Using fuzzy multiple criteria decision making in evaluation of software quality

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Abstract

The purpose of this study is to explain how to use the Fuzzy Multiple Criteria Decision Making (FMCDM). Most evaluations are carried out using classical logic, but the results of other studies do not sound true. Now using fuzzy logic and its application decision making, software quality is investigated in which the results sound more logical. Ambiguity in understanding because of expansion of phenomena and ambiguity in meaning are two inaccurate sources in Multiple Criteria Decision Making (MCDM) model. Trying to eliminate this ambiguity, using fuzzy hypothesis magnifies the efficiency of this technology in decision making and the results of this model regarding the meaning of natural language of decision making are closer to reality. We use of criteria according to standard ISO 9126 in evaluation quality of software in implementation this paper. This criteria are functionality, reliability, usability, efficiently, maintainability, portability.

Keywords: Decision making; Fuzzy logic; Multi criteria; Software quality

1. INTRODUCTION

Human decision making in accompanied with imprecise and vague concept which are often expressed as linguistic variable. On the basis of fuzzy logic, these imprecise elements are considered important factors in human intelligent. Fuzzy logic based on fuzzy sets theory deal with defining sets that maintain the approximate nature of human reasoning and uses them[1]. Evidence shows that the productivity of decision Makers who use fuzzy logic might increase few percents. Fuzzy approach to decision making can provide the possibility of intuitive deduction, innovation and experiences on the basis of rule of thumb[2].

A human judgment is naturally imprecise, which has different reasons including[3]:

A. Carelessness of human in expressing and describing condition or set of specific conditions.
B. uncertainty to rules that are used as the basis of human judgment.
C. vague, incorrect, lost and contradictory data.

Hence, most of the judgment and decision makings are done in vague condition and they cannot be expressed by quant tate method (link probability theory). In 1965, Dr Lotfi Askari Zadeh introduced Fuzzy sets to deal with Neal word vagueness. Concept of Fuzzy set brings about the possibility of scientifically expressing of subjective and qualitative data[5]. So individual mentalities and prejudices decrease and decision makings are done more logically.

Fuzzy logic with its extraordinary flexibility is used to analyze the meaning of natural language and can model and analyze the vagueness resulting from human mind and environment and also imprecise degree which is found in human judgment[6].

Investigation on MCDM as an important branch of research was introduced in early 1970. Hence. Some of the theories and models that could be used as a basis for systematic decision making with multiple criteria began to grow greatly. Often in real world, decision making issues consist of different, contradictory and multiple measurement criteria. Decision making is called multiple criteria decision making when multiple and contradictory qualitative factors are analyzed and suitable solution are selected among multiple choice[7]. Whenever weights of factors and values under evolution are presented by Fuzzy numbers or, language meanings, it is called Fuzzy multiple criteria decision making.

2. FUZZY LOGIC
In the special context of humanities, it can be said that Fuzzy logic theory is a method that shows the researcher another way of looking at truths than true or false logic of Aristotle in the world of social and human relation. In this method it is impossible to separate debility between true or false in the form of direct linear.

In the classical two-valued logic, in all cases it is assumed that there are precisely defined border and limits and item can or can’t be include in it. Much of the cases in real world do not have strict limits as mortal or immortal, woman or man, dead or alive and mostly are as rather intelligent, relatively tall, rather happy and soon. Classic logic has no solution to deal with problems about issues which have to do with a degree of belonging and normally a degree of belonging zero or one is considered. One of the main concepts in fuzzy logic is to make a frame to process vague, imprecise, in sufficient and even imperfect data.

Science history is an evident that human tends to deal quantitatively with concept, phenomena and methods. After the birth of computer as a powerful instrument for data processing, this tendency has accelerated, sets theory is one of most effective mathematical tools to provide a quantitatively view of phenomena. Prof. Lotfiskari zade know as zadeh gave suggestion to expand the theory and describing new sets in 1965. He believes that in cases that it difficult to express the issues precisely. These (sets) are more efficient than classic sets. Due to its capabilities in modeling imprecise issues and also due to its practical break troughs, this theory has attracted a lot of attention.

