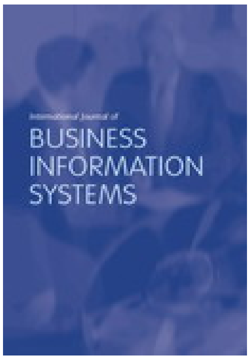

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Selection of goals with incomplete linguistic preference relations

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Abstract: In goal oriented requirements elicitation process (GOREP), the requirements of the stakeholders are refined and decomposed using AND/OR graph. Goal is a high level objective of a company which is refined and decomposed into sub-goals. After refinement and decomposition, a system may have several goals and it is not possible to implement all goals because of the time, budget, and other constraints of an organisation. It is a primarily research issue that how to select those goals that would be designed, implemented and tested during different phases of the software development process. On the basis of our review, we found that there is no support for the selection of goals in GOREP when preference relations are incomplete and the preferences of the decision-makers are represented by linguistic variables. Therefore, to address this research issue, we present a method for goal selection when linguistic preference relations are incomplete. Proposed method was applied to select the goals of the institute examination system.

Keywords: software goal selection; decision-making process; institute examination system; incomplete linguistic preference relation.

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1 Introduction

Information technology (IT) is the study of computers and telecommunications for storing, retrieving, and manipulating data and information in the context of business or an organisation. IT has an influence on decision making process and has been used to develop the decision support systems in the following areas (Awasthi and Verman, 2003; Li et al., 2007; Basar et al., 2017; Rao et al., 2017), i.e.:

a locating bank branches

b supplier selection problem

c facility location problem

d software requirements selection problem, etc.

For example, Basar et al. (2017) proposed a ‘decision support methodology for locating bank branches’. Rao et al. (2017) proposed a method for ‘supplier selection under sustainability’. IT creates different types of the electronic storage system, decision support systems to protect the valuable records of a company. These systems may have several goals, for example, 10, 25, 50 or more recommended by the stakeholders; and it is burdensome to select the goals that contribute the most to develop the successful software product (Aurum and Wohlin, 2003; Karlsson et al., 2007).

Goal-oriented requirements engineering (GORE) is used to identify the goals from the high level objective of an organisation. The concept of GORE has been used for eliciting the testing requirements (Sadiq and Nazneen, 2019), identifying the quality of web applications (Chawla et al., 2017), eliciting the requirements for IoT (Ferraris and Fernandez-Gago, 2020), etc. Keeping in view the importance of GORE, Ghasemi and Amyot (2020) performed a systematic literature review on *from event logs to goals*. In another study, Horkoff et al. (2019) performed a systematic mapping on GORE. In GORE, the high level objective of an organisation are refined and decomposed into sub-goals. A system may have several goals after refinement and decomposition of goals; and the selection of goals from the list of goals is an important research problem in the area of GORE when several stakeholders participate during decision-making process. Therefore, it motivates us to work in the area of goals selection.

Software requirements are identified from the selected software goals with the help of the software *requirements elicitation* techniques so that a successful software product can be developed for an organisation (Potts, 1995; Hickey and Davis, 2003). Requirements elicitation is employed to elicit the need of the clients. There are different methods which are used to elicit the software goals and software requirements like *traditional methods*, *cognitive method*, *group elicitation methods* and *contextual methods* (Hickey and Davis, 2003; Sadiq and Jain, 2015). These methods are used to identify or elicit the goals of the stakeholders. These goals are further refined and decomposed with the help of goal oriented methods to get the software requirements. The output of the requirements elicitation techniques are the list of the different types of the goals and requirements like *functional goals/requirements*, *non-functional goals/requirements*, *security goals/requirements* and *testing goals/requirements* (Hickey and Davis, 2003; Sadiq and Nazneen, 2019).

Every IT company wants to produce a successful software system so that the need of their clients can be satisfied. But in reality, different stakeholders participate during different phases of the software development; and each stakeholder has different opinion for the same software goal/requirements (Sadiq and Jain, 2015). Therefore, it is difficult task to acquire the highest degree of consensus among the stakeholders for the selection of goals (Sadiq and Jain, 2015). Software goals are broadly divided into 'functional goals' (FG) and 'non-functional goals' (NFG); and from these goals other types of the goals are identified like security goals, testing goals, etc. FG describes the functionality of software or 'what the system is supposed to do'. On the other hand, NFG describe the non-behavioural aspects of the system or 'how the system is supposed to be'. Software goal selection (SGS) problem can be defined as "a decision problem with several FGs and the group of stakeholders or decision makers whose objective is to achieve a common solution taking into account their preferences". In SGS problem, FGs are selected on the basis of the NFGs. In software engineering, NFGs are used as criteria for the selection of FGs (Sadiq and Jain, 2015). Selection and prioritisation of software goals is a key research issue in the area of software engineering, IT and decision making (Sadiq and Jain, 2015).

