On Fuzzy Qualitative and Quantitative Softgoal Interdependency Graph

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ABSTRACT
Non-Functional requirements serve as criteria for the selection and prioritization of software requirements. The objective of this paper is to propose an efficient method for the prioritization of non functional requirements. In this paper we use L^{-1}, R^{-1} inverse function arithmetic principle and graded mean integration for the elicitation of decision maker's weight for the qualitative and quantitative softgoal interdependency graph to model the non-functional requirements. Finally the utilization of proposed method is demonstrated with the help of an example.

Keyword
Softgoal Interdependency graph (SIG), Non-functional requirements (NFR), Trapezoidal fuzzy numbers (TFN), FQQSIG.

1. INTRODUCTION
Research in the area of trustworthy software system has received much attention by software engineering community in recent year. In 2014 "Make in India" project was started to increase the number of software product start-up in the country. India software industry is expected to grow to $225 billion by 2020.A software system can only be suitable if it is Trustworthy. Chen et. al.,[4] define software trustworthiness as a system which have the following characteristic like safety, security, reliability, maintainability etc. Software requirements are classified into functional requirements (FR) and non-functional requirements (NFR). Software system that lack FR i.e. Based on our literature review, we have identify different sets [9, 12, 13, 22, 21, 1] and NFR framework [9] and softgoal Interdependency graph (SIG) [8, 7, 5]. SIG mainly emphasis the importance of qualitative analysis, of NFRs. For example, Zayaraz and Sadana [2, 21], proposed a quantitative model that focus on priorities and analyzes the conflict NFRs. Marew [20], presented "quantified softgoal interdependency graph". In this graph precise values are used to express the degree of satisfaction. This method also used for arithmetic operation to calculate the contribution of NFRs. In 2011, Zhu [15], proposed a NFR tradeoff model in trustworthy software which uses a fuzzy qualitative and quantitative softgoal interdependency graph (FQQSIG). In this method RAGE defuzzification procedure is used to finish the defuzzification transformation process. In this paper, we proposed a fuzzy based approach for the non-functional prioritization using L^{-1}, R^{-1} function arithmetic principle and graded mean integration representation.

This paper is organized as follows: Section II presents the proposed method section III we present a case study of proposed method and finally conclusion and future work.

what the system is supposed to do and NFRs i.e. how the system is suppose to behave, such as reliability and performance carry the risk of failing to meet the customer and user expectation [23, 3]. In literature, NFRs has received less attention throughout the eliciting, capturing, modeling, testing, and maintaining process of software requirements.

2. PROPOSED METHOD
In this section we present the proposed method a fuzzy based approach for the NFR tradeoff model in trustworthy software. Proposed method includes the following steps:

Step 1: Identification of stakeholder
Stakeholder identification is a most important activity of a requirements elicitation process. Therefore, the first step of our method is to identify the primary and secondary stakeholders [17, 18]. Primary stakeholders include those who are central to any project initiative, i.e., beneficiaries, financial, politicians, sponsors, and decision maker. Secondary stakeholders include developers, experts, operators etc [19].

Step 2: In this step we decompose the NFRs.
Software requirements are divided into two categories: functional and non-functional [6]. Many researchers, including Boehm [26], Sommerville [25], and Chung [9], present various NFR classifications. These classifications contain the need for different application areas in different conditions. They are helpful for developers to quickly obtain the area knowledge and easily modify software requirements. In 2015 [16] there is another classification of NFR which is based on commonly used NFR's, on the basis of definition and attributes of NFRs, and on the basis of conflicted NFR's. In "commonly used NFR", only those NFRs are considered which are useful for the different types of systems like information system, web based system etc. On the basis of literature review, only five types of NFRs that are commonly used in different types of systems [14] like Performance, Reliability, Usability, Security, and Maintainability. In second type of NFRs which is "on the basis of definition and attribute" is to identify those requirements which are clearly defined in the literature, like. Performance, Security Usability etc. and also identify those requirements which are supported by their attributes like Accessibility, Adaptability, Availability, Efficiency etc.[16]. This classification is further divided on the basis of the following: (i) Have Definition and Attributes (ii) Have Definition (iii) Without Definition and

Attributes. The third type of classification of NFR is conflicted NFR for example, Accuracy and Performance [14, 16]. Conflicted NFRs further classify into three parts i.e. Absolute conflicted NFRs, Relative Conflicted NFRs and NFRs that are Never Conflicted. There are some NFRs which may conflict with other NFRs [16]. For example, reliability and performance.

