Contents

Preface v

1. An Introduction to Biometric Authentication Systems 1
1.1 Introduction 1
1.2 A Quick Historical Overview 2
1.3 The "Best" Biometric Characteristic 3
1.4 The Applications 4
1.5 A Taxonomy of Uses 5
1.6 A Taxonomy of Application Environments 7
1.6.1 Overt Versus Covert 7
1.6.2 Habituated Versus Non-Habituated 8
1.6.3 Attended Versus Non-Attended 8
1.6.4 Standard Versus Non-Standard Environment 8
1.6.5 Public Versus Private 8
1.6.6 Open Versus Closed 8
1.6.7 Examples of the Classification of Applications 9
1.7 A System Model 9
1.7.1 Data Collection 9
1.7.2 Transmission 11
1.7.3 Signal Processing 11
1.7.4 Storage 13
1.7.5 Decision 14
1.8 Biometrics and Privacy 14
1.9 The Road Ahead 17
References 17

2. Fingerprint Identification Technology 21
2.1 History 21
2.1.1 Early Biometric Efforts 21
2.2 Applications of Fingerprints 22
2.2.1 Forensics 22
2.2.2 Genetics 23
2.2.3 Civil and Commercial 23
2.2.4 Government 24
2.3 Early Systems 24
2.3.1 Manual Card Files 24
2.3.2 Classification 25
2.3.3 Searching 27
2.3.4 Matching 27
2.4 Early Automation Efforts 27
2.4.1 US NBS/NIST Research 28

2.4.2 Royal Canadian Police 28
2.4.3 FBI 28
2.4.4 United Kingdom 29
2.4.5 Japan 30
2.5 The Technology 30
2.5.1 Scanning and Digitizing 30
2.5.2 Enhancement 33
2.5.3 Feature Extraction 38
2.5.4 Classification 41
2.5.5 Matching 43
2.5.6 Searching 48
2.5.7 Manual Verification 49
2.6 Criminal Applications 49
2.6.1 National Systems 49
2.6.2 Local Systems 51
2.6.3 Interoperability 52
2.6.4 "Daubert" Questions 53
2.7 Civil Applications 54
2.7.1 Welfare Fraud Reduction 54
2.7.2 Border Control 55
2.7.3 Driver registration 55
2.8 Commercial Applications 56
2.8.1 Miniaturized Sensors 56
2.8.2 Personal Access Protection 57
2.8.3 Banking Security 58
2.8.4 Business-to-Business Transactions 58
References 59

3. Iris Recognition 63
3.1 Introduction 63
3.2 Anatomical and Physiological Underpinnings 65
3.3 Sensing 68
3.4 Iris signature representation and matching 74
3.4.1 Localization 74
3.4.2 Representation 77
3.4.3 Matching 79
3.5 Systems and performance 86
3.6 Future directions 90
References 92

4. Face Recognition 97
4.1 Introduction 97
4.2 Background 98
4.3 Face Detection 99
4.4 Face Recognition: Representation and Classification 100
4.4.1 Some Representation Techniques and Their Applications to Face Recognition 101

4.4.2 Some Classification Techniques and Their Applications to Face Recognition . . . 103
4.5 Kernel-Based Methods and 3D Model-based Methods for Face Recognition . . . 105
4.6 Learning the Face Space . . . 106
4.6.1 Evolutionary Pursuit . . . 106
4.6.2 Face Recognition Using Evolutionary Pursuit . . . 108
4.7 Conclusion . . . 109
References . . . 110

5. Elements of Speaker Verification . . . 115
5.1 Introduction . . . 115
5.1.1 The Speaker Verification Problem . . . 115
5.2 Features and Models . . . 120
5.2.1 Speech Features . . . 120
5.2.2 Speaker Models . . . 121
5.3 Additional Methods for Managing Variability . . . 126
5.3.1 Channel Normalization and Modeling . . . 126
5.3.2 Constraining the Text . . . 128
5.4 Measuring Performance . . . 129
5.4.1 How Well do These Systems Perform? . . . 131
5.5 Alternative Approaches . . . 131
5.5.1 Speech Recognition Approaches . . . 131
5.5.2 Words (and Phonetic Units) Count . . . 132
5.5.3 Models Exploring the Shape of Feature Space . . . 133
5.6 Summary . . . 133
References . . . 134

6. Technology Evaluation of Fingerprint Verification Algorithms . . . 137
6.1 Introduction . . . 137
6.2 FVC2000 Organization and Algorithms Submission Rules . . . 139
6.3 Databases . . . 142
6.4 Performance Evaluation . . . 149
6.5 Results . . . 151
6.6 Organization of FVC2002 . . . 155
6.7 Conclusions . . . 158
Appendix A . . . 159
Appendix B . . . 159
References . . . 204

7. Methods for Assessing Progress in Face Recognition . . . 207
7.1 Introduction . . . 207
7.2 Face Recognition Evaluations . . . 208
7.2.1 Introduction to FERET and FRVT 2000 . . . 208
7.2.2 September 1996 FERET Evaluation Protocol . . . 212
7.2.3 Data Sets . . . 215
7.2.4 FERET and FRVT 2000 Results . . . 218

