
Contents

Preface	xiii
Acknowledgements	xv
Foreword	xvii
PART I Introduction to iris and periocular recognition	1
1 Fundamentals in iris recognition	3
<i>Christian Rathgeb and Christoph Busch</i>	
1.1 Introduction	3
1.2 Iris recognition processing chain	4
1.2.1 Image acquisition	4
1.2.2 Pre-processing	5
1.2.3 Feature extraction	8
1.2.4 Comparison	9
1.3 Status quo in research and industry	10
1.3.1 Databases, competitions and software	10
1.3.2 Standardization and deployments	11
1.4 Challenges in iris recognition	12
1.4.1 Visible wavelength and unconstrained conditions	13
1.4.2 Security and privacy protection	14
1.4.3 Cross-sensor and cross-spectral recognition	16
1.4.4 Soft biometrics and template ageing	16
1.4.5 Large-scale identification and iris biometric fusion	17
1.5 Summary	19
References	20
2 An overview of periocular biometrics	29
<i>Fernando Alonso-Fernandez and Josef Bigun</i>	
2.1 Acquisition of periocular images	30
2.2 Detection of the periocular region	34
2.3 Feature encoding and comparison	36
2.4 Human performance evaluation	40
2.5 Comparison of periocular with other modalities	41
2.6 Other tasks using features from the periocular region	42
2.7 Summary and future trends in periocular research	44
Acknowledgments	45
References	46

PART II Issues and challenges	55
3 Robust iris image segmentation	57
<i>Peter Wild, Heinz Hofbauer, James Ferryman, and Andreas Uhl</i>	
3.1 Introduction	59
3.1.1 Segmentation accuracy	60
3.1.2 Iris segmentation quality	61
3.2 Advances in iris segmentation	62
3.2.1 From circular models to active contours	63
3.2.2 Near infrared vs. visible range segmentation	64
3.2.3 Learning-based techniques	65
3.2.4 Segmentation fusion	66
3.3 Experiments	68
3.3.1 Individual NIR vs. VIS performance	69
3.3.2 Impact of tuning	74
3.3.3 Combinations of segmentation performance	75
3.4 Conclusion and future work	75
References	78
4 Iris image quality metrics with veto power and nonlinear importance tailoring	83
<i>John Daugman and Cathryn Downing</i>	
4.1 Introduction	83
4.1.1 Related work	84
4.2 Normalisation of individual quality measures	84
4.3 Effectiveness of multiplying quality factors	86
4.4 Importance tailoring	87
4.5 Error reject curves	92
4.6 Discipline in punishment	94
4.7 Predictive value of the quality pseudonorm	96
4.8 Testing and adoption into an ISO/IEC quality standard	99
4.9 A possible criticism of the method	99
Acknowledgement	99
References	99
5 Iris biometric indexing	101
<i>Hugo Proen��a and Jo��o C. Neves</i>	
5.1 Introduction	101
5.2 State of the art	102
5.3 Indexing/retrieving poorly separated data	105
5.3.1 Indexing	105
5.3.2 Retrieval	109
5.3.3 Time complexity	111

5.4	Performance comparison	112
5.4.1	Synthetic IrisCodes	113
5.4.2	Well separated near infra-red data	116
5.4.3	Poorly separated visible wavelength data	118
5.5	Conclusions	122
	Acknowledgment	122
	References	122
6	Identifying the best periocular region for biometric recognition	125
	<i>Jonathon M. Smereka and B.V.K. Vijaya Kumar</i>	
6.1	Introduction	125
6.2	Experimental setup	127
6.3	Results	129
6.4	Summary	140
	References	145
7	Light field cameras for presentation attack resistant robust biometric ocular system	149
	<i>Raghavendra Ramachandra, Kiran B. Raja, and Christoph Busch</i>	
7.1	Introduction	150
7.2	Light-field imaging	153
7.3	Scheme for iris and periocular verification	153
7.3.1	Iris verification	154
7.3.2	Periocular verification	156
7.3.3	Combining iris and periocular characteristics	157
7.3.4	Database, experiments and results	157
7.4	Presentation attack resistant ocular biometrics in visible spectrum	159
7.4.1	PAD algorithm employing the depth images from LFC	160
7.4.2	Visible spectrum iris recognition system	164
7.4.3	Presentation attack database	164
7.4.4	Performance evaluation protocol	166
7.4.5	Experiments and results	167
7.5	Conclusion	171
	References	171
PART III	Soft biometric classification	175
8	Gender classification from near infrared iris images	177
	<i>Juan Tapia</i>	
8.1	Introduction	177
8.2	Anatomy structure of the eye	178
8.3	Feature extraction	179

