A DOCUMENT-BASED TRACEABILITY MODEL FOR TEST MANAGEMENT

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Specially dedicated to all my family and relatives.

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ABSTRACT

Software testing has became more complicated in the emergence of distributed network, real-time environment, third party software enablers and the need to test system at multiple integration levels. These scenarios have created more concern over the quality of software testing. The quality of software has been deteriorating due to inefficient and ineffective testing activities. One of the main flaws is due to ineffective use of test management to manage software documentations. In documentations, it is difficult to detect and trace bugs in some related documents of which traceability is the major concern. Currently, various studies have been conducted on test management, however very few have focused on document traceability in particular to support the error propagation with respect to documentation. The objective of this thesis is to develop a new traceability model that integrates software engineering documents to support test management. The artefacts refer to requirements, design, source code, test description and test result. The proposed model managed to tackle software traceability in both forward and backward propagations by implementing multi-bidirectional pointer. This platform enabled the test manager to navigate and capture a set of related artefacts to support test management process. A new prototype was developed to facilitate observation of software traceability on all related artefacts across the entire documentation lifecycle. The proposed model was then applied to a case study of a finished software development project with a complete set of software documents called the On-Board Automobile (OBA). The proposed model was evaluated qualitatively and quantitatively using the feature analysis, precision and recall, and expert validation. The evaluation results proved that the proposed model and its prototype were justified and significant to support test management.

ABSTRAK

Pengujian perisian menjadi semakin rumit dengan kemunculan rangkaian teragih, persekitaran masa-nyata, pembekal perisian pihak ketiga dan keperluan untuk menguji sistem pada pelbagai peringkat penggabungan. Senario-senario ini telah mencetuskan keprihatinan terhadap kualiti pengujian perisian. Kualiti perisian menjadi semakin kurang akibat aktiviti pengujian yang tidak cekap dan tidak berkesan. Salah satu kelemahan utama adalah berikutan penggunaan pengurusan ujian yang tidak efektif untuk menguruskan dokumen perisian. Dalam dokumentasi, adalah sukar untuk mengesan dan menjejak pepijat dalam beberapa dokumen berkaitan dimana jejak adalah kebimbangan utama. Pada masa kini, pelbagai kajian telah dijalankan pada pengurusan ujian, namun sangat sedikit memberi tumpuan kepada jujuk dokumen khususnya untuk menyokong penyebaran ralat berkenaan dengan dokumentasi. Objektif tesis ini adalah untuk membangunkan satu model jejak baharu yang menggabungkan dokumen kejuruteraan perisian untuk menyokong pengurusan ujian. Artifak-artifak itu merangkumi keperluan, reka bentuk, kod sumber, huraian ujian dan hasil ujian. Model yang dicadangkan ini dapat menangani masalah jejak perisian dalam kedua-dua jejak ke hadapan dan ke belakang dengan melaksanakan penuding berbilang dwi arah. Platform ini membolehkan pengurus ujian mengemudi dan menangkap satu set artifak yang berkaitan untuk menyokong proses pengurusan ujian. Prototaip baharu telah dibangunkan untuk memudahkan pemerhatian jujuk perisian pada semua artifak berkaitan di seluruh kitaran hayat dokumentasi. Model yang dicadangkan kemudiannya diaplikasikan ke atas satu kajian kes projek pembangunan perisian yang selesai dengan satu set lengkap dokumen perisian yang dipanggil *On-Board Automobile (OBA).* Model yang dicadangkan telah dinilai secara kualitatif dan kuantitatif menggunakan analisis ciri, *precision* dan *recall*, dan pengesahan pakar. Keputusan penilaian membuktikan bahawa model yang dicadangkan dan prototaipnya adalah wajar dan penting untuk menyokong pengurusan ujian.

