

Contents

Preface	xi
List of Symbols	xv
1 Binary Erosion and Dilation	1
1.1 Introduction	1
1.2 Euclidean and Discrete Binary Images	2
1.3 Erosion	4
1.4 Dilation	8
1.5 Algebraic Properties	12
1.6 Filter Properties	13
1.7 Relationship to Set Operations	16
1.8 Bounded Operators	17
1.9 Exercises	20
1.10 Laboratory Experiments	22
References	23
2 Binary Opening and Closing	25
2.1 Opening	25
2.2 Closing	27
2.3 Filter Properties	29
2.4 Application of Opening and Closing Filters	30
2.5 Alternating Sequential Filters	32
2.6 Invariance	33
2.7 τ -Openings	35
2.8 Demonstration	37
2.9 Exercises	42
2.10 Laboratory Experiments	44
References	44
3 Morphological Processing of Binary Images	45
3.1 Pixel Regions	45
3.2 Boundary Detection	48
3.3 Reconstruction	48
3.4 Conditional Dilation	52
3.5 Marker Selection in Reconstruction	54
3.6 Reconstructive τ -opening	58
3.7 Logical Openings	60

3.8	Logical Structural Filters	61
3.9	Connected Operators	64
3.10	Skeletonization	66
3.11	Distance Transform	69
3.12	Geodesic Distance Transform	72
3.13	Exercises	72
3.14	Laboratory Experiments	75
	References	76
4	Hit-or-Miss Transform	79
4.1	The Transform	79
4.2	Object Recognition	79
4.3	Thinning	83
4.4	Pruning	85
4.5	Exercises	87
4.6	Laboratory Experiments	90
	References	90
	Gray-Scale Morphology	91
5.1	Mathematical Preliminaries	91
5.2	Gray-Scale Erosion	95
5.3	Gray-Scale Dilation	99
5.4	Algebraic Properties	102
5.5	Filter Properties	103
5.6	Umbra Transform	105
5.7	Flat Structuring Elements	107
5.8	Gray-Scale Morphology for Discrete Images	110
5.9	Gray-Scale Morphology for Discrete Bounded Signals	113
5.10	Gray-Scale Opening and Closing	116
5.11	Exercises	124
5.12	Laboratory Experiments	125
	References	125
	Morphological Processing of Gray-Scale Images	129
6.1	Morphological Gradient	129
6.2	Top-Hat Transform	130
6.3	Gray-Scale Alternating Sequential Filters	135
6.4	Gray-Scale Morphological Reconstruction	136
6.5	Flat Zones and Connected Filters	141
6.6	Gray-Scale Reconstructive Opening	142
6.7	Connected Alternating Sequential Filters	143
6.8	Image Extrema	146
6.9	Markers From Regional Maxima of Filtered Images	147

6.10	Extinction Values	151
6.11	Demonstration	154
6.12	Exercises	155
6.13	Laboratory Experiments	158
	References	159
7	Morphological Segmentation—Watershed	163
7.1	Watershed From Markers	166
7.2	Watershed, Voronoi Diagram, and SKIZ	169
7.3	Segmentation of Overlapped Convex Cells	171
7.4	Inner and Outer Markers	174
7.5	Hierarchical Watershed Transform	177
7.6	Watershed Transform Algorithms	181
7.7	Demonstrations	184
7.8	Exercises	189
7.9	Laboratory Experiments	191
	References	191
8	Granulometries	193
8.1	Granulometries Generated by a Single Opening	193
8.2	Discrete Size Distributions	194
8.3	The Open and Discrete-Size Transforms	199
8.4	Granulometries on Random Binary Images	201
8.5	Granulometric Classification	204
8.6	General Granulometries	207
8.7	Logical Granulometries	210
8.8	Discrete Granulometric Bandpass Filters	213
8.9	Gray-Scale Granulometries	217
8.10	Exercises	220
8.11	Laboratory Experiments	223
	References	223
9	Automatic Design of Morphological Operators	227
9.1	Boolean Functions	227
9.2	Morphological Representation	229
9.3	Optimal W -Operators	233
9.4	Design of Optimal W -Operators	235
9.5	Optimal Increasing Filters	238
9.6	Differencing Filters	243
9.7	Resolution Conversion	247
9.8	Multiresolution Analysis	250
9.9	Envelope Filters	255
9.10	Aperture Filters	256

9.11 Relation to Pattern Recognition	260
9.12 Exercises	264
References	265

Index	269
--------------	------------