FUZZY LOGIC BASED INTELLIGENT SOFTWARE REQUIREMENT ELICITATION TECHNIQUE SELECTION MODEL

By

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ABSTRACT

Software development by its very nature consists of several knowledge-intensive processes. Requirement Engineering is one and perhaps the first of these processes. Requirement Elicitation is the first phase of Requirement Engineering and deals with seeking, uncovering, acquiring, and elaborating requirements for computer based systems. Requirements elicitation is a multifaceted process linking many activities with a diversity of available techniques, approaches, and tools for performing them. The success or failure of this process is based on identifying the significant stakeholders and discovering their requirements as well as the excellence of discovered requirements. With the increasing complexity of the projects the complexity of Requirement Elicitation process also increases.

The quality of the requirements elicited during the elicitation phase depends mainly on how well the requirement elicitation technique is selected. Mostly the techniques are selected on the basis of personal preferences or on hand company practices rather than on the basis of attributes of technique, project and stakeholders. The aim of this research work is to identify the attributes of elicitation techniques, projects and the stakeholders which influence the elicitation technique selection process. After that, to propose a Fuzzy Logic based intelligent requirement elicitation technique selection model which reduces the human biasness while elicitation technique selection.

The methodology used in this study is literature survey and a questionnaire of 23 questions for feedback. During literature survey it was observed that a number of research papers have been presented that promulgates only a specific technique. Few research papers model elicitation process in general. Intelligent models suing ontology and fuzzy logic have been presented in literature aiming requirement specification and prioritization but it is hard to find intelligent elicitation technique selection model. Ten attributes of elicitation techniques and the stakeholders which affect the technique selection process were also finalized via literature survey and interviews with professionals. Feedback through questionnaire guided us how to use these attributes for technique selection.

Based on the results of literature survey and feedback through questionnaire, membership functions were derived. Rules for fuzzy logic based intelligent model were generated through WEKA (Waikato Environment for Knowledge Analysis) using FURIA (Fuzzy Unordered Rule Induction Algorithm) algorithm.

Finally the proposed model was also verified on WEKA via training set, split 80% train and remainder test, and 10-folds cross validation. Different statistics like accuracy, Precision, True Positive Rate (TPR), False Positive Rate (FPR), Kappa statistic, ROC area have been used and compared to determine the strength of proposed model. The results showed that our proposed model helps in suitable technique selection and will eventually enhance the quality of elicited requirements.

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Wajid A. Abbasi

DECLARATION

I hereby declare that this research, neither as whole nor as part has been copied out from any source. It is further declare that I have prepared this report entirely on the basis of my personal efforts made under the sincere guidance of teachers especially my supervisor and co-supervisor. If any part of this thesis is proved to be copied out from any source or found to be reproduction of some other, I will stand by the consequences. No potion of the work presented has been submitted in support of any application for any other degree or qualification of this or any other university or institute of learning.

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Dedicated to

My adored Grand Father, Habib-U-Allah Khan Abbasi, who is not in this world but in my heart

ACRONYMS & ABBREVIATIONS

Acronyms	Full Name
RE	*Requirement Engineering*
JAD	*Joint Application Development*
CREWS	*Cooperative Requirements Engineering With Scenarios*
CRC	*Cooperative Requirement Capture*
AUC	*Area Under Curve*
WEKA	*Waikato Environment for Knowledge Analysis*
FURIA	*Fuzzy Unordered Rule Induction Algorithm*
CF	*Certainty Factor*
M	*Medium*
L	*Low*
H	*High*
TP	*True Positive*
FP	*False Positive*
ROC	*Receiver Operating Characteristic*
TN	*True Negative*
FN	*False Negative*
CCI	*Correctly Classified Instances*
ICI	*Incorrectly Classified Instances*
AC	*Accuracy*
TPR	*True Positive Rate*
FPR	*False Positive Rate*
IEEE	*Institute of Electrical and Electronics Engineers*
FL	*Fuzzy Logic*
FES	*Fuzzy Expert System*
ARM	*Association Rule Mining*
NBC	*Naive Bayesian Classifier*

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THESIS APPROVAL SHEET

It is to certify that Mr. Wajid Arshad Abbasi, student of MS (SE) Department of Computing & Technology, Student ID (051-11-114202) of IQRA University Islamabad, has submitted the final thesis report on "**Fuzzy Logic Based Intelligent Software Requirement Elicitation Technique Selection Model**". We have read the report and it fulfills the partial requirements for the degree of Master of Science in Software Engineering (MSSE).

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Chapter 1

Introduction

Computer systems have become so important and vital that we cannot imagine our lives without them. Since 1948, when first real computer was invented, the change in our life is called digital revolution. The use of computer applications in everyday life and day to day business is very much common. Due to development of the commercial of the shelf products, a vast range of fields that use computer and different services are expected by the customers, which make it challenging to develop products which fulfill the customer's expectations and needs [1].

Since 1960, the development of computer system is facing many problems like not meeting the requirements, or satisfying the intended purpose [2]. This problem resulted in the dissatisfaction of the users. One of main reason stated for this problem is inefficient requirement gathering, as the Requirement Engineering (RE) is the first step in software development life cycle [2].

1.1. Requirement Engineering (RE)

The requirement engineering is defined by Leite [3] as "It is a process in which "what is to be done" is **elicited** and **modeled**. This process has to deal with difference viewpoints, and it uses a combination of **techniques**, **tools**, and **actors**. The product of this process is a model, from which a document, called **Requirements Specification**, produced".

It is one of the most critical phase in the software development lifecycle because the hardest thing to know what to build [4]. Many requirements error replicate to later stages of development then it become difficult and costly to rectify them. This is the stage where system analyst needs to be more attentive because getting vague requirements may result in wrong solution.

The requirement engineering is repetitive and systematic process where requirements are gathered, analyzed and evaluated in terms of validity, consistency and completeness at every step [2]. Cost of RE ranges from 10 to 15% of overall budget, depending on the complexity of the project [2]. To rectify a requirement error at latter stages requires rework at design, implantation and testing which increases cost to 100 times [2].

1.2. Requirement Engineering Process

Like Software Engineering, Requirement Engineering is also consist of activities which interact with each other to form a whole RE process lifecycle. The RE process contains following set of activities [5]

- Feasibility Study
- Requirement Elicitation
- Requirement Analysis
- Requirement Specification
- Requirement Validation
- Requirement Management

The lifecycle of the RE process is shown in Figure 1.1.

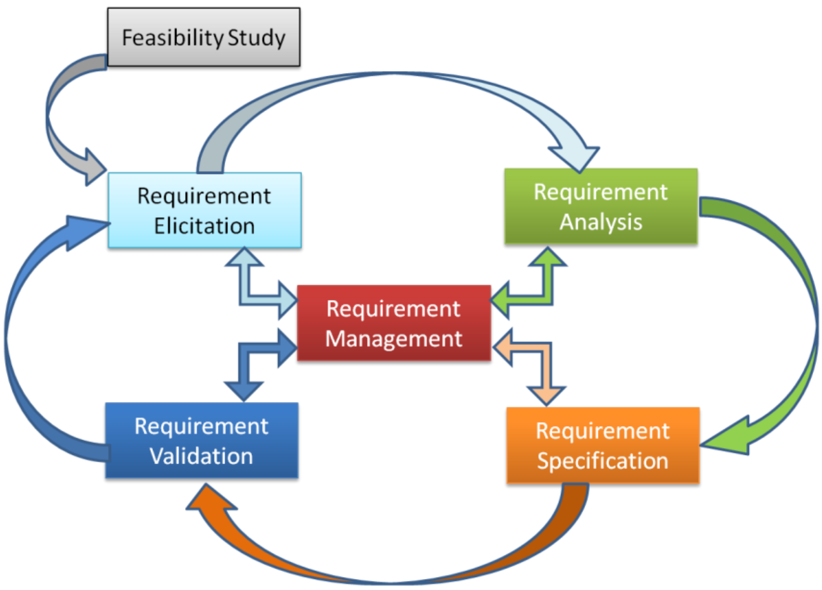

Figure 1.1: Requirement Engineering Process

In current research work, we are only interested in requirement elicitation. As the failure and success of proposed system depends on the quality of requirements similarly, the RE process depends upon how well the elicitation activities have been performed. Elicitation process takes much of the time in RE process as shown in Figure 1.2.

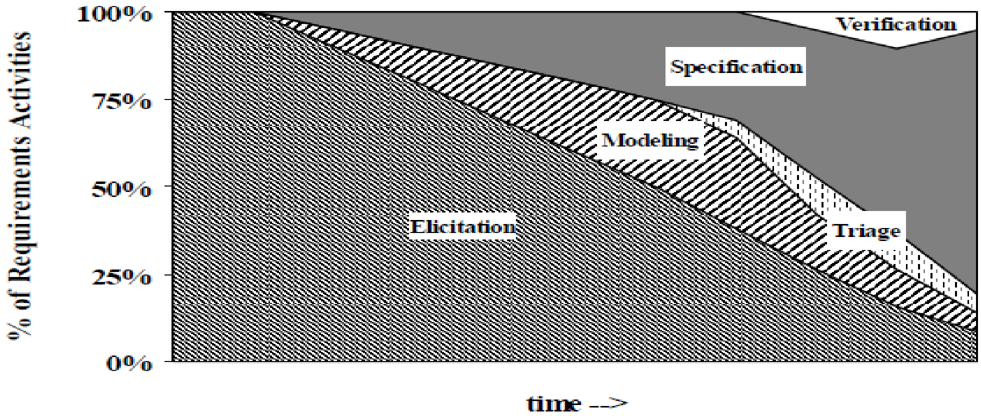

Figure 1.2: Parallel Model of Requirement Engineering Process [6]

1.3. Requirement Elicitation

Requirement elicitation in RE is used to determine the system boundaries and to specify the behavior of the system. Its success depends on the identification of stakeholders (end users, customers, developers, sponsors) and knowing their requirements. Elicitation is used to address following problems.

- What the proposed system should do?
- What are expected services the system should provide?
- To know the required attributes of the system.
- To know the hardware and software constraints.

Frequent sources for this phase are:

- End Users/Customers
- Domain experts
- Existing system documentation
- Users of existing system

- Similar applications

While requirement elicitation, it is important for analyst to consider all the possible sources in order to better understand the application domain. During elicitation process analyst face number of challenges like

- Lack of domain knowledge
- Communication breach
- Resolving good requirement source
- Political influences
- Budget constraints
- Time constraints

In order to cope with all above challenges, several requirement elicitation techniques have been developed. These techniques vary in term of effectiveness depending on project's nature. While requirement elicitation, proper technique selection plays crucial role. The importance of technique selection in requirement elicitation process has already been highlighted in literature. Many models for requirement elicitation have been proposed where technique selection got focus.

One problem with all presented models in literature is that all have human interventions while technique selection. This human involvement may bias the technique selection decision. This is the main focus of this research work.

1.4. Purpose of the study

The main purpose of this study is to automate the requirement elicitation technique selection process and to reduce the human involvements in requirement technique selection process.

1.5. Problem Domain

The success of software development projects depends on how well they focus to meet the user's requirements. Therefore requirement engineering process plays important role in the success story of the software development. Requirement Elicitation is the first phase of the Requirement Engineering (RE).

The success of requirement elicitation process depends upon how well the requirement elicitation technique gets selected for a particular project. Therefore a fair and unbiased requirement selection process is vital.

1.6. Aims and Objectives

The aims and objectives of this research work are:

- ✓ To identify attributes of the elicitation techniques through literature survey which differentiate them.
- ✓ To determine different natured projects and recommendations of techniques through questionnaire.
- ✓ To fully automate the requirement elicitation techniques selection process.
- ✓ To develop the Fuzzy Logic Based Intelligent Requirement elicitation techniques Selection Model.
- ✓ To develop industry specific rules to optimize the requirement elicitation technique selection.
- ✓ To reduce human involvement and bias in elicitation technique selection.

1.6. Thesis Structure

The study is distributed on several chapters:

Chapter 2 (**Review of Literature**): This chapter presents related work and research in the area of requirement elicitation process.

Chapter 3 (**Research Design and Methodology**): The way in which this research work conducted is given in this chapter.

Chapter 4 (**Proposed Model**): The proposed model is discussed in this chapter.

Chapter 5 (**Results and Discussion**): The results of our study, their analysis and comparison of results with literature are presented in this chapter.

Chapter 6 (**Epilogue**): The conclusions of our work and future suggestions for research work in this domain are given in this chapter.

Chapter 2

Review of Literature

The critical and important role of Requirement Engineering (RE) in the development of software systems has already been highlighted by many researchers [7-9]. The process of RE encompasses Elicitation, Analysis, Specification, Validation and Management of requirements [2]. Major problem areas discussed in literature concerning RE are Acquisition, Conception and Unpredictability of requirements [10]. The Requirement Elicitation is the first and the most important phase of RE which deals with the acquisitions of requirements [11, 12].

Most of the research work in RE is focused on the requirement representation and modeling but not how these requirements are to be well collected [13]. RE is first and important step in the development of software similarly Elicitation is also the first and important step in RE [4]. This research work is focused on Requirement Elicitation.

2.1. Requirement Elicitation

Requirement elicitation is the process of determining needs of stakeholders. It involves learning, uncovering, extracting, surfacing, or discovering needs of customers, users, and other potential stakeholders [14]. It incorporates a set of overlapping activities which facilitate communication, prioritization, collaboration and negotiation with relevant stakeholders. The nature of these activities is highly communicative. In literature these activities are divided as follows:

- **To understand the application domain**

  It involves investigation and examination of environment in which the system will ultimately work [15]. All the social, political, organizational and cultural aspects of environment get studied. Business goals are identified.

- **Requirement sources identification**

  In software development a range of requirement sources involved [16]. These sources include users, subject matter expert, existing systems, documentation of old systems and the business processes.

- **Stakeholders Analysis**

  Stakeholders are the people who are affected directly or indirectly by the development and implementation of the system. Customers and project sponsors are considered to be the important stakeholders. Robertson *et., al*. provide a list of potential stakeholders [17]. This analysis is important in the sense all the identified stakeholders are consulted during elicitation [18].

- **Tools, Technique and Approach selection**

  There are variety of requirement elicitation techniques and tools. The selection of technique is important for success and it depends on context of project [4]. This activity is majorly focused in this research work.

- **Eliciting the requirements from stakeholders**

  After identification of sources and stakeholders, requirement eliciting begins with selected tools and techniques. During this activity, scope of the project must be considered. Requirements should be complete and consistent.

Requirement elicitation cannot be conducted in emptiness however it is influenced by characteristics of project, organization and environment [19]. The budget, schedule and the volatility level of the project also affect its operation. Typically the process begins with high-level mission statement of system which forms the basis for further investigation and acquisition of requirements in an iterative process [20].

