An Approach of Change Impact Analysis in Web Systems

Zafar Mehboob (B.S. (Comp. Sci.), M.S. (Soft. Eng.))

A Thesis Submitted for the Degree of

MASTER OF SCIENCE IN COMPUTING SCIENCES (RESEARCH)

University of Technology Sydney
Faculty of Engineering & Information Technology

2013

Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Production Note:
Signature removed prior to publication.

Signature of Student:

Date: 26-03-2013

Acknowledgement

This thesis was completed with the support and guidance of a great number of people whose contribution in various ways to the research and the making of the thesis deserved special mention.

I would like to express my sincere gratitude to Professor Didar Zowghi for her understanding, encouragement and personal guidance, provided me a good basis to conduct this research. I am grateful to Professor David Lowe for his detailed and constructive comments, and his valuable advice to improve the quality of this thesis.

I owe my gratitude to Professor Jaya Kandasamy and Dr. Paul Kennedy Paul for their support, guidance and constructive discussions to finish my research work.

I warmly thank to all the participants took active part in interview based study. I owe deep gratitude to Mr. Mohammad Aamir Khan who gave me the opportunity to conduct the case study in his organisation. I thank to Professor Marco Brambilla from Politecnico di Milano, Italy, for his valuable advice and friendly help in relation to exemplar system study. I am thankful to him for giving me insights into WebML modelling software and provide timely feedback on the WebML design Models. I am truly grateful to my father, mother, brothers and sister for their best wishes, prayers and support.

Lastly, and most importantly, I would like to dedicate this thesis to my father and my dearest mother who formed part of my vision and taught me to keep learning and taking on greater challenges. It would not have been possible to finish my research work without their understanding, patience, guidance, and continual support.

Preface

Some of the work described in this thesis has been published previously in several conference proceedings and international journals:

1. (Mehboob, Z. et al., 2007) describes preliminary research direction, based on the investigation from the state of the art, as discussed in Chapter 2
2. (Mehboob, Z. et al., 2008) describes research investigation toward change impact analysis in Web systems and research scope based on the investigation from the state of the art, as discussed in Chapter 2.
3. (Mehboob, Z. et al., 2009) describes a comparison study and the findings from the comparison of existing architecture level CIA approaches and their relevance in Web systems, discussed in Chapter 2.
4. (Mehboob, Z. & Zowghi, D. 2009) discusses the perspectives on Architecture level Change Impact Analysis in Web Systems Evolution, leads to the findings from the state of the practices in relation to change impact analysis approaches in Web systems projects, discussed in Chapter 4.
5. (Mehboob, Z. et al., 2011) presents a Process Model of Change Impact Analysis (PMCIA) for Web Systems Using Design Knowledge. This work is discussed in Chapter 5.
6. (Mehboob, Z., 2013) presents a comparison study for PMCIA with other similar approach proposed to perform CIA for Web systems.
7. (Mehboob, Z. & Khan, A. M., 2013) presents case study design in brief and investigation results in relation to validate PMCIA, discussed in Chapter 6 and 7.

Table of Content

Chapter 1: Introduction 14
1.1 Overview 14
1.2 Motivation 14
1.3 Problem Establishment 17
1.4 Research Objectives/Questions 25
1.5 Proposed Approach and Justification 26
1.7 Research Approach and Thesis Structure 29
Chapter 2: Literature Review 32
2.1 Introduction 32
2.2 Web Systems 34
2.3 Web Systems Characteristics 37
2.4 Evolution, Nature and Types of Change in Web Systems 43
2.4.1 System evolution 43
2.4.2 Nature of changes 44
2.4.3 Types of change 45
2.5 Web Systems Development 46
2.5.1 Web systems modelling languages 48
2.5.2 Architecture design of Web systems 49
2.5.3 Web systems and information architecture 51
2.5.4 Early identification of change impacts 52
2.6 Change Impact Analysis 54
2.6.1 Change management 54
2.6.2 Overview of change impact analysis 54
2.6.3 Basic change impact analysis mechanism 56
2.6.4 Change impact analysis at architecture level 59
2.7.1 Traceability analysis 61
2.7.2 Dependency analysis 62
2.7.3 Change impact analysis process 65
2.7.4 Change impact analysis tools 66
2.7.5 Existing Web systems CIA techniques 67
Chapter 3: Research Methodology 79
3.1 Introduction 79
3.2 Research Study 79
3.2.1 Purpose of research 81
3.2.2 Types of research questions 83
3.3 Research Design 86
3.3.1 Quantitative research 86
3.3.2 Qualitative research 86
3.3.3 Mixed approaches research 87
3.3.4 Triangulation 88
3.4 Mapping Research Objective, Questions and Strategies 89
3.5 Research Methods 90
3.6 Research Methods for Stage 1 91
3.6.1 Justification of methods selected 92
3.6.2 Data collection methods 92
3.6.3 Data analysis methods 92
3.7 Research Methods for Stage 2 93
3.7.1 Justification of methods selected 93

