

Contents

Chapter 1. Introduction	2
1.1 Motivation.....	2
1.1.1 Human-computer interaction	2
1.1.2 Software systems and development tools.....	4
1.2 Problem Statement.....	9
1.3 Research Questions	12
1.4 Thesis Objectives.....	13
1.5 Research Methodology	15
1.6 Expected Contributions.....	17
1.7 Thesis Context.....	19
1.8 Thesis Outline.....	19
Chapter 2. Theoretical Framework	23
2.1 Overview	23
2.2 A theoretical framework for Human-Computer Interaction ...	24
2.2.1 Gestures related definition	24
2.2.2 Classification of gestures	25
2.2.3 Gesture recognition algorithms	27
2.2.4 Gesture-based interaction	29
2.3 A theoretical framework of Model-Driven paradigm	29
2.3.1 Model related definition	30
2.3.2 MDA Conceptual framework	31
2.3.3 Model Transformations	32
2.3.4 Transformation Language	34
2.3 Summary	35
Chapter 3. State of Art	38

3.1	Motivation.....	38
3.2	Gesture representation.....	39
3.3	Gesture recognition tools	47
3.4	The role of gesture-based interfaces in Information Systems Engineering	50
3.5	Model-driven engineering in Human-Computer Interaction 53	
3.6	Evaluation between model-driven paradigm and other methodologies	56
3.7	Technical action research to validate software systems ...	62
3.8	Range of Improvements.....	63
3.9	Summary	64
Chapter 4. gestUI: A Model-Driven Method		66
4.1	Overview	66
4.2	Why a Model-Driven method?	68
4.3	Why a Model-View-Controller design pattern?.....	69
4.4	Determining needed resources	71
4.5	gestUI: our proposal.....	73
4.5.1	Features of gestUI	74
4.5.2	Metamodel of the gesture catalogue modelling language	76
4.5.3	Components of gestUI	86
4.5.4	Model transformations	90
4.6	Personalization of gesture definition.....	94
4.6.1	Introduction	94
4.6.2	Enhancing the metamodel	95
4.7	Overview of gestUI to include gesture-based interaction in a user interface	98

4.7.1 Introduction	98
4.7.2 Including gesture-based interaction in a user interface ...	99
4.7.3 Redefining a gesture during the execution time	106
4.8 Summary	111
Chapter 5. gestUI Tool Support.....	113
5.1 Introduction	113
5.2 Components of the tool support	114
5.2.1 Subsystem “Gesture Catalogue Definition Module”	115
5.2.2 Subsystem “Gesture-Action Correspondence Definition Module”	116
5.2.3 Subsystem “Model Transformation Module”	119
5.3 Development methodology of the tool support.....	120
5.4 Implementation of the tool support.....	120
5.3.1 Option 1: “Gesture catalogue definition”	121
5.3.2 Option 2: “Specific catalogue”	123
5.3.3 Option 3: “Gesture-action correspondence definition” .	124
5.3.4 Module to redefine gesture.....	127
5.5 Demonstration of the tool support.....	128
5.5.1 Applying the method and tool to testing a gesture catalogue.....	128
5.5.2 Applying the method and the tool to integrate gestUI into user interface development.....	130
5.6 Summary and Conclusions	133
Chapter 6. Empirical Evaluation.....	135
6.1 Introduction	135
6.2 Experimental planning	136
6.2.1 Goal	136

6.2.2 Research Questions and Hypothesis Formulation.....	137
6.2.3 Factor and Treatments.....	139
6.2.4 Response variables and metrics.....	139
6.2.5 Experimental Subjects.....	143
6.2.6 Experiment design	144
6.2.7 Experimental objects	147
6.2.8 Instrumentation	148
6.2.9 Experiment procedure	149
6.2.10 Threats of validity	158
6.2.11 Data analysis	162
6.3 Results.....	164
6.3.1 RQ1: Effectiveness in the inclusion of gesture-based interaction.....	164
6.3.2 RQ2: Effectiveness in the definition of custom gestures	167
6.3.3 RQ3: Efficiency in the inclusion of gesture-based interaction.....	169
6.3.4 RQ4: Efficiency in the definition of custom gestures.....	172
6.3.5 RQ5: Perceived Ease of Use	175
6.3.6. RQ6: Perceived Usefulness	177
6.3.7 RQ7: Intention to Use	180
6.3.8 Effect-size calculation	182
6.4 Discussion.....	185
6.4.1 Effectiveness	185
6.4.2 Efficiency	187
6.4.3 Satisfaction.....	189
6.5 Conclusions	190
Chapter 7. Technical Action Research	193

