

Aspects of Requirements Prioritization: A Study

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Abstract

Requirements in the context of software engineering refer to the demands from the stakeholders to create their desired product. However, requirements are usually come in bulk and it is impossible to implement them in just one single release of software. Therefore, requirements prioritization is a process to determine the sequence candidate of requirements to be included in the software release. However, requirements prioritization is always been overlooked and carried out at the later stage software development life cycle. In fact, requirements prioritization is important to filter unnecessary requirements for a better quality of the requirements before requirements implementation. This paper focuses on the study of the requirements prioritization in order to find out the issues and provide path for future work for researchers. We analyzed the methods used for requirements prioritization and compared the aspects focused in the proposed approach for requirements prioritization. The result from our literature study shows that most of the researcher extends their work based on the well-established conventional requirements prioritization techniques by focusing on the importance of requirements. The limitation of usability and scalability for requirements prioritization still remain unsolved.

Keywords: Requirements Engineering, Requirements Prioritization, Aspects of Requirements Prioritization, Software Engineering

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Introduction

Requirements prioritization is one of the activities found in requirements engineering. Requirements prioritization is important for its features of filtering, ranking and organizing the requirements based on the importance level and other aspects available. However, the activity of requirements prioritization has been frequently overlooked by requirements engineers [1]. When the requirements are not prioritized, the importance level of the requirements stayed unknown. The system is

developed solely based on the opinions or intuitive feelings of requirements engineers. The ignorance on the activity of requirements prioritization results in customers' dissatisfaction on the product and it is considered as project failure in this case.

In addition, requirements prioritization is often carried out at the later stage in requirements engineering which refer to the design and testing phase. The delayed requirements prioritization activity causes requirements

defects and requirements risk to be remained. This phenomenon requires higher cost and effort to fix the requirements defects and requirements risk hidden at the later stage of requirements engineering. We believed that it is beneficial to implement requirements prioritization as early as possible to remove the requirements defects and requirements risk mentioned. Therefore, the quality of the requirements is greatly improved when there is a minimal requirements defect and risk. Most importantly, the improved quality of requirements has directly proportional relationship with the quality of the system developed.

The reasons mentioned above motivate us to venture into the topic of requirements prioritization with aim to improve and emphasize on the activity of requirements prioritization. In this paper, we conducted study on the techniques available for requirements prioritization in order to find out the current issues existed. We further investigated on the aspects focused for requirements prioritization techniques mentioned.

This paper composes of five sections. The first section provides introduction followed by a brief introduction to requirements prioritization with definition in the second section. The third section comprises of our study on the literature for the topic of requirements prioritization techniques. Next, we further discuss on the literature by tabulating and comparing the data collected into table form. We draw out the limitation and provide the gap found in requirements prioritization as the future works based on our literature study. In the last section, we conclude our study for requirements prioritization.

Requirements Prioritization

Requirements prioritization, defined by Firesmith, is the process of providing the

perfect order for requirements implementation based on the importance level of requirements [3]. In a simpler word, requirements prioritization aids in the selection of requirements by uncovering the most important requirements within resource constrains [2].

Requirements are usually comes in bulk from stakeholders during the requirements elicitation, the first stage of activity in requirements engineering. It is a challenge for requirements engineers to allocate the requirements especially when the number of the requirements is exceeding its competency for example resources, time and cost. Unnecessary requirements can be removed from the early stage of development by requirements prioritization. Hence, it is essential to differentiate the bulk of requirements by its priority level. Requirements prioritization is part of an activity found in requirements analysis and recognized as an important activity [4].

Requirements prioritization solves requirements' ambiguity, conflicts and disagreement, discover requirements defects, the limited resources are well assigned based on priority, create understanding between stakeholders and requirements engineers by having more interactions and etc. There are three stages to be carried out [2][5] in requirements prioritization. The first stage is preparation stage followed by the execution stage. The third and last activity is the presentation stage where the result gained from requirements prioritization is presented. A set of desired requirements are filtered in accordance to the preference of the stakeholders in a single release. There are others different of factors, included in our previous study in [2], to be considered during requirements prioritization except for the importance of the requirements decided by stakeholders.

