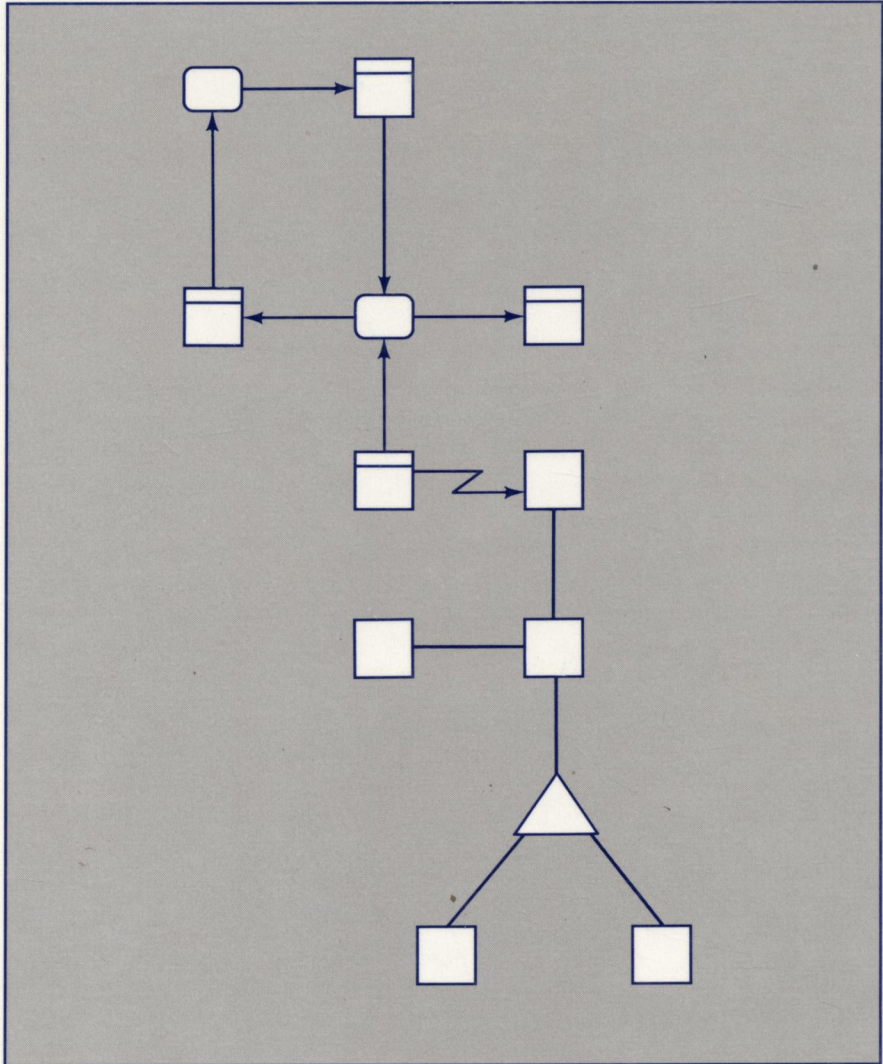


# Object-Oriented Systems Analysis

## A Model-Driven Approach



**David W. Embley**  
**Barry D. Kurtz**  
**Scott N. Woodfield**

# Contents

## **Preface**

**xiii**

## **1 Introduction**

**1**

- 1.1 Systems 1**
- 1.2 Systems Analysis 2**
- 1.3 Approaches to Systems Analysis 2**
  - 1.3.1 Natural Language Analysis, 2
  - 1.3.2 Process-Oriented Analysis, 3
  - 1.3.3 Object-Oriented Analysis, 4
- 1.4 Model-Driven Analysis 5**
- 1.5 Representing Reality 6**
- 1.6 Degree of Formality 7**
- 1.7 An OSA Overview 7**
  - 1.7.1 Object-Relationship Models, 8
  - 1.7.2 Object-Behavior Models, 8
  - 1.7.3 Large OSA Models, 11
  - 1.7.4 Object-Interaction Models, 12
  - 1.7.5 Model Integration, 12
  - 1.7.6 The Model-Building Process, 12

- 1.8 OSA 15
- 1.9 Bibliographic Notes 15

## 2 *The Object-Relationship Model*

17

- 2.1 Objects 18
- 2.2 Relationships 18
- 2.3 Object Classes 24
- 2.4 Relationship Sets 25
- 2.5 Constraints 30
  - 2.5.1 Participation Constraints, 30
  - 2.5.2 Co-occurrence Constraints, 34
  - 2.5.3 Object-Class Cardinality Constraints, 37
- 2.6 Special Relationship Sets 38
  - 2.6.1 Generalization—The *Is A* Relationship Set, 38
    - 2.6.1.1 Specialization constraints, 39
    - 2.6.1.2 Roles, 40
    - 2.6.1.3 Inheritance, 42
    - 2.6.1.4 Multiple inheritance, 43
  - 2.6.2 Aggregation—The *Is Part of* Relationship Set, 44
  - 2.6.3 Association—The *Is Member of* Relationship Set, 46
- 2.7 Special Object Classes 47
  - 2.7.1 Singleton Object Classes, 47
  - 2.7.2 Relational Object Classes, 49
- 2.8 General Constraints 50
- 2.9 Membership Conditions 52
- 2.10 Notes 55
- 2.11 Bibliographic Notes 56
- 2.12 Exercises 57

