Journal of Process Control 21 (2011) 1183–1192

Contents lists available at ScienceDirect

Journal of Process Control

journal homepage: www.elsevier.com/locate/jprocont

An improved model predictive control approach based on extended non-minimal state space formulation

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ARTICLE INFO

Article history:
Received 2 July 2010
Received in revised form 6 May 2011
Accepted 16 June 2011
Available online 28 July 2011

Keywords:
Model predictive control
State space feedback control
Extended non-minimal state space model
Discrete time processes

ABSTRACT

This paper presents a new design method of model predictive control (MPC) based on extended non-minimal state space models, in which the measured input and output variables, their past values together with the defined output errors are chosen as the state variables. It shows that this approach does not need the design of an observer to access the state information any more and by augmenting the process model and its objective function to include the changes of the system state variables, the control performances are superior to those of the controller that does not bear this feature. Furthermore, closed-loop transfer function representation of the model predictive control system facilitates the use of frequency response analysis methods for the nominal control performances of the system.

1. Introduction

Model predictive control (MPC) has found numerous theoretical design methods and industrial applications since it first appeared in the 1970s. The three most general MPC design methods are based on finite impulse response (FIR) and step response models, transfer function models and state space models. The FIR model based MPC can only deal with stable processes and the design model order is high. Typical algorithms are dynamic matrix control (DMC) [1] and quadratic DMC [2]. Transfer function model based MPC enjoys a larger range of stable and unstable processes and one of the typical algorithms is generalized predictive control (GPC) by Clarke, et al. [3]. However, it is considered to be less effective for multivariable processes and real-time application. The third category is MPC based on state space models, and there have been lots of representative articles on that. Such as the paper by Balchen [4], the papers by Muske et al. [5,6], and Scokaert et al. [7]. Ricker [8] proposed a design method based on state space models in 1990 and the next year a tutorial paper [9]. Bitmead et al. [10] presented an analysis framework of GPC base on state space method.

Among the numerous state space model based predictive control designs, the non-minimal state space MPC (NMSSPC) proposed by Wang [11] is widely recognized since it overcomes the observer-based obstacles, such as the convergence rate, robustness of the observer-based control system and still bears the good features of transfer function based design. This is done by selecting measured process input, output and their past measured values as the state variables and incorporating them into a non-minimal state space model. The NMSS model and relevant control algorithms are first presented by Young [12], and subsequently several control methods based on it were presented [13–16]. It is shown that this non-minimal state space model is defined from the transfer functional model and can directly provide the design basis for MPC. What's more, this design offers the advantages of both transfer function design and state space design, such as simple design framework, ease of analysis, etc. [11].

After careful research with the approach, it can be seen that when the mismatch between the plant and its model is activated, the NMSSPC becomes a much more complicated issue. Generally, the control performances deteriorate, as can be seen by the simulation examples given in this paper. This is partly due to the fact that control designs based on state space models are sensitive to model mismatch, which is also known in modern control theory. However, this paper will further investigate into this issue. By exploiting an extended NMSS model and objective function, the MPC design in this paper maintains the good merits of the state space framework in Wang [11], and furthermore, it overcomes the control performances deterioration when plant and model mismatch is present in controller design. The idea of extending the state space model is not quite new, the authors once presented a single-input and

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doi:10.1016/j.jprocont.2011.06.009