

A Practical Guide to Requirements Elicitation Techniques Selection - An Empirical Study

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Abstract: Requirements elicitation (RE) is the most critical phase in requirement engineering. It is the moment in which analysts elicit, understand and validate the requirements of a system from stakeholders. RE process is resource-intensive and it is therefore accomplished with the support of predetermined techniques. The advancement of technology has introduced many RE techniques and thus analysts are provided with various possible options. The options however are not always obvious. It is uncertain on how to select the right techniques for specific situations under certain conditions. Although several selection guidelines do exist, they are mainly theoretical rather than pragmatic. This study addressed this issue by conducting in-depth interviews with five experienced practitioners from four Middle-Eastern software organisations. The objective of the study was to identify the important factors that contribute to RE techniques selection from the perspective of practitioners in the industry. Four factors were identified by using content analysis, namely technique features, stakeholder characteristics, requirements sources and project environment. The factors form a practical guide that could help analysts to determine the appropriate RE techniques for a given project.

Key words: Requirements elicitation % Techniques selection % Empirical study

INTRODUCTION

Requirements elicitation (RE) is the initial step of requirements engineering where requirements analysts elicit information about the problem domain from stakeholders [1]. RE is a complex process as it constitutes seeking, determining, learning, acquiring, discovering and elaborating requirements of potential stakeholders [2-3]. It involves interactions between two dependent but yet different worlds: technical and business among analysts and stakeholders. Analysts are technical people who have to communicate with stakeholders who own business processes in order to solve specific business problems. Although challenging, the interactions can be accomplished fruitfully with the advancement of RE techniques.

There are many RE techniques such as interviews [4], focus groups [5], Joint-Application-Development (JAD) [6], protocol analysis [7], observations and prototyping. They are used by analysts to determine the needs of stakeholders and build systems that meet those needs [8]. There is no ideal RE technique that can satisfy every

situation. They work best at different scenarios and conditions. Moreover, they often operate in concert and complementarily where the limitation of one technique is compensated by the strength of the other [9-10]. With the available choices, analysts should be able to analyse and decide which techniques to be used in a project. Inappropriate RE techniques negatively influence the development phases, which results in utter failures in meeting the needs of users. This subsequently impacts the project by delaying product delivery [11], increasing its costs, causing poor product utilisation and finally decreasing its success rate [12].

The success of RE does not depend entirely on the selection of techniques. Due to the heterogeneity of stakeholders, RE process must be carefully handled by effectively applying the appropriate techniques towards the people [13]. High quality requirements depend on the right people who engage a number of RE techniques. The suitable stakeholders need to be identified and motivated so that they could dynamically participate towards the success of RE process [14]. It is therefore essential to ensure that analysts are

conversant with a variety of RE techniques and proficient enough to choose the appropriate ones for a given project based on the characteristics of stakeholders and project environment [15]. As the task can be intricate, it would be very helpful if analysts can be provided with a mechanism that defines such selection criteria [1].

This paper aims to address the above issue by providing a practical guide for selecting the right RE techniques based on technique features, stakeholder characteristics, requirements sources and project environment. The guide was formulated based on an empirical study involving five practitioners from software industry. The paper is organised as follows. The following section provides the related work concerning RE techniques selection. It is then followed by the methodology used in the study and the results. Later, the outcomes and contribution of the study are discussed. Finally, the last section concludes the paper with a summary of the main findings and future work.

Background: Understanding the characteristics of RE techniques is crucial as it helps to identify the appropriate ones to be selected for a particular project. Zhang [15] has introduced a general guideline for selecting RE techniques based on four categories: observational, conversational, analytic and synthetic. The study identified four perspectives that influence the selection, which are requirements abstraction level, requirements source, communication obstacles and level of certainty. One example of the findings is that observational techniques support RE process well when the objective is to analyse problem (requirements abstraction level) of a new domain (level of certainty) from sources other than human being (requirements source) in an organisation that has strong culture (communication obstacles). Similar to earlier studies [16-17], these criteria were merely proposed based on experts' perception about the ideas. There is no empirical evidence that support whether or not such proposals work in practice.

