

Contents

List of Contributors	xiii
Symbols	xix
Abbreviations	xxi
Introduction	1
<i>Oliver Schreer, Peter Kauff and Thomas Sikora</i>	
Section I Applications of 3D Videocommunication	5
1 History of Telepresence	7
<i>Wijnand A. IJsselstein</i>	
1.1 Introduction	7
1.2 The Art of Immersion: Barker's Panoramas	10
1.3 Cinerama and Sensorama	11
1.4 Virtual Environments	14
1.5 Teleoperation and Telerobotics	16
1.6 Telecommunications	18
1.7 Conclusion	19
References	20
2 3D TV Broadcasting	23
<i>Christoph Fehn</i>	
2.1 Introduction	23
2.2 History of 3D TV Research	24
2.3 A Modern Approach to 3D TV	26
2.3.1 A Comparison with a Stereoscopic Video Chain	28
2.4 Stereoscopic View Synthesis	29
2.4.1 3D Image Warping	29
2.4.2 A 'Virtual' Stereo Camera	30
2.4.3 The Disocclusion Problem	32
2.5 Coding of 3D Imagery	34
2.5.1 Human Factor Experiments	35

2.6	Conclusions	36
	Acknowledgements	37
	References	37
3	3D in Content Creation and Post-production	39
	<i>Oliver Grau</i>	
3.1	Introduction	39
3.2	Current Techniques for Integrating Real and Virtual Scene Content	41
3.3	Generation of 3D Models of Dynamic Scenes	44
3.4	Implementation of a Bidirectional Interface Between Real and Virtual Scenes	46
	3.4.1 Head Tracking	49
	3.4.2 View-dependent Rendering	50
	3.4.3 Mask Generation	50
	3.4.4 Texturing	51
	3.4.5 Collision Detection	52
3.5	Conclusions	52
	References	52
4	Free Viewpoint Systems	55
	<i>Masayuki Tanimoto</i>	
4.1	General Overview of Free Viewpoint Systems	55
4.2	Image Domain System	57
	4.2.1 EyeVision	57
	4.2.2 3D-TV	58
	4.2.3 Free Viewpoint Play	59
4.3	Ray-space System	59
	4.3.1 FTV (Free Viewpoint TV)	59
	4.3.2 Bird's-eye View System	60
	4.3.3 Light Field Video Camera System	62
4.4	Surface Light Field System	64
4.5	Model-based System	65
	4.5.1 3D Room	65
	4.5.2 3D Video	66
	4.5.3 Multi-texturing	67
4.6	Integral Photography System	68
	4.6.1 NHK System	68
	4.6.2 1D-II 3D Display System	70
4.7	Summary	70
	References	71
5	Immersive Videoconferencing	75
	<i>Peter Kauff and Oliver Schreer</i>	
5.1	Introduction	75
5.2	The Meaning of Telepresence in Videoconferencing	76
5.3	Multi-party Communication Using the Shared Table Concept	79

5.4	Experimental Systems for Immersive Videoconferencing	83
5.5	Perspective and Trends	87
	Acknowledgements	88
	References	88
Section II 3D Data Representation and Processing		91
6	Fundamentals of Multiple-view Geometry	93
	<i>Spela Ivekovic, Andrea Fusiello and Emanuele Trucco</i>	
6.1	Introduction	93
6.2	Pinhole Camera Geometry	94
6.3	Two-view Geometry	96
	6.3.1 Introduction	96
	6.3.2 Epipolar Geometry	97
	6.3.3 Rectification	102
	6.3.4 3D Reconstruction	104
6.4	N -view Geometry	106
	6.4.1 Trifocal Geometry	106
	6.4.2 The Trifocal Tensor	108
	6.4.3 Multiple-view Constraints	109
	6.4.4 Uncalibrated Reconstruction from N views	110
	6.4.5 Autocalibration	111
6.5	Summary	112
	References	112
7	Stereo Analysis	115
	<i>Nicole Atzpadin and Jane Mulligan</i>	
7.1	Stereo Analysis Using Two Cameras	115
	7.1.1 Standard Area-based Stereo Analysis	117
	7.1.2 Fast Real-time Approaches	120
	7.1.3 Post-processing	123
7.2	Disparity From Three or More Cameras	125
	7.2.1 Two-camera versus Three-camera Disparity	127
	7.2.2 Correspondence Search with Three Views	128
	7.2.3 Post-processing	129
7.3	Conclusion	130
	References	130
8	Reconstruction of Volumetric 3D Models	133
	<i>Peter Eisert</i>	
8.1	Introduction	133
8.2	Shape-from-Silhouette	135
	8.2.1 Rendering of Volumetric Models	136
	8.2.2 Octree Representation of Voxel Volumes	137
	8.2.3 Camera Calibration from Silhouettes	139
8.3	Space-carving	140

