

## Design and Development of Decision Making System Using Fuzzy Analytic Hierarchy Process

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**Abstract:** This article aims to develop a fuzzy Multicriteria Decision Making (MCDM) tool that equips with Analytic Hierarchy Process (AHP) framework to help users in semi-structured and unstructured decision making tasks. The tool provides portability and adaptability features by deploying the software on web platform. In addition, this system provides an integrated domain reference channel via a database connection to assist the user obtains relevant information regarding the problem domain before constructing the AHP hierarchy attributes. Our decision making tool combines the characteristics of real time information retrieval through Internet and MCDM problem analytical processing logic.

**Key words:** Multicriteria decision making, analytic hierarchy process (AHP), fuzzy set theory

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### INTRODUCTION

Decision making analysis aims to realize conflicts that occur due to various different opinions, fluctuating environment conditions, subjective assessments, etc. In real world, decision often been made under various alternatives with their associated criteria. Improper final selection may cause unpleasant outcome with undesired results of misuse in resources, manpower as well as precious time. Hence, it is important to achieve an optimal decision in real world problems which involve multiple alternatives and criteria in qualitative and quantitative domains.

One of the famous Multicriteria Decision Making (MCDM) methodology is the Analytical Hierarchy Process (AHP) pioneers by Saaty<sup>[1,2]</sup>. Voluminous literatures have applied the framework of AHP for modeling unstructured problems in the areas of economics<sup>[3,4]</sup>, social<sup>[5]</sup>, industrial<sup>[6,7]</sup> and military<sup>[8,9]</sup>. Due to its effectiveness and popularity, commercial software such as Expert Choice (<http://www.expertchoice.com>), Web-HIPRE (<http://www.hipre.hut.fi>), Criterium DecisionPlus (<http://www.infoharvest.com>) and ERGO (<http://www.technologyevaluation.com>) are adopting their systems and designs base on the AHP framework.

One of the important procedures in AHP is the pair-by-pair comparison values for a set of predefined objects (alternatives). The AHP requires the decision makers furnish with complete information and ample

knowledge of all aspects of the problem statements during their judgments under a predefined semantic scale. However, the nature of the real-world problems often relates to fuzziness and ambiguousness which initiates by the unprecedented environment conditions, human factors, incomplete information and etc. Numerous studies<sup>[10-12]</sup> implement the fuzzy set theory in the AHP problem to tolerate the vagueness conditions.

In this study, we develop an AHP multicriteria decision making tool which equips with fuzzy set theory<sup>[13]</sup> to tolerate the fuzziness in decision maker's judgements. Most of the current AHP decision support commercial software is largely bases on the local machine executable format where user needs to setup the software prior to use. In our system design, we provide portability and adaptability features by deploying the software on web platform. In addition, this tool provides an integrated domain reference channel via a database connection to assist the end user obtain relevant information regarding the problem domain before constructing the AHP hierarchy tree. Hence, our decision making tool combines the characteristic of real time information retrieval through internet and MCDM problem analytical processing logic.

### MATERIALS AND METHODS

**System development:** We select Visual Studio.NET (<http://msdn2.microsoft.com>) as our compiler in the

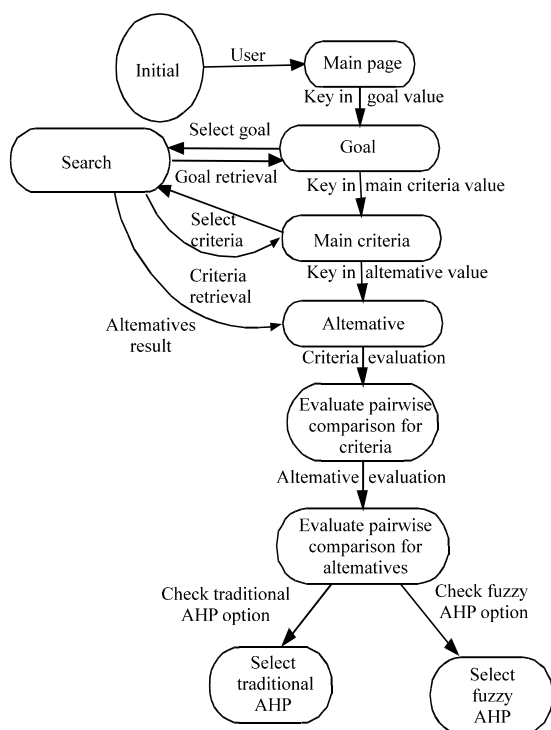
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software development phase. NET platform offers a new software development model that allows applications create in disparate programming languages to communicate with each other. In addition, NET architecture also offers Web services which allow applications in the Internet. C#.NET is our main language in the coding phase. We adopt C#.NET application into web application using ASP.NET (<http://www.asp.net>). We find it useful with various

