

Evidence in Requirements Engineering: A Systematic Literature Review Protocol

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Abstract— Requirements Engineering (RE) is recognized as one of the critical phases in software development. RE has its own journals and conferences where lots of work has been published. As the area is maturing, increasingly large numbers of empirically supported studies have been reported in RE. There is a need to synthesize evidence based RE literature. We plan to systematically investigate evidence based RE studies to see and report state of the art in evidence based RE reported research. This paper aims at providing a systematic literature review (SLR) protocol to describe a process for synthesizing the empirically supported work in the area of RE that will eventually present a state of the art of the field. This SLR intends to not only summarize the empirical data regarding RE but will also be helpful for various practitioners in this field to find out areas of RE rich in terms of tools, techniques, frameworks, models and guidelines to aid in their work. It will also facilitate RE researchers to identify knowledge gaps to recognize needs and chances for future research directions in this field.

Keywords-systematic literature review; requirements engineering; evidence-based software engineering.

I. INTRODUCTION

Software Requirements Knowledge Area (KA) is concerned with the elicitation, analysis, specification, and validation of software requirements [1]. Requirements engineering is known as the key to success to software and systems development [2].

Requirements are very fundamental aspect of a software system as Fredrick Brooks illustrates “The hardest part of building a software system is deciding precisely what to build. No other part of the work so cripples the resulting system if done wrong. No other part is more difficult to rectify later” [3].

RE is recognized as one of the important activities in software development that deals with the requirements, from their elicitation until the system is validated for completion of requirements. Software requirement elicitation, analysis of the requirements, and writing good requirements are the most difficult parts of software engineering. As Karl Wiegers [4] describes, “If you don’t get the requirements right, it doesn’t matter how well you do anything else”, because if requirements are wrongly captured or developed it results in a flawed product.

Software requirements have been considered a problem repeatedly during the past 36 years [17]. Ross and Schoman [10] broadly described the scope of requirement engineering. Since then the work progressed in this field in terms of research and development.

A lot of research has been done in all the areas of requirement engineering. Some of the famous international Journals and Conferences [5,6] of requirement engineering have published significant research in this field.

But, after all the research in this field, the question arises; how much of RE literature is supported by evidence? What is the nature of evidence in RE studies? What is the strength of evidence in RE studies? These are important questions. Answers to these questions will help RE researchers and practitioners to work with clear focus and see where more attention needs to be given. For finding solution to these questions, one needs to look for ways to gather this important information. One of the way of gathering information related to some specific topic of interest is through a systematic way of discovering, synthesizing and then reporting that information, i.e., through the methodology of SLR. Despite of significant research in the field of RE, there has not been done any effort of carrying out an SLR for the whole field of RE. The SLR described in this paper, intends to capture all the useful information related to software requirement engineering in a systematic way. This process of capturing information based on evidence is rigorous and repeatable. To the best of our knowledge, no such systematic review has been reported at this level of RE yet, so this SLR is first of its kind that will review all evidence based RE studies covering all the subareas of RE.

This paper aims at providing a systematic literature review protocol to describe a process for capturing the current empirically evaluated knowledge in the area of software requirement engineering and to recognize needs and chances for future research in this field. The rest of the paper consists of following sections; Section II presents background, Section III describes the systematic literature review protocol, while Section IV concludes the paper along with future work.

II. BACKGROUND

Requirement Engineering is an important phase in software development because a software success is strongly tied to the fulfillment of requirements as put by various stakeholders. Having recognized this fact, there is a vast amount of research available in all the areas of this field, aiming at providing specific tools, techniques, and guidelines for improving sub areas of RE. Despite of all this research, RE lacks a study describing the state of the art of this field.

To carry out such a study which is based on evidence, there are specific methodologies like Systematic Literature Review [12] and Systematic Mapping [18], which have been frequently used by many research fields like evidence-based

medicine. But they have not been much employed in software engineering for validation of empirical studies.

In the field of software engineering, there has been a new drift towards evidence-based software engineering (EBSE) [7] with an emphasis on new empirical and systematic research methods.

EBSE is concerned with capturing current best evidence from research and then integrating it with practical experience and human values in the software development decision making process [8,9]. The main tool of EBSE is Systematic Literature Review [12] which has been employed in this review.

The main motive to undertake this SLR is to discover gaps and commonalities in software requirement engineering empirical research and providing a summary of the existing empirical evidence in this field to form a stepping-stone for future research in this field and for practitioners for their practical use

III. SYSTEMATIC LITERATURE REVIEW PROTOCOL

There are three main phases of a systematic literature review process; planning, conducting and reporting of review as described by Kitchenham [12].

This paper aims at describing the first phase of the review i.e., planning the review, in the specified field of requirement engineering. The output achieved after completion of this phase is a systematic review protocol which has significance as it tells about rationale and process of carrying out the whole systematic review step by step. A systematic review protocol developed in such a way in the start of a systematic review lessens the risk of bias on the part of a researcher [12].