In a classic set, an item belonging of an item to a set is not an absolute concept; rather each can be a member of a set with degree of belonging which is specified by the membership function of that fuzzy set. Fuzzy set theory is the development of probability measure. Fuzzy concept as used in fuzzy logic refers to different kinds of vagueness and uncertainly and especially to speaking language and human attitude and form uncertainly oriented by probability theory. A simple example for probabilistic uncertainly is the chance of coming 3 in rolling a dice. A mount of probabilistic uncertainly can be investigated by repeating the tests.

On the other hand, the measurement criteria for words like “pretty” depends to present view of a person who judges an them, so it is impossible to set a strict rule for judging them even by doing indefinite tests. Words like “pretty” are subjective which dependants to the situation are where they are used. Fuzzy logic can deal mathematically with this vagueness. Now, we proceed with application of fuzzy logic. The firs and most successfully application of fuzzy logic has been in control issues. Now a day, fuzzy logic has differed usages in factories and organization. Fuzzy logic is commonly used in intelligence and knowledge processing.

Different intelligence systems with numerous applications such as consolation for investment, strategic programs of management, bus timing schedules have found their way into market. The goal of all of this application is to express the scientific processing ability of human on computer. In recent years, Non-engineering usages of fuzzy logic in social and environment systems have been tested and investigated and led to conclusions.

The expansion of fuzzy logic can be expected. Its worth to mention there are numerous future application for fuzzy logic. Fuzzy can be used for more effectiveness of this application. In this direction, understanding the essence of fuzzy logic necessary.

2-1. Fuzzy Sets

In a daily conversation, a lot of vogues words are used. For example, “cypress is beautiful” or “value of dollar is relatively high”. Fuzzy sets have been introduced to deal with uncertain words and statement. Fuzzy sets can handle uncertain concept like” set of tall people” which cannot be expressed by ordinary sets.

2-2. Fuzzy relations

Fuzzy relation is a development of relations in ordinary sets theory. Ordinary relations introduced by ordinary sets and fuzzy relations can be defined for operation such union, intersection and complement.

2-3. Fuzzy Rules

Deduction rules are needed to execute fuzzy reasoning. Dedicate rules for fuzzy reasoning is called fuzzy”if-then” rules. Fuzzy reasoning can be divided into direct and indirect methods. Most of the common reasoning methods are direct ones. Although indirect methods are attractive technically, but have relatively complex
method. The most famous direct method was first suggesting mamdani. Mamdani direct method consists of simple structure of executing min and max. So their applications are numerous.

2-4. Fuzzy System

In some application issues eg. Controller designing, a fuzzy logic system is constituted of four parts:
- Rules base, decision maker logic, fuzzifier, non-fuzzifier
- Fuzzifier part: products an input fuzzy set for deduction using input number value.
- Rules base: include some rules describing the system behavior in the specific domain.
- Decision making: gives the out put as fuzzy sets using rules and input.
- Non-fuzzifier: converts output fuzzy sets to a numerical value.

3. Importance of fuzzy logic in decision making

In classic decision making, when resulting value of a choice is more than the other, it ranks higher. But in practice, the numbers are imprecise and secondly transmitting the prioritization is not always correct, so these problems encourage us to fuzzy logic. Applying the fuzzy logic in the domain of management science was following the creation of decision making models. Decision making is one of most important tasks of manages, so that Herbert Symen summarizes the management science in decision making. Hence applying right methods of decision making always been given attention and finding new ways of decision making is vital [6].

Human decision making many advantages between variables does not have mathematically precise defamations, so machine cannot make a correct decision about it. To make decision, there are usually numerous methods and rules, reach of them considering the input results in a specific output. Usually, combining the result to make the final decision through precise mathematical relations do not end up to the best answer.

