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The Evaluation of Computer Algebra Systems Using Fuzzy Multi-Criteria Decision-Making Models:
Fuzzy AHP and Fuzzy TOPSIS

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ABSTRACT

The main purpose of this study is to present a systematic methodology based on fuzzy Multi-Criteria Decision-Making (FMCDM) models to help users evaluate computer algebra systems (CAS). CAS is a software package for the manipulation of mathematical formulas. The suggested methodology is user-centred which involves users' subjective evaluation judgments. User judgments are represented by means of fuzzy linguistic modelling techniques. An evaluation criteria framework based on the concept of the usefulness of CAS is developed. Next, two FMCDM models – fuzzy Analytical Hierarchy Process (FAHP) and fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) are proposed for the evaluation procedure. The FAHP is applied to determine the relative importance weights of qualitative evaluation criteria; the FTOPSIS is applied to rank the CAS alternatives. The illustrated case study demonstrates the applicability and effectiveness of the proposed methodology.

KEYWORDS

AHP, Computer Algebra Systems, Decision Making, Fuzzy Logic, Linguistic Evaluation, Problem-Solving Capability, TOPSIS, Usability

INTRODUCTION

Over the last years, the number of Computer Algebra Systems (CAS) on the market have been increasing at an explosive rate: Derive Maple, Mathematica, Maxima, MuPAD, WIRIS, and etc. A CAS is computer-based educational software to manipulate and simplify algebraic expressions (Lauri, Marina, & Eno, 2011; Feride & Nilcan, 2012). Such a system might be used for symbolic integration or differentiation, substitution of one expression into another, simplification of an expression. The primary goal of CAS is to automate tedious algebraic manipulation tasks. The specific uses and capabilities of these systems vary greatly from one system to another (Kostas, 2008). Users of CAS are considered as primary stakeholders. Their opinions are central for successful design. In such a market environment, evaluation (or selection) of a CAS becomes an important problem to a user who must choose the most appropriate CAS that meets s/he preferences (or requirements). Since

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the final decision needs to satisfy, simultaneously, several users with heterogeneous characteristics, the evaluation of a CAS can be considered as a complex Multi Criteria Decision Making (MCDM) problem. Such a problem comprises a finite set of alternatives, amongst which the decision makers must select according to the weights of a finite set of criteria (or attributes). The MCDM approach has previously been applied to the process of software evaluation in (Tanja & Borka, 2007), where the authors have demonstrated the applicability and flexibility of the approach to the evaluation of learning management systems. Another research is the work (Daniel & Yi- Shun Wang, 2008) which employs the MCDM approach to the evaluation of web-based e-learning systems based on learner satisfaction. However, during the research process, the authors have not encountered a research on the evaluation of CAS based on a model of MCDM, although there is a study which compares the CAS- based teaching method of mathematics with the traditional teaching method of mathematics in terms of learning outcomes of learners (Vlachos & Kehagias, 2000; Ahmad Fauzi Mohd Ayub, 2010). Recently, the authors have begun a research to attempt to employ fuzzy Analytical Hierarchy Process (FAHP) method to the evaluation process of CAS (Ilham & Feride, 2013). The purpose of this paper is to develop ideas presented by (Ilham & Feride, 2013). Particularly, both criteria set and MCDM model are expanded. The concept of the usefulness is a starting point of the evaluation procedure to indicated systems, how well a given system supports the satisfaction and needs of users. It is called the user centered evaluation framework which incorporates users' evaluation judgments. Users' judgments are intrinsically imprecise, uncertain, imperfect, ambiguous, and vague information. However, the MCDM methods mentioned above are not able to make an adequate decision under uncertain information. It has been presented by (Bellman & Zadeh, 1970; Enrique, Eduardo & Jose, 2007) that the decision analysis process with uncertain information can adequately be handled by means of fuzzy linguistic modeling techniques. The concept of the usefulness of a computer-based system can further be analyzed within the usability and utility concepts (Nielsen, 1993). The usability is based on the use of a software, i.e. interface offered by a software, and the utility is based on the tasks that can be done by a software, i.e. content offered by a software (https://msdn.microsoft.com/en-us/library/ms997577.aspx).

The main purpose of this study is to present a systematic methodology based on a fuzzy MCDM (FMCDM) model to help users evaluate CAS. First, the evaluation criteria framework based on the usefulness of CAS is developed. Second, FAHP method is complimented by other MCDM method - fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS) - for the evaluation procedure of CAS. The FAHP is applied to determine the relative importance weights of qualitative evaluation criteria; the FTOPSIS is applied to rank the CASs alternatives. The illustrated case study demonstrates the applicability and effectiveness of the proposed methodology.

The paper is organized as follows. Section 2 presents theoretical basics: i) modeling users' preferences using linguistic techniques of fuzzy logic, and ii) basic operations with fuzzy numbers. A systematic evaluation methodology based on two FMCDM methods - FAHP and FTOPSIS - is presented in Section 3. Section 4 considers a case study of applying the proposed methodology by constructing a tree type hierarchal criteria structure and by applying FAHP and FTOPSIS methods. Section 5 presents the evaluation results of the case study. Section 6 concludes the suggested methodology and discusses future of the research in the field.

THEORETICAL BASICS

Linguistic Modeling of Preferences

It is much more convenient for users, experts, and decision makers to express their preferences (or evaluation judgments) in a language that is close to natural language. Such subjective preferences are perception-based and qualitative nature. They are inherently vague, incomplete and uncertain knowledge. Linguistic techniques of fuzzy logic provide a framework to deal with this kind of

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