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Software Requirements Selection using AHP

Nadiya Afzal[1], Mohd. Sadim[2]
[1] M.Tech. Scholar, Department of Computer Science and Engineering, School of Engineering and Technology, Al-Falah University, Dhauj, Faridabad, Haryana, India (Corresponding author)
[2] Department of Computer Science and Engineering
School of Engineering and Technology, Al-Falah University, Dhauj, Faridabad, Haryana, India

Abstract: Analytic hierarchy process (AHP) is a "multicriteria decision making"(MCDM) process whose objective is to select the alternatives from the set of alternatives. AHP has been applied in different areas of science and engineering for the "selection and prioritization"of the alternatives like "supplier selection problem", "facility location selection problem", "software requirements selection problem" (SRSP), etc. The objective of this paper is to apply the AHP for the selection of the software requirements. Therefore,in this paper, we compute the ranking values of the "software requirements of Institute Examination System" (IES) so that it can be decided which set of requirements would be implemented during different releases of the software requirements. In our work, we consider the ten functional requirements of IES and evaluate it on the basis of cost.
Keywords: Analytic hierarchy process, AHP, multicriteria decision making, MCDM, software requirements selection, pairwise comparison matrices.

1. Introduction

Analytic Hierarchy Process (AHP) is a "multi-criteria decision making" method which was developed by "Thomas. T. Saaty" in 1972 for "pair-wise comparisons among the alternatives". AHP has been applied in "software testing", "business applications", "software requirements selection" [1, 2, 3], etc. In AHP, the "hierarchical structure"(HS) is designed after the "refinement and decomposition of the goals into sub-goals". Fig. 1 exhibits the HS of "software requirements selection and prioritization" (SRSP) problem.

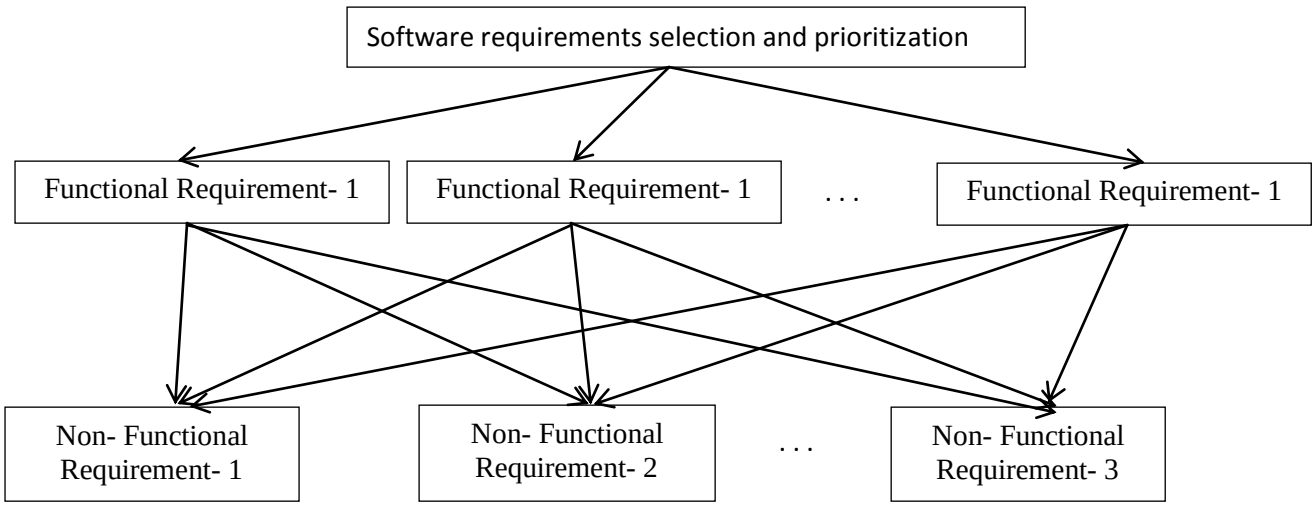

Fig. 1: HS of SRSP problem

Fig. 1 exhibits the hierarchical structure of SRSP problem in which functional requirements (FRs) are selected on the basis of non-functional requirements (NFRs). In AHP, the entire FRs would be evaluated on the basis of all the NFRs; and during evaluation a pairwise comparison matrix (PCM) would be used to specify the preferences of the decision makers. In AHP, PCM are used to specify the preferences of the stakeholders. Different algorithms have been developed to compute the priority values of the PCM. In our work, we will apply the algorithm A to compute the ranking values of the PCM. For the evaluation of the alternatives on the basis of different criteria's, Saaty [1, 3] proposed a scale to specify the preferences of one alternative over another. One common scale, adopted by the Saaty is shown in Table 1.