Step 3: In this step we collect expert fuzzy assessment.

Step 4: To elicit the DMs weight vectors we use the $L^{-1} - R^{-1}$ inverse function arithmetic principle and graded mean integration representation [27].

Step 5: In this step we construct the FQQSIG graph.

3. CASE STUDY

In this section we applied the proposed method with help of five decision makers (DMs) opinion on NFR degree assessment of criteria. In this case study, we use seven ranking parameters i.e. Weak (W), Medium Weak (MW), Fair (F), Medium Strong(MS), Strong (S), Very Strong (VS), Extremely Strong (ES) etc. DMs fuzzy assessment parameter is shown in Table 1.

Table 1. Trapezoidal Fuzzy Linguistic variables set for NFR.

Linguistic variables Set	Abbreviation	Trapezoidal fuzzy numbers S1(n1,n2,n3,n4)(i=1,……,9)
S1:Weak	W	(0.176,0.235,0.294,0.353)
S2:Medium Weak	MW	(0.294,0.353,0.412,0.471)
S3:Fair	F	(0.412,0.471,0.529,0.588)
S4:Medium Strong	MS	(0.529,0.588,0.647,0.706)
S5:Strong	S	(0.647,0.706,0.765,0.824)
S6:Very Strong	VS	(0.765,0.824,0.882,0941)
S7:Extremly Strong	ES	(0.882,0.941,1,1)

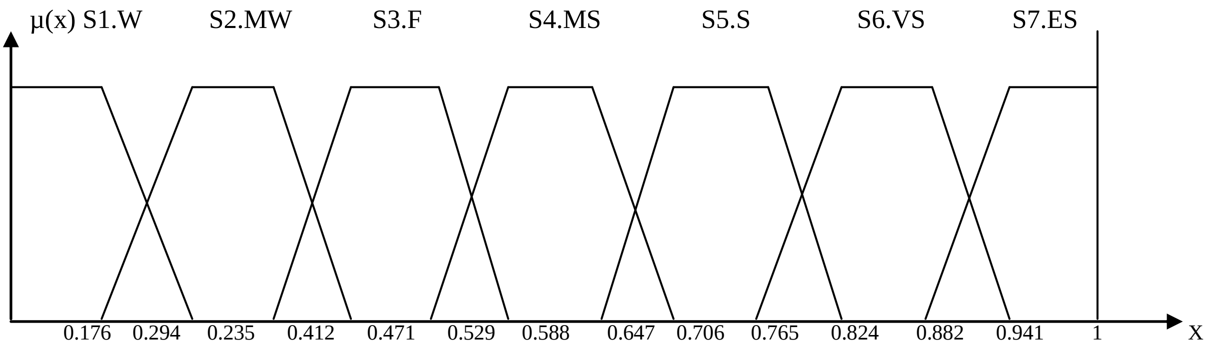

Fig. 2. Membership functions for a fuzzy set including seven variables.

Step 3: Collect expert fuzzy assessments

In this step to achieve TS system we decompose the Information system and proposed a NFR classification in [16].

We classify NFRs into three layers L1 (i=1, 2, 3…n) in Table 2.

Table 2 Classification of NFRs and their fuzzy assessment by DMs

NFRs(i=40) Primary Layer	DM1	DM2	DM3	DM4	DM5	W i-j
L1- Trustiness	F	W	MW	VW	F	3.588
L2- IS/safety	F	VS	ES	S	VS	3.901
L3- IS/Real	MS	S	F	MS	F	2.969
L4- IS/web	F	MS	S	VS	MS	3.322
L5- IS/Real/Web	S	ES	F	MS	ES	3.772
Secondary Layer						
L1-1 Provability	S	MS	F	VS	S	3.44
L1-2 Reusability	VS	S	S	MS	VS	3.793
L1-3 Standardizability	MS	VS	F	S	S	3.44
L1-4 Traceability	VS	MW	MS	F	VS	3.205

