Classification and Qualitative Analysis of Non-Functional Requirements Approaches

M. Mahmudul Hasan, Pericles Loucopoulos, and Mara Nikolaidou

Harokopio University of Athens, Athens, Greece
{m.hasan,p.loucopoulos,mara}@ hua.gr

Abstract. A considerable number of methods and tools have been proposed for the treatment of non-functional requirements (NFRs). There is ample evidence that NFRs play a significant role in the Information Systems Engineering process. However, there is surprisingly an absence of an agreed position regarding the definition of NFRs, their classification and presentation. This paper reports on a systematic literature review of the documented NFR approaches, classifies these approaches according to different criteria and provides a qualitative analysis of their scopes and characteristics. The results of this analysis can serve system developers as the means of deriving appropriate methods and tools of NFRs engineering process in the system development.

Keywords: Requirement Engineering; Non-functional requirements; NFRs; NFRs approach; Systematic Literature Review.

1 Introduction

Requirements Engineering (RE) is arguably one of the most challenging area in system development with many challenges still remaining [1]. Within RE, the treatment of Non-Functional Requirements (NFRs) has received much but fragmented attention. The primary agenda of NFRs research is to deal with quality aspects of the target system, be it a business process or a software system. NFRs are often ignored and inadequately specified and rarely treated as first-class elements as Functional Requirements (FRs) [2]. It is not too farfetched to state that the reasons that can help us understand why these approaches are not explicitly dealt with in the system development projects are the high abstraction level and lack of understanding of their positions, operational scopes and characteristics [3].

There is certainly a paucity of studies that identifies, classifies and analyzes the documented NFRs methods and techniques and discusses their positions, scopes and characteristics. The work presented in this paper is partly based on the study by Loucopoulos et al. [2] that classified NFRs approaches into discovery, specification, negotiation and validation & verification phases of NFRs engineering process. However, the classification has its own credits and shortcomings. This paper augments this work by presenting a systematic literature review (SLR) of documented NFRs approaches, classifying these approaches and providing a qualitatively discussion of

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their scopes, characteristics and merits. The findings of this paper can serve system developers as the means of deriving appropriate methods and tools of NFRs engineering process of a system development based on the scopes and characteristics of the solution design.

This paper is organized as follows. First, the research methodology is defined and described the strategic operations and introduced the classification scheme. Second, the selected papers are categorized and discussed according their relevance to the categories of classification scheme. Third, an analysis of the results is provided to answer the research questions. Finally, the paper concludes with reflections and suggestions for future research.

2 Methodology

This study is based on a systematic literature review described in [4] to investigate and classify primary studies in the area of NFRs. The SLR process can be one of the two types [5], the review aggregates results related to a specific research question named conventional SLR and the review finds and classifies the primary studies in a specific research topic named mapping SLR. This study falls into the mapping category of SLR and follows the systematic steps (Fig.1) suggested by Kitchenham [4] and Petersen [6]. Mapping SLR is the best choice of research methodology because this study undertakes qualitative analysis of NFRs approaches by illustrating them in a tabular form of specific categories and discussing their relative characteristics other than quantitative-based statistical form of analysis led by conventional SLR [5].

Fig. 1. Systematic Literature Review [4-6]

2.1 Research Questions (RQs)

The focus of the RQs is to identify and classify documented methods and techniques in NFRs engineering process phases and discuss their operational scopes and characteristics. This study addresses the following particular research questions:

RQ1. What are the documented approaches in NFRs engineering process?
RQ2. What are the scopes and characteristics of these NFRs approaches?

To address RQ1, this paper identifies and classifies the documented approaches in different NFRs engineering process phases suggested by [7]. In order to derive appropriate methods and tools for the systematic treatment of quality requirements in NFRs engineering process of a system development, it is essential to identify the scope of

the approaches, i.e. how and in what circumstances the methods and tools operate in different NFRs engineering process phases. Therefore, RQ2 addresses the scopes and characteristics of the NFRs approaches. The researchers argue for three different scopes of NFRs solution design. First, integrate goals in the solution design suitable for the large and complex system development environment to show the interrelations of domain elements and alternative design decisions [8]. Second, aspect-oriented solution design promotes automated tools and methods to separate concerns and concentrate one concern at a time to reduce system development complexities [9]. And third, pattern-based solution designs are suitable in the process of using previous practice assuming similar kind of system development environment to optimize available experience in shortening required time and effort of dealing NFRs [10]. These three scopes are selected in the classification process to discuss the common characteristics of solution designs in each scope.

