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論 文 題 目	A Study on Evaluation Models for Multiple Attribute Decision Making with Incomplete Linguistic Information (不完全な言語的情報を基に多属性による意思決定モデルに関する研究)
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## 論文の内容の要旨

In practice, most of the multiple attribute decision making (MADM) problems involve both kinds of qualitative and quantitative attributes, which may be represented by a hierarchy. While quantitative attributes can be measured by means of numeric scales in the form of numbers, intervals or fuzzy numbers, qualitative attributes which are often associated with imprecise, vagueness and uncertain information perhaps can only be assessed by linguistic information. In such situations, how to represent and aggregate linguistic information essentially plays an important role in decision analysis. In the literature, one of reasonable ways is the use of “fuzzy linguistic approach which provides tools to model and represent qualitative attributes by means of linguistic values of linguistic variables” (Zadeh, 1975). The use of linguistic information implies the necessity of operating with the mechanism for “computing with words (CW)” (Zadeh, 1996) so as to fusion linguistic information and then provide an evaluation for decision making.

In this research, we first briefly recall some key concepts of CW. Then, through a further study on CW and fuzzy linguistic approach, we analyze the relationship between MADM with linguistic information and CW, and the mechanism that how fuzzy linguistic approach is used to deal with linguistic information in the decision making process. Further, according to three categories of linguistic computational models based on fuzzy linguistic approach in the literature, we review the main features of several classic linguistic computational models in detail, including “linguistic computational model based on membership functions”, “linguistic computational model based on ordinal scales”, “linguistic computational model based on 2-tuple representation” and “linguistic computational model based on proportional 2-tuple representation”. Meanwhile, the limitations and restrictions of these previous models

have been found during the review process, such as loss of information during the evaluation process, with too much requirements when applied to MADM problems, without considering uncertain subjective judgments represented by linguistic distributions over the linguistic term set, without taking into account incomplete linguistic information and so on.

Inspired by providing more efficient measures to represent and aggregate linguistic information, three evaluation models, i.e., proportional 3-tuple fuzzy linguistic representation model, proportional fuzzy linguistic distribution model, interval fuzzy linguistic distribution model, are developed in this research aiming at overcoming the main limitations and restrictions of previous models, and meanwhile, providing some new ways to deal with more general cases of linguistic assessments. Some related concepts, such as preference-preserving proportional 3-tuple transformation, which is used for the transformation and unification of linguistic assessments represented by proportional 3-tuple between two different linguistic term sets, expected utility in proportional or interval fuzzy linguistic distribution, which is employed for obtaining an ranking order among different alternatives provided to decision makers as a reference for their final decisions are proposed in this research. Further, some corresponding aggregation operators are developed for the three evaluation models respectively according to their own representation forms of linguistic information. Besides, three practical application examples taken from the literature as well as a simple illustration example are used respectively in order to compare the results with previous models, and also for the purpose of illuminating the features and capabilities of the proposed models.

After illustration by examples, it is shown that the proposed evaluation models in this research not only overcome the limitations and restrictions of previous models, but are also inherent with some special features, such as no loss of information during the evaluation process, ease operation in the complicated linguistic context, flexible operation space for evaluators under uncertainty, taking the ignoring information into account and so forth. These features of the three evaluation models can help decision makers to easily deal with MADM problems with incomplete linguistic information, largely improve the precision, reasonability and reliability of final results, and finally, provide a more comprehensive guidance for decision makers.

Finally, four interesting aspects for future work are explored, which can be as the directions for continuing this research in order to extend the applicability of these three evaluation models proposed in this research. Meanwhile, the contributions of this research to Knowledge Science are summarized.

**Keywords:** Computing with words, decision making, incomplete assessments, linguistic modeling, multiple attribute.

## 論文審査の結果の要旨

There are many decision situations in practice in which the decision information cannot be precisely and quantitatively assessed by means of numerical values but may be only assessed by qualitative judgments making use of linguistic terms, which are inherently vague and imprecise. Conducting decision analysis in such situations necessarily requires the use of an appropriate linguistic approach to represent and aggregate linguistic information. Particularly, in such a linguistic approach, linguistic terms and their associated semantics must be defined first for representation of linguistic information and then methods for aggregation of linguistic information will be developed accordingly. During the last decades, many linguistic decision models have been developed for solving decision problems with linguistic information. However, most of these previous models, either based on a fuzzy-computation based approach or a symbolic-computation based approach, have an unavoidable limitation of the loss of information caused by the process of linguistic approximation, whilst the other models may not be capable of handling incompleteness and uncertainty of linguistic information.

The research of this dissertation is therefore aimed at developing evaluation models for dealing with multiple attribute decision making problems under incomplete and uncertain linguistic information. The research problem is well described and motivated, and an adequate overview of relevant theoretical and practical background literature is provided in the dissertation. As for the contributions of this research, three evaluation models, namely *proportional 3-tuple fuzzy linguistic representation model*, *proportional fuzzy linguistic distribution model*, *interval fuzzy linguistic distribution model*, have been developed. These models not only can overcome the disadvantages of the linguistic decision models proposed previously but also provide new ways to deal with more general cases of linguistic assessments in decision analysis. In the meanwhile, different operators for aggregation of linguistic information have been also respectively developed within these evaluation models. Three practical application examples taken from the literature have been also used to demonstrate the applicability of the developed evaluation models; however, in the future work, more efforts should be paid to clarify their effectiveness.

The research work presented in this dissertation has resulted in three journal papers, two of which has been accepted for publication, and four refereed conference papers.

In summary, this dissertation fulfills the requirements of the PhD program and, after the final oral defense, all committee members approve awarding a doctoral degree to Mr. GUO Wentao.