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LIST OF ABBREVATIONS

CSCI	-	Computer Software Configuration Item
DAS	-	Driving Assistance System
DBT	-	Document-based Traceability
DoD	-	Department of Defense
ERD	-	Entity Relationship diagram
IEEE	-	Institute of Electrical and Electronics Engineers
IRS	-	Interface Requirements Specification
ISO	-	International Organization for Standardization
OBA	-	On-Board Automobile
SDCP	-	Safe Drive Control Panel
SDD	-	Software Design Document
SDLC	-	Software Development Life Cycle
SDP	-	Software Development Plan
SRS	-	Software Requirements Specification
STD	-	Software Test Description
STR	-	Software Test Result
UML	-	Unified Modeling Language
UTM	-	Universiti Teknologi Malaysia
XML	-	Xtensible Markup Language

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CHAPTER 1

INTRODUCTION

1.1 Overview

Software testing is a vital phase in software development life cycle preceding the software maintenance. Software testing has increased colossal significance in the present competitive world of innovation, complexity and challenging age of which software is expected to be more efficient and reliable (Kassab *et al*., 2016). Software testing activities are carried out throughout the software development lifecycle (SDLC) that involves several phases towards the end of the test summary (Spillner *et al*., 2014). In general, software testing can be divided into four categories; unit testing, integration testing, system testing and acceptance testing (Jorgensen, 2014). As testing is an important platform to ensure software quality and conformity involving many staff and documentations, it is quite hard to effectively manage these activities at a time (Naik and Tripathy, 2011). Test management is dedicatedly engaged to manage all these activities and to find ways to reduce the complexities.

Test management is the process of organizing testing and validating the software. Effective test management is a vital part of developing high quality software product (Kukreja *et al*., 2015). Through well-planned and well-managed testing processes, the team can ensure that they are producing the high quality software. The team is led by test manager who has the responsibility to manage risk, reviews, assessments and audits. The function of a software test manager is to

effectively and efficiently lead the testing team. To fulfil this role, the leader must comprehend the order of testing and how to successfully execute a testing procedure while satisfying the customary administration part of a manager (Shuja and Krebs, 2007). The role includes quality and test advocacy, asset arranging and administration, and determination of issues that block the test effort.

One of the main challenges in test management is to manage software documentations. Documentation in software engineering is an artefact with the purpose to share the information of which systems it belongs to. Test documentation is identified as the pivotal point as stated by the IEEE829:2010 in order to manage and to report test contents (Sidek, Noraziah and Wahab, 2011). In other perspective, test maturity model takes documentation as an important measure to associate test management to software test process improvement (Van Veenendaal and Cannegieter, 2010). In other words, for test management to remain useful throughout the phases with acceptable maintenance features built-in is to adopt a good documentation model.

One of the activities involved in test management is traceability. Traceability is the ability of linking various artefacts in software development life cycle in forward and backward way (Schwarz, 2012). In the test management, traceability is used to track the bugs back to the corresponding version of requirements. Traceability has been proven to increase the effectiveness or the efficiency of test management.

1.2 Background of the Problem

Nowadays software is becoming more complex. It consists of diverse components with distributed locations, complex algorithms, on varieties of platforms, many sub-contractors with different kind of development methodologies. Complexity brings the fact that no software parts are indistinguishable. A software can be considered as good and high quality if it has a vigorous software testing. Software testing starts as early as software development begins with an enormous testing activities (Parizi *et al.*, 2014). These activities in software testing need to be planned and managed properly; especially the defects or bugs are found during testing. Each of the defects found needs to be traced to the corresponding requirements. This practice is called software traceability.

Traceability is a vital part of software development and maintenance and broadly recognized as a key to quality of the software (Zhang *et al*., 2016). It is used to capture the link between software artefacts. It is required for the development of safety-critical systems such as in domain of an aerospace (ISO12207, DO-178B), railway (EN50128) and etcetera (Bouillon *et al.*, 2013). In addition, several international quality standards recommended traceability such as IEEE 1291, ISO 9000ff, ISO 15504 and SEI, CMM/CMMI (Wiederseiner *et al*., 2011).