Babar M. I. et al. [6] conducted a study on the challenges and the future trends for requirements prioritization and hence proposed a solution based on their study. According to their literature evidence, the problems associated with requirements prioritization are as followed:

1. Scalability issues for current requirements prioritization techniques
2. Time Consuming for current requirements prioritization techniques
3. The result for current requirements prioritization techniques are error prone
4. The result can't be recalled
5. Mostly solve small scale of requirements

In addition, they have found from their survey that the current requirements prioritization techniques are not sufficient for large projects contain large number of stakeholders and requirements that might lead to conflicts.

Literature Review

We focused our literature study on the topic related to requirements prioritization techniques that are currently being practiced and the issues existed. There are extensions of works from the previous well known requirements prioritization methods as well as newly proposed method to handle requirements prioritization.

Hassan S. U. and Awan S. A. [7] conducted a questionnaire survey to find the factors affecting requirements prioritization. Their survey concludes that analyst's qualification, age and experience are the factors affecting requirements prioritization process. They claimed that the three factors mentioned help to minimize the gap between stakeholders by solving the communication issue.

We found a few works were done by comparing the conventional techniques of

requirements prioritization. For example, Goel L.B. and Thakur S. [8] examined five of the most common requirements prioritization techniques (AHP, Bubble Sort, Priority Groups, Minimal Spanning Tree and Binary Tree) and proposed a framework for requirements prioritization adopting AHP method by ranking the requirements with the relative level of value, cost, effort and threat associated with each of the requirements. The main objective of the proposed framework is to calculate the important factors that are necessary to address while prioritizing requirements. However, their proposed framework is experiencing the issue of scalability just like most of the techniques for requirements prioritization. This work is merely a proposed framework and is considered immature as it is not evaluated.

Siddiqui S. and et al. [9] also did a simple comparison between Analytical Hierarchy Process (AHP) and Planning Game (PG) and found that PG is more promising than the other requirements prioritization method. In fact, there are a lot more available techniques for requirements prioritization that are neglected by them for comparison. Their study is considered simple as it does not include other methods for comparison in order to find the best or effective method for requirements prioritization.

Further, Khan J. A. et al. [10] described an assessment on the examination of various requirements prioritization techniques including Binary Search Tree, AHP, Hierarchical AHP, Spanning Tree Matrix, Priority Group/Numerical Analysis, Bubble Sort, MoSoW, Simple Ranking and Planning Game. The objective of their study is to find the best or most suited technique for requirements prioritization. Based on their result of the study, it shows that AHP is the best requirements prioritization technique since it provides the most reliable, on a rational scale, and efficient result. Nevertheless, AHP

is facing the issues of scalability when the number of requirements increased. The number of requirements is directly proportional to the number of decision needed to be made during requirements prioritization and hence the requirements prioritization technique becomes complex when the number of requirements increased.

Khan J. A. et al. [11] continued their work from previous year on the same topic and elaborated on the seven of the conventional requirements prioritization techniques available including Analytic Network Process (ANP), Binary Search Tree, Hierarchical AHP, Spanning Tree Matrix, Priority Group and Bubble Sort. An experiment was conducted to evaluate the requirements prioritization techniques and the results shows that ANP is the most promising techniques among the rest. The core characteristic of the requirements prioritization technique of ANP is its reliability and the result from fault tolerance. They proposed a method to prioritize dependent and independent requirements with ANP. However, the process to carry out requirements prioritization is rather complicated due to its greater number of decision is required.

Chopra R. K. et al. [12] carried out experiment to examine on efficacy of existing requirements prioritization technique, AHP, for nonfunctional requirement in different complexity of the project. Firstly, the authors examine on the accuracy of requirements prioritization technique followed up by the impact of the complexity of the software on the accuracy of the requirements prioritization technique. They concluded that nonfunctional requirements should be prioritized separately from the functional requirements to improve requirements prioritization efficiency.