8.4	State of the art	181
8.5	Databases	184
8.5.1	BioSecure multimodal database	184
8.5.2	Gender from iris dataset (ND-GFI)	185
8.6	Feature selection	186
8.7	Research trends and challenges	190
8.7.1	Segmentation	190
8.7.2	Accuracy	191
8.7.3	Fragile bits	191
8.7.4	Sensors	191
8.7.5	Makeup	192
8.8	Concluding remarks	193
	Acknowledgments	193
	References	194
9	Periocular-based soft biometric classification	197
	<i>Damon L. Woodard, Kalaivani Sundararajan, Nicole Tobias, and Jamie Lyle</i>	
9.1	Introduction	197
9.2	Approach	199
9.2.1	Data	199
9.2.2	Preprocessing	200
9.2.3	Feature representations	202
9.2.4	Classification	206
9.3	Experiment results	207
9.3.1	Experiment protocol	207
9.3.2	Gender classification	207
9.3.3	Ethnicity classification	208
9.3.4	Gender and ethnicity classification	209
9.4	Summary	209
	References	210
10	Age predictive biometrics: predicting age from iris characteristics	213
	<i>Márjory Da Costa-Abreu, Michael Fairhurst, and Meryem Erbilek</i>	
10.1	Introduction	213
10.2	Background discussion and related studies	215
10.3	Predicting age in diverse scenarios	217
10.4	Experimental infrastructure for iris-based predictive biometrics	218
10.5	Experimental analysis of individual classification systems for iris-based predictive biometrics	220
10.6	Experimental analysis of iris-based multiclassifier systems	222
10.7	Experimental analysis of multiagent intelligent systems for iris-based predictive biometrics	224
10.8	Discussion	226

10.9	Experimental analysis of multimodal iris-based predictive systems	227
10.10	Final remarks	230
	References	230
PART IV	Security aspects	235
11	Presentation attack detection in iris recognition	237
	<i>Javier Galbally and Marta Gomez-Barrero</i>	
11.1	Introduction	237
11.2	Presentation attacks in iris recognition	241
11.3	Presentation attack detection in iris recognition	243
11.3.1	Sensor-level approaches	244
11.3.2	Feature-level approaches	249
11.4	Evaluation of presentation attack detection methods	251
11.5	Conclusion	255
	References	257
12	Contact lens detection in iris images	265
	<i>Jukka Komulainen, Abdenour Hadid, and Matti Pietikäinen</i>	
12.1	Introduction	265
12.2	Literature review on contact lens detection	269
12.2.1	Textured contact lens detection	269
12.2.2	Classification of contact lens type	271
12.3	Case study: generalised software-based textured contact lens detection	273
12.3.1	Pre-processing	275
12.3.2	Texture description	276
12.3.3	Experimental analysis	277
12.4	Discussion	281
12.4.1	Further work on generalised textured contact lens detection	281
12.4.2	The role of pre-processing in contact lens detection	282
12.4.3	On the evaluation of contact lens detection algorithms	284
12.5	Conclusions	285
	Acknowledgement	286
	References	286
13	Software attacks on iris recognition systems	291
	<i>Marta Gomez-Barrero and Javier Galbally</i>	
13.1	Introduction	291
13.2	Hill-climbing based attacks	293
13.3	Synthetic iris generation	297
13.3.1	False acceptance attacks based on fully synthetic iris	298
13.3.2	Inverse biometrics attacks	301

