10. Guidelines, Idioms and Patterns

Oscar Nierstrasz
Roadmap

> Idioms, Patterns and Frameworks
  — Programming style: Code Talks; Code Smells

> Basic Idioms
  — Delegation, Super, Interface

> Some Design Patterns
  — Adapter, Proxy, Template Method, Composite, Observer, Visitor, State
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Sources


Kent Beck, *Smalltalk Best Practice Patterns*, Prentice Hall, 1997


The “Design Patterns” book by Gamma et al. (also known as the “Gang of Four”, or GOF) was the first book to systematically document design patterns. The book describes patterns encountered by the four authors during their experience working on various projects in different object-oriented languages. The patterns are language-agnostic, and discuss trade-offs in different languages.

Many other authors have documented other design patterns since then, both in books and in conferences, particularly the Pattern Languages of Programs (PLoP) series. There exist also books dedicated to how design patterns can be implemented in specific languages, like Java.
Design patterns are *common solutions to recurring design problems*.

Design patterns are not just about structure, they also cover interaction between objects — *communication patterns*. Also deal with *strategies for inheritance and containment*.

The GOF book presents three groups of patterns:

*Creational patterns* create objects for you. You can decide which objects are created given a specific case.

*Structural patterns* help you to compose objects into larger structures.

*Behavioral patterns* help you to define communication between objects and how the flow is controlled in a complex program.
**Code Talks**

> Do the simplest thing you can think of (KISS)
  — Don't over-design
  — Implement things *once and only once*
  — *First do it, then do it right, then do it fast*
    (don’t optimize too early)

> Make your intention clear
  — Write *small methods*
  — Each method should *do one thing only*
  — Name methods for *what they do*, not how they do it
  — Write to an *interface*, not an implementation
**Simplicity in design** should be a key goal (used in the Apollo project). Simplicity denotes beauty, purity, and clarity. Or if code speaks and no one is around to hear it, does it still make a sound?

*Extreme Programming* encourages starting with the simplest solution and refactoring to better ones. The difference between this approach and more conventional system development methods is the focus on designing and coding for the needs of today instead of those of tomorrow, next week, or next month. Proponents of XP acknowledge the disadvantage that this can sometimes entail more effort tomorrow to change the system; their claim is that this is more than compensated for by the advantage of not investing in possible future requirements that might change before they become relevant. Coding and designing for uncertain future requirements implies the risk of spending resources on something that might not be needed.

Related to the “communication” value, simplicity in design and coding should improve the (quality of) communication. A simple design with very simple code could be easily understood by most programmers in the team.
Refactoring

Redesign and refactor when the code starts to “smell”


> Methods *too long* or too complex
  — decompose using helper methods

> **Duplicated code**
  — factor out the common parts
    (e.g., using a *Template method* Pattern)

> Violation of *encapsulation*
  — redistribute responsibilities

> Too much communication (*high coupling*)
  — redistribute responsibilities

*Many idioms and patterns can help you improve your design ...*
Object-oriented programs live best and longest with *short methods*. The payoffs of indirection — explanation, sharing and choosing — are supported by little methods. Everybody knows short is good.

99% of the time, just use **Extract Method** to shorten a method. Find a part that goes together and make a new method.

Parameters and temporary variables get in the way of extracting methods. Use **Replace Temp with Query** to remove the temporaries and **Introduce Parameter Object** or **Preserve Whole Object** to slim down the parameter lists.

If you still have too many temps and parameters, it’s time for the heavy artillery: **Replace Method with Method Object**

*Look for comments.* A block of code with a comment should be replaced by a method named to match the comment. *Even a single line is worth extracting if it needs explanation.*

Look for conditionals and loops. Use **Decompose Conditional**. Extract each loop into its own method.
Refactoring Long Methods

Short is good!
If you need to comment then Extract as Method.
What are Idioms and Patterns?

<table>
<thead>
<tr>
<th><strong>Idioms</strong></th>
<th>Idioms are <em>common programming techniques</em> and conventions. They are often <em>language-specific</em>. (<a href="http://c2.com/ppr/wiki/JavaIdioms/JavaIdioms.html">http://c2.com/ppr/wiki/JavaIdioms/JavaIdioms.html</a>)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Patterns</strong></td>
<td>Patterns document <em>common solutions to design problems</em>. They are <em>language-independent</em>.</td>
</tr>
<tr>
<td><strong>Libraries</strong></td>
<td>Libraries are <em>collections of functions, procedures or other software components</em> that can be used in many applications.</td>
</tr>
<tr>
<td><strong>Frameworks</strong></td>
<td>Frameworks are open libraries that define the <em>generic architecture</em> of an application, and can be extended by adding or deriving new classes. (<a href="http://martinfowler.com/bliki/InversionOfControl.html">http://martinfowler.com/bliki/InversionOfControl.html</a>)</td>
</tr>
</tbody>
</table>

Frameworks typically make use of common idioms and patterns.
Idiom: the peculiar character or genius of a language — a distinct style or character, in music, art, e.g., the idiom of Bach.

