An Ontology Based Test Case Generation Framework

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2018

Declaration

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Abstract

Software testing is a crucial part of the software development life cycle which ensures that the developed product meets the user requirements. Currently, test cases which come under the test design phase are written almost manually based on user requirements in the companies who follow Agile methodology. This tedious manual process requires 40-70% of the software test life cycle which has affected on cost, time and effort factors due to the frequent changes in requirements and having different terminologies. Companies that follow Agile practices along with Behaviour Driven Development approach capture requirements through user stories written in natural language. Representation of requirements in a formalized way affect the high effectiveness of requirement management by reducing the time and cost factors. Ontology is such an approach where it leads to knowledge reuse for sharing common terminologies and concepts by modelling the requirement domain knowledge constructed with the reasoning behaviour. To achieve automated test case generation, an Ontology-based system has been developed with the purpose of maximising semantic technology representation for the requirement domain.

Instead of writing test cases manually, this thesis investigates a practical solution for automatically generating test cases within an Agile software development using natural language-based user stories with an Ontology-based approach for requirement representation. To establish the feasibility, a framework has been developed that uses NLP techniques which can auto-generate functional positive test cases from the requirements provided through user stories, based on that developed Ontology. The use of an Ontology knowledge base for the software requirement domain has given a better manageability of the requirement domain while the framework reduces the effort required to create the test cases. Also the thesis has introduced a new concept as an Ontologist role into the software development process for the evolvement of the Ontology model. Results from the system evaluation and user evaluation are presented in this thesis. Comparing these results with the test cases taken from the industry which are manually written, the system provides a considerable amount of test coverage for the positive test cases.

Acknowledgement

We take this opportunity to express our sincere appreciation towards all the people who has sacrificed their time all along this thesis and guiding us to concentrate on our work.

First we would like to express our sincere gratitude to our supervisor, Prof. N. D. Kodikara for the continuous support throughout our research study and for guiding us towards the right path at time when we were blindly moving. We would like to thank him for the enormous knowledge provided and motivation. Besides our supervisor, we would like to give special appreciation to Senior Lecturer Dr. A.R. Weerasinghe as our co-supervisor for his help, useful comments and cooperation during the project.

Moreover, our sincere gratitude goes to our examiners Senior Lecturer Dr. H.A. Caldera and Senior Lecturer Mr. G.P.Seneviratne for their valuable and encouraging comments with respect to the improvements of the research.

Furthermore, our sincere appreciation goes to Dr. Kosala Yapa Mudiyanselage, Professional in Ontology studies for the support and experience that given to the research study. Also we would like to express sincere gratitude to Mr. Dharshana Warusavitharana, Efficiency Engineer at WSO2 and Mr. Nadeesha Gamage, Lead Solutions Engineer at WSO2 for the technological support and industrial experience given to the project.

Moreover, we thank our fellow batch mates who works in the field of Software Quality Assurance for the support given by involving in user evaluation process of the project.

Last but not the least; we would like to express our heartiest gratitude towards our family members for understanding each and every situation and for being our pillars of success.

Contents

List of Figures ix
List of Tables xi
Abbreviations xii
Chapter 1 1
1.1 Overview 2
1.2 Motivation 3
1.3 Research Questions 6
1.4 Aim and Objectives 7
1.5 Scope of the project 7
1.6 Justification as product based 8
1.7 Overview of methodology 9
1.8 Outline of the thesis 10
Chapter 2 11
2.1 Introduction 11
2.2 Software Testing 11
2.2.1 Concepts of software testing 12
2.2.2 Importance of software testing 12
2.2.3 Test Case 13
2.2.4 User story 14
2.3 Software Development Industry in Sri Lanka 15
2.4 Automated test case generation 16
2.4.1 Requirement based test case generation 16
2.4.2 Model based test case generation 17
2.4.3 Source code based test case generation 18
2.5 Entity extraction using Natural Language Processing 19
2.5.1 Stanford CoreNLP 19
2.5.2 Triplet Extraction 21
2.6 Use of Ontology 23
2.6.1 Software Engineering Ontologies 24
2.6.2 Ontology representation and implementation 25
2.6.3 Ontology Languages 27
2.6.4 Ontology building tools 28

2.6.5 Apply reasoning on Ontology 29
2.6.6 Ontologies in test case generation 30
2.7 Similar systems and solutions 31
2.8 Summary 34
Chapter 3 **35**
3.1 Introduction 35
3.2 Method Overview 35
3.3 User stories as representation of software requirements 37
3.4 Involvement of an Ontologist in the software industry 39
3.5 Software Requirement Ontology 39
3.5.1 Class hierarchy of the Ontology 40
3.5.2 Object Properties of the Ontology 42
3.5.3 Data properties of the Ontology 43
3.5.4 Identified categories for class action 45
3.6 Entity extraction using natural language processing 46
3.6.1 Pre-Process 48
3.6.2 Split Sentence 48
3.6.3 Dependency Parsing 49
3.6.4 Lemmatization 51
3.6.5 Advanced Filtering 51
3.7 Test Case Generation Using Reasoning 53
3.7.1 Identify subclass of an action 54
3.7.2 Identify implicit relationships of an action 55
3.7.3 Extract data properties 55
3.8 Workflow for complete the test suit 57
3.9 A Simple Example 57
3.10 Summary 59
Chapter 4 **61**
4.1 Introduction 61
4.2 Design Goals 61
4.3 Design Constraints 62
4.4 System Design 63
4.5 System Architecture 64
4.6 Summary 66
Chapter 5 **67**
5.1 Introduction 67

5.2 Implementation Details 67
5.3 Graphical User Interface 70
5.3.1 GUI components 70
5.4 Implementation of Ontology 74
5.4.1 OWL and RDF 74
5.4.2 Protégé Tool 75
5.5 Implementation of Entity Extraction with NLP techniques 76
5.6 Test case generation 78
5.7 Workflow component 79
5.8 Summary 80
Chapter 6 81
6.1 Introduction 81
6.2 Datasets 81
6.3 Software Requirement Ontology Evaluation 82
6.3.1 Application-Based Evaluation 83
6.3.2 Reasoner Based evaluation 83
6.4 Analysis of Triplet Extraction 85
6.4.1 Analysis of actor 85
6.4.2 Analysis of action extraction 86
6.4.3 Analysis of object extraction 86
6.5 Ontology based test case generation system evaluation 88
6.5.1 Discussion of the System Evaluation Results 93
6.6 User Evaluation 93
6.6.1 Discussion of the User Evaluation 96
6.7 Findings of the Base Analysis and User Evaluation 96
Chapter 7 97
7.1 Conclusion 97
7.1.1 Contributions of Automatic Test Case Generation Framework 98
7.2 Future Works 98
7.2.1 Evolve of Ontology 98
7.2.2 Enhance Actor Identification 99
7.2.3 For Service Based Companies 99
References 100
Appendix A – Individual Contributions 105
A.1. Name: H.N. Anjalika (2013/CS/009) 105
A.2. Name: M.T.Y Salgado (2013/CS/106) 106

A.3. Name: P.I. Siriwardhana (2013/CS/115) 107
Appendix B - Dataset-1 .... **108**
Appendix C - Conducted Surveys **110**
C.1. Survey I 110
C.2. Survey II 116

List of Figures

Figure 2.1. Typical test case information adopted [15] 14
Figure 2.2. Template for a user story...15
Figure 2.3. Schematic of the Litmus Tool [21]...16
Figure 2.4. An overview of generic Ontology and application-specific Ontology of software engineering [6] 25
Figure 2.5. Classification of Ontology building languages [45]..27
Figure 3.1. Phases of Automatic Test Case Generation...36
Figure 3.2. Brake Down of Epic 37
Figure 3.3. Ontology Class Hierarchy 40
Figure 3.4. Instances of Class Action 41
Figure 3.5. Object Properties of Defined Ontology 42
Figure 3.6. Data Properties of Defined Ontology 43
Figure 3.7. Relationship between class Actor and Action 45
Figure 3.8. Sample User Stories 46
Figure 3.9. Extract Triplet from a user story using Stanford Dependency Parser 47
Figure 3.10. Semantic graph representation using Stanford dependency parser 49
Figure 3.11. Typed Dependencies 49
Figure 3.12. Penn Treebank Part-of-Speech tagging [58] 51
Figure 3.13. Typed dependencies extracted for the sentence “add members using member list”..53
Figure 3.14. Find Out Ontology path for given parameters...54
Figure 3.15. Flow of reasoning to generate test cases 56
Figure 4.1. System design..63
Figure 4.2. System Architecture Diagram 65
Figure 5.1. Spring MVC - Hibernate architecture of the system 69
Figure 5.2. Home page...70
Figure 5.3. User Story Form 71
Figure 5.4. View Selected User Story...72
Figure 5.5. Test Suite for Epics 73
Figure 5.6. User Stories in the Epic 73
Figure 5.7. Test Cases for a Relevant User Story 73
Figure 5.8. Part of RDF file 74
Figure 5.9. The classes of the user story portal and Entity Extraction 77
Figure 5.10. The classes of the test case generation and workflow 78
Figure 6.1. Protégé with no reasoner 84
Figure 6.2. Protégé with HermiT 1.3 Reasoner 84
Figure 6.3. Typed dependencies extracted for sentence “pay for my order” 87
Figure 6.4. Set of user stories used for the evaluation purpose 88
Figure 6.5. Test cases generated by the system for the dataset-2 from user story ID 1-5 89

Figure 6.6. Test cases generated by the system for the dataset-2 from user story ID 6-12 90
Figure 6.7. Comparison between all the test cases generated manually with positive test cases generated automatically by the system 91
Figure 6.8. Comparison between all the positive test cases generated manually with positive test case generated automatically by the system 92
Figure 6.9. User stories given for the user evaluation 94
Figure 6.10. Automatically generated test case coverage vs test cases generated by each user manually 94
Figure 6.11. User preference: Manual vs Automatic test case design 95

List of Tables

Table 2.1. Total effort breakdown for projects of different sizes [14] 13
Table 2.2. Semantic Web technology layers description [37] 26
Table 2.3. List of Ontology Languages [37]..28
Table 2.4. List of Ontology Building Tools...29
Table 3.1. Classes of Defined Ontology 41
Table 3.2. Object Properties of Defined Ontology 42
Table 3.3. Data Properties of Defined Ontology 43
Table 3.4. Pre-processing a user story 48
Table 3.5. Splitting a user story into separate two sub sentences 48
Table 3.6. Extracted relations as triplet from dependency parser...50
Table 3.7. Extracted actor names and expected actor names..52
Table 6.1. An overview of approaches to Ontology evaluation [61].......................................82
Table 6.2. The number of all test cases manually written by each user and the number of all positive testcase among them...94
Table 6.3. User Responses to survey question...95

Abbreviations

IT	Information Technology
EE	Efficiency Engineer
QA	Quality Assurance
BDD	Behaviour Driven Development
TDD	Test Driven Development
NLP	Natural Language Processing
OWL	Ontology Web Language
RDF	Resource Description Framework
SPARQL	Simple Protocol and RDF Query Language
W3C	World Wide Web Consortium
URI	Uniform Resource Identifiers
UML	Unified Modelling Language
POS	Part Of Speech
JDBC	Java Database Connectivity
MVC	Model-View-Controller
API	Application Program Interface
JSP	Java Servlet Pages
HTML	Hyper Text Markup Language
POS	Part Of Speech
TFS	Team Foundation Server
SVM	Support Vector Machine

Chapter 1

Introduction

Software development is a complicated process of computer programming which includes computer hardware and computer software. While hardware provides the physical capability, the software provides the brains that carry out useful work. Therefore both the hardware and the software industries have become rapidly growing areas all over the world. When concerning the software industry, it can be mainly categorized as service based and product based with respect to their final deliverable. Service-based companies are implementing and supporting software for companies that produce nontechnical items or services. Product based companies are the companies who create enterprise software for business niches.

The structure imposed on developing a software product is called a software development process which is a framework that is used to structure, plan, and control the process of developing software products. Irrespective of what the process is, a software development process shares a combination of common stages such as analysing the problem, gathering requirements, devising a plan or design, implementation, testing, deployment and maintenance with a lot of paperwork and documentation. The business analysing team has the first-hand knowledge of the customers' requirements. Based upon these specific requirements, senior software developers create architecture for the products along with functional and design specifications. Afterword the development process starts and the software testing is done in parallel with the development process. The need for better quality software is one important fact of the development process and it is considered at the testing stage to ensure that software fulfils its requirements.

Both service-based companies and product based companies follow different software development processes, and they are mainly targeting to provide qualitative software on time by ensuring the customers' reliability and their satisfaction. Therefore whatever the approach a company follows, testing is one of the most important phases of software development life cycle as to point out the defects and bugs that were resulted during the development phases.

1.1 Overview

The importance of software testing is widely recognized nowadays, and there is a growing concern in how to improve the accomplishment of the software testing process [1]. Agile software development [2] methods were designed to keep up with the rapid changes in the requirements of the customers, and software testing is continuously integrated into Agile, from early developmental stages to ensure defect-free continuous deployment and that all requirements are met.

Software testing includes executing a program on a set of test cases and comparing the actual results with the expected results [3]. A test case is a general software artifact that includes test case input values, expected outputs for the test case, and any inputs that are necessary to put the software system into a state that is appropriate for the test input values. There is a typical cycle for software testing irrespective of the organization or the development process. Test planning, test design, test execution, test reporting and test result analysing are stages in the testing cycle. Test design is the task of defining how the product is tested by defining the number of tests to be performed, the ways that testing will be approached, and the test conditions that need to be exercised. The test execution is the process of executing the code and comparing the expected and actual results. Providing higher requirement coverage and defect detection through testing is largely dependent on this test design and test execution phases. In the current software industry, test execution phase is almost automated while the test design phase is still being manual.

User requirements play a major role in the test design phase since test cases are formed by looking at these requirements. Therefore representation of requirements in a formalised way might affect the effectiveness of requirement management. Ontology is such a knowledge-based system where particular domain knowledge can be represented in a formalised way using a common structure.

The aim of this thesis is to establish the feasibility of automatic generation of test cases based on an Ontology to overcome the drawbacks of the manual test design phase.

1.2 Motivation

The success of software defect detection mainly depends on test design phase and test execution phase as aforementioned, and therefore those phases are given a higher consideration within software testing. Both test design and test execution phases contribute to a large percentage (40-70%) of overall project cost [4]. Automation of software testing with respective to these both phases is expected to give significant benefits since the manual testing incurs high personnel costs, effort and risks of having incorrect or missing tests.

Test design specification is one of most important documents in manual software testing. It records what needs to be tested, and is derived from the documents that come into the testing stage, such as requirements and designs. It records which features of a test item are to be tested, and how a successful test of these features would be recognized. The test design does not record the values to be entered for a test, but describes the requirements for defining those values. This document is very valuable, but is often missing on many projects nowadays. The reason is that, industry starts writing test cases before deciding what have to be tested.

More details on the testing processes of some companies were obtained through the informal discussions conducted with some Quality Assurance (QA) leads of major Information Technology (IT) companies in Sri Lanka. One was a product based company and their QA team members are called Efficiency Engineers (EE). The company manages the tool ‘Redmine’ as their project management tool to write details of the projects using English language. The primary method of keeping the user requirements is by writing down them as user stories. EE use the Redmine tool to write user stories by providing all prerequisite activities and acceptance criteria according to the user requirements of the project. The user stories written down in Redmine can also be accessed by the developers who have been assigned to that project. The writing of test cases is done manually by EE with referring the user stories which represent the project requirements. The company uses another tool called ‘TestLink’ to manage test cases, and according to the test case type, the execution happens either manually or automatically. It can be seen that the aforementioned company already use automated tools for the test execution but the test design is done manually. At the present the company is planning to automate the test design phase to reduce the effort of EE team.

Another company uses Team Foundation Server (TFS), a Microsoft product as the project management tool to manage user requirements by categorizing them into epics, features and stories. These stories are the user stories. Once the Business Analyst writes user

stories, those are sent to the client for reviewing, and then passed for development only after attaining the client's approval. By looking at the user stories, QA team write test cases manually for all the requirement categories, and use 'Coded UI' and 'Selenium' for test automation. The test design phase could be seen as a manual process also within this company.

There's a another company which follows Behaviour-Driven Development (BDD) approach as their software development process where BDD provides a predefined template for a user story, which is the feature or requirement, to be implemented [4]. The company uses 'Cucumber' software testing tool that runs automated acceptance tests written in BDD style and therefore the company is not writing any user stories, and only writes a template called feature file which is being used in Cucumber tool. A drawback in Cucumber tool is that it is a software tool which runs automated acceptance test, written in BDD style. The BDD approach was created to overcome the limitations of Test-Driven Development (TDD) since TDD was considered to be highly unstructured where it is an approach for developing software by writing test cases before writing functional code [5]. However both of these are two widely prevalent testing development approaches that were developed before automated testing, but these are unable to deliver a complete testing process.

According to those mentioned facts, most of the companies are managing user requirements in a form of natural language representation rather than drawing diagrams. As stated by those companies, it is harder for the clients who are not familiar with UML diagrams to get an understanding of the requirement which have required, by looking at UML diagrams. Also if strict software engineering tools are not understood and followed within the project, the communication between and among teams will be difficult since there are many large IT organizations with software engineers who are not acquainted with software engineering methodologies such as object oriented analysis and design in UML [6].

Consequently it is possible to state that many companies have invested in automated test execution which is called test automation, but test design is almost exclusively manual. Therefore manual test design can be seen as a remarkable issue in current software industry with respect to cost and time factors.

Under test design, test cases play a central role in software testing in gathering both functional and non-functional information that relates to the quality of the software under test. Therefore generation of test cases needs to be given a higher importance in order to come up with a solution for manual test design. It is obvious that when the better test cases

are created, the most efficient time and the cost of the test process would be given with automatic test case generation.

There are several approaches of developing efficient conceptual data representations in a formalised way and this has shown efficient results on many areas like search engines, agents, personal desktops, knowledge management and so on [7]. Ontology is also one such approach where it leads to knowledge reuse for sharing common terms and concepts by modelling the domain knowledge constructed with the reasoning behaviour. But it is notable that there are only few amounts of Ontology-based systems that have been emerged as mainstream applications [8].

Test cases are written based on user requirements in natural language and those are written as user stories mostly in the current industry by different people. Therefore requirements terminologies lacks standardization where it leads to confusion and delay among testers which affect cost and time within a company [9]. If requirements domain can be represented in an efficient manner then the reuse of such domain becomes more usable while sharing common terms within that domain. There comes the term Ontology where it provides clarification to remove the confusion of various terms used by users to describe the same component. Hence opportunities for Ontology-based approaches are wide open for the generation of test cases and such systems could be considered as a subclass of knowledge-based software testing systems that has become the dream of software testing practitioners.

This thesis investigates the possibility of a solution to overcome the limitations of the current practices in test design phase and proposes a framework to bridge the gap between requirements and test cases with automatic generation of test cases in natural language by reasoning on an Ontology that can be incorporated into any software testing system.

1.3 Research Questions

To find the feasibility of generating test cases from requirements written in natural language with reasoning by an Ontology, has opened up following research questions.

1. *How to develop an Ontology for software requirement domain?*

This research is concerned on finding an opportunity in Ontology-based approach as an efficient way of conceptual data representation. Due to less existence of Ontology based application areas there's a need of developing an Ontology while finding about existing Ontologies in software requirement domain. The underlying concept of the developed Ontology module will be considered as a main research component as it needs to facilitate the reusability of Ontology in any of the software requirements domains.

2. *How to extract entities and relations from user stories?*

The intention is to generate test cases based on requirements that are written in the form of user stories in natural language. Therefore by taking user stories which are written in natural language as the input, this question needs to get addressed. The entities and relationships that need to be extracted would depend according to the Ontology module concept that will come up with when developing the Ontology structure. Selecting the most appropriate Natural language Processing techniques and by applying them on the user stories should be given the best output that matches with the basic Ontology module concept.

3. *How to generate test cases from user stories?*

The outcome of this question will address the overall problem that need to get solved. That is how the automatic generation of test cases for a given user story can be done using the developed Ontology. Identifying the possibilities of how to do reasoning on the data represented in the Ontology and thus the selected reason mechanism should be able to extract the best possible results from the Ontology.

1.4 Aim and Objectives

The aim of this research study is to establish the feasibility of automatic generation of test cases with an Ontology-based approach. The goal is to introduce a concept of using Ontology application which is a knowledge based system that is developed for the software requirements domain. The proposed framework focuses on generating test cases from user stories, by exploring possibilities of Ontology such that to minimize the quality assurance engineers' effort and enhance the efficiency and effectiveness of software testing process.

According to the research questions and the aim of this thesis, following objectives are to be met.

- Creation of common feasible template to write user stories
- Extracting entities and relations from user stories
- Developing an Ontology that satisfies with software requirement domain
- Generating test cases for a particular user story when it is given as an input
- Create a full test suite which contains all the test cases of particular user story group called epic
- Reduce effort required by the QA team by introducing the concept of Ontologist into software industry
- Make the software testing process faster and cheaper
- Support for a better maintainability of the testing process
- Increase the reusability of software requirement domain with respect to overcome the limitations in software testing

1.5 Scope of the project

As pointed out in Section 1.2 test cases need to be considered with both functional and non-functional aspects to achieve a better quality. Functional test cases refer to activities that verify a specific action or function of the code and they are usually found in the requirements documentation. Non-functional requirements reflect the quality of the product, particularly in the context of the suitability perspective of its users. Among functional and non-functional test cases this would be focusing only on functional test cases. There are two major categories of functional testing and they are positive and negative functional testing. Positive functional testing involves inputting valid inputs to see how the application responds

to them and negative functional testing involves using different invalid inputs. Only the positive test cases would be considered throughout this study.

Companies that follow agile practises as the development methodology would be only able to make use of this ultimate framework since this is mainly focused on requirements that are written in natural language in the form of user stories. Therefore as mentioned in Section 1.2, companies who follow BDD approach but does not write user stories are not concerned with this approach. And also the convenience of this process is only shown for the product based companies who follow agile practises.

1.6 Justification as product based

This research study addresses the software engineering domain and problems of product based companies using research and development context. This project is taken as a product based project in which a framework is developed to generate test cases such that to minimize the quality assurance engineers' effort and enhance the efficiency and effectiveness of testing process.

Basically this research and development follows up a real requirement of WSO2. This project will be an innovative solution for QA process and it can be used as an open source framework within software industry. As a framework, this project is completed using manifold integrations. So there are continuous deliverables as a software engineering project.

Requirement analysis and specification, design and related documentations were also maintained during the software development life cycle. Quality assurance aspects, software project management, version controlling and deployments activities were also followed. Collaborative approaches of three members and individual contribution are key aspects of development team.

And another important point is the project was carried out in three parallel research components followed by an integration process. Therefore according to software engineering guideline project can be easily executed.

Furthermore, the project contains software engineering guidelines and principles, technologies, tools, automations, integrations, collaborative works, optimizations etc. So these factors are the considerable proofs to take this project as a Product based Software Engineering project.

1.7 Overview of methodology

The proposed solution is to create a framework that can capture user stories as an input and produce test cases as an output. The framework will provide a flexible template to write user stories and therefore all the members in QA team can write user stories in a common way. User stories are provided in Agile development in the format of "As a [actor], I want [action] + [object], so that [business value]." These user stories will then be processed using natural language processing techniques to identify the entities and relations within the sentence.

According to the studies since there are no any existing Ontology that could find in the software testing domain, an Ontology would be developed from the scratch with capturing all the entities and their relationships within particular requirements domain. The basic concept that is underlying in the structure of the Ontology developed is on the actor, action and object of a user story where it is referred as subject, verb and object in the context of English. This would called as triplets and in the triplet extraction words representing actor, action and object of a particular user story will be extracted and they will be then passed to the Ontology which is developed within the domain.

Once these parameters are passed to the Ontology, test cases are generated by applying reasoning rules on the developed Ontology. Once the test cases are generated, in order to make them complete and overcome the incompleteness, a workflow will be provided where QA person can do some validations by updating or deleting before finalize test cases. After validation of test cases a complete test suite which contains all the test cases that is relevant to a particular user story can be generated.

1.8 Outline of the thesis

The rest of this thesis is organized as follows. The background study and literature survey on software testing from manual process to automatic test case generation approaches are discussed in Chapter 2. With the gained knowledge from the background study, an Ontology based methodology for test case generation has introduced in Chapter 3. The system design of the proposed methodology is discussed in Chapter 4. The implementation details of designed system and used tools are described in the Chapter 5. The performance of the framework in test case generation is evaluated in Chapter 6. Conclusion of the work and Future Works are stated in final Chapter.

Chapter 2

Background and Literature Survey

2.1 Introduction

This chapter discusses the main concepts and approaches for automated test case generation in software development with analysing the work done by various research studies. Further, this discusses about software testing concepts along with test cases, user stories and user requirements with their importance regarded in the current software industry. It also analyses existing approaches that has been used to generate test cases. Furthermore, this chapter focuses on semantic web technology concepts for representation of requirement domain knowledge in Natural Language and knowledge based approaches in test case generation.

The background study was conducted with regard to the following major areas which have influenced our design, and this discusses how the solution introduced in this thesis would diverse from other related works.

2.2 Software Testing

The foundational philosophy of software testing as an art of finding bugs was introduced by Glenford J. Myers in 1979. This art is all about the quality as well as the reliability of the produced program where reliability means an error free program [10]. Software testing is an essential and important process followed widely in industry in order to ensure the quality of products.

Software testing is a broad area of research where research groups, professionals and practitioners from both academia and industry have been contributing to the literature with voluminous amount of research papers, books, practical reports, review papers etc. [11]. Despite such a progress, Bertolino [12] has argued that software testing research still faces lot of challenges due to its naturally unpredictably effective.

2.2.1 Concepts of software testing

Testing techniques are considered as different approaches used to perform the testing processes. There are testing techniques that has been classified as static and dynamic testing where dynamic techniques need the execution of the software while static techniques are about reviewing and analysing the code [13]. There are two techniques with respect to dynamic testing and they are white box testing and black box testing. White box testing is to examine the internal structure of the program and designing of its test cases are based on the implementation of the software entity. Black box testing is to find out situations that the system behaves in such way it shouldn't without interfere with the internal structure of the program and it is also called as functional testing. Functional testing is based on requirement or design specification when design the test cases.

2.2.2 Importance of software testing

Software testing put great emphasis on the importance evaluation in support of quality assurance through gathering information about the software under test. There are several testing activities within the testing process like planning, executing, checking results and bug reporting and testing effort that need to be taken differs according to the activity. The main challenge in testing process is that it is costly with respect to testing effort and has flaws of designing good test cases. Testing effort depend on the size and the nature of the software product. Following Table 2.1 visualizes the size of testing efforts relative to software activities and how it grows with respect to the size of the product measured in KLOC which is called as 1000 lines of code.

Table 2.1. Total effort breakdown for projects of different sizes [14]

Activity					
KLOC	Requirements	Architecture & planning	Construction	System Test	Management overheads
1	4%	10%	61%	16%	9%
25	4%	14%	49%	23%	10%
125	7%	15%	44%	23%	11%
500	8%	15%	35%	29%	13%

According to Table 2.1 about 16% - 29% of the total effort of the project requires in the testing activities and hence testing process should be given much concentration with new research areas.

When considering the testing concepts, testing activities and the effort factors the most important consideration in software testing is the test case [10].

2.2.3 Test Case

The IEEE Standard Glossary of Software Engineering Terminology [14] defines test case as "A set of input values, execution preconditions, expected results and execution post conditions, developed for a particular objective or test condition, such as to exercise a particular program path or to verify compliance with a specific requirement". So a test case can be considered as a road map that provides the information necessary to execute the testing process. The elements of a test case are test case values, expected results, prefix values and postfix values [13]. Figure 2.1 shows how a test case would look like according to Jorgensen [15].

Figure 2.1. Typical test case information adopted [15]

As Figured under the motivation topic in the current industry the test cases are written based on user requirements in natural language. In the agile software development it follows an iterative approach to develop products incrementally with keeping the customer involved from the beginning until to the end of the product. This methodology helps with the frequent changes in requirements. Agile approach breaks down larger functionality into smaller pieces called user stories and they are delivered within short two week cycles.

