Using Social Network and Fuzzy Set Theory for Elicitation and Prioritization of Software Requirements

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***Abstract*—Stakeholders' identification is one of the key activities of the software requirements elicitation process. In real-life applications, various stakeholders participate during the software development process and the information about these stakeholders is stored using social networks which can be used to identify the key stakeholders. Based on our review, we found that requirements elicitation and prioritization methods do not support the following: (a) social network-based approach for the analysis of the large set of stakeholders before the starting of the requirements elicitation process (b) dealing with imprecision and vagueness during the recommendation of stakeholders by other stakeholders so that large set of software requirements can be elicited and selected based on the ranking values. Therefore, to address these issues, this paper presents a method for software requirements elicitation and prioritization in which social network has been used to identify and analyze the key stakeholders and a fuzzy based method is applied for prioritizing the large set of software requirements. Finally, the applicability of the proposed method is discussed with the help of the software requirements of an institute examination system.**

***Index Terms*—Fuzzy logic, software requirements, social-networks, stakeholders.**

I. Introduction

The requirements engineering (RE) is one of the key parts of any software development process that specifies, analyzes, and defines the goal and limitations of the software product [1]. The problems related to software requirements (SRs), especially those requirements which are originating from insufficiencies in the human-intensive task of identification of the stakeholders' need and wants, have contributed to several failed and challenged software projects. It is true for large scale projects in which several stakeholders are involved during the requirements elicitation process. This process is a human intensive task in which several elicitation techniques such as traditional methods, goal-oriented methods, are used to elicit the requirements of a system according to the desires and wants of different types of the stakeholders. Despite the availability of several methods for requirements elicitation, various large-scale projects failed because of the scaling up the requirements process [2]. A small-scale project contains 15 requirements; on the other hand, a large-scale project contains the more than 50 requirements [3], [4]. The documentation of the SRs has a great impact on the quality of the final software product. RE can be defined as a series of five sub-processes like requirements elicitation, requirements modeling, requirements analysis, and requirements management. Among these sub-processes, requirements elicitation is the key activities of software development and imperfect execution of the requirements elicitation may lead to the failure of software [3].

The requirements elicitation process can be improved only when the stakeholders have been identified and analyzed correctly [4]. At this time, the relationship between the development team, requirements analyst, and other stakeholders are established. In spite of the importance, the stakeholders and their relationships are poorly achieved during the software development projects. The relationships among the stakeholders are established using social network graph (G) in which nodes (N) and edges (E) represent the stakeholders and their relationships, respectively [5]. The information of a graph G is stored in computer's memory using adjacency matrix of size $N \times N$, in which $a_{ij} = 1$, if there exists a path from N_i to N_j; on the other hand, $a_{ij} = 0$, if there is no path. The social network of eleven stakeholders is given in Fig. 1.

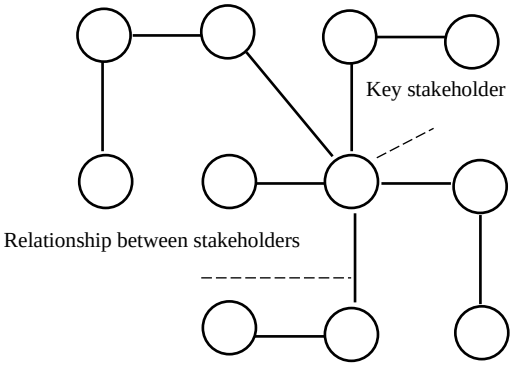

Fig. 1. Social network of stakeholders.

In Fig. 1, nodes represent the stakeholders (S). The key stakeholders can be identified by computing its degree. For example, the degree of key stakeholder in Fig. 1 is 5. In real life applications, several stakeholders participate during the requirements elicitation process and they may use the linguistic variables instead of crisp numbers for the evaluation of the requirements [1], [3]. It is an important issue how to deal with the large set of stakeholders and their requirements under fuzzy environment. Based on our literature review, we found that existing methods of requirements elicitation and prioritization do not support the

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following:

1) Social network-based approach for the identification of key stakeholders from the large set of stakeholders before the beginning of the requirements elicitation process
2) Dealing with the imprecision and vagueness during the recommendation of stakeholders by other stakeholders so that large set of software requirements can be elicited and prioritized

To address the above issues, this paper presents a method for SRs elicitation and prioritization in which social network has been used to identify and analyze the key stakeholders and a fuzzy based method is applied for prioritizing the large set of SRs. This work makes the following contributions:

1) A method has been proposed for the elicitation and prioritization in which social network and fuzzy set theory are applied to deal with the large set of SRs
2) A systematic methodology has been used to analyze the large set of stakeholders in which the confidence value is used for the recommendation of stakeholders
3) The applicability of the proposed method is discussed with the requirements of an institute examination system (IES)

The remaining part of this paper is organized as follows: Section II presents the related work on software requirements elicitation and prioritization with main emphasis on the stakeholders' analysis. The proposed method for the requirements elicitation and prioritization using social network and fuzzy set theory is discussed in Section III. The application of the proposed methodology to deal with large stakeholders and large set of software requirements is discussed in Section IV. The comparative study between the proposed methodology and other selected methodologies is discussed in Section V. Finally, the conclusion and suggestions for future work are discussed in Section VI.

II. Related Work

Several methods have been developed for the elicitation and prioritization of SRs. For example, Pereira and Soares [6] developed a method for organizational analysis so that the quality of requirements of an information system can be improved. In their work, the authors have used social network for the refinement, classification, and prioritization of the requirements. Lim *et al*. [7] developed a web-based tool, i.e., StakeSource, to automate the stakeholder's analysis in which a stakeholder can recommend another stakeholder according to the need of the project. In StakeSource [7], the information about the stakeholders is captured using social network analysis. In another study, Lim and Finkelstein [8] developed a method using social networks for dealing with large-scale requirements elicitation in which collaborative filtering was used for the recommendations of the stakeholders. This method is referred to as StakeRare method [8] and it was evaluated for a 30, 000 user systems. Based on the survey and interview of 87 stakeholders, it was found that the StakeRare method predicts the stakeholders more accurately and produces the complete and more correct list of the requirements.

Damian *et al*. [9] focused on the requirements gathering process in the context of the global software development. Ahmad *et al*. [10] developed a fuzzy based MoSCoW method for prioritizing the requirements of library management system (LMS). In a recent study, Sadiq and Devi [11] proposed a method for the prioritization and selection of the SRs using rough set theory. In another work, Sadiq and Devi [12] developed a fuzzy-soft set-based method for the prioritization of the requirements of an institute examination system. Sadiq [4] proposed a method for stakeholders' prioritization based on the importance of the SRs. Mohammad *et al*. [13] proposed a method for software requirements analysis using multiple stakeholders in which fuzzy attributed values were used for the selection of the requirements. Sadiq *et al*. [14] have also discussed the importance of stakeholders during the elicitation of the security requirements. The social networks-based RE approaches overcome the limitations of traditional RE. Seyff *et al*. [15] focused on the end users and proposed a method using social networks for elicitation, prioritization, and negotiation of software requirements. Motivated by the work of Lim and Finkelstein [8], Tanveer *et al*. [5] developed a StakeSoNet method for the identification and analysis of stakeholders in which linguistic variables were used to capture the opinions of stakeholders. In [5], the social network was used to identify the key stakeholders so that the requirements of software can be identified. The aim of the present work is to elicit and prioritize the large set of SRs in which social network is used to analyze and identify the key stakeholders and the fuzzy set theory has been used to deal with the imprecision and vagueness during the decision-making process.

III. Proposed Method

The aim of this section is to discuss the method for the elicitation and prioritization of SRs. The block diagram of the proposed method is exhibited in Fig. 2. The proposed method includes the following steps: (1) Identify the initial set of stakeholders and their roles, (2) Construct the social network of stakeholders, (3) Elicitation of SRs for large scale project, and (4) Fuzzy based approach for the prioritization of SRs. The explanation of the steps of the proposed method is given below:

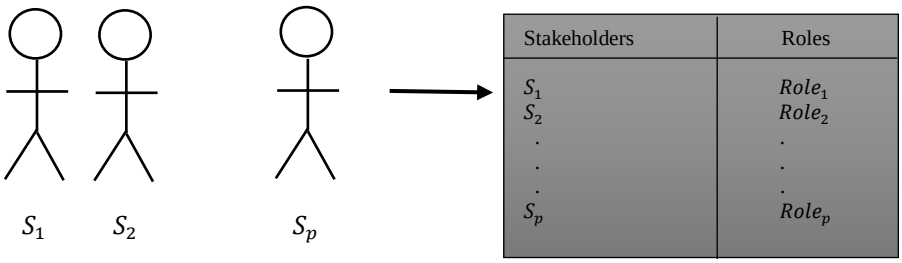
Step 1: Identify the initial set of stakeholders and their roles

