USE OF WIENER NONLINEAR MPC TO CONTROL A CSTR WITH MULTIPLE STEADY STATE

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Abstract— In this paper a Nonlinear Model Predictive Control based on a Wiener Model with a Piecewise Linear gain is presented. The major advantages of this algorithm is that it retains all the interesting properties of the classical linear MPC and the computations are easy to solve due to the canonical structure of the nonlinear gain. The proposed control scheme is applied to a nonlinear CSTR that presents multiple steady states.

Keywords— Model Predictive Control, Wiener Models, Piecewise Linear Approximation.

I. INTRODUCTION

Model predictive control (MPC) refers to a class of computer control algorithms that control the future behavior of a plant through the use of an explicit process model. At each control interval the MPC algorithm computes an open-loop sequence of manipulated variable adjustments in order to optimize future plant behavior. The first input in the optimal sequence is injected into the plant, and the entire optimization is repeated at subsequent control intervals. MPC technology was originally developed for power plant and petroleum refinery applications, but can now be found in a wide variety of manufacturing environments including chemicals, food processing, automotive, aerospace, metallurgy and pulp and paper (Qin and Badgwell, 1997).

Though manufacturing processes are inherently nonlinear, the vast majority of MPC applications to date are based on linear dynamic models, the most common being step and impulse response models derived from the convolution integral. There are several potential reasons for this, for example, by using a linear model and a quadratic objective, the nominal MPC algorithm takes the form of a highly structured convex Quadratic Programming problem (QP), for which reliable solution algorithms and software can easily be found. This is important because the solution algorithm must converge reliably to the optimum in no more than few tens of seconds to be useful in manufacturing applications.

Nevertheless, there are cases where nonlinear effects are significant enough to justify the use of Nonlinear Model Predictive Control (NMPC). With the introduction of a dynamic nonlinear models within the NMPC algorithm, the complexity of the predictive control problem increases significantly. Review papers by Henson (1998) and Bequette (1991) elaborate on the various approaches to handling nonlinear systems via MPC. For example, many researches have used empirical models for NMPC (Norquay et al., 1998; Su and McAvoy, 1997; Zhu and Seborg, 1994).

In particular, Wiener models have a special structure that facilitates their application to NMPC. Its application has been proved both in academic (Norquay et al., 1998) and practical aspects (Norquay et al., 1999). These models represent a process with linear dynamic but a nonlinear gain, and can represent many of the memoryless nonlinear systems commonly encountered in industrial processes. Due to the static nature of the nonlinearities, they can be removed from the control problem. However some computational difficulty is potentially present and due to that an implicit inversion of the nonlinear static gain is needed. In this work the application of a discrete time nonlinear predictive control of Wiener systems to the control of a CSTR with multiple steady states is analyzed. More specifically, the Wiener structure consists of a linear dynamic element followed in series by a Static nonlinear element. The linear dynamic element uses a discrete state space model and the nonlinear element uses the Piecewise Linear approximation (Julian 1999). The paper is organized as follows: In section II a description of the proposed control scheme is included. In section III the case study is analyzed and finally, some conclusions are discussed in section IV.

II. NONLINEAR WIENER MPC USING PWL FUNCTIONS

Let us assume that the system to be controlled can be described by the following discrete-time, nonlinear, state-space model:

\[ x(k+1) = g(x(k), u(k)) \]
\[ y(k) = h(x(k)) + d(k) \]  (1)

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