

TRACEABILITY APPROACH FOR MANAGING CHANGES INVOLVING  
SOFTWARE TESTING ARTEFACTS

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*ALHAMDULILLAH Praise be to Allah, and may His peace and blessings be upon  
Muhammad s.a.w,*

*For my beloved parents Hjh Asmah Basir, Haji Mohd Yusop Nami, Hjh Sainah  
Dahlan, my beloved wife, Noraini binti Shaari and my bubbly little daughter, Dhia  
Humaira' binti Othman who have given me the strength and courage.*

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*OMY, Presint 18, Putrajaya*

## ABSTRACT

Software change is inevitable for software product to remain relevant and reusable. As software evolves over time due to specific changes at any point in time during software development and maintenance, the managing aspect of changes may get more complicated and risky. The outdated links would cause the affected artefacts to be not updated timely and effectively. Most of the existing traceability approaches and tools are dedicated and limited to high level artefacts such as requirements and fewer capability made available to address the lower level artefacts such as classes and codes. Most maintainers limit their links to begin at the requirement perspective but there is no valid traceability link being made to support the fine grained level involving testing components. This thesis proposes a new traceability approach to manage changes with the emphasis on the integration of the development artefacts and testing artefacts. The working artefacts cover requirements, packages, classes, methods, test case, and codes. The proposed approach provides a know-how solution to the IEEE 829:2010 standards associated to testing that demands for the support at testing perspective. This approach has the capability to horizontally and vertically manage artefacts from requirement down to code and vice versa. The proposed traceability approach was applied to a case study of a software development project called On-Board Automobile (OBA) with a complete set of documentation including test cases. The evaluation results prove that the proposed traceability approach is significant and useful in managing software changes involving testing artefacts.

## ABSTRAK

Pindaan perisian tidak dapat dielakkan bagi produk perisian untuk ianya kekal berfungsi dan berkebolehan untuk diguna semula. Oleh kerana perisian berubah sepanjang masa disebabkan wujudnya pindaan tertentu pada mana-mana tempat semasa pembangunan perisian dan penyenggaraan, aspek pengurusan pindaan boleh menjadi lebih rumit dan berisiko. Jalinan yang luput mungkin menyebabkan artifak yang terlibat tidak dapat dikemaskini dalam masa yang ditetapkan dan menjadikannya tidak berkesan. Kebanyakan pendekatan jejak semasa dan alatan adalah khusus dan terhad kepada artifak aras tinggi seperti keperluan berbanding sokongan untuk menangani artifak aras lebih rendah seperti kelas dan kod. Kebanyakan penyenggara menghadkan jalinan jejak untuk bermula pada perspektif keperluan tetapi tiada jalinan jejak yang sah untuk menyokong aras butiran halus yang melibatkan komponen pengujian. Tesis ini mencadangkan pendekatan jejak yang baharu untuk menguruskan pindaan dengan penekanan kepada integrasi terhadap artifak pembangunan dan artifak pengujian. Artifak yang diusahakan merangkumi keperluan, pakej, kelas, kaedah, kes pengujian dan kod. Pendekatan yang dicadangkan menyediakan penyelesaian pengetahuan untuk IEEE 829: 2010 standard berkaitan dengan pengujian yang memerlukan sokongan pada perspektif pengujian. Pendekatan ini mempunyai keupayaan untuk menguruskan secara jalinan mendatar dan jalinan menegak untuk urusan artifak daripada fasa keperluan ke kod dan sebaliknya. Pendekatan jejak yang dicadangkan ini diaplikasikan dengan bantuan kajian kes projek pembangunan perisian yang dipanggil *On-Board Automobile (OBA)* termasuk satu set dokumentasi yang lengkap bagi kes-kes pengujian. Keputusan penilaian membuktikan bahawa keberkesanan pendekatan yang dicadangkan adalah signifikan dan berguna dalam menguruskan perubahan perisian yang melibatkan artifak pengujian.

