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Multi-layer hybrid fuzzy polynomial neural networks: a design in the framework of computational intelligence

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Abstract

We introduce a new architecture of hybrid fuzzy polynomial neural networks (HFPNN) that is based on a genetically optimized multi-layer perceptron and develop their comprehensive design methodology involving mechanisms of genetic optimization. The construction of HFPNN exploits fundamental technologies of computational intelligence (CI), namely fuzzy sets, neural networks, and genetic algorithms (GAs). The architecture of the resulting genetically optimized HFPNN (namely gHFPNN) results from a synergistic usage of the hybrid system generated by combining fuzzy polynomial neurons (FPNs)-based fuzzy neural networks (FNN) with polynomial neurons (PNs)-based polynomial neural networks (PNN). The design of the conventional HFPNN exploits the extended group method of data handling (GMDH) with some essential parameters of the network being provided by the designer and kept fixed throughout the overall development process. This restriction may hamper a possibility of producing an optimal architecture of the model. The augmented gHFPNN results in a structurally optimized structure and comes with a higher level of flexibility in comparison to the one we encounter in the conventional HFPNN. The GA-based

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design procedure being applied at each layer of HFPNN leads to the selection of preferred nodes (FPNs or PNs) available within the HFPNN. In the sequel, two general optimization mechanisms are explored. First, the structural optimization is realized via GAs whereas the ensuing detailed parametric optimization is carried out in the setting of a standard least square method-based learning. The performance of the gHFPNN is quantified through experimentation where we exploit data coming from processes of pH neutralization and NOx emission. These datasets have already been used quite intensively in fuzzy and neurofuzzy modeling. The obtained results demonstrate superiority of the proposed networks over the existing fuzzy and neural models.

Keywords: Hybrid fuzzy polynomial neural networks (HFPNN); Fuzzy neural networks (FNN); Polynomial neural networks (PNN); Multi-layer perceptron; Group method of data handling; Fuzzy polynomial neuron; Polynomial neuron (PN); Genetic algorithms; Design procedure

1. Introduction

Recently, a great deal of attention has been directed towards advanced technologies of computational intelligence (CI) and their usage in system modeling. The challenging quest we are faced there comes with the multitude of demanding and conflicting objectives we wish to satisfy. The problem of designing models that exhibit significant approximation and generalization abilities as well as are easy to comprehend has been within the community for decades. Neural networks, fuzzy sets and evolutionary computing regarded as the leading technologies of CI have expanded and enriched a field of system modeling quite immensely. They have given rise to a number of new methodological issues and increased our awareness about tradeoffs one has to make in system modeling [1,3,10]. The most successful approaches to hybridize fuzzy systems and endow them with learning and adaptive abilities have been realized in the realm of CI. Especially neural fuzzy systems and genetic fuzzy systems enhance the variety of mechanisms of approximate reasoning encountered in fuzzy systems with the learning capabilities of neural networks and structural optimization being supported by evolutionary algorithms [2].

When the dimensionality of the model goes up (the number of system's variables increases), so do the difficulties. In particular, when dealing with high-order nonlinear and multivariable equations of the model, we require a vast amount of data for estimating all its parameters. In the sequel, to build models with good predictive abilities as well as approximation capabilities, there is a need for advanced tools.

As one of the representative and advanced design approaches comes a family of multi-layer self-organizing neural networks [16–20,26] such as hybrid fuzzy polynomial neural networks (HFPNN) as well as polynomial neural network (PNN) and fuzzy polynomial neural networks (FPNN) being treated as a new category of neuro-fuzzy networks. The design procedure of the multi-layer self-organizing neural networks exhibits some tendency to produce overly complex networks. The design comes with a repetitive computation load caused by the trial