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A Multi-Criteria Group Decision Support Approach for Requirements Elicitation Techniques Selection

Yirsaw Ayalew and Audrey Masizana-Katongo
Department of Computer Science, University of Botswana, UB 0704, Gaborone, Botswana

Abstract: Requirements elicitation is concerned with the extraction of users' requirements, which involves cognitive, social, communication and technical issues. To support and improve the elicitation process, there are many techniques each with its own strengths and weaknesses. However, some of them are misused, others are never used and only a few are applied again and again. The reason is that requirement engineers have difficulty in deciding what elicitation techniques to use in a particular software development project due to lack of information regarding the available elicitation techniques, their usefulness and how suitable they are to the project. This study proposes a multi-criteria group decision support approach for the selection of requirements elicitation techniques by incorporating the factors that affect the selection of elicitation techniques. This approach is based on the practice of decision making process which involves a group of requirements engineers selecting a particular technique or set of techniques which are suitable for the project at hand. The multi-criteria group decision support based on AHP (Analytic Hierarchy Process) provides a formal model of specifying the relative importance of the selection factors and the applicability of the techniques with respect to each of the factors. AHP can prevent subjective judgment errors and increase the likelihood that the results are reliable.

Key words: Requirements engineering, requirements elicitation, elicitation techniques selection, analytic hierarchy process, group decision support

INTRODUCTION

Requirements elicitation is concerned with the extraction of users needs from different sources. Unfortunately, users needs are not out on a surface, they are rather in the depth of the social and organizational structure of organizations (Goguen, 1996). This makes the task of requirements elicitation very challenging and calls for systematic approaches that help in extracting appropriate, consistent, unambiguous and complete requirements. Some of the challenges in requirements elicitation include:

- The domain knowledge might be distributed across many sources and is rarely available in an explicit form.
- There may be conflicts between requirements from different sources.
- Users may find it difficult to articulate what they want the system to do.
- Limited observability (i.e., users may not be available for observation due to tight schedules or presence of an observer may change the problem).
- The problem of trust (i.e., users may not be free to tell the requirements engineer what he/she needs to know or they may not want to tell him/her what he/she needs to know).

To deal with the variety of problems and support and improve the elicitation process, there are many techniques proposed (Cysneiros, 2002; Goguen and Linde, 1993; Hickey and Davis, 2003a; Maiden and Rugg, 1996; Motoshi *et al*., 1996). However, the suitability of these techniques varies from project to project and hence choosing the most appropriate ones for a particular project becomes difficult. One of the reasons could be that requirements engineers are not aware of the available techniques and even if they are aware, it is difficult to find comprehensive information regarding the techniques that describes when to use a particular technique or a combination of techniques. For this reason, some of them are misused, others are never used and only a few are applied again and again. Thus, researchers conducted a number of experiments to find out the applicability of the individual techniques in different project settings (Cysneiros, 2002; Davis *et al*., 2006; Goguen and Linde,

Corresponding Author: Yirsaw Ayalew, Department of Computer Science, University of Botswana, UB 0704, Gaborone, Botswana

1993; Hickey and Davis, 2003a; Maiden and Rugg, 1996; Motoshi *et al*., 1996). Their applicability varies depending on the requirements types to be extracted, the project environment and the inherent characteristics of the techniques. One observed problem is the lack of a guiding mechanism that helps analysts in selecting appropriate elicitation techniques that are suitable for their projects. To address this issue, recently, researchers proposed selection frameworks which take into account a number of factors including the ones mentioned above (Abebe and Ayalew, 2005; Ayalew, 2006; Hickey and Davis, 2003a, b; Maiden and Rugg, 1996; Tsumaki and Tamai, 2005). However, there is still a lack of empirical evidence regarding the suitability of these frameworks and/or a comprehensive assessment of the strengths and weaknesses of the proposed frameworks.

The other issue is associated with the subjectivity of decision making using those frameworks. Even though the frameworks provide the selection factors that need to be considered during the selection process, most of them do not provide an objective measure of decision making during the elicitation techniques selection. Elicitation techniques selection is a decision making problem that involves setting preferences on selection factors and on the available techniques in terms of their ability to facilitate communication with stakeholders/clients/users, ability to support extraction of a specific type of requirement, ability to get domain knowledge, ability to understand social issues, etc (Jiang, 2005). We argue that the elicitation technique selection process can benefit from a formal decision support model that helps in dealing with the subjectivity of decision making. Ruhe (2003) demonstrated that decision support approaches in software engineering provide a methodology for generation, evaluation, prioritization and selection of solution alternatives. He provided a discussion of the fundamental principles and expectations on software engineering decision support. In requirements elicitation, multi-criteria are often used to evaluate the set of techniques where some criteria could be more important than others in selecting the most suitable technique (Ayalew, 2006; Hickey and Davis, 2003b; Tsumaki and Tamai, 2005). In addition, in software development projects, elicitation technique selection is performed at a group level and at an individual level.

This study first discusses the approach we have taken to developing a framework to help requirement engineers decide which elicitation techniques should be used under certain circumstances. It then proposes a multi-criteria group decision support approach using AHP to elicitation techniques selection. This method uses a "pair-wise" comparison matrix to calculate the relative importance of selection factors and elicitation techniques to one another.

Related work: There are some research that address some of the issues in the provision of elicitation techniques selection frameworks. These frameworks describe the factors that need to be considered during the techniques selection and provide criteria about when to use a particular elicitation technique. Even though the existing frameworks are not yet matured (in terms of empirical evidence), some of them provide a good reference in identifying selection factors and criteria that can be used during the selection process. However, the final decision of which technique to use that is suitable for the project at hand remains subjective.

