

# Contents

PART I: Research Context and Problems.....	24
Chapter 1: Introduction .....	25
Context.....	26
Motivation.....	27
Objectives .....	29
Organisation of the Thesis Document.....	29
Chapter 2: The Initial Hypothesis .....	32
Chapter 3: Research Methodology.....	35
Underlying Theories in Research in Software Engineering.....	35
The Choice of Research Methodology.....	36
“Design Science Methodology” in Practice.....	39
Identification of the Problem and Motivation .....	39
The Definition of Objectives of the Solution.....	39
Design and Development .....	41
Demonstration .....	42
Evaluation .....	42
Communication.....	43
PART II: Exploration of the Problem.....	45
Chapter 4: Techniques and Tools .....	46
Introduction.....	46
An Exploration of the Problem: Necessities in Software Assistance to Knowledge Generation in Cultural Heritage.....	47
Tools for Detecting Conceptual Necessities .....	48
Conceptual Characteristics and Particularities in Cultural Heritage.....	48
Tools for Detecting Process Necessities.....	50
Consolidated Knowledge: A Methodological Proposal for Integrating Discourse Analysis in Software Engineering.....	50
The Characterisation of Expressed Knowledge: A Characterisation of Cognitive Processes in Cultural Heritage .....	77
The Empirical Validation of Characterisations of Cognitive Processes: The Design of Thinking Aloud Empirical Studies in Software Assistance Contexts. ....	90
Tools for Detecting Interaction and Presentation Necessities.....	96
Suitability of Software Presentation and Interaction with the Aim of Providing Assistance: A Study of Information Visualisation Techniques in Cultural Heritage .....	96
Chapter 5: Prior Empirical Results.....	101
Introduction.....	101
The Design of the Empirical Studies .....	102
Empirical Studies.....	104

## Contents

Tools for Detecting Process Necessities: Results .....	104
Tools for Detecting Interaction and Presentation Necessities: Results .....	108
Conclusions .....	112
PART III: Solution .....	114
Chapter 6: Framework Overview .....	115
Introduction .....	115
Our Proposal: Subject Matter, Cognitive Processes and Presentation and Interaction Mechanisms .....	116
The General Structure .....	117
Chapter 7: Subject Matter .....	119
Conceptual Modelling and Cultural Heritage .....	119
CHARM (Cultural Heritage Abstract Reference Model) .....	119
The Characteristics of CHARM .....	120
CHARM's Extension Mechanisms .....	123
Other Structural Aspects in CHARM .....	124
Our Proposal: CHARM as the Basis for the Knowledge Generation .....	126
The Use of the Package Mechanism .....	126
The Use of the Cluster Mechanism .....	126
Conclusions .....	127
Chapter 8: Cognitive Processes .....	129
Introduction .....	129
The Proposed Solution .....	129
Conclusions .....	131
Chapter 9: Presentation and Interaction Mechanisms .....	133
Introduction .....	133
Formal Representation in Software Presentation and Interaction for Data Analysis .....	134
Challenges Identified .....	137
The Proposed Solution .....	138
LEVEL 1: Data-Analysis Interaction Unit .....	140
LEVEL 2: Structure IU .....	141
LEVEL 2: Value-Combination IU .....	141
LEVEL 2: Conglomerate IU .....	142
LEVEL 2: Trend IU .....	142
LEVEL 2: Timeline IU .....	143
LEVEL 2: Geographic Area IU .....	143
LEVEL 2: Sequential IU .....	144
LEVEL 3: Row Aggregation Pattern .....	144
LEVEL 3: Column Aggregation Pattern .....	145
LEVEL 3: Set Pattern .....	145
LEVEL 3: Additional Information Pattern .....	146
LEVEL 3: First Focus Pattern .....	146

## Contents

LEVEL 3: Colour Assignment Pattern .....	147
LEVEL 3: Size Assignment Pattern.....	147
LEVEL 3: Scale Relation Pattern.....	148
LEVEL 3: Fuzzy Control Pattern.....	148
Applying Interaction Patterns in Cultural Heritage .....	150
STRUCTURE IU .....	152
VALUE-COMBINATION IU.....	156
CONGLOMERATE IU.....	159
TREND IU .....	161
TIMELINE IU.....	165
GEOGRAPHIC AREA IU.....	168
SEQUENTIAL IU.....	170
Conclusions .....	175
Chapter 10: Integration, Interoperability and Consistency between Framework Models .....	178
Introduction.....	178
Expressing Connections between Models.....	180
Our Approach Based on Interoperability.....	182
The Integration Metamodel .....	186
Interoperability Guidelines .....	187
Conclusions .....	190
PART IV: Validation.....	191
Chapter 11: Analytical Validation: A Romea as a Case Study.....	192
Introduction.....	192
Validation by Way of a Case Study.....	192
A Romea as a Case Study: A General Overview.....	193
Description of the Site and the Associated Archaeological Research.....	195
A Romea: Subject Model.....	197
A Romea: Cognitive Processes Model.....	213
A Romea: Presentation and Interaction model.....	214
A Romea: Integration, Interoperability and Consistency between Models .....	218
Obtaining Information on Integration.....	218
Implementing Interoperability.....	224
Conclusions .....	225
Chapter 12: Empirical Validation.....	227
Introduction.....	227
Prototyping Process and Prototype Characteristics .....	228
Validation Methodology.....	236
The Validation Process .....	236
Conclusions .....	282
PART V: Final Considerations.....	288
Chapter 13: Discussion.....	289

## Contents

Introduction.....	289
The Development of the Hypothetico-deductive Reasoning Adopted.....	289
Secondary Question SQ1.....	290
Secondary Question SQ2.....	291
Secondary Question SQ3.....	292
Main Question MQ.....	293
A Critical Analysis.....	295
Chapter 14: Conclusions.....	298
Introduction.....	298
Main Contributions of this Research.....	298
Main contribution.....	298
First Contribution.....	299
Second Contribution.....	299
Third Contribution.....	299
Fourth Contribution.....	299
Fifth Contribution.....	299
Publications and Other Dissemination Activities of the Results.....	300
Publications.....	301
Other Dissemination Activities.....	303
Emerging Lines of Research.....	305
APPENDIX I: A Compendium of the Prior Empirical Studies.....	309
APPENDIX II: Case Study Implementation.....	339
APPENDIX III: Empirical Validation Materials.....	351
References.....	390

## Contents