Experience Guided Mobile Manipulation Planning

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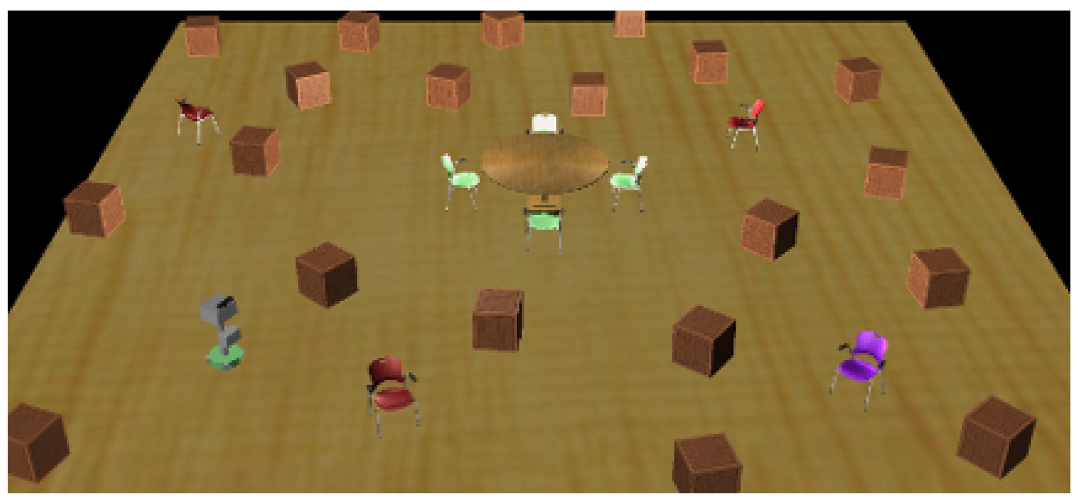
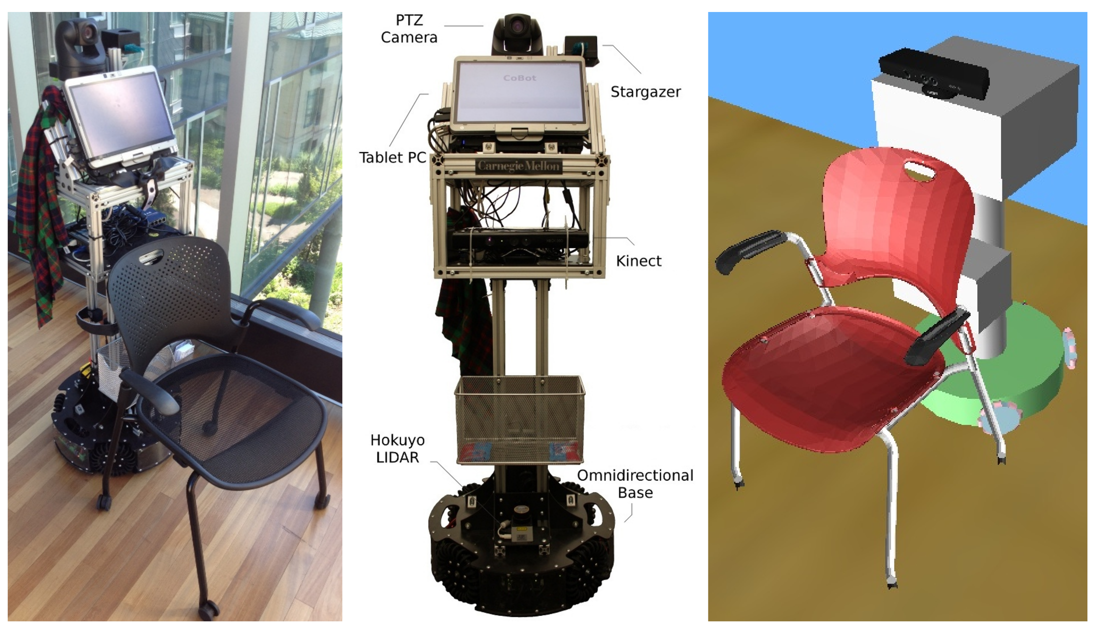
Introduction

- Partial motion plans represented as **state-action sequences** are utilized for efficient mobile manipulation planning and execution in **prehensile** (with grasping) and **non-prehensile** (without grasping) scenarios.
- Fine manipulation moves performed within the close vicinities of the targets are **reused**.
- Chairs with freely rolling caster wheels need to be arranged in a predefined seating formation.



- Realistically simulated version of the **CoBot-2** robot is used as the mobile manipulator.



