Appendix A: Design-Pattern Quick Reference

This appendix is a reference of the Gang-of-Four design patterns to jog your memory about how the patterns work. Ironically, the original GoF presentation was this brief, but they expanded things in the book to make it more accessible. Once you know the patterns, however, brevity is good. This catalog probably won't be of much use if you don't already have some familiarity with the patterns, however. A lot of the material you'd find in an intro-level discussion is either missing or very condensed in the current document.

Though I've followed the Gang-of-Four organization (alphabetical by category), I have deliberately not followed the Gang-of-Four format for the pattern description itself. In particular, I've restated their "intent" section to make it more understandable. I've also used very-stripped-down examples, which are usually not the same examples that you'll find in the GoF book. If you want a more-formal presentation and more elaborate examples, get a copy of the GoF book, too. My examples are also not the same as the GoF examples. In particular, since most of us aren't doing GUI work, I've tried to eliminate GUI-related example code.

I've tried to make up for some of this brevity by adding a list of places where the design patterns are found in the Java packages, so that you can see how they're applied in practice. (Some patterns don't appear in Java, in which case the "Usage" example will say so. Also, detailed code similar to my stripped-down examples can be found in one or another of the volumes of Chan, Lee, and Kramer's *The Java Class Libraries* or in the Java documentation or Tutorials available on the Sun web site.

I've played a bit loose with the code in the interest of saving space, leaving out required `import` statements, access privileges, exceptions, etc. The formatting isn't ideal in places. I'm assuming that you know what you're doing in the Java-programming department and are more interested in the clarity of the example than in having cut-and-paste code. Don't expect the code to compile cleanly as it stands.

Finally, I've said a few things in these notes which you may find shocking if you haven't read the rest of the book or some of my other work—things like "objects must be responsible for building their own user interfaces." There's simply no room to explain this sort of thing in a quick reference. Sorry. (You may want to check out the "articles" section of my web site http://www.holub.com, for illumination.)

Note: when printing two sided, this page should be an odd (right-hand) page number so that each two-page pattern description will appear on two facing pages.

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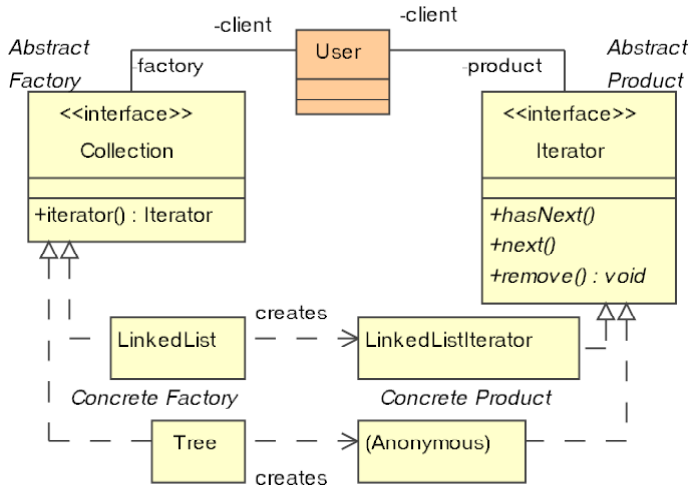
* Rather an odd thing to say, since the page isn't blank at all—it contains the text "This page intentionally left blank" —but imagine that it's blank.

Creational Patterns

The creational patterns are all concerned with object creation (fancy that!). Most of them provide ways to create objects without knowing exactly what you're creating (beyond the interfaces supported by the created objects). Programming in terms of interfaces rather than concrete-classes is essential if you intend to write flexible, reusable code. My rule of thumb is that as much as 80% of my code should be written in terms of interfaces.

Abstract Factory

Create objects knowing only the interfaces they implement (without knowing the actual class). Typically, create one of a "family" of objects (one of several kinds of Iterators, one of several kinds of graphical widgets, etc.)..



Abstract Factory: Interface to the actual factory.
Concrete Factory: Implements the Abstract Factory interface to create a specific class of object.
Abstract Product: The sort of product that the abstract factory creates.
Concrete Product: The actual object (whose class you don't know) created by the factory.
Client: Uses the created objects only through their interfaces.

What Problem Does It Solve?

Abstract Factory makes it easy to create and manipulate objects without knowing exactly what they are. (This example uses an `Iterator`—it doesn't care what kind.) . This way, It's easy to add new sorts of concrete products to the system without changing any of the code that uses those products.

Abstract factory also makes it easy for your code to operate in diverse environments. The system creates a unique Concrete Factory (which creates unique Concrete Products) for each environment, but since you use the interface, you don't actually know which environment (or which Concrete Product) you're using.

Pros (✓) and Cons (✖)

✓ The anonymity of the Concrete Factory and Product promotes reuse—the code that uses these objects doesn't need to be modified if the Factory produces instantiations of different classes than it used to.
✖ If the product doesn't do what you want, you may have to change the Abstract Product interface, which is difficult. (You have to change all the Concrete Product definitions).

Often Confused With

Builder: Builder's Director might use an Abstract Factory to create Builder objects, but the point of Builder is that the Director doesn't know what it's building.
Factory Method: A Factory Method is an abstract method that a derived class overrides. The Abstract-Factory operation that creates objects is not typically a "Factory Method" (though it can be in some implementations).

See Also

Singleton, Factory Method, Builder

Implementation Notes and Example

```
interface Collection
{  Iterator iterator();
   //...
}
interface Iterator
{  boolean hasNext();
   Object next();
   //...
}
class Tree implements Collection
{  public Iterator iterator()
   {  return new Iterator()
      { // Implement Iterator interface
        // here (to traverse a Tree).
        // (See description of Iterator
        // pattern for implemenation.)
      }
   }
}
class User  // uses only interfaces
{
   public void operation( Collection c )
   {  Iterator i = c.iterator();
      while( i.hasNext() )
        do_something_with( i.next() );
   }
}
```

`Collection` is the Abstract Factory, `Iterator` is the Abstract Product, `Tree` is the Concrete Factory, and the anonymous-inner-class `Iterator` implementation is the Concrete Product.

There are many variants to Abstract Factory, probably the most common of which is a concrete factory that comprises its own interface—there is no "Abstract Factory" interface as such. This concrete factory is typically a Singleton. The methods of the class effectively comprise the Abstract Factory interface:

```
class SingletonFactory
{  private static SingletonFactory instance =
             new SingletonFactory();
   public static SingletonFactory instance()
   {  return instance;
   }

   void factoryOperation1(){/*...*/}
   void factoryOperation2(){/*...*/};
}
```

A similar, though more abstract, example is described in the entry for Factory Method.

There's no reason why, in the no-Abstract-Factory variant, the Concrete Factory cannot create a user interface that allows the physical user to select which of several possible concrete products to create. Consider a drawing program whose "shape" factory creates a user interface showing a palate of possible shapes. The user can then click on a shape to determine which Concrete Product (shape derivative) to create in response to a `new_shape()` request.

Usage

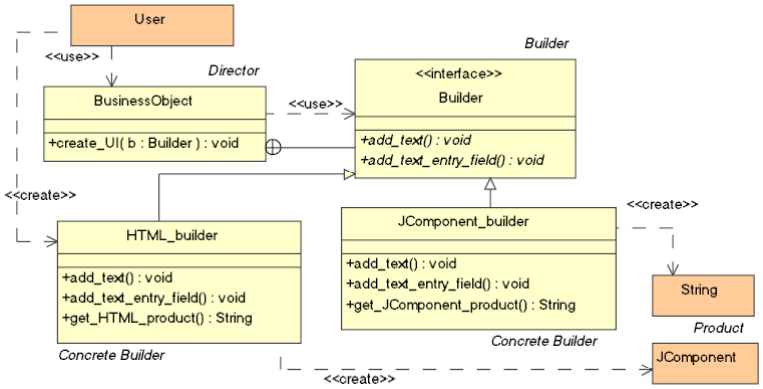
`f(Collection c)`
`{  Iterator i = c.iterator();`
`  //...`
`}`
	`Collection` and `Iterator` are the Abstract Factory and Product. Concrete Factories and Products are anonymous.

`ButtonPeer peer =`
`  Toolkit.getDefaultToolkit().`
`  createButton(b);`
	`Toolkit` is both a Singleton and an Abstract Factory. Most of the methods of Toolkit are abstract, and `getDefaultToolkit`() returns an unknown derivative of `Toolkit`. There is no need for an Abstract Factory interface per se.

`URL home = new URL("http://www.holub.com");`
`URLConnection c = home.getConnection();`
`InputStream in = c.getInput();`
	`URL` is a concrete `URLConnection` factory and `URLConnection` is an abstract `InputStream` factory, so `URLConnection` is both an Abstract Product and an Abstract Factory, depending on context. `URL`, `URLConnection`, and `InputStream` are interfaces by use, not by declaration.

Builder

Separate the construction of a complex object from its representation so that the same construction process can create different representations without having to modify the constructing object.



Director: Builds an object without knowing exactly what it's building.
Builder: Interface used by the Director to do the construction.
Concrete Builder: Actually builds the product by following directions given by the Director. Typically created externally (by the Client) or by an Abstract Factory.
Product: The object built by the Builder under the direction of the Director.

What Problem Does It Solve?

It's desirable to separate business logic from user-interface (UI) logic, but in an OO system, you cannot expose implementation details, A well done class definition will not have "get" methods that return state information, so an object must build it's own UI. Nonetheless, it's sometimes necessary for an object to build more than one representation of itself, and it's undesirable to clutter up the business-logic code with the details needed to build multiple representations.

Builder solves this problem by putting the representation-specific code into a Builder object that's distinct from a Director ("business")object. Builder also easily lets you add additional representations at a later date without impacting existing code at all.

In non-UI applications. For example, in credit-card processing, every credit-card-payment processor requires a different protocol, with identical information presented in different ways. Builder lets you build a packet to send to an unknown processor—protocol information is hidden from you in a hidden "concrete builder" that you talk to via a public interface.

Pros (✓) and Cons (✖)

✓ Builder nicely isolates the construction of a UI from it's representation inside the "business" object, making it easy to add new (or change) representations of an object without modifying business logic.
✖ A change in the Builder interface mandates changes in all implementing classes.
✖ It's awkward to represent some UI elements cleanly in all representations. (e.g. HTML vs. Swing).

Often Confused With

Bridge: An application building a UI using AWT is a Director—the actual representation is unknown to the application. In this way, AWT reifies both Builder and Bridge.

Visitor: A visitor could build a UI by visiting every element of a data structure. It is "pulling" information for UI construction from the model rather than having that information "pushed" onto it.

See Also

Bridge, Visitor.

Implementation Notes and Example

```
class BusinessObject
{  public void create_UI( Builder b )
   {  b.add_text();
      b.add_text_entry_field();
      //...
   }
   public interface Builder
   {  void add_text();
      void add_text_entry_field();
      //...
   }
}

class HTML_builder implements BusinessObject.Builder
{  // Implement Builder methods here. This
   // Implementation creates an HTML
   // representation of the object.
   //...
   public String get_HTML_product();
}
class JComponent_builder
            implements Director.Builder
{  JCOmponent product.
   // Implement Builder methods here. This
   // Implementation creates a Jcomponent
   // that represents the object.
   //...
   public Jcomponent
            get_JComponent_product(){/*...*/}
}

class Client
{  Business_object director;
   //...
   public void add_your_ui_to(
                           Jcontainer here)
   {
      JComponent_builder b =
                new JComponent_builder();
      director.create_UI( b );
      some_window.add( b.get_JComponent_product() );
   }
}
```

The `create_UI()` method is passed a Builder that could be an HTML_builder (that creates an HTML representation) or a `JComponent_builder` (that produces a `JComponent`). The Director object doesn't know which of these products it is building—it just calls interface methods.

The Client object that's driving this process *does* know what it's building since it created the Builder. Consequently, it's reasonable for it to extract the correct product.

You could get better abstraction by using an Abstract Factory to create the Builder objects rather than `new`. By the same token, if all output was going to a file, you could add a `print_yourself_to_file( String name)` method to the Builder interface; the Director could call that method at an appropriate time, and the Client wouldn't have to extract anything; it would just supply a file name.

There's no reason why the Builder implementations couldn't be public inner classes of the Director. I'd probably do it that way unless I expected that Builders would be defined elsewhere in the code.

The Director is "pushing" information into the builder. Consequently there is no need for accessors (*`get`* methods) in the Director, and the coupling between the Builder and Director is very light. In general, accessors violate the integrity of the object by exposing implementation detail. Avoid them at all cost.

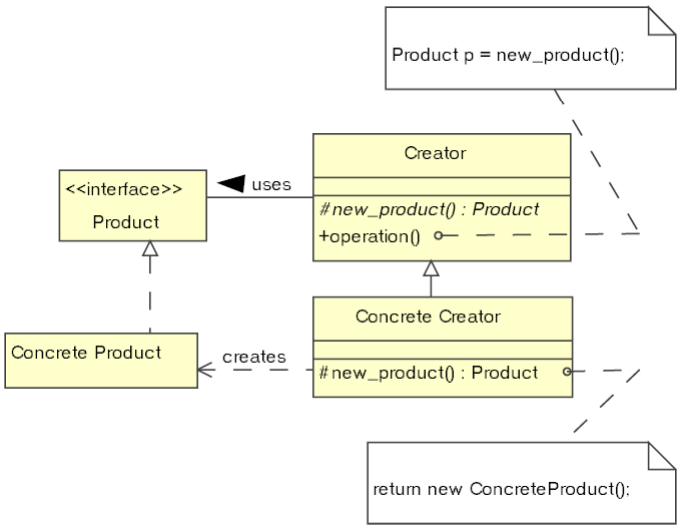
Usage

```
URL url = new URL("http://www.holub.com");
URLConnection connection = url.openConnection();
connection.setDoOutput( true );
connection.connect();
OutputStream out = connection.getOutputStream();
while( c = get_character_from_somewhere() )
    out.write( c );
out.close();
```

This code comprises a Director. It uses Abstract Factory (`URLConnection`) to get a Builder (the `OutputStream`) which builds an HTTP packet. The Director doesn't know that it's building an HTTP packet, however. (If an `ftp://` URL had been specified, it would be building an FTP packet.) The `close()` call, instead of getting the product, just sends it off.

Factory Method

Base classes use objects that are created by their subclasses. These objects implement an interface known to the base class, but the base class does not know the actual object type. This way you can defer explicit knowledge of concrete classes to the subclasses.



Creator: Defines a method that needs to create an object whose actual type is unknown. Does so using abstract-method call
Concrete Creator: Derived class that overrides the abstract object-instantiation method to create the Concrete Product.
Product: Interface implemented by the created product. Creator accesses the Concrete Product object through this interface.
Concrete Product: Object used by the Creator (base-class) methods, implements the Product interface.

What Problem Does It Solve?

This pattern is useful when you can do all (or most) of the work at the base-class level, but want to put off deciding exactly which sort of object that you'll be working on until run time. (You'll manipulate objects that a derived-class creates through an interface that you define.)

This way of doing things is often useful when you create an implementation-inheritance-based "Framework," that you expect users to customize using derivation.

Pros (✓) and Cons (✖)

✓ Easy to implement when a full-blown Abstract Factory (see) is overkill.
✖ This pattern forces you to use implementation inheritance, with all it's associated maintenance problems.
✖ Inheritance-based framework architectures, in which Factory Methods are usually found, are not the best way to achieve reuse. Generally, it's best if a framework class can simply be instantiated and used without forcing a programmer to create a derived class to make the base-class useful. Implementation inheritance should be reserved for situations where you need to modify base-class behavior to perform in a unusual way.

Often Confused With

Abstract Factory. Factory Method can be used by the Concrete Factory to create Concrete Products the creational method does not have to use this design pattern, though.

A method is not a Factory Method simply because it manufactures objects. (I've seen the term misused in the Java documentation, among other places.) In Factory Method, a derived-class override makes the object.

