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Requirement Prioritization Approaches and Evaluation Strategies: A Systematic Literature Review

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Abstract: Requirements prioritization is one of process in requirement engineering which aim to manage the order of urgency and implementation a set of requirements. Requirement prioritization also used in software development project to cope with the limited resources allocated. Many research have been done at industrial and academic level in this particular area. There are many techniques applied by using several approaches. However, the evaluation towards the effectiveness and efficiency of these available techniques still can be examined. There is a need to identify the approaches used and the evaluation performed towards these techniques. A comprehensive and systematic exploration to distinguish the state-of-the-art approaches been used to develop, as well as methods used to evaluate those prioritization techniques is planned. The plan is elaborated in detail within this paper by using the Systematic Literature Review (SLR) protocol. Initial finding for this planning phase for SLR is a collection of scrutinized and significant research literatures. The extracted data from these literatures later will be used to summarize state of the art approaches to develop techniques for prioritizing requirement. Additionally, findings about the evaluations strategy will serve as a basis for researcher's perception in planning their research. It also will benefited the practitioners to choose a high quality and evaluated techniques. Furthermore, the findings will be useful for the researcher and academician to discover the knowledge gap for their future research and contribution.

Key words: Systematic literature review, requirement engineering, requirement prioritization, prioritization technique

INTRODUCTION

Requirement prioritization is an activity of handling the relative importance and urgency a set of requirements to cope with restricted software development project's resources. This activity creates a benchmark or guideline to ensure that the most important or critical requirements are implemented instantly before the budget or other resources run out. It serves two distinct purposes which are to define project's scope and to schedule project's implementation.

There are many potential benefits of applying this activity such as identification a subset of requirement for early implementation stage (Berander, 2004), prioritized investment, improve customer satisfaction and as prevention of over-scoping (Firesmith, 2004). Prioritizing requirement also is a major activity in decision making which requires sound domain knowledge and professional skills among requirement engineers (Laurent *et al*., 2007).

The usage of large scale, complex and dynamic software applications which is rapidly increase now a days requires software engineers to utilize special tools or techniques in developing such software applications effective and efficiently. Complexities derived from a large number of requirements can caused the project's objectives diverted. Such complexities can be controlled with the usage of right requirement prioritization technique.

Research and development of various aspects of requirement prioritization and prioritization techniques itself are actively done by many researchers in this area. There are many contributions that attempt to overcome the limitation in current technique by using different approaches. However the opportunity to improve and enhance these techniques in order to address several critical issues and challenges in this area are still open.

In this research, we conducted in-depth software engineering based Systematic Literature Review (SLR)

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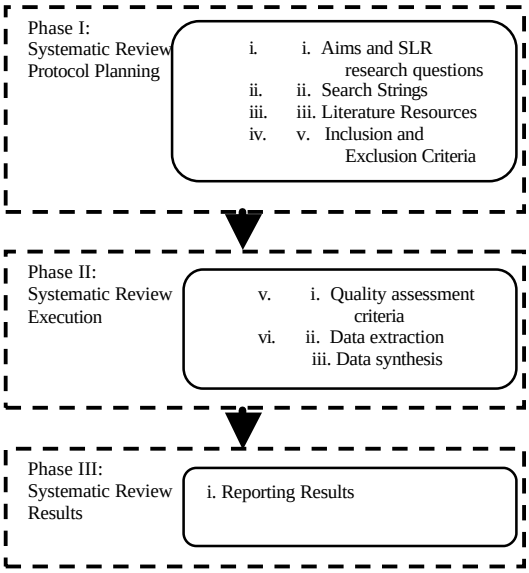

Fig. 1: Phase in conducting SLR

which was focused on identifying, evaluating and interpreting all available research relevant to the research questions and topic area of interest. SLR is chosen, as it helps to conduct a thorough and fair literature review due to its predefined search strategy. SLR synthesis has been widely applied especially to medicine and healthcare field and it has been proved as valuable for enabling the researchers to summarize complex scenarios, identifying gaps and overcoming harmful interventions (Kitchenham *et al*., 2009). Researchers can get the clear reporting and evidence to formulate future planning in any domain by performing SLR. The successful use of the SLR in different fields can adequately prove that it is an effective and efficient solution for performing overview on specific topics. It is a critical study work for the researchers to get deep understanding about the research area. Due to the complexity of SE solutions, SLR has become an important research methodology in SE field since 2004 to produce valuable contributions (Zlatko *et al*., 2012).

