CSE 331
Software Design & Implementation

Hal Perkins
Winter 2015
Design Patterns, Part 2
(Based on slides by Mike Ernst, Dan Grossman, David Notkin, Hal Perkins)
Administtrivia

- HW9 due Wednesday night
  - Usual late days apply if any left
- We want to show off projects on Friday – please let us know if we can use yours!
- No more quizzes (everyone has enough to do already)
- Final exam next Monday, **8:30 am** (sigh), here
  - Review Q&A Sunday, 2 pm, EEB 037
- Course evals: please fill them out sometime this week
Outline

✓ Introduction to design patterns
✓ Creational patterns (constructing objects)
⇒ Structural patterns (controlling heap layout)
• Behavioral patterns (affecting object semantics)
Structural patterns: Wrappers

A wrapper translates between incompatible interfaces
Wrappers are a thin veneer over an encapsulated class
  – Modify the interface
  – Extend behavior
  – Restrict access
The encapsulated class does most of the work

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Functionality</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapter</td>
<td>same</td>
<td>different</td>
</tr>
<tr>
<td>Decorator</td>
<td>different</td>
<td>same</td>
</tr>
<tr>
<td>Proxy</td>
<td>same</td>
<td>same</td>
</tr>
</tbody>
</table>

Some wrappers have qualities of more than one of adapter, decorator, and proxy
Adapter

Change an interface without changing functionality
  – Rename a method
  – Convert units
  – Implement a method in terms of another

Example: angles passed in radians vs. degrees

Example: use “old” method names for legacy code
Adapter example: scaling rectangles

We have this `Rectangle` interface

```java
interface Rectangle {
    // grow or shrink this by the given factor
    void scale(float factor);
    ...
    float getWidth();
    float area();
}
```

Goal: client code wants to use this library to “implement” `Rectangle` without rewriting code that uses `Rectangle`:

```java
class NonScaleableRectangle { // not a Rectangle
    void setWidth(float width) { ... }
    void setHeight(float height) { ... }
    // no scale method
    ...
}
```
Adapter: Use subclassing

class ScaleableRectangle1
    extends NonScaleableRectangle
    implements Rectangle {
    void scale(float factor) {
        setWidth(factor * getWidth());
        setHeight(factor * getHeight());
    }
}
Adapter: use delegation

Delegation: forward requests to another object

class ScaleableRectangle2 implements Rectangle {
    NonScaleableRectangle r;
    ScaleableRectangle2(float w, float h) {
        this.r = new NonScaleableRectangle(w, h);
    }
    void scale(float factor) {
        r.setWidth(factor * r.getWidth());
        r.setHeight(factor * r.getHeight());
    }
    float getWidth() { return r.getWidth(); }
    float circumference() {
        return r.circumference();
    }
    ...
}

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Subclassing vs. delegation

Subclassing
- automatically gives access to all methods of superclass
  - built in to the language (syntax, efficiency)

Delegation
- permits removal of methods (compile-time checking)
  - objects of arbitrary concrete classes can be wrapped
  - multiple wrappers can be composed

Delegation vs. composition
- Differences are subtle
  - For CSE 331, consider them equivalent (?)
Types of adapter

Goal of adapter: connect incompatible interfaces

Adapter with delegation

Adapter with subclassing:
no extension is permitted
Decorator

• Add functionality without changing the interface

• Add to existing methods to do something additional
  – (while still preserving the previous specification)

• Not all subclassing is decoration
Decorator example: Bordered windows

interface Window {
    // rectangle bounding the window
    Rectangle bounds();
    // draw this on the specified screen
    void draw(Screen s);
    ...
}

class WindowImpl implements Window {
    ...
}
Bordered window implementations

Via subclassing:

```java
class BorderedWindow1 extends WindowImpl {  
    void draw(Screen s) {  
        super.draw(s);  
        bounds().draw(s);  
    }  
}  
```

Via delegation:

```java
class BorderedWindow2 implements Window {  
    Window innerWindow;  
    BorderedWindow2(Window innerWindow) {  
        this.innerWindow = innerWindow;  
    }  
    void draw(Screen s) {  
        innerWindow.draw(s);  
        innerWindow.bounds().draw(s);  
    }  
}  
```

Delegation permits multiple borders on a window, or a window that is both bordered and shaded.
A decorator can remove functionality

Remove functionality without changing the interface

Example: UnmodifiableList
– What does it do about methods like add and put?