E.g., Interface in Java

A Library is about reusable behavior, a framework is about reusable architecture.

A library is something you call or inherit from your code.

A framework is something that calls your code to provide services for your code.

A framework is an abstract design that embodies how an application works and it has hooks where you can inject your module or component.
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Delegation

How can an object share behaviour without inheritance?
✔ Delegate some of its work to another object

Inheritance is a common way to extend the behaviour of a class, but can be an inappropriate way to combine features.

Delegation reinforces encapsulation by keeping roles and responsibilities distinct.
Delegation is the handing of a task to another part of the program. One object, the *delegator*, defers a task to another object, known as the *delegate*.

Delegation is used to separate concerns and distribute responsibilities. The opposite of delegation is concentration of responsibilities (as seen in the *God class* anti-pattern).

Some programming languages, like JavaScript (JS), are fully based on delegation. JS is based on prototypes rather than classes: to create a new object, you clone an existing object (a *prototype*) instead of instantiating a class. Class-based inheritance is simulated by *delegation*: if an object does not understand a message (i.e., a request) it delegates it to its prototype (and so on).
Delegation

Example

> When a TestSuite is asked to run(), it delegates the work to each of its TestCases.

Consequences

> More flexible, less structured than inheritance.

Delegation is one of the most basic object-oriented idioms, and is used by almost all design patterns.
public class TestSuite implements Test {
    ...
    public void run(TestResult result) {
        for(Enumeration e = fTests.elements(); e.hasMoreElements();)
        {
            if (result.shouldStop())
                break;
            Test test = (Test) e.nextElement();
            test.run(result);
        }
    }
}
Instead of a test suite directly running tests, it delegates the task to its individual test cases. The form of delegation is also fundamental to the *Composite pattern* (discussed later): when a composite object is asked to perform a task, it typically delegates the tasks to its components. Here the test suite is the composite and the test cases are the components.
How do you extend behavior inherited from a superclass?

- Overwrite the inherited method, and send a message to “super” in the new method.

Sometimes you just want to extend inherited behavior, rather than replace it.
Instead of replacing behavior from the superclass, you would like to extend it. The super construct allows you to override the inherited method and extend it by invoking that behavior by calling super. The extended behavior will occur before, after or around the old behavior.

```java
public T foo() {
    T result;
    // new behavior before
    result = super.foo();
    // new behavior after
    return result;
}
```
**Examples**

> `Place.paint()` extends `Panel.paint()` with specific painting behaviour

> Constructors for many classes, e.g., `TicTacToe`, invoke their superclass constructors.

**Consequences**

> Increases coupling between subclass and superclass: if you change the inheritance structure, super calls may break!

*Never use super to invoke a method different than the one being overwritten — use “this” instead!*
NB: It is bad practice to use `super` to invoke an inherited method when this will do. Consider the following classes A and B:

```java
class A {
    void m1() {
        ... }  
}
class B extends A {
    void m2() {
        ... super.m1(); ... } // should use `this.m1()`
}
```

Now, if we later override `m1()` in B, then `m2` will call the wrong method!

```java
class B extends A {
    void m2() {
        ... super.m1(); ... } // calls wrong `m1()`!
    void m1() {
        ... } // overrides `A.m1()`
}
```

The correct thing to do is to call `this.m1()`.
public class Place extends Panel {
    ...
    public void paint(Graphics g) {
        super.paint(g);
        Rectangle rect = g.getClipBounds();
        int h = rect.height;
        int w = rect.width;
        int offset = w/10;
        g.drawRect(0,0,w,h);
        if (image != null) {
            g.drawImage(image, offset, offset, w-2*offset, h-2*offset, this);
        }
    }
    ...
}

public class TicTacToe extends AbstractBoardGame {
    public TicTacToe(Player playerX, Player player0) {
        super(playerX, player0);
    }
}
In the first example we extend the behavior of the `paint()` method with our specific painting behavior. In general, whenever you override a method inherited from a framework, *it is good practice to explicitly call the overridden method using `super`. If you don’t then you may break the framework behavior. Here, if you fail to call `super.paint()`, nothing will work.*

In the second example, we explicitly call the constructor of the superclass. By default classes in Java only inherit the default constructor of the superclass.

