Towards a Systematic Literature Review of Non-Functional Requirement Prioritization Approaches

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Abstract

The success of any software system depends on implementation of functional requirements followed by non-functional ones. There are various studies about prioritizing functional requirements and improving the prioritization techniques, but the work related to non-functional requirements prioritization is limited and there are no guidelines about which technique to be executed under particular circumstances. This paper does an empirical systematic review of the literature to identify and critically review the disseminated work based on empirical studies of software industries or presenting the non-functional requirement (NFR) prioritization approaches. The literature review yielded various insights; prominent amongst them includes, ad-hoc manner of NFR prioritization, neglection of NFRs, and the need for validation of existing NFR prioritization approaches on live data set with large number of NFRs which are always changing.

Keywords: *Literature review, functional requirements, non-functional requirements, incremental software development*

1. Introduction

In any incremental software development process, there is large number of candidate requirements for implementation at any increment. The software industries select most important requirements so that less number of requirements could be implemented under budget and resource constraints. There are numerous techniques available for prioritization of functional requirements like AHP (Analytic Hierarchy Process), numerical assignment, QFD (Quality Function Deployment), cost-value approach, *etc*. which are critically reviewed and presented in (Achimugu *et. al.*, 2014).

Non-functional requirements determine the needed properties of any software as they are necessary conditions to be met for functional requirements to get implemented and used properly. For example, without fulfilling the security requirement for a flight or hotel booking software, it is not possible to implement all of the functional requirements.

Although non-functional requirements are considered to be very important for project success rate, unfortunately the literature lacks the methods for prioritization of non-functional requirements (Gupta *et. al.*, 2016). The non-functional requirements are generally handled in an ad-hoc manner by the software developers (Gupta *et. al.*, 2016).

The objective of this paper is to review the literature for identifying and analyzing the work related to NFR prioritization. A systematic review answers a number of defined research questions by collecting and summarizing all empirical evidence that fits pre-specified eligibility criteria. We apply the review process given in Figure 1 which is adopted from (Kitchenhan *et. al.*, 2007) and (Brereton *et. al.* 2016).

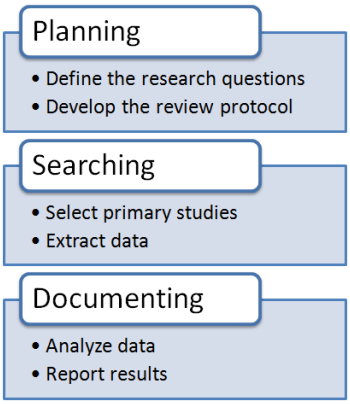

Figure 1. Review Process

The paper is structured as follows: Section 2 and 3 explains the research questions and the methodology. Section 4 presents the details of the selected papers. Section 5 and 6 analyses the results and discusses the threats to validity respectively. Finally the paper is concluded and future work is suggested in Section 7.

2. Research Questions

This work aims to explore the various techniques of NFR prioritization that exist in the literature. To achieve this goal, the literature is systematically searched for the following research questions:

RQ1: How are non-functional requirements prioritized?

RQ2: What is the state of the art for NFR prioritization in industries?

3. Methodology

To answer the determined research questions, this paper follows the systematic literature survey guidelines as given by (Kitchenhan *et. al.*, 2007). The following bibliographic databases were searched against the search string "Non-functional Requirements" AND "Prioritization" for the years in range of 2008 to 2017 (including two ends).

1) IEEE xplore (search in metadata)

2) Springer link (search in title)

3) Science Direct (search in title)

Only the papers based on answering either of two research questions are selected for further necessary analysis. The number of papers obtained after doing search and those finally selected are given in Table 1.

Table 1. Number of Selected Papers from Each Database.

Bibliographic Databases	Number of Papers Returned	Final Selected Papers
IEEE Explore	11	7
Springer Link	20	1
Science Direct	1	1

4. Details of Extracted Papers

1. (Svensson *et. al.,* 2011) interviewed 11 project managers and 11 product managers of 11 companies to study about the quality requirement (QR) prioritization performed, and the parameters used for the process as well as their variations at product and project levels.

The study revealed that the industries either employ ad-hoc prioritization or numerical assignment technique. Moreover, QR is always considered to be of lowest priority. The industries either do not use any parameter during prioritization or use customer input to decide implementation ordering of NFRs. Besides, ad-hoc prioritization is done at product level and NFRs is difficult to be decomposed at project level.

