ROBUST INTERCONNECTION AND DAMPING ASSIGNMENT PASSIVITY-BASED CONTROL VIA NEURAL BAYESIAN INFERENCE

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Problem

Control of underactuated systems with model uncertainties

Previous Methods

Passivity-based control

Previous Methods

Reinforcement learning

Passivity-Based Control

Consider a mechanical system with total energy

$$H(q,p) = \frac{1}{2} p^\top M^{-1}(q) p + V(q),$$

with $M(q) \succ 0$. The dynamics is

$$\begin{bmatrix} \dot{q} \\ \dot{p} \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & I \\ -I & 0 \end{bmatrix}}_{J = -J^\top} \begin{bmatrix} \nabla_q H \\ \nabla_p H \end{bmatrix} + \underbrace{\begin{bmatrix} 0 \\ G(q) \end{bmatrix}}_{g(q)} u \tag{1}$$

Find $u(q,p) = u_{es}(q,p) + u_{di}(q,p)$ such that

1. closed-loop system is passive w.r.t. a storage function H_d
2. H_d has a minimum and the desired equilibrium $(q,p) = (q^\star, 0)$.

IDA-PBC for Underactuated Mechanical Systems

In IDA-PBC, H_d is chosen to be of the form

$$H_d(q,p) = \frac{1}{2} p^\top M_d^{-1}(q) p + V_d(q), \tag{2}$$

and the control action u is comprised of

$$u = \underbrace{\left(G^\top G\right)^{-1} G^\top \left(\nabla_q H - M_d M^{-1} \nabla_q H_d\right)}_{\text{energy shaping}} - \underbrace{K_d G^\top \nabla_p H_d}_{\text{damping injection}}$$

Finding suitable functions M_d and V_d requires solving a nonlinear PDE.