

Mobile Manipulation



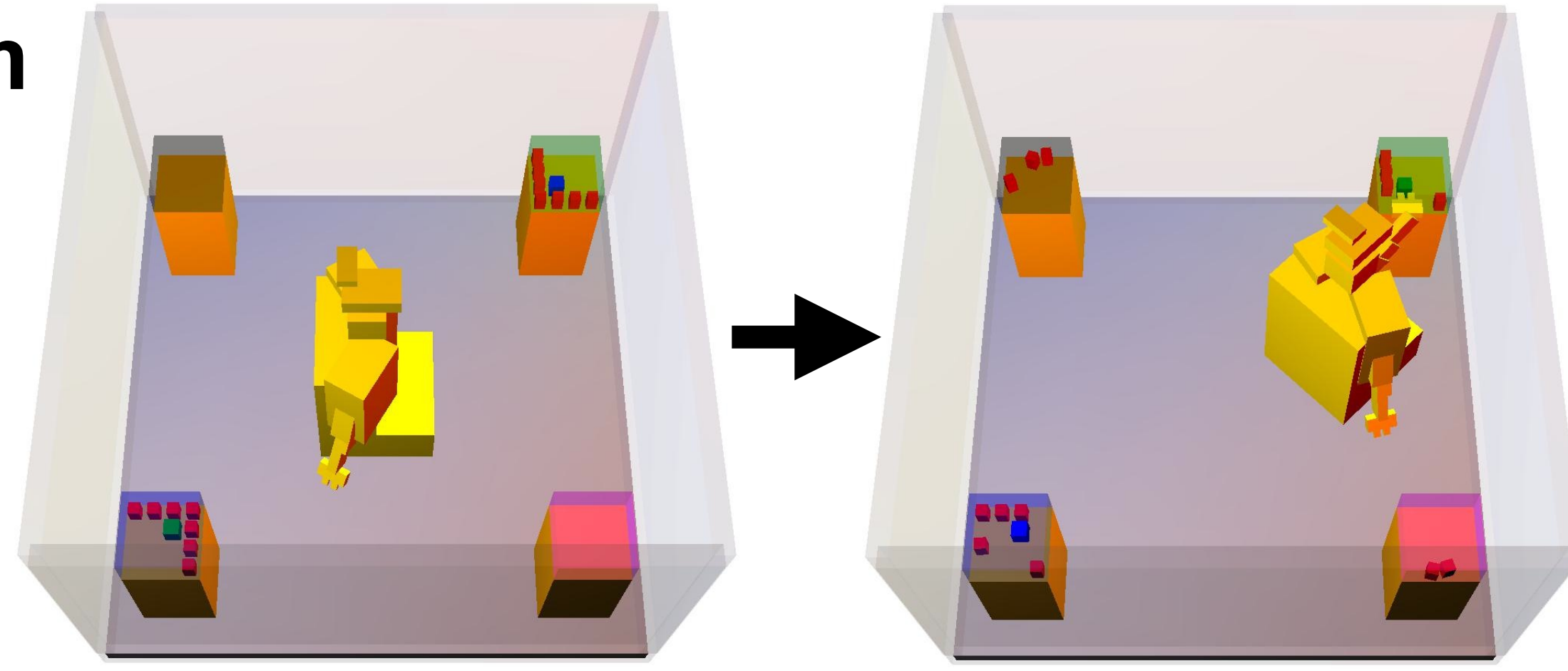
Mobile Manipulation – robot moving and manipulating world to achieve goals

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

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

Pick and Place Problem

Grasp and transport objects to goal positions while avoiding colliding with obstacles in a deterministic world

