

Software Design

WILEY
INTERNATIONAL
EDITION

RESTRICTED: NOT FOR SALE
IN NORTH AMERICA

*From Programming
to Architecture*

Eric Braude

Preface	vii
Acknowledgments	xi
PROLOGUE <i>THE SOFTWARE PROCESS</i>	1
0.1 Introduction to Software Process	1
0.1.1 The Phases of Software Process	1
0.1.2 Styles of Software Process	2
0.1.3 Common Procedures for Software Process: Writing Against Prior Phases; Inspection	4
0.2 Requirements Analysis	4
0.2.1 Styles of Requirements Analysis	5
0.2.2 Tips on Analyzing and Specifying Requirements	7
0.3 Design (What this book covers!)	7
0.3.1 The Meaning of “Software Design”	8
0.3.2 The Manner in Which This Book Teaches Design	8
0.4 Coding	9
0.4.1 When Does Design Stop and Coding Begin?	9
0.4.2 Basic Coding Tips	9
0.5 Testing	15
0.5.1 Testing and Correctness	15
0.5.2 Types of Testing	15
0.5.3 Tips on Testing	16
0.6 Maintenance	17
0.6.1 The Meaning of “Maintenance”	17
0.6.2 How Maintenance Considerations Affect Process	17
Summary of Software Process	18
Exercises	18

**PART I. DESIGN PRINCIPLES, THE UNIFIED
MODELING LANGUAGE, AND CODE-LEVEL
DESIGN**

CHAPTER 1 <i>PROGRAMMING REVIEW AND INTRODUCTION TO SOFTWARE DESIGN</i>	21
--	----

1.1 “Software Design:” Its Meaning and How this Book Introduces It	21
1.1.1 Part I of this Book: Design Principles, the Unified Modeling Language, and Code-Level Design	22
1.1.2 Part II of this Book: Design Patterns	22
1.1.3 Part III of this Book: Components	22
1.1.4 Part IV of this Book: Object- Oriented Analysis and Design	22
1.2 Documenting Functions	22
1.2.1 Java Coding Standards Used in this Book	23
1.2.2 Specifying What a Function Does	23
1.2.3 Describing <i>How</i> a Function Satisfies Its Specification	25
1.2.4 Error Processing	27
1.3 Review of Good Programming Habits for Writing Functions	27
1.4 Goals of Software Design	27
1.4.1 An Example	28
1.4.2 Correctness, Sufficiency, Modularity, and Readability	31
1.4.3 Robustness	31
1.4.4 Flexibility	36
1.4.5 Reusability	37
1.4.6 Efficiency	37
1.4.7 Other Design Goals: Reliability and Usability	37
1.5 The Need for a Software Design Notation ...	38
Chapter Summary	38
Exercises	38
Appendix: Nonrobust Code for <i>CommandLineCalculator</i> Example	41

CHAPTER 2 *OBJECT-ORIENTATION*

2.1 The Goals of Object-Orientation	44
2.2 Classes and Objects	46
2.2.1 Introducing Classes	46
2.2.2 Instantiation	47
2.2.3 The Members of a Class	47

2.2.4 The “Client” Concept in Object-Orientation	48
2.3 Key Features of Object-Orientation.....	49
2.3.1 Inheritance	50
2.3.2 Polymorphism.....	50
2.3.3 Interfaces and Encapsulation	55
2.4 Issues to Be Addressed.....	57
Chapter Summary	58
Exercises.....	58

CHAPTER 3 THE UNIFIED MODELING LANGUAGE 61

3.1 Goals of the Unified Modeling Language	61
3.2 Classes in UML.....	61
3.3 Class Relationships in UML.....	63
3.3.1 Inheritance	63
3.3.2 Aggregation.....	63
3.3.3 Dependency	65
3.3.4 Association	65
3.3.5 An Example.....	66
3.4 Use Cases	67
3.4.1 What Are Use Cases?	67
3.4.2 Collections of Use Cases	68
3.4.3 Combining Use Cases	69
3.5 Sequence Diagrams.....	69
3.5.1 The Parts of a Sequence Diagram.....	70
3.6 State Models	72
3.6.1 The Meaning of <i>State</i>	72
3.6.2 Events	73
3.6.3 Transitions	73
3.6.4 State-Transition Diagrams.....	74
3.7 Activity Diagrams.....	74
3.7.1 Activity Diagram Notation.....	74
3.7.2 Example Using Activity Diagrams.....	75
3.8 An Example	76
Chapter Summary	79
Exercises.....	80