Among RE techniques, conversational approaches such as interviews have been identified as the most employed [18]. This is due to the ability of the technique to acquire comprehensive information and knowledge. Based on systematic reviews of empirical studies conducted on RE techniques [8], interviews seem to be the most effective [19-20] and complete [21] technique as compared to protocol analysis, sorting and laddering [22]. Since interviews are normally time consuming, they however are less efficient than others [19, 23].

Several studies proposed selection guidelines based on RE process. For instance, a pragmatic RE

strategy was introduced to manage diverse views, information and proficiency brought by stakeholders during RE process [24]. The strategy focuses on objective and scope that comprises four principles: divide and conquer, communicate to promote, stimulate for innovation and unify diversity. The idea is to bring stakeholders together so that they could generate creative ideas towards future work practice of end users. The strategy adopts several RE techniques. To comprehend the contemporary work practice for instance, scenario based analysis is employed. For gathering visions from end users, user-stories seem to be appropriate. To allow in-depth discussion, workshops and online conferences are used with technical users. In many occasions, analysts depend heavily on their knowledge when selecting techniques and they use techniques that they know efficiently. As a result, they tend to select a preferred technique that they are familiar with to collect requirements for numerous projects [25].

The selection of RE techniques could also be based on the nature of software projects. For instance, a study has suggested the use of more than one RE technique in high requirements volatility projects such as supply-chain [13]. Interviews, workshops and evolutionary prototyping techniques are combined to collect the needs from those projects as they are complicated and involve randomly varying requirements. For distributed or geographical software development however, groupware techniques such as voice conferencing, question-and-answer method, use cases and brainstorming besides efficient requirements management are recommended [26].

Although previous studies have proposed a number of possible approaches for selecting RE techniques, there are mainly narrowed and hypothetical. Projects normally require pragmatic approaches that are workable under real world's conditions and constraints. Analysts therefore need a practical guidance, which is derived from practitioners' experience and empirical evaluation.

MATERIALS AND METHODS

The purpose of this paper is to provide a practical guide that could help analysts to determine the appropriate techniques to be used in a project. The guide contains a set of important factors that affect the selection of RE techniques, which were gathered from a field study. The field study involved several experienced practitioners from software industry. In general, this study aimed to answer the following research questions (RQ):

How do practitioners select RE techniques? Which techniques are suitable for which situations?

This study employed qualitative method because it is appropriate to answer the above RQs. In particular, qualitative method is used when the variables are unknown [27]. Among many techniques in qualitative method, interviews were selected in this study as they are good at acquiring experts' knowledge and experience [28]. The goal of the interviews was to investigate and understand how analysts select RE techniques. The interviews were audio-recorded, which data were then transcribed for analysis. During the interview sessions, an interview protocol was used to ensure the allocated time was followed and the intended questions were asked. The interview questions were semi-structured where structured and open-ended questions were used together. A number of structured questions were carried out to understand and describe the important factors existed in the situation [29]. In addition, a set of open-ended questions were prepared to acquire practitioners' thoughts and opinions relating to RE techniques selection. The open-ended questions were deemed as necessary as they helped in getting experts' perspectives without any constraints. The questions were formulated based on the theoretical factors found in the literature.

A purposeful research sampling was used in this study. The purposeful sampling is meant for exploring and understanding the "central phenomenon" [27]. In purposeful sampling, it is necessary to identify sampling strategy, which depends on the research problem and questions. Homogeneous sampling is one of the types of purposeful sampling, which was the strategy for this study. The study identified a number of characteristics that the potential informants should possess. Later, the criteria for selecting the informants were determined. The criteria consisted of the following: a) The informants possess at least ten years of experience in performing RE; b) The informants have been involved in various types of software project.