The aim of this step is to find the preliminary set of stakeholders (S), i.e., $< S_1, S_2, \ldots, S_p >$ according to the need of the project. Different types of the stakeholders are involved in any software project. The project scope is discussed with the preliminary set of stakeholders; and as a result, these stakeholders can recommend the other stakeholders so that other stakeholders according to their roles can be identified. The recommendation about the new stakeholder for the project is represented by the following quaternion:

$< recommended\ by, stakeholder\ after\ recommendation, stakeholders\ role, confidence >$

All the preliminary set of stakeholders participates in group elicitation process to introduce the name of the new stakeholders according to the need of the project. For example, S_1recommends a new stakeholder, i.e., S_2. The role of S_2 is cost and benefit analysis of the project. The S_1 has high confidence on the recommended stakeholder. This information will be represented as:

$< S_1, S_2, cost\ and\ benefit\ analysis, high >$

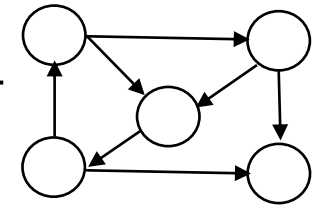


Step 1: Initial set of stakeholders (S)

Stakeholders	Roles
S_1	$Role_1$
S_2	$Role_2$
.	.
.	.
.	.
S_p	$Role_p$

Stakeholders and their roles

Stakeholders group	Goals
StG_1	G_1
StG_2	G_2
.	.
.	.
.	.
StG_t	G_t



Step 2: Social network of stakeholders

Clustering of functional goals (FG) and non-functional goals (NFGs)

Recommend the stakeholders in a group using collaborative filtering based on goals

Step 3: Elicitation of requirements for large scale project

Elicitation of functional requirements and non-functional requirements using goal- oriented concepts

Step 4: Ranking of requirements

Functional requirements (FRs)	FR_1	FR_2	...	FR_z
Ranking values ($RVal$)	$RVal_1$	$RVal_2$	...	$RVal_z$

Fig. 2. Block diagram of the proposed method.

This type of information for the new stakeholders can help the requirements analysts to construct the social network of stakeholders so that the key stakeholders can be identified after applying the social network measures. The *confidence* value is the linguistic variable because in real life applications stakeholders use linguistic variables to specify their preferences during the decision-making process.

Step 2: Construct the social network for the stakeholders

The identified stakeholders are selected on the basis of their roles and responsibility. The social network of the selected stakeholders is constructed to classify the stakeholder's using centrality measures of social networks based on the following: (i) stakeholders who have high influence and high interest in the project (ii) stakeholders who have high influence and less interest in the project (iii) stakeholders who have less influence and high interest in the project, and finally, (iv) stakeholders who have less influence and less interest in the project. The degree centrality and closeness centrality measures of social networks have been used for the classification of the stakeholders [16]. The degree centrality is used to identify the connected and most influential stakeholders who hold most of the information about the project. Suppose the information of the stakeholders is stored using the adjacency matrix $AdMat = (a_{ij})$. The degree centrality ($DegCent$) can be calculated using the following equation:

$$DegCent\ (x) = \sum_{i=1}^{n} a_{ix} \quad (1)$$

The closeness centrality ($ClosCent$) of a stakeholder specifies how a stakeholder is adjacent to all other

stakeholders. It can be calculated as:

$$ClosCent(x) = \frac{1}{\sum_{i=1}^{n} dist(x,i)} \quad (2)$$

where, $dist(x,i)$ is the distance between the stakeholder x and other stakeholders in the stakeholder network. The lesser value of $ClosCent$ of a stakeholder designates the more central stakeholder.

Step 3: Elicitation of software requirements for large scale project

In this step, the traditional method of requirements elicitation is used for gathering the goals of the stakeholders. The unsupervised clustering is used to cluster the functional goals (FGs) and non-functional goals (NFGs). The collaborative recommendation system is then used to recommend the stakeholders in the groups based on the similar interest. For example, few stakeholders want to develop an economic system then these stakeholders will be grouped in one cluster, i.e., development of economic system. The objective of creating such groups is to refine and decompose the requirements using goal-oriented method so that functional requirements (FRs) and non-functional requirements (NFRs) from FGs and NFGs can be identified for large scale projects [1], [17].

