An Automated Tool for Inspection of Requirements Engineering Techniques

Mona Batra, Archana Bhatnagar

Abstract*— From last few decades, researchers and practitioners have well recognized the significance of Requirements Engineering. Requirements Engineering stage is the foundation stone on which the entire building named software can be built. There are several Requirements Engineering (RE) techniques exists but requirements engineer choose a specific technique for a particular software project with their own preferences or organization standards. There is not only little guidance available for analyzing Requirements Engineering techniques but also all the existing researches focus on qualitative measures. There is no consideration of physical measures while analyzing and accepting a technique for a particular project. Nowadays customers satisfaction is also gaining great importance so customer perspective should also be taken into account. We have performed deep literature review and noted that analysis and selection of Requirements Engineering technique should consider all relevant attributes of each techniques and their mapping with project, people or other factors. There is a need to thoroughly comprehend and evaluate all the existing techniques with respect to analyst preferences, client experiences, project attributes, software process model characteristics. To do so, fuzzy clustering method is implemented in MATLAB. The key emphasis of this paper is to study and list all possible Requirements Engineering techniques related to Elicitation, Prioritization, Documentation, Verification and Validation, etc. The research work also analyzes attributes of each RE technique using Fuzzy C mean clustering and K mean clustering methods. The results of clustering provide a set of techniques, from which requirements engineer can select for specific phase of Requirements Engineering. The substantiation of the research work is done with the help of a case study that is having some known problem domain characteristics.

Keywords: Software Engineering, Requirements Engineering, Technique Selection, Clustering, Requirement Elicitation, Elicitation Techniques etc.

I. INTRODUCTION

The elementary purpose of Software Engineering (SE) is to strategize, implement and maintain high standardized and qualitative software products within the pre-agreed budget and in predictable time duration. Conflicting this motive of software engineering, researches illustrates that most of the software projects fail due to issues like poor requirements, missing requirements, conflicting requirements, inappropriate quality, schedule and cost [16][18]. Requirements Engineering (RE) stage is a central part in application development that produces comprehensive qualitative application software [1][2][3][20]. Complete understandable requirements eliminate misinterpretations and faults in earlier stage of development. As the system starts to be developed, the time and the cost of fixing these errors goes farther. To perform qualitative requirements engineering, analyst or requirements engineer should have in-depth knowledge and understandability of all RE techniques and other situational characteristics that impact the software project development. Presently, there are plenty of techniques available that illustrates all different facets of the RE process and their support to implement several types of projects [7]. Though, the applicability of RE technique with respect to particular software project is not known in advance due to its intrinsically indefinite nature. This is the biggest challenge confronted by all requirements engineers' group. Therefore, up till now very inadequate literature work has been published that helps to analyze RE techniques [14][8][9][4].

However, existing researches does not deliver adequate amount of information about RE techniques analysis. Hence, a logical linking between available RE techniques and factors affecting the selection process is required. There is a need to build a framework that helps the analyst or requirements engineer to understand which techniques is better for what situation and related to project perspective, analyst preferences, client experiences, software process model characteristics. This part of our research shows how to analyze various attributes with respect to RE techniques.

The goal of this research work is to study and analyze all possible requirements engineering techniques related to Elicitation, Prioritization, Documentation, Verification and Validation, etc. All the attributes of requirement engineering techniques are analyzed and input matrix is formed comprehending weight to each attribute. We have used Fuzzy C mean clustering and K mean clustering algorithm to create clusters that suggest set of RE techniques for Elicitation, Documentation, Prioritization, Verification and Validation as per input matrix. This research work is an automated tool that perform attribute analysis of each RE techniques and create a recommendation space. A recommendation space is an assemble(group) of techniques that suggest RE techniques for a given set of problem domain variables i.e. project attributes like project complexity, size, experience, time constrain, cost, safety criteria, dynamicity, experience of project team etc. In the present automation tool, if there is a change occur in the environment variables then it will update the recommendation space with respect to changed variables.

The systematization of this paper is as follows. The methodology for analyzing RE techniques is described in section II. Section III, describes an overview of study and

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listing of all possible requirement engineering techniques. In Section IV identification and analysis of attributes of requirement engineering techniques is explained whereas Section V explains basic clustering algorithm for technique selection. Case study for evaluation of the methodology is described in Section VI. At the end, conclusion is presented in Section VII.

