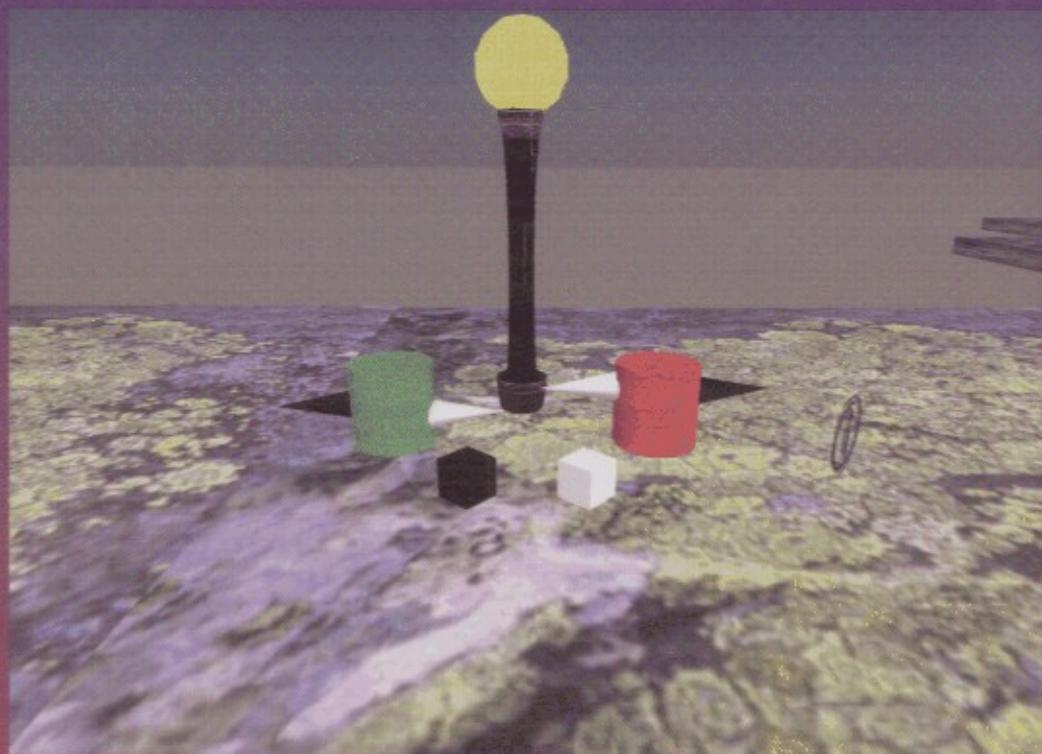


CHAPMAN & HALL/CRC COMPUTER and INFORMATION SCIENCE SERIES

# Handbook of Dynamic System Modeling



Edited by  
Paul A. Fishwick

 Chapman & Hall/CRC  
Taylor & Francis Group

# Contents

---

Abstract .....	xiii
Intended Audience .....	xv
Preface .....	xvii
Editor .....	xix
Contributors .....	xxi

## I Introduction

---

1	The Languages of Dynamic System Modeling	<i>Paul A. Fishwick</i> .....	1-1
1.1	Introduction .....		1-1
1.2	Dynamic System Modeling Examples .....		1-2
1.3	Taxonomic Approaches .....		1-3
1.4	Language .....		1-3
1.5	Syntax .....		1-5
1.6	Semantics .....		1-7
1.7	Pragmatics .....		1-10
1.8	Summary .....		1-10
2	The Dynamics of the Computational Modeling of Analogy-Making		
	<i>Robert M. French</i> .....		2-1
2.1	Introduction .....		2-1
2.2	Analogy-Making as <i>Sameness</i> .....		2-2
2.3	Analogy-Making as a Means of “Bootstrapping” Cognition .....		2-3
2.4	The Necessity of Malleable Representations .....		2-3
2.5	The Dynamics of Representation-Building in Analogy-Making .....		2-5
2.6	Context-Dependent Computational Temperature .....		2-6
2.7	Interaction between Top-Down and Bottom-Up Processes: An Example .....		2-6
2.8	Computational Models Implementing this Bottom-Up/Top-Down Interaction .....		2-8
2.9	Architectural Principles .....		2-8
2.10	How this Type of Program Works: The Details .....		2-12
2.11	How Tabletop Finds a Reasonable Solution .....		2-13
2.12	The Issue of Scaling Up .....		2-16
2.13	The Potential Long-Term Impact of the Mechanisms Presented .....		2-16
2.14	Conclusions .....		2-16