A number of process models for the requirement elicitation have been proposed by many researchers over past few decades [2, 21]. Most of these models provide a map where variety of tasks can be incorporated in the process. In these models the completion of process is mostly determined by budget and schedule constraints rather complete and quality requirements. The processes in these models result set of basic needs of stakeholders in plain language or pictorial depiction with sometimes rationales and sources descriptions. Normally the requirement elicitation is performed poorly due to lack of expertise on the part of active engineers, lack of domain knowledge, budget and schedule constraints [22, 23]. To overcome the problem, different elicitation techniques developed over the past two decades discussed in [24].

2.2. Requirement Elicitation Techniques

A technique is basically a practical method applied to some task and an approach is the systematic arrangements of ideas to deal with some situation [2]. The requirement elicitation techniques are the methods applied by the experts to elicit the requirements of the proposed system. The success of large projects mostly depends on the quality of requirements elicited during requirement elicitation. This quality is normally achieved by appropriate selection of techniques from available ones.

A range of elicitation techniques has been proposed in literature like interviews [25], protocol analysis [26], JAD [27], repertory grid [28], workshops [29] etc. As the stakeholders involved in elicitation process belong to a variety of backgrounds having different capabilities and domain knowledge. Therefore in most of the cases a single technique cannot give the best results [30]. Organizational processes, domain type, resources availability and individuals liking are the factors which affect technique competence. Most of the time combinations of techniques are also used to deal with issues that one method cannot address [31].

Several elicitation techniques are available to address different requirement problems and having varying amount of advantages in terms of simplicity, complexity and maturity [32]. These techniques are divided into four categories with respect to mean of communication: Conversational, Observational, Analytical and Synthetic [30]. No doubt, in literature there are dozens of requirement elicitation techniques but we are interested in techniques which are widely used and representation of range described in literature. We also tried to include at least three techniques from each of above categories. Techniques selected for this study are shown in Table 2.1.

Table 2.1 Requirement elicitation techniques along category**.**

S. #	Technique Category	Elicitation Techniques
1	Conversational	Interviews
		Requirement Workshop
		Focus Group
		Brain Storming
2	Observational	Social Analysis/Observation
		Ethnographic study
		Protocol Analysis
3	Analytical	Requirement Reuse
		Documentation Study
		Laddering
		Card sorting
		Repertory Grid
4	Synthetic	Scenarios
		Prototyping
		JAD
		Contextual Inquiry

2.2.1. Conversational Techniques

These techniques facilitate verbal communication between the stakeholders. These techniques are quite straight forward and provide usual way to extract ideas and needs [30]. Conversation is considered a best way to interact and people always feel happy to articulate their feelings through it. Techniques in this category are also called verbal techniques. Because of practicality and efficiency of these techniques to collect non-tacit knowledge, the requirements collected through these techniques are called non-tacit requirements [33]. However, these techniques are time and efforts intensive due to setting up meetings, documentation and analysis of records [19]. The detail of techniques in this category is given below:

2.2.1.1. Interviews

Interview is considered as the most conventional and familiar elicitation technique [34]. This is a purely human social activity and its efficiency depends upon the quality of interaction between the participants. The quality of the requirements collected through interview appreciably depends on the skill of the interviewer [35]. For a successful interview the misunderstandings between the participants should be resolved. Normally interviews have two categories [36].

- Closed interview: In this category the analyst has pre-determined list of questions which he asked to stakeholders.
- Open Interview: This type of interviews is in the form of open discussion and there are no pre defined questions.

In open interviews there is no control over discussion directions. Therefore some areas of the problem get much attention and others are neglected at all [37]. This type of interviews is best suited for explorative studies where domain knowledge is limited, or as a forerunner to more closed interviews. The success of the closed interviews depends on the right selection of questions. Different templates are available like Volere [17] to support this technique. Closed interviews limit the invention of new ideas.

2.2.1.2. Requirement Workshops

It involves different kind of group meetings where the agenda is to discover and develop the requirements of the system [38]. These workshops may be in the form of cross functional where different stakeholders from diverse areas of business participate or Cooperative Requirement Capture (CRC) where set of activities are pre defined and development community involves for creativity [39].

2.2.1.3. Focus Group

It works in the form of qualitative study group to capture the stakeholder’s needs and requirements. It supports the analyst to observe organizational issues through user impulsive response. Stakeholders involve in focus group should have in depth domain knowledge. Moderator with preplanned agenda and goals plays important role. Focus groups are especially helpful for web projects to know how web site will be used by target audience [40]. This technique is ineffective in highly political tense situation [41].

2.2.1.4. Brainstorming

An elicitation technique used to generate ideas for the solution of the problem [42]. It is the way of generating innovative ideas and possible solutions. It has close resemblance with focus group with six to ten members. Each member has freedom of expressing his ideas. In this technique it is essential to assess ideas and solutions in detail. At the end of meeting the best idea can be selected through voting as problem solution. It is not normally the aim of brainstorming to resolve conflicts and making key decisions.

This technique is used to develop mission statement of the project. Brainstorming is not normally recommended for projects with small group of stakeholders having varied requirements [43]. It cannot also be used to resolve the major issues [41].

2.2.2. Observational Techniques

Sometimes it is difficult for stakeholders to articulate what he is doing because they do not bother to what is familiar to them. Such requirements are tacit in nature and it is quite tough to collect them through verbal communication. To collect such requirements observational techniques can be used.

Observational techniques can also be used when analyst has limited domain knowledge. These techniques are inefficient when there is stiff schedule at requirement phase [30]. The detail of techniques under this category is as follows

2.2.2.1. Social Analysis/ Observation

It is most widely used elicitation technique. In this technique the analyst observe the actual working process of user without interfering. Most of the times, this technique is used in conjunction with interviews or task analysis [24]. This technique is expensive and requires significant skills on the part of analyst to understand and articulate the user actions. The success of this technique depends on how easy the user feels to perform actions when someone is observing him.

2.2.2.2. Ethnographic study

This is very common technique to capture tacit knowledge. It gives insight how the user use his system in the real world [44]. The analyst participates actively or passively in user activities [45]. This technique is useful when project is complex, addressing contextual factors like usability, and domain knowledge is limited. This technique is especially important when there is a need of new system due to the problems with procedures and processes of the existing solutions. This technique is in feasible when there are time constraints.

2.2.2.3. Protocol Analysis

Protocol analysis is also called thinking aloud. In this technique user verbalize loudly his action while performing a task [35]. The analyst can record user actions in the form of video, audio or notes to extract requirements of proposed system [46]. This technique is useful for providing rationales of requirements [37]. Protocol analysis requires strong domain knowledge on analyst part otherwise complex parts of user behavior cannot be recorded. In large projects with number of stakeholders, this technique is not recommended. This technique also does not give much structured script and therefore not easy to analyze [46].

2.2.3. Analytical Techniques

Conversational and observational techniques are used to trace requirements directly from stakeholder through verbal conversations or behavior. But still there is some kind of requirements which cannot be addressed through these techniques. To cater with these kinds of requirements, analytical techniques are used which explore the existing documents and knowledge [24]. These techniques are used to get information about work flow, domain and feature support by studying reports, charts and on hand documentation [30]. These techniques have the advantages of to save time and money, and also represent requirements in hierarchical flow. The disadvantages associated with these techniques are the obligation of on hand documentation, tapered vision and error reproduction. The techniques in this category are:

2.2.3.1. Requirement Reuse

Most of the efforts in software development organizations are directed towards the development of timely and cost effective products. By using the requirements of a product similar in functionality bring cost saving and reduced time. Requirement reuse is the elicitation technique that is used to achieve these goals. Requirement reuse can save 10% to 35% of development cost [47]. It is also observed that most of requirements of new system have requirements similar to legacy systems, so the requirement reuse is quite justified [35]. This method is quite useful in low budget and tense schedule.

2.2.3.2. Documentation Study

In this technique different documents like Organizational policies, Standards, Legacy system specifications and market knowledge get studied to find useful requirements. Reviews of existing documents are also fall in this technique [48].

2.2.3.3. Laddering

This technique is used to create and review the expert's knowledge in tree form. It was first formulated in sixties by psychologists to comprehend people's mind-set and belief's [49]. In this technique stakeholders are asked questions called probes and answers are arranged hierarchically [50]. It is less time consuming and requires less expert guideline during elicitation [51]. Not all type of requirements can be extracted in this way, so the appropriateness of particular domain is necessary [50]. It is used to elucidate requirements and to systematize domain entities.

2.2.3.4. Card sorting

In this technique of requirement elicitation stakeholder sort a set of cards into groups where each card has description of domain printed on it. During sorting, criteria for sorting and naming the groups should have rationales [45]. For card sorting to be efficient all the entities must be included in the sorting process. For this domain understanding is indispensable for analyst and participants. In web projects, card sorting can be used to gather requirement close to user thinking and mental model [52].

This technique has advantages of to recall the domain understanding and to distinguish high and low level problems [53].

2.2.3.5. Repertory Grid

This technique is used to know what people think about a given problem. It involves identifying domain entities and rating them according to certain criteria called constructs [54]. The entities and constructs are obtained from subject or experimenter. Basic output of this technique is grid with n rows and m columns. This technique helps to define precisely concepts and to determine the association between these concepts [55].

The repertory grid is efficiently used when participants have strong practical experience with domain so that entities identification and their comparison can be performed easily. Helen Edwards *et., al*. argue that Rep. Grid technique is the best used for exploration and evaluation [56]. Niu & Easterbrook also used this technique for requirements discovery [57].

2.2.4. Synthetic Techniques

The techniques discussed previously are good and handy in particular framework and situation. But in complex projects it is often difficult to elicit the entire requirement using only technique. To cater this problem a good idea is to combine different elicitation techniques to collect requirements. Like, it is better to have interviews along with ethnographic studies [30]. Combination of techniques compensates the weaknesses of other. Instead of combining different techniques the synthetic methods form a rational entire single technique by methodically combining conversational, observational and analytical techniques [30]. The techniques falling under this category are:

2.2.4.1. Scenarios

This technique is used to elicit actions and interactions between users and system [24]. It gives working method of state and interaction sessions of the concerned system [58]. Like use cases, this technique does not consider the internal structure of system and works iteratively. Different approaches have been developed to elicit requirements using scenario like CREWS [59], the inquiry cycle [60] and scenario plus [61]. Way to prepare scenario is presented in [62].

2.2.4.2. Prototyping

It is basically the demonstration and revelation of the actual system [17]. It is an effective to get detail requirements and relevant feedback. It is the most common technique in use and it is also used in conjunction with interviews and JAD [24, 63]. This technique helps stakeholders to comprehend the system trough visualization which has not yet been developed. This technique is used when project is new and stakeholders do not have any idea, these stakeholders cannot articulate their requirements, and when developing Human computer interface. Prototyping reduces development cost and time but it is complex to develop due to technical limitations [64]. One of the major problem with this technique is stakeholders get attached with it and resist alternate solutions [24].

2.2.4.3. JAD

Joint Application Development (JAD) is a technique which involves all stakeholders to investigate problem solutions through discussion [27]. The success of this technique depends on leader of JAD and the participation of stakeholders [65]. A project is suitable to use JAD if it has following characteristics [66]:

- Large number of stakeholders.
- First time and critical to the future of organization.
- Users are willing.
- Complex and large.

The JAD process is described in [67]. The main difference between JAD and brainstorming is that the main goals in JAD have already been established and JAD is well structured [24]. The focus of this technique is user's needs rather technical detail.

2.2.4.4. Contextual Inquiry

This technique of requirement elicitation helps the analyst to gain real understanding of the application domain and to collect detailed requirements by observing and interaction with users in natural environment. Contextual inquiry has four basic principals like context, partnership, interpretation and focus [68]. This technique is used to get rationales of why something get done or not.

It can be done through various ways like work-based interviews, post observation inquiry and artifact walkthrough depending on project nature [69]. This technique is used to elicit requirements for several complex projects like CivicInfo.bc website by Rosenthal [70].

2.3. Requirement Elicitation Techniques Selection Models

As we have studied that there are many requirement elicitation techniques with primary aim of assisting analysts to understand the user needs [71]. It is sometimes mistakenly assumed by analysts that one single technique can be sufficient to elicit all type of requirements [72, 73]. Different studies have demonstrated that elicitation techniques are not identical and there exist obvious difference between them [74, 75]. There exist issues like quantity of information and elicitation efficiency that differentiate these techniques [76].

As there is no absolute technique for a particular project, therefore, there is a strong need to select a particular technique from numerous available [41]. Analysts normally select a technique for any of the following four reasons [6]: a) Only technique known by the analyst, b) Analyst's favorite technique, c) the technique is prescribed by the methodology followed by the analyst, d) the analyst select instinctively a suitable technique. Mostly analysts are influenced by first three reasons although the fourth one is most mature [6].

In literature there exist three kinds of models for elicitation technique selection [77]: a) Those that model elicitation process in general, b) Those that select a particular technique without considering knowledge, c) Those that select a particular technique by considering knowledge. Studies like [6, 77] highlight the weaknesses of the first two classes of the models and proposed third class. In the third class of model there exist technique selection processes where domain knowledge was considered but fail to reduce the human involvement in elicitation selection process. Human involvement in technique selection process would always bias the selection although different attributes of domain get considered.

All this goes to justify the objective of this research, namely, to propose an intelligent model for the elicitation technique selection by considering technique's, project's and stakeholder's attributes. The intelligent requirement elicitation technique selection model will ultimately reduce the human biasness from selection process.

Chapter 3

Research Design and Methodology

This chapter gives an introduction of approach adopted for this study in terms of research design and justifications for methodology used. In this research we are interested in selection of a set of requirement elicitation techniques, their attributes, the attributes of the project on which different techniques are applied to elicit requirements and attributes of Stakeholders. Finally mapping between technique's and project's attributes will be performed.

3.1. Research Design

In this study an intelligent model for requirement elicitation technique selection will be proposed, for which we require a set of techniques, their attributes and project characteristics. Set of techniques and their attributes will be selected through literature survey and the characteristics of projects will be collected through a survey via questionnaire. After that, preferred attributes will be mapped using Fuzzy Logic approach to have an intelligent model. The approach adopted for this study is shown in Figure 3.1.