## 3 *The Object-Behavior Model*

60

- 3.1 States 60
- 3.2 Triggers and Transitions 61
- 3.3 Actions 62
- 3.4 State Nets for Behavior Modeling 63
  - 3.4.1 State Modeling, 63
  - 3.4.2 Transition Modeling, 64
  - 3.4.3 Concurrency, 66
- 3.5 Trigger Conditions and Events 66
  - 3.5.1 Condition-Based Triggers, 67

- 3.5.2 Event-Based Triggers, 67
- 3.5.3 Events as Objects, 68
- 3.5.4 Compound Triggers, 70
- 3.6 State Net Configurations 71**
  - 3.6.1 Subsequent States, 71
  - 3.6.2 Prior States, 73
  - 3.6.3 Initial Transitions, 76
  - 3.6.4 Final Transitions, 77
  - 3.6.5 Shorthand for Specifying Transitions, 79
  - 3.6.6 Remaining in an Enabling State When a Trigger Fires, 80
- 3.7 Exceptions 82**
- 3.8 Real-Time Constraints 84**
- 3.9 State Nets and Generalization-Specialization 88**
  - 3.9.1 Developing State Net Generalizations-Specializations, 88
  - 3.9.2 Shorthand for State Net Specialization, 90
- 3.10 A Sample State Net 91**
- 3.11 Bibliographic Notes 93**
- 3.12 Exercises 95**

## **4 Managing Complexity with Views**

98

- 4.1 Views for Object-Relationship Models 98**
- 4.2 Object-Class Views 100**
  - 4.2.1 Dominant and Independent Object-Class Views, 101
  - 4.2.2 Nested Object-Class Views, 103
  - 4.2.3 Valid Object-Class Views, 103
- 4.3 Relationship-Set Views 105**
  - 4.3.1 Participation Constraints in Relationship-Set Views, 106
  - 4.3.2 Relationship-Set Views Constructed from Parallel Relationship Sets, 106
  - 4.3.4 Valid Relationship-Set Views, 107
  - 4.3.5 A High-Level ORM for the Green-Grow Seed Company, 107
- 4.4 High-Level Views for State Nets 109**
- 4.5 High-Level State Views 113**
  - 4.5.1 Arrow Connections for State Views, 109
  - 4.5.2 Valid State Views, 113
- 4.6 High-Level Transition Views 116**
  - 4.6.1 Triggers and Actions in Transition Views, 118
  - 4.6.2 Exceptions and Transition Views, 118
  - 4.6.3 Valid Transition Views, 118
- 4.7 A High-Level State Net for a Packager 121**
- 4.8 Bibliographic Notes 122**

**4.9 Exercises 123****5 High-Level Modeling in OSA****126****5.1 High-Level Object Classes 127**

- 5.1.1 Dominant High-Level Object Classes, 127
- 5.1.2 Independent High-Level Object Classes, 127
- 5.1.3 Similarities and Differences Among ORM Aggregation Mechanisms, 135
- 5.1.4 Top-Down Perspective, 135

**5.2 High-Level Relationship Sets 136**

- 5.2.1 Construction by Set Operators, 137
- 5.2.2 Construction by Composition, 138
- 5.2.3 Other Constructions, 142
- 5.2.4 Top-Down Perspective, 143

**5.3 High-Level States 143**

- 5.3.1 Top-Down Development of State Details, 143
  - 5.3.1.1 *Entry specification for low-level state nets, 145*
  - 5.3.1.2 *High-level exit from low-level state nets, 145*
  - 5.3.1.3 *Controlled entry into low-level state nets, 146*
- 5.3.2 Bottom-Up Development of High-Level States, 148
  - 5.3.2.1 *Exit specification for low-level state nets, 148*
  - 5.3.2.2 *Controlled exit from low-level state nets, 148*
  - 5.3.2.3 *Entry and exit specifications and boundary-crossing connections, 151*
- 5.3.3 High-Level States and Aggregations, 154

**5.4 High-Level Transitions 158**

- 5.4.1 Top-Down Development of Transitions, 158
- 5.4.2 Bottom-Up Development of Transitions, 159