See Also

Abstract Factory, Template Method

Implementation Notes and Example

```
abstract class Factory
{  private static Factory instance;

   public static synchronized
   Factory instance()
   {  if( instance == null )
         instance = new_instance();
      return instance;
   }

   abstract protected Factory new_instance();
   abstract public void operation1();
   abstract public void   operation2();

   public void operation3()
   {  // Define methods at this level if
      // possible.
      instance.operation1();
      //...
   }
}
class ConcreteFactory
{  protected Factory new_instance()
   {  return new ConcreteFactor();
   }
   public void operation1(){...};
   public void operation2(){...};
}
```

This implementation of Abstract Factory (see) uses Factory Method to instantiate the Concrete Factory. The Factory cannot be an interface, here, because it contains a method definition. It is effectively an interface in terms of how it's used, however.

This structure gives you one benefit: You can refactor the Factory to support new Concrete Factories (and their associated Concrete Products) simply by deriving a new class from Factory and providing an appropriate derived-class method to create instances.

The negative side to this architecture is that you often must modify the base-class if you add a derived class. The `java.awt.Toolkit` Abstract Factory overcomes this problem while still using an abstract-base-class architecture by instantiating objects with `Class.forname()` rather than an abstract-method call. This structure is still Factory Method, since the decision about which class to instantiate is deferred to run time—it's just not a derived class that's making the decision.

It is inappropriate to use Factory Method if the only method provided by the derived class is the factory method itself. You're adding complexity with no commensurate benefit.

Never leverage the fact that `protected` grants package access in Java. The `new_instance()` method should not be called from anywhere other than the `Factory` base class.

This pattern is so trivial as to almost not be worth calling it a pattern. It's more interesting in C++, where it's called a "virtual constructor," and is implemented by overriding `operator new()`.

Usage

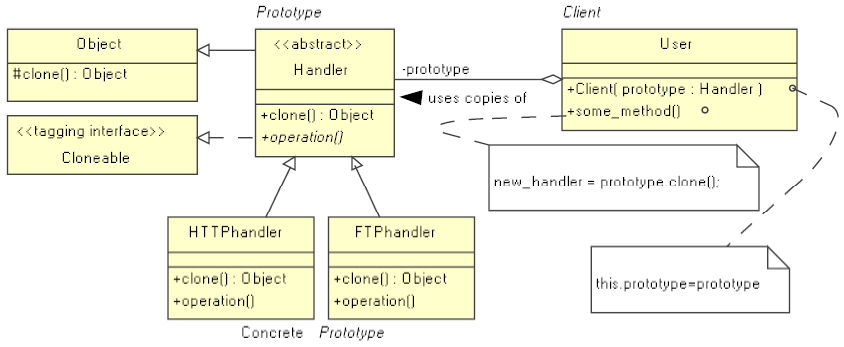
```
public class HTMLPane extends JEditorPane
{ public HTMLPane()
  { setEditorKit(
      new HTMLEditorKit()
      { public ViewFactory getViewFactory()
        {    return new CustomViewFactory();
        }
      }
    );
  }
  private class CustomViewFactory
                extends HTMLEditorKit.HTMLFactory
  { public View create(Element e)
    { return new View()
      { protected Component createComponent()
        {    return new Component(){/*...*/};
        }
      }
    }
  }
}
```

In Swing's `EditorPane`. Various HTML elements are displayed as "views." When a parser recognizes an HTML element, it requests a "view" that renders the component. You specify a custom representation of an HTML element by providing a derived-class override of a `create()` method that returns a component of your choice.

`Component` is the *Product*. The (anonymous) implementation of `Component` is the *Concrete Product.* The `HTMLFactory` is the *Creator* and the `CustomViewFactory` is the *Concrete Creator*. `createComponent()` is the *Factory Method.* Similarly `getViewFactory()` is a *Factory Method* that produces custom view factories. A derived class specifies alternative view factories by overriding `getViewFactory()`.

Prototype

Create objects by making copies of ("cloning") a prototypical object. The prototype is usually provided by an external entity or a Factory, and the exact type of the prototype (as compared to the interfaces it implements) may not be known.



Prototype: Interface of object to copy, must define a mechanism for cloning itself.
ConcretePrototype: (Object that's copied, implements cloning mechanism.
Client: Creates a new object by asking the Prototype for a clone.

What Problem Does It Solve?

(1) In *Abstract Factory*, information needed to initialize the Concrete Product (constructor arguments, for example) must be known at compile time. Most Abstract Factory reifications use the default, "no-arg," constructor. When you use Abstract Factory to make objects that must be in a non-default state, you must first create the object, then modify it externally, and this external modification may happen in many places in the code. It would be better to create objects with the desired initial (non-default) state and simply copy those objects to make additional ones. You might use Abstract Factory to make the prototype object.
(2) Sometimes. objects will be in only a few possible states, but you have many objects in each state. (The GoF describe a Note class in a music-composition system; there are many instances of whole-note, half-note, and quarter-note objects—but there all whole notes are in an identical state.
(3) Sometimes classes are specified at runtime and are created with "dynamic loading" [e.g. `Class.forname("class.name")`] or a similarly expensive process (when initial state is specified in an XML file, for example). Rather than repeatedly going through the expense of creating an object, create a single prototype and copy it multiple times.

Pros (✓) and Cons (✖)

✓ You can install a new concrete product into a Factory simply by giving it a prototype at run time. Removal is also easy.
✓ Prototype can reduce object-creation time.
✓ Abstract factory forces you to define classes with marginally different behavior using subclassing. Prototype avoids this problem by using state. When an object's behavior changes radically with state, you can look at the object as a dynamically specifiable class, and Prototype is your instantiation mechanism.
✖ You must explicitly implement `clone()`, which can be quite difficult. Worry about the memory-allocation issues discussed below. Also think about deep-vs.-shallow copy issues (should you copy a reference, or should you clone the referenced object?). Finally, sometimes the clone method should act like a constructor and initialize some fields to default values. A clone of a list member cannot typically be in the list, for example.

See Also

Abstract Factory, State

Implementation Notes and Example

```
abstract class Handler implements Cloneable
{  // Derived classes of Handler must be placed
   // in the com.holub.tools.handlers package,
   // and must have the name ProtocolHandler,
   // where Protocol is the handled protocol.

   public Object clone()
   {  Handler copy =
            (Handler)(super.clone());
      // initialize fields of copy here...
      return copy;
   }
   abstract public operation();
}

class User
{  private Handler prototype;
   public User( Handler prototype )
   {  this.prototype = prototype;
   }
   public some_method()
   {  Handler new_handler=prototype.clone();
      //...
   }
}

class User_of_User
{  private User my_client;
   public User_of_user(String protocol)
   {  StringBuffer name = new StringBuffer
         ("com.holub.tools.handlers");
      name.append(protocol);
      name.append("Handler");
      my_client = new Client(
            Class.forname(name.toString()));
   }
}
```

In this example, we need to create many copies of a Handler derivitive for a particular protocol. The prototcol is specified using a string, and the Handler is created dynamically using `Class.forname()`. Prototype is used to avoid the overhead of multiple calls to `Class.forname()`.

You cannot use `new` to implement a "clone" method. The following code won't work:

```
Class Grandparent
{  public Grandparent(Object args){/*...*/}
   Base my_clone(){ return new Base(args);}
}
Class Parent
{  public Parent(){   super("arg");}
   Derived my_clone(){return new Parent(args)}
}
Class Child
{  public Child(){ super(); }
   /* inherit the base-class my_clone */
}
//...
Grandparent g = new Child();
//...
g.my_clone(); // Returns a Parent, not Child!
```

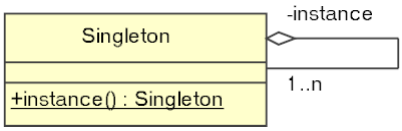
Using Java's `clone()` solves this problem by getting memory from `super.clone()`, but `clone()` is `protected` for some reason, so can't be used directly in Prototype. Expose `clone()` with a `public` pass-through method [`create()`];

Usage

(Not used)	Prototype is used in the implementations of several classes, but not in the external interfaces to any of the Java classes. You do see it in the "Bean Box" application that demonstrates GUI-style JavaBeans. When you customize an object and put it on the palate, you're creating a prototype. When you drag the customized object from the palate to the dialog box that you're constructing, you're making a copy of the prototype.

Singleton

A class with a constrained number of instances (typically one). The instance is globally accessible



Singleton: The object being created, defines a class-level (`static`) get-instance method that returns the instance. The class-level get-instance method may create the object if necessary.

What Problem Does It Solve?

Programs often have a need for single-instance objects. Objects, for example, might represent a single database, a single company, and so forth.

Pros (✓) and Cons (✖)

✓ Better than a global object in that access is controlled and the global name space isn't cluttered with hard-to-find objects.

✓ Guarantees that the object is created (and destroyed) only once—essential when the Singleton manages a global resource such as a database connection.

✖ Easy to abuse. A Singleton called `Globals` that contains nothing but public *variables* is an abomination. (A singleton containing global *constants* is reasonable if the values of the constants need to be initialized at run time. If the values are known at compile time, use an interface made up solely of static final fields and `implement` the interface when you need to use the constants.)

Another common abuse of Singleton is to create a `User` object that contains all the user-interface code. In a properly done OO system, objects must be responsible for building their own user interfaces. Similarly, you should not have a "system" or "main" singleton. The "system" is the entire program, not a single object. "System" objects are what Arthur Riel calls "God Classes" (in his book *Object Oriented Design Heuristics*, ISBN: 0-201-63385-X*).* Avoid them.

Often Confused With

Utility: A *Utility* is a class comprised solely of static methods, the purpose of which is to provide a grab-bag of global methods that often compensate for some deficiency in the language or libraries. Examples include Java's `Math` and `Arrays` utilities.

Singleton can be implemented exactly the same way as *Utility*—as a class made up solely of static methods. That is, when all fields of a class are static, the class is effectively an object: it has state and methods. The main disadvantage to this everything-is-static approach is that you can't change the behavior of a singleton using derivation.

See Also

Abstract Factory

Implementation Notes and Examples

```
Class Singleton1
{  private static Singleton instance;
   private Singleton1()
   {  Runtime.getRuntime().addShutdownHook
      ( new Thread()
        {  public void run()
           {  /* clean-up code here */
           }
        }
      );
   }

   public static synchronized
   Singleton instance()
   {  if( instance == null )
        instance = new Singleton();
      return instance;
   }
}

class Singleton2
{  private static final Singleton instance =
                            new Singleton2();
   public  static Singleton instance()
   {  return instance;
   }

   //...
   //Other than creating object in static
   //initializer, is identical to Singleton1
}

class Singleton3
{ static Type all_fields;
  static Type all_operations();

  // No instance() method, just use the
   // class name to the left of the dot.
}
```

Use the `Singleton1` form when you can't create the object at class-load time, (e.g. you didn't have information that's determined by program state or is passed to the creation method.

You *must* synchronize the `instance()` method of `Singleton1` as shown. "Clever" ways to eliminate synchronization such as "Double-Checked Locking" don't work. (Period. Don't do it!)

Use the `Singleton2` or `Singleton3` forms when possible; syncrhonization is not required during access. (The JVM may load the class at any time, but it shouldn't initilize the `Class` object until first use (*JLS* §12.4.1) ; static initializers shouldn't execute until first use.

Call `addShutdownHook()` in the constructor when program-shut-down clean-up activities (such as shutting down database connections in an orderly way) are required. Do not use a finalizer, which might never be called.

The `private` constructor prevents someone from saying `new Singleton()`, thereby forcing access through `instance()`.

There is no requirement that only one instance of the singleton exist, only that the number of instances are constrained and that access to the instances are global. For example, a DatabaseConnection.getInstance() method might return one of a pool of database connections that the Singleton manages.

In UML, The role associated with the singleton is usually also the class name

Usage

`Image picture = Toolbox.getDefaultToolbox().getImage(url);`	The `Toolbox` is a classic form of `Singleton1` in the Examples section. `getDefaultToolbox()` returns a `Toolbox` instance appropriate for the operating system detected at run time.
`Border instance = BorderFactory.createBevelBorder(3);`	Manages several `Border` instances, but only one instance of a `Border` object with particular characteristics (in this case, a 3-pixel beveled border) will exist, so it's a Singleton. All subsequent requests for a 3-pixel beveled border return the same object.
`Class class_object = Class.forName("com.holub.tools.MyClass");`	There's only one `Class` object for a given class, which effectively contain all static members.

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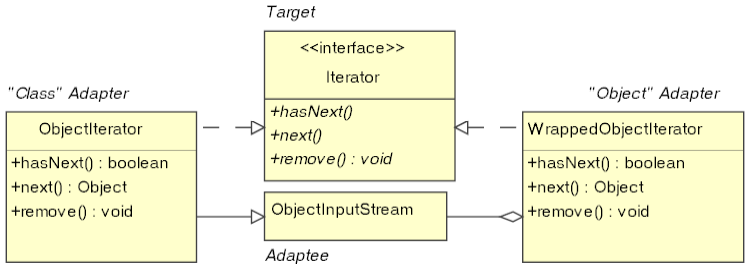
Structural Patterns

The structural patterns concern themselves with the organization of the program. I think of them as static-model patterns. Their intent is always to organize classes so that certain ends can be achieved. For example, the purpose of Bridge is to organize two subsystems in such a way that either subsystem can change radically (even be replaced entirely) without affecting the code in the other. The whole point of this organization is that you can make changes to the program without having to change the dynamic model at all.

Adapter

Make a class appear to support a familiar interface that it doesn't actually support. This way, existing code can leverage new, unfamiliar classes as if they are existing, familiar classes, eliminating the need to refactor the existing code to accommodate the new classes.



Adaptee: An object that doesn't support the desired interface
Target: The interface I want the Adaptee to support.
Adapters: The class that makes the Adaptee appear to support the Target interface. *Class* Adapters use derivation. *Object* Adapters use containment.

What Problem Does It Solve?

(1) A library that you're using just isn't working out, and you need either to rewrite it or to buy a replacement from a third party and slot this replacement into your existing code, making as few changes as possible.
(2) You may need to refactor a class to have a different interface than the original version (you need to add arguments to a method, or change an argument or return-value type). You could have both old-style and new-style versions of the methods in one giant class, but it's better to have a single, simpler class (the new one) and use Adapter to make the new object appear to be one of the old ones to existing code.
(3) Use an adapter to make an old-style object serialized to disk appear to be a new-style object when loaded.

Pros (✓) and Cons (✖)

✓ Makes it easy to add classes without changing code.
✖ Identical looking Object and Class adapters behave in different ways. (e.g. `f(new Adapter(obj))` is implemented in both Class and Object adapters; the Object Adapter simply wraps `obj`, but the Class adapter copies the fields of `obj` into its base-class component. Copying is expensive. On the plus side, a class adapter *is* an Adaptee, so can be passed to methods expecting an object of the Adaptee class and also to methods that expect the Target interface. It's difficult to decide whether an Object or Class adapter is best. It's a maintenance problem to have both.
✖ Difficult to implement when the library is designed poorly. For example, `java.io.InputStream` is an abstract class, not an interface, so you can't use the Class-Adapter pattern to create a `RandomAccessFile` that also supports the InputStream interface (you can't `extend` both `RandomAccessFile` and `InputStream`).

You *can* use Object Adapter, or you can refactor the code to make InputStream an interface (as it should have been) and then implement that interface in an `AbstractInputStream` that has all the functionality now in `InputStream`. Collections do it correctly.

Often Confused With

Mediator: Mediator is the dynamic-model equivalent of Adaptor. Adapters are passive, passing messages to single "adaptees." Mediators interact with many colleagues in complex ways.
Bridge: Adapters change interfaces. Bridges isolate subsystems. Adapters are little things, Bridges are big. Bridge might be reified as a set of 50 adapters (e.g. AWT peer interfaces define Adapters, but the complete set of peers are a Bridge).
Decorator: The encapsulated object in Decorator has the same interface as the container. The decorator modifies the behavior of some method. Object Adapters have different interfaces than the contained object and don't change behavior.

