Reactive Anticipatory Robot Skills with Memory

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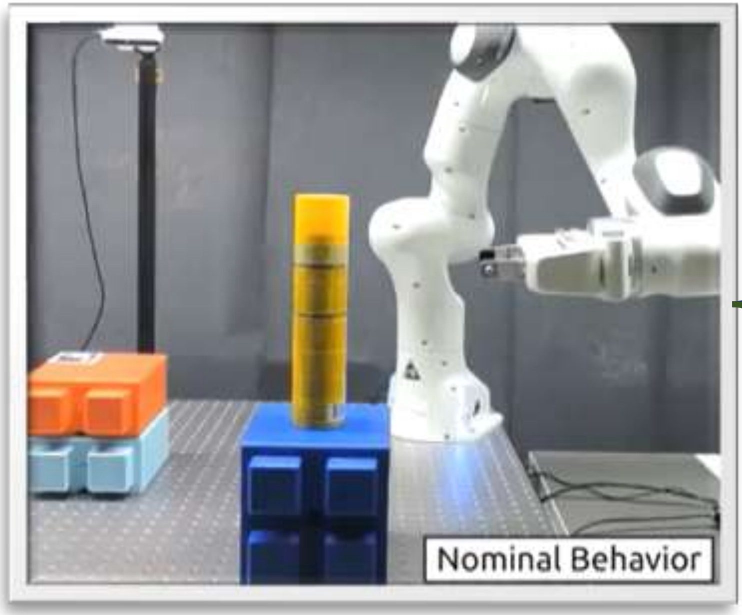
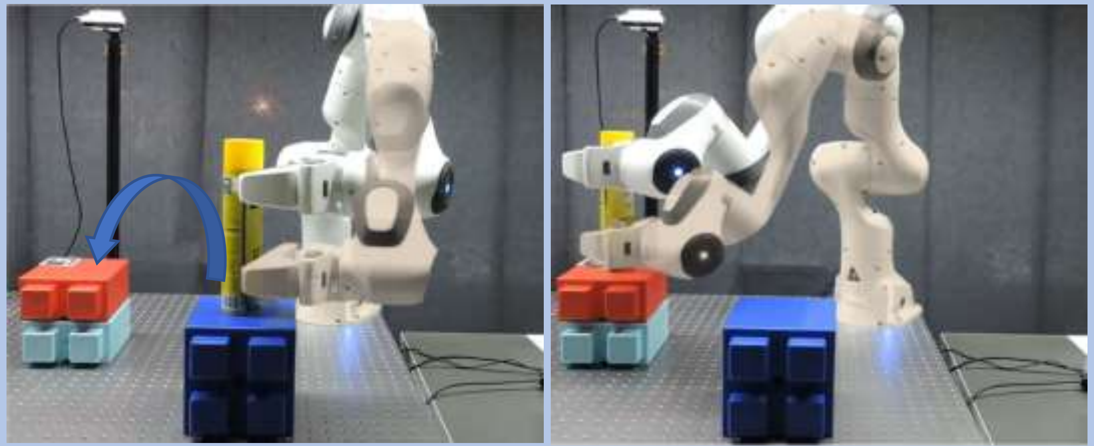
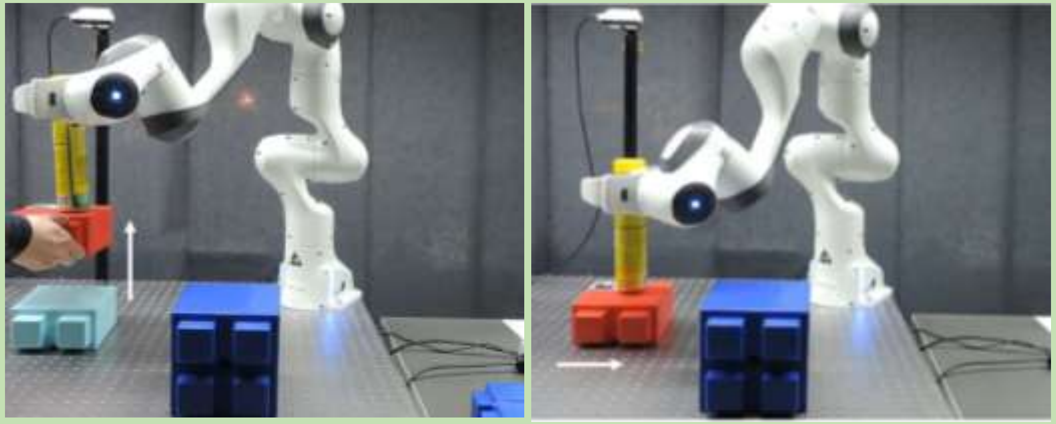
Motivations





Memory feedback: time-correlations between states



Fast adaptation to changing objectives

Background: System Level Synthesis

Linear Quadratic Regulator (LQR)

$$\begin{bmatrix} \boldsymbol{u}_0 \\ \boldsymbol{u}_1 \\ \vdots \\ \boldsymbol{u}_T \end{bmatrix} = \begin{bmatrix} \boldsymbol{K}^{0,0} & \boldsymbol{0} & \cdots & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{K}^{1,1} & \cdots & \boldsymbol{0} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{K}^{T,T} \end{bmatrix} \begin{bmatrix} \boldsymbol{x}_0 \\ \boldsymbol{x}_1 \\ \vdots \\ \boldsymbol{x}_T \end{bmatrix}$$