functions of ASP.NET to be deployed into our tool. Among the applications of ASP.NET are session variables concepts for passing data in different pages, usage of data grid and panels which are useful for structuring the output, WYSIWYG (what you see is what you get) features and also support various other third party component. The system architecture design, state transition diagram and use case diagram are illustrated as follows:

State diagram of decision making tool (Part 1 of 2)



State diagram of decision making tool (Part 2 of 2)

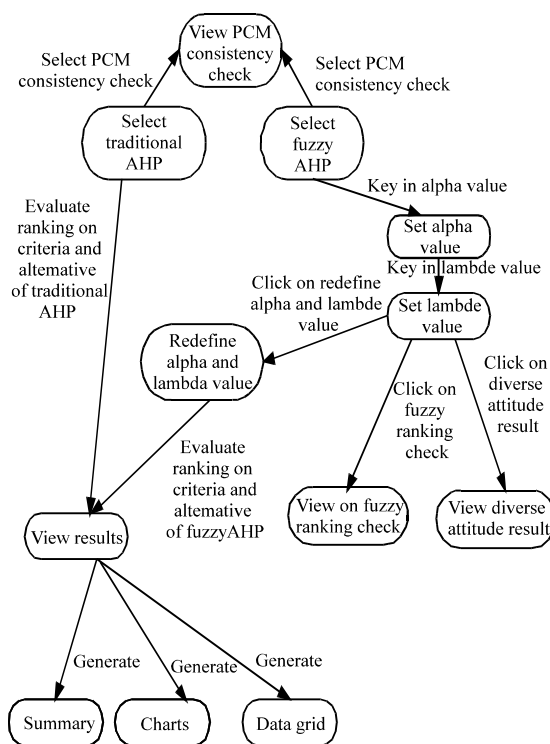


Diagram 1: State transition diagram

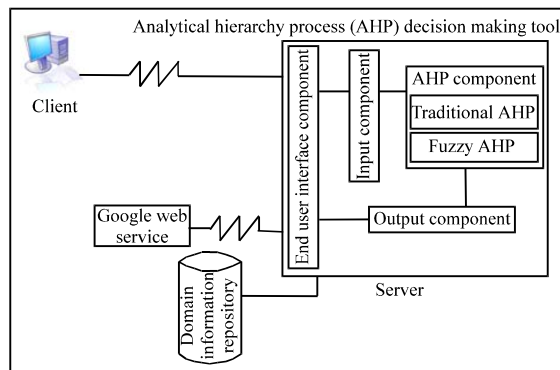


Diagram 2: Architecture Design

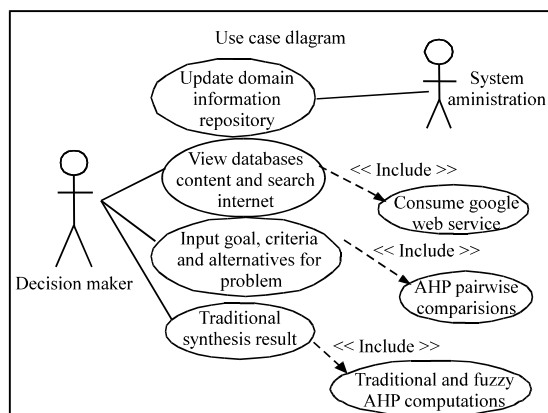


Diagram 3: Use case Diagram

**Computational algorithms**

**Step1: Fuzzy pairwise comparison matrices:** Due to simplicity and effectiveness, we select triangular fuzzy number as a reference to indicate the influence strength of each element in the hierarchy structure. Given a evaluation scale (Table 1) indicates from scores 1/9 to 9, the scores are fuzzified by the triangular fuzzy number  $f = (l,m,u)$  where  $l$  and  $u$  are the lower and upper bounds that represent the vagueness in the preferences scores.