See Also

Mediator, Bridge, Decorator

Implementation Notes and Example

```
class ObjectIterator extends ObjectInputStream
                     implements Iterator
{  private boolean at_end_of_file = false;
   public ObjectIterator(InputStream src)
                         throws IOException
   {   super(src);  }
   public boolean hasNext()
   {   return at_end_of_file == false;
   }
   public Object next()
   {   try
       { return readObject();
       }
       catch( Exception e )
       { at_end_of_file = true;
         return null;
       }
   }
   public void remove()
   {throw new UnsupportedOperationException();
   }
}
class WrappedObjectIterator
                       implements Iterator
{  private boolean at_end_of_file = false;
   private final ObjectInputStream in;
   public
   WrappedObjectIterator(
                       ObjectInputStream in)
   {   this.in = in;  }
   public boolean hasNext()
   {   return at_end_of_file == false;
   }
   public Object next()
   {   try
       { return in.readObject();
       }
       catch(Exception e){/* as above */}
   }
   public void remove()
   {throw new UnsupportedOperationException();
   }
}
```

`ObjectIterator` is a "Class" Adapter that adapts an `ObjectInputStream` to implement the `Iterator` interface. This way, you can use existing methods that examine a set of objects by using an `Iterator` to examine objects directly from a file. That is, the method doesn't know or care whether it's reading from a file or traversing a Collection of some sort This flexibilty can be useful when you're implementing an Object cache that can overflow to disk, for example. More to the point, you don't need to write two versions of the object-reader method, one for files and one for collections.

`WrappedObjectIterator` is an "Object" Adapter version of `ObjectIterator` that uses containment rather than inheritance.

The "Class" Adapter, since it *is* an ObjectInputStream that implements `Iterator`, can be used by any method that knows how to an use either `ObjectInputStream` or Iterator. The "Object" Adapter, since it encapsulates the input stream, cannot be used as an `ObjectInputStream`, but you can use the input stream for a while, temporarily wrap it in a `WrappedObjectIterator` to extract a few objects, then pull the input stream out again.

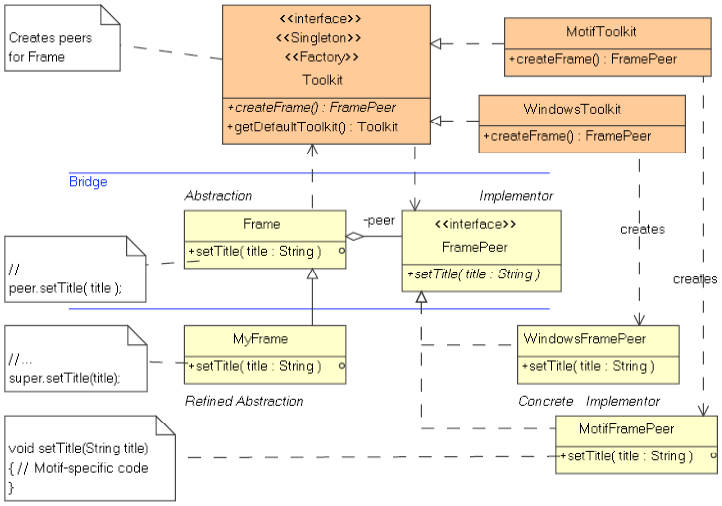
The two implementations require about the same amount of work. so it's a judgment call which one is best. It all depends on what you're using it for.

Usage

`InputStream in = new StringInputStream("hello");`	Adapter lets you access a `String` as if it were a file (`InputStream`). Similar adapters include `ByteArrayInputStream`, `CharArrayReader`, `PipedInputStream`, `PipedReader`, `StringReader`. Don't confuse these adapters with the Decorators in *java.io* (`BufferedInputStream`, `PushbackInputStream`, etc.)

Bridge

In order to decouple subsystems so that either subsystem can change radically without impacting any code in the other one, put a set of interfaces between two subsystems and code to these interfaces.



Abstraction: (`Frame`) A platform-independent portal into platform-specific code.
Implementor: (`Frame Peer`)An interface used by the Abstraction to talk to a platform-specific implementation. Typically is also the Abstract Product of an Abstract Factory.
Refined Abstraction: (`MyFrame`) Often omitted, a version of the Abstraction, customized for a particular application.
Concrete Implementor: (`WindowsFramePeer`, `MotifFramePeer`) platform-specific implementation of *Implementor*

What Problem Does It Solve?

Often used to achieve platform independence. Application-specific code on one side of the bridge (the "business logic") uses platform-dependant code on the other side through a well defined interface. You reimplement that interface, and the "business" logic doesn't know or care. Change the business logic, and the platform-specific interface implementations don't care. Often, you'll combine Bridge and Abstract Factory so that the Factory can supply the correct set of implementers at run time, further isolating the two sides of the bridge. Examples of Bridge in Java are AWT and JDBC.

Pros (✓) and Cons (✖)

✓ In a pure inheritance model, you'd have a base class that implemented some behavior, and derived classes that customized this behavior for a specific platform. In Bridge, the base class is effectively replaced by an interface, so the problems associated with implementation inheritance are minimized and the total number of classes are reduced.
✖ It's difficult to implement interfaces so that each implementation behaves identically . Java's AWT Bridge implements windowing components for different operating environments, but the Motif implementation behaved differently on the screen than the Windows implementation.

Often Confused With

Bridge is more of an architecture than a design pattern. A Bridge is typically a *set* of classes (called "Abstractions," unfortunately—they're typically not `abstract`) that contain references to objects that implent a platform-independent interface in a platform-dependant way (Adapters). The Adapters are typically created by the Abstraction object using a Singleton-based Abstract Factory.

Adapter. Bridges separate subsystems, Adapters make objects implement foreign interfaces. A one-interface bridge looks like a Class Adapter.
Façade: Façade simplifies the interface to a subsystem, but might not isolate you from the details of how that subsystem works. Changes made on one side of the façade might mandate changes both to the other side of the façade and to the façade itself.

See Also

Abstract Factory, Singleton, Adapter, Façade, Mediator

Implementation Notes and Example

```
interface FramePeer
{   void setTitle(String title);
}
// Many other peer interfaces...

class MotifFramePeer implements FramePeer
{   //...
    void setTitle(String title)
    { // Motif-specific code goes here
    }
}
class WindowsFramePeer implements FramePeer
{   //...
    void setTitle(String title)
    { // Windows-specific code goes here
    }
}
// Implementations for other platforms...
//=======================================
abstract class java.awt.Toolkit
{ abstract
    FramePeer createFrame(Frame target);
    static Toolkit getDefaultToolkit()
    {  // returns appropriate toolkit,
       // depending on operating environment.
    }
}
class WindowsToolkit extends Toolkit
{   FramePeer createFrame(Frame target)
     {  return new WindowsFramePeer(/*...*/);
    }
}
// Toolkit implementations for other
// platforms ...
//=======================================
class Frame extends java.awt.Container
{   FramePeer peer;
    public void addNotify()
    {   peer = Toolkit.getDefaultToolkit().
                       createFrame(this);
    }
    public void setTitle(String title)
    {   peer.setTitle();
    }
}
class MyFrame extends Frame
{   public void setTitle( String title )
    {   super.setTitle( title.toUpperCase() );
    }
}
```

Bridge is way too large a pattern to show a real example on half a pag, and the code at left is probably too condensed to be useful. I recommend that you look at the real code in the Java sources (which ship with the JDK). The bridge interfaces are the "Peers" defined in the *java.awt.peer* package. Implementations of the Peer interfaces are, unfortunately, not provided in the SDK.

In the current example, two design patterns are intermingled `Frame` and `FramePeer` comprise a Bridge between your application program and a platform-specific windowing system. (`Frame` has the role of *Abstraction*, and `FramePeer` has the role of *Implementor.*) FramePeer is an interface, and the Frame gets instances of platform-specific Implementations from an Abstract Factory (`Toolkit`). [`Toolkit` is the *Abstract Factory*, `WindowsToolkit` is a *Concrete Factory*, `FramePeer` is the *Abstract Product*, and `WindowsFramePeer` is a *Concrete Product.*] In Bridge, `WindowsFramePeer` has the role of *Concrete Implementor*, so it and the `FramePeer` interfaces simultaneously participate in two patterns.

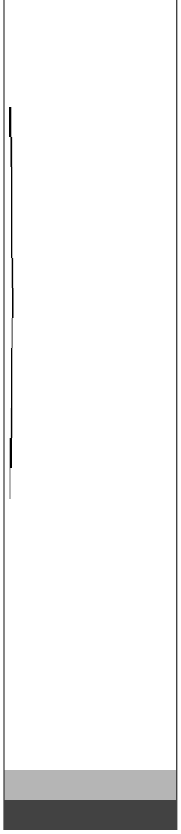
The main architectural issue is that the two sides of the bridge can change independently. That is, I can change both the `Frame` class and the application that uses `Frame` objects without impacting any of the *Implementor* objects on the other side of the bridge. By the same token, I can change an *Implementor* (or, because I've used an Abstract Factory, easily add an *Implementor* for a new platform) without affecting the `Frame` or the applications that use it.

Compo

Organize a
collection
stand-alone

ole/part) relationships as a
ters of this interfaces define
luding other containers.

Component: An interface or abstract class that represents all objects in the hierarchy.
Composite: A Component that can hold other Components. It doesn't know whether these subcomponents are other Composites or are Leaves.
Leaf: A Component that stands alone; it cannot contain anything.



What Problem Does It Solve?

Often data structures can be organized into hierarchies in which everything in the hierarchy has a common subset of similar properties. For example, directories are files that can contain other files; a file can be atomic (a simple file not containing anything) or a subdirectory (a file that holds references to other files, including subdirectories). *Composite* lets you create these sort of containment hierarchies in such a way that a given container doesn't need to know whether its contents are atomic or composite objects, they both implement the same interface, so can be treated identically.

Pros (✓) and Cons (✖)

✓ The container is very simple to implement because it treats all contents uniformly.
✓ It's easy to add new Component classes, just derive another class from the *Component* class (or interface).
✖ The *Component* tends to specify an unsatisfactory least-common-denominator interface.
✖ It's not always meaningful or appropriate for every Composite or Leaf to implement every method of the Component. It's an awkward runtime error if a unimplementable method throws an exception.

Often Confused With

Chain of Responsibility is also implemented using a runtime hierarchy of objects, but the point of Chain of Responsibility is to catch messages in appropriate places.
Decorator also uses a containment strategy, but Decorators add or modify functionality of a single containee. The point of Composite is to make it easier to manipulate a *set* of contained objects.

See Also

Chain of Responsibility, Decorator, Bridge, Builder

Implementation Notes and Example

```
abstract class Element
{  private Rectangle position;
   public Element(Rectangle position)
   {  this.position = position;
   }
   protected void prepare(Surface s)
   {  // modify the surfaces coordinate
      // system so that (0,0) is at the
      // current Elements position.
   }
   public abstract void render(
                Graphics parent_surface);
}

class Form extends Element
{  private Collection subelements
                      = new ArrayList();
   public Form( Rectangle position )
   {  super(position);
   }
   public void add(Element subelement)
   {  subelements.add( subelement );
   }
   public void render(Graphics s)
   {  prepare(s);
      Iterator i = subelements.iterator();
      while( i.hasNext() )
        ((Element)i.next()).render(s);
   }
}
class StaticText extends Element
{  private String text;
   public StaticText(Rectangle position,
                              String text)
   {  super(position);
      this.text = text;
   }
   public void render(Graphics s)
   {  prepare(s);
      s.draw_text(text);
   }
}
```

Bridge nicely complements Composite. For example, if `Form`, `StaticText`, and `Picture` were interfaces, implmented by concrete classes on the other side of a Bridge (and created with an Abstract Factory), then you could build a form without knowing exactly how it would render itself: It could just as easily render itself as a Swing JComponent as an XML file. A generic form *Builder* might parse a description of a form and construct one using the Abstract Factory/Bridge approach to Composite.

`Element`, at left, is an abstract class that defines operations common to all `Element` objects (e.g. the `Element`'s relative position on the form). I've avoided making this information public (thereby damaging the integrity of the object) by providing a `prepare()` method that modifies the coordinate system of some drawing `Surface` (not shown) so that the current object can render itself in the upper-left corner of the `Surface`. This way a `getPosition()` method is unnecessary and the resulting class system is more robust.

The `Form` class has the role of *Composite* with the pattern. It's an Element that holds other Elements, some of which might be Forms and some of which might be `StaticText`. The point is that the `Form` class's `render()` method doesn't know or care about the actual type of the subelement. All subelements are rendered identically [by passing them `render()` messages].

The `StaticText` class is a *Leaf*. It is an `Element` that doesn't contain other `Elements`, thus forms a leaf on the runtime-hierarchy tree. It has to know how to render itself, of course. Here, it just delegates to the `Surface` object.

Usage

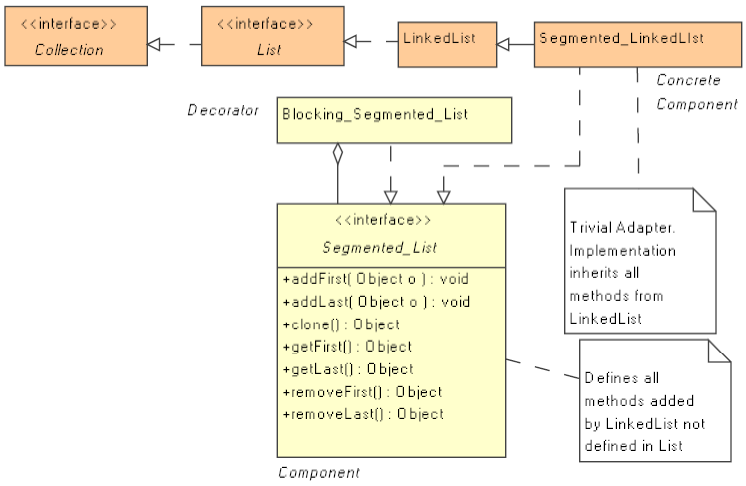
```
Dialog box = new Dialog();
box.add( new Label("Lots of information") );

Panel  subpanel = new Panel();
subpanel.add( new Label("Description") );
subpanel.add( new TextField() );
box.add( subpanel );
```

A `Dialog` is a *Composite* that can hold *Leaves* (like `Label`) and other *Composites* (like `Panel`). This example also nicely demonstrates the affinity between Composite and Bridge, since AWT is also a bridge. (A DialogFrame, for example simultaneously a *Composite* in *Composite* and an *Abstraction* in *Bridge*.

Another good example of Composite are the new JDOM classes (www.jdom.org). An XML document is a list of Elements.

Decorator

Attach new responsibilities to (or modify the behavior of) an *object* at run time. Decorators can vastly simplify class hierarchies by replacing subclassing with containment.



Component: an interface for objects that can have responsibilities added to them (or have behavior modified) at runtime.
Concrete Component: an object to which additional responsibilities or new behavior is attached.
Decorator: wraps a Component and defines an interface that conforms to the Component's interface.
Concrete Decorator: (implicit) extends the Decorator to define the additional behavior.
(The `Blocking_Segmented_List` combines the Decorator and Concrete Decorator roles into a single class—a commonplace reification of Decorator. See notes for the Example, at right.)

What Problem Does It Solve?

Using derivation hierarchies to add features is not a great idea. Consider an input stream. To add buffering, you'd derive a class that overrode the `input()` method to do buffering (doubling the number of classes). To add pushback, you'd have to derive from both classes, providing buffered and nonbuffered versions of `input()` that pushed characters back. In fact, every feature that you add through subclassing will require you to double the size of the class hierarchy. Decorator, on the other hand, is linear. To add a feature, you add exactly one Decorator class, no matter what the size of the original hierarchy.

Decorator also nicely solves the problem of runtime configuration. Sometimes, you don't know exactly how an object should behave until runtime. Behavior might be specified in a configuration file, for example. Decorator allows you to assemble (at run time) a composite object that contains exactly the mix of capabilities that you need without having to know which of these capabilities will be needed when you write the code.

Pros (✓) and Cons (✖)

✓ The size and complexity of the class hierarchy is considerably reduced.

✖ A feature introduced in a decorator (such as pushback) is at best hard (or even dangerous) to access if the decorator is itself decorated. The system is very sensitive to the order in which decorators are applied. Java's `PushbackInputStream` works well at the outermost layer, but a PushbackInputStream wrapped with a BufferedInputStream doesn't work (it doesn't push back into the buffer.

Often Confused With

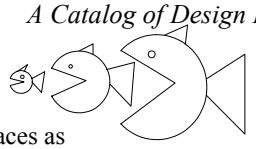
Adapter: changes an interface, *Decorator* changes behavior.
Chain of Responsibility: passes messages to the most appropriate handler. In *Decorator*, messages are handled by the outermost Concrete Decorator.
Composite: *Decorators* add responsibilities. Composites never do.

