Covers through Version 2.0 OMG UML Standard

UML Distilled Third Edition

A Brief Guide to the Standard Object Modeling Language

MARTIN FOWLER

Forewords by Cris Kobryn, Grady Booch, Ivar Jacobson, and Jim Rumbaugh

Foreword to the Third Edition

Since ancient times, the most talented architects and the most gifted designers have known the law of parsimony. Whether it is stated as a paradox ("less is more"), or a koan ("Zen mind is beginner's mind"), its wisdom is timeless: Reduce everything to its essence so that form harmonizes with function. From the pyramids to the Sydney Opera House, from von Neumann architectures to UNIX and Smalltalk, the best architects and designers have strived to follow this universal and eternal principle.

Recognizing the value of shaving with Occam's Razor, when I architect and read I seek projects and books that adhere to the law of parsimony. Consequently, I applaud the book you are reading now.

You may find my last remark surprising at first. I am frequently associated with the voluminous and dense specifications that define the Unified Modeling Language (UML). These specifications allow tool vendors to implement the UML and methodologists to apply it. For seven years, I have chaired large international standardization teams to specify UML 1.1 and UML 2.0, as well as several minor revisions in between. During this time, the UML has matured in expressiveness and precision, but it has also added gratuitous complexity as a result of the standardization process. Regrettably, standardization processes are better known for design-by-committee compromises than parsimonious elegance.

What can a UML expert familiar with the arcane minutiae of the specification learn from Martin's distillation of UML 2.0? Quite a bit, as can you. To start with, Martin adroitly reduces a large and complex language into a pragmatic subset that he has proven effective in his practice. He has resisted the easy route of tacking on additional pages to the last edition of his book. As the language has grown, Martin has kept true to his goal of seeking the "fraction of UML that is most useful" and telling you just that. The fraction he refers to is the mythical 20 percent of UML that helps you do 80 percent of your work. Capturing and taming this elusive beast is no mean accomplishment!

It is even more impressive that Martin achieves this goal while writing in a wonderfully engaging conversational style. By sharing his opinions and anecdotes with us, he makes this book fun to read and reminds us that architecting and designing systems should be both creative and productive. If we pursue the parsimony koan to its full intent, we should find UML modeling projects to be as enjoyable as we found finger-painting and drawing classes in grammar school. UML should be a lightning rod for our creativity as well as a laser for precisely specifying system blueprints so that third parties can bid and build those systems. The latter is the acid test for any bona fide blueprint language.

So, while this may be a small book, it is not a trivial one. You can learn as much from Martin's approach to modeling as you can learn from his explanations of UML 2.0.

I have enjoyed working with Martin to improve the selection and correctness of the UML 2.0 language features explained in this revision. We need to keep in mind that all living languages, both natural and synthetic, must evolve or perish. Martin's choices of new features, along with your preferences and those of other practitioners, are a crucial part of the UML revision process. They keep the language vital and help it evolve via natural selection in the marketplace.

Much challenging work remains before model-driven development becomes mainstream, but I am encouraged by books like this that explain UML modeling basics clearly and apply them pragmatically. I hope you will learn from it as I have and will use your new insights to improve your own software modeling practices.

Cris Kobryn
Chair, U2 Partners' UML 2.0 Submission Team
Chief Technologist, Telelogic

Foreword to the First Edition

When we began to craft the Unified Modeling Language, we hoped that we could produce a standard means of expressing design that would not only reflect the best practices of industry, but would also help demystify the process of software system modeling. We believed that the availability of a standard modeling language would encourage more developers to model their software systems before building them. The rapid and widespread adoption of the UML demonstrates that the benefits of modeling are indeed well known to the developer community.

The creation of the UML was itself an iterative and incremental process very similar to the modeling of a large software system. The end result is a standard built on, and reflective of, the many ideas and contributions made by numerous individuals and companies from the object community. We began the UML effort, but many others helped bring it to a successful conclusion; we are grateful for their contribution.

Creating and agreeing on a standard modeling language is a significant challenge by itself. Educating the development community, and presenting the UML in a manner that is both accessible and in the context of the software development process, is also a significant challenge. In this deceptively short book, updated to reflect the most recent changes to the UML, Martin Fowler has more than met this challenge.

In a clear and friendly style, Martin not only introduces the key aspects of UML, but also clearly demonstrates the role UML plays in the development process. Along the way, we are treated to abundant nuggets of modeling insight and wisdom drawn from Martin's 12-plus years of design and modeling experience.

The result is a book that has introduced many thousands of developers to UML, whetting their appetite to further explore the many benefits of modeling with this now standard modeling language.

We recommend the book to any modeler or developer interested in getting a first look at UML and in gaining a perspective on the key role it plays in the development process.

Grady Booch
Ivar Jacobson
James Rumbaugh

Preface

I've been lucky in a lot of ways in my life; one of my great strokes of fortune was being in the right place with the right knowledge to write the first edition of this book in 1997. Back then, the chaotic world of object-oriented (OO) modeling was just beginning to unify under the Unified Modeling Language (UML). Since then, the UML has become the standard for the graphical modeling of software, not just for objects. My fortune is that this book has been the most popular book on the UML, selling more than a quarter of a million copies.

Well, that's very nice for me, but should you buy this book?

I like to stress that this is a brief book. It's not intended to give you the details on every facet of the UML, which has grown and grown over the years. My intention is to find that fraction of the UML that is most useful and tell you just that. Although a bigger book gives you more detail, it also takes longer to read. And your time is the biggest investment you'll make in a book. By keeping this book small, I've spent the time selecting the best bits to save you from having to do that selection yourself. (Sadly, being smaller doesn't mean proportionately cheaper; there is a certain fixed cost to producing a quality technical book.)

One reason to have this book is to begin to learn about the UML. Because this is a short book, it will quickly get you up to speed on the essentials of the UML. With that under your belt, you can go into more detail on the UML with the bigger books, such as the *User Guide* [Booch, UML user] or the *Reference Manual* [Rumbaugh, UML Reference].

This book can also act as a handy reference to the most common parts of the UML. Although the book doesn't cover everything, it's a lot lighter to carry around than most other UML books.

It's also an opinionated book. I've been working with objects for a long time now, and I have definite ideas about what works and what doesn't. Any book reflects the opinions of the author, and I don't try to hide mine. So if you're looking for something that has a flavor of objectivity, you might want to try something else.

Although many people have told me that this book is a good introduction to objects, I didn't write it with that in mind. If you are after an introduction to OO design, I suggest Craig Larman's book [Larman].

Many people who are interested in the UML are using tools. This book concentrates on the standard and on conventional usage of the UML and doesn't get into the details of what various tools support. Although the UML did resolve the tower of Babel of pre-UML notations, many annoying differences remain between what tools show and allow when drawing UML diagrams.

I don't say much in this book about Model Driven Architecture (MDA). Although many people consider the two to be the same thing, many developers use the UML without being interested in MDA. If you want to learn more about MDA, I would start with this book to get an overview of the UML first and then move on to a book that's more specific about MDA.

Although the main point of this book is the UML, I've also added bits of other material about techniques, such as CRC cards, that are valuable for OO design. The UML is just a part of what you need to succeed with objects, and I think that it's important to introduce you to some other techniques.

In a brief book like this, it's impossible to go into detail about how the UML relates to source code, particularly as there is no standard way of making that correspondence. However, I do point out common coding techniques for implementing pieces of the UML. My code examples are in Java and C#, as I've found that these languages are usually the most widely understood. Don't assume that I prefer those languages; I've done too much Smalltalk for that!

Why Bother with the UML?

Graphical design notations have been with us for a while. For me, their primary value is in communication and understanding. A good diagram can often help communicate ideas about a design, particularly when you want to avoid a lot of details. Diagrams can also help you understand either a software system or a business process. As part of a team trying to figure out something, diagrams both help understanding and communicate that understanding throughout a team. Although they aren't, at least yet, a replacement for textual programming languages, they are a helpful assistant.

Many people believe that in the future, graphical techniques will play a dominant role in software development. I'm more skeptical of that, but it's certainly useful to have an appreciation of what these notations can and can't do.

Of these graphical notations, the UML's importance comes from its wide use and standardization within the OO development community. The UML has become not only the dominant graphical notation within the OO world but also a popular technique in non-OO circles.

Structure of the Book

Chapter 1 gives an introduction to the UML: what it is, the different meanings it has to different people, and where it came from.

Chapter 2 talks about software process. Although this is strictly independent of the UML, I think that it's essential to understand process in order to see the context of something like the UML. In particular, it's important to understand the role of iterative development, which has been the underlying approach to process for most of the OO community.

I've organized the rest of the book around the diagram types within the UML. Chapters 3 and 4 discuss the two most useful parts of the UML: class diagrams (core) and sequence diagrams. Even though this book is slim, I believe that you can get the most value out of the UML by using the techniques that I talk about in these chapters. The UML is a large and growing beast, but you don't need all of it.

Chapter 5 goes into detail on the less essential but still useful parts of class diagrams. Chapters 6 through 8 describe three useful diagrams that shed further light on the *structure* of a system: object diagrams, package diagrams, and deployment diagrams.

Chapters 9 through 11 show three further useful *behavioral* techniques: use cases, state diagrams (although officially known as state machine diagrams, they are generally called state diagrams), and activity diagrams. Chapters 12 through 17 are very brief and cover diagrams that are generally less important, so for these, I've only provided a quick example and explanation.

The inside covers summarize the most useful parts of the notation. I've often heard people say that these covers are the most valuable part of the book. You'll probably find it handy to refer to them as you're reading some of the other parts of the book.

Changes for the Third Edition

If you have earlier editions of this book, you're probably wondering what is different and, more important, whether you should buy the new edition.

The primary trigger for the third edition was the appearance of UML 2. UML 2 has added a lot of new stuff, including several new diagram types. Even familiar diagrams have a lot of new notation, such as interaction frames in sequence diagrams. If you want to be aware of what's happened but don't want to wade through the specification (I certainly don't recommend that!), this book should give you a good overview.

I've also taken this opportunity to completely rewrite most of the book, bringing the text and examples up to date. I've incorporated much that I've learned in teaching and using the UML over the past five years. So although the spirit of this ultrathin UML book is intact, most of the words are new.

Over the years, I've worked hard to keep this book as current as is possible. As the UML has gone through its changes, I've done my best to keep pace. This book is based on the UML 2 drafts that were accepted by the relevant committee in June 2003. It's unlikely that further changes will occur between that vote and more formal votes, so I feel that UML 2 is now stable enough for my revision to go into print. I'll post information any further updates on my Web site (**http://martinfowler.com**).

Acknowledgments

Over many years, many people have been part of the success of this book. My first thanks go Carter Shanklin and Kendall Scott. Carter was the editor at Addison-Wesley who suggested this book to me. Kendall Scott helped me put together the first two editions, working over the text and graphics. Between them, they pulled off the impossible in getting the first edition out in an impossibly short time, while keeping up the high quality that people expect from Addison-Wesley. They also kept pushing out changes during the early days of the UML when nothing seemed stable.

