Rule base simplification by using a similarity measure of fuzzy sets

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Abstract. In fuzzy models, redundancy may be present in the form of similar fuzzy sets, especially in the construction of a fuzzy system from a set of given training examples. In this paper, a simple formula for calculating the degree of similarity of Trapezoidal membership functions is derived in order to merge similar membership functions and hence to obtain a more transparent rule-base with a minimum number of membership functions. A simplification algorithm by using the proposed similarity measure has been applied to fuzzy models of nonlinear functions approximation.

Keywords: Interpretability, fuzzy rule base simplification, distinguishability, similarity measure, trapezoidal membership functions

1. Introduction

One of the most important motivations for building up a fuzzy model is to let users gain a deep insight into an unknown system through the easily understandable fuzzy rules. Another main attraction undoubtedly lies in the unique characteristics that the fuzzy logic systems possess. They are capable of handling complex, nonlinear, and sometimes mathematically intangible dynamic systems.

Many techniques to design fuzzy inference system (FIS) from data are available; they all take advantage of the property of FIS to be universal approximators. In order to compare FIS with other modeling techniques, their performance is usually measured by a numerical index, the mean square error. But the blind improvement of the performance may conflict with the originality of fuzzy logic: its interpretability.

Interpretability [2, 9] refers to the capability of the fuzzy model to express the behavior of the system in a human being understandable way. This is a subjective property that depends on several factors, mainly the model structure, the number of input variables, the number of fuzzy rules, the number of linguistic terms, and the shape of the fuzzy sets [2].

According to the excellent discussions made in literature, one major component of interpretability of a fuzzy model strongly depends on the distribution of membership functions (MFs) [9, 17, 18]. As a basic criterion, distinguishability is the first concern in interpretable fuzzy modeling [13, 21–23, 25, 26]. Distinguishability is an intuitive and basic criterion, because, in input space partitioning for interpretable fuzzy modeling, fuzzy sets should clearly define the distinctive ranges in the universe of discourse of a variable, and each MF should be different enough from each other so as to represent a term with a clear semantic meaning [30].

Generally, Distinguishability can be maintained or enhanced during the fuzzy system’s generation or obtained by post-processing of the resulting data-driven fuzzy system [20]. Examples for the first approach include constraints on membership functions and their shapes.