The Power of Events

An Introduction to Complex Event Processing in Distributed Enterprise Systems

David Luckham

AAddison-Wesley Boston • San Francisco • New York • Toronto • Montreal London • Munich • Paris • Madrid Capetown • Sydney • Tokyo • Singapore • Mexico City

Contents

	Pre	face	XV
	Ack	knowledgments	xix
PA	RT	A Simple Introduction to Complex	
Ev	ent	Processing	I
1	Th	e Global Information Society and the Need	
for	Ne	w Technology	3
	1.1	Distributed Information Systems Everywhere	4
	1.2	The Global Communication Spaghetti Pot	7
		1.2.1 Event Causality	10
	1.3	Electronic Archeology: Layers upon Layers	10
		1.3.1 A Layered Enterprise System	11
		1.3.2 Vertical Causality: Tracking Events up and	
		down the Layers	15
		1.5.5 Event Aggregation: Making High-Level Sense	16
	11	The Cathering Storm of New Activities on the Web	10
	1.4	Clabal Electronic Trade	1/
	1.0	A sile Systems	10
	1.0	Aglie Systems	21
	1./	Cyber Wartare and the Open Electronic Society	23
	1.8	Summary: Staying ahead of Chaos	26
2	Ma	naging the Electronic Enterprise in the Global	
Eve	ent	Cloud	27
	2.1	How the Global Event Cloud Forms	28
		2.1.1 The Open Enterprise	28
		2.1.2 The Global Event Cloud	28
		2.1.3 The Electronic Enterprise	29
	2.2	Operating in the Global Event Cloud	30
	2.3	Going Beyond Workflow	33
	2.4	Parallel and Asynchronous Processes	35
	2.5	On-the-Fly Process Evolution	37

