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A New Interval-based Method for Handling Non-Monotonic Information

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Abstract—**The focus of this paper is on handling non-monotone information in the modelling process of a single-input target monotone system. On one hand, the monotonicity property is a piece of useful prior (or additional) information which can be exploited for modelling of a monotone target system. On the other hand, it is difficult to model a monotone system if the available information is not monotonically-ordered. In this paper, an interval-based method for analysing non-monotonically ordered information is proposed. The applicability of the proposed method to handling a non-monotone function, a non-monotone data set, and an incomplete and/or non-monotone fuzzy rule base is presented. The upper and lower bounds of the interval are firstly defined. The region governed by the interval is explained as a coverage measure. The coverage size represents uncertainty pertaining to the available information. The proposed approach constitutes a new method to transform non-monotonic information to interval-valued monotone system. The proposed interval-based method to handle an incomplete and/or non-monotone fuzzy rule base constitutes a new fuzzy reasoning approach.**

Keywords*: *Fuzzy ordering, monotonicity property, interval-valued, coverage measure, fuzzy sets, fuzzy reasoning

I. Introduction

A common problem in modelling a target monotone system is to approximate an unknown monotone function based on the available information. Examples of information include a set of experimental data, a mathematical model, or a set of fuzzy rules for a Fuzzy Inference System (FIS). It should be noted that the available information may not always satisfy the monotonicity property. Examples include non-monotonically ordered experimental data, non-monotone mathematical model, and non-monotonically ordered fuzzy rules for a target monotone system. The monotonicity property has been shown to be useful prior (or additional) information which can be exploited for modelling a monotone target system. However, exploitation of the monotonicity property in modelling is difficult, if the provided information does not conform to the monotonicity property. Therefore, it is important to represent non-monotone information as a monotone system to ensure the usefulness of the resulting model.

A search in the literature reveals that techniques to handle such information are available. As an example, noise was defined in the form of non-monotonicity, and a method to relabel non-monotone data set was proposed [1]. In [2], an original estimate (in the form of a non-monotone mathematical function) was considered. A method to re-arrange and transform the original estimates into a monotone form of estimates was proposed. In [3-4], methods to re-label non-monotone fuzzy rules were also proposed.

Three potential options for handling non-monotone experimental data have been discussed in [1]: (i) keep the data samples as they are; (2) identify noisy data samples and remove them; (3) identify noisy data samples and re-label them. In this paper, we argue that these options may also be applicable to non-monotone functions and non-monotone fuzzy rules. As a result, three potential options for handling non-monotone information are: (1) keep the information as it is; (2) identify and remove noisy information; and (3) identify and modify noisy information. Examples of the third option include the re-labeling techniques for non-monotone experimental data [1], the re-arrangement techniques to monotonize a non-monotone original function [2], and the development of fuzzy rule re-labeling techniques to re-label non-monotone fuzzy rules of an FIS [3-4].

The focus of this paper is on the first option, i.e., keep the information as it is, and the focus is on fuzzy modeling. While this option has been discussed [1], it is not clear how it can be implemented practically. In this paper, non-monotone information that describes a target monotone system is defined as a form of noise. The monotonicity property is exploited as a piece of useful prior (or additional) information for modelling a monotone system. An interval-based method to analyze noisy information is further suggested. The idea is to keep the original noisy information as it is, and represent the noisy information as an interval. As such, the upper and lower bounds of the interval are firstly defined. The region governed by the interval is explained as a coverage measure, and the coverage size represents the degree of uncertainty of the information. It is important to represent non-monotone information as an interval because it provides the lower and upper limits of the output for a particular input point of a monotone system.

In this paper, the use of the proposed interval-based