Outline

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

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

• 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, $x=\text{foo}*b+c/d$;
  – How do we traverse/process these expressions?
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 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. type hierarchy

• AST for "a + b":

  - (PlusOp)
  - a (VarRef)
  - b (VarRef)

• Class hierarchy for Expression:

  - Expression
  - PlusOp
  - VarRef
  - EqualOp
  - CondExpr
Operations on abstract syntax trees

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

<table>
<thead>
<tr>
<th>Operations</th>
<th>CondExpr</th>
<th>EqualOp</th>
</tr>
</thead>
<tbody>
<tr>
<td>typecheck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pretty-print</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? i.e., do we package the operations in rows or columns? (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

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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 typeCheckCondExpr(CondExpr e) {
        Type condType = typeCheckExpr(e.condition); // type of "a"
        Type thenType = typeCheckExpr(e.thenExpr); // type of "b"
        Type elseType = typeCheckExpr(e.elseExpr); // type of "c"
        if ((condType == BoolType) && (thenType == elseType)) {
            return thenType;
        } else {
            return ErrorType; }
    }

    // typecheck "a==b"
    Type tcEqualOp(EqualOp 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) {
      return typeCheckCondExpr((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)

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

What happened to all the `instanceof` operations?
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(s) shared by visitor methods
Another solution: move more work into the visitor itself

```java
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)