Step 4: Fuzzy based approach for the prioritization of software requirements

In real life applications, linguistic variables are used in SRs prioritization process to capture the opinions of the stakeholders about the requirements. The notion of fuzzy logic was introduced by Lotfi A. Zadeh in 1965 as a mathematical tool which allows intermediate values between TRUE/FALSE, YES/NO, HIGH/LOW, etc. Fuzzy sets are used to develop the fuzzy systems for representing and manipulating the imprecise and uncertain information [18].

Fuzzy logic is a multivalued logic and it is used to deal with uncertainty which is due to vagueness. On the other hand, probability is used to deal with uncertainty which is due to randomness. The fuzzy sets were introduced to overcome the limitations of the crisp sets. The fuzzy sets are used as a tool to define control rules and to make inferences.

Let X be an ordinary set. A mapping M from X into the unit interval [0,1] is called a fuzzy set on X. The value $M(x)$ of M in $x \in X$ is called the degree of membership of x in M. The set of all elements having nonzero degree of membership in M is called the support of $M, i.e.,$

$$supp\ (M) = \{x | x \in X \text{ and } M(x) > 0\} \quad (3)$$

The set of elements that completely belong to M is called the Kernel of M, i.e.,

$$\ker(M) = \{x | x \in X \text{ and } M(x) = 1\} \quad (4)$$

The aim of this step is to prioritize the elicited requirements using "canonical representation of multiplication operation" associated with L^{-1} R^{-1} inverse arithmetic principle and the "graded mean integration representation" using triangular fuzzy numbers (TFNs) [19].

Let $B_1 = (c_1, d_1, e_1)$ and $B_2 = (c_2, d_2, e_2)$ be two TFNs, as shown in Fig. 3.

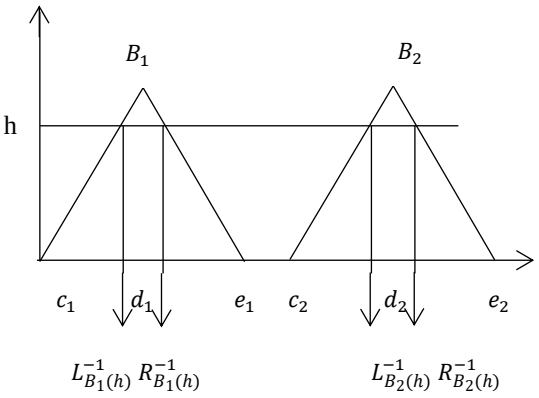


Fig. 3: Representation of B_1 and B_1

Here,

$$L_B(x) = \frac{x-c}{d-c},\ c \le x \le d,$$

and

$$R_B(x) = \frac{x-e}{d-e},\ q \le x \le e;$$
$$L_B^{-1}(h) = c + (d-c)h$$

and

$$R_B^{-1}(h) = e + (d-e)h \quad 0 \le h \le 1$$

Here, $L_B(x)$ and $R_B(x)$ are the function L and R of the fuzzy number B, respectively. The inverse functions of $L_B(x)$ and $R_B(x)$ at level h is represented as $L_B^{-1}(x)$ and $R_B^{-1}(x)$, respectively. The multiplication of B_1 and B_2 at h-level can be computed as [19]:

$$B_1(h) \times B_2(h) = (L^{-1}_{B_1(h)}L^{-1}_{B_2(h)}, L^{-1}_{B_1(h)}R^{-1}_{B_2(h)}, R^{-1}_{B_1(h)}L^{-1}_{B_2(h)}, R^{-1}_{B_1(h)}R^{-1}_{B_2(h)} \quad (5)$$

The graded mean integration representation of B_1 and B_2 at h-level is given as follows:

$$P(B_1 \times B_2) = \int_0^1\int_0^1\int_0^1 \left[\left(h_{B_1}L^{-1}{}_{B_{1(h)}}\right)\left(h_{B_2}L^{-1}{}_{B_{2(h)}}\right) + \left(h_{B_1}L^{-1}{}_{B_{1(h)}}\right)\left(h_{B_2}R^{-1}{}_{B_{2(h)}}\right) + \left(h_{B_1}R^{-1}{}_{B_{1(h)}}\right)\left(h_{B_2}L^{-1}{}_{B_{2(h)}}\right) + \left(h_{B_1}R^{-1}{}_{B_{1(h)}}\right)\left(h_{B_2}R^{-1}{}_{B_{2(h)}}\right)\right] \times \frac{h_{B_1B_2}dh_{B_1}dh_{B_2}dh_{B_1B_2}}{\int_0^1 h_{B_1}dh_{B_1}\int_0^1 h_{B_2}dh_{B_2}\int_0^1 h_{B_1B_2}dh_{B_1B_2}} \quad (6)$$