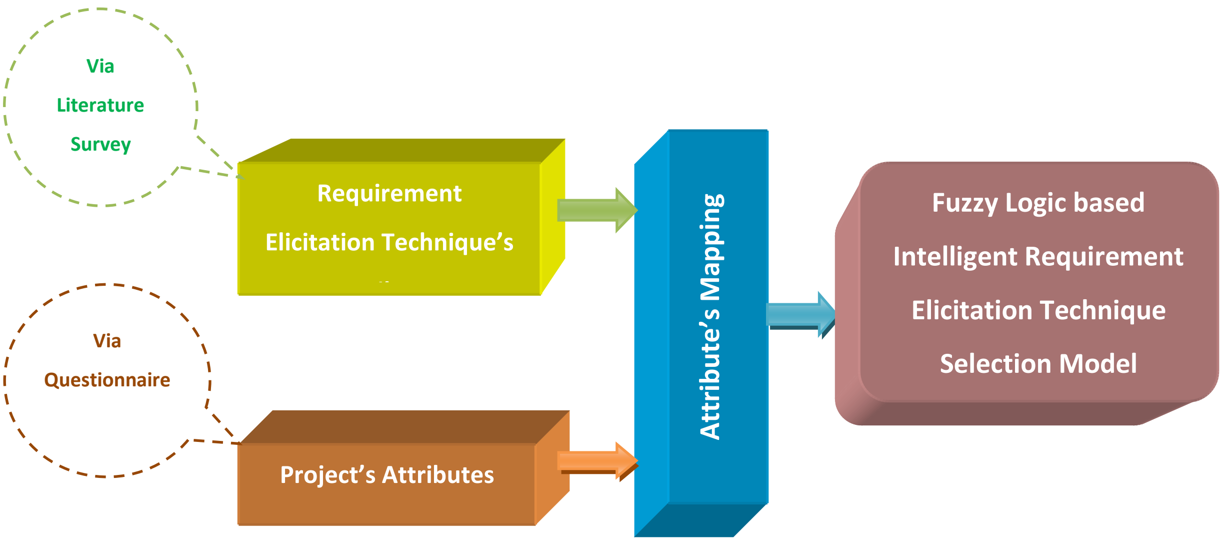

Figure 3.1: Approach adopted to make requirement elicitation technique selection process intelligent.

3.2. Methodology

In literature, research work is presented using literature survey or through practical means. In this study we used both. The main constraints while choosing methodology for this work are time and reliability. The methods used are:

- Literature Survey
- Questionnaire
- Fuzzy Logic based implementation
- Experimentation

3.2.1. Literature Survey

Literature review is a dependable way to read and examine various articles, thesis and books. For deeper understanding of problem domain, domain expert's opinions matter and literature survey facilitate to achieve this. This method is also helpful to know how much research work has always been done in a given field. At the end to compare practical results with theoretical one this method is useful.

The literature in this work is mainly collected from IEEE, ACM, and Springer etc. The articles were searched by giving different keywords in Google and Yahoo search engines. Once the articles and books were found then selection criteria would be:

Dependability: Articles published in IEEE, ACM and Springer are mostly reliable and the books referred are mostly from course literature.

Timeline: The articles and books referred in this thesis contain advance domain knowledge. To explain basic principles some old papers were selected however most of the articles are recent.

Reputation: Google scholar is used to get the literature's reputation. The articles presented in this thesis are cited by many authors.

3.2.2. Questionnaire

Questionnaire require less time than interview as it could be distributed to many respondents at the same time. Similarly face to face meeting is not required in this method. Questionnaire for this study will be designed after studying the ways of designing good questionnaire by Moore et al. 2000 [78].

Questionnaire needs to be consisted of questions to get real stance of professionals in field of software development, about the elicitation techniques and issues they faced at industrial level.

The main parameters that has been considered while surveying through questionnaire are:

Sample Size: The more are the respondents the more reliable the data will be. Although time limitations are there for our study but we will try to have as much respondents as possible.

Reliability: All the respondents will be chosen on the basis bond and familiarity with software development and RE principles. It will also be tried to have respondents from well reputed software development firms who have practical experience.

Distribution: The questionnaire will be distributed via email and also received back through e mail. The email addresses of the respondents will be taken from the official websites of the respected companies.

3.2.3. Fuzzy Logic based implementation

Fuzzy Logic (FL) is a form of logic normally used in expert systems and other artificial intelligent applications where variables may have degrees of truthfulness and falsehood ranging from 0(false) to 1(true). It has immense powers to express precisely what is imprecise. It is considered as generalization of multi valued logic [79]. In FL everything can be granulated with a granule being cluster of attribute values drawn on the basis of difference, similarity, proximity or functionality.

Here the model is fuzzy logic based as the attributes on which this model is based cannot be described using binary valued sets. The attributes has been expressed as low, medium and high but the set of these levels is hard to define because when we talk about low then there is no distinct cut-off point at which low begins. In Fuzzy Logic rules are formed that are based upon multi-valued logic and so introduced the concept of set membership.

In Fuzzy Logic, the output of any operation can be expressed as a probability rather than certainty. Like output might be true, possibly true, false or possibly false.

3.2.3. Experimentation

To check the accuracy of results of model and its impact on requirement elicitation process, experimentation on running industrial projects will be required. But due to time limitation, the accuracy of the model will be checked by using some tool like WEKA (Waikato Environment for Knowledge Analysis). Experimentation with the proposed model on running industrial projects will be done in future.

Chapter 4

Proposed Model

To reduce the biasness from the requirement elicitation technique selection process, there is a need to have an intelligent model which requires less human involvement and helps suitable technique selection on the basis of attributes of elicitation techniques, stakeholders and projects.

4.1. Elicitation technique's attributes selection

To select the attributes of elicitation techniques and stakeholders which play important role while technique selection, literature was surveyed intensively and professionals working in different software houses were consulted. After literature survey and discussion with professionals, 10 different attributes of stakeholders and techniques were selected which play important role while technique selection. The selected attributes are shown in Figure 4.1.

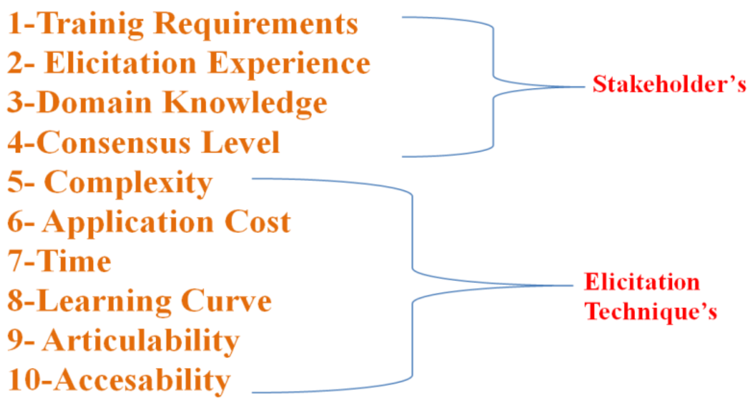

Figure 4.1: Preferred attributes of requirement elicitation techniques for intelligent model.

First four attributes 1-4 are specifically related to the person involved in elicitation process or stakeholder while last six 5-10 attributes are directly related to elicitation techniques.

After the selection of attributes, there is a need to express theses attributes in a form so that their role in technique selection can be determined. Some of the preferred attributes had already been expressed in literature in the form of low, medium and high. But these levels are qualitative; means there is no way to resolve how much high and low. Moreover to use these levels more effectively in the technique selection process, there is a need to express these levels numerically on some scale.

To express the preferred attributes numerically in terms of low, medium and high, on a 0-10 scale, section III of the questionnaire (Appendix A) was designed.

4.2. Fuzzy Logic based intelligence model

The proposed intelligent model will be the Fuzzy Expert System (FES). FES will be modeled as follows:

- Fuzzy variables definition
- Development of fuzzy sets or membership functions
- Generation of fuzzy rules
- Working of the model
- Implementation and evaluation of the model

4.2.1. Fuzzy variables definition

A fuzzy variable is considered as an opinion. In Fuzzy Logic (FL), it is a quantity that can take on linguistic rather than specific numerical values. In FL a fuzzy variable is considered as input or output variable. In present study, all attributes will be considered as input variable and the elicitation technique is in turn considered as output variable. Each variable will have three parameters Low, Medium and High. These parameters will be scaled on a scale with rang 0 to 10.

4.2.2. Development of fuzzy sets or membership functions

Fuzzy variables are introduced as random variables whose values are not real but fuzzy numbers, and subsequently redefined as a particular kind of fuzzy set. Expectations of fuzzy variables, characteristic functions of fuzzy events, probabilities connected to fuzzy variables, and conditional expectations and probabilities relating to fuzzy variables are defined as images of the fuzzy set representing the fuzzy variable under appropriate mappings [80].

For each fuzzy variable, three fuzzy sets were defined. First set defining the concept of low, second set defining the concept of medium and third set defining the concept of high. An advantage of the fuzzy approach is that we don't have to define each possible level. Intermediate levels are accounted for as they can have membership on more than one fuzzy set.

4.2.3. Generation of fuzzy rules

Fuzzy rules have been recognized as key apparatus for expressing pieces of knowledge in FL [81]. FL deals with reasoning that is approximate rather than fixed and exact. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false [82].

A **fuzzy rule** is defined as a conditional statement in the form:

IF *x is A* **THEN** *y is B*

Where x and y are linguistic variables; A and B are linguistic values determined by fuzzy sets on the universe of discourse *x* and y, respectively.

The most common and widely used interpretation considers a fuzzy rule "if *x* is A then y is B" as a fuzzy point A×B and a collection of fuzzy rules "if x is Ai then y is Bi" i =1, …, n as a fuzzy graph providing a rough description of the relation between x and y [83,84].

In this study x implies all the preferred attributes of elicitation techniques, A implies low, medium or high, y implies selected technique and B implies any elicitation technique from the 16 techniques.

4.2.4. Working of the Model

The working of the proposed model or Fuzzy Expert System (FES) is shown in Figure 4.1. All the attributes of elicitation techniques, stakeholders and projects serve as input vector. Input vector is interpreted and based on the generated rules requirement elicitation techniques are suggested as output vector (Figure 4.1).

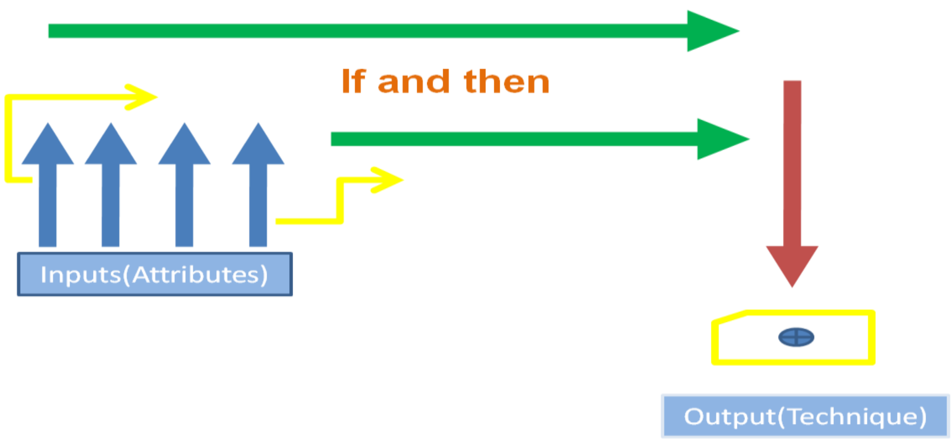

Figure 4.2: Working of Fuzzy Expert System

4.2.5. Implementation and evaluation of the Model

The model will be implemented in WEKA (Waikato Environment for Knowledge Analysis) using an algorithm called FURIA (Fuzzy Unordered Rule Induction Algorithm). As rule generation is the backbone of our model therefore, FURIA was chosen because this algorithm induces rules for each class separately using the "one class – other classes" dividing strategy. Also the representation of rule generated through FURIA is more readable and advanced; in essence, a fuzzy rule is obtained through replacing intervals by fuzzy intervals [85].

The model will also be tested on WEKA using training set, split train and test and 10-fold cross validation options. Different measures like Kappa statistics, TP & FP rate, ROC area and confusion matrix will be considered to determine proposed model's accuracy.

Chapter 5
Results and Discussion

In this chapter, the results obtained from literature review, survey via questionnaire and implementation of intelligent model in WEKA 3.7.5 are listed down and discussed accordingly.

5.1. Literature Review

In this section the results, which have been obtained through literature review of various journal papers, books and conference proceedings have been presented. These sources were read, examined and results were composed. This review was conducted keeping in view two important aims; 1) to know and collect the important attributes of Elicitation techniques, stakeholders and the projects which contribute in elicitation technique selection process, 2) to assign a level in terms of Low (L), Medium (M) and High (H) to these attributes with respect to each elicitation technique.

5.1.1. Assigning a level in terms of High (H), Medium (M) and Low (L) to attributes

In order to assign levels in the form of High (H), Medium (M) and Low (L) to different attributes of requirement elicitation techniques and the stakeholder's through literature survey, literature about requirement elicitation techniques in the form of books and research papers (Journal's and conference's) were searched and studied thoroughly. The results obtained are shown in Table 5.1.

Only few attributes for some techniques had been allotted levels in the form of low, medium and high. We did not find any value for the attributes like Application cost, Complexity and Articulability in this format. We also didn't find any detail related to the assignment of said levels to preferred attributes of the technique like social analysis, Requirement Reuse, Documentation Study and Contextual Inquiry (Table 5.1).

For our proposed model, we require attributes of elicitation techniques expressed in terms of low, medium and high levels quantitatively. But due to unavailability of data in required format, we relied on the professional's response through questionnaire.

Table 5.1: Requirement Elicitation Technique's Profile

S.#	Techniques	Attributes									
		Stakeholder's				Technique's					
		Training Requirement	Elicitation Experience	Domain Knowledge	Consensus Level	Complexity	Application Cost	Time Constraints	Learning Curve	Articulability	Accessibility
1	Interview	M [35]	L [86]	L [87]	L[86]	**	**	H [32]	**	H [32]	L[86]
2	Requirement Workshops	L [86]	L[86]	L[86]	H[86]	**	**	H [86]	**	M[86]	L[86]
3	Focus Group	L [86]	M [86]	L [86]	M[86]	**	**	H [86]	**	M[86]	L[86]
4	Brainstorming	M [86]	L [86]	L [86]	M[86]	**	**	H [86]	**	M[86]	L[86]
5	Social Analysis	**	**	**	**	**	**	**	**	**	**
6	Ethnographic Studies	M [86]	M [86]	H [86]	M[86]	**	**	**	**	**	**
7	Protocol Analysis	L [86]	L [86]	H [86]	L[86]	**	**	H[86]	**	H [32]	L[86]
8	Requirement Reuse	**	**	**	**	**	**	**	**	**	**
9	Documentation Study	**	**	**	**	**	**	**	**	**	**
10	Laddering	L [86]	M [86]	L [86]	L[86]	**	**	M[86]	**	M[86]	L[86]
11	Card Sorting	L [86]	M [86]	L [86]	L[86]	**	**	M[86]	**	M[86]	L[86]
12	Repertory Grid	L [86]	M [86]	L [86]	L[86]	**	**	L [86]	**	M[86]	M[86]
13	Scenarios	L [86]	M [86]	H [86]	L[86]	**	**	M[86]	**	M[86]	L[86]
14	Prototyping	L [86]	M [86]	L [86]	M[86]	**	**	H [86]	**	H[86]	L[86]
15	JAD	L [86]	L [86]	L [86]	M[86]	**	**	L [32]	**	H[86]	M[86]
16	Contextual Inquiry	**	**	**	**	**	**	**	**	**	**

H: High, M: Medium, L: Low; ** Literature is silent

5.2. Feedback through questionnaire

In order to get feedback of professionals working in industry about the usage of requirement elicitation techniques, different nature of projects, role of RE in software development and to express the preferred attributes of elicitation techniques, stockholders and projects numerically in the form of low, medium and high, questionnaire was distributed among more than 70 professionals all over the world.