<b>3</b>	<b>Impact of the Semantic Web on Modeling and Simulation</b>		
	<i>John A. Miller, Congzhou He and Julia I. Couto</i>	3-1	3-1
3.1	Introduction	3-1	3-1
3.2	Semantic Web: Relevant Issues	3-2	3-2
3.3	Conceptual Basis for Discrete-Event Simulation	3-4	3-4
3.4	Types of Mathematical Models	3-6	3-6
3.5	Adding Semantics to Simulation Models	3-10	3-10
3.6	Overview of DeSO	3-12	3-12
3.7	Overview of DeMO	3-14	3-14
3.8	Summary	3-18	3-18
<b>4</b>	<b>Systems Engineering</b>	<i>Andrew P. Sage</i>	4-1
4.1	Introduction		4-1
4.2	Systems Engineering		4-2
4.3	The Importance of Technical Direction and Systems Management		4-4
4.4	Other Parts of the Story		4-8
4.5	Summary		4-9
<b>5</b>	<b>Basic Elements of Mathematical Modeling</b>	<i>Clive L. Dym</i>	5-1
5.1	Principles of Mathematical Modeling		5-2
5.2	Dimensional Consistency and Dimensional Analysis		5-3
5.3	Abstraction and Scale		5-9
5.4	Conservation and Balance Principles		5-17
5.5	The Role of Linearity		5-19
5.6	Conclusions		5-20
<b>6</b>	<b>DEVS Formalism for Modeling of Discrete-Event Systems</b>	<i>Tag Gon Kim</i>	6-1
6.1	Introduction		6-1
6.2	System-Theoretic DES Modeling		6-3
6.3	DEVS Formalism for DES Modeling		6-3
6.4	DES Analysis with DEVS Model		6-7
6.5	Simulation of DEVS Model		6-10
6.6	Conclusion		6-12

## II Modeling Methodologies

---

<b>7</b>	<b>Domain-Specific Modeling</b>	<i>Jeff Gray, Juha-Pekka Tolvanen, Steven Kelly, Aniruddha Gokhale, Sandeep Neema and Jonathan Sprinkle</i>	7-1
7.1	Introduction		7-1
7.2	Essential Components of a Domain-Specific Modeling Environment		7-2
7.3	Case Studies in DSM		7-6
7.4	Overview of Supporting Tools		7-17
7.5	Conclusion		7-18
<b>8</b>	<b>Agent-Oriented Modeling in Simulation: Agents for Modeling, and Modeling for Agents</b>	<i>Adelinde M. Uhrmacher and Mathias Röhl</i>	8-1
8.1	Introduction		8-1
8.2	Agents for Modeling in Simulation		8-3

8.3	Modeling and Simulation for Agents .....	8-6
8.4	Conclusion .....	8-10
<b>9</b>	<b>Distributed Modeling</b> <i>Simon J. E. Taylor</i> .....	<b>9-1</b>
9.1	Introduction .....	9-1
9.2	Modeling with COTS Simulation Packages .....	9-2
9.3	Distributed Simulation .....	9-3
9.4	CSP-Based Distributed Simulation .....	9-5
9.5	A Standards-Based Approach .....	9-7
9.6	Case Study .....	9-13
9.7	Conclusion .....	9-16
<b>10</b>	<b>Model Execution</b> <i>Kalyan S. Perumalla</i> .....	<b>10-1</b>
10.1	Introduction .....	10-1
10.2	Time-Stepped Execution .....	10-5
10.3	Discrete-Event Execution .....	10-7
10.4	Summary .....	10-13
<b>11</b>	<b>Discrete-Event Simulation of Continuous Systems</b> <i>James Nutaro</i> .....	<b>11-1</b>
11.1	Introduction .....	11-1
11.2	Simulating a Single Ordinary Differential Equation .....	11-2
11.3	Simulating Coupled Ordinary Differential Equations .....	11-6
11.4	DEVS Representation of Discrete-Event Integrators .....	11-8
11.5	The Heat Equation .....	11-13
11.6	Conservation Laws .....	11-16
11.7	Two-Point Integration Schemes .....	11-19
11.8	Conclusions .....	11-21