	2.6	Exceptions Must Be First-Class Citizens	
		in Process Design	39
	2.7	Summary: Managing the Electronic Enterprise	41
3	Vie	ewing the Electronic Enterprise—Keeping	
th	e H	uman in Control	43
	3.1	Today's Event Monitoring Is Too Primitive	44
		3.1.1 System Monitoring Focuses on the Network	4.4
		2.1.2 Network-Level Monitoring Doesn't Even Solve	44
		Network Problems	45
	3.2	An Example of Causal Tracking	46
	3.3	Information Gaps	49
		3.3.1 Examples of Information Gaps	50
	3.4	Problem-Relevant Information	51
	3.5	Viewing Enterprise Systems	53
	3.6	Creating and Coordinating Multiple Views	55
	3.7	Hierarchical Viewing	56
		3.7.1 An Example of Hierarchical Viewing	57
	3.8	Summary: Viewing the Electronic Enterprise	59
4	De	signing the Electronic Enterprise	61
4	De 4.1	signing the Electronic Enterprise Process Architectures	61 62
4	De 4.1 4.2	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle	61 62 63
4	De: 4.1 4.2 4.3	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures	61 62 63 67
4	De 4.1 4.2 4.3	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations	61 62 63 67 67
4	De 4.1 4.2 4.3	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations 4.3.2 Architectural Structure 4.3.3 Interface Communication Architectures	61 62 63 67 67 68 68
4	De : 4.1 4.2 4.3	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations 4.3.2 Architectural Structure 4.3.3 Interface Communication Architectures 4.3.4 Architecture Diagrams	61 62 63 67 67 68 68 68 70
4	De 4.1 4.2 4.3	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations 4.3.2 Architectural Structure 4.3.3 Interface Communication Architectures 4.3.4 Architecture Diagrams 4.3.5 Behavior Specification	61 62 63 67 67 68 68 70 72
4	De: 4.1 4.2 4.3	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design Constraints	61 62 63 67 67 68 68 70 72 74
4	De 4.1 4.2 4.3	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design ConstraintsExamples of Informal Annotations	61 62 63 67 67 68 68 70 72 74 74
4	De: 4.1 4.2 4.3 4.3	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design ConstraintsExamples of Informal AnnotationsDynamic Process Architectures	61 62 63 67 67 68 68 70 72 74 74 74
4	De 4.1 4.2 4.3 4.3	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design ConstraintsExamples of Informal AnnotationsDynamic Process Architectures4.5.1 Diagrams for Dynamic Architectures?	61 62 63 67 67 68 68 70 72 74 74 78 81
4	De: 4.1 4.2 4.3 4.4 4.5 4.6	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design ConstraintsExamples of Informal AnnotationsDynamic Process Architectures4.5.1 Diagrams for Dynamic Architectures?Layered Architectures and Plug-and-Play	61 62 63 67 67 68 68 70 72 74 74 74 74 81
4	De: 4.1 4.2 4.3 4.4 4.5 4.6	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations 4.3.2 Architectural Structure 4.3.3 Interface Communication Architectures 4.3.4 Architecture Diagrams 4.3.5 Behavior Specification 4.3.6 Design Constraints Examples of Informal Annotations Dynamic Process Architectures 4.5.1 Diagrams for Dynamic Architectures? Layered Architectures and Plug-and-Play 4.6.1 Abstraction Principle	61 62 63 67 67 68 68 70 72 74 74 74 78 81 81
4	De: 4.1 4.2 4.3 4.3 4.4 4.5 4.6 4.7	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design ConstraintsExamples of Informal AnnotationsDynamic Process Architectures4.5.1 Diagrams for Dynamic Architectures?Layered Architectures and Plug-and-Play4.6.1 Abstraction PrincipleSummary: Technology to Support ProcessArchitecture	61 62 63 67 67 68 68 70 72 74 74 74 74 81 81 83
4	De: 4.1 4.2 4.3 4.3 4.4 4.5 4.6 4.7	signing the Electronic EnterpriseProcess ArchitecturesRoles of Architecture in the Process LifecycleConstituents of Process Architectures4.3.1 Annotations4.3.2 Architectural Structure4.3.3 Interface Communication Architectures4.3.4 Architecture Diagrams4.3.5 Behavior Specification4.3.6 Design ConstraintsExamples of Informal AnnotationsDynamic Process Architectures4.5.1 Diagrams for Dynamic Architectures?Layered Architectures and Plug-and-Play4.6.1 Abstraction PrincipleSummary: Technology to Support ProcessArchitecture	61 62 63 67 67 68 68 70 72 74 74 74 78 81 81 83 84
4	De: 4.1 4.2 4.3 4.4 4.5 4.6 4.7 Evo	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations 4.3.2 Architectural Structure 4.3.3 Interface Communication Architectures 4.3.4 Architecture Diagrams 4.3.5 Behavior Specification 4.3.6 Design Constraints Examples of Informal Annotations Dynamic Process Architectures 4.5.1 Diagrams for Dynamic Architectures? Layered Architectures and Plug-and-Play 4.6.1 Abstraction Principle Summary: Technology to Support Process Architecture ents, Timing, and Causality	 61 62 63 67 67 68 68 70 72 74 74 78 81 81 83 84 87
4	De: 4.1 4.2 4.3 4.3 4.4 4.5 4.6 4.7 Evo 5.1	signing the Electronic Enterprise Process Architectures Roles of Architecture in the Process Lifecycle Constituents of Process Architectures 4.3.1 Annotations 4.3.2 Architectural Structure 4.3.3 Interface Communication Architectures 4.3.4 Architecture Diagrams 4.3.5 Behavior Specification 4.3.6 Design Constraints Examples of Informal Annotations Dynamic Process Architectures 4.5.1 Diagrams for Dynamic Architectures? Layered Architectures and Plug-and-Play 4.6.1 Abstraction Principle Summary: Technology to Support Process Architecture ents, Timing, and Causality What Events Are	 61 62 63 67 67 68 68 70 72 74 74 74 78 81 81 83 84 87 88

Contents

	5.3 Time, Causality, and Aggregation	94
	5.3.1 The Cause-Time Axiom	96
	5.4 Genetic Parameters in Events	96
	5.4.1 Timestamps ,	96
	5.4.2 Causal Vectors	97
	5.5 Time	97
	5.6 Causality and Posets	- 100
	5.7 Causal Event Executions—Real-Time Posets	102
	5.8 Orderly Observation	109
	5.9 Observation and Uncertainty	110
	5.10 Summary	111
6	Event Patterns, Rules, and Constraints	113
	6.1 Common Kinds of Pattern Searching	113
	6.2 Event Patterns	114
	6.3 A Strawman Pattern Language	116
	6.3.1 Pattern Matching	117
	6.3.2 Writing Patterns in STRAW-EPL	117
	6.4 Event Pattern Rules	119
	6.5 Constraints	124
	6.6 Summary	126
7	Complex Events and Event Hierarchies	127
	7.1 Aggregation and Complex Events	127
	7.2 Creating Complex Events	129
	7.3 Event Abstraction Hierarchies	131
	7.3.1 Viewing a Fabrication Line	132
	7.4 Building Personalized Concept Abstraction	
	Hierarchies	133
	7.4.1 Viewing Network Activity	134
	7.4.2 Viewing Stock-Trading Activity	138
	7.5 Summary	141
P/	ART II Building Solutions with CEP	143
8	The RAPIDE Pattern Language	145
	8.1 Event Pattern Languages—Basic Requirements	146
	8.2 Features of RAPIDE	147
	8.3 Types	148
	8.3.1 Predefined Types	149
	8.3.2 Structured Types	150

