A Recommendation Framework Based on the Analytic Network Process and its Application in the Semantic Technology Domain

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1 Introduction

When users face a certain problem needing a product, service, or action to solve it, selecting the best alternative among them can be a difficult task due to the uncertainty of their quality. This is especially the case in the domains where users do not have an expertise, like for example in Software Engineering.

Multiple criteria decision making (MCDM) methods are methods that help making better decisions when facing the complex problem of selecting the best solution among a group of alternatives that can be compared according to different conflicting criteria. In MCDM problems, alternatives represent concrete products, services or actions that will help in achieving a goal, while criteria represent the characteristics of these alternatives that are important for making a decision.

Various MCDM methods have been developed to this date (e.g., PROMETHEE [1], Analytic Hierarchy Process (AHP) [2], Analytic Network Process (ANP) [3], and others). Although MCDM methods are widely accepted and used in many different fields for recommendation problems, different MCDM methods are suitable for different kind of problems, and no method is considered to be the best to be applied in every decision making problem [4].

Quality models provide a common framework for quality specification and evaluation by specifying a consistent terminology for quality and by providing guidance for its measurement, and they have been successfully used to date with MCDM methods in recommendation problems. Some MCDM methods (e.g., the AHP and ANP) require the recommendation problem to be formalized into a model, which consists of the alternatives and criteria, and is regarded as one of the main advantages of such methods. In the Software Engineering field, and in the case of the AHP which requires a hierarchical structured model, hierarchical

software quality models (e.g., ISO 9126 [5] or SQuaRE [6]) are very convenient, and different authors have used software quality models based on the ISO 9126 together with the AHP.

Semantic technologies provide new ways to express in machine-processable formats knowledge and data that can be exploited by software agents, and we have seen an exponential growth of these technologies in recent years. Different types of semantic technologies exist, which can be used for different tasks, and which fulfill different requirements. For example, ontology editors are used for implementing ontologies, while ontology matching tools are used for mapping concepts of one ontology to concepts of other.

In the field of the Semantic Web, developers often have to use various tools that belong to different types of semantic technologies, and there exist a large number of tools for every type of technology already. Selecting the right tool or set of tools can help developers to perform their tasks more efficiently, and using the high quality tools will improve the quality of the products. Therefore, the selection of appropriate tools that best suit developers' needs is of crucial importance in the development of the emerging area of the Semantic Web.

The main goal of this thesis is to develop a theoretical recommendation framework based on a MCDM approach, and to apply it in the domain of semantic technologies. One characteristic of semantic technologies is that the quality criteria among them are mutually dependent. When it comes to the MCDM field, the ANP is a method that has been specifically designed to take into account the dependencies between the criteria in the decision process. Therefore, the ANP has been taken as a basis for the recommendation framework to be developed.

We have performed an extensive analysis of the previously mentioned topics in order to analyze the state of the art and to identify the insufficiencies. We found that the following insufficiencies are present:

- *Lack of an approach in the Analytic Network Process that will enable automatic comparisons of alternatives based on real evaluation results.*
  In MCDM recommendation problems, comparisons between alternatives are usually performed by experts in the field, or by users themselves. In some cases, however, it is difficult for ordinary users to make comparisons because of their lack of expertise. Furthermore, although expert opinion is highly valuable in many cases, it can be subjective and expensive, and not every expert may have expertise in every alternative. Also, those cases when new alternatives are added require additional expert comparisons.
  In those cases where the evaluation of alternatives has already been performed and evaluation results are available, it can be useful to ground the comparisons of alternatives in such evaluation results.
- *Lack of an approach in the Analytic Network Process that will enable recommendations based on user quality requirements.*
  The model of the problem is usually developed by experts, and it includes every criteria that are relevant for the recommendation of the best alternatives. Sometimes, however, not every criteria are relevant to the problem that a user faces, for which he or she can have specific quality requirements.

In these cases, constructing models and comparing alternatives separately for each user would be a resource consuming task.

– *Lack of an open source software support for the ANP method, including the support for the evaluation results and user quality requirements.*
– *Lack of an application that will provide users with semantic technology recommendations based on their needs and real evaluation results.*
As it is often the case that when solving certain problems users have to use various semantic technologies that belong to different types, selecting the right technologies for solving a problem can be a difficult task, especially for less experienced users.

2 Hypotheses

In this thesis, we state the following hypotheses:

– **H1**: The algorithm for the automatic comparison of alternatives is able to produce a set of outputs that, for a given criteria and a set of evaluation results, defines the difference among the alternatives with a degree equivalent to a difference in the evaluation results. In order to accept or reject this hypothesis, we plan to test the algorithm on random evaluation datasets with various statistical distributions and observe the produced outputs.
– **H2**: The algorithm for the automatic construction of the ANP network from user quality requirements can produce recommendations that are closer to user's needs in terms of the number of satisfying requirements. In order to accept or reject this hypothesis, we plan to compare the recommendations obtained with and without the use of the algorithm.
– **H3**: The quality model is independent of the MCDM method that is planned to be used for the recommendations. As in our case we use the ANP, in order to accept or reject this hypothesis we plan to fin other examples where quality models with the same structure are used with different MCDM methods.
– **H4**: Instantiation of the proposed ANP recommendation framework in the domain of semantic technologies can produce correct recommendations. In order to accept or reject this hypothesis, we plan to compare the recommendations obtained with the proposed recommendation framework with a previously defined benchmark/golden standard, which can be extracted from the SEALS European project.