2.2 Search Strategy

Four databases, IEEE Xplore, Springer Link, Science Direct and ACM digital library selecting all journals and conference proceedings were explored in the literature search process. DBLP citation index and Google Scholar search engine were also explored in order to find relevant literature. A comprehensive set of keywords was generated based on the documented definitions and terminology of NFRs [11, 12]. The keywords were used in the search process applying its synonyms as well as combination and altering the word's order to identify the utmost number of relevant primary studies. For example:

- ("Non-functional") AND ("Requirements" OR "Characteristics" OR "Attributes" OR "Properties" OR "Restrictions" OR "Constraints").
- ("Quality") AND ("Requirements" OR "Characteristics" OR "Attributes" OR "Properties" OR "Restrictions" OR "Constraints")

The literature search was conducted in December 2013 and there was no time frame limitation of the research publication, i.e. publications from any year were considered. Backward and forward search procedures were also used in the literature search in order to obtain relevant citation of the articles found by the literature search. Backward search was performed by reviewing relevant citation in the reference list of identified literature. Forward search was performed by reviewing the literature that cited the identified literature. Furthermore, author citation index of the selected literature was also reviewed to find the relevant literature on NFRs.

2.3 Inclusion and Exclusion Criteria

The inclusion criteria of the literature selection were solely correlated to the relevance of NFRs to answer the research questions. The literatures were included based on:

- The publications written only in English language were considered.
- The abstracts explicitly in the notion of NFRs as a primary focus were considered.

The exclusion criteria were based on the deceive concept of NFRs to answer the research questions. The literatures were excluded based on:

- If there were more publications of the same Research Group on the same approach development then the most complete publication of the approach were considered.
- The literatures those were not considered NFRs as the primary contribution.

2.4 Quality Assessment

In order to ensure the validity of search strategy, literature selection and data extraction, multiple discussions were carried out among the authors to decide the search strategy and inclusion/exclusion criteria of primary studies. Furthermore, Kitchenham [4] suggests for an investigation of documented SLR studies in identical research fields to validate the search strategy. A recent study [2] employed SLR in the field of NFRs was reviewed and observed the reference list to assess the volume of potential relevant primary studies and validate the adopted search strategy of this paper. Once the relevant primary studies on NFRs have been obtained through the adopted search strategy, the primary studies need to be assessed for their actual relevance to provide evidence of answering the research questions [13]. Since all the information from selected primary studies is not obviously relevant to the research questions hence the relevant information needs to be extracted avoiding the likelihood biasness. Therefore, data extraction criteria were discussed among the authors to ensure the reliability of data extraction of answering the research questions.

2.5 Literature Selection and Data Extraction

A total of 372 papers were found from the results of different searches and initial screening based on title, abstract and keywords. From these 120 papers address NFRs as primary contribution were selected based on inclusion and exclusion criteria and 92 papers of NFRs approach development were finally selected for data extraction. The data were extracted reading abstract, introduction and conclusion of the literatures to identify the contributions. Irrelevant literatures were excluded attaching a short description of its rationale. The extracted data from each article includes:

1. Literature reference;
2. Name of the approach;
3. Process of the approach;
4. Scope of the approach;
5. Other characteristics of the approach.

The approaches are categorized in five NFRs engineering process phases [7]: elicitation of the requirements in system development, specify their necessary details in informal documentation language, prioritization among alternative requirements, modelling the requirements in formal languages, and finally validation and verification of the quality of specified requirements.

2.6 Data Analysis

This paper presents the documented NFRs approaches according to their respective phases of NFRs engineering process and scope of the solution design. And, qualitatively analyze and discuss the results and answer the research questions accordingly. The field 'name of the approach' and 'process of the approach' answer RQ1 discussing NFRs approaches in different process phases. The field 'scope of the approach' and 'other characteristics of the approach' address RQ2 discussing the scopes and characteristics of the documented NFRs approaches.