This study selected five practitioners as informants. The informants were from four different organisations in Yemen: three software companies and one government agency. The five informants were involved in more than sixty-five projects and had a total of fifty-eight years of experience in RE, with an average of twelve years per informant. The types of project that they participated comprise finance, human resource, telecommunication and electronic government. Their roles in the projects include analyst, project manager, consultant and director.

During the analysis, the interview transcripts from the five informants were transcribed and grouped based on the questions asked by using Nvivo 9 [30]. Nvivo 9 provides an efficient way to handle unstructured data and facilitate the process of indexing, analysing, querying and

visualising the data. The data were analysed by using content analysis [31]. The content analysis was chosen as it performs thematic analysis that helps to identify factors and the relationships between them [32]. Furthermore, content analysis allows the discovery of trends in existing phenomena [33]. It enables the identification of significant themes in the responses of the experts in terms of existence, frequency and relations between keywords and concepts [34]. To initiate the process of content analysis, the coding procedure was conducted. The coding procedure started by giving a label to each text segment. A text segment may range from few words to a paragraph. The goal of coding is to rearrange and integrate the related words, sentences or paragraphs together in order to draw a meaningful description about the data [29]. The data then form a major idea, which represents a specific theme. In this study, the themes are indeed the factors that contribute to RE techniques selection.

Figure 1 below provides the conceptual view of the methodology used in this study.