3.7.2 Data collection methods....94
3.7.3 Data analysis methods....94
3.8 Research Methods for Stage 3 (Development, Illustration and Valid)....99
3.8.1 Development of the process model of CIA....101
3.8.1.1 Justification of method selected....102
3.8.1.2 Data collection methods....103
3.8.1.3 Data analysis method....103
3.8.2 Illustration of the process model approach....104
3.8.2.1 Justification of methods selected....104
3.8.3 Validation of process model approach....107
3.8.3.1 Justification of methods selected....107
3.8.3.2 Data collection methods....108
3.8.3.3 Data analysis methods....109
3.9 Research Reliability and Validity....109
3.9.1 Reliability....109
3.9.2 Internal validity....110
3.9.3 External validity....111
3.10 Ethical Considerations....112
3.11 Chapter Summary....113
Chapter 4: Features of a Change Impact Analysis Approach for Web systems....115
4.1 Introduction....115
4.2 Interview Objectives....116
4.3 Research Questions....116
4.4 Interview Study Setting....117
4.4.1 Establishment of the participant criteria....118
4.4.2 Questionnaire development....119
4.4.3 Contacting potential participants....120
4.4.4 Pilot study and refinement....120
4.5 Data Analysis....121
4.6 Analysis Results....123
4.6.1 Features for CIA....124
4.6.2 Frequency distribution analysis of features for CIA....125
4.7 Classifications of Needs for Change Impact Analysis....128
4.7.1 Traceability and dependency analysis....130
4.7.2 Process level support....131
4.7.3 Effectiveness of analysis....133
4.7.4 Design information reuse....135
4.7.5 Understanding specific Web systems characteristics....136
4.8 Chapter Summary....137
Chapter 5: A Process Model of Change Impact Analysis....139
5.1 Introduction....139
5.2 Extensions of Existing CIA Approaches....140
5.3 Using Design Rules and Constraints for PMCIA....141
5.4 Data Model....143
5.4.1 Description of data model....147
5.5 Process Model....148
5.5.1 Initial inputs....153
5.5.2 Step#1: Examine initial effects of changes....155
5.5.3 Step#2: Examine the ripple effects of change....158
5.5.4 Step#3: Perform architectural changes....161

5.6 Mapping between Identified CIA features and PMCIA 162
5.7 Discussions 165
5.8 Chapter Summary 168
Chapter 6: The Case Study Methodology 170
6.1 Introduction 170
6.2 Case study - A Research Methodology 171
6.3 Case Study Protocol 173
6.4 Case Study Design 175
6.4.1 Components of case study design 175
6.4.2 Case study site selection 178
6.5 Applying Case Study Design 180
6.5.1 Phase 1: Organisational context 181
6.5.2 Phase 2: Examining current CIA approaches (pre-study Analysis) 182
6.5.3 Phase 3: Instantiation of process model of CIA 182
6.5.4 Phase 4: Validation of process model of CIA 182
6.6 Data Collection 183
6.6.1 Interviews 184
6.6.2 Document inspections, direct observations and discussions /meetings 185
6.6.3 Project documents 185
6.6.4 Design decisions repository 186
6.6.5 Meeting observations 186
6.6.6 Archival records 187
6.7 Data Analysis 187
6.8 Reporting 189
6.9 Research Reliability, Validity, and Generalisability 189
6.9.1 Reliability 190
6.9.2 Construct validity 190
6.9.3 Internal validity 190
6.9.4 External validity (generalisability) 191
6.9.5 Ethical considerations 191
6.10 Chapter Summary 192
Chapter 7: Case Study Findings 193
7.1 Introduction 193
7.2 Case Study Objectives 193
7.3 Case Study Settings 194
7.4 Phase_1: Understanding Organisational Context 194
7.4.1 Phase_1: Data collection and analysis 195
7.4.2 Phase_1: Findings 196
7.4.2.1 Organisation's background 196
7.4.2.2 Web system project overview 198
7.4.2.3 Project release_A 200
7.4.2.4 Project release_B 200
7.5 Phase_2: Change Impact Analysis-Project Release_A 201
7.5.1 Phase_2: Data collection and analysis methods 201
7.5.1.1 Data collection 201
7.5.1.2 Data analysis 203
7.5.2 Phase_2: Case study findings from project release_A 204
7.5.2.1 Business processes changes 204
7.5.2.2 Identified change impacts at architecture design 204
7.5.3 Phase_2: Pre-study interview findings and analysis 206