L1-5 Viability	MW	F	W	MS	F	2.269
Tertiary Layer						
L2-1 Reliability	S	MS	ES	S	ES	3.218
L2-2 Availability	VS	MW	F	ES	S	3.431
L2-3 Accuracy	VS	MS	MS	S	F	3.923
L2-4 Confidentiality	S	S	F	VS	ES	3.783
L2-5 Verifiability	F	MS	MS	S	F	2.969
L3-1 Interoperability	MS	W	F	F	MS	2.504
L3-2 Privacy	ES	S	MS	VS	ES	4.125
L3-3 Security	S	VS	ES	F	MS	3.665
L3-4 Performance	VS	ES	S	MS	F	3.665
L3-5 Usability	F	MS	S	MS	F	2.969
L3-6 Completeness	S	S	VS	F	S	2.823
L3-7 Maturity	F	F	MS	MW	W	3.058
L3-8 Compliance	MW	MW	F	MS	MW	1.909
L3-9 Confidentiality	ES	S	VS	MS	S	1.881
L3-10 Availability	S	MS	ES	S	S	3.165
L3-11 Access control	S	S	F	MS	VS	3.047
L3-12 Authentication	VS	F	ES	S	MS	2.587
L3-13 Integrity	S	F	F	VS	MS	3.048
L3-14 Learnability	MW	MS	MW	S	F	2.586
L4-1 Operability	W	S	F	MS	MS	3.047
L4-2 Ease of use	S	F	S	MS	MS	2.588
L4-3 Usefulness	W	VS	MS	F	F	2.116
L4-4 Productivity	F	ES	ES	S	VS	2.112
L4-5 Response time	VS	S	VS	F	ES	2.823
L4-6 Space	S	MS	VS	F	ES	2.241
L4-7 Capacity	MS	F	S	S	S	3.155
L4-9 Throughput	VS	S	F	S	VS	3.164
L4-10 Protected	ES	F	S	MS	VS	3.664
L4-11 Genuine	S	MS	F	F	S	3.087
L4-12 Bonafide	F	MS	S	F	S	3.085

Step 4: Apply L^{-1}, R^{-1} inverse function arithmetic principle and graded mean integration for the elicitation decision maker's weight

In this paper we apply L^{-1}, R^{-1} function arithmetic principal and graded mean method for the elicitation of decision maker's weight. A brief introduction is given below:
Let $A_1 = (a_1, b_1, c_1)$ and $A_2 = (a_2, b_2, c_2)$ be two trapezoidal fuzzy numbers as Fig. 1. The addition of A_1 and A_2 at h-level is:

$$A_{1(h)} \oplus A_{2(h)} = \left(L^{-1}_{A1(h)} + L^{-1}_{A2(h)}, L^{-1}_{A1(h)} + R^{-1}_{A2(h)}, R^{-1}_{A1(h)} + L^{-1}_{A2(h)}, R^{-1}_{A1(h)} + R^{-1}_{A2(h)}\right) \quad (1)$$

L_{A1} and R_{A1} are the functions L and R of fuzzy number A_1, respectively. $L^{-1}_{A1(h)}$ and $R^{-1}_{A1(h)}$ are the inverse functions of functions L_{A1} and R_{A1} at h-level, respectively. L_{A2} and R_{A2} are the functions L and R of fuzzy number A_2, respectively. $L^{-1}_{A2(h)}$ and $R^{-1}_{A2(h)}$ are the inverse functions of functions L_{A2} and R_{A2} at h-level, respectively.
Suppose the membership functions of $A_1 = (a_1, b_1, c_1)$ is

$$f_{A1}(x) = \begin{cases} \frac{(x-a_1)}{(b_1-a_1)}, a_1 \le x \le b_1, \\ \frac{(x-c_1)}{(b_1-c_1)}, b_1 \le x \le c_1, \\ 0, \quad otherwise. \end{cases} \quad (2)$$

