

Table of Contents

| | |
|--|------|
| FOREWORD by Gregg Favalora | xi |
| PREFACE | xiii |
| ACKNOWLEDGEMENTS | xvii |
| SUMMARY OF ACRONYMS | xix |
| 1. FOUNDATIONS | |
| 1.1 Introduction | 1 |
| 1.2 Creative Display and Interaction Paradigms | 3 |
| 1.3 Historical Note | 6 |
| 1.4 The Conventional Interface: Flatlands | 10 |
| 1.5 Inhibiting Human-Computer Interaction | 13 |
| 1.5.1 Augmented Realism: Suspension of Disbelief | 13 |
| 1.5.2 Augmented Information Content | 17 |
| 1.5.3 Creative Design | 18 |
| 1.5.4 Multifaceted Applications | 22 |
| 1.6 Concerning Graphics | 23 |
| 1.6.1 Projection Geometry for a Single View | 23 |
| 1.6.2 Surface Rendering | 25 |
| 1.6.3 Working with Volumetric Data | 26 |
| 1.7 Display Subsystems | 28 |
| 1.8 Forms of Space | 30 |
| 1.9 Discussion | 31 |
| 2. PERCEPTION: VISION | |
| 2.1 Introduction | 33 |
| 2.2 Some Facets of Light | 34 |
| 2.2.1 Colour | 36 |
| 2.2.2 Light Energy | 37 |
| 2.2.3 Diffraction in Optical Systems | 41 |
| 2.3 The Visual System | 44 |
| 2.3.1 The Eye as an Optical Instrument | 45 |
| 2.3.2 The Retina | 47 |
| 2.3.3 Eye Movements and Saccades | 52 |
| 2.3.4 The Detection of Colour | 59 |
| 2.4 Beyond the Eye | 60 |
| 2.4.1 The Lateral Geniculate Nucleus | 61 |
| 2.4.2 Reflex Feedback | 62 |
| 2.4.3 The Primary Visual Cortex (V1) | 63 |
| 2.4.4 The Dorsal and Ventral Pathways | 63 |
| 2.4.5 The M and P Pathways | 65 |
| 2.4.6 Detection of Binocular Disparity | 65 |
| 2.5 Some Visual Characteristics | 66 |
| 2.5.1 The Visual Field | 66 |
| 2.5.2 Spatial Resolution | 66 |

| | | |
|-----------|---|-----|
| 2.5.3 | Sensitivity and the Impact of Spatial Frequency | 70 |
| 2.6 | Perception of Space and Form | 71 |
| 2.6.1 | Pictorial Depth Cues | 73 |
| 2.6.2 | Oculomotor Cues | 76 |
| 2.6.3 | Parallax Cues | 77 |
| 2.6.4 | Absolute and Relative Depth Perception | 78 |
| 2.6.5 | Consistency and Conflict Between Depth Cues | 78 |
| 2.6.6 | The Perception of Form | 81 |
| 2.6.7 | The Gestalt Theory of Visual Perception | 82 |
| 2.6.8 | The Pulfrich Effect | 84 |
| 2.7 | Temporal Resolution: Fusion and Motion | 85 |
| 2.8 | Discussion | 86 |
| 3. | PERCEPTION: HAPTICS | |
| 3.1 | Introduction | 89 |
| 3.2 | Somatosensory Receptors | 91 |
| 3.3 | Cutaneous Sensitivity | 92 |
| 3.4 | Proprioception | 95 |
| 3.5 | Somatosensory and Motor Pathways | 99 |
| 3.6 | Discussion | 101 |
| 4. | HISTORICAL PERSPECTIVE | |
| 4.1 | Introduction | 103 |
| 4.2 | The Development of Perspective Techniques | 104 |
| 4.2.1 | Early Sculpture and Architecture | 108 |
| 4.2.2 | An Accurate Mathematically-Based Perspective | 120 |
| 4.2.3 | The Centre of Projection | 123 |
| 4.3 | The Transition to Perspective in Painting | 123 |
| 4.3.1 | Brunelleschi Revisited | 125 |
| 4.4 | Geometry for Linear Perspective | 127 |
| 4.5 | Evolving Ideas of Vision and Perception | 129 |
| 4.6 | Neuroanatomy in the Sistine Chapel Frescoes | 138 |
| 4.7 | The Camera Obscura and Lucida | 146 |
| 4.7.1 | The Camera Obscura | 146 |
| 4.7.2 | The Camera Lucida | 147 |
| 4.8 | Discussion | 149 |
| 5. | INTERACTION | |
| 5.1 | Introduction | 151 |
| 5.2 | An Early Evaluation of Interaction Tools | 153 |
| 5.2.1 | Interaction Space and Tool Set | 154 |
| 5.2.2 | Interaction Tool Evaluation | 158 |
| 5.2.3 | Interaction Issues | 159 |
| 5.3 | Fitts' Model and Its Application | 160 |
| 5.3.1 | An Application of Fitts' Model | 163 |
| 5.3.2 | Further Aspects of Fitts' Model | 164 |
| 5.4 | Interaction Paradigms | 166 |
| 5.4.1 | Transferred Interaction | 167 |
| 5.4.2 | Direct Interaction | 167 |
| 5.5 | Touch Screen Technologies | 168 |
| 5.5.1 | A Row and Column Technique | 169 |