II. METHODOLOGY FOR ANALYZING REQUIREMENTS ENGINEERING TECHNIQUES

The techniques listed in Table1 are the selected demonstrative RE techniques that widely known in industry and possess well-defined scope in major phases of the RE process. This mechanism categorized and analyzed each technique. This mechanism offers a means to describe major properties, advantages and constraints of each technique, that can be depicted as attributes. Set of rules is used to assign weight for each attribute for further classification and perform clustering to get recommended space (group of RE techniques) for software under construction. Analysis of requirements engineering techniques comprises of below three steps:

I. Study and listing of all possible requirements engineering techniques.

II. Identification and Analysis of attributes of requirement engineering techniques and formation of input matrix.

III. Detailed analysis of each technique using fuzzy clustering method.

Subsequent sections explain in details about the whole technique analysis process.

III. STUDY AND LISTING OF ALL POSSIBLE REQUIREMENTS ENGINEERING TECHNIQUES

We have performed in depth literature study for identification of available RE techniques [24][23][22]. We have gathered valuable information related to RE techniques and their related parameters from research papers published in IEEE conferences, reputed IEEE transactions, Scopus indexed journals, Elsevier, white papers, existing project documents and experience reports [16][20][8][24][23]. We have found that requirements engineering is not only affected by problem domain perspective but also with the project characteristics, developer experience and knowledge, stakeholder’s knowledge, organization and social related parameters. We have identified 55 RE techniques. All the RE techniques and their related applicability in RE process is illustrated in Table 1[13][21][15] [14][20][23][22]. Several techniques are available for various phases of Requirements Engineering. Following criteria is accepted for the cataloging all RE techniques: -

- RE techniques that were widely used commonly were listed.
- RE techniques that usually use for at least two phases of RE process model were given priority as use of single technique in various phases may require less expertise of RE engineers and project team will also feel comfortable due to familiarity with techniques.
- RE techniques that already used in previous research journals whose results and feedback available were chosen so that output of this framework can be easily compare with previous research work.
- RE techniques were selected in such a way that almost every attribute can be addressed.
- RE techniques were selected in such a way that physical estimation of maximum attributes was possible.

Cataloging and listing of existing techniques needs description of each attributes that demonstrate these techniques. Table 1 depicts of cataloging of techniques identified in this research and their contribution in a particular phase of RE.

Table 1: RE Techniques

Serial Number	Technique Name	Major contribution of specific step of RE
1.	Brain Storming and Idea Reduction	Requirements Elicitation
2.	Observation	Requirements Elicitation
3.	Ethnography	Requirements Elicitation
4.	Focus Group	Requirements Elicitation
5.	Interview	Requirements Elicitation
6.	Contextual Inquiry	Requirements Elicitation
7.	Analysis Laddering	Requirements Elicitation
8.	Viewpoint-Based Elicitation	Requirements Analysis
9.	Exploratory Prototypes	Requirements Elicitation, Analysis, Verification and Validation
10.	Evolutionary Prototypes	Requirements Elicitation, Analysis, Verification and Validation
11.	Viewpoint-Based Analysis	Requirements Analysis
12.	Repertory Grids	Requirements Elicitation
13.	User Scenarios	Requirements Elicitation
14.	JAD	Requirements Elicitation
15.	Soft System Methodology (SSM)	Requirements Analysis
16.	Goal-Oriented Analysis	Requirements Analysis