Prehensile Manipulation

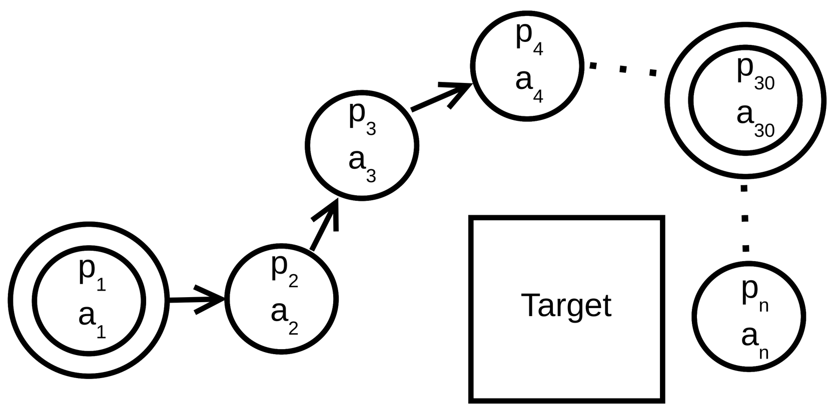
- Memorized state-action sequences are used to create "regions" around the targets instead of defining targets as single poses to be reached.
- The **RRT*** planner generates a small number of nodes to "roughly reach" the critical motion regions around the targets.
  - The generative planner is **early-terminated** when one of the "recalled" states is reached coincidentally.
  - Each frame of the state-action sequences are treated as **subgoals** to deliberately bias the generative planner towards them.
- Delicate motions are handed over to the memorized state-action sequences.

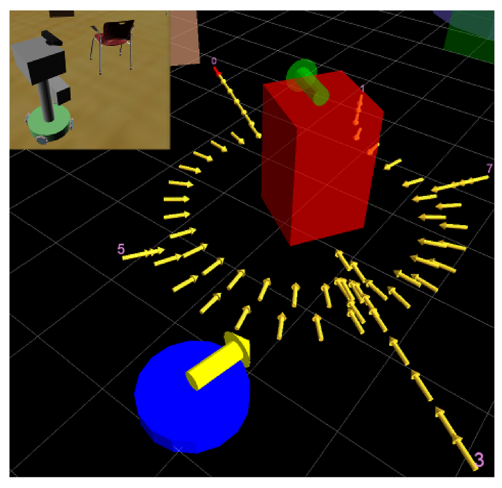
Non-prehensile Manipulation

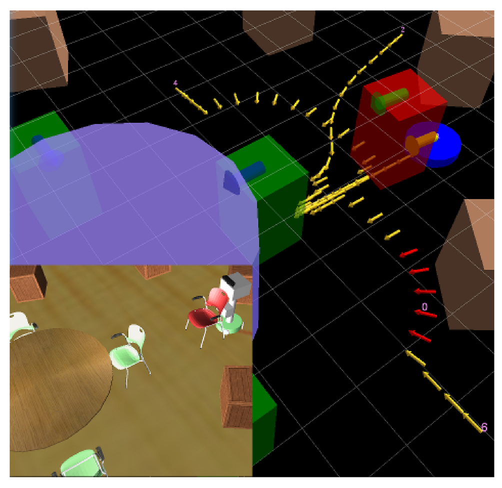
- Past observed behavior of the object in response to various **pushing actions** are used to **foresee the future** and plan accordingly.
- Chairs could be placed accurately despite the small number of pushing **demonstrations**.

Memory-based Prehensile Manipulation

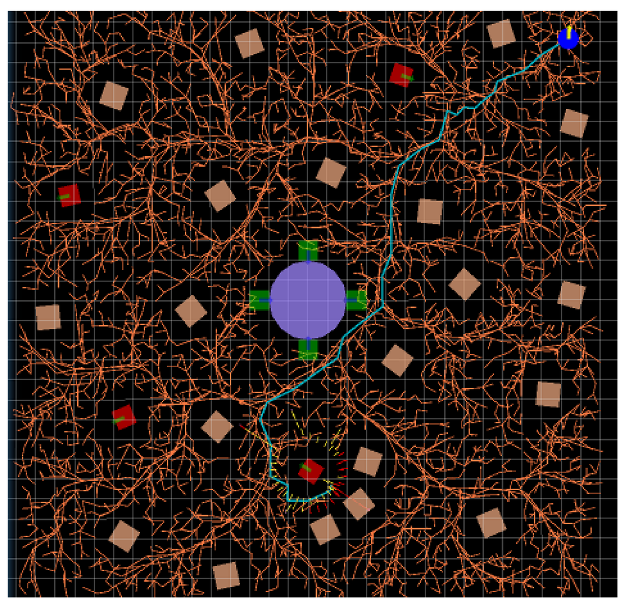
- Planning fine moves from scratch each and every time the object needs to be manipulated becomes burdensome and inefficient.
- We make the robot **memorize** these finite amount of target-specific fine reaching and manipulation moves represented as **sequences** of state-action pairs as we demonstrate the robot how to perform them.
- The sequences are accessed through **entry points** defined at every n^{th} frame.