Problem: UnmodifiableList is a Java subtype, but not a true subtype, of List

Decoration via delegation can create a class with no Java subtyping relationship, which is often desirable
Proxy

- Same interface and functionality as the wrapped class
  - So, uh, why wrap it?...

- Control access to other objects
  - Communication: manage network details when using a remote object
  - Locking: serialize access by multiple clients
  - Security: permit access only if proper credentials
  - Creation: object might not yet exist (creation is expensive)
    - Hide latency when creating object
    - Avoid work if object is never used
Composite pattern

- Composite permits a client to manipulate either an atomic unit or a collection of units in the same way
  - So no need to “always know” if an object is a collection of smaller objects or not

- Good for dealing with “part-whole” relationships

- An extended example…
Composite example: Bicycle

- Bicycle
  - Wheel
    - Skewer
      - Lever
    - Body
    - Cam
    - Rod
  - Hub
  - Spokes
  - Nipples
  - Rim
  - Tape
  - Tube
  - Tire
  - Frame
  - Drivetrain
  - ...

abstract class BicycleComponent {
    int weight();
    float cost();
}

class Skewer extends BicycleComponent {
    float price;
    float cost() { return price; }
}

class Wheel extends BicycleComponent {
    float assemblyCost;
    Skewer skewer;
    Hub hub;
    ...
    float cost() {
        return assemblyCost + skewer.cost() + hub.cost() + ...;
    }
}
Composite example: Libraries

Library
  Section (for a given genre)
  Shelf
  Volume
  Page
  Column
  Word
  Letter

interface Text {
    String getText();
}
class Page implements Text {
    String getText() {
      ... return concatenation of column texts ...
    }
}

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Outline

- Introduction to design patterns
- Creational patterns (constructing objects)
- Structural patterns (controlling heap layout)
  - Behavioral patterns (affecting object semantics)
    - Already seen: Observer
    - Will just do 2-3 related ones
**Strategy**

- **Situation:** We have an abstraction that needs to exhibit different behaviors or use different variants of an algorithm
  - We don’t want to, or can’t, predetermine all of the possible behaviors (might want to expand later, can’t anticipate all possible future uses, …)
- **Solution:**
  - Create a Strategy (algorithm, behavior) interface
  - Provide multiple implementations of the Strategy to work with the core abstraction
Strategy example

• We’ve been using this already!
• Graph ADT for the project:
  – Want different kinds of searches (BFS, Dijkstra’s, maybe others later)
  – Don’t want to have to modify core Graph when we add or change search strategies
  – Doesn’t make sense to have some strategies included in the basic Graph and others external
• Solution: define search strategies external to the Graph and compose the search(es) and Graph to solve specific problems (Marvel, campus paths, …)
Traversing composites

• Goal: perform operations on all parts of a composite

• Idea: generalize the notion of an iterator – process the components of a composite in an order appropriate for the application

• Example: arithmetic expressions in Java
  – How do we represent, say, \( x = \text{foo} \times b + c/d; \)
  – How do we traverse/process these expressions?
New example: Representing Java code

\[ x = \text{foo} \times b + c \div d; \]
Abstract syntax tree (AST) for Java code

class PlusOp extends Expression { // + operation
    Expression leftExp;
    Expression rightExp;
}
class VarRef extends Expression { // variable use
    String varname;
}
class EqualOp extends Expression { // test a==b;
    Expression leftExp; // left-hand side: a in a==b
    Expression rightExp; // right-hand side: b in a==b
}
class CondExpr extends Expression { // a?b:c
    Expression testExp;
    Expression thenExp;
    Expression elseExp;
}
Object model vs. type hierarchy

- AST for $a + b$:

- Class hierarchy for **Expression**:
# Operations on abstract syntax trees

Need to write code for each entry in this table

<table>
<thead>
<tr>
<th>Types of Objects</th>
<th>CondExpr</th>
<th>EqualOp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CondExpr</strong></td>
<td>typecheck</td>
<td></td>
</tr>
<tr>
<td><strong>print</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Question: Should we group together the code for a particular operation or the code for a particular expression?
  - That is, do we group the code into rows or columns?
- Given an operation and an expression, how do we “find” the proper piece of code?
Interpreter and procedural patterns

