

Extended Contents List

Preface	xi
About the authors	xvii

CHAPTER 1 Introduction 1

1.1 Overview.....	1
1.2 Human and Computer Vision	2
1.3 The Human Vision System	4
1.3.1 The Eye.....	5
1.3.2 The Neural System	8
1.3.3 Processing	9
1.4 Computer Vision Systems.....	12
1.4.1 Cameras	12
1.4.2 Computer Interfaces.....	15
1.4.3 Processing an Image	17
1.5 Mathematical Systems	19
1.5.1 Mathematical Tools	19
1.5.2 Hello Matlab, Hello Images!	20
1.5.3 Hello Mathcad!	25
1.6 Associated Literature	30
1.6.1 Journals, Magazines and Conferences	30
1.6.2 Textbooks	31
1.6.3 The Web	34
1.7 Conclusions	35
1.8 Chapter 1 References	35

CHAPTER 2 Images, Sampling and Frequency Domain Processing 37

2.1 Overview.....	37
2.2 Image Formation	38
2.3 The Fourier Transform.....	42
2.4 The Sampling Criterion	49
2.5 The Discrete Fourier Transform (DFT)	53
2.5.1 One Dimensional Transform	53
2.5.2 Two Dimensional Transform	57
2.6 Other Properties of the Fourier Transform.....	63
2.6.1 Shift Invariance	63
2.6.2 Rotation	65
2.6.3 Frequency Scaling	66
2.6.4 Superposition (Linearity)	67
2.7 Transforms other than Fourier	68
2.7.1 Discrete Cosine Transform.....	68
2.7.2 Discrete Hartley Transform	70
2.7.3 Introductory Wavelets	71
2.7.3.1 <i>Gabor Wavelet</i>	71
2.7.3.2 <i>Haar Wavelet</i>	74

2.7.4 Other Transforms	78
2.8 Applications using Frequency Domain Properties.....	78
2.9 Further Reading	80
2.10 Chapter 2 References	81

CHAPTER 3 Basic Image Processing Operations 83

3.1 Overview.....	83
3.2 Histograms	84
3.3 Point Operators	86
3.3.1 Basic Point Operations	86
3.3.2 Histogram Normalisation.....	89
3.3.3 Histogram Equalisation	90
3.3.4 Thresholding	93
3.4 Group Operations.....	98
3.4.1 Template Convolution	98
3.4.2 Averaging Operator	101
3.4.3 On Different Template Size.....	103
3.4.4 Gaussian Averaging Operator.....	104
3.4.5 More on Averaging	107
3.5 Other Statistical Operators	109
3.5.1 Median Filter	109
3.5.2 Mode Filter	112
3.5.3 Anisotropic Diffusion	114
3.5.4 Force Field Transform	121
3.5.5 Comparison of Statistical Operators	122
3.6 Mathematical Morphology	123
3.6.1 Morphological Operators.....	124
3.6.2 Grey Level Morphology	127
3.6.3 Grey Level Erosion and Dilation	128
3.6.4 Minkowski Operators	130
3.7 Further Reading	134
3.8 Chapter 3 References	134

CHAPTER 4 Low-Level Feature Extraction (including Edge Detection) 137

4.1 Overview.....	138
4.2 Edge Detection	140
4.2.1 First Order Edge Detection Operators.....	140
4.2.1.1 <i>Basic Operators</i>	140
4.2.1.2 <i>Analysis of the Basic Operators</i>	142
4.2.1.3 <i>Prewitt Edge Detection Operator</i>	145
4.2.1.4 <i>Sobel Edge Detection Operator</i>	146
4.2.1.5 <i>The Canny Edge Detector</i>	153
4.2.2 Second Order Edge Detection Operators	161
4.2.2.1 <i>Motivation</i>	161
4.2.2.2 <i>Basic Operators: The Laplacian</i>	163
4.2.2.3 <i>The Marr-Hildreth Operator</i>	165
4.2.3 Other Edge Detection Operators	170
4.2.4 Comparison of Edge Detection Operators.....	171

4.2.5 Further Reading on Edge Detection	173
4.3 Phase Congruency	173
4.4 Localised Feature Extraction	180
4.4.1 Detecting Image Curvature (Corner Extraction)	180
<i>4.4.1.1 Definition of Curvature</i>	180
<i>4.4.1.2 Computing Differences in Edge Direction</i>	182
<i>4.4.1.3 Measuring Curvature by Changes in Intensity (Differentiation)</i>	184
<i>4.4.1.4 Moravec and Harris Detectors</i>	188
<i>4.4.1.5 Further Reading on Curvature</i>	192
4.4.2 Modern Approaches; Region/Patch Analysis.....	193
<i>4.4.2.1 Scale Invariant Feature Transform (SIFT)</i>	193
<i>4.4.2.2 Speeded Up Robust Features (SURF)</i>	196
<i>4.4.2.3 Saliency</i>	198
<i>4.4.2.4 Other Techniques and Performance Issues</i>	198
4.5 Describing Image Motion	199
4.5.1 Area-based approach	200
4.5.2 Differential approach.....	204
4.5.3 Further Reading on Optical Flow	211
4.6 Further Reading	212
4.7 Chapter 4 References	212

