# Design patterns (part 3)

CSE 331
University of Washington

Michael Ernst

# Outline

✓ Introduction to design patterns

✓ Creational patterns (constructing objects)

✓ Structural patterns (controlling heap layout)

⇒ Behavioral patterns (affecting object semantics)

# 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

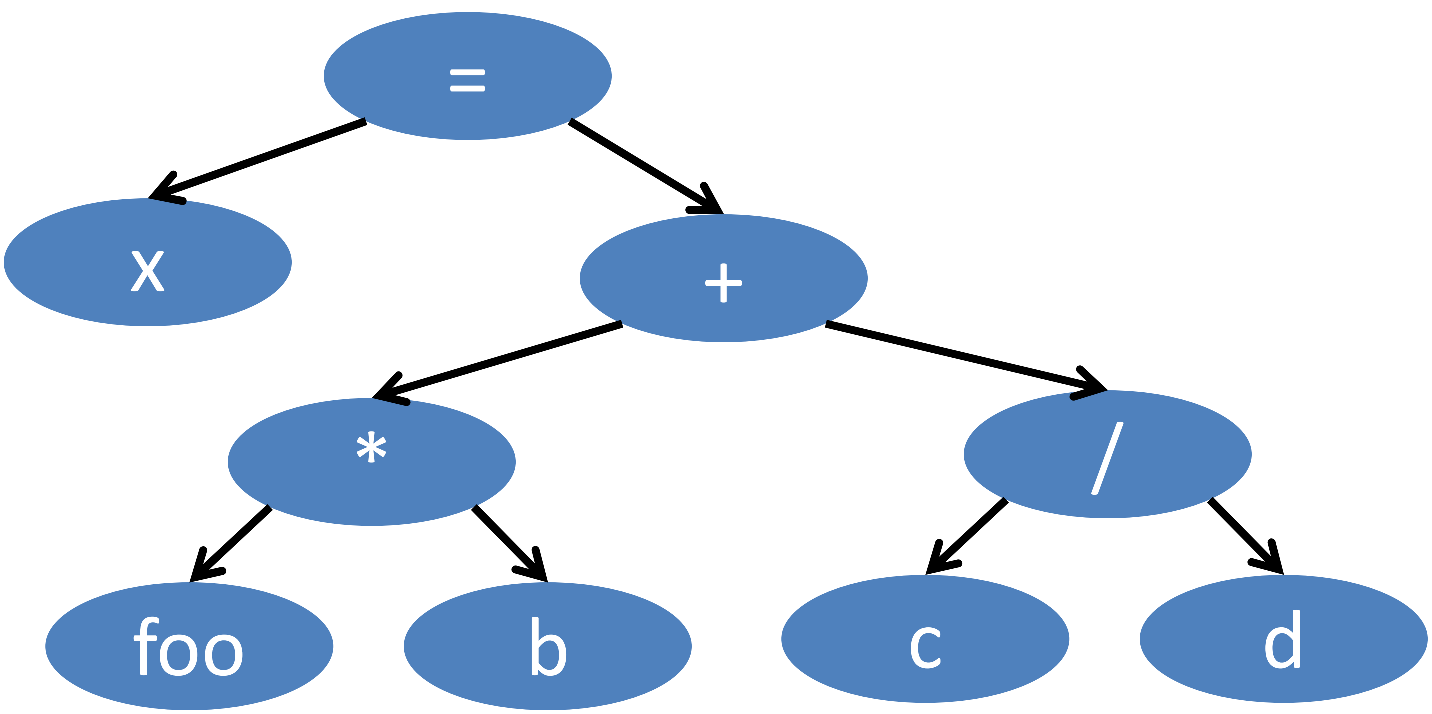
```
interface Text {
  String getText();
}
class Page implements Text {
  String getText() {
    ... return the concatenation of the column texts ...
  }
}
```

# Traversing composites

Goal: perform operations on all parts of a composite

# Representing Java code

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

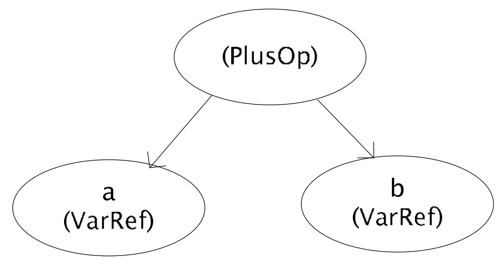


# Abstract syntax tree (AST) for Java code

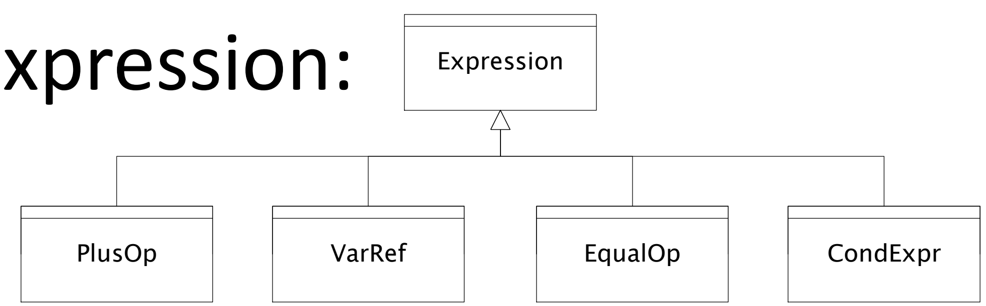
```
class PlusOp extends Expression {    // + operation
  Expression leftExp;
  Expression rightExp;
}
class VarRef extends Expression {    // variable reference
  String varname;
}
class EqualOp extends Expression {  // equality test a==b;
  Expression lvalue;    // left-hand side; "a" in "a==b"
  Expression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




- 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() { ... }
}
```

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

# 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) {
    ...
  }
}
```

How to invoke the right implementation?

# 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

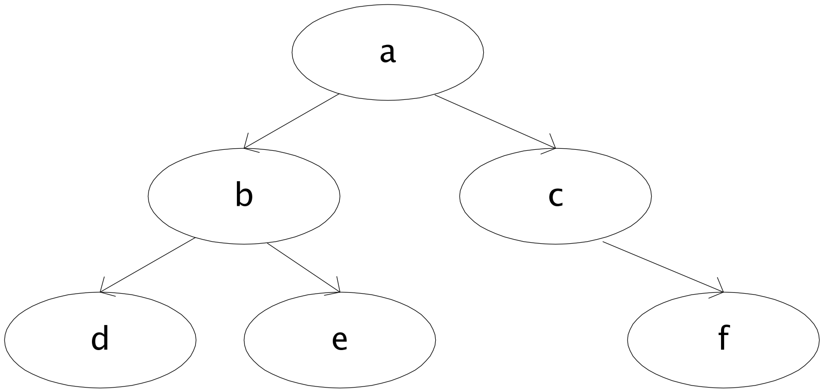
Visitors visit nodes (objects)

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

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

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)