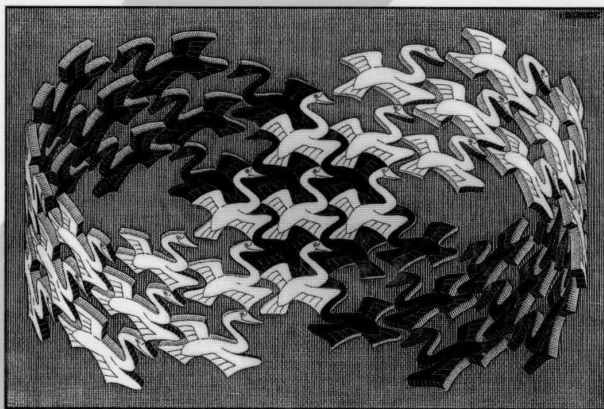


# Design Patterns

## Elements of Reusable Object-Oriented Software

Erich Gamma  
Richard Helm  
Ralph Johnson  
John Vlissides



Cover art © 1994 M.C. Escher / Cordon Art - Baarn - Holland. All rights reserved.

Foreword by Grady Booch



ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES

**Material from *A Pattern Language: Towns/Buildings/Construction* by Christopher Alexander, copyright © 1977 by Christopher Alexander is reprinted by permission of Oxford University Press, Inc.**

Many of the designations used by manufacturers and sellers to distinguish their products are claimed as trademarks. Where those designations appear in this book, and we were aware of a trademark claim, the designations have been printed in initial capital letters or in all capitals.

The author and publisher have taken care in the preparation of this book, but make no expressed or implied warranty of any kind and assume no responsibility for errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of the use of the information or programs contained herein.

The publisher offers discounts on this book when ordered in quantity for special sales. For more information, please contact:

Pearson Education Corporate Sales Division  
201 W. 103rd Street  
Indianapolis, IN 46290  
(800) 428-5331  
corpsales@pearsoned.com

Visit AW on the Web: [www.awl.com/cseng/](http://www.awl.com/cseng/)

*Library of Congress Cataloging-in-Publication Data*

Design Patterns : elements of reusable object-oriented software / Erich Gamma . . . [et al.].

p. cm.—(Addison-Wesley professional computing series)

Includes bibliographical references and index.

ISBN 0-201-63361-2

1. Object-oriented programming (Computer science) 2. Computer software—Reusability.

I. Gamma, Erich. II. Series.

QA76.64.D47 1994

005.1'2—dc20

94-34264

CIP

Copyright © 1995 by Addison-Wesley

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form, or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior consent of the publisher. Printed in the United States of America. Published simultaneously in Canada.

Cover art © M.C. Escher/Cordon Art - Baarn - Holland. All rights reserved.

Text printed on recycled and acid-free paper.

ISBN 0201633612

23 2425262728 CRW 05 04 03 02

23rd Printing March 2002

and the distribution of responsibilities. Each design pattern focuses on a particular object-oriented design problem or issue. It describes when it applies, whether it can be applied in view of other design constraints, and the consequences and trade-offs of its use. Since we must eventually implement our designs, a design pattern also provides sample C++ and (sometimes) Smalltalk code to illustrate an implementation.

Although design patterns describe object-oriented designs, they are based on practical solutions that have been implemented in mainstream object-oriented programming languages like Smalltalk and C++ rather than procedural languages (Pascal, C, Ada) or more dynamic object-oriented languages (CLOS, Dylan, Self). We chose Smalltalk and C++ for pragmatic reasons: Our day-to-day experience has been in these languages, and they are increasingly popular.

The choice of programming language is important because it influences one's point of view. Our patterns assume Smalltalk/C++-level language features, and that choice determines what can and cannot be implemented easily. If we assumed procedural languages, we might have included design patterns called "Inheritance," "Encapsulation," and "Polymorphism." Similarly, some of our patterns are supported directly by the less common object-oriented languages. CLOS has multi-methods, for example, which lessen the need for a pattern such as Visitor (page 331). In fact, there are enough differences between Smalltalk and C++ to mean that some patterns can be expressed more easily in one language than the other. (See Iterator (257) for an example.)