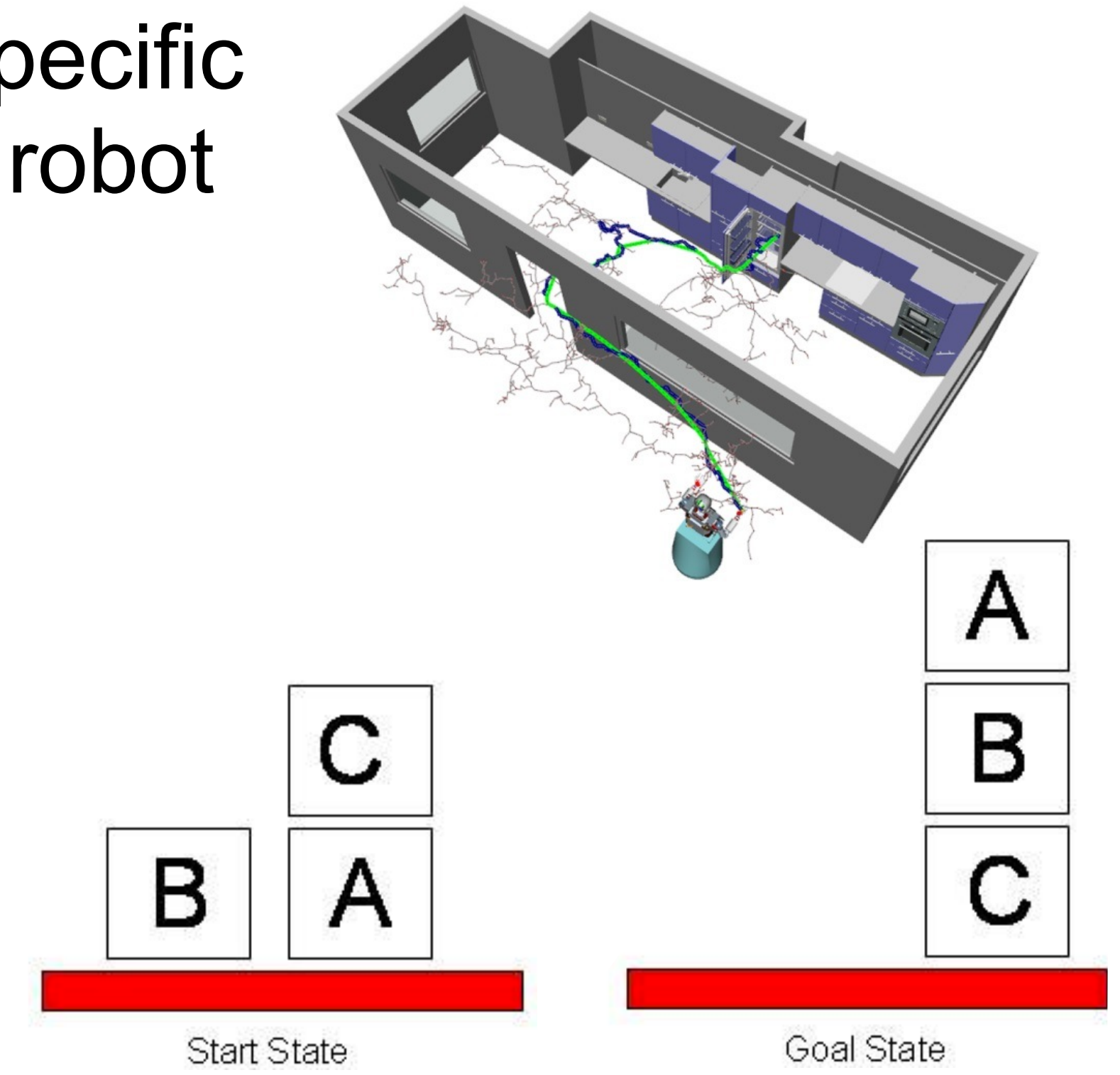


Background

Motion Planning – planning motor specific movements to navigate between two robot configurations

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

Combination reduces exponential dimensionality of planning



Prior work combines both but treats each as a “black box”

- Motion planner evaluates state as semantic attachment
- Symbolic planner heuristic guides motion planner

Our contribution integrates both as 1 heuristic search problem

Actions and CRG

Discretize planning problem by sampling configurations

Pick(C1, O, G, P, C2):

pre: HandEmpty, Pose(O, P), RobotConf(C1), CanGrasp(O, P, G, C2), Reachable(C1, C2)

add: Holding(O, G), RobotConf(C2)

delete: HandEmpty, RobotConf(C1)

Place(C1, O, G, P, C2):