13.4 Software attacks on biometric template protection schemes	303
13.4.1 Stolen key-inversion attacks	304
13.4.2 Attacks via record multiplicity	305
13.5 Countermeasures to software attacks	306
13.6 Conclusions	308
References	308
PART V Privacy protection and forensics	317
14 Iris biometric template protection	319
<i>Christian Rathgeb, Johannes Wagner, and Christoph Busch</i>	
14.1 Introduction	319
14.2 Iris template protection schemes	321
14.2.1 Iris-biometric cryptosystems	322
14.2.2 Cancelable iris biometrics	324
14.3 Implementation of iris template protection schemes	326
14.3.1 Iris fuzzy vault	326
14.3.2 Bin-combo for iris-codes	329
14.4 Experimental evaluations	329
14.4.1 Performance evaluation	330
14.4.2 Discussion	332
14.5 Summary and research directions	334
References	336
15 Privacy-preserving distance computation for IrisCodes	341
<i>Julien Bringer, Hervé Chabanne, and Constance Morel</i>	
15.1 Introduction	341
15.2 Secure distance computation in the semi-honest model	343
15.2.1 Oblivious transfer	343
15.2.2 Yao's garbled circuits	344
15.2.3 GSHADE in the semi-honest model	345
15.2.4 Privacy-preserving distance computation for IrisCodes in the semi-honest model	346
15.3 Secure distance computation in the malicious model	349
15.3.1 Yao's garbled circuits in the malicious setting	349
15.3.2 GSHADE in the malicious setting	350
15.3.3 Privacy-preserving distance computation for IrisCodes in the malicious model	351
15.4 Application to other iris representations	355
15.5 Conclusion	355
Acknowledgments	356
References	356

16 Identifying iris sensors from iris images	359
<i>Luca Debiasi, Christof Kauba, and Andreas Uhl</i>	
16.1 Techniques for sensor identification/dataset classification	362
16.1.1 PRNU-based sensor identification (PSI)	363
16.1.2 Iris texture classification (ITC)	365
16.2 Datasets	367
16.3 Experimental setup	369
16.4 Experimental results	370
16.5 Practical discussion	374
16.6 Conclusion	376
References	377
17 Matching iris images against face images using a joint dictionary-based sparse representation scheme	383
<i>Raghavender Jillela and Arun Ross</i>	
17.1 Introduction	383
17.2 Database	387
17.2.1 Challenges	387
17.3 Outline of experiments	391
17.4 Iris recognition	391
17.4.1 Open source algorithm	392
17.4.2 Commercial algorithm	396
17.5 Ocular recognition	397
17.5.1 Baseline – local binary patterns	397
17.5.2 Normalized gradient correlation	399
17.6 Ocular matching using joint dictionary approach	401
17.6.1 Sparse representation framework	401
17.6.2 Joint dictionary approach	402
17.6.3 Dictionary learning and matching	403
17.7 Computational details	406
17.8 Score-level fusion	407
17.9 Summary	407
References	407
PART VI Future trends	411
18 Iris biometrics for embedded systems	413
<i>Judith Liu-Jimenez and Raul Sanchez-Reillo</i>	
18.1 Introduction to embedded systems	413
18.2 Design strategies for developing embedded systems	414
18.2.1 General architecture of an embedded system	414
18.2.2 Architecture alternatives	415

18.3	Biometric requirements for embedded systems	419
18.3.1	Functional requirements	419
18.3.2	Security requirements	420
18.4	Iris biometrics analysis for embedded systems	423
18.4.1	Data capture	423
18.4.2	Preprocessing	425
18.4.3	Feature extraction	426
18.4.4	Comparison	426
18.5	Existing implementations	427
18.5.1	Custom hardware-FPGA	428
18.5.2	Software implementations	428
18.6	Conclusions	430
	References	431
19	Mobile iris recognition	435
	<i>Akira Yonenaga and Takashi Shinzaki</i>	
19.1	Background	435
19.2	Mobile iris authentication	435
19.3	Technologies for the future	436
19.4	Summary	438
	References	438
20	Future trends in iris recognition: an industry perspective	439
	<i>Daniel Hartung, Ji-Young Lim, Sven Utcke, and Günther Mull</i>	
20.1	Customer requirements	439
20.1.1	Robustness	439
20.1.2	Performance	440
20.1.3	Usability	443
20.1.4	Choosing a modality	444
20.2	Development process	445
20.2.1	Bias and variability	445
20.2.2	Parameter optimisation	446
20.2.3	Evaluation and tools	448
20.3	Future trends and challenges	449
20.3.1	Sensor-related trends	449
20.3.2	Presentation attack detection	455
20.3.3	Deep learning	456
20.3.4	Standards	457
20.4	Summary	459
	Acknowledgement	459
	References	459
Index		465