Symbolic State Space Optimization for Long Horizon Mobile Manipulation Planning

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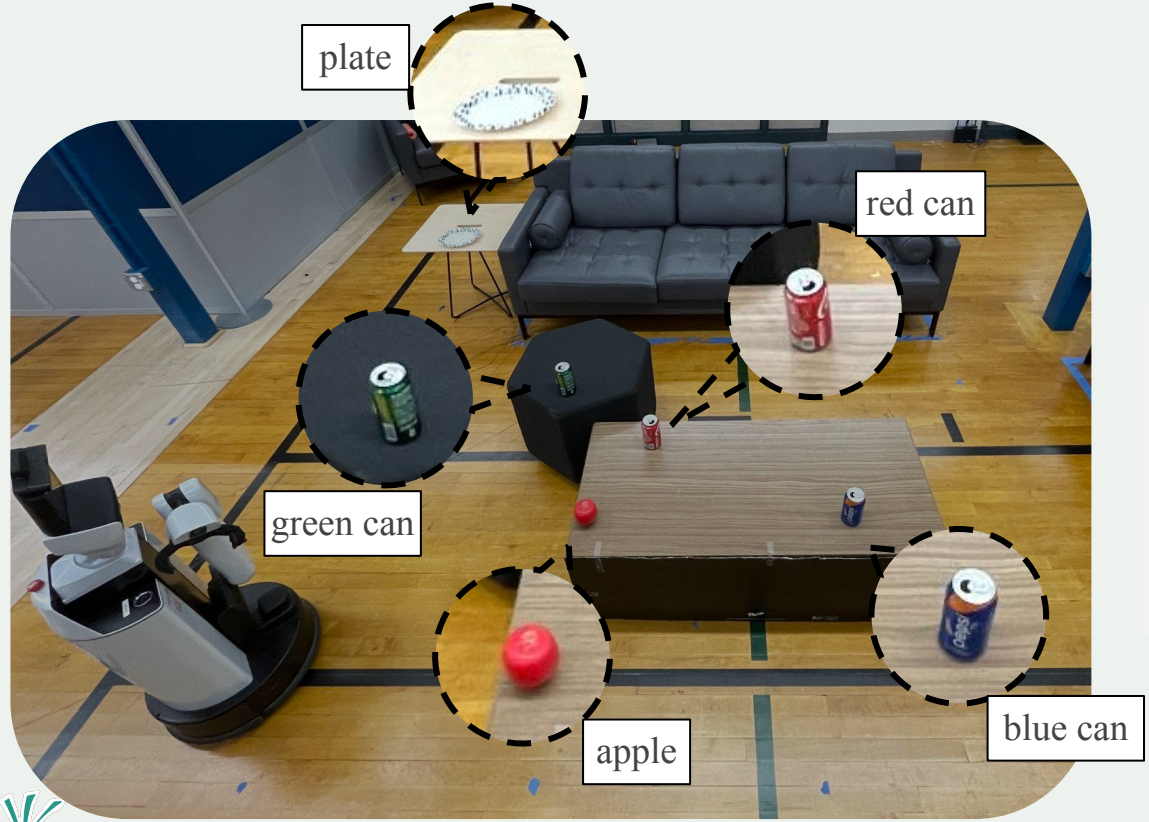
[1] SUNY Binghamton [2] UT Austin [3] SONY AI



