

Multi-Expert Decision-Making with Incomplete and Noisy Fuzzy Rules and the Monotone Test

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Abstract—The use of Fuzzy Inference System (FIS) in decision making problems has received little attention so far. This may be due to the difficulty in gathering a complete set of fuzzy rules, which is free from noise, and the complexity in constructing an FIS model that is able to satisfy a number of important properties, including the monotonicity property. Previously, we have proposed a single-input Monotone-Interval FIS (MI-FIS) model, which can handle incomplete and non-monotone fuzzy rules. Besides that, we have proposed the idea of a monotone test (MT) for a set of fuzzy rules, which give an indication pertaining to the degree of monotonicity of a fuzzy rules set. In this paper, a multi-input MI-FIS model is firstly presented. The focus of this paper is on the use of MI-FIS and MT for undertaking multi expert decision-making (MEDM) problems. A three-phase MEDM framework consists of modelling, aggregation, and exploitation phases is proposed. In the modelling phase, an MT index for each fuzzy rule base from each expert, which is potentially non-monotone and incomplete, is obtained. The provided fuzzy rule bases are also modelled as MI-FISs. In the aggregation phase, an overall collective rating score of an alternative from a number of experts is obtained through the fuzzy weighted averaging operator. We suggest including MT as part of the aggregation phase. In exploitation phase, a rank ordering procedure among the alternatives is established using a possibility method. The developed framework is evaluated with simulated information. The results show that including the MT index in the aggregation phase is able to increase the robustness of the proposed FIS-MEDM model in the presence of noisy fuzzy rule sets.

Keywords—Fuzzy inference system, decision making, multi-expert, monotonicity, monotone test, noisy fuzzy rules

I. INTRODUCTION

The importance of monotonicity in Fuzzy Inference System (FIS) modelling is generally known [1-7]. Indeed, many mathematical conditions for FIS models to satisfy the monotonicity property has been developed, e.g., Mamdani FIS [1][2], Sugeno FIS [3], [4], single-input rule module FIS [5], hierarchical FIS [6], and interval type-2 FIS [7]. To develop a monotone zero-order Sugeno FIS model, a complete and monotone rule base is required [4]. However, this is not always the case in practice [4], [8].

Previously, we have argued that noise (i.e., in terms of human judgment errors [8], [9]) can happen in fuzzy rules, resulting in a non-monotone fuzzy rule base [4] (Theorem 1 in Section II is violated). Besides that, fuzzy rules can be incomplete too. Supporting techniques for these problems have been developed, e.g., fuzzy rule relabeling [9] to relabel a set of original non-monotone fuzzy rules from expert to become monotone, monotone similarity reasoning [4] to

approximate the missing fuzzy rules of an incomplete fuzzy rule base, and the monotone interval FIS (MI-FIS) model [8] to transform the original incomplete and/or non-monotone fuzzy rule base into an interval-valued fuzzy rule base. With MI-FIS [8], the original fuzzy rule base which is potentially non-monotone and/or incomplete is retained (instead of approximated or removed) and transformed into a set of interval-valued fuzzy rules. Worth mentioning, our monotone similarity reasoning [4] and MI-FIS [8] are inspired from a number of important fuzzy reasoning approaches, e.g., fuzzy rule interpolation [10], [11], [12], analogical reasoning [13], and completion algorithm [14], to approximate missing fuzzy rules. Our monotone similarity reasoning [4] and MI-FIS [8] were proposed to tackle problems that require monotonicity fulfilment, while fuzzy rules is incomplete.

The focus of this paper is on the zero-order Sugeno FIS [15] model for tackling Multi-Expert Decision-Making (MEDM) problem. Decision making problems usually involve a number of experts who recognize the existence of a common issue and attempt to reach an overall collective rating score of alternatives [16]. Each expert is characterized by his/her judgements or preferences on a predefined set of alternatives with respect to each attribute(s) [16]. However, experts' judgements are often presented qualitatively with imprecise and uncertain knowledge, rather in a quantitative form due to the unquantifiable nature or computational constraints to quantify real-world phenomenon. As such, over the years, fuzzy sets associated with linguistic terms (i.e., fuzzy judgements) are often used to model real world problems qualitatively in fuzzy MEDM environments [17], [18], [19].

The use of FIS for tackling MEDM problems is motivated by a number of reasons: 1) the capability of FIS in modelling the nonlinear relationship between the input(s) (i.e., attribute(s)) and output (i.e., individual overall rating score of alternatives) from an expert, instead of using mathematical approximation methods that linearize the complex nonlinear problems [20]; 2) customization of the decision making model based on an expert's knowledge provided in the form of fuzzy "IF-THEN" rules is allowed; 3) input attribute(s) for an expert is captured qualitatively using fuzzy logic. However, a search in the literature reveals that, the use of FIS in multi-expert context has received little attention. This is due to the tedious and time consuming process in collecting a set of complete and monotone (i.e., without noise) fuzzy rules for an FIS model in a single expert context, not to mention the use of FIS in the multi-expert context. The failure to handle the issues of