Multiobjective Genetic Fuzzy Systems
- Accurate and Interpretable Fuzzy Rule-Based Classifier Design -

Plenary Talk

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Fuzzy rule-based systems are universal approximators of non-linear functions [1] as multilayer feedforward neural networks [2]. That is, they have a high approximation ability of non-linear functions. A large number of neural and genetic learning methods have been proposed since the early 1990s [3, 4] in order to fully utilize their approximation ability. Traditionally, fuzzy rule-based systems have been mainly applied to control problems with a few input variables. Recently, they have also been applied to approximation and classification problems with many input variables.

The main advantage of fuzzy rule-based systems over black-box non-linear models such as neural networks is their linguistic interpretability. Fuzzy rules are often written in the if-then form with linguistic terms such as "If x_1 is *small* and x_2 is *small* then y is *large*" and "If x_1 is *large* and x_2 is *large* then Class 1". In this case, it is easy for human users to understand fuzzy rule-based systems since each fuzzy rule is linguistically interpretable.

As we have already explained, fuzzy rule-based systems have two advantages: high approximation ability and high interpretability. These advantages, however, often conflict with each other as shown in Fig. 1. For example, accuracy maximization (i.e., error minimization in Fig. 1) often leads to accurate but complicated fuzzy rule-based systems with low interpretability. On the other hand, interpretability maximization (i.e., complexity minimization in Fig. 1) often leads to interpretable but inaccurate fuzzy rule-based systems.

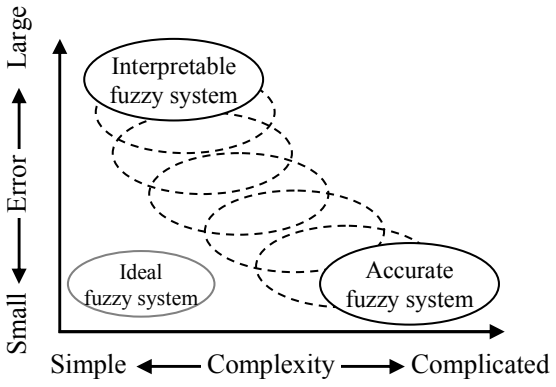

Fig. 1. Tradeoff between accuracy and complexity.

These discussions mean that we usually do not have an ideal fuzzy rule-based system with high accuracy and high interpretability. Thus the design of fuzzy rule-based systems can be viewed as finding a good compromise (i.e., tradeoff) between accuracy and interpretability [5, 6]. One approach to this problem is to integrate accuracy and interpretability into a single objective function. Another approach is the use of constraint conditions on fuzzy rule-based systems in order to maintain their interpretability. A large number of genetic algorithm-based techniques have been proposed under the name of genetic fuzzy systems [7] to find a single fuzzy rule-based system on the accuracy-interpretability tradeoff curve.

Recently the design of fuzzy rule-based systems has been handled as multi-objective optimization problems [8] as

$$\text{Maximize } \mathit{Accuracy}(S) \text{ and } \mathit{Interpretability}(S), \qquad (1)$$

where $\mathit{Accuracy}(S)$ and $\mathit{Interpretability}(S)$ measure the accuracy and the interpretability of a fuzzy rule-based system S. Multiobjective genetic algorithms are used to search for a large number of non-dominated fuzzy rule-based systems on the accuracy-complexity tradeoff curve of (1).

In this talk, first we explain some fuzzy rule generation methods for classification problems. Next we explain single-objective and multi-objective approaches to the design of accurate and interpretable fuzzy rule-based classifiers. Then we discuss the interpretability of fuzzy rule-based classifiers.

References

[1] L. X. Wang and J. M. Mendel, Fuzzy basis functions, universal approximation, and orthogonal least-squares learning. *IEEE Trans. on Neural Networks* 3: 807-814 (1992).
[2] K. Hornik et al., Multilayer feedforward networks are universal approximators. *Neural Networks* 2: 359-366 (1989).
[3] J. S. R. Jang, ANFIS: Adaptive-network-based fuzzy inference system. *IEEE Trans. on SMC* 23: 665-685 (1993).
[4] C. L. Karr and E. J. Gentry, Fuzzy control of pH using genetic algorithms. *IEEE Trans. on Fuzzy Systems* 1: 46-53 (1993).
[5] J. Casillas et al. (eds.), *Accuracy Improvements in Linguistic Fuzzy Modeling*, Springer, Berlin (2003).
[6] J. Casillas et al. (eds.), *Interpretability Issues in Fuzzy Modeling*, Springer, Berlin (2003).
[7] F. Herrera, Genetic fuzzy systems: Taxonomy, current research trends and prospects. *Evolutionary Intelligence* 1: 27-46 (2008). See also his GFS Webpage: http://sci2s.ugr.es/gfs/
[8] M. Cococcioni, Evolutionary Multiobjective Optimization of Fuzzy Rule-Based Systems Bibliography Page (EMOFRBSs): http://www2.ing.unipi.it/~g000502/emofrbss.html