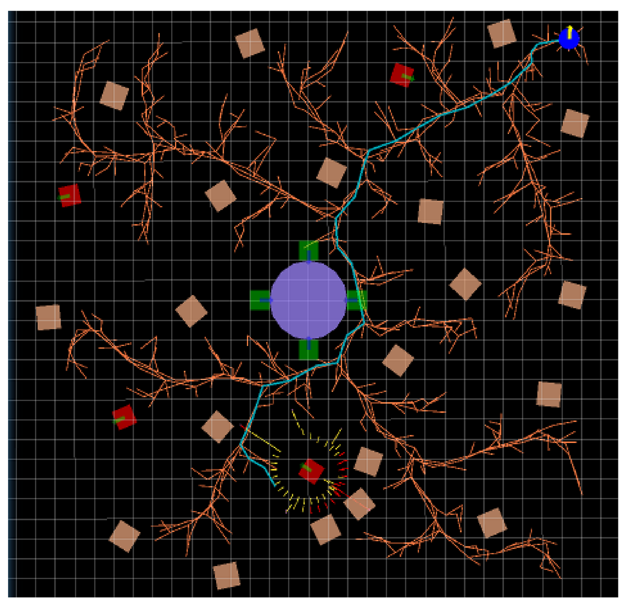


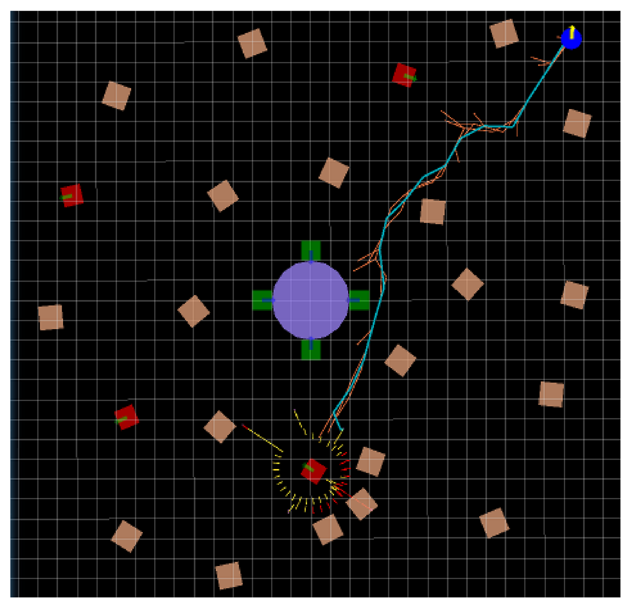




- **Feasible entry points** are either used to *early-terminate* planning when one of them is reached coincidentally, or as **subgoals** to direct the generative planner.
- Keeping the number of generated nodes low in RRT-based algorithms reduces the planning and execution time significantly.







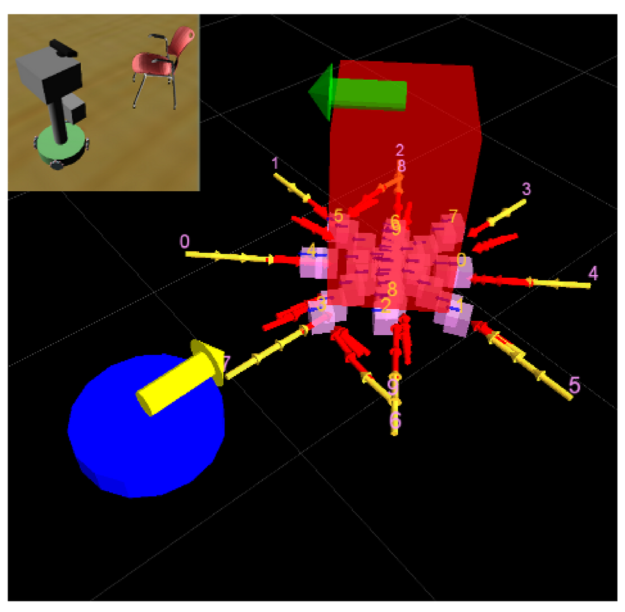
- Utilizing the bigger region around the target instead of merely increasing the single goal bias reduced the overall planning and execution time and increased the success rate significantly.