After simplification, following equations is employed to calculate the ranking order of the FRs based on the NFRs:

$$P(B_1 \times B_2) = \left(\frac{c_1+4d_1+e_1}{6}\right) \times \left(\frac{c_2+4d_2+e_2}{6}\right) \quad (7)$$

IV. Case Study

In the literature of software engineering and requirements engineering different systems have been employed as a part of the case studies like (a) institute examination system (IES),

(b) ambulance dispatching system, (c) online national election voting systems, (d) library management system, and (e) Mobee: a system for public transport [20]. In our work, the steps of the proposed method are explained with help of the requirements of an IES.

Step 1: Identify the initial set of stakeholders and their roles

In this study, following preliminary stakeholders for an IES have been identified, i.e., Director of an Institute or Head of the Department (S_1), Financer (S_2), and Controller of Examinations (S_3). The project scope is discussed with the preliminary set of stakeholders; and as a result, these three stakeholders recommend the other stakeholders so that the new list of stakeholders according to their roles can be identified.

The stakeholder S_3 recommended the name of one of the companies for the development of the IES. For example, S_3 recommend new stakeholder S_4 "*Bakewarr Software Solutions*" (BSS), New Delhi, India, for the development of an IES. The BSS is the group of engineers and researchers which deal with the research training, industrial training, executive education, and software development. This is the new startup in the field of Information Technology and Systems. The recommendation about this new stakeholder for the project by stakeholder S_3 is represented by the following quaternion:

$$< S_3, S_4 \ from \ BSS, Development \ of \ an \ IES, Very \ High >$$

The stakeholder S_4 recommends the stakeholder S_5 for the elicitation and analysis of the requirements of an IES and stakeholder S_6 for the estimation of the cost of IES. The same procedure was adopted to get the complete list of the stakeholders according to the scope of the project.

Step 2: Construct the social network of the stakeholders

Finally, 23 stakeholders were identified for the elicitation of the SRs. The relationship among the stakeholders based on their roles and responsibilities are represented by social network diagram of stakeholders, as shown in Fig. 4. To identify the influential stakeholder, the $\boldsymbol{DegCent}$ of each stakeholder using Eq ($\mathbf{1}$) was computed; and it is found that stakeholder $\boldsymbol{S_5}$ is the most influential stakeholder and it has more interest in the project.

Step 3: Elicitation of software requirements for large scale project

A form was designed to collect the requirements of an IES and the name of the stakeholders, see Fig. 5. This form was distributed to more than 100 participants which includes Ph.D. scholar, M. Tech, and working professionals. These participants are working in Delhi/NCR region, India. The data obtained from the participants were tested for reliability using IBM-SPSS statistical tool. The data are obtained based on five-point fuzzy scale, i.e., Very High (VH), High (H), Medium (M), Low (L), and Very Low (VL). The Cronbach's alpha (C_{alpha})value was computed for the data and it is found that the value of $C_{alpha} = 0.75$. The value of $C_{alpha} = 0.6$ designates the high reliability and uniformity of data [21]. The aim of this step is to elicit the SRs of an IES using goal-oriented methodology [1]. To elicit the requirements, the AND/OR graph was constructed to visualize the different types of the SRs, i.e., FRs and NFRs. After completing the requirements elicitation process, we have identified 119 requirements of the IES, as shown in Fig. 6. The elicited requirements were clustered using K-means clustering to identify the group of FRs and NFRs. We have developed a program using Python to cluster the FRs and NFR; and the results are exhibited in Fig. 7. As a result, we have identified three cluster of the FRs based on six NFRs as shown by red color (cluster-1), yellow color (cluster-2) and cyan color (cluster-3). The opinions of the stakeholders about the FRs and NFRs were captured using the following linguistic variables:

- Very High (VH)
- High (H)
- Medium (M)
- Low (L)
- Very Low (VL)

It is then used as an input for computing the ranking order of the FRs based on the NFRs, i.e., Security: NFR1, Performance: NFR2, Cost: NFR3, Usability: NFR4, Reliability: NFR5, and Maintainability: NFR6.