The fuzzy pairwise comparison matrix,  $\tilde{P}$ , is defines as:

$$\begin{bmatrix} (p_{11/l} p_{11/m} p_{11/u}) & (p_{12/l} p_{12/m} p_{12/u}) & \dots & (p_{1n/l} p_{1n/m} p_{1n/u}) \\ (p_{21/l} p_{21/m} p_{21/u}) & (p_{22/l} p_{22/m} p_{22/u}) & \dots & (p_{2n/l} p_{2n/m} p_{2n/u}) \\ \square & \square & & \square \\ \square & \square & & \square \\ \square & \square & & \square \\ (p_{m1/l} p_{m1/m} p_{m1/u}) & (p_{m2/l} p_{m2/m} p_{m2/u}) & \dots & (p_{mn/l} p_{mn/m} p_{mn/u}) \end{bmatrix}$$

**Step 2- Fuzzy weighted performance matrix:** We define the weight measurement of each criterion and the performance of respected alternative performance as follows:

$$\tilde{\omega}_j = [(w_{1l} w_{1m} w_{1u}) \quad (w_{2l} w_{2m} w_{2u}) \quad \dots \quad (w_{nl} w_{nm} w_{nu})]$$

$$\tilde{A}_i = \begin{pmatrix} (a_{11/l} a_{11/m} a_{11/u}) \\ (a_{21/l} a_{21/m} a_{21/u}) \\ \vdots \\ \vdots \\ (a_{ij/l} a_{ij/m} a_{ij/u}) \end{pmatrix};$$

Table 1: Evaluation scales

Score	fuzzy No.	Score	fuzzy No.
1	(1,1,1) if diagonal; (1,1,3) otherwise	1/1	(1,1,1) if diagonal; (1,1,3) otherwise
2	(1,2,4)	1/2	(1/4,1/2,1/1)
3	(1,3,5)	1/3	(1/5,1/3,1/1)
4	(2,4,6)	1/4	(1/6,1/4,1/2)
5	(3,5,7)	1/5	(1/7,1/5,1/3)
6	(4,6,8)	1/6	(1/8,1/6,1/4)
7	(5,7,9)	1/7	(1/9,1/7,1/5)
8	(6,8,10)	1/8	(1/10,1/8,1/6)
9	(7,9,11)	1/9	(1/11,1/9,1/7)

where  $i = 1,2,3, \dots, r, j = 1,2,3, \dots, s$  and  $k = r$ , or  $k = s$ . After that, a fuzzy weighted performance matrix ( $\tilde{W}$ ) can thus be obtained by multiplying the weight vector with the decision matrix.

$$\tilde{W} = \tilde{A}_i * \tilde{\omega}_j = \begin{pmatrix} (w_{1l} a_{11/l} w_{1m} a_{11/m} w_{1u} a_{11/u}) \\ (w_{2l} a_{21/l} w_{2m} a_{21/m} w_{2u} a_{21/u}) \\ \vdots \\ \vdots \\ (w_{nl} a_{ij/l} w_{nm} a_{ij/m} w_{nu} a_{ij/u}) \end{pmatrix};$$

$$= \begin{pmatrix} W_{1l} W_{1m} W_{1u} \\ W_{2l} W_{2m} W_{2u} \\ \vdots \\ \vdots \\ W_{il} W_{im} W_{iu} \end{pmatrix}$$

