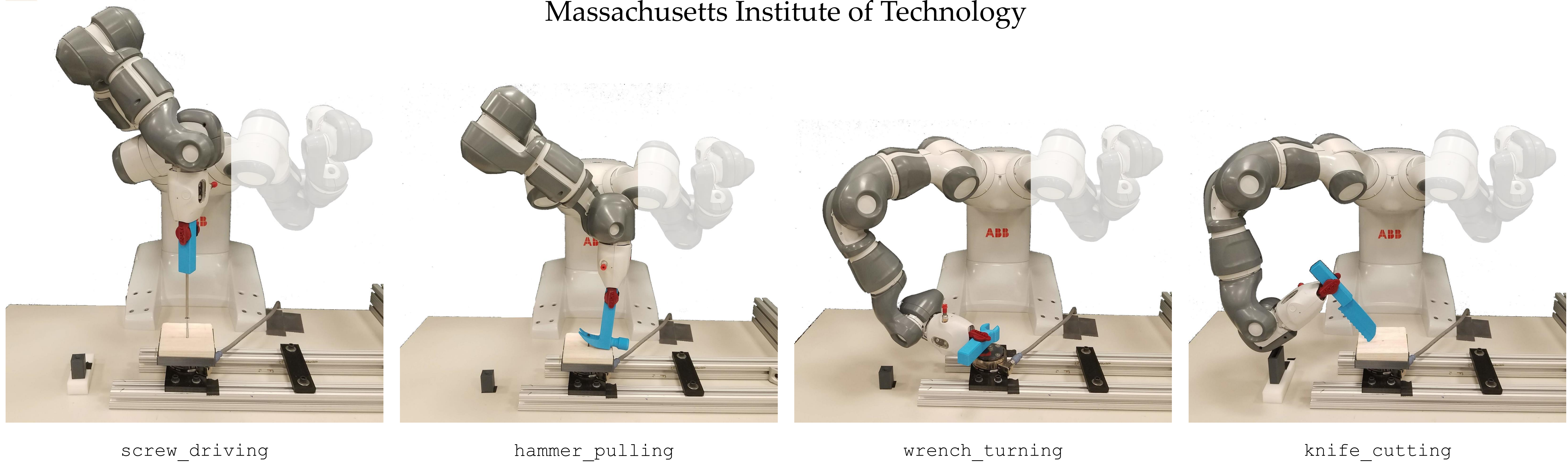


Force-and-Motion Constrained Grasp Planning for Tool Use



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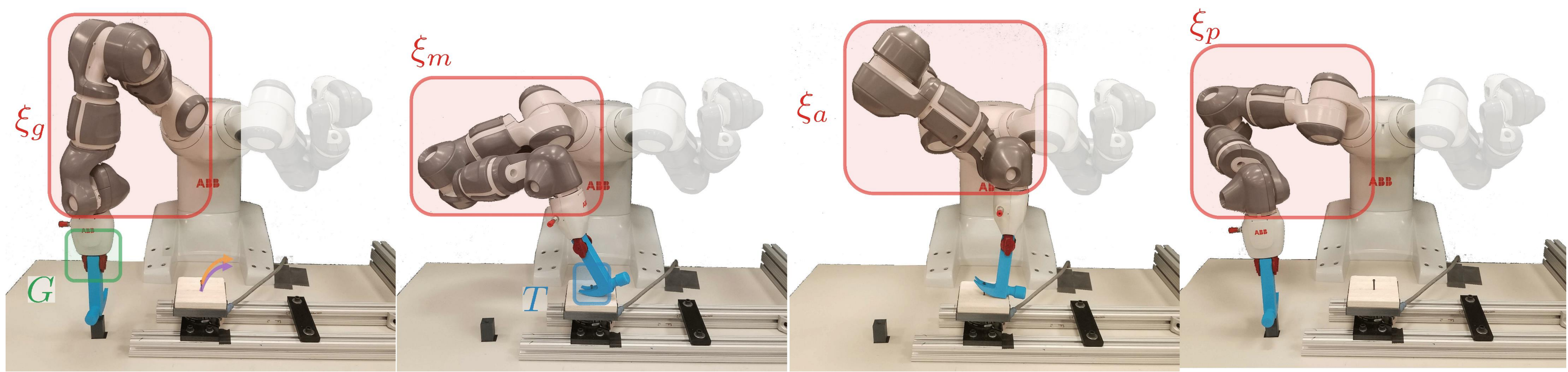
screw_driving

hammer_pulling

wrench_turning

knife_cutting

Tool Use as a *constraint satisfaction* problem, with high-dimensional continuous variables