7.5.3.1 Participants overview 206
7.5.3.2 CIA practices adopted in project release_A 206
7.5.4 Phase_2: Summary of change impact analysis during project release_A 214
7.6 Phase 3: Instantiation of PMCIA 215
7.6.1 Phase_3: Data collection and analysis 215
7.6.2 Phase_3: Case study findings from project release_B 216
7.6.2.1 Business processes change 216
7.6.2.2 Identified Change Impacts on Architecture design 217
7.6.3 Phase_3: Summary of the change impact analysis_2 218
7.7 Phase_4: Validation of the Process Model of CIA (PMCIA) 218
7.7.1 Phase_4: Data collection and analysis 219
7.7.2 Phase_4: Findings from validation of process model of CIA (PMCIA) 220
7.7.2.1 Current CIA practices 220
7.7.3 Phase_4: Summary of validation of process model of CIA 227
7.8 Chapter Summary 227
Chapter 8: Conclusions 230
8.1 Introduction 230
8.2 Research Objectives and Questions Revisited 230
8.3 Research Outcome 239
8.4 Thesis Contributions Revisited 240
8.5 Implication for Research and Industry 242
8.6 Research Limitations 244
8.7 Suggestion for Future Work 245
8.8 Concluding Remarks 245
Appendix A 247
Appendix B 248
Appendix C 249
PART A: Change Impact Analysis in Web systems Development 249
PART B: Company and Project details 251
Appendix D 253
Appendix E 254
1. Instantiation of Process model of CIA 254
1.1 Web system details 254
1.2 Overview of WebML and design models for exemplification 256
1.3 Changes in business processes 257
1.4 CIA related Architecture Design information 257
1.5 Instantiation of process Model of CIA 257
Appendix F 266
Appendix G 267
Appendix H 271
Appendix I 275
References 284

List of Figures

Figure 1.1 : Software change impact analysis – Adopted from (Bohner and Arnold, 1996)

Figure 3.1: Three stage research methodology

Figure 4.1: High-level features based on the frequency distribution of 15 identified features

Figure 5.1: Data model to support data input requirements of PMCIA

Figure 5.2: Envisioning design rules, design entities and design entity relationships

Figure 5.3: Dependency graph

Figure 5.5: Process Model for Change Impact Analysis, illustrating three steps and the activities in each step.

Figure 5.6: Detail of Step#1 in the PMCIA as shown in figure 5.5

Figure 5.7: Detail of Step#2 in the Process model as shown in figure 5.5

Figure 5.7a: An example of design rule adopted from (Garrido et al., 1997).

Figure 6.1: The four phases of case study design to validate process model of CIA

Figure 7.1: The four phases of case study design to validate PMCIA

Figure 7.2: Percentage of different types of changes during Project Release_A

Figure 7.3: Identified impacts at architecture design and later stages of system development to address business processes changes during *Project Release_A*

Figure 7.4: Possible ways of performing change impact analysis during *Project Release_A*

Figure 7.5: Importance of CIA related items

Figure 7.6: Participant agreements on supported aspects of existing CIA approach

Figure 7.7: Participants perspectives on process aspects of current CIA approach

Figure 7.8: Percentage of different types of changes during *Project Release_B*

Figure 7.9: Identified impacts at architecture design and later stages of system development to address business processes changes during *Project Release_A and Project Release_B*

Figure 7.10: Comparison of possible way to perform change impact analysis in two different releases by using two different CIA approaches