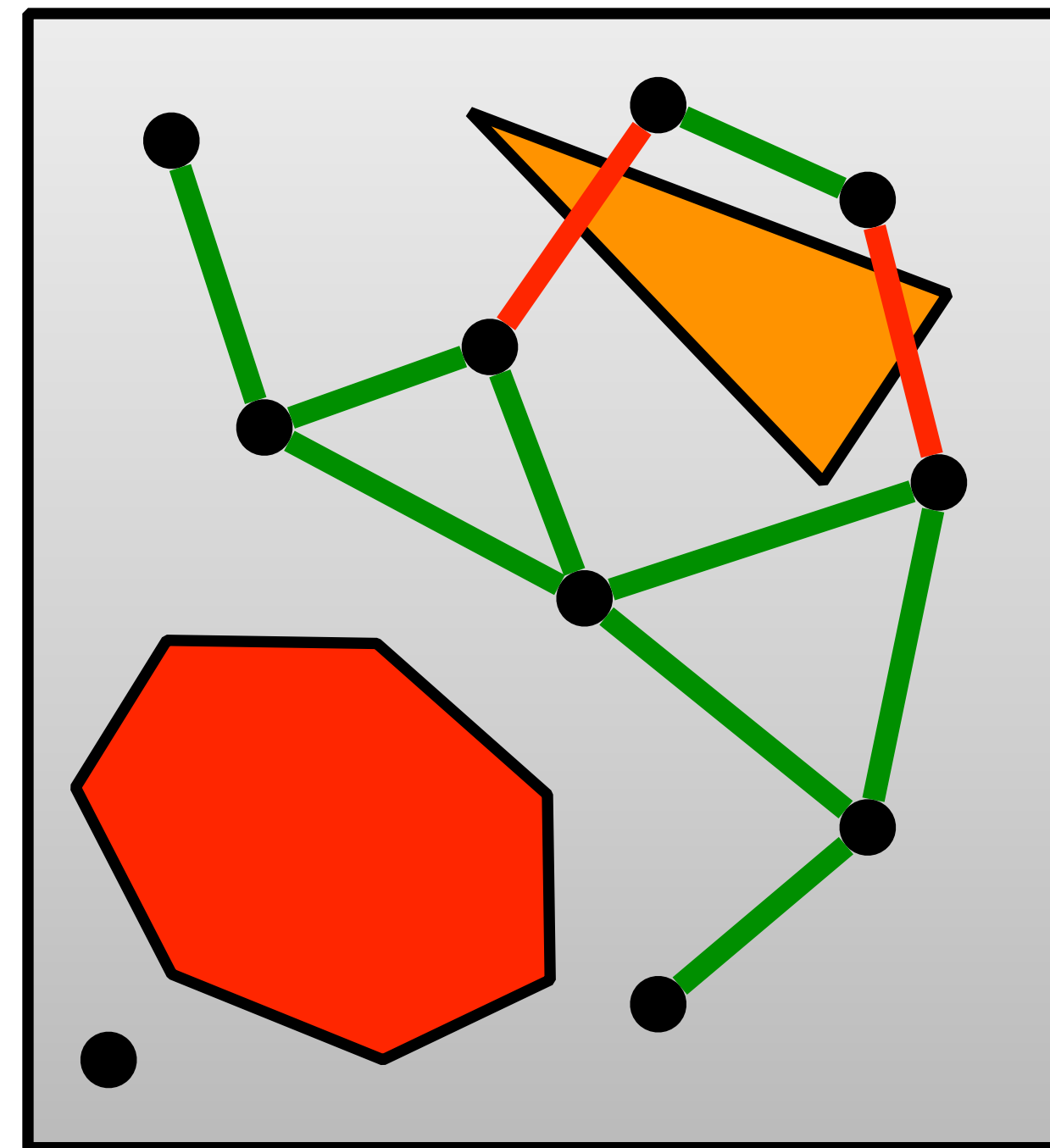
pre: Holding(O, G), RobotConf(C1), CanGrasp(O, P, G, C2), Reachable(C1, C2)

add: HandEmpty, Pose(O, P), RobotConf(C2)

delete: Holding(O, G), RobotConf(C1)

Conditional Reachability Graph (CRG)