2.2.4 User story

As mentioned in previous Section 2.2.3, larger user requirements are broken down into smaller pieces in Agile methodology because larger requirements capture high-level behaviour and so they can be too large to complete in a single iteration. Therefore they are broken down into smaller sets called user stories. In Agile approach, the user stories have lot of advantages [16]. Some of them are it replaces time-consuming documentation and encourage face-to-face communication between developers and business owners which would lead to better understanding of requirements while decrease in misunderstanding.

Solis and Wang [17] discuss a template (shown in Figure 2.2) for a user story to extract the information about the requirement that is needed for a particular user role.

As a - [user role]
I want - [functionality]
In order to - [provide business value]

Figure 2.2. Template for a user story

According to the above studies, it shows that user stories and test cases have been played an important role in the Agile environment. For further evaluation a survey was done to do a background study on the Sri Lankan software development Industry.

2.3 Software Development Industry in Sri Lanka

Following details were able to discover by concerning 26 Software companies in Sri Lanka. Through the study that have been done, 88.5% companies are following Agile development as the software development methodology among 26 companies 57.7% companies write user stories. The percentage of the companies who are not using design diagrams are about 15.4% and 42.3% of the companies use design diagrams occasionally, depending on the software product. The rest 42.3% frequently use design diagrams. According to the survey the test design phase is a manual process in all those companies. 61.5% of companies are doing the test design in the testing phase of the software and only 34.6% is designing test cases at the requirement gathering phase. But survey also shows that doing the test design in testing phase has been leaded to conflicts between test cases written at the testing phase and the requirements written at requirement gathering phase. 77% of companies have experienced the conflicts in software requirement and designed test cases. The results relevant to this survey are shown in Appendix C.

According to the all above background analysis, it is possible to say that in the current software industry the Agile practises are being followed and they are writing requirements in the form of user stories while going along with a most suitable and common template to write user stories. This study so far illustrated that software requirements in natural language establish basis for development of quality software through generating proper and valid test cases. According to the analysis details, currently test cases are generated manually and it is better if writing test cases are based on the requirements to get rid of the conflicts that can occur. Since test cases are written manually, automation of test case generation requires more consideration.

2.4 Automated test case generation

According to Nasser and Weichang (2010) in automated test case generation, test cases are automatically generated based on a software artifact. These software artifacts can be requirements, design diagrams (model based) or source code [18]. Rane (2017) has observed that test case generation follows one of the above mentioned techniques.

2.4.1 Requirement based test case generation

The requirements are the fundamental inputs to the system and therefore test cases need to be originated from the requirements and then the functionality of the system being evaluated with the expected outcome. Majority of these software project requirements have written in Natural Language [19]. According to Tahat and Vaysburg, requirements base techniques interpret the required behaviour of the system which can be used as footing for creation of functional test cases [20]. They concluded this as the key advantage of requirement base technique.

Dwarakanath and Sengupta introduced a tool called "Litmus" to generate test cases from a functional requirement document [21]. According to the study, generating test cases from natural language requirements form an intimidating challenge because requirements do not follow a predefined structure. Dwarakanath and Sengupta forced to not allow constraints on the structure of the requirement sentence. The tool generates one or more test cases through a six-step process.

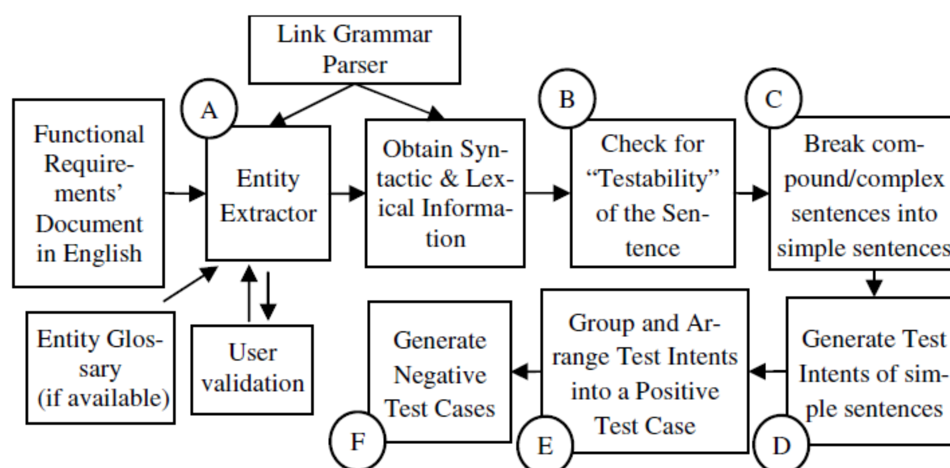

Figure 2.3. Schematic of the Litmus Tool [21]

Figure 2.3 illustrates the sequential process of Litmus that generates test cases from the requirements document. Link Parser grammar with natural language processing techniques has been used to implement the tool.

With the NLP techniques they have used, the automatically identified entities are presented to the user for validation and this user verification helps increase the accuracy of Litmus. Also Litmus has the capability of identifying Test Cases that were missed by the human analysts. However, there are some scenarios where Litmus fails to generate accurate Test Cases. In their methodology to generate Test Intents has been worked well in most cases, however, in a few instances, the Test Intents seem incomplete and not understandable due to the NLP boundaries that have been used.

2.4.2 Model based test case generation

Test cases are derived from the model of the system and according to the Neto and Subrahmanyan model-based testing classified as requirements described in UML diagrams, requirements described in Non-UML diagrams, Information from internal software structure (architecture, components, and interfaces) described in UML and Non-UML diagrams [22]. According to them reusing or extracting a test model from the behavioural software models improves the productivity of test team and software product quality.

Unified Modelling Language (UML) was developed and introduced by Object Management Group (2003) to provide visualization of the behaviour and interaction of system objects [2]. With the advantage of maintaining the consistency between design and specification through UML diagrams encouraged much research on using UML in software testing [23]. The dynamic UML diagrams consist of Use Case Diagram, Activity Diagram and State diagram [4]. Noraida, Rosziati and Noraini (2007) have introduced automatic test case generation from Use-Case Diagram [23]. According to Noraida, Rosziati and Noraini, at first system's requirements are transformed into a UML Use case diagram. Second, the test cases will be automatically generated according to the respective use cases. Use cases are developed based on the user perspective and which represent the functional requirement of the system. If the requirements are gathered correctly, good use case diagram can be composed. The suggested tool (GenTCase) by Noraida, Rosziati and Noraini generate test cases once the use case diagram has been finalized.

Chevalley and Pascale have introduced a mechanism for an automated generation of statistical test cases from UML state diagrams [24]. According to Chevalley and Pascale the

techniques of software development have been evolved with object-oriented technology. Therefore high-quality object-oriented software requires relevant testing to ensure that software meets its requirement specification. The state diagram, which widely used to represent dynamic behaviour of object, has used to generate test inputs. Moreover, for the generation of test cases include both the input values and the expected values. In this case the testing criterion used to mentor selection of input values of test cases is the coverage of the transitions of the UML state diagrams. Then the generic algorithm was applied for random generation of input values which produce sequences of test cases. Chevalley and Pascale have mentioned that this approach represents a challenge for the testing of complex systems.

In 2001 Wang and Yuan introduced a method for generating test cases from UML Activity Diagram [25]. They examined that test cases are usually generated from the requirement or the code. However, according to the approach, test cases are generated from UML activity diagram using the grey-box method. The mentioned that activity diagram is related to the design phase of software development but using this methodology where the design is reused to avoid the cost of test model creation. Activity diagrams have used to model the workflow of the business requirement or complex behaviour of an operation. In here Wang and Yuan examined that the design specifications are the intermediate artifact between software requirement specification and final source code. Within that basis, Wang and Yuan introduced the grey-box method to generate test cases which combined both white box method [15] and black box method [26] in testing.

2.4.3 Source code based test case generation

In 2001 Fraser and Arcuri introduced a tool called “EvoSuite” for automatic test suite generation for object oriented software [27]. It generates test cases with assertions for java classes. The tool applied a novel hybrid approach that generates and optimizes whole test suites to complete the coverage of test suites. This approach directly bound with implementation phase. It requires Java byte code of the class under test and its dependencies to generate test cases. It is observed that this tool is only supported with Java based software and current software industry use many programming languages for software products. Also they mentioned that the test case generation lot depend on the flow of implementation and which lead to some missing of crucial path of find defects.

According to the research review done by Shivani Kaushik [28], source code based technique has identified as a way of test case generation. It shows that source code based techniques are based on the control flow information where control flow information has

been used to point out a set of path to be covered and generated test cases for these paths. It has identified some researchers who have done researches on this area during the years 1995 to 2008 and they have shown that the source code based techniques have given fewer concentrations within that period of time.

Model-Based approaches where requirements are transformed from natural language into computational models using Unified Modelling Language (UML) can be lead to misunderstandings because of strict notations and principles [6]. In the current software industry, the development methodologies have been changed due to unstable requirements. Such new methodologies like Agile has given much concern on the requirement based approaches rather than model-based approaches and source code based approaches while concerning them with customer perspectives. Therefore requirements written in natural language have gained the interest over others.

2.5 Entity extraction using Natural Language Processing

Natural Language Processing (NLP) techniques play an important role within the test case generation process as shown in Section 2.4.1. Existing NLP techniques such as POS Tagging, Dependency Parsing and Lemmatization can be used for entity extraction. This section discusses the performance of Stanford CoreNLP, OpenNLP and Linked Parser toolkits with respect to some algorithms which could be used for identification of POS tags, lemma and dependencies while entity extraction in a triple form.

2.5.1 Stanford CoreNLP

Stanford CoreNLP is an open source Java-based suite of natural language processing tools, initially developed in 2006 by the Stanford Natural Language Processing (NLP) Group by Dan Klein and Christopher D [29]. This tool supports with various functions like tokenizer, sentence splitter, POS tagger and dependency parser with analyzing sentiments to provide syntactic analysis of a sentence. A natural language parser analyzes the grammatical structure of sentences using probabilistic knowledge of the language. Probabilistic parsers produce the most likely analysis of sentences and perform better than statistical parsers [30]. The Stanford NLP parser implements a probabilistic natural language parser based on Probabilistic Context-Free Grammars (PCFG) and outputs Universal Dependencies and Stanford Dependencies. The idea of grammatical structure consists of words linked by binary asymmetrical relations called dependency is the underlying assumption of dependency

parsing. These dependencies represent the relationship between the words of a sentence and help in extracting relevant information from a complex sentence.

- **Treebank**

A treebank is a set of words represented in a tree form annotated with syntactic information. Treebanks perform annotation based on the phrase structure of a sentence and the dependencies between words where phrase tags are assigned to a group of co-located words in a sentence which is similar to the POS tags. The Stanford Parser uses the Penn Treebank for annotating the sentences with parts-of-speech tag sets. The Penn Treebank is a human-annotated collection of 4.5 million words [31] which groups elements using phrase tags and POS tags in a phrase tree structure.

- **Stanford Dependency Representation**

There are two types of dependency representations and they are Stanford dependency and Universal dependency. The Stanford typed dependencies representation [32] extracts textual relations based on the grammatical structure of a sentence. Stanford parser provides four variations of typed dependency representations and they are basic, collapsed, propagation and collapsed tree. The main difference between the typed dependencies is the manner of representation which is in a tree form, or in a cyclic graph form. In the Stanford CoreNLP, Universal dependencies are the default representation for extracting grammatical relations since version 3.5.2. The new Universal Dependencies created in 2014 is a single framework designed to add or improve the defined syntactic relations to better accommodate different grammatical structures in various languages [33]. The current version of Stanford typed dependencies contains 50 grammatical relations which make use of the Penn Treebank POS and phrase tags [34]. The dependencies are in the form of binary relations where a grammatical relation holds between a governor which is also known as a regent or a head and a dependent. The Stanford typed dependencies are a better representation which provides a simple description of the grammatical relationships in a sentence that can comfortably be understood and productively used by people without linguistic expertise who want to extract textual relations.

2.5.2 Triplet Extraction

From a given sentence to extract the entities and their relations that sentence needs to be applied to some NLP techniques. A triplet in an English sentence can be defined as a relation between subject and object and the relation being the predicate. In the triplet extraction it is trying to extract sets in the form of {subject, predicate, object} out of sentences. There is much research and implementation has been carried out in the area of extracting triplets from sentences and they have been used machine learning technique and Treebank Parser as two main techniques.

1. Machine Learning Technique

A machine learning approach has been used [35] to extract subject-predicate-object triples from English sentences. They have used an SVM to train a model on human annotated triplets, and the features are computed from three parsers. The sentence is tokenized and after that stop words and punctuation are removed among tokens. Then by taking a list of important tokens in the sentence, all possible ordered combinations of three tokens from the list are taken. The resulted combinations are the triplet candidates. From there onwards the problem is seen as a binary classification problem where the triplet candidates must be classified as positive or as negative. The SVM model assigns a positive score to those candidates which should be extracted as triplets, and a negative score to the others and the higher positive score words formed the resulting triplet. In practice in this classification described here there are many false positives, and therefore it does not work to take them all as the resulting triplets and instead it only takes the top few from the descending ordered list of triplet candidates.

2. Tree Bank Parser

This approach is to extract subject-predicate-object triples using available syntactic parsers that generate parse trees with parser dependent techniques. Two different algorithms could be founded that uses treebank parser and they are 'Triplet extraction algorithm for Treebank parsers' and 'Multi-Liaison algorithm.

- **Triplet Extraction Algorithm for Treebank Parsers**

Extraction of triplets in a sentence from the parse trees using different parser dependent techniques that used in publicly available parsers have been presented by Delia

Rusu, Lorand Dali, Blaž Fortuna, Marko Grobelnik, Dunja Mladenić [29]. The approach has introduced an algorithm for extracting triplets from a treebank output in the form of subject - predicate - object. In this algorithm, a sentence is represented by the parser as a tree having a Noun Phrase (NP), a Verbal Phrase (VP) and the 'full stop' as its three children. The root of the tree will be 'S'. To find the subject of the sentence it searches in the NP sub-tree and by performing Breadth First Search, selects the first descendant of NP which is a noun. In determining the predicate of the sentence, the search will be performed in the VP sub-tree and selects the deepest verb descendent of the verb phrase as the predicate. According to their algorithm, the objects of the sentence can be retrieved from all siblings of the VP sub-tree containing the predicate.

Performance

The extracted triplets are in the of form subject - predicate - object and to measure the performance of the above algorithm they have used different publicly available parsers.

Using Stanford Parser, the above algorithm was implemented in Java and it has parsed the sentences in 178.1 seconds with generating 118 triples. Using OpenNLP which is a collection of projects for natural language processing, the above algorithm was implemented in C# and has parsed the sentences in 29.95 seconds with generating 168 triples. Triplet extraction using Link Grammar Parser, the application was written in C++ and generates a linkage after parsing a sentence using the Link Grammar. It parsed the sentences in 271 seconds with generating 110 triples.

Litmus tool which discussed in above Section 2.4.1 also uses Link Grammar parser and the aim is to extract entities by picking up all entities from the requirement document and the every requirement sentence is parsed by Link Grammar.

- **The Multi-Liaison Algorithm**

This is an approach for extracting multiple connections or links between subject and object from natural language input, which can have one or more than one subject, predicate and object [34]. It has used the Stanford parser dependencies to extract the information from a given sentence while the output displays which subject is related to which object and the connecting predicate. The Multi-Liaison Algorithm output can be beneficial for text mining applications where a variety of sentences are to be mined. The algorithm name uses 'Liaison' since the relationship and association between the subjects and predicates are being displayed

by this. The output would be used for natural language processing, information retrieval, information extraction and also text mining applications.

Performance

The application was written in Java using Stanford parser and it parsed a single sentence of 12 words in 8.35 seconds.

Treebank parsers techniques are likely to be used rather than machine learning techniques applied with NLP. Both the algorithms discussed above using treebank parsers have the intention of finding entities as in a triplet form where they concerned on extracting more than one entity per category. In the first algorithm mentioned has used a tree to present the sentence and in the other algorithm it has used dependency parser which concerns relations among the words in the sentence. According to the performance analyzed by those researchers, have shown that the applications for extracting triplets written using OpenNLP in C# have given better performances compared to Stanford parsers and Link Grammar Parser. However, at the same time it shows that the Stanford Parser in Stanford CoreNlp toolkit is a widely used technique as it can be used with Java language with many of the open source the implementations.

According to the stated details above, it has identified that requirement needs to be given a higher consideration with the test case generation. Therefore a good representation of domain knowledge of requirement can be given much attention to making a better use of the requirements.

2.6 Use of Ontology

Ontology can be identified as a formal explicit description of concepts in a domain of discourse [36]. Properties of each concept explain different characteristics and attributes of the concepts. Not only that Ontology act together with a set of individual instances of classes constitutes a knowledge base. According to the Natalya and Deborah studies, Ontology defines a common vocabulary for the researchers who work and want to share information in a particular domain. Therefore Ontology provides a shared understanding of the structure of information, enable reusability of domain knowledge, make explicit assumptions for the domain, and analysis of domain knowledge.

According to the Mansoor Ontology-based system have emerged in many application domains namely E-commerce, Medical, Chemistry and the foremost Knowledge Management System (KMS) [37]. There are three kinds of Knowledge management Ontologies ((Gómez-Pérez, Fernández-López, & Corcho, 2004 [38])

1. Information Ontology: Contains generic concepts and attributes
2. Domain Ontology: Is used to describe the contents
3. Enterprise Ontology: Is used for the organization description.

In 2007 Breitman stated that Ontologies should provide classes which various preset concepts in the domain, relationships among these concepts and properties to possess the concept's attributes [39].

2.6.1 Software Engineering Ontologies

Wongthongtham, Chang and Dillon have introduced a new approach to software engineering which organizes software engineering concepts, ideas and knowledge concerning the software development methodologies, tools and techniques into Ontologies [6]. Then use Ontologies as a foundation for classifying the concepts in knowledge sharing and communication. The necessity of a common communication mechanism in software development industry is vital because the complexity of the industry is getting increased. The studies described the features of software engineering Ontologies and how software engineering Ontologies can be developed. According to the studies, researchers proposed two Ontologies for software engineering.

1. Generic Ontology

This Ontology is a set of software engineering terms which include the vocabulary, the semantic interconnections and some simple rules of inference and underlying logic for software development. In general contents of software engineering are elucidated with a concept or relationship from the generic Ontology.

2. Application specific Ontology

This Ontology provides an explicit specification of software engineering concerning the particular development project. Application specific Ontology ensures consistent understanding among project members, software agents according to the project agreement.

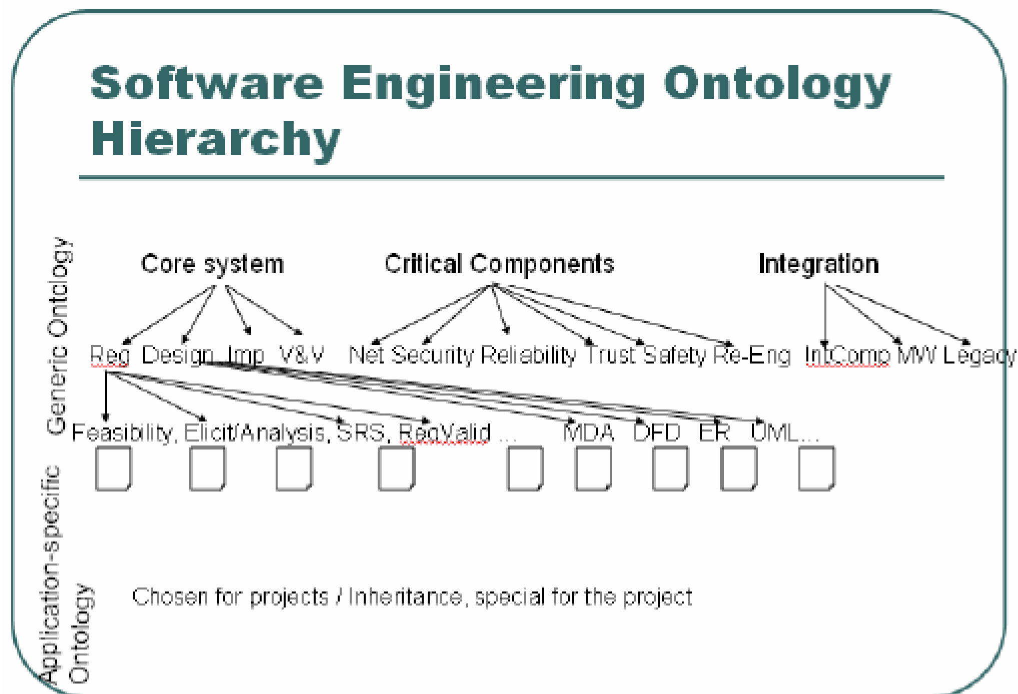

Figure 2.4. An overview of generic Ontology and application-specific Ontology of software engineering [6]

Figure 2.4 illustrates an overview of generic Ontology and application specific Ontology with relationship between internal components and their attributes.

2.6.2 Ontology representation and implementation

According to the definition of W3C Vocabularies are the basic building blocks for inference techniques on the Semantic Web [40]. The W3C said that, there is no clear division between "vocabularies" and "Ontologies" concerning the domain of existence. The word "Ontology" has been used for more complex, and possibly quite a formal collection of terms. Mansoor mentioned that semantic web has a proficiently defined combined with its rules of reasoning for data representation [37]. Ontology Web Language (OWL) is used to describing the meaning of the resources and supporting its reasoning in the semantic web. According to Antoniou and Harmelan (2008) semantic web technology lie on technologies layers which are built on each other [41]. The web data provided by layers is linked and connected to its

resources by the Uniform Resource Identifiers (URIs). Table 2.2 depicts the description of semantic web technology layers.

Table 2.2. Semantic Web technology layers description [37]

Layer	Definition
URI	The Uniform Resource Identifier (URI) is a string of characters for identifying an abstract or physical object or resource. URI is particularly suitable for referring to objects on the web.
XML	The Extensible Markup Language (XML) is a language for users to mark up content using tags to structure a web document. XML is particularly suitable for sending documents across the Web.
RDF	The Resource Description Framework (RDF) is a language that has XML-base syntax for representing information about resources in the web. RDF is particularly suitable for representing metadata about web sources.
RDF(S)	The Resource Description Framework Schema RDF(S) is a language to create vocabulary for describing the RDF resources such as classes, subclasses, and properties. RDF(S) is particularly suitable for providing modelling for the Web objects.
RIF	The Rule Interchange Format (RIF) is a language (under process) to give the basic rules for checking.
OWL	The Web Ontology Language (OWL) is another extension of RDF(S) for describing and sharing Ontologies (more info about Ontology on chapter 3). OWL is defined as three sublanguages: OWL Full, OWL DL, and OWL Lite.
SPARQL	The Protocol and RDF Query Language (SPARQL) is a special query language for express queries across diverse data sources. SPARQL is particularly suitable as the results of query can be result set or RDF graph.

The representation and implementation of an Ontology are crucial whether it is generic Ontology or application specific Ontology. According to the Wongthongtham, Chang and Dillon study there are many languages to represent an Ontology such as Knowledge Interchange Format (KIF), Ontology Exchange Language (XOL), Ontology Markup Language (OML), Ontology Inference Layer (OIL, DAML+OIL) and Web Ontology Language (OWL) [6]. Researchers used OWL because it has become the official W3C standard since 2004 which was released by the World Wide Web Consortium [42]. OWL

Ontology consists of individuals, properties and classes and describes the relationships for the domain. For the implementation of Ontology researchers used Protégé OWL tool.

According to the Dermeval and Vilela OWL Ontologies are mostly serialized with RDF or XML representation which is also a part of W3C technologies [43]. It is a triple format which models the knowledge information using triples. This triple is in the form of subject, predicate and object expressions. Therefore information in RDF format can be queried using SPARQL [44] query language. When compared with SQL, additionally SPARQL used Semantic Web Rule Language (SWRL) which extends the set of OWL axioms.

2.6.3 Ontology Languages

In the study done by Mansoor [37], mentioned the need of representing and exchanging data on the internet. Therefore some languages have created to support Ontology in the context of the semantic web. Figure 2.6 depicts the classification of Ontology building languages and Table 2.3 illustrates the summary of the most famous Ontology languages.

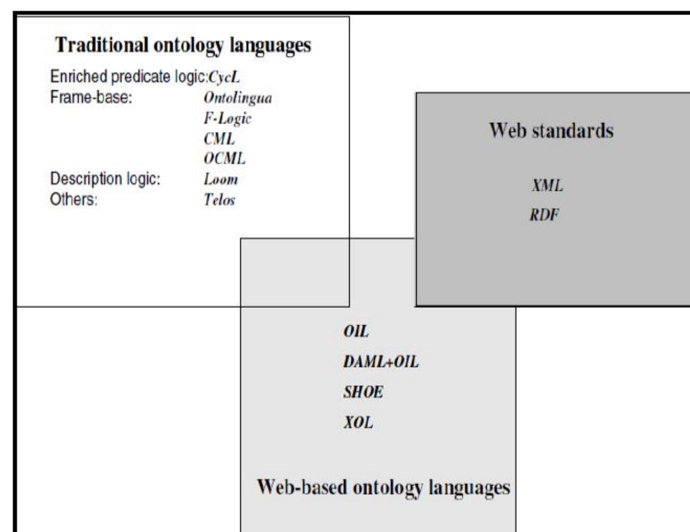

Figure 2.5. Classification of Ontology building languages [45]

Table 2.3. List of Ontology Languages [37]

Name of Ontology Languages	Developed On	Developed By	Purpose
Ontology Exchange Language (XOL)	XML	(Karp, Chaudhri, & Thomere, 1999)	To provide a format for exchanging Ontology definitions among a heterogeneous set of software systems.
Simple HTML Ontology Extension (SHOE)	HTML	(Luke S, 2000)	To improve search mechanisms on the Web by collecting meaningful information about Web pages and documents.
Ontology Inference Layer (OIL) + DARPA Agent Markup Language (DAML)	RDF(S)	(Horrocks, 2002)	To allow semantic markup of Web resources.
Web Ontology Language (OWL)	XML & RDF(S)	(McGuinness & Van Harmelen, 2004)	To publish and share Ontologies in the Web

According to the research study identified that, for the context of semantic web use the XML based language such as RDF and OWL are effective. The main advantages of that selection are comfortable reading and managing with support from the different groups and communities. Also, provide availability if more tools to update and develop the Ontology.

2.6.4 Ontology building tools

Some tools have been introduced to help the users to develop their Ontology tasks. According to Gomez (2004), these tools target to enable the process development and reusability of Ontologies [38]. Perez had classified Ontology tools as development tools, evaluation tools, merge and alignment tools, Ontology-based annotation tools, querying tools, inference engines and learning tools. Table 2.4 depicts the summary of tools that relevant to facilitate the development of Ontologies according to the study of Su and Ilebrekke in 2006 [45].

Table 2.4. List of Ontology Building Tools

Ontology Tool	Developed by	Special Purposes
Ontolingua	Farquhar, Fikes, & Rice - 1997 [46]	Development of Ontologies in s shared environment among distributed teams
WebOnto	Domingue - 1998 [47]	For corporate browsing, creating and modifying Ontologies
Prot´eg´e-2000	Noy, Fergerson, & Musen - 2000 [48]	For grapghical software development platforms
OilEd	Bechhofer, Horrocks, Goble, & Stevens - 2001 [49]	To automatic concept classification
OntoEdit	Sure et al. - 2002 [50]	To support the plug-in architecture
WebODE	Arpírez, Corcho, Fernández-López, & Gómez-Pérez - 2003 [51]	To ease the access services

For the study of suggested solution, Prot´eg´e-2000 has been selected as Ontology building tool because it is an open source standalone application. Also, the application is written in Java and supports as OWL editor and reasoner. Moreover according to current development environment graphical visualization is very vital. Prot´eg´e-2000 provides that feature by visualizing classes and properties of Ontology in different colours. Therefore developers can easily do their works [37].

For deriving implicit knowledge from a knowledge base that is written in a knowledge representation language, Reasoning gets involved. Since Ontology being a knowledge base representation, it needs to be applied with the reasoning to obtain implicit knowledge represented in the knowledge base.