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Overview**

This chapter introduces the research and elaborates its background in detail and subsequently describes the problem statement, research objectives, research scopes and the significance of this study.

#### **1.2 Background Problem**

It is inevitable for the software to evolve in order to cope with emerging changes. Changes in software could mostly would occur due to internal or external requests i.e. user's requests. User change requirements can occur after the delivery of the complete software artefacts such as a system, documentations, or during the progression of the software development phases involving requirement, design and testing. Hence it is widely accepted within software engineering community that software changes or software evolution is a part of software maintenance process. The term software evolution and software maintenance are used interchangeably and in short practitioners classify it as maintenance (Bennett and Rajlich, 2000). In maintenance process, traceability is important. Facilitating the changes during maintenance using traceability is a crucial step in ensuring the affected artefacts across software development phases, are well maintained (Rochimah *et al.*, 2009; Shahid and Ibrahim, 2013).

During the maintenance phase, some activities needs to be managed. These activities are maintaining traceability, change management, and maintaining affected software artefacts. Prior to implementing any changes, ones need to comprehend before and after changes take place. For example, changes made at testing level

or any other level throughout software development phases, often occurred without updating the relevant documentations (Mäder and Egyed, 2012). Due to this negligence, it automatically causes the traceability link between the affected artefacts becoming obsolete. In addition, some organizations are neglecting the traceability implementation due to laborious works that need to be considered (Lormans *et al.*, 2004). In spite of the existence of change management tools to update the traceability link, the maintenance routine they need to incur, is not practical and time consuming (Heindl and Biffel, 2005). Most of the change management tools support either at file structure or at source code file level and whenever an update gets introduced at either level, the traceability links that supposed to be maintained, are left forgotten and outdated. Hence, updating the traceability link upon changes among the artefacts at higher and lower level are often a failure whenever there is a change occurred (Cleland-Huang *et al.*, 2003).

In the context of the bigger system, there are possibly a lot of artefacts need to be managed and tested. Each of the changes made has to be retested and verified to ensure changes realisation. Traceability ensures the right artefacts get amended and tested. Poorly maintenance of the traceability link due to an increase of testing activities as an example, can affect negatively on the cost of maintenance (Sherba, 2005; Tamai and Kamata, 2009). Freese (2003), stated the expenditure for software maintenance can increase to as much as 80% of the total lifecycle cost of a software system. In addition, traceability maintenance requires consistent updating and due to the nature of larger system having many artefacts to maintain, improper and imprecise traceability approach could happen (Sherba, 2005). Therefore traceability link maintenance is considered as an essential element of software development lifecycle (Cleland-Huang *et al.*, 2014).

Changes can span from coarse artefacts (i.e. SDP, SRS, SDD, STD, and STR) to fine-grained artefacts (i.e. test objects, classes, methods) (Omar, 2013; Shahid and Ibrahim, 2016). The problem may arise while doing maintenance if software changes impacting more than a single software artefact. Thus, it causes more than one artefacts need to be amended accordingly. The number of software changes can grow from single artefacts to many artefacts. In order to manage and resolve many changed artefacts, managing via traceability must be implemented. Currently, many works have been done on focusing changes from requirement perspective (Ibrahim *et al.*, 2005; Rochimah *et al.*, 2009; Omar, 2013; Shahid and Ibrahim, 2013). There are other works too that focusing changes from other phases in software development lifecycle i.e. component level (Mei *et al.*, 2002), modelling language (Murta *et al.*, 2008a),

methods and classes level (Junqueira *et al.*, 2008), architectural level (Nguyen *et al.*, 2005), and test-driven (Freese, 2003). The latter was focusing on broader perspective, specifically at process level instead of file structure or fine-grained artefacts. (Cleland-Huang *et al.*, 2014) even added in their research studies on the current trend of software traceability, in which they quoted the USA Federal Aviation Administration (FAA) and USA Food and Drug Administration (FDA) are emphasising on software traceability from source code to software requirement and therefore it is clear indication of the current traceability trend, there is still a lack of consideration from testing artefacts perspective.