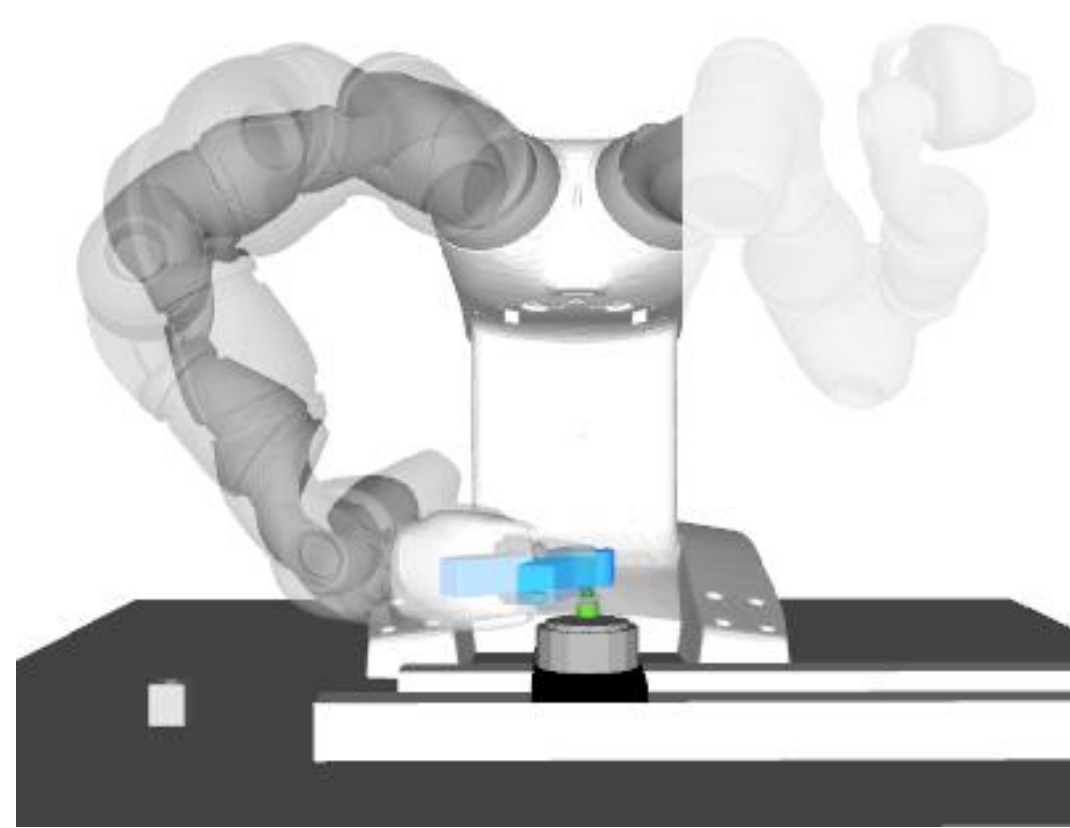


Choose a grasp G such that:

1. Kinematically Suitable
2. Reachable
3. Force Suitable

Kinematic Suitability

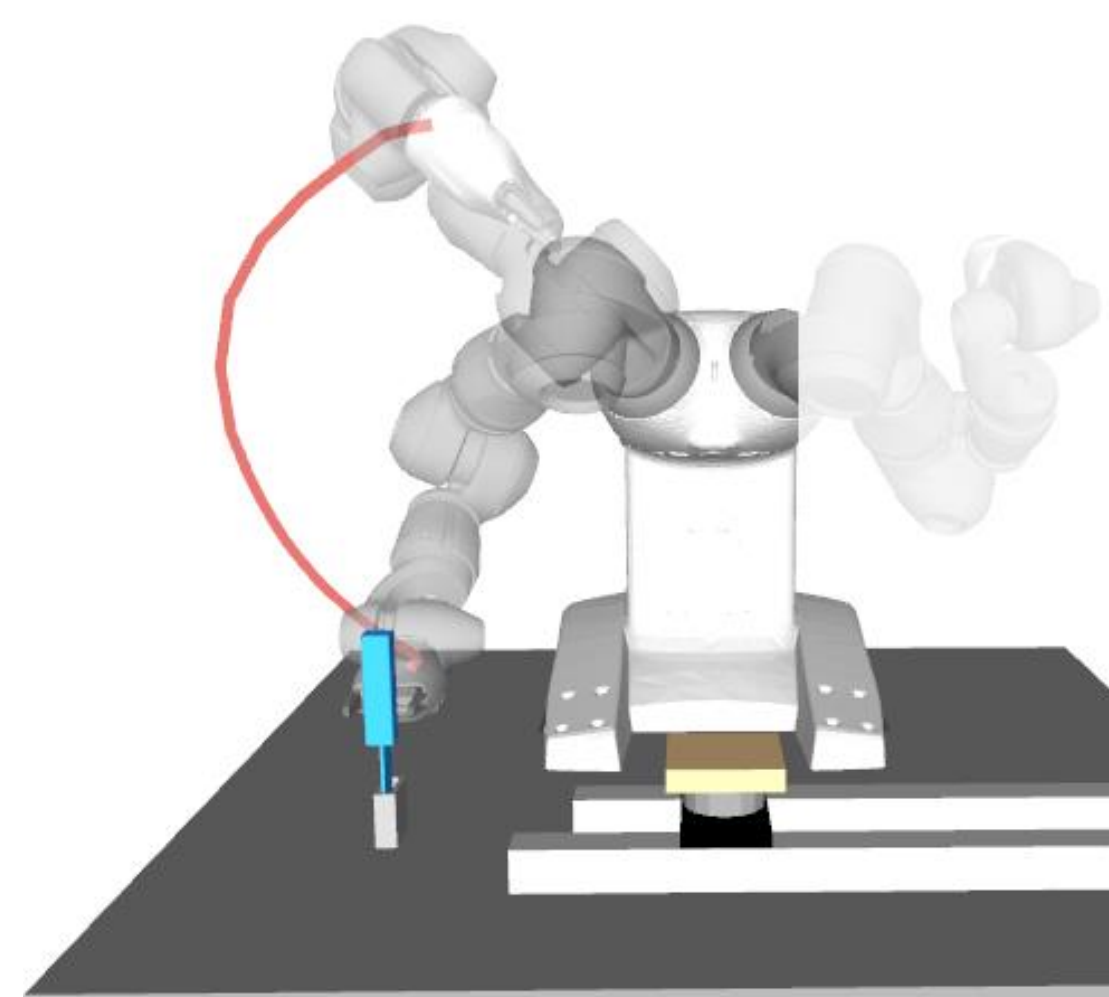
Goal: Enables Tool Path while respecting torque limits



