisfaction Problem

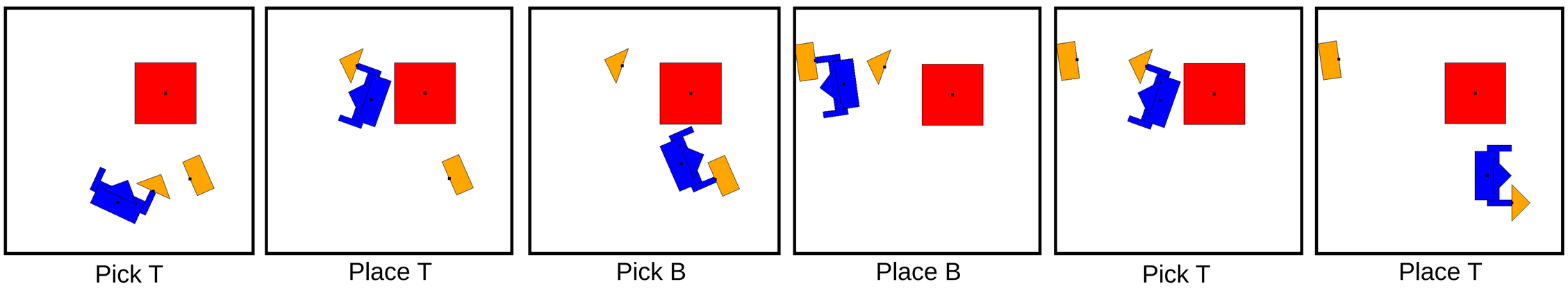
Formulate Task Planning as CSP (Constraint Satisfaction Problem)

Use Motion Planning to evaluate the constraints

- Configuration reachable
- Grasping object
- Object in region
- Objects not colliding



Re-grasp Problem

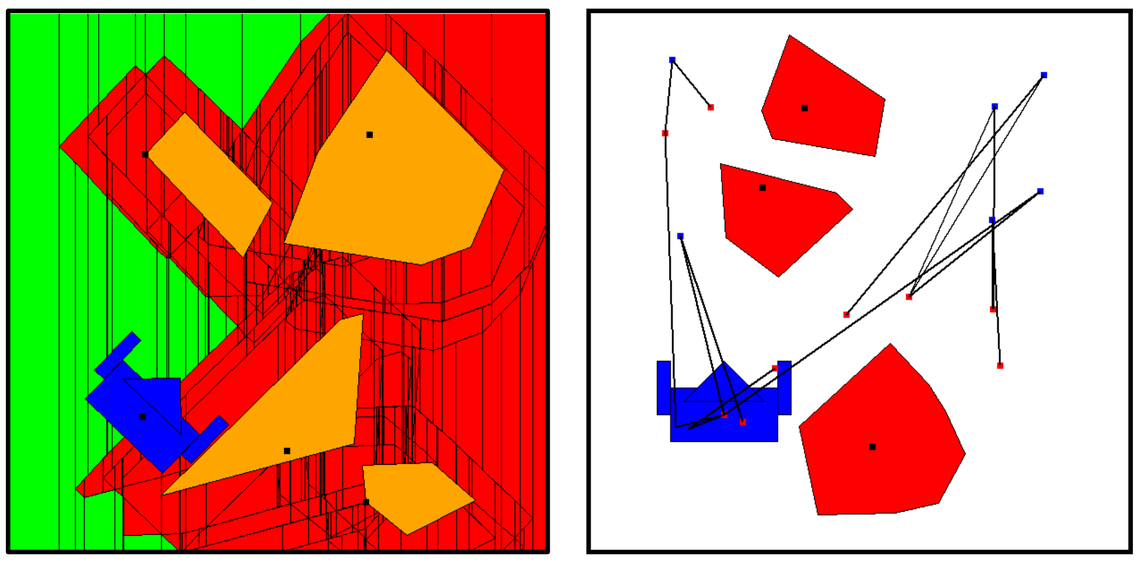


Reachability

Need efficient method of testing reachability constraint

- Calling motion planner for each query is slow
- Object placements will change
- Need to balance saving work with dynamic changes
- Reconnect data structure when placement disconnects

Decomposition versus **Sampling-Based** Methods



Trapezoidal Decomposition

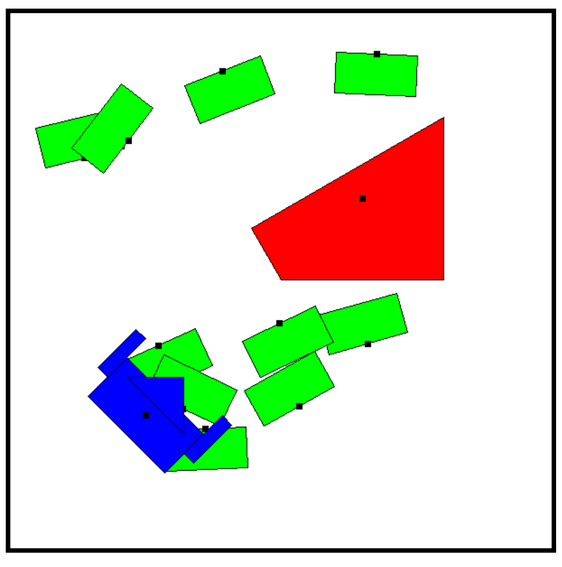
Visibility PRM

Object Placements

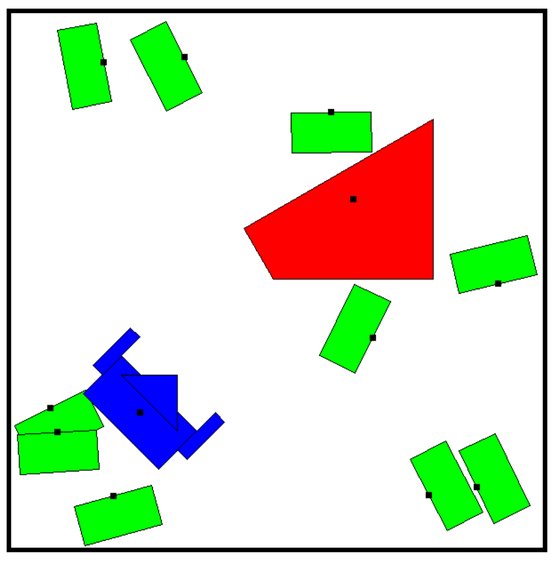
CSP formulation needs discrete set of placements

- Uniform sampling considers many similar placements
- Random sampling prone to missing smart placements

Solution – guide random sampling by biasing towards placements that are on boundary of reachable robot space
Future Research – treating placements symbolically



Random Sampling



Biased Sampling