Despite the fact that the use of decision support techniques for requirements elicitation techniques selection is still lacking, we were able to observe the application of these techniques in other areas of software engineering. Therefore, the related works explore how the decision support techniques have been applied for other similar problems and the benefits obtained by applying these decision support techniques.

In requirements prioritization area, Mead (2006) evaluated a number of methods and demonstrated the suitability of AHP for security requirements prioritization. The main issue was the prioritization of security requirements as there may be time and budget constraints to implement all the requirements that have been elicited for a system. Wanyama and Lumela (2007), presented an agent-based decision support system that can assist developers of COTS-based software to select appropriate COTS for their software. It provides a COTS selection process model that supports the activities of individuals and groups concurrently. Furthermore, it provides a number of agents corresponding to the different stakeholders who participate in the COTS selection to facilitate information sharing. Lu *et al*. (2005) proposed a web-based multi-criteria group decision support system that can be used in any organizational decision-making process that involves group members. This approach also addresses the uncertainty factors that are involved in a group decision making process such as decision-makers roles, preferences for alternatives and judgments for assessment-criteria. This approach proposes a general fuzzy number to deal with the uncertainty factors which are usually described using linguistic terms. Lai *et al*. (2002) reported the result of their case study where AHP was employed to support the selection of a multi-media authoring system in a group decision environment. In their case study, they made a comparison of the Delphi method and AHP and found out that AHP helped group members center a discussion around objectives, rather than alternatives. They also found out that the AHP to be more conducive to consensus building in group decision settings.

In summary, we can see that group decision support techniques can play an important role in dealing with subjective decision making which is common in software engineering. The above works demonstrated how decision support systems provide an objective measure for decision making in different settings including group decision making.

ELICITATION TECHNIQUES SELECTION FRAMEWORK

An elicitation technique could be effective in one situation, incomplete in some other situation and even inappropriate in another situation. Thus, the main challenge in requirements engineering process is deciding which technique to use in the existing situation (Goguen and Linde, 1993). Most requirement engineers, especially the novice ones, in addition to lack of complete knowledge on available elicitation techniques, have a problem on what factors to consider for deciding which techniques to use for a specific situation (Hickey and Davis, 2003a; Maiden and Rugg, 1996). To address this issue, as mentioned in Section 1, a number of frameworks have been proposed. Among the frameworks proposed, we employ the frameworks provided by Abebe and Ayalew (2005) and Ayalew (2006) that describe the different factors that affect the selection of elicitation techniques for a given project at a given time. These factors are categorized in three groups. The first category deals with factors that relate to the type of requirements to be elicited. The second category consists of environmental factors that describe the characteristics of the project environment in which the project is situated. The third category consists of factors related to the characteristics of the elicitation techniques. Since elicitation techniques selection depends on the characteristics of the techniques, we studied and characterized about twenty techniques (Davis, 1992; Goguen and Linde, 1993; Jarke and Kurki-Suoni, 1998; Maiden and Rugg, 1996; Motoshi *et al*., 1996; Potts, 1997) which are believed to be the most common and representatives of the majority of elicitation techniques. These are Document Analysis, Questionnaires, Structured interview, Unstructured Interview, JAD session, Video and Audio, Observation, Ethnography, Card sorting, Laddering, Protocol Analysis, Repertory Grids, Brainstorming, Prototyping, Scenario Analysis, IBIS, Introspection, Requirements Reuse, Focus Group, Interaction Analysis.

Next, we provide a brief discussion of the factors that affect the selection of elicitation techniques which are provided in the framework.

Elicitation goal: The goal of an elicitation session deals with extraction of project mission or clarifying ambiguous requirements or resolving conflicting requirements, etc. An elicitation technique which is appropriate for one elicitation goal may not be applicable for another goal. For example, JAD is more suitable for the resolution of conflicting requirements that involves more than two stakeholders (Cysneiros, 2002). However, this technique may not be suitable for other goals.

From different studies on requirements elicitation activities (Christel and Kyo, 1992; Goguen and Linde, 1993; Hickey and Davis, 2003a, b) and our own experience, the following seven common types of goals are identified:

- Identification of organizational context.
- Identification of boundaries of a system.
- Identification of features of a system.
- Detail investigation of a given feature.
- Identification of rationales for requirements.
- Clarification of uncertainty or ambiguities in requirements.
- Requirements conflict resolution.

Project environment: The project environment encompasses the client's space, the developer's space and the specific project space. Among the existing elicitation techniques, some of them may be more suitable for one particular situation than others. Requirements elicitation occurs as part of the requirements engineering process. This process determines the context in which elicitation takes place and imposes some constraints on the use of the techniques and the selection (Cysneiros, 2002). In project environment, we consider factors such as communication among stakeholders, cost/schedule constraints, skill of requirement engineers, relationship between clients and requirement engineers, etc. For example, the technique that we use when stakeholders do not want to spend a long time during the elicitation session is different from the technique that we use when stakeholders have time for the elicitation session. Similarly, if requirements engineers are under time pressure, they cannot apply techniques like ethnographic methods even though this technique enables them to observe activities that users may not be able to explain. Based on the different studies such as Christel and Kyo (1992), Dubois *et al*. (1988) and Macaulay *et al*. (1990) we group factors from the project environment into the following sub-factors.

- Stakeholders size.
- Degree of maintenance required for an existing system.
- Interactive nature of the prospective system.
- Requirement engineer-client relationship.
- Skill/experience of requirement engineers.
- Documentation culture of the client organization.
- Availability of key stakeholders.
- Users expressiveness.
- Computer skill level of users.
- Degree of project schedule constraint.
- Degree of financial constraint.
- Degree of constant flux of stakeholders.
- Diversity of stakeholders.
- Relationship among stakeholders.
- Availability of communication technology.
- Availability of reusable requirements.
- Availability of information resource.
- Degree of manpower constraint on developers.
- Familiarity to the problem domain.
- Type of problem domain.