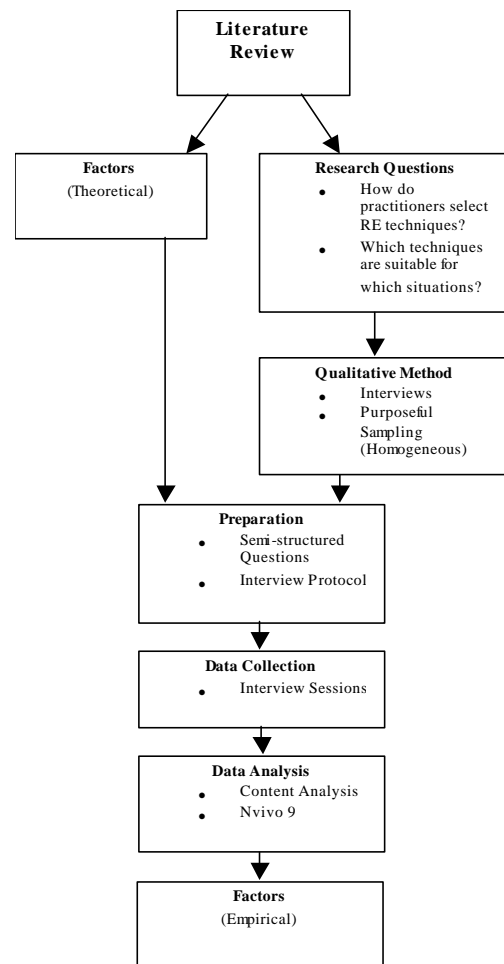


Fig. 1: Research methodology

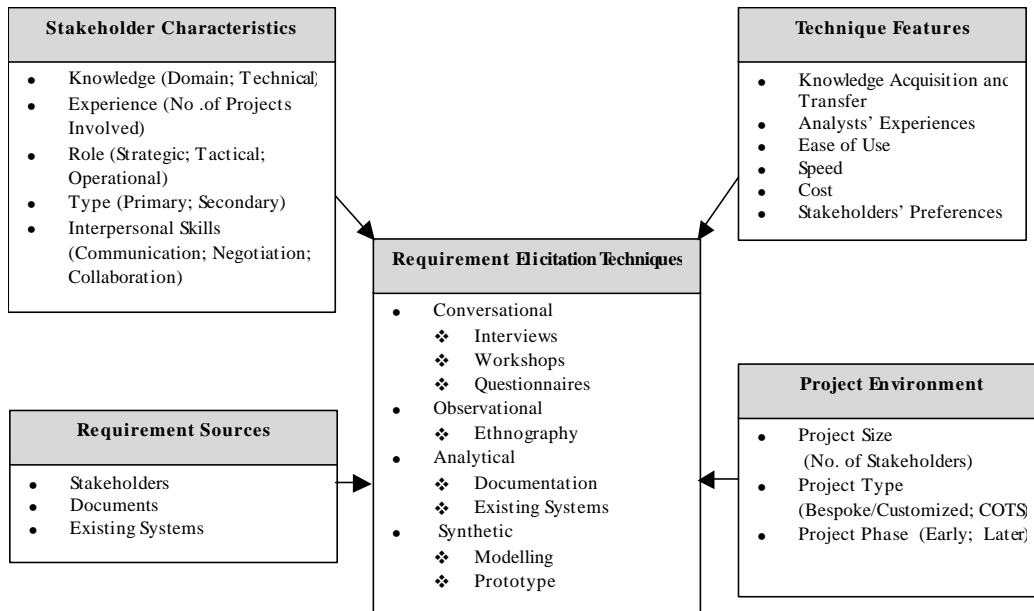


Fig. 2: Factors of requirements elicitation techniques selection

RESULTS

There are a lot of techniques and tools available for RE. Analysts should be aware of factors that they should consider before deciding the best techniques to be used in a specific project. Several factors that affect RE techniques selection have been identified through the analysis, as illustrated in Figure 2. There are one affected factor and four affecting factors. The affected factor is the RE techniques whereas the affecting factors are stakeholder characteristics, project environment, techniques features and requirements sources. Each factor comprises a set of elements. The inter-relationship between these elements determines the possible RE techniques to be used.

In general, RE techniques can be classified into four categories [15]: conversational, observational, analytical and synthetic. Conversational techniques (interviews, workshop/focus group and brainstorming) allow analysts to interact with stakeholders in direct manners, normally in the form of deep face-to-face interactions. Observational techniques (ethnography, protocol analysis) require analysts to be on-site where they spend a considerable time monitoring and analysing how stakeholders actually work. Analytic techniques (requirements reuse, documentation, repertory grid, laddering, card sorting) involve comprehensive analyses where analysts extract the required information from documentation or code of existing systems. Synthetic techniques (JAD, prototype, contextual inquiry, scenarios/storyboards) combine conversation,

observation and analysis approaches systematically into single methods. The techniques are also referred as collaborative methods [35] where analysts and stakeholders cooperate in diverse ways to reach common understandings.

The following paragraphs describe in detail how the above-described technique categories are being affected in terms of selection by four affecting factors: technique features, stakeholder characteristics, requirements sources and project environment. Unlike Zhang [15], the factors are based on empirical findings. The analysis considered the techniques as groups by following the four categories. Any specific instances of techniques mentioned by informants are stated in the parentheses in the paragraphs. The instances provided by informants include interviews, workshops, questionnaires, ethnography, documentation, existing systems, modelling and prototype.

Technique Features: Table 1 below illustrates the responses received from the informants when they were asked about factors that lead to the selection of a particular RE technique. Regardless of technique categories, informants indicated that the ability of the technique to facilitate knowledge acquisition and transfer between users and analysts is the most important factor. The next important factor is the analysts' experiences with a particular technique. The ease of use is the third factor that affects the selection. Speed, cost and stakeholders' preferences are other factors mentioned by the informants.

Table 1: Selection factors based on technique features

Technique Category	Factor	Frequency (No. of Informant)
Conversational; Observational; Analytical; Synthetic	Knowledge Acquisition and Transfer	5/5 (100%)
	Analysts' Experiences	5/5 (100%)
	Ease of Use	3/5 (60%)
	Speed	2/5 (40%)
	Cost	2/5 (40%)
	Stakeholders' Preferences	1/5 (20%)