8.4	Epipolar Image Analysis	143
8.4.1	Horizontal Camera Motion	143
8.4.2	Image Cube Trajectory Analysis	145
8.5	Conclusions	148
	References	148
9	View Synthesis and Rendering Methods	151
	<i>Reinhard Koch and Jan-Friso Evers-Senne</i>	
9.1	The Plenoptic Function	152
9.1.1	Sampling the Plenoptic Function	152
9.1.2	Recording of the Plenoptic Samples	153
9.2	Categorization of Image-based View Synthesis Methods	154
9.2.1	Parallax Effects in View Rendering	154
9.2.2	Taxonomy of IBR Systems	156
9.3	Rendering Without Geometry	158
9.3.1	The Aspen Movie-Map	158
9.3.2	Quicktime VR	158
9.3.3	Central Perspective Panoramas	159
9.3.4	Manifold Mosaicing	159
9.3.5	Concentric Mosaics	161
9.3.6	Cross-slit Panoramas	162
9.3.7	Light Field Rendering	162
9.3.8	Lumigraph	163
9.3.9	Ray Space	164
9.3.10	Related Techniques	164
9.4	Rendering with Geometry Compensation	165
9.4.1	Disparity-based Interpolation	165
9.4.2	Image Transfer Methods	166
9.4.3	Depth-based Extrapolation	167
9.4.4	Layered Depth Images	168
9.5	Rendering from Approximate Geometry	169
9.5.1	Planar Scene Approximation	169
9.5.2	View-dependent Geometry and Texture	169
9.6	Recent Trends in Dynamic IBR	170
	References	172
10	3D Audio Capture and Analysis	175
	<i>Markus Schwab and Peter Noll</i>	
10.1	Introduction	175
10.2	Acoustic Echo Control	176
10.2.1	Single-channel Echo Control	177
10.2.2	Multi-channel Echo Control	179
10.3	Sensor Placement	181
10.4	Acoustic Source Localization	182
10.4.1	Introduction	182
10.4.2	Real-time System and Results	183

10.5	Speech Enhancement	185
10.5.1	Multi-channel Speech Enhancement	186
10.5.2	Single-channel Noise Reduction	187
10.6	Conclusions	190
	References	191
11	Coding and Standardization	193
	<i>Aljoscha Smolic and Thomas Sikora</i>	
11.1	Introduction	193
11.2	Basic Strategies for Coding Images and Video	194
11.2.1	Predictive Coding of Images	194
11.2.2	Transform Domain Coding of Images and Video	195
11.2.3	Predictive Coding of Video	198
11.2.4	Hybrid MC/DCT Coding for Video Sequences	199
11.2.5	Content-based Video Coding	201
11.3	Coding Standards	202
11.3.1	JPEG and JPEG 2000	202
11.3.2	Video Coding Standards	202
11.4	MPEG-4 — an Overview	204
11.4.1	MPEG-4 Systems	205
11.4.2	BIFS	205
11.4.3	Natural Video	206
11.4.4	Natural Audio	207
11.4.5	SNHC	208
11.4.6	AFX	209
11.5	The MPEG 3DAV Activity	210
11.5.1	Omnidirectional Video	210
11.5.2	Free-viewpoint Video	212
11.6	Conclusion	214
	References	214
Section III	3D Reproduction	217
12	Human Factors of 3D Displays	219
	<i>Wijnand A. IJsselstein, Pieter J.H. Seuntiëns and Lydia M.J. Meesters</i>	
12.1	Introduction	219
12.2	Human Depth Perception	220
12.2.1	Binocular Disparity and Stereopsis	220
12.2.2	Accommodation and Vergence	222
12.2.3	Asymmetrical Binocular Combination	223
12.2.4	Individual Differences	224
12.3	Principles of Stereoscopic Image Production and Display	225
12.4	Sources of Visual Discomfort in Viewing Stereoscopic Displays	226
12.4.1	Keystone Distortion and Depth Plane Curvature	227
12.4.2	Magnification and Miniaturization Effects	228

