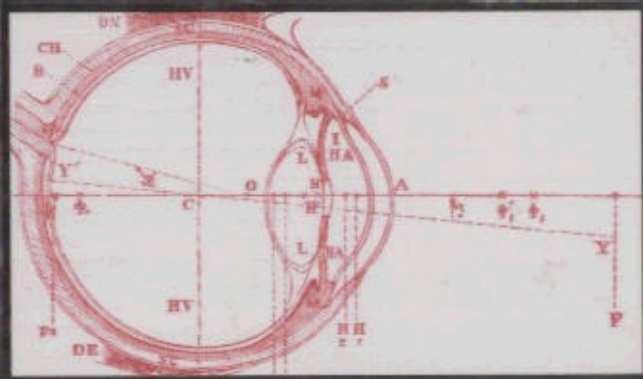


CREATIVE 3-D DISPLAY AND INTERACTION INTERFACES



A TRANS-DISCIPLINARY APPROACH

BARRY G. BLUNDELL • ADAM J. SCHWARZ

CONTENTS

Preface	xiii
Acknowledgments	xvii
Glossary of Abbreviations	xxiii
1 The Nature of the Quest	1
1.1 Introduction	1
1.2 Creative Display and Interaction Paradigms	4
1.3 A Little History	6
1.4 The Conventional Interface: Working in Flatlands	10
1.5 Inhibiting the Human–Computer Interaction Process	14
1.5.1 Augmented Realism: Suspension of Disbelief	15
1.5.2 Augmented Information Content	19
1.5.3 Creative Design	20
1.6 Graphics Issues	23
1.6.1 Projection Geometry for a Single View	24
1.6.2 Surface Rendering	25
1.6.3 Working with Volumetric Data	27
1.7 Display Sub-Systems	30
1.8 From the Laboratory to the Application	32
1.8.1 Development Strategies	33
1.8.2 Generality of Purpose	35
1.9 Discussion	36
1.10 Investigations	36
2 The Perception of Our Space: Vision	39
2.1 Introduction	39
2.2 Some Facets of Light	41
2.2.1 Color	41
2.2.2 Light Energy	44
2.2.3 Diffraction in Optical Systems	47
2.3 The Visual System	50
2.3.1 The Eye as an Optical Instrument	51
2.3.2 The Retina	54
	vii

2.3.3	Eye Movements and Saccades	58
2.3.4	The Detection of Color	62
2.4	Beyond the Eye	63
2.4.1	The Lateral Geniculate Nucleus	65
2.4.2	Reflex Feedback	66
2.4.3	The Primary Visual Cortex (V1)	66
2.4.4	The Dorsal and Ventral Pathways	67
2.4.5	The M and P Pathways	68
2.4.6	Detection of Binocular Disparity	69
2.5	Some Visual Characteristics	70
2.5.1	The Visual Field	70
2.5.2	Spatial Resolution	70
2.5.3	Sensitivity and the Impact of Spatial Frequency	74
2.6	Perception of Space and Form	76
2.6.1	Pictorial Depth Cues	77
2.6.2	Oculomotor and Parallax Cues	80
2.6.3	Absolute and Relative Depth Perception	82
2.6.4	Consistency and Conflict Between Depth Cues	83
2.6.5	The Perception of Form	85
2.6.6	The Gestalt Theory of Visual Perception	85
2.6.7	The Pulfrich Effect	88
2.7	Temporal Resolution: Fusion and Motion	89
2.8	Discussion	90
2.9	Investigations	91
3	The Perception of Our Space: Haptics	93
3.1	Introduction	93
3.2	Somatosensory Receptors	95
3.3	Cutaneous Sensitivity	97
3.4	Proprioception	101
3.5	Somatosensory and Motor Pathways	105
3.6	Discussion	108
4	A Backward Glance	111
4.1	Introduction	111
4.2	The Development of Perspective Techniques	112
4.3	The Transition to Perspective in Painting	123
4.4	Mathematical Schemes for Linear Perspective	125
4.5	Evolving Ideas of Vision and Perception	128
4.6	The Cameras Obscura and Lucida	135
4.7	Discussion	138
4.8	Investigations	139

