What About Catalogs of Non-Functional Requirements?

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Abstract

[**Context and Motivation**] Satisfying Non-Functional Requirements (NFRs) in software development is challenging. There are many types of NFRs and each one requires specialized knowledge. Moreover, they can be correlated, which means that achieving one NFR can impact the achievement of another, positively or negatively. A common solution in the literature for helping developers to deal with these issues at the beginning of the development is the usage of NFR catalogs. Then, there is a need to know the current NFR catalogs to both support software development and to identify their challenges. [**Question/Problem**] However, the literature lacks a synthesized study of existing catalogs to help developers and researchers. Then, this work aims to identify what catalogs have been proposed in the literature and how they have been represented, defined and evaluated. [**Principal ideas/results**] To achieve our goal, we performed a literature review through a systematic mapping study. We then identified 102 catalogs supporting 86 NFRs. They are mostly represented by Softgoals Interdependency Graphs and are built through literature review. [**Contribution**] Our results provide not only an overview of the area to guide researchers and practitioners who wish to build their catalogs, but also can help developers to reuse the knowledge presented in these catalogs.

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1 Introduction

Dealing with NFRs that are quality characteristics (e.g. Usability, Security) during development brings several issues to be overcome. One is that there are many types of them, and each requires specialized knowledge on how to support it in software development. This knowledge is not always effortlessly available for developers especially for those who have no experience with NFRs [2]. Also, NFRs can interact with each other [1], which means that achieving one NFR can impact the achievement of another. This impact can be either positive or negative [1]. When negative, this impact is called conflict or negative correlation.

A common solution in the literature for helping developers to fulfill NFRs is the usage of NFR catalogs [2] [5]. A catalog is a body of knowledge that was accumulated from previous experience. They are known for improving specifications since it allows the reuse of requirements. However, several catalogs are scattered in online libraries of scientific studies [2] [3] [4], making their reuse more challenging. The requirements community lacks a synthesized study about catalogs in order to help developers identifying strategies and conflicts and to define trends and future research. Thus, this work aims to give an overview about the existing NFR catalogs.

To do this, we conducted a systematic mapping (SM) study [6] [7] [10], since it is a research method that provides an overview of an area and allows to discover research gaps and possible trends. Based on the SM study, this paper presents a set of NFRs catalogs that a developer can consult while dealing with NFRs at the beginning of the development. Additionally, we provide a synthesis of research opportunities in this area.

2 Background and Related Work

According to the NFR Framework [2], there can be three types of NFR catalogs: *(i)* catalog of subcharacteristics; *(ii)* catalog of methods (*i.e.*, strategies to support the quality characteristic in a system) and *(iii)* catalog of correlations.

Subcharacteristics represent a more specific knowledge about a NFR. For example, Security can be decomposed into three subcharacteristics, Confidentiality, Integrity and Availability. Methods represent development solutions intended to satisfy NFRs in a system. A method can be of any type, such as a function or some component in architecture, a design constraint or a design guideline. These methods can even be refined into more specific ones. Correlations represent the interactions in NFRs, which can be defined in several levels: a) correlation between top-level NFRs, e.g., Usability hurts Security; b) correlation between subcharacteristics; c) correlation between method and top-level NFR; and d) correlation between method and subcharacteristic.

The literature has several NFRs catalogs. For example, there is a catalog for Security, Performance and Accuracy in [2], Usability in [4], Transparency in [8], Privacy in [9]. However, we did not find a work that synthesizes the existing catalogs through a systematic study and organizes them to help researchers and developers. Therefore, we believe that a study summarizing and classifying the knowledge about catalogs of NFRs could be useful for researchers and developers to both understand the current state-of-the-art of this area and improve their practices.

3 Research Method

To perform our SM study, we followed a process with three main phases proposed by [10] for systematic studies: *(i)* Planning; *(ii)* Conducting, and *(iii)* Reporting, described as follows.

3.1 Planning

The aim of the planning phase is the definition of a protocol. This document is usually composed of the following data: research goal, questions, databases, selection criteria, screening process and extraction strategy, explained as follows[1].

