The Design of Fuzzy-Sliding Mode Control with the Self Tuning Fuzzy Inference Based on Genetic Algorithm and Its Application

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Abstract

This paper proposes a self tuning fuzzy inference method by the genetic algorithm in the fuzzy-sliding mode control for a robot. Using this method, the number of inference rules and the shape of membership functions are optimized without an expert in robotics. The fuzzy outputs of the consequent part are updated by the gradient descent method. And, it is guaranteed that the selected solution become the global optimal solution by optimizing the Akaike's information criterion. The trajectory tracking experiment of the polishing robot system shows that the optimal fuzzy inference rules are automatically selected by the genetic algorithm and the proposed fuzzy-sliding mode controller provides reliable tracking performance during the polishing process.

1. Introduction

To reduce the inherent chattering of the sliding mode control, the fuzzy-sliding mode control was designed [7]. However, the number of inference rules and the shape of membership functions of the fuzzy-sliding mode controller should be determined only through the trial and error method by an expert who had the expert knowledge of robot systems. And also, it could not be guaranteed whether the selected inference rules were the global optimal solution or not because the expert used the trial and error method to determine the inference rules.

This study proposed a self tuning fuzzy inference method by the genetic algorithm [4,5]. Using the genetic algorithm [6], the number of inference rules and the shape of membership functions of the fuzzy-sliding mode controller are optimized without the expert in robotics. And, the fuzzy outputs of the consequent part are updated by the gradient descent method [2]. Also, it is guaranteed that the selected inference rules become the global optimal solution by optimizing the Akaike's information criterion [1,2]. Therefore, although a designer is a non-expert who has not the expert knowledge of robot systems, the fuzzy-sliding mode controller can be designed by the proposed self tuning fuzzy inference method based on the genetic algorithm.

To automate the polishing process, this study developed the automatic polishing robot system [3,8,9]. The developed polishing system has always a big contact force change by removing tool marks and a vibration of tool by rotating a polishing tool during polishing. Unless disturbances of polishing system are compensated for properly, satisfactory control performance cannot be expected. Thus, in order to evaluate the learning and the trajectory tracking performances of the fuzzy-sliding mode controller using the genetic algorithm, the trajectory tracking experiment of the polishing robot system is carried out. And, polishing experiment on the die of the shadow mask is performed to evaluate the trajectory tracking performances of the proposed fuzzy-sliding mode controller during polishing process.

2. Fuzzy-sliding mode controller with genetic algorithm

The simplified dynamic equation of a robot system can be written as follow [4,5,7,9]:

$$J_i\ddot{\theta}_i + B_i\dot{\theta}_i + F_i = k_i u_i \tag{1}$$

In order to determine automatically the fuzzy-sliding mode controller, this study proposed the self tuning fuzzy inference method by the genetic algorithm [4,5]. A control input of the fuzzy-sliding mode controller can be easily obtained from (1). In order to satisfy the existence condition of the sliding mode, when the unmodeled nonlinear terms are replaced by disturbances, a control input is proposed as follow [4,5]:

$$u_i = \psi_{\alpha i}e_i + \psi_{fuzzy} + \psi_{\beta i}\dot{\theta}_{di} + \psi_{\gamma i}\ddot{\theta}_{di} \tag{2}$$

where $\psi_{\beta i}$ and $\psi_{\gamma i}$ are feed-forward control input terms to satisfy the existence condition of sliding mode against unfavorable effects due to the desired angular velocity $\dot{\theta}_{di}$ and the desired angular acceleration $\ddot{\theta}_{di}$ on the trajectory tracking. ψ_{fuzzy} is the control input term for compensating disturbances. In (2), the limit values of the switching parameter $\psi_{\alpha i}$, $\psi_{\beta i}$, and $\psi_{\gamma i}$ can be derived from the existence condition of sliding mode. And, ψ_{fuzzy} is selected by the genetic algorithm [4,5].

In the genetic algorithm, an individual is expressed by binary coding. Thus, the number and shape of membership function of the fuzzy-sliding mode control are expressed in terms of string consisting of 0 and 1 as shown in Fig. 1. And, to evaluate fitness of each individual in the population, the Akaike's information criterion C is employed