The rationale behind these opinions is that RE phase is knowledge-intensive where implicit and explicit knowledge need to be articulated and conveyed. No matter how sophisticated a technique is, the process would be unsuccessful if the technique could not promote knowledge acquisition and transfer activities. As software projects are normally schedule-oriented, analysts normally tend to select techniques that they are familiar or have experienced in order to shorten the learning curve. They could not afford to learn many techniques due to project constraints. They therefore are fluent in using only certain techniques. This particularly concerns the techniques that have been proven to work well in past projects. On the other hand, easy-to-use techniques are preferable as it could expedite the RE process. Although they might promote knowledge activities, complex techniques [36-37] seem to be impractical. In addition, some informants also mentioned that speed, cost and stakeholders' preferences may need to be considered especially for agile projects. This is due to the principles in agile development: fast delivery, maintain simplicity and customer involvement [38].

Stakeholder Characteristics: Stakeholders are people who have a stake in a development effort, stand to gain and lose from it [39]. Stakeholders can be customers, users, sponsors or even developers. They can also be employees of an organisation or outsiders. In this study, stakeholders mainly concern users, who are not only the system's consumers but also the participants in RE process.

The analysis revealed that stakeholders' knowledge in many ways influence the selection of RE techniques. There are two types of knowledge involved during RE, namely domain and technical knowledge. Domain knowledge means deep understanding about the system to be built and its business processes. With deep domain knowledge among users, conversational (interviews and questionnaires) techniques are preferred. This is because conversational techniques such as interviews allow

two-way communication and in-depth discussions. When users are unable to express what they want and analysts have shallow domain understanding, observational (ethnography) and synthetic (prototype) techniques are used. In contrast, conversational techniques like questionnaires are better if analysts have some domain understanding as they help users to say out what they want. Questionnaires however require predetermined questions and answers, which have to be carefully prepared. On the other hand, technical knowledge refers to understanding of software development methods and tools. If users have an adequate level of technical knowledge, synthetic techniques (modelling and prototype) are applicable. This is due to the reason that such techniques require the use of certain notations and technology, which users have to comprehend and appreciate. In cases where users do not possess technical knowledge, conversational, observational, analytical techniques are more suitable.

Experience refers to the degree of involvement in past software projects. The more projects the users have participated, the more experienced they are. For experienced users, they prefer conversational (interviews and workshops) techniques because they have much information and knowledge to share. Analysts also choose those techniques as they allow in-depth investigation of the domain. Prior to that, analysts normally employ analytical (documentation and existing systems) techniques as a preparation before meeting users who are indeed the domain experts. Some experienced users possess technical knowledge and thus, synthetic (modelling) techniques may also be used. For less experienced users, analysts use any combination of techniques based on users' preferences.

Occasionally, users' role, type and interpersonal skills also influence analysts' decisions on the techniques. It seems that conversational (interviews) and synthetic (modelling) techniques are normally selected for eliciting requirements for systems that involve users with several roles. The roles include three levels, which are strategic, tactical and operational. Conversational (interviews) and synthetic (prototype) techniques are also used if users possess good interpersonal skills as users can efficiently transfer knowledge with better support from analysts. Otherwise, observational (ethnography) techniques are employed especially when conversational techniques are ineffectual due to communication problems. For projects with different user types, conversational (questionnaires) and synthetic (prototype) techniques are selected. User types in this case mean primary and secondary stakeholders [40].

Requirements Sources: Requirements are elicited from three main sources, namely stakeholders, documents and existing systems. The knowledge of stakeholders is the most important source. Stakeholders' ideas are necessary to define the requirements of a system. In order to ensure high quality requirements, identifying the relevant stakeholders is indeed a central task of requirements engineering [41]. It is therefore vital to select the right stakeholders systematically based on certain quality criteria [14].

Documents consist of manuals, forms, job descriptions and corporate reports, which can provide analysts with useful information about the target system and the organisation. They can also be universal documents such as standards and legal documents. However, examining existing documents consumes a lot of time as analysts need to cautiously review and choose the ones that are directly related to the project. This source is useful for capturing other knowledge, which cannot be directly acquired from stakeholders. In particular, it is good at exploring domain knowledge that is difficult to articulate and understand.