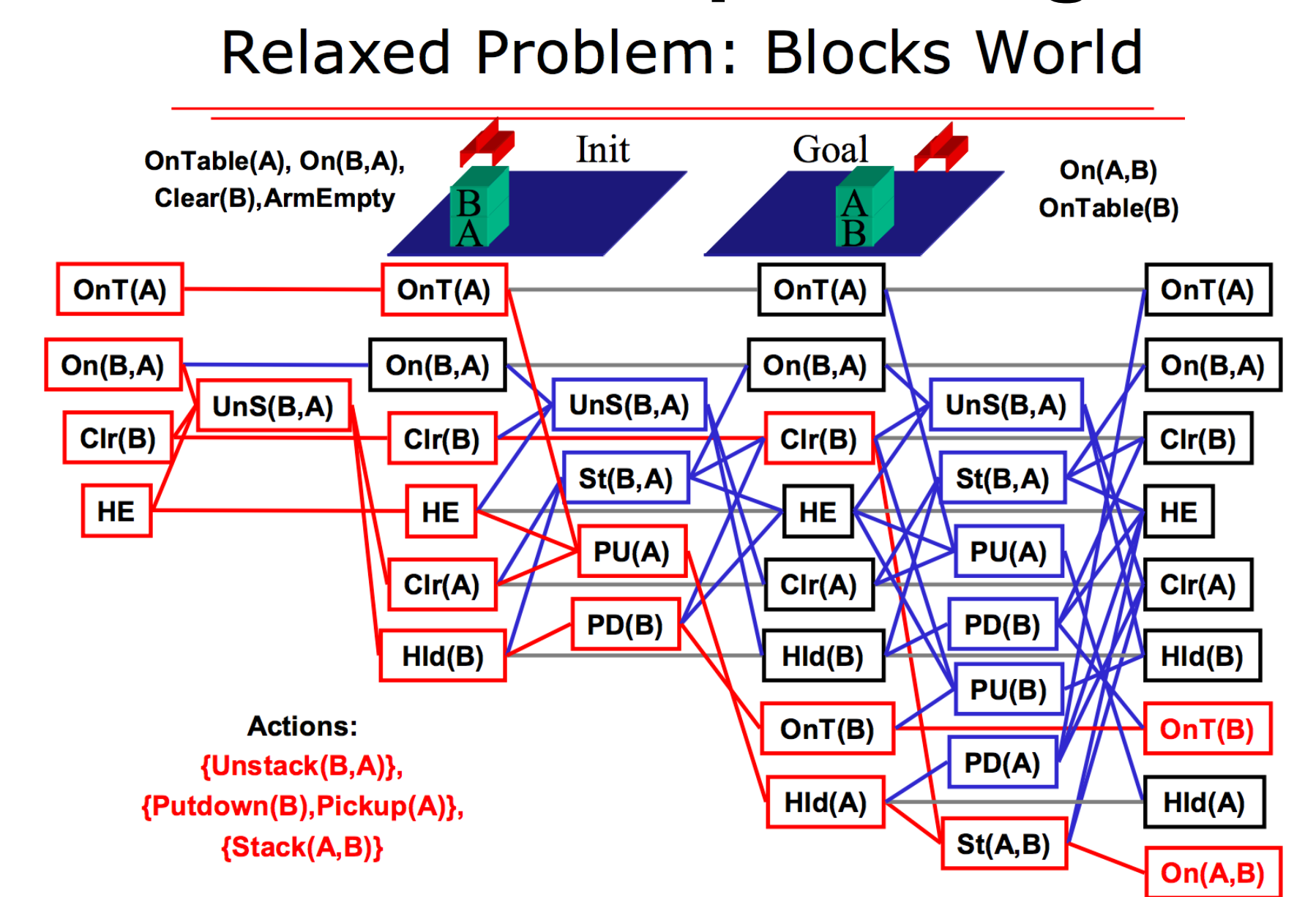
- Work in full PR2 configuration space
- Connect sampled action configurations with a Probabilistic Roadmap (PRM)
- CRG updates reachable configurations given state i.e. *Reachable(C1, C2)*
- Dense roadmap ensures multiple paths
- Lazy collision caching efficiently reuses expensive geometry computations



