

## **CHAPTER 1** *Introduction*

Motivation .....	7
<i>Potential Applications</i> .....	9
<i>Design and Development of Interactive Illustrations</i> .....	10
<i>The Market for Interactive 3D Illustrations</i> .....	12
Thesis Objective .....	13
Thesis Structure .....	14

## **CHAPTER 2** *Interactive Illustrations*

Interactive 3D Illustrations .....	17
Functions of Interactive 3D Illustrations .....	18
<i>Decoration and Orientation</i> .....	21
<i>Presentation and Focusing</i> .....	21
<i>Simulation and Exploration</i> .....	22
<i>Delimitation From Other Visualization Applications</i> .....	23
Illustration Design Foundations .....	25
<i>Information Presentation Functions</i> .....	25
<i>Media Elements in Interactive 3D Illustrations</i> .....	28
<i>Reality Cues</i> .....	28
<i>3D Graphics and Depth Cues</i> .....	29
<i>Animation</i> .....	31
<i>Interactivity</i> .....	33
<i>Other Reality Cues</i> .....	35
<i>Illustration Techniques</i> .....	35
Technological Framework .....	38
<i>The Model-View-Controller Framework</i> .....	38
<i>The Visualization Pipeline Framework</i> .....	39
<i>The Interactive Graphics Loop Framework</i> .....	40

## **CHAPTER 3** *State of the Art*

Introduction .....	43
Interactive Illustration Applications .....	43
<i>Desktop 3D</i> .....	44
<i>Cyberbikes</i> .....	45
<i>ScienceSpace</i> .....	45
<i>Exploratories</i> .....	46
<i>Information-Rich Environments</i> .....	47
<i>Zoom Illustrator</i> .....	48
<i>The Virtual Explorer</i> .....	49
<i>SAIL / CPU city</i> .....	50
<i>Conclusions</i> .....	50
Design Processes and Tools .....	51
<i>Stakeholders</i> .....	54
<i>Tools</i> .....	55
<i>Design Automation</i> .....	56
Technological Basics .....	59

<i>3D Graphics APIs and Toolkits</i> .....	61
<i>Low-Level Immediate Mode 3D APIs</i> .....	63
<i>High-Level 3D Toolkits</i> .....	64
<i>Overview and Discussion</i> .....	70

## CHAPTER 4 Requirements Analysis

Interactive Illustration Design .....	73
Analysis Method .....	75
Literature Review .....	76
Structured Interviews and Survey .....	77
Project Studies .....	79
<i>History of Animation</i> .....	79
<i>100 Years Westfalia Separator</i> .....	81
<i>Virtuelle Wissensfabrik</i> .....	82
<i>3D Navigation Aids</i> .....	83
Results .....	84
<i>Process Level Requirements</i> .....	84
<i>Task Level Requirements</i> .....	85

## CHAPTER 5 Design Framework

Conceptual Models .....	87
The Conceptual Model of i4D .....	88
Primary Concept: Actors .....	90
<i>Content Actors</i> .....	93
<i>Camera Actors</i> .....	94
<i>Lights</i> .....	94
<i>Abstract Actors</i> .....	94
Secondary Concepts: .....	95
<i>Illustrations</i> .....	95
<i>Stages</i> .....	96
<i>Monitors</i> .....	96
Discussion of the Actor Model .....	96
The i4D Design Process .....	97
<i>i4D Design Process Overview</i> .....	99
<i>Design Process Planning</i> .....	101
<i>Application Level: Context of Use Specification</i> .....	103
<i>Application Level: Requirements Specification</i> .....	104
<i>Application Level: Design</i> .....	109
<i>Application Level: Evaluation</i> .....	111
<i>Concept Level: Requirements Analysis</i> .....	115
<i>Concept Level: Design</i> .....	117
<i>Concept Level: Evaluation</i> .....	118
<i>Actor Level: Requirements Analysis</i> .....	119
<i>Actor Level: Design</i> .....	120
<i>Actor Level: Evaluation</i> .....	121
<i>The i4D Design Process within the Conceptual Model</i> .....	122