While distributing questionnaire it was taken care of that the selected respondent should have experience in software development and must be associated with software development industry. The questionnaire distribution was not bounded only in Pakistan but it was distributed to other countries like Denmark, Australia, and Germany etc. We had also the respondents working in Microsoft. In this way we have gotten an international point of view about the requirement elicitation techniques. We also got enough responses to present our model reliably.

The collected responses were compiled and shown as follows:

5.2.1. Questionnaire responses in summarized form

The responses collected were summarized in terms of %ages and shown in tabular form (Table 5.2). All the multi choice questions in questionnaire are summarized here in terms of %age of selection of different choices. The maximum numbers of choices of a question in the questionnaire are 16. Some of the questions have also multi select provision. In the Table 5.2 "**" shows where the given question doesn't have the particular option and "*" shows that a particular option got nil response.

The results in the table can be interpreted as, for example question No. 1 in section II of the questionnaire (S. # 1 of Table 5.2) "Size of last project" had 5 options like 1)Very Small, 2) Small, 3) Large, 4) Very Large, 5) Not Applicable. Options 1, 2 and 5 got no response where as option 3 got 65% response and option 4 got 35% response. It means out of all respondents 65% think that the projects they are working on are large and 35% think that they are working on very large projects.

Moreover 50% respondent gave critical role to elicitation techniques in successful execution of project and 43% gave significant and only 7% thought that elicitation techniques have no role in successful execution of project. More than 72% respondents felt that they encounter requirement change and creeping in their projects (Table5.2).

Table 5.2: Questionnaire responses in summarized form

S. #	Question	Options Selection(in %age)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Size of the last project	*	*	65	35	*	**	**	**	**	**	**	**	**	**	**	**
2	Role of elicitation technique in successful execution of project	7	43	50	**	**	**	**	**	**	**	**	**	**	**	**	**
3	Time consumed in requirement engineering	14	51	35	**	**	**	**	**	**	**	**	**	**	**	**	**
4	Role of changing requirements during project execution	93	7	**	**	**	**	**	**	**	**						
5	Do you frequently encounter requirement change in project life cycle	72	28	**	**	**	**	**	**	**	**	**	**	**	**	**	**
6	Does it require a lot of investment to manage change in the requirements	79	21	**	**	**	**	**	**	**	**	**	**	**	**	**	**
7	Requirements creeping (new requirements) in your project	72	28	**	**	**	**	**	**	**	**	**	**	**	**	**	**
8	Define project success in your organization	28	79	64	64	86	28	21	64	57	43	50	*	**	**	**	**
9	What kind of requirement elicitation techniques, do you apply in your requirements elicitation phase	86	29	36	93	29	7	36	50	71	7	*	*	71	71	21	43
10	Do you have time constraints to complete RE phase	64	36	**	**	**	**	**	**	**	**	**	**	**	**	**	**
11	Do you have budget constraints to complete RE phase	57	43	**	**	**	**	**	**	**	**	**	**	**	**	**	**

*Nil; **Option was not given in question

5.2.2. Application of selected Elicitation Techniques in different projects

Professional's response regarding frequency of application of selected elicitation techniques in different projects had been taken and shown in Table 5.3.

Table 5.3: Use of Elicitation Techniques in Different Projects

S.#	Elicitation Technique	Responses in %age				
		Never	**Rare**	**Often**	**Rapid**	**Always**
1	Interviews	7	*	21	7	64
2	Requirement Workshop	21	36	7	7	7
3	Focus Group	14	29	7	7	7
4	Brain Storming	*	7	14	43	43
5	Social Analysis/Observation	7	7	21	7	14
6	Ethnographic study	36	7	*	*	7
7	Protocol Analysis	29	7	14	7	7
8	Requirement Reuse	*	7	29	7	21
9	Documentation Study	14	7	21	7	43
10	Laddering	36	7	*	*	*
11	Card sorting	29	21	*	*	*
12	Repertory Grid	29	21	*	*	*
13	Scenarios	*	*	36	29	7
14	Prototyping	*	*	14	29	21
15	JAD	29	7	7	*	7
16	Contextual Inquiry	7	7	14	21	7

*Nil

64% respondents declare that they always used interview in their projects while 7% never used or used rapidly, 21% mention that they used interview oftenly whereas there was no response regarding rare use of interview (Table 5.3).

Interesting results were obtained about Requirement Workshop, Focus Group, Ethnographic study, Protocol Analysis, JAD and Contextual Inquiry, where very small %age of respondents declare that they used these techniques often, rapid and always in their projects. Similarly there was no response about the usage of Laddering, Card sorting and Repertory Grid often, rapid and always (Table 5.3).

These results showed biasness in selection of elicitation techniques and justified this study to present an intelligent elicitation technique selection model to remove this biasness and to facilitate the technique selection process based on the technique's, stakeholder's and project's attributes.

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5.2.3. Numeric expression of attributes of elicitation techniques

To express preferred attributes of elicitation techniques numerically in terms of low, medium and high, professional's response was taken through section III of the questionnaire. Levels low, medium and high were scaled on scale with 0 to 10 ranges. The summary of obtained results was shown in Table 5.4.

Different %ages of responses were represented with different colors like above 60%, 30% to 59% and below 30% were represented with green, orange and red respectively.

For interview more than 60% respondents believe that the attribute "Training Requirement" is low and 30% to 59% believe that it is medium and similarly below 30% believe that Training Requirement for interview is high.

Likewise for interview "Elicitation Experience" got more than 60% score for low and below 30% both for medium and high. All the other results in table 5.4 can be interpreted on same fashion.

5.2.3.1 Membership function

While assigning numeric values to levels low, medium and high of attributes of elicitation techniques, 100% respondents believe that range 0 and 1 is low i.e. 1/0, 1/1 while some percentage also place 2, 3 and 4 in low i.e. 0.9/2 (90%), 0.8/3 (80%), 0.4/4 (40%). Similarly 100 % respondents place 5 in medium while a few %age also place 2, 3, 4, 6, 7 and 8 as medium. Alike 100% respondents believe that 9 and 10 is high while a few %age also place 6, 7 and 8 in high. These results are expressed as membership functions as follows:

Fundamentally, a fuzzy rule is obtained through replacing intervals by fuzzy intervals, namely fuzzy sets with trapezoidal membership function. A fuzzy interval of that kind is specified by four parameters and will be written as:

$$I^F = (\phi^{s;L}; \phi^{c;L}; \phi^{c;U}; \phi^{s;U})$$

$\phi^{c;L}$ and $\phi^{c;U}$ are, respectively, the lower and upper bound of the core (elements with membership 1) of the fuzzy set; likewise, $\phi^{s;L}$ and $\phi^{s;U}$ are, respectively, the lower and upper bound of the support (elements with membership > 0)(Figure 5.2). Also a fuzzy interval can be opened to one side ($\phi^{s;L} = \phi^{c;L} = -\infty$ or $\phi^{c;U} = \phi^{s;U} = \infty$.)[88].

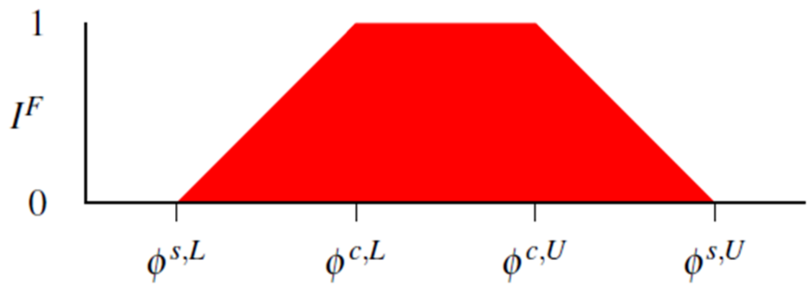

Figure 5.1: Fuzzy Interval I^F [88]

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Training Requirement (TR)
Low = TR_L = {1/0, 1/1, 0.9/2, 0.8/3, 0.4/4}
Medium = TR_M = {0.1/2, 0.2/3, 0.6/4, 1/5, 0.9/6, 0.7/7, 0.2/8}
High = $TR_{H=}$ {0.1/6, 0.3/7, 0.8/8, 1/9, 1/10}

Elicitation Experience (EE)
Low = EE_L = {1/0, 1/1, 0.8/2, 0.7/3, 0.5/4}
Medium = EE_M = {0.2/2, 0.3/3, 0.5/4, 1/5, 0.8/6, 0.7/7, 0.1/8}
High = $EE_{H=}$ {0.2/6, 0.3/7, 0.9/8, 1/9, 1/10}

Domain Knowledge (DK)
Low = DK_L = {1/0, 1/1, 0.9/2, 0.8/3, 0.5/4}
Medium = DK_M = {0.1/2, 0.2/3, 0.5/4, 1/5, 0.7/6, 0.8/7, 0.2/8}
High = $DK_{H=}$ {0.3/6, 0.2/7, 0.8/8, 1/9, 1/10}

Consensus Level (CL)
Low = CL_L = {1/0, 1/1, 0.8/2, 0.7/3, 0.4/4}
Medium = CL_M = {0.2/2, 0.3/3, 0.6/4, 1/5, 0.9/6, 0.7/7, 0.3/8}
High = $CL_{H=}$ {0.1/6, 0.3/7, 0.7/8, 1/9, 1/10}

Complexity (C)
Low = C_L = {1/0, 1/1, 0.8/2, 0.6/3, 0.2/4}
Medium = C_M = {0.2/2, 0.4/3, 0.8/4, 1/5, 0.9/6, 0.7/7, 0.3/8}
High = $C_{H=}$ {0.1/6, 0.3/7, 0.7/8, 1/9, 1/10}

Application Cost (AC)
Low = AC_L = {1/0, 1/1, 0.9/2, 0.8/3, 0.3/4}
Medium = AC_M = {0.1/2, 0.2/3, 0.7/4, 1/5, 0.9/6, 0.6/7, 0.3/8}
High = $AC_{H=}$ {0.1/6, 0.4/7, 0.7/8, 1/9, 1/10}

Time (T)
Low = T_L = {1/0, 1/1, 0.9/2, 0.7/3, 0.4/4}
Medium = T_M = {0.1/2, 0.3/3, 0.6/4, 1/5, 0.9/6, 0.7/7, 0.3/8}
High = $T_{H=}$ {0.1/6, 0.3/7, 0.7/8, 1/9, 1/10}

Learning Curve (LC)
Low = LC_L = {1/0, 1/1, 0.8/2, 0.7/3, 0.4/4}
Medium = LC_M = {0.2/2, 0.3/3, 0.6/4, 1/5, 0.9/6, 0.7/7, 0.4/8}
High = $LC_{H=}$ {0.1/6, 0.3/7, 0.6/8, 1/9, 1/10}

Articulability (Ar)
Low = Ar_L = {1/0, 1/1, 0.8/2, 0.6/3, 0.2/4}
Medium = Ar_M = {0.2/2, 0.4/3, 0.8/4, 1/5, 0.8/6, 0.5/7, 0.3/8}
High = $Ar_{H=}$ {0.1/6, 0.5/7, 0.7/8, 1/9, 1/10}

Accessibility (Ac)
Low = Ac_L = {1/0, 1/1, 0.8/2, 0.7/3, 0.3/4}
Medium = Ac_M = {0.2/2, 0.3/3, 0.7/4, 1/5, 0.8/6, 0.6/7, 0.1/8}
High = $Ac_{H=}$ {0.2/6, 0.4/7, 0.9/8, 1/9, 1/10}

Table 5.4: Feedback Regarding Requirement Elicitation Technique's Attributes

S.#	Techniques	Attributes																													
		Stakeholder's												Technique's																	
		Training Requirement			Elicitation Experience			Domain Knowledge			Consensus Level			Complexity			Application Cost			Time			Learning Curve			Articulability			Accessibility		
		L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
1	Interviews	Green	Orange	Red	Green	Red	Red	Orange	Green	Red	Red	Green	Orange	Green	Red	Red	Green	Orange	Red	Red	Orange	Green	Green	Red	Red	Red	Green	Orange	Green	Orange	Red
2	Requirement Workshop	Red	Green	Orange	Red	Orange	Green	Green	Orange	Red	Red	Green	Orange	Red	Green	Orange	Orange	Green	Red	Orange	Red	Green	Red	Red	Green	Red	Green	Red	Green	Orange	Red
3	Focus Group	Orange	Green	Red	Red	Orange	Green	Red	Orange	Green	Red	Green	Orange	Orange	Green	Red	Orange	Green	Red	Red	Green	Orange	Red	Green	Orange	Orange	Green	Red	Green	Orange	Red
4	Brainstorming	Green	Red	Red	Green	Orange	Red	Red	Orange	Green	Green	Orange	Red	Green	Red	Red	Green	Orange	Red	Orange	Green	Red	Red	Green	Orange	Orange	Green	Red	Red	Orange	Green
5	Social Analysis/ Observation	Orange	Green	Red	Green	Orange	Red	Green	Red	Red	Orange	Green	Red	Green	Red	Red	Red	Green	Orange	Orange	Red	Green	Green	Red	Red	Red	Red	Green	Green	Red	Red
6	Ethnographic study	Green	Red	Red	Green	Orange	Red	Green	Red	Red	Orange	Green	Red	Green	Red	Red	Green	Red	Red	Orange	Green	Red	Green	Red	Red	Red	Orange	Green	Green	Red	Red
7	Protocol Analysis	Green	Orange	Red	Orange	Green	Red	Orange	Red	Green	Green	Orange	Red	Red	Green	Orange	Orange	Green	Red	Red	Green	Orange	Green	Orange	Red	Red	Orange	Green	Orange	Green	Red
8	Requirement Reuse	Red	Orange	Green	Red	Green	Orange	Green	Orange	Red	Green	Red	Red	Green	Red	Red	Green	Red	Red	Green	Red	Red	Green	Red	Red	Red	Green	Orange	Orange	Green	Red
9	Documentation Study	Green	Red	Red	Green	Red	Red	Orange	Green	Red	Green	Red	Red	Green	Red	Red	Green	Red	Red	Orange	Green	Red	Green	Red	Red	Red	Green	Orange	Green	Orange	Red
10	Laddering	Red	Orange	Green	Red	Green	Orange	Red	Orange	Green	Green	Red	Red	Red	Green	Orange	Red	Green	Orange	Green	Orange	Red	Red	Green	Orange	Red	Orange	Green	Red	Green	Orange
11	Card Sorting	Red	Green	Orange	Orange	Green	Red	Red	Red	Green	Red	Orange	Green	Red	Orange	Green	Orange	Green	Red	Orange	Green	Red	Red	Green	Orange	Red	Orange	Green	Green	Orange	Red
12	Repertory Grid	Red	Green	Orange	Red	Orange	Green	Red	Orange	Green	Red	Orange	Green	Red	Green	Orange	Orange	Green	Red	Green	Orange	Red	Red	Green	Orange	Red	Green	Orange	Red	Green	Orange
13	Scenarios	Red	Orange	Green	Green	Orange	Red	Orange	Green	Red	Red	Green	Orange	Green	Orange	Red	Red	Orange	Green	Red	Green	Orange	Orange	Green	Red	Red	Orange	Green	Green	Orange	Red
14	Prototyping	Red	Orange	Green	Red	Orange	Green	Red	Green	Orange	Red	Orange	Green	Red	Green	Orange	Red	Orange	Green	Red	Orange	Green	Green	Orange	Red	Red	Orange	Green	Green	Orange	Red
15	JAD	Green	Orange	Red	Green	Orange	Red	Green	Orange	Red	Red	Green	Orange	Green	Red	Red	Orange	Green	Red	Orange	Green	Red	Green	Red	Red	Red	Orange	Green	Red	Orange	Green
16	Contextual Inquiry	Green	Orange	Red	Green	Orange	Red	Green	Red	Red	Green	Orange	Red	Green	Red	Red	Green	Red	Red	Green	Red	Red	Green	Red	Red	Red	Red	Green	Green	Red	Red