Step 4: Fuzzy based approach for the prioritization of software requirements

Based on the results of Fig. 7, it is clear that in the first cluster only five NFRs are used. These NFRs are used during the computational process. To compute the ranking order of the FRs following TFNs are used: VL$= (0,0,0.25)$, L $= (0,0.25,0.5)$, M $= (0.25, 0.5, 0.75)$, H $= (0.5, 0.75,1)$, and VH $= (0.75, 1,1)$. The opinions of the stakeholders for FR1, i.e., login module of an IES, based on five NFRs, NFR1, NFR2, NFR3, NFR4, and NFR5, is exhibited in Table I.

In Table I, the stakeholder S_1 evaluated the FR1 and found that FR1 should be more secure (VH) and the performance of this requirement should be high (H). The cost of FR1 is high (H) because more security is required at the time of the implementation. It should be usable so that FR1 can be used by different users efficiently. The requirement FR1 need high (H) maintainability since different users wants to access the system using FR1. These opinions are stored in Table I. Similarly, the remaining 22 stakeholders evaluated the FR1 based on five NFRs, i.e., NFR1, NFR2, NFR3, NFR4, and NFR5; and the results are exhibited in Table I. After that, the Eq. (7) is used to compute the ranking values of FR1 based on the five NFRs. After applying the Eq (7), it is found that ranking value of FR1 is 26.02. The same procedure was adopted to compute the ranking values of all the clusters. Based on the ranking values, the developer can select top t FRs [22]. In our case, we select top ten ($t = 10$) FRs for the implementation in the first release of software. The list of the top ten requirements is given below: FR1: Login module of examination systems, FR2: Deposit examination fee, FR3: Generation of the detained students based on attendance, FR4: Generation of hall ticket for end semester examination, FR5: Fill examination form, FR6: Enter the marks of students, FR7: List of backlog papers of students, if any, FR8: Conducting

the mid and end-semester examinations in online mode due to COVID-19 pandemic, FR9: View results of end semester examination, and to examination activities. FR10: Legal requirements related to examination activities.

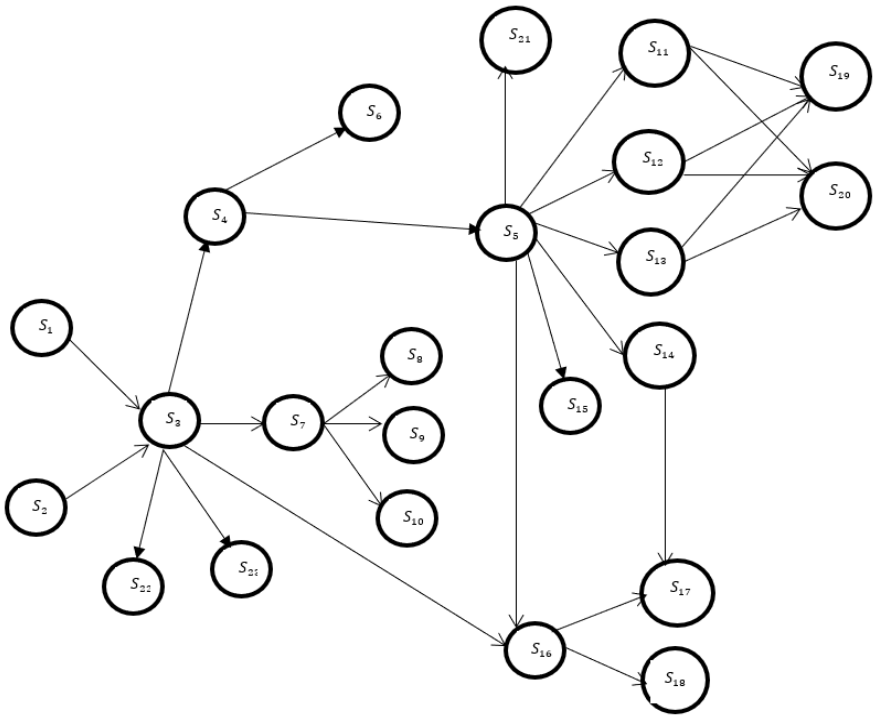


Fig. 4. Social Network of Stakeholders.