Jim Odell has been my mentor and guide for much of the early part of my career. He's also been deeply involved with the technical and personal issues of making opinionated methodologists settle their differences and agree to a common standard. His contribution to this book is both profound and difficult to measure, and I bet it's the same for the UML too.

The UML is a creature of standards, but I'm allergic to standards bodies. So to know what's going on, I need a network of spies who can keep me up to date on all the machinations of the committees. Without these spies, including Conrad Bock, Steve Cook, Cris Kobryn, Jim Odell, Guus Ramackers, and Jim Rumbaugh, I would be sunk. They've all given me useful tips and answered stupid questions.

Grady Booch, Ivar Jacobson, and Jim Rumbaugh are known as the Three Amigos. Despite the playful jibes I've given them over the years, they have given me much support and encouragement with this book. Never forget that my jabs usually sprout from fond appreciation.

Reviewers are the key to a book's quality, and I learned from Carter that you can never have too many reviewers. The reviewers of the previous editions of this book were Simmi Kochhar Bhargava, Grady Booch, Eric Evans, Tom Hadfield, Ivar Jacobson, Ronald E. Jeffries, Joshua Kerievsky, Helen Klein, Jim Odell, Jim Rumbaugh, and Vivek Salgar.

The third edition also had a fine group of reviewers:

Conrad Bock

Andy Carmichael

Alistair Cockburn

Steve Cook

Luke Hohmann

Pavel Hruby

Jon Kern

Cris Kobryn

Craig Larman

Steve Mellor

Jim Odell

Alan O'Callaghan

Guus Ramackers

Jim Rumbaugh

Tim Seltzer

All these reviewers spent time reading the manuscript, and every one of them found at least one embarrassing howler. My sincere thanks to all of them. Any howlers that remain are entirely my responsibility. I will post an errata sheet to the books section of **martinfowler.com** when I find them.

The core team that designed and wrote the UML specification are Don Baisley, Morgan Björkander, Conrad Bock, Steve Cook, Philippe Desfray, Nathan Dykman, Anders Ek, David Frankel, Eran Gery, Øystein Haugen, Sridhar Iyengar, Cris Kobryn, Birger Møller-Pedersen, James Odell, Gunnar Övergaard, Karin Palmkvist, Guus Ramackers, Jim Rumbaugh, Bran Selic, Thomas Weigert, and Larry Williams. Without them, I would have nothing to write about.

Pavel Hruby developed some excellent Visio templates that I use a lot for UML diagrams; you can get them at **http://phruby.com**.

Many people have contacted me on the Net and in person with suggestions and questions and to point out errors. I haven't been able to keep track of you all, but my thanks are no less sincere.

The people at my favorite technical bookstore, SoftPro in Burlington, Massachusetts, let me spend many hours there looking at their stock to find how people use the UML in practice and fed me good coffee while I was there.

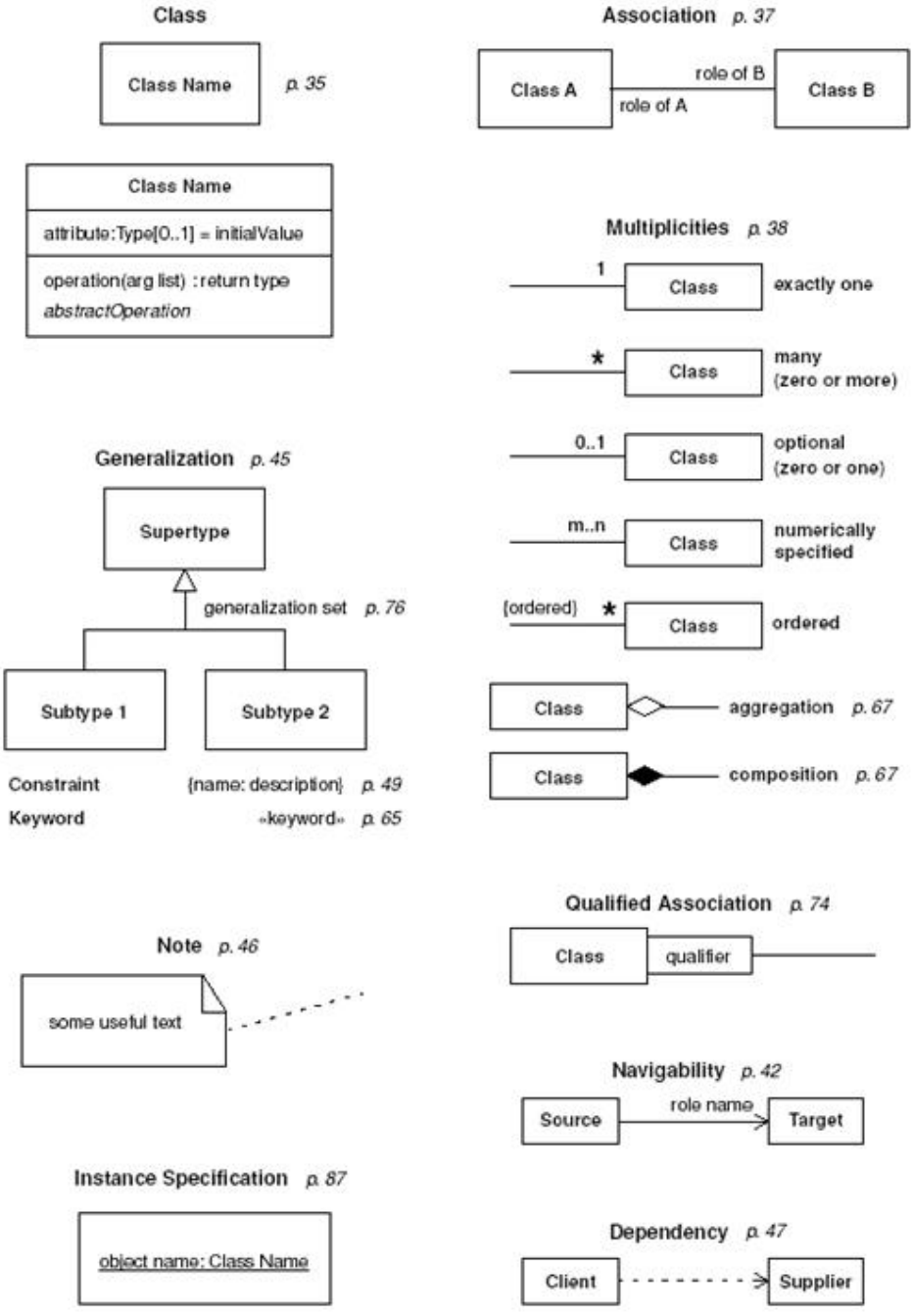
For the third edition, the acquisition editor was Mike Hendrickson. Kim Arney Mulcahy managed the project, as well as did the layout and clean-up of the diagrams. John Fuller, at Addison-Wesley, was the production editor, while Evelyn Pyle and Rebecca Rider helped with the copyediting and proofreading of the book. I thank them all.

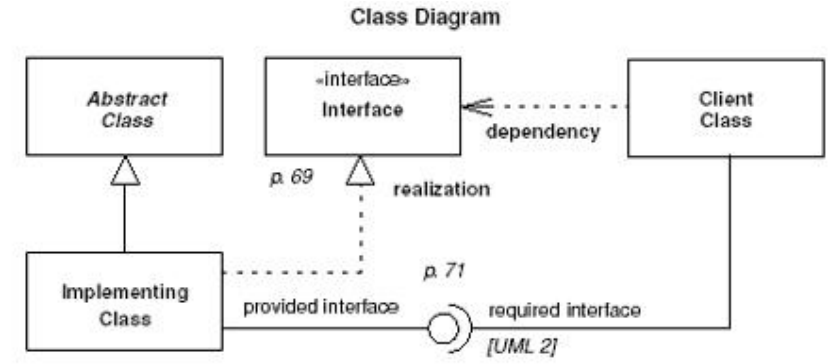
Cindy has stayed with me while I persist in writing books. She then plants the proceeds in the garden.

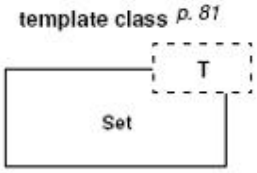
My parents started me off with a good education, from which all else springs.

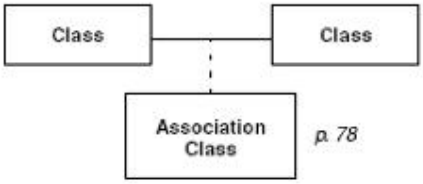
Martin Fowler
Melrose, Massachusetts
http://martinfowler.com

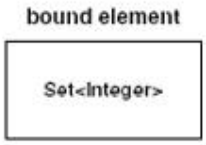
Diagrams

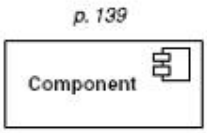

Class
Class Name
p. 35
Class Name
attribute:Type[0..1] = initialValue
operation(arg list) : return type
abstractOperation
Association p. 37
Class A
role of B
role of A
Class B
Multiplicities p. 38
1
Class
exactly one
*
Class
many
(zero or more)
0..1
Class
optional
(zero or one)
m..n
Class
numerically
specified
{ordered}
*
Class
ordered
Class
aggregation p. 67
Class
composition p. 67
Generalization p. 45
Supertype
generalization set p. 76
Subtype 1
Subtype 2
Constraint
{name: description} p. 49
Keyword
«keyword» p. 65
Qualified Association p. 74
Class
qualifier
Note p. 46
some useful text
Navigability p. 42
Source
role name
Target
Instance Specification p. 87
object name: Class Name
Dependency p. 47
Client
Supplier

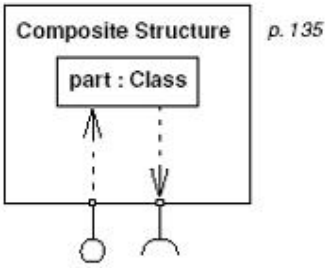

Class Diagram
Abstract Class
«interface»
Interface
Client Class
dependency
p. 69
realization
Implementing Class
p. 71
provided interface
required interface
[UML 2]