17.	Viewpoint-Based Documentation	Requirements Documentation
18.	Workshop	Requirements Elicitation
19.	Representation Modeling	Requirements Analysis
20.	Functional Decomposition	Requirements Analysis
21.	Decision Tables	Requirements Analysis, Documentation and Verification
22.	State Machine	Requirements Analysis, Documentation and Verification
23.	State Charts	Requirements Analysis, Documentation and Verification
24.	Petri-nets	Requirements Analysis, Documentation and Verification
25.	Structured Analysis	Requirements Analysis, Documentation and Verification
26.	Real Time Structured Analysis	Requirements Analysis, Documentation and Verification
27.	Object Oriented Analysis	Requirements Analysis, Documentation and Verification
28.	Problem Frame Oriented Analysis	Requirements Analysis, Documentation and Verification
29.	Survey/Questionnaire	Requirements Elicitation
30.	Introspection	Requirements Elicitation
31.	Document Analysis	Requirements Elicitation
32.	Prototyping	Requirements Elicitation
33.	Card Sorting	Requirements Elicitation
34.	Quality Function Deployment	Requirements Documentation
35.	Fault Tree Analysis	Requirements Analysis
36.	Structured Natural Language Specification	Requirements Documentation
37.	Viewpoint- Based Verification and Validation	Requirements Documentation
38.	Unified Modeling Language (UML)	Requirements Documentation
39.	Zed (Z)	Requirements Documentation, Analysis, Verification
40.	LOTOS	Requirements Documentation, Analysis, Validation
41.	SDL	Requirements Documentation, Analysis, Validation
42.	Formal Requirements Inspection	Requirements Verification and Validation
43.	Requirements Checklist	Requirements Verification and Validation
44.	Utility Test	Requirements Verification and Validation
45.	Brain Storming	Requirements Elicitation
46.	Bubble Sort Technique	Requirements Elicitation
47.	MOSCOW	Requirements Prioritization
48.	Hundred Dollar Method	Requirements Prioritization
49.	Analytical Hierarchical Processing	Requirements Prioritization
50.	Numerical Assignment	Requirements Prioritization

51.	Value Oriented Prioritization	Requirements Prioritization
52.	Priority Weighting	Requirements Prioritization
53.	Cumulative Voting	Requirements Prioritization
54.	Playing Game	Requirements Prioritization
55.	Vienna Development Method (VDM)	Requirements Documentation, Analysis, Validation

IV. IDENTIFICATION AND ANALYSIS OF ATTRIBUTES OF REQUIREMENT ENGINEERING TECHNIQUES AND FORMATION OF INPUT MATRIX

Attributes are the parameters that differentiate each and every technique from one another. Attributes selection focuses on five major factors [24]: Project domain attributes, software process model attributes, organizational aspects, analyst understandability, client's preferences and experience. Both functional and nonfunctional requirements were considered for RE technique attributes selection. Attributes analysis process follows following steps:

- RE technique attributes were listed from existing research papers and journals as their results can be compared with our research.
- RE technique attributes were selected such that they cover all major factors of RE process.
- RE technique attribute were analyzed in such a way that they can be analyzed or we can say estimated from set of rules. For example, complexity is rated Very High if higher mathematical calculation involves, time consuming process, least derivation may tend wrong results etc. Cost may treat very low if technique may implement with existing resources, less RE staff required and project team already familiar with the techniques due to its common nature.
- RE technique attribute analysis and weight is assign to each attribute.

With the in-depth analysis, we recognize 38 attributes for RE techniques. Below Table 2 shows list of attributes that link with the one of the phases of the RE process.

Table 2 Attributes of Requirements Engineering Techniques

Serial No.	Attributes
1.	Scalability
2.	Feasibility
3.	Degree of Communication
4.	Use of latest calculation and scientific tools
5.	Modularity
6.	Express ability
7.	Reusability
8.	Requirements verification capability
9.	Requirements pre processing capability
10.	Validation capability
11.	Number of RE phases covers
12.	Social issues understanding capabilities
13.	Capability of gathering and use of Non-functional requirements
14.	Ability to get domain knowledge
15.	Customer Negotiation capabilities
16.	Capability to get implicit knowledge
17	Ability to identify stakeholders
18	Capability to identify non-functional requirements
19	Competence to identify various viewpoints
20	Ability to model and understand requirements
21	Understanding ability for the notations used in analysis
22	Competence to facilitate the negotiation with customer
23	Competence to prioritize the requirements
24	Capability to identify the accessibility of the system
25	Capacity to model interface requirements
26	Capability to identify and support requirements reuse
27	Capabilities to identify the unambiguous requirements
28	Completeness of semantics of the notation
29	Capacity to write unambiguous and precise requirements by using the notation

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30	Capabilities to write complete requirements
31	Competence for requirements management Modularity
32	Capabilities to identify the interaction
33	Capabilities to recognize the incomplete requirements
34	Capabilities to provision COTS-based RE process
35	Maturity of the supportive tool
36	Learning curve (also named as Introductory cost)
37	Cost Application Development
38	Techniques Complexity

To each attribute, there is a list of measures and conditions to certify its measurability. Weight Assignment Method is used for all attributes, i.e. the attribute values are set as not relevant, very low (very small), low(small), medium, high(large) and very high (very large). The weight assignment method is shown in Table 3. An ordinal scale is used in weight assignment method for all attributes. For example, if project Size (no. of requirements) are less than 10 it is considered as Very Small or Very Low. If the project Size is greater than 5000 so it is considered as Very Large project or Very High, so associated value is assigned. This way an input matrix is formed.

