A UNIFIED APPROACH TO ENTERPRISE ARCHITECTURE MODELLING

By Gerald R. Khoury


2007
To my lovely wife Isabelle, who has provided me with unwavering support throughout my research program.

And to my dear Mother and Father, for encouraging a love of learning.
Acknowledgments

I would like to extend my sincere thanks and appreciation to my thesis supervisor, Associate Professor Simeon J. Simoff. I am very fortunate that he accepted me as a student. Simeon’s keen sense of diplomacy, combined with a kind and good-humoured nature, allowed me the room to grow and express myself through my work. All the while, Simeon’s pragmatism, keen analytical mind and vision provided the framework needed to ensure a sound research program.

I would also like to thank my co-supervisor, Dr Roger Jenkins, for his kind and generous support. Roger provided me with valuable input when it was most needed, while also providing me with an inspiring introduction to the ‘classics’.

A special thanks to the ITD Team at UTS who, despite their hectic schedules, were kind enough to support this research program. In particular, I would like to thank the Director Peter James for his generous reception to the project, Peter Demou and Ian Waters for their close involvement in the development of the project artefacts, and all of the ITD managers for their important contributions to the development of the EA models. I would also like to thank the independent Enterprise Architects who contributed to this research: Trevor Christie-Taylor, Luke Vassallo, Som Adel and George Wanat.
## Overview of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Figures</td>
<td>i</td>
</tr>
<tr>
<td>List of Tables</td>
<td>iii</td>
</tr>
<tr>
<td>Abbreviations</td>
<td>iv</td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2 Enterprise Architecture and Systems Modelling</td>
<td>17</td>
</tr>
<tr>
<td>3 Metaphor</td>
<td>56</td>
</tr>
<tr>
<td>4 Theoretical Principles for The Development of Unified EA Modelling</td>
<td>76</td>
</tr>
<tr>
<td>Languages</td>
<td></td>
</tr>
<tr>
<td>5 The LEAN Ontology</td>
<td>89</td>
</tr>
<tr>
<td>6 Experimental Research Methodology</td>
<td>112</td>
</tr>
<tr>
<td>7 Experimental Studies</td>
<td>119</td>
</tr>
<tr>
<td>8 Conclusions and Future Research Directions</td>
<td>153</td>
</tr>
<tr>
<td>9 Bibliography</td>
<td>159</td>
</tr>
<tr>
<td>10 Appendix A – Project Summary for UTS EA Project</td>
<td>169</td>
</tr>
<tr>
<td>11 Appendix B – Final Project Report for UTS EA Project</td>
<td>174</td>
</tr>
<tr>
<td>12 Appendix C – Questionnaires</td>
<td>211</td>
</tr>
<tr>
<td>13 Appendix D – USDoS ITA</td>
<td>218</td>
</tr>
<tr>
<td>14 Appendix E – USDoS ITA LEAN Models</td>
<td>261</td>
</tr>
<tr>
<td>15 Appendix F – Designing and Re-Engineering Subsystems</td>
<td>278</td>
</tr>
</tbody>
</table>
# Detailed Table of Contents

## List of Figures

- i

## List of Tables

- iii

## Abbreviations

- iv

## Abstract

- v

## 1 Introduction

1.1 Research Problem  4  
1.2 Research Hypothesis 6  
1.3 Justification and Significance of the Research 7  
1.4 Research Methodology 9  
1.5 Thesis Outline 10  
1.6 Outcomes 12  
1.7 Expected Benefits 12  
1.8 Summary 15

## 2 Enterprise Architecture and Systems Modelling

2.1 The Need for Enterprise Architecture 17  
2.2 Defining Enterprise Architecture 19  
2.3 Defining a System 20  
2.4 Defining a Model? 20  
2.4.1 Requirements of Modelling Languages 21  
2.4.2 Models as Abstractions 22  
2.4.3 Views and Viewpoints 23  
2.4.4 Visualising Models 26  
2.5 A Review of EA Modelling Languages 28  
2.5.1 Unified Modeling Language (UML) 30  
2.5.2 ArchiMate Enterprise Architecture Language 31  
2.5.3 Integrated Definition Languages (IDEF) 33  
2.5.4 Unified Enterprise Modelling Language (UEML) 34  
2.5.5 Conceptual Graphs 34  
2.5.6 Ad-Hoc Modelling Languages 36  
2.6 A Review of EA Approaches 36  
2.6.1 Soft Systems Methodology (SSM) 39  
2.6.2 The Zachman Framework 41  
2.6.3 The Information Framework 45  
2.6.4 The Open Group Architecture Framework (TOGAF) 45  
2.6.5 ISO Reference Model of Open Distributed Processing (RM-ODP) 46  
2.6.6 Purdue Enterprise Reference Architecture (PERA) 47  
2.6.7 Computer Integrated Manufacturing - Open System Architecture (CIMOSA) 47  
2.6.8 Generalized Enterprise Reference Architecture and Methodology (GERAM) 48  
2.6.9 IEEE Standards 49
6.5 Summary