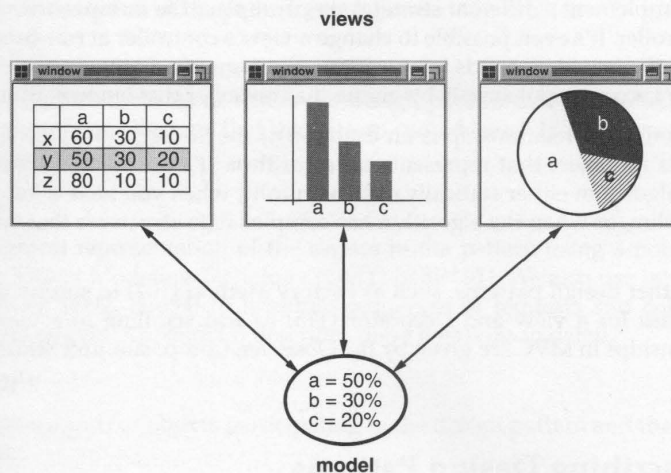
## 1.2 Design Patterns in Smalltalk MVC

The Model/View/Controller (MVC) triad of classes [KP88] is used to build user interfaces in Smalltalk-80. Looking at the design patterns inside MVC should help you see what we mean by the term "pattern."

MVC consists of three kinds of objects. The Model is the application object, the View is its screen presentation, and the Controller defines the way the user interface reacts to user input. Before MVC, user interface designs tended to lump these objects together. MVC decouples them to increase flexibility and reuse.

MVC decouples views and models by establishing a subscribe/notify protocol between them. A view must ensure that its appearance reflects the state of the model. Whenever the model's data changes, the model notifies views that depend on it. In response, each view gets an opportunity to update itself. This approach lets you attach multiple views to a model to provide different presentations. You can also create new views for a model without rewriting it.

The following diagram shows a model and three views. (We've left out the controllers for simplicity.) The model contains some data values, and the views defining a spreadsheet, histogram, and pie chart display these data in various ways. The model communicates with its views when its values change, and the views communicate with the model to access these values.



Taken at face value, this example reflects a design that decouples views from models. But the design is applicable to a more general problem: decoupling objects so that changes to one can affect any number of others without requiring the changed object to know details of the others. This more general design is described by the Observer (page 293) design pattern.

Another feature of MVC is that views can be nested. For example, a control panel of buttons might be implemented as a complex view containing nested button views. The user interface for an object inspector can consist of nested views that may be reused in a debugger. MVC supports nested views with the CompositeView class, a subclass of View. CompositeView objects act just like View objects; a composite view can be used wherever a view can be used, but it also contains and manages nested views.

Again, we could think of this as a design that lets us treat a composite view just like we treat one of its components. But the design is applicable to a more general problem, which occurs whenever we want to group objects and treat the group like an individual object. This more general design is described by the Composite (163) design pattern. It lets you create a class hierarchy in which some subclasses define primitive objects (e.g., Button) and other classes define composite objects (CompositeView) that assemble the primitives into more complex objects.

MVC also lets you change the way a view responds to user input without changing its visual presentation. You might want to change the way it responds to the keyboard, for example, or have it use a pop-up menu instead of command keys. MVC encapsulates the response mechanism in a Controller object. There is a class hierarchy of controllers, making it easy to create a new controller as a variation on an existing one.

A view uses an instance of a Controller subclass to implement a particular response strategy; to implement a different strategy, simply replace the instance with a different kind of controller. It's even possible to change a view's controller at run-time to let the view change the way it responds to user input. For example, a view can be disabled so that it doesn't accept input simply by giving it a controller that ignores input events.

The View-Controller relationship is an example of the Strategy (315) design pattern. A Strategy is an object that represents an algorithm. It's useful when you want to replace the algorithm either statically or dynamically, when you have a lot of variants of the algorithm, or when the algorithm has complex data structures that you want to encapsulate.

MVC uses other design patterns, such as Factory Method (107) to specify the default controller class for a view and Decorator (175) to add scrolling to a view. But the main relationships in MVC are given by the Observer, Composite, and Strategy design patterns.

### 1.3 Describing Design Patterns

How do we describe design patterns? Graphical notations, while important and useful, aren't sufficient. They simply capture the end product of the design process as relationships between classes and objects. To reuse the design, we must also record the decisions, alternatives, and trade-offs that led to it. Concrete examples are important too, because they help you see the design in action.

We describe design patterns using a consistent format. Each pattern is divided into sections according to the following template. The template lends a uniform structure to the information, making design patterns easier to learn, compare, and use.

#### Pattern Name and Classification

The pattern's name conveys the essence of the pattern succinctly. A good name is vital, because it will become part of your design vocabulary. The pattern's classification reflects the scheme we introduce in Section 1.5.

#### Intent

A short statement that answers the following questions: What does the design pattern do? What is its rationale and intent? What particular design issue or problem does it address?

#### Also Known As

Other well-known names for the pattern, if any.

#### Motivation

A scenario that illustrates a design problem and how the class and object structures