The problems related to the software goals and software requirements have been with us for a long time. Research in requirements engineering (RE) and GORE have received lot of recognition in academia as well as in industry. Ross (1977) proposes *structured analysis and design technique as a language for communicating ideas*. Ross and Schoman (1977) write a seminal paper in the area of RE in which they explain the scope of RE and suggests the following concepts of *goals*, *viewpoints*, *data*, *operations*, *agents* and *resources* as prospective components of RE. RE is a process in which requirements of software products are identified according to the needs of customers and users (Cheng and Atlee, 2009; Zave, 1977). Several *goal oriented requirements elicitation processes* (GOREPs) like *knowledge acquisition in automated specification* (KAOS) (Dardenne et al., 1993), *non-functional requirements* (NFR) framework (Mylopoulos et al., 1992), i* framework (Yu, 1995), goal-based requirements analysis methods (GBRAM) (Anton, 1996), attributed goal oriented requirements analysis (AGORA) (Kaiya et al., 2002), goal oriented idea generation (GOIG) method for requirements elicitation (Oshiro et al., 2003), TROPOS (Bresciani et al., 2004), goal oriented and ontology driven requirements elicitation (GOORE) (Shibaoka et al., 2007), FAGOSRA (Mohammad et al., 2016; Mohammad et al., 2018), PRFGOREP (Sadiq and Jain, 2014), etc., have been proposed to do some particular task. For example, KAOS was developed to focus on the following issues: "to elicit and structure the user requirements, (ii) to clarify the responsibility of all project stakeholders, who will participate in requirements elicitation process, (iii) to provide an environment where stakeholders can communicate easily, etc." (Dardenne et al., 1993).

In GOREP, stakeholders specify their preferences in a matrix called preference matrix or pairwise comparison matrix (Sadiq and Jain, 2015). These matrices may be complete or incomplete. If stakeholders can specify their preferences over a finite set of goals then such type of preference matrices are called complete preference relations (CPRs), otherwise, it is referred to as incomplete preference relations. CPRs have been widely used in literature during SGS. For example, Kaiya et al. (2002) use the CPR for the selection of goals in AGORA method. Mohammad et al. (2018) also used the CPR for the selection of requirements in FAGOSRA method, which is the extended version of AGORA method. Several researchers have applied *incomplete preference relations* (IPRs) in a group decision-making process (Nakamura, 1986; Wang and Chen, 2010; Wang and Xiong, 2011; Xu, 2011; Xu, 2006), for example, Xu (2011) discussed several formats that can be used for IPR in group decision making process. Xu (2006) discussed *incomplete linguistic preference relations and its fusion*. In a similar study, Wang and Chen (2010) focused on *incomplete fuzzy linguistic preference relations under uncertain environments*.

Generally, decision makers use linguistic terminologies (LTs) during decision making process instead of crisp data in describing their preferences during SGS. For example, the information system should be *more* secure. Here, the term *more* is a LT (Zadeh, 1975). The weights assigned to software goals and requirements by decision makers are often described qualitatively. Therefore, fuzzy logic is a suitable tool to handle LTs mathematically (Zadeh, 1965). Based on our literature review (Sadiq and Jain, 2013; Sadiq and Jain, 2015; Sadiq and Jain, 2014; Sadiq, 2017a), we identify that GOREPs do not support the selection of goals from the selected set of goals when preference relations are incomplete under fuzzy environment. In 2015, Sadiq and Jain (2015) proposed a *fuzzy-based MCDM method for the selection of goals from the set of goals when the preference relation is complete*. Therefore, the objective of this paper is to extend the work of Sadiq and Jain (2015) by considering the incomplete LPR during the SGS process.

The remaining part of this paper is organised as follows: problem definition and related work on goal selection are given in Section 2. In Section 3, we present the method for the selection of goals when the linguistic preference relations are incomplete. Explanation of the proposed method with the help of a case study is given in Section 4. The comparative study of the proposed method with the selected GOREPs is given in Section 5. Finally, Section 6 presents the conclusions and suggestion for future work in the area of SGS problem.

2 Problem definition and literature review

In this section, we first present the problem definition and then discuss the literature review on software goal selection.

2.1 Problem definition

Suppose there are *n* set of *functional goals* (FG), i.e., FG_1, FG_2,…, FG_n and we want to select these FGs on the basis of the following set of *m* non-functional goals (NFG), i.e., NFG_1, NFG_2, NFG_m when *q* decision makers (DM) are participating in the decision making process, i.e., DM_1, DM_2, …, DM_q. The weight of these DMs are represented by WDM_1, WDM_2, …, WDM_q. It is given that

$$WDM_k \geq 0 \text{ and } k = 1, 2, \ldots, q \tag{1}$$

$$\sum\nolimits_{k=1}^{q} WDM_k = 1 \tag{2}$$

During group decision making process, decision makers specify their choices about their FGs over *n* set of FGs on the basis of *m* NFGs into preference relations. These preference relations may be complete or incomplete. CPRs are those relations in which DMs can specify their choices over the finite set of FGs. Sometimes it is difficult to evaluate the FGs on the basis of NFGs because of *schedule constraints*, *lack of knowledge* and *DMs* *limited familiarity* with the application domain (Xu, 2006, 2011). In such situation, DMs may develop an incomplete preference relation with missing elements after specifying their preferences on goals using linguistic terminologies. Therefore, the objective of this paper is to select the FGs from the set of FGs when preference relations are incomplete under fuzzy environment.

