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A Bidirectional Reasoning Based on Fuzzy Interpolation

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ABSTRACT

In order to deal with both the "curse of dimensionality" and the "sparse rule base" simultaneously, an initial idea of hierarchical bidirectional fuzzy interpolation is presented in this article, combining hierarchical fuzzy systems and forward/backward fuzzy rule interpolation. In particular, backward fuzzy interpolation can be employed to allow interpolation to be carried out when certain antecedents of observation variables are absent, whereas conventional methods do not work. Hierarchical bidirectional fuzzy interpolation is applicable to situations where a multiple multi-antecedent rules system needs to be reconstructed to a multi-layer fuzzy system and any sub-layer rule base is sparse. The implementation of this approach is based on fuzzy rule interpolative reasoning that utilities scale and move transformation. An illustrative example and application scenario are provided to demonstrate the efficacy of this proposed approach.

KEYWORDS

Backward Fuzzy Rule Interpolation, Curse Of Dimensionality, Hierarchical System, Sparse Rule Base

1. INTRODUCTION

"Curse of dimensionality" is a common problem in big data and other real applications (Raju and Zhou, 1993; Raju and Zhou, 1993; Jin et al., 2018). Provided that each variable has M membership functions for K input variables, and needs rules to build a system of the domain covering the substantive issues entirely, the rule-explosion problem can be addressed in two ways. The first option is to reduce the number of fuzzy partitions, which usually results in significant reduction of model accuracy (Sugeno and Kang, 1986; Sugeno et al., 1995; Environmental, 2012). Besides, for many practical applications, there may not be sufficient historical data to support the creation of the needed rules that would cover the entire problem space, but only a sparse rule base. Fortunately, fuzzy rule interpolation can be employed for dealing with the above-mentioned problems. The other way is to reduce the dimensionality of the sub-rule bases sing meta-levels or hierarchical fuzzy rule bases. A potentially more powerful case is the combination of both, which could improve the computational complexity dramatically (Kóczy et al., 2000; Layeb and Saidouni, 2010; Wibig, 2010). In such a combined hierarchical interpolation system, however, situations may become even more complicated where certain crucial antecedents may be absent from given observations. This is because missing antecedents may well be involved in the subsequent (sub-system) inference process, causing the final conclusion is not deductible.

To address the underlying problem of performing interpolation for certain antecedent variables, an original technique for backward fuzzy rule interpolation (B-FRI) has been proposed (Jin et al., 2014). This technique is a branch of FRI and an extension of the existing FRI techniques. B-FRI

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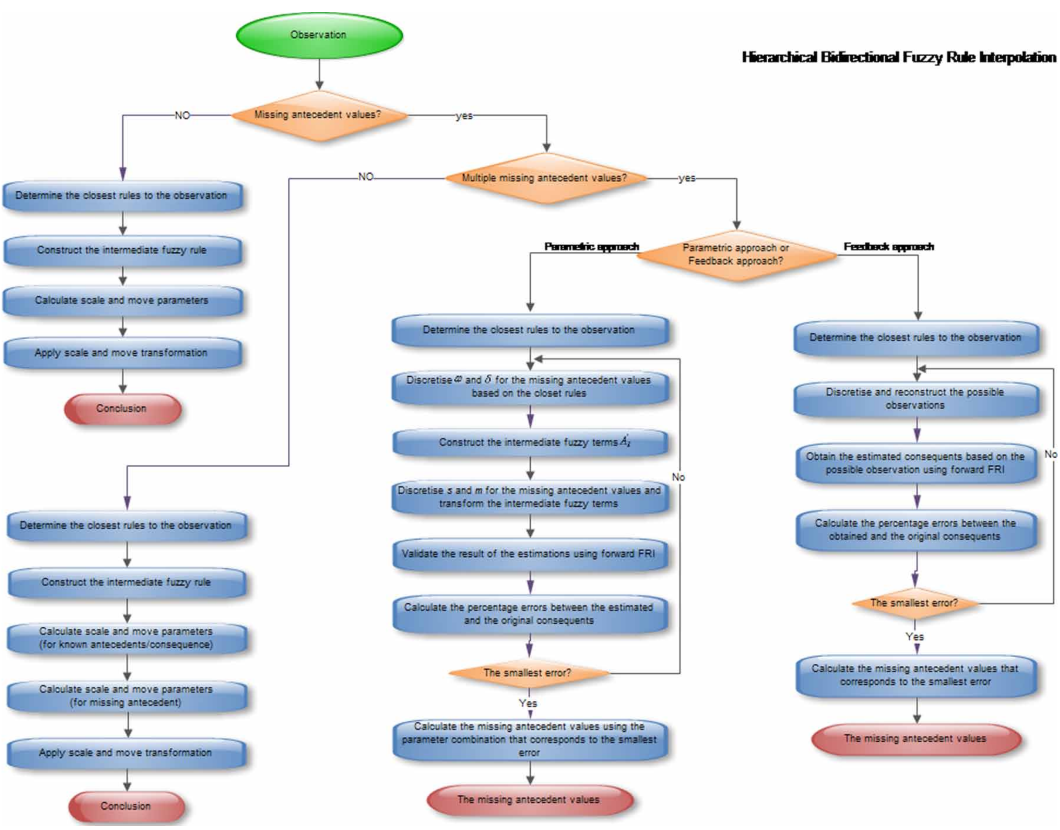
can be employed to allow interpolation to be carried out when certain antecedents of observation variables are absent, whereas conventional methods do not work. The missing antecedents may be inferred or interpolated using the known antecedents and given conclusion during the interpolative reasoning process. B-FRI can also be employed to calculate certain antecedents for testing purposes, no matter whether the antecedents are known or not. It supports both interpolation and extrapolation which involve multiple intertwined fuzzy rules, with each having multiple antecedents. This allows missing observations that are directly related to the conclusion to be inferred or interpolated from the other known antecedents and the given conclusion. In addressing real-world problems, the rules adopted are typically irregular in nature (i.e., they may not always address the same antecedents). Indeed, rules may be arranged in an inter-connected mesh, where observations and conclusions in different subsets of rules may overlap, and yet may not be directly related throughout the entire rule base. For such complex systems, any missing values in a given set of observations may lead to failure if only unidirectional interpolation is employed.

In this paper, the initial theoretical work of hierarchical bidirectional fuzzy rule interpolation (HB-FRI) is proposed to meet the aforementioned challenges. Based on previous research work (Jin et al., 2014; Jin et al., 2013; Jin et al., 2012), hierarchical bidirectional fuzzy rule interpolation based on T-FRI can be proposed as outlined in the flowchart given in Figure 1. HB-FRI is herein implemented using scale and move transformation-based fuzzy interpolative reasoning (T-FRI) (Huang and Shen, 2006; Huang & Shen, 2008), owing to their popularity and availability (although other FRI methods may be adapted to serve as the alternative if preferred). In particular, T-FRI offers a flexible means to handle both interpolation and extrapolation involving multiple, multi-antecedent fuzzy rules. It

Figure 1. Structure of hierarchical bidirectional fuzzy rule interpolation



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