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A. A. Bachnas, S. Weiland and R. Tóth
Dept. of Electrical Engineering
Control System group, TU/e
a.a.bachnas@tue.nl, s.weiland@tue.nl, r.toth@tue.nl

1 Introduction

Model Predictive Control (MPC) is widely applied in the field of process control. The aforementioned control scheme is able to realize control objectives while obeying safety constraint on the input side. However, desired performance of the controller can only be sustained in small time periods after its commissioning. The performance degradation is usually caused by the change of disturbance characteristics and/or growing plant-model mismatch. These phenomena have led to numerous proposed solutions to prolong the lifetime of an MPC controller.

In this work, a novel solution is proposed by employing a flexible model structure, namely an orthonormal basis function (OBF) model structures into the MPC scheme. Due to its model characteristics, structured model updates can be conducted iteratively in a closed loop setting via latest measured input-output data. Small updates towards model coefficients are done iteratively to fine tune the prediction part of the control scheme. If the change of the plant and/or disturbances persist for a long period, model overhaul is conducted by re-updating the basis functions. This will reduce the modeling uncertainty to ensure that the plant can still be accurately described by the selected basis functions. Moreover, since OBF model structures can be seen as a generalization of FIR model structures, the wide application of FIR model in the industrial MPC scheme is another appealing reason for the proposed solution.

2 Formulation

The OBF model structure utilizes a broader selection of orthonormal basis functions \{\phi_i(z)\}_{i=1}^{n_g} instead of just the pulse basis \{z^{-i}\}_{i=1}^{n_g} which are used in FIR model structures. The formulation of an OBF model of an LTI system is:

\[
y(k) = \sum_{i=1}^{n_g} w_i \phi_i(q) u(k) + v(k),
\]

where \(w \in \mathbb{R}_{n_g}^n \) being the collection of expansion coefficients, and \(v(k)\) is the noise process which is assumed to be white. The output error noise structure provides consistent estimation in the close loop setting. With appropriately selected basis functions, the plant dynamics can be described by a small amount model coefficients. This leads to a parsimonious model of the system.

2.1 Coefficient estimation

Data-driven estimation is conducted iteratively to re-estimate expansion coefficients \(w\) by minimizing the least square prediction error criterion. The size of the measured data as well as possible weighting on the criterion, will be a design parameter to mitigate or adapt any changes in the plant behavior. Lastly, the OBF model and the identification criterion can be easily formulated a state-space description which is better suited for the standard MPC problem formulation.

2.2 MPC formulation

The proposed scheme uses standard MPC formulation with quadratic cost function to penalize deviations of the predicted outputs \(y(k+i|k)\) from a reference trajectory \(r(k+i|k)\)

\[
V(k) = \sum_{i=0}^{H_p} ||y(k+i|k) - r(k+i|k)||^2_Q + \sum_{j=0}^{H_u} ||\Delta u(k+j|k)||^2_R
\]

where \(\Delta u\) is the input increment, and \(H_p, H_u\) is the prediction and control horizon respectively. Expression \(||x||^2_Q\) is equivalent with \(x^T Q x\) where \(Q\) is the symmetric tuning matrix. The task of the control scheme is to compute the optimal input sequence that minimizes the cost function while satisfying operational constraint on input and output.

2.3 Joint data-driven scheme

Since \(y(k+i|k)\) is the future prediction of a model which is iteratively updated from measured input-output data (in a least square fashion), the quadratic cost function \(V(k)\) can be formulated solely based on the collection of measured data. Thus, the computation of the optimal input sequence and model coefficient can be done in one single formulation. Besides of the data-driven case, the performance level of the whole scheme can be monitored periodically. In case the level dropped below some threshold, model overhaul by re-optimizing the selected basis functions can be conducted to adapt the model towards major changes in the system or disturbance characteristics.

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References