Contents

J 1	151
8.3.4 Execution Types	153
8.3.5 Subtyping of Executions	155
8.4 Attributes of Events	155
8.5 Basic Event Patterns	157
8.6 Placeholders and Pattern Matching	158
8.6.1 Matching Basic Event Patterns	- 159
8.6.2 Placeholder Bindings	159
8.6.3 Notation to Aid in Writing Patterns	161
8.7 Relational Operators and Complex Patterns	163
8.7.1 Relational Operators	165
8.8 Guarded Patterns	167
8.8.1 Content-Based Pattern Matching	167
8.8.2 Context-Based Pattern Matching	168
8.8.3 Temporal Operators	169
8.9 Repetitive Patterns	169
8.10 Pattern Macros	172
8.11 Summary	174
CEP Rules and Agents	175
9.1 Overview	176
9.2 Event Pattern Rules	$\Gamma T T$
9.2 Event Pattern Rules9.2.1 Definition of Event Pattern Rules	177 178
9.2 Event Pattern Rules9.2.1 Definition of Event Pattern Rules9.2.2 Rule Bodies	177 178 178
9.2 Event Pattern Rules9.2.1 Definition of Event Pattern Rules9.2.2 Rule Bodies9.2.3 Context and Visibility Laws	177 178 178 179
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 	177 178 178 179 180
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 	177 178 178 179 180 182
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 	177 178 178 179 180 182 184
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.2.2 Pattern Rules 	177 178 178 179 180 182 184 184
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 	177 178 178 179 180 182 184 184 184
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4 Event Pattern Filters 	177 178 178 179 180 182 184 184 184 185 187
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Remediate of Ether 	177 178 178 179 180 182 184 184 184 185 187 187
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.2 Manual Eikern 	177 178 178 179 180 182 184 184 184 184 185 187 187 188
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 	177 178 178 179 180 182 184 185 187 185 187 187 188 190
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 9.4.5 Context Filters 	177 178 178 179 180 182 184 184 184 185 187 187 187 188 190 191
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 9.4.5 Context Filters 	177 178 178 179 180 182 184 184 184 185 187 187 187 188 190 191 191
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 9.4.5 Context Filters 9.5 Event Pattern Maps 9.5 1 Definition of Maps 	177 178 178 179 180 182 184 184 184 185 187 187 187 188 190 191 191 191
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 9.4.5 Context Filters 9.5 Event Pattern Maps 9.5.1 Definition of Maps 9.5.2 Semantics of Maps 	177 178 178 179 180 182 184 184 184 185 187 187 187 188 190 191 191 191 192 193 193
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 9.4.5 Context Filters 9.5 Event Pattern Maps 9.5.1 Definition of Maps 9.5.2 Semantics of Maps 9.6 Event Pattern Constraints 	177 178 178 179 180 182 184 184 184 185 187 187 187 188 190 191 191 192 193 193 195
 9.2 Event Pattern Rules 9.2.1 Definition of Event Pattern Rules 9.2.2 Rule Bodies 9.2.3 Context and Visibility Laws 9.2.4 Semantics of Event Pattern Rules 9.2.5 Examples of Rules 9.3 Event Processing Agents 9.3.1 Definition of EPAs 9.3.2 Semantics of EPAs 9.4 Event Pattern Filters 9.4.1 Definition of Filters 9.4.2 Semantics of Filters 9.4.3 Action Name Filters 9.4.4 Content Filters 9.4.5 Context Filters 9.5 Event Pattern Maps 9.5.1 Definition of Maps 9.5.2 Semantics of Maps 9.6 Event Pattern Constraints 9.6.1 Definition of Constraints 	177 178 178 179 180 182 184 184 185 187 187 187 187 188 190 191 191 192 193 193 193 195 195

