Design & Tuning
of
Fuzzy Logic Control Systems

By:

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Certificate

This is to certify that the thesis entitled, "*Design and Tuning of Fuzzy Logic Control Systems*" being submitted by **S. Saeed Mortazavi** for the award of the degree of the **Doctor of Philosophy** to the Indian Institute of Technology, Delhi is a record of the bonafide research work he has carried out under our supervision. The results contained in this thesis have not been submitted to any other University or Institute for the award of a degree or diploma.

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(Saeed Mortazavi)

Abstract

Fuzzy logic controllers (FLCs) have shown significant advantages in many real-world applications. They have demonstrated a good capability in controlling complex systems under wide ranges of operations. FLC can be designed with minimum system modeling information. However, so far there is no standard design procedure for FLCs. Changing of operating conditions, complexity of the process to be controlled, and plenty of input/output variables make it more difficult to design and tune a fuzzy logic controller for a particular application. In first part of this work, it is shown that it is possible to tune and adapt a fuzzy logic controller by only using nonlinear scaling factors. In this regard, all membership functions and rules are kept fixed and all nonlinearities and adaptation algorithms are shifted to nonlinear scaling factors. To show the capability of this method, a set of nonlinear scaling factors are proposed. The performance of FLC with nonlinear scaling factors in closed loop with various applications is demonstrated. Further, in this work, two qualitative adaptation techniques for applications to fuzzy logic control systems are introduced (called self-tuning and auto-tuning algorithms). Self-tuning algorithm uses overall objective variables (e.g. rise time, maximum overshoot, integral absolute error, etc) for optimization and auto-tuning algorithm uses locally available state variables (e.g. error, change in error) as objectives for optimization. Auto-tuning method is a qualitative approximation (and generalization) for nonlinear scaling factors algorithm mentioned above. Fast tracking property of auto-tuning is an interesting specification which is demonstrated in this work.

It is envisaged that controlling higher order systems with proposed types of fuzzy logic controllers is not an easy task. To handle the control of higher order systems,

variable structure fuzzy logic controller is proposed. Conventionally, variable structure controller (VSC) can control nonlinear system with enough robustness. Variable structure FLC (VS-FLC) can control nonlinear complex systems by minimum system model information and with more robustness. VSC and VS-FLC in discrete time systems applications lead to instability. In this work a nonlinear mapping is proposed which along with VS-FLC can control higher order systems in discrete time applications while preserving the closed loop stability.

Morover, in real time applications we may face in complex systems including more modules (e.g. multi-model system) and/or more contexts. In this regard this thesis proposes an alternative structure for fuzzy logic controller (FLC), called multi-storey FLC. Multi-sorey FLC takes into account multiple-model of controller (or process). Multi-storey FLC is capable of control and modeling of more complex control systems including more contexts. Multi-storey FLC can integrate experiences coming from various disciplines extracted from various sources. Multi-storey FLC is also capable of having both known models for FLC (Mamdani and Sugeno models) in its distinct stories simultaneously. This important flexibility helps in handling more real-world problems.

The heart of the fuzzy system is the approximate reasoning. So far, various methods of approximate reasoning have been proposed for inference engine of FLC. Each of the proposed algorithms may show different performance in different applications. Even though it is desirable to have a generalized unique reasoning algorithm, but since that is not known to us, we propose multi-reasoning FLC to handle more complex systems while getting benefit from different specifications of various approximate reasoning algorithms. In more complex control systems that FLC is supposed to handle, a full set of rules may be extracted from several operators' experiences. A single approximate reasoning algorithm out of the reported algorithms may not be able to emulate reasoning schemes of all operators. However application of multi-reasoning FLC may make this emulation closer to reality. Further, this thesis proposes a new alternative implication algorithm for fuzzy logic controller. Comparative study shows that the proposed multi-storey and multi-reasoning FLCs present improved performance with respect to classic FLC. Moreover simulation results showed that new implication method presents much improvement in application fuzzy logic to control systems (specially for around Zero operation).

To my family

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