Requirements Engineering Techniques: A Systematic Literature Review

Kanos Matyokurehwa¹, Nehemiah Mavetera², Osden Jokonya³

¹Software Engineering Department, Botho University
²,³Information Systems Department, North West University
Botswana

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Abstract—Requirements engineering is a torrid task to requirements engineers because requirements keep changing and this affect the project’s delivery schedule and cost. Although various authors proposed numerous techniques to be used in requirements engineering, software projects still fail. The issue now lies on which technique to use to minimize project failures. The aim of the study was to identify gaps in requirements engineering techniques used. The paper used a systematic literature review of requirements engineering techniques used from January 2000 to July 2016. The study found out that a lot of techniques are used in requirements engineering and some of the techniques used are not adequately addressing the problem space but the solution space. The study identified some gaps in requirements engineering techniques that need further research in order to solve those gaps.

Keywords—Requirements Engineering, Project Failure, Techniques, Changing Requirements, Technique limitations

1. INTRODUCTION

A software requirement simply put is the need of stakeholders or users that needs to be captured in a system. This is the foundation of any software project because if this software requirement is not captured correctly; the whole system development will be bound to fail since the final product will not address the needs of stakeholders. Requirements engineering is a process that encompasses the following activities namely; requirements gathering, requirements analysis, specification, requirements validation and the requirement management [2]. Requirements gathering identify the stakeholders to find the requirements for the project, requirements analysis checks for the completeness of the requirements from the requirements gathering stage, requirement specification is simply the recorded requirement that should be acted by a system and they are recorded using use cases. The requirements validation checks if the requirement truly reflects what the stakeholders want while requirement management rank requirements in terms of their priorities and also accommodate changes to requirements as suggested by the stakeholders. Reference [3] argued that there are some challenges and communication issues experienced by the requirements engineers during the requirements engineering process. The difficulties are mainly due to conflicting requirements due to functional and non-functional requirements. The functional requirement spells out what the system should do while a non-functional requirement places some constraints on how the requirement will be met by the system such as speed, security and other characteristics. Reference [5], the Standish Group reported that at least 24% of projects fail and close to 44% are challenged. The major reasons for projects failing is due to partial requirements given to the requirements engineers and constant requirements changes during the course of the project.

Requirements engineering not properly conducted will translate to project failures [7]. Requirements Engineers are often subjected to a daunting task on which technique to choose to best address the software requirements. The paper seeks to examine the various techniques being employed by requirements engineers during the requirements engineering process and any limitations of those techniques basing on the context and the domain of the project. The aim of the paper is to identify areas of further research in requirements engineering that were not adequately addressed by other authors. This will help in reducing project failures which started in 1968 with the software crisis and over the years more advances were made in requirements engineering to address projects running over budgets, projects taking longer time than anticipated and some projects failing to meet the stakeholder requirements [46]. The study looked at various techniques such as tools and frameworks used in requirements engineering by the requirements engineers.

II. RESEARCH METHODOLOGY

A systematic literature review is a secondary study that search for relevant information from the primary studies conducted; evaluate the information and do interpretations basing on the research questions or the area of study [6]. The goal of the systematic research is to identify gaps that may exist in the researches done and propose areas for further investigation. The review will be done following the guidelines postulated by [6] shown in Table 1.

Table 1. Literature Review Guidelines

<table>
<thead>
<tr>
<th>Stage 1: Formulate Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 2: Identify the Data Sources</td>
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<tr>
<td>Stage 3: Define the Search Strategy to be used</td>
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</tbody>
</table>
1. **Research Questions (RQ)**

RQ1. What are the techniques used in requirements engineering?
The Research question looked at the techniques that are currently being used in requirements engineering.

RQ2. What are the limitations of the existing techniques used in requirements engineering?
The limitations of the existing techniques used in requirements engineering were looked at.

RQ3. How do changing software requirements affect requirements analysis?
The research question looked at the effects of software requirements changes on requirement analysis.

2. **The Data Sources**
The electronic databases selected were those databases that are mostly used by authors and also some databases with restricted access and the study focused on six electronic databases shown below:

   - Emerald Insight
   - Science Direct
   - IEEE Xplore
   - Ebscohost
   - Google Scholar
   - Academic Search Complete

The restricted sources were chosen because they have relevant information in far as Software Engineering is concerned [1].

3. **The Search Strategy**
The search strategy adopted consisted of key words derived from the research questions and also utilized the Boolean expressions using the (AND) and (OR) expressions in performing the searches. A search was performed on the six electronic databases using the search strings derived from the research questions and consistency of search strings was adhered to in all the six electronic databases. The search considered the articles published from the period 2000 to 2016. The search keywords were confined to the research questions such as (“requirements engineering AND techniques, requirements engineering OR limitations, changing requirements AND requirements analysis, requirements engineering frameworks OR tools, requirements engineering models OR Graphical Models”).

A total of 420 articles were retrieved from the six electronic databases which fell in the search strings and the stated time frame. After using the exclusion strategy on the 420 articles a total of 43 articles were selected.