CHAPTER 4 DESIGN PRINCIPLES I: CORRECTNESS AND ROBUSTNESS 82

4.1 Correctness and Sufficiency.....	82
4.1.1 Approaches to Correctness.....	82
4.1.2 Interfaces to Modules	88
4.1.3 Modularization.....	91
4.1.4 Refactoring for Correctness and Sufficiency.....	93

4.2 Robustness.....	94
4.2.1 Verifying Input (Ensuring Environmental Robustness).....	94
4.2.2 Initializing to Improve Robustness	95
4.2.3 Parameter Passing Techniques to Improve Robustness.....	96
4.2.4 Enforcing Intentions.....	98
4.3 Design Details: How Much is Enough?	99
Chapter Summary	100
Exercises	100

CHAPTER 5 DESIGN PRINCIPLES II: FLEXIBILITY, REUSABILITY, AND EFFICIENCY..... 104

5.1 Flexibility.....	104
5.1.1 The Goals of Flexibility	104
5.1.2 Designs for Adding <i>More of the Same Kind</i> of Functionality.....	104
5.1.3 Design for Adding <i>Different Functionality</i>	105
5.1.4 Design for Flexibility.....	107
5.2 Reusability	107
5.2.1 The Goals of Reusability.....	108
5.2.2 Reusability of Function Design	108
5.2.3 Class Selection for Reuse.....	109
5.2.4 Class Combination for Reuse	110
5.3 Efficiency.....	114
5.3.1 Speed Efficiency	116
5.3.2 Storage Efficiency	118
5.4 Trade-offs Among Robustness, Flexibility, Reusability, and Efficiency	118
Chapter Summary	120
Exercises	121

PART II. DESIGN PATTERNS

CHAPTER 6 INTRODUCTION TO DESIGN PATTERNS 123

6.1 Recurring Design Purposes.....	123
6.1.1 An Example of a Recurring Design Purpose	124
6.2 What Are Design Patterns?.....	125
6.2.1 Example Application: Without Applying Design Patterns.....	126
6.2.2 Example Application: Applying a Design Pattern	126

