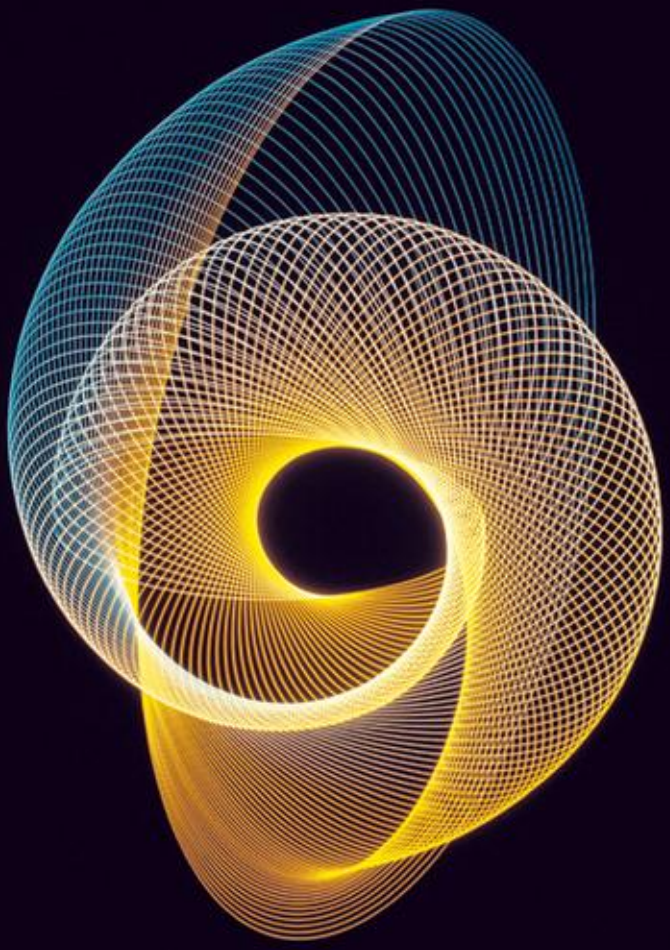
J. R. Parker

Algorithms for Image Processing and Computer Vision



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J.R. Parker

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"Sin lies only in hurting other people unnecessarily.
All other 'sins' are invented nonsense.
(Hurting yourself is not a sin—just stupid.)"

—Robert A. Heinlein

Thanks, Bob.

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J.R. Parker is a computer expert and teacher, with special interests in image processing and vision, video game technologies, and computer simulations. With a Ph.D. in Informatics from the State University of Gent, Dr. Parker has taught computer science, art, and drama at the University of Calgary in Canada, where he is a full professor. He has more than 150 technical papers and four books to his credit, as well as video games such as the *Booze Cruise*, a simulation of impaired driving designed to demonstrate its folly, and a number of educational games. Jim lives on a small ranch near Cochrane, Alberta, Canada with family and a host of legged and winged creatures.

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Almost all the images used in this book were created by me, using an IBM PC with a frame grabber and a Sony CCD camera, an HP scanner, and a Sony Eyetoy as a webcam. Credits for the few images that were not acquired in this way are as follows:

Corel Corporation made available the color image of the grasshopper on a leaf shown in Figure 3.33, and also was the origin of the example search images in Figure 10.5.

The sample images in Figure 10.1 were a part of the ALOI data set, use of which was allowed by J. M. Geusebroek.

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Most importantly, I need to thank my family: my wife, Katrin, and children, Bailey and Max. They sacrificed time and energy so that this work could be completed. I appreciate it and hope that the effort has been worthwhile.