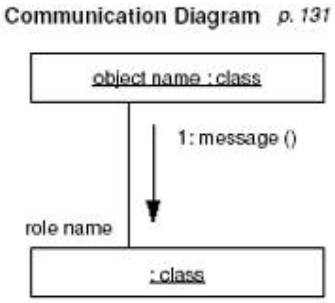

template class p. 81
T
Set

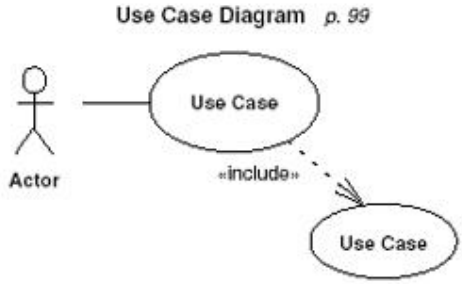

Class
Class
Association Class
p. 78


bound element
Set<Integer>

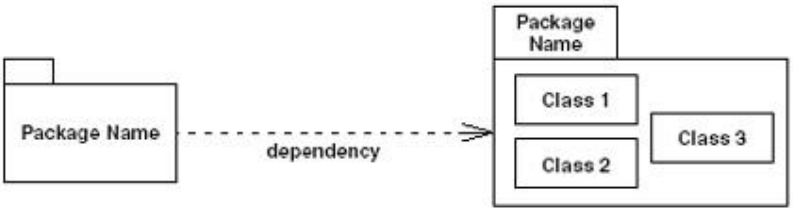

p. 139
Component


Composite Structure
p. 135
part : Class

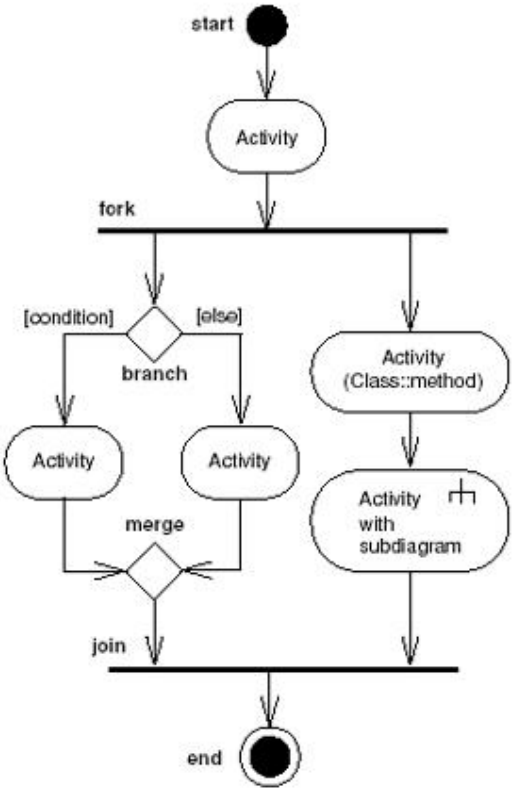

Communication Diagram p. 131
object name : class
1: message ()
role name
: class

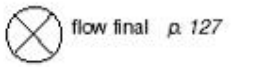

Use Case Diagram p. 99
Use Case
Actor
«include»
Use Case

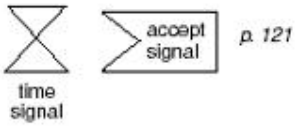
Package Diagram *p. 89*



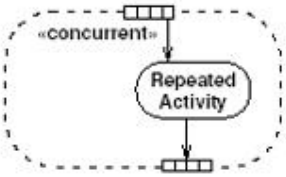
Activity Diagram *p. 117*



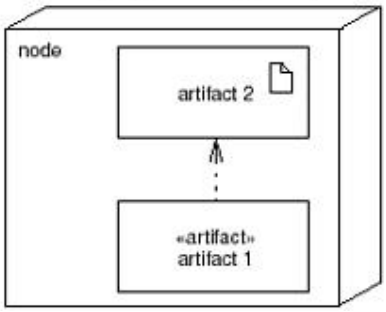




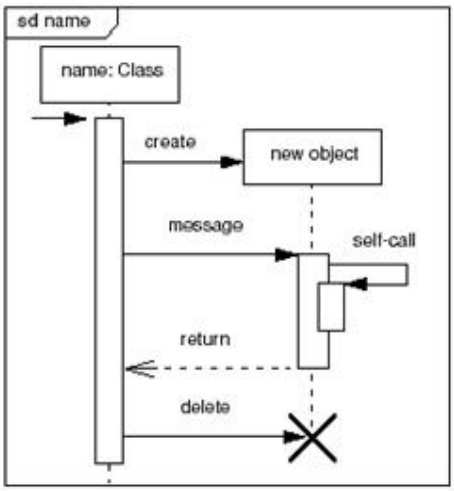
Expansion Region *p. 127*

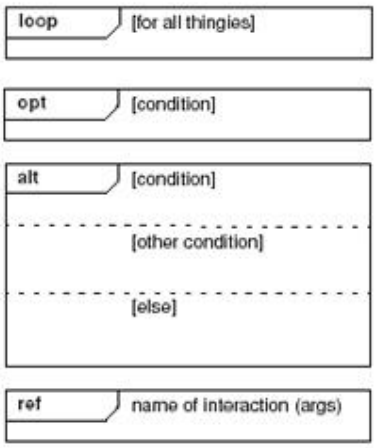


Deployment Diagram *p. 97*



Sequence Diagram *p. 53*





p. 57

synchronous *p. 61*

asynchronous *[UML >= 1.4]*

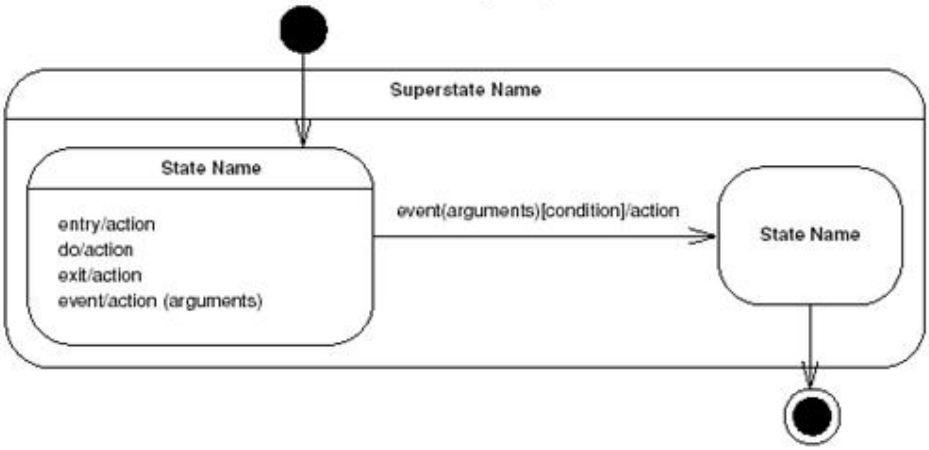
asynchronous *[UML <= 1.3]*

*: iteration message ()

[condition] message ()

[UML 1] p. 59

State Diagram *p. 107*



Chapter 1. Introduction

What Is the UML?

The Unified Modeling Language (UML) is a family of graphical notations, backed by single meta-model, that help in describing and designing software systems, particularly software systems built using the object-oriented (OO) style. That's a somewhat simplified definition. In fact, the UML is a few different things to different people. This comes both from its own history and from the different views that people have about what makes an effective software engineering process. As a result, my task in much of this chapter is to set the scene for this book by explaining the different ways in which people see and use the UML.

Graphical modeling languages have been around in the software industry for a long time. The fundamental driver behind them all is that programming languages are not at a high enough level of abstraction to facilitate discussions about design.

Despite the fact that graphical modeling languages have been around for a long time, there is an enormous amount of dispute in the software industry about their role. These disputes play directly into how people perceive the role of the UML itself.

The UML is a relatively open standard, controlled by the Object Management Group (OMG), an open consortium of companies. The OMG was formed to build standards that supported interoperability, specifically the interoperability of object-oriented systems. The OMG is perhaps best known for the CORBA (Common Object Request Broker Architecture) standards.

The UML was born out of the unification of the many object-oriented graphical modeling languages that thrived in the late 1980s and early 1990s. Since its appearance in 1997, it has relegated that particular tower of Babel to history. That's a service I, and many other developers, am deeply thankful for.

Where to Find Out More

This book is not a complete and definitive reference to the UML, let alone OO analysis and design. A lot of words are out there and a lot of worthwhile things to read. As I discuss the individual topics, I also mention other books you should go to for more in-depth information there. Here are some general books on the UML and object-oriented design.

As with all book recommendations, you may need to check which version of the UML they are written for. As of June 2003, no published book uses UML 2.0, which is hardly surprising, as the ink is barely dry on the standard. The books I suggest are good books, but I can't tell whether or when they will be updated to the UML 2 standard.

If you are new to objects, I recommend my current favorite introductory book: [Larman]. The author's strong responsibility-driven approach to design is worth following.

For the conclusive word on the UML, you should look to the official standards documents; but remember, they are written for consenting methodologists in the privacy of their own cubicles. For a much more digestible version of the standard, take a look at [Rumbaugh, UML Reference].

For more detailed advice on object-oriented design, you'll learn many good things from [Martin].

I also suggest that you read books on patterns for material that will take you beyond the basics. Now that the methods war is over, patterns (page 27) are where most of the interesting material about analysis and design appears.

Ways of Using the UML

At the heart of the role of the UML in software development are the different ways in which people want to use it, differences that carry over from other graphical modeling languages. These differences lead to long and difficult arguments about how the UML should be used.

To untangle this, Steve Mellor and I independently came up with a characterization of the three modes in which people use the UML: sketch, blueprint, and programming language. By far the most common of the three, at least to my biased eye, is **UML as sketch**. In this usage, developers use the UML to help communicate some aspects of a system. As with blueprints, you can use sketches in a forward-engineering or reverse-engineering direction. **Forward engineering** draws a UML diagram before you write code, while **reverse engineering** builds a UML diagram from existing code in order to help understand it.

The essence of sketching is selectivity. With forward sketching, you rough out some issues in code you are about to write, usually discussing them with a group of people on your team. Your aim is to use the sketches to help communicate ideas and alternatives about what you're about to do. You don't talk about all the code you are going to work on, only important issues that you want to run past your colleagues first or sections of the design that you want to visualize before you begin programming. Sessions like this can be very short: a 10-minute session to discuss a few hours of programming or a day to discuss a 2-week iteration.

With reverse engineering, you use sketches to explain how some part of a system works. You don't show every class, simply those that are interesting and worth talking about before you dig into the code.

Because sketching is pretty informal and dynamic, you need to do it quickly and collaboratively, so a common medium is a whiteboard. Sketches are also useful in documents, in which case the focus is communication rather than completeness. The tools used for sketching are lightweight drawing tools, and often people aren't too particular about keeping to every strict rule of the UML. Most UML diagrams shown in books, such as my other books, are sketches. Their emphasis is on selective communication rather than complete specification.

In contrast, **UML as blueprint** is about completeness. In forward engineering, the idea is that blueprints are developed by a designer whose job is to build a detailed design for a programmer to code up. That design should be sufficiently complete in that all design decisions are laid out, and the programmer should be able to follow it as a pretty straightforward activity that requires little thought. The designer may be the same person as the programmer, but usually the designer is a more senior developer who designs for a team of programmers. The inspiration for this approach is other forms of engineering in which professional engineers create engineering drawings that are handed over to construction companies to build.

Blueprinting may be used for all details, or a designer may draw blueprints to a particular area. A common approach is for a designer to develop blueprint-level models as far as interfaces of subsystems but then let developers work out the details of implementing those details.

In reverse engineering, blueprints aim to convey detailed information about the code either in paper documents or as an interactive graphical browser. The blueprints can show every detail about a class in a graphical form that's easier for developers to understand.

Blueprints require much more sophisticated tools than sketches do in order to handle the details required for the task. Specialized CASE (computer-aided software engineering) tools fall into this category, although the term CASE has become a dirty word, and vendors try to avoid it now. Forward-engineering tools support diagram drawing and back it up with a repository to hold the information. Reverse-engineering tools read source code and interpret from it into the repository and generate diagrams. Tools that can do both forward and reverse engineering like this are referred to as **round-trip** tools.

