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Continuous higher order sliding mode control for a class of uncertain MIMO nonlinear systems: an ISS approach

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Abstract

In this article, we propose a new approach towards the design of higher order sliding mode (HOSM) control, for a class of multiple input multiple output (MIMO) uncertain nonlinear systems subject to matched and unmatched uncertainties. In the proposed method, nonlinear sliding surfaces incorporating the system initial conditions and exponential functions, which guarantee the existence of sliding mode from an initial state are utilized and appropriate control inputs are designed . The control inputs are designed to enforce second order sliding mode w.r.t the sliding variables via the use of multivariable super-twisting algorithm (STA) in finite time. The resulting sliding motion is in turn proved to be input-to-state-stable (ISS) with respect to the perturbations and unmatched uncertainties. The developed sliding mode control strategy is applied for the posture stabilization of a unicycle mobile robot. The proposed method is illustrated through simulations.

Keywords: Nonlinear sliding surface, Super-Twisting Algorithm, Input-to-State Stability, Unicycle mobile robot, Posture stabilization.

1. Introduction

There has been a growing interest among researchers in the control of nonlinear systems in the presence of external disturbances and parametric uncertainties. One of the popular robust control strategies to deal with systems subject to uncertainties is the sliding mode control (SMC), wherein the system states are constrained to remain on a predefined surface within the state space called the sliding surface. In the sliding mode, the system is insensitive to perturbations satisfying the well known matching condition – invariance property [1]. In SMC design, the system is required to be in regular form for analysis, which in turn provides a key to the design of sliding surfaces. The transformation matrix for conversion to the regular form is easier to calculate for linear systems. But for nonlinear systems especially the MIMO ones, it is not always possible to convert it to the conventional regular form. In this regard, a diffeomorphic state space transformation has been computed in order to represent the initial multivariable nonlinear model in an appropriate regular form [2]. In [3], a generalized regular form has been proposed for a class of nonlinear systems which includes the conventional regular form as a special case. SMC as a robust control strategy focuses on reducing the effect of disturbances as much as possible. This is mainly achieved through the selection of appropriate sliding surface and the control gains. The integral [4] and exponential sliding surfaces [5] have been introduced in this respect to alleviate the effect of disturbances in the reaching phase. The matching condition or the invariance condition proposed by Drazenovic in 1969, is a sufficient condition to reject disturbances in the sliding mode. However, when it comes to unmatched uncertainties, certain conditions are required to be satisfied so that the sliding mode dynamics

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