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Role of Fuzzy Logic in Requirement Prioritization

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ABSTRACT: Requirement may be defined as desired functions that states, how the products should be regarding its functionality, structure and behavior. To develop cost effective quality software it always challenges for all people to select right requirement among several set of requirements. Requirement prioritization helps people to discover the most desirable requirements. Prioritization decisions are carried out by users, managers, developers and their representatives. In this paper firstly we introduced the brief meaning of requirement prioritization and existing techniques that are used to prioritize the requirements then paper summarizes some of parameters which are used in prioritization process. Paper also evaluates the challenges that a requirement prioritization team faced during prioritization and need of fuzzy logic in prioritization process. Finally paper provides a novel solution in a field of requirement prioritization using fuzzy logic.

KEYWORDS: Requirement prioritization, Challenges, Prioritization techniques, Fuzzy logic.

I. INTRODUCTION

Requirement prioritization is the middle step of requirement engineering that select most beneficial requirement from the abundant accumulative list of all significant and insignificant requirements [3]. It's the step that clarifies the value of each project and value is measured against criteria. Criteria may be: Strategic criteria: It may be defined as change in way things are done like grographic expension, customer segment, competitive positioning. Operational criteria: It is about improving your current business like growing revenue, improving cost, customer satisfaction and reducing cost. Project may contain a large number of requirements and good management of these requirements can be important for making project successful. Due to limited resources it is not always possible to implement all requirements. So it becomes mandatory process for project to prioritize the requirements to make valuable project [7]. We can reduce the time and cost of project by defining high priority requirement before the lower one. Figure1 shows the relationship between the software engineering, requirement engineering and requirement prioritization. Requirement engineering is one of the important domain of software engineering that identify, document and model the customers' needs. Various constraints are associated with project such as time, budget, value, risk. Requirement prioritization helps us to identify all essential requirements that provide higher customer satisfaction and implement within these constraints.

Requirement prioritization have been used in various applications of daily life such as for enhance business performance, supplier chain management, social network, security, educational and entertainment system [22]. Various concerns are associated with requirement prioritization and various negotiation and prioritization techniques have been developed in literature. It is observed that none of the prioritization technique may be absolutely perfect which provide the result according to specific criteria [21]. Different techniques have different perspective and view point to prioritize the requirement. Our main aim is to provide novel solutions that prioritize the requirements more efficiently according to organization goal using fuzzy logic.

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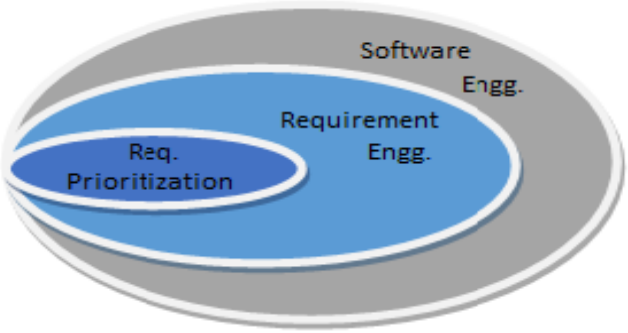

Fig.1 Requirement Prioritization

The organizations of the rest of paper are as follows: Section II provides the literature survey of various techniques that have been used in prioritization process. Section III presents the various parameters which have needed to concentrate during prioritization. In section IV we have discussed challenges that are faced during prioritization process. Section V shows the role of fuzzy logic in requirement prioritization and explains how the fuzzy logic system works. Finally section VI describe the comparatively study of various techniques and proposed solution.

II. RELATED WORK

Over the last few years, several researches have been devoted to develop cost effective quality software. Various authors such as Nuseibeh and Easterbrook (2000), Bergman and Klefsjo (2003) think the various challenges faced with software engineering and conclude that really the developed software project fulfill the customer needs. There are not fixed solution to analyze that. However requirement engineering is the first step toward software development process that identify, document and model the customers' need. Requirement prioritization is one of the critical activity of requirement engineering that helps to implements the requirements according to customers need [20]. Various techniques have been proposed to prioritize the requirements**.**

A. Analytical Hierarchical Process

AHP was developed by Saaty and applied to software engineering field by Karlsson. It is multi-criteria decision making technique that uses a pairwise comparison matrix to compute the relative importance of requirements with respect to one another. In AHP first define the objective and structure the elements in groups of criteria, sub-criteria, and alternatives. Make a pairwise comparison of elements in each groups and assign the value ranging from 9 to 1/9, like A and B are two criteria then: Assign 1 if both criteria have same importance, Assign 9 if criteria A is 9 times more important than B and Assign 1/9 if criteria B is times more important than A. Assign the result in matrix and compute the Normalized principal Eigen vector of the matrix. Calculate the weight and consistency ratio and evaluate alternatives according to weighting to get final ranking.

