

APPLYING UML AND PATTERNS

An Introduction to Object-Oriented Analysis
and Design and the Unified Process

SECOND EDITION



"People often ask me which is the best book to introduce them to the world of OO design. Ever since I came across it, *Applying UML and Patterns* has been my unreserved choice."

—Martin Fowler, author, *UML Distilled* and *Refactoring*

CRAIG LARMAN

Foreword by Philippe Kruchten

TABLE OF CONTENTS

Foreword xv

Preface xvii

PART I INTRODUCTION

- 1 Object-Oriented Analysis and Design 3
 - Applying UML and Patterns in OOA/D 3
 - Assigning Responsibilities 6
 - What Is Analysis and Design? 6
 - What Is Object-Oriented Analysis and Design? 7
 - An Example 7
 - The UML 10
 - Further Readings 11
- 2 Iterative Development and the Unified Process 13
 - The Most Important UP Idea: Iterative Development 14
 - Additional UP Best Practices and Concepts 18
 - The UP Phases and Schedule-Oriented Terms 19
 - The UP Disciplines (was Workflows) 20
 - Process Customization and the Development Case 23
 - The Agile UP 24
 - The Sequential “Waterfall” Lifecycle 25
 - You Know You Didn’t Understand the UP When... 26
 - Further Readings 26
- 3 Case Study: The NextGen POS System 29
 - The NextGen POS System 29
 - Architectural Layers and Case Study Emphasis 30
 - The Book’s Strategy: Iterative Learning and Development 31

PART II INCEPTION

- 4 Inception 35
 - Inception: An Analogy 36
 - Inception May Be Very Brief 36
 - What Artifacts May Start in Inception? 37
 - You Know You Didn’t Understand Inception When... 38
- 5 Understanding Requirements 41
 - Types of Requirements 42
 - Further Readings 43
- 6 Use-Case Model: Writing Requirements in Context 45
 - Goals and Stories 46
 - Background 46
 - Use Cases and Adding Value 47
 - Use Cases and Functional Requirements 48
 - Use Case Types and Formats 49
 - Fully Dressed Example: Process Sale 50
 - Explaining the Sections 54
 - Goals and Scope of a Use Case 59
 - Finding Primary Actors, Goals, and Use Cases 63
 - Congratulations: Use Cases Have Been Written, and Are Imperfect 67
 - Write Use Cases in an Essential UI-Free Style 68
 - Actors 70
 - Use Case Diagrams 71
 - Requirements in Context and Low-Level Feature Lists 73
 - Use Cases Are Not Object-Oriented 75

	Use Cases Within the UP	75
	Case Study: Use Cases in the NextGen Inception Phase	79
	Further Readings	79
	UP Artifacts and Process Context	81
7	Identifying Other Requirements	83
	NextGen POS Examples	84
	NextGen Example: (Partial) Supplementary Specification	84
	Commentary: Supplementary Specification	88
	NextGen Example: (Partial) Vision	91
	Commentary: Vision	93
	NextGen Example: A (Partial) Glossary	98
	Commentary: Glossary (Data Dictionary)	99
	Reliable Specifications: An Oxymoron?	100
	Online Artifacts at the Project Website	101
	Not Much UML During Inception?	101
	Other Requirement Artifacts Within the UP	101
	Further Readings	104
	UP Artifacts and Process Context	105
8	From Inception to Elaboration	107
	Checkpoint: What Happened in Inception?	108
	On to Elaboration	109
	Planning the Next Iteration	110
	Iteration 1 Requirements and Emphasis: Fundamental OOA/D Skills	112
	What Artifacts May Start in Elaboration?	113
	You Know You Didn't Understand Elaboration When...	114

PART III ELABORATION ITERATION 1

9	Use-Case Model: Drawing System Sequence Diagrams	117
	System Behavior	118
	System Sequence Diagrams	118
	Example of an SSD	119
	Inter-System SSDs	120
	SSDs and Use Cases	120
	System Events and the System Boundary	120
	Naming System Events and Operations	121
	Showing Use Case Text	122
	SSDs and the Glossary	122
	SSDs Within the UP	123
	Further Readings	124
	UP Artifacts	125
10	Domain Model: Visualizing Concepts	127
	Domain Models	128
	Conceptual Class Identification	132
	Candidate Conceptual Classes for the Sales Domain	136
	Domain Modeling Guidelines	137
	Resolving Similar Conceptual Classes—Register vs. "POST"	139
	Modeling the <i>Unreal</i> World	140
	Specification or Description Conceptual Classes	140
	UML Notation, Models, and Methods: Multiple Perspectives	144
	Lowering the Representational Gap	146
	Example: The NextGen POS Domain Model	148
	Domain Models Within the UP	148
	Further Readings	150

