

Contents

1	Basic Probability Review	1
1.1	Basic Definitions	1
1.2	Random Variables and Distribution Functions	4
1.3	Mean and Variance	10
1.4	Important Distributions	13
1.5	Multivariate Distributions	23
1.6	Combinations of Random Variables	31
1.6.1	Fixed Sum of Random Variables	32
1.6.2	Random Sum of Random Variables	32
1.6.3	Mixtures of Random Variables	34
	Appendix	35
	Problems	37
	References	43
2	Basics of Monte Carlo Simulation	45
2.1	Simulation by Hand	46
2.2	Generation of Random Numbers	49
2.2.1	Multiplicative Linear Congruential Generators	50
2.2.2	A Multiple Recursive Generator	52
2.2.3	Composite Generators	53
2.3	Generation of Random Variates	55
2.3.1	Discrete Random Variates	55
2.3.2	Continuous Random Variates	61
2.3.3	Bivariate Continuous Random Variates	64
2.3.4	Random Variates from Empirical Distributions	66
	Appendix	67
	Problems	69
	References	72

3	Basic Statistical Review	73
3.1	Collection of Data	73
3.1.1	Preliminary Definitions	74
3.1.2	Graphical Representations	75
3.2	Parameter Estimation	78
3.2.1	Method of Moments	80
3.2.2	Maximum Likelihood Estimation	81
3.3	Confidence Intervals	82
3.3.1	Means	83
3.3.2	Proportions	87
3.3.3	Variances	87
3.3.4	Correlation Coefficient	89
3.4	Fitting Distributions	90
3.4.1	The Chi-Square Test	91
3.4.2	The Kolmogorov-Smirnov Test	95
3.5	Fitting Models	99
3.5.1	Ordinary Least Squares Regression	100
3.5.2	Maximum Likelihood Estimates for Linear Models	105
	Appendix	105
	Problems	109
	References	113
4	Poisson Processes	115
4.1	Basic Definitions	115
4.2	Properties and Computations	118
4.3	Extensions of a Poisson Process	121
4.3.1	Compound Poisson Processes	121
4.3.2	Non-stationary Poisson Process	123
4.4	Poisson Regression	124
4.4.1	Poisson Regression with One Independent Variable	124
4.4.2	Poisson Regression with Several Independent Variables	128
	Appendix	133
	Problems	136
	References	139
5	Markov Chains	141
5.1	Basic Definitions	142
5.2	Multistep Transitions	145
5.3	Classification of States	149
5.4	Steady-State Behavior	157
5.5	Computations	162
	Appendix	169
	Problems	171
	References	178

6	Markov Processes	181
6.1	Basic Definitions	181
6.2	Steady-State Properties	184
6.3	Revenues and Costs	188
6.4	Time-Dependent Probabilities	191
	Appendix	195
	Problems	196
7	Queueing Processes	201
7.1	Basic Definitions and Notation	201
7.2	Single Server Systems	203
7.2.1	Infinite Capacity Single-Server Systems	203
7.2.2	Finite Capacity Single Server Systems	210
7.3	Multiple Server Queues	213
7.4	Approximations	217
	Appendix	219
	Problems	220
	References	225
8	Queueing Networks	227
8.1	Jackson Networks	227
8.1.1	Open Jackson Networks	228
8.1.2	Closed Jackson Networks	232
8.2	Network Approximations	235
8.2.1	Deterministic Routing with Poisson Input	236
8.2.2	Deterministic Routing with non-Poisson Input	242
	Appendix	245
	Problems	246
	References	249
9	Event-Driven Simulation and Output Analyses	251
9.1	Event-Driven Simulations	251
9.2	Statistical Analysis of Output	262
9.2.1	Terminating Simulations	263
9.2.2	Steady-State Simulations	266
9.2.3	Comparing Systems	275
	Problems	279
	References	284
10	Inventory Theory	285
10.1	The News-Vendor Problem	286
10.2	Single-Period Inventory	289
10.2.1	No Setup Costs	289
10.2.2	Setup Costs	292
10.3	Multi-Period Inventory	295

Problems	299
References	303
11 Replacement Theory	305
11.1 Age Replacement	305
11.1.1 Discrete Life Times	306
11.1.2 Continuous Life Times	309
11.2 Minimal Repair	312
11.2.1 Minimal Repairs without Early Replacements	313
11.2.2 Minimal Repairs with Early Replacements	314
11.3 Block Replacement	316
Problems	319
12 Markov Decision Processes	323
12.1 Basic Definitions	324
12.1.1 Expected Total Discounted Cost Criterion	326
12.1.2 Average Long-Run Cost Criterion	327
12.2 Stationary Policies	327
12.3 Discounted Cost Algorithms	329
12.3.1 Value Improvement for Discounted Costs	331
12.3.2 Policy Improvement for Discounted Costs	332
12.3.3 Linear Programming for Discounted Costs	336
12.4 Average Cost Algorithms	337
12.4.1 Policy Improvement for Average Costs	340
12.4.2 Linear Programming for Average Costs	344
12.5 The Optimal Stopping Problem	346
Problems	349
13 Advanced Queues	355
13.1 Difference Equations	356
13.2 Batch Arrivals	358
13.2.1 Quasi-Birth-Death Processes	360
13.2.2 Batch Arrivals (continued)	362
13.3 Phase-Type Distributions	364
13.4 Systems with Phase-Type Service	368
13.4.1 The M/Ph/1 Queueing System	368
13.4.2 The M/Ph/c Queueing System	372
13.5 Systems with Phase-Type Arrivals	374
Problems	375
References	379
A Matrix Review	381
A.1 Matrix Addition and Subtraction	382
A.2 Matrix Multiplication	382
A.3 Determinants	383
A.4 Determinants by Cofactor Expansion	385

A.5 Nonsingular Matrices 386

A.6 Inversion-in-Place 387

A.7 Derivatives 390

References 392

Index 393