Soumya Krishnan M. [13] carried out a study on the requirements prioritization techniques in order to identify the most prominent

technique or approach along with their key features. A simple solution model, based on any (RFPs) supplied by the client, was also suggested for requirements prioritization in the study which helps to resolve issues found. The author studies on 7 requirements prioritization techniques which are commonly adopted in the industry including Value Oriented prioritization (VOP), Analytical Hierarchical Process (AHP), EVOLCE, Software Engineering Risk Understanding and Management (SERUM), Planning Game (PG), Cumulative Voting (CV) and lastly Cost Value. Yet, the proposed solution for requirements prioritization only considered the pre mentioned non-functional elements. The proposed solution performs feasibility analysis on the non-functional requirements and cost/value is treated as the primary factor to be considered. The proposed approach is not exactly a requirements prioritization method since it needs to be pair with other existing requirements prioritization techniques to prioritize requirements. It is just merely a simple approach to be performed before requirements prioritization.

Researches Qadduora R. et al. [4] scrutinize 10 different types of techniques and the activity for requirements prioritization including analytic hierarchy process, binary search tree, numerical assignment technique, minimal spanning tree, planning game, hundred dollar method, theory W, priority groups, bubble sort and lastly machine learning and data mining techniques. A comparison is done based the complexity, ease of use, reliability, fault tolerance, speed and the number of requirements among all the techniques mentioned above for requirements prioritization. However, these methods compared are the existing conventional methods available in requirements prioritization. In fact, it is not novel in comparison since similar comparison has been done to the existing approaches by other researches in requirements prioritization.

In fact, we also found some researchers proposing requirements prioritization technique including work from Minhas N. M. and Majeed A. [14]. They proposed an integrated approach for requirements prioritization with reference to global software development whereby the stakeholders are located in various distance across difference time zone. Their proposed approach considered stakeholders' weightage and requirements weightage with respect to global software development impact factor. Their proposed framework started with requirements elicitation process and followed by the rest of the four major steps. Even though their idea on proposing requirements prioritization technique is presented with the desired steps in detail, there is no any validation on their proposed approach on the efficacy. Their approach is considered as immature as it is not ready to be adopted by any industries.

Babar M. I. et al. [6] proposed a solution by extending the study of value based intelligent requirements prioritization on expert driven fuzzy logic. The study claimed that the new proposed solution is more time efficient and scalable compared to other requirements prioritization techniques and yet the proposed solution is not verified by any experiment.

Deepali S. and Ashish S. proposed a requirements prioritization approach called Gradient Descent Raking (GDRank)[15]. The proposed requirements prioritization approach combines stakeholders' preferences with functional and non-functional requirements. Their ordering and approximations are estimated through machine learning techniques. GDRank prioritization process is initiated on requirements elicitation. They consider requirements elicitation by adopting Quality Function Deployment (QFD). Balancing of functional and non-functional requirement will be done with the aid of Pattern Driven Architectural Partitioning (PDAP). Next, a set of sampled requirements

pairs is selected from the requirements whose relative preference is unknown. GDRank adopted Analytical Hierarchy Process (AHP) to create pair sampling for the requirements. The pair sampling will serve as the input for priority elicitation process to produce basis of the priorities state by a domain expert as a set of ordered requirements pairs. Given a set of priority ranking function and partial elicited priority from the stakeholders, and estimated rank is produced by the learning algorithm (Ranknet algorithm) and the final corresponding approximated rank for the requirements. The output of the GDRank is an estimate of the exact ranking. However, GDRank did not consider the issue of scalability, changes of requirements are not allowed during the process. In addition, GDRank assumed that requirements are well elicited from the requirements elicitation activity to further on requirements prioritization.

A different approach was developed by Dabbagh M. and Lee S. P. [16], namely Integrated Prioritization Approach (IPA), by integrating both functional and nonfunctional requirements for requirements prioritization. One of the core characteristic of their approach is that it only requires one decision matrix in order to perform requirements prioritization process. The outcome of their approach is to produce two different lists of prioritized requirements. The researchers compared their proposed requirements prioritization techniques with the existing Analytical Hierarchy Process (AHP) and Hybrid Assessment Method (HAM). Based on their result from the experiment, they claimed that their proposed integrated approach outperforms the popular approach AHP and HAM in terms of time consumption. Despite of the consideration to prioritize nonfunctional requirements with respect to functional requirements in IPA, their proposed approach did not consider scalability issue which is one

of the biggest issue in the existing requirements prioritization techniques.

