

# Contents

<b>Preface to the Second Edition</b> . . . . .	v
--	---

<b>Preface</b> . . . . .	vii
--------------------------	-----

## **Part I Introduction**

<b>1 Hidden Markov Model Processing</b> . . . . .	3
1.1 Models, Objectives, and Methods . . . . .	3
1.2 Book Outline . . . . .	3

## **Part II Discrete-Time HMM Estimation**

<b>2 Discrete States and Discrete Observations</b> . . . . .	15
2.1 Introduction . . . . .	15
2.2 Model . . . . .	16
2.3 Change of Measure . . . . .	20
2.4 Unnormalized Estimates and Bayes' Formula . . . . .	26
2.5 A General Unnormalized Recursive Filter . . . . .	28
2.6 States, Transitions, and Occupation Times . . . . .	30
2.7 Parameter Reestimation . . . . .	33
2.8 Recursive Parameter Estimation . . . . .	38
2.9 Quantized Observations . . . . .	40
2.10 The Dependent Case . . . . .	43
2.11 Problems and Notes . . . . .	52
<b>3 Continuous-Range Observations</b> . . . . .	55
3.1 Introduction . . . . .	55
3.2 State and Observation Processes . . . . .	55
3.3 Conditional Expectations . . . . .	56
3.4 Change of Measure . . . . .	58
3.5 Filter-Based State Estimation . . . . .	61
3.6 Smoother-Based State Estimation . . . . .	65

3.7	Vector Observations .....	72
3.8	Recursive Parameter Estimation .....	74
3.9	HMMs with Colored Noise .....	77
3.10	Mixed-State HMM Estimation .....	79
3.11	Problems and Notes .....	80
<b>4</b>	<b>Continuous-Range States and Observations .....</b>	<b>83</b>
4.1	Introduction .....	83
4.2	Linear Dynamics and Parameters .....	83
4.3	The ARMAX Model .....	87
4.4	Nonlinear Dynamics .....	90
4.5	Kalman Filter .....	98
4.6	State and Mode Estimation for Discrete-Time Jump Markov Systems .....	106
4.7	Example .....	139
4.8	Problems and Notes .....	139
<b>5</b>	<b>A General Recursive Filter .....</b>	<b>143</b>
5.1	Introduction .....	143
5.2	Signal and Observations .....	143
5.3	Change of Measure .....	144
5.4	Recursive Estimates .....	146
5.5	Extended Kalman Filter .....	148
5.6	Parameter Identification and Tracking .....	149
5.7	Formulation in Terms of Transition Densities .....	153
5.8	Dependent Case .....	155
5.9	Recursive Prediction Error Estimation .....	159
5.10	Problems and Notes .....	161
<b>6</b>	<b>Practical Recursive Filters .....</b>	<b>163</b>
6.1	Introduction .....	163
6.2	Recursive Prediction Error HMM Algorithm .....	166
6.3	Example: Quadrature Amplitude Modulation .....	171
6.4	Example: Frequency Modulation .....	179
6.5	Coupled-Conditional Filters .....	187
6.6	Notes .....	194

### Part III Continuous-Time HMM Estimation

<b>7</b>	<b>Discrete-Range States and Observations .....</b>	<b>197</b>
7.1	Introduction .....	197
7.2	Dynamics .....	197
7.3	A General Finite-Dimensional Filter .....	203
7.4	Parameter Estimation .....	209
7.5	Problems and Notes .....	211

<b>8</b>	<b>Markov Chains in Brownian Motion</b>	213
8.1	Introduction	213
8.2	The Model	213
8.3	A General Finite-Dimensional Filter	214
8.4	States, Transitions, and Occupation Times	216
8.5	Parameter Estimation	219
8.6	Finite-Dimensional Predictors	220
8.7	A Non-Markov Finite-Dimensional Filter	225
8.8	Problems and Notes	232

## Part IV Two-Dimensional HMM Estimation

<b>9</b>	<b>Hidden Markov Random Fields</b>	237
9.1	Discrete Signal and Observations	237
9.2	HMRF Observed in Gaussian Noise	254
9.3	Continuous-State HMRF	260
9.4	Example: A Mixed HMRF	264
9.5	Problems and Notes	269

## Part V HMM Optimal Control

<b>10</b>	<b>Discrete-Time HMM Control</b>	273
10.1	Control of Finite-State Processes	273
10.2	More General Processes	279
10.3	A Dependent Case	284
10.4	Problems and Notes	288
<b>11</b>	<b>Risk-Sensitive Control of HMM</b>	291
11.1	Introduction	291
11.2	The Risk-Sensitive Control Problem	292
11.3	Connection with $H^\infty$ Control	297
11.4	Connection with $H_2$ or Risk-Neutral Control	299
11.5	A Finite-Dimensional Example	303
11.6	Risk-Sensitive LQG Control	309
11.7	Problems and Notes	313
<b>12</b>	<b>Continuous-Time HMM Control</b>	315
12.1	Introduction	315
12.2	Robust Control of a Partially Observed Markov Chain	315
12.3	The Dependent Case	328
12.4	Hybrid Conditionally Linear Process	340
12.5	Problems and Notes	348
<b>A</b>	<b>Basic Probability Concepts</b>	351
<b>B</b>	<b>Continuous-Time Martingale Representation</b>	359

**References . . . . . 365**

**Author Index . . . . . 373**

**Subject Index . . . . . 375**

Hidden Markov Models

Estimation and Control

Elliott, R.J.; Aggoun, L.; Moore, J.B.

1995, XIV, 382 p., Hardcover

ISBN: 978-0-387-94364-0