Contents at a Glance

Preface		**xxi**
Chapter 1	**Practical Aspects of a Vision System — Image Display, Input/Output, and Library Calls**	**1**
Chapter 2	**Edge-Detection Techniques**	**21**
Chapter 3	**Digital Morphology**	**85**
Chapter 4	**Grey-Level Segmentation**	**137**
Chapter 5	**Texture and Color**	**177**
Chapter 6	**Thinning**	**209**
Chapter 7	**Image Restoration**	**251**
Chapter 8	**Classification**	**285**
Chapter 9	**Symbol Recognition**	**321**
Chapter 10	**Content-Based Search — Finding Images by Example**	**395**
Chapter 11	**High-Performance Computing for Vision and Image Processing**	**425**
Index		**465**

Contents

Preface **xxi**

Chapter 1 Practical Aspects of a Vision System — Image Display, Input/Output, and Library Calls **1**

OpenCV 2
The Basic OpenCV Code 2
The IplImage Data Structure 3
Reading and Writing Images 6
Image Display 7
An Example 7
Image Capture 10
Interfacing with the AIPCV Library 14
Website Files 18
References 18

Chapter 2 Edge-Detection Techniques **21**

The Purpose of Edge Detection 21
Traditional Approaches and Theory 23
Models of Edges 24
Noise 26
Derivative Operators 30
Template-Based Edge Detection 36
Edge Models: The Marr-Hildreth Edge Detector 39
The Canny Edge Detector 42
The Shen-Castan (ISEF) Edge Detector 48
A Comparison of Two Optimal Edge Detectors 51

Color Edges 53
Source Code for the Marr-Hildreth Edge Detector 58
Source Code for the Canny Edge Detector 62
Source Code for the Shen-Castan Edge Detector 70
Website Files 80
References 82

Chapter 3 Digital Morphology 85
Morphology Defined 85
Connectedness 86
Elements of Digital Morphology — Binary Operations 87
Binary Dilation 88
Implementing Binary Dilation 92
Binary Erosion 94
Implementation of Binary Erosion 100
Opening and Closing 101
MAX — A High-Level Programming Language for Morphology 107
The ''Hit-and-Miss'' Transform 113
Identifying Region Boundaries 116
Conditional Dilation 116
Counting Regions 119
Grey-Level Morphology 121
Opening and Closing 123
Smoothing 126
Gradient 128
Segmentation of Textures 129
Size Distribution of Objects 130
Color Morphology 131
Website Files 132
References 135

Chapter 4 Grey-Level Segmentation 137
Basics of Grey-Level Segmentation 137
Using Edge Pixels 139
Iterative Selection 140
The Method of Grey-Level Histograms 141
Using Entropy 142
Fuzzy Sets 146
Minimum Error Thresholding 148
Sample Results From Single Threshold Selection 149

The Use of Regional Thresholds 151
Chow and Kaneko 152
Modeling Illumination Using Edges 156
Implementation and Results 159
Comparisons 160
Relaxation Methods 161
Moving Averages 167
Cluster-Based Thresholds 170
Multiple Thresholds 171
Website Files 172
References 173

Chapter 5 Texture and Color 177
Texture and Segmentation 177
A Simple Analysis of Texture in Grey-Level Images 179
Grey-Level Co-Occurrence 182
Maximum Probability 185
Moments 185
Contrast 185
Homogeneity 185
Entropy 186
Results from the GLCM Descriptors 186
Speeding Up the Texture Operators 186
Edges and Texture 188
Energy and Texture 191
Surfaces and Texture 193
Vector Dispersion 193
Surface Curvature 195
Fractal Dimension 198
Color Segmentation 201
Color Textures 205
Website Files 205
References 206

Chapter 6 Thinning 209
What Is a Skeleton? 209
The Medial Axis Transform 210
Iterative Morphological Methods 212
The Use of Contours 221
Choi/Lam/Siu Algorithm 224
Treating the Object as a Polygon 226
Triangulation Methods 227

Force-Based Thinning 228
Definitions 229
Use of a Force Field 230
Subpixel Skeletons 234
Source Code for Zhang-Suen/Stentiford/Holt Combined Algorithm 235
Website Files 246
References 247