7.1 Introduction	193
7.2 Background: Capability Design Tool.....	196
7.3 Validation using Technical Action Research	199
7.3.1 Goal of the TAR	199
7.3.2 Experimental subjects.....	200
7.3.3 Research questions	200
7.3.4 Factor and Treatment	200
7.3.5 Response variables.....	202
7.3.6 Instruments for the TAR.....	202
7.3.7 Experimental Object	202
7.4 Action Research Procedure.....	203
7.5 Analysis and Interpretation of results.....	206
7.6 Threats to validity	210
7.7 Conclusions	211
Chapter 8. Conclusions, Contributions and Future Work.....	214
8.1 Summary of the thesis	214
8.2 Contribution of this thesis.....	216
8.3 Future work.....	218
8.4 Conclusion.....	219
8.5 Publications.....	220
Appendix A. A code-centric method for develop user interfaces with gesture-based interaction.....	223
A.1 Introduction	223
A.2 The code-centric method	223
References	227

List of Figures

<i>Figure 1. Design science research iterates over two problem-solving activities (taken from [30])</i>	16
<i>Figure 2. Overview of the research methodology</i>	18
<i>Figure 3. Types of semaphoric gestures</i>	26
<i>Figure 4. MDA Layers</i>	32
<i>Figure 5. MDA Transformations</i>	33
<i>Figure 6 Model-to-Model Transformation</i>	34
<i>Figure 7. Model-to-text transformation</i>	35
<i>Figure 8. quill's main interface</i>	48
<i>Figure 9. \$N's main interface</i>	48
<i>Figure 10. iGesture main interface</i>	49
<i>Figure 11. Software System with traditional interaction</i>	70
<i>Figure 12. Modifying the controller to support gesture-based interaction</i>	71
<i>Figure 13. Metamodel of the gesture catalogue modelling language</i>	76
<i>Figure 14. States of a posture</i>	82
<i>Figure 15. Precedence relation between postures</i>	83
<i>Figure 16. Interval of time between postures</i>	84
<i>Figure 17. A general excerpt of any method for develop user interfaces</i>	86
<i>Figure 18. gestUI method overview (Taken from [31])</i>	87
<i>Figure 19. Platform-independent gesture definition</i>	88
<i>Figure 20. An excerpt of Figure 18 showing the M2M transformation</i>	91
<i>Figure 21. An excerpt for the M2M transformation</i>	92
<i>Figure 22. An excerpt of Figure 18 showing the M2T transformation to obtain the gesture-based user interface</i>	93
<i>Figure 23. An excerpt of Figure 18 showing the M2T transformation to obtain the test gesture</i>	93
Figure 24. An excerpt for the M2T transformation	94
<i>Figure 25. An excerpt of gestUI showing the redefinition of a gesture</i>	95
Figure 26. Enhanced version of the metamodel	96
<i>Figure 27. Users defining their own gestures catalogue to apply it in the same user interface</i>	97
<i>Figure 28. An excerpt of the map representation of gestUI</i>	98
<i>Figure 29. MAP representation of gestUI</i>	100
<i>Figure 30. User defining a gesture</i>	103
<i>Figure 31. Platform-independent gesture catalogue</i>	104
<i>Figure 32. A specific-platform gesture catalogue</i>	105