7.2.5 Conclusions Drawn from the FERET Evaluations and FRVT 2000 . . . 225
7.3 Meta-Analysis . . . 227
7.3.1 Introduction to Meta-Analysis . . . 228
7.3.2 Methodology for Selecting Papers . . . 229
7.3.3 Analysis of Performance Scores – Viewing the Data Through Histograms . . . 230
7.3.4 Evaluation of Experiments with a Baseline . . . 232
7.3.5 Meta-Analysis Conclusions . . . 234
7.4 Conclusion . . . 236
Acknowledgements . . . 237
References . . . 237

8. The NIST speaker recognition evaluation program . . . 241
8.1 Introduction . . . 241
8.2 NIST Speaker Recognition Evaluation Tasks . . . 242
8.2.1 One-Speaker Detection . . . 243
8.2.2 Two-Speaker Detection . . . 243
8.2.3 Speaker Tracking . . . 243
8.2.4 Speaker Segmentation . . . 244
8.3 Data . . . 244
8.3.1 Speaker Training . . . 245
8.3.2 Test Segments . . . 245
8.4 Performance Measure . . . 247
8.5 Evaluation Results . . . 248
8.6 Factors Affecting Detection Performance . . . 249
8.6.1 Duration . . . 250
8.6.2 Pitch . . . 250
8.6.3 Handset Differences . . . 251
8.6.4 Handset Type . . . 252
8.6.5 Landline vs. Cellular . . . 255
8.7 Extended Data Evaluation . . . 256
8.8 Multimodal Evaluation . . . 258
8.9 Future Plans . . . 260
References . . . 261

9. Large-Scale Identification System Design . . . 263
9.1 Introduction . . . 263
9.1.1 Historical Background . . . 263
9.1.2 Large-Scale Identification Systems: Requirements and Basic Features . . . 265
9.2 Extrapolation of Accuracy . . . 266
9.2.1 Introduction . . . 266
9.2.2 Key Concepts . . . 268
9.2.3 Method 1: Extrapolation from Experiences . . . 269
9.2.4 Method 2: Identification as a Succession of *N* Verifications . . . 270
9.2.5 Method 3: Extrapolation with Extreme Value . . . 272

9.2.6 Method 4: Extrapolation when the Distance Can Be Modeled . . . 275
9.2.7 Influence of Classification . . . 276
9.3 Conclusion . . . 279
Appendix . . . 281
References . . . 286

10. Biometric System Integration . . . 289
10.1 Understanding, Describing and Documenting the Requirements . . . 289
10.2 Choosing the Technology . . . 291
10.3 Application Development . . . 294
10.4 Integration with Existing System Architecture . . . 296
10.5 Templates and Enrollment Management . . . 297
10.6 Understanding User Psychology . . . 300
10.7 Fine Tuning the System . . . 302
10.8 Ongoing Management . . . 305
10.9 Related Issues . . . 306
References . . . 309

11. Biometrics and the US Constitution . . . 311
11.1 Introduction . . . 311
11.1.1 Privacy Versus Security; Mankind Versus Machine . . . 311
11.1.2 The Growth of Both Anonymous Public Transactions and the Complexity of Identification . . . 312
11.1.3 Constitutional Concerns . . . 313
11.2 Due Process . . . 314
11.2.1 Entitlements and Rights . . . 314
11.2.2 Instrumental and Intrinsic Approaches . . . 315
11.2.3 Constitutional Development: From the Intrinsic to the Instrumental Approach of Procedural Due Process . . . 317
11.2.4 The Enigma of Substantive Due Process . . . 320
11.3 Individual Privacy . . . 322
11.3.1 The Basis of an Inferred Right to Privacy . . . 322
11.3.2 Privacy and the Fourth Amendment . . . 323
11.3.3 Privacy and the Fifth Amendment . . . 325
11.3.4 Privacy of Personal Information . . . 326
11.4 Conclusions . . . 328
References and Notes . . . 329

12. Privacy Issues in the Application of Biometrics: a European Perspective . . . 335
12.1 Introduction . . . 335
12.2 Privacy – from Philosophical Concept to a Human Right . . . 337
12.3 The European Personal Data Directive . . . 340
12.4 Applying the Directive and National Laws to Biometric Systems . . . 342
12.4.1 Biometric Data as "Personal Data" . . . 343
12.4.2 Biometrics and Sensitive Data . . . 345

12.4.3 Proportionality Principle 346
12.4.4 First Principle Compliance – Fair and Lawful Processing 346
12.4.5 Fourth Principle Compliance – Accuracy 347
12.4.6 Seventh Principle Compliance – Security 347
12.4.7 Eighth Principle Compliance – Transfer to Third Countries 348
12.4.8 Automatic Decision-Making 348
12.4.9 Exemptions 349
12.5 Article 8 of the European Human Rights Convention 349
12.6 The Role of Privacy-Enhancing Technologies 350
12.7 Looking to the Future 351
12.8 Social and Psychological Context of the Application of Biometric Methods 353
12.9 Conclusions 356
References 356

Index **361**