Experience: human and learning ability along with probable ability of decision making rules is important privilege of human. Preference speed and the ability to process a huge volume of information is one of the human’s privileges. [1-3]

4. SOFTWARE QUALITY CRITERIA

4-1. User view

Principally, user study and evaluate a product fro the view of its functional capabilities, efficiency and effects resulting from its usage. Since the user was not present in producing process and not familiar with its internal structure, factors related to producing. Essentially, user evaluates the product fro following angles:
- Has the product needed functional capabilities?
- Is the product reliable?
- Has the product the necessary efficiency?
- Is the product easy to use by users?
- Is it easy to carry the product from optional environment to one this one?
- How much flexible is the product in face of needs?

4-2. Developer View

To produce a product in accordance with needs, user and producer must follow a same criteria will be different from view point of user and producer. Producer might use of different measuring units for a criteria in product system cycle. More over. View of producer will also encompass specific criteria related to product support and maintenance phase which is offer of importance to user[4].

4-3. Manager View
Management has a comprehensive viewpoint in which qualitative factors have been included along with non-qualitative factors. So, in this view point, qualitative criteria have its own specific value which might be affected by criteria and qualitative factors. Manager usually valuates the quality comprehensively, and other them dealing with managerial considerations such as cost, he will consider scheduled delay in supplying the product, market situation, limitation of human, time and equipment sources[5-6].

5. Evaluation of Software Product

In this section, regarding the different standards in evaluation of software products, standard ISO 9126 will be explained. Also the article will explain how to use the fuzzy multiple criteria decision making in evaluation of software quality using the criteria of standard ISO 9126[7].

5-1. ISO 9126

International standard of ISO 9126:1991 was published under the name of information technology-evaluation of software product - qualitative characteristics and using guidelines by international standard organization (ISO) in 1991. Devoted exclusively to the issues of software product evaluation, this standard is one of the most comprehensive references about evaluation criteria.

ISO 9126 have a software qualitative features or in another words evaluation criteria which have the least overlapping) in level 1 which each of them in turns has sub-features. [7]

5-2. Functionality:

A set of specific characteristics of software about satisfying the goal and necessary functional needs. This characteristic includes sub-characteristic as
- Suitability: appropriateness of functions for the specified tasks.
- Accuracy: to provide the right or agreed result and effects.
- Interoperability: the capability of software to internet with other specified system in its functional and execution range.
- Compliance: software feature about rules and legal regulations or standards linked to applied program.
- Security: preventing unintended access and resist deliberate attacks to programs or data.

5-3. Reliability

A set of specific characteristic of software about desired efficiency level under the specified conditions or efficiency time. This characteristic include sub-characteristic as follow:
- Maturity: software feature to frequency of software failure due to faults.
- Fault tolerant: capability to maintain a specified level of performance incases of software faults.
- Recoverability: capability is re-establish the desired level of performance and recover the data directly affected in the case of a failure.

5-4. Usability:

A set of specific features of software related is required ability and knowledge of learning and evaluating this ability ad knowledge by a group of users. This characteristic include sub-characteristic as follow:
- Understandability: features of software to recognize the logical concepts of software and its application by user.
- Learn ability: features of software concerning the necessary amount of effort for the user to learn the applied program.
- Operability: features of software concerning the necessary amount of effort for the user to adjust the software function.
5-5. Efficiency

A set of features the relation between the software efficiency level and the used resources under stated conditions. Resource can include:
Software, hardware, supplies (consumer and non-consumer) and operational and maintenance service.
- Time behavior: features of software concerning the processing and response time.
- Resource behavior: features of software concerning the amount and duration of using resources.

5-6. Maintainability:

A set of software concerning its maintenance and modifying its features during time. Modifications can include correcting, improving or conforming the software to environment changes, requirements and functional characteristic. This characteristic include sub-characteristic as follow:
- Analyzability: software feature related to diagnosing the deficiencies or cause of failures in the software, or identifying the parts to be modified.
- Changeability: software features concerning necessary capability to implement modifications, fixing the fault and deficiencies or conforming to environment change.
- Stability: software features concerning stability and endurance against the risk of unexpected effects from modifications.
- Testability: software features related to capability to enable modified software to be validated.