<i>Figure 33. An excerpt of the source code of a user interface containing widget definition and keywords</i>	105
<i>Figure 34. Map representation of the software system with the redefinition feature included</i>	109
<i>Figure 35. gestUI tool support</i>	115
<i>Figure 36. An excerpt of Figure 35 showing the subsystem "Gesture Catalogue Definition Module"</i>	116
<i>Figure 37. An excerpt of Figure 35 showing the subsystem "Gesture-action Correspondence Definition Module"</i>	117
<i>Figure 38. Excerpt of Figure 35 showing the subsystem "Model Transformations Module"</i>	120
<i>Figure 39. Main interface of the tool support</i>	121
<i>Figure 40. Screenshot of the interface of gestUI to sketch gestures</i>	122
<i>Figure 41. User sketching a gesture and storing it in a repository</i>	122
<i>Figure 42. Screenshot of the user interface to obtain the platform-independent gesture catalogue</i>	123
<i>Figure 43. An excerpt of a rule of the M2M transformation</i>	124
<i>Figure 44. M2M transformation parameters</i>	124
<i>Figure 45. Interface for defining gesture-action correspondence and to generate source code</i>	125
<i>Figure 46. SWT components to define actions</i>	126
<i>Figure 47. JFace and SWT components used to define an action in a user interface</i>	126
<i>Figure 48. Interface to execute a model-to-text transformation</i>	127
<i>Figure 49. An example of the module to redefine custom gestures</i>	128
<i>Figure 50. Gesture catalogue defined by gestUI</i>	129
<i>Figure 51. Gesture description files: \$N (left), quill (centre), iGesture (right)</i>	129
<i>Figure 52. Importing the gesture catalogue to the quill framework</i>	130
<i>Figure 53. Examples of multi-stroke gestures: \$N (left) and quill (centre) and iGesture (right)</i>	130
<i>Figure 54. UML class diagram of the demonstration case</i>	130
<i>Figure 55. Screen mockups (gestures are shown in red, next to action buttons)</i>	131
<i>Figure 56. Using gestures to execute actions on the interfaces</i>	132
<i>Figure 57. Software system supporting traditional interaction</i>	147
<i>Figure 58. Software system supporting gesture-based interaction</i>	151
Figure 59. Gesture-action correspondence definition using tool support	157

<i>Figure 60</i>	<i>Box-and-whisker plot of PTCCI</i>	165
<i>Figure 61</i>	<i>Box-plot-whisker of PTCCG</i>	168
<i>Figure 62</i>	<i>Box-plot for TFTI</i>	170
<i>Figure 63</i>	<i>Box-plot of TFTG</i>	173
<i>Figure 64</i>	<i>Box-plot for PEOU</i>	176
<i>Figure 65</i>	<i>Box-plot of PU</i>	178
<i>Figure 66</i>	<i>Box-plot of ITU</i>	180
<i>Figure 67</i>	<i>An excerpt of User Experience Questionnaire (taken of www.ueq-online.org)</i>	195
<i>Figure 68</i>	<i>An excerpt of the 118 positive and negative phrases of Microsoft Reaction Cards</i>	196
<i>Figure 69</i>	<i>CDT with traditional interaction using keyboard and mouse</i>	198
<i>Figure 70</i>	<i>CDT with gesture-based interaction</i>	198
<i>Figure 71</i>	<i>Excerpt of a model defined in Everis</i>	203
<i>Figure 72</i>	<i>UEQ results: custom gesture definition interaction</i>	207
<i>Figure 73</i>	<i>UEQ results: inclusion of gesture-based interaction</i>	207
<i>Figure 74</i>	<i>Reaction cards positive results</i>	209
<i>Figure 75</i>	<i>Reaction cards negative results</i>	210
<i>Figure 76</i>	<i>A code-centric method for develop user interfaces with gesture-based interaction</i>	224

List of Tables

<i>Table 1. Examples of application of gesture-based interaction outside the office</i>	5
<i>Table 2. Some software development kit including toolbox to design user interfaces</i>	7
<i>Table 3. Objectives for the research questions</i>	13
<i>Table 4. Related areas in the thesis</i>	23
<i>Table 5. A summary related with gesture representation</i>	44
<i>Table 6. Summary of works related with role of gesture-based interfaces in Information Systems Engineering</i>	52
<i>Table 7. Summary of works related with Model-driven engineering in Human-Computer Interaction</i>	55
<i>Table 8. Summary of works related with Evaluation between model-driven paradigm and other methodologies</i>	59
<i>Table 9. Detected problems vs. Benefits of model-driven paradigm to solve them</i>	75
<i>Table 10. Business rules for the "Catalogue" class</i>	76
<i>Table 11. Business rules of the "Gesture" class</i>	77
<i>Table 12. Business rule of the "Action" class</i>	78
<i>Table 13. Business rule of the "Stroke" class</i>	78
<i>Table 14. Business rules for the "Posture" class</i>	79
<i>Table 15. Business rule for the "Precedence" class</i>	79
<i>Table 16. Business rule for the "Point" class</i>	80
<i>Table 17. Data structure of a gesture</i>	81
<i>Table 18. Constraints and business rules of gesture definition</i>	85
<i>Table 19. Business rules for the "User" class</i>	96
<i>Table 20. Business rules for the "UserInterface" class</i>	97
<i>Table 21. Strategies of gestUI</i>	101
<i>Table 22. Strategies of the software system with gesture-based interaction</i>	110
<i>Table 23. Platform-independent gesture catalogue definition</i>	131
<i>Table 24. Factor and treatments of the experiment</i>	139
<i>Table 25. Response variables to evaluate effectiveness and efficiency of gestUI</i>	141
<i>Table 26. Responses variables to measure satisfaction of use gestUI</i>	142
<i>Table 27. Summary of RQ's, hypotheses, response variables and metrics</i>	143
<i>Table 28. Summary of demographic questionnaire</i>	145
<i>Table 29. Crossover design</i>	146