| | | |
|-----------|---|-----|
| 5.5.2 | A Resistance Technique | 170 |
| 5.5.3 | A Projected Capacitance Technique | 172 |
| 5.5.4 | Infrared Techniques | 173 |
| 5.5.5 | Dispersive Signal Technology | 174 |
| 5.5.6 | Frustrated Total Internal Reflection | 174 |
| 5.6 | Spatial Interaction | 178 |
| 5.6.1 | Interaction Using a 3-DOF Wand | 178 |
| 5.6.2 | Interaction Using a 6-DOF Wand | 181 |
| 5.6.3 | Free-Hand Gesture-Based Spatial Interaction | 182 |
| 5.7 | Discussion | 185 |
| 6. | STEREOSCOPIC TECHNIQUES | |
| 6.1 | Introduction | 189 |
| 6.2 | Display Classification | 190 |
| 6.3 | The Origins of Stereoscopic Image Depiction | 191 |
| 6.4 | The Geometry of Stereopsis | 206 |
| 6.4.1 | Stereoscopic Fixation and the Horopter | 207 |
| 6.4.2 | Autostereograms | 209 |
| 6.4.3 | Horizontal Disparity | 215 |
| 6.4.4 | Accommodation and Convergence | 218 |
| 6.4.5 | Vertical Disparity | 218 |
| 6.5 | Stereoscopic Display Techniques | 220 |
| 6.5.1 | Temporally Coded Systems | 221 |
| 6.5.2 | Locally Coded Systems | 224 |
| 6.5.2.1 | Chromatic Coding (Anaglyph Technique) | 224 |
| 6.5.2.2 | Field Coding | 225 |
| 6.5.3 | Spatially Coded Systems | 226 |
| 6.5.4 | An Early Stereoscopic Television System | 227 |
| 6.6 | Computation for Stereoscopic Views | 228 |
| 6.7 | Creating a Stereoscopic Image | 231 |
| 6.8 | Discussion | 235 |
| 7. | IMAGES AND SPACE | |
| 7.1 | Introduction | 239 |
| 7.2 | Classes of Image Space | 240 |
| 7.2.1 | The Planar Image Space | 240 |
| 7.2.2 | The Apparent Image Space | 244 |
| 7.2.3 | The Physical Image Space | 246 |
| 7.2.4 | The Ethereal (Free) Image Space | 247 |
| 7.2.5 | The Virtual Image Space | 249 |
| 7.3 | Pepper's Ghost and Augmented Reality | 249 |
| 7.4 | Phantasmagoria: An Ethereal Image Space | 252 |
| 7.5 | Discussion | 266 |
| 8. | AUTOSTEREOSCOPIC: CLASS I | |
| 8.1 | Introduction | 271 |
| 8.2 | Multiview Systems | 272 |
| 8.2.1 | The Parallax Barrier Technique | 273 |
| 8.2.2 | The Lenticular Sheet Technique | 281 |
| 8.2.3 | Dynamic Multiview Systems | 283 |
| 8.2.3.1 | Collimated Views | 284 |

| | | |
|-----------|--|-----|
| 8.2.3.2 | The Moving Slit Approach | 285 |
| 8.2.3.3 | The Electronic Dynamic Barrier | 287 |
| 8.3 | Virtual Reality Systems | 289 |
| 8.3.1 | IVR Using HMD Technology | 294 |
| 8.3.2 | IVR Using CAVE and CAVE-Like Techniques | 298 |
| 8.3.3 | Augmented Reality | 301 |
| 8.4 | Discussion | 305 |
| 9. | AUTOSTEREOSCOPIC: CLASS II | |
| 9.1 | Introduction | 307 |
| 9.2 | The Volumetric Approach | 308 |
| 9.2.1 | Swept-Volume Systems | 313 |
| 9.2.2 | Static-Volume Systems | 328 |
| 9.2.3 | Hybrid Volumetric/Multiview Techniques | 334 |
| 9.3 | Towards an Ethereal Image Space | 336 |
| 9.3.1 | Projections to form a Type I Ethereal Image Space | 336 |
| 9.3.2 | Projections to form a Type II Ethereal Image Space | 338 |
| 9.4 | Varifocal Systems | 340 |
| 9.4.1 | Hybrid Varifocal/Stereoscopic Techniques | 344 |
| 9.5 | Direct Projection onto the Retina | 346 |
| 9.6 | Discussion | 347 |
| | APPENDIX: THE CHIMENTI CONTROVERSY | 353 |
| | REFERENCES | 357 |
| | INDEX | 385 |