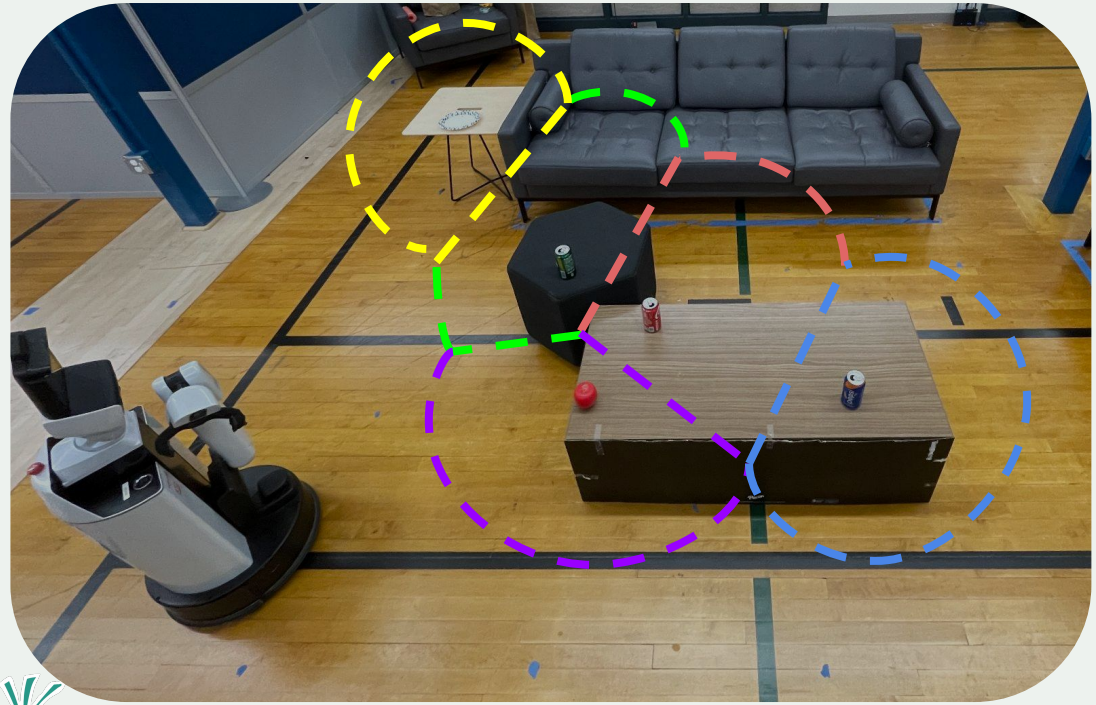
Task: Tidy Home

Collected (green_can)

Collected (red_can)

Collected (blue_can)

On (apple, plate)



Task Planner:

LOCATION (green_can)

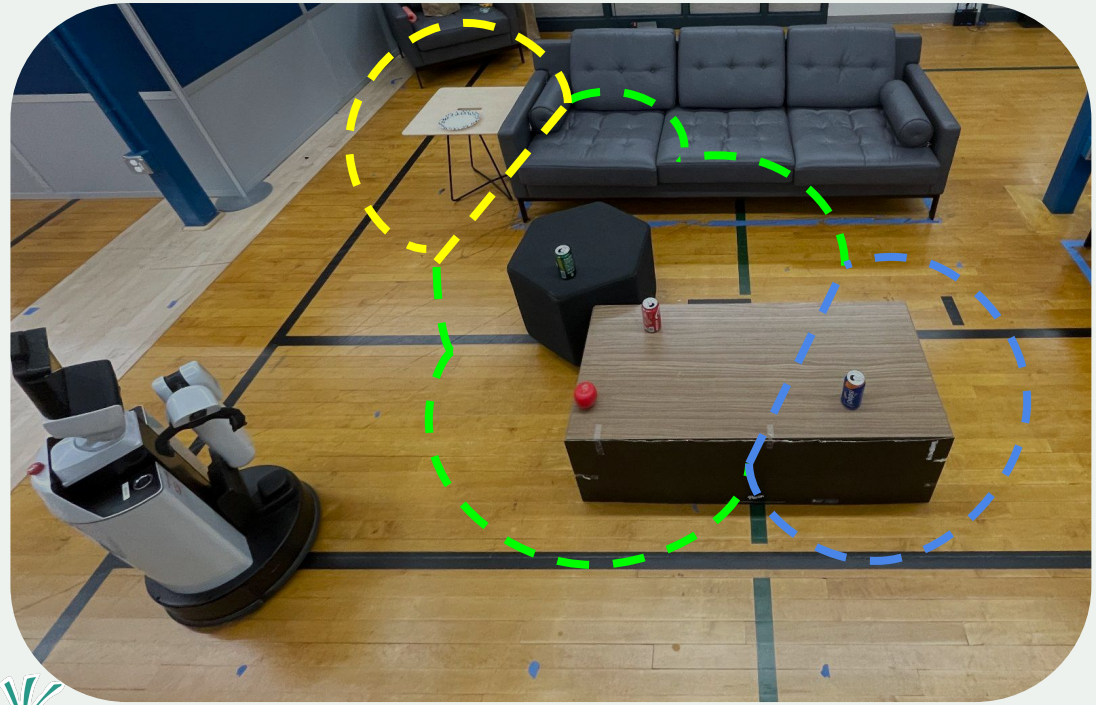
LOCATION (apple)