<i>Table 30 Operators and average time on KLM</i>	146
<i>Table 31 Estimating time for the experiment</i>	147
<i>Table 32 Instruments defined for the experiment</i>	149
<i>Table 33 Gesture catalogue defined in the experiment</i>	150
<i>Table 34 An excerpt of the Task Description Document containing the sequence of steps for custom gesture definition using the code-centric method</i>	153
<i>Table 35 An excerpt of the Task Description Document containing the sequence of steps for gesture-based interaction inclusion using the code-centric method</i>	155
<i>Table 36 An excerpt of the Task Description Document for custom gesture definition using gestUI</i>	156
<i>Table 37 Gesture-action correspondence step-by-step definition</i>	157
<i>Table 38 Non-parametric Levene's test for the variables in the experiment</i>	164
<i>Table 39 Descriptive statistics for PTCCI</i>	165
<i>Table 40 Spearman's Rho correlation coefficient of PTCCI</i>	166
<i>Table 41 Wilcoxon Signed-rank test for PTCCI</i>	166
<i>Table 42 Wilcoxon Signed-rank test statistics for PTCCI</i>	167
<i>Table 43 Descriptive statistics for PTCCG</i>	167
<i>Table 44 Spearman's Rho correlation coefficient of PTCCG</i>	168
<i>Table 45 Wilcoxon Signed-rank test for PTCCG</i>	169
<i>Table 46 Wilcoxon Signed-rank test statistics for PTCCG</i>	169
<i>Table 47 Descriptive statistics for TFTI</i>	170
<i>Table 48 Spearman's Rho correlation coefficient of TFTI</i>	171
<i>Table 49 Wilcoxon Signed-rank test for TFTI</i>	171
<i>Table 50 Wilcoxon Signed-rank test statistics for TFTI</i>	172
<i>Table 51 Descriptive statistics for TFTG</i>	172
<i>Table 52 Spearman's Rho correlation coefficient of TFTG</i>	174
<i>Table 53 Wilcoxon Signed-rank test for TFTG</i>	174
<i>Table 54 Wilcoxon Signed-rank test statistics for TFTG</i>	174
<i>Table 55 Descriptive statistics for PEOU</i>	175
<i>Table 56 Spearman's Rho correlation coefficient of PEOU</i>	175
<i>Table 57 Wilcoxon Signed-rank test for PEOU</i>	176
<i>Table 58 Wilcoxon Signed-rank test statistics for PEOU</i>	177
<i>Table 59 Descriptive statistics for PU</i>	177
<i>Table 60 Spearman's Rho correlation coefficient of PU</i>	178
<i>Table 61 Wilcoxon Signed-rank test for PU</i>	179

<i>Table 62 Wilcoxon Signed-rank test statistics for PU</i>	<i>179</i>
<i>Table 63 Descriptive statistics for ITU</i>	<i>180</i>
<i>Table 64 Spearman's Rho correlation coefficient of ITU</i>	<i>181</i>
<i>Table 65 Wilcoxon Signed-rank test for ITU</i>	<i>181</i>
<i>Table 66 Wilcoxon Signed-rank test statistics for ITU</i>	<i>182</i>
<i>Table 67 Summary of the results obtained in the experiment</i>	<i>183</i>
<i>Table 68 Effect size of the metrics</i>	<i>184</i>
<i>Table 69. Instruments defined for the validation</i>	<i>201</i>
<i>Table 70. Gesture catalogue defined by the subjects</i>	<i>202</i>
<i>Table 71. A summary of the experiment procedure</i>	<i>205</i>
<i>Table 72. Results obtained from the UEQ</i>	<i>206</i>
<i>Table 73. Reaction cards positive results</i>	<i>208</i>
<i>Table 74. Reaction cards negative results</i>	<i>208</i>