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Subject review

Investigation of Requirements Interdependencies in Existing Techniques of Requirements Prioritization

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Abstract: Requirements prioritization (RP) is considered as a key role in producing a successful system by selecting the most important requirements to be released. Requirements interdependencies (RI) is one of the crucial aspects that need to be addressed in RP, since most of the requirements in reality are not independent and have dependencies between each other. Thus, ignoring RI in RP process may lead to produce inaccurate prioritization result which directly impacts the system's success. In spite of this, little is known about the impact of RI, and obviously further research is urgently required to measure the RI in the RP techniques. Hence, this study aims to investigate and analyze the existence and the execution steps of handling RI in the existing RP techniques to improve the performance of techniques in generating accurate result and assist the researchers and practitioners to select the appropriate technique that can handle RI in prioritization process. The findings indicate that, out of 65 techniques, there are only 4 techniques that handle the RI. The result reveals that these four techniques still suffer from issues of manual process and heavily rely on the experts' participation. Proposing a new technique is recommended to overcome the identified limitations.

Keywords: prioritization; requirements; requirements interdependencies

1 INTRODUCTION

System development life cycle is constructed with the various phases to be used in order to develop a good quality system [1-3]. Requirement elicitation is an important phase of system development life cycle, since it is the phase where the requirements are elicited and extracted from the stakeholders [4-6] Implementing and developing all the elicited requirements is extremely difficult with limited resources such as budget constraints, short schedule, and limited staff power [7, 8]. On the other hand, the implementation of the stakeholders' requirements is considered as a main factor that can lead to develop and deliver a successful system [4, 9-11]. Prioritizing the requirements is considered as one of the solutions in such a case, since requirements prioritization (RP) is defined as a process of prioritizing the requirements based on the stakeholders' preferences in order to identify the most important requirements among others and to produce a ranked list of requirements [12-14] This requirement list is used in release planning and implementation of the system. Hence, RP is one of the key aspects in producing a successful system that meets the stakeholders' needs [4, 15].

Various techniques have been proposed to perform the prioritization process such as AHP [16], PHandler [4], and Dot Voting techniques [17] etc. The major issue that needs to be considered in executing RP is the existence of the dependencies among the requirements, since requirements are not considered as separated segments and requirements are 80% interdependent and affect each other [18, 19]. These dependencies contribute to the complexity issue in prioritizing the requirements for project release plan [13, 19-21]. For instance, in order to implement requirement B, requirement A must be implemented as it is a prerequisite of requirement B. This implies that ignoring requirement dependencies in the RP process will give rise to a conflict during the implementation release planning of the requirements which is executed based on the produced prioritized list of requirement. There will be possibilities of having high priority requirements that have some prerequisite requirements at a lower priority, so it will be difficult to implement these high priority requirements first unless the prerequisite requirements of a lower priority should be considered and developed [19, 22]. Despite this, not many researches have focused on the impact of requirements interdependencies in prioritizing the requirements. Further research is needed to measure the existence and execution steps of addressing the RI in the existing RP techniques [19, 20]. Therefore, the overall aim of this study is to investigate the existence of the requirements dependencies in the existing techniques that are available in performing the RP. In addition, the study will investigate how the dependencies between requirements are handled in these techniques.

The rest of this paper is organized as follows: Section 2 explains the research methodology which is used to conduct this study. Section 3 elaborates and discusses the findings of this study, while section 4 highlights the conclusion along with future recommendation based on the identified issues.

2 RESEARCH METHOD

To achieve the defined aim of this research, a research method was constructed as shown in Fig. 1. It is comprised of 4 phases: research questions, search process, related studies selection, and analysis of the selected studies. The research activities began with research questions phase, where the scope of this study is defined by formulating the research questions based on the identified objective of this research. The objective of this study is to analyze, review and investigate the requirement interdependencies in existing requirements prioritization techniques. To obtain the defined objective, two research questions were formulated as follows:

- RQ1: What are the existing techniques of RP that handle the requirement interdependencies in prioritizing the requirements?
- RQ2: How do the current RP techniques handle RI in the prioritization process?

After specifying the research questions, search process phase was executed by searching for the possible related existing studies. The related existing studies were elicited and collected based on the specified research questions

from the published research studies of conferences, IEEE Bulletins, journals, workshops, books chapters. Relevant and well-known electronic resources used for extracting the related studies include IEEE Computer Society Digital Library, the Springer link, ISI Web of Knowledge, the Springer link, ACM and Science Direct, Google Scholar [12, 23, 24]. In addition, list of keywords was formulated based on the research questions to search for related research studies. The list of keywords used was employed with combination of Boolean operators (AND, OR) in order to extend the searching process. The formulated lists of keywords used are as follows:

- Requirements Prioritization (OR, AND) selection.
- Requirements interdependencies OR dependency.
- Requirements interdependencies in Requirements prioritization.
- Requirements prioritization techniques OR methods OR frameworks, OR approaches OR models.
- Requirements interdependencies (OR) dependency in requirements prioritization techniques OR methods OR frameworks, OR approaches OR models.

