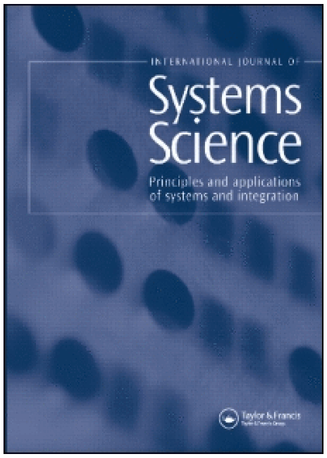

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Editorial 1: Higher order sliding mode observers

Control under uncertainty is a major topic of interest in modern control theory. The uncertainty may manifest itself both as an uncertainty of the mathematical model and as a lack of state variables (i.e., states) available for feedback control. The idea of using a dynamical system for generating estimates of the system states – an *observer* – was proposed in 1963 by Luenberger for linear systems. In spite of the extensive development of robust control techniques, *sliding mode control* (SMC) remains a key choice in handling bounded uncertainties/disturbances and unmodeled dynamics as well as estimating them. The main idea involves steering the system trajectory to a custom-chosen sliding manifold and keeping it on the manifold thereafter by means of high-frequency switching control.

During the last decade, SMC techniques have been widely used for designing observers/estimators (*sliding mode observers*) suitable for *robust* state estimation and parameter identification as well as estimation of unknown bounded inputs.

The main advantages of sliding mode observers for state, parameter and input observation/identification in dynamic systems can be summarized as:

- Insensitivity, which is stronger than robustness, to unknown bounded inputs.
- Use of the so-called "equivalent injection", which represents the average effect of the applied discontinuous injection signal required to maintain a sliding mode, for unknown input and parameter identification.

The difficulties of traditional SMC techniques, i.e., first order relative degree with respect to the sliding variable and high frequency switching control action, are mitigated by newly developed high-order sliding mode (HOSM) control that stabilizes not only the sliding variable to zero, but also its "*k-1*" successive derivatives, where k is the order of the HOSM scheme. Use of HOSM allowed A. Levant to design the robust exact differentiator based on the super twisting algorithm (second order sliding mode) in 1998 and the arbitrary order sliding mode, robust, exact differentiators in 2003. These HOSM-based differentiation algorithms appear to be very useful in designing a new generation of sliding mode observers.

The Special Issue of the International Journal of Systems Science on "Advances in Sliding Mode Observation and Estimation" naturally divides into two issues. The first one is dedicated to advances in HOSM-based observers; and the second one contains papers on new methods of identification and fault detection using the equivalent injection signal and a variety of applications of sliding mode observers.

In the first issue, the first three papers present three different strategies for high order sliding mode observation. The paper "Observation of linear systems with unknown inputs via high-order sliding-modes" by L. Fridman, A. Levant, and J. Davila presents HOSM observers for linear time-invariant systems with bounded unknown inputs. It is shown that the proposed HOSM-based observer reconstructs the system states in finite time for strongly observable systems and estimates the states asymptotically for strongly detectable systems. Moreover, a modified HOSM observation scheme allows exact identification of the Lipshitzian unknown inputs in finite time. The theorems that estimate the observation and identification errors in terms of the sampling steps and bounded deterministic noise are provided and proved.

The next paper "Hierarchical second-order sliding-mode observer for linear time invariant systems with unknown inputs" by F. J. Bejarano, A. Poznyak, and L. Fridman proposes a *hierarchical* sliding mode observation scheme based on the super twisting (ST) algorithm for linear time-invariant systems with unknown bounded inputs. The proposed estimation algorithm does not require any filtering procedures. Finally, it is demonstrated that the constructed algebraic observer allows the system states and Lipshitzian unknown inputs to be exactly estimated in finite time.

T. Floquet and J. P. Barbot in the paper "Super twisting algorithm based step-by-step sliding mode observers for nonlinear systems with unknown inputs" design step-by-step observers based on ST algorithm. It is, probably, the first design of an exact observer for MIMO nonlinear systems with unknown inputs that converges in finite time without filtering. In order to design such an observer, the authors derived structural matching condition that must be met.

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It is shown that this observer is applicable for hybrid systems and systems with observability singularities.

In the paper "Describing function analysis of second order sliding mode observers" the authors I. Boiko, M. I. Castellanos, and L. Fridman study second order sliding mode observers in the frequency domain. The obtained frequency response of the observer's dynamics allows the frequency range for which the observations are accurate to be estimated.

The paper "Frequency characteristics of Levant's differentiator and adaptive sliding mode differentiator" by S. Kobayashi and K. Furuta studies an adaptive algorithm for on-line adjustment of the parameters of the Levant's ST-based differentiator. The proposed adaptive differentiator is found to have improved frequency bandwidth.

Lastly, A. Pisano and E. Usai in the paper "Globally convergent real-time differentiation via second order sliding modes" designed a novel real-time globally convergent second sliding mode-based differentiator with adjustable gain and switching logic. A new generation of sliding mode observers can be developed based on the proposed enhanced differentiator.

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