The problem domain (in s and t above) refers to the domain to which the project belongs. Domains have their own special characteristics, which favor some of the elicitation techniques and discourage others (Cysneiros, 2002). For example, if we take the health-care domain, using techniques like protocol analysis and interview is not encouraged (Cysneiros, 2002). On the other hand, some techniques might be applicable partially for a certain group of stakeholders. Cysneiros (2002) indicated that Questionnaire technique is not applicable for extracting requirements from nurses and physicians but found it suitable for upper management. In other cases, a technique or set of techniques may be totally inapplicable for a certain domain. For example, using video and audio techniques during interviews as well as in the working areas in the domains of military/defense may be discouraged due to legal and security problems. Similarly, the techniques that can be used when requirement engineers are familiar to the domain may not be applicable if the requirement engineers do not have any knowledge of that application domain. For example, to elicit requirements in an unfamiliar application domain, goal-oriented and brainstorming type approaches are more suitable (Tsumaki and Tamai, 2005).

Characteristics of elicitation techniques: The characterization of elicitation techniques provides a means to evaluate different aspects of the techniques. This focuses on the attributes that describe the ability of elicitation techniques to support the extraction of the desired requirements.

According to the studies by Coughlan and Macredie (2002) and Pumareja (2002), ease of use and the capability to facilitate good communication were the most important reasons for selecting an elicitation technique. Moreover, the choice of elicitation techniques depends on the time, resources available and the kind of information that needs to be elicited. The usability of an elicitation technique is also vital to the success of the requirements elicitation process. Other attributes include analyst's familiarity with the technique, techniques compliance to organization standard, availability of tool support, simplicity, cost effectiveness, domain specificity and easiness to adopt and to apply (McPhee and Eberlein, 2002; Nikula, 2004).

In summary, the applicability of elicitation techniques deals with attributes that describe their ability to facilitate communication, ability to understand social issues, ability to get domain knowledge, ability to identify stakeholders, ability to identify non-functional requirements, etc.

The next study presens a discussion of the group decision support using AHP as it applies to requirements elicitation techniques selection.

MULTI-CRITERIA GROUP DECISION SUPPORT

For a given requirements elicitation task, requirements engineers first try to set the goal of that particular elicitation session. For example, in their first elicitation activity, they usually try to get background information regarding the organization for which the system is to be developed. Once the necessary background information is gathered, they will start working on the extraction of individual requirements. At this stage, they will start to think of the elicitation techniques that will be more appropriate for that particular elicitation session. It is at this stage that the issue of choosing one technique over the other comes into play. Usually, requirement engineers choose a particular technique over the others because they feel that it is a commonly employed technique or because they have an experience in applying it or because it is the only one they know (Hickey and Davis, 2003b). In all cases, they have to make a decision based on the characteristics of the software development project they are working on. Therefore, the process of elicitation techniques selection is actually a decision making problem. From this observation, we believe that elicitation techniques selection will benefit from a formal model of decision making technique such as AHP. As indicated in this study, elicitation techniques selection involves a number of selection factors. Since AHP is a multi-criteria decision making technique, it can properly handle the elicitation technique selection process.

The AHP was originally devised by Saaty (1988b) and is a method for converting subjective assessments of relative importance to a set of overall scores or weights. The AHP is applicable to decision making situations involving subjective judgments provided by a decision maker and determines the priority any alternative has relative to the overall goal of the problem of interest. The method has found a wide application in real life problems (AbouRizk *et al*., 1994; Ramanathan and Ganesh, 1995; Saaty, 1988a) and is able to handle both quantitative and qualitative judgments. It also provides measures of consistency for preferences provided by the decision maker.

By reducing complex decisions to a series of one-on-one comparisons, then synthesizing the results, AHP not only helps decision makers arrive at the best decision, but also provides a clear rationale that it is the best.

The advantage of AHP is that it can also be extended to group decision making (Saaty, 1988a, b). Modeling group decision making is a much more realistic representation of a real life as most decisions involve more than one decision maker. AHP has been applied in group decision making e.g., (Bryson and Joseph, 1999; Dyer and Forman, 1992; Forman and Peniwati, 1998; Ramanathan and Ganesh, 1995; Saaty and Aczel, 1983; Saaty, 1988a) and also to software selection problems in a group environment (Lai *et al*., 2002).

In order to apply AHP to group decisions, two scenarios have to be considered, either a scenario where a group of decision makers/experts may act as unit or as separate individuals (Forman and Peniwati, 1998). According to Bryson and Joseph (1999), the aggregation is done in two independent approaches: the first approach termed Aggregating of Individual Judgments (AIJ) apply where experts act as a unit and a consensus has to be reached to represent the group's judgments. The approach allows the group to participate together in constructing a hierarchy and making judgments. At each level of the hierarchy, the expert's judgements are set into aggregated group judgements. This is then translated as the judgments provided by a 'new' individual who represents that group. Group synthesis is obtained by an additional aggregation procedure for combining individual judgements into a single group priority. The second approach, termed Aggregating Individual Preferences (AIP), applies where experts are significantly different in opinions and a consensus on judgments cannot be reached. In this situation, each expert can give their judgments into separate model and the overall preferences of the expert on alternatives are done separately. Here a group synthesis is obtained but an additional aggregation procedure for combining the individual priorities into a group preference is required. The group synthesis stage for both AIJ and AIP is commonly achieved by applying either of the 2 techniques, Geometric Mean technique (GM), or a Weighted Average Mean technique (WAM). According to Forman and Peniwati (1998) and Saaty and Aczel (1983), GM is more suitable for AIJ while for AIP both procedures are meaningful. This study assumes the decision makers are working as a unit and adopts the AIJ approach to demonstrate the applicability of AHP to the requirements elicitation techniques selection decision making problem using the following steps.

