



## Contents

<i>List of Contributors</i> . . . . .	vii
<i>Preface</i> . . . . .	ix

### PART I PATTERN RECOGNITION

#### 1. Elements of Pattern Recognition

R. O. DUDA

I. Introduction . . . . .	3
II. A Recognition Problem . . . . .	5
III. The Classical Model . . . . .	22
IV. Additions to the Classical Model . . . . .	31
References . . . . .	32

#### 2. Statistical Pattern Recognition

K. S. FU

I. Statistical Pattern Recognition Systems and Bayes Classifiers . . . . .	35
II. Sequential Decision Model for Pattern Classification . . . . .	39
III. Forward Sequential Classification Procedure with Time-Varying Stopping Boundaries . . . . .	42
IV. Backward Sequential Classification Procedure Using Dynamic Programming . . . . .	45
V. Backward Sequential Procedure for Both Feature Selection and Pattern Classification . . . . .	48
VI. Feature Selection and Ordering: Information Theoretic Approach . . . . .	50
VII. Feature Selection and Ordering: Karhunen-Loève Expansion . . . . .	56
VIII. Bayesian Estimation in Statistical Classification Systems . . . . .	61
IX. Nonsupervised Learning Using Bayesian Estimation Technique . . . . .	66
X. Mode Estimation in Pattern Recognition . . . . .	68
XI. Conclusions and Further Remarks . . . . .	75
References . . . . .	76

**3. Algorithms for Pattern Classification**

R. L. KASHYAP

I. Introduction . . . . .	81
II. Nonoverlapping Classes with Reliable Samples . . . . .	85
III. Nonoverlapping Classes with Erroneously Classified Samples . . . . .	96
IV. Overlapping Classes . . . . .	103
V. Multiclass Algorithms . . . . .	107
VI. Comparison and Discussion of the Various Algorithms . . . . .	111
References . . . . .	112

**4. Applications of Pattern Recognition Technology**

S. S. VIGLIONE

I. Introduction . . . . .	115
II. Pattern Recognition Mechanisms . . . . .	117
III. Applications . . . . .	133
Appendix . . . . .	158
References . . . . .	161

**5. Synthesis of Quasi-Optimal Switching Surfaces by Means of Training Techniques**

J. M. MENDEL

I. Introduction . . . . .	163
II. Quasi-Optimal Control . . . . .	164
III. The Method of Trainable Controllers . . . . .	168
IV. Feature Processing . . . . .	177
V. Applications: A Brief Review . . . . .	190
VI. Conclusions . . . . .	191
References . . . . .	192

<b>Part I Problems.</b> . . . . .	<b>195</b>
-----------------------------------	------------

**PART II ADAPTIVE AND LEARNING SYSTEMS****6. Gradient Identification for Linear Systems**

J. M. MENDEL

I. Introduction . . . . .	209
II. System Description . . . . .	211
III. Gradient Identification Algorithms: Stationary Parameters . . . . .	214
IV. Gradient Identification Algorithms: Time-Varying Parameters . . . . .	227
V. Noisy Measurement Situation . . . . .	237
VI. Conclusions . . . . .	240
References . . . . .	241

**7. Adaptive Optimization Procedures**

G. J. MCMURTRY

I. Introduction . . . . .	243
II. Unimodal Techniques . . . . .	247
III. Multimodal Techniques . . . . .	272
IV. Conclusions . . . . .	283
References . . . . .	284

**8. Reinforcement-Learning Control and Pattern Recognition Systems**

J. M. MENDEL AND R. W. McLAREN

I. Introduction . . . . .	287
II. Formulation of a Stochastic, Reinforcement-Learning Model . . . . .	290
III. Reinforcement-Learning Control Systems. . . . .	292
IV. Reinforcement-Learning Pattern Recognition Systems . . . . .	306
References . . . . .	317

<b>Part II Problems . . . . .</b>	<b>319</b>
-----------------------------------	------------

## PART III SPECIAL TOPICS

**9. Stochastic Approximation**

R. L. KASHYAP, C. C. BLAYDON, AND K. S. FU

I. Introduction . . . . .	329
II. Algorithms for Finding Zeroes of Functions . . . . .	332
III. Kiefer-Wolfowitz Schemes . . . . .	334
IV. Recovery of Functions from Noisy Measurements . . . . .	336
V. Convergence Rates . . . . .	345
VI. Methods of Accelerating Convergence . . . . .	347
VII. Conclusion . . . . .	350
Appendix 1 . . . . .	350
Appendix 2. . . . .	352
References . . . . .	354

**10. Applications of the Stochastic Approximation Methods**

C. C. BLAYDON, R. L. KASHYAP, AND K. S. FU

I. Introduction . . . . .	357
II. Pattern Classification Examples . . . . .	358
III. Estimation of Probability Distribution and Density Functions . . . . .	364
IV. State and Parameter Estimation Methods . . . . .	371
V. Bang-Bang Feedback Control . . . . .	383
VI. Conclusions . . . . .	391
References . . . . .	391

11. Stochastic Automata As Models of Learning Systems

K. S. Fu

- I. Introduction to Stochastic Automata . . . . . 393
- II. Synthesis of Stochastic Automata . . . . . 399
- III. Deterministic Automata Operating in Random Environments 406
- IV. Variable Structure Stochastic Automata As Models of Learning Systems . . . . . 410
- V. Generalizations of the Basic Reinforcement Learning Model . 414
- VI. Automata Games . . . . . 417
- VII. Conclusions and Further Remarks . . . . . 428
- VIII. Nomenclature. . . . . 428
- References . . . . . 429

Part III Problems . . . . . 433

*Index* . . . . . 439