Existing systems are normally legacy, predecessor or competing systems. Those systems provide real experience of running systems, which users and analysts can make as baselines. The use of such systems may also generate ideas for improvement required in the future system to be developed. Nowadays, it is not necessary for systems to be developed from scratch. It has become a norm that future systems are developed based on existing systems. There are quite a number of exemplary systems that analysts and users can refer and try out in order to elicit requirements.

From the analysis, it is found that those three sources are used complementary. Stakeholders often become the main source, followed by documents and existing systems. If users are cooperative and can be accessed easily, conversational (interviews, questionnaires and workshops) and synthetic (modelling and prototype) techniques are preferred. Otherwise, observational (ethnography) and analytical (existing systems and documentation) techniques are used. Whenever there are no documents explaining the business processes and insufficient project information, observational (ethnography) techniques are the most appropriate. Analytical (documentation) techniques are particularly viable when the organisation has clear policy and procedures that are properly documented.

Project Environment: Project environment may also influence the selection of RE techniques. The analysis has found that project type, size and phase play a role. For example, if the system is bespoke or customised for a specific organisation, all techniques except analytical are mainly needed. Conversational techniques like questionnaires are possible when the system is stereotype whereas interviews are otherwise. This is due to the availability of common information and level of details required to build the system. If the system is to be developed through Commercial-Off-The-Shelf (COTS) or reuse approach, analytical (existing systems and documentation) and synthetic (prototype) techniques are employed.

Project size in the study refers to the number of stakeholders involved. If the project involves many users who come from various units, conversational (workshops and questionnaires) and analytical (documentation) techniques seem to be more practical. Workshops are also conducted to resolve the discrepancies of information between users during interviews. Whenever workshops cannot be accomplished due to too large number of users required, questionnaires seem to be a viable option.

Analytical (existing systems and documentation) and observational (ethnography) techniques are advisable in the early stage of RE process. This is due to project immaturity where not much is known about the domain and system to be developed. Those techniques enable the identification of domain terminology and concepts as well as the construction of system overview. In fact, they prepare analysts with some basic knowledge before applying resource-intensive and focused techniques such as interviews. Towards the end of RE process, synthetic techniques (modelling and prototype) are used when the requirements are almost complete after executing other techniques. Through these techniques, analysts provide users with the opportunity to ensure that the information collected during RE process are complete and correct. This mostly concerns information about business process and system components in organisations that have clear policy and procedures.

DISCUSSION

This study has discovered several important factors that are normally considered by practitioners when they need to make decisions on which requirements elicitation techniques should be selected for a project. In general,

practitioners tend to select techniques that have certain quality values and support closely the environment of the project. They also choose techniques based on their stakeholders' characters as well as the sources from which the requirements are gathered. Among four categories of RE techniques, conversational techniques are predominantly preferred where interviews are still the most widely used and successful technique in practice. In many situations, more than one technique is used together. Practitioners mainly believe that the combination of techniques could help them in eliciting high quality requirements from stakeholders and getting better understanding of the problem domain.

The guideline provided by this study is seen as useful particularly to analysts who opt for realistic solutions. Unlike previous guidelines, it does not merely rely on what one believes. Rather, the guideline is based on what is being practised in industry that seems to be effective and feasible.

CONCLUSION

Requirements elicitation is the first stage of requirements engineering that requires the use of certain techniques. Selecting the right techniques has a pertinent influence on the quality of a software system. This paper has presented some recommendations about the situations in which elicitation techniques shall be useful. Factors that are affecting the selection process have been identified through a field study by involving five experienced practitioners from the industry. The factors form a practical guide that matches techniques to stakeholders and project characteristics as well as requirements sources. For the future work, more field studies will be conducted to confirm these factors and to discover other relevant factors. Later, a systematic strategy to select the appropriate techniques based on those factors will be developed.

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