Some tools use the source code itself as the repository and use diagrams as a graphic viewport on the code. These tools tie much more closely into programming and often integrate directly with programming editors. I like to think of these as **tripless** tools.

The line between blueprints and sketches is somewhat blurry, but the distinction, I think, rests on the fact that sketches are deliberately incomplete, highlighting important information, while blueprints intend to be comprehensive, often with the aim of reducing programming to a simple and fairly mechanical activity. In a sound bite, I'd say that sketches are explorative, while blueprints are definitive.

As you do more and more in the UML and the programming gets increasingly mechanical, it becomes obvious that the programming should be automated. Indeed, many CASE tools do some form of code generation, which automates building a significant part of a system. Eventually, however, you reach the point at which all the system can be specified in the UML, and you reach **UML as programming language**. In this environment, developers draw UML diagrams that are compiled directly to executable code, and the UML becomes the source code. Obviously, this usage of UML demands particularly sophisticated tooling. (Also, the notions of forward and reverse engineering don't make any sense for this mode, as the UML and source code are the same thing.)

Model Driven Arquitecture and Executable UML

When people talk about the UML, they also often talk about **Model Driven Architecture** (**MDA**) [Kleppe et al.]. Essentially, MDA is a standard approach to using the UML as a programming language; the standard is controlled by the OMG, as is the UML. By producing a modeling environment that conforms to the MDA, vendors can create models that can also work with other MDA-compliant environments.

MDA is often talked about in the same breath as the UML because MDA uses the UML as its basic modeling language. But, of course, you don't have to be using MDA to use the UML.

MDA divides development work into two main areas. Modelers represent a particular application by creating a **Platform Independent Model** (**PIM**). The PIM is a UML model that is independent of any particular technology. Tools can then turn a PIM into a **Platform Specific Model** (**PSM**). The PSM is a model of a system targeted to a specific

execution environment. Further tools then take the PSM and generate code for that platform. The PSM could be UML but doesn't have to be.

So if you want to build a warehousing system using MDA, you would start by creating a single PIM of your warehousing system. If you then wanted this warehousing system to run on J2EE and .NET, you would use some vendor tools to create two PSMs: one for each platform. Then further tools would generate code for the two platforms.

If the process of going from PIM to PSM to final code is completely automated, we have the UML as programming language. If any of the steps is manual, we have blueprints.

Steve Mellor has long been active in this kind of work and has recently used the term **Executable UML** [Mellor and Balcer]. Executable UML is similar to MDA but uses slightly different terms. Similarly, you begin with a platform-independent model that is equivalent to MDA's PIM. However, the next step is to use a Model Compiler to turn that UML model into a deployable system in a single step; hence, there's no need for the PSM. As the term *compiler* suggests, this step is completely automatic.

The model compilers are based on reusable archetypes. An **archetype** describes how to take an executable UML model and turn it into a particular programming platform. So for the warehousing example, you would buy a model compiler and two archetypes (J2EE and .NET). Run each archetype on your executable UML model, and you have your two versions of the warehousing system.

Executable UML does not use the full UML standard; many constructs of UML are considered to be unnecessary and are therefore not used. As a result, Executable UML is simpler than full UML.

All this sounds good, but how realistic is it? In my view, there are two issues here. First is the question of the tools: whether they are mature enough to do the job. This is something that changes over time; certainly, as I write this, they aren't widely used, and I haven't seen much of them in action.

A more fundamental issue is the whole notion of the UML as a programming language. In my view, it's worth using the UML as a programming language only if it results in something that's significantly more productive than using another programming language. I'm not convinced that it is, based on various graphical development environments I've worked with in the past. Even if it is more productive, it still needs to get a critical mass of users for it to make the mainstream. That's a big hurdle in itself. Like many old Smalltalkers, I consider Smalltalk to be much more productive than current mainstream languages. But as Smalltalk is now only a niche language, I don't see many projects using it. To avoid Smalltalk's fate, the UML has to be luckier, even if it is superior.

One of the interesting questions around the UML as programming language is how to model behavioral logic. UML 2 offers three ways of behavioral modeling: interaction diagrams, state diagrams, and activity diagrams. All have their proponents for programming in. If the UML does gain popularity as a programming language, it will be interesting to see which of these techniques become successful.

Another way in which people look at the UML is the range between using it for conceptual and for software modeling. Most people are familiar with the UML used for software modeling. In this **software perspective**, the elements of the UML map pretty directly to elements in a software system. As we shall see, the mapping is by no means prescriptive, but when we use the UML, we are talking about software elements.

With the **conceptual perspective**, the UML represents a description of the concepts of a domain of study. Here, we aren't talking about software elements so much as we are building a vocabulary to talk about a particular domain.

There are no hard-and-fast rules about perspective; as it turns out, there's really quite a large range of usage. Some tools automatically turn source code into the UML diagrams, treating the UML as an alternative view of the source. That's very much a software perspective. If you use UML diagrams to try and understand the various meanings of the terms *asset pool* with a bunch of accountants, you are in a much more conceptual frame of mind.

In previous editions of this book, I split the software perspective into specification (interface) and implementation. In practice, I found that it was too hard to draw a precise line between the two, so I feel that the distinction is no longer worth making a fuss about. However, I'm always inclined to emphasize interface rather than implementation in my diagrams.

These different ways of using the UML lead to a host of arguments about what UML diagrams mean and what their relationship is to the rest of the world. In particular, it affects the relationship between the UML and source code. Some people hold the view that the UML should be used to create a design that is independent of the programming language that's used for implementation. Others believe that language-independent design is an oxymoron, with a strong emphasis on the moron.

Another difference in viewpoints is what the essence of the UML is. In my view, most users of the UML, particularly sketchers, see the essence of the UML to be the diagrams. However, the creators of the UML see the diagrams as secondary; the essence of the UML is the meta-model. Diagrams are simply a presentation of the meta-model. This view also makes sense to blueprinters and UML programming language users.

So whenever you read anything involving the UML, it's important to understand the point of view of the author. Only then can you make sense of the often fierce arguments that the UML encourages.

Having said all that, I need to make my biases clear. Almost all the time, my use of the UML is as sketches. I find the UML sketches useful with forward and reverse engineering and in both conceptual and software perspectives.

I'm not a fan of detailed forward-engineered blueprints; I believe that it's too difficult to do well and slows down a development effort. Blueprinting to a level of subsystem interfaces is reasonable, but even then you should expect to change those interfaces as developers implement the interactions across the interface. The value of reverse-engineered blueprints is dependent on how the tool works. If it's used as a dynamic browser, it can be very helpful; if it generates a large document, all it does is kill trees.

I see the UML as programming language as a nice idea but doubt that it will ever see significant usage. I'm not convinced that graphical forms are more productive than textual forms for most programming tasks and that even if they are, it's very difficult for a language to be widely accepted.

As a result of my biases, this book focuses much more on using the UML for sketching. Fortunately, this makes sense for a brief guide. I can't do justice to the UML in its other modes in a book this size, but a book this size makes a good introduction to other books that can. So if you're interested in the UML in its other modes, I'd suggest that you treat this book as an introduction and move on to other books as you need them. If you're interested only in sketches, this book may well be all you need.

How We Got to the UML

I'll admit, I'm a history buff. My favorite idea of light reading is a good history book. But I also know that it's not everybody's idea of fun. I talk about history here because I think that in many ways, it's hard to understand where the UML is without understanding the history of how it got here.

In the 1980s, objects began to move away from the research labs and took their first steps toward the "real" world. Smalltalk stabilized into a platform that people could use, and C++ was born. At that time, various people started thinking about object-oriented graphical design languages.

The key books about object-oriented graphical modeling languages appeared between 1988 and 1992. Leading figures included Grady Booch [Booch, OOAD]; Peter Coad [Coad, OOA], [Coad, OOD]; Ivar Jacobson (Objectory) [Jacobson, OOSE]; Jim Odell [Odell]; Jim Rumbaugh (OMT) [Rumbaugh, insights], [Rumbaugh, OMT]; Sally Shlaer and Steve Mellor [Shlaer and Mellor, data], [Shlaer and Mellor, states]; and Rebecca Wirfs-Brock (Responsibility Driven Design) [Wirfs-Brock].

Each of those authors was now informally leading a group of practitioners who liked those ideas. All these methods were very similar, yet they contained a number of often annoying minor differences among them. The same basic concepts would appear in very different notations, which caused confusion to my clients.

During that heady time, standardization was as talked about as it was ignored. A team from the OMG tried to look at standardization but got only an open letter of protest from all the key methodologists. (This reminds me of an old joke. Question: What is the difference between a methodologist and a terrorist? Answer: You can negotiate with a terrorist.)

The cataclysmic event that first initiated the UML was when Jim Rumbaugh left GE to join Grady Booch at Rational (now a part of IBM). The Booch/Rumbaugh alliance was seen from the beginning as one that could get a critical mass of market share. Grady and Jim proclaimed that "the methods war is over we won," basically declaring that they were going to achieve standardization "the Microsoft way." A number of other methodologists suggested forming an Anti-Booch Coalition.

By OOPSLA '95, Grady and Jim had prepared their first public description of their merged method: version 0.8 of the *Unified Method* documentation. Even more significant, they announced that Rational Software had bought Objectory and that therefore, Ivar Jacobson would be joining the Unified team. Rational held a well-attended party to celebrate the release of the 0.8 draft. (The highlight of the party was the first public display of Jim Rumbaugh's singing; we all hope it's also the last.)

The next year saw a more open process emerge. The OMG, which had mostly stood on the sidelines, now took an active role. Rational had to incorporate Ivar's ideas and also spent time with other partners. More important, the OMG decided to take a major role.

At this point, it's important to realize why the OMG got involved. Methodologists, like book authors, like to think that they are important. But I don't think that the screams of book authors would even be heard by the OMG. What got the OMG involved were the screams of tools vendors, all of which were frightened that a standard controlled by Rational would give Rational tools an unfair competitive advantage. As a result, the vendors energized the OMG to do something about it, under the banner of CASE tool interoperability. This banner was important, as the OMG was all about interoperability. The idea was to create a UML that would allow CASE tools to freely exchange models.

Mary Loomis and Jim Odell chaired the initial task force. Odell made it clear that he was prepared to give up his method to a standard, but he did not want a Rational-imposed standard. In January 1997, various organizations submitted proposals for a methods standard to facilitate the interchange of models. Rational collaborated with a number of other organizations and released version 1.0 of the UML documentation as their proposal, the first animal to answer to the name Unified Modeling Language.

Then followed a short period of arm twisting while the various proposals were merged. The OMG adopted the resulting 1.1 as an official OMG standard. Some revisions were made later on. Revision 1.2 was entirely cosmetic. Revision 1.3 was more significant. Revision 1.4 added a number of detailed concepts around components and profiles. Revision 1.5 added action semantics.

