Bruce Batchelor and Frederick Waltz

Interactive Image Processing for Machine Vision

With 666 Figures

Springer-Verlag
London Berlin Heidelberg New York
Paris Tokyo Hong Kong
Barcelona Budapest

Contents

1 Setting the Scene 1
- 1.1 Human and Animal Vision 1
- 1.2 Machine Vision 2
  - 1.2.1 Machine Vision Functions 3
- 1.3 Applications of Image Processing 4
  - 1.3.1 Health Services 4
  - 1.3.2 Security and Forensic Science 5
  - 1.3.3 Military 5
  - 1.3.4 Commercial 6
  - 1.3.5 Industrial 6
  - 1.3.6 Earth Resources 7
  - 1.3.7 Entertainment and Leisure 7
  - 1.3.8 Domestic 7
  - 1.3.9 Broadcast Television 8
  - 1.3.10 Agriculture and Food 8
  - 1.3.11 Communications 8
  - 1.3.12 Education and Training 9
  - 1.3.13 Service Industry, Transport 9
  - 1.3.14 Research 9
- 1.4 Problems of System Design 10
  - 1.4.1 Simplifying the Task 11
  - 1.4.2 A Warning 12
  - 1.4.3 Non-Industrial Image Processing 12
- 1.5 Interactive Image Processing (IIP) 12
- 1.6 Practical Uses of Interactive Image Processing 13
- 1.7 Purpose and Outline of This Book 15

2 Principles of Digital Image Processing 17
- 2.1 Digital Representations of Images 18
  - 2.1.1 Monochrome (Grey-Scale) Images 19
  - 2.1.2 Binary Images 20
  - 2.1.3 Color and Multispectral Images 20
  - 2.1.4 Stereoscopic Image Pairs 21
  - 2.1.5 Moving Images 21
- 2.2 Processing Functions 22
  - 2.2.1 Notation 23
  - 2.2.2 Monadic Point-by-Point Operators 24
  - 2.2.3 Dyadic Point-by-Point Operators 26
  - 2.2.4 Local Operators 27

2.2.4.1 Linear Local Operators 28
2.2.4.2 Non-Linear Local Operators 29
2.2.4.3 Using Direction Codes 31
2.2.5 n-tuple Operators 31
2.2.6 Edge effects 32
2.2.7 Global Image Transforms 33
2.2.8 Geometric Transforms 34
2.3 Binary Images 38
2.3.1 Measurements on Binary Images 43
2.4. Commentary 45

3 Syntax of IIPL 47
3.1 Introduction 47
3.2 Basic Commands 48
3.3 Command Sequences 52
3.4 Registers 53
3.5 Looping, Jumps, and Conditional Jumps 54
3.6 Macros 55
3.6.1 Macro Names 55
3.6.2 Macros Take Precedence Over Basic Commands 55
3.6.3 Programming Style 56
3.6.4 Macro Arguments, Numeric Values 56
3.6.5 Macros Incorporating Other Macros 57
3.6.6 Macro Arguments Generalized 58
3.6.7 Recursion 58
3.6.8 Library and User-Defined Macros 58
3.6.9 Further Remarks Relating to Macros 59
3.7 Histogram Buffer 59
3.8 Character Strings 60
3.9 Miscellaneous Control Features 61
3.10 Calling User-Defined Functions 63
3.11 Discussion and Summary 65
3.11.1 Choice of Mnemonic Form 65
3.11.2 Repertoire of Basic Commands 66
3.11.3 History, Variations on a Theme 67
3.11.4 Résumé 68
3.12 Addendum 69
3.12.1 Incorporating Basic-Like Features into IIPL 69
3.13 Prolog+, Merging Prolog with IIPL 70

4 Practical Considerations 71
4.1 Workstation Layout 71
4.1.2 Ergonomic Factors 72
4.1.3 System Response Times 74
4.1.4 Recording Results 74

4.2 Extending the Scope of IIPL 76
4.2.1 Controlling Dedicated Image Processing Hardware 76
4.3 Adding a Processor to Control the IIP 77
4.4 Using a Journal to Generate Macros 78
4.5 Can We Use AI Techniques to Guide the IIPL User? 79
4.6 Generating Software for Target Systems 79
4.7 Hardware-Based Versions of IIPL 81
4.7.1 IIPL/H System 1: A Basic System 81
4.7.2 IIPL/H System 2: Added Capabilities 84
4.7.3 IIPL/H System 3: A System for Desktop Computers 85
4.7.4 Status of IIPL/H Implementations 89
4.8 Menu Selection of Commands 90
4.9 Using a Mouse in IIPL 91
4.10 Pseudo-Color 92
4.11 Conclusions 93