Major drawback is that it works only where single decision maker is involved but in real life various stakeholders are involved to give different opinions. Suitable for small numbers of requirements, it become cumbersome when number of requirements are thousand i.e. when n requirements then n(n-1)/2 pairwise comparisons are required at each hierarchical level [7,14]. Karlsson [18] introduced extension of AHP called Hierarchy AHP which use AHP to prioritize requirements only at same hierarchy level and reduce the number of redundant comparison. Another extension of AHP is Fuzzy AHP which is used to resolve the incompleteness and fuzzyness associated with requirements by single stakeholder.

B. Cumulative Voting

Cumulative voting is faster and easier technique that produce prioritize in ratio scale. It not only prioritizes the requirements but also determine their importance. Prioritization is done either by single stakeholder or by multiple stakeholders. In cumulative voting give 100 points to each stakeholder that can spend on the prioritization item.

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Stakeholder can spend any amount of points from 100 to any items. Stakeholder may have freedom to spend all points on one item, distribute points among all items or distribute points on some of items. Some stakeholder's votes are more important than others, in such a case the priorities of each stakeholder may be multiplied by individual's coefficient. The final priority list can be calculated by adding up the points to each stakeholder [16]. The main drawback is that it becomes more difficult when number of requirements is increased.

C. Numerical Assignment Technique

Numerical Assignment is the most common technique for requirement prioritization. This technique is based on grouping which group the requirement according to their specific traits in different priority group. Generally priority groups are critical, standard, optional or high, medium, low depend upon specified criteria. All the requirements in one priority group have equal priority. Now these requirements are given to each stakeholder and each stakeholder assigned a number on a scale of 1-5 to each requirement within these groups. After calculating average of all the numbers of each requirement we can get the final priority list.

This technique poses several problems:

- Have not clear definition of groups and
- Even with clear definitions stakeholder will tends to put most of requirements in one group.

This technique is not effective when numbers of requirements are low but it might be better when prioritizing medium or large number of requirements [5].

C. Ranking

Ranking is based on an ordinal scale and requirements are ranked without ties from 1to n; where n is the number of requirements. In this technique each requirement has the unique rank. It is also called simple ranking.

- Assign rank 1 to highest priority requirement.
- Assign rank 2 to least priority requirement.

Ranking can be implementing by using various algorithms i.e. binary search tree and bubble sort etc. Karlsson first introduced BST and bubble sort in the field of requirement prioritization to provide ranking. **Binary Search Tree** uses the basic BST data structure concept to assign the ranking to requirements. In BST each node have atmost two children, right node have highest priority requirements and left node have least priority requirements. The benefit for using BST is that with *n* requirements, it takes only *n* log *n* comparisons to insert all the requirements in order. **Bubble sort** compare two requirements at a time and swap them if the two requirements are in the wrong order. The result of bubble sort is a list of ranked requirements and have the complexity is O (n^2). Major problem with this technique is that it can create conflict to assign rank of particular requirement when applied in an environment of multiple stakeholders but suitable when single stakeholder is involved [5, 7].

D. Wieger's Method

It is semi quantitative analytical approach for requirement prioritization based on the value cost and risk. Wieger use the scale 1-9 to set their rating, 1 for minimum and 9 for maximum.

- Make the list of all the requirements that you want to prioritize and fix the relative weight for benefits, penalty, cost and risk.
- Estimate the relative benefits of each requirements and relative penalty that the customer would suffer if the requirement is not included.
- Calculate the value that is the sum of relative benefits and penalty and value%.
- Estimate the relative cost to implement the requirement and calculate cost%.
- Estimate the relative risk and calculate risk%.
- Calculate the priority of each requirement by using:
  Priority = (value %) / [(cost% *cost weight) + (risk% * risk weight)] [3, 13].