LOCATION (plate)

LOCATION (blue_can)

LOCATION (red_can)

Previous Task and Motion Planning (TAMP) methods assume predefined symbolic locations



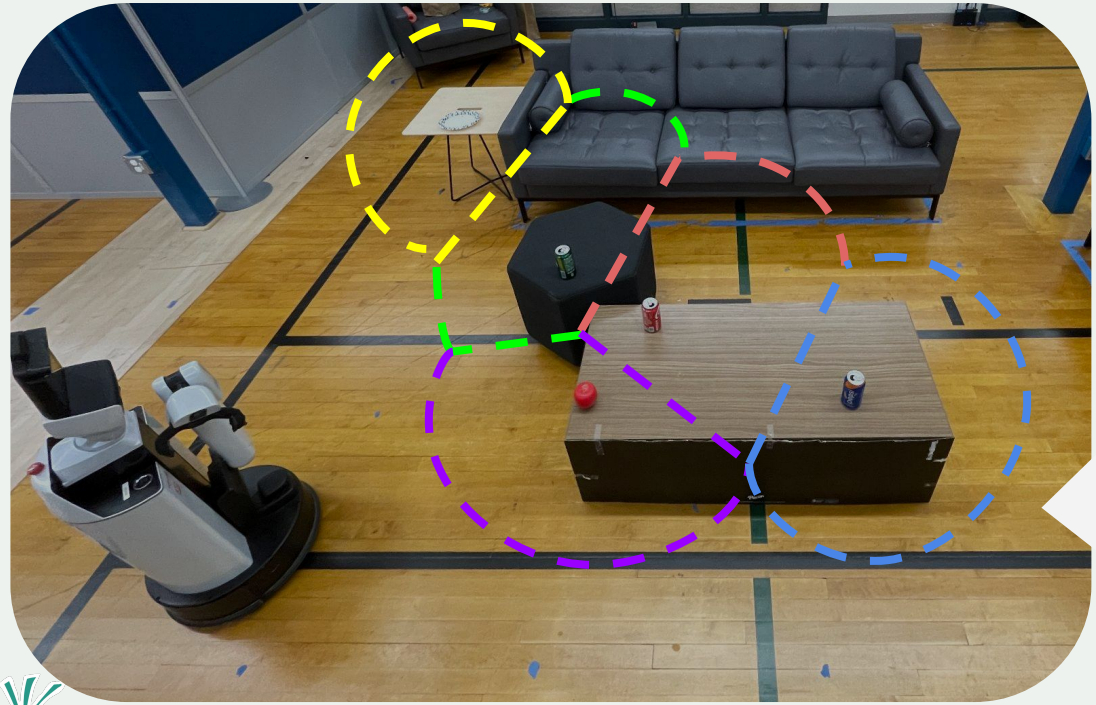
Task Planner:

LOCATION (**green_can, red_can, apple**)

LOCATION (**plate**)

LOCATION (**blue_can**)

Focus: optimize abstracted locations and their geometric groundings



Previous Work:

goto (**green_can**)

collect (green_can)

goto (**apple**)

pickup (apple)

goto (**plate**)

placeon (apple, plate)

goto (**blue_can**)

collect (blue_can)

goto (**red_can**)

collect (red_can)

Previous Work:

goto (**green_can**)

collect (green_can)

goto (**apple**)

pickup (apple)

goto (**plate**)

placeon (apple, plate)

goto (**blue_can**)

collect (blue_can)