5 Applications Case Studies 95
5.1 Crack Detection in Metal Components 95
5.2 Robotic Manipulation of Objects 97
5.3 Form Measurement of Glassware (Bottle) 98
5.4 Examination of Aerosol Sprays 101
5.5 Examination of Paint Work 103
5.6 Inspecting Factory-Made Cakes 105
5.7 Inspection of the Cap of an Electric Light Bulb 106
5.8 Measurement of Coiling of a Helical Lamp Filament 108
5.9 Detecting Glass Flakes 109
5.10 Locating the Ends of Floppy Serpentine Objects 111
5.11 Verifying the Existence of a Chamfer 112
5.12 Inspecting Non-Populated Printed Circuit Boards 113
5.13 Checking the Roundness of Fruit 116
5.14 Reading Punched Lettering on a Metal Surface 119
5.15 Identifying a Playing Card 120
5.16 Determining the Orientation and Pitch of a Grid 122
5.17 Existential Inspection of Internal Threads 124
5.18 Processing Laser Scanner Data of Metal Surfaces 125
5.19 Checking LCD Displays 127
5.20 Aligning Teeth on a Gear 130
5.21 Determining Hardness of a Metal Surface 133
5.22 Counting Diskettes in a Cardboard Box 134
5.23 Deciding on the Toss of a Coin 135
5.24 Counting the Teeth on a Rubber Belt 137
5.25 Calibrating a Spirit Level 138

6 Integrating IIPLwith Prolog 141
Glossary 141
6.1 Introduction 141
6.1.1 Predicates 143
6.1.2 Facts 143
6.1.3 Queries 144
6.1.4 Rules 145
6.1.5 Back-Tracking 146
6.1.6 Recursion 147
6.1.7 Lists 147
6.1.8 Built-in Predicates 148
6.2 Earlier Attempts to Combine Prolog and Image Processing 148
6.3 Specification of Prolog+ 149
6.3.1 Syntax 149
6.3.2 Accommodating IIPL Commands with No Arguments 150
6.3.3 Accommodating IIPL Commands with Arguments 150
6.3.4 Passing Parameters Follows Normal Conventions 151
6.3.5 Interactive Operation of Prolog+ 152
6.3.6 Prolog+ Rules Replace IIPL Macros 152
6.3.7 Program Control 153
6.3.8 Predicates for Controlling Other Devices 154
6.4 Some Applications 154
6.5 Implementation of Prolog+ 155
6.6 Discussion 157

7 In Conclusion 159
7.1 A Seeing Is Worth 10,000 Tellings 159
7.2 Alternative Modes of Interactive Image Processing 160
7.2 Future Prospects 162

Appendix A Basic Functions 165
Basic Functions 165-245
Images Illustrating Basic Functions 247-274

Appendix B Sample Macros 275
B.1 Edge Detectors 275
B.2 Feature Detectors 277
B.3 Filters 278
B.4 Image Generation 288
B.5 Intensity-Based Functions 290
B.6 Binary Images 293
B.7 Control 301
B.8 Image Measurement 302
B.9 Utilities 303

Appendix C Images for Applications Case Studies 305
1 Crack Detection in Metal Components 305
2 Robotic Manipulation of Objects 307
3 Form Measurement of Glassware 310
4 Examination of Aerosol Sprays 311
5 Examination of Paint Work 314
6 Inspecting Factory-Made Cakes 316
7 Inspection of the Cap of an Electric Light Bulb 319
8 Measurement of Coiling of a Lamp Filament 324
9 Detecting Glass Flakes 326
10 Locating the Ends of Floppy Serpentine Objects 328
11 Verifying the Existence of a Chamfer 330
12 Inspecting Printed Circuit Boards 332
13 Checking the Roundness of Fruit 336
14 Reading Punched Lettering on a Metal Surface 338
15 Identifying a Playing Card 341
16 Determining the Orientation and Pitch of a Grid 343
17 Existential Inspection of Internal Threads 345
18 Processing Laser Scanner Data of Metal Surfaces 347
19 Checking LCD Displays 350
20 Aligning Teeth on a Gear 352
21 Determining Hardness of a Metal Surface 355
22 Counting Diskettes in a Cardboard Box 356
23 Deciding on the Toss of a Coin 358
24 Counting the Teeth on a Rubber Belt 360
25 Calibrating a Spirit Level 362

References 365

Table of IIPL Basic Commands 369

Index 371