

Chapter 6

Robust Stability Self-Tuning Fuzzy PID Digital Controller

Ginalber Serra

Federal Institute of Education, Science, and Technology, Brazil

Edson B. M. Costa

IFMA, Brazil

ABSTRACT

A self-tuning fuzzy control methodology via particle swarm optimization based on robust stability criterion, is proposed. The plant to be controlled is modeled considering a Takagi-Sugeno (TS) fuzzy structure from input-output experimental data, by using the fuzzy C-Means clustering algorithm (antecedent parameters estimation) and weighted recursive least squares (WRLS) algorithm (consequent parameters estimation), respectively. An adaptation mechanism based on particle swarm optimization is used to tune recursively the parameters of a fuzzy PID controller, from the gain and phase margins specifications. Computational results for adaptive fuzzy control of a thermal plant with time varying delay is presented to illustrate the efficiency and applicability of the proposed methodology.

INTRODUCTION

In general, the most practical control loop is characterized by changes in the plant to be controlled due to uncertainty, nonlinearity, stochastic disturbances, change in the nature of the input, propagation of disturbances along the chain of unit processes, varying time pure delay, etc. In all such situations, a conventional controller presents limitations to maintain the performance of the control loop at acceptable levels. Therefore, to overcome this problem, there is a need for an adaptive control, which can automatically sense these unforeseen variations in the plant behavior and be able to correct itself so guarantee the desired performance of the control loop. Adaptive control was first proposed in 1951 by (Draper & Li, 1951) to optimize the performance of an internal combustion engine in the presence of uncertainties, in which an optimal control law was automatically designed according to the operating point. The next major step in adaptive control was taken by Whitaker et al. (1958) when they considered adaptive aircraft flight control systems, employing a reference model to obtain error signals between the actual

DOI: 10.4018/978-1-5225-3129-6.ch006

and desired behavior, which were used to modify the controller parameters to attain ideal behavior to the extent possible in spite of uncertain and time varying dynamic behavior.

In fact, the adaptive control has proved its viability with important current and potential applications (Nair et al., 2015; Masumpoor et al., 2015; Mendes & Neto, 2015; Niu et al., 2014; Fuhrhop et al., 2013). Although has reached a considerable degree of maturity with respect to significant theoretical and algorithmic advances, adaptive control is still an open field for the proposal of new methodologies. In this context, a self-tuning adaptive fuzzy control methodology based on robust stability criterion via particle swarm optimization is proposed. The plant to be controlled is identified by a TS fuzzy inference structure from input-output experimental data, by using the fuzzy C-Means clustering algorithm and WRLS algorithm for antecedent and consequent parameters estimation, respectively. An adaptation mechanism based on particle swarm optimization is used to tune the fuzzy PID controller parameters, via Parallel Distributed Compensation (PDC) strategy (Wang et al., 1995), based on gain and phase margins specifications, recursively, according to identified fuzzy model parameters of the plant to be controlled. Computational results for adaptive fuzzy control of a thermal plant with time varying delay is presented to illustrate the efficiency and applicability of the proposed methodology.

BACKGROUND

The pioneer researches in adaptive control occurred in the early 1950s motivated mainly by the design of autopilots for high-performance aircraft. The main complexities in such projects are the wide range of speeds and altitudes that the aircraft operates, nonlinear dynamics and time varying characteristics. Primary results on adaptive flight control are given in Gregory (1959), Mishkin and Braun (1961) and Whitaker et al. (1958). Although these works were successful, the lack of concise theoretical framework and a disaster in a flight test diminished the interest in the area (Taylor and Adkins, 1965).

However, the interest in adaptive control increased again in the 1970s due to many contributions to control theory in the 1960s (Astrom, 1983). State space techniques, stochastic control and stability theory based on Lyapunov were introduced. Dynamic programming introduced by Bellman (1957) and dual control theory introduced by Feldbaum (1960-1961), increased the understanding of the adaptive process. Tsytkin (1971), who showed that many schemes for learning and adaptive control could be described in a common framework as recursive equations of the stochastic approximation type, also made fundamentals contributions. There were also important developments in systems identification and in parameters estimation (Astrom and Eykhoff, 1971).

The adaptive control theory has matured since contributions mentioned above, and have emerged in three main adaptive control schemes: *Gain scheduling*, *model reference adaptive systems* and *self-tuning controllers*. Gain scheduling approach is used when it is possible to find measurable variables, called scheduling variables, which correlate well with changes in the process dynamics in various operations points. These variables are normally obtained based on knowledge of the physics of the system. The controller parameters are determined for each operating point and stored into a look-up table. The gain scheduler consists of an adjustment mechanism, which detects the system operating point through the scheduling variables and selects the corresponding values of the controller parameters in the look-up table. In the model reference adaptive control approach, some reference model is defined to specify the desired performance of the control system. The parameters of the controller are adjusted by an adjustment mechanism, in such a way that the error between the model output and the process output becomes

12 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the publisher's webpage:

www.igi-global.com/chapter/robust-stability-self-tuning-fuzzy-pid-digital-controller/189319

Related Content

Towards a Model of Fuzzy Commonsense Reasoning

Xenia Naidenova (2010). *Machine Learning Methods for Commonsense Reasoning Processes: Interactive Models* (pp. 279-318).

www.irma-international.org/chapter/towards-model-fuzzy-commonsense-reasoning/38487

Resource Scheduling in Fog Environment Using Optimization Algorithms for 6G Networks

Gaurav Goeland Rajeev Tiwari (2022). *International Journal of Software Science and Computational Intelligence* (pp. 1-24).

www.irma-international.org/article/resource-scheduling-in-fog-environment-using-optimization-algorithms-for-6g-networks/304440

An Automated Approach to Historical and Social Explanation

Juan A. Barceló (2009). *Computational Intelligence in Archaeology* (pp. 297-331).

www.irma-international.org/chapter/automated-approach-historical-social-explanation/6827

Computationally Simple and Efficient Method for Solving Real-Life Mixed Intuitionistic Fuzzy 3D Assignment Problems

P. Senthil Kumar (2022). *International Journal of Software Science and Computational Intelligence* (pp. 1-42).

www.irma-international.org/article/computationally-simple-and-efficient-method-for-solving-real-life-mixed-intuitionistic-fuzzy-3d-assignment-problems/291715

A PSO-Based Framework for Designing Fuzzy Systems from Noisy Data Set

Satvir Singh, J. S. Saini and Arun Khosla (2012). *Machine Learning Algorithms for Problem Solving in Computational Applications: Intelligent Techniques* (pp. 210-228).

www.irma-international.org/chapter/pso-based-framework-designing-fuzzy/67705