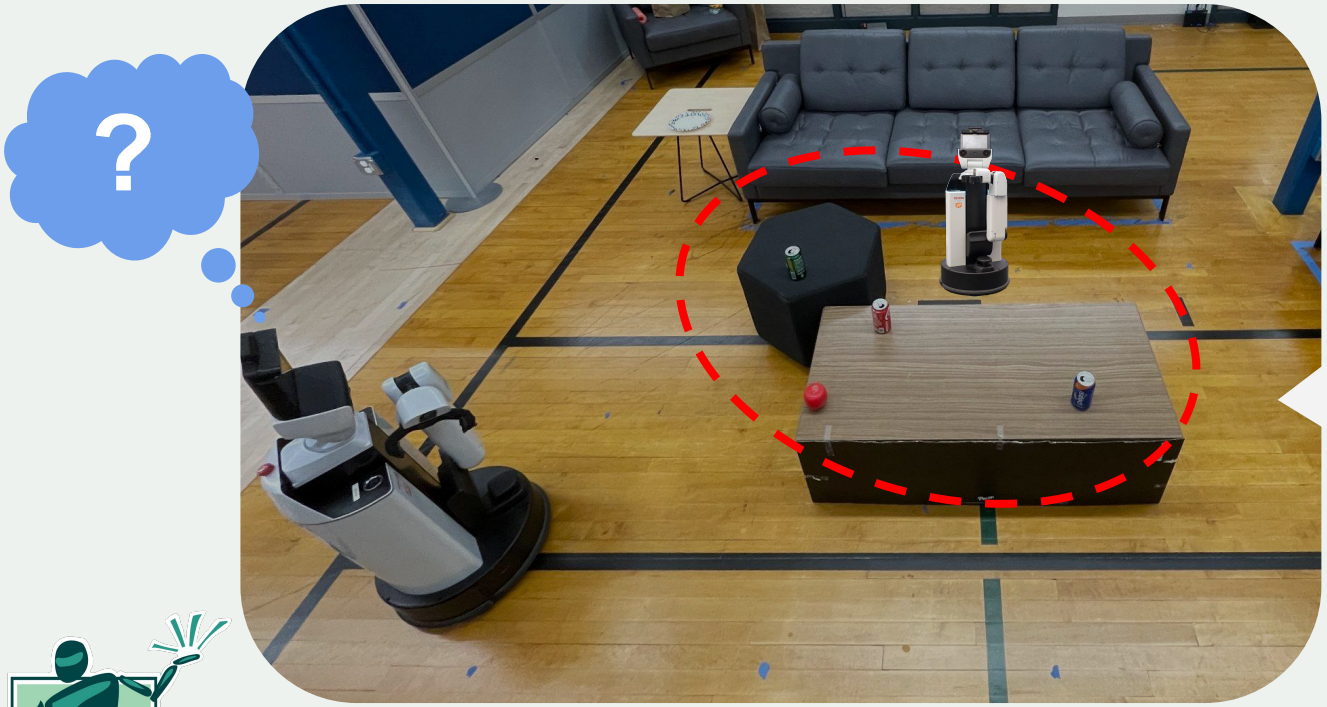
goto (**red_can**)

collect (red_can)

[Lo et al., 2020; Zhang et al., 2022]

Feasibility

Efficiency



goto (**apple**, **green_can**, **red_can**, **blue_can**)

collect (green_can)

collect (blue_can)

collect (red_can)

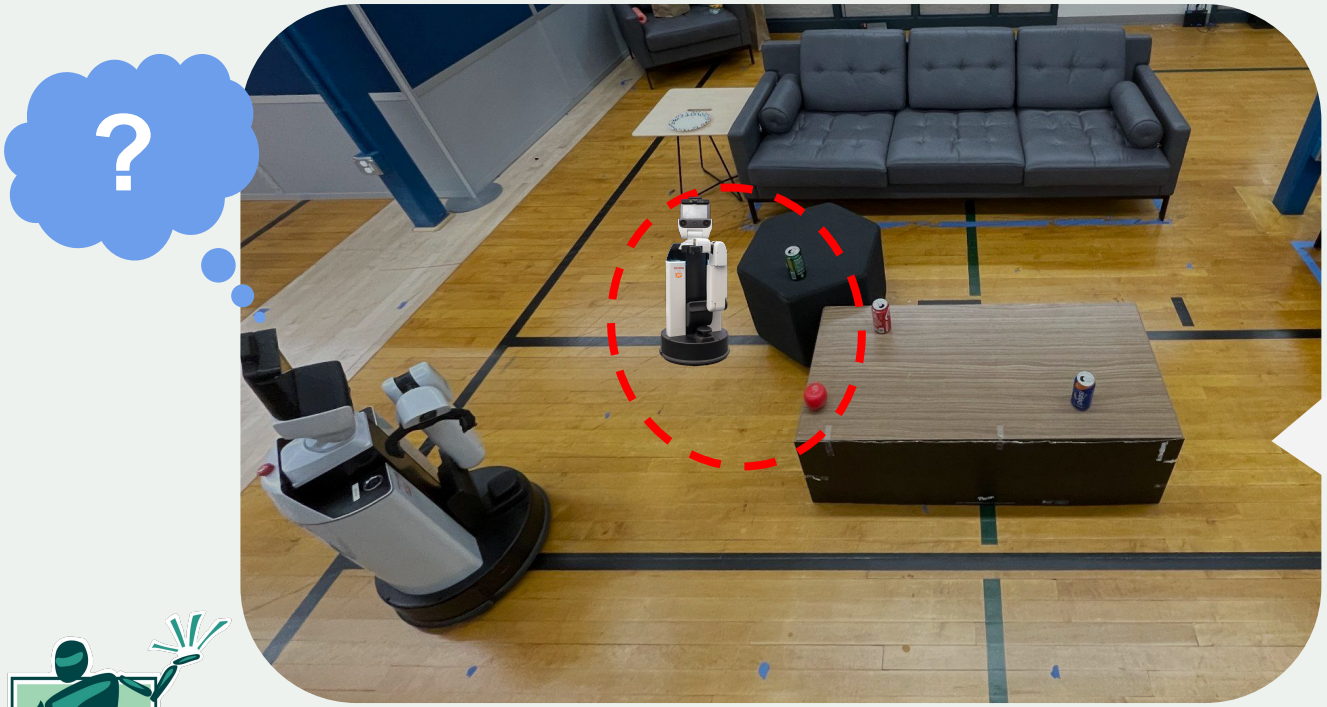
pickup (apple)