Group prioritization process

Problem structuring: The decision problem is structured hierarchically at different levels, each level consisting of a finite number of decision elements. At the top of the hierarchy is the overall goal or prime objective one is seeking to fulfill, while the succeeding lower levels represent the progressive decomposition of the problem. The lowest level is composed of all possible alternatives. In requirements elicitation techniques selection, the overall goal (top level) will be selection of elicitation techniques and the second level hierarchy represents the three categories of selection factors. The next level represents each sub-factor under the three selection factors. The lower level of the hierarchy represents the alternatives (in this case the elicitation techniques).

Derivation of local priorities: The relative importance of the decision elements (weights of criteria and scores of alternatives) is assessed indirectly from comparison judgments during the second step of the decision process. The decision-maker is required to provide his/her preferences by comparing all criteria, sub-criteria and alternatives with respect to upper level decision elements. The pair-wise comparison expresses the strength of importance of one element over another, represented numerically on an absolute scale, named the Saaty scale, which uses values ranging from 1-9 as shown Table 1.

Consider a prioritization problem at a level with n elements, where pair-wise comparison ratios represent judgments captured from the decision maker using Saaty scale. An $n \times n$ reciprocal comparison matrix $A = \{a_{ij}\} = \{a_{ij} / i = 1, 2, \dots, n-1, j = 1, 2, \dots, n\}$ can be constructed as follows:

Table 1: Saaty scale

Verbal judgments preference	Numerical rating
Extremely preferred	9
Very strong to extremely	8
Very strongly preferred	7
Strongly to very strongly	6
Strongly preferred	5
Moderately to strongly	4
Moderately preferred	3
Equally to moderately	2
Equally preferred	1

$$A = \{a_{ij}\} = \begin{vmatrix} 1 & a_{12} & \dots & a_{12} \\ a_{21} & 1 & \dots & a_{2n} \\ . & . & . & . \\ a_{n1} & a_{n2} & \dots & 1 \end{vmatrix} \quad (1)$$

The entries a_{ij} describe the relative importance of the i^{th} element of A over the j^{th} element of A and $a_{ii} = 1$. Also A is a reciprocal matrix such that $a_{ij} = 1/a_{ji}$. A is also assumed to be consistent such that $a_{im} = a_{ij} \bullet a_{jm}$ for all i,j,m.

We extend the matrix (1) and construct a matrix $A_k = \{a_{ijk}/i = 1, 2, \dots, n\text{-}1, j = 1, 2, \dots, n,, k = 1, 2, \dots, K, j > i\}$ such that a_{ijk} indicates the relative importance of the decision element P_i over P_j with respect to the upper element assessed by the k^{th} expert and hence the new matrix is represented as follows:

$$A_k = \begin{vmatrix} 1 & a_{12k} & \dots & a_{12k} \\ a_{21k} & 1 & \dots & a_{2nk} \\ . & . & . & . \\ a_{n1k} & a_{n2k} & \dots & 1 \end{vmatrix} k = 1, 2, \dots, K \quad (2)$$

In order to aggregate these entries and derive one judgment a_{ij} as in matrix (1) that expresses the overall feeling of the experts, a geometric mean technique is applied. The geometric mean takes the average of a set of numbers expressing the same judgment by applying their product such that:

$$A_{ij} = \left(\prod_{i=1}^{k} a_{ijk}\right)^{1/k} k = 1, 2, \dots, K \quad (3)$$

The aggregation process converts matrix (2) back into a form of matrix (1) with new entries as 'aggregated judgments'. The above model assumes that all experts have equal power whereas it is not always the case. An incorporation of expertise, experience and confidence level of the decision maker can be factored in a group decision by assigning weights to the experts as in Lu *et al*. (2005).

If each expert E_k has been assigned a weighting vector v_k, k = 1, 2, …,n, a weight vector is obtained such that:

$$V = \{v_k, k = 1, 2, \dots, n\} \quad (4)$$

The normalized weight of the group members can be calculated as follows.

$$v_k^* \frac{v_k}{\sum_{i=i}^{n} v_i} \qquad \text{for } k = 1, 2, \dots, n \quad (5)$$

A weighted normalized vector can be obtained from (3) and (5) such that

$$A_{ij} = (v_1^*, v_2^*, \dots, v_n^*)\left(\prod_{i=1}^{k} a_{ijk}\right)^{1/k} k = 1, 2, \dots, K \quad (6)$$

Once the matrix provided by the 'new individual' has been constructed, the problem is to derive the overall priority vector $w = (w_1, w_2, .. w_n)^T$ such that the priority ratios w_i/w_j are estimated by a_{ij} in matrix (1), i.e., $a_{ij} = w_i/w_j$. The priority vector presents the overall weight of the elements at each level after the pair-wise comparison. Researchers have proposed solution methods to this problem such as Goal Programming (Bryson, 1995), Least Squares method (Chu *et al*., 1979), Logarithmic Least Squares method (Crawford and Williams, 1985), FPM (Mikhailov and Singh, 1999) and Fuzzy FPM (Masizana and Mikhailov, 2004). The original AHP, though, calculates the weights for each matrix by applying the standard eigenvector prioritization approach proposed by Saaty (1988b) which works as follows:

