(Semi-) Autonomous Control of Manipulator Robots in Challenging Environments

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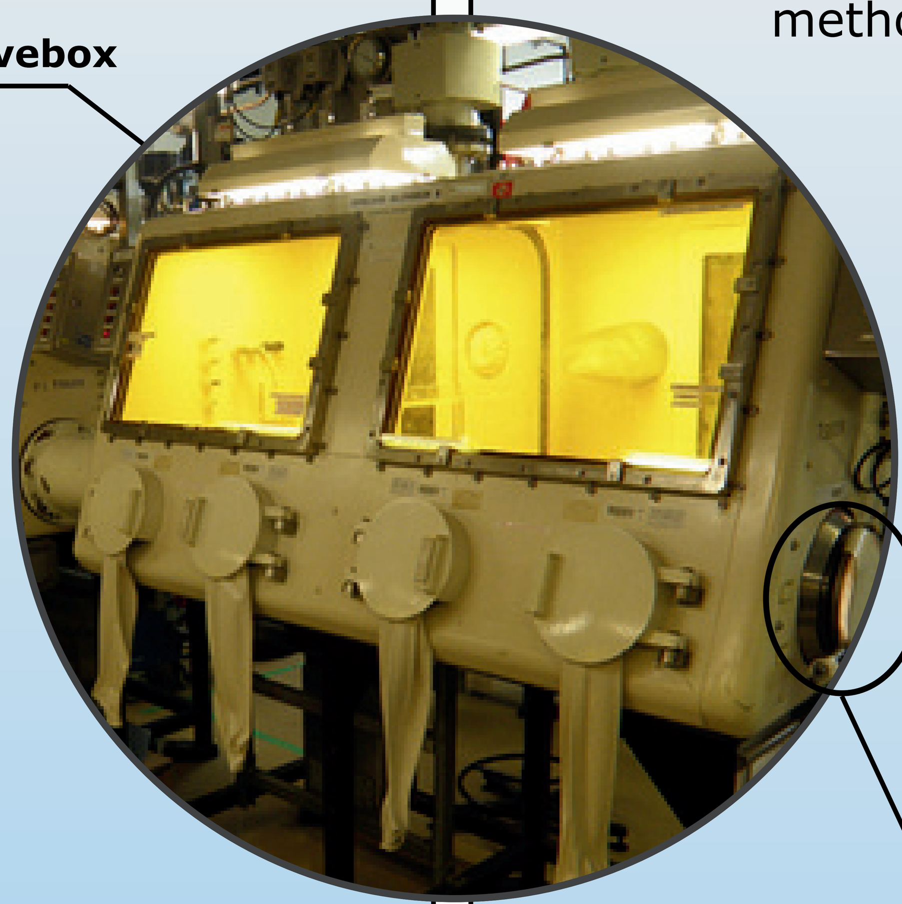
RAICo ROBOTICS AND AI COLLABORATION

① Introduction:

Automation in Decomissioning of Nuclear Gloveboxes which are **constrained spaces** require **safe** manipulation of robots [1].

