Fuzzy Logic Applications to MCDM Problem

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Abstract: Multicriteria decision making (MCDM) is a modeling and methodological tool for dealing with complex engineering problems. In these problems, sometimes, it is challenging for decision makers to find solutions because the information they get may be incomplete and vague. To deal with the vague, ambiguous, and imprecise input or knowledge, fuzzy logic is a simple and well-studied method. This is due to the fact that the fuzzy logic is suitable for describing uncertainties and dealing with different MCDM problems. Therefore, the fuzzy logic has been widely adopted to cope with a large fraction of imperfect information in different circumstances and contexts. Over the years, there have been a number of successful applications and implementations of the fuzzy logic in the MCDM. The MCDM has become one of the branches in which the fuzzy logic finds its wide applications.

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Introduction: Multicriteria decision making (MCDM) is used to achieve the optimal alternative that has the maximum level of satisfaction among a group of feasible alternatives that contain multiple criteria. Many MCDM tools such as the traditional TOPSIS express the problem in the form of a decision matrix filled with crisp data, with the assumption that the provided information is precisely defined. However, this might not be applicable in some real world MCDM problems. Due to the time barrier and the limited knowledge about the problem domain, decision makers tend to express their preferences with ranges and verbal descriptions, instead of crisp data or exact numbers. For this reason, fuzzy logic is suggested by many researchers to be used in MCDM problems to overcome this issue. The concept of fuzzy logic has been presented by Zadeh to form human logic from lacking and imprecise information by providing definitions to vague expressions (Zadeh, 1965, 1973). Fuzzy logic also can integrate human experiential data and give it an engineering perception to control and form such unclear systems with uncertainty (Siddique & Adeli, 2013). Therefore, implementing fuzzy logic in MCDM tools will include a higher degree of uncertainty in the decision making process. Hence, this will provide more realistic and accurate decision making outcomes and results (Yang et al., 2017). The combination of fuzzy logic and MCDM is often called the fuzzy-MCDM approach, which can be helpful in handling the imprecise information and data by converting them into linguistic variables (Siddique & Adeli, 2013).

In order to clearly demonstrate the concept of fuzzy logic, classical logic should be defined first. In classical logic a proposition is either true or false, 'cold or hot,' which is imprecise, unrealistic, and cannot define many real life problems. On the other hand, fuzzy logic is a change from absolute truth to partial truth. A clear example of using the fuzzy logic concept is by changing the obsolete truth in the variable x (Cold or Hot) to a partial truth in the linguistic variable 'Very cold,' 'Slightly cold,' 'Warm,' 'Slightly hot,'and 'Very hot' (Siddique & Adeli, 2013). Theses linguistic terms can be translated to crisp number such as '1' for 'very cold' and '5' for 'warm.' The process in which these crisp data are converted to fuzzy numbers is called the fuzzification process. The major issue in the fuzzification process in MCDM problems is choosing the suitable membership function that will be responsible for the conversion of fuzzy numbers. A membership function can be described as a curve that expresses how each point in the input space is represented by a membership value (degree of membership) between 0 and 1, which is usually given in the form of fuzzy numbers, that is, uCj (xi). The membership functions are usually developed from many basic functions such as piecewise linear function, Gaussian distribution function, sigmoid curve, and quadratic and cubic polynomial curves (Maity & Chakraborty, 2013).

Fuzzy sets theory, which was introduced by Bellman and Zadeh (1970), was the first implementation of fuzzy numbers in MCDM. This concept has been developed to assist decision makers in solving MCDM problems, considering the fuzziness in decision makers' preferences and the uncertainty of the objects. They suggested that the decision makers could implement the uCj (xi) to show their preference about the membership grade of a specific alternative xi with respect to a criterion Cj ; in other words, it means the grade to which the alternative xi satisfies the criterion Cj . In the practical MCDM procedure, decision makers usually give their opinions 27 regarding the grade to which the alternative xi not only satisfies but also dissatisfies the criterion Cj . For this reason, Atanassov (1986) developed the concept of intuitionistic fuzzy set (IFS), where decision makers can express their preferences about a membership grade and a nonmembership grade of an alternative xi with respect to a criterion Cj meeting the condition that the sum of its membership grade and its nonmembership grade is equal to or less than 1. The IFS concept has been widely employed in real-world MCDM issues and problems. Moreover, much research has been conducted on the application of MCDM problems with IFSs.

Fuzzy Topsis Applications to MCDM Problems

The TOPSIS method has been extended and studied by many researchers for solving MCDM problems in many fuzzy environments such as fuzzy number contexts, interval fuzzy set contexts, IFS contexts, hesitant fuzzy set contexts, and hesitant fuzzy linguistic term set contexts (Chen, 2000; Chen & Tsao, 2008; Boran, Genc, Kurt, & Akay, 2009; Xu & Zhang, 2013; Beg & Rashid, 2013; Chen, 2016). However, the fuzzy TOPSIS methods and its extensions have been ineffective to deal with Pythagorean fuzzy environments. For this reason, Zhang and Xu (2014) developed the TOPSIS approach to successfully address the MCDM problem with Pythagorean fuzzy information.