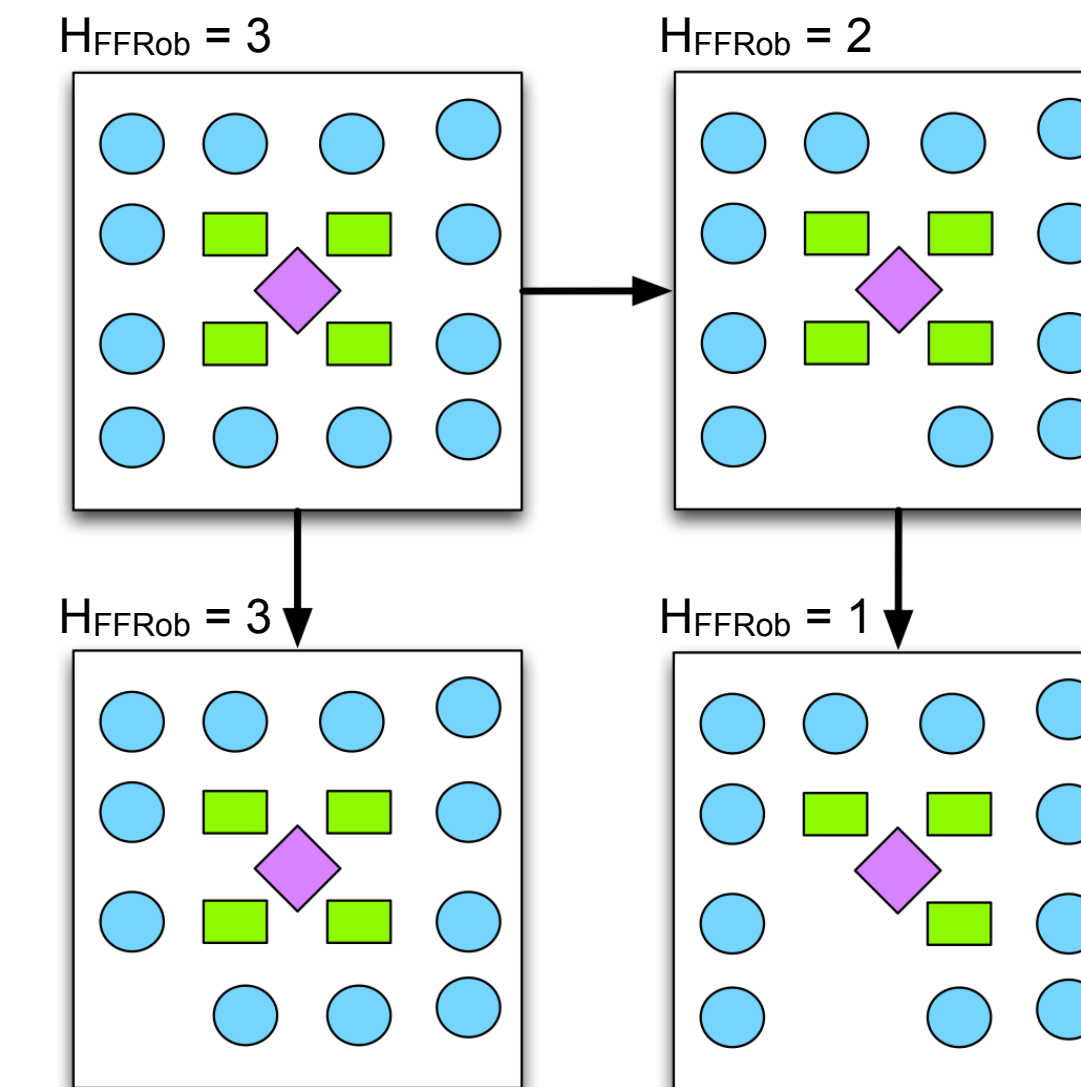
FFRob

Adapt techniques from classical deterministic planning

- Enforced hill-climbing forward heuristic search
- Relaxed planning heuristics remove negative effects of action. Solve easier problem to guide solution to true problem
- FastForward (FF) Heuristic extracts relaxed plan



