Adaptive Manipulator Control using Active Inference with Precision Learning

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Context

Previous work performed joint control and state-estimation of a robot arm under the Active Inference framework [1].

The AIC was compared to state-of-the-art methods and showed adaptive behaviour. However, it requires the definition of several parameters including covariance matrices.

In this work we learn the covariance matrices thus creating **'self-tuning' controllers.**

Background

Similar to [1], we assume Gaussianity on the observation and transition models. We then obtain the following cost function for the **free-energy F**:

$$F = \frac{1}{2}(\boldsymbol{\varepsilon_o}^\top \Sigma_o^{-1} \boldsymbol{\varepsilon_o} + \boldsymbol{\varepsilon_{o'}}^\top \Sigma_{o'}^{-1} \boldsymbol{\varepsilon_{o'}} + \boldsymbol{\varepsilon_\mu}^\top \Sigma_\mu^{-1} \boldsymbol{\varepsilon_\mu} + \boldsymbol{\varepsilon_{\mu'}}^\top \Sigma_{\mu'}^{-1} \boldsymbol{\varepsilon_{\mu'}} + \ln|\Sigma_o| + \ln|\Sigma_{o'}| + \ln|\Sigma_\mu| + \ln|\Sigma_{\mu'}|) + C.$$

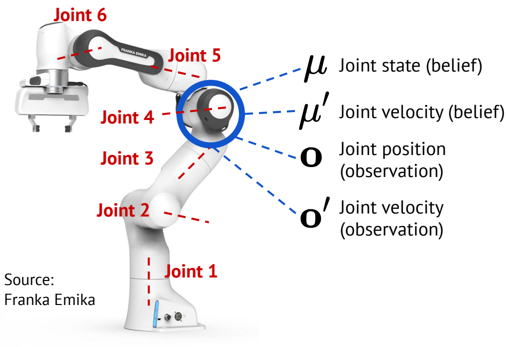
Actions and state-estimates are obtained using **gradient descent on F**.

Method

In our approach we learn the inverse covariance matrices (precision matrices).

Similar to control and state-estimation we obtained **update rules for the associated covariances** of the observation models. This allowed us to **adapt our controller online**.

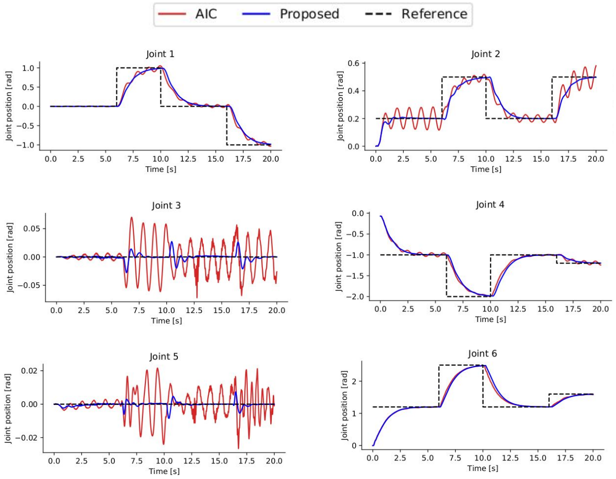
$$\dot{\Sigma}_o^{-1} = -\kappa_\sigma \frac{\partial F}{\partial \Sigma_o^{-1}}, \quad \dot{\Sigma}_{o'}^{-1} = -\kappa_\sigma \frac{\partial F}{\partial \Sigma_{o'}^{-1}}$$



Source: Franka Emika

Results

We compared with [1] in a manipulation scenario. [1] performs well when the covariances are properly tuned, but performs poorly when if the initial covariance are perturbed. Our approach is 're-tuned' during run time using the update rules we derived.



Video

Code

[1] C. Pezzato, R. Ferrari and C. H. Corbato, "A Novel Adaptive Controller for Robot Manipulators Based on Active Inference," in IEEE Robotics and Automation Letters, 2020.