TABLE OF CONTENTS

	UP Artifacts	151
11	Domain Model: Adding Associations	153
	Associations	153
	The UML Association Notation	154
	Finding Associations—Common Associations List	155
	Association Guidelines	157
	Roles	157
	How Detailed Should Associations Be?	159
	Naming Associations	160
	Multiple Associations Between Two Types	161
	Associations and Implementation	161
	NextGen POS Domain Model Associations	162
	NextGen POS Domain Model	163
12	Domain Model: Adding Attributes	167
	Attributes	167
	UML Attribute Notation	168
	Valid Attribute Types	168
	Non-primitive Data Type Classes	170
	Design Creep: No Attributes as Foreign Keys	172
	Modeling Attribute Quantities and Units	173
	Attributes in the NextGen Domain Model	174
	Multiplicity From SalesLineItem to Item	175
	Domain Model Conclusion	175
13	Use-Case Model: Adding Detail with Operation Contracts	177
	Contracts	177
	Example Contract: enterItem	178
	Contract Sections	179
	Postconditions	179
	Discussion—enterItem Postconditions	182
	Writing Contracts Leads to Domain Model Updates	183
	When Are Contracts Useful? Contracts vs. Use Cases?	183
	Guidelines: Contracts	184
	NextGen POS Example: Contracts	185
	Changes to the Domain Model	186
	Contracts, Operations, and the UML	186
	Operation Contracts Within the UP	188
	Further Readings	191
14	From Requirements to Design in this Iteration	193
	Iteratively Do the Right Thing, Do the Thing Right	193
	Didn't That Take Weeks To Do? No, Not Exactly.	194
	On to Object Design	194
15	Interaction Diagram Notation	197
	Sequence and Collaboration Diagrams	198
	Example Collaboration Diagram: makePayment	199
	Example Sequence Diagram: makePayment	200
	Interaction Diagrams Are Valuable	200
	Common Interaction Diagram Notation	201
	Basic Collaboration Diagram Notation	202
	Basic Sequence Diagram Notation	208
16	GRASP: Designing Objects with Responsibilities	215
	Responsibilities and Methods	216
	Responsibilities and Interaction Diagrams	217
	Patterns	218

TABLE OF CONTENTS

	GRASP: Patterns of General Principles in Assigning Responsibilities	219
	The UML Class Diagram Notation	220
	Information Expert (or Expert)	221
	Creator	226
	Low Coupling	229
	High Cohesion	232
	Controller	237
	Object Design and CRC Cards	245
	Further Readings	246
17	Design Model: Use-Case Realizations with GRASP Patterns	247
	Use-Case Realizations	248
	Artifact Comments	249
	Use-Case Realizations for the NextGen Iteration	252
	Object Design: makeNewSale	253
	Object Design: enterItem	255
	Object Design: endSale	260
	Object Design: makePayment	264
	Object Design: startUp	269
	Connecting the UI Layer to the Domain Layer	273
	Use-Case Realizations Within the UP	276
	Summary	278
18	Design Model: Determining Visibility	279
	Visibility Between Objects	279
	Visibility	280
	Illustrating Visibility in the UML	284
19	Design Model: Creating Design Class Diagrams	285
	When to Create DCDs	285
	Example DCD	286
	DCD and UP Terminology	286
	Domain Model vs. Design Model Classes	287
	Creating a NextGen POS DCD	287
	Notation for Member Details	296
	DCDs, Drawing, and CASE Tools	298
	DCDs Within the UP	298
	UP Artifacts	299
20	Implementation Model: Mapping Designs to Code	301
	Programming and the Development Process	302
	Mapping Designs to Code	304
	Creating Class Definitions from DCDs	304
	Creating Methods from Interaction Diagrams	307
	Container/Collection Classes in Code	309
	Exceptions and Error Handling	309
	Defining the Sale--makeLineItem Method	310
	Order of Implementation	311
	Test-First Programming	311
	Summary of Mapping Designs to Code	313
	Introduction to the Program Solution	313

PART IV ELABORATION ITERATION 2

21	Iteration 2 and its Requirements	319
	Iteration 2 Emphasis: Object Design and Patterns	319
	From Iteration 1 to 2	319
	Iteration 2 Requirements	321

TABLE OF CONTENTS

	Refinement of Analysis-oriented Artifacts in this Iteration	322
22	GRASP: More Patterns for Assigning Responsibilities	325
	Polymorphism	326
	Pure Fabrication	329
	Indirection	332
	Protected Variations	334
23	Designing Use-Case Realizations with GoF Design Patterns	341
	Adapter (GoF)	342
	"Analysis" Discoveries During Design: Domain Model	345
	Factory (GoF)	346
	Singleton (GoF)	348
	Conclusion of the External Services with Varying Interfaces Problem	352
	Strategy (GoF)	353
	Composite (GoF) and Other Design Principles	358
	Facade (GoF)	368
	Observer/Publish-Subscribe/Delegation Event Model (GoF)	372
	Conclusion	380
	Further Readings	380