System Level Synthesis (SLS)

$$\begin{bmatrix} \boldsymbol{u}_0 \\ \boldsymbol{u}_1 \\ \vdots \\ \boldsymbol{u}_T \end{bmatrix} = \begin{bmatrix} \boldsymbol{K}^{0,0} & \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{0} & \boldsymbol{0} \\ \boldsymbol{K}^{1,0} & \boldsymbol{K}^{1,1} & \boldsymbol{0} & \cdots & \boldsymbol{0} & \boldsymbol{0} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \boldsymbol{K}^{T,0} & \boldsymbol{K}^{T,1} & \boldsymbol{K}^{T,2} & \cdots & \boldsymbol{K}^{T,T-1} & \boldsymbol{K}^{T,T} \end{bmatrix} \begin{bmatrix} \boldsymbol{x}_0 \\ \boldsymbol{x}_1 \\ \vdots \\ \boldsymbol{x}_T \end{bmatrix}$$

Contributions

extended SLS (eSLS)
Solves for linear quadratic tracking tasks

iterative SLS (iSLS)
Solves for nonlinear nonquadratic tasks

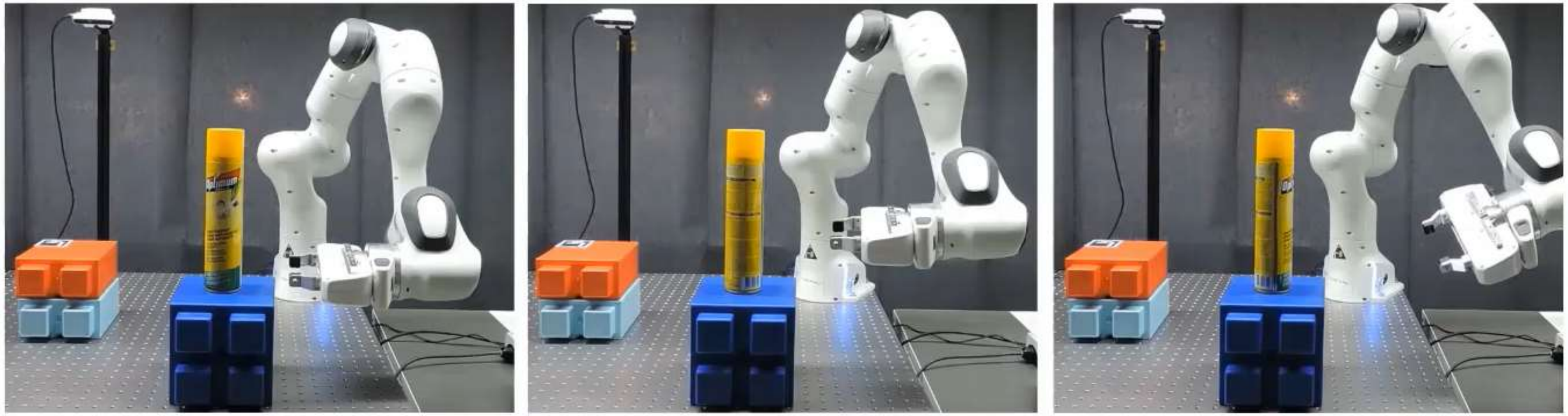
$$\boldsymbol{u} = \boldsymbol{K}\boldsymbol{x} + \boldsymbol{k}$$

Memory feedback and **time-correlations**

Fast adaptation to changing objectives

Experimental Results

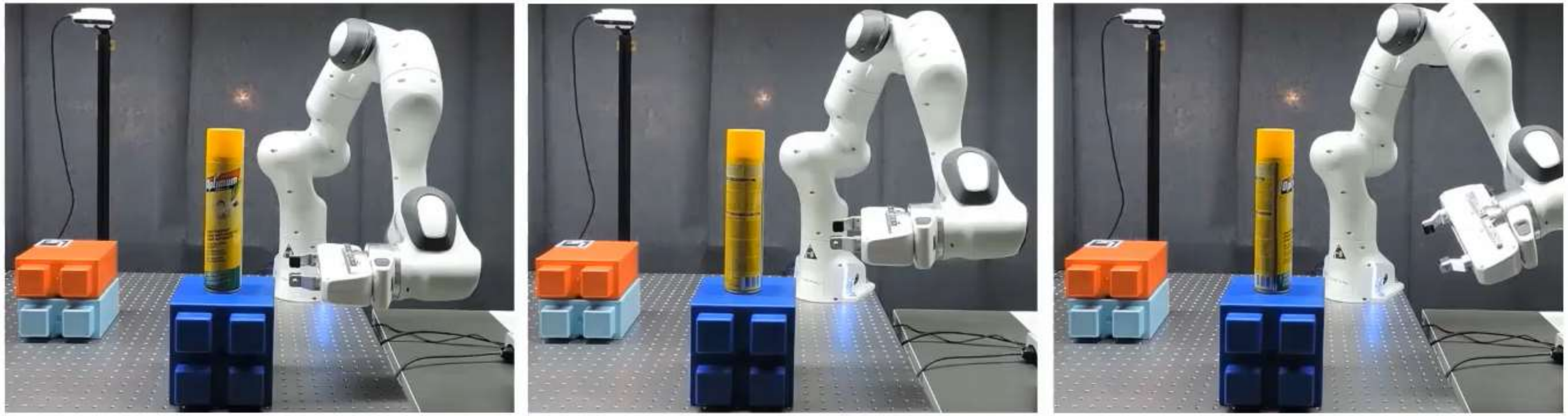
Memory feedback and **time-correlations**