**Step 3: Fuzzy number ranking evaluation:** In order to make a crisp choice among the alternatives, we need to check and compare the ranking of the fuzzy numbers. We apply the alpha-cuts-based method [14] to the total weighted performance matrices for each alternative and check the ranking consistency for each alternative under different alpha level. The alpha-cuts-based method 1 states that if let  $\tilde{A}$  and  $\tilde{B}$  be fuzzy numbers with  $\alpha$ -cuts,  $A_\alpha = [a_\alpha^-, a_\alpha^+]$  and  $B_\alpha = [b_\alpha^-, b_\alpha^+]$ . It say  $A$  is smaller than  $B$ , denotes by  $\tilde{A} \leq \tilde{B}$ , if  $a_\alpha^- < b_\alpha^-$  and  $a_\alpha^+ < b_\alpha^+$  for all  $\alpha \in (0,1]$ . The advantage of this method is the conclusion is less controversial.

**Step 4: Confidence level fuzzy number:** A level threshold  $(0, \alpha, 1)$  of the fuzzy set is defines to show the decision-makers' confidence to their judgements. The confidence value ranges between 0 and 1, from the least confidence to the most confidence. The definition of the symmetrical triangle fuzzy number ( $f = (l,m,u)$ ) with the interval confidence at level,  $\alpha$ , can be determined by:

$$\tilde{W}_\alpha = \begin{pmatrix} [W_{1left}^\alpha, W_{1right}^\alpha] \\ [W_{2left}^\alpha, W_{2right}^\alpha] \\ \vdots \\ [W_{ileft}^\alpha, W_{iright}^\alpha] \end{pmatrix}, \text{ where}$$

$W_{Left}^\alpha(i) = [\alpha(m-1)+1]$  and  $W_{Right}^\alpha(i) = [\alpha(m-u) + u]$  respectively.

**Step 5: Optimistic level evaluations:** The nature optimistic level of the decision maker can be optimistic, moderate or pessimistic. The decision maker's optimistic level with fixed  $\alpha$  is denoted as:

$$DM_\lambda^\alpha(i) = \lambda W_{right}^\alpha(i) + (1-\lambda) W_{left}^\alpha(i)$$

where  $\lambda \in [0,1]$ . This crisp performance matrix is represented by:

$$C_\lambda^\alpha = \begin{pmatrix} DM_\lambda^\alpha(1) \\ DM_\lambda^\alpha(2) \\ \vdots \\ DM_\lambda^\alpha(i) \end{pmatrix}$$

Finally, we normalize the  $C_\lambda^\alpha(i)$  to evaluate the highest degree of suitability among the selection with respect to i-alternatives using the following formula:

$$C_\lambda^\alpha(i) = \frac{C_\lambda^\alpha(i)}{\sum C_\lambda^\alpha(i)}$$

**EMPIRICAL APPLICATION**

**Problem formulation:** Consider a fresh graduate student would like to choose a job that can provide overall satisfactions in term of benefits, colleagues, location and reputation. Says, the available jobs are job A, B and C. The problem formulation process involves the goal, criteria and alternatives (three level hierarchy) as indicates in Fig. 1. When the user has a clear picture in mind regarding the problem, one can start by inserting the values for each level in the main page. Else, the system provides a domain information repository (DIR) and Google search to assist the user in problem determination.