2.6.5 Apply reasoning on Ontology

Ontology is one of an interpretation of the semantic web. The reasoning is another term that tightly coupled with Ontology. Reasoning in Ontologies and knowledge bases provide explicitly deriving from facts which are not directly expressed in Ontology or knowledge base. According to Ameen, Rahman and Ram (2014) semantic web use automated tools and reasoners for supporting knowledge management with extracting new knowledge

from existing knowledge and checking inconsistencies [52]. This paper depicts that Jena API which is an open source semantic web framework for Java and it can be used to extract data from and write to RDF graphs and OWl Ontologies.Also mentioned that SPARQL could be used to query the RDF graph or OWL Ontologies. The reasoning of Jena works on the Ontology to derive truth from the model. Additional facts such as transitive and reflective properties can be derived using a range of reasoners provide by the Jena inference subsystems. Another advantage of Jena Ontology API is, it is independent of Ontology language.

In 2014 Glimm and Horrocks introduced another OWL reasoner called HermiT, which supports all features of OWL 2 Ontology language including all data types and data properties [53]. Apart from the standard reasoning tasks, HermiT also supports for SPARQL querying and ensure efficient processing of real-world Ontologies. When comparing with Jena and HermiT, Jena supports for all Ontology languages and HermiT concentrate on OWL which can be taken as a drawback.

As stated so far Ontology has become a widely applicable area concerning to the representation of domain knowledge where that knowledge can be reused within the domain. Therefore analyzing the opportunities of Ontology-based approaches that have been used with the generation of test cases so far can be taken as an important aspect.

2.6.6 Ontologies in test case generation

The primary objective of the project is to find the possibility of automatically generate test cases based on an Ontology. Hence the usage of Ontology in test case generation plays a vital role in this background analysis. Therefore identifying existing Ontologies for the required domain, studying the features in Ontology such as relationship identification, rules, and reasoning, and observations of already introduced solutions earn big attraction to prove the suggested objective mentioned above.

According to the Nasser's and Weichang's test generation framework in 2010, used Ontology approach to implement the solution [18].They used the behavioral model Ontology to describes concepts related to the software artifact elements, the relationship between them and their instances. Expert knowledge Ontology used and it extends the behavioral model Ontology and knowledge is utilized by the coverage criteria rules for identification of test objectives. It is observable that Ontology has the advantage of hold the knowledge concerning the particular domain. Experts can be worked on particular knowledge Ontology

and they can use reasoning on Ontologies to derive necessary outcomes. They concluded that Ontologies should be developed for the software artifacts and to the required domain.

According to these, it can be seen that there is no such existing Ontology developed for software requirement domain. There are some properly identified mechanisms with how to develop an Ontology for a particular domain, but there are no any Ontology-based proposed approaches that have been used practically so far.

Though there are no any Ontology-based approaches, there could have some other mechanisms or similar solutions that have been proposed through various systems. To get the details if there exist any such solutions this thesis analyses further about similar systems and solutions.

2.7 Similar systems and solutions

Three similar systems that have been proposed to automatic test case generation have been found.

As stated in Section 2.4.1 Litmus is a requirement based automatic test case generation tool which identifies a requirement as a sentence that has a label (given for traceability) in a requirement document and generates one or more Test Cases. This one Test Case includes the Test Condition, the Test Sequence and the Expected Result. A "Test Condition" is defined as the entry criterion for the Test Case or the particular condition which is being tested. The ordered sequence of steps a tester would have to execute to perform the test is called "Test Sequence". Litmus uses a syntactic parser called Link Grammar parser to parse the requirement sentence and has a set of pattern matching rules to check the testability, identify Test Intents and generate Positive and Negative Test Cases in a systematic manner. If the parser is unable to link the sentence, it is reported as a "failed case" and the analysis moves to the next sentence. If the testable requirement is a compound or complex sentence, it is simplified into a set of simple sentences. This simplification is made by identifying the links from the LG parse that represent compound/complex sentences and handling them appropriately. Generating of Test Intents is done according to predefined rules. For a compound/complex sentence, the Test Case is generated for each simplified sentence and merged according to the semantics of the conjunctions. Litmus has been implemented as a plug-in into Microsoft Word and Excel using .NET. The implementation calls the LG parser run-time (in C) as a managed code library from the .NET environment. Litmus was tested

over actual requirement documents from various projects in the industry. The overall accuracy of Litmus was seen at 77% and varied from a low of 56% to a high of 84%. But one of the issues is Litmus is driven largely on the syntax of the sentence. Some lexical semantics is inbuilt, for handling coordinating and subordinating conjunctions. Such semantics are context and domain agnostic. Still Litmus is not popular among software companies since it has been implemented as a plug-in into Microsoft Word and Excel using .NET.

Cucumber [54] is a command line, automatic test case generation tool which is for the companies who follows a BDD approach. Though such companies follow BDD approach, because of the Cucumber tool they have no intention of keeping user stories and rather they keep requirements in a file called feature file. These files are written using keywords such as "Given", "Then", "And" and etc. When the feature file is executed, a method is implemented directly into a code level without the method body.

The usage of cucumber has limitation since it can be used by BDD driven companies but most of the BDD driven companies tend to write user stories because of the customer requirements. Also it is an additional effort and cost for creating feature files used in Cucumber tool. Since the method body is not automatically generated, it has to be written by a QA engineer. Therefore to use Cucumber QA team has to be aware of some programming.

J-pet is a code based, white box test-case generator (TCG) which can be used during software development of Java applications within the Eclipse environment. jPET builds on top of PET. PET is a research prototype which aims at automatically generating test cases from Java bytecode programs by relying on the technique of partial evaluation. The system receives as input a bytecode program and a set of optional parameters, including a description of a coverage criterion; and yields as output a set of test cases which guarantee that the selected coverage criterion is achieved and optionally, a test case generator.

jPET incorporates a test-case viewer to visualize the information computed in the test-cases (including the objects and arrays involved). It can display the test-case trace, i.e., the sequence of instructions that the test-case exercises. jPET can also parse method preconditions written in JML [55]. This can be very useful for avoiding the generation of uninteresting test-cases, as well as for focusing on (or finding) specific ones. jPET can be used as this. Once a Java source file is opened, the user can select in the outline view of Eclipse the methods for which he/she wants to generate test-cases. Once selected, clicking on the jPET icon opens the preferences window of jPET which allows setting preferences. The obtained test-cases are then shown in a tree-like structure organized in packages, classes and methods in the jPET view.

The test-case viewer basically consists of three modules. The output of PET has been extended so that an XML file containing all the information of the obtained test-cases is generated [55]. The Graph Manager, based on JGraph manages the graphical representations based on the heap data structure. Each graphical representation is basically a graph that encapsulates the heap, or part of it, and contains information about how it should be displayed by the interface [55].

On top there have a Swing based interface that allows the programmer to interact with the Graph Manager by creating, displaying and exploring their preferred representations of the heap [55]. jPET symbolic execution engine works at the bytecode level, allows using it for Java bytecode programs for which the source is not available. This could be very useful from the point of view of reverse engineering.

But Jpet has some issues since it is a code level test case generation plugin written for java.

2.8 Summary

This background analysis has explored almost all the areas that could come up with the test design phase in the software testing phase. Software testing is a main concern in order to build up a better quality product and the test design phase within software testing phase has a large impact on time, cost and effort factors. But both in theoretically as well as in practically the test design phase is still a manual process where writing of test cases is needed to be done by looking at the user requirements for the reason of removing conflicts that could occur at other phases of testing.

There are 3 different approaches introduced for the automatic test case generation and they are requirement based approach, model based approach and source code based approach. Also when comparing these 3 approaches the requirement based approach has gain the interest over others due to the Agile practises that follows in the current software industry. Along with the Agile practises, user requirements are written in the form of user stories and there is a typical common template that has been introduced for the writing of user stories.

As aforementioned, requirements written in natural language has gained attention with generation of test cases which underlies the effectiveness and efficiency of the testing process with respect to those factors mentioned. Natural Language Processing techniques are concerned with requirements for the extraction of entities and relationships reside in the given sentences. Multi-Liaison Algorithm has introduced a dependency parsing technique which can be seen as a more useful mechanism with extracting entities since it considers on how entities are related. Stanford CoreNLP toolkit has been used popularly compared to other tools because of the capability of using it with open source Java implementation. In that Stanford typed dependencies are a better representation which provides a simple description of the grammatical relationships in a sentence.

Semantic web technology holds various promises for developing efficient conceptual web data represented in a formalism approach and Ontology is one such approach where it stands out as a promising technology for knowledge development and representation. There are some conceptual level Ontology based approaches with test case generation but nothing can be founded as a developed existing one. However this chapter stated that Ontology based idea opens up many possibilities with knowledge representation and there is a high chance that this technology can bring many benefits with the automation of test case generation.

Chapter 3

Methodology

3.1 Introduction

This chapter describes the proposed research approach for the Ontology based test case generation methodology. It is introduced as a series of transformations from a user story up to the generation of test suites in natural language. To be more precise this discussion goes along with present software requirements as user stories, process user stories in English using natural language processing, involvement of an Ontologist to software industry, an Ontology based representation of software requirements, implementation of software requirement Ontology, reasoning the Ontology for generate test cases and workflow for derive test suites according to the user stories. The research approach has discussed along with the above mentioned transformations and the methods of data collection by selecting a sample user story which will process through the followed steps within the methodology up to derivation of the output as test cases.

3.2 Method Overview

The method generates a test suite in 3 main phases. Figure 3.1 illustrates the phases of test case generation framework with their inputs and outputs. Phase 1 extracts the set of entities from user stories then phase 2 performed to find out test cases by applying reasoning on Ontology, Ontology acted as the pre implemented inputs for this phase. In phase 3, a completed test suite can be derived by doing modification and insertion on that automatically derived test cases.

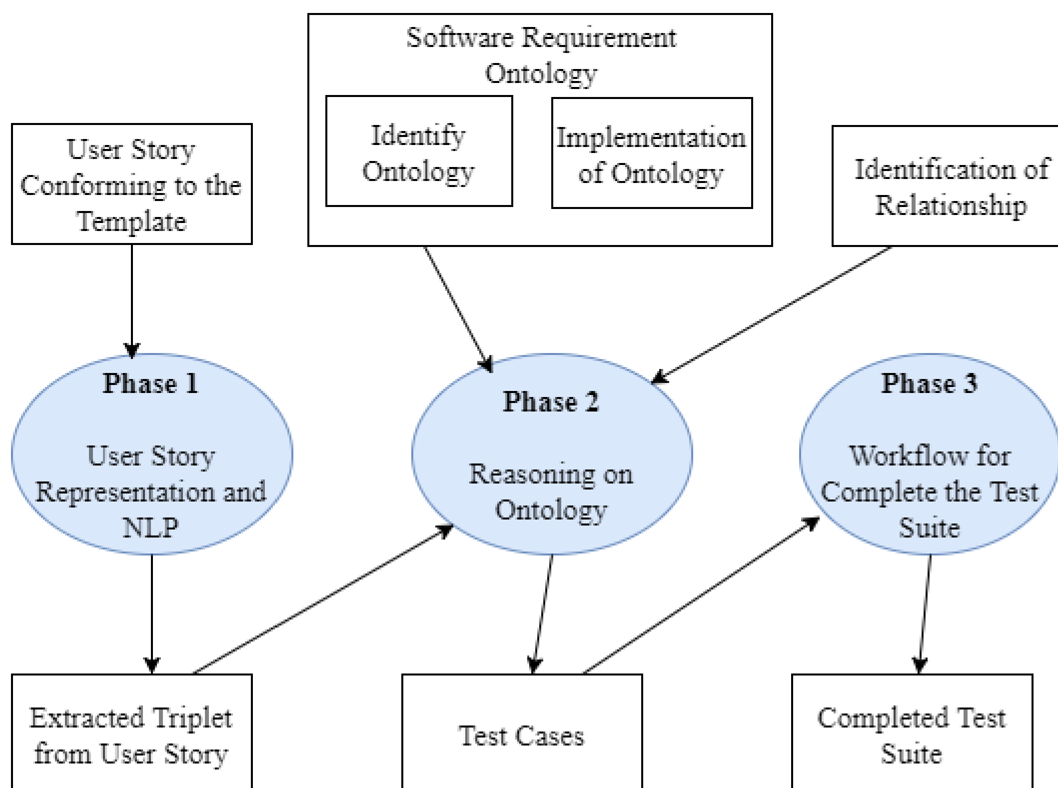

Figure 3.1. Phases of Automatic Test Case Generation

Phase 1 - User story representation and NLP: Inputs are given in the form of user stories and a suitable user story template was need to identify. Then the user stories are taken as an input by using that template created. Next the Natural Language Processing techniques are used to extract three main entities as actor, action, object from given user stories as a triple. This entity triple is taken as the input for reasoning on Ontology.

Phase 2 - Reasoning on Ontology: Requirement Ontology identification and Ontology implementation are prior constraints which need to be applied for extracting test cases. Applying reasoning mechanisms to the implemented Ontology test cases are derived according to the user story.

Phase 3 - Workflow for complete the test suite: This phase is presented to generate complete positive test cases based on given functional requirements. Derived test cases from the phase 2 are used to generate complete functional positive test cases. Modifications and new insertions can be applied as needed on this phase in order to come up with a complete test suite that consists of all the positive test cases relevant to a particular set of user stories.

As identified in the chapter 2, since user requirement plays a vital role within test case generation methods, in this proposed method also takes requirements as input in user story user stories format. Representation of software requirement in the form of user stories was taken into consideration with respect to Agile practises.

3.3 User stories as representation of software requirements

Agile development has three terminologies for describe requirements in software as epic, feature and user story. These terminologies are being used differently in different development environment and it is based on how a developer defined them. Developer can state there are only epics and user stories and there are no features because there are no sub tasks to consider as features. Depending on which agile framework (scrum, kanban, or your own unique flavour) is using, epics can be defined in different ways. For kanban, epics are defined as swimlanes to segment different streams of work in requirements. If using scrum, epics help to label the work in the sprints where sprints are some set of tasks that delivered within short period of time.

An epic can be divided into several subtasks which are called features. A feature is a distinct element of functionality which can provide capabilities to the business. It generally takes many iterations to deliver a feature. A user story is defined as a subtask of a feature where one feature can contain several user stories. The following Figure 3.2 shows this intention.

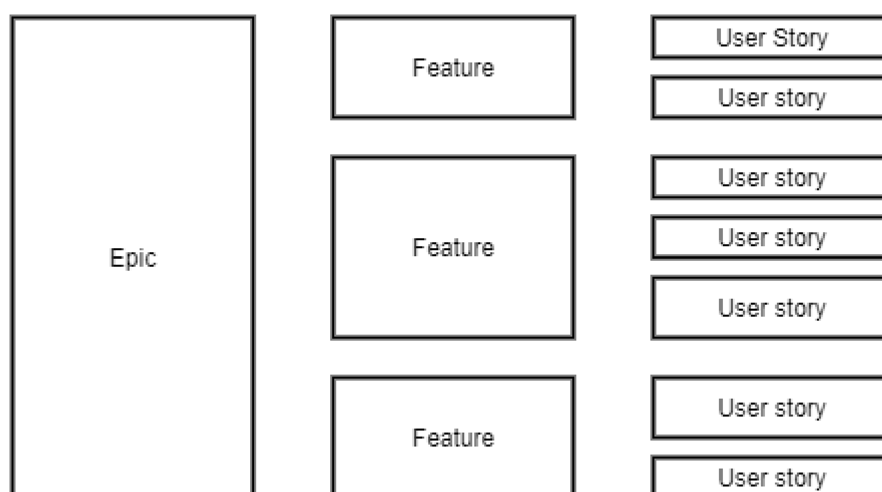

Figure 3.2. Brake Down of Epic

As discussed in Section 2.3 in Background chapter, user story is a requirement representation method which is most favoured in the software industry. Most of the companies are using a same template as shown in Figure 2.2. This proposed methodology also used this user story template that comes under epics as the input.

The following scenario is an example for an epic and user stories.

Epic: Group Management

Sub tasks within this epic are as follows:

Add a new Group

Update a Group

Delete a Group

View Users who belong to a Group

View Groups of a User

List Groups

Search for existing Groups

User stories for each of above subtasks will be written and user story for the sub task “Add a new group” will be written as follow.

A Subtask of epic: Add a new Group:
User story: “As a User Admin, I want to add a new user group to the system, so that I can add users to that group and manage them easily.”

With studying and suggesting a way to write user stories, then the next consideration was given to the Ontology module development with the concept of introducing of a new role as an Ontologist into the current software industry.

3.4 Involvement of an Ontologist in the software industry

An Ontologist is an expert in study of Ontology. The mission of the Ontologist is to create knowledge graphs and linked metadata schemes for a required domain. An Ontologist should have an ability to develop and implement Ontologies for the domain, integrate Ontology requirements across components, identify mapping approaches for conversion between different Ontologies, maintain knowledge related to Ontology tools, metrics, and process improvements, validate and review requests for Ontology changes. Apart from above major requirement Ontologist should be familiar with lexical semantics, NLP and semantic analysis.

According to the capabilities of an Ontologist as mentioned above, software industry can be effectively improved with the involvement of an Ontologist. The application of the role of an Ontologist in the agile software development methodology is depicted through this research project. The aforementioned issue regarding the inconsistencies between the user stories and test case can be reduced with the use of an Ontologist. The proposed solution has identified that the role of an Ontologist can be used in the requirement gathering phase in order to map the requirements of the product owner with the proposed Ontology model. The proposed Ontology model is discussed in Section 3.5. The knowledge base of the proposed solution can be evolved with the contribution of the Ontologist.

3.5 Software Requirement Ontology

The software requirement Ontology is the Ontological representation of software requirements. This Ontology model is based on software requirements presented by the product owners and the model will be developed by an Ontologist according to the requirements domain. In this proposed methodology, a generic Ontology is to be developed apart from an application specific Ontology since the intention is to make reuse of the developed Ontology within the overall testing process. The need of an Ontologist was discussed in the Section 3.4 where Ontologist need to be a member of clients' meeting where requirements are discussed between client or product owner and Business Analysts in the company. While BA person scratched down the requirements, Ontologist can get a better idea about the requirement domain by participating in these discussions. By analysing the requirements Ontologist can identify what are the main entities that are needed to inject into the developed Ontology in a case of a new entity representation.

Developing a complete full Ontology from the scratch for the entire software requirement domain is a harder approach and therefore this proposed framework would be given as a generic solution for the 'Group Management' epic, a frequently used epic in most of the software systems. Since Ontology provides a structured means of storing information and linked data, the usage of Ontology for test case generation can be well justified using this epic scenario. System objects, actions and properties are mapped to Web Ontology Language (OWL) as classes and properties.

3.5.1 Class hierarchy of the Ontology

The class hierarchy of the developed Ontology module in this proposed methodology is shown in the following Figure 3.3.

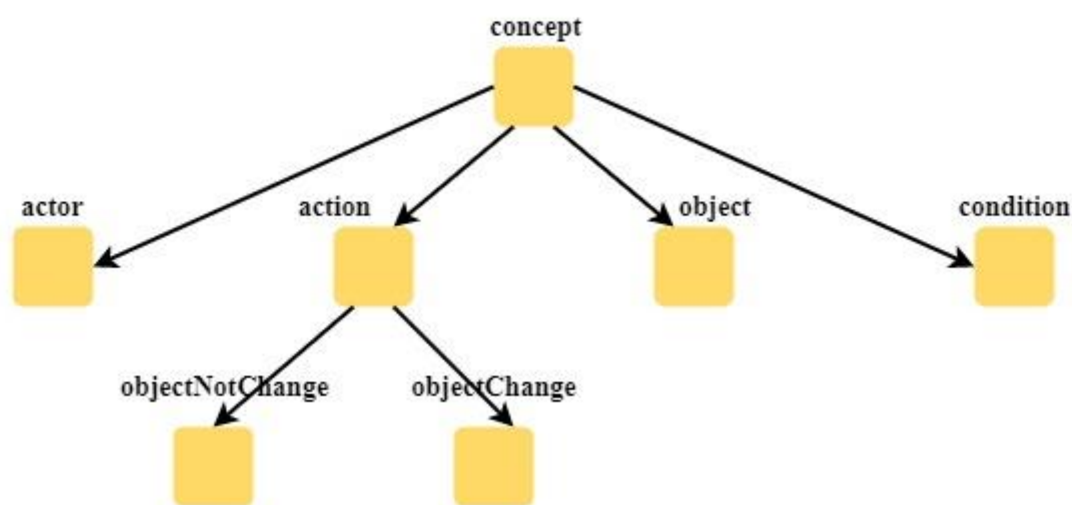

Figure 3.3. Ontology Class Hierarchy

Anything entered into the Ontology is called as a concept. Class concept is further divided into subclasses as *actor, action, object* and *condition*. After studying the sample user stories and their test cases, it could be identified that most of the test cases are based on the functionality and the object where functionality is directly addressing in the user story. Therefore the actor, action and the object were identified as the classes of the Ontology model concept. Actor in a software engineering domain is the one who is performing or having the authority for a particular functionality of the system. The actions described the system functionalities.

The following Table 3.1 shows the definitions of the classes which have been used in the Ontology model and its' description.

Table 3.1. Classes of Defined Ontology

Class	**Description**
actor	An actor represents the subject, the doer who is doing the action of a sentence.
action	An action represents system functionalities, which system users (actors) can perform inside its' sub classes.
objectChange	An objectChange action is a kind of an action where the direct object of that action is changed once the action is performed.
objectNotChange	An objectNotChange action is a kind of action where the direct object of that action does not changed once the action is performed.
object	An object represents the object of a sentence on which the action is directly performed.
condition	A condition represents situations as preconditions that needs to be checked before doing an action.

Class action is divided into two subclasses as *objectNotChange* and *objectChange* as shown above. Section 3.5.4 is discussed about this further.

Every class has its instances called as individuals. The following Figure 3.4 shows some instances for the class 'action'.

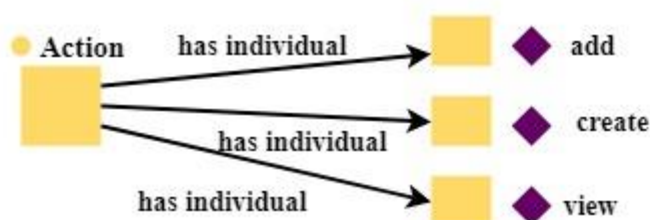

Figure 3.4. Instances of Class Action

Each of the individuals defined in the Ontology can have properties and they can be categorized as object properties and data properties.

3.5.2 Object Properties of the Ontology

The relationship between two classes can be defined as Object property with respect to those two instances. Relationship between two instances in the same class also defined as object properties. The following Figure 3.5 shows some examples for those object properties.

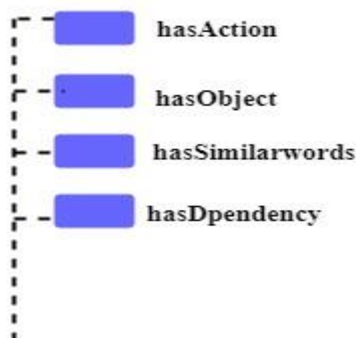

Figure 3.5. Object Properties of Defined Ontology

Following Table 3.2 shows a description of object properties in the proposed Ontology.

Table 3.2. Object Properties of Defined Ontology

Object Property	**Domain**	**Range**	**Description**
hasAction	actor	action	The relationship between classes actor and action is defined as *hasAction*.
hasObject	action	object	The relationship between classes action and object is defined as *hasObject*.
hasSimilarword	action	action	A relationship between two instances of class action.
hasDependency	action	action	A relationship between two instances of class action.

The object properties *hasSimilarword* and *hasDependency* are defined for handle special cases. User stories are written by different users, therefore they might use different words to describe the same things with relevant to their knowledge. To handle this critical condition, object property *hasSimilarword* has been introduced with the intention of reducing the redundancy. Properties have defined into one instance and those properties are accessing through *hasSimilarword* object property.

There can be implicit user stories which are indirectly depend on another user story. As an example, when a user performs action ‘update’, it indirectly depend on the action ‘view’ and therefore action ‘update’ has object property *hasDependency* on the action ‘view’. To handle those kinds of situations, the object property *hasDependency* was introduced.

3.5.3 Data properties of the Ontology

Properties of an instance are defined as data properties. The following Figure 3.6 shows some examples for the data properties and Table 3.3 describes some of the data properties which have been defined in the Ontology.

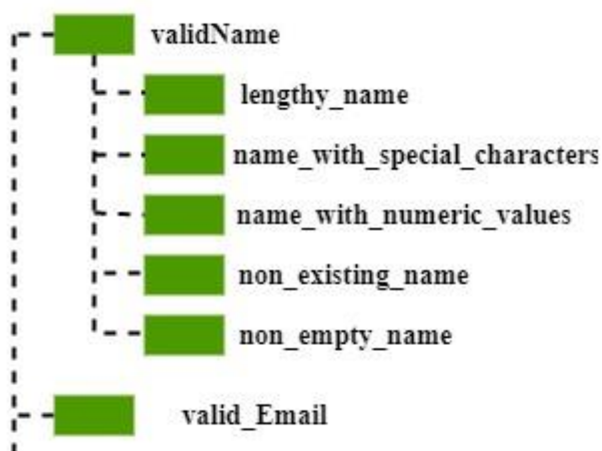

Figure 3.6. Data Properties of Defined Ontology

Table 3.3. Data Properties of Defined Ontology

Data property	Domain	Description
validName	actor, object	This property belongs to both actor and object since when creating an actor or an object, the name should be valid.
lengthy_name	actor, object	lengthy_name is a sub data property of valid name. An instance of a given domains can be created with a lengthy name.
lengthy_name	actor, object	lengthy_name is a sub data property of valid name. An instance of a given domains can be created with a lengthy name.

name_with_special_characters	actor, object	This is a sub property of property validName. An instance of a given domains can be created with special characters such as ‘@’,’$’.
non_empty_name	actor, object	non_empty_name data property has two domains actor and object, since when an instance is created its’ name is mandatory.
non_existing_name	actor, object	When an instance is create its’ name should not be an already existing name, therefore non_existing_name has defined as a data property.
ID	actor, object	Both actor and object has data property ID which is a unique number.
valid_Email	actor	An instance of actor has a valid_Email.
view	objectNotChange	Action view is belonged to sub property objectNotChange and has sub data properties view_all_objects and view_top_N_view of objects.
view_all_objects	objectNotChange	Action view has data property view_all_objects. When a user needs to perform action view, it can be to view all instances of particular class.
view_top_N_view of objects	objectNotChange	This is sub data property of data property view. When a user needs to perform action view, it can be to view only top N number of instances of particular class.
delete	objectNotChange	This property is defined for action delete, having sub data properties, delete_after_the_approval and send_confirmation_message.
delete_after_the_approval	objectNotChange	This sub data property is defined to give the knowledge of action delete to the Ontology. Before performing action delete, an approval must be taken.
send_confirmation_message	objectNotChange	After deleting a particular instance a confirmation message need to be send.For that, the sub data property send_confirmation_message has been introduced.

An example scenario has discussed below to illustrate on this Ontology development concept for adding a new user to a group. The entered user story would be like "As an admin I want to add a new user to the system so that I can manage user groups."

Ontologist will identify *admin* as an instance of the class *actor* and *add* as an instance of the class *action*. By action *add*, a new instance of an *object* is created. That means when performing the action *add*, the properties of the object *user* get changed and so it need to be considered, therefore action *add* is belongs to subclass *objectChange*. Actor admin has data properties such as name, id, email, etc. and object *user* has data properties such as name and id.

The relationship between class *actor* and action is defined as *has_action*. The following Figure 3.7 shows this relationship.

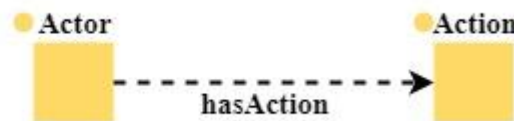

Figure 3.7. Relationship between class Actor and Action

In above example user story *add* is the action. Ontology has another action called *create*, which has same semantic to action *add*. Relationships and relevant properties have been defined to action *create*, not to action *add*. To handle this sort of situations, action need to be checked for *hasSimilarword* objectproperty and if there are any similar words defined, then that similar word's properties need to be considered for the next reasoning phase.