L: Low; M: Medium; H: High

Green: 60% and above; Orange: 30-59%; Red: below 30%;

5.3. Implementation and evaluation of intelligent model

The implementation and testing of our intelligent model is done in WEKA (Waikato Environment for Knowledge Analysis) which contain collection of visualization tools and algorithms for data analysis and predictive modeling [89].The usage of WEKA in research projects of varying domain is huge like Systems for natural language processing [90], Knowledge discovery in biology [91], Distributed and parallel data mining [92], Scientific workflow environment [93]. Therefore, the loyalty of WEKA for this study cannot be questioned.

5.3.1. Used data sets and the preprocessing

The detail of data set used in this study was given in Table 5.5. Total 16 classes with 10 attributes were used. Each class has 20 instances therefore the total instances were 320. WEKA performed initial preprocessing on data set and calculated minimum values of each of attribute, its maximum value, mean and standard deviation (Table 5.6). The allocation of values of attributes to different classes with respect to different ranges was shown in Figure 5.2.

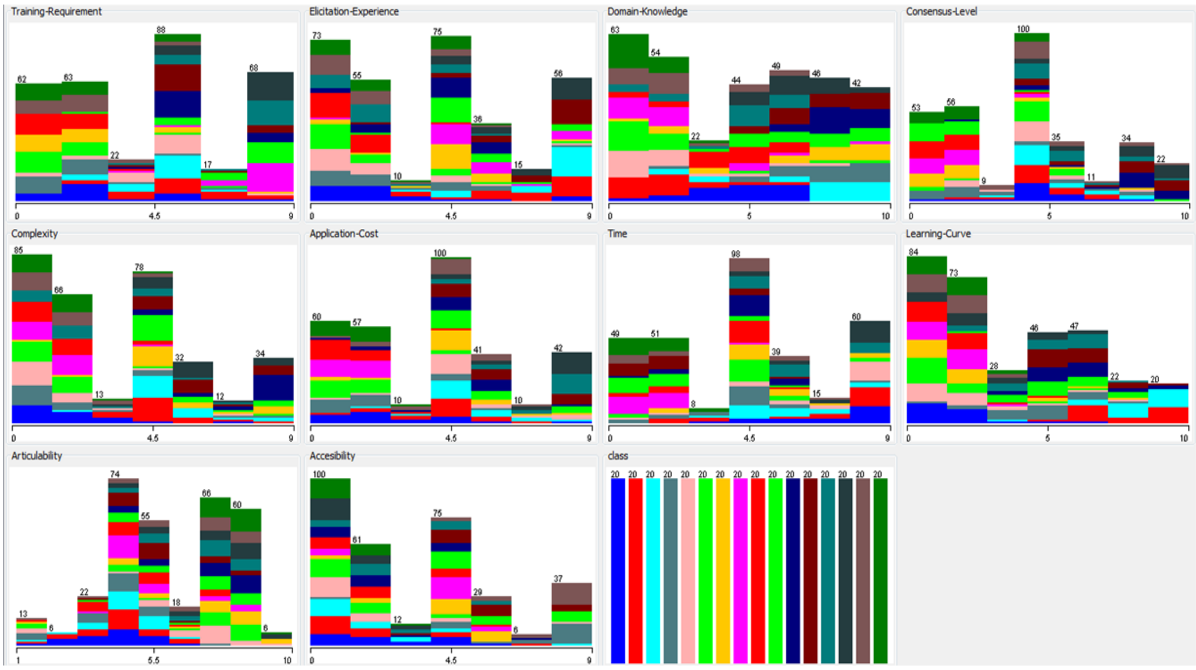

Figure 5.2: Allocation of attributes values in different classes.

Table 5.5: Requirement elicitation technique selection model data set description.

Number of Attributes	10	Training-Requirement
		Elicitation-Experience
		Domain-Knowledge
		Consensus-Level
		Complexity
		Application-Cost
		Time
		Learning-Curve
		Articulability
		Accessibility
Number of classes	16	Interviews
		Requirement-Workshop
		Focus-Group
		Brain-Storming
		Social-Analysis-Observation
		Ethnographic-Study
		Protocol-Analysis
		Requirement-Reuse
		Documentation-Study
		Laddering
		Card-Sorting
		Repertory-Grid
		Scenarios
		Prototyping
		JAD
		Contextual-Inquiry
Number of instances		320; 20 for each class

Table 5.6: Detail of attributes after preprocessing through WEKA.

Attribute	Type	Missing (%)	Min	Max	Mean	Std.Dev
Training Requirement	Num	0	0	9	4.506	2.739
Elicitation Experience	Num	0	0	9	4.194	2.682
Domain Knowledge	Num	0	0	10	4.763	2.962
Consensus Level	Num	0	0	10	4.434	2.562
Complexity	Num	0	0	9	3.641	2.497
Application Cost	Num	0	0	9	4.169	2.482
Time	Num	0	0	9	4.622	2.564
Learning Curve	Num	0	0	10	3.775	2.675
Articulability	Num	0	1	10	6.5	2.031
Accessibility	Num	0	0	9	3.528	2.594

5.3.2. Fuzzy Rules Generation

The scheme used for rules generation is WEKA→classifiers→rules→FURIA. FURIA (Fuzzy Unordered Rule Induction Algorithm) was proposed by Hühn and Hüllermeier in 2009 [88]. The use of FURIA can be justified through its capability to generate more understandable rules as compared to other classifiers [94]. Using FURIA When the classifier is trained using one class, other classes are not considered. This helps to attain a state when there is not one main rule and the sequence of classes in the training process does not matter. However, if a class is equally covered by more than one rule than Certainty Factor (CF) has to be calculated to measure the strength of the rule [94]. The 40 generated rules through FURIA 1.0.0 are given below:

1. (Time in [6, 7, inf, inf]) and (Application-Cost in [-inf, -inf, 3, 4]) and (Learning-Curve in [-inf, -inf, 2, 5]) and (Elicitation-Experience in [0, 1, inf, inf]) => class=Interview (CF = 0.83)
2. (Elicitation-Experience in [-inf, -inf, 3, 5]) and (Time in [8, 9, inf, inf]) and (Articulability in [-inf, -inf, 5, 6]) => class=Interview (CF = 0.69)
3. (Elicitation-Experience in [-inf, -inf, 3, 5]) and (Domain-Knowledge in [2, 4, inf, inf]) and (Learning-Curve in [-inf, -inf, 2, 4]) and (Consensus-Level in [4, 5, inf, inf]) and (Accesibility in [-inf, -inf, 4, 5]) => class=Interview (CF = 0.83)
4. (Learning-Curve in [6, 7, inf, inf]) and (Domain-Knowledge in [-inf, -inf, 4, 5]) => class=Requirement-Workshop (CF = 0.66)
5. (Learning-Curve in [7, 8, inf, inf]) and (Domain-Knowledge in [7, 8, inf, inf]) and (Time in [4, 5, inf, inf]) and (Accessibility in [-inf, -inf, 4, 6]) => class=Focus-Group (CF = 0.87)
6. (Elicitation-Experience in [7, 8, inf, inf]) and (Training-Requirement in [-inf, -inf, 6, 7]) and (Time in [2, 4, inf, inf]) and (Time in [-inf, -inf, 6, 7]) and (Consensus-Level in [2, 4, inf, inf]) => class=Focus-Group (CF = 0.86)
7. (Accessibility in [6, 7, inf, inf]) and (Articulability in [-inf, -inf, 6, 7]) and (Consensus-Level in [-inf, -inf, 3, 4]) => class=Brain-Storming (CF = 0.84)

8. (Articulability in [-inf, -inf, 5, 6]) and (Domain-Knowledge in [6, 7, inf, inf]) and (Training-Requirement in [-inf, -inf, 3, 5]) and (Accessibility in [2, 5, inf, inf]) => class=Brain-Storming (CF = 0.83)
9. (Application-Cost in [-inf, -inf, 0, 1]) and (Domain-Knowledge in [4, 5, inf, inf]) => class=Brain-Storming (CF = 0.53)
10. (Time in [6, 7, inf, inf]) and (Complexity in [-inf, -inf, 1, 2]) and (Domain-Knowledge in [-inf, -inf, 2, 3]) => class=Social-Analysis-Observation (CF = 0.77)
11. (Domain-Knowledge in [-inf, -inf, 1, 2]) and (Application-Cost in [3, 4, inf, inf]) and (Accessibility in [-inf, -inf, 1, 2]) and (Elicitation-Experience in [-inf, -inf, 2, 3]) => class=Social-Analysis-Observation (CF = 0.77)
12. (Time in [6, 7, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 4, 5]) and (Consensus-Level in [-inf, -inf, 4, 5]) and (Training-Requirement in [3, 5, inf, inf]) and (Training-Requirement in [-inf, -inf, 5, 7]) => class=Social-Analysis-Observation (CF = 0.73)
13. (Application-Cost in [-inf, -inf, 2, 3]) and (Consensus-Level in [4, 5, inf, inf]) and (Domain-Knowledge in [-inf, -inf, 2, 3]) and (Learning-Curve in [-inf, -inf, 1, 2]) => class=Ethnographic-Study (CF = 0.81)
14. (Training-Requirement in [-inf, -inf, 3, 4]) and (Articulability in [7, 8, inf, inf]) and (Time in [3, 5, inf, inf]) and (Accessibility in [-inf, -inf, 2, 4]) and (Domain-Knowledge in [-inf, -inf, 5, 6]) => class=Ethnographic-Study (CF = 0.82)
15. (Application-Cost in [-inf, -inf, 2, 5]) and (Time in [4, 5, inf, inf]) and (Articulability in [8, 9, inf, inf]) and (Complexity in [-inf, -inf, 2, 4]) => class=Ethnographic-Study (CF = 0.73)
16. (Consensus-Level in [-inf, -inf, 2, 3]) and (Complexity in [2, 4, inf, inf]) and (Learning-Curve in [-inf, -inf, 2, 4]) and (Domain-Knowledge in [1, 2, inf, inf]) => class=Protocol-Analysis (CF = 0.88)
17. (Domain-Knowledge in [8, 9, inf, inf]) and (Complexity in [-inf, -inf, 4, 5]) and (Application-Cost in [2, 4, inf, inf]) => class=Protocol-Analysis (CF = 0.64)

18. (Training-Requirement in [6, 7, inf, inf]) and (Application-Cost in [-inf, -inf, 2, 4]) and (Time in [-inf, -inf, 4, 5]) and (Complexity in [-inf, -inf, 5, 6]) => class=Requirement-Reuse (CF = 0.91)
19. (Consensus-Level in [-inf, -inf, 1, 2]) and (Complexity in [-inf, -inf, 1, 2]) and (Training-Requirement in [2, 4, inf, inf]) => class=Requirement-Reuse (CF = 0.83)
20. (Consensus-Level in [-inf, -inf, 2, 3]) and (Elicitation-Experience in [-inf, -inf, 2, 4]) and (Articulability in [-inf, -inf, 6, 8]) and (Learning-Curve in [-inf, -inf, 3, 4]) and (Time in [-inf, -inf, 5, 8]) => class=Documentation-Study (CF = 0.89)
21. (Application-Cost in [-inf, -inf, 2, 3]) and (Domain-Knowledge in [2, 4, inf, inf]) and (Articulability in [6, 7, inf, inf]) and (Articulability in [-inf, -inf, 8, 9]) => class=Documentation-Study (CF = 0.52)
22. (Consensus-Level in [-inf, -inf, 2, 3]) and (Learning-Curve in [3, 4, inf, inf]) and (Training-Requirement in [5, 6, inf, inf]) and (Elicitation-Experience in [1, 2, inf, inf]) => class=Laddering (CF = 0.9)
23. (Complexity in [5, 8, inf, inf]) and (Accessibility in [7, 8, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 5, 6]) => class=Laddering (CF = 0.53)
24. (Complexity in [6, 7, inf, inf]) and (Consensus-Level in [6, 7, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 5, 6]) => class=Card-Sorting (CF = 0.86)
25. (Domain-Knowledge in [6, 7, inf, inf]) and (Articulability in [8, 9, inf, inf]) and (Learning-Curve in [2, 4, inf, inf]) and (Time in [1, 2, inf, inf]) => class=Card-Sorting (CF = 0.81)
26. (Learning-Curve in [7, 8, inf, inf]) and (Application-Cost in [-inf, -inf, 3, 4]) and (Elicitation-Experience in [-inf, -inf, 6, 9]) and (Domain-Knowledge in [2, 9, inf, inf]) => class=Card-Sorting (CF = 0.53)
27. (Complexity in [6, 8, inf, inf]) and (Consensus-Level in [6, 8, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 6, 7]) and (Time in [2, 5, inf, inf]) => class=Card-Sorting (CF = 0.85)
28. (Consensus-Level in [7, 8, inf, inf]) and (Time in [-inf, -inf, 2, 4]) and (Learning-Curve in [4, 5, inf, inf]) and (Complexity in [-inf, -inf, 8, 9]) => class=Repertory-Grid (CF = 0.84)