3.1.1 Research Goal and Questions.

The goal of this SM is *to provide an overview of the literature regarding NFRs catalogs.* To achieve this goal, we investigate the following research questions (RQs):

- **RQ1. What NFR catalogs have been proposed in the literature?**
- **RQ2. How is the information represented in the NFR catalogs?**

[1]Detailed information is available in https://github.com/great-ufc/SM-NFRsCatalogs/blob/master/ProtocolandResults.pdf

Table 1: Search String.

("quality characteristic" OR "non-functional requirement" OR NFR OR "quality attribute" OR "non-functional property" OR "extra-functional requirement" OR "non-behavioural requirement" OR "quality requirement" OR "quality factor" **AND** catalog OR catalogue OR SIG OR "softgoal interdependency graph"

- **RQ3. How are the NFR catalogs defined?**
- **RQ4. How are the NFR catalogs evaluated?**

3.1.2 Search String and Databases.

The strategy PICO (Population, Intervention, Comparison, and Outcomes) suggested by [6] was considered to identify keywords and thus formulate the search string from research questions. To evaluate its quality, we selected three control papers that we knew before the execution of the database search [3] [12] [13], then we defined the final string only if it brought these papers. Table 1 presents it.

As databases, Web of Science and Scopus were chosen, since they have good coverage and stability. Also, Scopus cover other bases, such as IEEE. We also added one specific database from the requirements area: Workshop on Requirements Engineering (WER). We have chosen it for three reasons: it represents an important event in the area where researchers usually publish NFRs catalogs, publications from there are not all indexed in the databases we previously choose, and it provides a search engine of its own, making the search for catalogs easier.

3.1.3 Selection Criteria.

We have defined the following inclusion (IC) and exclusion (EC) criteria to select the most suitable studies: IC1 - the study presents a NFR catalog; EC1 - the study is not written in English; EC2 - the study is not from Computer Science or Engineering related areas; and EC3 - the paper does not present a NFR catalog.

3.1.4 Data Extraction.

An extraction form was elaborated to be used for each selected paper in this phase. This form is organized into four parts. The first one is related to data from the accepted papers and the other parts are related to data to answer the each RQ (RQ1, RQ2, RQ3, RQ4).

3.1.5 Data Analysis.

The extracted data was analyzed according to the type of data extracted. For RQ1 and RQ2, a quantitative analysis was performed due to the nature of the data collected, which were numerical in a nominal scale. A measure of central tendency (mode) and a measure of dispersion (frequency) were used to present the results. Regarding RQ3 and RQ4, the data extracted from the literature provided a significant amount of textual information. Therefore, we decided to use a qualitative method called Content Analysis (CA) to analyze the data and, consequently, answer more appropriately the questions [11].

3.2 Conducting

This phase was performed in five steps, described as follows.

3.2.1 Database Search.

This step is about applying the search string (see Table 1) into the search machines of the libraries (Scopus and Web of Science). To select the most suitable set of papers after applying the search string, a screening step was performed using the following five filters: (1) Applying EC1 and EC 2 in the found studies; (2) Excluding duplicate studies; (3) Applying the exclusion criteria in the abstract and title reading; (4) Applying the exclusion criteria in the introduction and conclusion reading, also apply the exclusion criteria by checking if there is an image of a catalog in the study (*e.g.*, graph, table); and (5) Applying the exclusion criteria in the entire paper reading.

The filter 1 was performed in the own search machines (Web of Science and Scopus) whereas the other filters (2, 3, 4 and 5) were performed with supporting of Parsif.al tool[2]. Filters 3, 4 and 5 were executed by peers -

[2]Free online collaborative tool for systematic reviews: https://parsif.

one student and one expert in NFRs catalog. First, a student performed the filter alone. Then, an expert who has been working with NFRs catalogs reviewed only excluded papers. For example, if a student had excluded a paper by reading the abstract and title, the expert should review them to check whether he-she agrees with the exclusion. If not, the paper would be included in the study again.