CHAPTER 5 High-Level Feature Extraction: Fixed Shape Matching 217

5.1 Overview.....	218
5.2 Thresholding and Subtraction	220
5.3 Template Matching	222
5.3.1 Definition.....	222
5.3.2 Fourier Transform Implementation	230
5.3.3 Discussion of Template Matching.....	234
5.4 Feature Extraction by Low Level Features	235
5.4.1 Appearance-Based Approaches.....	235
<i>5.4.1.1 Object Detection by Templates</i>	235
<i>5.4.1.2 Object Detection by Combinations of Parts</i>	237
5.4.2 Distribution-Based Descriptors	238
<i>5.4.2.1 Description by Interest Points</i>	238
<i>5.4.2.2 Characterising Object Appearance and Shape</i>	241
5.5 Hough Transform (HT)	243
5.5.1 Overview	243
5.5.2 Lines	243
5.5.3 HT for Circles.....	250
5.5.4 HT for Ellipses	255
5.5.5 Parameter Space Decomposition.....	258
<i>5.5.5.1 Parameter space reduction for lines</i>	259
<i>5.5.5.2 Parameter space reduction for circles</i>	261
<i>5.5.5.3 Parameter space reduction for ellipses</i>	266
5.5.6 Generalised Hough Transform (GHT)	271
<i>5.5.6.1 Formal Definition of the GHT</i>	272
<i>5.5.6.2 Polar definition</i>	273
<i>5.5.6.3 The GHT Technique</i>	274

<i>5.5.6.4 Invariant GHT</i>	279
<i>5.5.7 Other Extensions to the HT</i>	287
5.6 Further Reading	288
5.7 Chapter 5 References	280

CHAPTER 6 High-Level Feature Extraction: Deformable Shape Analysis 293

6.1 Overview.....	293
6.2 Deformable Shape Analysis.....	294
6.2.1 Deformable Templates	294
6.2.2 Parts-based Shape Analysis	297
6.3 Active Contours (Snakes)	299
6.3.1 Basics.....	299
6.3.2 The Greedy Algorithm for Snakes	301
6.3.3 Complete (Kass) Snake Implementation	308
6.3.4 Other Snake Approaches	313
6.3.5 Further Snake Developments	314
6.3.6 Geometric Active Contours (Level-Set Based Approaches).....	318
6.4 Shape Skeletonisation.....	325
6.4.1 Distance Transforms.....	325
6.4.2 Symmetry	327
6.5 Flexible Shape Models – Active Shape and Active Appearance	334
6.6 Further Reading	338
6.7 Chapter 6 References	338

CHAPTER 7 Object Description 343

7.1 Overview.....	343
7.2 Boundary Descriptions.....	345
7.2.1 Boundary and Region	345
7.2.2 Chain Codes	346
7.2.3 Fourier Descriptors.....	349
7.2.3.1 Basis of Fourier Descriptors.....	350
7.2.3.2 Fourier Expansion	351
7.2.3.3 Shift invariance	354
7.2.3.4 Discrete computation	355
7.2.3.5 Cumulative Angular Function.....	357
7.2.3.6 Elliptic Fourier Descriptors.....	369
7.2.3.7 Invariance	372
7.3 Region Descriptors	378
7.3.1 Basic Region Descriptors	378
7.3.2 Moments	383
7.3.2.1 Basic Properties.....	383
7.3.2.2 Invariant Moments	387
7.3.2.3 Zernike Moments.....	388
7.3.2.4 Other Moments.....	393
7.4 Further Reading	395
7.5 Chapter 7 References	395