2.2 Literature review on software goal selection

Requirements engineering (RE) is a key activity of software development process and it has received lot of attention in academia and software industry (Ambreen et al., 2018). The RE has been classified based on their applications into different types, i.e., goal oriented RE (Horkoff et al., 2019), data warehouse RE (Prakash and Prakash, 2019), emotion oriented RE (Curumsing et al., 2019), etc. One of the important sub-processes of RE is the requirements elicitation whose objective is to understand the need of the stakeholders (Pacheco et al., 2018). Different techniques have been proposed to elicit the need of the stakeholders; and also to identify the software requirements of an information system (IS), for example, elicitation based on behavioural data (Liu et al., 2017), elicitation based on goal concepts (Sadiq and Jain, 2015), etc. These techniques are used to find out the list of the software requirements so that the end product which is developed on these requirements can satisfy the customers and end users (Angelis et al., 2018). Agrawal et al. (2019) explored the *e-service quality and its relations with customer satisfaction in the field of banking*. The success of an IS plays a vital role to improve the efficiency and productivity of an organisation. There are different factors which affect the success of IS, i.e., organisational, technological, and individual factors (Aboaoga et al., 2020).

Software goal selection is a key activity of GOREP in which the need of the stakeholders are refined and decomposed into sub-goals. These sub-goals are further refined and decomposed into sub-sub-goals. The process of refinement and decomposition continues until the responsibilities of the sub-goals are assigned to some agent or some system. Among various GOREP, in KAOS, goal models are constructed by the requirements analyst to identify the goals of the new systems with the help of the traditional requirements elicitation techniques, i.e., "interviewing current users as well as future users, analysis of the existing documents and system, and reading the available technical documents, etc." (Sadiq, 2017a). In NFR framework, NFR soft-goals are examined as criteria during SGS. Tropos (Bresciani et al., 2004) is an agent oriented method in which the idea of the actors and the goals were adopted from i* framework (Yu, 1995). In Tropos, contribution analysis based on positive contribution or negative contributions are performed for the selection of goals. The focus of the requirements analyst in Tropos is to identify the FGs and NFGs for the system-to-be.

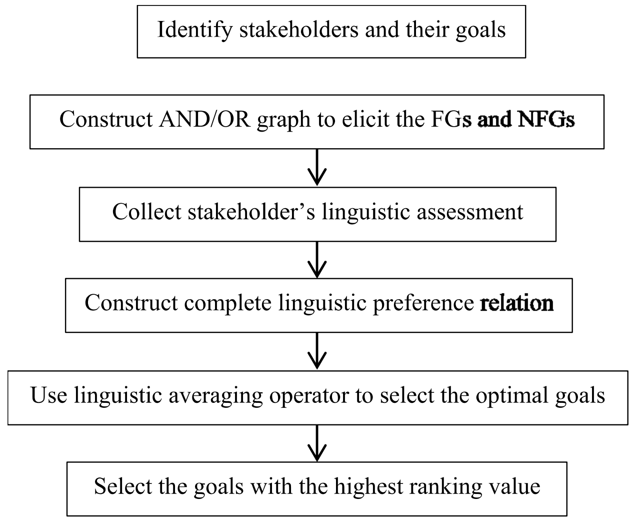
Decision-making (DM) process for the selection of goals is a key activity of GOREP. There are different methods in which systematic methodologies have been developed to select the goals from the set of goals. For example, Sadiq and Jain (2015) proposed a method for goals selection with CPR under fuzzy environment. Different methods have been developed for the selection of software requirements. These requirements are derived after refinement and decomposition of goals. During requirements elicitation process, various stakeholders are involved to deal with the different activities of the IS development process. Therefore, to prioritise the stakeholders based on the roles and responsibilities, in 2017, Sadiq (2017b) proposed a method based on the importance of the SRs using fuzzy logic. Based on our review, we found that fuzzy *analytic hierarchy process* (AHP) and *technique for order preference by similarity to ideal solutions* (TOPSIS) are widely used methods in the field of business and management. For example, Sani et al. (2019) used fuzzy AHP and fuzzy TOPSIS methods for *knowledge management adoption to financial institutions*. Tabaroki et al. (2019) applied fuzzy AHP to prioritise the critical success factors for research projects. Kumar and Suganthi (2019) developed a hybrid fuzzy AHP and *data envelopment analysis* (DEA) approach to determine the relative efficiency of the social *customer relationship management* (CRM) packages.