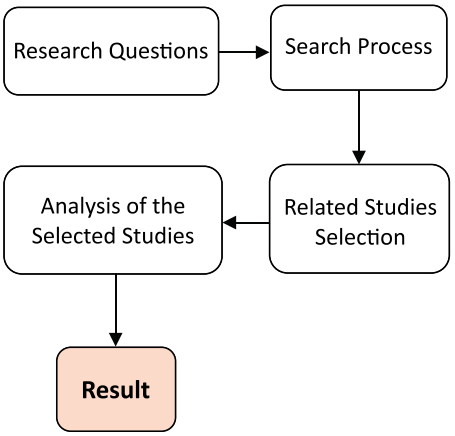

Figure 1 Research method

Furthermore, the study selection phase was executed based on the identified research questions. The title, abstract and content of each collected study was critically studied to select only the studies that can at least provide potential answer to the research questions. Thus, 52 studies were selected as most relevant studies based on the defined research questions that are capable to address the listed research questions. Finally, analysis of the selected studies was performed to analyze the findings and result of the study. The selected relevant studies have been analyzed critically to answer the formulated research questions.

3 FINDINGS AND DISCUSSION

To address the specified research questions as mentioned in previous section, each prioritization technique was identified and analyzed critically in terms of addressing the RI and how RI was handled in the prioritizing process. Tab. 1 presents the outcome result of the analysis of all RP techniques (65 techniques) that were identified from the selected studies. Based on the derived result, most of the RP techniques did not address the RI in their prioritization processes due to the fact that majority of the techniques were proposed with the aim of prioritizing requirements and assuming that the requirements are free of dependencies. However, most of the RP studies highlight the requirements interdependencies as a required future enhancement in their research. Thus, only 4 out of 65 RP techniques handled the RI in their prioritization processes. These techniques are Multi-Aspects Based RP [25], Value Based Requirements Prioritization [26], Mathematical Programming [19], and Interactive Requirements Prioritization techniques [27].

The aim of Multi-Aspects Based Requirement Prioritization technique was to prioritize the requirements based on the business aspects [25]. In this technique, RI was considered as one of the business aspects (dependency aspect), where the technique allows the stakeholders to assign a value of the dependency to each requirement individually. However, handling RI in this way is poor, since the dependencies between the requirements have to be taken based on the dependency rate of the requirement on others instead of letting the stakeholders directly give a value of the dependency to each requirement separately without considering the possible dependencies of the requirements among each other [27].

On the other hand, the Value Based Requirements Prioritization technique was reported in [26]. This technique addresses the dependencies among requirements in the requirements selection process as compared to other techniques. The dependencies are addressed using comma separated lists of requirements. The way to address RI in these techniques is considered as poor handling with large set of requirements, since it will be hard to fill in the dependencies between the requirements. In addition, the inability to sort hierarchically the requirements is reported as another issue in this technique.

Mathematical Programming technique was proposed to perform the RP process with addressing the dependencies between the requirements [19]. In this technique, the dependency was identified by randomly generating the dependency ratio between the requirements with the condition that the requirement cannot be selected and released unless its predecessor is selected prior to it. In conclusion, more effort is needed in order to evaluate the technique's way of addressing the RI and generalize the result. Also, the difficulties of pointing out the priority value of each requirement is identified as another issue in this technique [19].

In [27], another technique named "Interactive Requirements Prioritization" was presented to prioritize the requirements with considering the dependencies between them. The analyst (who elicited these requirements) provides the list of the requirements along with the classification of each requirement in three priority groups: high, medium, low. The priority rank is induced by the dependencies between requirements. For example, the requirements in the high rank priority group should precede those requirements that are in medium priority group. Although this technique provided such a good solution of handling RI during prioritizing the requirements compared to other techniques, the participation of the highly professional analyst is required to conduct the process. Also there is a need to conduct more case studies to evaluate its effectiveness [27].