7 Experimental Studies
7.1 Study One: Modelling a Large Enterprise
   7.1.1 Introduction
   7.1.2 Research Approach
   7.1.3 Project Outline
   7.1.4 The Survey Questions
   7.1.5 Results
      7.1.5.1 Business Users Survey Results
      7.1.5.2 Enterprise Architect Survey Results
   7.1.6 Analysis of Results
      7.1.6.1 Closed Questions
      7.1.6.2 Open Questions
      7.1.6.3 Analysis of Models
   7.1.7 Summary
7.2 Study Two: Re-Modelling a Public Domain Architecture
   7.2.1 Introduction
   7.2.2 The USDoS Enterprise Architecture
   7.2.3 Analysis
   7.2.4 Summary
7.3 Evaluation

8 Conclusions and Future Research Directions
8.1 Conclusions
8.2 Future Research Directions
8.3 Closing Remarks

9 Bibliography

10 Appendix A – Project Summary for UTS EA Project
11 Appendix B – Final Project Report for UTS EA Project
12 Appendix C – Questionnaires
13 Appendix D – USDoS ITA
14 Appendix E – USDoS ITA LEAN Models
15 Appendix F – Designing and Re-Engineering Subsystems
   15.1 Developing a Unified Modelling Language
   15.2 Reengineering Existing Interfaces
      15.2.1 Decomposition and Mapping
         15.2.1.1 Hotmail Interface
         15.2.1.2 Yahoo Interface
         15.2.1.3 Lotus Notes Interface
      15.2.2 Interface Recomposition
         15.2.2.1 Hotmail Interface
LIST OF FIGURES

Figure 1- Research Methodology 10
Figure 2 - Thesis Structure and Flow 11
Figure 3 - The relationship between Level of Description and Level of Machine Orientation for a selection of Modelling Languages 15
Figure 4 - Levels of Abstraction, Structures and Models Based on a talk given by Luciano Floridi, Informational Realism, Proceedings Computing and Philosophy conf., Canberra, Nov.2003 23
Figure 5 – An Example of the Decomposition of an EA into Various Architectural Views 25
Figure 6 - ArchiMate Concepts (Instituut, 2004) 32
Figure 7 - Situated Components of an Enterprise Architecture 37
Figure 8 - The Zachman Framework 42
Figure 9 - Possible modelling languages with which to populate the Zachman framework. From (Noran, 2003) 44
Figure 10 - The Relationship between the Source and Target of a Metaphor 57
Figure 11 - Scope and Level of Metaphors (partially based on (Hammond and Allison, 1987)) 69
Figure 12 - Metaphor Hierarchy from Elastic to Concrete 70
Figure 13 - The Relationship between Models, Metaphors and Concept Type Hierarchies 77
Figure 14 - Enterprise System Hierarchy with Enterprise as Global Supertype 80
Figure 15 - Enterprise System Hierarchy with New Enterprise Supertype 81
Figure 16 - The Applicability of LEAN at Various Levels of Abstraction 84
Figure 17 - Methodology for Developing and Applying a Unified Language 85
Figure 18 - LEAN in relation to EA views and domain specific models 87
Figure 19 – Views, Viewpoints and Architectural Areas of Concern 96
Figure 20 - The Graphical Representations of LEAN Nodes 99
Figure 21 - A LEAN Relationship 100
Figure 22 - A LEAN Universal and Non-Universal Type 104
Figure 23 - Primary Research Approaches 112
Figure 24 - Responses for Two Groups (Business Users and EA's) Compared by Question and Test Area. 134
Figure 25 - Top Level Generic Activity Model 148
Figure 26 - Hotmail Interface 281
Figure 27 - Hotmail Functions 282
Figure 28 - Decomposition and Mapping of Hotmail Functions 283
Figure 30 - Yahoo functions 284
Figure 29 - Yahoo Interface 284
Figure 31 – Decomposition and Mapping of Yahoo Functions 285
Figure 32 - Lotus Notes Interface 286
Figure 33 - Lotus Notes functions 286
Figure 34 - Lotus Notes "Tools" Drop Down Menu 286
Figure 35 - Decomposition and Mapping of Lotus Notes Functions 287
Figure 36 - Recomposed Hotmail Functions 288
Figure 37 - Recomposed Hotmail Functions - Expanded 288
Figure 38 - Recomposition of Hotmail Interface based on Unified Metaphor 288
Figure 39 - Recomposed Yahoo Functions 289
Figure 40 - Recomposed Yahoo Functions - Expanded 289
Figure 41 - Recomposition of Yahoo Interface based on Unified Metaphor 290
Figure 42 - Recomposed Lotus Notes Functions 290
Figure 43 - Recomposed Lotus Notes Functions - Expanded 291
Figure 44 - Recomposition of Lotus Notes Interface based on Unified Metaphor 292
Figure 45 - Mapping of New Email Interface Functions 293
Figure 46 - New Email Interface Functions 294
# LIST OF TABLES

