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Selection of alternatives using fuzzy networks with rule base aggregation

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Abstract

This paper introduces a novel extension of the Technique for Ordering of Preference by Similarity to Ideal Solution (TOPSIS) method. The method is based on aggregation of rules with different linguistic of the output of fuzzy networks to solve multi-criteria decision-making problems whereby both benefit and cost criteria are presented as subsystems. Thus the decision maker evaluates the performance of each alternative for decision process and further observes the performance for both benefit and cost criteria. The aggregation sub-stage in a fuzzy system maps the fuzzy membership functions for all rules to an aggregated fuzzy membership function representing the overall output for the rules. This approach improves significantly the transparency of the TOPSIS methods, while ensuring high effectiveness in comparison to established approaches. To ensure practicality and effectiveness, the proposed method is further tested on portfolio selection problems. The ranking produced by the method is comparatively validated using Spearman rho rank correlation. The results show that the proposed method outperforms the existing TOPSIS approaches in term of ranking performance.

Keywords: TOPSIS; Fuzzy networks; Selection alternatives; Fuzzy sets; Interval type 2 fuzzy sets; Z-numbers; Stock selection; Spearman rho; Type 1 fuzzy sets

1. Introduction

Multi-criteria decision making (MCDM) problems are often observed in reality, and decision makers are faced with the challenge of making decisions in the presence of multiple criteria. The focus is on identifying the best performing solution among feasible alternatives assessed by a group of decision maker and evaluated through multiple criteria [1]. There have been important advances in this field since the start of the modern multiple-criteria decision-making discipline in the early 1960s. Various MCDM techniques have been developed with the overall objective to assist decision makers solve complex decision problems in a systematic, consistent and more productive way.

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TOPSIS is an MCDM technique for ranking and selection of alternatives. The TOPSIS analysis considers two reference points – a positive ideal solution (PIS) and a negative ideal solution (NIS) – as well as the distances to both PIS and NIS. The preference order is ranked according to the closeness of PIS and NIS, and according to a combination of the two distance measures [2].

Fuzzy systems are vital within the armoury of fuzzy tools and applicable to real-life decision-making environment. There are three type of fuzzy systems introduced in the literature – systems with a single rule base, systems with multiple rule bases, and systems with networked rule bases. Systems with a single rule base are characterised with a black box nature, where the inputs are mapped directly to the output without considering any internal connection. Systems with multiple rule bases are characterises with a white box nature, where the inputs are mapped to the outputs through interval variables as connections. This type of systems is also termed chained fuzzy systems or hierarchical fuzzy systems. The third types of fuzzy systems incorporate networked rule bases, and are termed fuzzy networks (FN). Fuzzy networks are introduced as a theoretical concept in [3], and are characterised with a white box nature where the inputs are mapped to the outputs through intermediate variables.

According to [4], the accuracy of single rule base is moderate but the level of transparency is low, while multiple rule bases are regarded as having low accuracy in dealing with complex processes management. While in most decision making studies, single rule bases and multiple rule bases are common approaches [5], in this research we focus on fuzzy networks as they are highly transparent and moderately accurate. A node represents each subsystem in a FN and the interactions among subsystems are the connections between nodes. Therefore FNs consider the interaction between subsystems. This ability brings considerable benefits to modelling complex processes, and although FNs have been introduced recently, a cohort of researchers are dedicated to the theoretical development and applications of FNs [3,4,6–9].

The reliability of decision knowledge and the experience of experts are still in need of better incorporation into modelling complex decision-making processes. For instance, how assured in their choices are shareholders as decision makers, and how much experience experts as financial analysts have in relevant asset classes and markets. Besides, existing TOPSIS methods have a very low transparency level, and consequently are not able to track the performance of benefit and cost criteria [10]. In decision-making processes, it is essential that decision makers are aware of how the numerous criteria are performing.

The inadequacies described above bring the motivation of this study. This paper introduces novel application of fuzzy networks with aggregation of rule bases for decision-making problem solving. This approach is different from other similar approaches such as merging of rule bases [11]. In this case, aggregation is the process of combining a set of fuzzy rules into a single fuzzy rule. It also includes the defuzzification for each output of the system. This process is important because decisions are made based on considering all rules in the system. In order to make better decision, the rules must be combined. Moreover, the proposed methodology helps to improve significantly the transparency of TOPSIS methods, while ensuring high effectiveness in comparison to established approaches. Also the methodology can help experts to trace the performances of criteria and afterwards make better decisions.

The paper is structured as follows: Section 2 briefly reviews the concepts fuzzy systems, and the operation of fuzzy networks. The novel methodology of TOPSIS using fuzzy networks with aggregation of rule bases FN-TOPSIS is formulated in Section 3. Section 4 illustrates the application of FN-TOPSIS to the problem of ranking stock. Further discussion and analysis of the FN-TOPSIS ranking performance are provided in Section 5. The main conclusions are summarised in Section 6.

2. Preliminaries

2.1. Fuzzy systems

A fuzzy system consists of a single rule base where inputs are processed simultaneously without taking into account the connections and the structure of the system. This is shown in Fig. 1, where $\{p_1, \ldots, p_n\}$ is the set of inputs and q is the output of the system. For this type of system, the rules are derived based on expert knowledge about the process. The results are normally quite accurate but the poor transparency of the system can be an obstacle to understanding complex processes.

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