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Advancements in Multi-Criteria Decision Making Based on Interval-Valued Intuitionistic Fuzzy Set

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Abstract:- Multi-criteria decision-making (MCDM) problem is the process of finding the best option from all of the feasible alternatives where all the alternatives can be evaluated according to a number of criteria or attribute. Since human judgments including preferences are often vague and cannot estimate his preference with an exact numerical value. Multi-criteria decision-making problems usually consist of uncertain and imprecise data and information. To deal with vagueness/imprecision Atanassov's intuitionistic fuzzy set [1] has found to be highly useful and they are successfully applied to the field of multi criteria decision making problems. Later on, integrating interval valued fuzzy sets with IFSs; Atanassov introduced the concept of interval valued intuitionistic fuzzy sets (IVIFSs) [2]. As a generalization of an intuitionistic fuzzy set, it is more flexible for IVIFSs to deal with uncertain and fuzzy problems. There are many situations in multi attribute decision making where IVIFS theory is more appropriate to deal with. In this paper we will review all the major contribution done in the area of multiple attribute decision-making based on interval-valued intuitionistic fuzzy sets (IVIFSs) theory.

Keywords:- Intuitionistic Fuzzy sets (IFS), Interval-Valued Intuitionistic Fuzzy sets (IVIFS), Multi-Criteria Decision Making (MCDM).

I. INTRODUCTION

It has been widely recognized that most decisions made in the real world take place in an environment in which the goals and constraints, because of their complexity, are not known precisely, and thus, the problem cannot be exactly defined or precisely represented in a crisp value. Bellman, Zadeh (1970) and Zimmermann (1978) introduced fuzzy sets into the MCDM field. They cleared the way for a new family of methods to deal with problems that had been inaccessible to and unsolvable with standard MCDM techniques. Bellman and Zadeh (1970) introduced the first approach regarding decision making in a fuzzy environment.

The concept of an intuitionistic fuzzy set can be viewed as an alternative approach to define a fuzzy set in cases where available information is not sufficient for the definition of an imprecise concept by means of a conventional fuzzy set. In general, the theory of intuitionistic fuzzy sets is the generalization of fuzzy sets. Therefore, it is expected that intuitionistic fuzzy sets could be used to simulate human decision-making processes and any activities requiring human expertise and knowledge which are inevitably imprecise or not totally reliable. IFS theory has been extensively applied to areas like Artificial Intelligence, networking, Soft decision making, Programming logic, operational research etc. One the promising role of IFS has been emerged in Decision making Problems. In some real-life situations, a decision makers may not be able to accurately express their preferences for alternatives as they may not possess a precise or sufficient level of knowledge of the problem or the decision makers are unable to discriminate explicitly the degree to which one alternative are better than others [3], in such cases, the decision makers may provide their preference for alternatives to a certain degree, but it is possible that they are not so sure about it [4]. Thus, it is very suitable to express the decision maker preference values with the use of intuitionistic fuzzy values rather than exact numerical values or linguistic variables [5, 6, and 7]. To satisfy the need of decision making problem with imprecision and uncertainty many researchers have been concentrated on IFS theory. In year 1989 Atanassov introduced Interval-valued intuitionistic fuzzy sets and many researchers have shown interest in the IVIFS theory and successfully applied it to the field of multi-criteria decision making. In this paper, we will review the contribution in the field of multi-criteria decision making based on IVIFS theory.

This paper is organized as follows. The definitions of Interval-valued intuitionistic fuzzy sets and intuitionistic fuzzy sets are briefly introduced in Section 2. In Section 3 we discuss the role of IVIFS in Multi criteria decision making, finally conclusion is given in Section 4.

II. PRELIMINARIES

1.1 Definitions of intuitionistic fuzzy sets

Let a set E be fixed. An IFS A in E is an object of the following form:

$A = \{(x, \mu_A(x), \upsilon_A(x))\ x \in E\}$,

where the functions $\mu_A(x) : E \rightarrow [0, 1]$ and $\upsilon_A(x) : E \rightarrow [0, 1]$ determine the degree of membership and the degree of non-membership of the element $x \in E$, respectively, and for every $x \in E$:

$0 \le \mu_A(x) + \upsilon_A(x) \le 1$

When $\upsilon_A(x) = 1 - \mu_A(x)$ for all $x \in E$ is ordinary fuzzy set.

In addition, for each IFS A in E, if

$\pi_A(X) = 1 - \mu_x - \upsilon_x$

Then $\pi_A(X)$ is called the degree of indeterminacy of x to A [3], or called the degree of hesitancy of x to A.