Karlsson et al. [18] introduces minimal spanning tree and priority groups in requirement prioritization. MST minimizes the redundancy and number of comparisons from AHP. The basic idea in minimal spanning tree is that all the redundant comparisons from AHP need not to be performed at all. By this reduce the number of comparisons to (n-1) when compared to n(n-1)/2 required by AHP. Priority groups use the basic idea of numerical assignment. In numerical assignment technique groups requirement into priority groups only once but in priority group repeatedly divide the

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groups in priority groups. MoSCoW[19] is another techniques that categories the requirements into must have, should have, could have, won't have groups. Requirement Triage and Theory W [20] are the negotiation based technique. Negotiations are conducted among various stakeholders to resolve the differences.

Karlsson et al.[18] perform an experimental study to evaluate six prioritization techniques namely AHP, Hierarchy AHP, Spanning tree matrix, bubble sort, BST, priority groups with 13 quality requirements and found that AHP provide most reliable result but time consuming and required largest number of decision to assign priority. Hierarchy AHP and BST reside in middle. Bubble sort has relatively good fault tolerance than spanning tree but has the same problem of number of decision as AHP. Among these no techniques is suitable for large number of requirements because some has scale up problem and some has degree of accuracy problem.
Hatton [19] perform another experiment on simple ranking, MoSCoW, AHP, and cumulative voting. the result shows these techniques accurately indicate the clients' priorities. Simple ranking, MoSCoW, are easy to use and take less time to perform. AHP is hardest to perform and take long time. Cumulative voting is work between them and contains high user confidence.

III. PRIORITIZATION PARAMERTERS

Requirement parameter plays an important role in prioritization process. Generally prioritization based on single parameter or multiple parameters, when parameter is single such as business value then those requirements which give higher customer satisfaction will have highest priority but when parameter is multiple it become complex thing because change in one parameter may result in change in another parameter [12].
Mostly value, cost and risk plays an important role in prioritizing user requirement because the project should deliver value to the customer and major risk ought to be handle early on.

A. Value

Value is 'what the customer really wants'. To make valuable product we have need to implement such requirements which has highest priority and provide highest level of customer satisfaction.

B. Cost

The 'price' has to be paid in order to acquire something. Usually the developing organizations estimate the implementation cost [11]. In business environment it is measured in term of effort, material, resources and time.

C. Risk

Risk is a loss or any negative occurrences that is caused by external or internal vulnerabilities. Risk can comes from different ways i.e. from project failure, not satisfy the customer needs. To make quality software, identify ways to reduce risk and prioritize risk reduction measure based on strategy [2].

D. Time

Time stands that the duration is required to fulfill all the customer requirements. It helps in identifying those requirements that could be fulfilled in short duration and long duration [11].

E. Penalty

Penalty is punishment measures that have been adopted when the requirements are not fulfilled. It reduces the software defects and hence ensures quality software.

F. Volatility

Requirement volatility represents the change in requirement over time due to market change, business requirement change, user change etc. Volatility requirements affect the stability and planning of project and also increase in overall costs due to change in development cycle [12].

IV. CHALLENGES

1. To select relevant requirement from given set of thousand of requirements.
2. To deliver most important functionality on time and within budget while meting higher customer satisfaction is always challenges.
3. When customer put all the requirements are in mandatory group.
4. Changes in need and business environment may change in priority.
5. When new requirements are added then relative priorities of previous one may change.

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6. The customer may misunderstand the prioritization process.
7. Limiting domain knowledge to the requirements mapping.
8. Stakeholder and developer collaboration because the stakeholders can properly prioritize the requirements, while the developers can properly estimate the resources that required prioritizing the requirements. This requires stakeholders and developers to collaborate during requirements prioritization, and this may be very difficult and always challenges in requirement prioritization process [1, 2].
9. To handle contradictory requirements, focus the negotiation process, and resolve disagreements between stakeholders.
10. To specify the parameters for quality requirements is also challenges in prioritization process.
11. When requirements may vary in later stages, it also leads to changes in priorities [15].

