

Review of the dissertation thesis

Reviewer:

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Thesis title:

Hybridized Integrated Methods in Fuzzy Multi-Criteria Decision Making (with Case Studies)

Author:

Ing. Eric Afful-Dadzie

Supervisor:

doc. Ing. Zuzana Komínková Oplatková, Ph.D.

Aim, scope and structure

The thesis forms Ph.D. dissertation in the field of engineering informatics, it present state of the art in uncertainty processing in automated multi-criteria decision making and then it presents authors original approach using fuzzy intuitionistic sets. Then it also thoroughly and rigorously describes case studies using original methods presented in previous chapters. The thesis is well-structured and the extent is appropriate.

Its main focus is given to fuzzy MCDM methods and their combinations related to the efficiency of hybridized algorithms. The interesting value of thesis also lies in the fact that the author experimented with various current methods and showed their advantages and flaws.

Originality, scientific value

The approach presented is novel, it utilizes several existing formalisms in hybrid MCDM algorithm and it is not only passively designed and presented but also implemented and its efficiency is well evaluated on case studies. The presented methods are already published in peer reviewed journals with

impact factor (5) and in Scopus journal (1), which itself proves high scientific value of the author's approach together with originality of the thesis content. The thesis has not only high scientific value, but its theoretical part could also serve as an educational tool describing various methods used in decision making process.

Formal quality

The thesis has also very good typesetting and clear and concise language. The figures and schemes are very illustrative and they are of high quality with only few exceptions (e.g. page 39). I have been highly appreciating the formal quality of the text especially non-TeX tool was probably used. The bibliography is appropriate and rich, containing both well-proved monographs and fresh content from respected journal and conferences.

Remarks and queries

I really appreciate that the author responded to almost all of my former remarks to his previous SDZ thesis. I think the thesis has solid theoretical background and my only remark regards usage of several different t-norms which could be interesting to see how it affects efficiency of the approach.

Did you think about the usage of fuzzy linguistic expressions – maybe it could interesting to use them in fuzzy decision making in conjunction with your method?

Did you use some special fuzzy logic tools for modeling of the fuzzy sets and inference?

Did you perform some experiments with huge data sets? If yes, could you please present time efficiency results of your method?

How your methods compare with other approaches (e.g. some “connectionistic” ones)?

Final evaluation and recommendations

The thesis and its contents are of the high standards required for a Ph.D. candidate. **I recommend it for presentation and for acceptance as the Ph.D. thesis in partial fulfillment of the requirements Ph.D. study in the field of Engineering Informatics. I also highly recommend with pleasure to award Ing. Eric Afful-Dadzie the Ph.D. degree in the mentioned field of study.**

Ostrava, 30.12.2015.



Doc. RNDr. PaedDr. Hashim Habiballa, PhD., Ph.D.

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Doctoral thesis review

The doctoral thesis named „**Hybridized Integrated Methods in Fuzzy Multi-Criteria Decision Making**“, submitted by **Eric Afful-Dadzie, Msc.**, is a comprehensive summary of authors work in the challenging field of multi-criteria decision making (MCDM). On more than 100 pages, the author introduces the conducted research, its premises and theoretical background, and provides a sound motivation for the main objective of the study, a novel hybrid method for MCDM. The main objective of the work is the development and evaluation of new hybrid MCDM model utilizing elements of fuzzy set theory (in particular intuitionistic fuzzy TOPSIS method) and conjoint analysis. The latter approach is used to model the preferences of a large group of non-expert decision makers while the former is employed to rank competing alternatives on the basis of expert knowledge. This original 2-tier strategy, described in the thesis in detail and illustrated on several examples, is the major contribution of this work.