3.2.2 Snowballing.

We have used the backward snowballing procedures to complement the set of papers found by the database search. The backward procedure consists of checking the references list of a set of papers. In our case, the set of papers were the ones selected in the databases searches. We adapted the procedure from [**?**] and [**?**], which consisted of four filters. These filters are not totally similar to the filters we used earlier since the selection through backward snowballing is slightly different. First, we started by manually reviewing all references from each accepted paper from databases searches. Then, for each reference we applied the following filters: (1) Applying all exclusion criteria in the reference. In this case, we had to be more specific since we were reading only titles, authors, venue and year. Thus, we accepted papers who presented any keyword from our search string; (2) Applying all exclusion criteria in the abstract reading; (3) Applying the exclusion criteria in the most relevant part of the papers (introduction, conclusion, and images of catalogs); and (4) Applying the exclusion criteria in the entire paper reading.

3.2.3 WER Search.

WER exists since 1998 and has been an advance for the Ibero-American community. This workshop provides a Google search engine[3] that explores papers in all WER editions. Therefore, we applied the same search string from Table 1 on it and the same filters for the databases searches.

3.2.4 Data Extraction

After performed all searches, the data extraction took place. In this way, first, the extraction of data was done in the papers found in the electronic databases. Then the extraction was done in the papers of snowballing and, finally, the extraction was carried out in the papers from the workshop.

Regarding to the papers obtained by the databases, the same student who performed the filters during the filtering phase also performed the data extraction. Each extraction was reviewed by the expert. The extractions of the papers obtained by the snowballing and the workshop were made by the expert and reviewed by the student.

During extraction, the form was updated to include a data not considered during planning: "type of correlation". Through one of the obtained papers, it was possible to note that the correlations can appear between NFRs (*e.g.*, Usability and Performance), which is called INTER-NFRs, or within a same requirement (*e.g.*, Performance subcharacteristics conflict with one another), called INTRA-NFR. Thus, all papers that had already been extracted were reviewed again to extract this specific data.

3.2.5 Data Analysis

This phase was about analyzing the extracted data. RQ1 and RQ2 were indeed analyzed with the measures Mode and Frequency. RQ3 and RQ4 were also analyzed using quantitative measures, but they were also analyzed through a qualitative method, Content Analysis [11]. The main procedure is this method is the data coding, which means extracting and relating codes from raw data through inspection. Codes are conceptual names that represent the understanding of the researcher about a text. A set of codes can be grouped to form a category, which is a higher-level concept. Then, each extracted data from RQ3 and RQ4 were carefully read and coded. The, these codes were grouped to the similar ones into categories[4].

4 Results

This systematic study obtained 53 papers (38 from databases and 15 from snowballing). The key results from the extraction and analysis of these papers can be viewed in Figure 1, which presents an overview for each RQ.

Answering *RQ1*, 102 catalogs were obtained. We realized that they cannot be classified as mutually exclusive in three types of catalogs, as previously proposed by [2]. Then, we extended the classification of [2] to: T1 –

[3] http://wer.inf.puc-rio.br/index.html

[4] The MAXQDA12 tool was used to support CA method - https://www.maxqda.com/

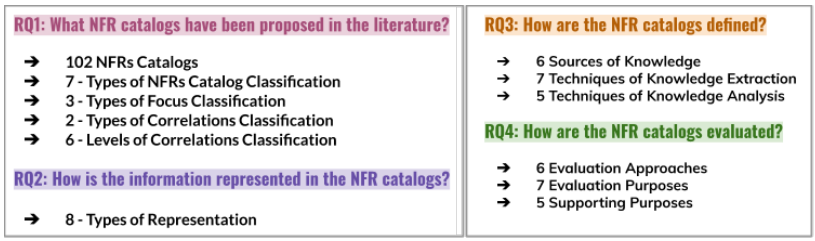

Figure 1: Key Findings of the SM Study.

Subcharacteristics, T2 - Subcharacteristics and strategies, T3 - Subcharacteristics, Strategies and Correlations, T4 – Strategies, T5 - Strategies and Correlations, T6 – Correlations and T7 - Subcharacteristics and correlations.

Initially it was expected that the catalogs could be for a specific area, but with this study, we realized that they can be proposed to particular areas, domains or artifacts. These different views are named as the "focus" of the catalog.