Cluttered Inside the Glovebox

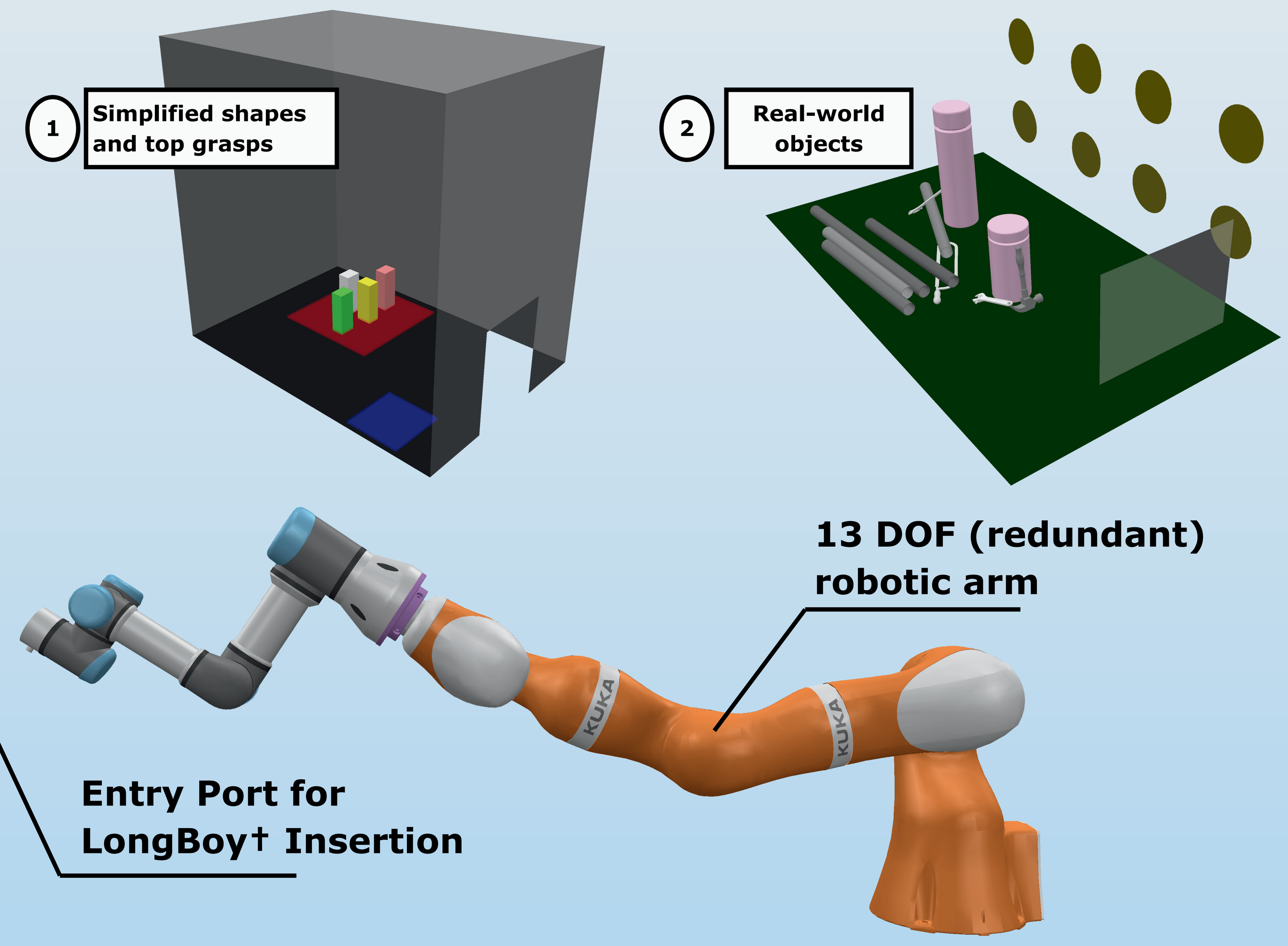
Glovebox



The robotic manipulator needs to **declutter** > **rerrange** > **remove** the items inside.

② Objective:

Our goal is to achieve **non monotonous rearrangement inside a constrained space** like glove box via **Task and Motion Planning** methods.



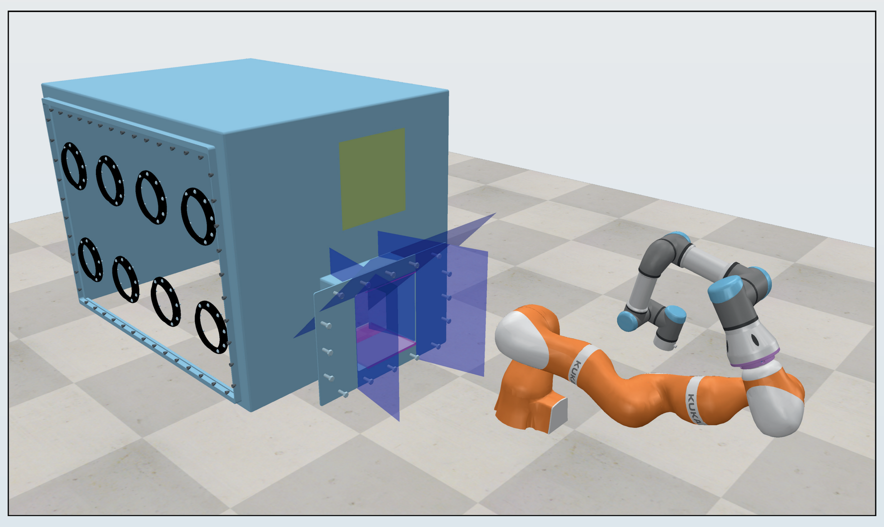
③ Methodology:

Constrained Kinematic Controller

$$u \in \arg\min_{\dot{q}} \|J\dot{q} + \eta\tilde{x}\|_2^2 + \lambda^2 \|\dot{q}\|_2^2$$

Subject to

$$W\dot{q} \leq w$$



Constraint based Planning with stream generators [3, 4]

Problem is defined by tuple

$$\langle A, S, I, G \rangle$$

A, set of parameterized actions, a
S, set of streams, s
I, set of initial state(ground literals)
G, set of goal state

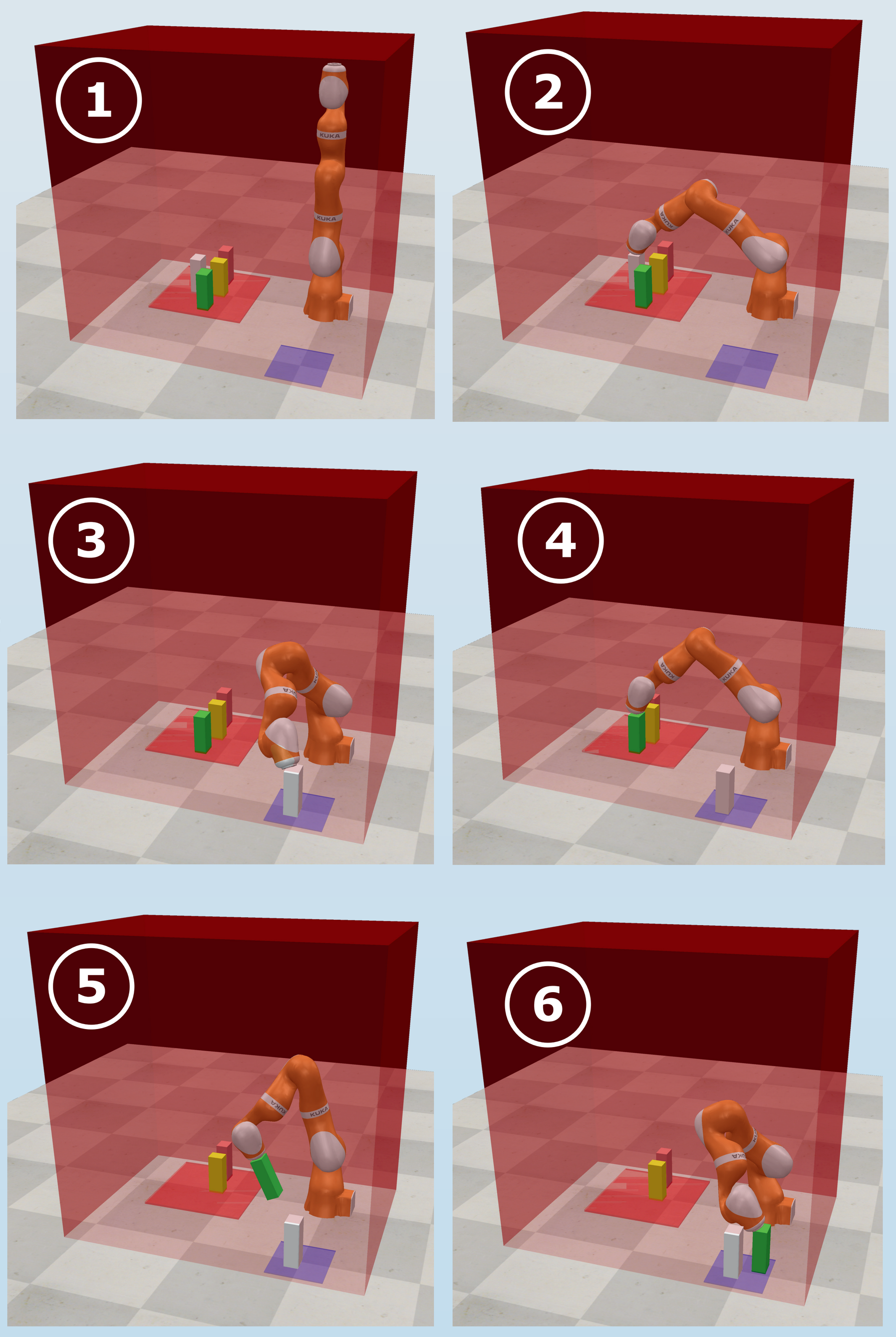
A plan

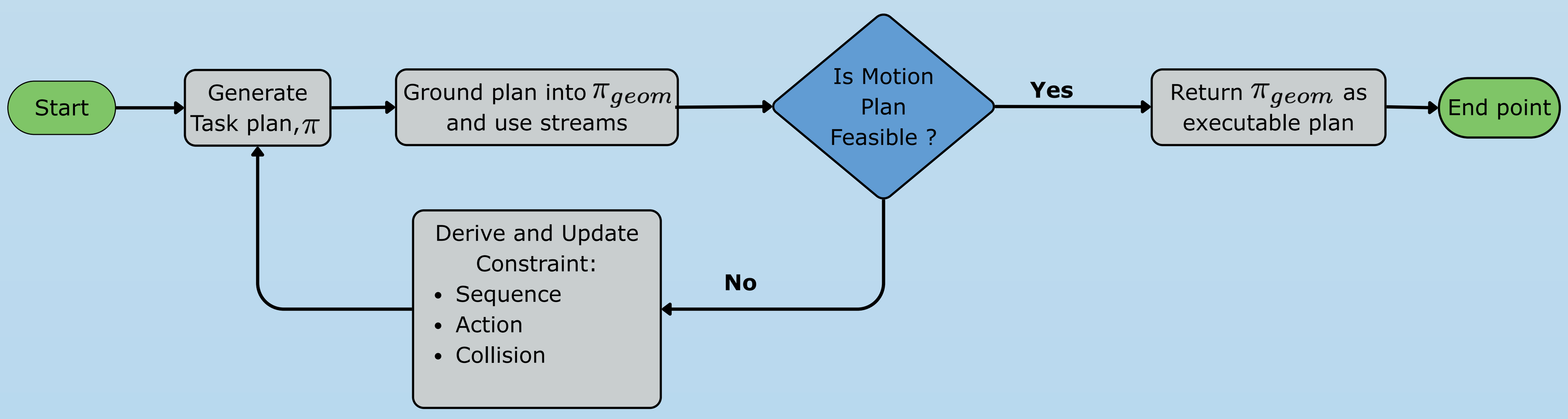
$$\pi = [a_1, ..., a_n]$$

is such that each parameterized action, $a \in A$ accepts parameters $\theta_a = (\theta_1, ..., \theta_n)$ which can be discrete or continuous values and consist of **constraints**, **preconditions**, **effects**, and **costs**.

Condition:

1. PDDLStream Executability
2. Geometric Feasibility of all Actions
3. Constraint Satisfaction



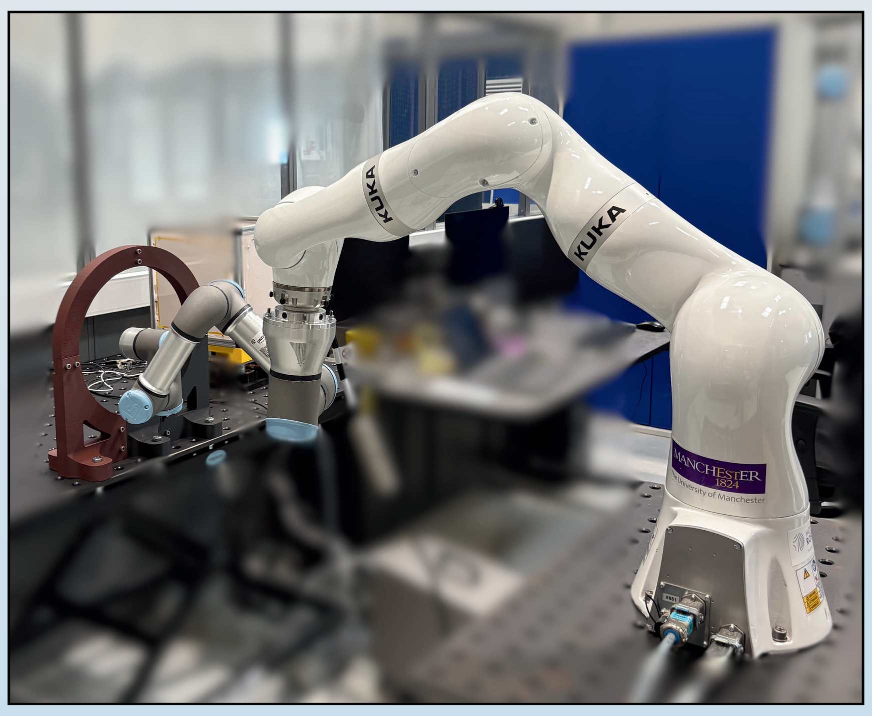


Example Plan: Placing a green object on the blue grid

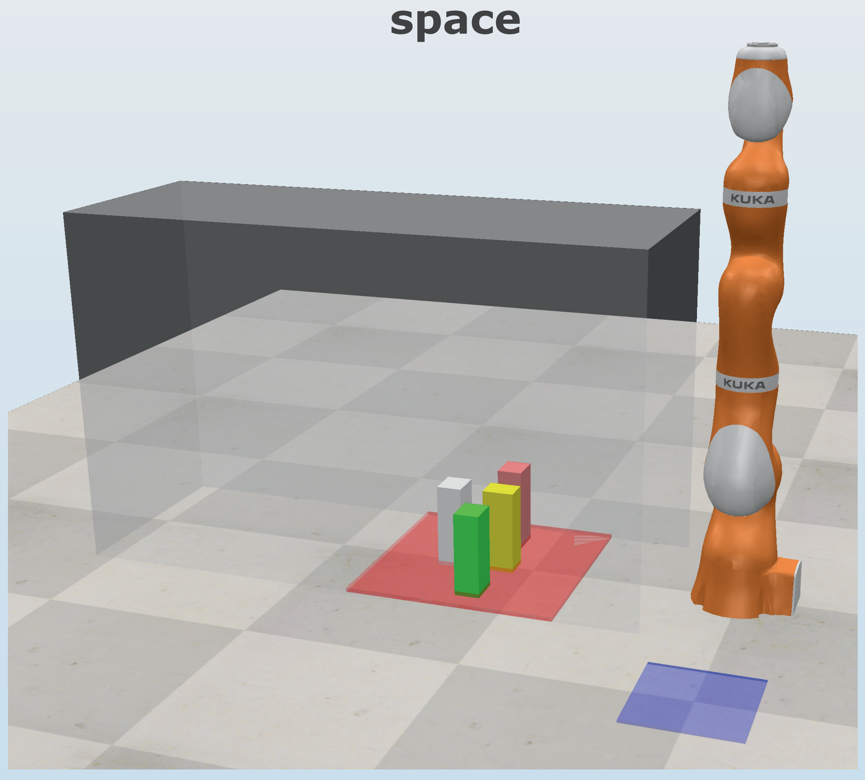
$$\pi = [MoveFree(q_0, q_1, \tau_1), Pick(green, g, p_o, q_1), MoveHold(green, g, q_1, q_2, \tau_2), Place(green, g, p_1, gridBlue, q_2)]$$