Let $A = [a_{ij}]$ be a consistent $n \times n$ matrix of component a_{ij} (i,j =1,.. .n), then $a_{ij} = w_i/w_j$ becomes

$$\sum_{i=1}^{n} a_{ij} w_j * 1/w_i = n \quad (i = 1, \dots, n) \quad (7)$$

or

$$\sum_{j=1}^{n} a_{ij} w_j * nw_i \quad (i = 1, \dots, n) \quad (8)$$

This is equivalent to

$(A - nI)\,w = 0$ where $w^T = (w_1, w_2, \dots, w_n)$ which can be rearranged as follows:

$$Aw = nIw \Rightarrow (A - nI)w = 0$$

Since, $a_{ij} = 1$ and $A \neq I$, it can be shown that the Eigen values of A are zero except one Eigen value, n. Clearly n is the largest Eigen value of A and therefore the maximum Eigen value, λ_{max}. For a more common case where A is inconsistent, then $\lambda_{max} > n$ and any common deviation of a_{ij} keeps the largest Eigen values close to n and the remaining Eigen values close to zero. Therefore, we want to find the eigenvector w which satisfies the equation

$$A \bullet \hat{w} = \lambda_{max} \bullet \hat{w}, \lambda_{max} \geq n \quad (9)$$

This eigenvector corresponding to the maximum eigenvalue indicates the priorities of the elements. This method also provides a measure of the reliability of information elicited from the judgments or the deviation of λ_{max} from n termed Consistency Index (CI) and estimated by

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (10)$$

If CI is large the decision maker may be asked to revise his/her judgments as they will be largely inconsistent. The normal acceptable value is less than 10%.

Calculation of global priorities: The last step of the AHP is to determine the composite overall score for each element over the hierarchy. The weights along the path from the top of the hierarchy are multiplied and the sum of all those elements over all the different pathways to that element is obtained. If the pairwise comparison are performed with respect to some criteria Ci, i = 1, 2, .. j, we can obtain scores of each element r_{ij}, which would be the relative score of each element A_i with respect to some criterion C_j. The eigenvector method is used to derive weights of the criteria $w = (w_1, w_2, .. w_n)^T$ where, w_j is the weight of Cj. These may be repeated for each element such that the overall score of each element with respect to the goal of the problem is given by a weighted sum of:

$$A^* = \frac{\sum_{j=1}^{n} w_j r_{ij}}{\sum_{j=1}^{n} w_j} \quad (11)$$

The global priorities thus obtained are used for final ranking of the alternatives.

Applying group AHP as discussed above to elicitation techniques selection, we get a ranked list of elicitation techniques. From the ranked list, analysts can choose either a single technique or group of techniques depending on the elicitation session goals.

Note that group decision making can also be extended to handle uncertainty by integrating approximation theory with aggregating individual preferences into a group consensus. For example, Lu *et al.* (2005) uses linguistic variables to present a model for assessing political factors and providing a satisfactory group decision. Lee (1996) models approximation of aggregative risk in software development by accepting input data as fuzzy sets. They adopt a goal programming approach to obtain the optimal solutions. Group decision making using the AHP method can also be extended to represent uncertainty. Yu (2002) proposes a method that can concurrently tackle the AHP structure to capture group preference. They use linguistic variables to approximate judgments and apply the geometric mean to aggregate preferences in ranking the alternatives.

Example: In this study, a Clinical Data Management (CDM) system, which is in the health-care domain, is used to illustrate the use of AHP for requirements elicitation techniques selection. This example has been used in our previous study (Abebe and Ayalew, 2005) to illustrate a fuzzy-logic based approach for requirements elicitation techniques selection. Before we use AHP prioritization technique, we want to illustrate the previous method of ranking as it will help us explain where the pair-wise comparison values are derived from.

In that research, we have used almost the same type of selection factors but a different way of ranking the elicitation techniques. In the first category of selection factors, that is the elicitation session goal, requirement engineers were required to choose one or more elicitation goals. Then among the available elicitation techniques, the ones that are applicable to the chosen goal(s) are filtered. In the second category of selection factors, that is project environment factors, requirement engineers were required to rate each of the project environment factors on a scale of 0-4 to indicate the degree of importance for that particular project. For example, for the project environment sub-factor "Availability of Stakeholders", the following were the choices available for the requirement engineer:

0 : Stakeholders are not available at all.
1 : Stakeholders are available once in a blue moon.
2 : Stakeholders are fairly available.
3 : Stakeholders are available most of the time.
4 : Stakeholders are always available.

Once the rating of project environment factors is completed, those elicitation techniques which are applicable for the elicitation goal and the project environment are selected based on the processing rules. In the third step, information about domain constraints was collected and used to further filter the final set of techniques, which is the set of applicable techniques to the goal, project environment and domain.

In that example, the following were the choices made by the requirements engineers:

- From the goal of elicitation factors, "Identification of organizational context" has been chosen.
- From the project environment factors, all factors were rated based on the scale described earlier. For example, for the factor "Availability of Reusable requirements", a rating value of 4 was chosen. This indicates that there are plenty of reusable requirement artifacts in the specific problem area.
- From the application domain factors, type of domain was chosen as health care and familiarity to domain was rated as 2 indicating an average familiarity.

In order to compute the ranking using AHP, we used the same choices and ratings made by the requirement engineers. The only thing that we have done is transforming those choices and ratings into AHP's pair-wise comparison. We handled this by defining a transformation function to map the rating values into AHP's 9 point scale. Similarly, for the pair-wise comparison of the elicitation techniques with respect to each of the selection factors, we used the applicability values of elicitation techniques with respect to each of the factors as compiled from our study of elicitation techniques by Abebe and Ayalew (2005).

