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Control design for arbitrary complex nonlinear discrete-time systems based on direct NNMRAC strategy

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ABSTRACT

A novel scheme of neural network model reference adaptive control is proposed for arbitrary complex nonlinear discrete-time systems, i.e., non-minimum phase system, time-delay system and minimum phase system. An improved nearest neighbor clustering algorithm using an optimization strategy is introduced as the on-line learning algorithm to regulate the parameters of the RBFNN, which can simplify the neural network structure and accelerate the convergence speed. The clustering radius can be regulated automatically to guarantee the rationality of radius. Through constructing the pseudo-plant, the direct NNMRAC is also effective to the nonlinear non-minimum phase system. With the help of simulations, the control strategy based on direct RBFNN model reference adaptive control can not only make the multi-dimension nonlinear plants track multi-dimension reference signals quickly, but also endow the control systems with satisfying robustness.

1. Introduction

The model reference adaptive control (MRAC) scheme which guarantees the global asymptotic stability for linear discrete-time system and nonlinear minimum phase system was proposed in Refs. [1,2]. Rohrs et al. [3] has demonstrated, however, that MRAC scheme may result in the instability of closed loop system if there is unstable zero-dynamics. MRAC for the linear system and nonlinear system has developed significantly during the last few decades [4–7,9,10,17–19,30]. But the actual plants always have strong nonlinearities, and it is difficult to define them with precise mathematical models. So Hwang et al. [7] proposed a MRAC scheme with fuzzy logic for the air motor with dead zone compensation. Neural network is another important method in describing a nonlinear function for its capability in approximating arbitrary map with any desired accuracy [8]. In the last two decades, the neural networks have been widely discussed for the control of non-linear industrial processes, such as CSTR, commercial poly propylene process, Dearomatisation process, bytronic process, etc., which were often not available or extremely difficult to formulate [17–27,30,31]. There are various types of neural networks to be used for this purpose. Radial basis function neural network (RBFNN) [17,20,21,24–26] is a good candidate because of its simple structure, ease of implementation. Furthermore, using RBFNN in a self-generating structure can enhance its performance for on-line identification of parsimonious models. Neural network model reference adaptive control (NNMRAC) and neural network self-tuning control (NNSTC) were formed by combining neural network and adaptive control [4,5,9,10,17–19,30,31].

All the aforementioned work only considered the nonlinear actuate industrial processes as the minimum phase systems [17,20,21,23–26,30,31]. Generally speaking, nonlinear discrete-time system always has time-delay, or non-minimum phase characteristics [22,27–29]. And we know that NNMRAC is the method based on generalized inverse control. But the inverse system of non-minimum phase system is unstable, so general NNMRAC cannot be used directly. Common NNMRAC has two flaws, the first one is the slow convergence speed, and the second and also the worse one is the invalidation to unstable zero-dynamics system. These defects limit the scope in which the NNMRAC is applied. To overcome the two flaws of the common NNMRAC, a direct NNMRAC based on RBFNN is proposed in this paper. In order to accelerate the convergence speed, an improved nearest neighbor clustering algorithm using an optimization strategy is introduced as the on-line learning algorithm to regulate the parameters of the RBFNN. Through constructing the pseudo-plant to solve the invalidation to unstable zero-dynamics system, a direct NNMRAC scheme which is effective to the nonlinear non-minimum phase system is put forward. And by adjusting the two parameters of the pseudo-plant, the scheme of the direct NNMRAC is still

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