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On type-reduction of type-2 fuzzy sets: A review

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ABSTRACT

As an undetachable module of type-2 (T2) fuzzy computations and reasoning, type-reduction methods play an important role in various fuzzy disciplines including fuzzy logic systems and fuzzy clustering. Importance of type-reduction techniques lies in the fact that they are the main tools for collecting the entire inherent vagueness of the data. Therefore, type-reduction methods form the output of type-2 fuzzy sets (T2 FSs) as the representative of the entire uncertainty in a given space. Hence, their accuracy, precision, and performance speed is of much interest. This paper, presents a comprehensive review on various type-reduction and defuzzification strategies for general and interval type-2 fuzzy sets and systems. It is tried to analyze the existing approaches from different point of views accompanied by extensive comparisons on different features of type-reduction methods to facilitate further research studies by the fuzzy community.

1. Introduction

Uncertainty is an inherent feature of information. Today, most of decision making processes involve retrieving and analyzing information which is mostly vague, incomplete, noisy, fragmentary, or sometimes contradictory. With the advent of soft computing (SC) methods, several powerful tools in the field of computational intelligence were introduced including: type-1 fuzzy logic, neural networks, evolutionary algorithms, and hybrid intelligent systems (HIS) [59–61].

As an efficient tool, type-1 fuzzy sets (T1 FSs) have long been employed in various disciplines such as pattern recognition, medical applications, engineering problems, etc. Although for many cases, application of T1 FSs makes sense but in more uncertain environments it does not seem to be appropriate. T1 FSs assign a single value from the interval [0,1] to each member of the primary domain as membership value while sometimes membership of an object to the universe of discourse is uncertain itself. This property led the researchers to interval type-2 fuzzy sets (IT2 FSs) whose membership functions are an interval instead of a single value. IT2 FSs are a special form of general type-2 fuzzy sets (GT2 FSs) whose secondary membership values for the entire members of the primary domain are 1. This property reduces computational efforts needed for analysis of GT2 FSs while remarkably enhancing imprecision handling capabilities of traditional T1 FSs.

Most approaches being constructed on the concept of T1 FSs need to perform an operation called defuzzification in order to integrate environment uncertainty and to give a single value which represents the entire imprecision of the environment. On the contrary, T2 FSs require an additional step for representing a single value as the representative of the uncertainty. This step is called type-reduction which converts a T2 FS into its T1 counterpart. Type-reduction is a necessary step in different computational intelligence fields including fuzzy systems, clustering, and classification.

The general T2 FLS schema is illustrated in Fig. 1. This process is similar to T1 FLS and the main difference between T1FLSs and T2FLSs can be observed in defuzzification step. T2 FSs are described by MF which is more flexible than T1 FSs. In Fig. 2, an overview of applications published in the literature on T2 fuzzy logic accompanied by the position of type-reduction process is depicted. According to Fig. 2, 14 groups can be considered in T2 fuzzy logic, and four classes of exact methods, uncertainty bounds approaches, approximate and geometrical methods can be listed as type reduction approaches. Most of the researches emphasize on IT2 FSs, because of their manageability and docility; however, the influence of GT2 fuzzy models has gradually increased these days. This paper focuses on state of the art T2 fuzzy logic type reduction methods. It has been tried to collect the entire existing type-reduction strategies in the literature for both IT2 and GT2 FSs. Then, comprehensive comparisons from diverse aspects including