### III Multiobject and System

---

<b>12</b>	<b>Toward a Multimodel Hierarchy to Support Multiscale Simulation</b> <i>Mark S. Shephard, E. Seegyong Seol and Benjamin FrantzDale</i> .....	<b>12-1</b>
12.1	Introduction .....	12-1
12.2	Functional and Information Hierarchies in Multiscale Simulation .....	12-4
12.3	Constructing a Multimodel: Design of Functional Components to Support Multiscale Simulations .....	12-10
12.4	Example Multimodel Simulation Procedures .....	12-14
12.5	Closing Remarks .....	12-15
<b>13</b>	<b>Finite Elements</b> <i>Marc Hoit and Gary Consolazio</i> .....	<b>13-1</b>
13.1	Finite Element Theory .....	13-1
13.2	Membrane Elements .....	13-9
13.3	Flat Plate and Shell Elements .....	13-12
13.4	Solid Elements .....	13-15
13.5	Dynamics .....	13-16
13.6	Summary .....	13-21

<b>14</b>	<b>Multimodeling</b>	<i>Minho Park, Paul A. Fishwick and Jinho Lee</i>	14-1
14.1	Introduction		14-1
14.2	Scene Construction		14-5
14.3	Multimodeling Exchange Language (MXL)		14-11
14.4	Dynamic Exchange Language (DXL)		14-13
14.5	A Boiling Water Example		14-20
14.6	Conclusion		14-27
<b>15</b>	<b>Hybrid Dynamic Systems: Modeling and Execution</b>	<i>Pieter J. Mosterman</i>	15-1
15.1	Introduction		15-1
15.2	Hybrid Dynamic Systems		15-3
15.3	Hybrid Dynamic System Behaviors		15-9
15.4	An Implementation		15-12
15.5	Advanced Topics in Hybrid Dynamic System Simulation		15-17
15.6	Pathological Behavior Classes		15-22
15.7	Conclusions		15-23
<b>16</b>	<b>Theory and Practice for Simulation Interconnection: Interoperability and Composability in Defense Simulation</b>	<i>Ernest H. Page</i>	16-1
16.1	Introduction		16-1
16.2	The Practice of Simulation Interconnection—Simulation Interoperability		16-2
16.3	The Theory of Simulation Interconnection—Simulation Composability		16-6
16.4	Conclusions		16-9
 <b>IV Model Types</b>			
<b>17</b>	<b>Ordinary Differential Equations</b>	<i>Francisco Esquembre and Wolfgang Christian</i>	17-1
17.1	Introduction		17-1
17.2	Numerical Solution		17-3
17.3	Taylor Methods		17-5
17.4	Runge–Kutta Methods		17-7
17.5	Implementation		17-8
17.6	Adaptive Step		17-11
17.7	Implementation of Adaptive Step		17-12
17.8	Performance and Other Methods		17-15
17.9	State Events		17-19
17.10	The OSP Library		17-20
<b>18</b>	<b>Difference Equations as Discrete Dynamical Systems</b>	<i>Hassan Sedaghat</i>	18-1
18.1	Introduction		18-1
18.2	Basic Concepts		18-2
18.3	First-Order Difference Equations		18-4
18.4	Higher Order Difference Equations		18-8
<b>19</b>	<b>Process Algebra</b>	<i>J.C.M. Baeten, D.A. van Beek and J.E. Rooda</i>	19-1
19.1	Introduction		19-1
19.2	Syntax and Informal Semantics of the $\chi$ Process Algebra		19-4
19.3	Algebraic Reasoning and Verification		19-11
19.4	Conclusions		19-19