From traceability issues, some challenges that are related to tracing the prospect impacting software artefacts can occur as pointed out by this study (Ibrahim *et al.*, 2005). The main problem to maintainer is that seemingly small changes can ripple-effect throughout the system to cause substantial impact elsewhere. Besides tracing the changes from one artefact to another across entire software development lifecycle, establishing traceability itself is rarely done (Grechanik *et al.*, 2007).

Based on the above scenarios, it is evident at the time of this research was conducted, there are fewer efforts done to manage affected testing artefacts via traceability. Implementing changes can be exhaustive, frustrating and costly due to the amount of laborious manual works and the issues will worsen if the software developers are clueless of how to identify the affected artefacts due to poor traceability practices and undesirable change management. Therefore, it is an important necessary to establish traceability link to manage changes made from any phases of software development process that particularly might affect testing artefacts as well. The traceability establishment could span from the requirement to testing phases and vice versa and the link will not be limited to different phases but the establishment of the traceability link will accommodate artefacts within the same phase of software development lifecycle.

### **1.3 Problem Statement**

In maintenance process, managing changes through traceability link will ensure the affected artefacts i.e. functional and non-functional requirements, design model and component, and test artefacts get amended accordingly as the new change was introduced. In the real process, the work will be more simplified if the developers or

maintainers can find their own way to establish the traceability link between the high level and lowest level artefacts.

Current traceability approaches as discussed in section 1.2, have shown limited coverage of traceability links whereas changes could happen from a testing perspective. Due to highlighted issues, extending the traceability coverage is essential and will be made helpful to support changes from testing standpoint as well. Therefore this research will focus on finding support through traceability approach whilst managing the affected artefacts from testing perspective.

This research is intended to deal with the lack of traceability support on test artefacts as discussed in previous section. The support will cover artefacts from a higher level of abstraction to the lowest level of abstraction. It will be done through the establishment of traceability either horizontally (across different phases of the lifecycle) or vertically (within a phase in the lifecycle) and the output of this research is expected of an improvement of managing involving test artefacts via traceability approach. Hence the hypothesis leads to this research question:

*"How affected test artefacts due to changes across and within phases of software development lifecycle could be managed effectively through traceability approach?"*

To be able to answer the above questions, a set of sub-questions is formed below to provide detail insight of the outlining research problem:

**RQ1:** Why current traceability approaches do not satisfy the developer/tester during software testing lifecycle?

**RQ2:** How to facilitate changes that are potentially affected and propagated to other artefacts during managing the evolving test artefacts?

**RQ3:** How traceability approach will improve the developers/testers tasks in coping up with changes across the entire phases and within the same phase of software development lifecycle?

**RQ4:** How to validate the effectiveness of the proposed traceability approach to some significant level?

## 1.4 Objectives of the Study

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

- (i) To study and investigate the current issues of traceability approaches to manage changes involving test artefacts.
- (ii) To develop a new traceability approach that support affected changes across phases and within a phase in software development lifecycle as well as from coarse level to the fine-grained level of artefacts.
- (iii) To design and formulate algorithms to support the proposed approach.
- (iv) To evaluate the effectiveness of the proposed approach against the existing approaches through obtained results.