3 Objectives

This thesis aims to provide solutions to the insufficiencies of the State of the Art mentioned in the introduction. In particular, as the main contributions it will provide:

1. A generic recommendation framework built on top of the ANP, which will be able to ground the recommendations in evaluation results and take into account users' needs. The framework is shown on Figure 1.
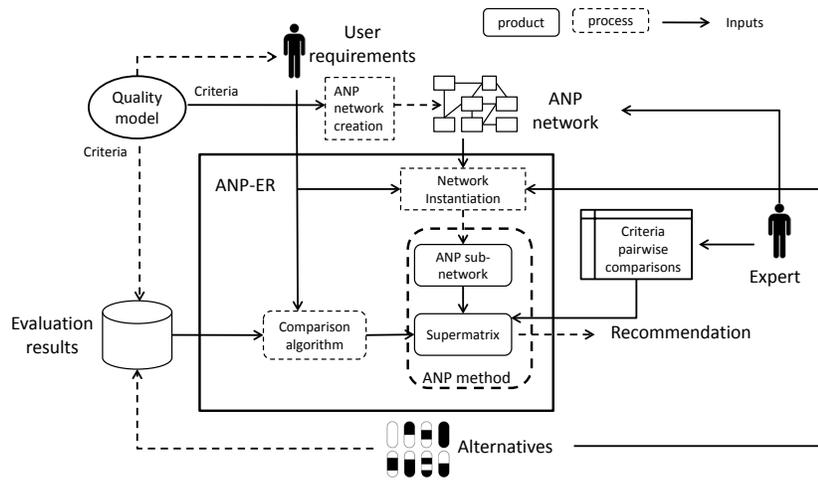
Fig. 1: ANP-based recommendation framework to be developed in the thesis.

2. A software support for the recommendation framework in terms of a Java API and a generic web application for the recommendations.
3. An instantiation of the ANP recommendation framework based on the comparison algorithm in the domain of semantic technologies through a web application for the recommendation of semantic technologies according to users' needs. This web application will exploit the results of semantic technology evaluations produced in the SEALS European project [7].

To achieve the previously specified goals, we will perform the following tasks:

– Develop a domain independent ANP-based comparison algorithm which exploits real evaluation results for automatic comparison of the alternatives based on user requirements. Instead of relying on expert opinions, the comparisons will be based on the results of the process of evaluation of the alternatives. Furthermore, the comparisons in the algorithm will be based on user quality requirements, i.e., the comparison of the two alternatives will depend on a threshold (a minimum quality that a user wants to be satisfied) specified by the user.
– Develop an algorithm for the automatic construction of the ANP network from the user quality requirements. Such a network can be constructed from a broader ANP network that is defined for a particular domain and, because it is grounded in user quality requirements, will be specific for the problem that a particular user faces.
– Develop a software support for the ANP method based on the comparison algorithm, which includes generic programming interface, and a generic Web application for the recommendations.
– Develop a quality model for semantic technologies, which will provide a basis for the specification of user quality requirements.

– Construct an ANP network for the domain of semantic technologies, starting from the semantic technology quality model.
– Perform the pairwise comparisons for the criteria in the ANP network for the semantic technologies, which is a requirement for the ANP method. Alternatives will be compared automatically using the comparison algorithm.
– Implement a web application for the recommendation of semantic technologies.
– Perform an evaluation of the main contributions of this thesis.

4 Methodology And Work Plan

In order to achieve the previously defined objectives, several tasks have to be performed:

– The comprehensive analysis of the state of the art in the field of software quality models will be performed in order to determine which software quality model will be the most suitable to adopt and extend in order to include the particularities of the semantic technology domain. Also, the purpose of this task is to analyze the existing methods for extending the software quality models.
– The analysis of the state of the art in the evaluations of semantic technologies will be performed in order to determine which quality characteristics are the most evaluated, and which quality measures are used to evaluate the quality. One important aspect of this task will be on the process of evaluation and methods for the calculation of quality measures.
– Development of the quality model for the semantic technologies. The most suitable method for extending quality models will be used and an existing software quality model will be extended. In the case that none of the existing methods can be used, a new method for extending software quality models will be developed.
– The comprehensive analysis of the state of the art in the field of multiple criteria decision making will be performed. The results of the state of the art analysis will help us to find the most suitable MCDM method that can be used for the recommendation of semantic technologies, and to identify existing gaps. This task has already been performed, and the ANP is adopted in this thesis.
– The adopted multiple criteria decision making method will then be extended to fit the requirements of the semantic technology domain, and a theoretical recommendation framework will be defined. The theoretical framework will be based on the user quality requirements and real evaluation results.
– The theoretical framework will be implemented into a semantic technology recommendation system, which will be realized in the form of a Web application.
– The proposed semantic technology quality model and the recommendation framework will be evaluated in order to verify the results of the performed work.

5 Relevance

This thesis will provide a valuable extension of the ANP method upon which a research community can rely on when facing specific problems of recommendations in which the key focus is on evaluation of quality of alternatives, and providing to wider range of users a possibility to specify their requirements.

Selecting an appropriate software product is not an easy task and it is regarded as a very important problem. For example, it is a well known fact that selection of ERP systems is highly sophisticated process [8] which requires deep analysis of available software, and where wrong decision can lead not just to significant financial loss and failed investment, but can also have negative influence on companys business. The recommendation framework that is going to be developed in this thesis will be a useful tool for industry practitioners that will help them to provide recommendations in any domain, and that will help users of the framework to find the best solutions for their problems. Furthermore, the web application for the recommendation of semantic technologies will help semantic web developers to choose the best tools for their tasks.

Acknowledgments

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