Even a local controller can exploit memory feedback!

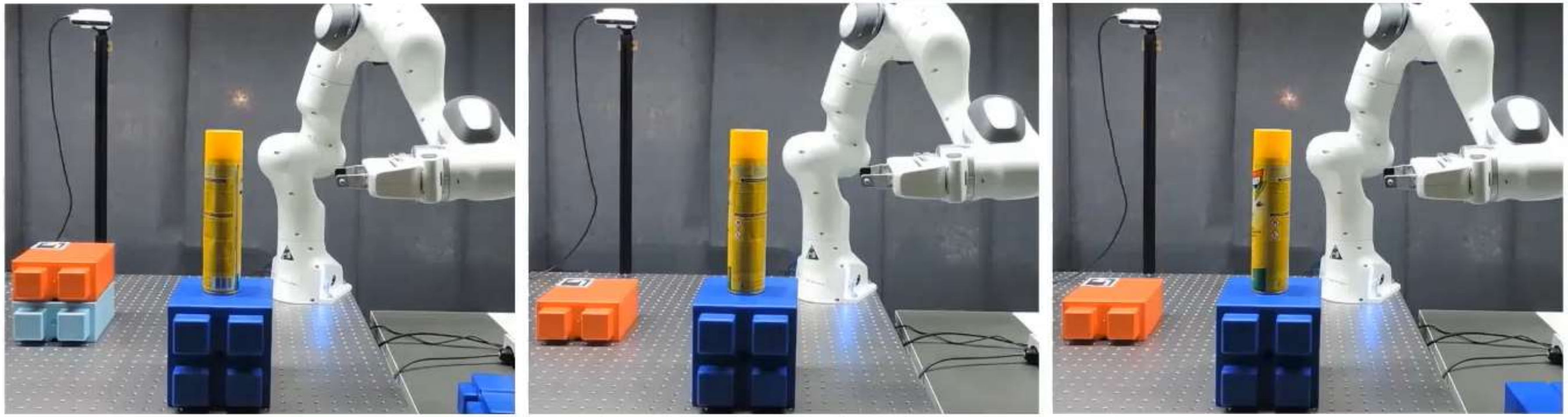
Experimental Results

Memory feedback and **time-correlations**



Even a local controller can exploit memory feedback!

Fast adaptation to changing objectives



Local: without resolving the problem

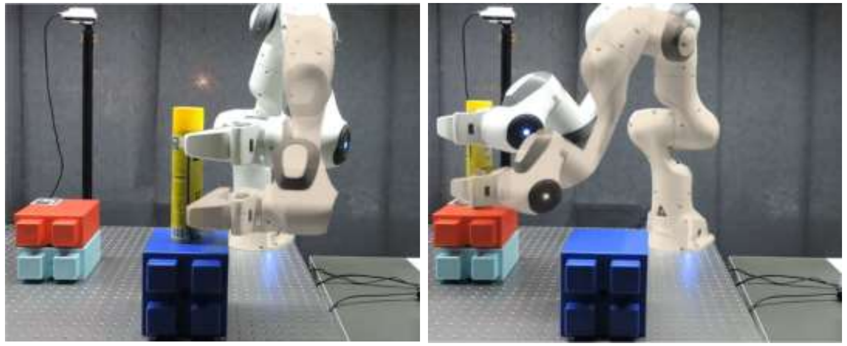
Fast: only a matrix-vector multiplication

Discussion

$$u = Kx + k$$

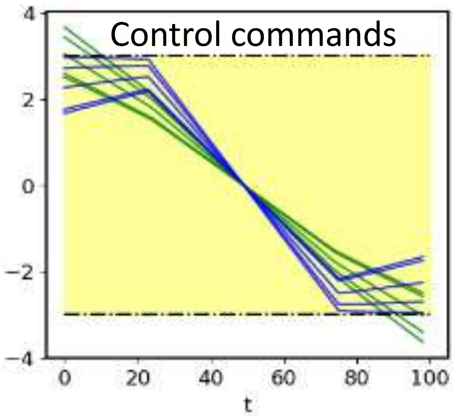
Memory feedback and time-correlations	Fast adaptation to changing objectives

- ❑ Learning time-correlations from demonstrations for **inverse optimal control**



Time-correlations or independent variations?

- ❑ Increase the validity region of the local controller?



Robustly constrained iSLS

Warm-starting MPC?