The steps followed in this review protocol have been developed according to guidelines provided by Kitchenham [12]. This protocol describes various steps for carrying out a systematic review that aims at reviewing primary studies related to software requirement engineering to present an outline of existing information related to this field that will eventually help in drawing a broad category of conclusions from this information.

The review intends to find a state of the art in the field of software requirement engineering and the research questions have been formulated according to the motive of the review. The research questions are:

RQ₁: What is state of the art in empirical studies of RE?

The purpose of this question is to empirically evaluate the status of the software requirement engineering and finding out future research directions in this field

For this purpose specific information will be collected through existing research papers in the software requirement engineering field by carrying out a systematic review of research papers in this field.

RQ₂: What is the strength of empirical evidence reflected in empirical requirement engineering literature?

The aim of this question is to find out the strength of empirical evidences, i.e., what we actually know regarding the evidences we collected. This question will

provide information about the strength of the studies in terms of sources of the evidence and research approach used.

A. Search Strategy

The search strategy contains different decisions like search string, resources to be searched and selection items to be searched.

This has been done in steps as:

- Identifying Major Terms from Research Question

Major terms from research questions are:

- RQ1: Software, Requirements Engineering, Empirical studies
- RQ2: Software, Requirements Engineering, Empirical studies

- Identifying Alternate Spellings and Acronym for Major Terms

Alternate Spellings and Acronym for Major Terms are:

- A: (All synonyms of requirement engineering) requirements process, requirements development, requirements elicitation, requirements gathering, requirements identification, requirements discovery, requirements analysis, requirements specification, requirements validation, requirements verification, requirements testing, requirements checking, requirements negotiation, requirements documentation, requirements management, requirements change management.
- B: (All synonyms of empirical studies) empirical, case study, experiment, industrial report, experience report, observational study, survey.

- Formulating Search String

The final search string will be like:

(All synonyms of requirement engineering ORed)
AND
(All synonyms of empirical studies ORed)

The search string will be modified according to the search criteria provided by different sources like Compendex, ACM digital Library, etc. during the conduction of review.

- Deciding Resources to be Searched

Resources to be searched include:

IEEE Explore, ACM digital library, ScienceDirect, SpringerLink and Compendex.

- Selecting Items to be Searched

The items to be searched include: Journal articles, Workshop papers and Conference papers.

- Deciding Language of Review Studies

The research papers in English language will be selected for review.

- Deciding Publication Period

Publication period included in the review will be from the start period as specified in the resource to be searched up to year 2011.

B. Publication Selection

• **Inclusion Criteria**

The study will be included that fits the criteria as:

- The study is about RE
- OR the study is about any of sub-areas of RE
- AND the study has empirical evidence.

• **Exclusion Criteria**

The study will be excluded that:

- Is in the form of books or thesis or unpublished articles
- OR the study that does not directly address RE or any of its sub areas
- OR the study that lacks empirical evidence

• **Selecting Primary Studies**

The primary studies included in the review will be selected in two iterations:

- Level 1 screening

Initially the papers will be selected by reviewing the title, keywords and abstract. By doing this, the studies which are relevant to the research questions will be selected and those lacking this relevance will be excluded. If there is any uncertainty about any paper for inclusion/exclusion in level 1 screening then the paper will not be excluded at this level rather it will be iterated through level 2 screening.

- Level 2 screening

The candidate primary studies selected initially in level 1 will then be checked against the aforementioned inclusion/exclusion criteria by reviewing the studies thoroughly by going through their full text. A secondary reviewer will then review the studies against the Inclusion/Exclusion criteria to cross-check the results of inclusion and exclusion. Studies that lack empirical evidence or that are not about RE will be excluded in this process. And those matching with the inclusion criteria will be selected as primary studies for the review.

C. Publication Quality Assessment

Quality Instrument will be used to evaluate quality of empirical evidences as described in the primary studies. The Quality instrument used in this review consists of 5 sections; a section having general checklist items which are applicable to all the studies included while other 4 sections are specifically for various research method used in the study i.e., experiment, survey, case study and experience report. These criteria have been adopted from SLR guidelines [12] [13] [14] [15] [16]. The formulation of this checklist is a joint group effort of various researchers. Table 1 shows the detailed checklist.

