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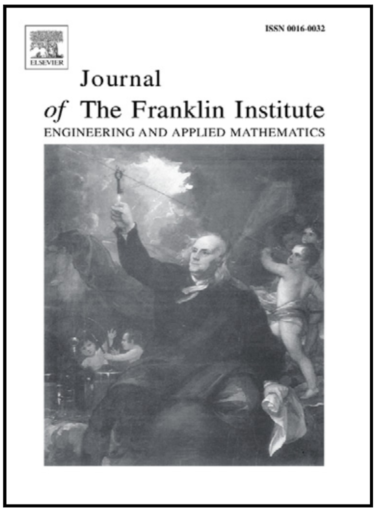

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A Nonhomogeneous Super-Twisting Algorithm for Systems of Relative Degree More Than One

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Abstract

This paper presents a nonhomogeneous continuous super-twisting algorithm for systems of relative degree more than one. The conditions of finite-time convergence to the origin are obtained and the robustness of the designed algorithm is discussed. The paper concludes with numerical simulations illustrating performance of the designed algorithms.

I. Introduction

It is well known that the classical discontinuous sliding mode control provides finite-time convergence for a system of relative degree one [1]. A finite-time stabilizing control for a system of relative degree two is realized using the twisting algorithm [2], where the second order sliding mode control is also discontinuous. Both algorithms are robust with respect to bounded disturbances. On the other hand, using a continuous second-order sliding mode super-twisting algorithm [3], a state of a relative degree one system can be stabilized along with its first derivative. The super-twisting algorithm is robust with respect to unbounded disturbances satisfying a Lipschitz condition. There are a number of papers applying twisting and super-twisting algorithms to robust regulator and observer design. Various modifications of the sliding mode technique have always been actively used in industrial applications ([4], [5], [6], [7], [8], [9], [10], [11], [12]), including fault detection/correction and data-driven control and monitoring ([13], [14], [15], [16], [17], [18], [19]).

The finite-time convergence of the designed algorithms is conventionally established using geometrical techniques [2], [3], [20], direct Lyapunov method [21], [22], [23], or homogeneity approach [24], [25], [26]. The explicit Lyapunov functions for their second-order super-twisting algorithms can be found in [23]. The homogeneity approach, mentioned even in the classical book [27], was consistently developed in the mentioned papers and applied to the observer design in [28]. The homogeneity is a commonly accepted tool for establishing finite-time convergence of the control laws: for instance, the classical signum control [1] and the super-twisting algorithm [3] are homogeneous. The recent paper [29] presents a homogeneous continuous super-twisting algorithm for systems of relative degree more than one, which assures finite-time convergence to the origin for all system states; as a consequence, it is applicable to homogeneous systems only.

This paper corrects the indicated flaw and presents a nonhomogeneous continuous super-twisting algorithm for systems of relative degree more than one, which assures finite-time convergence to the origin for all system states. A considerable advance of the proposed algorithm with respect to [29] consists in assigning not necessarily homogeneous exponents in the control law, which makes it more flexible and practically useful in comparison to the mandatorily homogeneous control law in [29]. Indeed, the homogeneity property is not robust with respect to internal actuator disturbances, so implementation of a homogeneous control law may be unreliable in real technical systems.

First, the case of relative degree two is addressed. The conditions of finite-time convergence to the origin equilibrium are obtained and the robustness of the designed algorithm is discussed. Similar results are then obtained for systems of relative degree more than two. The paper concludes with numerical simulations illustrating performance of the designed algorithms.

The paper is organized as follows. The problem statement is given in Section 2. A nonhomogeneous super-twisting-like control algorithm for systems of relative degree two is designed in Section 3. The corresponding

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