See Also

Strategy.

Implementation Notes and Example

```
public interface Segmented_List extends List
{  void     addFirst(Object o);
   void     addLast(Object o);
  //...
   Object       removeFirst();
   Object       removeLast();
}
public class Segmented_LinkedList
   extends     LinkedList
   implements Segmented_List
{}
public class Blocking_Segmented_List
            implements Segmented_List
{  private Segmented_List  component;
   private int             max_size ;
    public Blocking_Segmented_List(
            Segmented_List component,
            int max_size )
   {  this.component = component;
      this.max_size  = max_size;
   }

   private void block_if_empty() {/*...*/}
   private void block_if_full() {/*...*/}

   public synchronizedboolean
                     contains(Object o)
   {return component.contains(o);    }
   public synchronizedObject get(int index)
   {return component.get(index);     }
   //...

   public synchronized void addFirst(Object o)
   {  block_if_full();
      component.addFirst(o);
   }
   public synchronized Object removeLast()
   {  block_if_empty();
      return component.removeLast();
   }
   //...
}
```



Think fish. Bigger fish are *Decorators* that implement the same interfaces as as the smallest fish (the *Component*). If a smaller fish has swallowed a hook and line; talk to it by yanking the string.

Since `LinkedList` doesn't implement an interface that defines all its methods, I created `Segmented_List` and `Segmented_LinkedList`, a simple Class Adapter (that makes LinkedList appear to implement an interface that it doesn't implement).

`Blocking_Segmented_List` is a *Decorator* that modifies the behavior of the LinkedList so that a thread that a thread that tries to remove something from an empty list will block (be suspended) until some other thread adds something to the list—a common inter-thread communication architecture.

Many methods (such as `contains()` and `get()` behave exactly as they do in the LinkedList, so they are implemented as simple pass-through methods. Other methods (such as `addFirst()` and `removeLast()` implement different behavior, so must be implemented at length in the *Concrete Decorator*.

The behavior of every method in the blocking version at left have changed: everything is now synchronized. If only a handful of methods change behavior (or a Decorator just adds a method), simplify implementation with an abstract *Decorator* class that does nothing but define simple pass-through methods to the contained object. Extend the abstract class to form a *Concrete Decorator*, overriding those methods whose behavior changes.

Other Decorators might add other features. A `Lazy_List` might add a `close()` method which allows from the list, but disallow additions, for example.

Usage

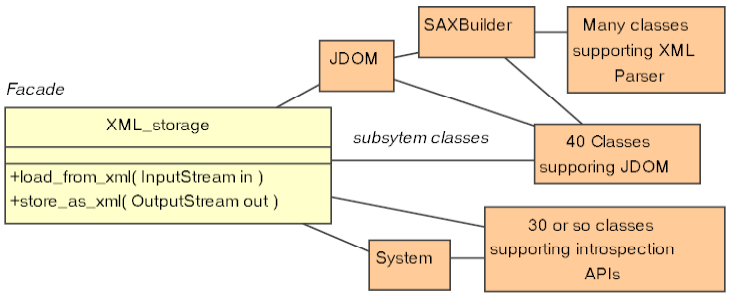
`JComponent widget = new JtextArea(80,200);`
`widget = new JScrollPane(widget);`
`Jframe frame  = new JFrame();`
`Frame.getContentPane().add( widget );`
	Combines *Decorator* and *Composite*: *Composite* because everything's a `JComponent`, *Decorator* because each successive layer adds functionality (and changes appearance).

`InputStream in = new FileInputStream("x.txt");`
`in = new BufferedInputStream( in );`
`in = new PushBackInputStream( in );`
	The data source is wrapped by a decorator that adds buffering, which is in turn wrapped by a decorator that supports pushback. Could add decompression, etc., with additional decorators (`GzipInputStream`, `etc`).

Facade

Provide a single interface through which all the classes in a complex subsystem are manipulated. Façade allows you to treat a complex subsystem as if it were a single course-grained object with a simple easy-to-use interface.

Facade: Provides a simple interface to a complex subsystem.



Subsystem Classes: Classes that comprise one or more complex subsystems.

What Problem Does It Solve?

Subsystems, especially older ones, are masses of spaghetti code. When two subsystems must interact, they often make calls directly into each other, and these myriad tendrils of connectivity are a maintenance nightmare. The subsystems become very delicate since making seemingly insignificant changes in a single subsystem can affect the entire program. Façade addresses the problem by forcing programmers to use a subsystem indirectly through a well-defined single point of access, thereby shielding the programmers from the complexity of the code on the other side of the façade.

Façade improves the independence of the subsystems, making it easy to change—or even replace—them without impacting outside code.

Façade also provides a manageable way to migrate legacy code to a more object-oriented structure. Start by breaking up the existing code into a small number of independent subsystems, modeled as very heavyweight objects with well-defined, simple interfaces. Eliminate all "end runs" around these interfaces. Then systematically replace each subsystem. This evolutionary approach significantly reduces the risk inherent in an all-at-once rewrite.

Pros (✓) and Cons (✖)

✓ Coupling relationships between subsystems are weakened, improving maintenance and flexibility.

✖ It's still possible for programmers to ignore the Façade and use subsystem classes directly. Though some designers see this direct access as an asset. I see little to recommend the practice. One exception would be a "private" subsystem interface that the Façade method makes available only to certain clients (who are properly authenticated, for example). A Façade method might return an object that implements an auxiliary interface to the guarded subsystem, for example.

Often Confused With

Bridge: Both Façade and Bridge help maintenance by isolating subsystems from each other. Façade makes a subsystem look like a single object, however. Bridges are typically made up of large collection of objects. You can use a façade is to simplify access to a bridge. (e.g. A `Company` class could act as a facade to the JDBC bridge. You'd say Company.`get_employee()` and the façade takes care of the complex series of JDBC calls needed to create the `Employee` object.)

Mediator: A Façade's communication with a subsystem is unidirectional, or at least simple. Your program sends a message to the Façade, which causes it to send several messages to a subsystem. The subsystem does not talk to, or even know about, the Façade object. Mediators have complex bi-directional conversations with subsystems.

See Also

Bridge, Mediator, Observer

Implementation Notes and Example

```
class XML_storage
{
   public store_to_XML(OutputStream out);
   { /* Code goes here that uses the
      * introspection APIs in the System
      * class to get the class name and the
      * values of all the public fields in
      * the class. The name and the values of
      * those fields are then used to build a
      * JDOM tree, which is passed to an
      * "outputter" to send an XML
      * represenation of the tree to the
      * OutputStream.
      */
   }

   public Object load_from_XML(
                          InputStream in);
   {  /* Code goes here that creates a
      * JDOM SaxBuilder for the InputStream,
      * uses it to build a JDOM, instantiates
      * a class named in the XML file,
      * then initializes that class using
      * one of the constructors or a series
      * of get/set methods.
      */
   }
}
```

The problem with providing a full-blown example of a Façade is that there's entirely too much code to represent in 40 or so lines—that's the whole point of the pattern.

I'm imagining that the stoarge method uses Java's introspection APIs to analyze the document and discover the fields to save. (It could just save everything that's public, or it could look for "JavaBean" style get/set methods.) I would use the JDOM XML APIs to build a tree representation of an XML output file, and then send the tree to a JDOM "outputter" class that would write the appropratie XML to a file. The loading function reverses this proces. By using the façade, you isolate yourself from all the mechanics of introspection, XML parsing, and JDOM.

Messaging is "one-way;" there is no complex back-and-forth interaction between the `XML_storage` façade and the subsystems that it uses. The Façade object simply builds a tree, then outputs the tree.

We have a façade within a façade here. The `SAXBuilder` class itself comprises a facade that isolates you from the mechanics of the SAX-parser subsystem.

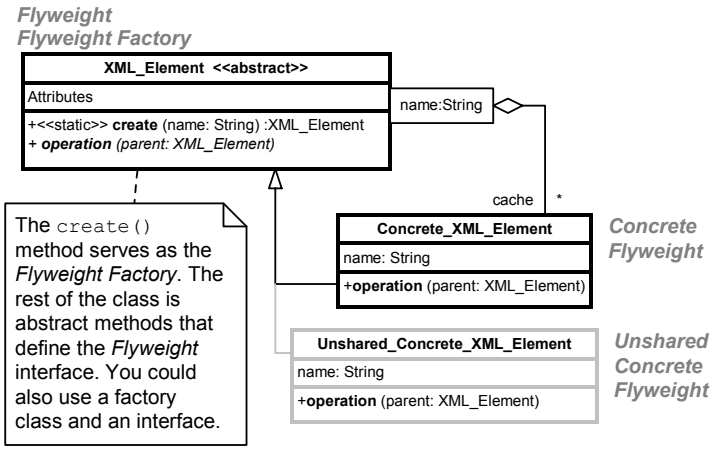
The JDOM, XML, and Introspection APIs can be accessed directly by the program. Ease of maintenance is compromised if you do so and any of these subsystems change. You could avoid this problem by putting the subsystems in an inaccessible class (such as the *com.sun.xxx* packages in Java). A Singleton can then be used to get a Façade, through which all access occurs.

Usage

`Some_string.matches("^[a-zA-Z]{1,3}$");`	`String` acts as a Façade for the regular-expression-matching package, isolating the user from things like `Pattern` objects.
`Socket s = new Socket("holub.com",7);` `InputStream in = s.getInputStream();`	These two lines hide several pages of C code, and all the enormous complexity needed to get a socket to work in a cross-platform way.
`AppletContext a = getAppletContext();` `a.showDocument("http://www.holub.com/index.html")`	`AppletContext` is a Façade for the browser subsystem. Note that this architecture prohibits "end runs" around the façade because subsystem classes are accessible only through the Façade. You can't get at them directly.

Flyweight

To minimize memory use, make objects smaller by using *extrinsic* state (e.g. putting state information into a container or computing it on each access) and *sharing* (using multiple references to single objects rather than multiple copies of objects).



Flyweight: Defines an interface for messages that use extrinsic state.
Concrete Flyweight: Implements *Flyweight* with methods that compute state information or get it from an external source (*extrinsic* state).
Unshared Concrete Flyweight: Not used here, but if present, implements *Flyweight* using internal state variables rather than extrinsic state.
Flyweight Factory: Creates and manages flyweights. Supplies an existing Concrete Flyweight if one exists, otherwise creates one.

What Problem Does It Solve?

An object is defined by *what* it does, not how it does it. Objects are collections of methods; state information can be inside or outside of the object.

Sometimes, programs with large numbers of objects require more memory for those objects than is available. In a document editor, every character of a naïve implementation might hold its value, font, color, size, encoding, position on the page, etc. This information, duplicated in most characters, can be moved to a containing Paragraph, If characters take up more space than references, keep multiple references to a single "character" object rather than many identical characters.

A naive implementation of the Game of Life "cell" might carry a Boolean "is-alive" state and references to eight neighbors. A small 1024x1024 grid requires about 40 Megabytes just to hold the cells. In a Flyweight version, the cell's container knows who the cell's neighbors are, and passes that information to the cell. The cell needs to remember its is-alive state only. By making the neighbor references *extrinsic*, you reduce the memory requirement for the basic grid to a single Megabyte.

In a "flyweight pool" all cells with the same state are represented by a single object.

Pros (✓) and Cons (✖)

✓ Some programs simply cannot be written in an object-oriented way without using flyweight.
✓ When you use flyweight pools, equality can be determined using Java's `==` operator.
✖ If extrinsic state is stored in a container, then you must access the object through the container. If extrinsic state is computed (e.g. go to a database every time a particular attribute is used), then access is slow.
✖ Flyweights add complexity to the code, impacting maintenance and increasing code size.

Often Confused With

Composite. Consider a paragraph that contains both font information and a list of contained glyph objects, one of which is set in a different font. Paragraph is a *Composite*. It *is* a glyph that *holds* other glyphs. (`Paragraph` extends `Glyph`.) The oddball glyph that's set in its own font is actually a `Paragraph` that contains a single character, but since a `Paragraph` is a `Glyph`, the containing `Paragraph` object doesn't need to know that the oddball character is not a single-character `Glyph`.

See Also

Composite, Prototype, Singleton

Implementation Notes and Example

```
abstract class XML_Element
{
   static Map cache = new HashMap();

   public static
   XML_Element create(String name)
   {
      name = name.intern();
      XML_Element exists =
           (XML_Element)(cache.get(name));
      if( exists == null )
      { exists =
           new Concrete_XML_Element(name);
        cache.put(name,exists);
      }
      return exists;
   }

   private XML_Element(){}

   abstract void operation(
                     XML_Element parent);

   private static class Concrete_XML_Element
                     extends XML_Element
   {  private String name;
      Concrete_XML_Element(String name)
      { this.name = name.intern();
      }
      void operation(XML_Element parent)
      { //...
      }
      public int hashCode()
      { return name.hashCode();
      }
      public boolean equals( Object o )
      { return name ==
          ((Concrete_XML_Element)o).name ;
      }
   }
```

`XML_Element` is a Featherweight that represents an "Element" in an XML "Document." (Effectively a node in a tree.) The element is identifed only by name, though a more realistic Implementation would identify it both by name and attribute values.

Sharing is used to guarantee that only one instance of a given element exists. (You could argue resonably that XML_Element is a *Singleton*; that is, sharing is implemented using *Singleton*.) The `private` constructor (and the fact that it's `abstract`) force users to use `create()` rather than `new XML_Element()`. The `create()` method keeps a cache of `XML_Element` objects, keyed by name. If an object with the requested name exists, it is just returned. The `create()` method adds an element to the cache only if an element with that name does not already exist. If the Element doesn't need to know its own name, its `name` field can be eliminated to save space.

Don't be confused by the fact that XML_Element fills two roles in the pattern: *Flyweight Factory* and *Flyweight*. Putting the abstract methods of `XML_Element` into an interface to separate them from the "factory" funtionality makes sense in many situations. Here, it just adds an unnecessary class.

The `intern()` method of the `String` class enforces sharing in a similar way (see Usage).

`XML_Element` also has one extrinsic attribute: its parent. A heavyweight implementation might keep a parent reference as a field, but here the parent reference is passed as an argument to `operation()`. This organization saves space, but means that operations on elements that need to know their parent must be started at the root node so that the parent reference can be passed down to them..

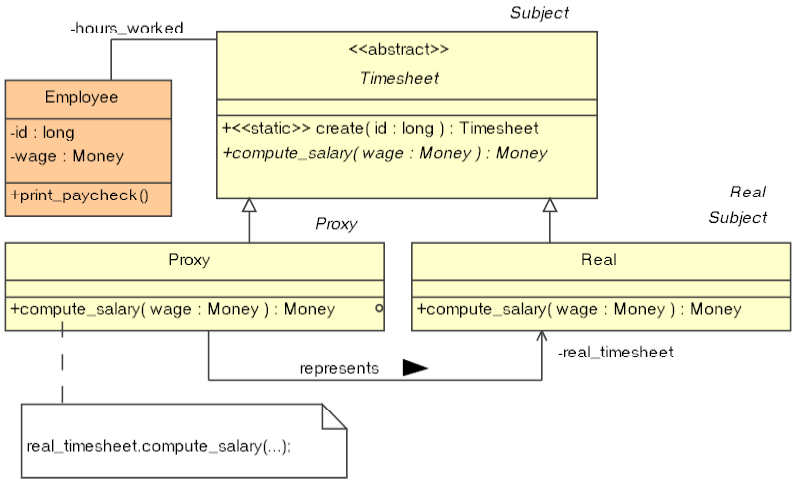
Usage

`JPanel p = new JPanel();`
`p.setBorder(`
`  BorderFactory.createEmptyBorder(5,5,5,5) );`
	The border size is extrinsic—it's fetched at runtime from the Component that it borders. The BorderFactory makes sure that two borders with the same internal state don't exist (when you ask for the second one, you get back a reference to the first one).

`StringBuffer b = new StringBuffer();`
`//...  assemble string here.`
`String s = b.toString().intern();`
	If an existing `String` literal has the same value as the assembled `StringBuffer`, then use the existing literal, otherwise add the new value to the JVM's internal table of `String` literals and use the new one.