Table 1 Analysis of the existing techniques of requirements prioritization

No	Technique Name	Year	Handle RI
1	A Clustering Based Technique For Large Scale Prioritization [7]	2014	×
2	A Conceptual Model And Process For Client-Driven Agile RP [17]	2010	×
3	A Preference Weights Model For Prioritizing Software Requirements [14]	2014	×
4	A Web-Based Multi-Criteria Decision Making Tool For Software RP [15]	2014	×
5	Analytic Hierarchy Process (AHP) [16]	1998	×
6	Architecture Trade-off Analysis Method (ATAM) [28]	2002	×
7	Attributed Goal Oriented Requirements Analysis [13]	2002	×
8	Benefit and Cost Prediction [13]	2008	×
9	Binary Priority List [7, 15]	2010	×
10	Binary Search Tree [16]	1998	×
11	Bubble Sort [16]	1998	×
12	Case Based Ranking [29]	2013	×
13	Cognitive Driven Requirement Prioritization [13]	2010	×
14	Conceptual Model of Agile Requirement Prioritization [17]	2008	×
15	Correlation-Based Priority Assessment Framework [30]	2006	×
16	Cost- Value Approach [13]	1997	×
17	Cost–Benefit Analysis Method [28]	2002	×
18	Cumulative Voting Or 100 Dollars [4]	2000	×
19	Dot Voting [17, 31]	2007	×
20	Eclipse Process Framework [17]	2008	×
21	Evolve [13]	2004	×
22	Fuzzy AHP [13]	2002	×
23	Fuzzy Hierarchical Cumulative Voting [32]	2014	×
24	Hierarchical Cumulative Voting (HCV) [4, 8]	2006	×
25	Hierarchy AHP [16]	1998	×
26	Interactive Requirements Prioritization [27]	2013	✓
27	Kano Model [17, 31]	2007	×
28	Lanchester Theory [13]	2008	×
29	Mathematical Programming Technique [19]	2010	✓
30	Moscow [31]	2007	×
31	Minimal Spanning Tree [16]	1998	×
32	Multi-Aspects Based RP [25]	2014	✓
33	Multi-Criteria Preference Analysis Requirements Negotiation [13]	2002	×
34	Multi-Objective Next Release Problem [21, 27]	2007	×
35	Multi-Voting System [31]	2006	×
36	Numerical Assignment [31]	1996	×
37	Pair-Wise Comparison [33]	1996	×
38	Partial Order Assimilation Approach [30]	2014	×
39	PHandler [4]	2015	×
40	Ping Pong Balls [17]	2004	×
41	Planguage [29]	2005	×
42	Planning Game [33]	1999	×
43	Planning Game Combined With AHP (PGCAHP) [33]	2004	×
44	Priority Groups [16]	1998	×
45	Quality Functional Deployment [29, 31]	1990	×
46	Ranking [16]	1998	×
47	Ranking Based On Product Definition [17, 31]	2002	×
48	Relative Weighting [17]	2005	×
49	Requirement Triage [34]	2009	×
50	Requirement Uncertainty Prioritization Approach [35]	2012	×
51	Round the Group Prioritization [17, 31]	2006	×
52	Software Engineering Risk: Understanding And Management (SERUM) [28]	1999	×
53	Simple Multi-Criteria Rating Technique by Swing [36]	2004	×
54	Software Architecture Analysis Method (SAAM) [28]	2002	×
55	StakeRare [8]	2012	×
56	Theme Screening/Scoring [17]	2005	×
57	Top Ten [4, 13]	2002	×
58	Two-Step Value-Based Requirements Prioritization Approach Based on TOPSIS [26]	2013	×
59	Using the Fuzzy Multi-Criteria Decision Making Approach for Software RP [13]	2015	×
60	Value Based Requirements Prioritization [26]	2013	✓
61	Value Based Intelligent Requirement Prioritization [4]	2011	×
62	Value Oriented Requirements Prioritization [28]	2007	×
63	Weighted Criteria Analysis [17, 31]	2005	×
64	Wiegers' Matrix Approach [31]	1999	×
65	Winwin[8, 13]	2000	×

4 CONCLUSION

RI is a key aspect in requirements prioritization, since prioritizing the requirements without handling the dependencies among them will impact the quality of the prioritization result. This study provided a comprehensive investigation of RI in the existing RP techniques in terms of measuring the RI existence in current techniques along with presenting the execution steps that are used to handle RI in their prioritization process. This will assist the researchers and practitioners to identify and select the suitable technique in handling the RI and help them to enhance the quality performance of the current techniques.

Moreover, this study was conducted based on the research method which consisted of 4 activities: research questions, search process, related studies selection, and analysis of the selected studies. The study's findings reveal that most of the current RP techniques lack handling the requirements interdependencies in the prioritization process. Out of 65 RP techniques, only 4 handle the RI. These techniques are Interactive Requirements Prioritization, Multi-Aspects Based RP, Mathematical Programming, and Value Based Requirements Prioritization techniques. As revealed from the findings, these four techniques have limitations in terms of manual process and the need of the experts' participation. Also, more work is needed to assess the effectiveness of these techniques in terms of evaluating and verifying the capability of their process in addressing the requirements interdependencies. Thus, a new technique is recommended to be proposed in order to handle the RI automatically with reducing the experts' involvement especially with the large set of requirements.

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