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ANALOG/DIGITAL PID-BASED SLIDING-MODE CONTROLLER DESIGN FOR NONLINEAR PROCESSES WITH LONG TIME DELAYS

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Abstract. This paper presents a methodology for the design of a cascaded analog/digital proportional-integral-derivative (PID)-based sliding-mode controller for continuous-time multivariable linear/nonlinear processes with long time delays. The optimal linear model (OLM) for an input/output time-delay nonlinear system is utilized to design the analog controller by using the dominant pole-assignment and the linear quadratic regulator (LQR) approaches. The Chebyshev quadrature digital redesign method is extended to convert the designed analog controller into the digital counterpart. Thus, the developed controllers exhibit the advantages of both the PID and sliding mode controllers regarding the tracking, robustness, and computer control of real processes affected by bounded uncertainties, unmodeled dynamics and disturbances. Furthermore, the ideal state reconstruction methods are newly developed for the input/output time-delay plants from the input-output data. Thus, the state-feedback controller can be designed for the input/output time-delay plant with in-accessible states. Two illustrative examples are given to show the proposed method.

Keywords. Nonlinear system, time delay, sliding mode control, PID, optimal linear model.

1 Introduction

Most real industrial/chemical processes are described more precisely by nonlinear dynamical models with long time delays, which often exhibit set point disturbances and modeling errors. In order to apply the well-developed linear control methodologies available in the literature, various linearization techniques for nonlinear dynamical systems have received increasing attention in recent years. In the time domain, there exist some popular linearization techniques, such as the gradient method [1], the nonlinear feedback linearization method [1] and the optimal linearization method [2] (see Appendix A).

In general, the linearized equivalent models obtained as a result of such techniques are often transfer function matrices [3] with long time delays [4-6] or state-space models with long time delays in states, inputs and outputs [7-8]. Additionally, in most cases model