Especially, if $\pi_A(X) = 0$, for all $x \in E$ then the IFS A is reduced to a fuzzy set.

2.2 Definitions of Interval-Valued intuitionistic fuzzy sets

Sometime it is not appropriate to assume that the membership degrees for certain elements of A are exactly defined, but a value range can be given. In such cases, Atanassov and Gargov defined the notion of interval-valued intuitionistic fuzzy set (IVIFS) as below:

Let $X=\{x_1, x_2, x_3....x_n\}$ be a given set and D[0,1] be the set of all closed subintervals of the interval [0,1], and X be ordinary finite non-empty sets. An interval valued intuitionistic fuzzy set A in X is an expression given by

$\tilde{A} = \{< x, \tilde{\mu}_{\tilde{A}}(x) + \tilde{\upsilon}_{\tilde{A}}(x) > x \in X\}$

Where

$\tilde{\mu}_{\tilde{A}} : X \rightarrow D[0,1], \tilde{\upsilon}_{\tilde{A}}: X \rightarrow D[0,1]$

with the condition $\sup(\tilde{\mu}_{\tilde{A}}(x)) + \sup(\tilde{\upsilon}_{\tilde{A}}(x)) \le 1$

Especially, if each of the intervals $\mu_{\tilde{A}}(x)$ and $\upsilon_{\tilde{A}}(x)$ contains exactly one element, i.e., if for every $x \in X$

$\mu_{\tilde{A}}(x) = \inf(\mu_{\tilde{A}}(x)) = \sup(\mu_{\tilde{A}}(x))$,

$\upsilon_{\tilde{A}}(x) = \inf(\upsilon_{\tilde{A}}(x)) = \sup(\upsilon_{\tilde{A}}(x))$

Then, the given IVIFS $\tilde{A}$ is transformed to an ordinary intuitionistic fuzzy set. Based on IVIFS, Xu defined the notion of interval-valued intuitionistic fuzzy number (IVIFN):

Definition: Let $\tilde{A} = \{< x, \tilde{\mu}_{\tilde{A}}(x) + \tilde{\upsilon}_{\tilde{A}}(x) > x \in X\}$, be an IVIFS, then we call the pair $(\tilde{\mu}_{\tilde{A}}(x) + \tilde{\upsilon}_{\tilde{A}}(x))$ an IVIFN.

III. ROLE OF IVIFS IN MULTI CRITERIA DECISION MAKING PROBLEMS

MCDM is concerned with structuring and solving decision and planning problems involving multiple criteria. Typically, there do not exist a unique optimal solution for such problems so it is necessary to use decision maker's preferences to differentiate between solutions. Multiple criteria decision making (MCDM) is often use for dealing with complex engineering problems. Cenigiz Kahraman gave very useful description about MCDM in his book on Fuzzy Multi criteria Decision Making[8]. In his book he explained MCDM problems with two basic approaches: multiple attribute decision making (MADM) and multiple objective decision making (MODM). MADM problems are distinguished from MODM problems, which involve the design of a "best" alternative by considering the tradeoffs within a set of interacting design constraints. MADM refers to making selections among some courses of action in the presence of multiple, usually conflicting, attributes. In MODM problems, the number of alternatives is effectively infinite, and the tradeoffs among design criteria are typically described by continuous functions.

MADM approaches can be viewed as alternative methods for combining the information in a problem's decision matrix together with additional information from the decision maker to determine a final ranking, screening, or selection from among the alternatives. Besides the information contained in the decision matrix, all but the simplest MADM techniques require additional information from the decision maker to arrive at a final ranking, screening, or selection. In the MODM approach, contrary to the MADM approach, the decision alternatives are not given. Instead, MODM provides a mathematical framework for designing a set of decision alternatives. Each alternative, once identified, is judged by how close it satisfies an objective or multiple objectives.

Fuzzy set theory has been used for handling fuzzy decision-making problems for a long span of time but many researchers have shown interest in the IFS theory and applied it to the field of decision making [9-12].

But after the introduction of IVIFS, there is a shift from IFS to IVIFS and researcher finds that Interval-valued intuitionistic fuzzy set (IVIFS) is effective in dealing with fuzziness and uncertainty inherent in decision data and multi-attribute decision making (MADM).

In year 2006 Chunqiao Tan and Qiang Zhang[13] presented a novel method for multiple attribute decision-making based on interval valued intuitionistic fuzzy sets (IVIFSs) theory and TOPSIS method in fuzzy environments. In their paper, the concept of interval-valued intuitionistic fuzzy sets is introduced, and the distance between two interval valued intuitionistic fuzzy sets is defined. Then, according to the ideal of classical TOPSIS method, a closeness coefficient is defined to determine the ranking order of all alternatives by calculating the distances to both the interval valued intuitionistic fuzzy positive-ideal solution and interval valued intuitionistic fuzzy negative-ideal solution. The multi-attribute decision-making process based on IVIFSs is given in fuzzy environments.

