
Contents

List of Figures	XXVI
List of Tables	XXXI
List of Listings	XXXII

Part I Introduction to the Human Visual System (HVS)

1 Visual Attention	3
1.1 Visual Attention: A Historical Review	4
1.1.1 Von Helmholtz's "Where"	4
1.1.2 James' "What"	5
1.1.3 Gibson's "How"	5
1.1.4 Broadbent's "Selective Filter"	6
1.1.5 Deutsch and Deutsch's "Importance Weightings"	6
1.1.6 Yarbus and Noton and Stark's "Scanpaths"	7
1.1.7 Posner's "Spotlight"	8
1.1.8 Treisman's "Glue"	10
1.1.9 Kosslyn's "Window"	10
1.2 Visual Attention and Eye Movements	11
1.3 Summary and Further Reading	13
2 Neurological Substrate of the HVS	15
2.1 The Eye	18
2.2 The Retina	18
2.2.1 The Outer Layer	21
2.2.2 The Inner Nuclear Layer	21
2.2.3 The Ganglion Layer	22
2.3 The Optic Tract and M/P Visual Channels	23
2.4 The Occipital Cortex and Beyond	24

2.4.1	Motion-Sensitive Single-Cell Physiology	25
2.5	Summary and Further Reading	26
3	Visual Psychophysics	29
3.1	Spatial Vision	29
3.2	Temporal Vision	33
3.2.1	Perception of Motion in the Visual Periphery	35
3.2.2	Sensitivity to Direction of Motion in the Visual Periphery ..	36
3.3	Color Vision	36
3.4	Implications for Attentional Design of Visual Displays	38
3.5	Summary and Further Reading	39
4	Taxonomy and Models of Eye Movements	41
4.1	The Extraocular Muscles and the Oculomotor Plant	41
4.2	Saccades	42
4.3	Smooth Pursuits	45
4.4	Fixations (Microsaccades, Drift, and Tremor)	46
4.5	Nystagmus	47
4.6	Implications for Eye Movement Analysis	47
4.7	Summary and Further Reading	48

Part II Eye Tracking Systems

5	Eye Tracking Techniques	51
5.1	Electro-OculoGraphy (EOG)	52
5.2	Scleral Contact Lens/Search Coil	52
5.3	Photo-OculoGraphy (POG) or Video-OculoGraphy (VOG)	53
5.4	Video-Based Combined Pupil/Corneal Reflection	54
5.5	Classifying Eye Trackers in “Mocap” Terminology	58
5.6	Summary and Further Reading	59
6	Head-Mounted System Hardware Installation	61
6.1	Integration Issues and Requirements	61
6.2	System Installation	64
6.3	Lessons Learned from the Installation at Clemson	66
6.4	Summary and Further Reading	67
7	Head-Mounted System Software Development	69
7.1	Mapping Eye Tracker Screen Coordinates	70
7.1.1	Mapping Screen Coordinates to the 3D Viewing Frustum ...	70
7.1.2	Mapping Screen Coordinates to the 2D Image	71
7.1.3	Measuring Eye Tracker Screen Coordinate Extents	72
7.2	Mapping Flock Of Birds Tracker Coordinates	74
7.2.1	Obtaining the Transformed View Vector	75

7.2.2	Obtaining the Transformed Up Vector	76
7.2.3	Transforming an Arbitrary Vector	77
7.3	3D Gaze Point Calculation	77
7.3.1	Parametric Ray Representation of Gaze Direction	80
7.4	Virtual Gaze Intersection Point Coordinates	81
7.4.1	Ray/Plane Intersection	81
7.4.2	Point-In-Polygon Problem	83
7.5	Data Representation and Storage	84
7.6	Summary and Further Reading	85
8	Head-Mounted System Calibration	87
8.1	Software Implementation	88
8.2	Ancillary Calibration Procedures	91
8.2.1	Internal 2D Calibration	92
8.2.2	Internal 3D Calibration	95
8.3	Summary and Further Reading	96
9	Table-Mounted System Hardware Installation	101
9.1	Integration Issues and Requirements	102
9.2	System Installation	104
9.3	Lessons Learned from the Installation at Clemson	105
9.4	Summary and Further Reading	106
10	Table-Mounted System Software Development	109
10.1	Linux Tobii Client Application Program Interface	110
10.1.1	Tet_Init	111
10.1.2	Tet_Connect, Tet_Disconnect	111
10.1.3	Tet_Start, Tet_Stop	112
10.1.4	Tet_CalibClear, Tet_CalibLoadFromFile, Tet_CalibSaveToFile, Tet_CalibAddPoint, Tet_CalibRemovePoints, Tet_CalibGetResult, Tet_CalibCalculateAndSet	112
10.1.5	Tet_SynchronizeTime, Tet_PerformSystemCheck ...	114
10.1.6	Tet_GetSerialNumber, Tet_GetLastError, Tet_GetLastErrorAsText	115
10.1.7	Tet_CallbackFunction	116
10.2	A Simple OpenGL/GLUT GUI Example	116
10.3	Caveats	121
10.4	Summary and Further Reading	121
11	Table-Mounted System Calibration	127
11.1	Software Implementation	128
11.2	Summary and Further Reading	136

