Design patterns (part 2)

CSE 331

Spring 2010

Outline

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

Structural patterns: Wrappers

The 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

Pattern	Functionality	Interface
Adapter	same	different
Decorator	different	same
Proxy	same	same

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

Adapter example: scaling rectangles

```
interface Rectangle {
  // grow or shrink this by the given factor
  void scale(float factor);
  ...
  float getWidth();
  float area();
}
class myClass {
  void myMethod(Rectangle r) {
    ...   r.scale(2);   ...
  }
}
```

Goal: be able to use this class instead:

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

Adapting scaled rectangles via subclassing

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

Adapting scaled rectangles via delegation

Delegation: forward requests to another object

```
class ScaleableRectangle2 implements Rectangle {
  NonScaleableRectangle r;
  ScaleableRectangle2(NonScaleableRectangle r) {
    this.r = r;
  }

  void scale(float factor) {
    setWidth(factor * r.getWidth());
    setHeight(factor * r.getHeight());
  }

  float getWidth() { return r.getWidth(); }
  float circumference() { return r.circumference(); }
  ...
}
```

Subclassing vs. delegation

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

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

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

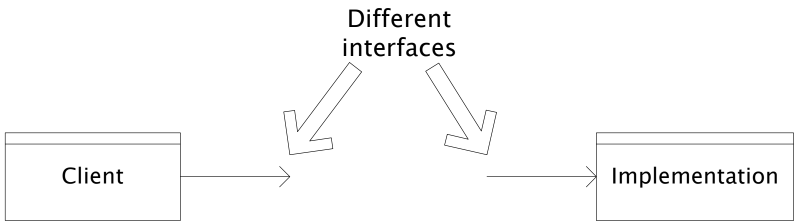
Delegation vs. composition

Differences are subtle

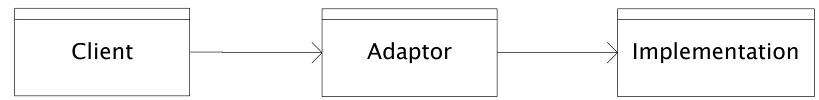
For CSE 331, consider them to be equivalent

Types of adapter

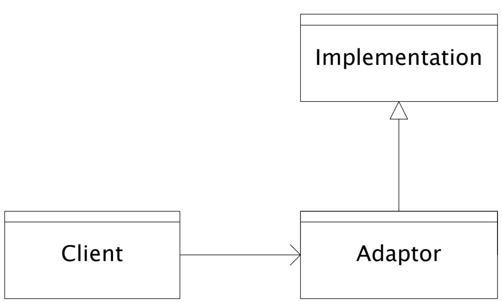
Goal of adapter:
connect incompatible interfaces



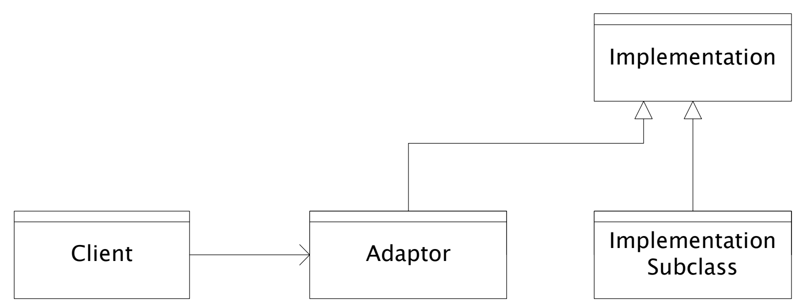
Adapter with delegation



Adapter with subclassing



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 subclasssing:

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

Via delegation:

```
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 (or either one of those)

Proxy

Same interface and functionality as the wrapped class

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
- Good for dealing with part-whole relationships

Composite example: Bicycle

- Bicycle
  - Wheel
    - Skewer
    - Hub
    - Spokes
    - Nipples
    - Rim
    - Tape
    - Tube
    - Tire
  - Frame
  - Drivetrain
  - ...

Methods on components

```
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 the concatenation of the column texts ...
  }
}
```

Traversing composites

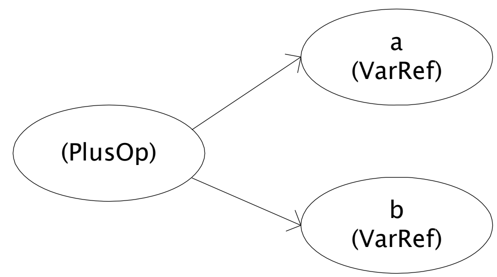
Goal: perform operations on all parts of a composite

Abstract syntax tree (AST) for Java code

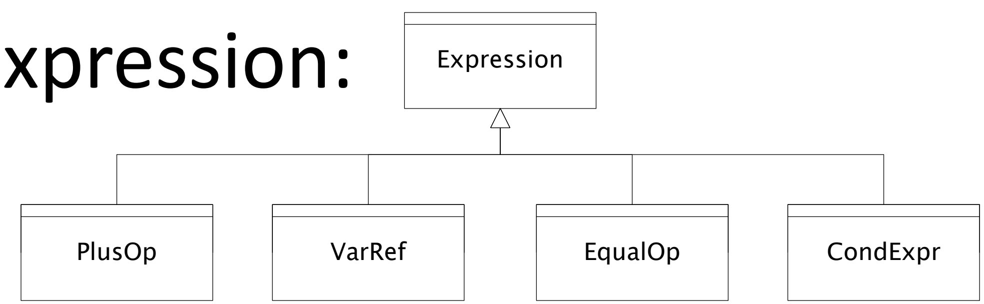
```
class PlusOp extends Expression {   // + operation
  Expression leftExp;
  Expression rightExp;
}
class VarRef extends Expression {   // variable reference
  String varname;
}
class EqualOp extends Expression {  // equality test a==b;
  Expression lvalue;    // left-hand side; "a" in "a==b"
  Expression rvalue;    // right-hand side; "b" in "a==b"
}
class CondExpr extends Expression {  // a?b:c
  Expression condition;
  Expression thenExpr;  // value of expression if a is true
  Expression elseExpr;  // value of expression if a is false
}
```

Object model vs. module dependence diagram

- AST for "a + b":



- Class hierarchy for Expression:



Perform operations on abstract syntax trees

Need to write code in each of the cells of this table:

		Objects	
		CondExpr	**EqualOp**
Operations	**typecheck**		
	pretty-print		

Question: Should we group together the code for a particular operation or the code for a particular expression?

(A separate issue: given an operation and an expression, how to select 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 objects, hard to add operations

Procedural: collects code for similar operations, spreads apart code for similar objects

- Makes it easy to add operations, hard to add objects
- The visitor pattern is a variety of the procedural pattern

Both interpreter and procedural have classes for objects

- The code for operations is similar
- The question is where to place that code

Selecting between interpreter and procedural:

- Are the algorithms central, or are the objects?
  (Is the system operation-centric or object-centric?)
- What aspects of the system are most likely to change?

Interpreter pattern

Add a method to each class for each supported operation