V. FUZZY LOGIC IN REQUIREMENT PRIORITIZATION

There is always certain amount of uncertainty involved in undertaking software engineering activities since these relate in many ways to software projects. Software projects may have several risk, assumption and conflicting requirements associated with them. Such type of problems can be better solved using fuzzy logic [11].

A. Why Fuzzy Logic in Requirement Prioritization

The key success to successful software development has always been accurate requirement framing from stakeholders communication and with customer minds [10]. For this purpose requirement prioritization has to be done. Requirement prioritization is decision making activity by the stakeholders about the priorities of requirements. During the early stages of project life cycle the understanding of stakeholders about the priorities of requirement may be uncertain, vague or imprecise. Hence, uses of requirement prioritization techniques that do not take uncertainty into account are of minimal use in case which involves minimal knowledge. Uncertainty bought on by lack of knowledge has to be modeled in some form during requirement prioritization.

Another concern is about aggregating the judgments of stakeholders. It is quite easy task to determine the priorities of requirements if a single stakeholder is involved but the scenario is diverse group of stakeholders to be involved and it is more challenging to aggregate their judgments.

The software projects may have several risk and conflicting requirements associated during the prioritization phase. Various stakeholders involved and they have their individual and consolidated concerns over the requirements. Individual concerns facilitate a stakeholder to obtain preference ordering of conflicting requirements and consolidated concerns assists developer to obtain consensual preference ordering that would satisfy all stakeholders. Conflicting requirements are vague, uncertain and subject in nature [6, 9]. Fuzzy decision making helps to solve such type of uncertainty and conflicting requirements to produce reliable work.

B. How Fuzzy Logic System Work

Fuzzy logic is an approach to computing based on ‘degree of truth’ rather than usual ‘true or false’. It serves as a conceptual framework which works to cater to the uncertainty in the knowledge representation. Fuzzy logic seems closer to the way our brains work. We aggregate data and form a number of partial truths which we aggregate further into higher truth [8]. Figure-2 shows working procedure of fuzzification and defuzzification in fuzzy logic system and step by step procedure are as follows:

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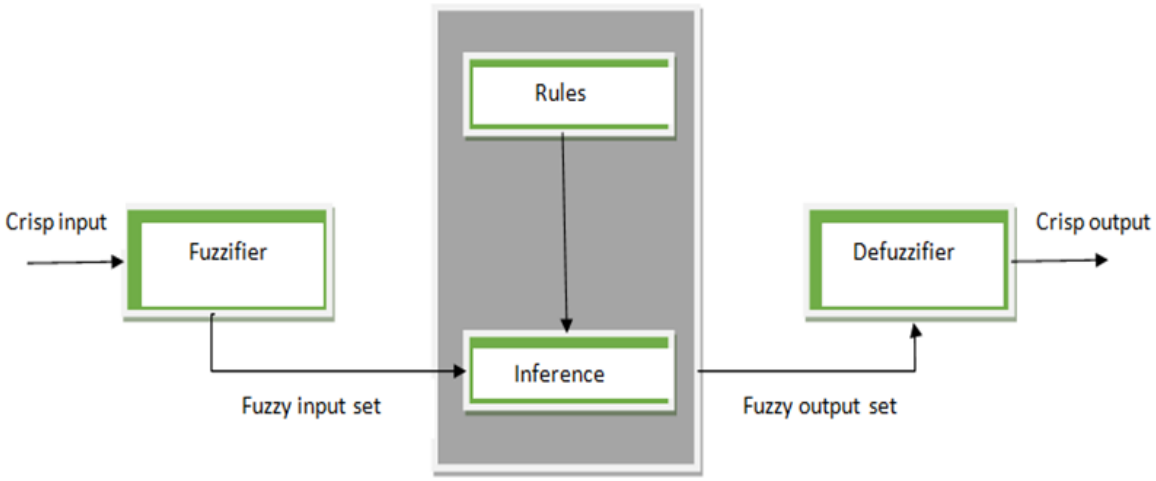

Fig. 2 Fuzzy Logic System

Initialization: First we define the linguistic variables, linguistic terms and construct the membership function. Linguistic variables are the input or output variables whose values are words or sentences from a natural language, instead of numerical values. Linguistic variable is generally decomposed into a set of linguistic terms.
A membership function serves as the characteristics function, which basically serves as fuzzy sets. The objective of this function is to associate a degree of membership of each of the elements of the domain to the corresponding fuzzy sets [11]. For each input and output variable selected, we define two or more membership functions, normally three but can be more. The shape of these function can be diverse but usually used shapes are triangular and trapezoids.