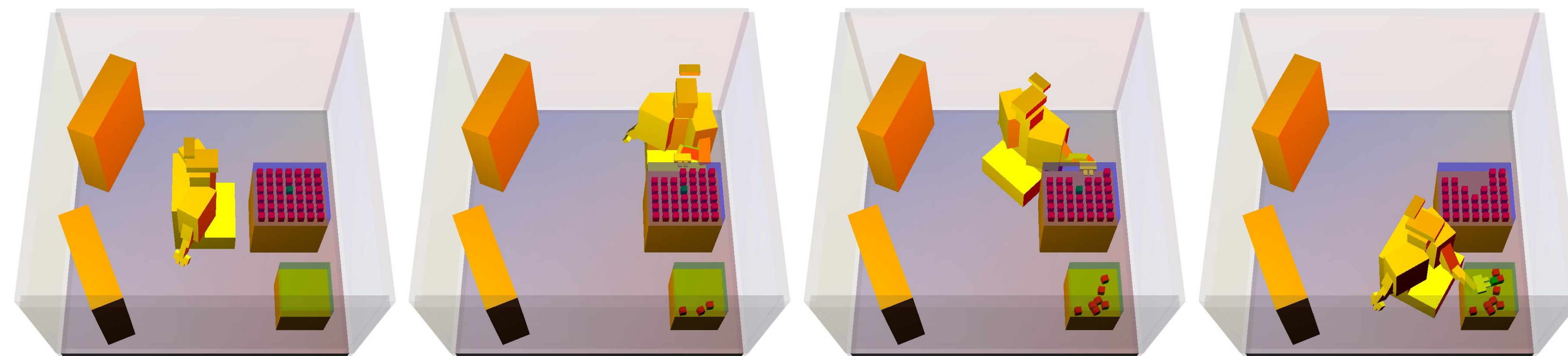
FFRob - FastForward Heuristic applied to robotics



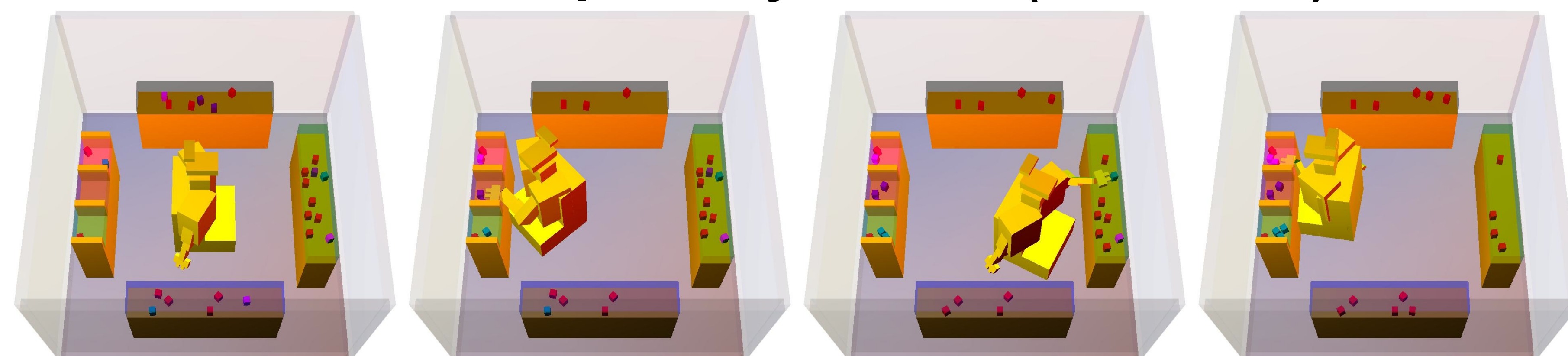
- Relaxation of continuous variables implies reachability can only increase
- Captures both geometric and symbolic action guidance
- Minimum Constraint Removal (MCR) back pointers to extract relaxed plan
- Low experimental amortized cost

Simulations

Simulation 4 - dig block out of packed region (20 actions)



Simulation 5 - clean up messy kitchen (28 actions)



Results and Future Work

T	Pre	No H			H _{FF}			H _{AddR}			H _{FFR} , H _A			H _{FFRB}			H _{FFRB} , H _A		
		t	m	s	t	m	s	t	m	s	t	m	s	t	m	s	t	m	s
0	21	265	35	48719	102	72	6123	41	19	536	6	5	78	7	5	87	2	0	23
1	25	300	0	63407	283	17	14300	162	55	2042	3	0	8	16	11	153	4	1	49
2	29	300	0	50903	300	0	8947	300	0	3052	5	1	12	17	13	114	7	2	32
3	23	300	0	39509	300	0	4849	300	0	1767	83	19	464	99	43	523	13	1	69
4	30	300	0	23920	300	0	1574	300	0	1028	300	0	1274	18	3	20	16	3	20
5	51	300	0	9422	300	0	1533	300	0	592	300	1	272	106	17	32	99	14	32

- Performance table of 6 worlds (T) with a 300 second timeout
- Median time in seconds (t), MAD time (m), median states (s)
- H_{FF} represents state of art, and H_{FFRB} , H_A is our best system

Future Work

- Generalization of theory
- Dynamic roadmap construction
- Uncertainty

