Performing Requirements Elicitation Activities Supported by Quality Ontologies

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Abstract
The requirements elicitation phase is often regarded as the most critical stage of the entire software engineering effort with strong evidence suggesting that increasing the effectiveness of requirements analysts and reducing requirements elicitation errors may be the key to improve project outcomes and deliver high quality software. This paper presents a requirements elicitation approach and associated tool aimed at empowering requirements analysts with a knowledge repository that helps in the process of capturing precise non-functional requirements specifications during elicitation interviews. The approach is based on the application of functional and non-functional domain ontologies (quality ontologies) to underpin the elicitation activities. We also discuss how the approach and tool are being used to effectively support the requirements elicitation stage of the new student intranet project of the University of Manchester (Manchester Unity Web Project).

Keywords: non-functional requirements, requirements engineering, requirements elicitation, ontologies.

1. Introduction
Requirements elicitation is the first step in the requirements engineering process and is often considered to be one of the most critical activities of software development [1]. Requirements elicitation presents several challenges to developers. According to [2] requirements elicitation challenges can be classified into three main themes: (1) problems of scope, in which the requirements may address too little or too much information; (2) problems of understanding, where communication and semantic interpretation of requirements may differ within groups as well as between groups such as users and developers; and (3) problems of volatility, i.e., the changing nature of requirements.
Problems of scope typically result from the fact that requirements analysts often have limited knowledge of the application domain which in turn limits their effectiveness in asking the right questions towards capturing a complete set of requirements during requirements elicitation interviews. Problems of understanding typically result from the fact that requirements elicitation involves many people’s expressed needs across different communities as opposed to the result of a single person’s perspective. These multiple perspectives present challenges with regard to redundancy of information, inconsistency, and point of view alignment [3]. Problems of understanding also arise in connection with non-functional requirements (NFR) or quality requirements elicitation. NFRs are viewed as system properties and constraints e.g. reliability, response time, storage requirements, safety etc. Some of the key difficulties relating to capturing a sound, complete and agreed upon set of quality requirements relate to:
• Quality requirements are of abstract and subjective nature with stakeholders having different perceptions of quality factors across different applications. Thus there is need for methods, techniques and tools to foster a shared collective understanding of the domain.
• A large scale project may involve hundreds of quality requirements, therefore, there is a need for a knowledge base of quality requirements linked to different application domains to remind requirements analysts of the breadth of NFRs that may be critical to a specific domain as well as the potential trade-offs that may be caused by conflicting quality requirements.

This paper presents a requirements elicitation approach and associated tool aimed at empowering requirements analysts with a knowledge repository that helps in the process of asking the right questions and capturing precise non-functional requirements specification during elicitation interviews. The approach is based on the application of functional and non-functional domain ontologies to underpin the elicitation activities. In particular, the non-functional ontology (quality ontology) helps to ensure all relevant quality requirements related to a domain are addressed during interviews (thus, reducing problems scope), and also helps in the process of creating standardized quality criteria that can be uniformly used by different analysts during interviews (thus, reducing problems of understanding).
For the purpose of this study we illustrate the effectiveness of the approach/tool in supporting the requirements elicitation stage of the university helpdesk functionality relating to a new student intranet development project of the University of Manchester (Manchester Unity Web Project).

The remainder of this paper is divided as follows: Section 2 discusses the benefits of using quality ontologies in requirements elicitation. Section 3 presents the related work in addressing quality factors in requirements elicitation. Section 4 describes the development of a quality ontology guided requirements elicitation approach. Section 5 discusses the process of requirement elicitation supported by the tool. Section 6, provides an elicitation process/tools evaluation. Section 7, summarizes the paper, discusses the key contributions, and the future work.

2. Benefits of Using Quality Ontologies in Connection with Requirements Elicitation

Ontologies, according to [4] is defined as “a formal, explicit specification of a shared conceptualization”. Ontologies can be used to capture quality dimensions of a domain of discourse. For example, the TOVE Quality Ontology-VB is the representational basis upon which formalised quality knowledge can be used to integrate quality-related decision making throughout an enterprise [5]. More recently, the Qurator project [6] uses ontologies to describe the quality of curated e-Science information resources assisting scientists and data curators in managing the quality of information. They provide scientists with the means of annotating information with explicit descriptions of its quality in terms that are relevant to the domain of interest and the specific application in hand. The ontologies were built around medical domains to support quality knowledge sharing of lab results between scientists.