3 Results

The results are presented in two dimensions. First, illustrate the results in a tabular format (table1 to table5) based on the NFRs engineering process and scope of each approach. Second, discuss their classifications and characteristics in details. Tables are generated into three sections to illustrate the approach's scope in each NFRs engineering process phase. Each entry of the approach is given a name tagged with its reference. Some of the approaches are explicitly named by the designer of the solutions and others are given a name within the notion of solution design to provide an easy way of distinguishing them beyond their actual reference.

Table 1. Elicitation of NFRs

Goal-oriented	Aspect-oriented	Pattern-based
• Use-case Questioner[14] • MOQARE[15] • NFRs elicitation model[16] • Actor–based model[17] • Usability catalogue[18] • NFRs Layered Framework[19] • Goal-based requirement extraction[20]	• Usability Elicitation Framework[21] • NFR Classifier[22] • Semi supervised text Analysis[23] • QA-Miner[24] • NFR Incorporation Framework[25] • Speech recognition[26]	• Experience-based Method[27] • NFRs elicitation Framework [28] • ElicitO[29] • Efficiency use-cases[30] • NFR recommendation[31]

In goal-oriented elicitation approach, goal-based questionnaire is proposed to extract NFRs by questioning stakeholders [14, 15], business process model [16], use-case of domain model [17], and taxonomy [18] in the system development. Goal decomposing [19] and goal analysis [20] methods are proposed to identify stakeholder, generate their expected goals based on developer's knowledge and experience, then decompose the goals into sub-goals and identify NFRs for each sub-goals. In aspect-oriented approach, automated [21, 22] and semi supervised [23-25] text analysis, speech detection [26] tool-based elicitation techniques are proposed to identify NFRs from available textual requirements documents and in the form of oral documents (e.g. meeting minutes, interview notes, and memos). In pattern-based approach, experience-based elicitation [27], domain ontology [28-30] are proposed to assist

requirements analysts in NFRs elicitation process. Recommendation system [31] is also proposed to understand expected realistic NFRs in the system development.

Table 2. Specification of NFRs

Goal-oriented	Aspect-oriented	Pattern-based
• Usability Elicitation Framework[21] • Performance evolution model[32]	• NFR classifier[33] • NFR Locator[34]	• NFR catalogue[35] • NFR taxonomy[36] • Usability catalogue[18] • NFR classification[37]

In goal-oriented approach, requirements are illustrated in hand-drawn user interface looks and specify necessary details of the requirements [21, 32]. In aspect-oriented approach, requirements specification techniques are proposed for automated requirements specification and categorization from a wide variety of requirements document [33, 34]. In pattern-based approach, NFRs documentation based on requirements analyst's prior experience on a particular situation of NFRs handling [35], NFR taxonomies [18, 36, 37] are proposed to guide requirements analysts in elicitation process.

Table 3. Prioritization of NFRs

Goal-oriented	Aspect-oriented	Pattern -based
• sureCM Framework[38] • sureCM Framework for security-usability conflicts resolution[39] • Analytical Hierarchy Process [40] • Matrix map conflicts[41] • Quality Attribute Risk and Conflict Consultant [42] • Quantifying NFRs[43] • Business rules [44] • Prioritized system QAs [45] • Pareto Algorithm[46] • Context-aware recommend [47] • FQQSIG model [48]	• NFR trade-off profiling[49]. • Personal Construct Theory[50] • Architecture-driven requirements prioritization[51] • NFR prioritization algorithm[52]	• NFRs conflicts catalogue[53] • NFR dependency classification[54] • NFR conflicts analysis[55] • Constraint hierarchy trade-off[56]

In goal-oriented prioritization approach, conflict analysis [38-43], business rules [44], user satisfaction priority lists [45, 46] based techniques are proposed to deal with NFRs interdependencies towards trade-off and prioritization. Techniques are also proposed to make automatic trade-off decision [47, 48] among NFRs alternatives based on their relative interdependencies. In aspect-oriented solution design, several approaches are proposed to provide required information about NFRs and its correlation [49-51], user satisfaction [52] to the process of trade-off analysis and requirements prioritization. In pattern-based approach, catalogue of potential NFRs conflicts [53], classification of NFRs dependencies [54], conflicts identification from prior

experience [55], quality constraint hierarchy [56] are proposed to aid conflict analysis in the selection among alternatives.