29. (Domain-Knowledge in [6, 7, inf, inf]) and (Application-Cost in [5, 6, inf, inf]) and (Accessibility in [2, 3, inf, inf]) and (Learning-Curve in [5, 6, inf, inf]) => class=Repertory-Grid (CF = 0.65)
30. (Elicitation-Experience in [6, 8, inf, inf]) and (Accessibility in [3, 5, inf, inf]) and (Consensus-Level in [1, 5, inf, inf]) and (Domain-Knowledge in [4, 5, inf, inf]) and (Training-Requirement in [4, 5, inf, inf]) => class=Repertory-Grid (CF = 0.86)
31. (Application-Cost in [5, 7, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 2, 3]) and (Training-Requirement in [6, 7, inf, inf]) => class=Scenarios (CF = 0.83)
32. (Application-Cost in [5, 6, inf, inf]) and (Domain-Knowledge in [-inf, -inf, 6, 8]) and (Elicitation-Experience in [-inf, -inf, 6, 7]) and (Training-Requirement in [6, 8, inf, inf]) and (Time in [5, 6, inf, inf]) => class=Scenarios (CF = 0.85)
33. (Application-Cost in [7, 8, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 2, 4]) and (Complexity in [2, 5, inf, inf]) and (Consensus-Level in [-inf, -inf, 8, 9]) => class=Scenarios (CF = 0.69)
34. (Complexity in [-inf, -inf, 2, 3]) and (Application-Cost in [2, 5, inf, inf]) and (Training-Requirement in [3, 5, inf, inf]) and (Domain-Knowledge in [3, 4, inf, inf]) and (Domain-Knowledge in [-inf, -inf, 5, 6]) => class=Scenarios (CF = 0.79)
35. (Application-Cost in [7, 8, inf, inf]) and (Elicitation-Experience in [6, 7, inf, inf]) and (Accessibility in [-inf, -inf, 2, 5]) => class=Prototyping (CF = 0.87)
36. (Complexity in [5, 6, inf, inf]) and (Time in [6, 7, inf, inf]) and (Training-Requirement in [5, 6, inf, inf]) => class=Prototyping (CF = 0.83)
37. (Consensus-Level in [7, 8, inf, inf]) and (Learning-Curve in [-inf, -inf, 2, 4]) and (Elicitation-Experience in [5, 6, inf, inf]) => class=Prototyping (CF = 0.82)
38. (Accessibility in [6, 7, inf, inf]) and (Learning-Curve in [-inf, -inf, 2, 4]) and (Consensus-Level in [4, 5, inf, inf]) => class=JAD (CF = 0.88)
39. (Accessibility in [4, 5, inf, inf]) and (Elicitation-Experience in [-inf, -inf, 3, 4]) and (Domain-Knowledge in [-inf, -inf, 2, 5]) and (Consensus-Level in [2, 3, inf, inf]) and (Learning-Curve in [-inf, -inf, 4, 7]) => class=JAD (CF = 0.86)

40. (Time in [-inf, -inf, 3, 4]) and (Accessibility in [-inf, -inf, 3, 4]) and (Articulability in [6, 8, inf, inf]) and (Domain-Knowledge in [-inf, -inf, 3, 4]) => class=Contextual-Inquiry (CF = 0.84)

5.3.2.1. Rules Interpretation

A fuzzy rule is exclusively characterized by its core and its support. It is legal inside the core and void outside the support; in-between, the legality drops in a steady way. Consider, for example, the rule ($A \leq 5|+$), which indicates that if attribute A is smaller or equal to 5 then the class is positive. Here, the rule is valid for $A \leq 5$ and invalid for $A > 5$. Similarly, a fuzzy rule ($A \in$ (-inf;-inf; 5; 8) |+) suggests that the rule is completely legal for $A \leq 5$, void for $A > 8$, and partially legal in-between [88].

5.3.2.2. Effective role of the generated rules in the intelligent model

Forty rules have been generated through FURIA for the selection of 16 elicitation techniques using 10 preferred attributes. More than one rule had been generated for one technique using different attributes. Every rule has assigned Certainty Factor (CF) which determines the worth of the respected rule. In this discussion we will take rules with higher CF value. Where the value of the CF is same for more than one rules of the same technique then that rule will be discussed which has drawn in more attributes.

Rules 1-3 are to select interview technique. Rules 1 and 3 has same CF but rule 3 has involved more attributes. In rule 3, 5 attributes, Elicitation Experience (EE), Domain Knowledge (DK), Learning Curve (LC), Consensus Level (CL) and Accessibility (Ac) are involved. The validity and invalidity of the rule for involved attribute's values are: Elicitation Experience (is completely valid for EE≤3, void for EE > 5, and partially valid in-between), Domain Knowledge (is completely valid for DK≥4, void for DK<2, and partially valid in-between), Learning Curve (is completely valid for LC≤2, void for LC > 4, and partially valid in-between), Consensus Level (is completely valid for CL≥5, void for CL<4, and partially valid in-between), Accessibility (is completely valid for Ac≤4, void for Ac > 5, and partially valid in-between). This rule suggests that if (Elicitation Experience is Low) and (Domain Knowledge is Low or Medium) and (Learning Curve is Low) and (Consensus Level is

Medium or High) and (Accessibility is Low or Medium) then the elicitation technique should be interview. These values are quite consistent with the detail given in Table 5.4.

Rule 4 is to select Requirement Workshop technique. In rule 4, 2 attributes, Learning Curve (LC) and Domain Knowledge (DK) are occupied. The validity and invalidity of the rule for involved attribute's values are: Learning Curve (is completely valid for $LC \geq 7$, void for $LC < 6$ and partially valid in-between), Domain Knowledge (is completely valid for $DK \leq 4$, void for $DK > 5$, and partially valid in-between). This rule advises that if (Learning Curve is High) and (Domain Knowledge is Low or Medium) then the elicitation technique can be Requirement Workshop. These values are fairly steady with the detail shown in Table 5.4.

Rules 5-6 are to select Focus Group technique. Rule 5 has higher CF. In rule 5, 4 attributes, Learning Curve (LC), Domain Knowledge (DK), Time (T) and Accessibility (Ac) are involved. The validity and invalidity of the rule for involved attribute's values are: Learning Curve (is completely valid for $LC \geq 8$, void for $LC < 7$, and partially valid in-between), Domain Knowledge (is completely valid for $DK \geq 8$, void for $DK < 7$, and partially valid in-between), Time (is completely valid for $T \geq 5$, void for $T < 4$, and partially valid in-between), Accessibility (is completely valid for $Ac \leq 4$, void for $Ac > 6$ and partially valid in-between). This rule proposes that if (Learning Curve is High) and (Domain Knowledge is High) and (Time is Medium or High) and (Accessibility is Low or Medium) then the elicitation technique should be Focus Group. These values are quite dependable with the information exposed in Table 5.4.

Rules 7-9 are to select Brainstorming technique. Rule 7 has higher CF. In rule 7, 3 attributes, Consensus Level (CL), Articulability (Ar) and Accessibility (Ac) are involved. The validity and invalidity of the rule for involved attribute's values are: Consensus Level (is completely valid for $CL \leq 3$, void for $CL > 4$, and partially valid in-between), Articulability (is completely valid for $Ar \leq 6$, void for $Ar > 7$, and partially valid in-between), Accessibility (is completely valid for $Ac \geq 7$, void for $Ac < 6$ and partially valid in-between). This rule shows that if (Consensus Level is Low) and (Articulability is Low or Medium) and (Accessibility is High) then the elicitation technique should be Brainstorming. These values are consistent with the detail given in Table 5.4.

Rules 10-12 are to select Social Analysis/Observation technique. Rules 10 and 11 has same CF but rule 11 has involved more attributes. In rule 11, 4 attributes, Domain Knowledge (DK), Application Cost (AC), Accessibility (Ac) and Elicitation Experience (EE) are involved. The validity and invalidity of the rule for involved attribute's values are: Domain Knowledge (is completely valid for DK≤1, void for DK >2 and partially valid in-between), Application Cost (is completely valid for AC≥4, void for AC<3 and partially valid in-between), Accessibility (is completely valid for Ac≤1, void for Ac>2 and partially valid in-between), Elicitation Experience (is completely valid for EE≤2, void for EE>3, and partially valid in-between). This rule suggests that if (Domain Knowledge is Low) and (Application Cost is Medium or High) and (Accessibility is Low) and (Elicitation Experience is Low) then the elicitation technique can be Social Analysis/Observation. These values are fairly consistent with the detail shown in Table 5.4.

Rules 13-15 are to select Ethnographic Study technique. Rule 14 has higher CF. In rule 14, 5 attributes, Domain Knowledge (DK), Training Requirement (TR), Accessibility (Ac), Time (T) and Articulability (Ar) are involved. The validity and invalidity of the rule for involved attribute's values are: Domain Knowledge (is completely valid for DK≤5, void for DK > 6, and partially valid in-between), Training Requirement (is completely valid for TR≤3, void for TR >4, and partially valid in-between), Accessibility (is completely valid for Ac≤2, void for Ac>4, and partially valid in-between), Time (is completely valid for T≥5, void for T<3 and partially valid in-between), Articulability (is completely valid for T≥8, void for T<7, and partially valid in-between). This rule advocates that if (Domain Knowledge is Low or Medium) and (Training Requirement is Low) and (Accessibility is Low) and (Time is Medium or High) and (Articulability is High) then the elicitation technique must be Ethnographic Study. These values are pretty dependable with the facts revealed in Table 5.4.

Rules 16-17 are to select Protocol Analysis technique. Rule 16 has higher CF. In rule 16, 4 attributes, Domain Knowledge (DK), Learning Curve (LC), Consensus Level (CL) and Complexity (C) are involved. The validity and invalidity of the rule for involved attribute’s values are: Domain Knowledge (is completely valid for $DK \geq 2$, void for $DK < 1$, and partially valid in-between), Learning Curve (is completely valid for $LC \leq 2$, void for $LC > 4$, and partially valid in-between), Consensus Level (is completely valid for $CL \leq 2$, void for $CL > 3$ and partially valid in-between), Complexity (is completely valid for $C \geq 4$, void for $C < 2$ and partially valid in-between). This rule implies that if (Domain Knowledge is Medium or High) and (Learning Curve is Low) and (Consensus Level is Low) and (Complexity is Medium or High) then the elicitation technique should be Protocol Analysis. These values are reasonably reliable with the detail publicized in Table 5.4.

Rules 18-19 are to select Requirement Reuse technique. Rule 18 has higher CF. In rule 18, 4 attributes, Training Requirement (TR), Application Cost (AC), Time (T) and Complexity (C) are involved. The validity and invalidity of the rule for involved attribute’s values are: Training Requirement (is completely valid for $TR \geq 7$, void for $DK < 6$, and partially valid in-between), Application Cost (is completely valid for $AC \leq 2$, void for $AC > 4$ and partially valid in-between), Time (is completely valid for $T \leq 4$, void for $T > 5$, and partially valid in-between), Complexity (is completely valid for $C \leq 5$, void for $C > 6$ and partially valid in-between). This rule recommends that if (Training Requirement is Medium or High) and (Application Cost is Low) and (Time is Low or Medium) and (Complexity is Low or Medium) then the elicitation technique can be Requirement Reuse. These values are moderately steady with the features shown in Table 5.4.

Rules 20-21 are to select Documentation Study technique. Rule 20 has higher CF. In rule 20, 5 attributes, Consensus Level (CL), Elicitation Experience (EE), Articulability (Ar), Learning Curve (LC) and Time (T) are involved. The validity and invalidity of the rule for involved attribute’s values are: Consensus Level (is completely valid for $CL \leq 2$, void for $CL > 3$and partially valid in-between), Elicitation Experience (is completely valid for $EE \leq 2$, void for $EE > 4$, and partially valid in-between), Articulability (is completely valid for $Ar \leq 6$, void for $Ar > 8$, and partially valid in-between), Learning Curve (is completely valid for $LC \leq 3$, void for $LC > 4$ and partially valid in-between), Time (is completely valid for $T \leq 5$, void for $T > 8$ and partially valid in-between). This rule puts forward that if (Consensus Level is Low) and (Elicitation Experience is Low) and (Articulability is Low or Medium) and

(Learning Curve is Low or Medium) and (Time is Low or Medium) then the elicitation technique selected should be Documentation Study. These principles are fairly regular with the elements agreed in Table 5.4.

Rules 22-23 are to select Laddering technique. Rule 22 has higher CF. In rule 22, 4 attributes, Consensus Level (CL), Learning Curve (LC), Training Requirement (TR) and Elicitation Experience (EE) are involved. The validity and invalidity of the rule for involved attribute's values are: Consensus Level (is completely valid for CL≤2, void for CL>3, and partially valid in-between), Learning Curve (is completely valid for LC≥4, void for LC<3, and partially valid in-between), Training Requirement (is completely valid for TR≥6, void for TR<5, and partially valid in-between), Elicitation Experience (is completely valid for EE≥2, void for EE<1, and partially valid in-between). This rule proposed that if (Consensus Level is Low) and (Learning Curve is Medium or High) and (Training Requirement is Medium or High) and (Elicitation Experience is Low) then the elicitation technique should be Laddering. These values are pretty consistent with the detail shown in Table 5.4.

Rules 24-27 are to select Card Sorting technique. Rule 24 has higher CF. In rule 24, 3 attributes, Complexity (C), Consensus Level (CL), and Elicitation Experience (EE) are involved. The validity and invalidity of the rule for involved attribute's values are: complexity (is completely valid for C≥7, void for LC<6 and partially valid in-between), Consensus Level (is completely valid for CL≥7, void for CL<6 and partially valid in-between), Elicitation Experience (is completely valid for EE≤5, void for EE>6 and partially valid in-between). This rule exposes that if (Complexity is High) and (Consensus Level is High) and (Elicitation Experience is Low or Medium) then the elicitation technique can be Card Sorting. These principles are rather consistent with the detail shown in Table 5.4.

