# Contents

Preface xiii

## 1 Definitions and Performance Measures

1.1 What Is Automatic Target Recognition (ATR)? 1
  1.1.1 Buyers and sellers 4

1.2 Basic Definitions 4

1.3 Detection Criteria 10

1.4 Performance Measures for Target Detection 13
  1.4.1 Truth-normalized measures 13
    1.4.1.1 Assigned targets and confusers (AFRL COMPASE Center terminology) 15
  1.4.2 Report-normalized measure 15
  1.4.3 Receiver operating characteristic curve 15
  1.4.4 $P_d$ versus FAR curve 18
  1.4.5 $P_d$ versus list length 19
  1.4.6 Other factors that can enter the detection equation 19
  1.4.7 Missile terminology 19
  1.4.8 Clutter level 20

1.5 Classification Criteria 21
  1.5.1 Object taxonomy 21
  1.5.2 Confusion matrix 25
    1.5.2.1 Compound confusion matrix 26
  1.5.3 Some commonly used terms from probability and statistics 26

1.6 Experimental Design 30
  1.6.1 Test plan 31
  1.6.2 ATR and human subject testing 32

1.7 Characterizations of ATR Hardware/Software 33

References 34

## 2 Target Detection Strategies

2.1 Introduction 37
  2.1.1 What is target detection? 38
  2.1.2 Detection schemes 38
3.2.2 Issue 2: Inputs and outputs 83
3.2.3 Issue 3: Target classes 84
3.2.4 Issue 4: Target variations 85
3.2.5 Issue 5: Platform issues 87
3.2.6 Issue 6: Under what conditions does a sensor supply useful data? 87
3.2.7 Issue 7: Sensor issues 88
3.2.8 Issue 8: Processor 89
3.2.9 Issue 9: Conveying classification results to the human-in-the-loop 89
3.2.10 Issue 10: Feasibility 91

3.3 Feature Extraction 94
3.4 Feature Selection 99
3.5 Examples of Feature Types 102
  3.5.1 Histogram of oriented gradients 103
  3.5.2 Histogram of optical flow feature vector 105
3.6 Examples of Classifiers 105
  3.6.1 Simple classifiers 106
    3.6.1.1 One-class classifiers 106
    3.6.1.2 Two-class linear classifiers 106
    3.6.1.3 Support vector machine 107
  3.6.2 Basic classifiers 110
    3.6.2.1 Single-nearest-neighbor classifier 110
    3.6.2.2 Naïve Bayes classifier 112
    3.6.2.3 Perceptron 113
    3.6.2.4 Learning vector quantization family of algorithms 115
    3.6.2.5 Feedforward multilayer perceptron trained with backpropagation of error 116
    3.6.2.6 Mean-field theory networks 116
    3.6.2.7 Model-based classifiers 118
    3.6.2.8 Map-seeking circuits 118
    3.6.2.9 Ensemble classifiers 120
  3.6.3 Contest-winning and newly popular classifiers 120
    3.6.3.1 Hierarchical temporal memory 122
    3.6.3.2 Long short-term memory recurrent neural network 122
    3.6.3.3 Convolutional neural network 123
    3.6.3.4 Sentient ATR 126

3.7 Discussion 127

References 133

4 Unification of Automatic Target Tracking and Automatic Target Recognition 137
4.1 Introduction 137
4.2 Categories of Tracking Problems 140
4.2.1 Number of targets 140
4.2.2 Size of targets 141
4.2.3 Sensor type 142
4.2.4 Target type 143

4.3 Tracking Problems 143
4.3.1 Point target tracking 143
4.3.2 Video tracking 148
  4.3.2.1 Correlation tracking (video data) 149
  4.3.2.2 Feature-vector-aided tracking (video data) 150
  4.3.2.3 Mean-shift-based moving object tracker (video tracking) 151

4.4 Extensions of Target Tracking 152
4.4.1 Activity recognition (AR) 152
4.4.2 Patterns-of-life and forensics 154

4.5 Collaborative ATT and ATR (ATT↔ATR) 155
4.5.1 ATT data useful to ATR 155
4.5.2 ATR data useful to ATT 156

4.6 Unification of ATT and ATR (ATT∪ATR) 157
4.6.1 Visual pursuit 158
4.6.2 A bat's echolocation of flying insects 159
4.6.3 Fused ATT∪ATR
  4.6.3.1 Spatiotemporal target detection 161
  4.6.3.2 Forecast of features and classes 163
  4.6.3.3 Detection-to-track association 165
  4.6.3.4 Track maintenance 166
  4.6.3.5 Incorporation of higher-level knowledge 166
  4.6.3.6 Implementation 167

4.7 Discussion 167
References 168

5 How Smart Is Your Automatic Target Recognizer? 171
5.1 Introduction 171
5.2 Test for Determining the Intelligence of an ATR 173
  5.2.1 Does the ATR understand human culture? 174
  5.2.2 Can the ATR deduce the gist of a scene? 174
  5.2.3 Does the ATR understand physics? 175
  5.2.4 Can the ATR participate in a pre-mission briefing? 177
  5.2.5 Does the ATR possess deep conceptual understanding? 177
  5.2.6 Can the ATR adapt to the situation, learn on-the-fly, and make analogies? 178
  5.2.7 Does the ATR understand the rules of engagement? 179
  5.2.8 Does the ATR understand order of battle and force structure? 181
  5.2.9 Can the ATR control platform motion? 182
5.2.10 Can the ATR fuse information from a wide variety of sources? 183
5.2.11 Does the ATR possess metacognition? 184
5.3 Sentient versus Sapient ATR 185
5.4 Discussion: Where Is ATR Headed? 186
References 190

Appendix 1: Resources 191
Appendix 2: Acronyms 225

Index 231