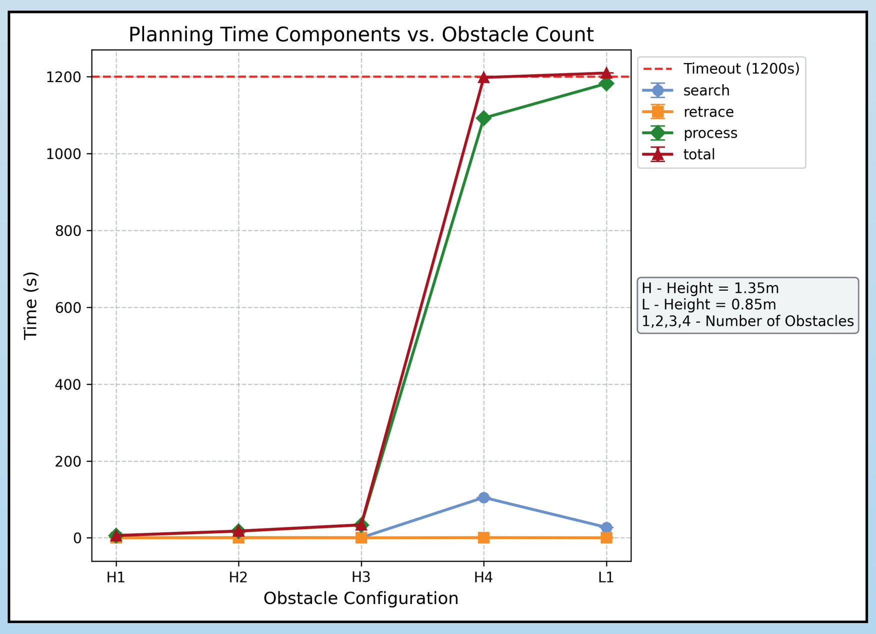
④ Experiments:

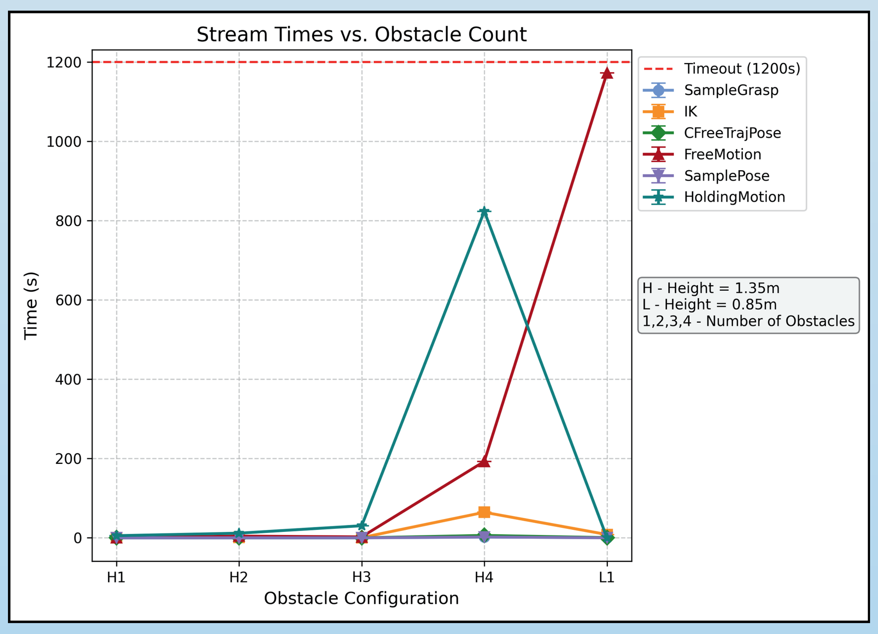
Insertion : Using LongBoy via Vector field inequalities [2]



TAMP Algorithm for Constrained space







⑤ Conclusion

TAMP methods are often used for open-tabletop manipulation

- Dont work well in constrained spaces
- Solutions arent real-time
- Cannot perform non monotonous rearrangement.
- Physical dependency isnt considered but only collisions

⑥ References

[1] Ozan Tokatli et al. (2021), Robot-Assisted Glovebox Teleoperation for Nuclear Industry.

[2] Murilo M. Marinho, Bruno V. Adorno, Kanako Harada, and Mamoru Mitsuishi (2018). Active Constraints Using Vector Field Inequalities for Surgical Robots.

[3] Brandon Vu, Toki Migimatsu, Jeannette Bohg (2024). COAST: Constraints and Streams for Task and Motion Planning.

[4] Garrett, C. (2021). PDDLStream: Integrating Symbolic and Geometric Planning.

† Presented work derived from “Path Planning for Glovebox Tasks Using the Redundant Robot LongBoy,” **TAROS 2024** (Ahmed Fahmy Soliman, Naseel Sinan, and Murilo Marques Marinho)