Chapter 7 Image Restoration 251
Image Degradations — The Real World 251
The Frequency Domain 253
The Fourier Transform 254
The Fast Fourier Transform 256
The Inverse Fourier Transform 260
Two-Dimensional Fourier Transforms 260
Fourier Transforms in OpenCV 262
Creating Artificial Blur 264
The Inverse Filter 270
The Wiener Filter 271
Structured Noise 273
Motion Blur — A Special Case 276
The Homomorphic Filter — Illumination 277
Frequency Filters in General 278
Isolating Illumination Effects 280
Website Files 281
References 283

Chapter 8 Classification 285
Objects, Patterns, and Statistics 285
Features and Regions 288
Training and Testing 292
Variation: In-Class and Out-Class 295
Minimum Distance Classifiers 299
Distance Metrics 300
Distances Between Features 302
Cross Validation 304
Support Vector Machines 306
Multiple Classifiers — Ensembles 309
Merging Multiple Methods 309
Merging Type 1 Responses 310
Evaluation 311
Converting Between Response Types 312

Merging Type 2 Responses 313
Merging Type 3 Responses 315
Bagging and Boosting 315
Bagging 315
Boosting 316
Website Files 317
References 318

Chapter 9 Symbol Recognition 321

The Problem 321
OCR on Simple Perfect Images 322
OCR on Scanned Images — Segmentation 326
Noise 327
Isolating Individual Glyphs 329
Matching Templates 333
Statistical Recognition 337
OCR on Fax Images — Printed Characters 339
Orientation — Skew Detection 340
The Use of Edges 345
Handprinted Characters 348
Properties of the Character Outline 349
Convex Deficiencies 353
Vector Templates 357
Neural Nets 363
A Simple Neural Net 364
A Backpropagation Net for Digit Recognition 368
The Use of Multiple Classifiers 372
Merging Multiple Methods 372
Results From the Multiple Classifier 375
Printed Music Recognition — A Study 375
Staff Lines 376
Segmentation 378
Music Symbol Recognition 381
Source Code for Neural Net Recognition System 383
Website Files 390
References 392

Chapter 10 Content-Based Search — Finding Images by Example 395

Searching Images 395
Maintaining Collections of Images 396
Features for Query by Example 399
Color Image Features 399
Mean Color 400
Color Quad Tree 400

Hue and Intensity Histograms 401
Comparing Histograms 402
Requantization 403
Results from Simple Color Features 404
Other Color-Based Methods 407
Grey-Level Image Features 408
Grey Histograms 409
Grey Sigma — Moments 409
Edge Density — Boundaries Between Objects 409
Edge Direction 410
Boolean Edge Density 410
Spatial Considerations 411
Overall Regions 411
Rectangular Regions 412
Angular Regions 412
Circular Regions 414
Hybrid Regions 414
Test of Spatial Sampling 414
Additional Considerations 417
Texture 418
Objects, Contours, Boundaries 418
Data Sets 418
Website Files 419
References 420
Systems 424

Chapter 11 High-Performance Computing for Vision and Image Processing 425

Paradigms for Multiple-Processor Computation 426
Shared Memory 426
Message Passing 427
Execution Timing 427
Using *clock()* 428
Using QueryPerformanceCounter 430
The Message-Passing Interface System 432
Installing MPI 432
Using MPI 433
Inter-Process Communication 434
Running MPI Programs 436
Real Image Computations 437
Using a Computer Network — Cluster Computing 440

A Shared Memory System — Using the PC Graphics Processor 444
GLSL 444
OpenGL Fundamentals 445
Practical Textures in OpenGL 448
Shader Programming Basics 451
Vertex and Fragment Shaders 452
Required GLSL Initializations 453
Reading and Converting the Image 454
Passing Parameters to Shader Programs 456
Putting It All Together 457
Speedup Using the GPU 459
Developing and Testing Shader Code 459
Finding the Needed Software 460
Website Files 461
References 461

Index **465**

Preface

Humans still obtain the vast majority of their sensory input through their visual system, and an enormous effort has been made to artificially enhance this sense. Eyeglasses, binoculars, telescopes, radar, infrared sensors, and photomultipliers all function to improve our view of the world and the universe. We even have telescopes in orbit (eyes outside the atmosphere) and many of those ''see'' in other spectra: infrared, ultraviolet, X-rays. These give us views that we could not have imagined only a few years ago, and in colors that we'll never see with the naked eye. The computer has been essential for creating the incredible images we've all seen from these devices.