goto (**plate**)

placeon (apple, plate)

Feasibility

Efficiency



goto (**green_can**, **apple**)

collect (green_can)

pickup (apple)

goto (**plate**)

placeon (apple, plate)

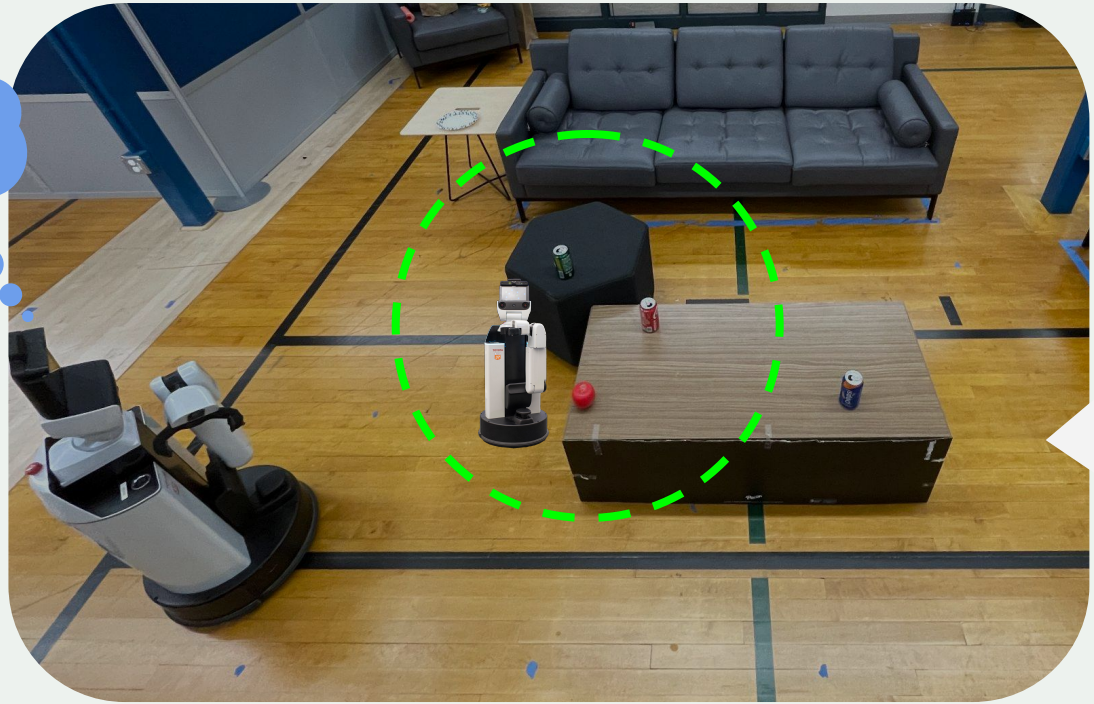
goto (**blue_can**)

collect (blue_can)

goto (**red_can**)

collect (red_can)

Feasibility ⟷ **Efficiency**



goto (**green_can**, **red_can**, **apple**)

collect (green_can)

collect (red_can)

pickup (apple)

