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# State Estimation of Rotary Inverted Pendulum Using HOSM Observers: Experimental Results

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**Abstract:** This paper presents the observer design for the state estimation of the rotary inverted pendulum (RIP) system. A Takagi-Sugeno (T-S) fuzzy descriptor approach is used for modeling the nonlinear dynamic system. Two higher-order sliding mode (HOSM) observers, based on the super-twisting algorithm, are proposed and applied to the RIP with real-time implementation. The experimental results illustrate the finite-time convergence and accuracy of the state estimates of the designed observers.

**Keywords:** *rotary inverted pendulum; T-S fuzzy descriptor model; super-twisting algorithm; higher-order sliding mode observer.*

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## 1 Introduction

Recently, sliding mode techniques have been widely used for the problems of dynamic systems control and observation due to their finite-time convergence and robustness against various kinds of uncertainties such as parameter perturbations and external disturbances [1]. In particular, higher-order sliding mode (HOSM) based observers can be considered as a successful technique for the state observation of perturbed systems, due to their high precision and robust behavior with respect to parametric uncertainties [13]. In [7], the step-by-step first-order sliding mode observers are designed for a class of systems in triangular input form. Nevertheless, the realization of first-order sliding mode implies the undesirable chattering phenomena.

Many observers, based on the high-order sliding mode technique, have been developed

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