In our attempt to review, we followed the original guidelines proposed by (Kitchenham *et al*., 2009). Our SLR divided of three phases (Fig. 1):

- Phase I: Systematic review protocol planning
- Phase II: Systematic review execution
- Phase III: Systematic review results reporting

MATERIALS AND METHODS

Systematic review protocol planning: The guideline and procedure of the SLR conducted in this research is adapted from the (Kitchenham and Charters, 2007; Salleh, 2008), whereby the review process in later work motivated by (Wohono, 2015; Khanian and Mohd; Khan and Mohd).

Table 1: SLR research questions and aims

SLR research question	Aim
SLR RQ 1: What approaches have been proposed to solve issues in existing requirement prioritization techniques?	To classify the approches that have been used by researchers in the existing requirement prioritization techniques
SLR RQ 2: What evaluation strategy have been used to evaluate the existing requirement prioritization techniques?	To identify the evaluation strategy that have been used to evaluate the existing requirement prioritization techniques

Aims and SLR research questions: The SLR research questions are developed prior to the SLR activity. SLR research questions are the aims set to be achive at the end of conducting this activity. There are mainly two major aims which are to classify the aproaches used in existing requirement priritization techniques and to identify the evaluation strategies that has been used to evaluate the technique. The different between this SLR and previous work done by (Achimugu *et al*., 2014) are on the aims we try to achieve. The SLR research questions and aims of conducting this activity are outlined in the Table 1. The SLR finding will be tabulated and explained based on the SLR research questions that have been determined.

Search strings: The next step is to develop the key string for searching the online databases. The main keyword are 'requirement' and 'prioritization'. The synonym words are also identified based on the main keyword. The Boolean operator like OR is used if the keyword is synonym while AND is used to link between the main keyword. The finalized search string is outlined in the Table 2.

Literature resources: Next, the finalized search string from Table 2 above is used to perform the primary search in few online databases listed in the Table 3. The reason of selection of listed databases was that they were acknowledged to include software engineering literature. Each database was reviewed for journals articles, workshop articles, conference articles, books chapters and published thesis. The articles that addressed the aim stated in Table 1 directly or indirectly were recognized as potentially relevant.

Articles from the start period up to year 2014 were searched from the resources and included in our study.

Inclusion and exclusion criteria: After the retrived articles are obtained from the online databases, the next step is to filter those articles according to the relevant

Table 2: List of search strings

Variable	Search string
SLR RQ1	"requirements AND (prioritization OR technique OR negotiation OR "release planning") AND (approaches OR methods OR methodologies)"
SLR RQ 2	"requirements AND (prioritization OR technique OR negotiation OR "release planning") AND (evaluation OR testing OR validation OR verification)"

Table 3: List of online databases

Online database	URL
ACM digital library	dl.acm.org
IEEEXplore	ieeexplore.ieee.org
SpringerLink	www.springerlink.com
Google Scholar	scholar.google.com
ScienceDirect	www.sciencedirect.com
Wiley Online Library	onlinelibrary.wiley.com

Table 4: Inclusion and exclusion criteria

Values	Criteria Description
IC1	The article is written in English language
IC2	The article which investigate about the software engineering requirement prioritization
IC3	The articles which able to answer at least one of the SLR research question
EC1	The articles that are written other than English language
EC2	The article which are not related to software requirement prioritization (e.g., prioritization in networks)
EC3	The duplicate studies like review protocols, annual scientific meeting, posters, article abstract and surveys

Table 5: Quality assessment criteria

Values	Quality assessmer criteria	QAC scale	QAC score
QAC1	Do the aims of the study clearly articulated?	Yes = 1 /Partially = 0.5 /No = 0	
QAC2	Do the proposed approach clearly described?	Yes = 1 /Partially = 0.5 /No = 0	
QAC3	Does the evaluation strategy is well perform and associated the results explicitly stated?	Yes = 1 /Partially = 0.5 /No = 0	

with the aim of SLR. At this point, filtering process will be performed by screening at the title and abstract of the articles. Any duplications of the article are also been removed during this time. A comprehensive filtering according to the inclusion and exclusion criteria is presented in the Table 4.