Table 4. Modelling of NFRs

Goal-oriented	Aspect-oriented	Pattern-based
• NFR Representation multi-model [57] • Ontology based Quality modelling [58, 59] • NFR use-case Model [60, 61] • NFR integration Framework[62] • NFR use cases and scenarios models[8] • NFR Framework[63-69]	• Activity-based quality model [70] • Efficiency use-cases[30] • Ontology-based NFR conceptualization[71] • NFR Traceability model[72] • QRA Framework[73, 74] • NFR integration Framework[75, 76] • ProcessNFL language[77] • UML Profile[78]	• Quality requirements BP framework[79-84] • NoFun language [85]

Several goal-oriented modelling approaches are proposed to represent the interrelations of different system development viewpoints [57], domain ontology and NFRs [58, 59], functional and non-functional requirements [60-62], soft-goal interdependencies of NFRs [8, 63-69]. Aspect-oriented activity-based modelling approaches are proposed to illustrate the elicitation process [30, 70], communication process of intra and interrelations among NFRs dependencies and functional requirements [71-76] for better traceability. Some approaches are proposed to develop new representation language [77] and extend an existed language [78] to describe NFRs properties in the system development process. In pattern-based modelling, approaches are proposed to illustrate the visibility of quality requirements in the operation process of business model [79-84] to aid requirements elicitation and evaluation process. A language is proposed to define ISO/IEC quality characteristics in different system development contexts for better requirements understanding [85].

Goal-oriented approaches are proposed to measure the adequacy and quality of NFRs in requirements specification using domain knowledge [86, 87], abstract interpretation [88], interrelations of NFRs [89], quantitative size and effort estimation [90, 91], goal-centric traceability links between NFRs [92], and reasoning on NFRs in different contexts [93]. Also, some approaches are proposed to evaluate and validate system behaviour conflicts [94], changing requirements during system development [95] and relative priority of NFRs in trade-off analysis [96]. In aspect-oriented approach, a text mining tool is proposed to identify possible defects for the measurement of NFRs quality in the specification document [97]. And, an evaluation approach is proposed to evaluate NFRs specification by the clarity of its description [98]. Pattern-based approaches are proposed for the assessment of NFRs specification based on experience accumulated from similar project development [99-102], knowledge of the requirements characteristics and catalogue in a particular domain [103, 104].

Table 5. Validation and Verification (V&V) of NFRs

Goal-oriented	Aspect-oriented	Pattern-based
• Spectrum analysis [86] • TCM Framework [87] • Abstract Interpretation-based verification[88] • EMIMCE model[89] • COSMIC-FFP method[90] • Quantitative measure[91] • Goal-centric traceability[92] • Automate verification[93] • Execution-based Model Checking[94] • Goal decomposition[95] • Quantitative priority assessment framework[96]	• QR mining framework[97] • NFR Evaluation Model[98]	• Bayesian Belief Network [99] • Bayesian Reliability Prediction[100] • Model-based approach[101] • NFR pattern approach[102] • Performance Requirements Framework[103] • Scenario-based assessment[104]

4 Analysis

In this section the available NFRs approaches are discussed in the scope of its common characteristics in each NFRs engineering process phase. The elicitation approaches promote three ways of NFRs extraction from different sources depending on the suitable context of system development. Goal-oriented approaches are appropriate in the process of asking goal based questionnaire to the NFRs sources, e.g. stakeholder, domain model, NFRs taxonomies, etc. Pattern-based approaches are suitable in the process of using expertise knowledge and skills of the system developers from their experience in similar kind of system development environment to extract NFRs. And, aspect-oriented approaches are the automated and semi supervised tools suitable for identifying NFRs from textual or oral documents.