Quality ontologies are also used in specifying quality of service (QoS) requirements of service-centric systems [7]. The approach described in [7] is based on defining quality characteristics that will be used in the process of matching functional and non-functional requirements during service sourcing and composition. With regard to supporting requirements elicitation, ontologies provide the following benefits:

- Ontologies promote a shared domain vocabulary that can be used to avoid ambiguities arising in projects involving teams of multiple requirements analysts and stakeholders. This shared vocabulary can also help to develop a common language that can be applied in several projects [8], across several teams to foster requirements reuse and uniform understanding across requirements elicitation activities.

- Ontologies are often used to encode specialized knowledge that is used to formulate competency questions [9]. In particular, questions with regard to the quality requirements relevant to a particular domain, facilitating the task of asking relevant questions to elicit a complete set of quality requirements during stakeholders’ interviews.

Quality ontologies, therefore, can have a positive impact on the requirements engineering phase when applied as a knowledge base during elicitation activities to focus on key quality characteristics of a domain.

3. Addressing Quality Factors in Requirements Elicitation: Related Work

In order to successfully integrate quality concepts and practices into the requirements engineering phase, satisfying the quality requirements of a software system, quality should be formally identified and addressed at very early stages of system development. There are two potentially complementary approaches for incorporating quality concerns into requirements elicitation activities:

Product-oriented: in this approach, quality criteria are made specific using quality models (e.g., ISO/IEC 9126[10]), NFR catalogues or patterns to enable precise descriptions of the characteristics and metrics relevant to an application domain. This is approach is concerned with modelling NFRs and measuring the extent to which a software system is in accordance with the set of NFR’s.

Process-oriented: in this approach, quality is regarded as goals to be achieved throughout the software design process. Methods such as softgoal analysis and design trade-offs are employed to discuss and reason about system quality characteristics.

One of the pioneer process-oriented approaches in capturing quality requirements during requirements elicitation is the NFR-goal framework [11] for NFRs elicitation and negotiation activities of the RE process, which views NFRs as goals that might conflict with each other during the elicitation process. The process-oriented approach discussed in [12] considers quality characteristics to be goals that need to be elicited from various stakeholders to achieve a certain level of service quality. A recent product-oriented approach by [13] emphasizes on the emerging field of reusability in requirements engineering. The work develops a knowledge base catalogue using i* framework to express aspects of usability that can be considered during requirements engineering.

4. Developing a Quality Ontology Guided Requirements Elicitation Approach

Despite the support in dealing with non-functional requirements during the elicitation phase, all approaches discussed above, however, have not adopted a standard
quality model (e.g., ISO/IEC 9126) to integrate the non-functional requirements with the functional requirements, covering a wide range of quality characteristics important for several application domains. Moreover, to the best of our knowledge, no requirements elicitation method has investigated the effectiveness of using automated knowledge bases such as ontology management systems to support the elicitation stage. Thus, our motivation is to develop an ontology driven requirements elicitation method, guided by a standard quality model. The quality model is encoded as quality ontology, and automated by a requirements elicitation tool, helping to address quality factors during elicitation interviews. Figure 1 illustrates the proposed approach.

![Figure 1. Ontology Guided Requirements Elicitation](image)

There are two types of ontologies needed to guide the process of capturing and addressing quality concerns in requirements engineering. These ontologies are:

- **Quality ontology**, which is based on software quality models, and it represents reusable knowledge about different quality characteristics, sub-characteristics, and metrics. For example, the quality characteristic reliability embraces the sub-characteristics maturity that can be measured by the level of accessibility anytime anywhere, fault tolerance measured by mean time between failure, and recoverability which can be measured by the mean time to repair. These quality factors are general and can be applied to any application domain, however, the level of quality required and the order of importance of these quality factors may vary from a domain to another and will be further detailed during elicitation interviews. Section 4.1 describes the quality ontology in more details.

- **Functional domain ontology**, which provides a conceptual structure of the domain (e.g. university helpdesk, in this paper) that information is collected and processed about. The domain entities are acquired (students, centers, services, labs, faculty, etc.) and properties or attributes attached to each entity (student-ID, name, address, etc.) and the relationship between these entities.

The cornerstone element of the proposed approach described in this paper (illustrated in Figure 1) is the use of a quality ontology representing quality characteristics found in a standard quality model (the ISO/IEC 9126 quality model) addressing quality as first class requirement in the requirements engineering process. The quality ontology explicitly implements the features of a formal quality model that is applied throughout the requirements engineering effort (in our case the requirements elicitation stage). Non-functional requirements are represented as quality requirements and quality metrics are explicitly specified and associated with the functional domain ontology. The second pivotal element is the process of using the quality ontology to guide requirements elicitation activities and the supporting tool to help the requirements analysts in the interviewing process.