Since

$$L_{A1}(x) = \frac{(x-a_1)}{(b_1-a_1)}, a_1 \le x \le b_1 \quad (3)$$

$$R_{A1}(x) = \frac{(x-c_1)}{(b_1-c_1)}, b_1 \le x \le c_1 \quad (4)$$

and

$$L^{-1}_{A1(h)} = b_1 + (b_1 - a_1)h, \quad 0 \le h \le 1,$$

$$R^{-1}_{A1(h)} = c_1 + (b_1 - c_1)h, \quad 0 \le h \le 1,$$

Similarly, suppose the membership function of $A_2 = (a_2, b_2, c_2)$ is

$$f_{A2}(x) = \begin{cases} \frac{(x-a_2)}{(b_2-a_2)}, \quad a_2 \le x \le b_2, \\ \frac{(x-c_2)}{(b_2-c_2)}, \quad b_2 \le x \le c_2, \\ 0, \quad otherwise. \end{cases} \quad (5)$$

Since

$$L_{A2}(x) = \frac{(x-a_2)}{(b_2-a_2)}, \quad a_2 \le x \le b_2, \quad (6)$$

$$R_{A2}(x) = \frac{(x-c_2)}{(b_2-c_2)}, \quad b_2 \le x \le c_2, \quad (7)$$

and

$$L^{-1}_{A2(h)} = a_2 + (b_2 - a_2)h, \qquad 0 \le h \le 1,$$

$$R^{-1}_{A2(h)} = c_2 + (b_2 - c_2)h, \qquad 0 \le h \le 1,$$

$$A_{1(h)} \oplus A_{2(h)} = \left(L^{-1}_{A1(h)} + L^{-1}_{A2(h)}, L^{-1}_{A1(h)} + R^{-1}_{A2(h)}, R^{-1}_{A1(h)} + L^{-1}_{A2(h)}, R^{-1}_{A1(h)} + R^{-1}_{A2(h)}\right)$$

$= [(a_1 + (b_1 - a_1)h) + (a_2 + (b_2 - a_2)h),\ (a_1 +$ $b1-a1h+ c2+b2-c2h,\ c1+b1-c1h+a2+b2-a2h,$ $c1+b1-c1h+c2+b2-c2h$.

According to equation 1, we have that
Second, we introduce briefly the graded integration representation method. Chen and Hsieh proposed the graded integration representation method of fuzzy numbers [10, 11, 12] based on the integral value of graded mean h-level of generalized fuzzy number. Here, we describe the meaning as follows.

In general, a generalized fuzzy number A is described as any fuzzy subset of the real line R, whose membership function u_A satisfies the following conditions.

(1). $\boldsymbol{u_A(x) = 0,\ -\infty < x \le c}$;

(2). $\boldsymbol{u_A(x)}$ **is strictly increasing on** $[\mathbf{c}, \mathbf{a}]$;

(3). $\boldsymbol{u_A(x) = w,\ a \le x \le b,\ where\ 0 < w \le 1}$;

(4). $\boldsymbol{u_A(x)}$ **is strictly increasing on** $[\mathbf{b}, \mathbf{d}]$;

(5). $\boldsymbol{u_A(x) = 0,\ d \le x \le \infty}$;

(6). $\boldsymbol{u_A}$ **is a continuous mapping from R to the closed** $[\mathbf{0}, \mathbf{1}]$;

Here a, b, c, and d are real numbers. We denote generalized fuzzy number A in Fig .1 as (a, b, c, d; $\boldsymbol{W_A}$) LR. When $\boldsymbol{W_A = 1}$. we simplify notation as A=(a, b, c, d) LR

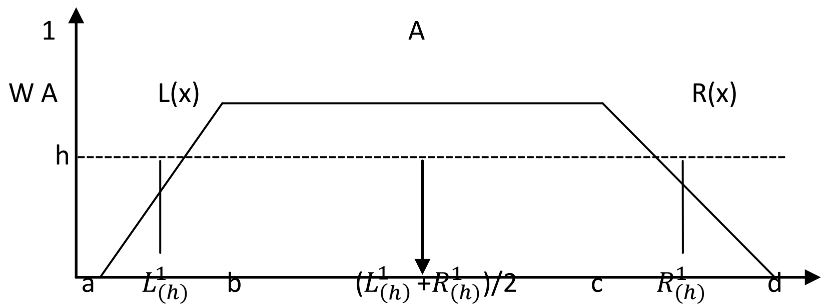

Fig 1.The graded mean h-level of fuzzy number A= (a, b, c, d; WA)$_{LR}$.