Yamamoto and Saeki (2007) developed a method in which the main focus during software requirements analysis and design was on the dependency among the software goals or alternatives; and the evaluation of the software goals based on multi-criteria and their trade-off. In their work, TOPSIS method was combined with the attributed goal graph technique for the selection of software components. In AGORA method (Kaiya et al., 2002), two different attributes are used in AGORA graph, a kind of AND/OR graph, for the selection of goals using crisp data, i.e., contribution values (CV) and preference matrices (PM). In this graph, CVs are attached to the edges of the AGORA graph between parent goals and its sub-goals. The requirements analyst can assign the CV from –10 to +10. PMs are constructed by considering the integer values from –10 to +10. In 2014, AGORA method was extended by Sadiq and Jain (2015) in which a fuzzy-based approach was developed for the selection of goals when the preference relation was complete, i.e., FBASG. In other study, Sadiq and Jain (2014) developed a method called PRFGOREP for the prioritisation of software requirements when the preference relation was complete. In 2018, Mohammad et al. (2018) proposed a *fuzzy attributed goal oriented software requirements analysis* (FAGOSRA) method by considering the CPR. Attributed goal graph was extended by Tanabe et al. (2008) to deal with the requirements change management in GOREP by considering the following: *version control for attributed goal* graph and *impact analysis when the goal graph is changed*. In literature, *fuzzy-based decision making* (FBDM) methods have gained recognitions over the last decade in the following areas in which CPR was used for the analysis: *technology transfer selection in biotechnology* (Chang and Chen, 1994), *supplier selection problem* (Li et al., 2007), *selection of object oriented simulation software for production system analysis* (Cochran and Chen, 2005), *non-functional requirements trade-off model in trustworthy software* (Zhu et al., 2012), etc. Based on our review, we identify that in the literature of GOREPs, i.e., KAOS, NFR framework, Tropos, GOIG, AGORA, etc., have received less attention for the selection of goals or requirements when the preference relations are incomplete. Therefore, to address this issue in this paper, we present a method for the selection of goals when the preference relations are incomplete under fuzzy environment.

3 Proposed method

Proposed method is a six step process which is used to select the goals when the linguistic preference relations are incomplete. The block diagram of the proposed method is given in Figure 1.

Figure 1 Block diagram of the proposed method



The explanations of the steps of the proposed method are given below:

Step 1 Identify stakeholders and their goals

Stakeholder identification is a key activity for the successful development of any software product (Sadiq, 2017b). In any project, different types of the stakeholders are involved; and they are divided into *primary stakeholders* and *secondary stakeholders*. Primary stakeholders include *those who are central to any project initiative*, i.e., *beneficiaries*, *financial* and *politicians*, *sponsors*. Secondary stakeholders include the following:

1 developers

2 experts

3 operators, etc.

Traditional methods of the requirements elicitation technique is employed to find out the goals of the different types of the stakeholders.

Step 2 Construct AND/OR graph to elicit the FGs and NFGs

Once we have identified the goals then the next step is to construct the AND/OR graph by decomposing the goals into sub-goals. In AND/OR graph we have two types of the decomposition, i.e., *AND decomposition* and *OR decomposition*. In AND decomposition, "if all of the sub goals or requirements are achieved, their parent goals can be achieved or satisfied". In case of OR decomposition, "the achievement of at least one-sub goal or requirement leads to the achievement of its parent goal" (Horkoff et al., 2019). After constructing the AND/OR graph, FGs and NFGs are identified.

Step 3 Collect stakeholder's linguistic assessment

Here, we collect the stakeholder's linguistic assessment during the evaluation of the FGs by using the linguistic variables defined by discrete terms set, i.e., *LA*, and constructs a linguistic preference (LP) relation = $(p_{ij})_{n\times n}$, where p_{ij} designate the preference degree or intensity for goal FG_i over FG_j. In this relation, $p_{ii} = la_0$ indicates *indifference between* FG_i *and* FG_j, $p_{ij} > la_0$ indicates that FG_i *is preferred to* FG_j, $p_{ji} > la_0$ indicates that FG_j is preferred to FG_i. Here, LA be a set of finite and totally ordered discrete terms with odd cardinality, i.e., 3 or 5; and is represented as $LA = \{la_\alpha \mid \alpha = -t, \ldots, t\}$. Each term in LA represents a possible value for a linguistic variable and has the following characteristics (Xu, 2006):

a For all elements in LA, $la_\alpha > la_\beta$ if and only if $\alpha > \beta$.

b There is a negation operator defined as:
- negation $(la_\alpha) = la_{-\alpha}$
- negation $(la_0) = la_0$ for self-judgement.

Let $P = (p_{ij})_{n\times n}$ be an incomplete linguistic preference (ILP) relation; P is acceptable if there exists at least one known element in each line or each column of P as provided by DMs (Xu, 2006).

Step 4 Construct complete linguistic preference relation

From the ILP relation, we shall construct the *complete linguistic preference* (CLP) relation. To get the CLP relation, all the known elements of P would be used to compute the unknown elements of P using the equations (3) to (5).