When people talk about the UML, they credit mainly Grady Booch, Ivar Jacobson, and Jim Rumbaugh as its creators. They are generally referred to as the Three Amigos, although wags like to

drop the first syllable of the second word. Although they are most credited with the UML, I think it somewhat unfair to give them the dominant credit. The UML notation was first formed in the Booch/Rumbaugh Unified Method. Since then, much of the work has been led by OMG committees. During these later stages, Jim Rumbaugh is the only one of the three to have made a heavy commitment. My view is that it's these members of the UML committee process that deserve the principal credit for the UML.

Notations and Meta-Models

The UML, in its current state, defines a notation and a meta-model. The **notation** is the graphical stuff you see in models; it is the graphical syntax of the modeling language. For instance, class diagram notation defines how items and concepts, such as class, association, and multiplicity, are represented.

Of course, this leads to the question of what exactly is meant by an association or multiplicity or even a class. Common usage suggests some informal definitions, but many people want more rigor than that.

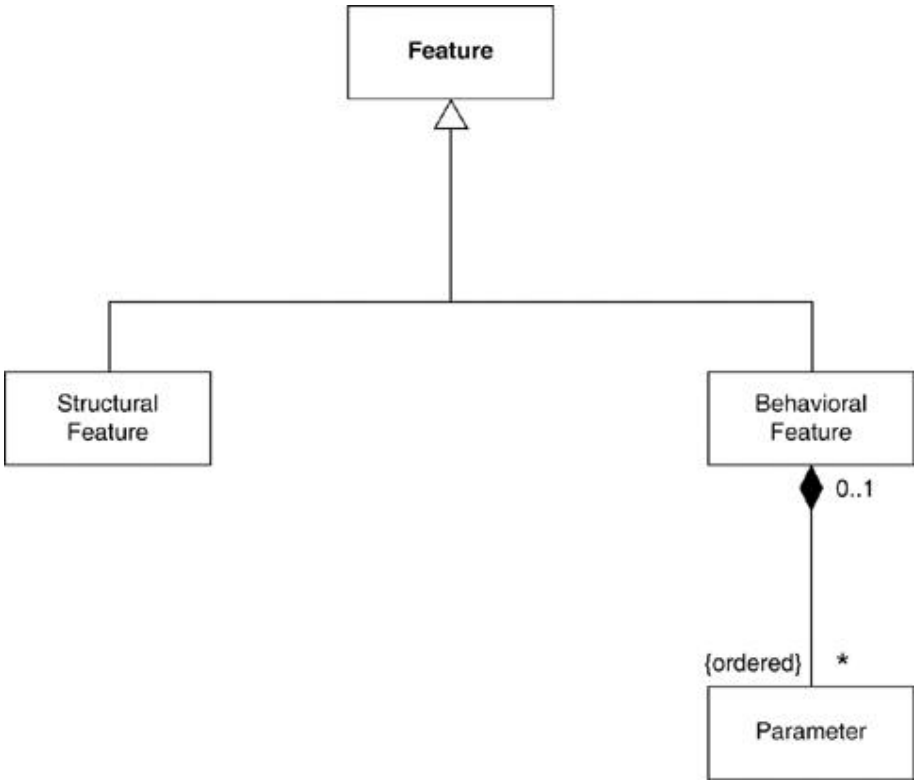
The idea of rigorous specification and design languages is most prevalent in the field of formal methods. In such techniques, designs and specifications are represented using some derivative of predicate calculus. Such definitions are mathematically rigorous and allow no ambiguity. However, the value of these definitions is by no means universal. Even if you can prove that a program satisfies a mathematical specification, there is no way to prove that the mathematical specification meets the real requirements of the system.

Most graphical modeling languages have very little rigor; their notation appeals to intuition rather than to formal definition. On the whole, this does not seem to have done much harm. These methods may be informal, but many people still find them useful—and it is usefulness that counts.

However, methodologists are looking for ways to improve the rigor of methods without sacrificing their usefulness. One way to do this is to define a **meta-model:** a diagram, usually a class diagram, that defines the concepts of the language.

Figure 1.1, a small piece of the UML meta-model, shows the relationship among features. (The extract is there to give you a flavor of what meta-models are like. I'm not even going to try to explain it.)

Figure 1.1. A small piece of the UML meta-model



How much does the meta-model affect a user of the modeling notation? The answer depends mostly on the mode of usage. A sketcher usually doesn't care too much; a blueprinter should care rather more. It's vitally important to those who use the UML as a programming language, as it defines the abstract syntax of that language.

Many of the people who are involved in the ongoing development of the UML are interested primarily in the meta-model, particularly as this is important to the usage of the UML and a programming language. Notational issues often run second place, which is important to bear in mind if you ever try to get familiar with the standards documents themselves.

As you get deeper into the more detailed usage of the UML, you realize that you need much more than the graphical notation. This is why UML tools are so complex.

I am not rigorous in this book. I prefer the traditional methods path and appeal mainly to your intuition. That's natural for a small book like this written by an author who's inclined mostly to a sketch usage. If you want more rigor, you should turn to more detailed tomes.

UML Diagrams

UML 2 describes 13 official diagram types listed in Table 1.1 and classified as indicated on Figure 1.2. Although these diagram types are the way many people approach the UML and how I've organized this book, the UML's authors do not see diagrams as the central part of the UML. As a result, the diagram types are not particularly rigid. Often, you can legally use elements from one diagram type on another diagram. The UML standard indicates that certain elements are typically drawn on certain diagram types, but this is not a prescription.

Figure 1.2. Classification of UML diagram types

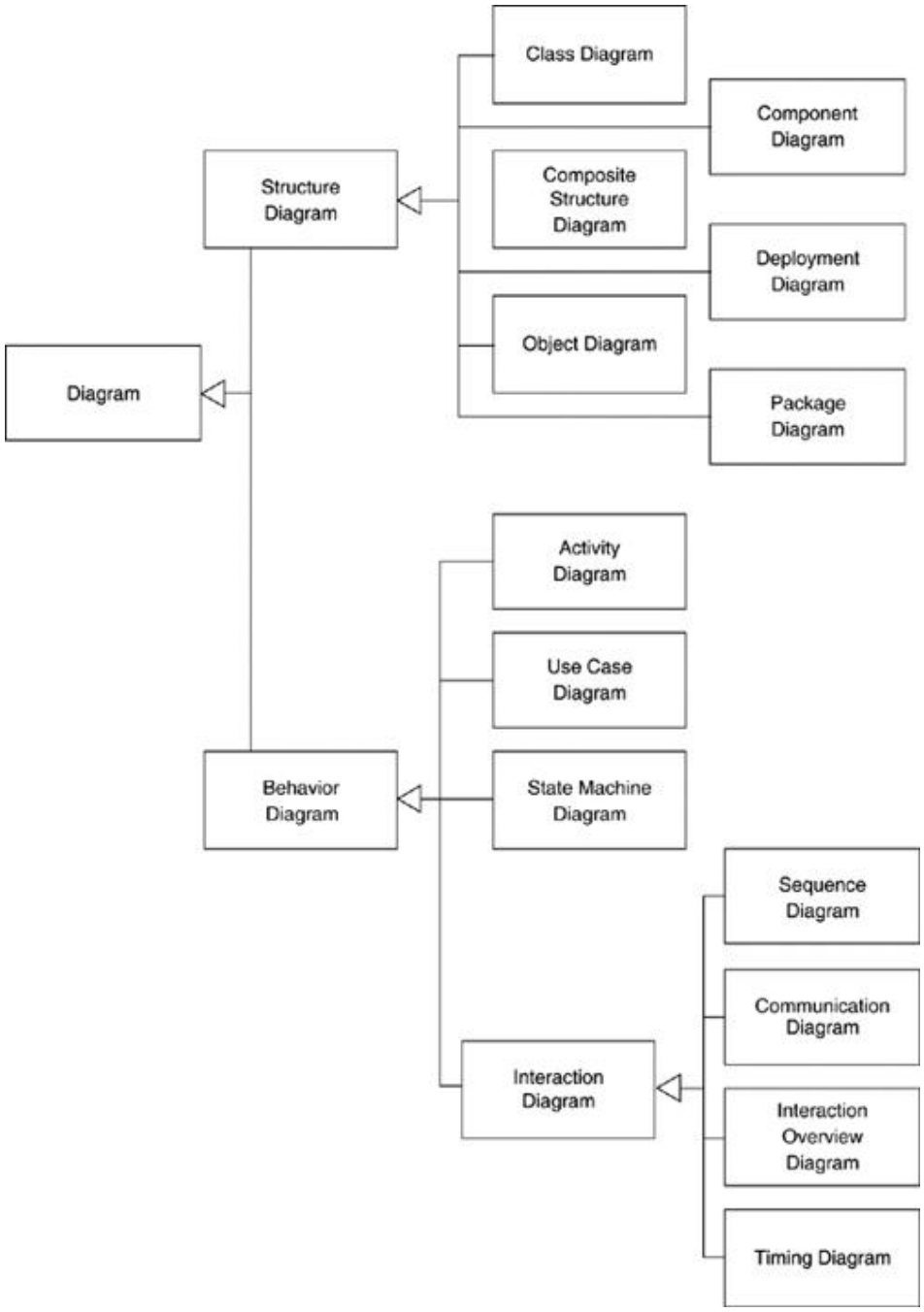


Table 1.1. Official Diagram Types of the UML

Diagram	Book Chapters	Purpose	Lineage
Activity	11	Procedural and parallel behavior	In UML 1
Class	3, 5	Class, features, and relationships	In UML 1
Communication	12	Interaction between objects; emphasis on links	UML 1 collaboration diagram
Component	14	Structure and connections of components	In UML 1
Composite structure	13	Runtime decomposition of a class	New to UML 2
Deployment	8	Deployment of artifacts to nodes	In UML 1

Table 1.1. Official Diagram Types of the UML

Diagram	Book Chapters	Purpose	Lineage
Interaction overview	16	Mix of sequence and activity diagram	New to UML 2
Object	6	Example configurations of instances	Unofficially in UML 1
Package	7	Compile-time hierarchic structure	Unofficially in UML 1
Sequence	4	Interaction between objects; emphasis on sequence	In UML 1
State machine	10	How events change an object over its life	In UML 1
Timing	17	Interaction between objects; emphasis on timing	New to UML 2
Use case	9	How users interact with a system	In UML 1

What Is Legal UML?

At first blush, this should be a simple question to answer: Legal UML is what is defined as well formed in the specification. In practice, however, the answer is a bit more complicated.

An important part of this question is whether the UML has descriptive or prescriptive rules. A language with **prescriptive rules** is controlled by an official body that states what is or isn't legal in the language and what meaning you give to utterances in that language. A language with **descriptive rules** is one in which you understand its rules by looking at how people use the language in practice. Programming languages tend to have prescriptive rules set by a standards committee or dominant vendor, while natural languages, such as English, tend to have descriptive rules whose meaning is set by convention.