Rules 28-30 are to select Repertory Grid technique. Rule 30 has higher CF. In rule 30, 5 attributes, Elicitation Experience (EE), Accessibility (Ac), Consensus Level (CL), Domain Knowledge (DK), and Training Requirement (TR) are involved. The validity and invalidity of the rule for involved attribute's values are: Elicitation Experience (is completely valid for EE≥8, void for EE<6 and partially valid in-between), Accessibility (is completely valid for Ac≥5, void for Ac<3, and partially valid in-between), Consensus Level (is completely valid for CL≥5, void for CL<1, and partially valid in-between), Domain Knowledge (is completely valid for $DK \geq 5$, void for $DK < 4$ and partially valid in-between), Training Requirement (is completely valid for $TR \geq 5$, void for $TR < 4$ and partially valid in-between). This rule advises that if (Elicitation Experience is High) and (Accessibility is Medium or High) and (Consensus Level is Medium or High) and (Domain Knowledge is Medium or High) and (Training Requirement is Medium or High) then the elicitation technique can be Repertory Grid. These values are fairly usual with the aspects agreed in Table 5.4.

Rules 31-34 are to select Scenario technique. Rule 32 has higher CF. In rule 32, 5 attributes, Application Cost (AC), Domain Knowledge (DK), Elicitation Experience (EE), Training Requirement (TR) and Time (T) are involved. The validity and invalidity of the rule for involved attribute's values are: Application Cost (is completely valid for $AC \geq 6$, void for $AC < 5$, and partially valid in-between), Domain Knowledge (is completely valid for $DK \leq 6$, void for $DK > 8$, and partially valid in-between), Elicitation Experience (is completely valid for $EE \leq 6$, void for $EE > 7$, and partially valid in-between), Training Requirement (is completely valid for $TR \geq 8$, void for $TR < 6$ and partially valid in-between), Time (is completely valid for $T \geq 6$, void for $T < 5$ and partially valid in-between). This rule points out that if (Application Cost is Medium or High) and (Domain Knowledge is Low or Medium) and (Elicitation Experience is Low or Medium) and (Training Requirement is High) and (Time is Meidum or High) then the elicitation technique should be Scenario. These values are relatively consistent with the detail shown in Table 5.4.

Rules 35-37 are to select Prototyping technique. Rule 35 has higher CF. In rule 35, 3 attributes, Application Cost (AC), Elicitation Experience (EE) and Accessibility (Ac) are involved. The validity and invalidity of the rule for involved attribute's values are: Application Cost (is completely valid for $AC \geq 8$, void for $AC < 7$ and partially valid in-between), Elicitation Experience (is completely valid for $EE \geq 7$, void for $EE < 6$, and partially valid in-between), Accessibility (is completely valid for $Ac \leq 2$, void for $Ac > 5$ and partially valid in-between). This rule stimulates that if (Application Cost is High) and (Elicitation Experience is Medium or High) and (Accessibility is Low) then the elicitation technique should be Prototyping. These values are moderately reliable with the features expressed in Table 5.4.

Rules 38-39 are to select JAD technique. Rule 38 has higher CF. In rule 38, 3 attributes, Accessibility (Ac), Learning Curve (LC) and Consensus Level (CL) are involved. The validity and invalidity of the rule for involved attribute's values are: Accessibility (is completely valid for $Ac \geq 7$, void for $Ac<6$ and partially valid in-between), Learning Curve (is completely valid for $LC \leq 2$, void for $LC>4$, and partially valid in-between), Consensus Level (is completely valid for $CL \geq 5$, void for $CL<4$, and partially valid in-between). This rule implies that if (Accessibility is Medium or High) and (Learning Curve is Low) and (Consensus Level is Medium or High) then the elicitation technique should be JAD. These values are moderately consistent with the information known in Table 5.4.

Rule 40 is to select Contextual Inquiry technique. In rule 40, 4 attributes, Time (T), Accessibility (Ac), Articulability (Ar), Domain Knowledge (DK) are involved. The validity and invalidity of the rule for involved attribute's values are: Time (is completely valid for $T \leq 3$, void for $T>4$ and partially valid in-between), Accessibility (is is completely valid for $Ac \leq 3$, void for $Ac>4$ and partially valid in-between), Articulability (is completely valid for $Ar \geq 8$, void for $Ar<6$ and partially valid in-between), Domain Knowledge (is completely valid for $DK \leq 3$, void for $DK>4$ and partially valid in-between). This rule urges that if (Time is Low or Medium) and (Accessibility is Low or Medium) and (Articulability is High) and (Domain Knowledge is Medium or Low) then the elicitation technique can be Contextual Inquiry. These principles are reasonably consistent with the detail shown in Table 5.4.

5.3.3. Fuzzy rule evaluation detail

The evaluation of fuzzy rules generated through FURIA is performed using three approaches: 1) Training Set, 2) Split 80.0% train, remainder test and 3) 10-fold cross-validation.

5.3.3.1. Evaluation on Training Set

The summarized form of evaluation results of fuzzy rules generated via FURIA through WEKA on training set is shown in Figure 5.3. The Confusion matrix is also shown in Figure 5.4.

```
Correctly Classified Instances         297               92.8125 %
Incorrectly Classified Instances        23                7.1875 %
Kappa statistic                          0.9233
Mean absolute error                      0.0108
Root mean squared error                  0.0796
Relative absolute error                  9.2309 %
Root relative squared error             32.8772 %
Coverage of cases (0.95 level)          97.1875 %
Mean rel. region size (0.95 level)       8.8477 %
Total Number of Instances              320

=== Detailed Accuracy By Class ===
```

	TP Rate	FP Rate	Precision	Recall	F-Measure	ROC Area	Class
	0.9	0.01	0.857	0.9	0.878	0.973	Interview
	0.85	0.01	0.85	0.85	0.85	0.943	Requirement-Workshop
	0.85	0.003	0.944	0.85	0.895	0.95	Focus-Group
	0.9	0	1	0.9	0.947	0.998	Brain-Storming
	0.75	0.003	0.938	0.75	0.833	0.947	Social-Analysis-Observation
	0.95	0.007	0.905	0.95	0.927	0.998	Ethnographic-Study
	0.9	0	1	0.9	0.947	0.974	Protocol-Analysis
	1	0.007	0.909	1	0.952	1	Requirement-Reuse
	0.95	0	1	0.95	0.974	0.999	Documentation-Study
	0.95	0	1	0.95	0.974	1	Laddering
	1	0	1	1	1	1	Card-Sorting
	1	0	1	1	1	1	Repertory-Grid
	1	0.017	0.8	1	0.889	1	Scenarios
	0.95	0.003	0.95	0.95	0.95	0.975	Prototyping
	0.9	0.01	0.857	0.9	0.878	0.999	JAD
	1	0.007	0.909	1	0.952	1	Contextual-Inquiry
Weighted Avg.	0.928	0.005	0.932	0.928	0.928	0.985	

Figure 5.3: Detail of Accuracy for Evaluation on training set.

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	<-- classified as
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	a = Interview
0	17	0	0	1	0	0	0	0	0	0	0	1	1	0	0	b = Requirement-Workshop
0	1	17	0	0	0	0	0	0	0	0	0	2	0	0	0	c = Focus-Group
0	0	0	18	0	0	0	1	0	0	0	0	0	0	1	0	d = Brain-Storming
1	1	0	0	15	1	0	0	0	0	0	0	1	0	0	1	e = Social-Analysis-Observation
0	0	0	0	0	19	0	0	0	0	0	0	0	0	1	0	f = Ethnographic-Study
0	0	0	0	0	1	18	0	0	0	0	0	0	0	1	0	g = Protocol-Analysis
0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	h = Requirement-Reuse
0	0	0	0	0	0	0	1	19	0	0	0	0	0	0	0	i = Documentation-Study
0	0	1	0	0	0	0	0	0	19	0	0	0	0	0	0	j = Laddering
0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	k = Card-Sorting
0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	l = Repertory-Grid
0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	m = Scenarios
0	0	0	0	0	0	0	0	0	0	0	0	1	19	0	0	n = Prototyping
2	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	o = JAD
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	p = Contextual-Inquiry

Figure 5.4: Confusion Matrix for Evaluation on training set.

5.3.3.2. Evaluation on split 80.0% train, remainder test

The summarized form of evaluation results of fuzzy rules generated via FURIA through WEKA on split 80.0% train, remainder test is shown in Figure 5.5. The Confusion matrix is also shown in Figure 5.6.

```
Correctly Classified Instances          41               64.0625 %
Incorrectly Classified Instances        23               35.9375 %
Kappa statistic                          0.6139
Mean absolute error                      0.0517
Root mean squared error                  0.1793
Relative absolute error                 43.9671 %
Root relative squared error             73.7192 %
Coverage of cases (0.95 level)          81.25   %
Mean rel. region size (0.95 level)      16.5039 %
Total Number of Instances               64
```

=== Detailed Accuracy By Class ===

	TP Rate	FP Rate	Precision	Recall	F-Measure	ROC Area	Class
	0.429	0.053	0.5	0.429	0.462	0.732	Interview
	0	0.016	0	0	0	0.706	Requirement-Workshop
	0.8	0.034	0.667	0.8	0.727	0.975	Focus-Group
	1	0.079	0.167	1	0.286	0.992	Brain-Storming
	0.75	0.017	0.75	0.75	0.75	0.988	Social-Analysis-Observation
	0.5	0	1	0.5	0.667	0.807	Ethnographic-Study
	0.5	0	1	0.5	0.667	0.992	Protocol-Analysis
	1	0.048	0.25	1	0.4	1	Requirement-Reuse
	0.8	0	1	0.8	0.889	0.986	Documentation-Study
	1	0	1	1	1	1	Laddering
	0.75	0.033	0.6	0.75	0.667	0.992	Card-Sorting
	0.625	0.018	0.833	0.625	0.714	0.913	Repertory-Grid
	0.667	0.049	0.4	0.667	0.5	0.798	Scenarios
	0.8	0.034	0.667	0.8	0.727	0.892	Prototyping
	0.333	0	1	0.333	0.5	0.82	JAD
	0.667	0	1	0.667	0.8	0.822	Contextual-Inquiry
Weighted Avg.	0.641	0.021	0.748	0.641	0.659	0.885	

Figure 5.5: Detail of Accuracy for split 80.0% train, remainder test.

5.3.3.3. Evaluation on 10-fold cross-validation

The summarized form of evaluation results of fuzzy rules generated via FURIA through WEKA on split 80.0% train, remainder test is shown in Figure 5.7. The Confusion matrix is also shown in Figure 5.8.

Correctly Classified Instances	203	63.4375 %
Incorrectly Classified Instances	117	36.5625 %
Kappa statistic	0.61	
Mean absolute error	0.0519	
Root mean squared error	0.1895	
Relative absolute error	44.308 %	
Root relative squared error	78.2979 %	
Coverage of cases (0.95 level)	77.8125 %	
Mean rel. region size (0.95 level)	14.1602 %	
Total Number of Instances	320	

=== Detailed Accuracy By Class ===

	TP Rate	FP Rate	Precision	Recall	F-Measure	ROC Area	Class
	0.3	0.023	0.462	0.3	0.364	0.782	Interview
	0.6	0.03	0.571	0.6	0.585	0.907	Requirement-Workshop
	0.55	0.023	0.611	0.55	0.579	0.782	Focus-Group
	0.6	0.033	0.545	0.6	0.571	0.791	Brain-Storming
	0.25	0.037	0.313	0.25	0.278	0.787	Social-Analysis-Observation
	0.65	0.04	0.52	0.65	0.578	0.845	Ethnographic-Study
	0.55	0.007	0.846	0.55	0.667	0.854	Protocol-Analysis
	0.8	0.02	0.727	0.8	0.762	0.915	Requirement-Reuse
	0.75	0.017	0.75	0.75	0.75	0.91	Documentation-Study
	0.85	0.017	0.773	0.85	0.81	0.938	Laddering
	0.65	0.02	0.684	0.65	0.667	0.828	Card-Sorting
	0.65	0.03	0.591	0.65	0.619	0.896	Repertory-Grid
	0.55	0.037	0.5	0.55	0.524	0.868	Scenarios
	0.65	0.02	0.684	0.65	0.667	0.854	Prototyping
	0.75	0.02	0.714	0.75	0.732	0.883	JAD
	1	0.017	0.8	1	0.889	0.997	Contextual-Inquiry
Weighted Avg.	0.634	0.024	0.631	0.634	0.627	0.865	

Figure 5.7: Detail of Accuracy on 10-fold cross-validation.

a b c d e f g h i j k l m n o p <-- classified as

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	<-- classified as
6	1	1	4	1	3	1	0	1	0	0	0	2	0	0	0	a = Interview
0	12	2	1	1	0	0	0	0	0	0	1	1	2	0	0	b = Requirement-Workshop
2	2	11	1	1	0	0	0	0	1	1	1	0	0	0	0	c = Focus-Group
1	0	0	12	0	2	0	1	2	1	1	0	0	0	0	0	d = Brain-Storming
2	2	0	0	5	3	1	0	0	0	0	0	4	0	2	1	e = Social-Analysis-Observation
1	0	0	0	4	13	0	1	0	0	0	0	0	0	1	0	f = Ethnographic-Study
0	0	1	1	1	1	11	0	1	0	0	2	0	1	1	0	g = Protocol-Analysis
0	0	0	0	0	0	0	16	0	0	0	0	1	0	1	2	h = Requirement-Reuse
0	0	0	0	0	2	0	1	15	0	0	0	0	0	0	2	i = Documentation-Study
0	1	0	1	0	0	0	0	0	17	0	0	0	0	1	0	j = Laddering
0	1	1	0	0	0	0	2	0	0	13	3	0	0	0	0	k = Card-Sorting
0	1	1	1	0	0	0	0	0	1	1	13	1	1	0	0	l = Repertory-Grid
1	0	0	0	2	0	0	1	1	1	1	0	11	2	0	0	m = Scenarios
0	1	1	0	0	0	0	0	0	0	2	2	1	13	0	0	n = Prototyping
0	0	0	1	1	1	0	0	0	1	0	0	1	0	15	0	o = JAD
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	p = Contextual-Inquiry

Figure 5.8: Confusion Matrix for 10-fold cross-validation.

5.3.4. Evaluation results interpretation

5.3.4.1. Confusion Matrix based accuracy measure

A confusion matrix contains information about actual and predicted classification performed by a classifier [95]. Performance of such classifier is normally evaluated using data in the matrix. The measures involved in this evaluation are shown in Figure 5.9.

		Predicted	
		Negative	Positive
Actual	Negative	**a**	**b**
	Positive	**c**	**d**

- *a* is the number of **correct** predictions that an instance is **negative**,
- *b* is the number of **incorrect** predictions that an instance is **positive**,
- *c* is the number of **incorrect** of predictions that an instance **negative**, and
- *d* is the number of **correct** predictions that an instance is **positive**.