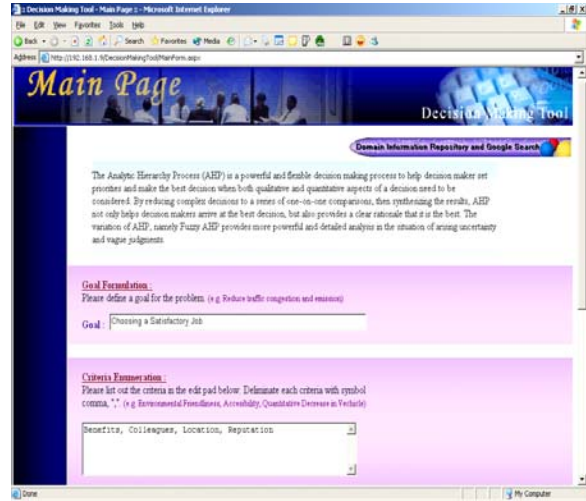


Fig. 1: Main page

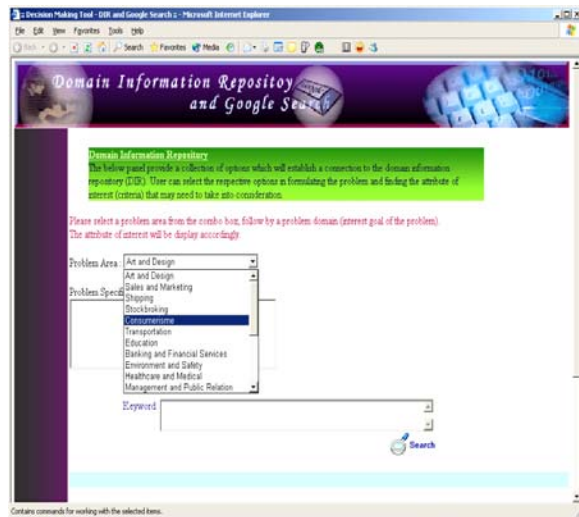


Fig. 2: Domain information repository (DIR) and Google search

**Pairwise comparison:** After the problem formulation (goal, criteria and alternatives), the system moves to the state of accepting pairwise judgment from the user. The scoring scale is according to the Saaty's original scale<sup>[1,2]</sup>.

**Consistency checking:** Before viewing the result of the AHP operation, user can select PCM Consistency Check (Fig. 3) button to check whether the evaluations are consistent (Fig. 4) enough to be useful. If the evaluation is inconsistent, the system will alert the user to redefine the pairwise comparison for the PCM.

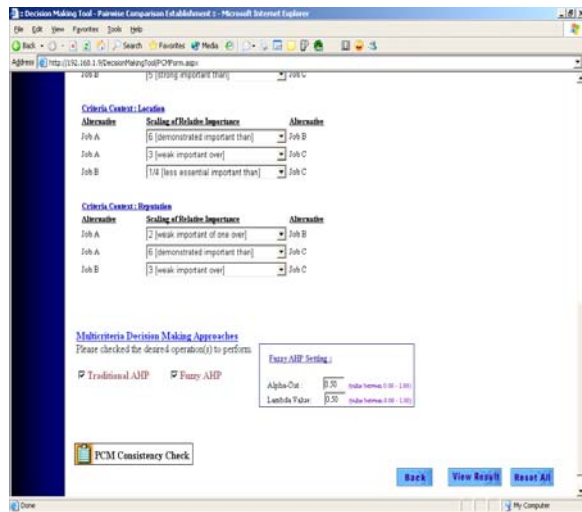


Fig. 5: Fuzzy Ranking Check

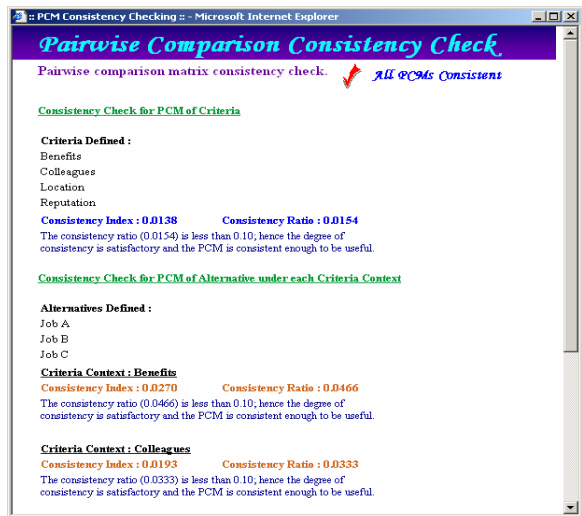


Fig. 6: Synthesis Result for Fuzzy AHP

In order to make a crisp choice among the alternatives, alpha-cuts-based method is used to check and compare the fuzzy number at all alpha level at certain point of optimistic threshold.

**Result visualization:** Finally, the results are indicated in Fig. 6.

### CONCLUSION

This program achieves simplicity and abstraction with fuzzy AHP algorithm that works behind the scene. The Web bases feature enhances the accessibility and portability of this tool. In addition, we also integrate the domain information repository to assist the user with

the information (criteria and alternatives) for certain common problem domains.

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