In year 2007 Zenshui and Chen [14] developed, the ordered weighted aggregation operator and hybrid aggregation operator for aggregating interval-valued intuitionistic preference information. Interval-valued intuitionistic judgment matrix and its score matrix and accuracy matrix are defined. Some of their desirable properties are investigated in detail. The relationships among interval-valued intuitionistic judgment matrix, intuitionistic judgment matrix, and complement judgment matrix, are discussed. On the basis of the arithmetic aggregation operator and hybrid aggregation operator, an approach to group decision making with interval-valued intuitionistic judgment matrices is given.

In year 2008 many authors contributed and their work is briefly discussed as following.

Zhoujing Wang et al. [15] in their paper used interval-valued intuitionistic fuzzy matrices, interval-valued intuitionistic fuzzy number and developed several optimization model to generate optimal weight of the attribute and the corresponding decision making methods.

Guiwu Wei and Gang Lan[16] proposed a modified grey relational analysis (GRA) method and used the traditional GRA method for calculating steps for solving interval-valued intuitionistic fuzzy multiple attribute decision-making problems with known weight information. The degree of grey relation between every alternative and positive ideal solution and negative ideal solution are calculated. Then, according to the concept of the GRA, a relative relational degree is defined to determine the ranking order of all alternatives by calculating the degree of grey relation to both the positive-ideal solution (PIS) and negative-ideal solution (NIS) simultaneously. Wei Yang and Yongfeng Pang [17] also worked on GRA method with IVIFS to solve MCDM problems.

Zhuo Xiao and Guiwu We [18] used interval-valued intuitionistic fuzzy information to deal with the supplier selection in supply chain management with, in which the information about attribute weights is completely known, and the attribute values take the form of interval-valued intuitionistic fuzzy numbers. A modified TOPSIS analysis method is also proposed.

In year 2009 following contribution has been made in area:

Zeng-Tai Gong and Yan Ma [19] introduced a score function and an accuracy function for ranking the order of interval-valued intuitionistic fuzzy sets. Then, obtain the criteria's optimal weights via a linear programming model to rank the alternatives and select the best one(s) in accordance with the value of the weighting function.

Luo Yongbiao et al. [20] used the weighted correlation coefficient of interval-valued intuitionistic fuzzy sets (IVIFSs) to identify the best alternative in multicriteria decision-making.

Weibo Lee [21] gave a novel method for ranking interval-valued intuitionistic fuzzy numbers and its application to Decision Making, A new score function is presented by taking into account the expectation of the hesitancy degree of interval-valued intuitionistic fuzzy sets (IVIFSs). And a deviation function is defined considering the variance of the hesitancy degree of IVIFSs. A new method for ranking interval-valued intuitionistic fuzzy numbers is then established based on the score function and deviation function. Their proposed method can nicely overcome the situation of difficult decision or wrong decision of existing measuring functions to the alternatives in some cases. Later on some other authors also worked on IVIFSs ranking and proposed new methods [22-23].

Weibo Lee [24] also gave an enhanced multicriteria decision-making method of machine design schemes under interval-valued intuitionistic fuzzy environment.

Hongjun Wang [25] utilized the interval-valued intuitionistic fuzzy weighted averaging (IIFWA) operator to aggregate the interval-valued intuitionistic fuzzy information corresponding to each alternative, and then rank the alternatives and select the most desirable one(s) according to the score function and accuracy function. Finally, an illustrative example about selecting an ERP system is given to verify the developed approach and to demonstrate its practicality and effectiveness.

Zhou-Jing Wang et al. [26] found that interval-valued intuitionistic preference relations are a powerful means to express a decision maker's uncertainty and hesitation about its preference over criteria in the process of multi-criteria decision making. In their paper, they established Goal programming models for generating priority interval weights based on interval-valued intuitionistic preference relations.

In year 2010 authors proposed various programming models to solve multiattribute decision-making (MADM) problems using IVIFSs. Their worked is briefed below.

Deng-Feng Li [27-28] developed a Linear and nonlinear-programming methodology that is based on the technique for order preference by similarity to ideal solution to solve multiattribute decision-making (MADM) problems with both ratings of alternatives on attributes and weights of attributes expressed with IVIF sets.