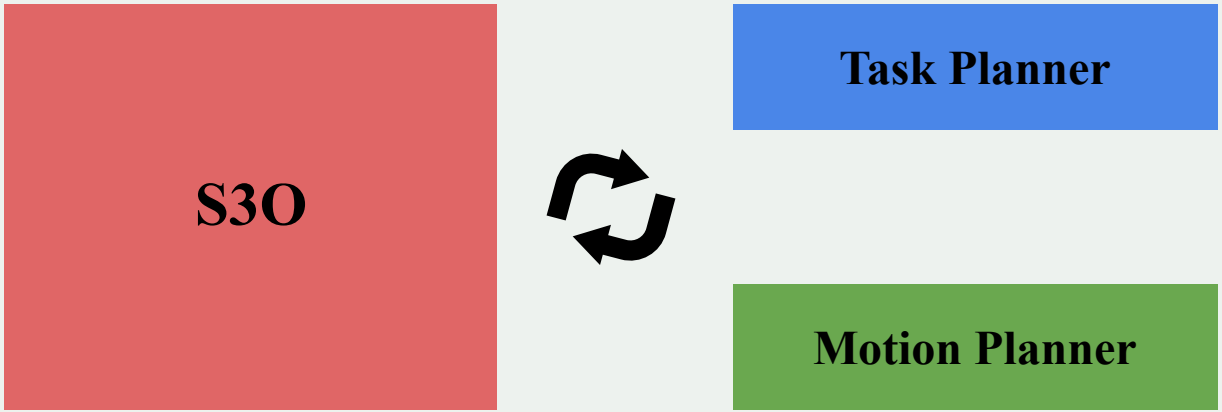
goto (**plate**)

placeon (apple, plate)

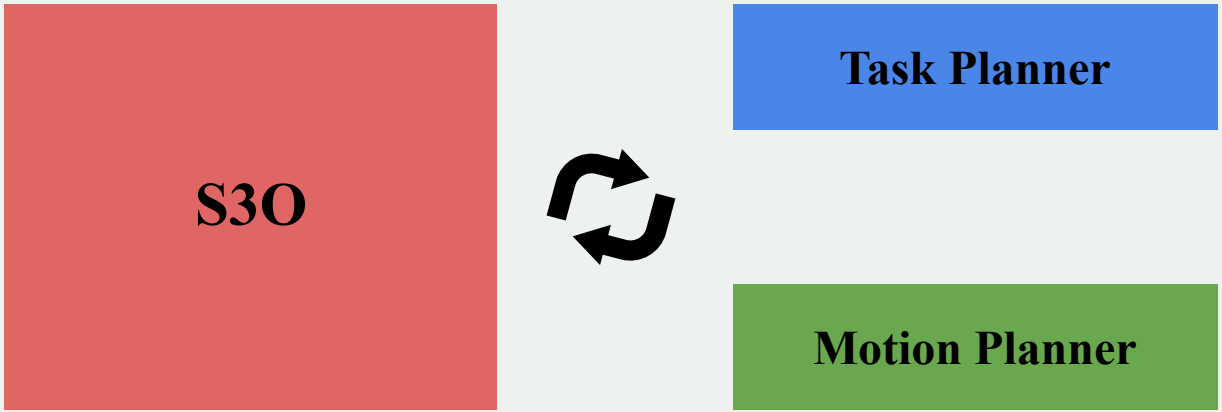
goto (**blue_can**)

collect (blue_can)

Symbolic State Space Optimization (S3O)