Jawale B. and Bhole Ashish T. [1] proposed a new approach for requirements prioritization based on Adaptive Fuzzy Hierarchical Cumulative Voting after comparing some of the requirements prioritization techniques for example Analytical Hierarchical Process (AHP), Cumulative Voting (CV), Hierarchical Cumulative Voting (HCV) and Fuzzy Hierarchical Cumulative Voting (Fuzzy HCV). Based on the comparison on the conventional techniques for requirements prioritization, they proposed a technique called AdaptiveFuzzy Hierarchical Cumulative Voting by combining fuzzy logic and adaptive mechanism. Yet, the proposed technique for requirements prioritization is merely a suggestion and has not been experimented.

Ejaz K. and Amjab A. [17]also presents a new approach of requirements prioritization. The requirements supplied by the client will hand over to the project manager in order to compile into compiled data by adopting greedy algorithm and low level algorithm. The compiled data of requirements will be converted to optimal data to determine the cost. The result of their study shows that the proposed requirements prioritization approach is able to provide refined decisions for requirements prioritization according to cost and benefits.

Vijay Anand R. and Dinakaran M.[18]proposed a requirements prioritization method adopting Apriori algorithm in order to overcome the problem of stakeholder conflicts in agile environment. Apriori algorithm joins and prunes iteratively, as a two steps process, searching for the frequent requirements and it is believed to be able to reduce stakeholders' conflict by finding the most frequently asked requirements. The authors claimed that their requirements prioritization is more efficient compared to then existing one as their

requirements prioritization method supports scalability.

We found a very short paper regarding requirements prioritization in the context of global software engineering from the author Gupta V. et al. [19]. They aim to analyze the existing requirements prioritization techniques in global software engineering environment in order to identify the problems.They were not able to find any research regarding requirements prioritization in global environment and claimed that a new technique is required to be proposed in global setting. However, their systematic literature review is unreliable due to the incomplete procedure as a systematic literature review.

In addition, we found a proper systematic literature review conducted by Thakurta R. on the same year for requirements prioritization [20].Firstly, the study elaborated the objective of requirements prioritization. The findings of the study are divided into three parts including types of software requirements prioritization artifacts, theoretical foundation for requirements prioritization and factors influenced in requirements prioritization. The study conducted benefits researcher to further investigate in requirements prioritization or to improve the process of requirements prioritization.

Discussion

Based on our study on the existing techniques for requirements prioritization, we compiled all the studies found above in the Table 1 below. The existing studies are arranged in accordance to the type of work contributed in the topic of requirements prioritization.

Type of study	Authors
Systematic Literature Review	[19][20]
Review /	[4][6][7][8][9][10][11][13][12]

Study	
Proposing new method	[1][6][14][8][15][16][11][17][18]

Table 1: Types of study

Based on Table 1 above, there are two studies conducted to have thorough understanding on requirements prioritization based on their systematic literature review. The study conducted by author Gupta V. et al.[19] is just a very short and unreliable systematic literature review. In fact, systematic literature review conducted should have followed a series of protocol in order to obtain compact findings in certain topic. While on the other hand, Thakurta R. addressed and answered four research questions regarding requirements prioritization in his literature review [20].

A total of nine studies had been done to investigate and review on the existing requirements prioritization approaches. Reviews are commonly found to be done on the conventional requirements prioritization methods available. We realized that there is none promising requirements prioritization method to be recognized by researchers in their study. In addition, some studies are conducted to discuss on the trends, challenges, advantages and disadvantages of the existing requirements prioritization approaches. There are still issues found inherent in the existing requirements prioritization methods. New approach for requirements prioritization should be introduced to tackle issues mentioned in their study in order to bridge the gap in the topic of requirements prioritization. However, some reviews are conducted merely to compare between two conventional approaches to show their advantages and disadvantages.

Likewise, there are a total of nine studies found to propose new method for requirements prioritization. We must admit that requirements prioritization has been a popular topic to be studied and discussed. Based on

our observation, a great number of studies have been done towards requirements prioritization. This simply indicates that requirements prioritization is getting more insight from the requirements engineers and researches for its importance role in requirements engineering. Approaches and methods are introduced with aim to improve the process of requirements prioritization in terms of time efficiency, scalability, communication between stakeholders and etc. Some of the requirements prioritization approaches are introduced to cater in the environment of global settings. We observed that part of the newly proposed methods for requirements prioritization are still considered as immature and has not been validated with any kind of experiment to prove its performance. Nevertheless, to the best of our knowledge, we found that there is none work proposed to improve the quality of requirements thru requirements prioritization technique.