3.5.4 Identified categories for class action

Based on the effect that can occur to the direct object by performing an action, the *action* class can be divided into different categories. To ensure this intention, hundreds of user stories from different companies were considered and identified the actions and their direct objects that can be founded in those user stories. The following Figure 3.8 shows sample data set which were collected for that research. The action was manually checked and labeled into *objectNotChange* and *objectChange*. According to this overall statistics it was possible to show that nearly 37% percent of actions could be labeled as *objectChange* and rest 63% could be labeled as *objectNotChange*.

USER STORY	ACTION	change object
As customer I want to purchase the goods in my shopping basket so that I can receive my products at home	purchase	no
As customer I want to log in with my account so I don't have to re-enter my personal information every time	login	no
As customer I want to review and confirm my order, so I can correct mistakes before I pay;	review	no
As customer I want to pay for my order with a wire transfer, so that I can confirm my order;	pay	no
As customer I want to pay for my order with creditcard, so that I can confirm my order;	pay	no
As customer I want to receive a confirmation e-mail with my order, so I have proof of my purchase;	receive	no
As shop owner I want to decline orders below 10 dollars, because I don't make any profit on them;	decline	no
As a fulfillment specialiist I wan to print picking report so that I can prepare products to ship	print	no
As shop owner I want to reserve ordered products from stock for 48 hours, so other customers see a realistic stock;	reserve	no
As shop owner I want to automatically cancel orders for which I have not received payment within 48 hours, so I can sell them again to other customers;	cancel	no
As a User Admin, I need to be able to view users of groups in the system, so that I can manage users in groups easily.	view	no
As a User Admin, I need to be able to list user groups in the system, so that I can manage user groups easily.	list	no
As a User Admin, I need to be able to update an existing group in the system, so that I can manage users in that group ea	update	yes
As a User Admin, I need to be able to view groups of a user in the system, so that I can manage users in groups easily.	view	no
As a low budget vacation traveler I want to find flights using a range of dates	find	no
As a project supervisor I want to create new projects in the system so that I can manage new projects	create	yes
As a project supervisor I want to create new deliverables so that I can assign tasks	create	yes
As a project supervisor I want to edit new sub projects so that I can make relevent changes	edit	yes
As a project supervisor I want to delete new sub projects so that I can remove not relevant projects	delete	no
As a project supervisor I want to create new activity so that I can assign new activities	create	yes
As a project administrator I want to add news to the project so that I can give comments to the team	add	yes

Figure 3.8. Sample User Stories

According to the Ontology model concept described in above Sections 3.5 the three entities actor, action and object need to be extracted from the user story. For that task Natural Language Processing techniques were needed to use.

3.6 Entity extraction using natural language processing

According to the Ontology model that has been developed, its underlying principle should match up with the concept of *actor, action, object* triple form and therefore those three entities are need to be extracted from a user story. Here ‘actor’ is the one who performs the action, ‘action’ is the activity that actor will performed and the ‘object’ is the item on which that action will performed by the actor and these terminologies were defined according to the developed Ontology that discussed in Section 3.5 of this chapter. For the entity extraction, Natural language processing techniques are used since the user stories are written in natural language.

As identified in chapter 2, one triplet extraction algorithm was focused on retrieving subject, verb, and object entities in a triple form without concerning how they are related or dependent of each other. It has used parse trees and POS tagging to get the output triplets and there are cases where one verb having many objects since they were not concerned on direct

mappings between entities. The Multi-Liaison algorithm has used Stanford parser dependencies which finding subjects with related objects and verbs. This mentioned dependency parser method can be also used within the proposed methodology for entity extraction from user stories by doing some relevant changes. That algorithm concern on finding more than one triplet but according to the Ontology model proposed above this proposed methodology needs only one triplet for a user story to do the reasoning. Therefore dependencies of the words in a user story needs to be concern. Since Stanford typed dependencies provide a simpler representation with describing relationships between entities, this framework would use the Stanford Dependency Parser in Stanford CoreNLP Toolkit.

This Section explains how triplet would extract with following steps shown in Figure 3.8. The input user story sentence is applied with NLP techniques to get the output of actor, action, and object triple.

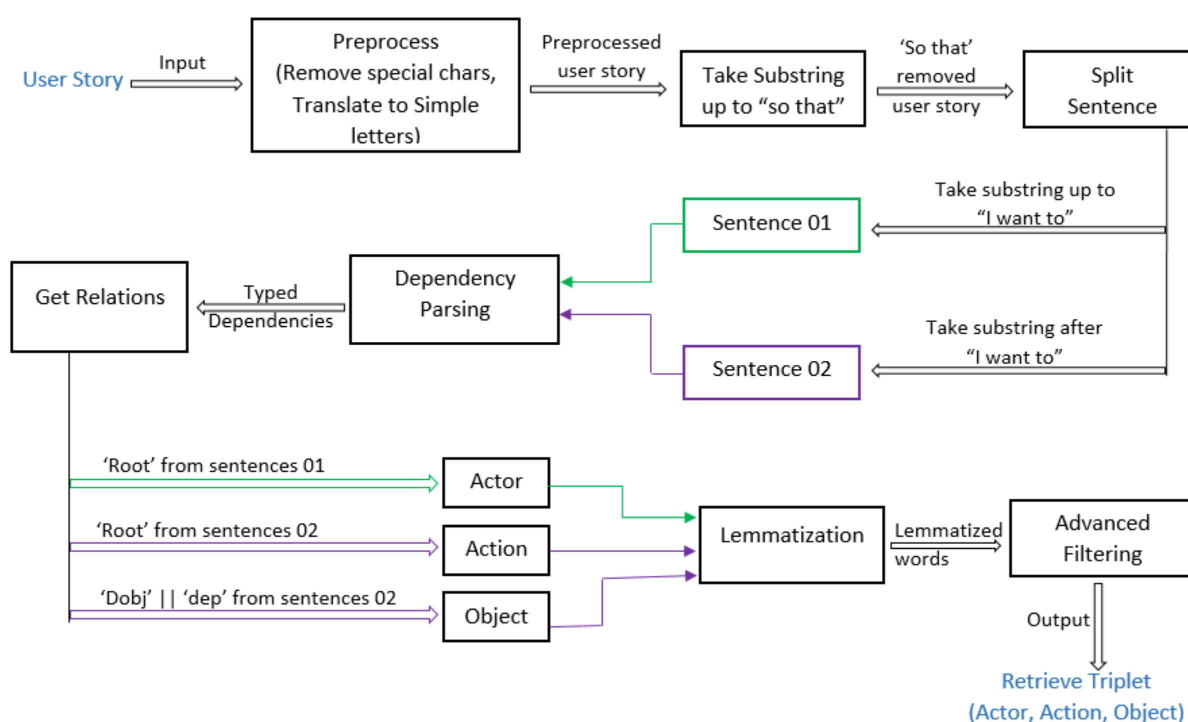

Figure 3.9. Extract Triplet from a user story using Stanford Dependency Parser

3.6.1 Pre-Process

As shown in Section 3.6 a user story is represented in “As a [Actor], I want to [Action]+ [Object], So that [some business value]”. The sentence after ‘So that’ substring contains some business value that would be achieved with the success of action. Therefore in such a user story, sentence after ‘so that’ string won’t take into consideration. In order to remove that part, first the complete user story will translate into lowercase in English and remove if there any special characters like punctuations or others. Then the ‘so that’ substring is removed and the rest substring is only taken as the sentence.

Table 3.4. Pre-processing a user story

Original User story	“As a User Admin, I want to add a new user group to the system, so that I can add users to that group and manage them easily.”
After preprocessed	“as a user admin I want to add a new user group to the system so that I can add users to that group and manage them easily”
User story after remove ‘so that’ part	“as a user admin I want to add a new user group to the system”

3.6.2 Split Sentence

According to the Actor, Action, Object concept of the developed Ontology model, only one triple from a user story need to be extracted. This leads to the requirement of a dependency parser to get the dependencies between words. But to extract the exact actor, action and object entities, the user story need to be split according to the method which this thesis is proposing. So the user story is split into two substrings as sentence 01 and sentence 02 where sentence 01 contains the substring upto string ‘I want to’ and sentence 02 contains the substring after string ‘I want to’. Each of these two sentences is then passed to the Dependency Parsing step separately.

Table 3.5. Splitting a user story into separate two sub sentences

Pre-processed user story	“as a user admin I want to add a new user group to the system”
Sentence 01	“as a user admin”
Sentence 02	“add a new user group to the system”

3.6.3 Dependency Parsing

The Stanford parser analyses and extracts the grammatical structure of the sentence which indicates how the words are related to each other. It identifies the subject, object, verb phrase between the subject and the object, and conditional statements. In this proposed method, first get the syntactic dependencies of the sentence and a semantic graph of it and then take typed dependency in that semantic graph. The output semantic graph and typed dependencies for the sentence "As a Admin I want to add users to group." are shown in Figure 3.10 and 3.11 respectively.

```
-> want/VBP (root)
  -> Admin/NNP (nmod:as)
    -> As/IN (case)
    -> a/DT (det)
  -> I/PRP (nsubj)
  -> add/VB (xcomp)
    -> to/TO (mark)
    -> users/NNS (dobj)
    -> group/NN (nmod:to)
      -> to/TO (case)
  -> ./. (punct)
```

Figure 3.10. Semantic graph representation using Stanford dependency parser

```
root(ROOT-0, want-5)
case(Admin-3, As-1)
det(Admin-3, a-2)
nmod:as(want-5, Admin-3)
nsubj(want-5, I-4)
xcomp(want-5, add-7)
punct(want-5, .-11)
mark(add-7, to-6)
dobj(add-7, users-8)
nmod:to(add-7, group-10)
case(group-10, to-9)]
```

Figure 3.11. Typed Dependencies

As identified in chapter 2, among all the introduced 50 grammatical relations, for this framework only few relations would be used since there is a particular way of writing a user story. Typed Dependency is a relation between two words and each Typed Dependency consists of a governor word, a dependent word, and a relation.

Example: dobj(add-7, users-8)

Here relation is ‘dobj’, governor word is ‘add’ and the dependent word is ‘users’.

Relation ‘root:root’

The root grammatical relation points to the root of the sentence and this root is the head of the entire structure corresponds to a sentence [56]. According to them a fake node “ROOT” is used as the governor.

Example: root (ROOT-0, want-5)

- **Relation ‘dobj: direct object’**

The direct object of a Verb Phrase is the noun phrase which is the object of the verb [56].

Example: dobj(add-7, users-8)

- **Relation ‘dep: dependent’**

When the Stanford dependency parser is unable to determine a more precise dependency relation between two words it sets the relation as dependent.

Example: Here if a sentence contains an substring as “book a room’, then the relation between the word ‘book’ and the word ‘room’ is unable to determine due to the ambiguity of the word ‘book’. In such situations parser would provide relation as below.

dep(book-1, room-3)

In this dependency parser step, the two sentences splitted from the user story would parse using the dependency parser and following relations in Table 3.6 are taken as actor, action, object from the typed dependencies that dependency parser creates.

Table 3.6. Extracted relations as triplet from dependency parser

Actor	Dependent word in the ‘root’ relation in sentence 01
Action	Dependent word in the ‘root’ relation in sentence 02
Object	Dependent word in the ‘dobj’ relation or ‘dep’ relation in sentence 02

3.6.4 Lemmatization

For grammatical reasons, sentences use different forms of a word. From the above step, once the triplet is extracted from a user story the three entities may or may not matches with the words given in the Ontology as Ontology refers to common set of vocabulary of words. Therefore the retrieved entities need to be lemmatized where lemmatization refers to the removal of inflectional endings only and to return the base or dictionary form of a word [57]. An inflectional ending is a group of letters added to the end of a word to change its meaning. So at the end of these steps, 3 lemmatized words as actor, action and object are retrieved from a user story according to the dependency relations created by the dependency parser.

3.6.5 Advanced Filtering

According to the dependency parser, the extracted 3 words are needed to be compared with the Part-of-Speech (POS) tag [58] of those words. Stanford uses Penn Treebank and there are 45 tags in the Penn Treebank tag set for English and it is shown in Figure 3.12.

Tag	Description	Example	Tag	Description	Example
CC	coordin. conjunction	*and, but, or*	SYM	symbol	+,%, &
CD	cardinal number	*one, two*	TO	"to"	*to*
DT	determiner	*a, the*	UH	interjection	*ah, oops*
EX	existential 'there'	*there*	VB	verb base form	*eat*
FW	foreign word	*mea culpa*	VBD	verb past tense	*ate*
IN	preposition/sub-conj	*of, in, by*	VBG	verb gerund	*eating*
JJ	adjective	*yellow*	VBN	verb past participle	*eaten*
JJR	adj., comparative	*bigger*	VBP	verb non-3sg pres	*eat*
JJS	adj., superlative	*wildest*	VBZ	verb 3sg pres	*eats*
LS	list item marker	*1, 2, One*	WDT	wh-determiner	*which, that*
MD	modal	*can, should*	WP	wh-pronoun	*what, who*
NN	noun, sing. or mass	*llama*	WP$	possessive wh-	*whose*
NNS	noun, plural	*llamas*	WRB	wh-adverb	*how, where*
NNP	proper noun, sing.	*IBM*	$	dollar sign	*$*
NNPS	proper noun, plural	*Carolinas*	#	pound sign	*#*
PDT	predeterminer	*all, both*	"	left quote	' or "
POS	possessive ending	*'s*	"	right quote	' or "
PRP	personal pronoun	*I, you, he*	(	left parenthesis	[, (, {, <
PRP$	possessive pronoun	*your, one's*	)	right parenthesis	],), }, >
RB	adverb	*quickly, never*	,	comma	,
RBR	adverb, comparative	*faster*	.	sentence-final punc	. ! ?
RBS	adverb, superlative	*fastest*	:	mid-sentence punc	: ; ... – -
RP	particle	*up, off*			

Figure 3.12. Penn Treebank Part-of-Speech tagging [58]

- **Actor Filtering**

Since the actor entity is extracted from the relation 'root' in the sentence 01, it could be either noun or a verb according to the given user story. But basically actor should be a noun that is NN according to Figure 3.12. Therefore the POS tag of the lemmatized word actor extracted from the previous step should be a noun. If the POS tag of that word actor is equals to 'NN' then it is taken as the correct actor word and system would process further.

Example:

"As a add I want to create users in the group"

Here the word 'add' is extracted from the dependency parser since it is the root word of the sub sentence "As a add". But it is not a noun (NN) so to handle such cases here the actor word 'add' should be compared with its POS tag. Since the POS tag of word 'add' is not a noun the system would reject that user story sentence.

There are cases where actor can be either noun or the noun phrase of the sentence. This actor being either noun or the noun phrase would be depend on the context of the software product in different software companies. Here in the above mentioned actor extraction method in this thesis, it has only considered on the noun word which is given from the dependency parser and it is shown in Table 3.7.

Table 3.7. Extracted actor names and expected actor names

Sentence	Expected actor word	System extracted actor word
As an admin	admin	admin
As an user admin	admin	admin
As an admin user	Admin user	user
As an system administrator	administrator	administrator
As an registered user	Registered user	user

- **Object Filtering**

In the dependency parsing step objects are extracted from the relation 'dobj' or 'dep' from the sentence 02. Here 'dobj' is the direct object relation in the sentence and 'dep' is the relation for words where parser cannot identify relation as described in above section. There can be more than one 'dobj' relations and 'dep' relations in a given sentence due to different

other words. Here what actually needed is the exact word of the object which is directly accessed by the extracted action word. Therefore in the typed dependencies, the dependent word should be extracted according to the governor word. If the governor word is the same word as the action word then that dependent word is the relevant object for that user story. This word also needs to be compared with its POS tag and it should be a noun tag. Only if these conditions satisfy then the system will process with the next steps with the extracted triplets.

```
root(ROOT-0, add-1)
dobj(add-1, members-2)
acl(members-2, using-3)
dobj(using-3, list-5)
compound(list-5, member-4)
```

Figure 3.13. Typed dependencies extracted for the sentence “add members using member list”

The above Figure 3.13 illustrates a situation where there are more than two direct objects (members and list) have identified from the dependency parser. But the system wants only the word ‘members’ which has the governor word as root word ‘add’. Therefore the correct direct object word can be filtered by comparing the governor word with the root word of that sentence.

According to the method mentioned above, the relevant entities are extracted from a given user story as Actor, Action, and Object in a triplel form. Then those entities are passed to the Ontology component for reasoning purpose and to drive the test cases of that user story.

3.7 Test Case Generation Using Reasoning

The software requirement Ontology is the knowledge base for the generation of positive test cases. Therefore this section describes the related reasoning logics that have been applied to the Ontology for the derivation of test cases. The required positive test cases are derived, based on the three major parameters which are extracted from the user stories as described in Section 3.6. The parameter list is taken as actor, action, and object.

The use of parameter list provides the flexibility to achieve the desired output, which is a test case. The first step of requirement Ontology traversal is to restrict possible paths concerning the given three parameters. As mentioned in early sections for a given user story relationships are coupled with actor, action and object inputs. In this first step the actor parameter finds out the existence of the given actor within the Ontology. If it exists then traverse through the Ontology to find what are the possible actions which have the relationship with given actor. If any, compare actions with given action parameter and take as the true path for the correct match with given action. Then find out the existence of given object parameter according to the relationship between given actor and action. The result is true for correct findings of relationships between given parameters. The false or unmatched situations occurred with if the required relationship not mentioned in requirement Ontology. This false situation is not eligible to generate any test case. The system provides another searching mechanism through the *hasSimilarWord* property. It finds if a given actor or action not directly matched finds a relationship for the similar word which indicates similar meaning. Figure 3.14 depicts the correct path finding for a given parameters.

Parameters: Actor_A, Action_B, Object_A

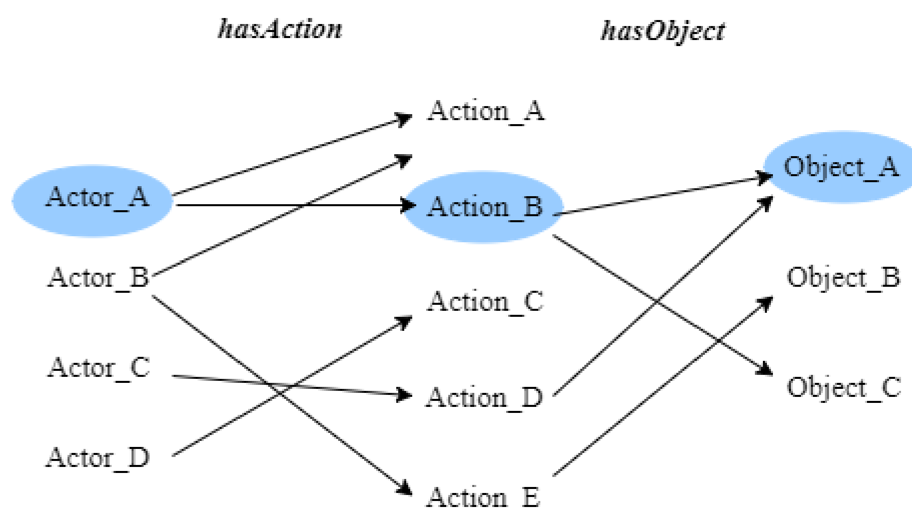

Figure 3.14. Find Out Ontology path for given parameters

3.7.1 Identify subclass of an action

The Section 3.5.4 described that each action belongs to a subclass according to its dependency on an object. The test case generation is directly coupled with this specific behavior of the action. Therefore identification of subclass is vital for further reasoning. The

action which belongs to *objectChange* subclass needs to consider about data properties of both action and related object. The action which belongs to *objectNotChange* subclass only considers the data properties of given action.

3.7.2 Identify implicit relationships of an action

The implicit relationship is a dependency on one or more actions for a given action. This relationship can be a one-way relationship or a two-way relationship. The developed software requirement Ontology maintains this implicit relationship knowledge. Therefore this reasoning mechanism is introduced to identify and extract of those related action entities.

The method checks if there exists *hasDependency* object property defined for the given action. The result set may be an empty set or set with one or more related actions. If any action instance has depended on another set of actions, then their properties and relationships also should be examined to generate test cases, because that information is essential to the consistency of the system. As mentioned in early sections the quality of the system is examined through test cases, and those test cases should cover every possibility of the relationship between system entities.

3.7.3 Extract data properties

The goal of this process is to extract the data properties concerning the given action and object. The data property represents the core information of a test case. These data properties are coupled with actions and objects in software requirement Ontology. According to the given parameter list, data properties are the output list of a valid traversal of Ontology graph.

There are two types of data properties,

1. Action Data Property: Describes characteristics of an action
2. Object Data Property: Describes features of an object

According to the methodology proposed in Section 3.5.4, the subclass of an action decides the type of data properties need to be extracted. The *objectNotChange* class instances only consider the action data properties. The *objectChange* class instances consider both action data properties and object data properties relevant to the given action.

The Figure 3.15 summarizes above-mentioned reasoning and illustrates as a flow diagram. Apart from the reasoning component, the flow diagram depicts a condition to find *hasPreCondition* of an action. In this case system searched for preconditions of an action that

has to be satisfied when to perform the relevant test case. If any precondition has been found it sends to the workflow component to handle in workflow component.

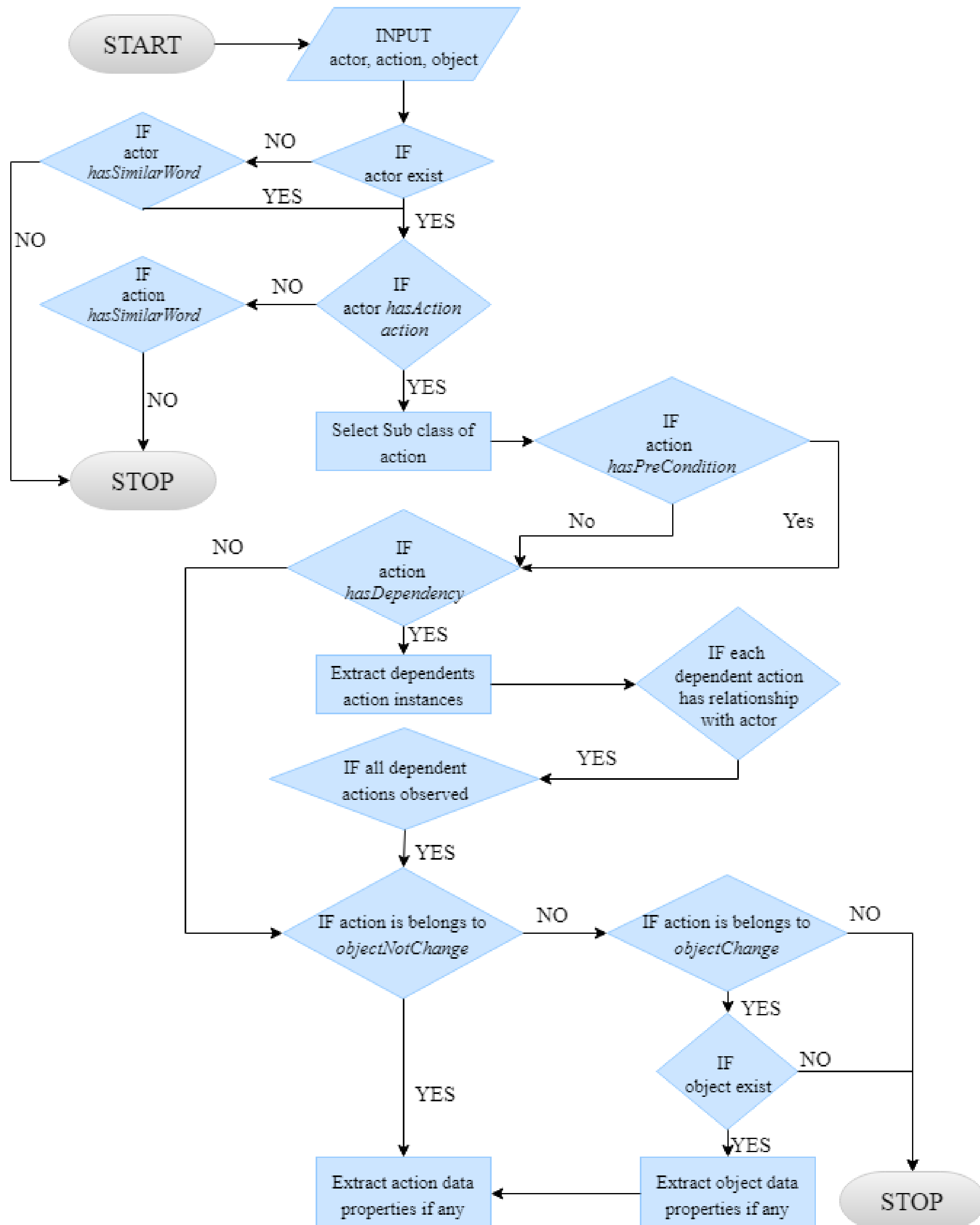

Figure 3.15. Flow of reasoning to generate test cases

3.8 Workflow for complete the test suit

The workflow component is used to complete the test suites which can be used to test entire functionalities of the system. The aforementioned methodology generates positive test cases using extracted action data properties and object data properties which cover a fair amount of test cases. As mentioned in early chapters testing is vital to develop a quality software product. Therefore test cases should cover the all the test objectives. This workflow component enables the flexible modification and insertion of test cases of the system. The automatically derived test cases may include unnecessary information or some essential information may be missed. The system user can use this component to modify derived test cases and add some new test cases or test steps. Also can set prerequisites of test cases according to the extraction through hasPreCondition of given action instance.

Apart from the modifications and insertions, this workflow component provides facility to maintain authoritative actions such as test suite recommendation and test suite approval from relevant system users.

3.9 A Simple Example

In this section a sample user story is used to generate test cases with following the above mentioned methodology. The user story is need to be written as the template discussed in the Section 3.3 and it would be as following.

"As a User Admin, I want to update an existing group in the system, so that I can manage users in that group easily."

Then entity extraction steps will be applied as below. Sentence will be pre-processed and 'so that' part will be removed from the user story.

"as a user admin I want to update an existing group in the system"

Then the user story will be splitted in to two seperate sub sentences as below.

Sentence 01: as a user admin

Sentence 02: update an existing group in the system

Then the each of the above two sentences are passed through the Dependency Parser and get relations according to the typed dependencies as described in Section 3.6.3.

Sentence 1: Actor- admin

Sentence 2: Action- update

Object- group

Then these words are lemmatized in order to get the base form of those words as below.

Actor: admin -> admin

Action: update -> update

Object: group -> group

Then these 3 entities are transformed into advanced filtering for the purpose described in section 3.6.5. POS tag of word ‘admin’ is NN (Noun) and since it is the correct tag for that word the process continues. Then checks if there are any other direct objects retrieved and if so, compare the object words with their governor word equals to action word ‘update’. Since this user story does not having any other direct objects the object will be filtered as word ‘group’.

As the final output in the entity extraction method, (admin, update, group) parameters are extracted and those will be passed to the Ontology for the reasoning and possible positive test cases for this user story will be extracted as follows.

For the reasoning first check the existence of the three entities and the existence of the relations between them. For the action update first check for hasDependency object property and found that update has dependency on view. First consider the action view. It belongs to objectnotchange subclass. Therefor first take the data properties of the action view as test cases and then consider the properties of the action update. Then consider the class of the action update. Here update is belongs to objectchange subclass, therefore data properties of the extracted object is need to consider and its’ data properties are given as the other set of test cases. Those test cases are shown below.

From action view:

view_top_N_views

View_all_objects

From action update:

Send_a_confirmation_message

Update_after_approval

From object group:

update group with non_existing_name

update group with non_empty_name

update group with name_with_numeric_values

update group with lengthy_name

update group with name_with_special_characters

update group with users

update group with user_roles

3.10 Summary

This chapter presented the proposed methodology for the research questions that were identified concerning manual test case design in software testing phase. According to the background analysis test cases, user stories and requirements were identified as main terminologies that impact in the test design phase. Basically, the overall research intent was to find a possible methodology for the automatic generation of test cases from user stories written in the natural language based on an Ontology. A complete possible methodology for developing an Ontology for software requirement domain, extracting entities from user stories written in English and generation of test cases from user stories has been proposed through this chapter.