Table 1: Saaty Rating Scale

Intensity of importance	Definition	Explanation
1	"Equal Importance"	"Two factors contribute equally to the objective"
3	"Somewhat more important"	"Experience and judgment slightly favour one over the other"
5	"Much more important"	"Experience and judgment strongly favour one over the other"
7	"Very much more important"	"Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice"
9	"Absolutely more important"	"The evidence favouring one over the other is of the highest possibly validity"
2,4,6,8	"Intermediate values"	"When compromise is needed"

Algorithm A:

Step 1: Add the column of the PCM and store the result in AHP_Column_{PCM}

Step 2: Normalized the AHP_Column_{PCM} and store the results in $AHP\_Normalized\_Column_{PCM}$

Step 3: Take the average of the row from $AHP\_Normalized\_Column_{PCM}$. As a result the we will get the priorities of the alternatives and store the results in $P_1, P_2, \ldots P_N$. Where N is the total number of requirements

Step 4: Multiply the first column with P_1, second column with P_2, and N^{th} column with P_N; and store the results in AHP_Weighted_Column

Step 5: Calculate the sum of each row from Weighted_Column; and store the results in AHP_Weighted_Sum (WS) as $WS_1, WS_2, \ldots WS_N$

Step 6: Divide the elements of the $WS_1, WS_2, \ldots WS_N$ by the $P_1, P_2, \ldots P_N$ as:

Lambda-1: WS_1/ P_1, Lambda-2: WS_2/ P_2 ... Lambda-N: WS_N/ P_N

Step 7: Compute the average of the Lambda-1, Lambda-2 and Lambda-N; and store the results in Lambda-Max (λ_{max})

Step 8: Calculate the consistency index (CI) as:

CI = (λ_{max}-N)/ (N-1)

Step 9: Now we calculate the CR, defined as:

CR = CI/RI

Here, RI is the consistency index of a randomly generated PCM. The value of the RI for 3, 4, 5, 6 requirements would be 0.58, 0.9, 1.12, and 1.24, respectively.

2. Applications of AHP in RE, ST, and WDI

In this section, we present the applications of AHP in the area of "requirements engineering" (RE), software testing (ST), and web development and internet (WDI). We have selected these areas because these fields have good scope of AHP for the selection and prioritization of the alternatives.

Herrmann and Daneva [4] present the results of the systematic literature review requirements prioritization in which cost and benefit are used as the criteria. Requirements based cost estimation includes the "sizing the FR and NFR" and what would be the cost of implementing the FR and NFR. In their analysis, author'spoints out that FR are sized by using the functional size measurement which is based on function point analysis (FPA). During their systematic literature review, authors have identified 15 requirements prioritization methods, i.e., "numerical assignment, cost benefit analysis, cumulative voting/$ 100 test, priority groups, top 10 requirements, multi-attribute utility theory, weighting method, planning game, AHP, hierarchy AHP, outranking, minimal spanning tree matrix, bubble sort, binary search tree, hierarchical cumulative voting".

Dabbagh et al. [5] performed "two control experiments with the aim of evaluating the current requirements prioritization approaches". In the first experiment they have compared the integrated prioritization methods with other methods called AHP; and in the second experiment, authors compare the integrated prioritization methods with hybrid assessment method. Karlsson et al. [6]evaluated the six different methods which are used for the "prioritization of the software requirements". As a result they identify that the "AHP is the most promising method for the prioritization of the software requirements".

In recent studies, we have identified the application of AHP, in which authors have developed new goal oriented methods for prioritization of the software requirements. For example, Sadiq et al. [7] developed a method with the help of the AHP for the prioritization of the "software requirements in goal oriented requirements elicitation method"; and they call it AHP_GORE_PSR. In another study, Sadiq and Afrin [8] developed a method to "extend the AHP_GORE_PSR by generating the different patterns of pairwise comparison matrices". As we know that in AHP, we have different criteria's; and these criteria may overlap with each other during decision making process. Abdulla [9] applies the "evidential reasoning algorithm" for MCDM to perform the aggregation of the assessment of multiple experts, one each for every day. Authors proposed two different variations of evidential reasoning; and

focus on the overlapping areas of the expertise among the subsystems. Therefore, in our work we mainly focus on AHP.