**5.5 Bibliographic Notes 164****5.6 Exercises 165****6 The Object-Interaction Model****167****6.1 Basic Interaction Diagrams 168****6.2 Interaction Descriptions 170****6.3 Synchronous Object Interaction 172****6.4 Asynchronous Object Interaction 173****6.5 Specifying Particular Interacting Objects 174****6.6 Interacting with Multiple Objects 175****6.7 Bidirectional Interaction 177**

- 6.8 Special Interaction Activities 178**
  - 6.8.1 Access, 179
  - 6.8.2 Modify, 179
  - 6.8.3 Remove and Destroy, 182
  - 6.8.4 Create and Add, 183
- 6.9 Bulletin-Board Communication 185**
- 6.10 Model Boundary-Crossing Interactions 186**
- 6.11 Continuous Interaction 186**
- 6.12 Time-Constrained Interactions 187**
- 6.13 General Interaction Constraints 188**
- 6.14 Interaction Within an Object Class 189**
- 6.15 High-Level Interactions 191**
  - 6.15.1 Interaction Sequences, 192
  - 6.15.2 Interaction Descriptions for High-Level Interactions, 194
  - 6.15.3 Views for High-Level Interaction Links, 196
- 6.16 Interactions and Generalization-Specialization 199**
- 6.17 Sample Interaction Diagrams 200**
  - 6.17.1 High-Level Interaction Within the Green-Grow Seed Company, 202
  - 6.17.2 Packager Interaction Within the Green-Grow Seed Company, 202
- 6.18 Bibliographic Notes 203**
- 6.19 Exercises 203**

## **7 Model Integration**

205

- 7.1 An Approach to Integration for OSA 205**
  - 7.1.1 Diagram Comparison, 206
  - 7.1.2 Diagram Conformance, 207
  - 7.1.3 Diagram Merge, 208
  - 7.1.4 Integration Policies, 208
- 7.2 Integration Framework 209**
- 7.3 ORM Integration 210**
  - 7.3.1 ORM Integration Strategy, 210
  - 7.3.2 Initial ORM Integration, 210
  - 7.3.3 Completion of ORM Integration, 213
  - 7.3.4 High-Level ORM Integration Views, 217
- 7.4 State-Net Integration 217**
  - 7.4.1 State-Net Integration Strategy, 218
  - 7.4.2 Initial State-Net Integration, 219
  - 7.4.3 Completion of State-Net Integration, 220
  - 7.4.4 State-Net Generalization, 224

7.5	<b>Mixed ORM and State-Net Integration</b>	<b>227</b>
7.6	<b>Integration Considerations for Object Interaction</b>	<b>229</b>
	7.6.1 New Object Classes,	230
	7.6.2 Additional State Nets,	230
	7.6.3 Adjustments to Existing State Nets,	230
7.7	<b>Summary Remark</b>	<b>235</b>
7.8	<b>Bibliographic Notes</b>	<b>235</b>
7.9	<b>Exercises</b>	<b>235</b>
<b>8</b>	<b><i>OSA Modeling—An Example</i></b>	<b>236</b>
8.1	<b>Amateur Radio Satellite Communication System</b>	<b>236</b>
8.2	<b>Satellite Information System</b>	<b>239</b>
8.3	<b>Real-Time and Simulated-Time Clocks</b>	<b>244</b>
8.4	<b>Satellite Tracking System</b>	<b>245</b>
8.5	<b>Antenna System</b>	<b>247</b>
8.6	<b>Summary Remark</b>	<b>252</b>
8.7	<b>Bibliographic Notes</b>	<b>252</b>
	<b><i>Appendix A A Formal Definition of OSA</i></b>	<b>253</b>
A.1	<b>Mapping from an ORM to First-Order Predicates and Rules</b>	<b>254</b>
	A.1.1 Predicates,	254
	A.1.2 Rules,	256
A.2	<b>Mapping from the First-Order Language to a Mathematical Model</b>	<b>264</b>
A.3	<b>The OSA Meta-Model</b>	<b>264</b>
	A.3.1 Translation of the First Constraint in Fig. A.4,	265
	A.3.2 Translation of the Second Constraint in Fig. A.4,	265
	A.3.3 Translation of the Third Constraint in Fig. A.4,	266
	A.3.4 Translation of the Fourth Constraint in Fig. A.4,	266
	<b><i>Appendix B Some Remarks on Specification, Design, and Implementation</i></b>	<b>286</b>
B.1	<b>OSS: Object-Oriented Systems Specification</b>	<b>286</b>
B.2	<b>OSD: Object-Oriented Systems Design</b>	<b>287</b>
B.3	<b>OSI: Object-Oriented Systems Implementation</b>	<b>288</b>
	<b><i>Appendix C References</i></b>	<b>289</b>
	<b><i>Index</i></b>	<b>293</b>