Stakeholder suggestion form for IES project

Place of survey/Interview: Bakewarr Software Solutions, New Delhi-25, India

Part-A

1. Name of the stakeholder: ----------
2. Place of study or work: ----------
3. Name of the Institution/University or company: ----------

Part-B

1. Have you worked earlier on any Information system-based projects in your Institution/University or company? If yes, what was your role in that project?
2. Below is summarized the goals of IES project which have been identified by using goal-oriented techniques:
   - Login from of IES project
   - Student module, teachers' module, and administrative module
   - News related to examination activities,
   - The IES should be secure and cost effective
   - The performance of IES project should be high and it should be scalable

Which goal you can achieve from the above-mentioned goals? If you are not comfortable with the above goal(s), can you suggest the other stakeholder with confidence value, i.e., Very high, High, Medium, Low, and Very low

3. Name of the newly suggested stakeholder(s) with confidence value: Very high, High, Medium, Low, and Very low ***(Tick any one)***
4. Name of the requirement that should be the part of an IES after the implementation.

Fig. 5. The software requirements and stakeholder suggestion form.

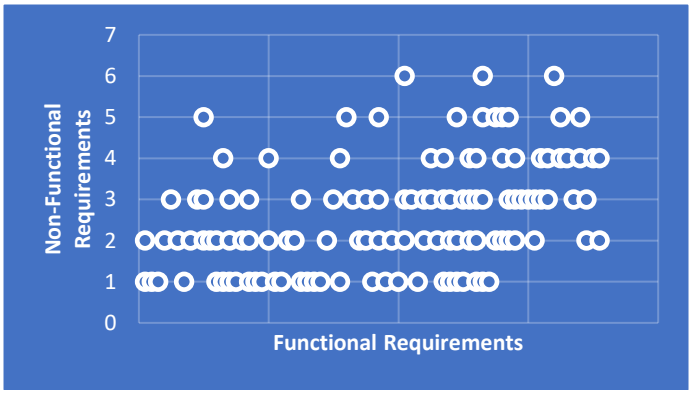


Fig. 6. Representation of FRs and NFRs.

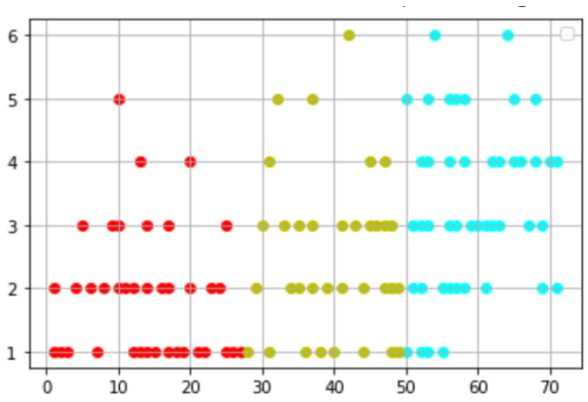


Fig. 7. Clustering of FRs and NFRs.

TABLE I: EVALUATION OF FR1 BASED ON NFRS BY TWENTY-THREE STAKEHOLDERS

Stakeholders	NFRs				
	NFR1	NFR2	NFR3	NFR4	NFR5
Director of an Institute or Head of the Department (S_1)	VH	H	H	M	H
Financer (S_2)	H	H	H	VH	H
Controller of Examinations (S_3)	VH	VH	H	M	H
Director from Bakewarr Software Solutions, New Delhi, India (S_4)	M	H	M	H	H
Requirements analysts (RA) (S_5)	VH	H	H	M	H
Cost Estimation (S_6)	VH	M	H	H	H
Assistant Controller of Examinations (S_7)	H	VH	H	H	H
Head (S_8)	M	H	VH	H	H
Faculty (S_9)	H	H	H	M	H
Students (S_{10})	VH	H	H	H	H
RA for Teacher Module (S_{11})	H	M	H	M	H
RA for Student Module (S_{12})	H	H	H	VH	H
RA for Administrative Module (S_{13})	VH	H	H	M	H
Graphics User Interface (S_{14})	H	H	M	H	H
RA for Legal Requirements (S_{15})	H	H	VH	M	M
Developer (S_{16})	VH	H	VH	M	H
Database Administrator (S_{17})	VH	M	H	H	H
Tester (S_{18})	H	M	M	M	H
RA for NFRs (S_{19})	VH	M	H	M	H
Interface Designer (S_{20})	H	H	H	H	H
Requirements Modeler (S_{21})	VH	H	H	H	H
Software Developer from Infosys, Jaipur, India (S_{22})	H	M	H	M	H
Software Developer from HCL, Noida, India: (S_{23})	M	M	H	M	H