**Interpreter:** collects code for similar objects, spreads apart code for similar operations
- Makes it easy to add types of objects, hard to add operations
- An instance of the Composite pattern

**Procedural:** collects code for similar operations, spreads apart code for similar objects
- Makes it easy to add operations, hard to add types of objects
- The Visitor pattern is a variety of the procedural pattern

(See also many offerings of CSE341 for an extended take on this question
- Statically typed functional languages help with procedural whereas statically typed object-oriented languages help with interpreter)
Interpreter pattern

Add a method to each class for each supported operation

```java
abstract class Expression {
    ...
    Type typecheck();
    String prettyPrint();
}
class EqualOp extends Expression {
    ...
    Type typecheck() { ... }
    String prettyPrint() { ... }
}
class CondExpr extends Expression {
    ...
    Type typecheck() { ... }
    String prettyPrint() { ... }
}
```

Dynamic dispatch chooses the right implementation, for a call like `e.typeCheck()`

Overall type-checker spread across classes
Procedural pattern

Create a class per operation, with a method per operand type

class Typecheck {
    Type typeCheckCondExpr(CondExpr e) {
        Type condType = typeCheckExpr(e.condition);
        Type thenType = typeCheckExpr(e.thenExpr);
        Type elseType = typeCheckExpr(e.elseExpr);
        if (condType.equals(BoolType) &&
            thenType.equals(elseType))
            return thenType;
        else
            return ErrorType;
    }
    Type tcEqualOp(EqualOp e) {
        ...
    }
}
Definition of `typeCheckExpr` (using procedural pattern)

```java
class Typecheck {
    ... 
    Type typeCheckExpr(Expression e) {
        if (e instanceof PlusOp) {
            return typeCheckPlusOp((PlusOp)e);
        } else if (e instanceof VarRef) {
            return typeCheckVarRef((VarRef)e);
        } else if (e instanceof EqualOp) {
            return typeCheckEqualOp((EqualOp)e);
        } else if (e instanceof CondExpr) {
            return typeCheckCondExpr((CondExpr)e);
        } else {
            ... 
        }
    }
}
```

Maintaining this code is tedious and error-prone
- No help from type-checker to get all the cases
  (unlike in functional languages)

Cascaded if tests are likely to run slowly (in Java)

Need similar code for each operation
Visitor pattern:
A variant of the procedural pattern

- Nodes (objects in the hierarchy) accept visitors for traversal
- Visitors visit nodes (objects)

```java
class SomeExpression extends Expression {
    void accept(Visitor v) {
        for each child of this node {
            child.accept(v);
        }
        v.visit(this);
    }
}

class SomeVisitor extends Visitor {
    void visit(SomeExpression n) {
        perform work on n
    }
}
```
Example: accepting visitors

```java
class VarOp extends Expression {
    ...
    void accept(Visitor v) {
        v.visit(this);
    }
}
class EqualsOp extends Expression {
    ...
    void accept(Visitor v) {
        leftExp.accept(v);
        rightExp.accept(v);
        v.visit(this);
    }
}
class CondOp extends Expression {
    ...
    void accept(Visitor v) {
        testExp.accept(v);
        thenExp.accept(v);
        elseExp.accept(v);
        v.visit(this);
    }
}
```

First visit all children

Then pass “self” back to visitor

The visitor has a `visit` method for each kind of expression, thus picking the right code for this kind of expression

- Overloading makes this look more magical than it is...

Lets clients provide unexpected visitors
Sequence of calls to accept and visit

a.accept(v)
b.accept(v)
d.accept(v)
v.visit(d)
e.accept(v)
v.visit(e)
v.visit(b)
c.accept(v)
f.accept(v)
v.visit(f)
v.visit(c)
v.visit(a)

Sequence of calls to visit: d, e, b, f, c, a
Example: Implementing visitors

class TypeCheckVisitor
    implements Visitor {
    void visit(VarOp e) { … }
    void visit(EqualsOp e) { … }
    void visit(CondOp e) { … }
}

class PrintVisitor implements Visitor {
    void visit(VarOp e) { … }
    void visit(EqualsOp e) { … }
    void visit(CondOp e) { … }
}