	9.	6.2 Semantics of Constraints	195
	9.	6.3 Examples of Constraints	199
	9.7 O	other Classes of EPAs	204
	9.8 S	ummary	205
10	Ever	nt Processing Networks	207
	10.1	Common Structures of EPNs	208
		10.1.1 Flexibility of Event Processing Networks	211
	10.2	Connecting Event Processing Agents	212
		10.2.1 Basic Connections	212
		10.2.2 Guarded Connections	214
		10.2.3 Multiple Basic Connections	215
	10.3	Dynamic Event Processing Networks	216
		10.3.1 Class Connections	216
		10.3.2 Connection Generators	217
	10.4	Architectures and Event Processing Networks	210
	10.4	10.4.1 Architecture Classes	221
		10.4.2 Semantics of Architecture Classes	222
	10.5	Examples of EPNs and Architectures	224
	10.6	Case Study: EPNs for Network Viewing	230
	10.0	10.6.1 Visual Tools for Constructing EPNs	234
		10.6.2 Security	235
		10.6.3 Scalability	235
	10.7	Summary	235
11	Cau	sal Models and Causal Maps	239
	11.1	Causality between Events, Revisited	240
	11.2	Why We Need Causal Models	242
	11.3	What Causal Models Are	243
	11.4	Defining a Causal Model and a Causal Map	244
	11.5	Using Pattern Pairs to Specify Causal Models	246
	11.5	11.5.1 Using Causal Rules	247
		11.5.2 Resolving Ambiguities	248
	11.6	Causal Maps	250
		11.6.1 A Small Example of a Causal Map	252
		11.6.2 A Second Example of a Causal Map	253
	11.7	Developing Accurate Causal Models	258
	11.8	Summary	260

12	Case	Study: Viewing Collaboration between	
Bu	siness	Processes	261
	12.1	A Collaborative Business Agreement	262
	12.2	An Interface Communication Architecture	264
	12.3	Causal Model	265
	12.4	Causal Map	265
	12.5	Examples of Causal Rules	267
	12.6 I	Examples of Constraints	269
	12.7	Analysis of Examples of Posets	269
	12.8	Constraint Checking Becomes Part	
	(of the Collaboration	274
13	Imple	ementing Event Abstraction Hierarchies	277
	13.1	The Accessible Information Gap	278
	13.2	Event Abstraction Hierarchies, Revisited	280
		1.3.2.1 Induced Causality	282
		13.2.2 Abstraction Effect on Constraints	282
		13.2.3 Modifiability	283
	13.3	Bridging the Information Gaps	285
	13.4	Steps to Apply a Hierarchy to a Target System	286
	13.5	A Hierarchy for a Fabrication Process	287
		13.5.1 Personal Views	288
		13.5.2 Implementation	290
		15.5.5 Diagnostics	290
14	Case	Study: Viewing a Financial Trading System	293
	14.1	A Small Stock-Trading System	294
	14.2	The Information Gap for STS	296
	14.3	An Event Abstraction Hierarchy for STS	298
	14.4	Building the Event Abstraction Hierarchy	299
		14.4.1 Level 1	300
	-	14.4.2 Level 2	301
		14.4.3 Level 3	311
	14.5	Implementing Hierarchical Viewing for STS	316
	14.6	Three Steps toward Human Control	319
	-	14.0.1 DIIII-DOWN Diagnostics	320 324
		14.6.2 The Abstraction Effect	324
	147	Summary	320
	17./ 1	Juliniary	541

15	Infrastructure for Complex Event Processing	329
	15.1 Examples of Forms of Observed Events	330
	15.2 Interfacing CEP Infrastructure to Target	
	Systems	335
	15.3 CEP Adapters	336
	15.4 CEP Runtime Infrastructure	339
	15.5 Infrastructure Interfaces and Components	340
	15.5.1 Functionality of the Interface	341
	15.6 Off-the-Shelf Infrastructure	343
	15.7 Event Pattern Languages	346
	15.8 Complex Event Pattern Matchers	348
	15.8.1 Quest for Scalability	348
	15.8.2 The Naive View of Pattern Matchers	348
	15.8.3 What Pattern Matchers Really Do	348
	15.8.4 Design Structure	349
	15.9 Rules Management	351
	15.10 Analysis Tools	353
	15.11 Summary	356
	Bibliography	357
	Index	359