```
class Expression {
  ...
  Type typecheck();
  String prettyPrint();
}

class EqualOp extends Expression {
  ...
  Type typecheck() { ... }
  String prettyPrint() { ... }
}

class CondExpr extends Expression {
  ...
  Type typecheck() { ... }
  String prettyPrint() { ... }
}
```

Procedural pattern

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

```
class Typecheck {
  // typecheck "a?b:c"
  Type tcCondExpr(CondExpr e) {
    Type condType = tcExpression(e.condition); // type of "a"
    Type thenType = tcExpression(e.thenExpr);  // type of "b"
    Type elseType = tcExpression(e.elseExpr);  // type of "c"
    if ((condType == BoolType) && (thenType == elseType)) {
      return thenType;
    } else {
      return ErrorType; }
  }

  // typecheck "a==b"
  Type tcEqualOp(EqualOp e) {
    ...
  }
}
```

Definition of tcExpression (in procedural pattern)

```
class Typecheck {
  ...
  Type tcExpression(Expression e) {
    if (e instanceof PlusOp) {
      return tcPlusOp((PlusOp)e);
    } else if (e instanceof VarRef) {
      return tcVarRef((VarRef)e);
    } else if (e instanceof EqualOp) {
      return tcEqualOp((EqualOp)e);
    } else if (e instanceof CondExpr) {
      return tcCondExpr((CondExpr)e);
    } else ...
    ...
  }

}
```

Maintaining this code is tedious and error-prone.

The cascaded if tests are likely to run slowly.

This code must be repeated in PrettyPrint and every other operation class.

Visitor pattern: a variant of the procedural pattern

Visitor encodes a traversal of a hierarchical data structure

Nodes (objects in the hierarchy) accept visitors

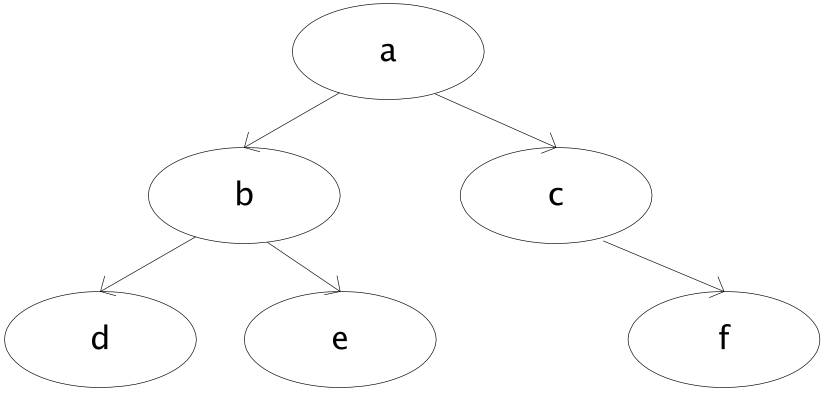
Visitors visit nodes (objects)

```
class Node {
  void accept(Visitor v) {
    for each child of this node {
      child.accept(v);
    }
    v.visit(this);
  }
}
class Visitor {
  void visit(Node n) {
    perform work on n
  }
}
```

`n.accept(v)` performs a depth-first traversal of the structure rooted at **`n`**, performing **`v`**'s operation on each element of the structure

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

Implementing visitor

- You must add definitions of **`visit`** and **`accept`**
- **`visit`** might count nodes, perform typechecking, etc.
- It is easy to add operations (visitors), hard to add nodes (modify each existing visitor)
- Visitors are similar to iterators: each element of the data structure is presented in turn to the **`visit`** method
  - Visitors have knowledge of the structure, not just the sequence

Calls to `visit` cannot communicate with one another

- Can use an auxiliary data structure
- Another solution: move more work into the visitor itself

```
class Node {
  void accept(Visitor v) {
    v.visit(this);
  }
}
class Visitor {
  void visit(Node n) {
    for each child of this node {
      child.accept(v);
     }
    perform work on n
  }
}
```

- Information flow is clearer (if visitor depends on children)
- Traversal code repeated in all visitors (acceptor is extraneous)