For the demonstration of ranking using AHP, we consider only the project environment factor. The reason is that in our previous research, goal and domain did not have rating scales that enable the analyst to rate each sub-factor. Instead, the analyst simply selected the sub-factors to be considered for a particular elicitation session. On the other hand, the project environment factor required the analyst to rate each sub-factor on a five rating scale of linguistic values: "very low", "low", "average", "high", "very high" as by Ayalew (2006) and a 5 rating scale of values 0-4 as by Abebe and Ayalew (2005). Therefore, the rating of project environment sub-factors can be easily transformed into AHP's pair-wise comparison whereas elicitation goal and application domain factors require an additional work so that rating and hence pair-wise comparison can be easily performed. Hence, the following discussion shows the process of ranking of elicitation techniques based on the data from our previous

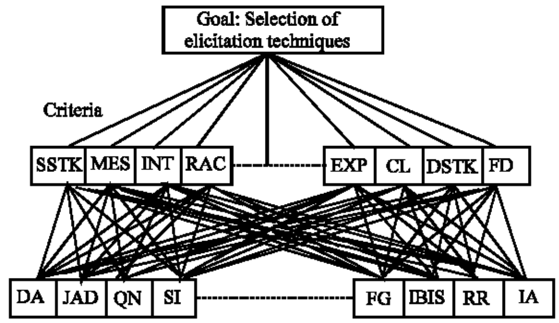


Fig. 1: Elicitation techniques selection decision hierarchy

reseaech using the pair-wise comparison of project environment factors and elicitation techniques with respect to each of the environment factors.

Problem structuring: building a decision hierarchy: The number of decision criteria and alternatives is usually determined by the complexity of the problem. The example requires a four level decision hierarchy. But for the purpose of demonstration, we show a three-layer decision hierarchy omitting the second hierarchy which consists of the three categories of selection factors. For the time being, we just want to use the data available from the case study in our previous work which didn't have a comparison of the three categories. The decision hierarchy with alternative techniques, criteria and sub-criteria is shown in Fig. 1.

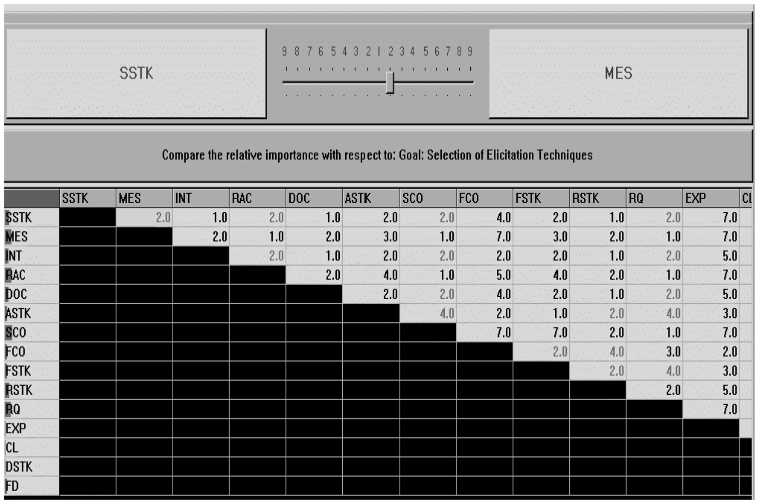
The following abbreviations are used for the selection factors and elicitation techniques:

Project Environment (PE) factors:

Size of Stakeholders (SSTK), Maintenance of the Existing System (MES), Interactive Nature of the prospective System (INT), Relationship between Analyst and Client (RAC), Documentation culture of the organization (DOC), Availability of key Stakeholders (ASTK), Degree of project schedule constraint (SCO), Degree of constant Flux of Stakeholders (FSTK), Degree of Financial Constraint (FCO), Degree of Relationship among Stakeholders (RSTK), Availability of reusable Requirements (RQ), Users Expressiveness (EXP), Computer Literacy (CL), Diversity of Stakeholders (DSTK), Familiarity to the Domain (FD).

Alternatives (Elicitation techniques):

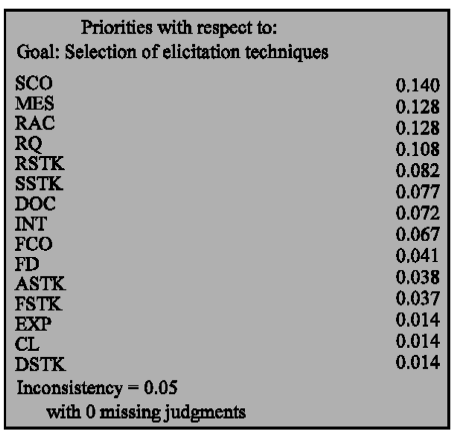
Document Analysis (DA), JAD Session (JAD), Questionnaire (QN), Structured Interview (SI), Unstructured Interview (UI), Observation (OB), Ethnography (ETH), Video and Audio (VA),



Compare the relative importance with respect to: Goal: Selection of Elicitation Techniques

	SSTK	MES	INT	RAC	DOC	ASTK	SCO	FCO	FSTK	RSTK	RQ	EXP	Cl
SSTK		2.0	1.0	2.0	1.0	2.0	2.0	4.0	2.0	1.0	2.0	7.0	
MES			2.0	1.0	2.0	3.0	1.0	7.0	3.0	2.0	1.0	7.0	
INT				2.0	1.0	2.0	2.0	2.0	2.0	1.0	2.0	5.0	
RAC					2.0	4.0	1.0	5.0	4.0	2.0	1.0	7.0	
DOC						2.0	2.0	4.0	2.0	1.0	2.0	5.0	
ASTK							4.0	2.0	1.0	2.0	4.0	3.0	
SCO								7.0	7.0	2.0	1.0	7.0	
FCO									2.0	4.0	3.0	2.0	
FSTK										2.0	4.0	3.0	
RSTK											2.0	5.0	
RQ												7.0	
EXP													
CL													
DSTK													
FD													