Proxy

Access an object through a "surrogate or placeholder" object.



Proxy: Maintains a reference, and controls access, to the *Real Subject*. Implements the same interface as the *Real Subject* so it can be used in place of the *Real Subject*.
Subject: An interface implemented by both the *Proxy* and the *Real Subject*, allows them to be used interchangeably.
Real Subject: The real object that the *Proxy* represents.

What Problem Does It Solve?

A *virtual proxy* creates expensive objects on demand. For example, database access might be deferred by a proxy until the data is acutually used. A large image may be fetched across the network in the background while the user of the image thinks that it's already there. This process is often called *lazy instantiation*. Virtual proxies are also useful in implementing a *copy-on-write* strategy. When you request a copy of an object, you get back a proxy that simply references the original object. Only when you modify the so-called copy does the proxy actually copy the state from the original object into itself.

A *remote proxy* is a client-side represention of a server-side object. The proxy relays requests across the network to be handled by a sever-side object. CORBA and RMI stubs are proxies for server-side skeleton objects

A *protection proxy* controls access to certain methods of a second object that implements the same interface. The proxy method might be passed an authentication token and throw an exception if the token didn't authorize the requested operation.

A *smart reference* automatically handles anoying backround tasks like deletion. Java's `WeakReference` is an example.

Pros (✓) and Cons (✖)

✓ Proxies hide many optimizations from their users, simplifying the code considerably.
✖ Once the real object has been created, access through the proxy adds overhead. The whole point of the pattern is to be able to treat the proxy as if it were the real object, so a method like `get_real_object()` violates the spirit of the pattern.
✖ You may need a myriad remote proxies into a large subsystem. It's beter to create a single remote proxy for a Facade than it is to create proxies for every class in the subsystem.

Often Confused With

Decorator: A protection proxy in particular could be looked at as a Decorator. There's no difference in structure, but the intent is different—*Decorator* permits undecorated objects that can be accessed indiscriminately.

See Also

Decorator, Flyweight

Implementation Notes and Example

```
class Employee
{  private long   id;
   private Money  wage; // hourly wage
   private  Timesheet hours_worked;
   public Employee(long id)
   {  this.id = id;
      hours_worked = Timesheet.create(id);
      wage  = Database.get_hourly_wage(id);
   }
   void print_paycheck()
   {  Money weekly_wage =
        hours_worked.compute_salary(wage);
      //...
   }
}
abstract class Timesheet
{  //...
   public static Timesheet create(long id)
   {  return ( data_already_in_memory )
        ? new Real(id)
        : new Proxy(id);
   }
   public abstract
   Money compute_salary(Money wage);
   //---------------------------------------
   private static class Proxy
                          extends Timesheet
   {  Timesheet real_timesheet = null;
      long    id;
      Proxy(long id){this.id = id;}
      public Money compute_salary(Money wage)
      {  if( real_timesheet == null )
         real_timesheet = new Real(id);

         return real_timesheet.
            compute_salary(wage);
      }
   }
   //---------------------------------------
   private static class Real extends Timesheet
   {  Real(long employee_id)
      { // load data from the database.
      }
      public Money compute_salary(
                               Money wage)
      { // Compute weekly salary.
        return null;
      }
   }
}
```

Assume that hourly wage is used heavily enough to justify a database access when the object is crated, but that the total hours worked is used only rarely and the `Timesheet` is needed by only a few methods.

I've made the employee identifier a `long` to simplify the example. In real code, it would be an instance of class `Identity`.

You could reasonably argue that that the `Employee` should just use lazy loading for the `Timesheet` and dispense with the Proxy object, but the more that `Timesheet` was used, the less weight this argument would hold.

I've made `Timesheet` an abstract class rather than an interface so that I can use it as a factory; otherwise, I'd need a separate `Timesheet_factory` class.

Accessor methods (get and set functions) are evil because they expose implementation detail and impact maintencance. Though it's tempting to use them in this pattern, you'll note that no `get_salary()` or `get_hours_worked()` method is needed because of the way that I've structured the messaging system. Don't ask for information you need to do the work; ask the object that has the information to do the work for you. One exception to the get/set-is-evil rule is `Database.get_hourly_wage()`. A database is fundamentally non-object-oriented; it's just a bag of data with no operations at all. Consequently, it must be accessed procedurally.

If the `Timesheet.Proxy` threw away the data after computing the salary, it would be a *Flyweight*, not a *Proxy*.

Usage

```
public void paint(Graphics g)
{  Image img=Toolkit.getDefaulToolkit().getImage(
       new URL("http://www.holub.com/image.jpg"));
   g.drawImage(img,...);
}
```

The object returned from `getImage()` is a proxy for the real image, which is loaded on a background thread. (`getImage()` is *asynchronous*; it returns immediately, before completing the requested work.) You can use the image as if all bits had been loaded, even

	when they haven't.

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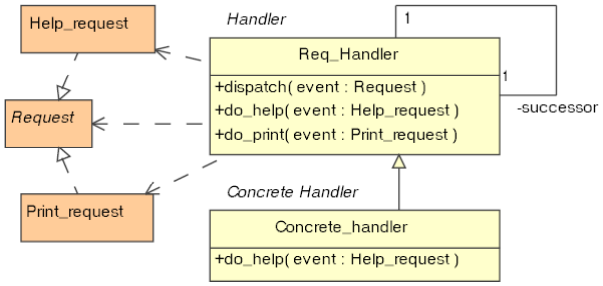
Behavioral Patterns

The behavioral patterns concern themselves with the runtime behavior of the program. I think of them as dynamic-model patterns. They define the roles that *objects* take on and the way that these objects interact with each other. For example, *Chain of Responsibly* defines the way that a set of objects route messages to each other at runtime (so that the object best suited to field a message actually handles the message). All of these objects are instances of the same class (or at least implement the same interface), so there's not much in the way of structure in this pattern. It's the dynamic behavior of the objects that are important.

Chain of Responsibility

A set of objects relay a message from one to another along a well defined route, giving more than one object a chance to handle the message. The object that's best suited to field a given message actually does the handling. It's possible for more than one object on the route to act on the message.



Handler: Defines event-handling interface and optional successor link.
Concrete Handler: Handles request or, by doing nothing, causes event to be forwarded to successor.
Request: Strictly speaking, not part of the pattern, but often present. Encapsulates information about event that occurred in order to pass this information to the *Handler*.

What Problem Does It Solve?

The classic example is a GUI system built on *Composite*, where the GUI is containment hierarchy. The leaves are the buttons and other "widgets," closest to the surface." Containers (frame windows, etc.) are interior nodes. A message (e.g. hot-key press) is routed up the tree until an object is found (a menu item?) that can process the message.

It's difficult to determine at compile time exactly which object is best suited to handle the message. In fact, the most suitable object might change with program state. Chain of Responsibility defers the choice of handler until runtime.

Servlet "filters" are an appropriate use of the pattern. An incoming HTTP packet is passed through a sequence of filters, which can process the packet directly or pass the packet to the next filter in the chain (or both).

Also consider a system of derived classes in which each constructor parses from a `String` the information of interest to it, and then it passes the `String` to the next constructor in the chain.

Pros (✓) and Cons (✖)

✓ The dynamic behavior of the program can be easily changed at runtime by adding new handlers to the chain or changing the ordering of handlers.
✓ The coupling between objects in the program is loosened if an implementation permits *Handler* classes not to know about each other.
✖ In Windows, when a mouse moves one pixel, the `WM_MOUSEMOVE` message is first received by the window that has focus, perhaps a text control. This control doesn't know how to handle it, so it passes the message to the containing panel, which passes it to the MDI child window, which passes it to the main frame, which passes it to the menu bar, which passes it to each menu item. None of these objects can handle the message, so it's discarded. This is a lot of to accomplish nothing.
✖ Many implementations force you to use implementation inheritance to specify a message-handler, inappropriately forcing strong coupling between *Handler* classes and introducing fragile base classes into the model.
✖ Visual event propagation mandates a *Controller* that fields events and sends messages to a model-level class. Controllers are difficult to maintain if the object model changes, and often force you to expose implementation details through get/set methods. This is one reason why the pattern was abandoned by Java for a system based on *Observer* (see).

Often Confused With

Composite specifies one way that a chain of responsibility might be ordered (from contained object to container, recursively). This is not the only way to order the chain, however.

See Also

Composite, Observer

Implementation Notes and Example

```
interface Request{};
class Help_request implements Request
{  // Help related state and methods
}
class Print_request implements Request
{  // Printing related state and methods
}

class Req_Handler
{  private Req_Handler successor;
   public Req_Handler(Handler successor)
   {  this.successor = successor;
   }
   public void dispatch( Request event )
   {  if(event instanceof Help_request)
        do_help((Help_request)event);
      else if(event instanceof Print_request)
        do_print( (Print_request)event);
   }
   protected void do_print(
                     Print_request event)
   {  successor.dispatch(event);
   }
   protected void do_help(Help_request event)
   {  successor.dispatch(event);
   }
}

class Concrete_handler extends Req_Handler
{  public Concrete_handler(Req_Handler next)
   {  super( next );
   }
   protected
   void do_help(Print_request event)
   {  // handle a help request here
   }
}
```

Define various kinds of events by deriving classes from `Request`. Derived-class state and methods are customized to handle a particular event type. `Request` itself is a "tagging" interface. It exists so that you can pass requests using a generic `Request` reference.

Initiate an event by creating a `Request` derivative of the appropriate type and then sending a `dispatch()` message to the *Handler* at the head of the chain (with that `Request` object as its argument). The `dispatch()` method figures out which kind of request is being made and calls the correct handler [`do_xxx()`]. Default handler methods do nothing, but relay the request to the next *Handler* in the chain.

The `dispatch()` method is particularly ugly since it has to be modified every time we add a new request type. It is type safe (because I'm using `instanceof`), but normally, good OO code avoids this sort of switch-like mechanism in favor of a interface-inheritance approach. You could eliminate the need to continually modify *dispatch()* by using Java's "introspection" APIs (in the `Class` class) to assemble the appropriate method call from the string version of the Reqest-class name [`Xxx_request` is mapped to `do_xxx()`], but that would be *really* ugly.

Normally, propagation stops at a Concrete Handler that overrides a `do_xxx()` method. The override can allow propagation to continue by calling `dispatch(event)` as the last thing it does.

The recursive list traversal is elegant, but might not work in memory-limited environments when there are a lot of handlers in the chain.

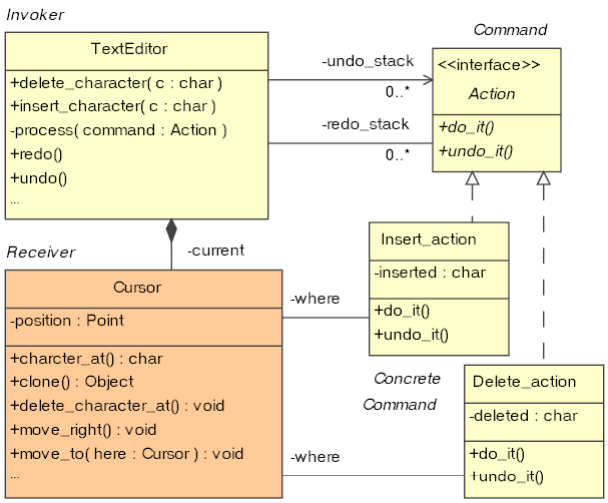
Usage

`public class MyFilter`
`  implements javax.servlet.Filter`
`{//...`
`public void doFilter(ServletRequest req,`
`ServletResponse rsp,`
`FilterChain chain)`
`{ //...`
`chain.doFilter(request, response );`
`//...`
`}`
`}`
	Each object on the route typically keeps a reference to its sucessor, but the pattern doesn't mandate this organization. For example, a centralized *dispatcher* might pass a message to several objects in turn. What's important is that the object, not the dispatcher, decides whether or not to handle the message. Servlet filters are dispatched by the web server. *Tomcat*, for example, uses information that you put into a configuration file to determine the dispatch sequence.

`class My_window extends Component`
`{ public boolean keyDown(Event e, int key)`
`{ // code to handle key press goes here.`
`}`
`}`
	Chain-of-Command GUI handling was abandoned as unworkable in version 1.1 of Java. (in favor of the better *Observer* pattern). This deprecated method is a holdover from then.

Command

Encapsulate a request or unit of work into an object. *Command* provides a more capable alternative to a function pointer because the object can hold state information, can be queued or logged, and so forth.



Command: Defines an interface for executing an operation or set of operations.
Concrete Command: Implements the *Command* interface to perform the operation. Typically acts as an intermediary to a *Receiver* object.
Invoker: Asks the command to carry out a request.
Receiver: Knows how to carry out the request. This functionality is often built in to the Command object itself.

What Problem Does It Solve?

You can't have a function pointer in an OO system simply because you have no functions, only objects and messages. Instead of passing a pointer to a function that does work, pass a reference to an object that knows how to do that work.

A Command object is effectively a transaction encapsulated in an object. Command objects can be stored for later execution, can be stored as-is to have a transaction record, can be sent to other objects for execution, etc.

Command is useful for things like "undo" operations. It's not possible to undo an operation simply by rolling the program back to a previous state, because the program might have had an effect on the outside world while transitioning from the earlier state to the current one. Command gives you a mechanism for actively rolling back state by actively reversing side effects like database updates.

By encapsulating the work in an object, you can also define several methods, and even state information, that work in concert to do the work. For example, a single object can encapsulate both "undo" and "redo" operations and the state information necessary to perform these operations.

Command also nicely solves "callback" problems in multithreads systems. A "client" thread creates a commend object that performs some operation, then notifies that client when the operation completes. The client then gives the *Command* object to a second thread on which the operation is actually performed.

Pros (✓) and Cons (✖)

✓ Command decouples operations from the object that actually performs the operation.

Often Confused With

Strategy. The invoker of a *Command* doesn't know what the *Command* object will do. A *Strategy* object encapsulates a method for doing a specific task for the invoker.

See Also

Memento, Strategy

Implementation Notes and Example

```
abstract class Cursor extends Cloneable
{  public Object clone();
   public char  character_at();
   public void  delete_character_at();
   public void  insert_character_at(
                          char new_character);
   public void  move_to(Cursor new_position);
   public void  move_right();
   //...
}
class Text_Editor
{  private Cursor current=Cursor.instance();
   private LinkedList undo_stack =
                          new LinkedList();
   private LinkedList redo_stack =
                          new LinkedList();
   public void insert_character(char c)
   {  process( new Inserter(c) );
   }
   public void delete_character()
   {  process( new Deleter() );
   }
   private void process( Action command )
   {  command.do_it();
      undo_stack.addFirst(command);
   }
   public void undo()
   {  Action action =
         (Action) undo_stack.removeFirst();
      action.undo_it();
      redo_stack.addFirst( action );
   }
   public void redo()
   {  Action action =
         (Action) redo_stack.removeFirst();
      action.do_it();
      undo_stack.addFirst( action );
   }
   private interface Action
   {  void do_it();
      void undo_it();
   }
   private class Inserter implements Action
   {  Cursor where = (Cursor) current.clone();
      char   inserted;
      public Insert_action(char new_character)
      { inserted = new_character;
      }
      public void do_it()
      { current.move_to( where );
        current.
           insert_character_at(inserted);
        current.move_right();
      }
      public void undo_it()
      { current.move_to( where );
        current.delete_character_at();
      }
   }
   private class Deleter implements Action
   {
      Cursor where = (Cursor) current.clone();
      char   deleted;
      public void do_it()
      { current.move_to( where );
        deleted = current.character_at();
        current.delete_character_at();
      }
      public void undo_it()
      { current.move_to( where );
        current.
           insert_character_at( deleted );
        current.move_right();
      }
   }
   //...
}
```

Most of the work is done by the `Cursor`, which reifies *Iterator* (see). The Text editor is driven by a Client class (not shown) that interprets user input and tells the editor to do things like insert or delete characters. The `Text_Editor` performs these request by creating *Command* objects that implement the `Action` interface. Each `Action` can both do something and also undo whatever it did. The editor tells the `Action` to do whatever it does, and then stacks the object. When asked to undo something, the editor pops the Action off the undo stack, asks it to undo whatever it did, and then puts it on a redo stack.. Redo works in the a similar way, but in reverse.

