



Real-time output trajectory tracking neural sliding mode controller for induction motors

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Abstract

This paper deals with real-time discrete adaptive output trajectory tracking for induction motors in the presence of bounded disturbances. A recurrent high order neural network structure is used to design a nonlinear observer and based on this model, a discrete-time control law is derived, which combines discrete-time block control and sliding modes techniques. Applicability of the scheme is illustrated via experimental results in real-time for a three phase induction motor.

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1. Introduction

The induction motor is well known as one of the most used actuator for industrial applications due to its reliability, ruggedness and relatively low cost. However, modelling and control of the induction motor is a challenging task since it constitutes a dynamical system, which is multi-variable, coupled, and highly nonlinear [7]. Different control techniques have been developed for induction motors; early research was focused on the field oriented control (FOC) [5,17], exact input–output linearization, adaptive input output linearization, direct torque control (DTC) [17], and the sliding mode technique [22,34]. All those designs are developed on continuous-time and implemented on digital devices. According to [12], an alternative is to design a digital controller directly using a digital model of the motor [7,24]. In [7], it was proposed a discrete-time model

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and a control algorithm assuming that the parameters and the load torque are known. Advancements in digital technology have attracted considerable research towards the design of high performance sampled-data control of continuous-time systems. This design usually is based on the approximate discrete-time model of the continuous-time system obtained using the Euler method. For these controllers, state of the continuous-time system is fed into the discrete-time controller via a sample-and-hold circuit. In a recent publication [23], the analyses of such kind of closed loop systems establish trajectory convergence, which implies asymptotic/exponential convergence for a sufficiently small but nonzero sampling time.

On the other hand, the performance of the above mentioned controllers depends significantly on the accurate knowledge of the system model. In practice, the rotor currents or fluxes are not easily measurable; therefore an observer is needed to estimate the unknown states. In [8,9], continuous-time observers for induction motors are considered and in [19] a discrete-time observer based on a linearization is proposed. All the mentioned observers are designed based on the physical model of the motor, which results in a sensitive control with respect to plant parameters variations.

Numerous approaches have been proposed for the design of nonlinear observers yielding many interesting results in different directions (see e.g. [8,27]). The transformation of a nonlinear system into the so-called canonical form is used in [26]. These approaches require that the system does not have uncertainties; in practice, there are external and internal uncertainties. Observers which work in presence of uncertainties have received less attention; they are known as robust observers. The variable structure approach with sliding mode [6,34] has been used to develop robust nonlinear observers [27]. All the approaches to develop observers (linear and nonlinear) above mentioned need a nominal mathematical model for the plant dynamics to be known, at least partially [27]. Recently, recurrent neural network observers have been proposed; they do not require any plant model. This technique has been successfully applied to provide an adequate state estimation [27,28]. These works, however, were only developed for continuous-time systems. Nonlinear discrete-time neural observers were seldom discussed [1].

In addition, neural networks have grown to be a well-established methodology, which allows to solve very difficult problems in engineering, as exemplified by their applications to modeling and control of general nonlinear and complex systems. The most used neural network structures are: feedforward networks and recurrent ones [27]. Since the seminal paper [25], there has been a continuously increasing interest in applying neural networks to identification and control of nonlinear systems. Specially, recurrent high order neural networks (RHONNs) are very attractive due to their excellent approximation capabilities, requiring less units, compared to the first order ones; they are also more flexible and robust when faced with new and/or noisy data patterns [13]. Furthermore, several authors have demonstrated the feasibility of using these architectures in applications such as system identification and control [4,28,1,2]. As is well known [29], RHONN offer many advantages for modelling of complex nonlinear systems. On the other hand Extended Kalman filter (EKF) training for neural networks allows to reduce the epoch size and the number of required neurons [15]. Besides, in [3], a RHONN trained with an EKF is used to design a neural identifier; however, such identifier requires the assumption that all the plant state variables, are measurable which is not always possible to ensure for real-time implementations, then it is necessary the design of an observer in addition to the neural identifier, complicating controller design and increasing the computational complexity of the algorithm. Considering these facts, we propose the use of the EKF training for RHONN in order to design a neural observer for unknown discrete-time nonlinear systems, and based on such observer to synthesize a controller which combines the discrete-time block control and sliding modes techniques.

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