**NB:** Subclass constructors should *always* explicitly call a constructor of the superclass to ensure that the invariant of inherited state is established.
How do you keep a client of a service independent of classes that provide the service?

Have the client use the service through an interface rather than a concrete class.

If a client names a concrete class as a service provider, then only instances of that class or its subclasses can be used in future.

By naming an interface, an instance of any class that implements the interface can be used to provide the service.
Interface

Example

> Any object may be registered with an Observable if it implements the Observer interface.

> **Consequences**

> Interfaces *reduce coupling* between classes.

> They also *increase complexity* by adding indirection.
Interfaces reduce coupling by removing the need to inherit from a specific class. If you declare a variable \( x \) to be of type \( A \), where \( A \) is a class, then \( x \) must be an instance of \( A \) or one of its subclasses. If, on the other hand, you declare \( x \) to be of type \( I \), where \( I \) is an interface, then \( x \) can be an instance of any class \( X \) that implements the interface \( X \). In the latter case, you reduce coupling between the class where \( x \) is declared and other class hierarchies. On the other hand, complexity is increased by adding a new interface \( I \) to the system. If the flexibility offered by the interface is not needed, it is pointless to add it.
public class GameGUI extends JFrame implements Observer {
    ...
    public void update(Observable o, Object arg) {
        Move move = (Move) arg;
        showFeedback("got an update: "+move);
        places_[move.col][move.row].setMove(move.player);
    }
    ...
}
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How do you use a class that provide the right features but the wrong interface?

Introduce an adapter.

An adapter converts the interface of a class into another interface clients expect.

> The client and the adapted object remain independent.
> An adapter adds an extra level of indirection.

Also known as Wrapper
This is one of the most basic and common design patterns. By defining an adapter around an existing class, you *avoid the need to modify directly the interface* of that class. Sometimes you may not even have access to the source code of the class to be adapted, or there may be a great deal of existing code that depends on the old interface. Writing an adapter may be the only way to avoid rewriting the source code of the adapted class. The down side is that the adapter introduces an *extra level of indirection*. Every access to the old class must go through the adapter, possibly impacting performance.
Adapter Pattern

Examples

> A WrappedStack adapts java.util.Stack, throwing an AssertionError when top() or pop() are called on an empty stack.

> An ActionListener converts a call to actionPerformed() to the desired handler method.
public class WrappedStack<E> implements StackInterface<E> {

    protected java.util.Stack<E> stack;

    public WrappedStack() {
        this(new Stack<E>());
    }

    public WrappedStack(Stack<E> stack) {
        this.stack = stack;
    }

    public void push(E item) {
        stack.push(item);
        assert this.top() == item;
        assert invariant();
    }
}

delegate request to adaptee
Patterns are more than just programming “tricks” and can involve considerable details and tradeoffs.
The basic idea of any given design pattern may be quite simple, but to fully discuss the pros and cons, implementation strategies and other tradeoffs may require several pages of documentation. Each of the design patterns in the original GOF book increases flexibility of your code at the expense of increased complexity. Understanding the tradeoffs is critical to applying design patterns judiciously.

Erich Gamma has a story of a design pattern “fan” who proudly told him that in his last project he successfully applied all the design patterns in the book. Erich, of course, was horrified.
How do you hide the complexity of accessing objects that require pre- or post-processing?

Introduce a proxy to control access to the object.

Some services require special pre or post-processing. Examples include objects that reside on a remote machine, and those with security restrictions.

A proxy provides the same interface as the object that it controls access to.
Proxy Pattern — UML
Proxy Pattern Example

Client «uses» Proxy «delegates» ReallImage

Image «interface»

displayImage()
public class ProxyImage implements Image {
    private String filename;
    private Image image;

    public ProxyImage(String filename) {
        this.filename = filename;
    }

    public void displayImage() {
        if (image == null) {
            image = new RealImage(filename); // load only on demand
        }
        image.displayImage();
    }
}
Proxies are used for remote object access

**Example**

> A Java “stub” for a remote object accessed by Remote Method Invocation (RMI).

**Consequences**

> A Proxy decouples clients from servers. A Proxy introduces a level of indirection.

Proxy differs from Adapter in that it does not change the object’s interface.
Superficially proxies look very much like adapters. Both wrap an existing class, adding a level of indirection. Their *intent*, and consequently the design considerations and tradeoffs are very different, however.