Fig. 2: Criteria comparison



Priorities with respect to:
Goal: Selection of elicitation techniques

SCO	0.140
MES	0.128
RAC	0.128
RQ	0.108
RSTK	0.082
SSTK	0.077
DOC	0.072
INT	0.067
FCO	0.041
FD	0.038
ASTK	0.037
FSTK	0.014
EXP	0.014
CL	0.014
DSTK	

Inconsistency = 0.05
with 0 missing judgments

Fig. 3: Derived local priorities of the criteria

Discourse Analysis (DIS), Introspection (INTRO), Card Sorting (CARD), Laddering (LAD), Focus Group (FG), IBIS, Requirement Reuse (RR), Interactive Analysis (IA).

Derivation of local priorities

Determine the weight of the criteria: The next step is to perform a pair-wise comparison of elements at the first level of the hierarchy which in this case are the project environment selection factors. The decision makers, who are the requirement engineers in this case, compare selection factors and provide pair-wise comparison judgments and the pair-wise comparison matrix A = $[a_{ij}]$ is constructed. These judgments are presented in Fig. 2.

As can be observed from Fig. 2, in terms of importance, the decision makers consider SSTK to be half of MES and RAC (red 2.0), Equal to INT and DOC, 2 times more than ASTK etc. It should be noted that due to the reciprocal properties of the comparison matrices, only the upper right elements are provided. This is derived from the rating of the selection factors from our previous research (Abebe and Ayalew, 2005).

An equation of type (2) is constructed from the given judgments. The resulting weights of the criteria presented in Fig. 3 are computed using Expert Choice tool (Anonymous, 2007) which uses the eigenvector approach explained earlier.

The results indicate the overall ranking of the criteria with SCO being the most important. The value of the consistency index, CI, which is less than 10% shows that the initial judgments are relatively consistent. Indeed, the solution ratios of the criteria weights are within the scopes of the judgments. For instance, SSTK was assessed by the decision makers as around half more important than MES (Fig. 2) and the obtained weight ratio after applying the eigenvector method is: SSTK/MES = 0.077/0.148 = 0.601 is close to the mean of the initial comparison judgment 0.5. Similarly, SSTK/INT = 0.07/0.67 = 1.15 and SSTK/ASTK = 0.077/0.038 = 2.03, which are very close to the corresponding means of the comparison judgments in Fig. 2.

Determine the weight of the alternatives (elicitation techniques): The next step is to perform pair-wise comparisons for alternative elicitation techniques with respect to the criteria in the next level of the decision hierarchy. A typical such matrix is shown in Fig. 4 where techniques are compared with respect to SSTK. For reasons of space, not all the pair-wise comparison results can be shown here.

Similarly, a total of (n =16) pair-wise comparison matrices were constructed to compare the elicitation techniques with respect to each of the criteria and the

Table 2: Pair-wise comparisons of elicitation techniques with respect to criteria

	SSTK	MES	INT	RAC	DOC	ASTK	SCO	FCO	FSTK	RSTK	RQ	EXP	CLI	DSTK	FD
DA	0.11	0.024	0.056	0.027	0.118	0.059	0.059	0.063	0.063	0.118	0.05	0.13	0.03	0.03	0.06
QUE	0.121	0.073	0.056	0.102	0.059	0.059	0.016	0.063	0.063	0.029	0.053	0.37	0.036	0.121	0.063
SI	0.062	0.073	0.056	0.109	0.059	0.059	0.059	0.063	0.063	0.029	0.053	0.012	0.036	0.11	0.063
UI	0.061	0.073	0.056	0.102	0.059	0.118	0.059	0.063	0.063	0.029	0.053	0.012	0.036	0.11	0.063
JAD	0.061	0.098	0.056	0.102	0.059	0.059	0.016	0.063	0.063	0.029	0.053	0.012	0.143	0.121	0.063
VA	0.032	0.092	0.056	0.0441	0.059	0.059	0.059	0.063	0.063	0.118	0.053	0.132	0.036	0.034	0.063
OB	0.061	0.059	0.056	0.027	0.059	0.059	0.016	0.063	0.063	0.118	0.053	0.132	0.036	0.121	0.063
ETH	0.061	0.037	0.056	0.027	0.059	0.059	0.016	0.063	0.063	0.118	0.053	0.132	0.036	0.034	0.063
DIS	0.064	0.075	0.056	0.109	0.059	0.059	0.016	0.063	0.063	0.059	0.053	0.40	0.036	0.034	0.063
INTRO	0.061	0.075	0.056	0.027	0.059	0.059	0.195	0.063	0.063	0.059	0.053	0.37	0.036	0.11	0.063
CARD	0.030	0.054	0.056	0.109	0.059	0.059	0.059	0.063	0.063	0.059	0.053	0.37	0.143	0.121	0.063
LAD	0.061	0.054	0.097	0.027	0.059	0.059	0.059	0.063	0.063	0.059	0.053	0.37	0.036	0.121	0.063
FG	0.030	0.046	0.059	0.027	0.059	0.059	0.059	0.063	0.063	0.029	0.053	0.37	0.143	0.121	0.063
IBIS	0.061	0.044	0.059	0.098	0.059	0.059	0.059	0.063	0.063	0.029	0.053	0.37	0.143	0.034	0.063
RR	0.061	0.033	0.059	0.032	0.059	0.059	0.195	0.063	0.063	0.059	0.211	0.37	0.036	0.034	0.063
IA	0.061	0.088	0.111	0.032	0.059	0.059	0.016	0.063	0.063	0.059	0.053	0.132	0.036	0.034	0.063