Generic	
Are the aims clearly stated?	YES/NO
Are the study participants or observational units adequately described?	YES/NO/PARTIAL
Was the study design appropriate with respect to research aim?	YES/NO/PARTIAL

Are the data collection methods adequately described?	YES/NO/PARTIAL
Are the statistical methods justified by the author?	YES/NO
Is the statistical methods used to analyze the data properly described and referenced?	YES/NO
Are negative findings presented?	YES/NO/PARTIAL
Are all the study questions answered?	YES/NO
Do the researchers explain future implications?	YES/NO
Survey	
Was the denominator (i.e., the population size) reported?	YES/NO
Did the author justified sample size?	YES/NO
Is the sample representative of the population to which the results will generalize?	YES/NO
Have “drop outs” introduced biasness on result limitation?	YES/NO/NOT APPLICABLE
Experiment	
Were treatments randomly allocated?	YES/NO
If there is a control group, are participants similar to the treatment group participants in terms of variables that may affect study outcomes?	YES/NO
Could lack of blinding introduce bias?	YES/NO
Are the variables used in the study adequately measured (i.e., are the variables likely to be valid and reliable)?	YES/NO
Case Study	
Is case study context defined?	YES/NO
Are sufficient raw data presented to provide understanding of the case?	YES/NO
Is the case study based on theory and linked to existing literature?	YES/NO
Are ethical issues addressed properly (personal intentions, integrity issues, consent, review board approval)?	YES/NO
Is a clear Chain of evidence established from observations to conclusions?	YES/NO/PARTIAL
Experience Report	
Is the focus of study reported?	YES/NO
Does the author report personal observation?	YES/NO
Is there a link between data, interpretation and conclusion?	YES/NO/PARTIAL
Does the study report multiple experiences?	YES/NO

TABLE 1: QUALITY CHECKLIST ADOPTED FROM [12] [13] [14] [15] [16].

The questions included in the checklist will be answered either *Yes*, *No* or *Partial* and will be rated as 2, 1 or 0 respectively. The sum of the scores from all these questions will be used for assessing the quality of the studies.

D. Data Extraction Strategy

Two reviewers will extract the data randomly and then will compare the results. In case of any disagreement, reviewer will arbitrate to reach on some agreement. Each study will be uniquely numbered and studies reported in more than one papers will be counted once. For each research question, relevant data will be extracted from all accepted papers and will be recorded in data synthesis forms. Data will be extracted contributing to each research question.

For RQ1 following information will be extracted:

- RE area (Elicitation, Analysis, Specification, etc.)
- Research output (New Tool, New Technique, New Process, Modification of Tool/Technique/Process, Usage Experience Tool, Usage Experience Technique, Usage Experience Process, RE issues and Challenges).
- Participant Type (Academia, Industry, Mixed)
- Country (involved in research)
- Conference/ Journal
- Year of Publication

For RQ2 following information will be extracted:

- Type of evidence (case study, experiment, experience report, etc.)
- Data collection method (interview, questionnaire, etc)
- Type of research: For extracting information about type of research we have consulted an already developed classification of research approaches by Wieringa [11] who has categorized research types as validation research, evaluation research, solution proposal, philosophical papers, opinion papers and experience papers.

E. Data Synthesis Strategy

Data from all the included papers will be extracted and recorded. Different kind of data will be extracted for each research question as has been described in section D of this paper. The data will be extracted by using well defined data extraction forms, where data will be fed to the best in a quantitative way so that data can finally be analyzed for various patterns.

Data related to RQ1 will help out in finding information like:

- Which area of requirements engineering is empirically evaluated more/less frequently and in what context these empirical studies have been carried out?
- What type of tools, techniques, frameworks and models, etc. are being used in the field of RE?
- Where these tools, techniques and models, etc. are adopted mostly?
- What are the areas of RE that are rich in terms of tools and techniques available and what are the areas where more attention needs to be given?
- What areas of RE are under more consideration and where more work is required?

- Which era of RE can be said as having maximum progress in terms of new advances?
- Which research participants are more involved in RE progress?
- What is the knowledge gap pointed by the evidence in RE?

Data related to RQ2 will help out in finding:

- Which research methods have been employed more frequently in RE?
- Which research methods have been employed for investigating which sub areas of RE?
- Which data collection method has been used for investigating which sub area of RE and by using which research method?
- What type of research has been presented more frequently by the empirical studies of RE?

The extracted data will then be analyzed using various quantitative and qualitative methods for synthesizing the data. Based on this data, different statistics and reports will be generated like:

- Percentage of studies containing case studies, experiments and experiences
- Percentage of studies for each RE area.
- Percentage of studies for different research types.
- Percentage of studies for different participant types.
- Analysis of evidence type versus participant type.
- Analysis of evidence type versus RE area type.
- Analysis of evidence type versus type of research.
- And more complex analysis comprising more than two parameters.

All of this information will be finally presented in the form of systematic maps like *bar graphs*, *bubble plots*, etc.

IV. CONCLUSION AND FUTURE WORK

Requirements engineering being a mature field of software engineering, presents a vast history of research and developments in all of its sub areas. But there lacks a study summarizing the whole field of RE with an emphasis on empirical evidences presented in this field to date. This paper in the form of a protocol provides a plan for carrying out a systematic literature review for the field of requirements engineering, describing state of the art of this field. The future work includes successful execution of the research plan presented in this paper to present a state of the art of software requirements engineering. It will help out various practitioners and researchers in the field to find out which areas of RE are rich in research and also to identify gaps and thus future research directions in this field.

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