UML is quite a precise language, so you might expect it to have prescriptive rules. But UML is often considered to be the software equivalent of the blueprints in other engineering disciplines, and these blueprints are not prescriptive notations. No committee says what the legal symbols are on a structural engineering drawing; the notation has been accepted by convention, similarly to a natural language. Simply having a standards body doesn't do the trick either, because people in the field may not follow everything the standards body says; just ask the French about the Académie Française. In addition, the UML is so complex that the standard is often open to multiple interpretations. Even the UML leaders who reviewed this book would disagree on interpretation of the UML standard.

This issue is important both for me writing this book and for you using the UML. If you want to understand a UML diagram, it's important to realize that understanding the UML standard is not the whole picture. People do adopt conventions, both in the industry widely and within a particular project. As a result, although the UML standard can be the primary source of information on the UML, it can't be the only one.

My attitude is that, for most people, the UML has descriptive rules. The UML standard is the biggest single influence on what UML means, but it isn't the only one. I think that this will become particularly true with UML 2, which introduces some notational conventions that conflict with either UML 1's definition or the conventional usage of UML, as well as adds yet more complexity to the UML. In this book, therefore, I'm trying to summarize the UML as I find it: both the standards and the conventional usage. When I have to make a distinction in this book, I'll use the term **conventional use** to indicate something that isn't in the standard but that I think is widely used. For something that conforms to the standard, I'll use the terms **standard** or **normative**. (Normative is the term standards people use to mean a statement that you must conform to be

valid in the standard. So non-normative UML is a fancy way of saying that something is strictly illegal according to the UML standard.)

When you are looking at a UML diagram, you should bear in mind that a general principle in the UML is that any information may be **suppressed** for a particular diagram. This suppression can occur either generally—hide all attributes—or specifically—don't show these three classes. In a diagram, therefore, you can never infer anything by its absence. If a multiplicity is missing, you cannot infer what value it might be. Even if the UML meta-model has a default, such as [1] for attributes, if you don't see the information on the diagram, it may be because it's the default or because it's suppressed.

Having said that, there are some general conventions, such as multivalued properties being sets. In the text, I'll point out these default conventions.

It's important to not put too much emphasis on having legal UML if you're a sketcher or blueprinter. It's more important to have a good design for your system, and I would rather have a good design in illegal UML than a legal but poor design. Obviously, good and legal is best, but you're better off putting your energy into having a good design than worrying about the arcana of UML. (Of course, you have to be legal in UML as programming language, or your program won't run properly!)

The Meaning of UML

One of the awkward issues about the UML is that, although the specification describes in great detail what well-formed UML is, it doesn't have much to say about what the UML means outside of the rarefied world of the UML meta-model. No formal definition exists of how the UML maps to any particular programming language. You cannot look at a UML diagram and say *exactly* what the equivalent code would look like. However, you can get a *rough idea* of what the code would look like. In practice, that's enough to be useful. Development teams often form their local conventions for these, and you'll need to be familiar with the ones in use.

UML Is Not Enough

Although the UML provides quite a considerable body of various diagrams that help to define an application, it's by no means a complete list of all the useful diagrams that you might want to use. In many places, different diagrams can be useful, and you shouldn't hesitate to use a non-UML diagram if no UML diagram suits your purpose.

Figure 1.3, a screen flow diagram, shows the various screens on a user interface and how you move between them. I've seen and used these screen flow diagrams for many years. I've never seen more than a very rough definition of what they mean; there isn't anything like it in the UML, yet I've found it a very useful diagram.

Figure 1.3. An informal screen flow diagram for part of the wiki (http://c2.com/cgi/wiki)

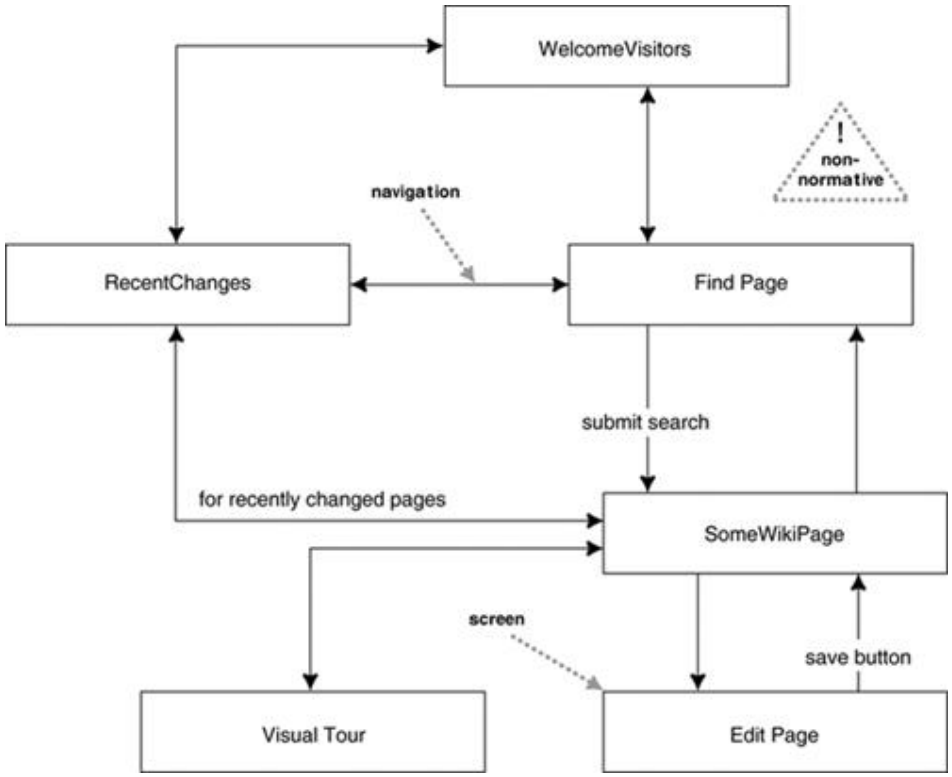


Table 1.2 shows another favorite: the decision table. Decision tables are a good way to show complicated logical conditions. You can do this with an activity diagram, but once you get beyond simple cases, the table is both more compact and more clear. Again, many forms of decision tables are out there. Table 1.2 divides the table into two sections: conditions above the double line and consequences below it. Each column shows how a particular combination of conditions leads to a particular set of consequences.

Table 1.2. A Decision Table

Premium customer	X	X	Y	Y	N	N
Priority order	Y	N	Y	N	Y	N
International order	Y	Y	N	N	N	N
Fee	$150	$100	$70	$50	$80	$60
Alert rep	•	•	•			

You'll run into various kinds of these things in various books. Don't hesitate to try out techniques that seem appropriate for your project. If they work well, use them. If not, discard them. (This is, of course, the same advice as for UML diagrams.)

Where to Start with the UML

Nobody, not even the creators of the UML, understand or use all of it. Most people use a small subset of the UML and work with that. You have to find the subset of the UML that works for you and your colleagues.

If you are starting out, I suggest that you concentrate first on the basic forms of class diagrams and sequence diagrams. These are the most common and, in my view, the most useful diagram types.

Once you've got the hang of those, you can start using some of the more advanced class diagram notation and take a look at the other diagrams types. Experiment with the diagrams and see how helpful they are to you. Don't be afraid to drop any that don't seem be useful to your work.

Chapter 2. Development Process

As I've already mentioned, the UML grew out of a bunch of OO analysis and design methods. To some extent, all of them mixed a graphical modeling language with a process that described how to go about developing software.

Interestingly, as the UML was formed, the various players discovered that although they could agree on a modeling language, they most certainly could not agree on a process. As a result, they agreed to leave any agreement on process until later and to confine the UML to being a modeling language.

The title of this book is *UML Distilled*, so I could have safely ignored process. However, I don't believe that modeling techniques make any sense without knowing how they fit into a process. The way you use the UML depends a lot on the style of process you use.

As a result, I think that it's important to talk about process first so that you can see the context for using the UML. I'm not going to go into great detail on any particular process; I simply want to give you enough information to see this context and pointers to where you can find out more.

When you hear people discuss the UML, you often hear them talk about the Rational Unified Process (RUP). RUP is one process—or, more strictly, a process framework—that you can use with the UML. But other than the common involvement of various people from Rational and the name "unified," it doesn't have any special relationship to the UML. The UML can be used with any process. RUP is a popular approach and is discussed on page 25.

Iterative and Waterfall Processes

One of the biggest debates about process is that between waterfall and iterative styles. The terms often get misused, particularly as iterative is seen as fashionable, while the waterfall process seems to wear plaid trousers. As a result, many projects claim to do iterative development but are really doing waterfall.

The essential difference between the two is how you break up a project into smaller chunks. If you have a project that you think will take a year, few people are comfortable telling the team to go away for a year and to come back when done. Some breakdown is needed so that people can approach the problem and track progress.

The **waterfall** style breaks down a project based on activity. To build software, you have to do certain activities: requirements analysis, design, coding, and testing. Our 1-year project might thus have a 2-month analysis phase, followed by a 4-month design phase, followed by a 3-month coding phase, followed by a 3-month testing phase.

The **iterative** style breaks down a project by subsets of functionality. You might take a year and break it into 3-month iterations. In the first iteration, you'd take a quarter of the requirements and do the complete software life cycle for that quarter: analysis, design, code, and test. At the end of the first iteration, you'd have a system that does a quarter of the needed functionality. Then you'd do a second iteration so that at the end of 6 months, you'd have a system that does half the functionality.

Of course, the above is a simplified description, but it is the essence of the difference. In practice, of course, some impurities leak into the process.

With waterfall development, there is usually some form of formal handoff between each phase, but there are often backflows. During coding, something may come up that causes you to revisit the analysis and design. You certainly should not assume that all design is finished when coding begins. It's inevitable that analysis and design decisions will have to be revisited in later phases. However, these backflows are exceptions and should be minimized as much as possible.

With iteration, you usually see some form of exploration activity before the true iterations begin. At the very least, this will get a high-level view of the requirements: at least enough to break the requirements down into the iterations that will follow. Some high-level design decisions may occur during exploration too. At the other end, although each iteration should produce production-ready integrated software, it often doesn't quite get to that point and needs a stabilization period to iron out the last bugs. Also, some activities, such as user training, are left to the end.

You may well not put the system into production at the end of each iteration, but the system should be of production quality. Often, however, you can put the system into production at regular intervals; this is good because you get value from the system earlier and you get better-quality feedback. In this situation, you often hear of a project having multiple **releases**, each of which is broken down into several **iterations**.

Iterative development has come under many names: incremental, spiral, evolutionary, and jacuzzi spring to mind. Various people make distinctions among them, but the distinctions are neither widely agreed on nor that important compared to the iterative/waterfall dichotomy.

You can have hybrid approaches. [McConnell] describes the **staged delivery** life cycle whereby analysis and high-level design are done first, in a waterfall style, and then the coding and testing are divided up into iterations. Such a project might have 4 months of analysis and design followed by four 2-month iterative builds of the system.

Most writers on software process in the past few years, especially in the object-oriented community, dislike the waterfall approach. Of the many reasons for this, the most fundamental is that it's very difficult to tell whether the project is truly on track with a waterfall process. It's too easy to declare victory with early phases and hide a schedule slip. Usually, the only way you can really tell whether you are on track is to produce tested, integrated software. By doing this repeatedly, an iterative style gives you better warning if something is going awry.

