It is known that type-2 fuzzy sets let us to model and to minimize the effects of uncertainties in rule-based fuzzy logic system (FLS). While a type-2 FLS has the capability to model more complex relationships, the output of a type-2 fuzzy inference engine needs to be type-reduced. As type-reduction is very computationally intensive, type-2 FLSs may not be suitable for certain real-time applications. This paper aims at developing more computationally efficient output processing consists of type-reduction followed by defuzzification. The type-reduced set is approximated by linear combinations of the inner- and outer-bound sets for the type-reduced set and also the crisp output of type-2 FLS is computed by another. Parameters of these functions are determined during the training phase. By this approach type-2 FLSs can handle such uncertainties in a better way because they provide us with more parameters and more design degrees of freedom. Simulation is presented to demonstrate that the proposed type-reducing and defuzzification algorithms have lower computational cost and better performances than the Karnik-Mendel and Wu-Mendel algorithms.

1. INTRODUCTION

Uncertainty affects decision-making and appears in a number of different forms. The concept of information is fully connected with the concept of uncertainty. The general framework of fuzzy reasoning allows handling much of this uncertainty. However, it is not reasonable to use an accurate membership function for something uncertain, so in this case what we need is another type of fuzzy sets, those which are able to handle these uncertainties, the so called type-2 fuzzy sets.

The concept of type-2 fuzzy sets (T2FSs) was first introduced in [1] as an extension of the well-known ordinary fuzzy sets, the type-1 fuzzy sets (T1FSs). A T2FS is characterized by a fuzzy membership function; i.e., the membership grade for each element is also a fuzzy set in [0, 1]. Therefore, fuzzy logic systems (FLS) that use type-2 fuzzy sets to represent the inputs and outputs of the FLS can handle the short and long term uncertainties to produce a good performance. So we can find some papers emphasizing on the implementation of a type-2 Fuzzy Logic System (FLS) [2]; in others, it is explained how type-2 fuzzy sets let us model and minimize the effects of uncertainties in rule base FLSs [3, 4].

The type-2 FLS had the problem that it was envisaged as a computability expensive system due to the computational overhead associated with type-reduction and the use of the iterative procedure.

There are no known closed-form formulas for type-reduction; however, Karnik and Mendel [5] have developed iterative algorithms for computing the type-reduced set exactly. Their algorithms have come to be known as the Karnik-Mendel (KM) algorithms.

When they are applied to a general T2 FLS they require an astronomical number of computations. Things simplify a lot when secondary membership functions are interval sets [6]. Karnik, Mendel, and Liang [2] have observed that an interval type-2 FLS (IT2 FLS) can be interpreted as a collection of embedded type-1 FLSs. They have found that embedded type-1 FLSs play very important roles in understanding uncertainty in a type-2 FLS. Two of them are enough for computing the type-reduced set. The computations associated with interval T2 FSs are very manageable, which makes an IT2 FLS quite practical [7].

However, the type-reduction represents a major bottleneck to the use of an interval type-2 FLS in real-time applications, especially when the rule base of the FLS and the number of input data are large [8]. An interesting alternative to inventing new kinds of TR has been provided by Wu and Mendel [8]. In their approach (WM), they replace type-reduction with lower and upper bounds—uncertainty bounds—for the endpoints of the type-reduced set, and those bounds, which