Simulation of a New Self-Structured Fuzzy Controller Applied to a Temperature Control Process

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ABSTRACT

A new methodology of Fuzzy Controllers that can change the internal parameters of the controller in real time is presented in this paper. The Self-structured algorithm is able to adapt their rules consequents and re-organize their MFs in real time according to the current state of the controlled plant. Via a simulation of a temperature control process, the authors have proved and demonstrated the effectiveness and usefulness of their control algorithm compared to a conventional FLC under the same condition and using the same Simulated plant.

Keywords: Online Adaptation, Self-Organising Control (SOC) System, Self-Structured Fuzzy Controller, Simulated Control Process, Temperature Control Process

1. INTRODUCTION

Nowadays, FLC are widely used due to their facilities, precision and stability. This paper presents an adaptive controller that overpasses the traditional criterions of controllers (effectiveness, precision and robustness ext.). The proposed adaptive algorithm is able to reduce the energy consumption during the control process compared with other conventional controllers. In the early 1950s began the first attempts of the elaboration of adaptive control systems. A formal definition of adaptive control has been center of interest for many Control engineers and for example the vocabulary including the terms “Self-Organising Control (SOC) system (Proczyk & Mamdani, 1979)”, “parameter adaptive SOC”, “performance adaptive SOC2”, and “learning control system” (Åström & Wittenmark, 1995) was proposed by a committee.
under the Institute of Electrical and Electronics Engineers (IEEE) in 1973. The acceptance of these terms were very limited, however, but a little later E.H. Mamdani and students invents a self-organizing fuzzy controller (SOC) (Procyk & Mamdani, 1979) who explains the meaning of these terms. Their idea is to try to identify and replace the responsible rule of the poor control performance with a convenient rule. In the majority of SOC approaches, this reliance is expressed using only the monotonicity sign (the Jacobian matrix is not always available). SOCs have showed great effectiveness in “simple” applications since only the rule consequents are to be tuned. In highly nonlinear plants, more sophisticated fuzzy controller have to be constructed, that’s because, SOCs are only capable of a coarse tuning of the controller parameters (Lin & Mon, 2003; Pourdehi, Karimipour, Noroozi, & Shabaninia, 2010; Park & Park, 2004; Cho, Park, & Park, 2002; Pomares, Rojas, González, Rojas, Damas, & Fernández, 2002). For example in Lin and Mon (2003) a nonlinear system is controlled by the suggestion of the hybrid adaptive fuzzy controller that adopts a state feedback control policy. The principal benefit of this approach is that the robust gain of the sliding-mode controller is tuned by the use of the adaptive fuzzy control law to coping with the uncertainties and modeling error of the nonlinear robotic system. In Cho, Park, and Park (2002) the parameters of fuzzy feedback linearization controller are adjusted indirectly from the estimates of plant parameters.

The presented methodology offers asymptotic tracking of a reference signal for the systems with uncertain or slowly time-varying parameters. The major disadvantage of the latter approach is that this parallel interaction is not always optimum and that a certain quantity of data should be extracted from the plant in real time in order to achieve global learning. The main focus of this paper is testing the performances of an Adaptive and Self-Structured FLC via simulation. Noting that the proposed algorithm is a real life controller and it can adapt and tune their internal parameters according to the state of the controlled plant. The proposed methodology should be robust against modification of the parameters of the plant (breakdowns). Our fuzzy controller can start with a set of empty rules, it is important to note, that no initial knowledge about the control policy is required. The proposed methodology has been used for a simulated temperature control process and the result was compared with a conventional Fuzzy Control algorithms, the result obtained explains the effectiveness and the robustness of our approach.

2. DESIGN OF CONTROLLERS

2.1 Design of Conventional Fuzzy Logic Controller

In this work a TSK-0 fuzzy logic controller (static controller) is used; with two inputs and one output (MISO). The controller inputs are the temperature error and its derivative (Te, Tė), the error is the difference between the required temperature (Tsp) and the temperature at instant (Ti), in fact, the error equation is: Te = Tsp – Ti. The controller output is the tension that controls the fan operation. For a typical fuzzy control design, the membership functions of each variable divide the input space to present the different states that can take this input during the control process, each one of these MFs have a linguistic label that describes the state of the input at this stage of control. In this paper, the membership functions are a set of triangular membership function that describes the state of these inputs over the permitted range (five for the first input and seven for the second one). For the output, we are using a TSK-0 type, so it should be a set of scalar values that will be used as a fan alimentation. To do that, five scalar values are used as the output MFs (0V, 3V, 5V, 9.5V, 15V), every one of these values have a linguistic label that describe the operation state of the Fan. Table 1 present the rules base of this controller; the rules contain the following expert knowledge (Take rule 1 (Table 1) as an example):

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