5-7. Portability

A set of features concerning the capability of transferring from operational environments to the other. This environment can be an organization, a new hardware or software.
- Adaptability: software features concerning the possibility of adapting it to different specified operational environments without doing anything special.
- Install ability: software features concerning capability of the software to be installed in a specified operational environment.
- Conformance: software features about observing the standards or rules of portability.
- Replace ability: software features about replacing with other specified software.

1. USING FUZZY DECISION MAKING IN EVALUATION OF SOFTWARE QUALITY

In this section we explain how to use fuzzy multiple criteria decision making in evaluation of software quality. To this end, following steps have to be done:
- Selecting the criteria of software quality.
- Selecting the membership function.
- Writing the necessary rule for the selected criteria.
- Executing Fuzzy section of matlab software
- Test

The selected criteria to do it, as mentioned completely in previous section, are standard is 9126. The Fuzzy system is shown in figure 1:
Now the membership function is described as below:

1. For a describe result at a criterion, a number above 75 is considered. So its membership function is as follows:
   \[
   \frac{1}{25}(x-75) \quad 75 \leq x \leq 100 \\
   H(x): \quad 1 \quad x > 100 \quad 0
   \]

2. For a rather of a criterion, a number and the range of 50 to 100 are considered, so for is choice it can be written as:
   \[
   \frac{1}{25}(x-50) \quad 50 \leq x \leq 75 \\
   H(x): \quad \frac{1}{25}(100-x) \quad 75 \leq x \leq 100
   \]

3. For an acceptable result of a criterion, a number on the range of 25 to 75 is considered, so for choice it can be written as:
   \[
   \frac{1}{25}(x-25) \quad 25 \leq x \leq 50 \\
   H(x): \quad \frac{1}{25}(75-x) \quad 50 \leq x \leq 75
   \]

4. For an acceptable result of a criterion, a number on the range of 0 to 50 is considered, so for choice it can be written as:
   \[
   \frac{x}{25} \quad 0 \leq x \leq 25 \\
   H(x): \quad \frac{1}{25}(50-x) \quad 25 \leq x \leq 50
   \]

5. For an acceptable result of a criterion, a number under 75 is considered, so for choice it can be written as:
   \[
   1 \quad x \leq 0 \\
   H(x): \quad \frac{1}{25}(25-x) \quad 0 \leq x \leq 25
   \]

Figure 2 shows the above mentioned memberships function:
Fuzzy set A (describe result) fuzzy set B (rather describe result), fuzzy set C (acceptable result); fuzzy set D (rather undesirable result) has been shown in the following figure.

Now considering the described inputs, we define the possible states for output.

A: below to be simple, just four states is considered:
State (1) - software quality is low.
State (2) - software quality is medium.
State (3) - software quality is good.
State (4) - software quality is high.

Considered membership function for the above state are as follow:
1. For a low result, a number below 33 is considered, so its membership function is as follow:
   
   \[
   H(x) = \begin{cases} 
   1 & x \leq 0 \\
   1/33 (33-x) & 0 \leq x \leq 33 
   \end{cases}
   \]

2. For a medium result, a value on the range 0 to 66 is considered, so for this choice it can be written as:
   
   \[
   H(x) = \begin{cases} 
   x/33 & 0 \leq x \leq 33 \\
   1/33 (66-x) & 0 \leq x \leq 25 
   \end{cases}
   \]

3. For a good result, a value on the range 66 to 100 is considered, so for this choice it can be written as:
   
   \[
   H(x) = \begin{cases} 
   1/33 (x-33) & 33 \leq x \leq 66 \\
   1/33 (100-x) & 66 \leq x \leq 100 
   \end{cases}
   \]

4. For a high result, a number above 66 is considered, so its membership function is as follow:
   
   \[
   H(x) = \begin{cases} 
   1/33 (x-66) & 66 \leq x \leq 100 \\
   1 & x > 100 
   \end{cases}
   \]

Rules related to sub-criteria of each main criterion:
There are specific sub-criteria for each of the above states that has defined according to standard 9126 to get to the main criterion[7]:

No considering the previous states, we write its relevant fuzzy rules, eg.

