Motivation

• Accuracy of learned dynamic models depends on collected data → how to explore system efficiently?
• Exploration strategies often aim to obtain a globally accurate model [1]
• Control laws often only require a locally accurate model to perform well

Quantifying Utility of Data

Given a finite discretization $X_{\text{ref}}$ of $\mathcal{X}$, the mutual information of a data point $\xi \in \mathcal{X}$ with respect to $X_{\text{ref}}$ is given by

$$I(y_t, y_{X_{\text{ref}}}) = \frac{1}{2} \log \left( \frac{k(\xi, \xi) + \sigma_t^2}{K_{X_{\text{ref}}}(\xi) + \sigma_t^2} \right).$$

Exploration Algorithm

Algorithm 1 LocalAL (Localized Active Learning)

Input: $x_t, f(\cdot, \cdot), k(\cdot, \cdot)$

1. for $t = 0, 1, 2, \ldots$ do
2. Compute point of maximal information $\xi^* = \arg \max \limits_{\xi \in \mathcal{X}} I(y_t, y_{X_{\text{ref}}})$
3. Compute solution of optimal control problem

$$U^* = \arg \min \limits_{U \in \mathcal{U}} \sum_{t} \left( \xi^* - x_t \right)^T Q (\xi^* - x_t)$$

s.t. $x_{t+1} = f(x_t, u) + g(x_t) + w_t,$ $w_t \in \mathcal{U}, \forall t \in [0, \ldots, N_H-1]$
4. Apply $u^{\text{ref}}$ to system, measure $x_{t+1}$, update GP model $\mu(\cdot), \Sigma(\cdot)$... end for

Visualization

Interpretation

$\mu(\cdot)$ is the estimated model, $\Sigma(\cdot)$ represents model uncertainty [2].

Monte Carlo Simulations

Toy problem

Pendulum

Cart-pole

Comparison

Our method consistently yields a more accurate model on $X_{\text{ref}}$ than the greedy entropy-based approach from [1].

References