Table 3 Weight Assignment Method

Very High/ Very Large	1
High/Large	0.8
Medium	0.6
Low/Small	0.4
Very Low/ Very Small	0.2
Not Related	0

V. DETAILED ANALYSIS OF THE TECHNIQUES USING A CLUSTERING METHOD

Clustering is a technique of unsupervised learning and has been extensively used for statistical data analysis. It is used in several domains viz. in medical domain for medical data analysis, data mining, and market data analysis. Clustering systematizes the data through extracting the fundamental assembly either as a set of entities or as an order of sets [5]. This means that clustering methodology let data elements having alike attributes to be systematized into groups. There are a various clustering method exists, such as K-Means clustering, Hierarchy Clustering and Fuzzy Clustering [6][10][11][17]. The Fuzzy C- mean clustering method is used in this research. Fuzzy Clustering is used for generating such set which depicts membership weight of each cluster member. The benefits of using Fuzzy C mean clustering are [5] [12][19]:

- It suggests bunch of RE techniques rather than single one.
- It suggests equally competent RE technique as an alternate.
- It accommodates change in environment variables and suggest alternate bunch in changed condition.
- Equally opposite techniques are also suggested.
- It permits regular associations of data points to clusters restrained as degrees in [0,1]. This offer the flexibility to specify that any data points can have its place in more than one cluster.

The elementary principle of Fuzzy Clustering algorithm is to minimize the below objective function [12]:

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m} \left\| x_i - c_j \right\|^2$$

$$1 \le m < \infty$$

In the above mentioned objective function, m is any real number which is greater than 1, $\mathbf{u_{ij}}$ depicts the membership of x_i in cluster j, $\mathbf{x_i}$ is the $i^{\mathbf{th}}$ of d-dimensional measured data, c_j is the d-dimensional center of the cluster, and ||*|| is any norm depicting the resemblance between any measured data and the center. Fuzzy partitioning is accomplished by an repetitive optimization of objective function along with the update of membership $\mathbf{u_{ij}}$ and the cluster centers $\mathbf{c_j}$ by:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\left\| x_i - c_j \right\|}{\left\| x_i - c_k \right\|}\right)^{\frac{2}{m-1}}}$$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \cdot x_i}{\sum_{i=1}^{N} u_{ij}^{m}}$$

This repetition will come to an end when $\max_{ij}\left\{\left|u_{ij}^{(k+1)} - u_{ij}^{(k)}\right|\right\} < \varepsilon$, where end condition lies between 0 and 1, while k represents iteration steps. This process congregates to local minimum or a saddle point of J_m. The proper algorithm is as follows:

1. Initialize $U=[u_{ij}]$ matrix, $U^{(0)}$
2. At k-step: calculate the centers vectors $C^{(k)}=[c_j]$ with $U^{(k)}$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} \cdot x_i}{\sum_{i=1}^{N} u_{ij}^{m}}$$

3. Update $U^{(k)}$, $U^{(k+1)}$

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\left\| x_i - c_j \right\|}{\left\| x_i - c_k \right\|}\right)^{\frac{2}{m-1}}}$$

4. If $\| U^{(k+1)} - U^{(k)} \| < \varepsilon$ then STOP; otherwise return to step 2.

In FCM, data elements are approximately destined to distinct cluster by means of Membership Function, which signifies fuzzy behavior of this algorithm. To achieve that an appropriate matrix termed as U is build whose factors are numbered between 0 and 1, and depicts the membership degree between data and centers of clusters. With the help of clustering we can take total advantage of the cohesiveness of the every RE technique in each cluster and also lessens the cost function. Clustering helps to assemble RE techniques with respect to their attributes. Techniques that makes their room in single cluster share common characteristics and create a foundation for selection to a particular problem domain.