## CHAPTER 6 Tools

The i4D System .....	125
<i>Component Management</i> .....	127
<i>Virtual Time</i> .....	128
<i>Rendering</i> .....	128
Modeling of Actors .....	130
i4D Actors .....	132
<i>3DObjects</i> .....	132
<i>Global3DObjects</i> .....	132
<i>Cameras</i> .....	133
<i>Lights</i> .....	134
<i>Devices</i> .....	135
Illustrations, Stages and Monitors .....	135
<i>Illustrations</i> .....	135
<i>Stages</i> .....	135
<i>Monitors</i> .....	135
Attributes .....	136
Behaviours .....	137
<i>Actions</i> .....	137
<i>Reactions</i> .....	138
Programming Interface .....	139
<i>I4D as a C++ Class Library</i> .....	139
<i>The i4D Scripting Interface</i> .....	140
I4D Tools .....	141
<i>The i4D Editor</i> .....	142
<i>I4D Evaluation Tools</i> .....	143
<i>Concept Design Tools</i> .....	144

## CHAPTER 7 Application Example: ENIGMA

Introduction .....	147
<i>A Short History of the Enigma</i> .....	148
The Design Process .....	151
Application Level Design .....	153
<i>Context of Use Specification</i> .....	153
<i>Requirements Specification</i> .....	153
<i>Design</i> .....	158
<i>Evaluation</i> .....	160
Concept Level Design .....	162
<i>Requirements Analysis</i> .....	163
<i>Design</i> .....	165
<i>Evaluation</i> .....	167
Actor Level Design .....	167
<i>Requirements Analysis</i> .....	168
<i>Design</i> .....	168
<i>Evaluation</i> .....	168
Results .....	169

## CHAPTER 8 Résumé

Summary and Contributions .....	171
Requirements and Results .....	178
<i>Process Level Requirements</i> .....	178
<i>Task Level Requirements</i> .....	180
Conclusions .....	182

## APPENDIX A

Retinal (or Binocular) Disparity .....	186
Convergence .....	191
Accommodation .....	192
Depth of Field / Image Blur .....	193
Interposition .....	194
Linear Perspective .....	195
Aerial Perspective .....	196
Detail Perspective .....	197
Textural Gradient .....	198
Relative Size .....	200
Relative Height .....	200
Light and Shading .....	201
Shadows .....	203
Motion parallax .....	204
Kinetic depth effect .....	205

## APPENDIX B

Overview .....	207
Design Elements of Interactive Illustrations .....	208
<i>Spatial Structures</i> .....	209
<i>Marks</i> .....	211
<i>Scopes of Interaction</i> .....	212
<i>Animation</i> .....	212
Techniques that Modify Existing Objects .....	216
<i>Transformation</i> .....	216
<i>Appearance</i> .....	218
<i>Substitutions</i> .....	219
Techniques that Modify Virtual Objects and Properties .....	220
<i>Camera</i> .....	220
<i>Lighting</i> .....	222
<i>Ambience</i> .....	223
<i>Render Style</i> .....	224
<i>Views</i> .....	225
Techniques that Introduce Additional (Meta-) Objects .....	225
<i>Annotations</i> .....	225
<i>Shadows</i> .....	226

<i>Ghostimages and Duplicates</i> .....	226
<i>Diagrams, Graphs and Glyphs</i> .....	227
<i>Pointers and Markers</i> .....	228
<i>Grids and Lattices</i> .....	229
<i>Virtual Tools</i> .....	229
<b>Navigation Aids</b> .....	<b>230</b>
<i>Perception</i> .....	231
<i>Planning</i> .....	232
<i>Memory</i> .....	232
<i>Execution</i> .....	232
<b>References</b> .....	<b>235</b>
Own Publications .....	252