1 Let $P = (p_{ij})_{n\times n}$ be a linguistic preference relation, then P is called a CLP relation, if

$$p_{ij} \in LA, \;\; p_{ij} \oplus p_{ji} = la_0, \;\; p_{ii} = la_0 \quad \text{for all } i, j \tag{3}$$

In P, stakeholders provide comparisons between each pair of the goals (Xu, 2006, 2011).

2 Let $P = (p_{ij})_{n\times n}$ be a linguistic preference relation; P is called a consistent CLP relation if

$$p_{ij} = p_{ik} \oplus p_{kj} \quad \text{for all } i, j, k \tag{4}$$

3 Let $P = (p_{ij})_{n\times n}$ be a linguistic preference relation; P is called an ILP relation if some of the elements cannot be provided by the DMs; and it is represented by x, which denotes unknown elements. The elements provided by the DMs should satisfy the following condition (Xu, 2006, 2011):

$$p_{ij} \in LA, \;\; p_{ij} \oplus p_{ji} = la_0; \;\; p_{ii} = la_0 \tag{5}$$

4 Let $P = (p_{ij})_{n\times n}$ be an ILP relation; P is called acceptable if each unknown element can be computed by its adjoining known elements, otherwise P is called unacceptable (Xu, 2006; Xu, 2011).

Step 5 Use linguistic averaging operator to select the optimal goals

We use the linguistic weighted averaging operator, as shown in equation (6), to fuse all the CLP relation into collective CLP relation. After that the linguistic averaging operator, as shown in equation (7), are used to select the goals from the given set of goals.

$$p_{ij} = W_1 p_{ij}^{(1)} \oplus W_2 p_{ij}^{(2)} \oplus \ldots \oplus W_q p_{ij}^{(q)} \qquad \text{for all } i \tag{6}$$

$$p_i = \frac{1}{n} p_{i1} \oplus \frac{1}{n} p_{i2} \oplus \ldots \oplus \frac{1}{n} p_{in} \qquad \text{for all } i \tag{7}$$

Now fuse all the preference degrees p_{ij} (j = 1, 2, …, n) in the i^{th} line of P, and then get the averaged one p_i of the i^{th} goals over all other goals.

Step 6 Select the goals with the highest ranking value

On the basis of the ranking values of goals, stakeholders will select the goals that would be implemented during different releases of the software.

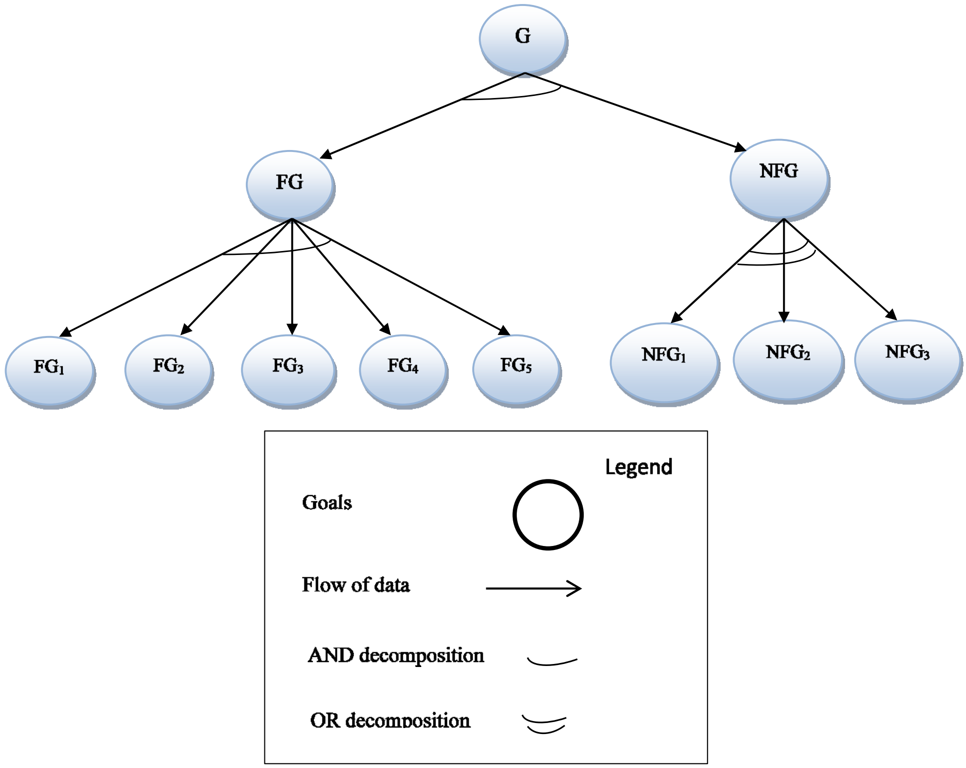
4 Case study

Software goal selection plays an indispensable role in deciding which goal to be implemented first according to the budget, time, cost, and customer's expectations, etc. In this case study, we consider an institute examination system (IES) for the explanation of the proposed methodology. The IES provides facilities for submitting online examination form, generates results of the students, and display news related to the examinations. The system generates examination fee receipts and provides facility of taking printout of receipts. The system also generates seating plan for the examinations (Sadiq and Jain, 2014, 2015).