According to this approach, the first main underlying concept is developing an Ontology model for the software requirement domain. Practically any of the requirement sentence can be recognized through the actor, action and object entities of that sentence and it could be shown that test cases are also based on those entities. Therefore the developed Ontology has its underlying concept model as actor, action, object and these were mapped as classes in Ontology. The action class was categorized into two different sub classes depending on whether the object changes once the action performed on that object. Object and data properties were defined for each of those identified classes and some object properties were defined to handle special cases like when there are implicit user stories or entities having similar words.

In the next phase NLP techniques were used to extract entities from input user stories in order to match them with the Ontology model concept developed. Therefore actor, action, object entities were extracted in the form of triplet by using typed dependency relations created from Dependency Parse tree. NLP method makes uses of parsing, lemmatization and POS tagging techniques while extracting the triplet.

For the test case derivation, those extracted triplet is then passed to the Ontology and reasoning would be done accordingly to retrieve the implicit information resides in that developed Ontology knowledge base. Whether to extraction action data properties or object data properties would depend on that identified two action categories. All the extracted information are then sent to the workflow to build the complete test suite for a particular epic scenario by allowing the user to do modifications as needed.

The feasibility of developing an Ontology from scratch is not possible and therefore only one requirement area was taken into consideration to show this proposed methodology. There comes the concept of involvement of an Ontologist into the software industry where Ontologist has the responsibility for evolving the knowledge-based as required.

Chapter 4

System Design

4.1 Introduction

This Chapter describes the design of the system that automates the test case generation based on Ontology according to methodology described in Chapter 3. This Ontology based test case generation framework covers the Ontologist involvement in software development, the system for test case generation and test case management activities. The system architecture consists of user story component, NLP component, Ontology component, reasoning component and workflow component as its main components. These components are further explained under this chapter with discussing the design aspects of the proposed methodology.

4.2 Design Goals

The goal of this proposed system is to generate functional positive test cases from user stories within the Agile development process. The user story is the main requirement representation mechanism in the existing agile process and it is currently used by the business owner or business analyst to provide information about the functionalities of the system to the developer.

The Ontology is the core component of the framework and this Ontology knowledge base model is not designed for a specific application domain. Therefore the underlying knowledge base in the developed Ontology can be evolved according to the requirements of software product with the involvement of an Ontologist.

Functional positive test cases are the primary output of this web-based system. The generated test cases can be managed through the system. The system aims to reduce the time and effort in manual test case writing. Not only that but also the user can generate complete

test suites from the system as their general test case design task and test suites can be taken as an input to their test management tool.

4.3 Design Constraints

The main design constraint of the suggested framework is that Ontology-based test case generation tool needs to be adapted to the existing Agile software development workflow as much as possible. The solution preserved agile terminologies such as user story and its characteristics. As described in Section 2.2.4, the story defines the requirements of the system in a way while expressing the functionalities. The framework use implemented Ontology knowledge model to derive positive test cases for a given user story. The proposed test case generation system is thoroughly dependent on the software requirement Ontology which is developed according to the information and observations collected through the research study.

The primary input to the system is a user story written in the natural language where in this approach it works only for English and it needs to follow the given format as described in Section 3.3. For the user stories are given in the correct format only be able to generate the relevant test cases through the system.

Another constraint is that the test case generation is a usable product of the introduced framework. The tool provides user story management functionalities such as update and deletes as well as provides management functionalities for test cases. The tool can be developed as a plugin for project management tools such as Redmine, Jira. Project management tool provides services such as estimations, requirement management, resource allocation, team collaboration options and documentation. Then generated test suite through the tool can be used as input for the test management tools such as Testlink. Test management tools are used to maintain information on how testing is to be done, test activities and status reporting of quality assurance activities. This system is a free-standing tool which does not have any link with project management or test management tools. Therefore tool can be integrated to those tools via integration mechanism such as plugin.

4.4 System Design

The design constraints that discussed in above section 4.3 helped to frame the design of Ontology-based test case generation tool.

Hence the overall design idea of the system is to automatically generate test cases based on an Ontology where requirements are taken in the form of user stories and the user stories are given as an input to the system. The Ontology domain is to build upon with requirement terminologies in the current Agile development process in the software industry. This developed Ontology would be reusable within any of the relevant software industry which follows specified Agile practices with writing requirements as user stories. Therefore if a particular company needs additional knowledge added to the developed Ontology, then it could be done with an involvement of an Ontologist into current software development process.

The input user story is provided by the relevant person who used to writes user stories in the software company environment and usually that would be QA person. The introduced framework accept this input if it is in the appropriate format and process them using NLP techniques that have been described in above Section 3.6 to extract triplets in the form of actor, action, object. Extracted triplets are used to query the Ontology described in above Section 3.5. Properties from the Ontology are retrieved and produced as test cases which are giving as the final output. The Figure 4.1 below shows the high-level picture of the system design. Set of test cases for each user story under an epic are presented as a test suite. This tool can be used as a user story management tool and the generated test suite can be passed to a test case management tool as described in Section 4.3.

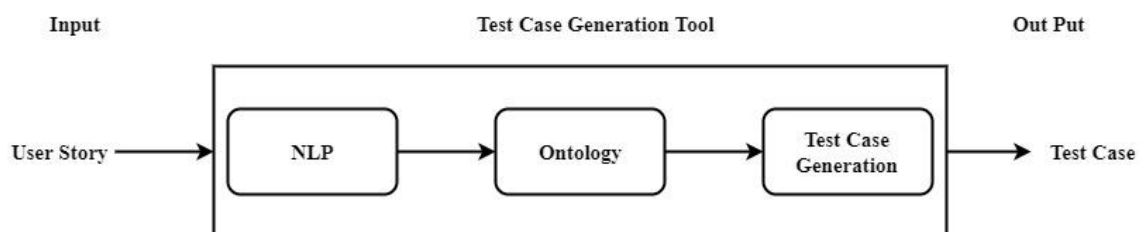

Figure 4.1. System design

The design of this suggested approach has adopted the principles, guidelines and terminologies of agile software development which encourage the product owners, developers and testers interest of use while keeping their familiarity within the process of software development. Moreover, Object Oriented Principles [59] have also gained

consideration with the design of the system. To build up the system design as shown in Figure 4.1, the element components described in the next section are considered to be more loosely coupled with achieving higher cohesion. Also the design has been considered using Design Patterns [59] like MVC. Both the Encapsulation and Abstraction Object Oriented Principles would be able to achieve through using this MVC design pattern in the design.

4.5 System Architecture

The System Architecture section provides an overview of this web-based system's dominant components and its architecture, as well as specifications on the interaction between the system and the user.

The suggested research-based solution is designed with the idea of being an independent component. As mentioned in chapter 2, most of the project management tools that use to write and maintain user stories are web-based systems. Therefore the design of this suggested system also considered on this aspect where such tools can be integrated with this. The main components of the system were determined as Ontology component, NLP component, Reasoning component, user story portal and database management system. The intention is to focus on an application architecture rather than enterprise architecture since applications architecture defines the interaction between application packages, databases which specified on business and functional requirements while application architecture is one of several architecture domains that form the pillars of enterprise architecture. Considering the components identified for the proposed system, 3-tier architecture can be recognized as the suitable application architecture. In 3-tier architecture these tiers represent different aspects of presentation, business logic, and data access to the application. Above components can be categorized into those layers accordingly and the overall system architecture can be shown as in the Figure 4.2.

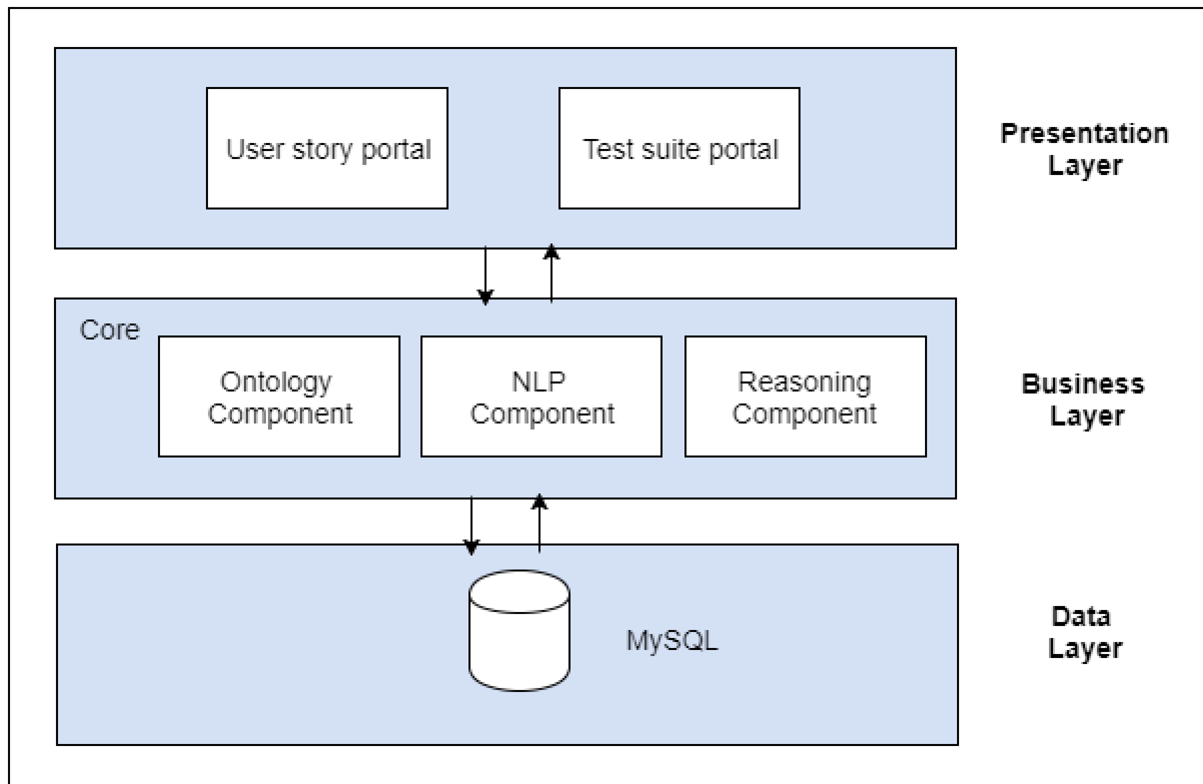

Figure 4.2. System Architecture Diagram

Architecture diagram in Figure 4.2 describes how the components match with each other in order to complete their works. User story portal component in presentation layer has been used as the user interface to write user stories and it provides functionalities for view and update of user stories. Generation of test cases for each user story can also be performed by the user by this component. Once the test cases are generated from the system, the user can update or delete them accordingly and that functionality provided by the test suite portal in the presentation layer.

The Business layer consists of the business logic of the suggested solution. It contains the Ontology component, NLP component and Reasoning component and it can be considered as the core component in this architecture. The Ontology has been developed and implemented according to the methodology described in Chapter 3 which is based on the research described in Chapter 2. The concept of actor, action and an object in a user story sentence was based on the developed Ontology and corresponded entities in user stories are extracted through the NLP component. In the Reasoning component, reasoning techniques will be applied on the knowledge base presented in the Ontology according to the extracted inputs from user story and get the required result as test cases. These results are then passed

to the test suite portal for the modifications that would need to be done. Test suite portal is in the presentation layer where user has the ability to do the necessary changes by adding or deleting relevant details in the derived test cases.

The Data Layer consists of the database and suitable logic. Data layer provides simplified access to data stored in persistent storage. In here a relational database management system has been proposed for providing efficient data access.

4.6 Summary

In this chapter it described the overall design of the proposed methodology discussed in the previous chapter. To achieve the design goal of generating functional positive test cases from user stories based on an Ontology module would be the target through several components. So the architecture for this designed system can be recognized as a 3-layer architecture that contains User story portal component and Test suite component in the presentation layer while NLP component, Ontology Component and Reasoning component in the Business layer and Database component in the Data layer. A user would be able to enter user stories into the system using user story portal component. Core components in the Business layer would derive test cases for that input user stories from the presentation layer. NLP component will extract relevant entity triplet and passed it to the Ontology component and then the Reasoning component would derive necessary test cases and passed them to the Test suite component to be displayed to the user. The database component provides relevant logics with a persistent storage needed within the user story and test suite components. All these components are designed with the consideration of achieving Object Oriented Principles while applying design patterns as far as possible.

Chapter 5

Implementation

5.1 Introduction

This chapter describes implementation details of the suggested Ontology-based test case generation method, which realizes the system design explained in Chapter 4. It has captured the fundamental implementation details with technologies and tools used. Further it focuses on the Graphical User Interfaces used within the implementation of this proposed tool and its features. According to the system architecture described in Chapter 4, the implementation details of core components which are Ontology component, Triplet extraction with user story portal, Test case generation and workflow component are illustrated in this chapter.

5.2 Implementation Details

The system is a web-based solution because users can easily access the application from any computer. Moreover, currently software companies use different tools for their project management and test management. The proposed system is a supportive independent solution to produce a bridge between project management and test management.

The Eclipse has been selected as the Integrated Development Environment (IDE) to develop the web-based tool which is an open source IDE. The used package of IDE was Eclipse Jee Neon for Java EE Developers. The Java, which is both a programming language and a platform, has been selected for the development of Ontology-based test generation system. The Java follow particular syntax and style for express its high-level object-oriented programming language capability. Also, Java platform is a specific environment in which Java programming language applications run. The proposed solution used Java Enterprise Edition as its programming language platform. The Java EE selected because it provides API

and runtime environment for developing multi-tiered, scalable and secure network applications. The proposed system follows three-tier architecture as described in Chapter 4. Not only that, Java EE provides libraries for JDBC for access Ontology-based test case generation database, Servlets and JSPs.

The Spring MVC framework has been used to develop the test case generation system. Spring is a powerful Java application framework which provides a very clean division between controllers, JavaBean models and views. The proposed system used UserstoryController, TestcaseController, and LoginController as its controllers to handle functionalities. Also used separate models and views accordingly as illustrated in Figure 5.1. Other advantage of Spring MVC is its flexibility, which entirely based on interfaces and Spring provides an integrated framework for all tiers of the application.

The Hibernate framework has been used to the development of the system to interact with the database. Hibernate considered as an open source lightweight Object Relational Mapping tool. The system used a relational database for manage user stories and test cases. Therefore ORM simplifies the data creation, data manipulation and data access using programming technique that maps the object to the stored data in the database. Automatic Table creation is one of the main advantages that was gained using the Hibernate framework within the system.

MySQL database has been used as the database, which is a free and open source database management system. The following Figure 5.1 depicts the spring MVC and hibernate architecture of the system according to the above-mentioned facts. The implementation architecture can be divided into layers as spring controller, service layer, and data access layer. The entire system implementation follows this architecture and will be explained in 5.4, 5.5, 5.6 and 5.7 respectively.

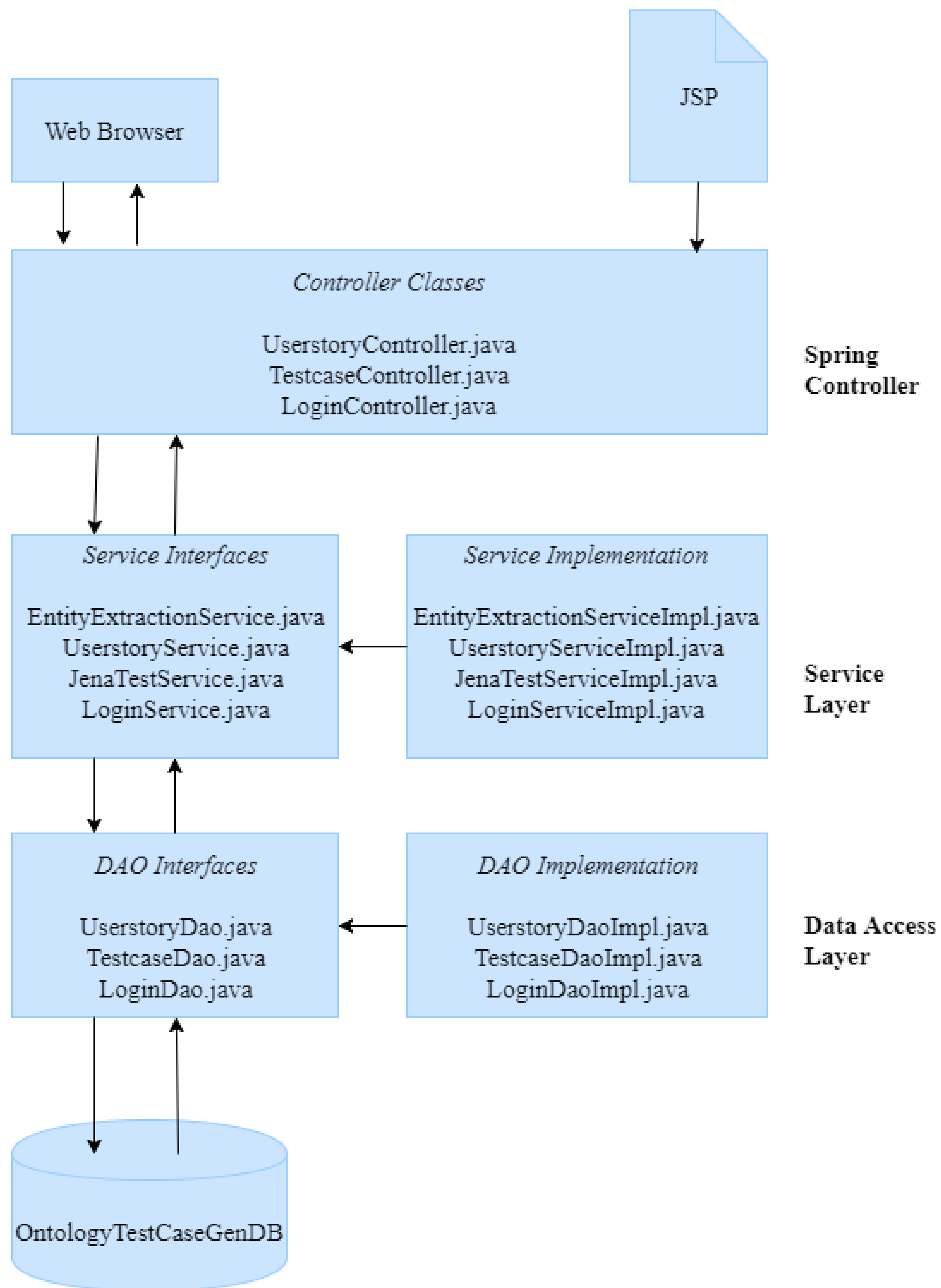

Figure 5.1. Spring MVC - Hibernate architecture of the system

5.3 Graphical User Interface

The Graphical User Interface (GUI) provides the user interaction with the system of the proposed framework. The GUI is created using Java Servlet Pages (JSP) which is a technology for developing web pages. JSP supports for dynamic content and helps developers to insert java code in HTML pages. Also JSP supports to collect input from users through web page forms, existing records from relations database and software requirement Ontology. The proposed system have been used JavaScript, JQuery and Bootstrap as front-end frameworks for facilitates interactive GUI through JSPs.

5.3.1 GUI components

GUI has been developed keeping into consideration the process, terms and functionality already used in Agile Software Development and Agile Testing. The GUI consists of the following main components.

When an authorized user logged in to the system, home page should be like following Figure 5.2 .This has functionalities for create new user stories and delete already created unimportant user stories.

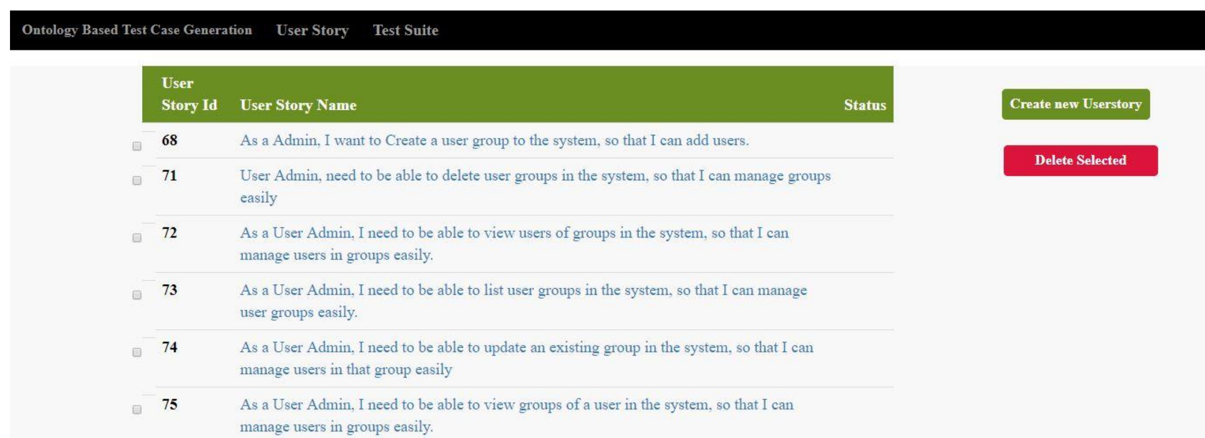

Figure 5.2. Home page

- **User Story Form**

User stories realized the features by describing the interaction between the system and the user. The user story must clarify the role of the user, the feature to be implemented and the benefit derived from the feature.

When a user needs to create a new user story, a user story template should be like Figure 5.3. Epic No is the Id of the Epic that user story is belongs to. The pre-defined template for user stories is as a [role], I want [functionality], so that [business value]. That should be entered in the User Story Name field. Assignee, status and priority need to be entered for manage the task. The user story may be used in different contexts. Each context and outcome of the user story is called acceptance criteria. Those every field is taken to cover a full user story and to improve the completeness of the system.

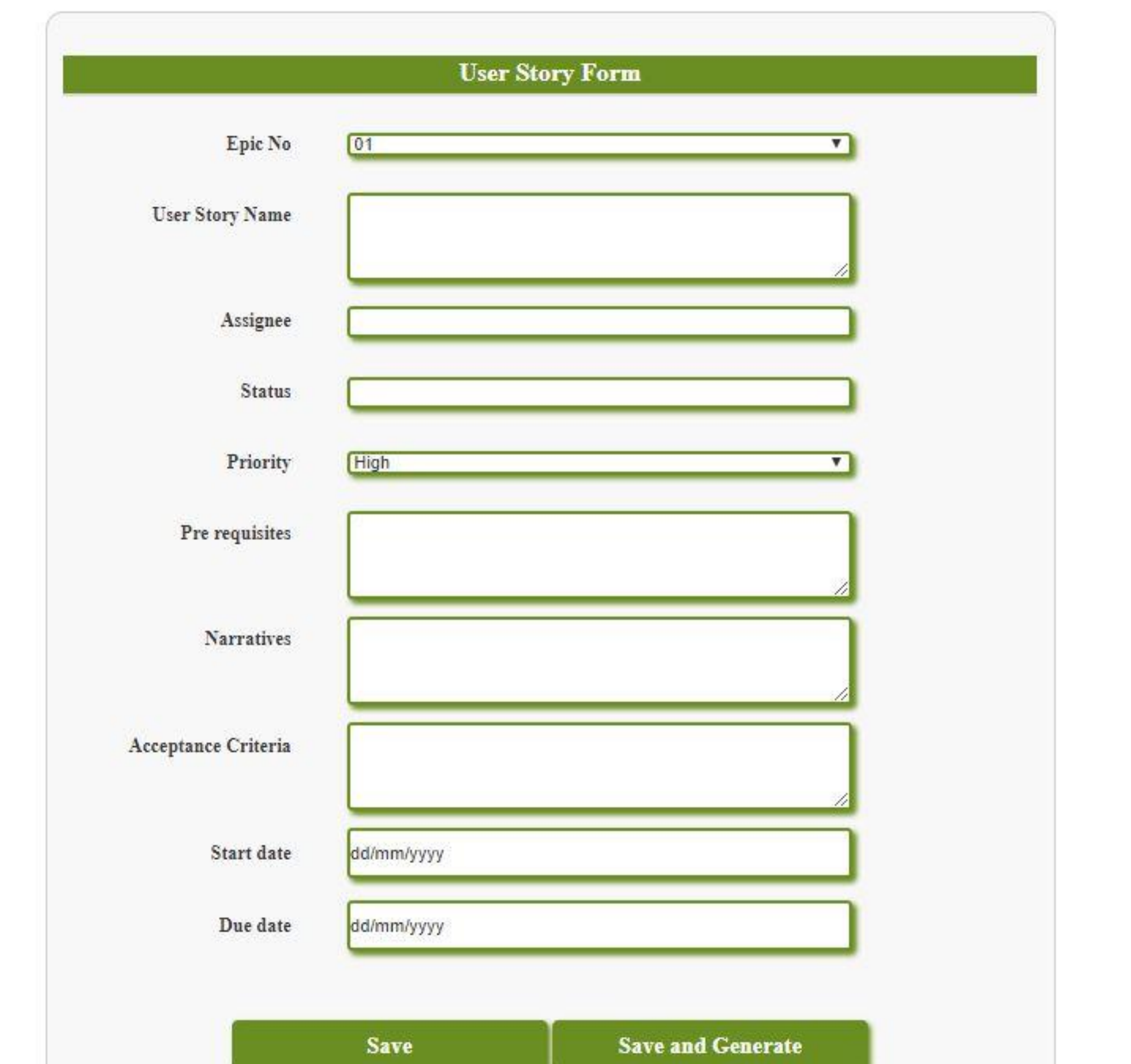

Figure 5.3. User Story Form

When an entered user story is clicked, its' details are shown as Figure 5.4.

User Story Id	68
User Story Name	As a Admin, I want to Create a user group to the system, so that I can add users.
Status	
Assignee	Pushpalanka Jayawardhana
Priority	Medium
Pre requisites	1. User must be logged into Admin Portal. 2. User must have the required privilege to add a group.
Narratives	User selects option to add a new group. 2. User selects the identity store that group needs to be added to. 3. User types the mandatory group name. 4. User optionally type a description. 5. User may optionally add users to the group if needed. 6. Use
acceptance Criteria	New group must appear in the group list. 2. Audit log must have an entry on the group addition and its users and roles. 3. Users added to the group must appear in the group's view. 4. If the action is successful, then it should be notified in the UI. 5. I
Start Date	03/01/2017
End Date	

Generate Edit Delete

Figure 5.4. View Selected User Story

Entered user stories can be Edit or Delete by clicking the user story to view. Those functionalities were given to improve the flexibility of the system. A user can save user stories without generating the test cases at the same time and can generate test cases when needed. Figure 5.4 depicts the filled user story which can be used to generate test case if not yet generated. Also, the system provides functionalities for editing and deleting user stories which have been already entered.

- **Test case management**

Generated test cases are shown as a test suite. The relevant test cases can be viewed by clicking on the user story. If the generated test case is not valid, an authorized user can delete or modify it to a valid one. New missing test cases also can be added to the system. Figure 5.5 represents the already generated test suites which are a collection of user stories as shown in Figure 5.6. The Figure 5.7 depicts the generated test cases for each relevant user story.

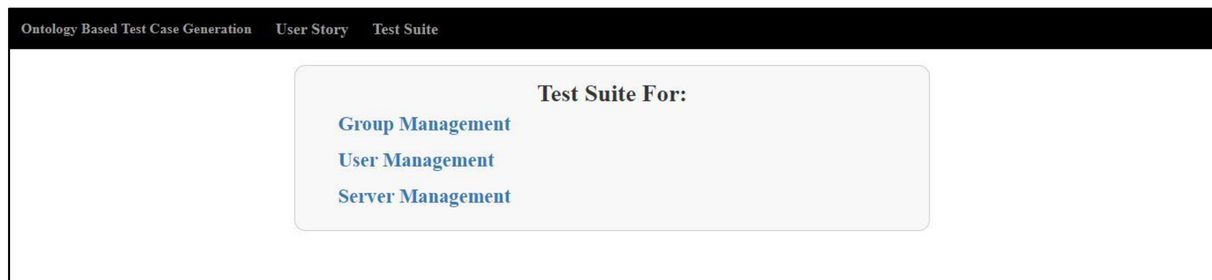

Figure 5.5. Test Suite for Epics

Ontology Based Test Case Generation User Story Test Suite

Epic Name- Group Management

User Story Id	User Story Name
1	As a Admin, I want to Create a user group to the system, so that I can add users.
2	User Admin, need to be able to delete user groups in the system, so that I can manage groups easily
3	As a User Admin, I need to be able to view users of groups in the system, so that I can manage users in groups easily.
4	As a User Admin, I need to be able to list user groups in the system, so that I can manage user groups easily.
5	As a User Admin, I need to be able to update an existing group in the system, so that I can manage users in that group easily
6	As a User Admin, I need to be able to view groups of a user in the system, so that I can manage users in groups easily.

