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EDITORIAL

Special issue on "Genetic Fuzzy Systems: Recent Developments and Future Directions"

Jorge Casillas · Brian Carse

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1 Introduction

Fuzzy systems have demonstrated their ability to solve different kinds of problems in various application domains. In most cases, the key for success was their ability to incorporate human expert knowledge. In the 1990s, despite the previous palmy history, a certain interest for the study of fuzzy systems with added learning capabilities emerged. Two of the most important approaches have been the hybridization attempts made in the framework of soft computing, where different techniques such as neural networks and evolutionary computation provide fuzzy systems with learning ability.

A Genetic Fuzzy System (GFS) is basically a fuzzy system, usually a fuzzy rule-based system (FRBS), augmented by a learning process based on evolutionary computation, which includes Genetic Algorithms, Genetic Programming, or Evolutionary Strategies, among others. Evolutionary learning processes cover different levels of complexity according to the structural changes produced in the fuzzy system by the algorithm.

The fusion of these population-based, robust search algorithms with a representation that offers linguistic interpretability such as fuzzy systems provides a powerful paradigm for computational intelligence research. Among the main reasons to bet the use of evolutionary algorithms instead other optimization/learning techniques to design fuzzy systems we can highlight the following. First, they provide a powerful and flexible search capability (such as the use of multiple objectives, constrained objectives, or multimodal objectives) that allow them to address a wide range of problems. Second, they can process flexible representation structures (such as mixed coding schemes or constrained representation) that allow them to deal with almost any kind of fuzzy system. Besides, they can run on distributed and cellular architectures, perform incremental learning, and easily hybrid with other techniques for complex tasks.

The field of GFS has now reached a stage of maturity after the earliest papers were published 17 years ago. Although the maturity of the GFS field means it is now being applied to an ever growing number of real-world applications, there are many basic issues yet to be resolved and there is an active and vibrant worldwide community of researchers working on these issues.

2 Contents of the special issue

This special issue collects a set of outstanding GFS proposals covering different aspects of the field, which we believe truly represent the special issue title: *recent developments* are proposed by successfully revisiting some open issues and some *future directions* are shown as examples of the imminent new issues that are coming. They include supervised (both classification and regression) and unsupervised learning, multi-objective optimization, consideration of unusual interpretability criteria and constrains, use of genetic programming and coevolutionary computation, distributed computation, and

J. Casillas (✉)
Department of Computer Science and Artificial Intelligence, University of Granada, 18071 Granada, Spain
e-mail: casillas@decsai.ugr.es
URL: http://decsai.ugr.es/∼casillas/

B. Carse
Bristol Institute of Technology, University of the West of England, Bristol BS16 1QY, UK
e-mail: Brian.Carse@uwe.ac.uk

processing of data with uncertainty, among others. The papers are briefly introduced in the following.

María J. Gacto et al. investigate the behavior of six different multi-objective approaches applied to the simultaneous task of tuning the membership functions and selecting a subset of rules of a previously learnt Mamdani-style FRBS. They focus the study on obtaining more compact but still accurate linguistic fuzzy models and they show that the multi-objective approaches outperform the accuracy-oriented single-objective approach even in terms of accuracy.

Alessio Botta et al. introduce a process to tune the membership functions of a Mamdani-style FRBS by using several linguistic modifiers. The use of an interpretability index which measures the distinguishability of the resulting fuzzy sets and its inclusion in a multi-objective optimization scheme ensure the algorithm to generate accurate and legible fuzzy models.

Jorge Casillas et al. propose a GFS for regression problems where a flexible structure of the antecedent for the sake of a more compact knowledge representation is considered. Constrains of consistency and non-overgenerality are imposed for a better understandability. These constrains are addressed by exploring the feasible search space instead using a posteriori repairing or fitness penalty approaches, which results in a more effective algorithm. A multi-objective optimization approach is used to generate a range of interpretability-accuracy tradeoffs.

Luciano Sánchez et al. introduce a genetic cooperative–competitive learning algorithm for regression tasks where each individual encodes a single fuzzy rule, but a set of them comprises a complete fuzzy system. Each individual is evaluated with two criteria and multi-objective optimization is performed. The algorithm is specially designed for data with uncertainty, though it shows to be effective in crisp data as well. The experimental results prove that compact fuzzy rule sets with good accuracy degrees are obtained.

Myriam R. Delgado et al. address the design of soft sensors from some other physical ones for industrial applications. The problem is formulated as a system identification task and solved by hybridizing neural networks with coevolutionary computation to learn second-order Takagi–Sugeno–Kang FRBSs. Four hierarchically organized species are considered to encode the whole fuzzy system comprising the fuzzy partitions, the fuzzy rule antecedents, the fuzzy rule set, and the inference operators. The proposal is experimented in the problem of inferring the product composition in petroleum refining processes.

Manuel Mucientes et al. present a genetic programming algorithm to learn Takagi–Sugeno–Kang FRBSs. The proposed context-free grammar allows a flexible structure in the consequent, which permits the system to reflect in a more understandable way the relationship among the input variables. The method is applied to the estimation of processing times in the wood furniture industry where the proposed fuzzy rule structure is easily interpreted by the experts.

Yusuke Nojima et al. exploit the advantages of GFSs for parallel computation. They address the fuzzy rule selection problem for classification tasks. Different approaches to divide (statically or dynamically) both the training data set and the population into subgroups (one per processor) are proposed. The experiments show the significant reduction of the run time consumption preserving a good accuracy.

Finally, Chun-Hao Chen et al. propose an algorithm to learn fuzzy association rules and their corresponding membership function parameters for problems with quantitative values. An interesting issue of the paper is the consideration of multiple minimum support values (one per item, i.e., variable) instead only one for the whole system as usual. It allows the process to adapt better to the different characteristics of each variable. They employ a clustering algorithm to gather similar items intro groups. This information is used to initialize the genetic algorithm, thus resulting in an improvement on the efficiency and effectiveness of the method.

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