For that reason alone, I strongly recommend that projects do not use a pure waterfall approach. You should at least use staged delivery, if not a more pure iterative technique.

The OO community has long been in favor of iterative development, and it's safe to say that pretty much everyone involved in building the UML is in favor of at least some form of iterative development. My sense of industrial practice is that waterfall development is still the more common approach, however. One reason for this is what I refer to as pseudoiterative development: People claim to be doing iterative development but are in fact doing waterfall. Common symptoms of this are:

- "We are doing one analysis iteration followed by two design iterations. . . ."
- "This iteration's code is very buggy, but we'll clean it up at the end."

It is particularly important that each iteration produces tested, integrated code that is as close to production quality as possible. Testing and integration are the hardest activities to estimate, so it's important not to have an open-ended activity like that at the end of the project. The test should be that any iteration that's not scheduled to be released could be released without substantial extra development work.

A common technique with iterations is to use **time boxing**. This forces an iteration to be a fixed length of time. If it appears that you can't build all you intended to build during an iteration, you must decide to slip some functionality from the iteration; you must not slip the date of the iteration.

Most projects that use iterative development use the same iteration length throughout the project; that way, you get a regular rhythm of builds.

I like time boxing because people usually have difficulty slipping functionality. By practicing slipping function regularly, they are in a better position to make an intelligent choice at a big release between slipping a date and slipping function. Slipping function during iterations is also effective at helping people learn what the real requirements priorities are.

One of the most common concerns about iterative development is the issue of rework. Iterative development explicitly assumes that you will be reworking and deleting existing code during the later iterations of a project. In many domains, such as manufacturing, rework is seen as a waste. But software isn't like manufacturing; as a result, it often is more efficient to rework existing code than to patch around code that was poorly designed. A number of technical practices can greatly help make rework be more efficient.

- **Automated regression tests** help by allowing you to quickly detect any defects that may have been introduced when you are changing things. The xUnit family of testing frameworks is a particularly valuable tool for building automated unit tests. Starting with the original JUnit **http://junit.org**, there are now ports to almost every language imaginable (see **http://www.xprogramming.com/software.htm**). A good rule of thumb is that the size of your unit test code should be about the same size as your production code.
- **Refactoring** is a disciplined technique for changing existing software [Fowler, refactoring]. Refactoring works by using a series of small behavior-preserving transformations to the code base. Many of these transformations can be automated (see **http://www.refactoring.com**).
- **Continuous integration** keeps a team in sync to avoid painful integration cycles [Fowler and Foemmel]. At the heart of this lies a fully automated build process that can be kicked off automatically whenever any member of the team checks code into the code base. Developers are expected to check in daily, so automated builds are done many times a day. The build process includes running a large block of automated regression tests so that any inconsistencies are caught quickly so they can be fixed easily.

All these technical practices have been popularized recently by Extreme Programming [Beck], although they were used before and can, and should, be used whether or not you use XP or any other agile process.

Predictive and Adaptive Planning

One reason that the waterfall endures is the desire for predictability in software development. Nothing is more frustrating than not having a clear idea how much it will cost to build some software and how long it will take to build it.

A predictive approach looks to do work early in the project in order to yield a greater understanding of what has to be done later. This way, you can reach a point where the latter part of the project can be estimated with a reasonable degree of accuracy. With **predictive planning**, a project has two stages. The first stage comes up with plans and is difficult to predict, but the second stage is much more predictable because the plans are in place.

This isn't necessarily a black-and-white affair. As the project goes on, you gradually get more predictability. And even once you have a predictive plan, things will go wrong. You simply expect that the deviations become less significant once a solid plan is in place.

However, there is a considerable debate about whether many software projects can ever be predictable. At the heart of this question is requirements analysis. One of the unique sources of complexity in software projects is the difficulty in understanding the requirements for a software system. The majority of software projects experience significant **requirements churn**: changes in requirements in the later stages of the project. These changes shatter the foundations of a

predictive plan. You can combat these changes by freezing the requirements early on and not permitting changes, but this runs the risk of delivering a system that no longer meets the needs of its users.

This problem leads to two very different reactions. One route is to put more effort into the requirements process itself. This way, you may get a more accurate set of requirements, which will reduce the churn.

Another school contends that requirements churn is unavoidable, that it's too difficult for many projects to stabilize requirements sufficiently to use a predictive plan. This may be either owing to the sheer difficulty of envisioning what software can do or because market conditions force unpredictable changes. This school of thought advocates **adaptive planning**, whereby predictivity is seen as an illusion. Instead of fooling ourselves with illusory predictability, we should face the reality of constant change and use a planning approach that treats change as a constant in a software project. This change is controlled so that the project delivers the best software it can; but although the project is controllable, it is not predictable.

The difference between a predictive project and an adaptive project surfaces in many ways that people talk about how the project goes. When people talk about a project that's doing well because it's going according to plan, that's a predictive form of thinking. You can't say "according to plan" in an adaptive environment, because the plan is always changing. This doesn't mean that adaptive projects don't plan; they usually plan a lot, but the plan is treated as a baseline to assess the consequences of change rather than as a prediction of the future.

With a predictive plan, you can develop a fixed-price/fixed-scope contract. Such a contract says exactly what should be built, how much it will cost, and when it will be delivered. Such fixing isn't possible with an adaptive plan. You can fix a budget and a time for delivery, but you can't fix what functionality will be delivered. An adaptive contract assumes that the users will collaborate with the development team to regularly reassess what functionality needs to be built and will cancel the project if progress ends up being too slow. As such, an adaptive planning process can be fixed price/variable scope.

Naturally, the adaptive approach is less desirable, as anyone would prefer greater predictability in a software project. However, predictability depends on a precise, accurate, and stable set of requirements. If you cannot stabilize your requirements, the predictive plan is based on sand and the chances are high that the project goes off course. This leads to two important pieces of advice.

1. Don't make a predictive plan until you have precise and accurate requirements and are confident that they won't significantly change.
2. If you can't get precise, accurate, and stable requirements, use an adaptive planning style.

Predictivity and adaptivity feed into the choice of life cycle. An adaptive plan absolutely requires an iterative process. Predictive planning can be done either way, although it's easier to see how it works with waterfall or a staged delivery approach.

Agile Processes

In the past few years, there's been a lot of interest in agile software processes. *Agile* is an umbrella term that covers many processes that share a common set of values and principles as defined by the Manifesto of Agile Software Development (**http://agileManifesto.org**). Examples of these processes are Extreme Programming (XP), Scrum, Feature Driven Development (FDD), Crystal, and DSDM (Dynamic Systems Development Method).

In terms of our discussion, agile processes are strongly adaptive in their nature. They are also very much people-oriented processes. Agile approaches assume that the most important factor in a project's success is the quality of the people on the project and how well they work together in human terms. Which process they use and which tools they use are strictly second-order effects.

Agile methods tend to use short, time-boxed iterations, most often of a month or less. Because they don't attach much weight to documents, agile approaches disdain using the UML in blueprint mode. Most use the UML in sketch mode, with a few advocating using it as a programming language.

Agile processes tend to be low in **ceremony**. A high-ceremony, or heavyweight, process has a lot of documents and control points during the project. Agile processes consider that ceremony makes it harder to make changes and works against the grain of talented people. As a result, agile processes are often characterized as **lightweight**. It's important to realize that the lack of ceremony is a consequence of adaptivity and people orientation rather than a fundamental property.

Rational Unified Process

Although the Rational Unified Process (RUP) is independent of the UML, the two are often talked about together. So I think it's worth saying a few things about it here.

Although RUP is called a process, it actually is a process framework, providing a vocabulary and loose structure to talk about processes. When you use RUP, the first thing you need to do is choose a **development case**: the process you are going to use in the project. Development cases can vary widely, so don't assume that your development case will look that much like any other development case. Choosing a development case needs someone early on who is very familiar with RUP: someone who can tailor RUP for a particular project's needs. Alternatively, there is a growing body of packaged development cases to start from.

Whatever the development case, RUP is essentially an iterative process. A waterfall style isn't compatible with the philosophy of RUP, although sadly it's not uncommon to run into projects that use a waterfall-style process and dress it up in RUP's clothes.

All RUP projects should follow four phases.

1. **Inception** makes an initial evaluation of a project. Typically in inception, you decide whether to commit enough funds to do an elaboration phase.
2. **Elaboration** identifies the primary use cases of the project and builds software in iterations in order to shake out the architecture of the system. At the end of elaboration, you should have a good sense of the requirements and a skeletal working system that acts as the seed of development. In particular, you should have found and resolved the major risks to the project.
3. **Construction** continues the building process, developing enough functionality to release.
4. **Transition** includes various late-stage activities that you don't do iteratively. These may include deployment into the data center, user training, and the like.

There's a fair amount of fuzziness between the phases, especially between elaboration and construction. For some, the shift to construction is the point at which you can move into a predictive planning mode. For others, it merely indicates the point at which you have a broad vision of requirements and an architecture that you think is going to last the rest of the project.

Sometimes, RUP is referred to as the Unified Process (UP). This is usually done by organizations that wish to use the terminology and overall style of RUP without using the licensed products of Rational Software. You can think of RUP as Rational's product offering based on the UP, or you can think of RUP and UP as the same thing. Either way, you'll find people who agree with you.

Fitting a Process to a Project

Software projects differ greatly from one another. The way you go about software development depends on many factors: the kind of system you're building, the technology you're using, the size and distribution of the team, the nature of the risks, the consequences of failure, the working styles

of the team, and the culture of the organization. As a result, you should never expect there to be a one-size-fits-all process that will work for all projects.

Consequently, you always have to adapt a process to fit your particular environment. One of the first things you need to do is look at your project and consider which processes seem close to a fit. This should give you a short list of processes to consider.

You should then consider what adaptations you need to make to fit them to your project. You have to be somewhat careful with this. Many processes are difficult to fully appreciate until you've worked with them. In these cases, it's often worth using the process out of the box for a couple of iterations until you learn how it works. Then you can start modifying the process. If from the beginning you are more familiar with how a process works, you can modify it from the beginning. Remember that it's usually easier to start with too little and add things than it is to start with too much and take things away.

Patterns

The UML tells you how to express an object-oriented design. Patterns look, instead, at the results of the process: example designs.

Many people have commented that projects have problems because the people involved were not aware of designs that are well known to those with more experience. Patterns describe common ways of doing things and are collected by people who spot repeating themes in designs. These people take each theme and describe it so that other people can read the pattern and see how to apply it.

Let's look at an example. Say that you have some objects running in a process on your desktop and that they need to communicate with other objects running in another process. Perhaps this process is also on your desktop; perhaps it resides elsewhere. You don't want the objects in your system to have to worry about finding other objects on the network or executing remote procedure calls.

What you can do is create a proxy object within your local process for the remote object. The proxy has the same interface as the remote object. Your local objects talk to the proxy, using the usual in-process message sends. The proxy then is responsible for passing any messages on to the real object, wherever it might reside.