Step 1 We have identified ten stakeholders namely stakeholders 'S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9 and S_{10}' who will participate in requirements elicitation process of IES. Here, three DMs namely 'DM_1, DM, and DM_3' are participating in group decision making process. In our study, we assume that stakeholder S_1 is the director of the institute/university. Stakeholders S_2 and S_3 are involved to identify the FGs and NFGs of IES. There is an in-charge of the entire project that will take care of all the activities of the development process; and it is represented by S_4. Stakeholders S_5 and S_6 are responsible for the identification of the NFGs. Stakeholders S_7 and S_8 are the end-users; and the need of these stakeholders will also be identified during the requirements elicitation process. There are two financers in the project and are represented by S_9 and S_{10}.

Step 2 Stakeholders of IES constructs an AND/OR graph by decomposing and refining the goal G, which is the high level objective of the stakeholder S1. After refining and decomposing the goal G, two sub-goals are identified, i.e., FG and NFG. These two sub-goals are connected with AND decomposition. FG are further sub-divided into five sub-goals, which are represented by FG_1, FG_2, FG_3, FG_4 and FG_5; and there is an AND decomposition among these goals. The meaning of these five FGs is given below: *student module* (FG_1), *teacher's module* (FG_2), *controller of examination module* (FG_3), *administrative module* (FG_4), and online conduct of examination module (FG_5). NFGs are decomposed into three sub-goals which are represented by effort (NFG_1), cost (NFG_2), and risk (NFG_3). The AND/OR graph of IES is exhibited in Figure 2. There is an OR connection among NFGs. It means that the achievement of any NFG will lead to the achievement of the NFG. Here, we evaluate the FGs on the basis of the NFG_2, i.e., cost because it is the most important criteria which are used during SGS.

Figure 2 AND/OR graph of IES (see online version for colours)



Step 3 Here, FGs are evaluated by DMs on the basis of the following linguistic assessment (*LA*):

$$\{la_0 = Fair, la_1 = Slightly\ good, la_2 = Good, la_3 = Very\ good,$$
$$la_4 = Extremely\ good, la_{-1} = Slightly\ poor, la_{-2} = Poor,$$
$$la_3 = Verry\ poor, la_{-4} = Extremely\ poor\}$$

Here, it is assumed that all the decision makers have equal weight, i.e., DM_1 = 0.3, DM_2 = 0.3, DM_3 = 0.3. The DMs evaluate each FG on the basis of the linguistic assessment defined in *LA*. The evaluation of the FGs by different DM is given below:

Evaluation by DM_1:

$$p_{i-1}^{(1)} = la_{-2};\ p_{1-3}^{(1)} = la_0;\ p_{i-4}^{(1)} = la_2;\ p_{1-5}^{(1)} = la_1$$

Evaluation by DM_2:

$$p_{1-3}^{(2)} = la_2;\ p_{2-3}^{(2)} = la_{-1};\ p_{4-3}^{(2)} = la_0;\ p_{5-3}^{(2)} = la_{-2};\ p_{4-5}^{(2)} = la_2$$

Evaluation by DM_3:

$$p_{1-2}^{(3)} = la_1;\ p_{1-3}^{(3)} = la_2;\ p_{1-4}^{(3)} = la_{-2};\ p_{1-5}^{(3)} = la_1;\ p_{2-3}^{(3)} = la_{-1}$$

In Table 1, DM_1 evaluate each FG by using the *LA* and build an acceptable ILP relation. In Table 1, evaluation of decision maker DM_1 is defined as follows: DM_1 evaluate FG_1 as poor in comparison of FG_2, and as a result la_{-2} is placed at location FG_1 (row) and FG_2 (column). FG_1 is compared with FG_3 and it is found that FG_1 is as important as FG_3, therefore, la_0 is placed at position FG_1 and FG_3. FG_1 is compared with FG_4 and as a result la_2 is placed at location FG_1 and FG_4 because FG_1 is better than FG_4. Similarly, FG_1 is compared with FG_5. In this case, DM_1 consider that FG_1 is slightly better than FG_5; and as a result la_1 is placed at position FG_1 and FG_5.

In some conditions, DMs cannot specify their preferences among different goals. For example, for two different functional goals, i.e., FG_2 and FG_3, DMs cannot specify their preferences because of the schedule constraints and lack of knowledge about these two functional goals. Therefore, in Table 1, *x* is placed at location FG_2 (row) and FG_3 (column) to show the incomplete information. Similarly, all the functional goals are evaluated by the DMs; and the results are exhibited in Tables 1, 2 and 3. In these tables, unknown elements are represented by *x*; and the known elements of these tables are used to find out the values of the unknown elements.