Applications of Fuzzy TOPSIS to MCDM Problems in Material Selections

In materials selection MCDM problems, weights are usually assigned by linguistic terms described by decision makers. Thus, the final decision results might encounter a risk due to this incomplete, vague and imprecise information. For this reason, using fuzzy logic in materials selection is to address the problem that might occur from assigning weight using linguistic terms described by decision makers. The application of fuzzy logic in this situation can be very helpful to deal with such materials selection problems because sometimes the evaluations completed by engineers, designers and decision makers throughout the initial design stage contain indefinite and uncertain requirements, parameters, and relationships. Thus, fuzzy logic is implemented as a supportive concept to express the action and approach of the decision makers while selecting the most suitable material alternative (Maity and Chakraborty, 2013). Since TOPSIS has demonstrated its applicability in materials selection problems, many researchers combine the use of TOPSIS under fuzzy environments to address the uncertainty and vagueness issues that might occur in the decision making process and that affect the final decision results. Maity and Chakraborty (2013) adopted fuzzy logic effectively with the TOPSIS method in selecting the most suitable material for a list of eight grinding wheel abrasives whose efficiency is assessed based on multiple criteria. Maldonado-Macías, Alvarado, García, & Balderrama (2014) introduced the use of the TOPSIS method under an intuitionistic fuzzy environment to select the best alternative among three CNC milling machines for an advanced manufacturing technology training center considering human factors and ergonomics attributes. The intuitionistic fuzzy TOPSIS method was very beneficial in dealing with the vagueness or sometimes incorrect information provided by decision makers in the evaluation process. Yang et al. (2017) studied how applying fuzzy TOPSIS for material selection in the initial phase could effectively improve the remanufacturability of automotive parts. Combining the TOPSIS method with fuzzy logic was very effective in reducing personal bias and uncertainty of the evaluation process. Liao (2015) developed a two-interval type 2 fuzzy TOPSIS method to handle the high nature of uncertainty and vagueness of material properties in the material selection process within the product design stage. Purohit and Ramachandran (2015) used a fuzzy Topsis approach in MCDM to select the best suitable alternative among five materials for making engine flywheels. They suggested that this approach can be implemented for any materials selection problem in a manufacturing field. However, to the best of our knowledge, no application of the MCDM method on material selection based on the use of the TOPSIS technique under the Pythagorean fuzzy environment is currently available in the open literature. To fill this gap, this research will suggest an effective Pythagorean fuzzy TOPSIS MCDM approach to be used in real life materials selection problems

Fuzzy Logic and its usage in MCDM techniquesBottom of Form

Fuzzy logic is a mathematical approach used in MCDM (Multi-Criteria Decision Making) technique to handle uncertainty and imprecision in decision-making. Fuzzy logic allows decision-makers to express judgments or preferences in linguistic terms rather than precise numerical values, which is often more realistic and practical.

In fuzzy logic, membership functions are used to represent the degree of membership of an element in a fuzzy set, which is a set of values that are not precisely defined but have some degree of membership. The membership function assigns a degree of membership between 0 and 1 to each element based on how well it satisfies the conditions for membership.

Fuzzy logic is important in MCDM technique because it allows decision-makers to handle the vagueness and uncertainty that often arise when evaluating alternatives based on multiple criteria. It provides a flexible and intuitive approach to modeling complex decision problems, allowing decision-makers to express their preferences in a more natural way. For example, in a decision problem involving the selection of a supplier, the decision-makers may have imprecise or uncertain information about the quality, price, and delivery time of the different suppliers. Fuzzy logic can be used to represent these criteria as fuzzy sets and evaluate the alternatives based on their degree of membership in each set.

Fuzzy Logic in Multiple Attribute Decision Making

The inclusion of fuzzy evaluations within Multiple Criteria Decision Making (MCDM) techniques has substantially increased their applicability as problem-solving methods when dealing with conflicting, uncertain criteria. Similarly, formal interactions between ranking methods such as Data Envelopment Analysis (DEA) and fuzzy logic are common in the operations research literature, broadening the scope and applicability of the resulting hybrid models. Despite the remarkable evolution of these areas in recent years, there is still ample room for the development of additional research lines dealing with underexplored - though essential - aspects, such as the integration of neutrosophic and fuzzy intuitionistic logic, and grey systems theory within multi-criteria evaluation frameworks. This Research Topic aims at extending the interactions between widely accepted and implemented MCDM methods, such as TOPSIS, VIKOR, PROMETHEE, ELECTRE, and DEA, and the most recent developments in neutrosophic and fuzzy intuitionistic logic, and grey systems theory. The manuscripts submitted should aim at extending the scope of applications of MCDM techniques across uncertain real-life scenarios while reinforcing the formalization of the interactions taking place across fuzzy or uncertain variables within standard MCDM methods. We encourage submissions that may focus on one of these complementary approaches: identifying the relationships among MCDM methods when interacting within the same uncertain fuzzy environment or illustrating the differences across MCDM techniques when different types of fuzzy variables are considered. Applications of the resulting evaluation structures to environmental and natural resource management, healthcare and medicine, as well as graphs and networks are particularly encouraged. Papers covering novel extensions of multi-objective optimization, networks and shortest path problems, involving interactions across different types of fuzzy variables, are also welcomed as contributions. This Research Topic aims to strengthen the complementarities existing between fuzzy and uncertain evaluation environments, and MCDM techniques both at formal and empirical levels. We also welcome theory-based papers supported by robust formulations and mathematical formalization. The main subtopics expected to be developed include, but are not limited to: · Fuzzy logic and uncertainty in multiple criteria decisions making; · Applications of neutrosophic and fuzzy intuitionistic logic, and of grey systems theory to Data Envelopment Analysis, TOPSIS, VIKOR, PROMETHEE, ELECTRE, Multi-objective optimization, Networks and shortest path problems.

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