CONTENTS

Preface xi

1 Introduction to Systems Simulation 1

1.1 Introduction 1
1.2 Applications of Simulation 2
1.3 Future Potential of Simulation 5
1.4 Plan of the Book 5
1.5 Concluding Remarks 7

2 Systems and Models 9

2.1 Introduction 9
2.2 Systems 9
2.2.1 Classification of Systems 12
2.2.2 Common Dynamic Systems Concepts 15
2.3 Models 27
2.3.1 Classification of Models 30
2.3.2 Model Experimentation 31
2.3.3 Some Remarks for Selection of a Modeling Method 35
2.3.4 Simulation-An Experimental Approach 36
2.4 Summary 37
2.5 Exercises 37

3 Simulation 39

3.1 Introduction 39
3.2 A Demonstrative Example of Simulation 40
3.3 A Numerical Example 42
3.4 Computer Representation of Simulation Models 46
3.4.1 Creation of Random Effects by Computer 47
3.4.2 Representation of Model Logics by Computer Programs 48
3.4.3 General Structure of Simulation Programs 57
3.5 Statistics in Simulation 58
3.6 Simulation Software Tools 61
3.7 EZSIM - A General Purpose Discrete System Simulation Tool 63
3.7.1 Procedure for Using EZSIM 64
3.7.2 EZSIM Program Generator Mode 73
3.7.3 Some Design Considerations 76
3.7.4 Demonstration of the EZSIM Application Procedure 76

3.8 The Simulation Process 81
3.9 Summary 83
3.10 Exercises 83

4 Common Processes in Discrete Systems 87
4.1 Introduction 87
4.2 A View of Common Processes in Discrete Systems 88
4.2.1 Entity Movement 89
4.2.2 Entity Multiplication and Reduction 94
4.2.3 Entity Use of Resources 95
4.2.4 Entity Accumulation 98
4.2.5 Auxiliary Operations 101
4.3 Summary 106
4.4 Exercises 106

5 EZSIM Modeling Objects and Capabilities 107
5.1 Introduction 107
5.2 SOURCE Node 107
5.3 TERMINATE Node 108
5.4 DELAY Node 108
5.5 FACILITY Node 109
5.6 QUEUE Node 110
5.7 ASSIGN Node 118
5.8 RESOURCE-Q Node 12
5.9 GATE-Q Node 124
5.10 SWITCH Node 124
5.11 MATCH-Q Node 12
5.12 GROUP-Q Node 129
5.13 UNGROUP Node 130
5.14 FILE Node 13
5.15 Summary 133
5.16 Exercises 133

6 Analysis of Simulation Inputs and Creation of Their Effects 13
6.1 Introduction 13
6.2 Random Effects in Simulation 138
6.3 Identifying the Distribution of Field Data 139
6.3.1 Goodness-of-Fit Tests 14
6.3.2 Selection of Distribution in the Absence of Field Data 14
6.4 Random Number Generation 14
6.4.1 Pseudorandom Number Generation Techniques 14
6.4.2 Methods for Testing Random Numbers 15
6.5 Random Variate Generation 15
6.5.1 Generation of Random Variates with Arbitrary Distributions 15
6.5.2 Other Methods for Random Variate Generation 16

6.6 Summary 163
6.7 Exercises 163
6.8 References and Further Reading 166

7 Analysis of Simulation Output 167

7.1 Introduction 167
7.2 The Importance of Simulation Output Analysis 168
7.3 Types of Simulation with Respect to Output Analysis 170
7.3.1 Nonterminating Systems 170
7.3.2 Terminating Systems 175
7.4 Problem of Data Dependency or Autocorrelation 181
7.5 Confidence Intervals 182
7.5.1 Estimation of Population Mean 183
7.5.2 Estimation of Proportion 188
7.5.3 Estimation of Difference between Means 191
7.6 Selection of Sample Size 194
7.6.1 Sample Size Based on Population Mean 194
7.6.2 Sample Size Based on Proportion 196
7.6.3 Sample Size Based on Difference between Means 197
7.7 Test of Hypothesis 198
7.8 The Independent Replications Method 200
7.9 The Batch Means Method 203
7.9.1 Runs Up and Down Test 204
7.10 Variance Reduction Techniques 206
7.11 Other Stages in the Simulation Process 207
7.11.1 Verification 207
7.11.2 Validation 211
7.11.3 Experimentation 214
7.11 .4 Documentation 216
7.12 Summary 217
7.13 Exercises 217
7.14 References and Further Reading 221

8 Applications of Simulation 223

8.1 Introduction 223
8.2 Application Examples in the Service Industries 226
8.2.1 Communication Systems 242
8.3 Application Examples in Manufacturing 248
8.3.1 Production and Inventory Control 260
8.3.2 Manufacturing Quality Control 263
8.4 Summary 266
8.5 Exercises 267

9 Simulation Tools and the Criteria for Their Selection 275

9. 1 Introduction 275
9.2 General Purpose Event-Oriented Simulation Languages 276
9.2.1 GASP IV 276

9.2.2 SIMSCRIPT 276
9.2.3 MODS 1M 277
9.3 General Purpose Process-Oriented L~guages 277
9.3.1 SLAM 278
9.3.2 GPSS 280
9.3.3 SIMAN 282
9.3.4 SIM~ll 284
9.4 Special Purpose Simulation Environments 284
9.5 Selection of a Simulation 11001 286
9.6 Summary 288

10 Future Directions of Simulation 289

10. 1 Introduction 289
10.2 Intelligent Simulation Environments 290
10.2.1 Machine Learning and Simulation 293
10.3 Object-Oriented Simulation 294
10.3.1 Advantages of Object-Oriented Simulation 296
10.4 Projections for Future Advancements in Simulation 297
10.5 Summary 298
10.6 References and Further Reading 298

Appendixes 301

A Program Listings for the Single-Server Queuing System 301
B Probability Distributions 311
C A Histogram Program 323
D Statistical llables 325

Index 331