V. COMPARATIVE STUDY

The aim of this section is to compare the proposed method with some selected methods [3, 8, 10] based on the following criteria: C1: Type of requirements elicitation technique, C2: Is there any support of recommendation systems during requirements elicitation? (Yes/No), C3: Is there any support of multicriteria decision making (MCDM) method during the selection and prioritization of requirements (Yes/No), C4: Type of data used for the analysis (crisp, fuzzy, and rough data), and C5: Size of project (small set/medium set/large set of requirements), and C6: System used for the analysis. The results after the comparison are summarized in Table II. Based on the comparative analysis, it is found that goal-oriented methods are widely used to elicit the requirements of software. Sadiq and Devi [3] developed a method for the selection of the large set of SRs. The rough-set theory was employed to compute the ranking values. In their work, goal-oriented and traditional methods were used for the elicitation of the requirements of an IES. In [3], there was no application of the recommendation systems for the recommendation of the SRs during the requirements elicitation process. In their work, the MCDM method was used for the selection of SRs. Ahmad *et al*. [10] developed a MoSCoW approach under fuzzy environment for the requirements prioritization. The goal-oriented method was used for the elicitation of the requirements of library management systems (LMS) and small dataset was used in the experimental work. This method supports fuzzy MCDM method during the prioritization of the SRs; and there is no support of the recommendation systems during the requirements elicitation process. Lim and Finkelstein [8] developed a StakeRare method to deal with the large set of software requirements using social networks and collaborative filtering. In StakeRare method [8], the crisp data was used for the analysis of the requirements of "*Replacement Access, Library and ID Card*" (RALIC) project and the traditional method was employed for the elicitation of the requirements of RALIC. The StakeRare method [8] does not support the MCDM approach during the selection of the requirements. One of the limitations of the StakeRare method [8] was that crisp values have been used during the experimental work. But in real life, stakeholders may use linguistic variables to specify the preference of the requirements. In [8], the main focus was on large number of stakeholders rather than on the large set of requirements. In [3] the main focus was on the methodology used for computing the ranking values using rough-data and no clustering approach was used to group the FRs and NFRs. In their work, the less attention was given on the analysis of the stakeholders. In the proposed method the traditional technique has been used to understand the background of the IES. After that the goals of the stakeholders are decomposed and refined using AND/OR graph. The K-means clustering is used to cluster the FRs and NFRs. In the proposed method, social network of stakeholders is analyzed to identify the key stakeholders based on the influence and interest in the project; and the fuzzy based approach is used to compute the ranking values of the requirements of an IES.

TABLE II: COMPARATIVE STUDY

S. No	Authors/Year	Criteria					
		C1	C2	C3	C4	C5	C6
1.	Sadiq and Devi [3]/2021	Goal oriented and traditional method	No	Yes	Rough data	50	IES
2.	Ahmad *et al*. [10] /2017	Goal oriented method	No	Yes	Fuzzy data	10	LMS
3.	Lim and Finkelstein [8]/2012	Traditional method	Yes	No	Crisp data	23	RALIC
4.	Proposed method	Goal oriented and traditional method	Yes	Yes	Fuzzy data	119	IES

VI. Conclusion and Future Work

This paper presents a method for the elicitation and prioritization of large set of requirements of an IES. In the proposed method, the stakeholders are analyzed using social network and the fuzzy-set theory is used to model the linguistic variables used by the stakeholders during the evaluation of the FRs based on the NFRs. The traditional and goal-oriented method have been used to identify the requirements of an IES and as a result we have identified 119 requirements from 23 stakeholders. These requirements are grouped into three clusters having different set of requirements with the objective to identify those FRs and NFRs that will be used during the decision-making process. After applying the L^{-1} R^{-1} inverse arithmetic principle and the "graded mean integration representation", it is identified that the ranking value FR1 is 26.02. The top ten FRs of an IES was selected for the implementation based on the ranking values of all the requirements.

One of the limitations of our work is that only one project, i.e., IES, has been considered for the evaluation and less attention is given on the analysis of the NFRs of the IES. To address these issues, in our future work, we shall evaluate the proposed method on some other real life case studies like RALIC, online national election voting systems, etc., by giving the more attention on the NFRs during the evaluation process.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All the authors have equal contributions; and all authors have approved the final version.

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