We also analyzed the NFRs supported by these catalogs. In total, 86 different NFRs were extracted. Performance was the most cited (34), followed by Security (29), Usability (23) and Reliability (14). Regarding subcharacteristics and methods, we found out 1269 and 1113, respectively.

Regarding correlations, this SM study found 473 positive and 395 negative correlations in total. They can occur not only between NFRs but also within the same NFR because their subcharacteristics or strategies may conflict with one another. In this way, a classification of correlation types was found out: INTER-NFRs and INTRA-NFR.

This last finding allowed us to establish a research opportunity related to the investigation of conflicting (positive or negative) correlations. For example, when a catalog states two NFRs is conflicting, and another catalog states they are cooperating.

Besides, this SM study found out that there are six levels of correlation. This level varies from the most generic, which are correlations directly between NFRs, to more specific levels, which are correlations between strategies and strategies and characteristics.

The identified catalogs are represented in eight different ways (answering *RQ2*): SIG (including SIG adaptations), matrices, i* notation, tables, hierarchical structures, list, template, and pattern. With this information, we established a second research opportunity related to the catalog's representation. Future research could investigate these representations in a way that could indicate which would be the most appropriate to deal with each knowledge of a catalog of NFRs: subcharacteristics, strategies and correlations.

Although there are catalogs defined by the authors themselves based on their experience, this study realized that the definition of a catalog can be done in two steps (answering *RQ3*). First, it is necessary to collect the information, and then it is necessary to analyze this information to arrive at a more organized knowledge. Concerning the collection, there are six external sources by which the catalog creator can search for information: literature, existing catalogs, existing systems, experts, stakeholders and architects/developers. Also, there are seven techniques to extract the information from these sources: bibliographic review, systematic review, interview, questionnaire, questions patterns, goal-question-operationalization and measurement. Finally, there are five techniques to analyze data: Collaboration Process with researchers, Consensus Meeting, Clustering Techniques, Content Analysis and a Technique based on Personal Construct Theory.

Therefore, a third opportunity is related to the definition of a complete catalog. Although some papers explain their ways of constructing the proposed catalogs, a generic framework or process that provides a detailed guideline to create NFRs catalog was not found.

The last findings were regarding the evaluation of a catalog (answering *RQ4*). Six evaluation approaches were found out: proof of concept, case study, survey, questionnaire, relative validity and controlled experiment. Seven evaluation purposes: designing a specific system considering a NFR; redesigning an existing system to show improvement with the use of the catalog; building a new model, often reusing knowledge from the existing catalog; remodeling an existing catalog; arguing about the effectiveness of the catalog; and support a system's implementation. Also, many catalogs are not evaluate themselves but used to support another proposal. Five supporting purposes were found out: to support evaluations, to be used in a model, to be used for comparison study, to be used in a tool, to be used in proposed approaches.

Then, a fourth and last opportunity is related to the evaluation of a proposed catalog. Few catalogs presented detailed evaluation procedures. Thus, there is a need to create a guideline to guide NFRs catalog evaluations.

5 Conclusion and Future Work

This paper has presented a study about NFRs' catalogs[5]. Through the SM method, together with quantitative and qualitative analysis (content analysis), it was possible to derive important information about the catalogs that are useful not only for researchers but also for developers who are concerned with satisfying NFRs in their systems. Thus, the contributions of this work have implications regarding both industry and academy.

For industry, this work generated a dataset containing more than 1000 subcharacteristics, 1113 implementation and design methods, 473 positive correlations, 395 negative correlations for 86 NFRs. We believe this base can be useful for developers to search several ways of implementing NFRs and thus reuse the knowledge gained from this research. For academy, this work generated a list of four high-level research opportunities that can improve the NFRs catalogs area. As a next step, we are using the results of this study to propose a process to define NFRs catalogs.

As future work, we plan to conduct a study in the industry to understand the usage of NFRs catalog in real scenarios. Then, the current challenges and issues the practitioners have faced in their work could be investigated. Furthermore, we encourage additional searches to possibly expand our database of NFRs catalogs.

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[5]All materials and results from this SM study are available at https://github.com/great-ufc/SM-NFRsCatalogs