ROBUST IDENTIFICATION OF PWL-WIENER MODELS: USE IN MODEL PREDICTIVE CONTROL

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***Abstract*— In this paper a robust identification strategy for Wiener like models constituted by a linear dynamic block in series with a Piecewise Linear (PWL) function as the nonlinear static gain is presented. The proposed realization allows straightforward characterization of the static gain uncertainty. A robust Model Predictive Control (MPC) algorithm, using the presented modeling strategy, is developed to guarantee that no constraints in the feedback loop are violated.**

***Keywords*— Identification, Wiener Model, Robustness, Model Predictive Control.**

I. INTRODUCTION

In the last years, several approaches to incorporate nonlinearities in to controller design strategies have been presented. In particular, the Wiener like models deserve attention as they are suitable for the description of systems which are internally linear but have a static nonlinear output transformation (e.g. pH neutralization processes). They can also be used for the approximation of nonlinear fading memory systems (Castro *et al.*, 1999). Most of the dynamical systems in industry belong to this class of nonlinear systems. The choice of Wiener models in control was also motivated by recent results on nonlinear system identification (Westwick and Verhaegen, 1996) and by their straightforward applications in nonlinear Model Predictive Control. Important results in this field can be found in Norquay *et al.*, (1998, 1999a) and in Gerksic *et al.* (2000). Moreover, some practical implementations of these algorithms have been reported by Norquay *et al.*, (1999b).

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 the future plant output. The first input in the optimal sequence is injected into the plant, and the entire optimization is repeated at subsequent control intervals (Qin and Badgwell, 1997).

Though manufacturing processes are inherently nonlinear, the vast majority of MPC applications up 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 Program (QP), for which reliable solution algorithms and software can easily be found. The algorithm solution must converge reliably to the optimum value in no more than a few tenths of a second to be useful in industrial applications. This is the reason why linear MPC is widely preferred over the nonlinear version.

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 model within the NMPC algorithm, the complexity of the predictive control problem increases significantly. Review papers by Bequette (1991) and Henson (1998) study the various approaches to handle nonlinear systems via MPC. In particular, the Wiener models (Norquay *et al.*, 1998, 1999a, 1999b; Gerksic *et al.*, 2000) have a special structure that facilitates their application to NMPC.

In this paper a particular realization for the Wiener model, where the static gain is described by a Piecewise Linear function (PWL) is presented. These PWL functions have proved to be a very powerful tool in the modeling and analysis of nonlinear systems. The PWL Functions are used since 1965 in the area of nonlinear circuit theory. In the 70's, they are specially relevant in the works of Leon Chua (1971) where the treatment of systems in $\Re^2$ is properly solved. But only recently with the work of Julián *et al.* (1999) on High Level (HL) PWL it is possible to obtain expressions to solve the general problems in $\Re^n$. These expressions allow the development of a systematic and uniform approximation of any continuous nonlinear function in a com-