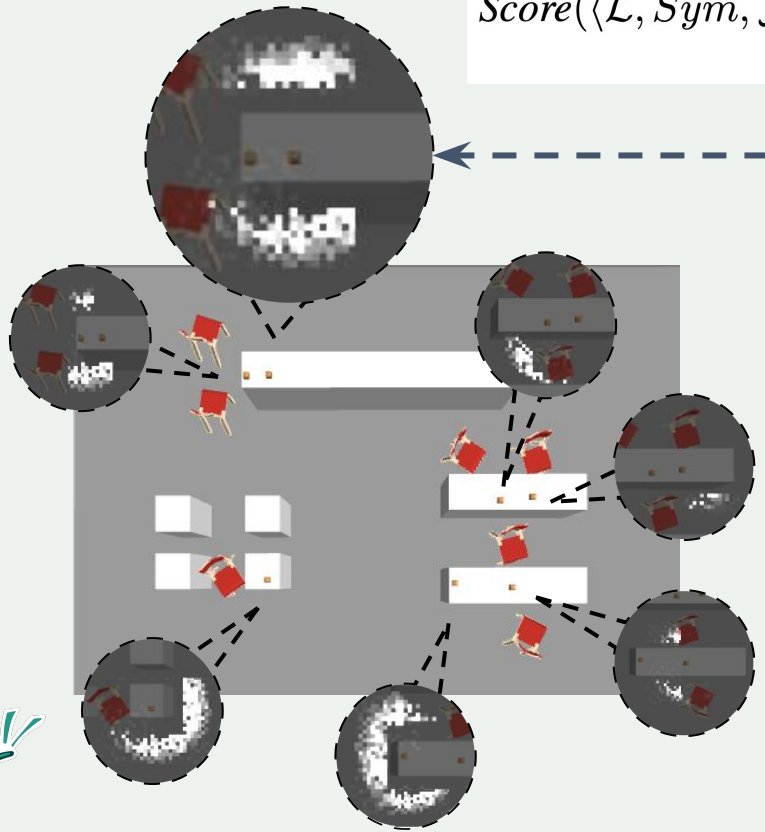


Symbolic State Space Optimization (S3O)

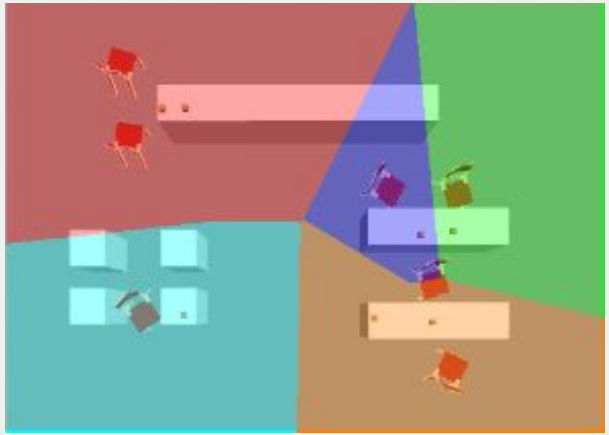


Challenge: How to reduce search complexity?

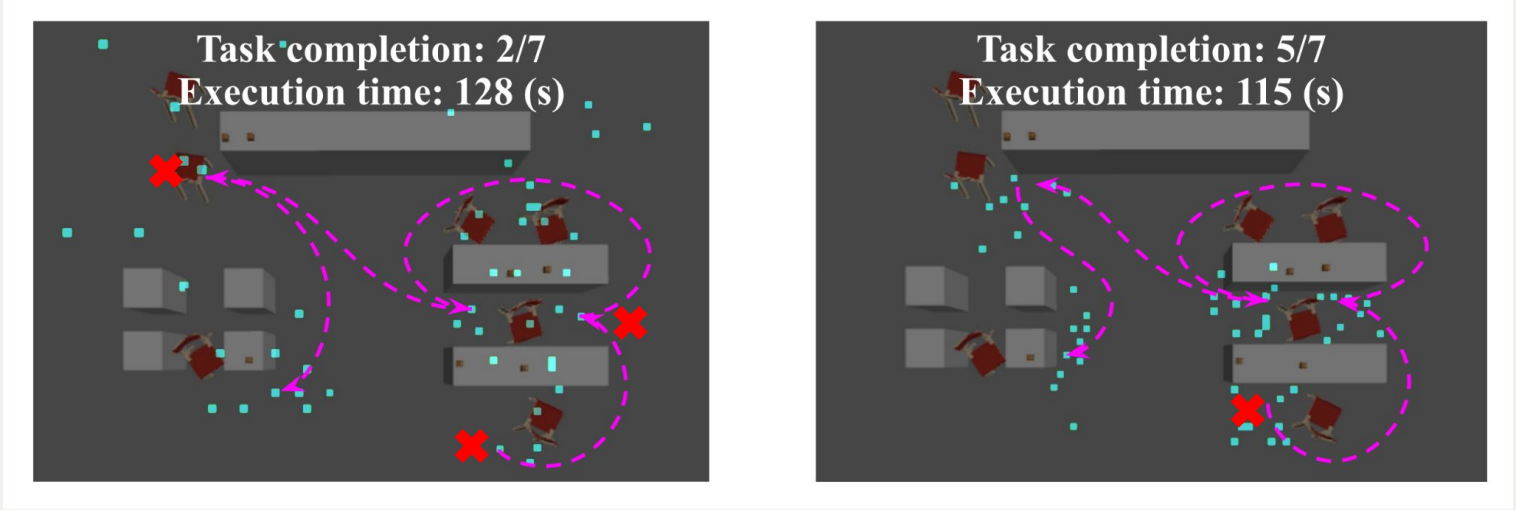
$$Score(\langle \mathcal{L}, Sym, \mathcal{Y} \rangle) = \sum_{o \in \mathcal{O}} Fea^t(l, o), \text{if } \texttt{at}(o,\ l)$$