Figure 7.11: Participants' agreement on traceability and dependency analysis in relation to PMCIA

Figure 7.12: Participants' response on availability of information using old CIA approach and PMCIA during *Project Release _A* and *Project Release _A* respectively.
Figure 7.13: Participants' Agreement on the process aspects of PMCIA during *Project Release_B*
Figure E1: Navigational flow of loan issuance for staff view [Tailored version, adopted from (Acerbis et al., 2008)]
Figure E2: Navigational flow of loan issuance for customer view [Tailored version, adopted from (Acerbis et al., 2008)]
Figure E3: Traceability Matrix
Figure E4: Forward tracing of design entity relationships
Figure E5: Dependency graph- Backward tracing of design decision information
Figure I1: Traceability Matrix showing the relationships between changed business processes and impacted Information Architecture requirements (adopted from *Project Release_B* of CMS project- from WSD)
Figure I2a: Forward tracing for design entity relationships
Figure I2b: Dependency graph- Backward tracing of design entity relationships

List of Tables

Table 2.1: A summary of design decision approaches/tools and their documented information constructs.

Table 3.1: Mapping Research Objectives, Questions and Strategies

Table 3.2: Data collection and analysis methods

Table 4.1: Stage 2 research objectives, research questions, corresponding questions from questionnaire, and research strategies

Table 4.2: Division of interview questions via topics

Table 4.3: Features for CIA approaches derived from interviews data

Table 4.4: High-level features of Change Impact Analysis

Table 4.5: Classification of high-level features of CIA

Table 5.1: Description of sources, appropriateness and the form taken by each element of data model from figure 1

Table 5.2: Mapping between CIA features and process model of CIA

Table E2: List of design entities with their Ids

Table E3: Dependencies between architecture requirements and design entities

Table E4: Design decision and other design information

Table E5: Design information extracted from table E4

Table E6: List of Design entities with their Ids for figure E4 and figure E5

Table I1: Dependencies between architecture requirements and design entities

Table I2. Design decisions related to each design entity in SIS

Table I3. Illustrating fan-in and fan-out for each design entity from EIS

Abstract

There are currently a high number of Web systems being developed; therefore, any consideration towards improving Web systems development practices will be worthy of research effort. Web systems are intricately interwoven into business processes so as to be supported by those systems. In other words, there are a multitude of fined-grained interconnections between business processes and the supporting architecture. Keeping in view the fine-grained interconnections, any change made in business processes can typically lead to more pervasive changes at the architecture (as compared to traditional software systems). Consequently, there is a much more fine-grained evolution at the architecture level in order to address the intricately interwoven characteristic. Partly as a consequence of the intricately interwoven characteristic, the connection between business processes and the architecture solution are also much tighter than for traditional software systems. Given this tight-connection, any change in business processes often leads to fundamental changes at the supporting architecture. Additionally, while addressing changes in business processes, a single change in architecture may have substantial impacts on other parts of the architecture and result in the ripple effects of the change being made to architecture.

The intricately interwoven characteristics, underpinning fine-grained evolution and the tight connection between business processes and the architecture design tend to differentiate Web systems from traditional software systems. To support the evolution and tight connection between business processes and architecture design, it would be beneficial to identify what needs to be modified in architecture to address business processes changes. Failure in attempts to identify change impacts on the architecture resulting from business processes changes leads to the problem where implementation (detailed design) begins before the impacts (on architecture) are adequately identified. As a consequence, many of the change impacts caused by business processes changes may go undetected or are identified very late and often lead to unnecessary re-work during the later stages of system development. We will refer to the identification of change impact on architecture before detailed design actually begins as "*early identification of change impacts*" in Web systems.

As presented in this thesis, the investigation from current state of the practices form a set of high level features/needs that a change impact analysis approach should support for Web systems. Keeping in view both the industrial perspectives and the issue where implementation (detailed design) actually begins before the change impacts (on architecture) are adequately identified, we proposed a systematic, structured and rigorous approach termed as the process model of CIA (PMCIA). We have captured various elements and necessary components derived both from the state of the art and state of the practice for the development of the process model of CIA. We have validated it with an industrial case study. The case study findings indicate that with the use of process model of CIA, practitioners indeed get support for early identification of change impacts in Web systems project and acquire an increased understanding of employing design information during change impact analysis.