

CONTENTS

LIST OF FIGURES xi

LIST OF TABLES xxiii

FOREWORD xxv

PREFACE xxvii

I MATHEMATICS OF INFORMATION-DRIVEN PLANNING AND CONTROL 1

1 DYNAMIC SYSTEMS 5

1.1 Feedback Control of Dynamic Systems 7

1.2 Modeling of Dynamic Systems 9

1.3 Properties of Dynamic Systems 15

Exercises 25

2 OPTIMAL CONTROL 29

2.1 Indirect Solution Approach 32

2.2 Direct Solution Approach 34

Extensions 38

Exercises 40

3 GRAPH THEORY 43

Extensions 50

Exercises 52

4	PROBABILITY THEORY	53
4.1	Axioms of Probability	54
4.2	Conditional Probability and Bayes' Rule	56
4.3	Random Variables	60
4.3.1	<i>Discrete Random Variables</i>	61
4.3.2	<i>Continuous Random Variables</i>	71
4.4	Stochastic Processes	73
4.4.1	<i>Markov Processes</i>	76
4.5	Markov Decision Processes and Bellman Equation	79
	Exercises	85
5	INFORMATION THEORY	91
	Exercises	101
6	PART I GLOSSARY	105
II	SENSOR SYSTEM MODELING	109
7	MOBILE PLATFORM MODELS	113
7.1	Ground Vehicles	114
7.2	Air Vehicles	119
7.2.1	<i>Fixed-Wing Aircraft</i>	119
7.2.2	<i>Quadcopters</i>	127
7.3	Underwater Vehicles	135
	Exercises	143
8	TARGET MODELS	147
8.1	Fixed Targets	149
8.2	Moving Targets	158
	Exercises	165
9	SENSOR MODELS	169
9.1	Measurement Models	172
9.1.1	<i>Physics-Based Methods</i>	173
9.1.2	<i>Estimation-Theoretic Methods</i>	181
9.1.3	<i>Probabilistic Methods</i>	186
9.2	Field-of-View (FOV) Model	202
	Exercises	213
10	MODELS OF ENVIRONMENTAL VARIABILITY	219
10.1	Gaussian Mixture Environmental Modeling	221
10.2	Kriging Environmental Interpolation	225
	Exercises	229
11	PART II GLOSSARY	231

III	SENSING PERFORMANCE AND OBJECTIVE FUNCTIONS	235
12	COVERAGE	241
12.1	Area Coverage	242
12.1.1	<i>Area Coverage of Omnidirectional Sensor Networks</i>	247
12.2	Track Coverage	254
Exercises		263
13	DETECTION	265
13.1	Target Search	266
13.2	Target Detection	273
13.3	Track Detection	278
Exercises		290
14	CLASSIFICATION	293
Exercises		303
15	TRACKING AND LOCALIZATION	305
15.1	Kinematic-Matching Approach	308
15.2	Likelihood Function Approach	316
15.3	Bayesian Approach	325
15.4	Target Localization	336
Exercises		344
16	PART III GLOSSARY	347
IV	INFORMATION-DRIVEN PLACEMENT AND OPTIMIZATION	351
17	PACKING ALGORITHMS	357
17.1	Circle Packing for Omnidirectional Sensor Networks	359
Exercises		368
18	VORONOI DIAGRAMS	371
18.1	Locational Optimization	374
18.2	Geometrical Optimization	382
18.2.1	<i>Multi-Incenter Optimization</i>	383
Exercises		387
19	MULTI-OBJECTIVE OPTIMIZATION	391
19.1	Unconstrained Gradient Optimization of a Global Criterion	396
19.2	Constrained Optimization	404
19.2.1	<i>State Inequality Constraints</i>	405
19.2.2	<i>MOO Constraints</i>	415
19.2.3	<i>Numerical Methods of Solution</i>	421
Exercises		428

20	METAHEURISTIC OPTIMIZATION	433
20.1	Grid Coverage and Optimization	435
20.2	Simulated Annealing	446
20.3	Genetic Algorithms	456
20.3.1	<i>Genetic Algorithms for Multi-Objective Optimization</i>	466
	Exercises	472
21	OPTIMAL PLACEMENT OF DYNAMIC SENSORS	477
	Exercises	488
22	PART IV GLOSSARY	489
V	INFORMATION-DRIVEN PLANNING AND CONTROL METHODS	493
23	SENSOR TRAJECTORY OPTIMIZATION	499
	Exercises	511
24	SENSOR PATH PLANNING	515
24.1	Cell Decomposition	525
24.2	Probabilistic Roadmap	534
24.3	Navigation Function	544
24.3.1	<i>Information Potential</i>	546
24.3.2	<i>Sensor Planning and Control</i>	553
24.3.3	<i>Sensor Network Planning and Control</i>	559
	Exercises	565
25	INTEGRATED SENSOR PLANNING AND CONTROL	571
	Exercises	582
26	PART V GLOSSARY	587
	REFERENCES	591
	CONTRIBUTORS	623
	INDEX	625