Fuzzification: Crisp set of input data are gathered and converted to fuzzy set using fuzzy linguistic variables, fuzzy linguistic term, and membership functions. This step is known as fuzzification.
Crisp sets are a special case of fuzzy sets, since the range of function is restricted to the value 0 and 1. Fuzzy sets are sets whose elements have degree of membership. Higher the degree of membership, greater the certainty of that element belonging to any particular set [17].

Inferencing: The task of inferencing process is to map the fuzzified inputs received from the fuzzification process to the rule base, and to produce a fuzzified output for each rule. A fuzzy rule is simple IF – THEN rule with a condition and a conclusion. That is, for the consequents in the rule output space, a degree of membership to the output sets are determined based on degrees of membership in the input sets and the relationships between the input sets. The relationships between input sets are defined by the logical operators which combines the sets in the antecedent. The output fuzzy sets in the consequent are then combined to form one overall membership function for the output of the rule [4].

Defuzzification: After the inferencing, the overall result is a fuzzy value. The result should be defuzzified to obtain the final crisp output. Defizzification is performed according to membership function of the output variable.

VI. COMPARATIVELY STUDY AND PROPOSED SOLUTION

After analyzing the various techniques and experimental result of various authors in literature survey we developed the comparatively study of widely used techniques with their silent features. Table 1 shows the strength and limitation of widely used techniques.

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Table no. I Comparison of Various Techniques

Technique	Concept	Project Size	Speed	Type	Ease of Use	Perspective
AHP	Pairwise Comparison	Small	Slow	Algorithmic	Very Complex	Product Manager
Hierarchy AHP	Pairwise Comparison	Medium	Average	Algorithmic	Complex	Product Manager
Fuzzy AHP	Pairwise Comparison	Medium	Average	Algorithmic	Very Complex	Product Manager
Bubble Sort	Pairwise Comparison	Medium	Average	Algorithmic	Complex	Product Manager
BST	Pairwise Comparison	Small	Average	Algorithmic	Complex	Product Manager
Ranking	Value Assign	Small	Fast	Manual	Easy	Requirement Specialist
Cumulative Voting	Value Assign	Small, Medium	Average	Manual	Complex	Customer
Numerical Assignment	Grouping	Medium, Large	Average	Manual	Easy	Product Manager, Requirement Specialist
Wieger's Method	Formula Base	Small, Medium	Slow	Algorithmic	Complex	Product Manager, Customer
Requirement Triage	Cluster and Negotiation	Medium, Large	Slow	Manual	Very Complex	Requirement Specialist

Comparatively study shows that all the techniques either the manual or algorithmic base. Codes written in various language are very complex task and very time consuming and in manual process the probability of making error are very high and heavy human effort are involved. Another thing is that each organization has different goal and different set of parameters for prioritization. So it is important to develop a product according to organization specified criteria that fulfill all customers' need. It is also seen that most of techniques either use the customers' perspective or developers' perspective to prioritize the requirement but not both.

To take into account all these things, to developing a rule based approach that aggregates the concept of both fuzzy logic with organization goal and take the advantage of customers' and developers' preference we can enhance the result of prioritization. Using fuzzy decision making we can solve the uncertainty, negotiation and conflicting requirement concept to produce the reliable result.

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VI. CONCLUSION

Requirement prioritization is one of the most critical activity in software development cycle. Various techniques have been emerged but there are not a single technique that considers all the parameters of requirement prioritization, mostly work on business value, cost and risk. By consider all the parameters in one technique we can prioritize the requirement more efficiently. Prioritization techniques did not consider the uncertainty and fuzziness associated with the requirements. To solve conflicting requirements using fuzzy based approach we can get better result. To minimize the gap between user and developer we can more enhance the result of prioritization techniques. Our future plan is to implement working method of proposed solution.

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