Currently there are many researchers working on traceability. This is due to the arise of many problem in the industries (Mustafa and Labiche, 2015). Though traceability is proven to be having great impact on software project, there are still a lot of problems such as it is an error prone and time consuming (Marques *et al*., 2015b), cost-intensive (Maro *et al*., 2016; Regan *et al*., 2012), laborious (Shao *et al*., 2013; Kamalabalan *et al*., 2015), ad-hoc traceability without strategy (Bouillon, Mäder and Philippow, 2013) and difficult (Regan *et al.,* 2012). There are a few researches on traceability regarding to testing artefacts such as unit testing and class (Qusef *et al.*, 2010), test artefacts and code (Wiederseiner *et al*., 2011), test cases

and requirements (Noack *et al*., 2014), bugs and test cases (Kaushik *et al*., 2011), design and test (Lormans and van Deursen, 2009). Although studies have shown an increase in testing traceability, the research focuses on test result, bugs and test cases is still vague (Garousi, Eskandar and Herkiloğlu, 2016). Research has revealed that poor traceability can be an essential contributing factor to software project failure (Parizi *et al*., 2014). Though, notwithstanding the available commercial tools to support traceability, the actual practice of traceability remains poorly documented (Cleland-Huang *et al.*, 2012; Maro *et al*., 2016).

A poorly documented traceability would jeopardize the quality of the software product especially in the critical-safety system. Software engineers depend on system documentation as a guide in comprehension of the practical, architectural design, and the usage of subtle elements of complex applications. Software engineers are compelled to depend exclusively on source code when the documentation does not exist. This is a failure-prone process and a time consuming (Roth *et al*., 2013), particularly when one considers the amount of information adaptation and domain mapping that is required to comprehend the architecture of a multi-function software system. There are various inadequacies in current project documentation methods (de Graaf *et al*., 2016). Since the initial days of software development some of these insufficiencies have existed, for example the absence of consistency between the source code and documentations. Other deficiencies have only recently become apparent as vital issues, such as the intricacy in incorporating existing documentations with newly created artefacts (Herwig, 2014). Numerous studies have demonstrated that documentation regularly experiences the accompanying issues:

(i) Nonexistent or of low quality (Alaranta and Betz, 2012; McBurney, 2015)

(ii) Out-dated (McBurney, 2015; Garousi *et al*., 2013; Satish and Anand, 2016)

(iii) Over abundant and without a definite objectives / incomplete (Parnas, 2011; Dautovic, 2011)

(iv) Difficult to access and manage (for instance when the records are scattered on different computers or in distinctive format: diagrams and text) (Choudhury and Thushara, 2014)

(v) Difficult to trace / Lack of traceability (Satish and Anand, 2016; Plosch, Dautovic and Saft, 2014)

The key point solution to the above problems is not the documentation itself, but how to manage the documentation. One or more types of documentation may be made available at each testing phase. The contents of document may reflect some duplication while others are disintegrated that make it difficult for test manager to access, update and control the visibility of current status of testing (Khan and Mattsson, 2012). Currently many researchers have been working on the software documentation however very few are working on the importance of test documentation as a way forward to support test management (Donald, 2013).

Despite this, test documentation is not given due respect by many testers (Andrade *et al,.* 2013). Test documentation is treated as a time consuming task that not many people would like to get involved with. Some organisations give less attention on documentation with reason being the lack of staffing (Khan and Mattsson, 2012). Worse, the distribution of man power allocated to testing activities is not justified in that it is far less than the allocation assigned to the development activities (Treude, Robillard and Dagenais, 2015). This gives more strong reason to why there is a need to have a special emphasis on the need of test documentations and the way to manage them.

Based on the evidence mention, there are fewer endeavours done to manage document traceability in software testing artefacts. Hence, the need to develop new traceability model that support test management is crucial.

1.3 Statement of the Problem

There is a need to establish integration amongst documentation such that all can be made accessible and easy to manage. Secondly as different organization may adopt different test documentation, it is necessary to make a survey to understand the most relevant information that is practically used and adopted by the industries. Thirdly, the existing software test documentations are difficult to manage. Thus, there is a need to propose a special mechanism or model to manage software testing documentation in integration. The key solution to above problems is to establish an effective traceability model to support software testing documentations.

This research investigates the need for customized software testing documentation and formulates a software traceability model to support documentation in software testing. The main research question is "*How to design and implement an effective software engineering documentation model based on Software Engineering Standards using traceability model to support Test Management?"*

The sub questions of the main research questions are as follows:

(i) **RQ1** : Why the existing software engineering documentation are not fully adopted by test management and why the existing traceability model still not able to manage the link between the artefacts?

