

# Humanoid Path Planner

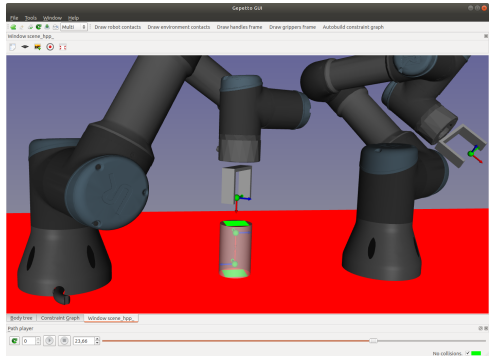
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# Definition of a manipulation planning problem

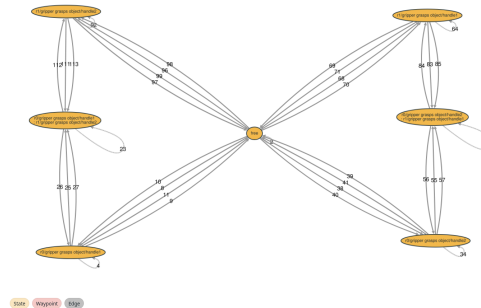
- ▶ grippers (frames attached to a joint),
- ▶ handles (frames attached to a joint),
- ▶ contact surfaces

define grasps and stable poses for objects.

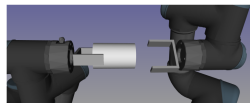
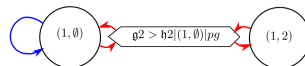


# The factory

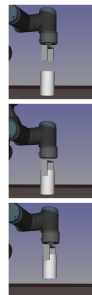
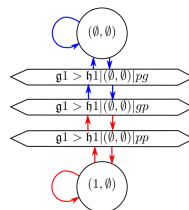
Given all the possible grasps (defined by grippers and handles), a factory builds the constraint graph with all possible states



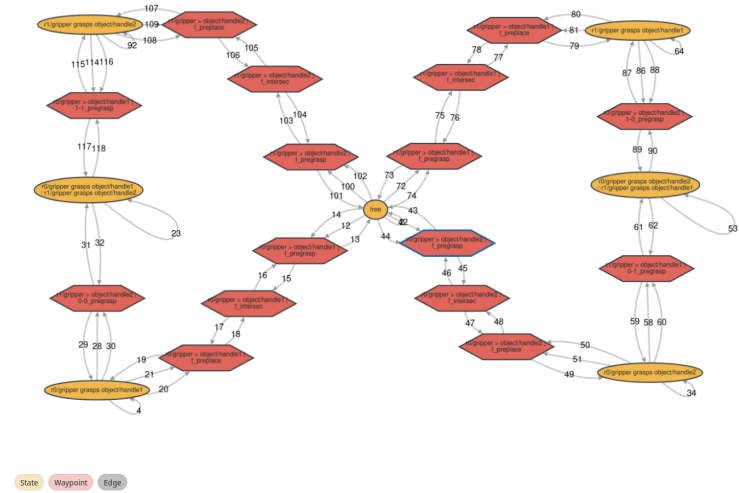
# Waypoint transitions and states



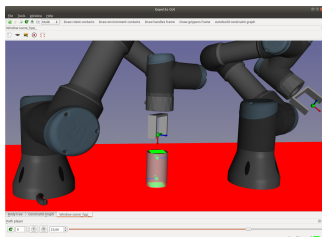
To ease manipulation planning resolution, some intermediate states are inserted by the factory.



# Waypoint transitions and states



# Motions on Lie groups



The configuration space of a manipulation problem, here  $\mathcal{C} = \mathbb{R}^6 \times \mathbb{R}^6 \times SE(3)$

- ▶ is a Cartesian product of  $\mathbb{R}^n$ ,  $SO(2)$ ,  $SO(3)$ ,  $SE(2)$ ,  $SE(3)$

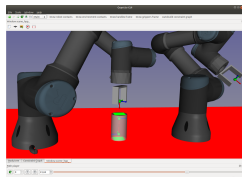
Each of those space share the properties of Lie groups.

# Motions on Lie groups

The elements and derivatives of those space are represented by vectors.

| Lie group type | configuration                                           | velocity                                      |
|----------------|---------------------------------------------------------|-----------------------------------------------|
| $SE(3)$        | $(x_1, x_2, x_3, p_1, \dots, p_4) \in \mathbb{R}^7$     | $(\mathbf{v}, \omega) \in \mathbb{R}^6$       |
| $SE(2)$        | $(x_1, x_2, \cos \theta, \sin \theta) \in \mathbb{R}^4$ | $(\mathbf{v}, \dot{\theta}) \in \mathbb{R}^3$ |
| $SO(3)$        | $(p_1, p_2, p_3, p_4) \in \mathbb{R}^4$                 | $\omega \in \mathbb{R}^3$                     |
| $SO(2)$        | $(\cos \theta, \sin \theta) \in \mathbb{R}^2$           | $\dot{\theta} \in \mathbb{R}$                 |

$$(q_1 \dots q_6 \ q_7 \dots q_{12} \ x \ y \ z \ p_1 \ p_2 \ p_3 \ p_4)$$



# Motions on Lie groups

$$\mathbf{q} = \left( \begin{array}{c} \mathbb{R}^6 \\ \mathbb{R}^6 \\ SE(3) \end{array} \right\{ \begin{array}{l} q_1 \\ \vdots \\ q_6 \\ q_7 \\ \vdots \\ q_{12} \\ x \\ y \\ z \\ p_1 \\ p_2 \\ p_3 \\ p_4 \end{array} \right)$$

$$\dot{\mathbf{q}} = \left( \begin{array}{c} \mathbb{R}^6 \\ \mathbb{R}^6 \\ \mathbb{R}^6 \end{array} \right\{ \begin{array}{l} \dot{q}_1 \\ \vdots \\ \dot{q}_6 \\ \dot{q}_7 \\ \vdots \\ \dot{q}_{12} \\ \mathbf{v} \\ \omega \end{array} \right)$$

# Motions on Lie groups

- ▶  $\mathbf{q} \oplus \dot{\mathbf{q}} \in \mathcal{C}$ ,  $\mathbf{q} \in \mathcal{C}$ ,  $\dot{\mathbf{q}} \in \mathcal{T}_{\mathcal{C}}$ , configuration reached from  $\mathbf{q}$  after following the constant velocity  $\dot{\mathbf{q}}$  during a unit time,
- ▶  $\mathbf{q}_2 \ominus \mathbf{q}_1 \in \mathcal{T}_{\mathcal{C}}$ ,  $\mathbf{q}_1 \in \mathcal{C}$ ,  $\mathbf{q}_2 \in \mathcal{C}$ , constant velocity that moves from  $\mathbf{q}_1$  to  $\mathbf{q}_2$  in unit time.
- ▶  $\mathbf{q}_1 + t(\mathbf{q}_2 \ominus \mathbf{q}_1)$  linear interpolation between  $\mathbf{q}_1$  and  $\mathbf{q}_2$ .

# Resources

- ▶ F. Lamiriaux and J. Mirabel, Prehensile Manipulation Planning: Modeling, Algorithms and Implementation, IEEE transactions on Robotics, 2022,
- ▶ Online documentation