A Multi-Objective Approach to Design of Interval Type-2 Fuzzy Logic Systems

Babak Rezaee
Department of Industrial Engineering
Bojnord University
P.O. Box 1339, Bojnord, Iran
babak.rezaee@aut.ac.ir

Abstract—One of the main advantages of interval type-2 fuzzy logic systems is their ability to produce prediction intervals as a by-product of the type reduction process. This is especially useful for the design of interval type-2 fuzzy logic systems, where the data are corrupted by noise, in such cases; a model that provides a granular output is more appreciable. Nevertheless, the methods have been proposed in the literature to design type-2 fuzzy logic systems only focused on optimizing a final performance measure, i.e., minimizing error of crisp output of system. This paper presents a multi-objective approach to derive interval type-2 fuzzy logic system used as predictive systems, in which there are three objective functions, such as minimizing of the crisp output error and interval output errors. To assess the potentiality of the approach, it has been applied to two synthetic datasets showing very promising results. The results show that the proposed multi-objective outperforms single-objective approach in terms of the crisp and interval output quality.

Keywords—Type-2 Fuzzy Logic Systems; Fuzzy Modeling; Multi-Objective;

I. INTRODUCTION

The problem of estimating an unknown function $F$ from samples of the form $\{x_l; y_l\}; l = 1, 2, \ldots, n$; with $y_l = F(x_l) \in \mathbb{R}$, and $x_l \in \mathbb{R}^d$ (i.e., function approximation from a finite number of data points), is one of the key issues in the field of fuzzy system modeling and function approximation theory. The principal goal is to learn an unknown functional mapping between input and output vectors, using a set of known training samples. Once this mapping is generated, it can be used for predicting the output values given new input vectors.

In many engineering problems, the calculation of reliable solutions depends on the availability of exact values for the variables of model equations. However, in daily practice, these precise values cannot be obtained because the existing information usually is incomplete, imprecise, noisy, vague, qualitative, or linguistic. Therefore, in this case the results obtained by deterministic approaches, which uses one specific crisp value as the most likely value for a variable, cannot be considered to be representative for the whole spectrum of possible results [1].

For such applications, prediction intervals as outputs are desirable since they provide a range of values that most likely include the true value to be predicted. Moreover, prediction intervals allow the user to perceive the accuracy of the estimation provided by the model, thus deciding to keep or reject the result.

More recently, Type-2 Fuzzy Logic Systems (T2FLSs) have been successfully applied to many diversified applications. A T2FLS is characterized by IF-THEN rules, which the parameters in antecedent or consequent parts of rules are type-2 fuzzy sets. A T2FLS provides the capability to model high levels of uncertainties. A distinct advantage of a type-2 fuzzy logic system is that it can produce prediction intervals as a by-product of the fuzzy type-reduction process.

The type-reduced set of a type-2 FLS shows the possible variation in the crisp output of the FLS due to uncertain natures of the antecedents and/or consequents. It establishes a band of values around a crisp output value in much the same way that a confidence interval establishes a band about a point estimate.

Many techniques have been proposed in the literature to design an interval type-2 FLS from numerical data [2-10]. Most of these techniques usually try to improve the performance associated to the crisp prediction error without paying a special attention to the interval output of system. On the other hand, the prediction performance of the type-reduction is inferior to the prediction performance of the crisp output.

In this paper, we propose an approach to design interval type-2 fuzzy logic systems such that the system provides an estimate of the uncertainty associated with predicted output values. In this approach three error functions have been defined for each one of the outputs of the IT2 FLS, instead of one to evaluate the performance of the whole system. Therefore, instead of minimizing an objective function based on the crisp output, the proposed approach attempts to minimize three objective functions based on the crisp output and the interval output of IT2 FLS. These problems motivate the use of multi-objective approach to design of interval type-2 FLS that is presented in this paper.

We test our approach on two synthetic datasets. Results confirm that using multi-objective approach to design T2 FLS generates solutions by better trade-offs between accuracy of the