CHAPTER 8 Intro. to Texture Description, Segmentation and Classification	399
8.1 Overview.....	399
8.2 What is Texture?	400
8.3 Texture Description.....	403
8.3.1 Performance Requirements	403
8.3.2 Structural Approaches	403
8.3.3 Statistical Approaches	406
8.3.4 Combination Approaches.....	409
8.3.5 Local Binary Patterns	411
8.3.6 Other Approaches.....	417
8.4 Classification.....	417
8.4.1 Distance Measures.....	417
8.4.2 The k -Nearest Neighbour Rule.....	424
8.4.3 Other Classification Approaches.....	428
8.5 Segmentation.....	429
8.6 Further Reading	431
8.7 Chapter 8 References	432
CHAPTER 9 Moving Object Detection and Description	435
9.1 Overview	435
9.2 Moving Object Detection	437
9.2.1 Basic Approaches	437
9.2.1.1 <i>Detection by Subtracting the Background</i>	437
9.2.1.2 <i>Improving Quality by Morphology</i>	440
9.2.2 Modelling and Adapting to the (Static) Background.....	442
9.2.3 Background Segmentation by Thresholding.....	447
9.2.4 Problems and Advances.....	450
9.3 Tracking Moving Features	451
9.3.1 Tracking Moving Objects	451
9.3.2 Tracking by Local Search.....	452
9.3.3 Problems in Tracking.....	455
9.3.4 Approaches to Tracking.....	455
9.3.5 MeanShift and Camshift	457
9.3.5.1 <i>Kernel-Based Density Estimation</i>	457
9.3.5.2 <i>MeanShift Tracking</i>	461
9.3.5.3 <i>Camshift Technique</i>	467
9.3.6 Recent Approaches	472
9.4 Moving Feature Extraction and Description	474
9.4.1 Moving (Biological) Shape Analysis.....	474
9.4.2 Detecting Moving Shapes by Shape Matching in Image Sequences.....	476
9.4.3 Moving Shape Description	480
9.5 Further Reading	484
9.6 Chapter 9 References	484
CHAPTER 10 Appendix 1: Camera Geometry Fundamentals	489
10.1 Image Geometry.....	
10.2 Perspective Camera.....	
10.3 Perspective Camera Model	

10.3.1 Homogeneous co-ordinates and Projective Geometry	
10.3.1.1 Representation of a Line and Duality	
10.3.1.2 Ideal Points	
10.3.1.3 Transformations in the Projective Space	
10.3.2 Perspective Camera Model Analysis	
10.3.3 Parameters of the Perspective Camera Model	
10.4 Affine Camera	
10.4.1 Affine Camera Model	
10.4.2 Affine Camera Model and the Perspective Projection	
10.4.3 Parameters of the Affine Camera Model	
10.5 Weak Perspective Model	
10.6 Example of Camera Models	
10.7 Discussion	
10.8 Appendix 1 References	

CHAPTER 11 Appendix 2: Least Squares Analysis 519

11.1 The Least Squares Criterion	
11.2 Curve Fitting by Least Squares	

CHAPTER 12 Appendix 3: Principal Components Analysis 525

12.1 Principal Components Analysis (PCA)	
12.2 Data	
12.3 Covariance	
12.4 Covariance Matrix	
12.5 Data Transformation	
12.6 Inverse Transformation	
12.7 Eigenproblem	
12.8 Solving the Eigenproblem	
12.9 PCA Method Summary	
12.10 Example	
12.11 Appendix 4 References	

CHAPTER 13 Appendix 4: Colour Images 541

13.1 Colour Images	
13.2 Tristimulus Theory	
13.3 Colour Models	
13.3.1 The Colorimetric Equation	
13.3.2 Luminosity Function	
13.3.3 Perception based Colour Models: The CIE RGB and CIE XYZ	
13.3.3.1 CIE RGB Colour Model: Wright-Guild Data	
13.3.3.2 CIE RGB Colour Matching Functions	
13.3.3.3 CIE RGB Chromaticity Diagram and Chromaticity Coordinates	
13.3.3.4 CIE XYZ Colour Model	
13.3.3.5 CIE XYZ Colour Matching Functions	
13.3.3.6 XYZ Chromaticity Diagram	
13.3.4 Uniform Colour Spaces: CIE LUV and CIE LAB	

13.3.5 Additive and Subtractive Colour Models: RGB and CMY.....	
13.3.5.1 <i>RGB and CMY</i>	
13.3.5.2 <i>Transformation between RGB Colour Models</i>	
13.3.5.3 <i>Transformation between RGB and CMY Colour Models</i>	
13.3.6 Luminance and Chrominance Colour Models: YUV, YIQ and YCbCr	
13.3.6.1 <i>Luminance and Gamma Correction</i>	
13.3.6.2 <i>Chrominance</i>	
13.3.6.3 <i>Transformations between YUV, YIQ and RGB Colour Models</i>	
13.3.6.4 <i>Colour Model for Component Video: YPbPr</i>	
13.3.6.5 <i>Colour Model for Digital Video: YCbCr</i>	
13.3.7 Perceptual Colour Models: HSV and HLS	
13.3.7.1 <i>The Hexagonal Model: HSV</i>	
13.3.7.2 <i>The Triangular Model: HSI</i>	
13.3.8 More Colour Models	
13.4 References	
Index	601