Let L^1 and R^1 be the inverse function of the functions L and R ,respectively ;then the graded mean h-level value of generalized number A is h $(L^1_{(h)} + R^1_{(h)})/2$ as shown in figure. Then the graded mean integration representation of A is

$$P(A) = \frac{\int_0^{wA} \left(h\left(L^{-1}_{(h)} + L^{-1}_{(h)}\right)/2\right) dh}{\int_0^{wA} h dh} \qquad (7)$$

$$P(A) = \frac{\int_0^{wA} (h(a + (b-a)h + d + (c-d)h)/2)\, dh}{\int_0^{wA} h dh}$$

$$= \frac{1}{6}(a + 2b + 2c + d) \qquad (8)$$

Here, a, b, c and d are numbers. We denote generalized fuzzy number A in Fig. 2 as A = (c, a, b, d)$_{LR}$. When $w_A = 1$, we simplify the notation as A = (a, b, c, d)$_{LR}$.

Generalized triangular fuzzy number K = (a, b, c, d) is a special case of generalized trapezoidal fuzzy number. The graded mean integration representation of the triangular fuzzy number Y becomes

$$TFN(K) = \frac{1}{6}(a + 2b + 2c + d) \qquad (9)$$

***Step 5*: Construct FQQSIG graph**.

In this step we construct FQQSIG graph .FQQSIG is an enhanced version of QSIG .In this step we assigned fuzzy linguistic variable i.e. we take a module of fees slip in this module we decomposes the NFRs through the prioritization till the last highest value by using fuzzy $L^{-1} - R^{-1}$ inverse linguistic variables function as shown in the Fig 4 the last attributes is completeness .After applying equation ,we have identify the weights of different measuring parameters ,i.e. we take an example performance VS=0.853,ES=0.960,S=0.735,MS=0.617,F=0.5 the final output in the figure is after normalized form. The normalized values (Fig. 4) are acquired by dividing the sum of all attributes values in the same layer; for example:0.14=2.82/(4.12+3.66+3.08+3.08+3.05+2.82).