12.4.3	Shear Distortion	229
12.4.4	Cross-talk	229
12.4.5	Picket Fence Effect and Image Flipping	230
12.5	Understanding Stereoscopic Image Quality	230
	References	231
13	3D Displays	235
	<i>Siegmund Pastoor</i>	
13.1	Introduction	235
13.2	Spatial Vision	236
13.3	Taxonomy of 3D Displays	237
13.4	Aided-viewing 3D Display Technologies	238
13.4.1	Colour-multiplexed (Anaglyph) Displays	238
13.4.2	Polarization-multiplexed Displays	239
13.4.3	Time-multiplexed Displays	239
13.4.4	Location-multiplexed Displays	240
13.5	Free-viewing 3D Display Technologies	242
13.5.1	Electroholography	242
13.5.2	Volumetric Displays	243
13.5.3	Direction-multiplexed Displays	244
13.6	Conclusions	258
	References	258
14	Mixed Reality Displays	261
	<i>Siegmund Pastoor and Christos Conomis</i>	
14.1	Introduction	261
14.2	Challenges for MR Technologies	263
14.3	Human Spatial Vision and MR Displays	264
14.4	Visual Integration of Natural and Synthetic Worlds	265
14.4.1	Free-form Surface-prism HMD	265
14.4.2	Waveguide Holographic HMD	266
14.4.3	Virtual Retinal Display	267
14.4.4	Variable-accommodation HMD	267
14.4.5	Occlusion Handling HMD	268
14.4.6	Video See-through HMD	269
14.4.7	Head-mounted Projective Display	269
14.4.8	Towards Free-viewing MR Displays	270
14.5	Examples of Desktop and Hand-held MR Systems	273
14.5.1	Hybrid 2D/3D Desktop MR System with Multimodal Interaction	273
14.5.2	Mobile MR Display with Markerless Video-based Tracking	275
14.6	Conclusions	278
	References	279

15 Spatialized Audio and 3D Audio Rendering	281
<i>Thomas Sporer and Sandra Brix</i>	
15.1 Introduction	281
15.2 Basics of Spatial Audio Perception	281
15.2.1 Perception of Direction	282
15.2.2 Perception of Distance	283
15.2.3 The Cocktail Party Effect	283
15.2.4 Final Remarks	284
15.3 Spatial Sound Reproduction	284
15.3.1 Discrete Multi-channel Loudspeaker Reproduction	284
15.3.2 Binaural Reproduction	287
15.3.3 Multi-object Audio Reproduction	287
15.4 Audiovisual Coherence	291
15.5 Applications	293
15.6 Summary and Outlook	293
References	293
Section IV 3D Data Sensors	297
16 Sensor-based Depth Capturing	299
<i>João G.M. Gonçalves and Vítor Sequeira</i>	
16.1 Introduction	299
16.2 Triangulation-based Sensors	301
16.3 Time-of-flight-based Sensors	303
16.3.1 Pulsed Wave	304
16.3.2 Continuous-wave-based Sensors	304
16.3.3 Summary	308
16.4 Focal Plane Arrays	308
16.5 Other Methods	309
16.6 Application Examples	309
16.7 The Way Ahead	311
16.8 Summary	311
References	312
17 Tracking and User Interface for Mixed Reality	315
<i>Yousri Abdeljaoued, David Marimon i Sanjuan, and Touradj Ebrahimi</i>	
17.1 Introduction	315
17.2 Tracking	316
17.2.1 Mechanical Tracking	317
17.2.2 Acoustic Tracking	317
17.2.3 Inertial Tracking	318
17.2.4 Magnetic Tracking	318
17.2.5 Optical Tracking	320
17.2.6 Video-based Tracking	320
17.2.7 Hybrid Tracking	323

17.3	User Interface	324
17.3.1	Tangible User Interfaces	324
17.3.2	Gesture-based Interfaces	325
17.4	Applications	328
17.4.1	Mobile Applications	328
17.4.2	Collaborative Applications	329
17.4.3	Industrial Applications	329
17.5	Conclusions	331
	References	331
	Index	335