6.3 Summary of Design Patterns by Type: <i>Creational, Structural, and Behavioral</i>	130
6.3.1 Creational Design Patterns.....	131
6.3.2 Structural Design Patterns.....	131
6.3.3 Behavioral Design Patterns.....	133
6.4 Characteristics of Design Patterns: <i>Viewpoints, Roles, and Levels</i>	136
6.4.1 Two Viewpoints for Describing a Pattern: <i>Static</i> and <i>Dynamic</i>	136
6.4.2 Two Levels of a Pattern: <i>Abstract</i> and <i>Concrete</i>	138
6.4.3 Three Roles Involved in Pattern Usage: <i>Pattern Application</i> , <i>Client</i> , and <i>Setup</i>	139
6.5 Design Pattern Forms: <i>Delegation</i> and <i>Recursion</i>	141
6.5.1 The Origins and Meaning of <i>Delegation</i>	141
6.5.2 The <i>Delegation</i> Design Pattern Form	141
6.5.3 The <i>Recursion</i> Design Pattern Form ..	143
Conclusion and Summary.....	144
Exercises.....	145
CHAPTER 7 <i>CREATIONAL DESIGN</i> <i>PATTERNS</i>	147
7.1 The Purposes of Creational Design	147
7.2 <i>Factory</i>	148
7.2.1 Design Purpose of <i>Factory</i>	148
7.2.2 The <i>Factory</i> Interface for Clients	148
7.2.3 The <i>Factory</i> Class Model.....	148
7.2.4 Sequence Diagram for <i>Factory</i>	150
7.2.5 Example <i>Factory</i> Application: E-Mail Generation	150
7.2.6 Use of <i>Factory</i> in the Java API.....	151
7.2.7 Comments on <i>Factory</i>	152
7.3 <i>Singleton</i>	153
7.3.1 Design Purpose of <i>Singleton</i>	153
7.3.2 The <i>Singleton</i> Interface for Clients ..	153
7.3.3 The <i>Singleton</i> Class Model.....	154
7.3.4 Example <i>Singleton</i> Application: Experiment	155
7.3.5 Use of <i>Singleton</i> in the Java API	155
7.3.6 Comments on <i>Singleton</i>	156
7.4 <i>Abstract Factory</i>	157
7.4.1 Design Purpose of <i>Abstract</i> <i>Factory</i>	157
7.4.2 The <i>Abstract Factory</i> Interface For Clients	158
7.4.3 The <i>Abstract Factory</i> Class Model.....	159
7.4.4 The <i>Abstract Factory</i> Sequence Diagram	161
7.4.5 Example <i>Abstract Factory</i> Application: "Word Processor"	161
7.4.6 Use of <i>Abstract Factory</i> in the Java API	163
7.4.7 Comments on <i>Abstract Factory</i>	164
7.5 <i>Prototype</i>	166
7.5.1 Design Purpose of <i>Prototype</i>	166
7.5.2 The <i>Prototype</i> Interface for Clients	167
7.5.3 The <i>Prototype</i> Class Model.....	169
7.5.4 The <i>Prototype</i> Sequence Diagram ..	169
7.5.5 Example <i>Prototype</i> Applications: Customer Information Entry	170
7.5.6 <i>Prototype</i> and the Java API.....	173
7.5.7 Comments on <i>Prototype</i>	178
Summary.....	179
Exercises.....	179
Appendix A: Code Listing for E-Mail Generation Example (<i>Factory</i> Design Pattern Application, Section 7.2).....	183
Appendix B: Code Listing for Experiment Example (<i>Singleton</i> Design Pattern Application, Section 7.3).....	188
Appendix C: Code Listing for Word Processor Example (<i>Abstract Factory</i> Design Pattern Application, Section 7.4).....	189
Appendix D: Code Listing for Customer Information Entry Example (<i>Prototype</i> Design Pattern Application, Section 7.5).....	199
CHAPTER 8 <i>STRUCTURAL DESIGN</i> <i>PATTERNS</i>	205
8.1 Structural Design Purposes.....	205
8.2 <i>Façade</i> : Interfacing for a Collection of Classes.....	205
8.2.1 The Design Purpose of <i>Façade</i>	205
8.2.2 Interface for Clients of <i>Façade</i>	206
8.2.3 The <i>Façade</i> Class Model	206
8.2.4 Example <i>Façade</i> Applications.....	206
8.2.5 Application of <i>Façade</i> in the Java API.....	210
8.2.6 Comments on <i>Façade</i>	210