When the first edition of this book was written, the Hubble Space Telescope was in orbit and producing images at a great rate. It and the European Hipparcos telescope were the only optical instruments above the atmosphere. Now there is COROT, Kepler, MOST (Canada's space telescope), and Swift Gamma Ray Burst Explorer. In addition, there is the Spitzer (infrared), Chandra (X-ray), GALEX (ultraviolet), and a score of others. The first edition was written on a 450-Mhz Pentium III with 256 MB of memory. In 1999, the first major digital SLR camera was placed on the market: the Nikon D1. It had only 2.74 million pixels and cost just under $6,000. A typical PC disk drive held 100–200 MB. Webcams existed in 1997, but they were expensive and low-resolution. Persons using computer images needed to have a special image acquisition card and a relatively expensive camera to conduct their work, generally amounting to $1–2,000 worth of equipment. The technology of personal computers and image acquisition has changed a lot since then.

The 1997 first edition was inspired by my numerous scans though the Internet news groups related to image processing and computer vision. I noted that some requests appeared over and over again, sometimes answered and sometimes not, and wondered if it would be possible to answer the more

frequently asked questions in book form, which would allow the development of some of the background necessary for a complete explanation. However, since I had just completed a book (*Practical Computer Vision Using C*), I was in no mood to pursue the issue. I continued to collect information from the Net, hoping to one day collate it into a sensible form. I did that, and the first edition was very well received. (Thanks!)

Fifteen years later, given the changes in technology, I'm surprised at how little has changed in the field of vision and image processing, at least at the accessible level. Yes, the theory has become more sophisticated and three-dimensional vision methods have certainly improved. Some robot vision systems have accomplished rather interesting things, and face recognition has been taken to a new level. However, cheap character recognition is still, well, cheap, and is still not up to a level where it can be used reliably in most cases. Unlike other kinds of software, vision systems are not ubiquitous features of daily life. Why not? Possibly because the vision problem is really a hard one. Perhaps there is room for a revision of the original book?

My goal has changed somewhat. I am now also interested in ''democratization'' of this technology — that is, in allowing it to be used by anyone, at home, in their business, or at schools. Of course, you need to be able to program a computer, but that skill is more common than it was. All the software needed to build the programs in this edition is freely available on the Internet. I have used a free compiler (Microsoft Visual Studio Express), and OpenCV is also a free download. The only impediment to the development of your own image-analysis systems is your own programming ability.

Some of the original material has not changed very much. Edge detection, thinning, thresholding, and morphology have not been hot areas of research, and the chapters in this edition are quite similar to those in the original. The software has been updated to use Intel's OpenCV system, which makes image IO and display much easier for programmers. It is even a simple matter to capture images from a webcam in real time and use them as input to the programs. Chapter 1 contains a discussion of the basics of OpenCV use, and all software in this book uses OpenCV as a basis.

Much of the mathematics in this book is still necessary for the detailed understanding of the algorithms described. Advanced methods in image processing and vision require the motivation and justification that only mathematics can provide. In some cases, I have only scratched the surface, and have left a more detailed study for those willing to follow the references given at the ends of chapters. I have tried to select references that provide a range of approaches, from detailed and complex mathematical analyses to clear and concise exposition. However, in some cases there are very few clear descriptions in the literature, and none that do not require at least a university-level math course. Here I have attempted to describe the situation in an intuitive manner, sacrificing rigor (which can be found almost anywhere else) for as