

Contents

1	Introduction	1
	1.1 Introduction	1
	1.2 Notation	3
	1.3 Figures	3
	References	4
2	Fuzzy Sets	5
	2.1 Introduction	5
	2.2 Fuzzy Sets	5
	2.2.1 Fuzzy Numbers	5
	2.2.2 Alpha-Cuts	7
	2.2.3 Inequalities	8
	2.2.4 Discrete Fuzzy Sets	8
	2.3 Fuzzy Arithmetic	8
	2.3.1 Extension Principle	8
	2.3.2 Interval Arithmetic	9
	2.3.3 Fuzzy Arithmetic	10
	2.4 Fuzzy Functions	11
	2.4.1 Extension Principle	11
	2.4.2 Alpha-Cuts and Interval Arithmetic	12
	2.4.3 Differences	13
	2.5 Ordering/Ranking Fuzzy Numbers	14
	2.6 Optimization	15
	2.7 Discrete Versus Continuous	15
	References	17
3	Fuzzy Estimation	19
	3.1 Introduction	19
	3.2 Fuzzy Probabilities	19
	3.3 Fuzzy Numbers from Confidence Intervals	20
	3.4 Fuzzy Arrival/Service Rates	22
	3.4.1 Fuzzy Arrival Rate	22
	3.4.2 Fuzzy Service Rate	23
	3.5 Fuzzy Probability Distributions	25
	3.5.1 Fuzzy Binomial	25

VIII Contents

3.5.2	Fuzzy Estimator of μ in the Normal	27
3.5.3	Fuzzy Estimator of σ^2 in the Normal	28
3.5.4	Fuzzy Exponential.....	32
3.5.5	Fuzzy Uniform	33
3.6	Summary.....	34
	References	34
4	Fuzzy Probability Theory	37
4.1	Introduction	37
4.2	Fuzzy Binomial	37
4.3	Fuzzy Poisson.....	39
4.4	Fuzzy Normal.....	42
4.5	Fuzzy Exponential.....	44
4.6	Fuzzy Uniform	46
	References	48
5	Fuzzy Systems Theory	49
5.1	Introduction	49
5.2	Fuzzy System	50
5.3	Computing Fuzzy Measures of Performance	51
	Reference	52
6	Simulation	53
	References	55
7	Queuing I: One-Step Calculations	57
7.1	Introduction	57
7.2	One-Step Calculations	57
7.2.1	Fuzzy Calculations	58
7.2.2	Simulation.....	61
7.3	Multi-Step Calculations	64
7.4	Rest of the Book	66
	References	67
8	Simulation Optimization	69
8.1	Introduction	69
8.2	Arrivals	69
8.3	Service	70
8.3.1	Exponential	70
8.3.2	Uniform	71
8.3.3	Normal	72
8.4	Probabilistic Transfer	73
8.5	Summary.....	73

9	Queuing II: No One-Step Calculations	75
	9.1 Introduction	75
	9.2 Case 1: First Simulation	75
	9.3 Case 2: Second Simulation	78
	9.4 Case 3: Third Simulation	79
	9.5 Summary	80
	Reference	80
10	Call Center Model	81
	10.1 Introduction	81
	10.2 Case 1: First Simulation	82
	10.3 Case 2: Second Simulation	83
	10.4 Case 3: Third Simulation	84
	10.5 Summary	85
	Reference	85
11	Machine Shop I	87
	11.1 Introduction	87
	11.2 Case 1: First Simulation	89
	11.3 Cases 2 and 3: Second and Third Simulation	91
	11.4 Summary	92
	Reference	93
12	Machine Shop II	95
	12.1 Introduction	95
	12.2 Case 1: First Simulation	97
	12.3 Case 2: Second Simulation	98
	12.4 Case 3: Third Simulation	100
	12.5 Summary	101
	Reference	101
13	Emergency Room Model	103
	13.1 Introduction	103
	13.2 Case 1: First Simulation	105
	13.3 Case 2: Second Simulation	107
	13.4 Case 3: Third Simulation	108
	13.5 Summary	108
	Reference	109
14	Machine Servicing Problem	111
	14.1 Introduction	111
	14.2 Case 1: First Simulation ($k = 1$)	112
	14.3 Case 2: Second Simulation ($k = 2$)	114
	14.4 Case 3: Third Simulation ($k = 3$)	115
	14.5 Case 4: Fourth Simulation ($k = 4$)	115