Systematic review execution

Quality Assessment Criteria (QAC): The quality assessment criteria are developed in order to assess the quality of the article after identification of the relevant article has been made. In this research, the quality assessment is tabulated in the Table 5. Each of the relevant article for the review purpose are assessed and given score based on three scale point which are suggested by (Kitchenham *et al*., 2009). The scale are; Yes = 1 point, Partially = 0.5 point and No = 0 point. The article are given 'Yes' if the criterion are met and 'No' if it is otherwise. The 'Partially' point are given to those article which answers are partly met. The treshold rating to select the articles are those with score greater than 2.0 (i.e., 50% of the percentage score).

Data extraction: The quality assessment and data extraction were perform in parallel. Each reviewed article is assessed according to the defined quality assessment according to the stated scored. In the mean time, relevant data which addressed the SLR questions were extracted by using the data extraction form. The data extraction form is devided into two groups which are overview data and specific data. The overview data are merely consists of the basic information about the article for instance the author, title of the article and year of publication. The specific data are those data which answered the SLR questions.

Data synthesis: At this phase, the extracted data are analyzed according to research questions that have been set at the beginning of this process. The aim of the synthesis process is to obtain and discover the results.

RESULTS AND DISCUSSION

In order to establish the requirements for an improve requirement prioritization technique, there are eight activities that have been defined and performed by using SLR methodology.

The searching process was done with six online databases which are ACM Digital Library, IEEEXplore, SpringerLink, Google Scholar, ScienceDirect and Wiley Online Library with the search string that has been defined. A total of 1168 articles were obtained from this searching process. After the retrived articles are obtained from the online databases, the next step is to filter those articles according to the relevant with the aim of SLR.

Then, there are 18 duplications of has been removed from the list. Next, the filtering process was performed by screening at the title and abstract of the articles. A comprehensive filtering according to the inclusion and exclusion criteria presented in the Table 4 was performed in parallel with the screening of the title and abstract, resulted a number of 202 articles were selected.

Finally, the quality assessment criteria that has been developed in order to assess the quality of the articles after identification of the relevant articles has been performed. The quality assessment criteria is presented in Table 5 (Fig. 2). Each of 202 articles were assessed and given score based on three scale point which are suggested (Salleh, 2008). The scale are; Yes = 1 point,

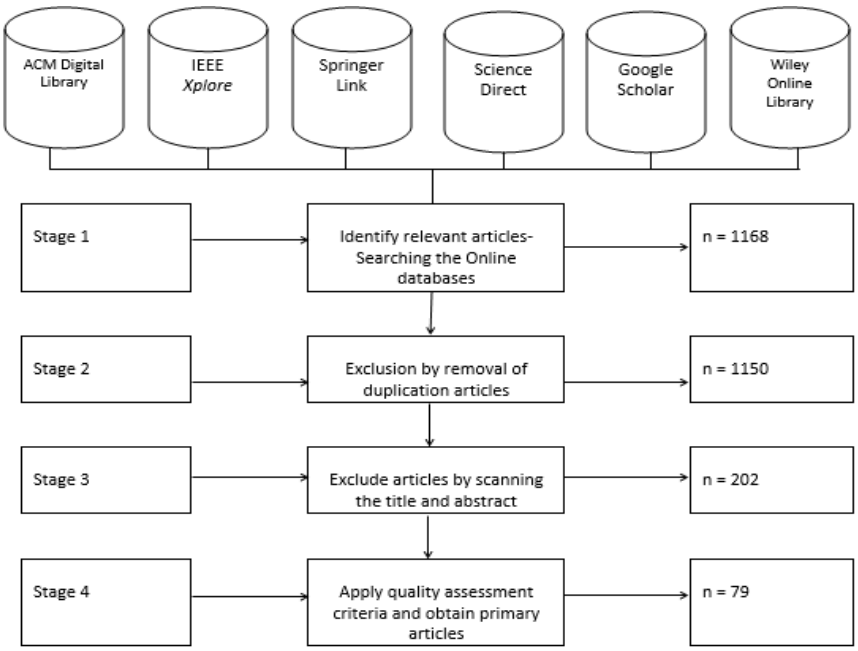

Fig. 2: Stages of the study selection process

Table 6: Requirement prioritization technique grouped according to the identified approaches