Accuracy (AC) $AC = \frac{a+d}{a+b+c+d}$

Recall or *true positive rate* (*TP*) $TP = \frac{d}{c+d}$

False positive rate (*FP*) $FP = \frac{b}{a+b}$

True negative rate (*TN*) $TN = \frac{a}{a+b}$

False negative rate (*FN*) $FN = \frac{c}{c+d}$

Precision (*P*) $P = \frac{d}{b+d}$

F-Measure (*F*) $F = \frac{(\beta^2+1)*P*TP}{\beta^2*P+TP}$

β has a value from 0 to infinity and is used to control the weight assigned to *TP* and *P*

Figure 5.9: Measures to evaluate performance of classifiers through confusion matrix.

5.3.4.2. Area under ROC as an accuracy measure

Besides confusion_matrices, Receiver Operating Characteristic (ROC) graphs are another way to evaluate the performance of classifiers [96]. ROC graph is a plot with parametric values of the type (*FP*, *TP*) pair and a series of such pairs can be used to plot an ROC curve.

Area beneath an ROC curve can be used as a measure of accuracy in many applications [96].

5.3.4.3. Accuracy and validity of the proposed model

Here in this section, the measures obtained through WEKA using FURIA classifier will be discussed to determine the accuracy and the validity of the proposed model. Most of the measures involved are summarized in Figure 5.9.

The Correctly classified Instances (CCI) and Incorrectly Classified Instances (ICI) show the percentage of test instances that were correctly and incorrectly classified respectively. The raw numbers are shown in the confusion matrices given in Figures 5.4, 5.6 and 5.8. The percentage of correctly classified instances is often called accuracy or sample accuracy. We got 92.81% accuracy using training set (Figure 5.10.A).

Along with the accuracy we have other measures like Kappa Statistic, True Positive Rate (TPR), False Positive Rate (FPR), Precision, Recall, F-measure and ROC area. The performance of model normally determined through higher TP rate and lower FP rate [97]. We have obtained results using 3 approaches 1) training set, 2)10-folds cross validation and 3) split 80% train, remaining test. The TP rate is higher in each approach (Figure 5.10.B).

Kappa Statistics is used to know how the observed agreement is different from expected one in a model [98]. Its values lei on -1 to I scale, where 1 is perfect, 0 is exactly what would be expected, and negative values indicate poor strength of model (Figure 5.10). Our results show value of Kappa statistic greater than 0.61 in each case (Figure 5.11.B), which shows substantial strength of our proposed model [99-101].

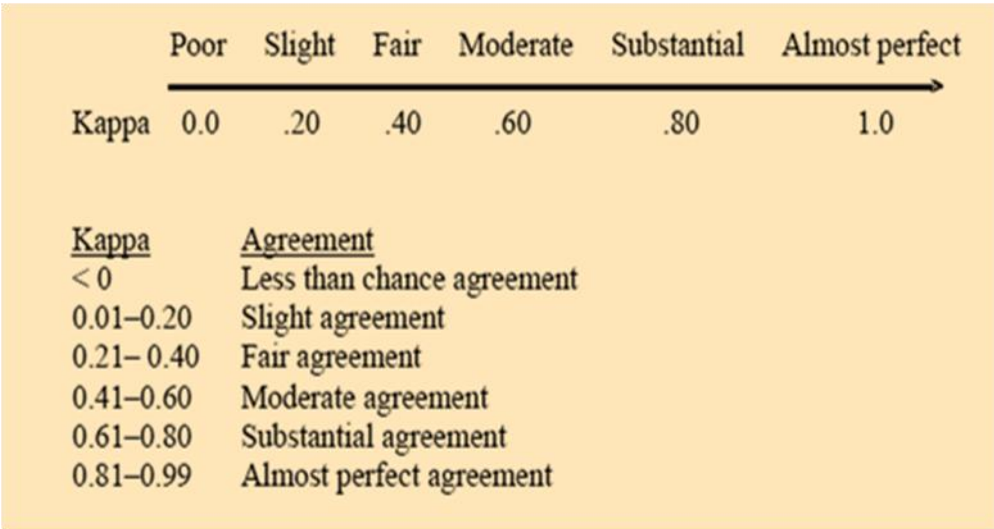

Figure 5.10: Kappa Interpretation [99].

ROC graphs are very useful tool for visualizing and evaluating classifiers. They are able to provide richer measure of classification performance than scalar measures such as accuracy, error rate or error cost [102]. Value of Area under ROC will always be between 0 and 1.0. However, no realistic classifier should have an AUC less than 0.5 [100-102]. We have ROC area greater than 0.865 in each approach (Figure 5.10.B).

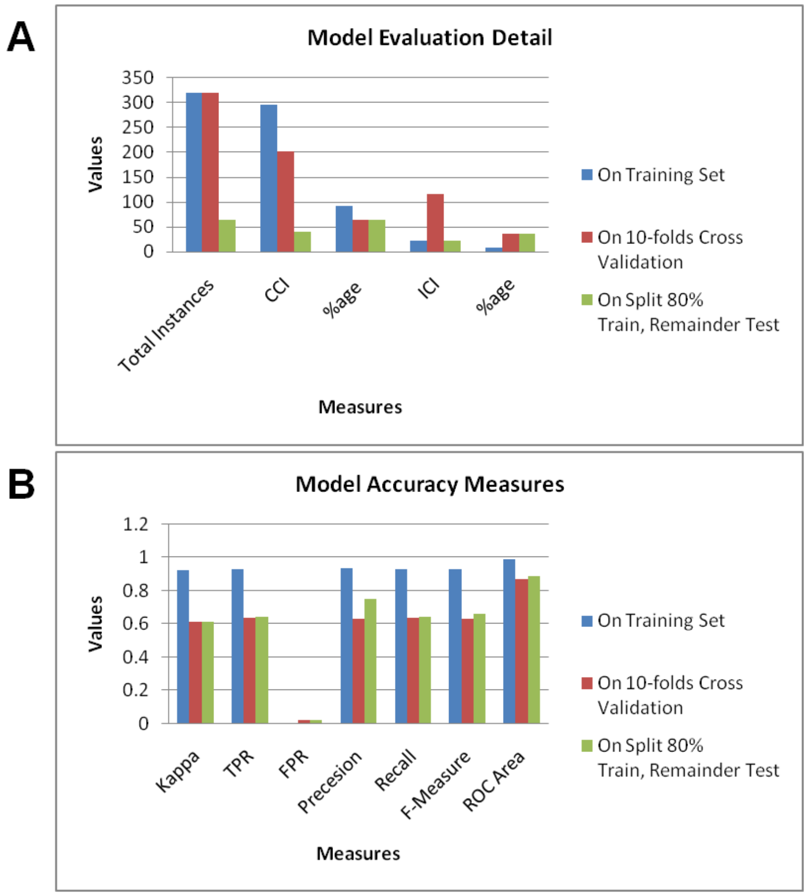

Figure 5.11: Graph showing different measures to determine the accuracy of the proposed intelligent model.

All of above discussed results show accuracy and validity of our proposed intelligent model for the unbiased selection of suitable elicitation techniques during requirement elicitation phase. This model will hopefully help to elicit quality requirements, improve the product quality and eventually reduce the software failure rate.

Chapter 6

Epilogue

6.1. Conclusions

Requirement engineering is the first and most crucial stage of software development which starts from requirement elicitation. Requirement elicitation is the largest phase in requirement engineering and has utmost importance in requirement gathering. Improper execution of this phase may result frequent requirement changes and creeping causing delay in product deliver or its failure mostly.

There are many techniques like interview, prototyping etc, which can be used to elicit requirements during requirement elicitation. The quality of the elicited requirements mainly based on the technique used. Major problem lies in the selection of proper technique out of many to elicit quality requirements. Some elicitation techniques selection models have been proposed in literature but all require human involvement which may result biased technique selection.

This study is carried out to address this problem of biasness and to propose a fuzzy based intelligent requirement elicitation techniques selection model. This model is based on 10 preferred attributes of elicitation techniques, stakeholders and projects. Forty fuzzy rules have been generated using FURIA to select an elicitation technique out of 16. The results of accuracy of model using WEKA justify the working of the model.

This model can be used to select intelligently requirement elicitation techniques based on the values of their attributes according to stakeholder's potential and project conditions. This model will reduce human biasness and result suitable technique selection which will eventually outcome quality requirements.

6.2. Future Work

This study has several aspects which can be addressed in future work. Some of them are as follows:

- There is a need to test this proposed model intensively over several running industrial projects to know the quality of results produced so that it can be optimized.
- We have modeled it through Fuzzy Logic similarly; it can be modeled using Association Rule Mining (ARM) and different kind of classification techniques such as Naive Bayesian Classifier (NBC), to compare results.
- To design a requirement elicitation technique that can incorporate value in it and would be known as Value Based Elicitation Technique.

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APPENDICES

Appendix A

Questionnaire to get data about requirement elicitation techniques

This questionnaire is just to know about the software projects and the requirement elicitation techniques employed

Return at: wajidarshad@gmail.com

Section-I: Respondent's Detail

1- **Name** ___________________________ 2- **Responsibility**______________
2- **Organization**______________________ 4- **URL** ______________________
5- **Email** _____________________________6- **Experience** _________________

(Note: - Most of the questions are in MCQ form. Please provide information on the basis of experiences, observations and practical implementations)

Section-II: Project History

1. **WHAT WAS THE SIZE OF THE LAST PROJECT?** (Select only one)

1.1	Very Small	
1.2	Small	
1.3	Large	
1.4	Very Large	
1.5	Not Applicable	

2. **WHAT SPECIFIC PROJECTS YOUR ORGANIZATION HANDLED?**

____
____
____
____

3. **SPECIFY DETAIL OF SUCCESSFUL PROJECTS**

____
____
____
____

4. **SPECIFY DETAIL OF CURRENTLY RUNNING PROJECTS**

____
____
____
____

5. **FOR SUCCESSFUL EXECUTION OF PROJECT, IN YOUR OPINION HOW MUCH ELICITATION TECHNIQUE PLAY A ROLE?**
☐ **Nominal** ☐ **Significant** ☐ **Critical**

6. **HOW MUCH TIME CONSUMED IN REQUIREMENT ENGINEERING?**
☐ **Low** ☐ **Medium** ☐ **High**

7. **IS CHANGING REQUIREMENTS PLAY A MAJOR ROLE DURING THE EXECUTION OF YOUR PROJECT?**
☐ **Yes** ☐ **No**

8. **DO YOU FREQUENTLY ENCOUNTER REQUIREMENT CHANGE IN PROJECT LIFE CYCLE?**
   ☐ **Yes** ☐ **No**

9. **DOES IT REQUIRE A LOT OF INVESTMENT TO MANAGE CHANGE IN THE REQUIREMENTS?**
   ☐ **Yes** ☐ **No**

10. **DO YOU FREQUENTLY ENCOUNTER REQUIREMENTS CREEPING (NEW REQUIREMENTS) IN YOUR PROJECT?**
    ☐ **Yes** ☐ **No**

11. **DESCRIBE THE PROCESS OF HANDLING REQUREMENT CHANGE OR CREEPING IN YOUR ORGANIZATION**
    ____
    ____
    ____
    ____

12. **HOW DO YOU DEFINE PROJECT SUCCESS IN YOUR ORGANISATION?**
    (Select ALL applicable to project success)

12.1	Triple Constraint (Time, Cost, Scope)	
12.2	Quadruple Constraint (Time, Cost, Scope, Quality)	
12.3	Delivery of business benefits	
12.4	Met project requirements	
12.5	User Satisfaction	
12.6	Sponsor Satisfaction	
12.7	Steering Group Satisfaction	
12.8	Stakeholder Satisfaction	
12.9	System Implementation	
12.10	System use	
12.11	Met business objectives	
12.12	Other (Please list below)	

13. **WHAT KIND OF REQUIRMENT ELICITATION TECHNIQUES, DO YOU APPLY IN YOUR REQUIREMENTS ELICITATION PHASE**
    (Multiple selections / Additional information can be given)

13.1	Interviews	
13.2	Requirement Workshop	
13.3	Focus Group	
13.4	Brain Storming	
13.5	Social Analysis/Observation	
13.6	Ethnographic study	
13.7	Protocol Analysis	
13.8	Requirement Reuse	

13.9	Documentation Study	
13.10	Laddering	
13.11	Card sorting	
13.12	Repertory Grid	
13.13	Scenarios	
13.14	Prototyping	
13.15	JAD	
13.16	Contextual Inquiry	
Comments(if any):		

14. HOW OFTEN DO YOU APPLY THESE TECHNIQUES IN SEVERAL PROJECTS? (Multiple selection) [**1**. Never, **2**. Rare, **3**. Often, **4**. Rapid, **5**. Always]

14.1	Interviews	
14.2	Requirement Workshop	
14.3	Focus Group	
14.4	Brain Storming	
14.5	Social Analysis/Observation	
14.6	Ethnographic study	
14.7	Protocol Analysis	
14.8	Requirement Reuse	
14.9	Documentation Study	
14.10	Laddering	
14.11	Card sorting	
14.12	Repertory Grid	
14.13	Scenarios	
14.14	Prototyping	
14.15	JAD	
14.16	Contextual Inquiry	
Comments(if any):		

15. DO YOU HAVE TIME CONSTRAINTS TO COMPLETE RE PHASE?

☐ **Yes** ☐ **No**

If yes, what was the duration?

16. DO YOU HAVE BUDGET CONSTRAINTS TO COMPLETE RE PHASE?

☐ **Yes** ☐ **No**

If yes, what was the amount?

Section-III: Stakeholder's & Elicitation Technique's Attributes

1. **PROVIDE LEVEL AND SCORE TO GIVEN ATTRIBUTES OF ELICITATION TECHNIQUES ON THE BASIS OF GIVEN SCALE.**
   (LEVEL:- L: LOW, M: MEDIUM, H: HIGH, SCORE: 0-10)
   (SCALE: [0^{L} 1 2 3 4 5^{M} 6 7 8 9 10^{H}])

S.#	Techniques	Attributes																			
		Stakeholder's								Technique's											
		Training Requirement		Elicitation Experience		Domain Knowledge		Consensus Level		Complexity		Application Cost		Time		Learning Curve		Articulability		Accessibility	
		Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score	Level	Score
1.1	Interviews																				
1.2	Requirement Workshop																				
1.3	Focus Group																				
1.4	Brain Storming																				
1.5	Social Analysis/Observation																				
1.6	Ethnographic study																				
1.7	Protocol Analysis																				
1.8	Requirement Reuse																				
1.9	Documentation Study																				
1.10	Laddering																				
1.11	Card Sorting																				
1.12	Repertory Grid																				
1.13	Scenarios																				
1.14	Prototyping																				
1.15	JAD																				
1.16	Contextual Inquiry																				

Thank You

Thank you for completing this Questionnaire.

Please feel free to add any additional comments, information or observations on additional pages.