Figure 5.6. User Stories in the Epic

Ontology Based Test Case Generation User Story Test Suite

Add New Group

Test Case ID	Test Case
1	Create a group with valid name
2	Create a group, name with special characters
3	Create a group name with numeric characters
4	Create a group with lengthy name

Send For Approve Edit Delete

Figure 5.7. Test Cases for a Relevant User Story

5.4 Implementation of Ontology

In Section 3.5 of the Chapter 3 Methodology, overall Software Requirement Ontology has been discussed. The implementation of Ontology and used technologies are discussed here.

The Ontology has developed using a tool called protégé in OWL language. The primary purpose of the Ontology is to classify things regarding semantics, or meaning. Classes and subclasses, instances of which in OWL are called individuals are used to achieve this in the OWL. The individuals that are members of a given OWL class are called its class extension. A class in OWL is a classification of individuals into groups which share common characteristics. If an individual is a member of a class, it tells a machine reader that it falls under the semantic classification given by the OWL class. Individuals in OWL are related by properties. There are two types of properties in OWL as Object properties which relate individuals of two OWL classes and Data properties which relate individuals of OWL classes to literal values. Figure 5.8 depicts segment of implemented Ontology file in RDF format.

```
<!-- http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#actor -->

<owl:Class rdf:about="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#actor">
    <rdfs:subClassOf rdf:resource="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#Concept"/>
</owl:Class>


<!-- http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#hasObject -->

<owl:ObjectProperty rdf:about="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#hasObject">
    <rdfs:domain rdf:resource="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#action"/>
    <rdfs:range rdf:resource="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#object"/>
</owl:ObjectProperty>


<!-- http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#ID -->

<owl:DatatypeProperty rdf:about="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#ID">
    <rdfs:domain rdf:resource="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#actor"/>
    <rdfs:domain rdf:resource="http://www.semanticweb.org/prabhavi/ontologies/2017/9/untitled-ontology-53#object"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#integer"/>
</owl:DatatypeProperty>
```

Figure 5.8. Part of RDF file

5.4.1 OWL and RDF

RDFS and OWL have been used to encode RDF data with semantic metadata. Therefore OWL is based on RDF and OWL Ontologies are RDF documents. OWL provides sufficient expressive richness to be able to describe the relationships and structure of entire worldviews or the so-called terminological construct in description logics. At the level of OWL Ontologies, RDF can capture virtually any relationship and aspects. RDF is expressed as a simple subject–predicate–object “triples” and substitute verb for predicate and noun for

subject and object. OWL is a way of adding semantic richness to RDF. Among other things, this allows automated reasoning/inferencing and represents using RDF triples and typically expressed using RDF/XML syntax. RDF defines the way how to write things while OWL defines ways what to write. RDF is a specification which tells how to define triples. The problem is that RDF allows defining everything. If the declaration is as follows, it will allow by the RDF.

Subj	predicate	object
Alex	Eats	Apples
Apples	Eats	Apples
Apples	Apples	Apples

When such triples are written with RDF, they form valid RDF documents. However, these are semantically incorrect and RDF cannot help to validate what have written. This is not a valid Ontology. OWL specification defines precisely what you can write with RDF to have a valid Ontology. Therefore when creating the Ontology and retrieving its data, both OWL and RDF are needed.

RDF work as a common framework and vocabulary for representing instance data, describing simple data structs to complete vocabularies/Ontologies for processing and inferencing rules. It is an emergent model. It begins as simple “fact” statements of triples as described above, so that may then be combined and expanded into ever-more complex structures and stories. As an internal, canonical data model, RDF has advantages over any other approach. It can represent, describe, combine, extend and adapt data and their organizational schema flexibly.

5.4.2 Protégé Tool

As the Ontology editor, Protégé the most famous editing tool has been used. Protégé is a feature-rich Ontology editing environment with full support for the OWL. It is a downloadable, open-source, platform independent tool which requires a Java Runtime Environment developed by the Stanford University School of Medicine to acquire, represent, and process information about human health. Protégé provides a consistent rendering of Ontology entities, using URI fragments or annotation values. In Protégé classes and individuals are represented as rounded squares and properties are drawn as arrows. The shapes and arrows have labels that hold the name of each class or property, except the *hasSubclass* relationship, which is given unlabelled to avoid cluttering the visualization.

5.5 Implementation of Entity Extraction with NLP techniques

Implementation of this was also based on the architecture shown in Figure 5.1. By following Spring MVC framework, as shown in that diagram the development classes and interfaces were defined as needed.

The primary input to the system would be user stories and once a user story was entered into the system, then test cases for that particular user story could be created. A user can enter details of user stories while creating a new user story and details can be edit and delete if needed since this is an agile environment. All those methods are accessed through *UserstoryController.java* class. These methods are implemented in the *UserstoryServiceImpl.java* class which implements the *UserstoryService.java* interface. These details would be saved within the database according to the methods implemented in the *UserstoryDaoImpl*,java class which implements the *UserstoryDao.java* interface.

When the user story has written, then if the user wants test cases can be generated. To create test cases, entities from the user story need to be extracted. *ExtractTriplets()* method is implemented in the *EntityEctractorServiceImpl.java* class and it makes use of the Stanford CoreNLP toolkit libraries for the NLP techniques needed. Stanford typed dependencies parser, lemmatization, POS tagging techniques was used for this implementation.

Following Figure 5.9 represent the implementation details regards to the user story creation and entity extraction.

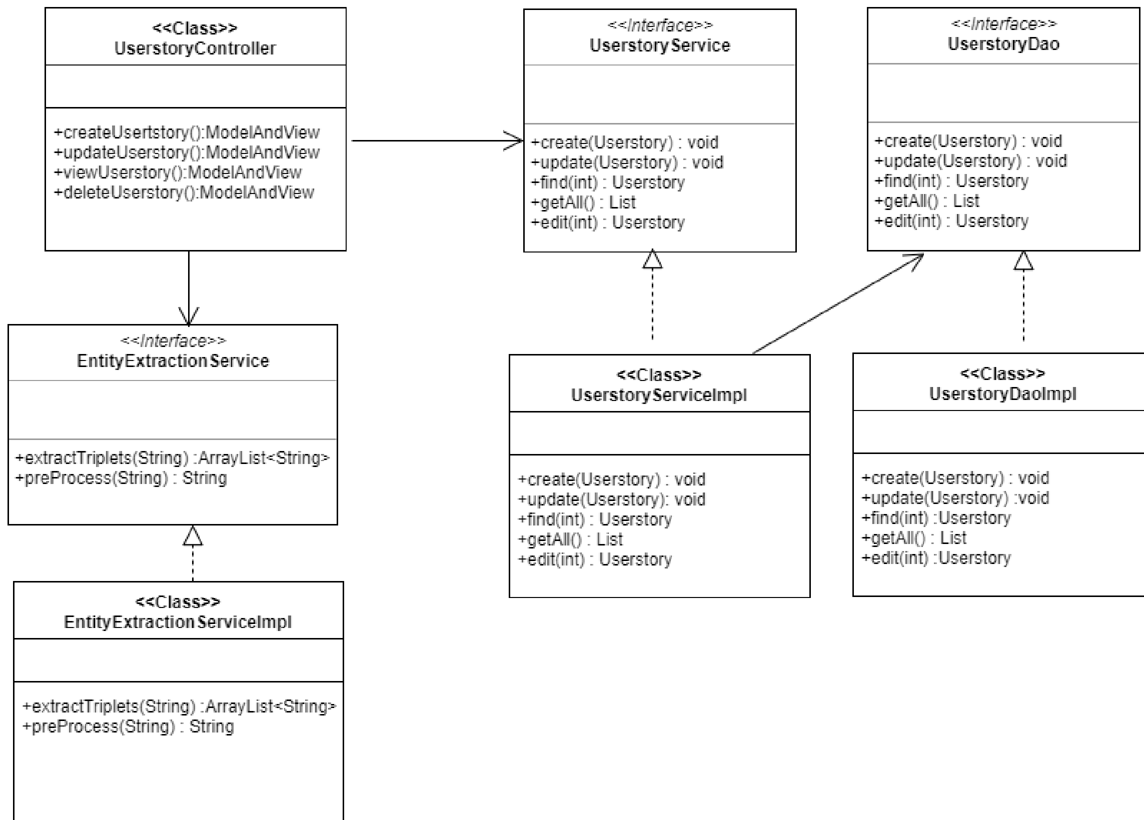

Figure 5.9. The classes of the user story portal and Entity Extraction

5.6 Test case generation

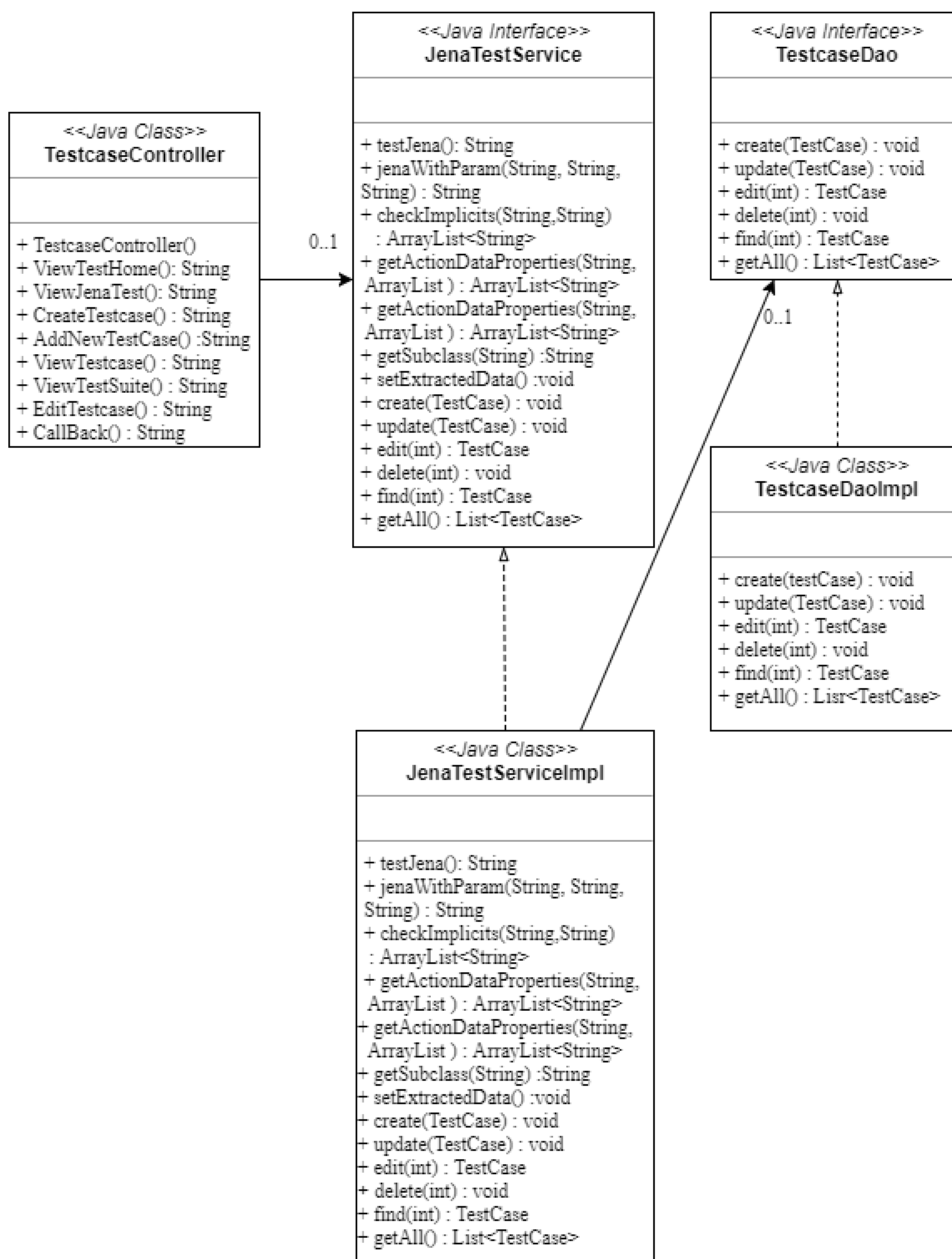

Figure 5.10. The classes of the test case generation and workflow

The test case generation component is related to reasoning on developed Ontology. As mentioned in Section 3.7 realization of reasoning carried out in several steps. The tool is

introduced as a web-based solution which is build based on Java EE. For the reasoning and derivation of test cases, Apache Jena API has been used. Apache Jena is a free and open source Java framework for building semantic web and linked data [60]. The web-based tool used apache-Jena 3.6 library to provide the service. This library contains the APIs, SPARQL engine, the TDB native RDF database and different types of command line scripts and tools.

According to the Spring MVC framework separate controller class namely, TestcaseController.java used to control the functionalities of test case generation. The Figure 5.8 depicts how the *TestcaseController* class process with service class to perform the reasoning on Ontology. *JenaTestService.java* class declare the methods and *JenaTestServiceImpl* class implemented the method for searching and retrieving knowledge relevant to test cases from the software requirement Ontology.

JenaTestServiceImpl uses the Jena API for selecting and adding test cases. It provides methods for loading OWL Ontology and retrieves relevant properties according to the given parameters. The underlying logic has been described in Section 3.7. In this class SPARQL query language has been used to query the results from the Ontology. SPARQL queries applied on OWL Ontology which was saved in RDF format. SPARQL provides explore data by data by querying unknown relationships and Transform RDF data from one vocabulary to another. Several numbers of queries have been used to derive test cases according to the mentioned methodology in Section 3.7. The *JenaTestServiceImpl* provides methods for restructuring the test cases according to retrieved properties and including methods for add other features such as precondition, steps and expected result. This realization of class functions related to the test case generation is shown in Figure 5.10.

5.7 Workflow component

The workflow component is more related to test case management. The component uses database management functionalities to maintain test cases, approval of generated test cases. As mentioned in Section 5.1.2, derived test cases are managed by this component. Modification to the test cases, ignore additional test cases, insert new test cases, set prerequisites of test cases which have extracted in reasoning component, manage approval of test cases, the complete creation of test suite and database operations are considered as principal operations of this component. The *JenaTestServiceImpl* provides methods for approve test case as a valid test case and creates a complete test suite. Then *TestcaseDaoImpl* provides methods for database activities such as insert, delete, update and delete. MySQL

relational database has been used to manage test cases and test suites. Figure 5.8 depicts methods of database activities of *TestcaseDaoImpl*. The use of workflow component encourages the flexibility and the maintainability of the proposed system.

5.8 Summary

To implement this web based system Eclipse IDE and Java EE has been used. The Spring MVC framework has been used to develop the test case generation system where Hibernate has been used as the ORM tool between the RDBMS and the object classes implemented.

For the implementation of Ontology, OWL language has been used where OWL Ontologies represented as RDF documents. As the Ontology editor, Protégé has been used which has a feature-rich Ontology editing environment with full support for the OWL and it presents as a downloadable, open-source product.

The user story form has been implemented in a way such that the system user can enter details of user stories and can make modifications or deletions as needed. To retrieve relevant test cases for a written user story then entity extraction need to be done and to implement that Stanford CoreNLP toolkit was used while making use of its libraries. Stanford typed dependencies were used to identify the relations between the word in a given sentence. All these were implemented using Spring MVC framework with defining relevant methods inside java classes while Hibernate supports as the connection between the database and its model classes.

The system implementation used Apache Jena API for manipulating OWL Ontology and SPARQL for reasoning. The Java methods have used to restructure derived test cases. The Java Hibernate framework used for manages test cases and test suite for providing usable end to process to the user. The primary objective of this system implementation is to reduce the manual involvement between requirement representation and test case designing in current software development industry.

Chapter 6

Results and Evaluation

6.1 Introduction

This Chapter describes present results of the proposed framework. These results can be divided into results of Ontology-based test case generation framework (base analysis) and user evaluation of proposed framework in software development industry. As mentioned in previous chapters the proposed solution has focussed on the generation of positive test cases. Therefore the analysis is based on whether test cases provide good test case coverage and if the system can generate accurate and quality test cases. The base analysis evaluates the performance of the system for the group management scenario of the specific end product of well-known software company in Sri Lanka.

The base analysis based on following aspects: triplet extraction from user stories, software requirement Ontology evaluation, Ontology-based test case generation system evaluation. User evaluation has been conducted to analyze system generated test case coverage with manually written test cases by users and analyze feedback to the system by experienced professionals.

6.2 Datasets

Two datasets were used for the evaluation of the system. To evaluate the NLP component described in Section 3.6 have used a set of user stories (Dataset-1). This dataset has been attached in Appendix B. The Dataset-2 was gained from user stories of Group management epic of the developed product by a software company and user stories of HR management product by another software company. These user stories have been used to

generate test cases automatically. The automatically generated test cases have been compared with manually written original test cases for the evaluation.

6.3 Software Requirement Ontology Evaluation

Ontology evaluation is a significant problem that must be addressed if Ontologies are to be widely adopted in the semantic web related applications. In general, evaluation of Ontology is a challenging task. There is no standard evaluation measures like precision and recall which are used in information retrieval or accuracy measure used in machine learning. The unsupervised nature of Ontology learning further makes the evaluation process complex. Users facing a multitude of Ontologies need to have a way of assessing them and deciding which one best fits their requirements the best. Various approaches to the evaluation of Ontologies have been considered in the literature, depending on what kinds of Ontologies are being evaluated and for what purpose [61]. Four identified approaches are as follows:

- Comparing the Ontology to a "golden standard"
- Using the Ontology in an application and evaluating the results
- Comparisons with a source of data (e.g. a collection of documents) about the domain to be covered by the Ontology
- Evaluation done by humans

It is further suggested that it is practical to focus at different levels of the Ontology separately in evaluation rather than directly evaluate the Ontology as a whole because of the complex structure of an Ontology [61]. The Table 6.1 illustrates how these different levels of Ontology development can be evaluated by each of the evaluation approaches stated above.

Table 6.1. An overview of approaches to Ontology evaluation [61]

Level	Gold standard	Application Based	Data driven	Human evaluation
Lexical vocabulary concept data	X	X	X	X
Hierarchy, taxonomy	X	X	X	X
Other semantic relationships	X	X	X	X

Context, application		X		X
Syntactic	X			X
Structure, architecture, design				X

This research use application based evaluation techniques out of the four Ontology evaluation techniques above.

6.3.1 Application-Based Evaluation

The Ontology will be used in some application or task. The outputs of the application, or its performance on the given task, might be better or worse depending partly on the Ontology used in it. Therefore a good Ontology is contributing for a good result of an application. Ontologies may, therefore, be evaluated simply by plugging them into an application and evaluating the results of that application. Therefore by evaluating the results of the Ontology-Based Test Case Generation Framework, the developed Ontology can be evaluated.

6.3.2 Reasoner Based evaluation

The Ontology is also can be evaluated by using reasoning service offered by reasoners plugged in Protégé. The main benefits of the services are computing the classes' hierarchy and logical consistency checking. Here HermiT 1.3.8 reasoner has been used as shown in Figure 6.1.

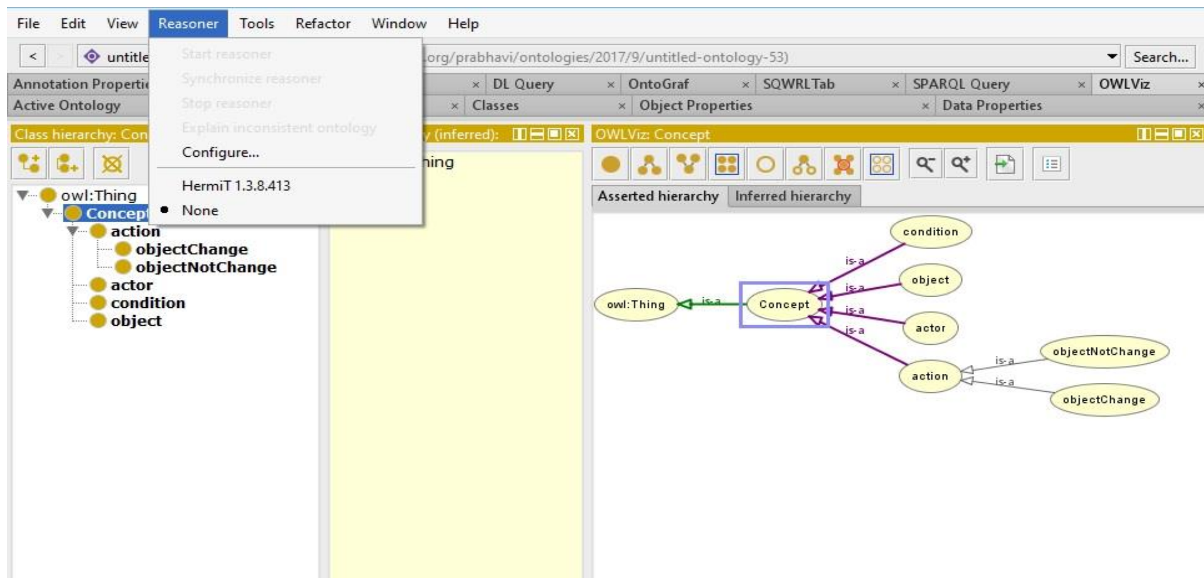

Figure 6.1. Protégé with no reasoner

Protégé has HermiT as its default reasoner to compute the OWL. The Ontology has been evaluated via HermiT 1.3.8. The following Figure 6.2 shows the inferred hierarchy graph.

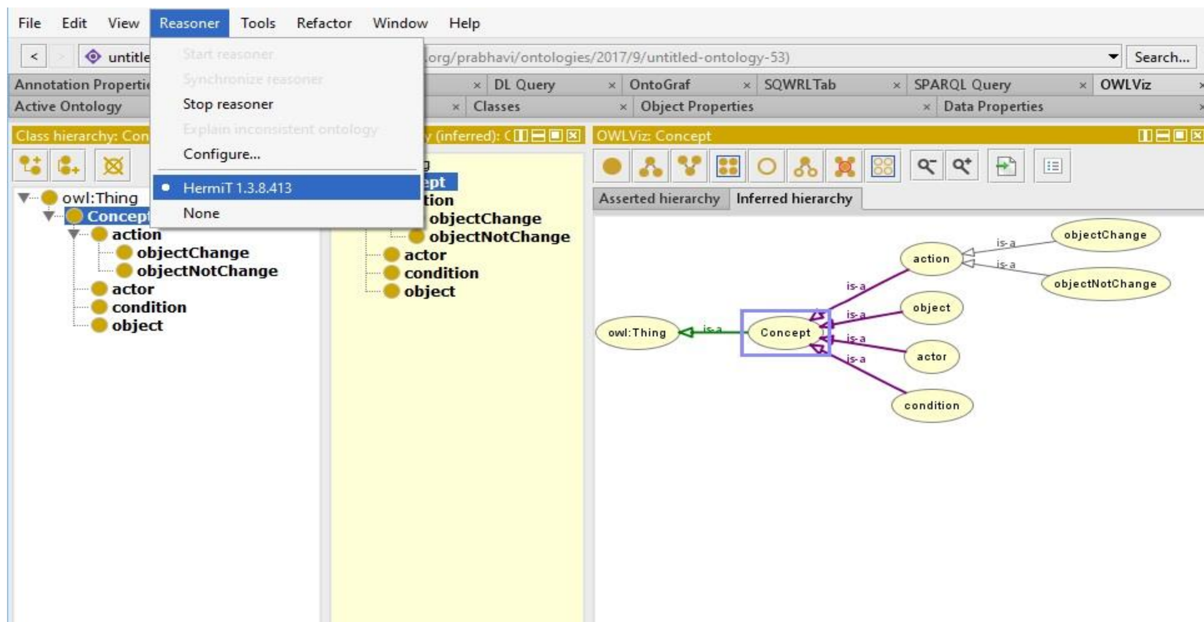

Figure 6.2. Protégé with HermiT 1.3 Reasoner

6.4 Analysis of Triplet Extraction

This analysis is based on the NLP component of the proposed system as described in Section 3.6. The principal objective of this analysis is to identify for what extent triplet extraction of the system performs well. Triplet is considered an actor, action and object which are taken as the input of reasoning.

6.4.1 Analysis of actor

The Advanced filtering method discussed in Section 3.6.5, the system identifies a valid actor word should be a noun which is extracted based on Stanford Dependency Parser [56]. From the sample data set identification of actor as a noun was 89% and 11% was identified as not a noun.

The nature of an actor word being either the noun or the noun phrase depends upon the context of the software product as mentioned in actor filtering topic under Section 3.6.5. According to the data set, valid actors for the system can be calculated by the following equation.

Valid Actor for the system = $\frac{\textit{No.of “correctly addresed” actors}}{\textit{No.of all actors}} \times \mathbf{100\%}$ = **65%**

No. of “correctly addressed” actors: Actor words that do not affect the functionality of software product and identified from the noun of noun phrase in user story.
No. of all actors: Actor words that identified as a noun from the user story dataset

According to the results, 65% actor words have been observed as a valid input to the proposed solution. However, 35% of actor words have affected the functionality of the software. This situation will affect the generation of test cases because the extracted actor word may or may not exist in the Ontology.

6.4.2 Analysis of action extraction

According to the comparison between extraction of action from the implemented NLP component and manual identification of action from user stories, the accuracy of the correctly extracted actions can be identified as follows.

From the comparison of actual action of user story with implemented NLP component results,

$$\textbf{Action Accuracy} = \frac{\boldsymbol{No.\ of\ "Correct"\ actions}}{\boldsymbol{No.\ of\ all\ actions}} \times \mathbf{100\%} = \mathbf{88\%}$$

No. of Correct actions: Total number of actions correctly extracted by NLP component as obtained in user stories which defined the functionality of the requirement
No. of all actions: Total number of actions obtained in user stories which defined the functionality of the requirement.

The system captures the action words as the root node of the given sentence as discussed in Section 3.6.3. There are words having multiple expressions with different meanings that cause ambiguity. Actual action word should be a verb but there are cases where actual action word has more than one meaning with different POS tags. In such cases the whole sentence becomes ambiguity and the dependency parser does not identify the word that system needs as the root relation. Therefore such scenarios that makes a sentence ambiguity has not taken care through this method.

Examples: As an admin, I want to view users of the system.

Here the substring of “view users of the system” is ambiguous because of the word ‘view’. The word ‘view’ can be taken as either noun or a verb and it depends on the sentence meaning that want. Though the word ‘view’ should be the action word of this sentence, because of the ambiguities it has not taken care through the system.

6.4.3 Analysis of object extraction

According to the comparison between extraction of object from the implemented NLP component and manual identification of object from user stories, the accuracy for the correctly extracted object can be identified as follows.

From the comparison of actual object of user story with implemented NLP component results,

$$\textbf{Object Accuracy} = \frac{\textit{No. of "Correct" objects}}{\textit{No. of all objects}} \times \mathbf{100\%} = \mathbf{81\%}$$

No. of Correct objects: Total number of object words correctly extracted by NLP component which are directly accessed by extracted action word in user stories.
No. of all objects: Total number of object words which are directly accessed by extracted action in user stories.

As described under object filtering topic in section 3.6.5 it is observed that the accuracy of identification of an actual object of a sentence is directly based on the action word identified in that sentence. In this proposed methodology for object extraction, it only finds for the direct object relation or the dependent relation. Here apart from the 'dobj' relation, 'dep' relation was used to handle ambiguities between the action word identified and its noun object to some extent. However, still there are cases where more than one dependent words are connected to the action word as objects. Among all these object words the system is not in a possible state to find the exact object word that related to the action word.