4. **Exclusion and Inclusion Strategy**
The articles that were included were those that addressed any one of the research questions such as the techniques used in requirements engineering, the limitations of the existing techniques used in requirements engineering and the effect of changing software requirements on requirements analysis. The inclusion strategy also catered for articles written in English language only and the inclusion covered articles done from 1 January 2000 to July, 2016. The exclusion strategy did not consider articles that did not address the research questions and also articles not written in English language.

5. **Quality Assessment of the Study**
The quality assessment of the study is crucial as it can be used to as a guide to interpret the findings from the study and any future research investigations. The study was evaluated according to the following assessment questions:

   1. Aims of the research are they clearly stated?
   2. Is the requirement engineering technique clearly elaborated?
   3. Does the research contribute value to the body of knowledge?
   4. Is the research approach clearly mentioned?

Each assessment question has got three possible answers which could be “Yes” or “Partial” or “No”. The possible answers were assigned weights of 2 to the “Yes”, 1 for the “Partial” and 0 for the “No”. The assessment questions were used to compute the sum for each article basing on the weights outlined above. The reliability of the study was in-formed by finding the sum of all the assessment questions and divides the sum by 4 and an acceptable selection criterion was chosen. All articles with assessment scores from 1 (50% in percentage terms) were considered.
6. The Data Extraction

At this stage, the data was extracted for analysis and the data was extracted to a table showing the name of the journal, the author(s) name; the date of publication; the requirements techniques used; type of technique; technique application area. The framework in this paper is defined as a skeleton or an abstract that can be used to come up with a model or a graphical model, the model is derived from a framework. So the framework lays the foundation for the model. Table 2 shows the names of techniques and the type of techniques currently used in requirements engineering. Table 2 also shows the application area for each technique in the requirements engineering process.

Table 2. Summary of Requirements Engineering Techniques

<table>
<thead>
<tr>
<th>NO</th>
<th>Author(s)</th>
<th>Ref</th>
<th>Name of Technique</th>
<th>Type of Technique</th>
<th>Application area</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Nuseibeh and Easterbrook 2000</td>
<td>[8]</td>
<td>Ethnography</td>
<td>Elicitation Technique</td>
<td>Requirements Gathering</td>
</tr>
<tr>
<td>10</td>
<td>Mauw et al 2000</td>
<td>[16]</td>
<td>SDL</td>
<td>Model</td>
<td>Analysis and Validation</td>
</tr>
<tr>
<td>11</td>
<td>Jones 2009</td>
<td>[17]</td>
<td>Joint Application Design</td>
<td>Elicitation Technique</td>
<td>Requirements gathering</td>
</tr>
<tr>
<td>16</td>
<td>Bleistein et al 2006</td>
<td>[22]</td>
<td>B-SCP</td>
<td>Framework</td>
<td>Complete Requirements Process</td>
</tr>
<tr>
<td>20</td>
<td>Tung and Chan 2009</td>
<td>[26]</td>
<td>UHRAF and SUM</td>
<td>Framework</td>
<td>Analysis and Validation</td>
</tr>
<tr>
<td>21</td>
<td>Uszok et al 2011</td>
<td>[27]</td>
<td>KAOS</td>
<td>Graphical Model</td>
<td>Complete Requirements Process</td>
</tr>
<tr>
<td>22</td>
<td>Thüm 2014</td>
<td>[28]</td>
<td>FeatureIDE</td>
<td>Framework</td>
<td>Complete Requirements Process</td>
</tr>
</tbody>
</table>
Table 2 above shows the various techniques used in requirements engineering together with their application areas. The techniques chosen were those that meet our inclusion and exclusion strategy and also the quality assessment. It can be noted that various techniques have been proposed by authors and some techniques are applicable in certain areas and some are only restricted to understanding the problem domain but some techniques go as far as the solution space. Requirements engineering should focus on getting the requirements right, like what does the stakeholder really want without overstepping to the design part on how to meet the stakeholder want. Table 3 grouped the requirements engineering techniques.

<table>
<thead>
<tr>
<th>Row</th>
<th>Authors and Year</th>
<th>Reference</th>
<th>Type of Technique</th>
<th>Name of Technique</th>
<th>Application Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Chatzikonstantinou and Kontogiannis 2016</td>
<td>[33]</td>
<td>ReqRV Framework</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Bachmann et al 2000</td>
<td>[41]</td>
<td>ADD Framework</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Suryan and Abran 2003</td>
<td>[42]</td>
<td>SQUARE Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Mead and Hough 2006</td>
<td>[43]</td>
<td>Accelerated Requirements Method Elicitation Technique</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Beecham et al 2005</td>
<td>[48]</td>
<td>R-CMM Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Hull 2002</td>
<td>[49]</td>
<td>DOORS Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Damian and Zowghi 2003</td>
<td>[50]</td>
<td>RequisitePro Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Cant et al 2006</td>
<td>[51]</td>
<td>HIVE Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Lu et al 2008</td>
<td>[52]</td>
<td>CaliberRM Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Stal 2012</td>
<td>[53]</td>
<td>IRQA Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Delor 2003</td>
<td>[54]</td>
<td>Objectiver Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Lami et al 2004</td>
<td>[55]</td>
<td>QuARS Graphical Model</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Wieringa and Ebert 2004</td>
<td>[56]</td>
<td>RMTrak Graphical Model</td>
<td>Management Process</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Wang and Zeng 2009</td>
<td>[57]</td>
<td>Quality Function Deployment Elicitation Technique</td>
<td>Requirements gathering</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Adam et al 2014</td>
<td>[59]</td>
<td>TORE Framework</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Jiang and Eberlein 2008</td>
<td>[60]</td>
<td>FREE Framework</td>
<td>Complete Requirements Process</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Grouping of Requirements Engineering Techniques
This section presents the findings from the review and the findings were based on the Research Questions.