Proxies are a common technique used in networks and elsewhere. People have a lot of experience using proxies, knowing how they can be used, what advantages they can bring, their limitations, and how to implement them. Methods books like this one don't discuss this knowledge; all they discuss is how you can diagram a proxy, although useful, is not as useful as discussing the experience involving proxies.

In the early 1990s, some people began to capture this experience. They formed a community interested in writing patterns. These people sponsor conferences and have produced several books.

The most famous patterns book to emerge from this group is [Gang of Four], which discusses 23 design patterns in detail. If you want to know about proxies, this book spends ten pages on the subject, giving details about how the objects work together, the benefits and limitations of the pattern, common variations, and implementation tips.

A pattern is much more than a model. A pattern must also include the reason why it is the way it is. It is often said that a pattern is a solution to a problem. The pattern must identify the problem clearly, explain why it solves the problem, and also explain the circumstances under which the pattern works and doesn't work.

Patterns are important because they are the next stage beyond understanding the basics of a language or a modeling technique. Patterns give you a series of solutions and also

show you what makes a good model and how you go about constructing a model. Patterns teach by example.

When I started out, I wondered why I had to invent things from scratch. Why didn't I have handbooks to show me how to do common things? The patterns community is trying to build these handbooks.

There are now many patterns books out there, and they vary greatly in quality. My favorites are [Gang of Four], [POSA1], [POSA2], [Core J2EE Patterns], [Pont], and with suitable immodesty [Fowler, AP] and [Fowler, P of EAA]. You can also take a look at the patterns home page: **http://www.hillside.net/patterns**.

However confident you are with your process when you begin, it's essential to learn as you go along. Indeed, one of the great benefits of iterative development is that it supports frequent process improvement.

At the end of each iteration, conduct an **iteration retrospective**, whereby the team assembles to consider how things went and how they can be improved. A couple of hours is plenty if your iterations are short. A good way to do this is to make a list with three categories:

1. *Keep:* things that worked well that you want to ensure you continue to do
2. *Problems:* areas that aren't working well
3. *Try:* changes to your process to improve it

You can start each iteration retrospective after the first by reviewing the items from the previous session and seeing how things have changed. Don't forget the list of things to keep; it's important to keep track of things that are working. If you don't do that, you can lose a sense of perspective on the project and potentially stop paying attention to winning practices.

At the end of a project or at a major release, you may want to consider a more formal **project retrospective** that will last a couple of days; see **http://www.retrospectives.com/** and [Kerth] for more details. One of my biggest irritations is how organizations consistently fail to learn from their own experience and end up making expensive mistakes time and time again.

Fitting the UML into a Process

When they look at graphical modeling languages, people usually think of them in the context of a waterfall process. A waterfall process usually has documents that act as the handoffs between analysis, design, and coding phases. Graphical models can often form a major part of these documents. Indeed, many of the structured methods from the 1970s and 1980s talk a lot about analysis and design models like this.

Whether or not you use a waterfall approach, you still do the activities of analysis, design, coding, and testing. You can run an iterative project with 1-week iterations, with each week a miniwaterfall.

Using the UML doesn't necessarily imply developing documents or feeding a complex CASE tool. Many people draw UML diagrams on whiteboards only during a meeting to help communicate their ideas.

Requirements Analysis

The activity of requirements analysis involves trying to figure out what the users and customers of a software effort want the system to do. A number of UML techniques can come in handy here:

- Use cases, which describe how people interact with the system.
- A class diagram drawn from the conceptual perspective, which can be a good way of building up a rigorous vocabulary of the domain.

- An activity diagram, which can show the work flow of the organization, showing how software and human activities interact. An activity diagram can show the context for use cases and also the details of how a complicated use case works.
- A state diagram, which can be useful if a concept has an interesting life cycle, with various states and events that change that state.

When working in requirements analysis, remember that the most important thing is communication with your users and customers. Usually, they are not software people and will be unfamiliar with the UML or any other technique. Even so, I've had success using these techniques with nontechnical people. To do this, remember that it's important to keep the notation to a minimum. Don't introduce anything that specific to the software implementation.

Be prepared to break the rules of the UML at any time if it helps you communicate better. The biggest risk with using the UML in analysis is that you draw diagrams that the domain experts don't fully understand. A diagram that isn't understood by the people who know the domain is worse than useless; all it does is breed a false sense of confidence for the development team.

Design

When you are doing design, you can get more technical with your diagrams. You can use more notation and be more precise about your notation. Some useful techniques are

- Class diagrams from a software perspective. These show the classes in the software and how they interrelate.
- Sequence diagrams for common scenarios. A valuable approach is to pick the most important and interesting scenarios from the use cases and use CRC cards or sequence diagrams to figure out what happens in the software.
- Package diagrams to show the large-scale organization of the software.
- State diagrams for classes with complex life histories.
- Deployment diagrams to show the physical layout of the software.

Many of these same techniques can be used to document software once it's been written. This may help people find their way around the software if they have to work on it and are not familiar with the code.

With a waterfall life cycle, you would do these diagrams and activities as part of the phases. The end-of-phase documents usually include the appropriate UML diagrams for that activity. A waterfall style usually implies that the UML is used as a blueprint.

In an iterative style, the UML diagrams can be used in either a blueprint or a sketch style. With a blueprint, the analysis diagrams will usually be built in the iteration prior to the one that builds the functionality. Each iteration doesn't start from scratch; rather, it modifies the existing body of documents, highlighting the changes in the new iteration.

Blueprint designs are usually done early in the iteration and may be done in pieces for different bits of functionality that are targeted for the iteration. Again, iteration implies making changes to an existing model rather than building a new model each time.

Using the UML in sketch mode implies a more fluid process. One approach is to spend a couple of days at the beginning of an iteration, sketching out the design for that iteration. You can also do short design sessions at any point during the iteration, setting up a quick meeting for half an hour whenever a developer starts to tackle a nontrivial function.

With a blueprint, you expect the code implementation to follow the diagrams. A change from the blueprint is a deviation that needs review from the designers who did the blueprint. A sketch is usually treated more as a first cut at the design; if, during coding, people find that the sketch isn't exactly right, they should feel free to change the design. The implementors have to use their judgment as to whether the change needs a wider discussion to understand the full ramifications.

One of my concerns with blueprints is my own observation that it's very hard to get them right, even for a good designer. I often find that my own designs do not survive contact with coding intact. I still find UML sketches useful, but I don't find that they can be treated as absolutes.

In both modes, it makes sense to explore a number of design alternatives. It's usually best to explore alternatives in sketch mode so that you can quickly generate and change the alternatives. Once you pick a design to run with, you can either use that sketch or detail it into a blueprint.

Documentation

Once you have built the software, you can use the UML to help document what you have done. For this, I find UML diagrams useful for getting an overall understanding of a system. In doing this, however, I should stress that I do not believe in producing detailed diagrams of the whole system. To quote Ward Cunningham [Cunningham]:

> *Carefully selected and well-written memos can easily substitute for traditional comprehensive design documentation. The latter rarely shines except in isolated spots. Elevate those spots . . . and forget about the rest. (p. 384)*

I believe that detailed documentation should be generated from the code—like, for instance, JavaDoc. You should write additional documentation to highlight important concepts. Think of these as comprising a first step for the reader before he or she goes into the code-based details. I like to structure these as prose documents, short enough to read over a cup of coffee, using UML diagrams to help illustrate the discussion. I prefer the diagrams as sketches that highlight the most important parts of the system. Obviously, the writer of the document needs to decide what is important and what isn't, but the writer is much better equipped than the reader to do that.

A package diagram makes a good logical road map of the system. This diagram helps me understand the logical pieces of the system and see the dependencies and keep them under control. A deployment diagram (see Chapter 8), which shows the high-level physical picture, may also prove useful at this stage.

Within each package, I like to see a class diagram. I don't show every operation on every class. I show only the important features that help me understand what is in there. This class diagram acts as a graphical table of contents.

The class diagram should be supported by a handful of interaction diagrams that show the most important interactions in the system. Again, selectivity is important here; remember that, in this kind of document, comprehensiveness is the enemy of comprehensibility.

If a class has complex life-cycle behavior, I draw a state machine diagram (see Chapter 10) to describe it. I do this only if the behavior is sufficiently complex, which I find doesn't happen often.

I'll often include some important code, written in a literate program style. If a particularly complex algorithm is involved, I'll consider using an activity diagram (see Chapter 11) but only if it gives me more understanding than the code alone.

If I find concepts that are coming up repeatedly, I use patterns (page 27) to capture the basic ideas.

One of the most important things to document is the design alternatives you didn't take and why you didn't do them. That's often the most forgotten but most useful piece of external documentation you can provide.

Understanding Legacy Code

The UML can help you figure out a gnarly bunch of unfamiliar code in a couple of ways. Building a sketch of key facts can act as a graphical note-taking mechanism that helps you capture important information as you learn about it. Sketches of key classes in a package and their key interactions can help clarify what's going on.

With modern tools, you can generate detailed diagrams for key parts of a system. Don't use these tools to generate big paper reports; instead, use them to drill into key areas as you are exploring the code itself. A particularly nice capability is that of generating a sequence diagram to see how multiple objects collaborate in handling a complex method.

Choosing a Development Process

I'm strongly in favor of iterative development processes. As I've said in this book before: You should use iterative development only on projects that you want to succeed.

Perhaps that's a bit glib, but as I get older, I get more aggressive about using iterative development. Done well, it is an essential technique, one you can use to expose risk early and to obtain better control over development. It is not the same as having no management, although to be fair, I should point out that some have used it that way. It does need to be well planned. But it is a solid approach, and every OO development book encourages using it—for good reason.

You should not be surprised to hear that as one the authors of the Manifesto for Agile Software Development, I'm very much a fan of agile approaches. I've also had a lot of positive experiences with Extreme Programming, and certainly you should consider its practices very seriously.

Where to Find Out More

Books on software process have always been common, and the rise of agile software development has led to many new books. Overall, my favorite book on process in general is [McConnell]. He gives a broad and practical coverage of many of the issues involved in software development and a long list of useful practices.

From the agile community, [Cockburn, agile] and [Highsmith] provide a good overview. For a lot of good advice about applying the UML in an agile way, see [Ambler].

One of the most popular agile methods is Extreme Programming (XP), which you can delve into via such Web sites as **http://xprogramming.com** and **http://www.extremeprogramming.org**. XP has spawned many books, which is why I now refer to it as the formerly lightweight methodology. The usual starting point is [Beck].

Although it's written for XP, [Beck and Fowler] gives more details on planning an iterative project. Much of this is also covered by the other XP books, but if you're interested only in the planning aspect, this would be a good choice.

For more information on the Rational Unified Process, my favorite introduction is [Kruchten].

Chapter 3. Class Diagrams: The Essentials

If someone were to come up to you in a dark alley and say, "Psst, wanna see a UML diagram?" that diagram would probably be a class diagram. The majority of UML diagrams I see are class diagrams.

The class diagram is not only widely used but also subject to the greatest range of modeling concepts. Although the basic elements are needed by everyone, the advanced concepts are used less often. Therefore, I've broken my discussion of class diagrams into two parts: the essentials (this chapter) and the advanced (Chapter 5).