12	Using an Open Source Application Program Interface	139
	12.1 API Implementation and XML Format	139
	12.2 Client/Server Communication	140
	12.3 Server Configuration	141
	12.4 API Extensions	142
	12.5 Interactive Client Example using Python	142
	12.5.1 Using Gazepoint's Built-in Calibration	143
	12.5.2 Using Gazepoint's Custom Calibration Capabilities	144
	12.6 Summary and Further Reading	148
13	Eye Movement Analysis	149
	13.1 Signal Denoising	151
	13.2 Dwell-Time Fixation Detection	151
	13.3 Velocity-Based Saccade Detection	153
	13.4 Eye Movement Analysis in Three Dimensions	156
	13.4.1 Parameter Estimation	161
	13.4.2 Fixation Grouping	164
	13.4.3 Eye Movement Data Mirroring	165
	13.5 Summary and Further Reading	165
14	Advanced Eye Movement Analysis	167
	14.1 Signal Denoising	167
	14.2 Velocity-Based Saccade Detection	169
	14.3 Microsaccade Detection	170
	14.4 Validation: Computing Accuracy, Precision, and Refitting	171
	14.5 Binocular Eye Movement Analysis: Vergence	175
	14.6 Ambient/Focal Eye Movement Analysis	177
	14.7 Transition Entropy Analysis	181
	14.8 Spatial Distribution Analysis	182
	14.9 Summary and Further Reading	182
15	The Gaze Analytics Pipeline	185
	15.1 Gaze Analytics in Five Easy Steps	186
	15.1.1 Step 0: Data Collection	187
	15.1.2 Step 1 (<code>dirs</code>): Directory Creation	188
	15.1.3 Step 2 (<code>raw</code>): Extract Raw Gaze Data	188
	15.1.4 Step 3 (<code>graph</code> or <code>process</code>): Graph or Process Raw Data ..	190
	15.1.5 Step 4 (<code>collate</code>): Collate Data Prior to Statistical Analysis	194
	15.1.6 Step 5 (<code>stats</code>): Perform Statistical Analyses	195
	15.2 Gaze Analytics: A Worked Example	195
	15.2.1 Scanpath Visualization	197
	15.2.2 Traditional Eye Movement Metrics	197
	15.2.3 Advanced Eye Movement Analysis	198
	15.3 Summary and Further Reading	201

16 Eye Movement Synthesis	203
16.1 Procedural Simulation of Eye Movements	203
16.1.1 Modeling Saccades	204
16.1.2 Modeling Fixations	205
16.2 Adding Synthetic Eye Tracking Noise	207
16.3 Summary and Further Reading	207

Part III Eye Tracking Methodology

17 Experimental Design	211
17.1 Formulating a Hypothesis	211
17.2 Forms of Inquiry	213
17.2.1 Experiments Versus Observational Studies	213
17.2.2 Laboratory Versus Field Research	214
17.2.3 Idiographic Versus Nomothetic Research	214
17.2.4 Sample Population Versus Single-Case Experiment Versus Case Study	215
17.2.5 Within-Subjects Versus Between-Subjects	216
17.2.6 Example Designs	217
17.3 Measurement and Analysis	220
17.4 Summary and Further Reading	223
18 Suggested Empirical Guidelines	225
18.1 Evaluation Plan	226
18.1.1 Data Collection	226
18.1.2 System Identification	229
18.1.3 Constraints	229
18.1.4 User Selection	230
18.1.5 Evaluation Locale	230
18.1.6 Task Selection	231
18.2 Practical Advice	232
18.3 Considering Dynamic Stimulus	233
18.4 Summary and Further Reading	233
19 Case Studies	235
19.1 Head-Mounted VR Diagnostics: Visual Inspection	236
19.1.1 Case Study Notes	237
19.2 Head-Mounted VR Diagnostics: 3D Maze Navigation	237
19.2.1 Case Study Notes	238
19.3 Desktop VR Diagnostics: Driving Simulator	239
19.3.1 Case Study Notes	240
19.4 Desktop Diagnostics: Usability	241
19.4.1 Case Study Notes	249
19.5 Desktop Interaction: Gaze-Contingent Fisheye Lens	251

19.5.1 Case Study Notes	255
19.6 Summary and Further Reading	255

Part IV Eye Tracking Applications

20 Diversity and Types of Eye Tracking Applications	259
20.1 Summary and Further Reading	260
21 Neuroscience and Psychology	261
21.1 Neurophysiological Investigation of Illusory Contours	262
21.2 Attentional Neuroscience	262
21.3 Eye Movements and Brain Imaging	265
21.4 Reading	267
21.5 Scene Perception	270
21.5.1 Perception of Art	274
21.5.2 Perception of Film	275
21.6 Visual Search	276
21.6.1 Computational Models of Visual Search	283
21.7 Natural Tasks	287
21.8 Eye Movements in Other Information Processing Tasks	291
21.9 Summary and Further Reading	294
22 Industrial Engineering and Human Factors	295
22.1 Aviation	295
22.2 Driving	298
22.3 Visual Inspection	304
22.4 Summary and Further Reading	314
23 Marketing/Advertising	315
23.1 Copy Testing	317
23.2 Print Advertising	318
23.3 Ad Placement	321
23.4 Television Enhancements	323
23.5 Web Pages	324
23.6 Product Label Design	327
23.7 Summary and Further Reading	328
24 Computer Science	329
24.1 Human–Computer Interaction and Collaborative Systems	329
24.1.1 Classic Eye-Based Interaction	330
24.1.2 Cognitive Modeling	331
24.1.3 Universal Accessibility	333
24.1.4 Indirect Eye-Based Interaction	335
24.1.5 Attentive User Interfaces (AUIs)	336

24.1.6 Usability	337
24.1.7 Collaborative Systems	338
24.2 Gaze-Contingent Displays	339
24.2.1 Screen-Based Displays	340
24.2.2 Model-Based Graphical Displays	346
24.3 Summary and Further Reading	354
25 Conclusion	355
References	357
Index	379