PART V ELABORATION ITERATION 3

24	Iteration 3 and Its Requirements	383
	Iteration 3 Requirements	383
	Iteration 3 Emphasis	383
25	Relating Use Cases	385
	The include Relationship	386
	Terminology: Concrete, Abstract, Base, and Addition Use Cases	388
	The extend Relationship	389
	The generalize Relationship	390
	Use Case Diagrams	391
26	Modeling Generalization	393
	New Concepts for the Domain Model	393
	Generalization	396
	Defining Conceptual Superclasses and Subclasses	397
	When to Define a Conceptual Subclass	400
	When to Define a Conceptual Superclass	403
	NextGen POS Conceptual Class Hierarchies	403
	Abstract Conceptual Classes	406
	Modeling Changing States	408
	Class Hierarchies and Inheritance in Software	409
27	Refining the Domain Model	411
	Association Classes	411
	Aggregation and Composition	414
	Time Intervals and Product Prices—Fixing an Iteration 1 "Error"	418
	Association Role Names	419
	Roles as Concepts vs. Roles in Associations	420
	Derived Elements	421
	Qualified Associations	422
	Reflexive Associations	423
	Ordered Elements	423
	Using Packages to Organize the Domain Model	423
28	Adding New SSDs and Contracts	431
	New System Sequence Diagrams	431
	New System Operations	433
	New System Operation Contracts	434

TABLE OF CONTENTS

29	Modeling Behavior in Statechart Diagrams 437 Events, States, and Transitions 437 Statechart Diagrams 438 Statechart Diagrams in the UP? 439 Use Case Statechart Diagrams 439 Use Case Statechart Diagrams for the POS Application 441 Classes that Benefit from Statechart Diagrams 441 Illustrating External and Interval Events 443 Additional Statechart Diagram Notation 444 Further Readings 446
30	Designing the Logical Architecture with Patterns 447 Software Architecture 448 Architectural Pattern: Layers 450 The Model-View Separation Principle 471 Further Readings 474
31	Organizing the Design and Implementation Model Packages 475 Package Organization Guidelines 476 More UML Package Notation 482 Further Readings 483
32	Introduction to Architectural Analysis and the SAD 485 Architectural Analysis 486 Types and Views of Architecture 488 The Science: Identification and Analysis of Architectural Factors 488 Example: Partial NextGen POS Architectural Factor Table 491 The Art: Resolution of Architectural Factors 493 Summary of Themes in Architectural Analysis 499 Architectural Analysis within the UP 500 Further Readings 505
33	Designing More Use-Case Realizations with Objects and Patterns 507 Failover to Local Services; Performance with Local Caching 507 Handling Failure 512 Failover to Local Services with a Proxy (GoF) 519 Designing for Non-Functional or Quality Requirements 523 Accessing External Physical Devices with Adapters; Buy vs. Build 523 Abstract Factory (GoF) for Families of Related Objects 525 Handling Payments with Polymorphism and Do It Myself 528 Conclusion 535
34	Designing a Persistence Framework with Patterns 537 The Problem: Persistent Objects 538 The Solution: A Persistence Service from a Persistence Framework 538 Frameworks 539 Requirements for the Persistence Service and Framework 540 Key Ideas 540 Pattern: Representing Objects as Tables 541 UML Data Modeling Profile 541 Pattern: Object Identifier 542 Accessing a Persistence Service with a Facade 543 Mapping Objects: Database Mapper or Database Broker Pattern 543 Framework Design with the Template Method Pattern 546 Materialization with the Template Method Pattern 546 Configuring Mappers with a MapperFactory 552 Pattern: Cache Management 552 Consolidating and Hiding SQL Statements in One Class 553

Transactional States and the State Pattern	554
Designing a Transaction with the Command Pattern	556
Lazy Materialization with a Virtual Proxy	559
How to Represent Relationships in Tables	562
PersistentObject Superclass and Separation of Concerns	563
Unresolved Issues	564

PART VI SPECIAL TOPICS

35	On Drawing and Tools	567
	On Speculative Design and Visual Thinking	567
	Suggestions for UML Drawing Within the Development Process	568
	Tools and Sample Features	571
	Example Two	573
36	Introduction to Iterative Planning and Project Issues	575
	Ranking Requirements	576
	Ranking Project Risks	579
	Adaptive vs. Predictive Planning	579
	Phase and Iteration Plans	581
	Iteration Plan: What to Do in the Next Iteration?	582
	Requirements Tracking Across Iterations	583
	The (In)Validity of Early Estimates	585
	Organizing Project Artifacts	585
	Some Team Iteration Scheduling Issues	586
	You Know You Didn't Understand Planning in the UP When...	588
	Further Readings	588
37	Comments on Iterative Development and the UP	589
	Additional UP Best Practices and Concepts	589
	The Construction and Transition Phases	591
	Other Interesting Practices	592
	Motivations for Timeboxing an Iteration	593
	The Sequential "Waterfall" Lifecycle	593
	Usability Engineering and User Interface Design	599
	The UP Analysis Model	599
	The RUP Product	600
	The Challenge and Myths of Reuse	601
38	More UML Notation	603
	General Notation	603
	Implementation Diagrams	604
	Template (Parameterized, Generic) Class	606
	Activity Diagrams	607
	Bibliography	609
	Glossary	615
	Index	621