Introduction
As digitalization thrives in industrial applications, pervasive sensors give us wide access to data. Meanwhile, Machine Learning (ML) is a field of computer science dedicated to extracting knowledge from large data. This thesis focus on implementing ML techniques in advanced process control (APC), especially model identification and integration of machine learning into optimal controller design.

Machine Learning based system identification

1. Validation model
Gaussian process and neural networks are used for system identification and tested on a four-tank system. This system is a multiple-input-multiple-output (MIMO) system and its states, the level of the water in each tank, are coupled. In this thesis, it is assumed that only the tank 1 and tank 2 are observed and no prior knowledge, including the number of the tanks, is presumed before system identification. The pumps of this system are controlled by two PID controllers, whose feedback signals are the level of tank 1 and tank 2.

2. Gaussian process (GP) based model
GP is a collection of random variables, any finite number of which have consistent joint Gaussian distributions. It is a non-parametric probabilistic model, with which an auto-regressive model is used as an system identification model.

\[ y(t+1) = GP(y(t), \ldots, y(T+1), u(t), \ldots, u(T+1)) \sim \mathcal{N}(\mu(x), \sigma^2(x)) \]

With this model, a multi-step-forward prediction is achieved by moment match method.

3. Neural network based model
Neural network is a scalable inter-connected model, including fully-connected networks, recurrent networks (RNN), etc. We propose a custom recurrent network structure with a special training mechanism, which is efficiently scalable to large system with strong compatibility with MPC.

Machine learning integrated controller

1. RNN based MPC
The model identified with custom RNN structure is integrated into the MPC framework, where interior point method is used to solve the non-linear programming problem. Following outcomes show the performance improvement in tracking and the robustness against unknown noise, which are tested on four-tank system with low level PID controllers.

2. GP based iterative learning control
GP model is integrated into a linear model to capture non-linear dynamics. It is tested both on active vibration compensation as well as iterative learning schemes. The following outcome shows the improvement in tracking iterative signals on four-tank system.

Conclusions & outlook
This thesis discusses the mechanism of the fully-connected networks. Later, investigated both GP and neural networks based system identification, in particular, a custom structure and training mechanism is proposed. On the basis of the RNN model, MPC is tested, exploiting the possibility of MPC with RNN. At last, an explicit-like MPC and GP based iterative learning control is explored. Later on, we will focus on building rigorous machine learning based scalable control methods.

References:

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