Approach	Requirement prioritization technique
Stakeholder judgment	Round-the-group prioritization, ping pong balls, $100 allocation (cumulative voting), multi voting system, win win (theory W), dot voting
Pair-wise comparison	Pair wise analysis, analytic hierarchy process, hierarchy aHP, incomplete AHP, minimal spanning tree
Algorithmic/Intelligence	Binary search tree, case based ranking, interactive genetic algorithm, B-tree, requirements uncertainty technique prioritization approach, pirogov, EVOLVE, binary priority list, adaptive fuzzy decision matrix model
Enhancement of the technique	Value based requirement prioritization, multi-criteria preference analysis, geographically distributed existing stakeholders requirements prioritization, composes Numeral Assignment and AHP Prioritization techniques(NAcAHP), Extensive Numerical Assignment (ENA), Hierarchical Cumulative Voting (HCV)
Business/market/cost/ project/risk-oriented and and value	Value Based Intelligent Requirement Prioritization (VIRP), cost-value approach, Goal Oriented Requirements Analysis Method (AGORA), Value Oriented Prioritization (VOP), Software Engineering Risk Understanding Management (SERUM), benefit and cost prediction requirement prioritization, value based requirements selection, lanchester theory requirements prioritization, market driven requirement prioritization model, Software Technology Risk Advisor (STRA), NFR prioritization algorithm
Classification/grouping	MoSCoW, weighted critical analysis, Technique of Ordered Preference by Similarity to Ideal Solution (TOPSIS), numerical assignment,, requirements prioritization using factor analysis, ranking product definition
Matrix	Quality functional deployment, wiegers' matrix approach, correlation-based priority assessment framework, prioritization of stakeholder value using metrics
Agile-based	Planning game, dynamic reprioritization of requirements in agile development
Natural language processing	SMT and NLP-based Interactive Requirements Prioritization (SNIPR)
Cognitive science	Cognitive driven requirement prioritization
Linear progamming	Mathematical programming technique for release planning

Partially = 0.5 point and No = 0 point. The articles were given 'Yes' if the criterion are met and 'No' if it were otherwise. The 'Partially' point were given to those article which answers were partly met. The treshold rating to select the articles are those with score greater than 2.0 (i.e., 50% of the percentage score). After applying the process of quality assessment criteria, a shortlisted of 79 articles were obtained as primary articles. After an exhaustive investigation towards the 79 primary articles, 55 requirement prioritization techniques are grouped according to the identified approaches. In Table 6, there are 11 approaches recognized.

These techniques are futher grouped into a software process model, they were used or able to tailor. Two process model mainly used for software development are iterative and incremental development and traditional waterfall development listed
in Table 7 and 8.

Table 7: Requirement prioritization techniques according to software process model

Model	Techinique
Software process model	Requirement prioritization techniques
Iterative and incremental development	Dynamic reprioritization of requirements in agile development, planning game, Prioritization of stakeholder value using metrics evolve
Traditional waterfall development	VIRP, CBPA, case based ranking, Cost-value approach, AGORA, winwin, Value based requirement prioritization, MPARN, TOPSIS, IGA, B-tree, RUPA, numerical assignment, VOP, HCV, pirogov, SERUM, BPL, cognitive driven requirement prioritization, adaptive fuzzy decision matrix model requirement prioritizations, benefit and cost prediction requirement prioritization, requirements prioritization using factor analysis, value based requirements selection, lanchester theory requirements prioritization, geographically distributed stakeholders requirements prioritization, machine learning techniques for requirements prioritization, MDRPM, NAcAHP, STRA, fuzzy HCV, fuzzy ,multi-attribute decision making for prioritizing requirements, hierarchy AHP, incomplete AHP, minimal spanning tree, ENA, NFR-prioritization algorithm

Table 8: Evaluation strategies used for IID-based requirement prioritization techniques

RPT	Evaluation strategy	Evaluation criteria
EVOLVE	Case study on sample project	Consistency and execution time
Planning game	Benchmarking	Time, ease of use
Dynamic reprioritization of requirements in agile development	Benchmarking	Efficiency
Prioritization of stakeholder value using metrics	Benchmarking	Efficiencys

CONCLUSION

Four techniques, namely evolve, planning game, dynamic reprioritization of requirements in agile and prioritization of stakeholder value using metrics which are used in an iterative and incremental software process development are further analysed. The evaluation strategies and evaluation criteria performed upon these prioritization techniques are extracted. This information will be used in our current research study. A new requirement prioritization technique which able to prioritize iteratively and accommodate the nature of requirement which always change will later be benchmark with these four techniques.

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