An *adapter* exists only to adapt the interface of a class to a different interface required a by a client.

A *proxy*, on the other hand, provides the same interface as the object it is a proxy for. Instead of adapting the interface, it provides additional pre- or post-processing.
Proxy remote access example

Machine A

:ServiceStub

1:doit()

1.1:doit()

Machine B

:Service
How do you implement a generic algorithm, deferring some parts to subclasses?

Define it as a Template Method.

A Template Method factors out the common part of similar algorithms, and delegates the rest to:

— hook methods that subclasses may extend, and
— abstract methods that subclasses must implement.
This is a behavioral pattern. It defines a program skeleton of an algorithm. The algorithm itself is made abstract, and the subclasses of the method override the abstract methods to provide concrete behavior.

First a class is created that provides the basic steps of the algorithm design. These steps are implemented using abstract methods. Later on the subclasses change the abstract methods to perform real actions. Thus, the general algorithm is saved in one place but the concrete steps may be changed by the subclasses.
Template Method Pattern

**Example**

> `TestCase.runBare()` is a template method that calls the hook method `setUp()`.

> `AbstractBoardGame`’s constructor defers initialization to the abstract `init()` method

**Consequences**

> Template methods lead to an *inverted control structure* since a parent classes calls the operations of a subclass and not the other way around.

*Template Method is used in most frameworks to allow application programmers to easily extend the functionality of framework classes.*
The Template Method pattern is fundamental to object-oriented frameworks, such as the original JUnit. Such a framework defines the architecture of a generic application in terms of interacting objects, but leaves open the details of the work to be done by a specific application.

The generic behaviour of the framework is defined in template methods, such as the methods that actually run tests and gather the test results. The details are deferred to hook methods, containing the actual tests. These are implemented by the specific application classes that inherit from framework classes, like TestCase.
Template Method Pattern — UML

The template method defines the skeleton of an algorithm. Concrete methods override the hook methods.
Template Method Pattern Example

Subclasses of `TestCase` are expected to override hook methods `setUp()` and possibly `tearDown()` and `runTest()`.

```java
public abstract class TestCase implements Test {
    ...
    public void runBare() throws Throwable {
        setUp();
        try { runTest(); } 
            finally { tearDown(); } 
    }
    protected void setUp() { } // empty by default
    protected void tearDown() { }
    protected void runTest() throws Throwable { ... }
}
```
How do you manage a part-whole hierarchy of objects in a consistent way?

Define a common interface that both parts and composites implement.

Typically composite objects will implement their behavior by delegating to their parts.
When working with tree-structured data, a programmer has to discriminate between a leaf node and a branch. This makes code more complex, thus error-prone.

A Composite is an object (e.g. a shape) designed as a composition of one or more similar objects (other kinds of shapes) exhibiting similar functionality.

This is known as a *has-a* relationship between objects. The key concept is that you can manipulate a single object just as you would a group of them.
Composite Pattern

> **Composite** allows you to treat a single instance of an object the same way as a *group* of objects.

> Consider a *Tree*. It consists of Trees (subtrees) and *Leaf* objects.
Composite Pattern — UML

```
<<interface>>
IComponent

operation()

Leaf

operation()

Composite

operation()
addComponent(IComponent)
removeComponent(IComponent)
getChildren() : Collection
```
Here we see the essence of the Composite pattern: both Leaf entities and Composites implement the same interface (possibly inheriting from a common superclass). The Composite is furthermore composed of entities that implement that same interface, i.e., the components may themselves be either leaves or composites.
Composite Pattern — Example

```
public double size() {
    double total = 0;
    for (Shape shape : shapes) {
        total += shape.size();
    }
    return total;
}
```
Recall the Shapes example from the first lecture. We could easily redesign it to make a Picture a Composite.

Here we see one of the key implementation considerations of the Composite pattern: operations defined in the common interface are often implemented in the composite by invoking those same operations in the individual components (i.e., possibly recursively), and combining their results. In this example, the sizes of the components are added together. In the JUnit example, tests are executed recursively and their test results are combined into an overall test report.
Observer Pattern

How can an object inform arbitrary clients when it changes state?

Clients implement a common Observer interface and register with the “observable” object; the object notifies its observers when it changes state.

An observable object publishes state change events to its subscribers, who must implement a common interface for receiving notification.
We saw the Observer pattern extensively in the GUI lecture. Observers can, however, be used in any setting where parts of an application need to be informed about events in another part. Consider an online shopping platform where users want to be informed if an item becomes available below a certain price, or sellers want to be informed if bids are issues for similar items that they are also selling. Such cases can be effectively handled using Observers, even though the domain has nothing to do with user interfaces.
Observer Pattern

Example

> See GUI Lecture

> A Button expects its observers to implement the ActionListener interface.