<b>20</b>	<b>Temporal Logic</b>	<i>Antony Galton</i>	20-1
20.1	Propositional Logic		20-1
20.2	Introducing Temporal Logic		20-3
20.3	Syntax and Semantics		20-5
20.4	Models of Time		20-6
20.5	Further Extensions to the Formal Language		20-11
20.6	Illustrative Examples		20-11
20.7	Conclusion		20-14
20.8	Further Reading		20-14
<b>21</b>	<b>Modeling Dynamic Systems with Cellular Automata</b>		
	<i>Peter M.A. Sloot and Alfons G. Hoekstra</i>		21-1
21.1	Introduction		21-1
21.2	A Bit of History		21-2
21.3	Cellular Automata to Model Dynamical Systems		21-3
21.4	One-Dimensional CAs		21-3
21.5	Lattice Gas Cellular Automata Models of Fluid Dynamics		21-5
<b>22</b>	<b>Spatio-Temporal Connectionist Networks</b>	<i>Stefan C. Kremer</i>	22-1
22.1	Introduction		22-1
22.2	Connectionist Networks (CNs)		22-2
22.3	Spatio-Temporal Connectionist Networks		22-4
22.4	Representational Power		22-6
22.5	Learning		22-6
22.6	Applications		22-8
22.7	Conclusion		22-9
<b>23</b>	<b>Modeling Causality with Event Relationship Graphs</b>	<i>Lee Schruben</i>	23-1
23.1	Introduction		23-1
23.2	Background and Definitions		23-2
23.3	Enrichments to Event Relations Graphs		23-7
23.4	Relationships to Other Discrete-Event System Modeling Methods		23-10
23.5	Simulation of Event Relationship Graphs		23-16
23.6	Event Relationship Graph Analysis		23-16
23.7	Experimenting with ERGs		23-17
<b>24</b>	<b>Petri Nets for Dynamic Event-Driven System Modeling</b>	<i>Jiacun Wang</i>	24-1
24.1	Introduction		24-1
24.2	Petri Net Definition		24-1
24.3	Transition Firing		24-3
24.4	Modeling Power		24-4
24.5	Petri Net Properties		24-5
24.6	Analysis of Petri Nets		24-7
24.7	Colored Petri Nets		24-10
24.8	Timed Petri Nets		24-12
24.9	Concluding Remark		24-16
<b>25</b>	<b>Queueing System Models</b>	<i>Christos G. Cassandras</i>	25-1
25.1	Introduction		25-1
25.2	Specification of Queueing System Models		25-2

25.3	Performance of a Queueing System .....	25-4
25.4	Queueing System Dynamics .....	25-6
25.5	Little's Law .....	25-7
25.6	Simple Markovian Queueing Models .....	25-8
25.7	Markovian Queueing Networks .....	25-11
25.8	Non-Markovian Queueing Systems .....	25-17
<b>26</b>	<b>Port-Based Modeling of Engineering Systems in Terms of Bond Graphs</b>	
	<i>Peter Breedveld</i> .....	26-1
26.1	Introduction .....	26-1
26.2	Structured Systems: Physical Components and Interaction .....	26-4
26.3	Bond Graphs .....	26-5
26.4	Multiport Generalizations .....	26-21
26.5	Conclusion .....	26-28
<b>27</b>	<b>System Dynamics Modeling of Environmental Systems</b> <i>Andrew Ford</i> .....	27-1
27.1	Introductory Examples .....	27-1
27.2	Comparison of the Flowers and Sales Models .....	27-4
27.3	Background on Daisy World .....	27-6
27.4	The Daisy World Model .....	27-6
27.5	The Daisy World Management Flight Simulator .....	27-9
<b>28</b>	<b>Dynamic Simulation with Energy Systems Language</b> <i>Clay L. Montague</i> .....	28-1
28.1	Introduction .....	28-1
28.2	Reading an Energy Systems Language Diagram .....	28-4
28.3	Translating a Diagram to Dynamic Equations .....	28-8
28.4	Calibration of Model Constants .....	28-21
28.5	Preparation for Simulation .....	28-22
28.6	Dynamic Output of the Marsh Sector Model .....	28-27
28.7	A Brief Comparison with Forrester's Systems Dynamics Approach .....	28-29
28.8	Conclusions .....	28-31
<b>29</b>	<b>Ecological Modeling and Simulation: From Historical Development to Individual-Based Modeling</b> <i>David R.C. Hill and P. Coquillard</i> .....	29-1
29.1	Introduction .....	29-1
29.2	An Old Story? .....	29-2
29.3	Determinism or Probability? .....	29-5
29.4	Modeling Techniques .....	29-5
29.5	The Use of Models in Ecology .....	29-6
29.6	Models are Scientific Instruments .....	29-7
29.7	Levels of Organization and Methodological Choices .....	29-8
29.8	Individual-Based Models .....	29-9
29.9	Applications .....	29-12
29.10	Conclusion .....	29-15
<b>30</b>	<b>Ontology-Based Simulation in Agriculture and Natural Resources</b>	
	<i>Howard Beck, Rohit Badal and Yunchul Jung</i> .....	30-1
30.1	Introduction .....	30-1
30.2	Ways in Which Ontologies can be Applied to Simulation .....	30-2

