Hand-arm coordination control for robot interaction tasks

Marko Guberina, Lund University
Dept. of Automatic Control, RobotLab LTH
Supervisors: Yiannis Karayiannidis (LU), Björn Olofsson (LU)

Motivation & Research Goals

Hand-arm coordination: simultaneous and possibly synchronized movement of robotic arms and grippers (hands) during object manipulation.
Research goals:

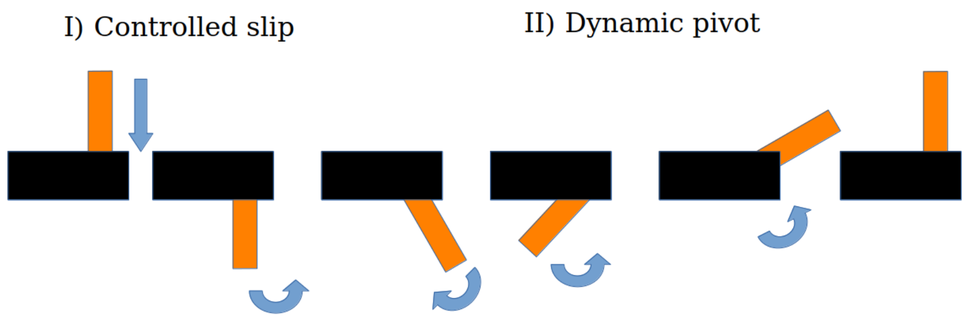
- enhancing robots' overall performance by overcoming the limitations of rigid grasping
- more natural and intuitive looking robotic motion

Problem description

By controlling the forces in the equation

$$\boldsymbol{M}\boldsymbol{q}_{\text{object}} = \boldsymbol{f}_{\text{contact}}(\boldsymbol{u}_f) + \boldsymbol{f}_{\text{acceleration}}(\boldsymbol{u}_a) + \boldsymbol{f}_{\text{friction}}(f_n) + \boldsymbol{f}_{\text{gravity}}$$

pivoting, **sliding** and their combinations can be used to regrasp the held object. Both kinds of movement can be achieved dynamically, e.g. a swing-up, or through gravity.



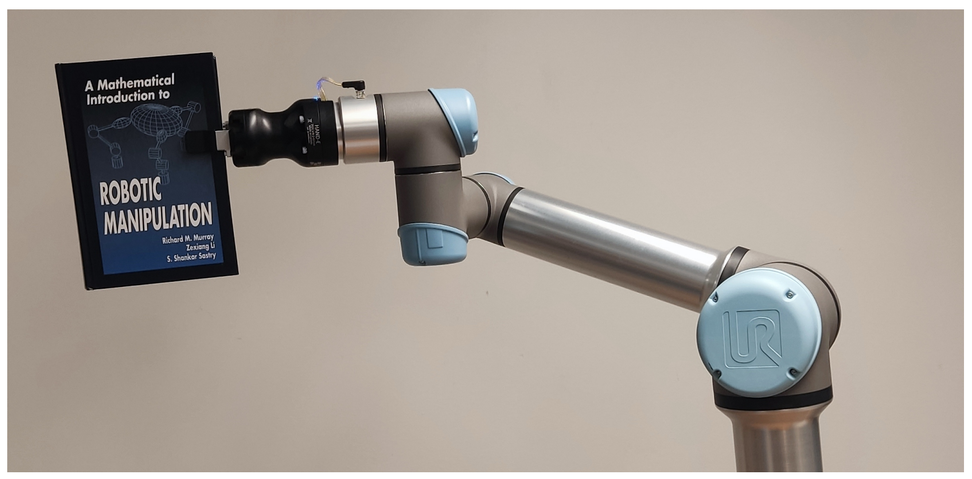
The problem is difficult due to underactiation, nonholonomic constraints, hybrid dynamics due to different dynamic modes (sticking or sliping, presence or absence of contacts) and the imprecision of haptics estimation.

Methods

Optimal control

Framework motivation:

- it accomodates constraints like the positivity of the pressing force and torque limits
- it can generate the necessarily dynamically feasible trajectories
- can achieve feedback via MPC



Contributions

1. Discovering the optimal regrasping maneuver for the given initial and goal object pose. Trajectory optimization results in more natural motion.
2. Decreasing problem complexity by reducing the number of dynamic modes and increasing physical realism of rollouts by utilizing the LuGre friction model.
3. Resolving stiff dynamics in optimal control in general.

References

[1] Waltersson, Gabriel Arslan, and Yiannis Karayiannidis. "Planar Friction Modelling with LuGre Dynamics and Limit Surfaces." IEEE Transactions on Robotics (2024).
[2] Mastalli, Carlos, et al. "Crocoddyl: An efficient and versatile framework for multi-contact optimal control." 2020 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2020.

WASP WALLENBERG AI, AUTONOMOUS SYSTEMS AND SOFTWARE PROGRAM