VI. CASE STUDY

To explore the advantages of proposed methodology a case study is conducted. However, in software engineering field case studies are the most effective way for the evaluation software engineering tools and techniques. When a client request for project development in a company, some know problem domain attributes is identified from client by requirements analyst. Table 3 depicts some known problem domain characteristics for this case study. This initial set of problem domain characteristics was used to choose best combination of RE techniques. These problem domain characteristics act as an input for performing clustering to get set of techniques for each relevant phase of RE. Figure 1 depicts the clustering of relevant RE techniques for this problem domain. The clusters of techniques are created via applying problem domain in our automated tool. Its very important to get all comprehensive set of techniques for each stages of requirements engineering. Table 4 briefly describe set of techniques for each phase of requirements engineering with their associated cluster values. Recommended Technique Set consists of all the techniques which comes as an output when we fed problem domain values to our automated tool.

Table 3 Problem domain with known characteristics

Project Size	Large (1000-4000)
Project Complexity	Very High
Requirements Volatility	Very Low
Degree of Criticalness	High
Time and cost constraint	Low
Project of existing domain	Existing

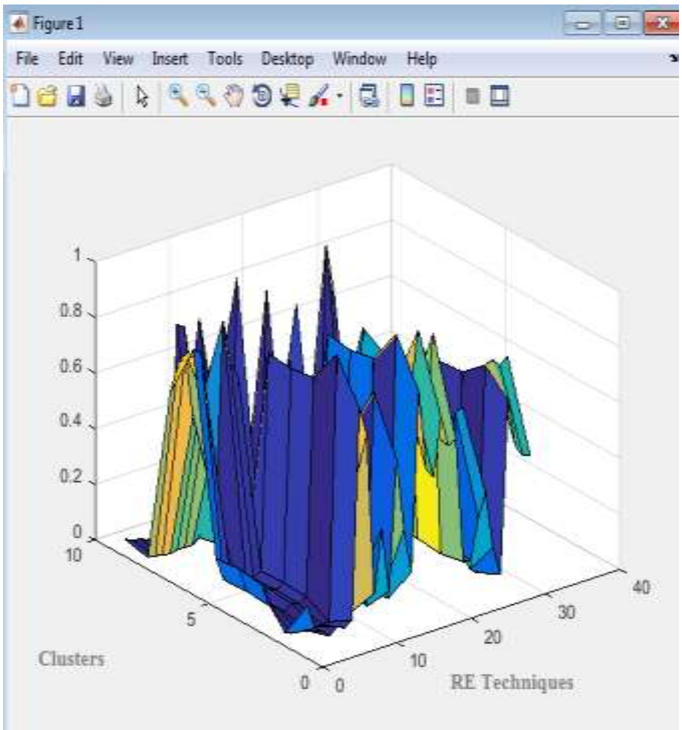

Figure 1 Clusters of RE technique

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Table 4 Recommended Techniques Sets

Serial Number	**Attributes of Project and Product (Condition attributes)**		**Recommended Technique Sets (Decision attributes)**
1	Project Size	Large (1000-4000)	**Elicitation**: Interview 0.5; FG 0.125; Prototyping 0.125; Brain 0.125; Ethnography 0.09375; JAD 0.02 **Analysis and Negotiation**: Scenario Approach 0.9; Goal Oriented Analysis 0.9; Card Sorting 0.8 **Prioritization**: AHP 0.42 **Documentation** UML 0.56; Structured Natural Language Based Specification 0.55; SDL 0.12 **Validation**: Req Inspection 0.9; Req Testing 0.8; View Point 0.56
	Project Complexity	Very High	
	Requirements Volatility	Very Low	
	Degree of Criticalness	High	
	Time and cost constraint	Low	
	Project of existing domain	Existing	

VII. CONCLUSION

Selecting nearly correct RE techniques for software product development results in inclusive accomplishment of a software project. However, selection process completely depends on in-depth understanding of RE techniques and the associations between them. This research work helps to understand various RE technique and attribute assignment to each technique. The presented work depicts that clustering method is one of the most efficient method for analyzing RE techniques. Future work may be done to incorporate more RE techniques and analyzing the output with applying clustering method with added RE techniques. Our work is to create a decision support system. The integration of the clustering mechanism into the whole RE process model still needs to be done.

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