$$\tau_{lim} > J^T(q) f_{ext}$$

Reachability

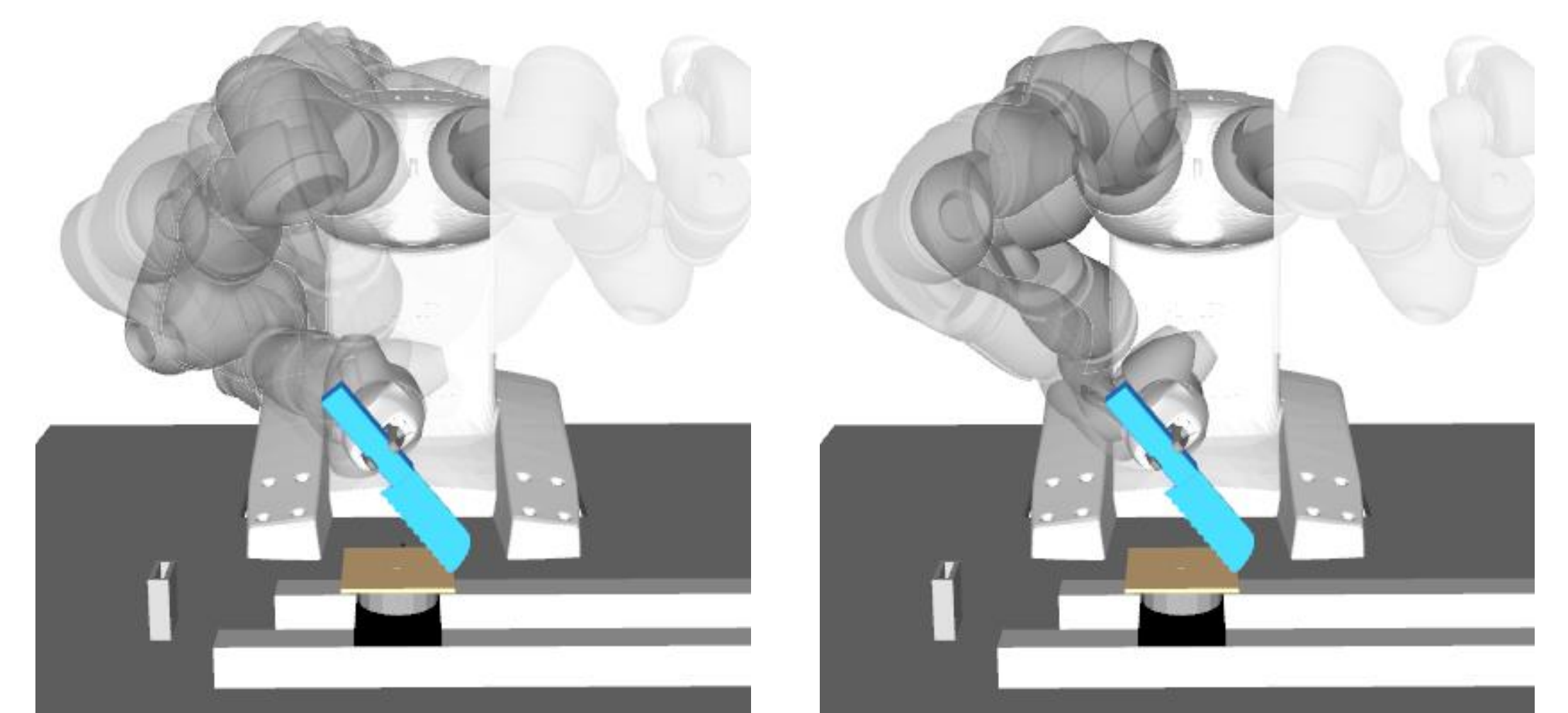
Goal: Exists collision-free path to grasp



How Difficult are the Tasks?

Task	C_0	C_1	C_2	$C_1 \cap C_2$	$C_0 \cap C_1 \cap C_2$	Difficulty
screw_driving	500	398	162	162	162	Easy
wrench_turning	52	369	220	219	27	Medium
knife_cutting	56	382	329	233	26	Medium
hammer_pulling	36	359	116	116	1	Hard

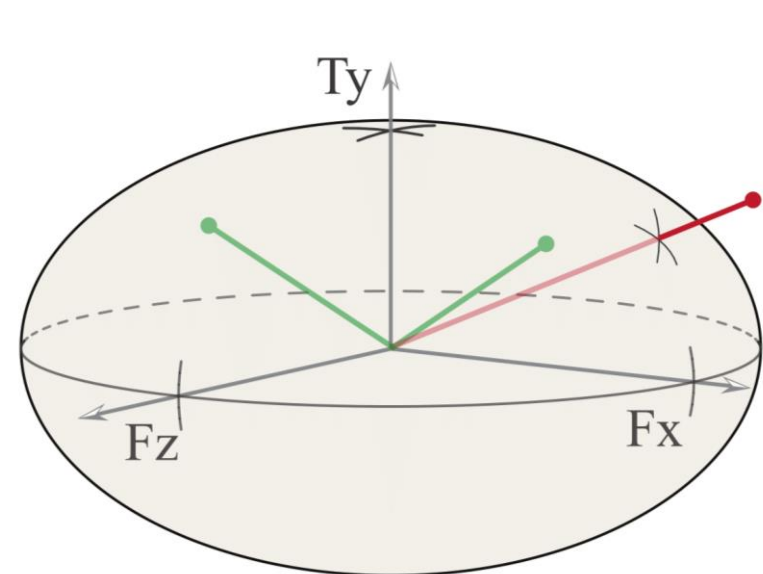
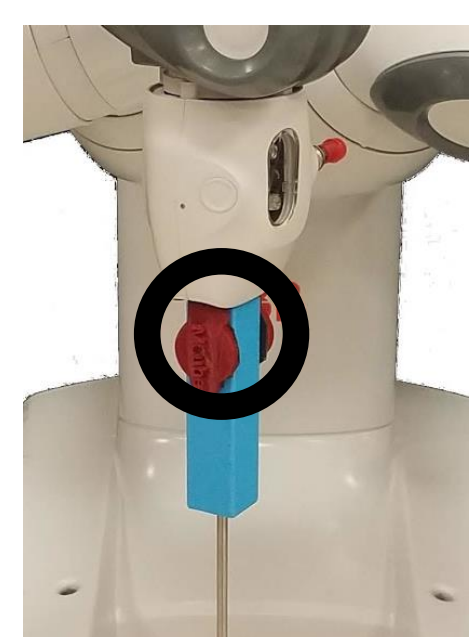
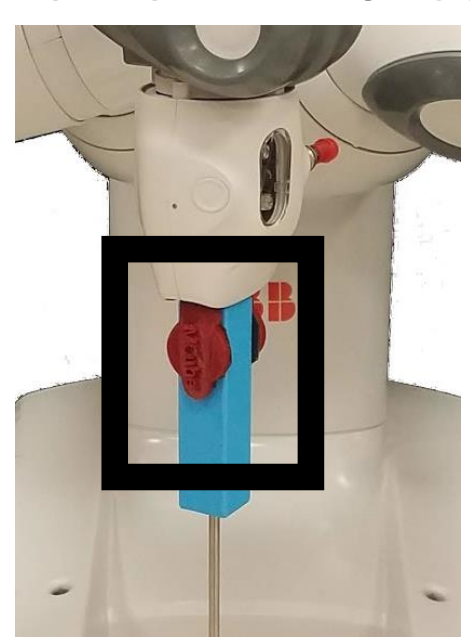
Force Kinematics



