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Optimal Design of the Fuzzy Sliding Mode Control for a DC Servo Drive

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A new controller for the optimal speed control of a DC drive is presented in this paper. The controller employs a variant of fuzzy sliding mode, optimized by a genetic algorithm. Proposed controller has many advantages, such as satisfactory control performance under a wide range of operating conditions, a faster response than conventional controllers and suppressed chattering phenomenon. The simulations, experimental results, and comparative analysis verify the efficiency, excellent performance, and robustness of such a control in the case of a DC servomotor.

Keywords: sliding mode control, fuzzy control, genetic algorithm, DC motor

0 INTRODUCTION

One of the possible approaches to the robust control of the uncertain systems has been found in variable structure systems and sliding mode control [1]. The principal goal of the sliding mode control technique is to force a system state to a certain prescribed manifold, known as the sliding hyper surface. Once the manifold is reached, the system is forced to remain on it thereafter. When in the sliding mode, the system is equivalent to an unforced system of lower order, which is insensitive to both parametric uncertainty and unknown disturbances that satisfy the matching condition. The main drawback of the sliding mode control is the requirement of a discontinuous control law across the sliding manifold. In practical systems, this leads to a phenomenon termed chattering [2]. Chattering involves high-frequency control switching and may lead to excitation of unmodeled high-frequency system dynamics. Chattering also cause high heat losses in electronic systems and undue wear in mechanical systems. Smoothing techniques such as boundary layer [3] have been employed in order to prevent chattering. However, such an approach leads to a loss of asymptotic stability and a controller that can guarantee final tracking accuracy only to within a certain vicinity of the demand.

Over the last few years, the apparent similarities between the sliding mode and fuzzy controllers [4] to [6] in diagonal form have been noticed. This fact has subsequently motivated considerable research effort in combining the two topologies [7] in a manner that serves to reduce the limitations of the sliding mode, while still maintaining the guarantees of global uniform ultimately bounded stability and invariance to matched disturbance [8] and [9]. The main difficulty in designing fuzzy controller is the acquisition of the controller parameters that are usually determined by human expert's knowledge or trail and error method. It is a difficult problem to find optimal parameters of the controller in order to achieve maximum performance.

Genetic algorithms [10] and [11] are optimization technique based on simulation of the phenomena taking place in the evolution of species. They have demonstrated very good performances as global optimizers in many types of control applications [12]. They are good optimizers for fuzzy controllers, also [13] and [14]. In this paper, the genetic algorithm is applied to determine optimal values of the key parameters required for the fuzzy sliding controller design [15] to [19].

To verify the efficiency of the proposed control method, simulation and experimental results of such control for a DC servo drive and comparative analysis with the other types of controllers are given in this paper, also.

1 SLIDING MODE CONTROL

Consider the system of the following form:

$$\boldsymbol{x}^{(n)} = f(\boldsymbol{x},t) + g(\boldsymbol{x},t)u + d \ , \qquad (1)$$

where $\boldsymbol{x} = \left(x, \dot{x}, ..., x^{(n-1)}\right)^T$ is the state vector, d represent disturbances, u is the control input and

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