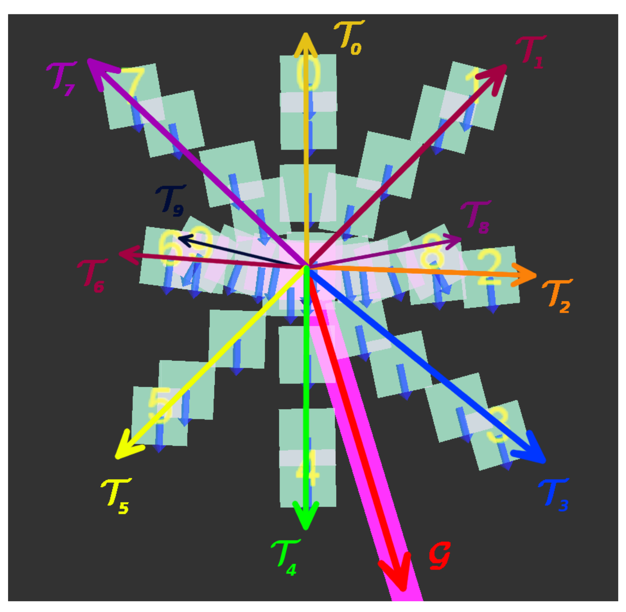
Method	# nodes	Planning time (sec)
RRT* alone	7690	309.682
Early termination	1249	0.821
Deliberate directing	44	0.081

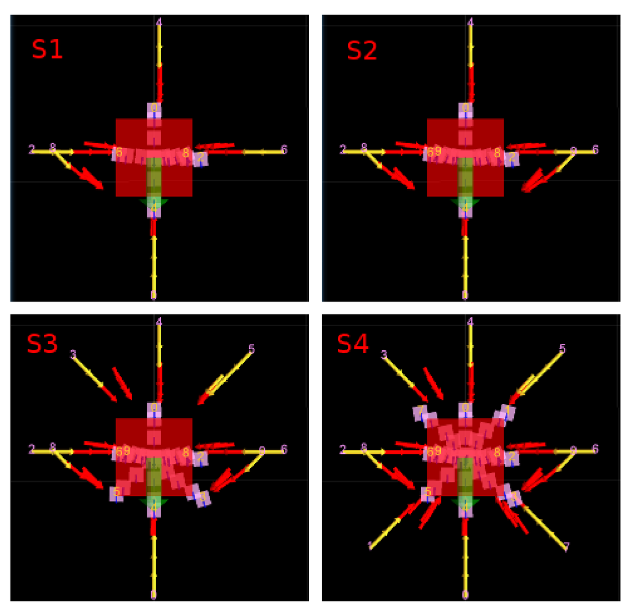
Method	Task completion time (sec)
RRT* alone	364.011
Early termination	280.779
Deliberate directing	259.439

Memory-based Non-prehensile Manipulation

- We make the robot **memorize** a small number of **pushing motions** from various directions and their **effects** on the object as we demonstrate them by joysticking the robot.
- A generative planner is used to construct a rough path for the object to follow towards the goal.
- *Cosine similarities* between the directions of each of the object trajectories (T_i) and the direction of the next waypoint on the guideline path (G) are computed.
- The sequence that results in the trajectory that is the most similar to the guideline or that reduces the orientation difference between the current and the goal pose the most is selected for execution.







- The robot was able to use the same set of sequences on chairs with different friction properties by computing a **scaling factor** and adjusting its execution speed accordingly.

Sequence set	Push count	μ_{dist} (cm)	$\mu_{\triangle\theta}$ (deg)
S_1	25	14.11	26.12
S_2	8	14.82	14.06
S_3	7	14.87	23.52
S_4	7	14.86	20.49

Friction	Push count	μ_{dist} (cm)	$\mu_{\triangle\theta}$ (deg)
1/4	7	14.97	16.83
1/2	8	11.07	24.63

References

- MERICLI, T., M. Veloso, and H. L. Akin, "Experience Guided Mobile Manipulation Planning", 8th International Cognitive Robotics Workshop, AAAI'12, Toronto, Canada, July 22-23, 2012. (Accepted)
- MERICLI, T., M. Veloso, and H. L. Akin, "A Case Based Approach to Push Planning for Passive Mobile Objects", IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Algarve, Portugal, October 7-12, 2012. (Submitted)