The text of the thesis is divided into several parts. The first part provides an introduction and a brief state of the art of MCDM. In the second (theoretical) part, the author presents theoretical foundations of MCDM and fuzzy set theory. Additionally, chapter 6 provides a broad review of hybrid (fuzzy) MCDM. The author also provides a bibliometric evidence for an intuitive observation that hybrid methods are becoming increasingly popular in the MCDM area. The proposed 2-tier model is detailed in chapter 8 and illustrated on three numerical examples in chapter 9. The suitability of the solutions obtained by the proposed method is validated by the means of sensitivity analysis. Finally, the work is summarized and conclusions are drawn in the last part of the text.

Overall, the quality of the text is good and satisfies the requirements for a doctoral thesis. The described research is clearly well developed and mature. It has been already presented on a number of international meetings and in relevant journals. The methodology and writing (language) of the thesis is on a good level. It is self-contained and well understandable. The results are clearly described and soundly interpreted. No major technical problems or mistakes are present. However, several minor problems do occur in the text. First of all, the organization of the thesis is a bit unclear: the author claims the work is organized into two parts (p. 110) but it is not clear where one part ends and the other starts. The reader can identify unnamed introductory part, then ‘theoretical part’, ‘investigative part’, ‘the concept of ‘weights’ in MCDM’ part, ‘proposed hybrid/integrated method’ part, ‘numerical examples’ part, and ‘sensitivity analysis’ part. That can lead to confusion and does not contribute to good orientation in the text. The typesetting and language of the thesis are generally good but inconsistent in parts. For example, in ch. 5, not all equations are numbered (e.g. on p. 39, 40, 41) and figure number and caption is missing on p. 41. The author does a good job introducing the fuzzy set theory to the reader in a general way. However, he is sometimes simplifying the theory too much. E. g. on p. 40, fuzzy set operations are defined. Here, the author does not mention the notion of triangular norms and co-norms and simply present a single set of fuzzy set operators (the traditional ones). These minor issues are, however, balanced by the broad extent of the work.

Despite the comments pointed out in this review, it can be stated that the submitted thesis is of a good scientific quality and meets all usual requirements for a doctoral thesis in the field of Computer Science. The author has clearly demonstrated deep domain knowledge, good practical skills, motivation and creativity, and in general ability to conduct original research in his field of expertise. His publication portfolio is appropriate and corresponds to the academic degree of doctor of philosophy. In conclusion, **I do recommend the thesis for defense.**




doc. Ing. Pavel Krömer, Ph.D.
Ostrava, 30. 12. 2015

Review of the Ph.D. thesis

„Hybridized Integrated Methods in Fuzzy Multi-Criteria Decision Making (With Case Studies)“

by Eric Afful-Dadzie, MSc.

The main aim of the Ph.D. thesis was to propose methods for multi-criteria decision making (MCDM) algorithms in situation where data are uncertain and traditional approaches based, e.g., on aggregation of weighted, normalised and unified criteria (all maximal, or all minimal) cannot be used.

Investigated topics and the aims of the thesis (mainly to design a new hybrid MCDM method, composed of Conjoint Analysis and Intuitionistic Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and its application in real-life case studies) are non-trivial, and there is no clear procedure for representing alternatives, comparing and choosing the best one. It can be stated that the **topic meets requirements for the doctoral dissertation** and is also important for the development of engineering informatics.

The Ph.D. thesis is logically structured into chapters and subchapters. It has a theoretical and a practical part. The theoretical part covering the first five chapters is very comprehensive and provides a wide survey of important results in the study area, their comparison and applicability in specific cases.

In his hybrid approach, the author among several possibilities of generalisations of fuzzy sets, such as rough sets, interval-valued fuzzy sets, hesitant fuzzy sets, soft sets, and type-2 fuzzy sets, proposes to use intuitionistic fuzzy sets by Atanassov, which define not only a membership functions, but also non-membership functions and hesitancy degrees.

The fundamental part of the Ph.D. thesis can be found in chapters 6 and 7. In Chapter 6, the author discusses hybrid MCDM in comparison with single-method solution, and in Chapter 7 he proposes his integrated Conjoint Analysis - Intuitionistic Fuzzy TOPSIS method. Here, in a precise mathematical form, all necessary expressions for MCDM, e.g., weights of criteria, are explained.

