Computational Intelligence for Nonlinear Systems

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Nonlinear control is one of the biggest challenges in modern control theory. While linear control system theory has been well developed, it is the nonlinear control problems that cause most headaches. Nonlinear processes are difficult to control because there can be so many variations of the nonlinear behavior. Traditionally, a nonlinear process has to be linearized first before an automatic controller can be effectively applied. This is typically achieved by adding a reverse nonlinear function to compensate for the nonlinear behavior so the overall process input-output relationship becomes somewhat linear. The issue becomes more complicated if a nonlinear characteristic of the system changes with time and there is a need for an adaptive change of the nonlinear behavior. These adaptive systems are best handled with methods of computational intelligence such as neural networks and fuzzy systems. The problem is that development of neural or fuzzy systems are not trivial.

Various learning method of neural networks including supervised and unsupervised methods are presented and illustrated with examples. General learning rule as a function of the incoming signals is discussed. Other learning rules such as Hebbian learning, perceptron learning, LMS - Least Mean Square learning, delta learning, WTA – Winner Take All learning, and PCA - Principal Component Analysis are presented as a derivation of the general learning rule. The presentation focuses on various practical methods such as Quickprop, RPROP, Back Percolation, Delta-bar-Delta and others. Main reasons of convergence difficulties such as local minima or flat spot problems are analyzed. More advance gradient-based methods including pseudo inversion learning, conjugate gradient, Newton and LM - Levenberg-Marquardt Algorithm are illustrated with examples.

Advantages and disadvantages of fuzzy systems will be presented and compared, including Mamdani, Takagi-Sugeno and other approaches. Special neural architectures for easy learning such as cascade correlation networks, Sarajedini and Hecht-Nielsen networks, functional link networks, polynomial networks, counterpropagation networks, and RBF-Radial Basis Function networks are described.

The presentation focuses on several methods of developing close to optimal architectures and on finding efficient learning algorithms. In the conclusion, advantages and disadvantages of neural and fuzzy approaches are discussed with a reference to their hardware implementation.

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