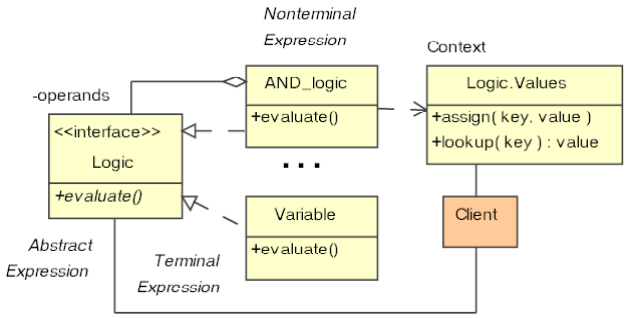
Usage

`new Thread()`
`{ public void run(){ /*...*/ }`
`}.start();`
	`Thread` is passed a `Runnable` *Command* object that defines what to do on the thread.

`java.util.Timer t = new java.util.Timer();`
`t.schedule( new java.util.TimerTask()`
`{ public void run()`
`{System.out.println(hello world);}`
`}, 1000);`
	Print "hello world." one second from now. The `TimerTask` is a *Command* object. Several `TimerTask` objects may be queued for future execution.

Interpreter

Implement an interpreter for a language, first defining a formal *grammar* for that language, and then implementing that grammar with a hierarchy of classes, one derived class per *production* or *nonterminal*.



Abstract Expression: Defines an "interpret" operation (or operations) . A node in the abstract syntax tree.
Terminal Expression: Implements an operation for a *terminal symbol* (which appears in the input).
Nonterminal Expression: Implements an operation for a *nonterminal symbol* (a grammatical rule).
Context: global information (e.g.: variable values.)

What Problem Does It Solve?

You sometimes cannot define all the required behavior of a program when you write it. For example, there's no way for the browser writer to predict the way a site designer might want a web page to behave. An interpretive language like JavaScript can add behavior to the program that wasn't contemplated by the author.

The interpreter pattern defines one way to build an interpreter. You first define a formal *grammar* that lists rules (called *productions*) that describe the syntax of the language. You then implement a class for each production. These classes share a *Context* object from which they get input, store variable values, and so forth. An interpreter might (or might not) create an efficient output processor (like a state machine) that does the actual work..

Pros (✓) and Cons (✖)

✖ The pattern says nothing about how to create the graph of objects that comprise the interpreter (the *Abstract Syntax Tree). Interpreter* often requires a nontrivial parser to construct this graph, and often this parser can just do the interpretation .

✓ Modifying the grammar is relatively straightforward: you just create new classes that represent the new productions.

✖ *Interpreter* doesn't work well if the grammar has more than a few productions. You need too many classes. Use traditional compiler tools (such as jyacc, cup, etc.) or a hand-coded recursive-decent parser for nontrivial languages.

✖ Why provide an interpreter when you have a perfectly good one already in memory: the JVM? Your users write scripts in Java and provide you with a string holding the class name. Use Java's "introspection" API's to load and execute the user-supplied code, or, if the user code implements a well-defined interface, then execute directly. Given:

```
public inteface User_extension
{   void do_something();
}
```

instantiate and execute a user object like this:

```
String name =
     System.getProperty("user.extension");
class user_mods = Class.forname(name);
User_extension user_extention_object =
    (User_extension) user_mods.newInstance();
user_extension_object.do_something();
```

Write your own class loader and/or security manager to create a sandbox .

Applets demonstrate this technique. Rather than interpret code (à la JavaScript), you provide a class to the browser, which it executes. Applets communicate with the browser via the `AppletContext` façade.

Often Confused With

Chain of Responsibility is used in interpreter to evaluate the input *sentence*. It's *Interpreter only* when the objects implement grammatical rules.

Interpreter is implemented as a *Composite.*

See Also

Strategy, Visitor

Implementation Notes and Example

```
interface Logic
{  public static class Values
   {  static Map vars = new HashMap();
      static void assign( String  key,
                          boolean value )
      { if(key==null || key.length() <= 0)
           throw new Exception("Logic");
        vars.put(key, value?Boolean.TRUE
                       :Boolean.FALSE);
      }
      static boolean lookup( String key )
      { Object got = vars.get(key);
        return ((Boolean)got).booleanValue();
      }
   }
   boolean evaluate();
}

class AND_logic implements Logic
{  Logic left, right;
   public AND_logic(Logic left, Logic right)
   {  this.left  = left;
      this.right = right;
   }
   public boolean evaluate()
   {  return left.evaluate()
             && right.evaluate();
   }
}

class OR_logic  implements Logic{/*...*/}
class NOT_logic implements Logic{/*...*/}

class Assignment_logic implements Logic
{  Logic left, right;
   public Assignment_logic(Logic l, Logic r)
   {  this.left = l;
      this.right= r;
   }
   public boolean evaluate()
   {  boolean r = right.evaluate();
      Logic.Values.assign(left.toString(),r);
      return r;
   }
}
class Variable implements Logic
{  private String name;
   public Variable(String s){name = s;}
   public String toString(){ return name; }
   public boolean evaluate()
   { return Logic.Values.lookup(name);
   }
}
```

Consider the following Boolean-expression grammar.

e ::= e '&' *e* | *e* '|' *e*
| '!' *e* | '(' *e* ')'
| *var* '=' *e* | *var*

The code at left comprises an interpreter for that grammar. (I've not shown `OR_logic`, and `NOT_logic` classes, since they're trivial variants on `AND_logic`.). Variable values are held in the `Values` *Singleton*. Create an interpreter for "X=(A & B) | !C" as follows:

```
Logic term = new AND_logic(
         new Variable("A"),
         new Variable("B")
       );
term = new OR_logic(
         term,
         new NOT_logic( new Variable("C") )
       );
term = new Assignment_logic(
         new Variable("X"), term );
```

Assign values in the code (or by reading user input) like this:

```
Logic.Values.assign("A", true);
Logic.Values.assign("B", true);
Logic.Values.assign("C", false);
boolean result = term.evaluate();
```

The *Interpreter* pattern makes no suggestions as to *how* you might construct the abstract-syntax tree that represents the expression (the tree of `Logic` objects), but some sort of parser is implied.

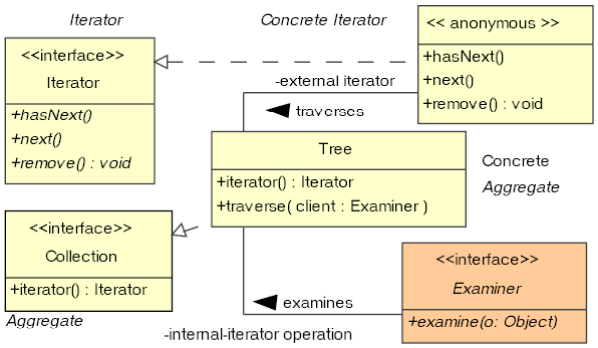
Alternatively, you could use *Visitor* to traverse the syntax tree: Visit the notes in depth-first order; code in the visitor object determines what happens as it visits each node. You could traverse once to test internal integrity, traverse again to optimize the tree, a third time to evaluate the expression, etc. Separating the structure of the abstract syntax tree from the logic of code generation and optimization can clean up the code substantially, but the visitor can end up as a quite-large class and will be hard to maintain as a consequence.

Usage

`java.util.regex.Pattern p=Pattern.compile("a*b");`
`java.util.regex.Matcher m =`
`p.matcher("aaaaab");`
`boolean b = m.matches();`
	Uses *Interpreter* internally (See the Source code shipped with the JDK.)

Iterator

Access the elements of an aggregate object sequentially without exposing how the aggregation is implemented.



Iterator: interface for accessing and traversing elements.
Concrete Iterator: Implements Iterator and keeps track of current position.
Aggregate: Defines an interface for creating an iterator. (Omit if no Abstract Factory required.)
Concrete Aggregate: Holds the data. Implements the creation interface to manufacture an iterator.

What Problem Does It Solve?

Iterators isolate a data set from the means that's used to store the set. For example, Java `Collection` and `Map` classes don't implement a common interface. You can, however, extract an iterator from a `Collection` [using `iterator()`]and from a Map [using `values().iterator()`]. Pass the iterator to a method for processing, thereby isolating that method from knowledge of how the objects are stored.

The set of objects need not be stored internally at all—an iterator across a *Flyweight* might read objects from disk, or even synthesize them.

Iterators make it easy to have multiple simultaneous iterators across an aggregation.

Iterators can manipulate the aggregation. The `Cursor` class in the *Command* example is an iterator. Java's `ListIterator` can modify the list.

External or *active* iterators are controlled by the client (e.g. Java's *Iterator* class). *Internal* or *passive* iterators are controlled by the aggregate object. A tree might have a `traverse_postorder()` method that's passed a *Command* object that is, in turn, passed each node in the tree. External iterators are often harder to implement than internal ones.

Pros (✓) and Cons (✖)

✓ Promotes reuse by hiding implementation.
✖ A client may modify the elements of the aggregation, damaging the aggregate (e.g. change the key in sorted aggregate.)
✖ The aggregate might store references to its iterators; memory leaks are possible if you discard an iterator without notifying the aggregate.
✖ It's difficult to control the traversal algorithm and retain the generic quality of an iterator. E.g.: There's no way to specify a post-order traversal from the iterator returned from a `TreeSet`. This problem extends to most *Composite* reifications.
✖ It's difficult to implement *Iterator* in a environment that supports simultaneous iteration and modification. (If you add an item to an aggregate while iterations are in progress, should the iterator visit the newly added item? What if the list is ordered and you've already passed the place where the new item is inserted? Should attempts to modify the aggregation fail if iterators are active? There are no "correct" answers to these questions.)

Often Confused With

Visitor is usually implemented with a passive iterator. Iterators should examine data, not modify it. Visitors always modify the data.

See Also

Composite, *Visitor*,

Implementation Notes and Example

```
class Tree implements Collection
{  private Node root = null;
   private static class Node
   {   public Node left, right;
      public Object item;
      public Node( Object item )
      {   this.item = item;      }
   }
   Iterator iterator()
   {  return new Iterator()
      {  private Node current = root;
         private LinkedList stack =
                     new LinkedList();
         public Object next()
         { while( current != null )
           {   stack.addFirst( current );
               current = current.left;
           }
           if( stack.size() != 0 )
           {  current = (Node)
                      ( stack.removeFirst() );
              Object to_return=current.item;
              current = current.right;
              return to_return;
           }
           throw new NoSuchElementException();
         }
         public boolean hasNext()
         {   return !(current==null
                        && stack.size()==0);
         }
         public void remove(){ /*...*/ }
      };
   }
   public interface Examiner
   {   public void examine( Object o );   }
   void traverse( Examiner client )
   {   traverse_inorder( root, client );
   }
   private void traverse_inorder(Node current,
                              Examiner client )
   {  if( current == null )
         return;
      traverse_inorder(current.left,  client);
      client.examine  (current.item );
      traverse_inorder(current.right, client);
   } // ...
}
```

The code at left implements a simple binary tree. (I've ommited the methods of `Collection` that aren't relevant to *Iterator*.) The `iterator()` method returns an external iterator that implments the `java.util.Iterator` interface. Use it like this:

```
Iterator i = t.iterator();
while( i.hasNext() )
   System.out.print(i.next().toString() );
```

You can't use recursive traversal in an external iterator because `next()` must return after getting each element, and you can't stop the recusion in mid stream. My implemenation uses a stack to remember the next parent to visit in the travsersal (the same information that would be on the runtime stack in a recursive traversal). You can easily see the extra complexity mandated by this approach, but other nonrecursive traversal algorithms are, if anything, messier.

The `traverse()` method demonstrates an internal iterator. You pass `traverse()` a *Command* (see) object that implements the `Examiner` interface. Traverse does a simple recursive traversal, passing each node to the Examiner's examine() method in order. Here's an example:

```
t.traverse(
        new Tree.Examiner()
        { public void examine(Object o)
          {System.out.print(o.toString());
          }
        }         );
```

As you can see, the code is much simpler, but you loose the flexibility of an external iterator (which you could keep positioned in the middle of the tree for example—an internal iterator doesn't give you the option of not advancing, or of terminating the iteration early).

Both iterators access private fields of Tree. Think of an external iterator as an extension of the object that creates it. Private access is okay if it doesn't expose implementation information.

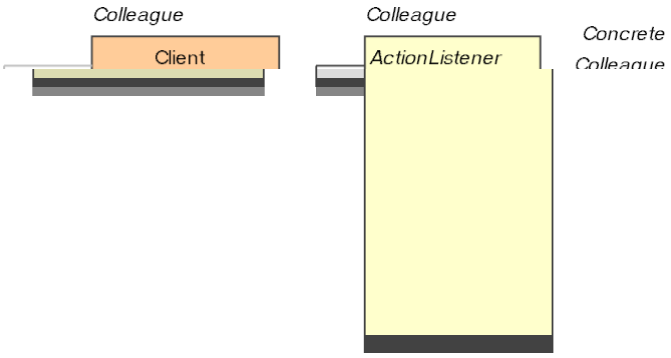
Usage

`f( Collection c )`
`{    Iterator i = c.iterator();`
`     while( i.hasNext() )`
`         do_something( i.next() );`
`}`
	Iterators are used heavily in all the Java Collection classes.

`String query = "SELECT ID FROM TAB";`
`ResultSet results = stmt.executeQuery(query);`
`while (results.next())`
`    String s = rs.getString("ID");`
	A database cursor iterates across rows in a table.

Mediator

Define a single object that encapsulates a set of complex operations. *Mediator* simplifies your code by hiding complexity; it loosens coupling between the objects that use the mediator and the objects the mediator uses.



Mediator: (Often omitted) defines an interface to Colleagues.
Concrete Mediator: Implements *Mediator* interface to interact with Colleagues and manage communication between them.
Colleagues: A system of interfaces and classes that communicate bidirectionally through the mediator rather than directly. Note that the client is a colleague

What Problem Does It Solve?

Mediator makes complex operations simple. Too-complex code is damaging to any program. *Mediator* solves this problem by taking complex code that would otherwise appear all over the program and concentrating it into a single object with a simple interface that's used all over the program. Mediators hide complex protocols.

Pros (✓) and Cons (✖)

✓ Mediators improve code organization in many ways: reducing subclassing, decoupling subsystems, and simplifying messaging systems and protocols.
✖ Complexity can creep into a Mediator over time as you customize it for new applications. You've missed the point if you allow a Mediator to become too complex.. Several Mediators tailored for specific applications can help. Be careful not to add back the complexity you're trying to eliminate.
✖ A mediator can turn into a "God" class if you're not careful. A good OO program is a network of cooperating agents. There is no spider in the middle of the web pulling the strands. Focus your mediators on doing only one thing.

Often Confused With

Façade eases simple one-way communication with a subsystem and also Isolates the entire subsystem from the rest of the program. Mediators encapsulate complex interactions, but communication is bi-directional and they do not isolate anything from anything.
Bridge and *Mediator* both reduce coupling between subsystems. Bridge define a standard (often complicated) interface and then implements it in various ways. Bridges are systems of *classes*. Mediators are *objects* that have simple interfaces, but do complex work. at run time. *Mediator* does promote decoupling, though. If a protocol changes, for example, the scope of that change is typically limited to the Mediator itself.

See Also

Façade, Bridge

Implementation Notes and Example

```
class Query
{ static String ask( String query )
  { final Object done  = new Object();
    final Object init  = new Object();
    final JFrame frame = new JFrame("Query");
    final JTextField answer= new JTextField();
    answer.setPreferredSize(
                      new Dimension(200,20) );
    frame.getContentPane().setLayout(
                      new FlowLayout() );
    answer.setPreferredSize(
                      new Dimension(200,20) );
    frame.getContentPane().add( answer );
    frame.getContentPane().add(
                          new JLabel(query) );
    answer.addActionListener  // submit
    (  new ActionListener()
       {  public void actionPerformed(
                              ActionEvent e )
          { synchronized( init )
             {  synchronized( done )
                {  frame.dispose();
                    done.notify();
    }}}});
    frame.addWindowListener  // cancel
    (  new WindowAdapter()
       {  public void windowClosing(
                               WindowEvent e)
          {  synchronized( init )
             {  synchronized( done )
               {  frame.dispose();
                  answer.setText("");
                  done.notify();
    }}}});
    synchronized( done )
    {  synchronized( init )
       {  frame.pack();
          frame.show();
       }
       try{ done.wait(); }
       catch( InterruptedException e ){}
    }
    return answer.getText();
  }
}
```

The code at left let's you ask the User a simple question. When you make this call:

`String answer = Query.ask("How are you");`

The method displays the small window shown at right. You type your answer and hit Enter, the window shuts down, and `ask(...)` returns what you typed (in this case, the string "`Fine`"). If you click the "X" box in the upper right corner of the control, the window shuts down and `ask(...)` returns an empty string.