The scope of NFRs specification process supports either NFRs elicitation process or requirements prioritization process. Pattern-based approaches aid NFRs elicitation process providing domain specific and generic NFRs taxonomies generated from previous experience to guide elicitation process. The elicited requirements, i.e. outcomes of the elicitation process are classified and documented according to their relevance from a wide variety of requirements by automated aspect-oriented methods and tools. Goal-oriented approaches specify necessary details of the documented requirements according to the context of system development. Therefore, both the categorized NFRs document outcomes of the aspect-oriented approaches and their specified details outcomes of the goal-oriented approaches help system developers understand requirements characteristics in the process of requirements prioritization.

The scope of NFRs prioritization process is divided into two prioritization activities. Aspect-oriented and pattern-based approaches provide reasons of NFRs conflicts describe their relative concerns and generate their compositions without being engaged in the core process of conflicts analysis and NFRs prioritization. The information of

requirements conflicts are generated from two sources. Aspect-oriented approaches are suitable in the process to provide dynamic context aware information of NFRs interdependencies and user satisfaction priorities of the system development. Pattern-based approaches are suitable to provide stationary information from the catalogue and prior recorded organizational experience. And, goal-oriented approaches are designed to perform the actual trade-off analysis and prioritize conflicting NFRs.

The scope of goal-based modelling illustrates viewpoints and use cases to represent various relationships among NFRs and activities to deal with NFRs with a specific purpose in mind. Goal-oriented modelling approaches are suitable for conceptual modelling to represent NFRs concepts in an organized manner. Aspect-oriented modelling approaches are suitable for mainly two modelling activities. First, visualize the intra relationships and dependencies among NFRs and interrelationships to functional requirements (FRs) in the process of integration and tracing NFRs into FRs of a system development. Second, develop and extend NFRs representation languages to describe NFRs and design decisions for maintaining traceability among them. And, pattern-based NFRs modelling approaches are suitable to describe NFRs and its visibility into another model, for example illustrate NFRs in business process model to aid software developer in capturing NFRs.

The scope of validation and verification process is mainly addressed into two types of activities in methods and techniques development. First, ensure the quality of NFRs specification is of high quality, i.e. identify missing and unnecessary requirements in the specification document. Goal-oriented approaches measure the adequacy and necessity of NFRs in requirements specification based on the interrelations of NFRs, the relative advantages and disadvantages of NFRs, etc. Aspect-oriented approaches evaluate the quality of requirements specification based on possible defects and clarity of requirement's descriptions in the specification document. Pattern-based approaches assess the quality of requirements specification based on the experience accumulated from similar project development knowledge of the requirements characteristics and catalogue in a particular domain. Second, some goal-oriented approaches are also appropriate to verify NFRs conflicts and priorities.

5 Conclusion

This paper systematically reviews the documented approaches dealing with NFRs in system development. The main contribution of this paper is to classify these approaches into its respective positions in NFRs engineering process and discuss their scopes and characteristics to guide system developers deriving appropriate methods and tools for the treatment of NFRs in system development. The review shows that methods and techniques are available in all NFRs engineering process phases and the approaches are developed within various scopes and characteristics. Elicitation approaches are designed to elicit NFRs from goal-oriented dynamic and pattern-based static sources of requirements with aspect-oriented methods and tools. NFRs taxonomies are developed in pattern-based specification approaches, aspect-oriented specification approaches list and classify elicited NFRs where goal-oriented approaches

specify necessary details of NFRs in a system development. Necessary information for the goal-oriented prioritization approaches are provided by aspect-oriented and pattern-based approaches. Goal-oriented modelling approach illustrates various NFRs concepts of system development, aspect-oriented modelling visualizes the dependencies among NFRs, and pattern-based modelling illustrates NFRs visibility into another model for ease the NFRs elicitation process. The adequacy and necessity of NFRs in requirements specification are assessed by the information of goal-oriented approaches and available experience of pattern-based approaches. Aspect-oriented approaches evaluate the quality of specification document. Some goal-oriented approaches also verify the requirement's conflicts and priorities. In overall, the analysis of the positions, scopes and characteristics of documented NFRs approaches would be useful for system developers to find the appropriate methods and techniques in handling NFRs engineering process of a system development. However, there is much work to do in the systematic process of NFRs engineering since all activities are isolated and disorderly sequenced of various methods and tools. Our future work puts forward the design of a comprehensive NFRs meta-modelling architecture of sequentially ordered activities with suitable methods and techniques of each process in NFRs engineering phase.

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