The proposed approach is a combination of product-oriented and process-oriented quality driven requirements elicitation approaches supported by a quality knowledge base (ontology). The quality knowledge base constructed helps in the process of capturing and validating requirements. The quality ontology is used to drive the process, and act as selection criteria. The elicitation tool offers functions and corresponding interfaces to assist in the requirements elicitation steps.

### 4.1. Adopting and Implementing a Baseline Quality Model Ontology

To develop a quality ontology to support requirements elicitation we chose to adopt the ISO/IEC 9126 software product quality model as the baseline quality model for developing the foundations for integrating quality engineering factors onto requirements engineering activities. To automate the ISO/IEC 9126 quality model, quality characteristics and sub-characteristics identified in the model are translated into a set of hierarchical classes in the Protégé ontology knowledge management environment as shown in Figure 2. The left-hand side of the figure shows how the quality characteristics, sub-characteristics and metrics are mapped into a hierarchy. The right-hand side of the figure defines each class, relationships, and asserted conditions.

Once the baseline quality ontology is specified Figure 2 (A) the next challenge is to associate the general quality ontology with the functional application domain ontology, as illustrated in Figure 2 (B) (a university helpdesk ontology for the example described in this paper). For example, how useable is the FAQ under the helpdesk services. This is achieved through OWL expressions denoting domain restrictions/constraints [14, 15] these
expressions allow cross-ontology assertions enabling the association of quality model characteristics with functional domain characteristics, as illustrated in Figure 2 (C). The advantage of using an ontology management system such as Protégé is that due to the ontology interoperability features supported, other functional domain ontologies can be rapidly imported and associated with the quality ontology; this can help with customizing the use of quality factors and their applications across a multitude of application domains.

5. Performing Requirements Elicitation Activities: Process and Tool Usage

Pre-requisite: Implementing the ontology – the ontology development process begins with the identification and structuring of the domain knowledge, describing the relevant functional and non-functional characteristics. In our case, we chose to study a university helpdesk. To structure the university domain knowledge and its quality characteristics, we used textbooks, standards, and interviews with domain experts (e.g., head of information services and five helpdesk operators with more than 5 years of experience each). The functional domain ontology was then mapped into Protégé as discussed in section 4. In addition to the university functional domain analysis, the quality ontology was developed by including quality characteristics pertaining to the ISO/IEC 9126 quality model. Finally, the quality model was mapped into a Protégé hierarchy as discussed in section 4. Once all the necessary quality requirements are captured and stored in the Protégé knowledge base, the final step is to develop a tool for supporting requirements analysts in the requirements elicitation phase. The process of requirements elicitation using the ontologies illustrated in Figure 3 using OMG’s Software Process Engineering Metamodel (SPEM) [16], starts when the requirements analyst performs interviews with the stakeholders towards capturing detailed functional/quality requirements relevant to the application domain.

The requirements elicitation tool – The quality ontology-guided elicitation tool supports the process by retrieving from the ontology knowledge base relevant quality characteristics attached to the domain that will underpin potential questions that the requirements analyst will need to ask when eliciting quality aspects relevant to a particular functional characteristic of the domain of discourse. Once all the requirements are identified, a list of detailed quality requirements is generated.

The main benefit of the elicitation tool is to help the requirements analysts in the process of requirements elicitation disregarding his/her level of expertise about the functional and non-functional requirements of a given domain. Having a list of functional and quality requirements for a specific application domain helps to decrease the occurrence of problems of scope (e.g., finding all relevant requirements) and understanding (e.g., enabling that all non-functional requirements are uniformly treated across different elicitation interviews conducted by different requirements analysts), thus, reducing the chances of missing out important requirements or not treating requirements uniformly. In addition, the explicitly defined quality characteristics and metrics associated to that domain will help during requirements negotiation and prioritization since precise and non-ambiguous specifications are developed. Figure 4 illustrates the tool front-end interface.

The requirements elicitation tool user interface is built using the Protégé API, which interacts with the objects stored in the knowledge base (functional and non-functional domain ontologies).

As illustrated in Figure 4, the tool supports the task of eliciting requirements and also facilitates the communication process between the stakeholders and the
requirements analysts. The top of the screenshot is the functional domain ontology representation, where the stakeholders can choose what part of helpdesk activity they need to specify with regard to quality requirements.