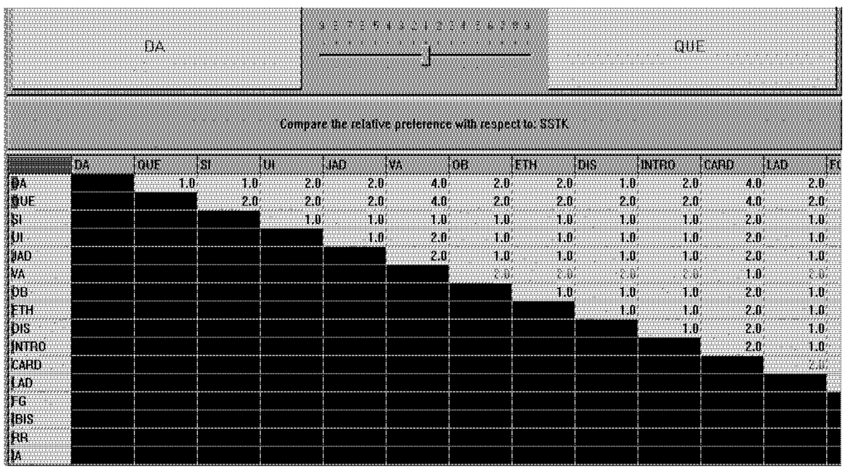


Fig. 4: Comparing alternatives with respect to SSTK

local priorities for the techniques derived for each of the matrices. The results are shown in Table 2.

Each column represents the overall local priorities of the alternative elicitation techniques compared among themselves with respect to the criteria in that column and the resulting weights. Note that the value of CI for all the resulting vectors (columns) is less than 10% and therefore the original pair-wise matrices are consistent.

Calculation of global priorities: These overall weights of the alternative elicitation techniques are obtained by aggregating the scores of the techniques over the hierarchy such that the local weights obtained in Table 2 are combined with local weights of the criteria in Fig. 3. Applying Eq. 9, the overall global scores for the alternative elicitation techniques based on the project environment factors are as follows:

DISCUSSION

The main question that could be raised is the validity of the result obtained after applying AHP. Referring to Fig. 5, the ranking indicates the degree of applicability of the elicitation techniques for that particular elicitation session. At this stage, we need to assess whether the AHP ranking result is logically reasonable. As we can see from Fig. 5, Requirements Reuse (RR) is the first candidate. This makes sense taking into consideration the rating of the requirement engineers for the project environment factors (Fig. 3). For example, the requirements engineers have assigned a higher rating value for the sub-factor "The degree of Maintenance required for the Existing System" (MES). In other words, maintenance of the existing system is a major work for this particular system. Hence, requirements reuse will be helpful in such a situation. Another example that we can see is that the factor The degree of Schedule Constraint for the project" (SCO) is assigned again a higher rating value. This means there is a serious schedule constraint on the project. Therefore, requirements reuse will be one solution to tackle this constraint. Similarly, availability of reusable requirements (ASTK) sub-factor is rated moderate. This facilitates the use of requirements reuse. Therefore, from

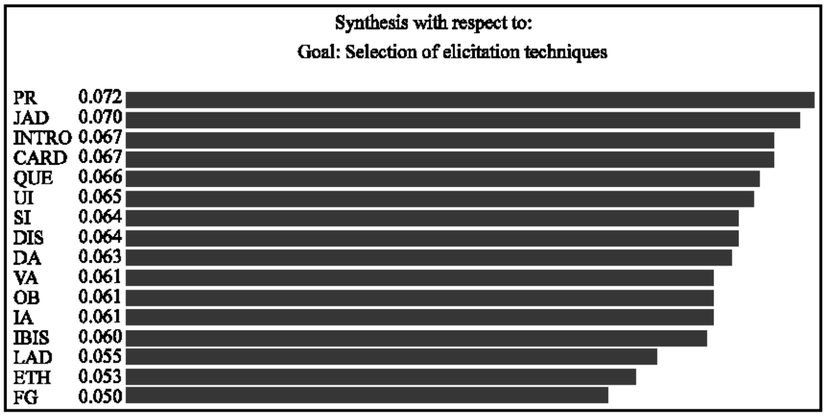


Fig. 5: Overall scores for elicitation techniques

this particular example, we can see that the AHP provides a logically reasonable prioritization of elicitation techniques.

Of course, it is impossible to make a generalization based on this particular example but we can see the logical soundness of the AHP approach for this particular decision making problem of elicitation techniques selection.

CONCLUSION

In this study, we have presented a framework that helps requirements engineers in deciding which factors to consider in selecting elicitation techniques for a particular project. The framework incorporated three factors-licitation goal, project environment and characteristics of elicitation techniques and under each factor, there are different sub-factors which the requirements engineer can select for a particular elicitation session. This framework provides a basis for systematic decision-making regarding elicitation techniques that can be used for an elicitation session.

Using the selection factors, we have provided a ranking technique based on a multi-criteria group decision support approach that uses AHP which can simplify the subjective decision of elicitation techniques selection. The example presented also demonstrated that AHP can provide a logically reasonable ranking scheme.

In this study, our approach assumed an equal weight for each group member who participates in the decision making process. However, there are situations where group members may have different judgment influences based on their role and expertise. In addition, the judgment might be fuzzy in some environments. Thus, our future research will look at incorporating unequal weights to group members and the issue of fuzzy preferences. In addition, we will work on integrating this approach into a decision support tool that handles all the computations and technicalities behind-the- scene.

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