1. **RQ1. What are the techniques used in requirements engineering?**
   The review identified 43 techniques used in requirements engineering but the techniques are based on our exclusion and inclusion search strategy and also the quality assessment of the study. There is no requirement engineering technique that can best solve all the issues in the software requirements domain but each issue can best address a certain problem provided it falls within that domain [58]. Choosing a requirements engineering technique can be a daunting task but factors to consider in selecting the best technique may include the size of the project, the category of the project, the funds available for the project and the complexity of the technique [61].

2. **RQ2. What are the limitations of the existing techniques used in requirements engineering?**
   From the findings there is a striking observation that [1] concurs with that the techniques used in requirements engineering usually addresses one activity of the requirements engineering process which cannot adequately address the dictates of the requirements engineering process as postulated by [35], which seeks to cover all the activities in the requirements engineering process. This shortfall should be addressed by coming up with a technique that addresses all the activities in the requirements engineering process. Some of the techniques did not take into consideration some projects that are in a dynamic environment where stakeholders keep changing the requirements as also eluded by [4] who aptly suggested that requirements engineering techniques should provide support for dynamic environment. This is critical because a successful project should be delivered on time and within budget [36]. It is crucial to identify key stakeholders during requirements elicitation and many techniques are silent on this issue. If key stakeholders are not identified during the elicitation stage, the project will be bound to change requirements constantly due to stakeholders conflicts and this will ultimately affect the project delivery time and at times the project may fail [45].

3. **RQ3. How do changing software requirements affect requirements analysis?**
   Research has shown that stakeholders do not understand what they really want from the project onset hence they change agreed requirements frequently which can have a negative effect on the project cost and delivery schedule [37]. Many projects have failed due to changing requirements since one requirement change can generate many changes in the project [38] and [39]. For a change in software requirement, a proper change impact analysis has to be carried out so that the change will not cost the project in terms of the delivery time and in monetary terms. If the change request is going to have ripple effects on the project, it is crucial to consider the requirement priority ranking in the project before a change can be done. Many techniques used in requirements engineering are too complicated making them in-applicable in a real world project. There is need to come up with techniques that are easy to follow through in a project but addressing all the activities in the requirements engineering process. Some of the techniques used in requirements engineering they go beyond the
problem space into the solution space. It is important to concentrate the effort in understanding the problem and avoid moving to the solution space. Requirements engineering should focus on one central theme “what the stakeholders want” without proposing the solution in the requirements engineering phase as some techniques did.

IV. LIMITATIONS OF THE RESEARCH

1. Research Completeness
The research was focused on commonly used databases and those databases with restricted access and a total of 43 requirements engineering techniques were looked at that met our assessment questions from the primary studies done. Although some databases were not checked but however our search strategy yielded positive results, the only drawback was that articles not written in English language were not considered and articles not falling in our inclusion and exclusion search strategy and also the quality assessment of the study were not considered.

V. FUTURE RESEARCH
The review provided an eye opener on areas that have not been adequately researched on in requirements engineering. Many software projects fail because one of the stages in the requirements engineering process was not properly done [44]. So the requirements engineering process should be a holistic process so that no activity is left out otherwise the project will fail. There is need to further research on the following areas of concern:
1. To come up with a requirements engineering technique that addresses all the activities of the requirements engineering process.
2. To come up with a requirements engineering technique that should provide support for projects in dynamic environment.
3. To take into consideration factors that should be used in identifying key stakeholders in a technique.
4. To take into consideration change impact analysis in a technique.
5. To come up with techniques that are simple to follow and applicable in real projects not to be theory based.

VI. CONCLUSIONS
The research paper looked at various techniques used in requirements engineering from January 2000 to July 2016. The goal of the systematic research was to identify gaps that may exist in the researches done and propose areas for further research. The primary studies looked at came up with various techniques that address stakeholder’s requirements in the following application areas: Requirements analysis, Analysis and Verification, Management and Complete Requirements Process.

There is scope for further investigation to come up with techniques to address all the activities in the requirements engineering process. There is also need to come up with techniques that are easy to follow and applicable in real projects. The review also identified that there is need to consider change impact analysis in a technique. Lastly, the technique should provide support for projects in dynamic environment.

REFERENCES


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