Portability criterions include the following sub-criteria:
• Adaptable briefly shown as Ad.
• Install ability briefly shown as in.
• Conformance briefly shown as Co.
• Replace ability briefly shown as Re.
• Portability briefly shown as Po.

Now reading the number of different state of fuzzy rules, it is written as:
If Ad, Co and Re are low, then Po will be low.
If Ad, In, Co and Re are medium, then Po will be medium.
...

Rules base for main criteria:

Now considering the mentioned criteria, the following rules are expressed according to standard ISO 9126, but due to increasing number of criteria, here just the criteria mentioned by standard ISO 9126 have considered:

- A1: functionality
- A2: reliability
- A3: usability
- A4: efficiently
- A5: maintainability
- A6: portability

Also the desired states are defined as follow:
- Low
- Medium
- Good
- High

So the defined membership function as previous ones will be as follow:

1. For a low result number below 33 is conserved, so its membership function is as follow:
   \[ H(x) = \frac{1}{33} (33 - x) \quad 0 \leq x \leq 33 \]

2. For a medium result, a number on the range of 0 to 66 is conserved so for this choice it can be written as:
   \[ H(x) = \frac{1}{33} (66 - x) \quad 33 \leq x \leq 66 \]

3. For a good result, a number on the range of 100 is conserved so for this choice it can be written as:
   \[ H(x) = \frac{1}{33} (100 - x) \quad 66 \leq x \leq 100 \]

4. For a high result, a number above 66 is conserved so its membership function is as follow:
   \[ H(x) = \frac{1}{33} (x - 66) \quad x > 100 \]

Now the following rules are considered:

- If A1, A2, A3, A4, A5 and A6 are low then software quality is low.
- If A1,A2,A3,A4,A5 ,...,A6 are medium then software quality is medium
- If A1, A2, A3, A4, A5... A6 are good then software quality is good.
- ...

Many rules with several number of state can be considered for the above mentioned criteria but we refrain writing them here, however to execute it on the matlab software, all the necessary rules have been used.

All of the above mentioned cases were executed in fuzzy section of matlab software it was found that in evaluating a software quality by fuzzy (logic), the result are more real.

Comparison between evaluation of specific software by classic logic and fuzzy logic has been summarized in table 1:
TABLE 1. COMPARISON BETWEEN CLASSIC AND FUZZY EVALUATION

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Classic evaluation</th>
<th>Fuzzy evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality</td>
<td>25</td>
<td>23.325</td>
</tr>
<tr>
<td>Reliability</td>
<td>75</td>
<td>73.256</td>
</tr>
<tr>
<td>Usability</td>
<td>25</td>
<td>33.453</td>
</tr>
<tr>
<td>Efficiency</td>
<td>50</td>
<td>47.325</td>
</tr>
<tr>
<td>Maintainability</td>
<td>100</td>
<td>98.545</td>
</tr>
<tr>
<td>Portability</td>
<td>75</td>
<td>72.533</td>
</tr>
</tbody>
</table>

Considering the evaluation it is found that the software criteria can be rated more precisely in fuzzy evaluation and result will found more precise.

6-CONCLUSION

A decision maker, with understanding the fuzzy logic and its basic principles, will be able to modeling and deciding about many complex problems and slave problems with improper and uncertain data. The importances of this understanding get clear when you know that today's world and all human's information are imprecise. Not only a statement has correctness in fuzzy logic but also the correctness value itself is relative. Considering the flexibility of fuzzy logic, many of the systems have applied it in real environment and today its usages in management are increasing. One of the issues which can be expressed is working with it in their jobs.

Multiple decision making issues are divided into two groups of multi-indexed and multi-purposed and each of them has different algorithms. We can use these algorithms regarding the problem and its complexity. Algorithms relevant to multi-purposed are usually used in designing while multi-indexed issues are often used for selecting better choice.

To know how and how much of goal has been satisfied and is these attempts and executed operational processes in the direction of accessing and meeting the goals, it is necessary to control the process by a proper total. One of the most important tools of controlling a process is evaluation. Software quality can be evaluation by fuzzy method considering different criteria, which (these criteria) differs depending a kind and application of software.

REFERENCES