Chapter 5

Adaptive Neuro–Fuzzy Control Approach Based on Particle Swarm Optimization

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ABSTRACT

This paper proposes a modified particle swarm optimization algorithm (MPSO) to design adaptive neuro-fuzzy controller parameters for controlling the behavior of non-linear dynamical systems. The modification of the proposed algorithm includes adding adaptive weights to the swarm optimization algorithm, which introduces a new update. The proposed MPSO algorithm uses a minimum velocity threshold to control the velocity of the particles, avoids clustering of the particles, and maintains the diversity of the population in the search space. The mechanism of MPSO has better potential to explore good solutions in new search spaces. The proposed MPSO algorithm is also used to tune and optimize the controller parameters like the scaling factors, the membership functions, and the rule base. To illustrate the adaptation process, the proposed neuro-fuzzy controller based on MPSO algorithm is applied successfully to control the behavior of both non-linear single machine power systems and non-linear inverted pendulum systems. Simulation results demonstrate that the adaptive neuro-fuzzy logic controller application based on MPSO can effectively and robustly enhance the damping of oscillations.

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INTRODUCTION

Particle Swarm Optimization (PSO) has been an increasingly hot topic in the area of computational intelligence. PSO is an optimization algorithm that falls under the soft computing umbrella that covers genetic and evolutionary computing algorithms as well. As such, it lends itself as being applicable to a wide variety of optimization problems (Esmin & Torres, 2004; Parsopoulos & Skokos, 2005; Helwig & Haubelt, 2005; Conradie & Miikkulainen, 2002).

PSO is a population-based algorithm that exploits a population of individuals, to search promising regions of the function space. In this context, the population is called swarm and the individuals are called particles. Each particle moves with an adaptable velocity within the search space, and retains in its memory the best position it ever encountered. In the global variant of the PSO the best position ever attained by all individuals of the swarm is communicated to all the particles. In the local variant, each particle is assigned to a neighborhood consisting of a pre-specified number of particles. In this case, the best position ever attained by the particles that comprise the neighborhood is communicated among them. The PSO like other evolutionary algorithms (e.g., genetic algorithm (GA)) performs searches using a population (called swarm) of individuals (called particles) that are updated from iteration to iteration. Compared to GA, PSO is fast to implement since it has no evolution operators such as crossover and mutation i.e., few parameters to be adjusted.

In Particle Swarm Optimization, each particle moves in the search space and updates its velocity according to best previous positions already found by its neighbors (and itself), trying to find an even better position. This approach has been proved to be powerful but needs tuning parameters predefined by the user (Magoulas & Eldabi, 2002; Mahmoud, 2010; Kiranyaz & Ince, 2010).

Power systems are modeled as large scale non-linear highly structured systems. The high complexity and nonlinearity of power systems have been created a great deal of challenge to power system control engineers for decades. One of the most important problems in the electric power systems is the damping of low-frequency oscillation (dynamic stability). Such oscillations may occur between the electrical and mechanical systems or between large inertia’s in the mechanical system. These oscillations are usually initiated by small disturbances such as small changes in the load levels or generator loading. If the disturbance is large (transient stability), the oscillations may be sustained for minutes and grow to cause system separation if no adequate damping at the system oscillating frequency is available (Ahmed, 2000). Therefore, a major effort has to be made to improve power system stabilizers (PSSs) performance and characteristics. PSSs are usually designed once a time, by conventional control methods, which restrict the system model to low order single-input-single-output linear models, where as the power system oscillatory instability is actually a large-scale multivariable problem.

In recent years, renewed interest has been shown in power system control using non-linear control theory, particularly to improve system transient stability (Nassef, 2005). Instead of using an approximate linear model, as in the design of the conventional power system stabilizer, non-linear models are used and non-linear feedback linearization techniques are employed on the power system models, thereby alleviating the operating point dependent nature of the linear designs. Non-linear controllers significantly improve the power system’s transient stability. However, non-linear controllers have a more complicated structure and are difficult to implement relative to linear controllers.

Fuzzy logic control systems have the capability of transforming linguistic information and expert knowledge into control signals and are preferred over traditional approaches such as optimal and