Table 1 - Research Questions and Qualities Corresponding to the Research Hypothesis.  
Table 2 – Some Integrated Modelling Languages  
Table 3 - IDEF Methods from (IDEF, 1992)  
Table 4 – Some Well Known EA Frameworks, Methods and Standards  
Table 5 - City Landscape Metaphor Mapping  
Table 6 - Definitions of Agent, Resource, Rule and Action Concepts  
Table 7 - Mapping Between a Generic Relationship Set and the Range of Possible Node Pairings  
Table 8 - ITD Project Objectives  
Table 9 - Study One Test Areas and Research Approaches  
Table 10 - Results of LEAN Survey for Business Users - Closed Questions  
Table 11 - Results of LEAN Survey for Business Users - Open Questions  
Table 12 - Results of LEAN Survey for Enterprise Architects - Closed Questions  
Table 13 - Results of LEAN Survey for Enterprise Architects - Open Questions  
Table 14 - Top Ten Words not in Wordlist  
Table 15 - Concordance List for High Frequency Words  
Table 16 - LEAN Node Frequency Distribution  
Table 17 – Relationship Frequencies in ITD EA Models  
Table 18 - Relationship Frequencies in USDoS ITA
## ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>CG</td>
<td>Conceptual Graph</td>
</tr>
<tr>
<td>CRM</td>
<td>Customer Relationship Management</td>
</tr>
<tr>
<td>DTH</td>
<td>Dynamic Type Hierarchy</td>
</tr>
<tr>
<td>EA</td>
<td>Enterprise Architecture or Enterprise Architect</td>
</tr>
<tr>
<td>EA’s</td>
<td>Enterprise Architectures or Enterprise Architects</td>
</tr>
<tr>
<td>EM</td>
<td>Elastic Metaphor</td>
</tr>
<tr>
<td>ERM</td>
<td>Enterprise Resource Management</td>
</tr>
<tr>
<td>HCI</td>
<td>Human Computer Interaction</td>
</tr>
<tr>
<td>HTML</td>
<td>Hypertext Mark-up Language</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
</tr>
<tr>
<td>IS</td>
<td>Information System</td>
</tr>
<tr>
<td>IT</td>
<td>Information Technology</td>
</tr>
<tr>
<td>ITA</td>
<td>Information Technology Architecture</td>
</tr>
<tr>
<td>ITD</td>
<td>Information Technology Department of UTS</td>
</tr>
<tr>
<td>LEAN</td>
<td>Lightweight Enterprise Architecture Notation</td>
</tr>
<tr>
<td>MCS</td>
<td>Minimal Common Supertype</td>
</tr>
<tr>
<td>ODBC</td>
<td>Open Data-Base Connectivity</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
<tr>
<td>USDoS</td>
<td>United States, Department of State</td>
</tr>
<tr>
<td>UTS</td>
<td>University of Technology, Sydney</td>
</tr>
<tr>
<td>VE</td>
<td>Virtual Environment</td>
</tr>
<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>WIMP</td>
<td>Windows, Icons, Mice, Pull-down menus</td>
</tr>
</tbody>
</table>
ABSTRACT

As IT environments grow in complexity and diversity, their strategic management becomes a critical business issue. Enterprise architectures (EA’s) provide support by ensuring that there is alignment between an enterprise’s business objectives and the IT systems that it deploys to achieve these objectives. While EA is a relatively new discipline, it has already found widespread commercial application. It is likely that EA will receive even more focus as IT environments continue to grow in complexity and heterogeneity.

Despite this widespread acceptance of EA as a valuable IT discipline, there are several serious challenges that contemporary EA approaches are yet to overcome. These arise from the fact that currently, there is no unified EA modelling language that is also easy to use. A unified EA modelling language is one that is able to describe a wide range of IT domains using a single modelling notation. Without a unified, easy to use EA modelling language, it is impossible to create integrated models of the enterprise. Instead, a variety of modelling languages must be used to create an EA, leading to enterprise models that are inconsistent, incomplete and difficult to understand. The need to use multiple modelling languages also places a high cognitive load on modellers and excludes non-IT specialists from developing or using these models, even though such people may be the most important stakeholders in an EA program.

The research presented in this thesis tackles these problems by developing a metaphor-based approach to the construction of unified EA modelling languages. Contemporary approaches to the understanding of metaphor are surveyed, and it is noted that one way to understand metaphor is to view it as part of a dynamic type hierarchy. This understanding of metaphor is related to the development of enterprise models and it is shown that highly abstract metaphors can be used to provide conceptually unified models of a range of enterprises and their component structures.

This approach is operationalised as methodology that can be used to generate any number of unified EA modelling languages. This methodology is then applied to generate a new, unified EA modelling language called ‘LEAN’ (Lightweight Enterprise Architecture Notation).
LEAN is evaluated using a mixed-methods research approach. This evaluation demonstrates that LEAN can be used to model a wide range of domains and that it is easy to learn and simple to understand.

The application of the theoretical principles and methodology presented in this thesis can be expected to improve the understandability and consistency of EA’s significantly. This, in turn, can be expected to deliver significant tangible business benefits through improved strategic change management that more closely aligns the delivery of IT services with business drivers.

The findings in this research also provide fertile ground for further research. This includes the development and comparative evaluation of alternative unified languages, further research into the use of the methodology presented to align architectures at various levels of abstraction, and the investigation of the applicability of this theoretical approach to other, non-IT disciplines.