The details of the code are actually not relevant to the current discussion. The main issue is that the code is quite complex for what it does (and would be even more complex if you were working in the raw OS rather than Java), but the user exercises all this complexity by doing a simple thing. The details are all hidden. Moreover, code that *uses* `Query` is now considerably simplified, and a lot of complicated junk isn't duplicated all over the program.

Note that *Mediator* does not isolate the program from the entire Swing subsystem. Unlike *Façade*, which discourages "end runs" around the Façade. *Mediator* does not prohibit other parts of your program from talking directly to Swing. Also note that the communication between the mediator (`Query`) and its colleagues (everything else) is bi-directional, and that all communication—at least in the context of asking the user a question—happens through the mediator.

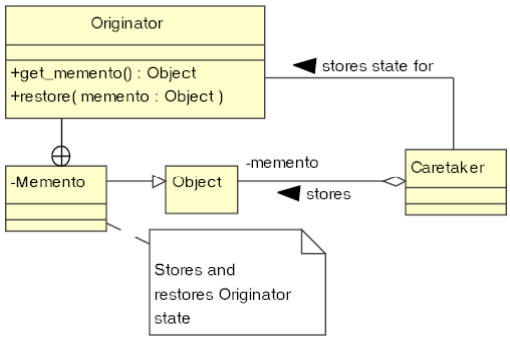
Usage

`URL home = new URL("http://www.holub.com");`
`URLConnection c = home.getConnection();`
`  //...`
`OnputStream out = c.getOutput();`
`c.write( some_data );`
	The output stream returned from the `URLConnection` is a *Mediator*. You just write data to it. It encapsulates the complex interaction needed to establish a connection and implement whatever protocol was specified in the original `URL`.

`JButton b = new JButton("Hello");` `//...`	The `JButton` deals with all the complexity of fielding mouse clicks, changing the image the user sees when the button should be "down," etc.
`JOptionPane.showMessageDialog("Error...");`	Hides the complexity of creating and showing a dialog box.

Memento

Encapsulate an object's state in such a way that no external entity can know how the object is structured. An external object (called a *caretaker*) can store or restore an object's state without violating the integrity of the object.



Originator: Creates a memento that holds a "snapshot" of its current state.
Memento: Stores the internal state of the Originator in a way that does not expose the structure of the Originator. Supports a "wide" interface used by the originator and a "narrow" interface used by everyone else.
Caretaker: Stores the mementos, but never operates on them.

What Problem Does It Solve?

The ubiquitous get/set (*accessor*) function is evil. Allowing access to internal fields—either directly by making them `public` or indirectly through an accessor—flies in the face of every basic object-oriented principle. The whole point of an OO structure is that you can make radical changes to an object's implementation without impacting the code that uses those objects. An object should not get the data that it needs to do work—it should ask the object that has the data to do the work for it (delegation). The only exception to this rule is an accessor that returns an object that opaquely encapsulates the data. The point is not to expose implementation details.

If you use simplistic accessors, even small changes, like changing a field's type, impact every part of the program that uses that accessor. Programs that use accessors are very difficult to maintain, and simply aren't object oriented. (A program isn't OO just because it uses classes, derivation, etc., or is written in Java or C++.).

But what if an external entity needs to remember the state of some object, perhaps to restore that state in an undo operation or equivalent? *Memento* solves this problem by having the original object return a black box, an impenetrable container that the caretaker can store, but not manipulate. The object that manufactures the black box *does* know what's in it, though, so *it* can use this information at will (to restore state, for example).

Pros (✓) and Cons (✖)

✓ Allows an object's state to be stored externally in such a way that the maintainability of the program is not compromised.
✓ Allows a "caretaker" object to store states of classes that it knows nothing about.
✖ Versioning can be difficult if the memento is stored persistently. The *originator* must be able to decipher mementos created by previous versions of itself.
✖ It's often unclear whether a memento should be a "deep" copy of the Originator. (i.e. should recursively copy not just references, but the objects that are referenced as well). Deep copies are expensive to manufacture. Shallow copies can cause memory leaks, and referenced objects might change values.
✖ Caretakers don't know how much state is in the memento, so they cannot perform efficient memory management.

Often Confused With

Command objects encapsulate operations that are known to the invoker. Mementos encapsulate state—operations are unknown to the caretaker.

Implementation Notes and Example

```
class Originator
{  private String     state;
   private int        more;

   private class Memento
   {  private String
                 state=Originator.this.state;
      private int more =Originator.this.more;
      public toString()
      { return state + ", " + more ;
      }
   }

   public Object get_memento()
   {  return new Memento();
   }

   public Object restore(Object o)
   {  Memento m = (Memento) o;
      state = o.state;
      more  = o.more;
   }
}

class Caretaker
{  Object memento;
   Originator originator;
   public void capture_state()
   {  memento = originator.get_memento();
   }
   public void restore_yourself()
   {  originator.restore( memento );
   }
}
```

Making `Memento` `private` with nothing but `private` fields guarantees that unsafe access is impossible. (Some idiot might try to circumvent encapsulation using the introspection APIs, but "against stupidity, even the gods themselves contend in vain.") The *caretaker* treats the memento as a simple `Object`. Memento defines a "narrow" interface (`toString()`) that doesn't expose structure. A much more complicated memento is preseted earlier in the book in the Game-of-Life example.

One great example of *Memento* is an "embedded" object in Microsoft's *OLE* (Object Linking and Embedding) framework. Consider an Excel spreadsheet that you've embedded as a table in a Word document. When you create the table, Excel is running. It negotiates with Word to take over some of its UI (Excel adds menus to Word's menu bar and is in control of the subwindow that holds the table, for example). When you click outside the table, Excel shuts down and produces a memento—a blob of bytes that holds its state—and an image that Word displays in place of the original Excel UI. All that Word can do with this image is display it. All that Word can do with the data "blob" is hold on to it. The next time the user wants to edit the table, Word passes the blob back to Excel, but Excel has to figure out what to do with it. Since Excel's data representation is complely hidden from Word, it can change the representation without impacting any of the code in Word itself.

A memento can have a "narrow" interface that does something like display its state on a screen or store its state as an XML file. Just make sure that this interface doesn't expose any structure to the caretaker.

"Undo" is hardly ever implementable solely with a memento (see Command).

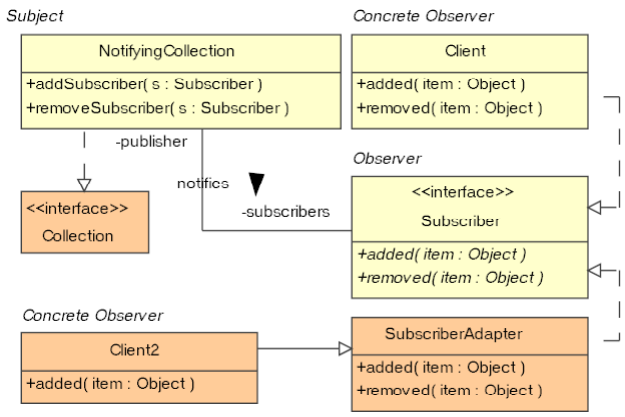
Usage

```
class Originator implements Serializable{ int x; }

ByteArrayOutputStream bytes = new ByteArrayOutputStream();
ObjectOutputStream out= new ObjectOutputStream( bytes );

Originator instance = new Originator();  // create
out.writeObject( instance );             // memento
byte[] memento = bytes.toByteArray();

ObjectInputStream in =                   // restore object
    new ObjectInputStream(               // from memento
          new ByteArrayInputStream(memento));
instance= (Originator) in.readObject();
```

A byte array is about as black as a box can be. *Decorator* is used, here, to produce a system of streams that manufacture the memento. This example also nicely illustrates a flaw in *Decorator*—that you sometimes have to access an encapsulated decorator to do work.

Observer (Publish/Subscribe)

When an object changes states, it notifies other objects that have registered their interest at run time. The notifying object (publisher) sends an event (publication) to all its observers (subscribers).



Subject: The Publisher—notifies Observers that some event has occurred. Keeps a subscription list and a means for modifying the list. Sometimes *Subject* is an interface implemented by a *Concrete Subject*.
Observer: Defines an interface for notifying observers.
Participant: Implements the *Observer* interface to do something when notified..

What Problem Does It Solve?

In *Chain of Responsibility* a button notifies a parent of a press event like this:

```
class Window
{   void button_pressed() {/*...*/}
        //...
}

class Button implements Window
{   private Window parent;
    public Button(Window parent)
    {   this.parent = parent;  }
    on_mouse_click()
    { parent.button_pressed(); }
}
```

An abstraction-layer (business) object must learn about presses through a *Mediator* called a *Controller*—a `Window` derivative that overrides `button_pressed()` to send a message to the business object .The coupling relationships between the controllers, the abstraction layer, and the presentation (the button) are too tight. There's too much code affected if anything changes.

The Observer pattern addresses the problem by adding an interface between the "publisher" of an event (the button) and a "subscriber" (the business object that's actually interested in the button press. This interface decouples the publisher and makes it reusable in the sense that it's a stand-alone component, with no dependencies on the rest of the system. A publisher can notify any class that implements the subscriber interface.

Pros (✓) and Cons (✖)

✓ Observer nicely isolates subsystems, since the classes in the subsystems don't need to know anything about each other except that they implement certain "listener" interfaces. This isolation makes the code much more reusable.
✖ There's no guarantee that a subscriber won't be notified of an event after the subscriber cancels its subscription—a side effect of a thread-safety. (AWT and Swing both have this problem.)
✖ Publication events can propagate alarmingly when observers are themselves publishers. It's difficult to predict that this will happen.
✖ Memory leaks are easily created by "dangling" references to subscribers. (When the only reference to an object is the one held by a publisher, a useless might not be garbage collected. It's difficult in Java, where there are no "destructor" methods, to guarantee that publishers are notified when an object becomes useless.

Often Confused With

Command, Strategy

See Also

Chain of Responsibility

Implementation Notes and Example

```
public final class NotifyingCollection
                        implements Collection
{  private final Collection c;
   public NotifyingCollection(Collection wrap)
   {  c = wrap;   }
   private final Collection subscribers
                          = new LinkedList();
   public interface Subscriber
   {  void added  ( Object item );
      void removed( Object item );
   }
   synchronized public void addSubscriber(
                           Subscriber subscriber)
   {  subscribers.add( subscriber ); }
   synchronized public void removeSubscriber(
                           Subscriber subscriber)
   {  subscribers.remove( subscriber );
   }
   private void notify(boolean add, Object o)
   { Object[] copy;
     synchronized(this)
     {  copy = subscribers.toArray();
     }
     for( int i = 0; i < copy.length; ++i )
     { if(add)((Subscriber)copy[i]).added  (o);
       else   ((Subscriber)copy[i]).removed(o);
     }
   }
   public boolean add(Object o)
   { notify(true,o);  return c.add(o);    }
   public boolean remove(Object o)
   { notify(false,o); return c.remove(o);  }
   public boolean addAll(Collection items)
   {   Iterator i = items.iterator()
      while( i.hasNext() )
         notify( true, i.next() );
      return c.addAll(items);
   }
   public int size()    { return c.size();  }
   public int hashCode(){ return hashCode();}
   // pass-through implementations of other
   // Collection methods go here...
}
```

The example at left is a *Decorator* (see) that wraps a collection to add a notification feature. Objects that are interested in finding out when the collection is modified register themselves with the collection.
In the following example, I create an "adapter" (in the Java/AWT sense, this is *not* the *Adapter* pattern) that simplifies subscriber creation. By extending the adapter rather than implementing the interface, we're saved from having to implement uninteresting methods. I then add a subscriber:

```
class SubscriberAdapter implements
            NotifyingCollection.Subscriber
{   public void added(Object item){}
    public void removed(Object item){}
}

 NotifyingCollection c =
     new NotifyingCollection(new LinkedList());
c.addSubscriber
(   new SubscriberAdapter()
    {  public void added( Object item )
       { System.out.println("Added " + item);
       }
    }
)
```

This implemenation of *Observer* is simplistc—copy is a very inefficent stragegy for solving the problem of one thread adding or removing a subcriber while notifications are in progress. A more realistic implementation was presented earlier in the book.

Observer encompasses both one-to-many and many-to-one implementations. For example, one button could notify several observers when it's pressed, but by the same token, several buttons could all notify the same subscriber, which would use some mechanism (perhaps an event object passed as an argument) to deermine the publisher.

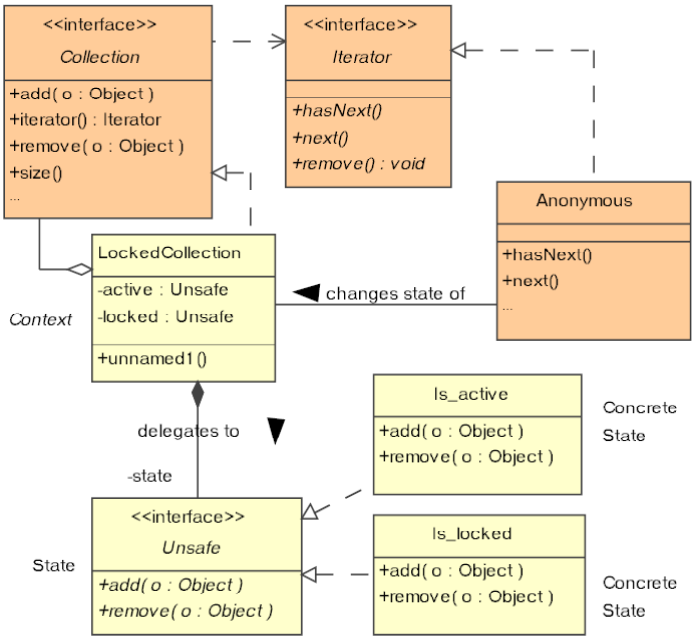
Usage

`JButton b = new JButton("Hello");`
`b.addActionListener(`
`  new ActionListener()`
`  {  public void actionPerformed(ActionEvent e)`
`    { System.out.println("World");`
`    }`
`  } );`
	Print *World* when the button is pressed. The entire AWT event model is based on Observer. This model supercedes a Chain-of-Responsibility-based design that proved unworkable in an OO environment..

`Timer t = new java.util.Timer();`
`t.scheduleAtFixedRate( new TimerTask()`
`{ public void run()`
`  { System.out.println(new Date().toString());`
`  }`
`}, 0, 1000 );`
	Print the time once a second. The `Timer` object notifies all its observers when the time interval requested in the schedule method elapses.

State

Objects often need to change behavior when they are in certain states. A good solution defines an interface comprising all methods who change behavior; interface implementations define each state.



Context: Defines a public interface to the outside world, methods of which change behavior with object state. Maintains an instance of a Concrete State class.
State: Defines an interface that comprises all the behavior that changes with state.
Concrete State: Implements State to define behavior for a particular state.

What Problem Does It Solve?

Objects often need to change behavior with state. The "obvious" way to implement this change is for each method to contain a large `switch` statement or equivalent, with a `case` for each possible state, and the selector is an instance variable. This structure is difficult to maintain at best, and changing the state table or introducing new states is difficult, requiring many changes to many methods.

In the *State* pattern, each state is represented by an object that implements the behavior of a single state. An instance variable references an object that implements the current-state's behavior. A public method that changes behavior with state just delegates to the current state-object. To change state, modify the current-state variable to reference an object that implements behavior for the new state.