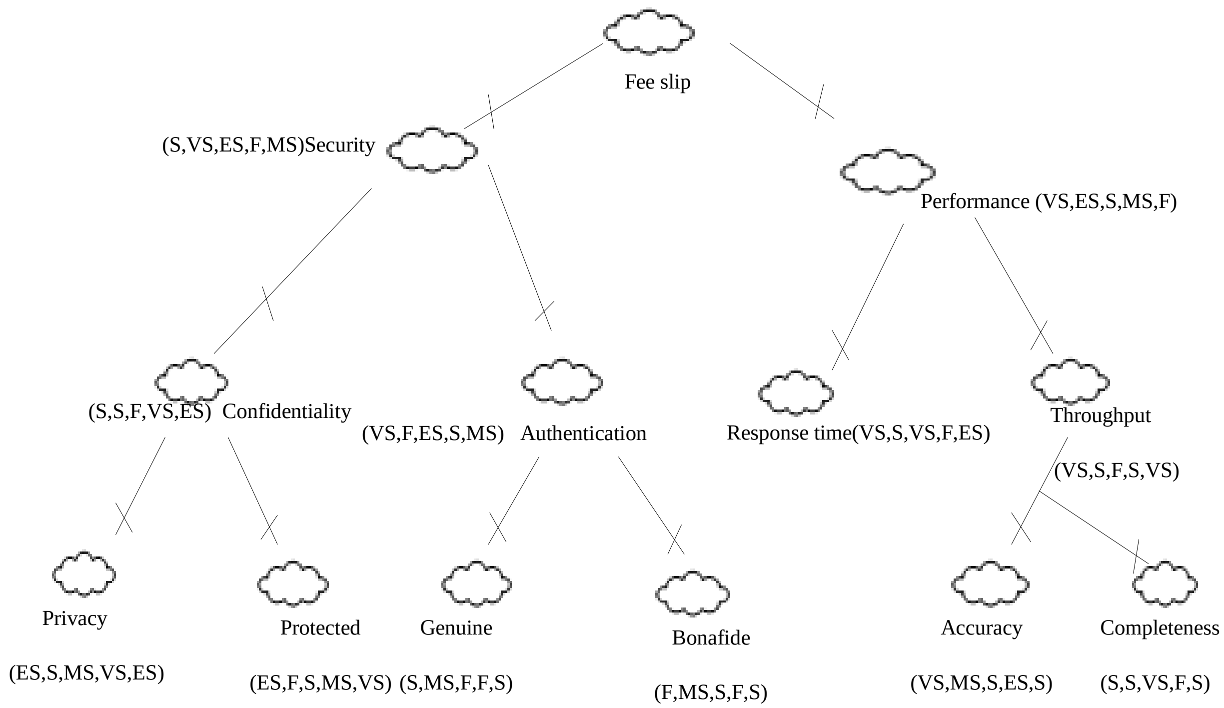

Fig 3.1.EFQQSIG

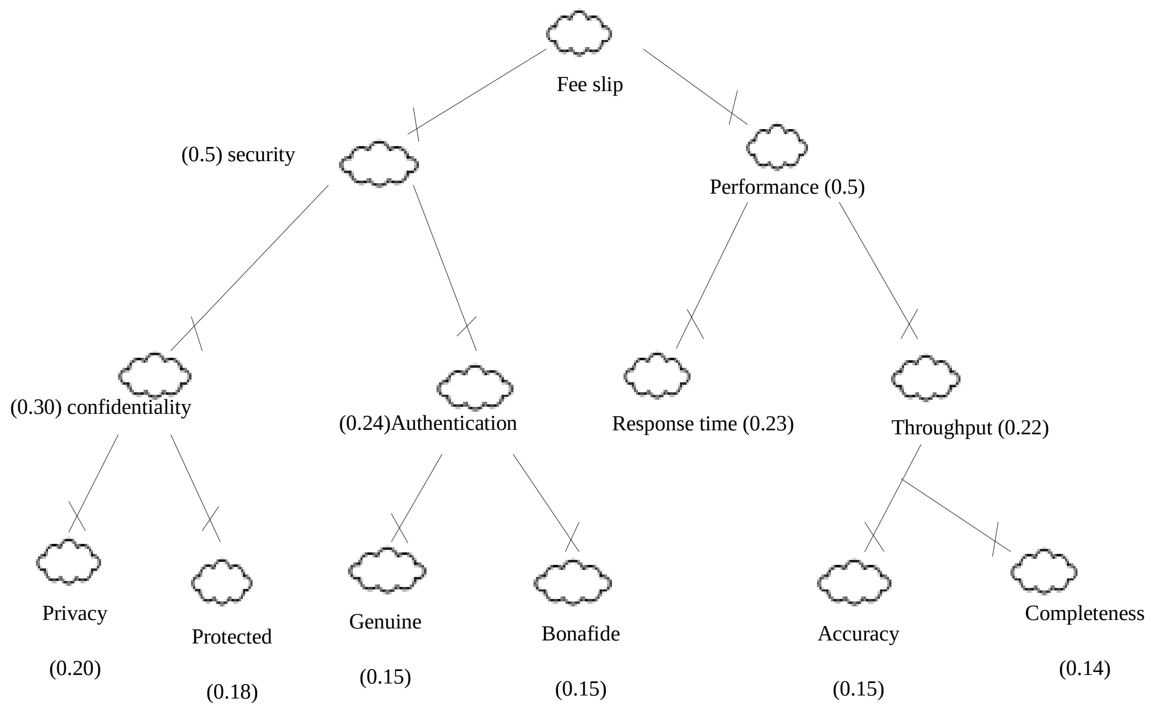

Fig. 3.2 .Normalized EFQQSIG

4. CONCLUSION AND FUTURE WORK

In this paper we present a method for prioritization of NFR using fuzzy linguistic variables when five decision maker involve in this process .The proposed method includes five step that is identifying stakeholders, decomposition of NFRs, collect experts fuzzy assessments, applying $L^{-1} - R^{-1}$ inverse function arithmetic principle and graded mean integration for the eliciting of decision makers weight and construct FQQSIG graph. In our case study we assume that five decision makers are involved in NFRs weight prioritization method. Future work includes:

1. To apply the proposed method in "Institute Examination System (IES)".
2. To strengthen the goal oriented elicitation process using proposed method.

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