CSE 331
Software Design & Implementation

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Design Patterns, Part 2
(Based on slides by Mike Ernst, David Notkin, Hal Perkins)

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

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

Example: use "old" method names for legacy code

Adapter example: scaling rectangles

We have this **Rectangle** interface
```
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**:
```
class NonScaleableRectangle { // not a Rectangle
  void setWidth(float width) { ... }
  void setHeight(float height) { ... }
   // no scale method
  ...
}
```


Adaptor: Use subclassing

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

Adaptor: 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) {
    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 in to the language (syntax, efficiency)

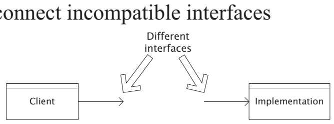
Delegation
- permits removal of methods (compile-time checking)
- objects of arbitrary concrete classes can be wrapped
- multiple wrappers can be composed

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

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

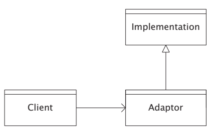
Types of adapter

Goal of adapter:
connect incompatible interfaces

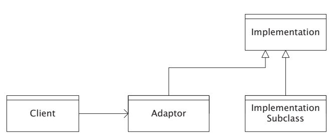


Adapter with delegation

Adapter with subclassing



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);
  }
}
```

Delegation permits multiple borders on a window, or a window that is both bordered and shaded

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);
  }
}
```

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
  - ...

Methods on components

```
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 ...
  }
}
```

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=foo*b+c/d;`
  - How do we traverse/process these expressions?

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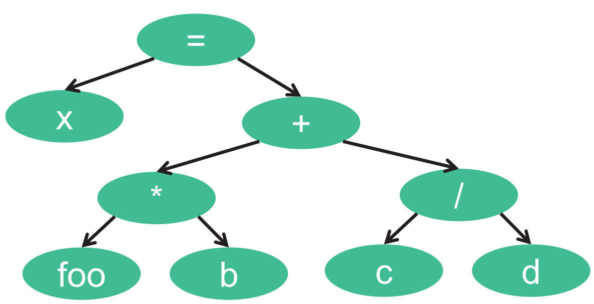
- Already seen: Observer
- Will just do 2-3 related ones

Representing Java code

```
x = foo * b + c / d;
```

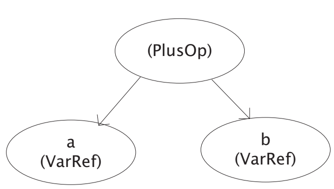


Abstract syntax tree (AST) for Java code

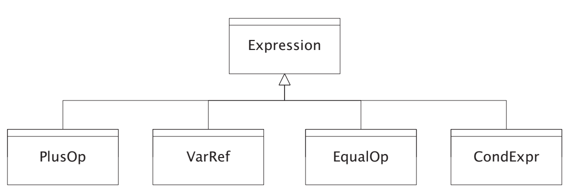
```
class PlusOp extends Expression { // + operation
  Expression leftExp;
  Expression rightExp;
}
class VarRef extends Expression { // variable use
  String varname;
}
class EqualOp extends Expression {  // test a==b;
  Expression leftExp; // left-hand side: a in a==b
  Expression rightExp; // right-hand 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

		Types of Objects	
		CondExpr	**EqualOp**
Operations	**typecheck**		
	print		

- Question: Should we group together the code for a particular operation or the code for a particular expression?
  - That is, do we group the operations in rows or columns?
- Given an operation and an expression, how do we "find" the proper piece of code?)

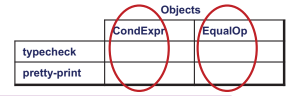
Interpreter and procedural patterns

Interpreter: collects code for similar objects, spreads apart code for similar operations
- Makes it easy to add 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 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

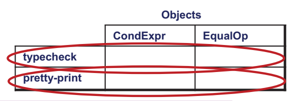


Add a method to each class for each supported operation

```
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**()
- But 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) {
    ...
  }
}
```

How to invoke the right method for an expression **e**?

Definition of typeCheckExpr (using procedural pattern)

```
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) {
      retu
    } else
    ...
  }

}
```

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

The cascaded if tests are likely to run slowly (in Java)

Need similar code for each operation

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 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
  }
}
```

n.accept(v) traverses the structure rooted at **n**, performing **v**'s operation on each element of the structure

Example: accepting visitors

```
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);
  }
}
```

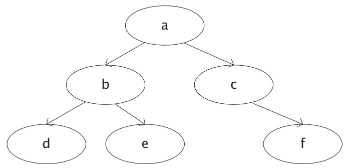
First visit all children

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 implement
  Visitor {
  void visit(VarOp e) { … }
  void visit(EqualsOp e) { …
  void visit(CondOp e) { … }
}
```

Now each operation has its cases back together

And type-checker should tell us if we fail to implement an abstract method in Visitor

Again: overloading just a nicety

Again: An OOP workaround for procedural pattern

- Because language/type-checker is not instance-of-test friendly