8.3	<i>Decorator</i> : Adding and Removing Responsibilities of a Class at Runtime.....	211
8.3.1	The Design Purpose of <i>Decorator</i>	211
8.3.2	Interface for Clients of <i>Decorator</i>	212
8.3.3	The <i>Decorator</i> Class Model.....	212
8.3.4	The <i>Decorator</i> Sequence Diagram.....	212
8.3.5	Example Application of <i>Decorator</i> : Customer / Account.....	213
8.3.6	Applications of <i>Decorator</i> in the Java API.....	215
8.3.7	Comments on <i>Decorator</i>	215
8.4	<i>Composite</i> : Representing Trees of Objects.....	216
8.4.1	The Design Purpose of <i>Composite</i>	216
8.4.2	Interface for Clients of <i>Composite</i>	216
8.4.3	The <i>Composite</i> Class Model.....	217
8.4.4	The <i>Composite</i> Sequence Diagram.....	218
8.4.5	Example <i>Composite</i> Application: Bank / Teller.....	218
8.4.6	The <i>Composite</i> Pattern in the Java API.....	220
8.4.7	Comments on <i>Composite</i>	221
8.5	<i>Adapter</i> : Interfacing in a Flexible Manner.....	221
8.5.1	The Design Purpose of <i>Adapter</i>	221
8.5.2	Interface for Clients of <i>Adapter</i>	222
8.5.3	The <i>Adapter</i> Class Model.....	222
8.5.4	The <i>Adapter</i> Sequence Diagram.....	222
8.5.5	Example Applications of <i>Adapter</i>	223
8.5.6	<i>Adapter</i> and the Java API.....	225
8.5.7	Comments on <i>Adapter</i>	225
8.6	<i>Flyweight</i> : Managing Large Numbers of Barely Distinguishable Objects.....	226
8.6.1	The Design Purpose of <i>Flyweight</i>	226
8.6.2	Interface for Clients of <i>Flyweight</i>	227
8.6.3	The <i>Flyweight</i> Class Model.....	227
8.6.4	<i>Flyweight</i> Sequence Diagram.....	228
8.6.5	Example <i>Flyweight</i> Application: Text Magnifier.....	228
8.6.6	<i>Flyweight</i> in the Java API.....	232
8.6.7	Comments on <i>Flyweight</i>	232
8.7	<i>Proxy</i> : Avoiding Unnecessary Operations.....	233
8.7.1	The Design Purpose of <i>Proxy</i>	233
8.7.2	Interface for Clients of <i>Proxy</i>	233
8.7.3	The <i>Proxy</i> Class Model.....	234
8.7.4	<i>Proxy</i> Sequence Diagram.....	234
8.7.5	<i>Proxy</i> in the Java API.....	235
8.7.6	Example Applications of <i>Proxy</i> : Telephone Numbers.....	235
8.7.7	Comments on <i>Proxy</i>	237
	Summary of Structural Design Patterns.....	237
	Exercises.....	238
	Appendix A: Source Code for Section 8.2.4.2 “Banking” Application (<i>Façade</i> Design Pattern Application).....	242
	Appendix B: Source Code for Customer / Account Example in Section 8.3.5 (<i>Decorator</i> Design Pattern Application).....	250
	Appendix C: Source Code for Bank / Teller Example in Section 8.4.5 (<i>Composite</i> Design Pattern Application).....	257
	Appendix D: Source Code for Text Magnifier Example in Section 8.6.5 (<i>Flyweight</i> Design Pattern Application).....	262
	Appendix E: Source Code for “Telephone Numbers” Example in Section 8.7.6 (<i>Prototype</i> Design Pattern Application).....	270
CHAPTER 9 BEHAVIORAL DESIGN PATTERNS.....		276
9.1	Behavioral Design Purposes.....	276
9.2	<i>Interpreter</i> : Parsing Expressions.....	276
9.2.1	<i>Interpreter</i> Design Purposes and Examples.....	276
9.2.2	<i>Interpreter</i> Interfaces for Clients.....	277
9.2.3	The <i>Interpreter</i> Class Model.....	278
9.2.4	The <i>Interpreter</i> Sequence Diagram.....	278
9.2.5	Example <i>Interpreter</i> Application: Network Assembly.....	279
9.2.6	<i>Interpreter</i> in the Java API.....	282
9.2.7	Comments on <i>Interpreter</i>	282
9.3	<i>Iterator</i> : Visiting the Members of a Collection.....	283
9.3.1	<i>Iterator</i> Design Purposes and Examples.....	283
9.3.2	<i>Iterator</i> Interfaces for Clients.....	284
9.3.3	The <i>Iterator</i> Class Model.....	286
9.3.4	Example <i>Iterator</i> Application: Organization Chart.....	287
9.3.5	<i>Iterator</i> in the Java API.....	290
9.3.6	Comments on <i>Iterator</i>	294
9.4	<i>Mediator</i>	295
9.4.1	The Design Purpose of <i>Mediator</i>	295
9.4.2	The <i>Mediator</i> Class Model.....	297
9.4.3	Sequence Diagram for <i>Mediator</i>	298
9.4.4	Example of <i>Mediator</i>	298
9.4.5	<i>Mediator</i> in the Java API.....	299
9.4.6	Comments on <i>Mediator</i>	300