5	Traditional Interaction Mechanisms	141
5.1	Introduction	141
5.2	An Early Evaluation of Some Interaction Tools	143
5.2.1	Interaction Space and a Tool Set	144
5.2.2	Interaction Tool Evaluation	148
5.2.3	Interaction Issues	149
5.3	Fitts' Model and Its Application	150
5.3.1	An Application of Fitts' Model	153
5.3.2	Further Aspects of Fitts' Model	155
5.4	Interaction Paradigms	157
5.4.1	Transferred Interaction	158
5.4.2	Direct Interaction	158
5.4.3	Pointer-Based Interaction	158
5.5	Discussion	159
5.6	Investigations	160
6	Depiction and Interaction Opportunities	161
6.1	Introduction	161
6.2	A Traditional Classification of Creative 3-D Displays	163
6.3	Enhancing the Monocular Display	165
6.3.1	Creating a Stereoscopic Display	165
6.3.2	Creating an Autostereoscopic Display	171
6.4	The Geometry of Stereopsis	173
6.4.1	Stereoscopic Fixation and the Horopter	174
6.4.2	Horizontal Disparity	176
6.4.3	Accommodation and Convergence	180
6.4.4	Vertical Disparity	180
6.5	Some Classes of Autostereoscopic Display	182
6.5.1	Virtual Reality Systems	182
6.5.2	Multi-view Systems: The Lenticular Sheet	185
6.5.3	AutoQ Systems	185
6.6	Interaction Paradigms in 3-D Space	189
6.6.1	Transferred Interaction	190
6.6.2	Direct Interaction	191
6.6.3	Pointer-Based Interaction	191
6.7	Working in a 3-D Space	192
6.7.1	The Application of the Direct Interaction Technique	193
6.7.2	Assisted Interaction Within a 3-D Space	195
6.7.3	User Mobility Issues	196
6.8	The "Free-Space" Image	197
6.8.1	A Theatrical Illusion	198

6.8.2	Volumetric Image Projection	199
6.9	Revisiting the Traditional Classification Scheme	202
6.9.1	A Multifaceted Approach	206
6.10	Discussion	207
6.11	Investigations	209
7	The Haptic Channel	211
7.1	Introduction	211
7.2	Physical Contact With Virtual Objects	213
7.2.1	Some Example Applications of Haptic Interaction	214
7.2.2	Some Examples of Haptic Interaction Devices	217
7.3	The Haptic Channel in Multisensory Visualization	221
7.3.1	The Haptic Interaction Loop	221
7.3.2	Force Feedback Refresh Requirements	222
7.4	Single-Point Haptic Interaction	225
7.4.1	Collision Detection	225
7.4.2	The Computation of Reaction Forces	229
7.4.3	The Virtual Proxy	231
7.5	Increasing the Realism of Force Feedback	235
7.5.1	Adding Frictional Forces	236
7.5.2	Incorporating Haptic Texture	238
7.5.3	Smoothing Polygon Edges by Force Shading	238
7.5.4	Intermediate Representations	239
7.5.5	More Complex Models, Torque, and Deformable Objects	240
7.6	Haptic Interaction With Volumetric Data	242
7.6.1	Exploration of Volumetric Data	244
7.6.2	Smoother Force Feedback	247
7.6.3	Additional Forces	247
7.6.4	The Impression of Surfaces Within Volumetric Images	248
7.6.5	Modification of Volumetric Data	250
7.7	Multichannel Software Architectures	251
7.8	Discussion	252
7.9	Investigations	254
8	The Visual Channel	255
8.1	Introduction	255
8.2	Stereoscopic Display Techniques	257
8.2.1	Temporally Coded Systems	257
8.2.2	Chromatically Coded Systems	259
8.2.3	Spatially Coded Systems	260
8.2.4	Computation for Stereoscopic Views	261

8.3	Multi-View Systems and Electroholography	264
8.3.1	Lenticular and Parallax Barrier Techniques	264
8.3.2	Dynamic Multi-view Systems	268
8.3.3	Electroholography	271
8.4	Virtual Reality Systems	274
8.4.1	Immersive Virtual Reality	275
8.4.2	The CAVE and Cybersphere	280
8.4.3	Mixed Reality Techniques	284
8.4.4	Pepper's Ghost Revisited	286
8.5	The Volumetric Approach	287
8.5.1	Swept Volume Systems	290
8.5.2	Static Volume Systems	293
8.5.3	Varifocal Mirror Systems	293
8.6	Discussion	294
8.7	Investigations	297
9	Adopting a Creative Approach	299
9.1	Introduction	299
9.2	Two-Handed Interaction	301
9.2.1	Bi-manual Task Performance	304
9.2.2	The Potential Benefits of Bi-manual Interaction	308
9.3	Augmenting the Desktop Interface	313
9.4	Readings on Implementations and Applications	315
9.5	Discussion	316
	Appendix A: The Chimenti Drawings	319
	Appendix B: Holographic Images	323
	General Bibliography	331
	References	341
	Index	367