Practical results of 2-tier decision model in three numerical examples are presented in Chapter 9. They are focused on: (1) selection of a new manager in a microfinance company where shareholder preference decisions are incorporated into board management decisions, (2) an ideal company distributor selection where customer preferences are merged into management decisions to arrive at a composite decision, and (3) selection of recruitment process outsourcing vendors where HR managers' preferences and trade-offs are incorporated into management decision.

Finally, in Chapter 10 the work tests the reliability of decisions arrived at in each of the studies by designing novel sensitivity analysis models to determine the congruent effect on the decisions.

The language of the Ph.D. thesis and its typographical standard are very good, the text contains almost no misprints. I have only found the following ones:

- Page 5: Abstract – comma should be placed after “Finally”.

- P. 6 : Abstract – comma should not be obtained in „Niměně, v mnoha“ (it should be in English connection after „Nevertheless“ or “However”).
- P. 20: „an extensive mathematical foundations“ – „an“ cannot be used with plural.
- “5.1.1 Properties on Fuzzy Sets” – probably “of” instead of “on”.
- P. 39: “decreases” – decreases; p. 44: “focusses” – focuses; p. 64 “from a competing sets of alternatives” – a competing set; p. 97 “whiles” – while.
- Equations (1), (4) and (5) use different size of basic symbols.
- Typography in (7): j and n should be in italics, p. 42: “ $y=f(x)$ ” ... $y=f(x)$; similarly i, j, m, n under Eq. (40) on page 67, etc.
- New notions could be written in italics, e.g. *intuitionistic fuzzy index* on page 45.
- P. 42: “In figure 6” - In Figure 6

Formal comments:

- P. 38: Eq. (9) and (10) – bad order of delimiters.
- Pp. 40, 41: Fuzzy union and fuzzy intersection are generally defined by a t -norm (in the case of intersection) and an s -norm (union), which must satisfy boundary condition, monotonicity, commutativity and associativity. Examples of t -norm are standard intersection (mentioned in thesis), algebraic product, bounded difference, drastic intersection; standard union (in thesis), algebraic sum, bounded sum and drastic union are s -norms.

Questions:

1. On page 43, you define basic operators on fuzzy numbers $+$, $-$, \times , \div . However, how to define relations $<$, \leq , $>$, \geq , which are necessary for comparisons of alternatives' parameters in dominance method-based decision making?
2. Can you explain the way of computing precise aggregated weights from linguistic terms (Very High, High, Medium, Low, Very Low) of decision-makers in Table 5 on page 59? Are these ratings uniquely defined by triangular or trapezoidal fuzzy numbers and these numbers are used, or correspond to values in Table 11 on page 80?
3. You propose a method which combines opinions of two groups of decision-makers, large group for evaluation of criteria weights and smaller one for selecting a best alternative from a competing set of alternatives. Why two groups, large and small? Are these groups (or even must be) disjoint, or may share their members?
4. How to determine the order of importance of decision makers? (Page 103).
5. Are examples of applications working with simulation data, or are these data taken from real practice?

Conclusion:

In my opinion, Eric Afful-Dadzie has proved to be capable of solving difficult research problems. The results in this thesis are new, interesting and non-trivial, the author successfully met submitted aims. He has proposed unique 2-tier hybrid method for fuzzy MCDM which integrates conjoint analysis and intuitionistic fuzzy technique for order

preference by similarity to ideal solution, and verified it on three different numerical examples.

The Ph.D. thesis satisfies conditions of the Czech Act 111/1998 and its Section 47, parts of the thesis have been published in 15 papers (6 in impacted journals and 9 in international conferences), and therefore

I recommend

Eric Afful-Dadzie's Ph.D. thesis to be accepted by the Committee to be presented and defended in the Engineering Informatics study branch.

Brno, 30th December 2015

A handwritten signature in blue ink, reading "Šeda".

Prof. RNDr. Ing. Miloš Šeda, Ph.D.
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