![Figure 4. Requirements Elicitation Tool GUI](image)

Once a certain activity is selected (e.g. FAQ) relevant quality characteristics that can be discussed with stakeholders towards developing NFR specifications are presented. The tool displays a list of quality characteristics, sub-characteristics, and metrics that will underpin the formulation of a precise requirement statement. The add requirements button allows the stakeholders to detail a quality requirement, in the given example, the tool provides the requirements analyst with the quality characteristics (usability and efficiency) and their associated sub-characteristics (understandability, attractiveness and time behavior) related to the functional activity FAQ. The tool also allows the requirements analyst to ask more specific questions about their quality requirements through metrics such as (number of links per page, number of words per page, and etc.). By specifying the metrics, the requirements can be measured and controlled. The tool also allows stakeholders to specify additional requirements that are not listed by the tool via add new metric button which can always be added and updated as a new class or knowledge in the quality ontology, thus helping to increase the knowledge about a particular domain.

### 6. Elicitation Process/ tool Evaluation

To evaluate the proposed elicitation tool, the authors attended a focus group session which was one of the ongoing sessions at the University of Manchester for the purpose of enhancing the current helpdesk website of the university. The participants were asked for what they want to see in the website and what the problems they come across using the website. It was a two hours interview session and the requirements elicited are listed in Table 1.

Table 1. Requirements Captured without the Tool Support

<table>
<thead>
<tr>
<th>User Requirements</th>
<th>Number of Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Provide information/pathway onto how to access web services (i.e. web mail, network drive, etc.)</td>
</tr>
<tr>
<td>R2</td>
<td>FAQ should be clear and simple in answering users technical problems</td>
</tr>
<tr>
<td>R3</td>
<td>Make the websites among different schools consistent</td>
</tr>
<tr>
<td>R4</td>
<td>Provide campus map when required</td>
</tr>
<tr>
<td>R5</td>
<td>Make the university regulations and policies easy to access</td>
</tr>
<tr>
<td>R6</td>
<td>Make students user names accessible to faculty when using WebCT (e-learning) to register students</td>
</tr>
<tr>
<td>R7</td>
<td>Provide information on how to report a problem and to whom</td>
</tr>
<tr>
<td>R8</td>
<td>Provide information about exam timetables and venues</td>
</tr>
<tr>
<td>R9</td>
<td>Provide links to the outside world</td>
</tr>
<tr>
<td>R10</td>
<td>Highlight important events or alerts</td>
</tr>
<tr>
<td>R11</td>
<td>Update the staff directory frequently</td>
</tr>
</tbody>
</table>

As it is illustrated in the table above, the amount of requirements collected were very limited and some of them were very general and not clear enough such as (provide links to outside world). In addition these requirements can be of different categories such as (email, regulations, computer services, presentation of the website, and security of the website) which are a mix of functional and non-functional requirements.

The main objective in the evaluation was to assess the effectiveness of the tool in complementing the outcome of the focus group towards improving the quality of the requirements captured.

Table 2 presents the set of requirements obtained after using the ontology based requirements elicitation tool after interviewing two of the participants (Intranet project manager and the IT services manager) from the focus group for two hours (same amount of time used during the focus group). It is evident from Table 2 that the ontology based tool has complemented the requirements captured during the focus group by helping to enhance the level of precision and the scope of requirements captured. This is due to the fact that the tool leverages the knowledge repository of functional and non-functional requirements relevant to the domain of discourse. The requirements analyst doesn’t have to be an expert in the domain as all needed expertise is stored in the ontology. The knowledge encoded in the ontology has a positive impact in reducing the problem of scope (helping requirements analysts to focus on the relevant aspects of the domain) and reducing the chances of missing out important aspects of quality requirements. The tool also helps to promote effective communications as the quality/functional requirements are better communicated with the stakeholders as they are defined and broken down into a set of measurable metrics. To illustrate this feature, consider for example one of the requirements elicited using the traditional approach (e.g. R2). The precision of the same requirement captured using the ontology based tool is highlighted in Table 2, in which this requirement is considered as one of the helpdesk services.
7. Conclusions and Future work

This paper proposes a requirements elicitation approach and associated tool aimed at supporting requirements analysts with a knowledge repository that helps in the process of capturing a comprehensive and precise set of quality requirements during elicitation interviews. The approach is based on the application of functional and non-functional domain ontologies (quality ontologies) to underpin the elicitation activities. The ontology guided requirements elicitation process has key substantial elements: (1) the quality ontology that is based on the ISO/IEC 9126 standard; (2) a functional domain ontology which describes all related objects and operations attached to a certain domain. The ontology-guided elicitation tool was constructed by developing a requirements elicitation application layer on top of Protégé’s application programming interface. We also reported on the application of the elicitation process/tool to support requirements elicitation activities of a student helpdesk project of the University of Manchester, where it complements the focus group session by helping the requirements analyst to develop detailed quality specifications with a superior level of precision. Future work will be made at an experimental level, as this tool will be tested by subject groups to check for its usability and functionality. We will also investigate how the ontology can help with requirements prioritization and negotiation.

8. References