X Contents

14.6	Case 5: Fifth Simulation ($k = 5$)	115
14.7	Summary	115
	Reference	116
15	Life Insurance: New Account Model	117
15.1	Introduction	117
15.2	Case 1: First Simulation	118
15.3	Case 2: Second Simulation	120
15.4	Case 3: Third Simulation	121
15.5	Summary	121
	Reference	121
16	Inventory Control I	123
16.1	Introduction	123
16.2	Case 1: First Simulation	125
16.3	Case 2: Second Simulation	127
16.4	Case 3: Third Simulation	128
16.5	Summary	129
	References	129
17	Inventory Control II	131
17.1	Introduction	131
17.2	Case 1: First Simulation	133
17.3	Case 2: Second Simulation	134
17.4	Case 3: Third Simulation	135
17.5	Summary	136
	Reference	136
18	Oil Tanker Problem	137
18.1	Introduction	137
18.2	Case 1: Super Tankers	139
18.3	Case 2: Big Tankers	139
18.4	Case 3: Regular Tankers	140
18.5	Summary	141
	References	142
19	Priority Queues	143
19.1	Introduction	143
19.2	Case 1: First Simulation	146
19.3	Case 2: Second Simulation	146
19.4	Case 3: Third Simulation	147
19.5	Summary	148

20	Optimizing a Production Line	149
	20.1 Introduction	149
	20.2 Simulations	151
	20.3 Summary	152
	Reference	154
21	Supermarket Model	155
	21.1 Introduction	155
	21.2 Case 1: First Simulation	158
	21.3 Case 2: Second Simulation	159
	21.4 Case 3: Third Simulation	160
	21.5 Summary	160
	Reference	160
22	Bank Teller Problem	161
	22.1 Introduction	161
	22.2 First Simulation: Multiple Queues	163
	22.3 Second Simulation: Single Queue	163
	22.4 Summary	163
	References	164
23	A Bus Stop	165
	23.1 Introduction	165
	23.2 Case 1: First Simulation	166
	23.3 Case 2: More Buses	167
	23.4 Case 3: Larger Buses	168
	23.5 Summary	168
	Reference	168
24	Process Failure/Spare Parts Problem	169
	24.1 Introduction	169
	24.2 Case 1: No Spare Parts	171
	24.3 Case 2: One Spare Part	171
	24.4 Case 3: Two Spare Parts	171
	24.5 Case 4: Three Spare Parts	172
	24.6 Summary	172
	Reference	173
25	Preemptive Service	175
	25.1 Introduction	175
	25.2 Case 1: First Simulation	177
	25.3 Case 2: Second Simulation	177
	25.4 Case 3: Third Simulation	179
	25.5 Summary	179
	Reference	179

26	Project Network Model	181
26.1	Introduction	181
26.2	Simulations	183
26.3	Maximize Profit	185
26.4	Summary	186
	References	186
27	Summary and Conclusions	187
	References	188
28	Simulation Programs	189
28.1	Introduction	189
28.2	Chapter 9	189
28.3	Chapter 10	191
28.4	Chapter 11	192
28.5	Chapter 12	192
28.6	Chapter 13	195
28.7	Chapter 17	196
28.8	Chapter 18	200
28.9	Chapter 22	201
28.10	Chapter 25	202
28.11	Chapter 26	203
	Index	205



<http://www.springer.com/978-3-540-24116-4>

Simulating Fuzzy Systems

Buckley, J.J.

2005, XII, 208 p., Hardcover

ISBN: 978-3-540-24116-4