## 1.5 Scope of the Study

This section describes the boundaries of this research. The scope of this study covers the following:

- (i) This research focuses on existing traceability approaches that relate to managing affected test artefacts upon changes, either explicitly or implicitly across or within phases of software development lifecycle.
- (ii) This study covers from coarse level artefacts (i.e. SDP, SRS, SDD, STR, and STD) to fine-grained level (i.e. requirement indexes, objects, classes, components, packages, methods, test cases, test suites and data elements) and all artefacts have a unique item identifications which conformed to (MIL-STD-498, 2005) documentation standard. Even though these research artefacts seem to bound to a specific documentation but the importance of this study is more on managing the artefacts via traceability itself.
- (iii) A medium size (approximately above 5000 usable line of code/LOC) case study based on the objected oriented approach will be adopted to address issues of managing the involving artefacts from testing perspective. The LOC was measured using an opened source tool, LOCMetrics by McCabe Metric (McCabe, 1976) and the technique was adopted by Software Engineering Institute (SEI) for LOC counting standards (Nguyen *et al.*, 2007).

- (iv) The effectiveness of the traceability approach will be quantitatively measured using precision and recall from Information Retrieval (IR) field. As these two parameters are used to prove an efficacy of any approach that adopts IR technique (Buckland and Gey, 1994).

## **1.6 Significant of the Study**

Harrold (2009) stated in her research, the most expensive activities could occur after software development completion is software retesting during maintenance testing phase. Further quote, 50% of software maintenance budget will consume by retesting activities. In software testing alone, a big chunk of budget, at estimation nearly 80% will spend for retest. Retest is needed to ensure change imposed on the system, does not propagate to the untouched features. Building up a model that can trace and foresee the candidate impacted artefacts is crucial during software maintenance and furthermore, maintenance testing is the most non-trivial part of the maintenance activities. To build up such a model, there are features needed to be considered; a traceability features. Traceability is necessary due to its capability to establish links among the artefacts. Time reduction whilst performing maintenance testing is an important factor too, hence the automated proposed approach.

Tracing and managing ever grow software artefacts due to changes are seemingly never ending maintenance activities. Updating the traceability links due to changes in any phases is making the software system itself growing, expanding, evolving, etc. Changes are inevitable due to factors namely, outdated software system, new platform of operating system, change requirements, new project management approach, new developers' techniques or methodologies, etc.

Poor in identifying which artefacts being affected due to changes indicate that traceability approach used is weak and poor. The issue gets further worse if the software artefacts are bigger in volume which involves many lines of source codes, documents, etc. Hence this study will provide a support for developers at testing lifecycle specifically maintenance testing, to tracing back which test component or test objects, test cases are affected due to changes in requirement. Found bugs will be included and tightly coupled with test cases/test script that initiated the bugs. The latter will be stored together with the test case inside a repository. In addition, in order to manage the evolution of the artefacts, the repository will be used to store the

traceability links update.

This study is targeting the developer's awareness of how important to keep their artefacts manageable and traceable right at their finger tips. Thus eliminating time and cost consuming at the later stage of maintenance testing phases. The test managers and testers would be having a complete transparent view from tester's perspective (abstract level) right down into developer's perspective (logical level) i.e. tracing bugs and the management level can make firm decision over the changes execution.

## 1.7 Thesis Outline

This thesis discusses on specific issues associated with managing involving test artefacts via software traceability. It highlights the limitation of current approaches in resolving the outdated traceability links upon software changes from a testing perspective. This thesis is organised as follows:

**Chapter 2:** Discusses the literature review about change management, existing traceability approaches and managing test artefacts during software change. This chapter also highlights some limitations of the existing traceability approaches that support changes from testing perspective. A comparative study was tabulated and limitations of the existing approaches are highlighted in table form. This study will lead to an opportunity for improvement in proposing a new software traceability approach.

**Chapter 3:** Highlights a research methodology that discusses the research design, formulation of research procedures and activities and the theoretical framework. This chapter also discusses on research instruments, evaluation criteria, assumption and limitation.

**Chapter 4:** Presents an explanation of the conceptual detailed of the new traceability approach in managing affected test artefacts during changes. A set of formal notations is used to represent the conceptual part of the approach. This is followed by a detailed discussion of the proposed approach. It explains two part of traceability; horizontal (explicit) traceability and vertical (implicit) traceability. This chapter explains the design and functionality of a developed tools to support



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