Structural Design Patterns

Amazon web services

- Applied for grant
- No guarantees yet
- Might provide some cash for each student.

Picture diagram question

We mean an architectural diagram, like the ones from the architecture lecture (January 19)

System Design and Planning Presentations

- Presentations due by class on Friday, Feb 4
- Turnin online (class web page) and also bring to class on memory stick
- Present – 10 min followed by Q&A:
  - What is it that you're building (remind us!)
  - What's your approach to building it and what challenges might you meet
  - How you will achieve your goals with the time and resources allocated

Convince us that you're on track for a successful delivery!

Structural patterns: Wrappers

- Problem: incompatible interfaces
- Solution: a thin veneer over an encapsulated class
  - modify the interface
  - extend behavior
  - restrict access
- The encapsulated class does most of the work

Types of wrappers

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 quadrupler {
  void quadruple(Rectangle r) {
    ...   r.scale(4);   ...
  }
}
```

Adapting scaled rectangles via subclassing

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

Could we use this class instead?

```
class NonScaleableRectangle {
  void setWidth(float width) { ... }
  void setHeight(float height) { ... }
  ...
}
```

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 * getWidth());
    setHeight(factor * getHeight());
  }

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

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 windows: two ways

- Via subclassing:
  - `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 and 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

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

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
    - 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

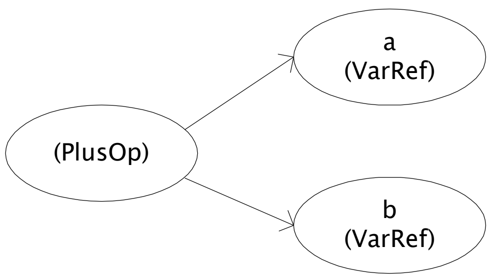
Goal: perform operations on all parts of a composite

Abstract syntax tree (AST) for Java code

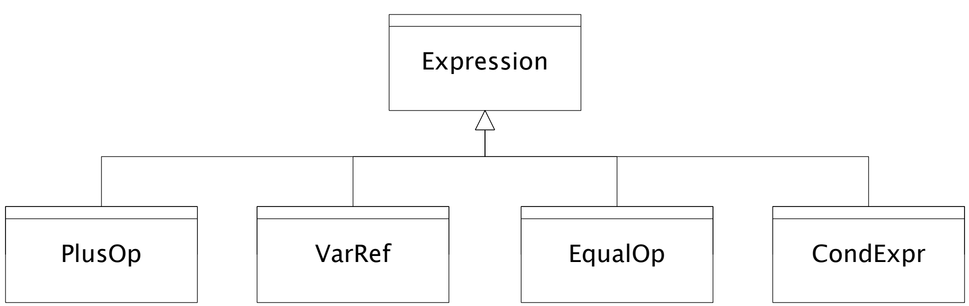
```
class PlusOp extends Expression {    // + operation
  Expression leftExp;
  Expression rightExp;
}

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. class hierarchy diagram

- AST for "a + b":



- Class hierarchy for Expression:



Perform operations on ASTs

- 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?

Interpreter and procedural patterns

- Interpreter: collects code for similar objects and spreads apart code for similar operations
  - easy to add objects, hard to add operations
- Procedural: collects code for similar operations and spreads apart code for similar objects
  - easy to add operations, hard to add objects
  - example: visitor pattern
- 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? 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.

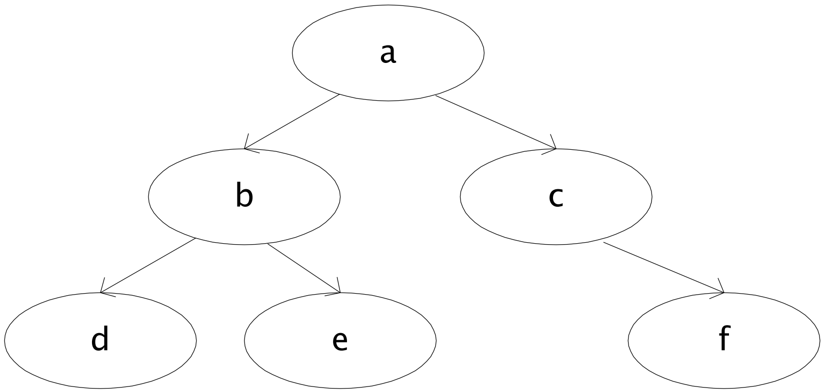
Visitor pattern: a variant of the procedural pattern

- 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

- One solution: 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