2. (Phillips *et. al.,* 2012) interviewed five Australian companies of different sizes, products and domains. The main result is that the most of the companies prefers accuracy over security and reliability when asked to prioritize from list of 26 NFRs. The implementation of QR varies in different companies.

3. (Farid and Mitropoulos, 2013) proposed two planning models called Riskiest Req's first and Riskiest Req's last (Non-functional Req's planning). The authors defined Project Management Metrics, Requirement Quality Metrics and risk calculation algorithm which computes risk score for both Functional and Non-Functional requirements. The computed risks are used to prioritize requirements using either "Riskiest requirement- First" and "Riskiest requirement- Last" priority schemes. These Risks driven priority schemes proved to be beneficial as they resulted in the reduction of project duration as revealed by experimentation.

4. (Dabbagh and Lee, 2013) proposed a new non-functional requirement prioritization method based on AHP and selection of high priority and those NFR's that affects the high priority NFR's negatively. The AHP is used to rank NFR's according to the two parameters *i.e.,* importance to users and importance to customers.

5. (Dabbagh *et. al.,* 2014) proposed the hybrid assessment method (HAM) to prioritize both functional and non-functional requirements. The authors proposed a five step model where AHP is used to rank NFR's and FR's are ranked in accordance with importance of each NFR wrt FR's. The Tool called Csharp Hybrid Assessment Method (CHAM) is also provided to automate the proposed method. The proposed approach is composed with AHP based approach on 15 FR and 5 NFR and results indicated that proposed approach outperforms the AHP technique from time consumption point of view.

6. (Fellir *et. al.,* 2014) proposed a new method to prioritize both functional and non-functional requirements. To do this all FR's are prioritized using AHP and then against

the NFR's. The priority of FR's are updated if priority of NFR is bigger than FR, else remains unaltered.

5. (Maiti and Mitropoulos, 2015) proposed a method to capture, elicit, predict and prioritize NFR's. The authors proposed that the NFR's are extracted from customer requirements documents, which are then subjected to prioritization using αβγ approach.

6. (Thakurta, 2013) proposed a prioritization method for NFR's which is based on business and project objectives. The representatives of business and project were involved for prioritization purpose. The indentified NFR are associated with identified scenarios. The association between scenarios is captured in association matrix and relative importance is calculated using weigers method. The scene is then adjusted and few NFR's are dropped from scenario.

7. (Chopra *et. al.*, 2016) conducted an experimentation on different approaches for the prioritization of Non-functional Requirements. The experimentation was conducted on low, medium and high complexity projects and it was reported that prioritizing NFR separately but in consideration with FR is the better approach than the others.

5. Analysis of the Results

The extracted papers are empirical or they present a new NFR prioritization technique. The empirical papers state that NFRs are mostly neglected in software industries or if considered, are handled in an ad-hoc manner. In addition, they do not have any scalable prioritization process for NFR's.

The papers that present new techniques propose new models and validate them. In almost all papers, the NFR's are selected considering their impact on FR's apart from other selection parameters/algorithmic steps. These papers had few limitations that need verification through experimentations.

1) Almost all papers employ AHP which requires subjective judgment.
2) The techniques may or may not work with even growing large number of NFR's. In other words, their scalability needs to be analyzed.
3) The effect of the prioritization approaches for functional and non-functional requirements needs to be checked on overall ranked list. For example, few authors first used AHP to create initial priority list and thereafter considered various parameters like impact to create final list.
4) The applicability of the prioritization approaches for ever increasing and changing requirements needs to be validated. In any incremental development process, the requirements appear in flood (Karlsson *et. al.*, 2002) and are continuously changing (Gupta *et. al.*, 2015), which makes it difficult to prioritize or reprioritize existing or new requirements, especially when pair wise based AHP is being employed (Berander 2007).

6. Threat to Validity

Although our review is replicable with the search strings, research questions, and the selected databases, however it may be threat to validity due to any human error (if any).

7. Conclusion & Future Work

The paper does an empirical study of the literature by doing systematic review of the three bibliographic databases *i.e.*, IEEExplore, SpringerLink and ScienceDirect. The identified papers were those highlighting the industrial practices of NFR prioritization

or those based on proposing new prioritization technique. The analysis of the work converges into meaningful conclusion that there is no theory or well-defined NFR prioritization technique that is proved to be well acceptable for particular problem at hand. Furthermore, the applicability of the proposed NFR prioritization approaches need to be validated for large number of ever changing requirements and efforts needs to be made to make the technique scalable and less effortful. In the future, scalable and highly accurate NFR prioritization techniques are needed. As a future work, we will extend our review with other databases and different relevant search strings.

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