30.3	How to Build an Ontology-Based Simulation— Bioprocessing Example .....	30-6
30.4	Tools for Ontology-Based Simulation .....	30-10
30.5	Conclusions .....	30-12
<b>31</b>	<b>Modeling Human Interaction in Organizational Systems</b>	
	<i>Stewart Robinson</i> .....	31-1
31.1	Introduction .....	31-1
31.2	Systems and Human Interaction .....	31-2
31.3	Why Model Human Interaction? .....	31-3
31.4	Modeling Human Interaction: Research and Practice .....	31-4
31.5	The KBI Methodology .....	31-5
31.6	A Case Study: Modeling Human Decision Making at Ford Motor Company .....	31-8
31.7	Conclusion .....	31-12
<b>32</b>	<b>Military Modeling</b> <i>Roger Smith</i> .....	32-1
32.1	Introduction .....	32-1
32.2	Applications .....	32-1
32.3	Representation .....	32-2
32.4	Dynamics .....	32-4
32.5	Modeling Approach .....	32-8
32.6	Military Simulation Systems .....	32-11
32.7	Conclusion .....	32-12
<b>33</b>	<b>Dynamic Modeling in Management Science</b> <i>Michael Pidd</i> .....	33-1
33.1	Introduction .....	33-1
33.2	An Approach to Dynamic Systems Modeling in Management Science .....	33-4
33.3	Discrete Event Simulation .....	33-7
33.4	System Dynamics in Management Science .....	33-16
33.5	Model Validation .....	33-21
33.6	Chapter Summary .....	33-22
<b>34</b>	<b>Modeling and Analysis of Manufacturing Systems</b>	
	<i>E. Lefeber and J.E. Rooda</i> .....	34-1
34.1	Introduction .....	34-1
34.2	Preliminaries .....	34-2
34.3	Analytical Models for Steady-State Analysis .....	34-3
34.4	Discrete-Event Models .....	34-7
34.5	Effective Process Times .....	34-8
34.6	Control of Manufacturing Systems: A Framework .....	34-10
34.7	Standard Fluid Model and Extensions .....	34-12
34.8	Flow Models .....	34-16
34.9	Conclusions .....	34-18
<b>35</b>	<b>Sensor Network Component-Based Simulator</b>	
	<i>Boleslaw K. Szymanski and Gilbert Gang Chen</i> .....	35-1
35.1	The Need for a New Sensor Network Simulator .....	35-1
35.2	Component Simulation Toolkit .....	35-3
35.3	Wireless Sensor Network Simulation .....	35-7
35.4	Conclusions .....	35-15

## V Case Studies

---

<b>36</b>	<b>Multidomain Modeling with Modelica</b>	
	<i>Martin Otter, Hilding Elmqvist and Sven Erik Mattsson</i> .....	36-1
36.1	Modelica Overview .....	36-1
36.2	Modelica Basics .....	36-3
36.3	Modelica Libraries .....	36-17
36.4	Symbolic Processing of Modelica Models .....	36-19
36.5	Outlook .....	36-25
<b>37</b>	<b>On Simulation of Simulink® Models for Model-Based Design</b>	
	<i>Rohit Shenoy, Brian McKay and Pieter J. Mosterman</i> .....	37-1
37.1	Introduction .....	37-1
37.2	The Case Study Example .....	37-3
37.3	Designing with Simulation .....	37-4
37.4	Obtaining Computational Models .....	37-4
37.5	The Robotic Arm Model .....	37-7
37.6	Using Computational Models for Control Design .....	37-12
37.7	Testing with Model-Based Design .....	37-16
37.8	Conclusions .....	37-19
	<b>Index</b> .....	<b>I-1</b>