Also when the action word is preceded by a preposition word attached to the actual object word then the 'dobj' relation is not further identified by the dependency parser and it provides another relation like 'nmod:for' which is related to preposition 'for' and that noun object 'order' word as below example Figure 6.3.

```
root(ROOT-0, pay-1)
nmod : for(pay-1, order-4)
case(order-4, for-2)
nmod : poss(order-4, my-3)]
```

Figure 6.3. Typed dependencies extracted for sentence "pay for my order"

Therefore such cases related with prepositions are not taken care with this proposed methodology of entity extraction.

6.5 Ontology based test case generation system evaluation

This is the primary evaluation of the base analysis that has been done with implemented Ontology and test case generation system. According to the involvement of Ontologist as described in Section 3.4 the implemented Ontology has been used as the knowledge base. The reasoning principles discussed in Section 3.7 have been applied with inputs provided through NLP component as discussed in Section 3.6. The performance and output of generated test cases depend on these mentioned methodologies. The dataset-2 which was set of user stories as shown in Figure 6.4 used as inputs for this evaluation.

User Story ID	User Story
1	As a User Admin, I want to add a new user group to the system, so that I can add users to that group and manage them easily.
2	As a User Admin, I want to delete user groups in the system, so that I can manage groups easily
3	As a User Admin, I want to view users of groups in the system, so that I can manage users in groups easily.
4	As a User Admin, I want to list user groups in the system, so that I can manage user groups easily.
5	As a User Admin, I want to update an existing group in the system, so that I can manage users in that group easily
6	As a editor I want to create department so that I can create deparment
7	As a editor I want to edit department so that I can edit department
8	As a editor I want to create subflows so that I can create sub-flows
9	As a editor I want to delete department so that I can delete departments
10	As a editor I want to delete site so that I can delete site
11	As a analyser I want to register subflows
12	As a analyser I want to approve department as new department

Figure 6.4. Set of user stories used for the evaluation purpose

The test cases generated by the system for this dataset are shown in Figure 6.5 and 6.6. The test cases generated for each and every user story are shown in these Figures with relevant user story ID.

User Story ID	Test Cases
1	create group with non_existing_name
	create group with non_empty_name
	create group with name_with_numeric_values
	create group with lengthy_name
	create group with name_with_special_characters
	create group with users
	create group with user_roles
	send_a_confirmation_message
	create_after_approval
2	delete_after_approval
	send_confirmation_message
	disable_visibility_of_object
3	view_top_N_views
	view_all_objects
4	list_top_N_objects
	list_all_objects
	sort_results
5	view_top_N_views
	view_all_objects
	update group with non_existing_name
	update group with non_empty_name
	update group with name_with_numeric_values
	update group with lengthy_name
	update group with name_with_special_characters
	update group with users
	update group with user_roles
	send_a_confirmation_message
	update_after_approval

Figure 6.5. Test cases generated by the system for the dataset-2 from user story ID 1-5

User Story ID	Test Cases
6	create depaartment with non_existing_name
	create depaartment with non_empty_name
	create depaartment with lengthy_name
	create depaartment with id
	create depaartment with address
	create depaartment with telephone_number
	create department with fax_number
	create department with valid_email
	send_a_confirmation_message
	create_after_approval
7	view_top_N_views
	view_all_objects
	update department with non_existing_name
	update department with non_empty_name
	update department with lengthy_name
	update department with id
	update department with address
	update department with telephone_number
	update department with fax_number
	update department with valid_email
	send_a_confirmation_message
	update_after_approval
8	create subflow with no_duplicates
	create subflow with non_empty
	send_a_confirmation_message
	create_after_approval
9	delete_after_approval
	send_confirmation_message
	disable_visibility_of_object
10	delete_after_approval
	send_confirmation_message
	disable_visibility_of_object
11	send_a_confirmation_message
	create_after_approval
	create subflow using non_duplicate
	create subflow using existing_major_flow
	create subflow using start_point
	create subflow using end_point
12	send_confirmation_email
	send_notification_from_system
	approve_one_object
	approve_multiple_object_at_once

Figure 6.6. Test cases generated by the system for the dataset-2 from user story ID 6-12

Figure 6.7 depicts the comparison between all the test cases generated manually with positive test cases generated automatically by the system according to the each given user story.

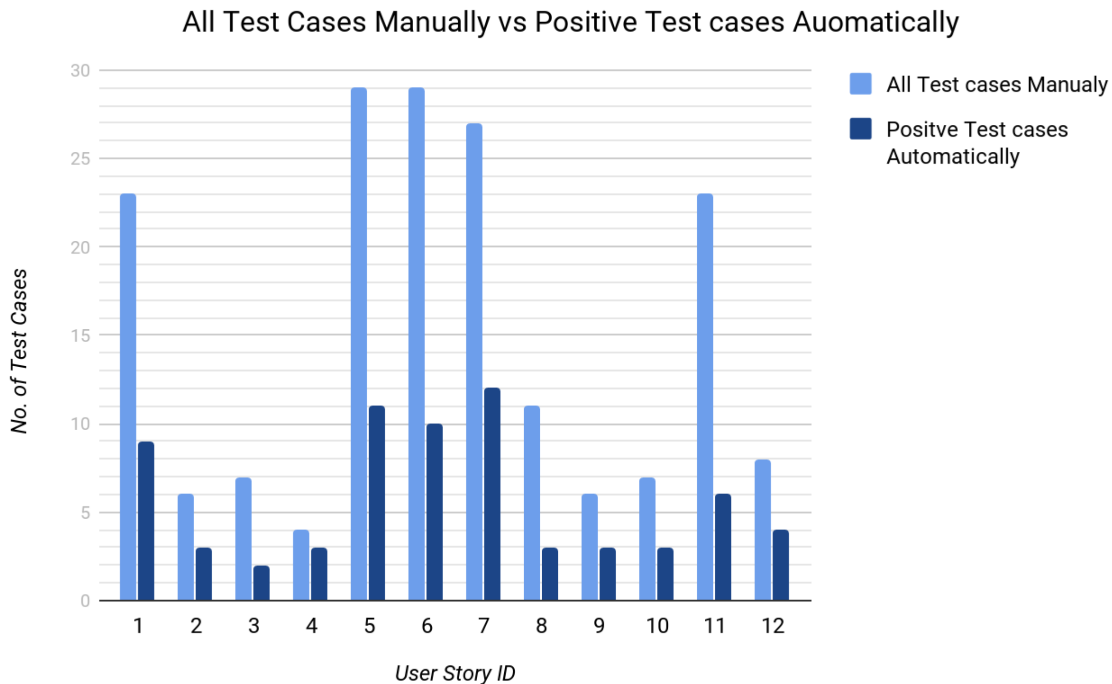

Figure 6.7. Comparison between all the test cases generated manually with positive test cases generated automatically by the system

From this comparison overall coverage of the test case generation system can be calculated as follows,

$$\textbf{Overall coverage} = \frac{\textbf{\textit{All the positive test cases automatically}}}{\textbf{\textit{All the test cases manually}}} \times \mathbf{100\%} = \mathbf{39\%}$$

All the test cases manually: Total number of all test cases written by users manually for each given user story

All the positive test cases automatically: Total number of all positive test cases generated by system for each given user story

Figure 6.8 represents the comparison between all the positive test cases generated manually with positive test case generated automatically by the system for each user story.

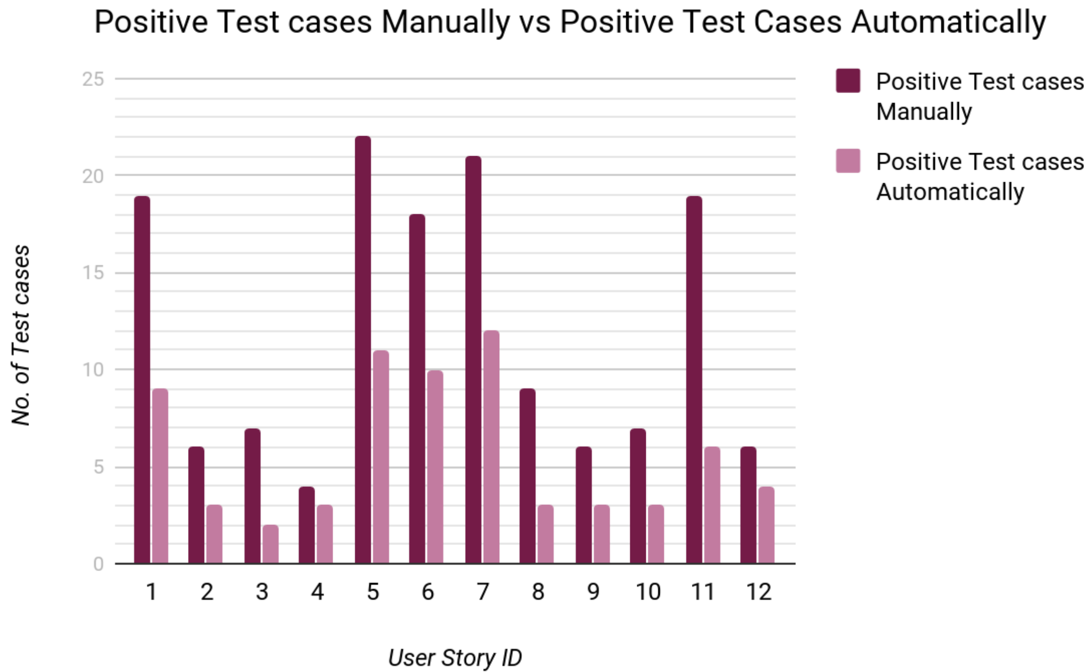

Figure 6.8. Comparison between all the positive test cases generated manually with positive test case generated automatically by the system

From this comparison positive coverage of the test case generation system is calculated as follows,

$$\textbf{Positive coverage} = \frac{\textit{All the positive test cases automatically}}{\textit{All the positive test cases manually}} \times \mathbf{100\%} = \mathbf{48\%}$$

All the positive test cases manually: Total number of all the positive test cases written by users manually for each given user story

All the positive test cases automatically: Total number of all positive test cases generated by system for each given user story

To measure the validity or the accuracy of the generated test cases by the system was done by comparing the actual test cases provided software companies to relevant user stories. The accuracy was 100% and it indicated that all the generated test cases are valid to test the software product.

6.5.1 Discussion of the System Evaluation Results

Within the system evaluation process, the primary task was to generate positive test cases based on the Ontology. The implementation of Ontology model was explained in Section 3.5 and the Ontology knowledge base can be evolved through the involvement of an Ontologist as described in Section 3.4. The implemented solution was able to generate positive test cases and for the given scenario positive test case coverage was 48%. However, with the involvement of Ontologist to the agile development, Ontologist can capture every requirement and evolve the Ontology according to them. Therefore positive test case coverage can be increased up to 100% which will be directly affected the overall coverage of test cases. In some cases according to the information included in software requirement Ontology knowledge the validity or the accuracy of the test cases may be varied. Therefore system provides workflow component for tracing these deviations and correct or ignoring additional test cases.

6.6 User Evaluation

The user evaluation of the proposed system was done with five software quality assurance professionals with testing knowledge and experience. 100% participants had over one year of testing experience. Each participant was given five user stories which are relevant to the Group management epic of a developed product by a software company to write test cases manually. Also, same user stories were given to the Ontology-based test case generation by each user to generate test cases automatically. The key parameters examined from the evaluation were positive test case coverage by the system with manually written test cases as the system was developed to generate positive test cases. Also the validity of automatically generated test cases were checked with users' experienced.

The Figure 6.9 depicts the user stories of given scenario, And Table 6.2 represents the number of all test cases written and the number of all positive test case included in all test cases by each user for user story IDs from 1- 5 in Figure 6.9. The total number of test cases generated by the system according to the given stories was 28. Figure 6.10 depicts the percentage of automatically generated test case coverage with test cases generated by each user manually.

User Story ID	User Story
1	As a User Admin, I want to add a new user group to the system, so that I can add users to that group and manage them easily.
2	As a User Admin, I want to delete user groups in the system, so that I can manage groups easily
3	As a User Admin, I want to view users of groups in the system, so that I can manage users in groups easily.
4	As a User Admin, I want to list user groups in the system, so that I can manage user groups easily.
5	As a User Admin, I want to update an existing group in the system, so that I can manage users in that group easily

Figure 6.9. User stories given for the user evaluation

Table 6.2. The number of all test cases manually written by each user and the number of all positive testcase among them

Manual	**User**				
	1	**2**	**3**	**4**	**5**
No. of all test cases	43	49	41	51	39
No. of positive test cases	39	41	33	38	33

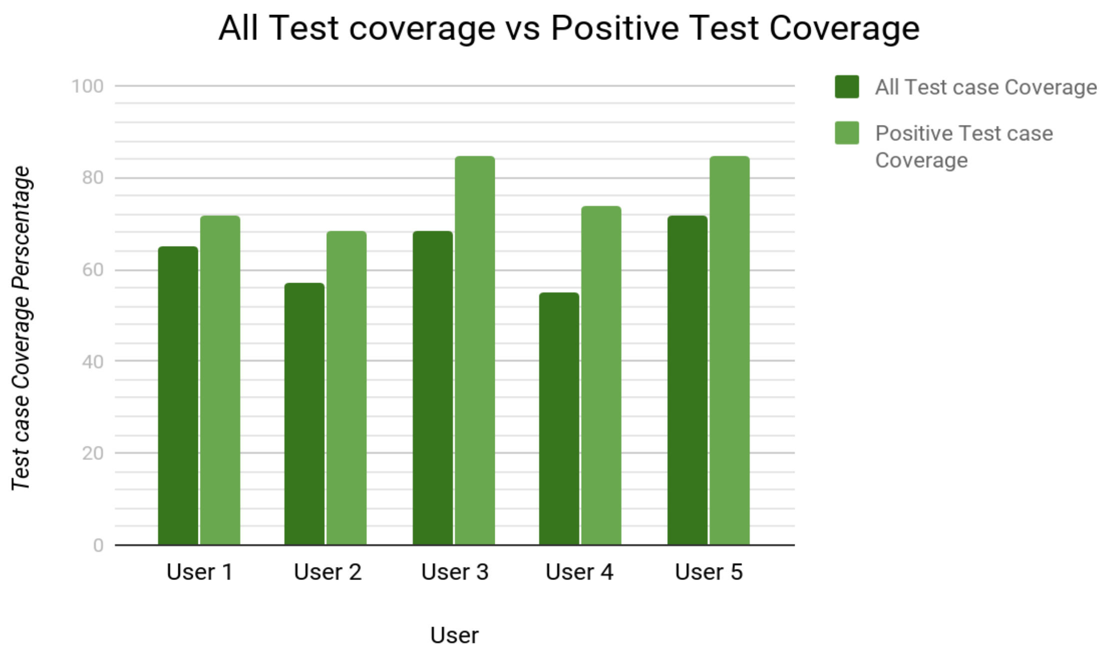

Figure 6.10. Automatically generated test case coverage vs test cases generated by each user manually

According to the analysis of automatically generated test cases with actual test cases written by users the automatically generated test cases had an accuracy of 100%, which

means that system automatically generated valid test cases. In other words, the test cases generated by the system should be included as a test case when test the software product.

The Figure 6.11 depicts that all the participants selected the automatic test case generation method to preferred method for generating the test cases concerning time-saving, lesser effort and reusability. One user mentioned that manual method of generating test cases required less effort due to experienced gained by the user will be increased with time.

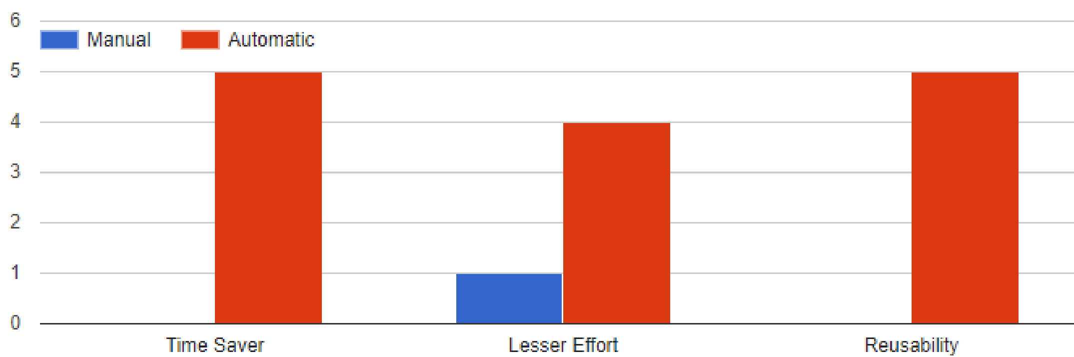

Figure 6.11. User preference: Manual vs Automatic test case design

The Table 6.3 summarizes the feedback collected from the five users who have involved in test case generation for the given user stories.

Table 6.3. User Responses to survey question

Rate satisfaction level of test coverage by automated system	Extremely satisfied	Highly satisfied	Moderately satisfied	Lesser satisfied	Not satisfied at all
	1	4	0	0	0
Rate the accuracy or validity of generated test cases	Extremely accurate	Very accurate	Moderately accurate	Slightly accurate	Not accurate at all
	2	3	0	0	0
Rate the ease of use of this system by a user with no testing experience	Extremely easy	Very easy	Moderately easy	Slightly difficult	Extremely difficult
	0	5	0	0	0

6.6.1 Discussion of the User Evaluation

The user evaluation was conducted with the assistance of only five users who have testing experience over one year. According to their feedback and preferences, the introduced methodology through the system senses good impact towards software industry. However, this situation may be changed with professionals who have more experience in testing.

The users have indicated that the effort will be reduced by using this tool while increasing the time saving and reusability. The users mentioned that the time taken to test case generation using the system is lesser, but they had the doubt about the evolvement time of the Ontology since it depends with the time taken by the Ontologist at their company. However, it is observed that if the existing Ontology has been developed very accurately and well-populated according to the requirements, it produces a considerable advantage to software development with cost factors such as monetary, time and effort.

6.7 Findings of the Base Analysis and User Evaluation

For the conclusion, if the discussion summarizes the findings and validating claims made in Section 1.4, Aims and objectives. The proposed methodology developed an Ontology model for software requirement domain which can be evolved through the involvement of Ontologist in Agile software development. It is observed that considerable amount of effort has been reduced since it will encourage the QA engineers to draw their attention and effort towards critical areas of the software product. According to the collected information from software companies, the conflicts between user stories and test cases have been reduced with this presented system because test case management and user story management can be done up to some satisfiable extent using the system. The identified drawbacks can be handled with future developments, and it will produce higher test case coverage while being faster and cheaper. It is also observed that reusability of software requirement has been improved through the Ontology and reusability of test cases also be increased.

Chapter 7

Conclusion and Future Work

7.1 Conclusion

Design test cases manually is a complicated process and very time consuming and costly phase in software development life cycle. In this thesis, a framework has been designed and implemented to auto-generate positive test cases using natural language processing and based on an Ontology for software engineering products in Agile development.

As the input to the framework, user stories were taken with relevant to the given template format which is popular in Agile development. An Ontology was developed from the scratch due to the unavailability of an existing Ontology in the software engineering, requirement domain. The Ontology model concept was developed based on actor, action and object triplet which directly affected the test cases. To extract the relevant data from the pre-developed Ontology those mentioned triplets were needed to extract from the user stories which were written in natural language. Therefore the user story was processed using NLP techniques to extract the entities which are essential to test case generation. Then the extracted triplets are used for Ontology reasoning to extract properties of relevant instances in the Ontology. Those properties were presented as test cases after some modifications. The generated test case was presented as a test suite and passed through a workflow to customize the output of the framework by removing faulty test cases and adding any missing test case. The final output of the framework is a set of positive test cases.

According to the objectives had at the beginning of this work, most of them have been covered at the end of this work. A common feasible template has been introduced, an Ontology has been developed and most of the test cases were generated using identified NLP techniques. Because of the developed Ontology, the risk gain due to shifting of employees is

reduced. When Identifying the actor of some user stories, this work has shown some conflicts and suggestions to solve those conflicts, are discussed in future work for automating test case generation section.

This research study has concluded that automatic generation of test cases based on an Ontology is a feasible approach and user stories can use to test case generation after applying NLP techniques. At the end of this research work, a new concept has introduced by forming the role of an Ontologist into the current software industry which follows Agile practices.

7.1.1 Contributions of Automatic Test Case Generation Framework

This framework decreases the time and effort taken to write test cases manually by generating positive test cases automatically and increase the reusability of generated test cases where the Ontology can be taken as a generic solution for a specified epic.

This work has used Stanford Dependency Parser for entity extraction by considering the grammatical structure of the sentences. The parser has been used in a different approach as the intention was to extract the most important actor, action and object from a user story which need for the test case generation. To achieve this intention, Stanford Dependency Parser has been used with a separately introduced method along with its grammatical relations, lemmatization and POS tagging techniques.

7.2 Future Works

At the end of this work, following future works have been identified as to fine tune the framework and the generated test cases based on the Ontology.

7.2.1 Evolve of Ontology

To use this system as a generic solution, evolvement of the Ontology is needed since this work has developed only for group management scenario. The Ontology can be evolved further, or it can be separately implemented as a new Ontology using the Protégé tool. The Ontology implementation and engage in the evolving process should be done by an Ontologist who has the basic knowledge about Ontology model concept. Therefore the role of the Ontologist would become important in the industry who follows agile development methodology. After evolving the Ontology by considering requirements of many different

systems, Ontology becomes rich with knowledge and this can be reused as a generic solution to generate test cases for many software development products.

7.2.2 Enhance Actor Identification

This work has some conflicts of extracting actor for some situation. As an example, “Registered user” is extracted as “user”. However, the word “Registered” is needed for test case generation if there are different kinds of users such as “Unregistered user”. This work was used Stanford Dependency Parser and POS tagging for triplet extraction. For the extraction of the actor, only the noun was taken after applying POS tagging to the first sentence gained by splitting the user story into two strings. The suggestion to solve this issue is to take the complete noun phrase not only the noun after applying the POS tagging.

7.2.3 For Service Based Companies

According to the scope, this work has been done for product based companies who are writing user stories and following agile practises within the software development. However, this can be also applied to service-based companies if they are following the agile practises and managing requirements as user stories. This is the need to be further developed for applying this methodology to all product and service-based companies. The suggestion is to introduce a role of an Ontologist to service-based companies to use this as a solution.

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Appendix A – Individual Contributions

A.1. Name: H.N. Anjalika (2013/CS/009)

According to the background analysis problem of requirement representation and so we got the chance of applying the Ontology concept into the requirement domain and see the possibility of automation the test case generation process. Therefore our main research intent "Ontology based test case generation" was divided into 3 main sub parts as Ontology identification and implementation, Natural Language Processing techniques to be applied with user stories and automatic generation of test cases using the Ontology.

As an individual contributor I was assigned for the task of Natural Language Processing techniques to be applied with user stories. Since our intention was to use user stories as the initial system input, they were need to process before using to the test case generation. According to the Ontology model developed, we needed a triplet as actor, action and object that was extracted from a user story. For this I went through some research papers to get an idea on how the triplet extraction has been done with respect to extract subject, verb and object of a sentence. I tried on applying those mentioned algorithms with our user stories using different approaches and I used Stanford CoreNlp toolkit. My first approach was following a Stanford Tree parser, but it couldn't give exact result what I needed. Then I applied Stanford dependency Parser and by defining a method that matches with the user stories, I could extract the correct entities up to some extent. There are some future works need to be considered with this method.

Implementation of the user story form and extracting entities from was done using Spring MVC framework and hibernate with MySQL database by applying OOP concepts as necessary. I also involved with designing the architecture and other diagrams while cooperating to produce various documents of the research. Finally the evaluation process was done by all 3 of us doing surveys and comparing the system generated results with manual results taken from sample user stories and test cases.

A.2. Name: M.T.Y Salgado (2013/CS/106)

Initially, as a group we have visited few Software Companies to get background knowledge about development methodologies and testing. Then we have identified that there is a gap between requirement representation and test case designing. Therefore we have started our research study to reduce this gap.

According to the industry requirement, we started background analysis of test case designing, then identified our research study as “An Ontology-based test case generation framework” as described in the thesis.

As an Individual contributor to the project, I engaged to study and development of a test case generation component which was one of the three main components of our project. This component contained reasoning on implemented Ontology to test case generation and workflow component to manage derived test cases. I have gone through studies of Ontology and identified its concepts and rooting. The studied about reasoning techniques, technologies and tools. Therefore I have learned about Apache Jena API for reasoning and applied theories to infer relevant information from Ontology to generate test cases. SPARQL query language used for query the data for given inputs. The extracted data have been structured according to the form of test case integrated with workflow component. Workflow component has included some user interfaces for user involvement. I have developed these UIs. Workflow component provides functionalities to the user to create a complete test suite for modifying extracted test cases, ignore additional test cases, add new test cases and gets approval for test cases.

I have also engaged in designing of design diagrams such as class diagram, data flow diagram, and sequence diagram. Moreover, also designed and implement database component relevant to the test case generation.

To complete a successful software engineering project we had to complete several documentations such as project proposal, interim and thesis. I have involved to those documentations and completed sections according to the studies in the project. Also, we have conducted few surveys relevant to the project and analyzed collected survey data and other information.

A.3. Name: P.I. Siriwardhana (2013/CS/115)

Our project was to research the feasibility of an Ontology to generate test cases and give a solution to auto generate test cases based on an Ontology using user stories.

To identify the background of this problem, we had few informal discussions with industry people. At that meetings we discussed about the current industry testing process and identified the proposed system design. We identified three core components in the proposed framework as Implement An Ontology, Entity Extraction Using NLP techniques and Ontology Reasoning and Test case Generation.

My contribution to this work is to research on the feasibility of test case generation based on an Ontology and to implement a feasible Ontology for software engineering requirement domain. This was a big challenge to me. Before implement a new Ontology I searched for an existing Ontology for the required domain. Therefore I contact some researchers who has done researches on Ontology based test case generation and their idea was also to implement an Ontology from the scratch due to unavailability of an existing Ontology to develop further. Implementation of an Ontology was the most challengeable task for me. For that I used sample user stories and their test cases as the data set and identified a relation between user stories and test cases. I identified most important words of the user story to write test cases as user role,his/her functionality and on which object that functionality is performed on. Therefore I defined that three words as the three concepts of the Ontology and named them as actor, action and object. According to the sample data set I used object properties which represent relationships between two classes and two instances, and data properties which represent data of instances, to set information about them.

Another challenge I faced was to handle similar words of an instances. To overcome that challenge I created an object property *hasSimilarWord* and formed a relationship among those similar instances. To handle the implicit scenarios I created an object property *hasDependancy*. To ensure the decision that I have taken, we had some informal discussions with an Ontology expert.

I contributed for GUI designing, documentations such as Project Proposal, Interim Report, Thesis and designed the architecture and other diagrams with the help of other two members.

Finally I contributed to collect sample user stories and to evaluate our product results.

Appendix B - Dataset-1

This dataset has been used to evaluate the NLP component of the system.

