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BACHELOR THESIS / MASTER'S THESIS

Scenario-Based Model Predictive Control with Particle Gibbs for Functional Electrical Stimulation

Problem description:

Functional electrical stimulation (FES) is a technique used for rehabilitation of stroke or otherwise paralyzed patients. FES uses low-energy electrical pulses to induce muscle contraction and to generate body movements. In general, the control of systems that closely interact with humans such as FES poses numerous challenges. On the one hand, it is usually difficult to derive an accurate model of the human using first principles. Data-driven system identification appears as a promising alternative. On the other hand, formal robustness guarantees are required whenever humans are involved. In addition, full state measurements are usually not available which limits the number of applicable methods.
Modeling approaches based on particle Gibbs sampling allow to learn the dynamics when only partial state measurements are available [1]. Additionally, the uncertainty over a prediction can be quantified. The result of a system identification with particle Gibbs are samples from the parameter posterior that represent a distribution over models. An unsolved problem is how these samples can be used for control in such a way that formal robustness guarantees for the resulting system can be given.
The so-called scenario approach can be used to derive probabilistic robustness guarantees based on sampled instances of the uncertainty affecting the system [2]. The scenario approach can be used for model predictive control. By combining particle Gibbs based models with this control approach it might be possible to obtain the desired guarantees.
The aim of this work is to develop a robust scenario-based model predictive control (MPC) with a particle Gibbs model for FES. Existing probabilistic robustness guarantees should be extended to hold for the resulting system.

Tasks:

- Literature research on particle Gibbs methods and scenario-based model predictive control
- Implementation of a scenario-based model predictive control with particle Gibbs
- Derivation of probabilistic robustness guarantees

Bibliography:

[1] A. Svensson and T. B. Schön, "A flexible state–space model for learning nonlinear dynamical systems," *Automatica*, vol. 80, pp. 189–199, 2017.
[2] G. C. Calafiore and M. C. Campi, "The scenario approach to robust control design," *IEEE Transactions on automatic control*, vol. 51, no. 5, pp. 742–753, 2006.

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