Table 1 Linguistic assessment of DM_1

FGs	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	la_{-2}	la_0	la_2	la_1
FG_2	la_2	la_0	x	x	x
FG_3	la_0	x	la_0	x	x
FG_4	la_{-2}	x	x	la_0	x
FG_5	la_{-1}	x	x	x	la_0

Table 2 Linguistic assessment of DM_2

FGs	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	x	la_2	x	x
FG_2	x	la_0	la_{-1}	x	x
FG_3	la_{-2}	la_1	la_0	la_0	la_2
FG_4	x	x	la_0	la_0	la_2
FG_5	x	x	la_{-2}	la_{-2}	la_0

Table 3 Linguistic assessment of DM_3

FGs	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	la_1	la_2	la_{-2}	la_1
FG_2	x	la_0	la_{-1}	x	x
FG_3	x	x	la_0	x	x
FG_4	x	x	x	la_0	x
FG_5	x	x	x	x	la_0

Step 4 In this step, the values of the unknown elements are computed. From Table 1, the values of $p_{2-3}^{(1)}$, $p_{2-4}^{(1)}$, $p_{2-5}^{(1)}$, $p_{3-4}^{(1)}$, $p_{3-5}^{(1)}$ and $p_{4-5}^{(1)}$ are computed to construct the CLP relation by using equations (3), (4) and (5):

$$p_{2-3}^{(1)} = p_{2-1}^{(1)} + p_{1-3}^{(1)} = la_2 + la_0 = la_2$$

$$p_{2-4}^{(1)} = p_{2-1}^{(1)} + p_{1-4}^{(1)} = la_2 + la_2 = la_4$$

$$p_{2-5}^{(1)} = p_{2-1}^{(1)} + p_{1-5}^{(1)} = la_2 + la_1 = la_3$$

$$p_{3-4}^{(1)} = p_{3-1}^{(1)} + p_{1-4}^{(1)} = la_0 + la_2 = la_2$$

$$p_{3-5}^{(1)} = p_{3-1}^{(1)} + p_{1-5}^{(1)} = la_0 + la_1 = la_1$$

$$p_{4-5}^{(1)} = p_{4-1}^{(1)} + p_{1-5}^{(1)} = la_{-2} + la_1 = la_{-1}$$

These computed values are stored in Table 4. For example, in Table 1, there is an unknown element x at p_{2-3}. After applying equations (3), (4) and (5), we got the value of $p_{2-3} = la_2$. Similarly, all the computed values are stored in the appropriate places in Table 4. The same procedure was applied to compute the unknown elements from Tables 2 and 3 to construct the CLP relations. The CLP relations by three DMs, i.e., DM_1, DM_2 and DM_3, are given in Tables 4, 5 and 6, respectively.

Table 4 CLP relation of DM_1

FGs	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	la_{-2}	la_0	la_2	la_1
FG_2	la_2	la_0	la_2	la_4	la_3
FG_3	la_0	la_{-2}	la_0	la_2	la_1
FG_4	la_{-2}	la_{-4}	la_{-2}	la_0	la_{-1}
FG_5	la_{-1}	la_{-3}	la_{-1}	la_1	la_0

Table 5 CLP relation of DM_2

FGs	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	la_3	la_2	la_2	la_0
FG_2	la_{-3}	la_0	la_{-1}	la_{-1}	la_{-3}
FG_3	la_{-2}	la_1	la_0	la_0	la_2
FG_4	la_{-2}	la_1	la_0	la_0	la_2
FG_5	la_0	la_3	la_{-2}	la_{-2}	la_0

Step 5 Now, the *linguistic weighted averaging operator* (LWAO) are used to fuse all the CLP relations according to equation (6). In Table 7, we summarised the results of the collective CLP relation. After that equation (7) is used to get the ranking values of the FGs.

Table 6 CLP relation of DM_3

Goals	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	la_1	la_2	la_{-2}	la_1
FG_2	la_{-1}	la_0	la_{-1}	la_{-3}	la_0
FG_3	la_{-2}	la_1	la_0	la_{-4}	la_{-1}
FG_4	la_2	la_3	la_4	la_0	la_3
FG_5	la_{-1}	la_0	la_1	la_{-3}	la_0

Table 7 Collective complete LPR

Goals	FG_1	FG_2	FG_3	FG_4	FG_5
FG_1	la_0	$la_{1.3}$	$la_{1.4}$	$la_{1.6}$	$la_{0.4}$
FG_2	$la_{-1.3}$	la_0	$la_{0.1}$	$la_{0.3}$	$la_{-0.9}$
FG_3	$la_{-1.4}$	$la_{-0.1}$	la_0	$la_{0.2}$	$la_{1.4}$
FG_4	$la_{-1.6}$	$la_{-0.3}$	$la_{-0.2}$	la_0	$la_{1.2}$
FG_5	$la_{-0.4}$	$la_{-0.9}$	$la_{-1.4}$	$la_{-1.2}$	la_0

Step 6 The final ranking order of FGs are given below:

$FG_5 < FG_2 < FG_4 < FG_3 < FG_1$

In this study, FG_1, i.e., student module has the highest priority. Therefore, this goal would be designed, implemented, and tested on priority basis for the inclusion in the first release of the software.