9.5	<i>Observer</i>	301
9.5.1	The Design Purposes of <i>Observer</i>	301
9.5.2	<i>Observer</i> Interfaces for Clients	301
9.5.3	The <i>Observer</i> Class Model	302
9.5.4	Example <i>Observer</i> Applications	302
9.5.5	<i>Observer</i> in the Java API	304
9.5.6	Comments on <i>Observer</i>	305
9.6	<i>State</i>	306
9.6.1	The Design Purposes of <i>State</i>	306
9.6.2	<i>State</i> Interfaces for Clients	306
9.6.3	The <i>State</i> Class Model	306
9.6.4	Example <i>State</i> Applications	307
9.6.5	<i>State</i> in the Java API	309
9.6.6	Comments on <i>State</i>	309
9.7	<i>Chain of Responsibility</i>	309
9.7.1	The Design Purpose of <i>Chain of Responsibility</i>	309
9.7.2	Interface to <i>Chain of Responsibility</i> for Clients	310
9.7.3	The <i>Chain of Responsibility</i> Class Model	310
9.7.4	Example <i>Chain of Responsibility</i> Application: Customer Information	311
9.7.5	<i>Chain of Responsibility</i> in the Java API	313
9.7.6	Comments on <i>Chain of Responsibility</i>	313
9.8	<i>Command</i>	314
9.8.1	The Design Purposes of <i>Command</i>	314
9.8.2	Interface to <i>Command</i> for Clients	314
9.8.3	The <i>Command</i> Class Model	314
9.8.4	Example <i>Command</i> Applications	315
9.8.5	<i>Command</i> in the Java API	318
9.8.6	Comments on <i>Command</i>	319
9.9	<i>Template</i>	319
9.9.1	The Design Purpose of <i>Template</i>	319
9.9.2	Interface to <i>Template</i> for Clients	320
9.9.3	The <i>Template</i> Class Model	320
9.9.4	Example <i>Template</i> Application: Quadratic Solutions	320
9.9.5	Application of <i>Template</i> in the Java API	323
9.9.6	Comments on <i>Template</i>	323
Summary	324
Exercises	324
Appendix A: Source Code for Network Assembly Example (Application of <i>Interpreter</i> Design Pattern)		328

Appendix B: Source Code for “Organization Chart” Example (Application of <i>Iterator</i> Design Pattern)	337
Appendix C: Source Code for Mutual Funds Example (Application of <i>Observer</i> Design Pattern)	350
Appendix D: Source Code for Customer Information Example (Application of <i>Chain of Responsibility</i> Design Pattern)	356
Appendix E: Source Code for Undo Example (Application of <i>Command</i> Design Pattern)	367
Appendix F: Source Code for Quadratic Solutions Example (Application of <i>Template</i> Design Pattern)	377

PART III. COMPONENTS

CHAPTER 10 <i>INTRODUCTION TO COMPONENTS</i>	384
10.1 Definition of Components	385
10.2 A Demonstration of Component Use	386
10.3 What Components Consist of	389
10.3.1 Properties, Methods, Events	389
10.3.2 Manifests	390
10.3.3 Introspection and Metadata	390
10.4 UML Component Notation	391
10.5 The Phases of a Component Lifetime	391
10.5.1 Design/Implementation Time	392
10.5.2 Instance Creation Time	393
10.5.3 Assembly Time	393
10.5.4 Deployment Time	394
10.5.5 Execution Time	394
10.6 The CORBA Component Standards	395
Summary of This Chapter	396
Exercises	397
Appendix: Source Code for <i>Juggler</i>	398
CHAPTER 11 <i>JAVABEANS</i>	404
11.1 The Goals of JavaBeans	404
11.2 Definition of JavaBeans	404
11.2.1 An Example: Estimating Chair Production	405
11.2.2 The Phases of a Bean	406
11.3 Phase 1: Creating Bean Classes	407
11.3.1 Example: Creating the <i>ChairMaker</i> Bean	412
11.4 Phase 2: Creating Multiple-Class Beans	415