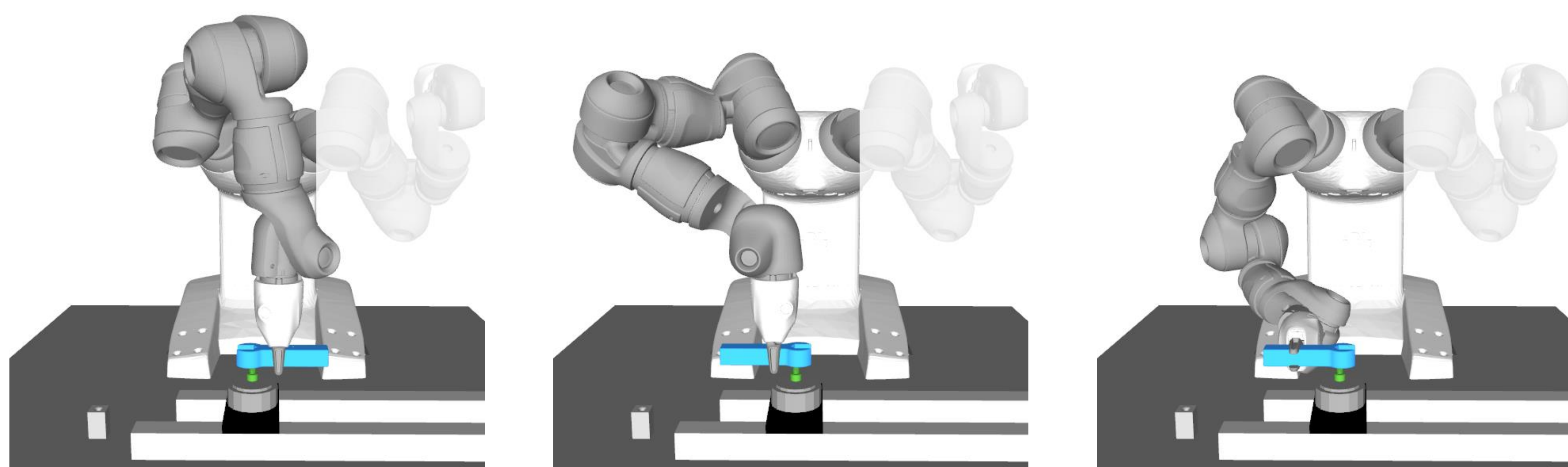
Goal: Frictional Joint "maintained" under external forces

Model grasp with planar patch contacts

Model finger friction with ellipsoidal approximation to limit surface.



$$\frac{f_x^c}{(N\mu)^2} + \frac{f_z^c}{(N\mu)^2} + \frac{t_y^c}{(N\mu)^2(rc)^2} < 1$$



Experimental Force/Torque Profiles