USER STORY
As a customer I want to purchase the goods in my shopping basket so that I can receive my products at home
As a customer I want to log in with my account so I don't have to re-enter my personal information every time
As a customer I want to review and confirm my order, so I can correct mistakes before I pay;
As a customer I want to pay for my order with a wire transfer, so that I can confirm my order;
As a customer I want to pay for my order with creditcard, so that I can confirm my order;
As a customer I want to receive a confirmation e-mail with my order, so I have proof of my purchase;
As a shop owner I want to decline orders below 10 dollars,so that I can cancel non profit orders;
As a fulfillment specialiist I want to print picking report so that I can prepare products to ship
As a shop owner I want to reserve ordered products from stock for 48 hours, so that other customers see a realistic stock;
As a shop owner I want to automatically cancel orders for which I have not received payment within 48 hours, so that I can sell them again to other customers;
As a NGO I want to be able to reset my password when my login fails, so I can try to log in again
As a NGO I want to log in with my account, so that I can access secure pages
As a NGO I want to register a new account if my login is not known, so that I can gain access to secure pages
As a add, I want to play music so that I can enable advertisement
As a add, I want to load video so that I can perform drafting of advertisement
As a site owner I want to block users that log in incorrectly three times in a row, so that I can protect the site against hackers
As a team member I want to view the Scrum Board on my desktop, so that I know the status of the sprint
As a team member I want to view the Scrum Board on my mobile phone, so that I know the status of the sprint
As a team member I want to view the Scrum Board on a touchscreen, so that I know the status of the sprint;
0
As a registered member I want to update my payment information so that I can add new details
As a first-time visitor, additional prompts appear on the site to direct me toward the most common starting points so that I learn how to navigate the system.
As a forgetful member, I want to request a password reminder so that I can log in without having to first call tech support
As a report viewer I want to filter my report by any combination of columns
As a possible room renter I want to find a room
As a possible room renter I want to book a room

As a User Admin, I want to add a new user group to the system, so that I can add users to that group and manage them easily.
As a User Admin, I want to delete user groups in the system, so that I can manage groups easily
As a User Admin, I want to view users of groups in the system, so that I can manage users in groups easily.
As a User Admin, I want to list user groups in the system, so that I can manage user groups easily.
As a User Admin, I want to update an existing group in the system, so that I can manage users in that group easily
As a User Admin, I want to view groups of a user in the system, so that I can manage users in groups easily.
As a low budget vacation traveler, I want to find flights using a range of dates
As a credit card purchaser, I want to pay by Amex, MasterCard, Visa or Discover
As a frequent user, I want to personalize my experience
As a hotel I want to registered to the OHRMS system
As a hotel user I want to update my profile so that users can get know new changes
As a hotel user I want to delete hotel details
As a registered hotel I want to view myprofile and the other hotels profiles
As a Admin I want to view registered hotel's profile.
As a Admin I want to create hotel account So that I can confirm whether provided informations are valid
As a admin I want to update the system So that I can improve the technologies that have been used
As a Admin I want to delete a registered hotel's profile.
As a user I want to reschedule my reservation period
As a user I want to Withdraw the reservation
As a project supervisor I want to login to the system
As a project supervisor I want to create new projects in the system so that I can manage new projects
As a project supervisor I want to create new deliverables so that I can assign tasks
As a project supervisor I want to edit new sub projects so that I can make relevent changes
As a project supervisor I want to delete new sub projects so that I can remove not relevant projects
As a project supervisor I want to create new activity so that I can assign new activities
As a project administrator I want to add news to the project so that I can give comments to the team

As a project administrator I want to add comment

As a project administrator I want to add a new document

As a project administrator I want to edit templates

As a project administrator I want to delete document

As a project administrator I want to add budget to the budget list

As a project administrator I want to edit budget to the budget list

As a user I want to add new message to the forum

As a project administrator I want to Upload procurement to a existing project

As a project administrator I want to manage roles of the users

As a examination branch member I want to login to the system

As a lecturer I want to login to the system

As a system administrator I want to login to the system

As a examination branch member I want to search student details

As a examination branch member I want to update student details

As a examination branch member I want to add student details

As a examination branch member I want to delete student details

As a examination branch member I want to view student details

As a lecture I want to list students

As a examination branch member I want to calculate GPA of student

As a lecture I want to add result of students

As a lecture I want to edit student's results

As a examination branch member I want to add results to the LMS

As a system administrator I want to create an account for examination branch member

As a system administrator I want to remove an account of examination branch member

As a System administrator I want to manage accounts by doing necessary updates in the account details

As a sales paerson I want to login to the system using a username and password.

As a Salesperson I want to view the list of products in the stock so that i can get an idea about the storage

As a admin user I want to change the details about products in the stock.

As a sales person I want to enter product code and quantity

As a branch manager I want to enter record of the first stock in every morning

As a branch manager I want to check the generated reports approve them

As a branch manager I want to check the generated balanced accounts and
finalize it with adding necessary transaction details

As a admin user I want to login to the system

As a admin user I want to add new users to the system

As a administrative user I want to edit user accounts

As a administrative user I want to delete user accounts

As a authorised user I want to add new asset to the system

As a authorised user I want to edit asset details

As a authorised user I want to dispose an asset

As a authorised user I want to view report

As a registered user I want to add feedback to a story

As a registered user I want to send messages

As a registered user I want to change username

As a registered user I want to change my password

As a registereed user I want to change my profile picture

As a registereed user I want to like stories

As a registered user I want to unlike stories

As a shoper I want to review my cart so that I can make adjustments prior to checkout

As a shoper I want to modify the list of products so that I can adjust our offferings over time

As a shop owner I want to decline orders below 10 dollars, because I don't make any profit on them

As a user I want to request DI PIN code reset so that I can reset DI PIN Code

As an administrator I want to reset DI user PIN codes so that I can give access to DI users who have requested PIN code resets.

As a user I want to login to DI for the first time sot that I can reset PIN and start accessing DI

As a user I want to create site so that I can create new site

As a user I want to single edit site so that I can single edit site

As a user I want to open flow in balance page so that I can view the selected flows in balance page

As a user I wan to view takt information so that I can view takt information

As a user I want to connect stations to one another so that I can connect/reconnect stations /move a station from one flow to another.

As a user I want to create next station loop so that I can loop a set of stations

As a user I want to delete next station loop so that I want to remove station loop

As a user I want to edit next station loop so that I want to update and save existing next station loop

As a user I want to view department so that I can view departments

As a user I want to create department so that I can create deparment

As a user I want to edit department so that I can edit department

As a user I want to create subflows so that I can create sub-flows

As a user I want to delete department so that I can delete departments

As a user I want to delete site so that I can delete site

Appendix C - Conducted Surveys

C.1. Survey I

First survey was conducted to gather information about software development and testing process in current software industry in Sri Lanka. 26 companies have been participated in the survey and responded.

Details of Software Development

Note : Designing test cases means writing test cases in English

* Required

1. Company Name *

Your answer

2. Development Methodology *

- ◯ Agile Development Methodolgy
- ◯ Waterfall Methodolgy
- ◯ Behavioral Driven Development
- ◯ Rapid Application Development
- ◯ Prototype Methodolgy
- ◯ Other:

2.1 If other mention here

Your answer

3. Do you write user stories? *

- ◯ Yes
- ◯ No

4. Do you use any design diagrams in your company? *

- ◯ yes, always
- ◯ no, not at all
- ◯ yes, sometimes
- ◯ Other: ____________

4.1 If you use any of the following diagram for a software product, select it

- ☐ Use Case Diagram
- ☐ Class Diagram
- ☐ Sequence Diagram
- ☐ Activity Diagram
- ☐ Other: ____________

4.2 If other, mention here

Your answer

5. Do you think using design diagrams as an extra cost or effort? *

- ◯ Yes
- ◯ No
- ◯ Maybe

6. How do you design test cases for a software product? (Designing test cases means writing test cases in English) *

- ◯ Manually
- ◯ Automatically

7. If you design test cases manually, then does that based on user requirements? *

- ◯ yes
- ◯ no

8. If use any automated test case generation tool mention here

Your answer

9. In which phase do you design test cases? *

- ☐ Requirement gathering
- ☐ Design phase
- ☐ Implementation phase
- ☐ Testing phase
- ☐ Other:

10. No of Software Engineers per team *

Your answer

11. No. of Quality Assurance Engineers per team *

Your answer

12. Do you experienced with conflicts in software requirements and designed test cases? *

- Yes
- No

13. Do you think it is advantage to have any automated test case generation tool? *

- Yes
- No

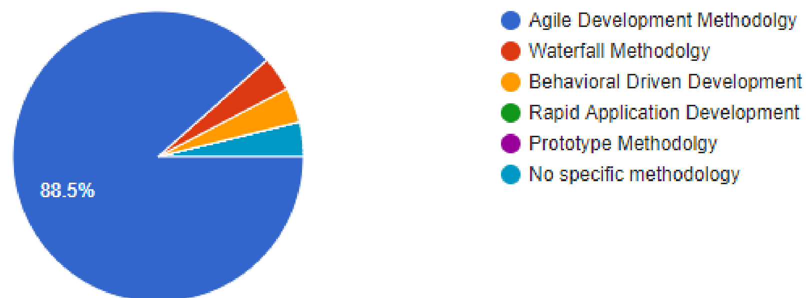
SUBMIT

Never submit passwords through Google Forms.

Below are the responses obtained for some questions from the Survey I.

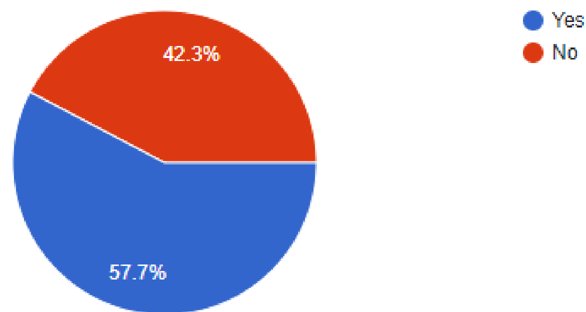
2. Development Methodology

26 responses



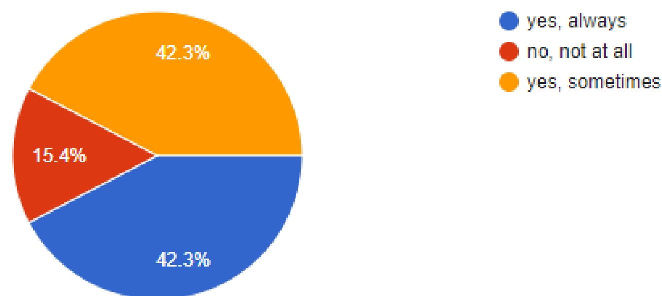
3. Do you write user stories?

26 responses



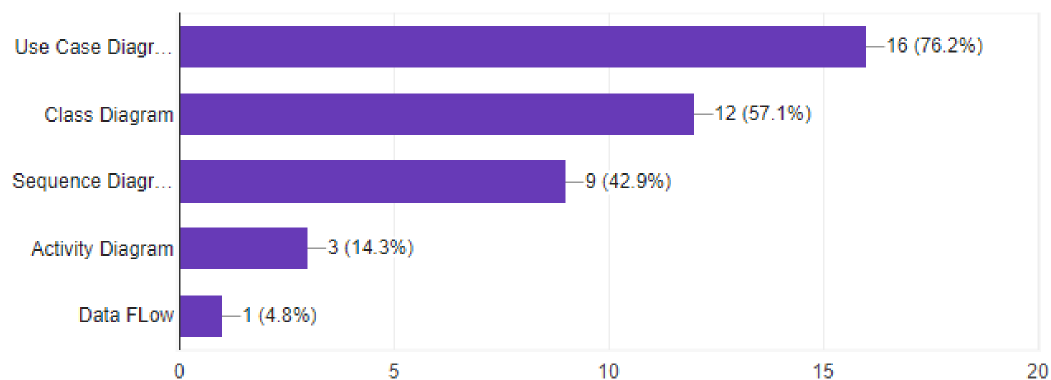
4. Do you use any design diagrams in your company?

26 responses



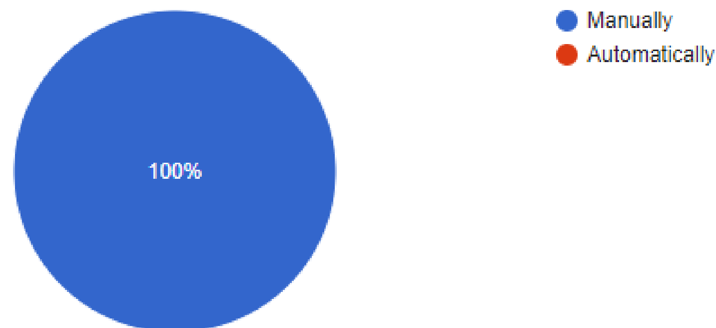
4.1 If you use any of the following diagram for a software product, select it

21 responses



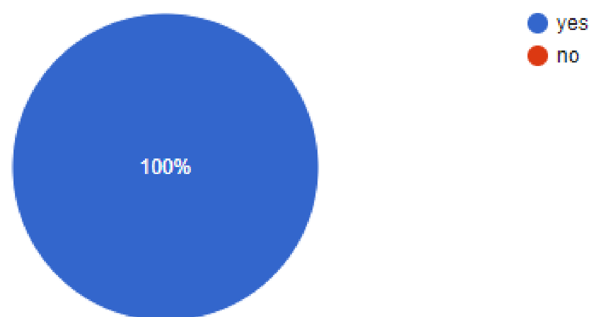
6. How do you design test cases for a software product? (Designing test cases means writing test cases in English)

26 responses



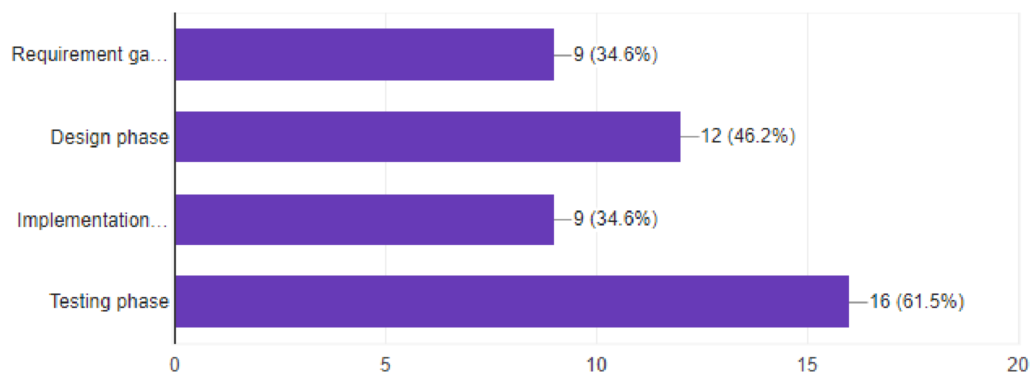
7. If you design test cases manually, then does that based on user requirements?

26 responses



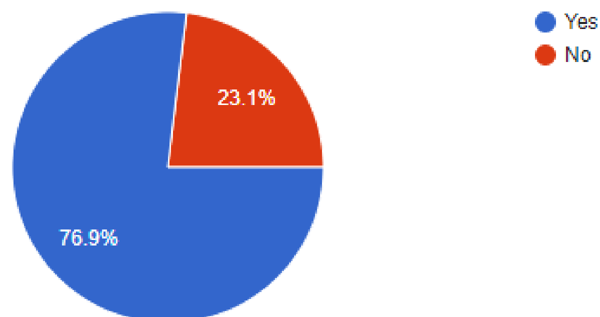
9. In which phase do you design test cases?

26 responses



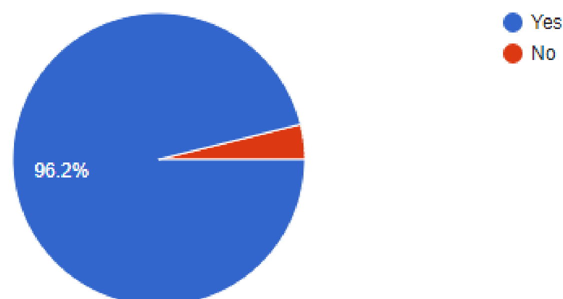
12. Do you experienced with conflicts in software requirements and designed test cases?

26 responses



13. Do you think it is advantage to have any automated test case generation tool?

26 responses



C.2. Survey II

The second survey was conducted in the evaluation phase to get user evaluation to the developed system and methodologies. For this survey 5 users have been involved who has more than one year experience in software testing.

Survey for Usability of Test case Generation System - QA Users

This survey is to compare experienced users feedback regarding test cases written in manually and positive test cases generated by system.
Following questions are based on the experience you gained from the user stories provided.

* Required

1. How many years of Software Testing experience do you have? *

- <1 year
- 1 - 2 years
- >2 years

2. What kind of Software Test designing experience have you had? *

- Manual
- Automated
- Both

3. Do you have experience with user stories? *

- Yes
- No

4. Number of all test cases designed manually *

Your answer

4. Do you use any design diagrams in your company? *

- ◯ yes, always
- ◯ no, not at all
- ◯ yes, sometimes
- ◯ Other: ____

4.1 If you use any of the following diagram for a software product, select it

- ☐ Use Case Diagram
- ☐ Class Diagram
- ☐ Sequence Diagram
- ☐ Activity Diagram
- ☐ Other: ____

4.2 If other, mention here

Your answer

5. Do you think using design diagrams as an extra cost or effort? *

- ◯ Yes
- ◯ No
- ◯ Maybe

10. Do the generated test cases are valid test cases for the given scenario?

- ◯ Yes
- ◯ No

11. Rate the accuracy of generated test cases *

- ◯ Extremely accurate
- ◯ Very accurate
- ◯ Moderately accurate
- ◯ Slightly accurate
- ◯ Not accurate at all

12. Rate the ease of use of this system by a user with no testing experience *

- ◯ Extremely easy
- ◯ Very easy
- ◯ Moderately easy
- ◯ Slightly difficult
- ◯ Extremely difficult

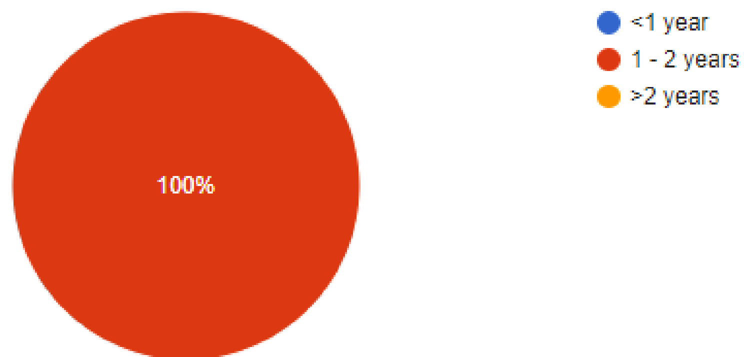
13. Do you think this methodology can be improved to cover all test cases? *

- ◯ Yes
- ◯ No

Below are the responses obtained from the Survey II.

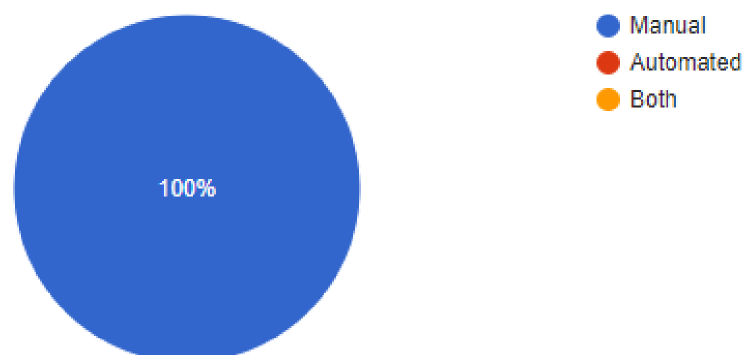
1. How many years of Software Testing experience do you have?

5 responses



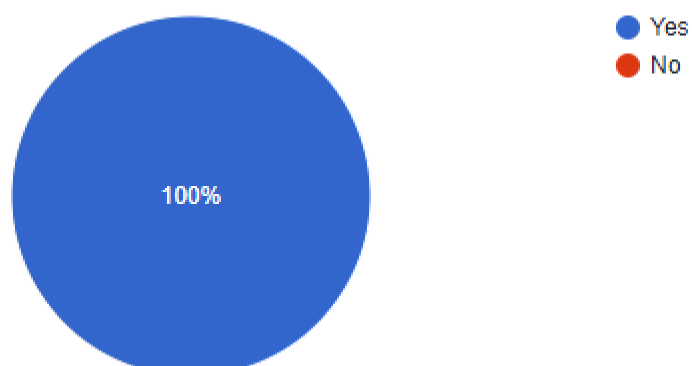
2. What kind of Software Test designing experience have you had?

5 responses



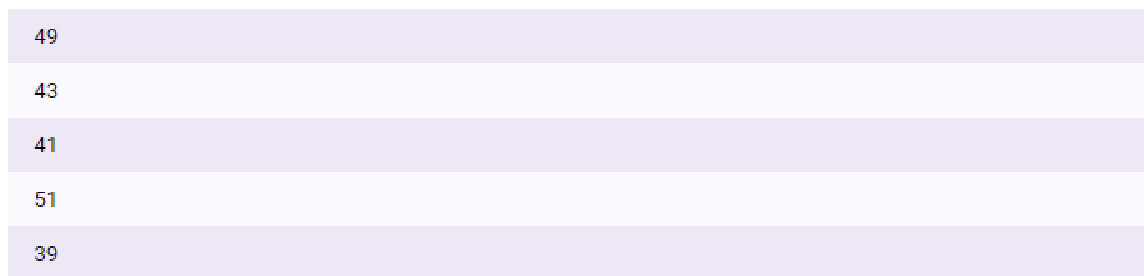
3. Do you have experience with user stories?

5 responses



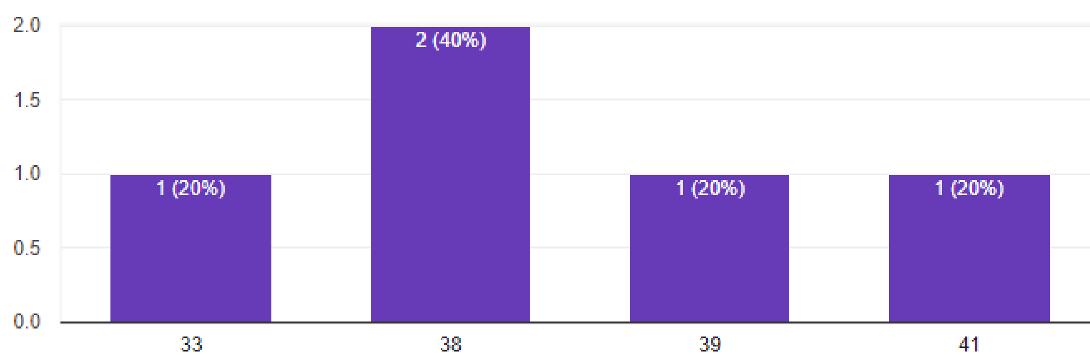
4. Number of all test cases designed manually

5 responses



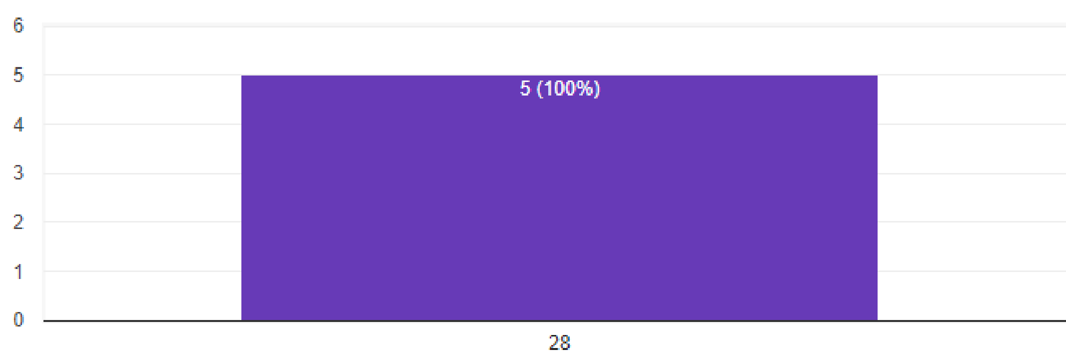
5. Number of all positive test cases designed manually

5 responses

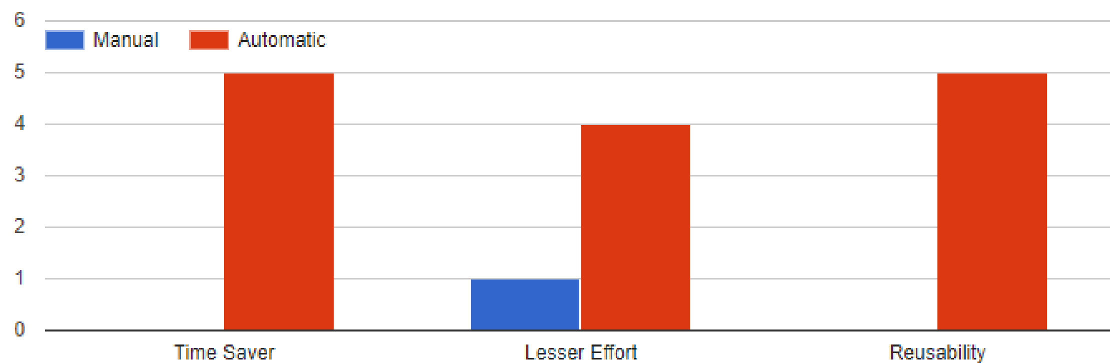


6. Number of all positive test cases generated by system

5 responses



7. Comparison with manual and automated test case generation



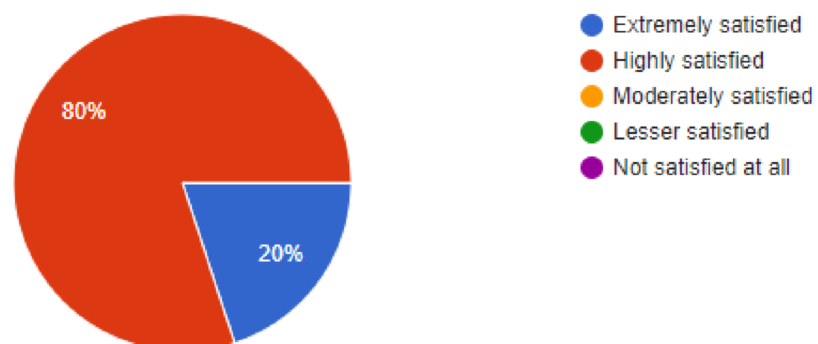
8. Please provide reasons if you select manual as preferred method

1 response

With experience gained effort will be reduced

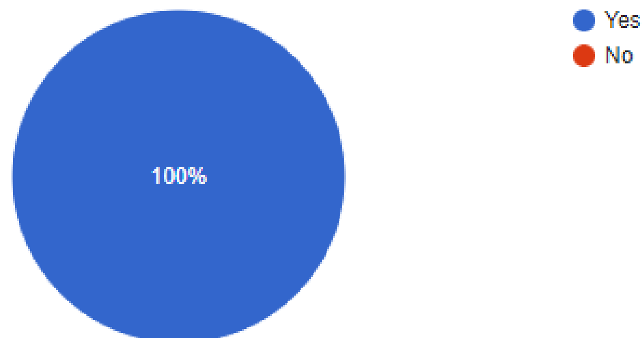
9. Rate satisfaction level of test coverage automated system

5 responses



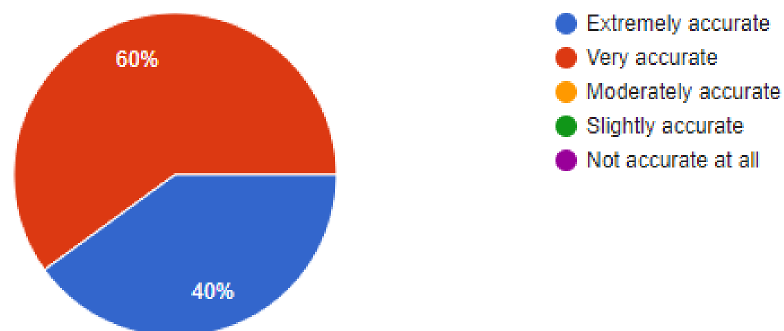
10. Do the generated test cases are valid test cases for the given scenario?

5 responses



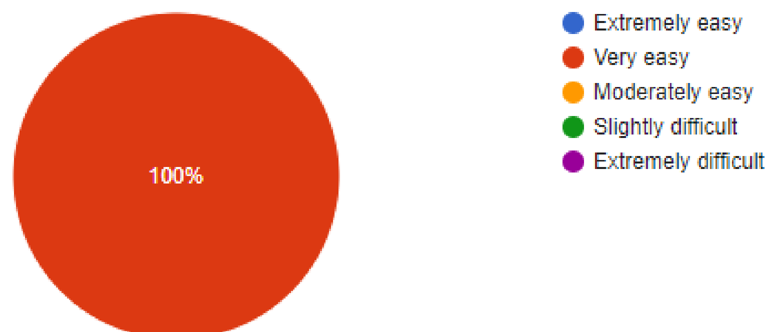
11. Rate the accuracy of generated test cases

5 responses



12. Rate the ease of use of this system by a user with no testing experience

5 responses



13. Do you think this methodology can be improved to cover all test cases?

5 responses