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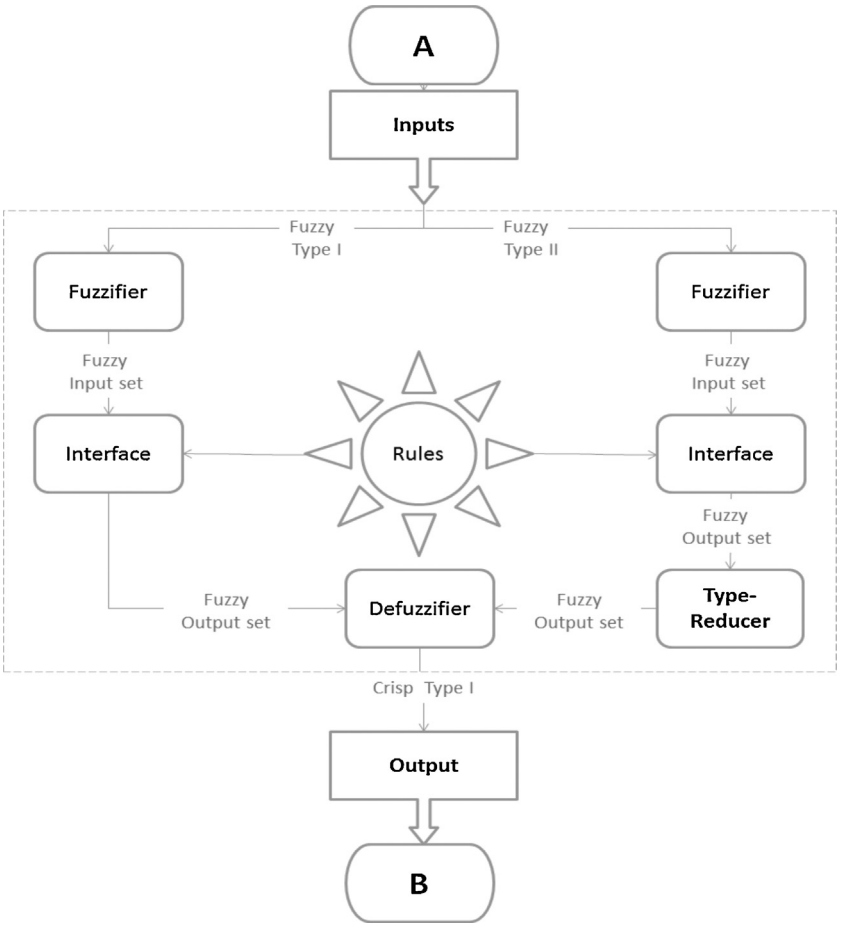

Fig. 1. Type-1 and type-2 fuzzy logic systems.

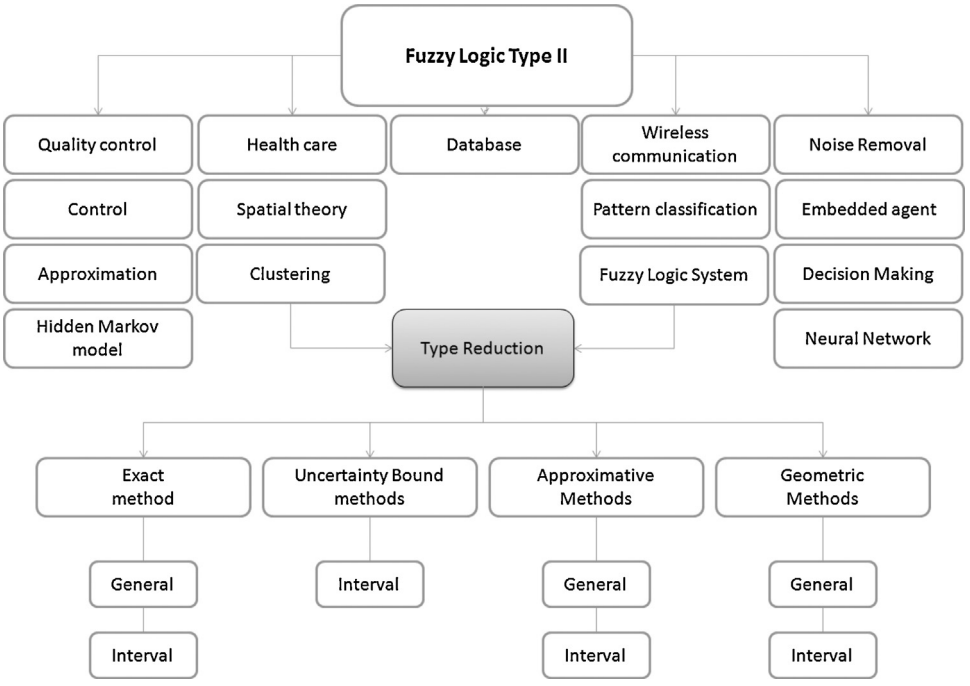

Fig. 2. Type reduction in T2 fuzzy logic architecture.

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