5 Comparative study

The objective of this section is to evaluate the following GOREPs, i.e., 'AGORA' (Kaiya et al., 2002), 'FBASG in GOREP' (Sadiq and Jain, 2015), 'FAGOSRA' (Mohammad et al., 2016), 'FAGOSRA_MS' (Mohammad et al., 2018), with the proposed method because in these methods most of the emphasis is given on the selection of goals or software requirements. For the comparative study, these methods are evaluated by considering the following criteria, i.e.,

a goal types

b types of goal links

c refinements and decompositions of goals

d selection of goal using crisp data

e fuzzy-based MCDM process (FBMCDMP) with complete preference relations and incomplete preference relations

f stakeholder's participation.

We further classify the types of goals into *achievement goal*, *maintenance goal* and *softgoal*. Goal links are divided into *inter-goal contribution links*, *AND/OR* *operationalising links* and *decomposition links*. The results of the comparative study are given in Table 8.

Table 8 Comparative study between proposed method and the other selected GOREP methods

Criteria for evaluation		*Selected GOREPs*				*Proposed method*
		AGORA (Kaiya et al., 2002)	*FBASG (Sadiq and Jain, 2015)*	*FAGOSRA (Mohammad et al., 2016)*	*FAGOSRA_MS (Mohammad et al., 2018)*	
Goal types	Achievement goal	√	√	√	√	√
	Maintenance goal	X	X	X	X	X
	Softgoal	√	√	√	√	√
Types of goal links	Inter-goal Contribution link	√	√	√	√	√
	AND/OR operationalisation link	√	√	√	√	√
	Decomposition link	√	√	√	√	√
Refinement and decomposition of goals		√	√	√	√	√
Stakeholders participation	Single	X	X	√	X	X
	Multiple	√	√	X	√	√
FBMCDMP	Complete preference relation	X	√	√	√	X
	Incomplete linguistic preference relation	X	X	X	X	√
Crisp data		√	X	X	X	X

From Table 8, we identify that all the methods use the *achievement goal* and *softgoal*. There is no support of *maintenance goal* in any method. Different types of the goal links are used in the following methods: AGORA, FBASG in GOREP, FAGOSRA, FAGOSRA_MS. These methods also hold up the goal refinement and decomposition process. Proposed method also support types of links, and the refinement and decomposition process to find out the sub-goals from the goals.

There is no support of FBMCDMP in AGORA method. This method was extended by FBASG in GOREP, FAGOSRA, and FAGOSRA_MS to support the FBMCDMP during software requirements analysis. In AGORA crisp data is used for SGS. FAGOSRA method was developed to support the single stakeholder during the decision making process. This method was extended by the Mohammad et al. (2018) to support the participation of the *multiple stakeholders* (MS); and they call it FAGOSRA_MS. From Table 8, we identify that existing methods supports the selection of goals when the preference relations are complete. As per our knowledge there is no study which supports the selection of goals when the linguistic preference relations are incomplete in GOREPs. Therefore, in this paper an attempt has been made to propose a method to select the goals of IES when the linguistic preference relations are incomplete.

6 Conclusions and future work

Software goal selection is a key activity of goal oriented requirements elicitation process (GOREP). Different methods have been developed to select the goals from the set of goals using complete preference relations in GOREPs. One of the key contributions of the paper is the selection of goals when preference relations are incomplete. In this paper, we proposed a six step process for goals selection when linguistic preference relations are incomplete. The steps of the proposed method includes the following:

1 identify stakeholders and their goals

2 construct AND/OR graph to elicit the FGs and NFGs

3 collect stakeholder's linguistic assessment

4 construct complete linguistic preference relation

5 use linguistic averaging operator to select the optimal goals

6 select the goals with the highest ranking value.

Proposed method was applied to select the goals of IES under incomplete preference relations; and preferences of decision makers are specified in the form of the linguistic variables. In our analysis, we found that FG1, i.e., student's module has first priority; therefore, this goal would be implemented in the first release of IES. Implementation of the highest priority goal before the low priority goal can reduce the cost and duration of the software project. Selection of goals through a systematic methodology, as proposed in this paper, can provide the following benefits to the software projects: "It improves customer satisfaction by increasing the likelihood that the customer's most important requirements are delivered first, and (ii) it enables the project manager and customers to modify and update the project schedule to deal with the project realities of limited resources and fixed deadlines" (Firesmith, 2004). Future research agenda includes the following:

a to develop a methodology for the selection of goals when different formats of incomplete preference relation are used during the SGS process

b to develop a methodology for the selection of goals with CLP relations and ILP relations.

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