Experimental Validation of Interval Sliding Mode Observers for Nonlinear Systems with Bounded Measurement and Parameter Uncertainty

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Abstract

A huge number of real-life models for dynamic systems in control engineering are characterized by nonlinear behavior. These systems often include both state variables that are not directly measurable and unknown or uncertain parameters. The uncertainty results from a lack of knowledge about specific system parameters, inaccurate measured data, and manufacturing tolerances. Nevertheless, estimation of non-measurable state variables as well as reliable online identification of unknown system parameters are important prerequisites for the design and implementation of controllers for nonlinear dynamic systems. Considering these facts, the application of common sliding mode techniques may not be reliable if they are used simultaneously to estimate time-varying system states and to identify constant parameters online. This unreliability is often caused by an observer design that is based on simplified system models. These models commonly have to satisfy restrictive matching conditions even for exactly known parameters. Since parameters and measured data are typically known only within given tolerance bounds, an interval sliding mode observer is presented which is designed to guarantee asymptotic stability by means of an online evaluation of a suitable candidate for a Lyapunov function [3, 4].

In this presentation, different alternatives are discussed for the interval evaluation of the Lyapunov function under consideration of uncertainties and desired operating ranges. Furthermore, an efficient strategy for the adaptation of the switching amplitude of the observer's variable structure part is presented to reduce the amplification of measurement noise as far as possible if time-varying state variables and time-invariant system parameters are estimated simultaneously. This interval sliding mode observer is implemented by using C++ S-functions in Matlab for an electric drive test rig that is available at the Chair of Mechatronics, University of Rostock. All arithmetic operations on interval variables are performed by means of the C++ software library C-XSC [2].

The estimation of unknown system parameters under consideration of suitable intervals in which the true but unknown parameter values are definitely included can be improved by means of an optimal input design. This is especially useful if a system includes parameters (e.g. friction coefficients) that do not vary as fast as the system states themselves (e.g. position, velocity, and acceleration). Then, it has to be analyzed how the system dynamics have to be excited to improve the system's observability and, thus, also the estimation quality. Such an optimal input design is described in [1], where experimental data is optimally discriminated by means of Pontryagin's maximum principle.

References

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