A Top-ranked State Space



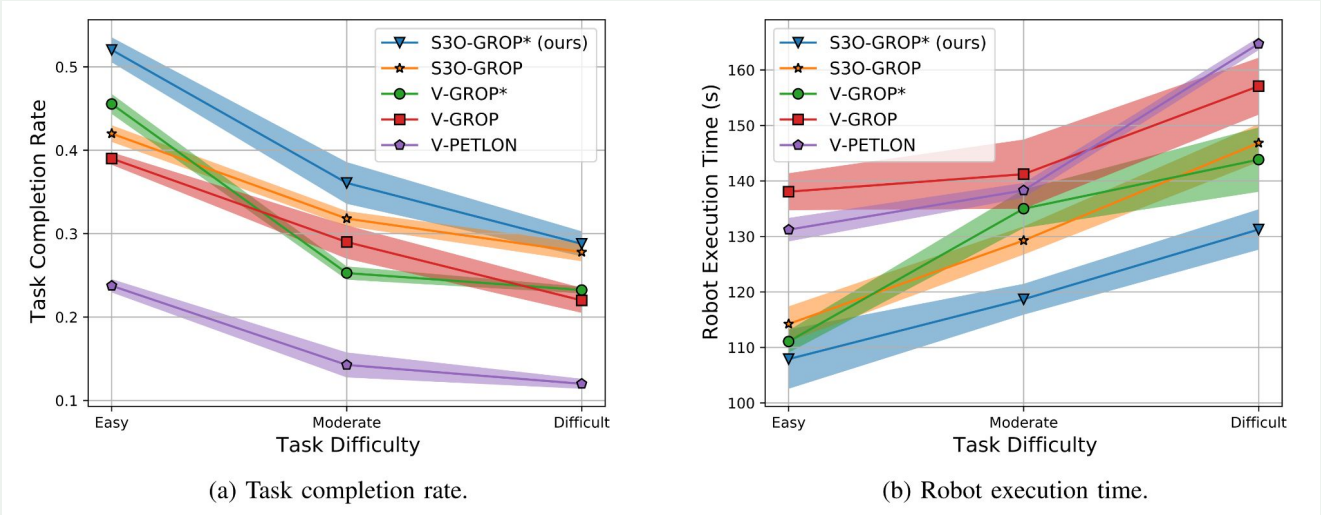
Sampled Robot Pose Failed Manipulation Robot Trajectory



CMA-ES Early Iteration CMA-ES Late Iteration

[Hansen, 2016]

Results



(a) Task completion rate.

(b) Robot execution time.

S3O produced the highest task completion rate while maintaining the lowest robot execution time.

This observation is consistent over tasks of different difficulties.

goto (green_can, red_can, apple)

collect (green_can)

collect (red_can)

pickup (apple)

goto (plate)

placeon (apple, plate)

goto (blue_can)

collect (blue_can)

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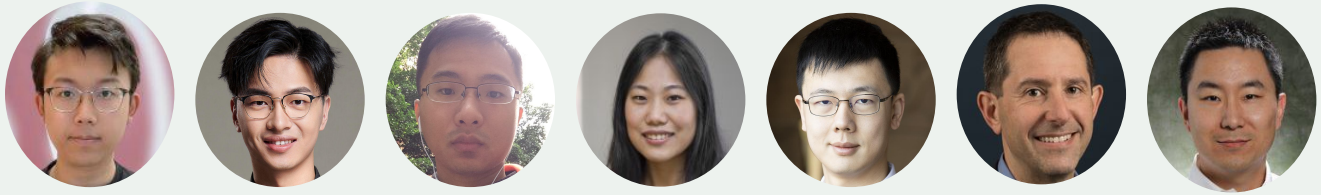

Paper