Test case prioritization is a key challenge in the area of software testing. In real life application there are different test cases that need to be tested during the first release of the software. During test case prioritization different criteria's are used. Therefore, software test cases selection is a MCDM problem. Therefore, different MCDM algorithms have been used to prioritize the test cases. For example, Tahavili et al. [10] apply the fuzzy based AHP to prioritize the test cases. In another study by Juan et al. [11], software testing evaluation model is performed using AHP to analyze the weight of influence of individual function unit of software. Klindeeand Prompoon [12] proposed a test case prioritization for software regression testing using AHP. Sadiq and Sultana [13] proposed a method for the "software testing techniques using AHP" by considering the following criteria: "New or modified system (NMS), Number of independent paths (NIP), Number of test cases (NTC), and Cost of requirements (CoR)". In another research group, Sadiq and Firoze [14] apply the "AHP for the selection of software testing automation framework".

In the area of web development, AHP has been used for evaluating course web site quality. For example, Lin [15] applies the "fuzzy AHP for evaluating course web site quality". In their work, authors conduct the review of the literature on course website quality and as a result they generate the 16 sub-criteria along with four criteria to measure course website quality. After that fuzzy AHP was applied to determine the relative weight to determine the high and low online learning experience groups. Lee and Kozar [16] investigate the "effect of web site quality on e-business success using AHP".

3. Example

In this section, we explain how AHP is used to prioritise the software requirements. Therefore, for the prioritization of the software requirements, we consider the set of software requirements of Institute Examination System from the work of [17].

- "fr1: students fee receipt
- fr2: recording of student's marks, i.e., sessional test marks and end semester marks;
- fr3: check semester result;
- fr4: generation of seating plan;
- fr5: online examination;
- fr6: completion of examination form; and after complete submission of the examination form,
- IES will display the following information, i.e., roll number of the student, name of the students, name of examination, code of different papers, name of the subject(s), backlogs papers information, if any, detail of examination fee(s)
- fr7: upload all the information related to semester examination;
- fr8: generation of hall ticket;
- fr9: examination form approved by Controller of Examination Department;
- fr10: payment of online examination fee"

Here, we assume that only one decision maker (DM) is participating in the decision making process. Therefore, the pairwise comparison matrix by DM-1 is given in Table 1. In Table-1, FR1 is compared with FR2 on the basis of cost then on the basis of the cost, DM-1, find out

that FR2 is slightly more costly than FR1, therefore, FR1 (row) and FR2 (column) contains ½ and on the other hand side, FR2 (row) and FR1 (column) contains 2. In the similar way, entire FRsare evaluated by the DM-1 in order to fill all the entries of Table 1.

Table 1: PCM by DM-1

FR	FR1	FR2	FR3	FR4	FR5	FR6	FR7	FR8	FR9	FR10
FR1	1	1/2	2	3	5	5	5	3	7	5
FR2	2	1	6	7	5	7	5	9	7	3
FR3	1/2	1/6	1	9	5	7	5	9	7	3
FR4	1/3	1/7	1/9	1	7	3	8	7	2	9
FR5	1/5	1/5	1/5	1/7	1	7	9	6	5	1/8
FR6	1/5	1/7	1/7	1/3	1/7	1	3	9	7	1/5
FR7	1/5	1/5	1/5	1/8	1/9	1/3	1	5	9	1/5
FR8	1/3	1/9	1/9	1/7	1/6	1/9	1/5	1	3	1/6
FR9	1/7	1/7	1/7	1/2	1/5	1/7	1/9	1/3	1	5
FR10	1/5	1/3	1/3	1/9	8	5	5	6	1/5	1

Now we apply algorithm A to compute the ranking values of the FRs, PCMs are given in Table 1. As a result we identify the following ranking values of different FRs:

FR1= 0.151
FR2= 0.254
FR3=0.157
FR4=0.118
FR5=0.080
FR6= 0.054
FR7=0.045
FR8=0.022
FR9=0.034
FR10= 0.085

The value of consistency index (CI) = 0.7878529 and the value of CI/RI = 0.7878529/1.49 = 0.5287. The value of the consistency check is 52%.

4. Conclusions and Future Work

In this paper, we present an application of AHP in the area of software engineering. We consider the set of ten functional requirements of Institute Examination System and evaluate it on the basis of cost by only one decision maker. After applying the AHP, we identify that FR2 is more important than the other requirements. The ranking values obtained by the AHP are used during the software development process. During the software development process, we cannot implement all the requirements due to cost, time, and other constraints. Therefore, in such situations, the ranking values play an important role to decide which requirements to

implement during different releases of the software. In future, we shall try to apply the TOPSIS for the selection of software requirements [18].

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