Zhoujing Wang and Jianhui Xu [29] several fractional programming models are derived from TOPSIS to determine the fuzzy relative closeness intervals of alternatives, and the corresponding decision-making method has also been developed. Feasibility and effectiveness of the proposed method are illustrated with an investment decision problem. Zhoujing Wang et al. [30] also worked on a linear programming method for interval-valued intuitionistic fuzzy multi attribute group decision making (MAGDM).

Yuan Yu et al. [31], proposed an approach that derives a linear program for determining attribute weights. The weights are subsequently used to synthesize individual IVIFN assessments into an aggregated IVIFN value for each alternative. In order to rank alternatives based on their aggregated IVIFN values, a novel method is developed for comparing two IVIFNs by introducing the formula of possibility degree and the ranking vector of the possibility degree matrix.

In year 2011 many researchers used IVIFS with different methods to deal with MADM problems more efficiently.

YingJun Zhang et al. [32] proposed a new axiomatic definition of entropy on interval-valued intuitionistic fuzzy sets (IVIFSs) and a method to construct different entropies on IVIFSs. They also developed a new multi-attribute decision making (MADM) method based on similarity measures using entropy-based attribute weights to deal with situations where the alternatives on attributes are expressed by IVIFSs and the attribute weights information is unknown.

Xiong Wei and Li Jinlong[33] proposed a group decision-making model for emergency decision making based on interval-valued intuitionistic fuzzy set. Through gathering the experts' evaluations in interval-valued intuitionistic fuzzy matric, they measure consistent estimate level of experts judgment and present a solution to get the expert weights, then obtain ranking of contingency plans through ideal point method based on Hamming distance which is a new method for solving the interval intuitionistic fuzzy problem of the experts, opinions, Finally, a case study on the fire disaster decision-making is conducted to illustrate the feasibility and effectiveness of the model.

Shyi-Ming Chen and Li-Wei Lee [34] used Karnik-Mendel algorithms to propose the interval-valued intuitionistic fuzzy weighted average operator. They also proposed a fuzzy ranking method for intuitionistic fuzzy values based on likelihood-based comparison relations between intervals. Using the two proposed concept they introduced a new method for multiattribute decision making.

Zhao Zhitao and Zhang Yingjun [35] developed a method that is based on the accuracy function to solve MADM problems with both ratings of alternatives on attributes and weights of attributes expressed with IVIFSs.

V. Lakshmana Gomathi Nayagam [36] et al. proposed a new method for ranking of interval-valued intuitionistic fuzzy sets and compared their new method with other methods. They use an illustrative example to verify the developed approach and to demonstrate its practicality and effectiveness.

Some other researcher like ZuBei Ying et al. [37] and Ting-Yu Chen et al. [38] also worked on multiple attribute group decision making based on interval-valued intuitionistic fuzzy sets.

In year 1212 only few researchers worked in this area and their worked is brief here:

Jian-qiang et al. [39] in their article analyze the limitations of existing score functions of intuitionistic fuzzy set. They introduced a new score function based on the prospect value function and used this prospect score function to develop an interval-valued intuitionistic fuzzy multi-criteria decision-making approach. This approach gives a matrix of score function values and a comprehensive evaluation value of each alternative. And the order of alternatives is listed by comparing the projection values of each alternative to the positive ideal solution.

Dejian Yu et al. [40] their study investigates the group decision making under interval-valued intuitionistic fuzzy environment in which the attributes and experts are in different priority level. They first propose some interval-valued intuitionistic fuzzy aggregation operators such as the interval-valued intuitionistic fuzzy prioritized weighted average (IVIFPWA) operator, the interval-valued intuitionistic fuzzy prioritized weighted geometric (IVIFPWG) operator. These proposed operators can capture the prioritization phenomenon among the aggregated arguments. Also introduce an approach to multi-criteria group decision making based on the proposed operators is given under interval-valued intuitionistic fuzzy environment.

IV. CONCLUSION

As we know that decision makers face many problems with incomplete and vague information in decision making problems since the characteristics of these problems often require this kind of information. So fuzzy approaches are suitable to use when the modelling of human knowledge is necessary and when human evaluations are needed. Out of several generalizations of fuzzy set theory for various objectives, the notions introduced by in defining intuitionistic fuzzy sets and interval-valued intuitionistic fuzzy sets (IVIFS) are interesting and very useful in modelling real life problems. An IVIFS set plays a vital role in decision-making, data analysis, artificial intelligence and socioeconomic system.

Considering this as an interesting area many researchers have worked in decision making problem based on Interval-valued intuitionistic fuzzy. In this paper we have discussed about all the major paper published in this area by different authors. We have also given the brief introduction of their approaches and methods introduced by the researchers in their paper.

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