XX CONTENTS

11.5 Phase 3: Creating Bean Instances	415
11.6 Phase 4: Combining and Deploying Beans... 416	
11.6.1 Phase 4a: Combining Beans	
in a Bean Environment.....	416
11.6.2 Phase 4b: Using Beans in	
Applications	419
11.7 Connecting Beans via Property Changes:	
“Bound” Variables	421
11.8 Using Beans in Java Server Pages	424
Summary	425
Exercises	426

CHAPTER 12 MICROSOFT ASSEMBLIES.....428

12.1 Microsoft .NET Overview	428
12.1.1 Goals of .NET.....	428
12.1.2 The Architecture of .NET	429
12.1.3 .NET Assemblies (Components)	431
12.2 Elements of the C# Language.....	431
12.3 A Simple HelloWorld .NET Assembly.....	435
12.4 A .NET Component Containing Multiple	
Classes	437
12.5 Metadata in .NET Assemblies	438
12.5.1 Summary of .NET Metadata.....	438
12.5.2 Viewing Metadata	439
12.5.3 Versioning.....	441
12.5.4 Attributes	444
12.6 Identifying an Assembly	449
12.6.1 Private Assemblies	449
12.6.2 Shared Assemblies	453
Summary	456
Exercises	456

PART IV. OBJECT-ORIENTED ANALYSIS AND DESIGN**CHAPTER 13 REQUIREMENTS AND DOMAIN CLASSES**458

13.1 Characteristics of Object-Oriented	
Analysis and Design	458
13.1.1 NonOOA&D Approaches to	
Application Development.....	459
13.1.2 The Basic OOA&D Approach	461
13.2 The <i>Encounter</i> Case Study Introduced	463
13.3 Obtaining Domain Classes	464
13.3.1 Use Case Requirements	
Description.....	465
13.3.2 Converting Use Cases to Sequence	
Diagrams	466

13.3.3 Harvesting Domain Classes from	
Sequence Diagrams.....	467
13.3.4 Finding Classes from Other	
Sources.....	467
13.4 Using Domain Classes to Organize	
Requirements	475
13.4.1 An Example Requirements	
Document Fragment.....	475
Summary of This Chapter	477
Exercises	477

CHAPTER 14 ARCHITECTURES AND FRAMEWORKS479

14.1 The Meaning of Software	
Architectures	479
14.2 Models of OO Analysis and Design	481
14.2.1 Use Case Model.....	481
14.2.2 Class Models	482
14.2.3 Data Flow Models.....	482
14.2.4 State Models	485
14.3 Software Architectures	487
14.3.1 Goals for Architecture and	
Modularization	487
14.3.2 Modularization, Cohesion, and	
Coupling	487
14.3.3 Using <i>Facade</i> Design Pattern	490
14.3.4 Standard Software Architectures	491
14.4 Frameworks.....	496
14.4.1 The Meaning and Usage of	
Frameworks	496
14.4.2 Framework Usages: Toolkits,	
Abstract Architecture, and Control....	498
14.4.3 Goals for Frameworks.....	498
14.4.4 Framework Development and	
Examples	500
14.5 Finalizing an Application Design.....	513
14.5.1 Designing Control	514
14.5.2 Designing for Interfaces.....	519
14.5.3 Connecting to Databases.....	524
14.5.4 Putting the Finishing Touches on	
Class Models	530
14.5.5 Completing the List of Functions	532
Summary	534
Exercises	534

REFERENCES.....537**INDEX**539