(see the Interface and Adapter examples)

Consequences

> Notification can be slow if there are many observers for an observable, or if observers are themselves observable!
Null Object Pattern

How do you avoid cluttering your code with tests for null object pointers?

Introduce a Null Object that implements the interface you expect, but does nothing.

Null Objects may also be Singleton objects, since you never need more than one instance.
The Null Object provides intelligent ∇ do nothing ∇ behavior.

It shifts the responsibility for “doing nothing” from the client to the supplier. Instead of having to actively check whether an object is a valid target for some action, we simply ensure that all objects support that action, even if it is a no-op. This considerably simplifies our code and avoids accidental “null object reference” errors.
Null Object Pattern — UML

Client «uses» AbstractClass

RealObject
request()

NullObject
request()

does nothing
The Client requires a collaborator.

AbstractObject declares the interface for Client’s collaborator. It implements default behavior for the interface common to all classes, as appropriate.

RealObject defines a concrete subclass of AbstractObject whose instances provide useful behavior that Client expects.

NullObject provides an interface identical to AbstractObject so that a null object can be substituted for a real object. It implements its interface to do nothing. (NB: what exactly it means to “do nothing” depends on the behavior Client is expecting.)

When there is more than one way to do nothing, more than one NullObject class may be required.
Null Object

**Examples**

> `NullOutputStream` extends `OutputStream` with an empty `write()` method

**Consequences**

> Simplifies client code

> Not worthwhile if there are only few and localized tests for null pointers
How can you write code that abstracts which classes to instantiate?

Define an interface for creating an object, but let subclasses decide which class to instantiate.

A Factory method lets a class defer instantiation to subclasses.
public void checkGame(...) {
    ...
    game = makeGame(X, O);
    ...
}

protected BoardGame makeGame(...) {
    return new Gomoku(X, O);
}
Factory Method

**Examples**

> AbstractBoardGameTest defines an abstract factory method `makeGame()` that is implemented in its subclasses

**Consequences**

> Abstracts away from which game to test

Factory methods are often combined with *AbstractFactories* to encapsulate creation of related objects.
Factory methods also reduce coupling by avoiding the need to explicitly name the classes to be instantiated in the host code. This can make your code much more easily configurable.

Abstract Factories take this idea further and offer a general interface for creating objects. Different factories can then be easily plugged into an application to configure it for one platform or another. For example, dedicated factories may create UI widgets for one operating system or another using a common interface.
Some other Design Patterns…

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State</strong></td>
<td>The state pattern is a behavioral design pattern, also known as the objects for states pattern. This pattern is used in to represent the state of an object. This is a clean way for an object to partially change its type at runtime.</td>
</tr>
<tr>
<td><strong>Decorator</strong></td>
<td>that allows new/additional behaviour to be added to an existing method of an object dynamically.</td>
</tr>
<tr>
<td><strong>Visitor</strong></td>
<td>a way of separating an algorithm from an object structure. A practical result of this separation is the ability to add new operations to existing object structures without modifying those structures.</td>
</tr>
</tbody>
</table>

and many more…
What Problems do Design Patterns Solve?

*Patterns:*

> document *design experience*
> enable widespread *reuse of software architecture*
> *improve communication* within and across software development teams
> *explicitly capture knowledge* that experienced developers already understand implicitly
> arise from *practical experience*
> help *ease the transition* to object-oriented technology
> *facilitate training* of new developers
> help to transcend “programming language-centric” viewpoints

*Doug Schmidt, CACM Oct 1995*
What you should know!

✎ What’s wrong with long methods? How long should a method be?
✎ What’s the difference between a pattern and an idiom?
✎ When should you use delegation instead of inheritance?
✎ When should you call “super”?
✎ How does a Proxy differ from an Adapter?
✎ How can a Template Method help to eliminate duplicated code?
✎ When do I use a Composite Pattern? Do you know any examples from the Frameworks you know?
Can you answer these questions?

- What idioms do you regularly use when you program? What patterns do you use?
- What is the difference between an interface and an abstract class?
- When should you use an Adapter instead of modifying the interface that doesn’t fit?
- Is it good or bad that java.awt.Component is an abstract class and not an interface?
- Why do the Java libraries use different interfaces for the Observer pattern (java.util.Observer, java.awt.event.ActionListener etc.)?
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