(ii) **RQ2** : What is the effective way to help test management in maintaining a software traceability within a software engineering documentation?

(iii) **RQ3** : How to provide traceability links between artefacts that will support test management ?

(iv) **RQ4** : How to evaluate the usability of the proposed model to support test management at some significant degree?

1.4 Objectives of the Study

The research objectives are mentioned based on the problem statement, are as follows:

(i) To study and investigate current issues in software traceability associated to software documentation and test management.

(ii) To formulate a new traceability model that integrates all software engineering artefacts within a repository to support test management.

(iii) To design and develop the prototype of the proposed document-based traceability model.

(iv) To evaluate the effectiveness and the efficiency of the proposed model.

1.5 Scope of the Research

The scope of this study covers the following:

(i) This research focuses on traceability for software testing and its associated components. This will involve the study on system level of software testing (unit, integration, system, and acceptance) but not on types of testing (example – smoke, security, performance, regression, compliance etc.)

(ii) The testing documents will be used are Software Test Description (STD) and Software Test Result (STR). No other testing documents will be used.

(iii) Software engineering documents will be used besides software testing documents are Software Requirements Specifications (SRS), Software Design Document (SDD) and source code.

(iv) This is not a bug tracking system. It just uses documentation to highlight the bugs inside the document.

1.6 Significance of the Study

Requirement traceability has been shown to give numerous advantages to organization that make utilization of traceability methods. This is the reason traceability is an imperative part of numerous standards for software development, such as the CMMI , ISO 9001:2000 and ISO/IEC 15504/SPICE (Gotel *et al*., 2012). Disregarding the advantages that traceability offers to the software engineering industries, its practice confronts numerous difficulties (Kannenberg and Saiedian, 2009; Cleland-Huang *et al.,* 2014). These difficulties can be distinguished under the zones of cost in terms of endeavor and time, the trouble of keeping up traceability through change, tool support, distinctive perspective focuses on traceability by diverse stakeholders, hierarchical issues and legislative issues, and poor documentation.

On the other hand, documentation plays a vital role in software development and maintenance. Typical software system documentation consists of different type of artefacts, ranging from source code, requirements, architecture design, testing and many more. Good software documentation provides multiple views of a system at different abstraction level and using different formats. As the quantity and variety of information about software system develops, so does the requirement for supporting consistency and traceability among distinctive levels of abstraction for engineers (Nair *et al.*, 2013).

A survey conducted by (Bouillon, Mäder and Philippow, 2013; Mustafa and Labiche, 2017) shows that traceability between requirements and others artefacts (especially testing) was rarely maintained in practice. Meanwhile, research conducted by (Regan *et al.*, 2012) indicates the needs of documentation in practice, and the tools and technologies used to maintain, verify and validate such documents.

Clearly, traceability is very important to trace the link between artefacts involved in software development and maintenance of a software system.

1.7 Thesis Outline

This thesis discusses the issues concerning to traceability that relate to testing artefacts which support test management. It highlights the problems and limitation of software documentation, test management, traceability and the similarity link between them. This thesis is organized as follows:

Chapter 2: Discusses in general about software testing, followed by test management and it approaches and issues. This chapter discusses about software documentation and the problems/issues. This chapter highlights the traceability approaches, traceability models and issues. A comparison study was tabulated and identifies the limitations and issues.

Chapter 3: Describes the research methodology in this research. It explains the resign design, procedure and activities which are used in this research. This chapter also discusses on the evaluation method, instrumentation, case study, assumptions and limitation that have been adopted and observed in this research.

Chapter 4: Presents a conceptual of the proposed model. It also describes the detailed component of the proposed model including the architecture and the process. This chapter explains the development of the proposed model in the UML notation.

Chapter 5: Elucidates the evaluation of the proposed model in terms of effectiveness, efficiency and satisfactory. The quantitative and qualitative method is apply; feature analysis, precision and recall, and expert validation. The results are based on customer perception and metric calculation.

Chapter 6: This chapter concludes the research by describing the research achievement and contributions. The last part explains the limitations and suggestions for future works.

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