We further our study to examine the recent proposed works for the aspects of requirements prioritization including importance, penalty, cost, time, risk, volatility, other aspects and combining different aspects. The explanation for each of the aspects is included in [2]. The table below shows a comparison between aspects for requirements prioritization based on our conducted literature review.

Aspects of Requirements Prioritization	Work Found
Importance	[6][14][15][16][1][11][18]
Penalty	
Cost	[6][14][8][17]
Time	[8]
Risk	[8]
Volatility	
Other Aspect	
Combining Different Aspect	

Table 2: Aspect focused in requirements prioritization for each of the proposed work

Based on Table 2 above, most of the studies focused on the importance of requirements in requirements prioritization. In another word, requirements prioritization methods proposed rank based on the importance or preference of the requirements. The aspects of the importance of the requirements are usually defined by the stakeholders based on their opinions and preferences towards the requirements. Those requirements with higher preference value are implemented than those requirements with lower preference value. This scenario is common since most of the clients are found to be unfamiliar with the development background and hence focus on their own preference and importance on the requirements to be implemented. The clients are actually not aware of the existence of other aspects to be considered in requirements prioritization which is equally important.

The aspect of cost refers to the money spent or the effort of human required on the project development. There is usually a certain amount of money to be allocated to specified project development. Software engineers need to develop the project based on the cost allocated. Hence, it is also common for requirements to be prioritized based on the cost to avoid budget overrun. We only found one work in requirements prioritization to prioritize based on the combining aspect of cost, time and risk.

We believed that the other aspects need to be carefully considered and handled during requirements prioritization. For example, the requirement risk aspect is important in requirements prioritization. It is undeniably that requirements risks are existed within requirements itself since requirements elicitation activity. Table 3 below shows part of the list of problems in requirements that regard as requirements risk.

Requirements Problems	
Incomplete requirements	Incomplete understanding of needs
Incomplete domain knowledge	Poor user's collaboration
Overlooking tacit assumptions	Incorrect requirements
Ill-defined system boundaries	Misunderstanding of system purpose
Ambiguous requirements	Synonymous and homonymous terms
Untestable term	Unnecessary design consideration
Inconsistent requirements	Non-solid intentions of requesters
Different views of different users	Unfixed requirements
Fluctuating requirements	Continuous acceptance of additional requirements
Excessive requirements	Unorganized bulky information sources
Too many	Over commitment by sales staff

The risks in requirements are often brought to requirements analysis for requirements defects removal. Most importantly, failure in requirements risk handling causes project failure. Therefore, the aspect of risk in requirements should be focused and emphasized in requirements prioritization for early risk assessment and mitigation. It is believed to be beneficial when the risks in requirements are prioritized for its seriousness caused to the project development. The quality of the requirements is increased when there is a minimal level of requirements risk involved. Hence, the risk of requirements should gained more focus for requirements prioritization in order to be identified and mitigated since the early stage of project development.

Conclusion

This paper aims to study the topic of requirements prioritization. The data collected from the literature study are analyzed and tabulated in the Table 1 and Table 2 in the discussion section respectively. In comparison to others topic in requirements engineering, requirements prioritization is actually overlooked by the requirements engineers or stakeholders for its importance. Requirements prioritization is indeed important to ensure the quality of the requirements to avoid rework or unnecessary cost. In addition, we found that the topic of requirements prioritization is getting more attention by the researchers in the recent years. There are more studies conducted and approaches proposed in requirements prioritization. However, most of the study found to be an extension from the previous well established approach. It is believed to be beneficial by adopting the conventional requirements prioritization techniques since their efficacy is proven and recognized. Future work is recommended to focus other aspects in requirements prioritization since most of the work found focused on the importance level of requirements to prioritize requirements. As far as we realized, the issue of usability and scalability still exists in the process of requirements prioritization based on our conducted literature study. Most of the industry didn't perform requirements prioritization properly and the current approaches only perform well when the number of requirements is low. There is a motivation for researchers to propose a requirements prioritization technique to cater the issues mentioned in our study.

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