Pros (✓) and Cons (✖)

✓ State machines are easier to maintain since all the behavior for a given state is in one place.
✓ Eliminates long hard-to-maintain switch statements in the methods.
✖ State tables (indexed by current state and stimulus, holding the next state) are difficult to implement.
✖ Increases the number of classes in the system along with concomitant maintenance problems.
✖ If only a few methods change behavior with state, this solution might be unnecessarily complex.

Often Confused With

Strategy. The state objects do implement a strategy for implementing a single state, but that strategy is not provided by an outside entity.

See Also

Singleton.

Implementation Notes and Example

```
public final class LockedCollection
                          implements Collection
{ private final Collection c;
  private int active_iterators = 0;

  private Unsafe active = new Is_active();
  private Unsafe locked = new Is_locked();
  private Unsafe state = active;

  public LockedCollection(Collection c)
  { this.c = c;
  }
  public Iterator iterator()
  { final Iterator wrapped = c.iterator();
    ++active_iterators;
    state = locked;

    return new Iterator()
    { private boolean  valid = true;
          //...
      public boolean hasNext()
      { return wrapped.hasNext();
      }
      public Object next()
      { Object next = wrapped.next();
        if( !hasNext() )
        { if( --active_iterators == 0 )
            state = active;
          valid = false;
        }
        return next;
      }
    };
  }
  public int size()
  { return c.size();  }
  public boolean isEmpty()
  { return c.isEmpty(); }
  // ...
  // Collection methods that don't
  // change behavior are defined here.

  public boolean add(Object o)
  {return state.add(o);}
  public boolean remove(Object o)
  {return state.remove(o);}

  private interface Unsafe
  { public boolean add(Object o);
    public boolean remove(Object o);
    //...
  }
  private final class Is_active
            implements Unsafe
  { public boolean add(Object o)
    {return c.add(o);}
    public boolean remove(Object o)
    {return c.remove(o);}
    //...
  }
  private final class Is_locked
            implements Unsafe
  { public boolean add(Object o)
    { throw new Exception("locked"); }
    public boolean remove(Object o)
    { throw new Exception("locked"); }
    //...
  }
}
```

This code combines *Decorator*, *Abstract Factory*, and *State*. It implements a `Collection` that changes behavior when iterators are active. "Active," means that an iterator has been created, but the last element of the Collection has not been examined through that iterator. (Java's Collection implemenations do just that, but it makes a good example.) The class tosses an excemption if you attempt to modify a collection while iterators are active.

The `Unsafe` interface defines those Collection methods that are unsafe to call during iteration. This interface is implemented by two classes: `Is_active` implements normal collection behavior. `Is_locked` implements the iterators-are-active behavior. The classes are *Singetons* whose instances are referenced by `active` and `locked`. The variable `state` defines the current state, and points to one or the other of the Singletons.

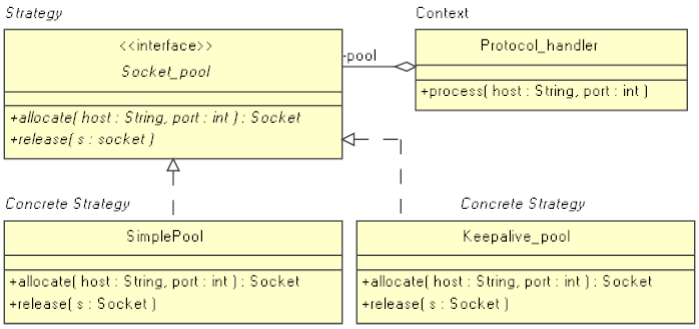
Public methods that don't change state with behavior [such as `size()`] delegate to the contained `Collection`, `c`. Public methods that do change state [such as `add(Object)`] delegate to whichever state object is referenced by `state`. The `iterator()` method forces a change of state to `locked` when it issues an iterator. It also increments an active-iterator count. This count is decremented by the Iterator's `next()` method when it reaches the last element, and when the count goes to zero, the `active` state is activated.

The iterator also changes behavior with state. but only one method is effected, so the *State* pattern isn't used.

There's no reason why you can't create new objects each time a state transition is made. This way the individual state object can itself keep local state information.

Strategy

Define an interface that defines a strategy for performing some operation. A family of interchangeable classes, one for each algorithm, implements the interface.



Strategy: an interface that allows access to an algorighm.
Concrete Strategy: Implements a particular algorithm to conform to the Strategy interface.
Context: Uses the algorithm through the Strategy interface.

What Problem Does It Solve?

Sometimes, the only difference between subclasses is the strategy that's used to perform some common operation. For example, a frame-window might lay out its components in various ways, or a protocol handler might manage sockets in various ways. You can solve this problem with derivation—several Frame derivatives would each lay out subcomponents in different ways, for example. This derivation-based solution creates a proliferation of classes, however. In *Strategy*, you define an interface that encapsulates the strategy for performing some operation (like layout). Rather than deriving classes, you pass the "Context" class the strategy it uses to perform that operation.

Pros (✓) and Cons (✖)

✓ Strategy is a good alternative to subclassing. Rather than deriving a class and overriding a method called from the base class, you implement a simple interface.
✓ The strategy object concentrates algorithm-specific data that's not needed by the "Context" class in a class of its own.
✓ It's very easy to add new strategies to a system, with no need to recompile existing classes.
✖ There's a small communication overhead. Some of the arguments passed to the strategy objects might not be used.

Often Confused With

Command objects are very generic. The invoker of the command doesn't have a clue what the command object does. A *Strategy* object performs a specific action.

See Also

Command

Implementation Notes and Example

```
interface Socket_pool
{ Socket  allocate( String host, int port )
  void    release ( Socket s )
}
class Simple_pool implements Socket_pool
{ public Socket allocate(String host,int port)
  { return new Socket(host, port);
  }
  public void release(Socket s)
  { s.close();
  }
};
class Keepalive_pool implements Socket_pool
{ private Map connections = new HashMap();
  public Socket allocate(String host,int port)
  { Socket connection =
       (Socket)connections.get(host+":"+port);
    if(connection == null)
      connection = new Socket(host,port);
    return connection;
  }
  public void release(Socket s)
  { String host =
            s.getInetAddress().getHostName();
    connections.put( host+":"+s.getPort(),s );
  }
  //...
}
class Protocol_handler
{ Socket_pool pool = new Simple_pool();
  public void process( String host, int port )
  { Socket in = pool.allocate(host,port);
    //...
    pool.release(in);
  }
  public void set_pooling_strategy( Socket_pool p)
  { pool = p;
  }
}
```

The code at left implements a skeleton protocol handler. Some of the hosts that the handler talks to require that sockets used for communication are closed after every message is processed. Other hosts require that the same socket be used repeatedly. Other hosts might have other requirements. Because these requirements are hard to predict, the handler is passed a socket-pooling strategy.

The default strategy (`Simple_pool`) simply opens a socket when asked and closes the socket when the `Protocol_handler` releases it.

The `Keepalive_pool` implements a different management strategy. If a socket has never been requested, this second strategy object creates it. When this new socket is released, instead of closing it, the strategy object stores it in a `Map` keyed by combined host name and port number. The next time a socket is requested with the same port name and host, the previously created socket is used. A more realistic example of this second strategy would probably implement notions like "aging," where a socket would be closed if it hadn't been used within a certain time frame.

In the interest of clarity, I've left out the exception handling.

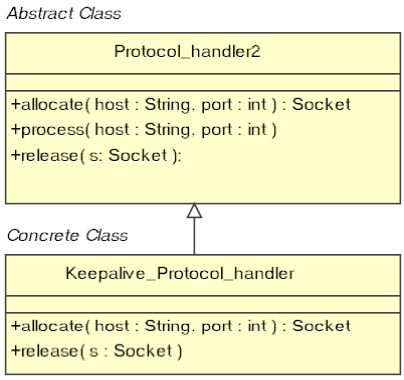
Usage

`JFrame frame = new JFrame();`
`frame.getContentPane().setLayout`
`( new FlowLayout() );`
`frame.add( new JLabel("Hello World");`
	The `LayoutManger` (`FlowLayout`) defines a strategy for laying out the components in a container (`JFrame`, the "Context");

`String[] array = new String[]{ ... };`
`Arrays.sort`
`(  array,`
`  new Comparator`
`  {  int Compare( Object o1, Object o2 )`
`  { return ((String)o1).compareTo((String)o2);`
`  }`
`  }`
`);`
	The `Arrays.sort(...)` method is passed an array to sort and a `Comparator` that defines a strategy for comparing two array elements. This use of *Strategy* makes `sort(...)` completely generic—it can sort arrays of anything..

Template Method

Define an algorithm at the base-class level. Within the algorithm, call an abstract method to perform operations that can't be generalized in the base class. This way you can change the behavior of an algorithm without changing its structure.



Abstract Class: Defines an algorithm that uses "primitive" operations that are supplied by a derived class.
Concrete Class: Implements the "primitive" operations.

What Problem Does It Solve?

Template method is typically used in derivation-based application frameworks. The framework provides a set of base classes that do 90% of the work, deferring application-specific operations to abstract methods. You use the framework by deriving classes that implement this application-specific behavior.

Pros (✓) and Cons (✖)

✖ Template method has little to recommend it in most situations. *Strategy*, for example, typically provides a better alternative. Well done class libraries work "out of the box." You should be able to instantiate a framework class and it should do something useful. Generally, the 90/10 rule applies (10% of the functionality is used 90% of the time, so that 10% should be define the default behavior of the class). In template method, however, the framework defines *no* default behavior, but rather, you are required to provided derived classes for the base class to do anything useful. Given the 90/10 rule, this means that you have to do unnecessary work 90% of the time.

Template method does not prohibit the class designer from providing useful default functionality, expecting that the programmer will modify the behavior of the base class through derived-class overrides. In an OO system, though, using derivation to modify base-class behavior is just run-of-the-mill programming, hardly worth glorifying as an official pattern.

✓ One reasonable application of *Template Method* is to provide empty "hooks" at the base-class level solely so that a programmer can insert functionality into the base class via derivation.

Often Confused With

Factory Method is nothing but a *Template Method* that creates objects.

See Also

Factory Method.

Implementation Notes and Example

```
class Protocol_handler2
{ public Socket allocate(String host,int port)
  { return new Socket(host, port);
  }
  public void release(Socket s)
  { s.close();
  }

  public void process( String host, int port )
  { Socket in =
       socket_pool.allocate(host,port);
    //...
    socket_pool.release(in);
  }
}

class Keepalive_Protocol_handler
{
  private Map connections = new HashMap();

  public Socket allocate(String host,int port)
  { Socket connection =
      (Socket)connections.get(host+":"+port);
    if(connection == null)
      connection = new Socket(host,port);
    return connection;
  }
  public void release(Socket s)
  { String host=
      s.getInetAddress().getHostName();
    connections.put( host+":"+s.getPort(),s);
  }
}
```

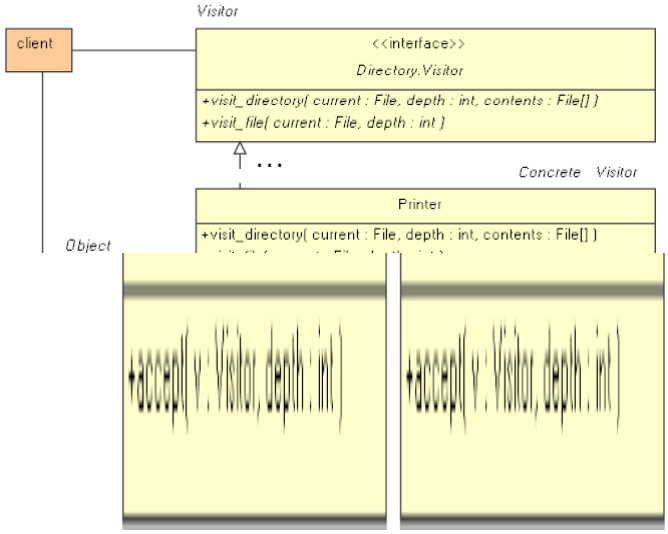
This example is the example from *Strategy* rewritten to sue *Template Method*. Rather than provide a strategy object, you derive a class that modifies the base-class behavior. Put differntly, you modify the behavior of the protocol-processing algorithm with respect to socket management.

Usage

`class my_Panel extens JPanel`
`{  public void paint( Graphics g )`
`  { g.drawString("Hello World", 10, 10);`
`  }`
`}`
	Define painting behavior by overriding the `paint(...)` method. You could easily do the same thing by passing a `Panel` a "paint" strategy.

Visitor

Add operations to a "host" object by providing a way for a visitor—an object that encapsulates an algorithm—to access the interior state of the host object. Typically, this pattern is used to modify or examine the elements of a composite structure.



Visitor: Defines an interface that allows access to a Concrete Element of an Object Structure. Various methods can access elements of different types.
Concrete Visitor: Implements an operation to be performed on the *Elements*. This object can store an algorithm's local state.
Element: defines an "accept" operation that permits a *Visitor* to access it.
Concrete Element: Implements the "accept" operation.
Object Structure: a composite object that can enumerate its elements.

What Problem Does It Solve?

SolvedProblem

Pros (✓) and Cons (✖)

✓ It's easy to add operations that you haven't thought of.
✓ Allows the class to be smaller since rarely used operations can be defined externally.
✓ Visitors can accumulate state as the visit elements. A "mobile agent" can visit remote objects (database servers, for example) and accumulate a composite result from a distributed database.
✖ The internal structure of the composite object is opened up to the visitor, violating encapsulation. For example, an evil visitor could be passed elements of a tree and change their "key" values, thereby turning the tree to garbage. The visitors are tightly coupled to the object they are visiting.

Often Confused With

Strategy. A Visitor is, in a way, a "visiting strategy." The focus of visitor is to visit every node of a data structure and do something. Strategy is much more general, and has no connection to a data structure.

See Also

Strategy

Implementation Notes and Example

```
class Directory
{
  public interface Visitor
  { void visit_file(File current, int depth);
    void visit_directory( File current,
                  int depth, File[] contents );
  }
  public interface Element
  { void accept( Visitor v, int depth );
  }
  public class Directory_Element
                            implements Element
  { private File f;
    public Directory_Element(File f){this.f=f;}
    public void accept( Visitor v, int depth )
    { v.visit_directory(f,depth,f.listFiles());
    }
  }
  public class File_Element implements Element
  { private File f;
    public File_Element(File f){this.f = f;}
    public void accept( Visitor v, int depth )
    { v.visit_file( f, depth );
    }
  }
  //============================
  private File root;
  public Directory(String root)
  { this.root = new File(root);
  }

  public void traverse( Visitor visitor )
  { top_down( root, visitor, 0 );
  }

  private void top_down( File root,
                  Visitor visitor, int depth )
  { Element e =
      root.isFile()
       ? (Element)(new File_Element(root))
       : (Element)(new Directory_Element(root))
       ;

    e.accept( visitor, depth );

    if( !root.isFile() )
    {
      File[] children = root.listFiles();
      for(int i = 0; i < children.length; ++i)
        top_down(children[i],visitor,depth+1);
    }
  }
}
```

Print a directory tree like this:

```
class Printer implements Directory.Visitor
{ public void visit_file(File f, int depth)
    {}
    public void visit_directory( File f,
                    int depth, File[] children)
    { while( --depth >= 0 )
          System.out.print("..");
      System.out.println( f.getName() );
    }
}
Directory d = new Directory("c:/");
d.traverse( new Printer() );
```

The implementation at left is a bit more complex than it needs to be so that I could demonstrate the general structure of traversing a heterogeneous composite object.

The key feature of *Visitor* is that it provides a way to add methods to an existing class without having to recompile that class. To my mind, that means that the "composite" could legitimately contain only one element. Consider this class:

```
class Money
{ long value; // value, scaled by 100
  Money increment( Money addend )
  { value += addend.value;
    return value;
  }
  //...
  public interface Modifier // visitor
  { long modify(long current);
  }
  operate( Modifier v )
  { value = v.modify(value);
  }
}
```

It's impractical to define every possible operation on money, but you can effectively add an operation by implementing a *Visitor* (`Modifier`). Compute the future value of money like this:

```
class Future_value impelements Money.Modifier
{ Future_value(float interest,int period)
  {/*...*/}
  public long modify( long current_value )
  { // return future value of current_value
  }
}
Money present_value = new Money(100000.00);
money.operate( new Future_value(.05,24) );
```