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
      - Lever
      - Body
      - Cam
      - Rod
      - Acorn nut
    - 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

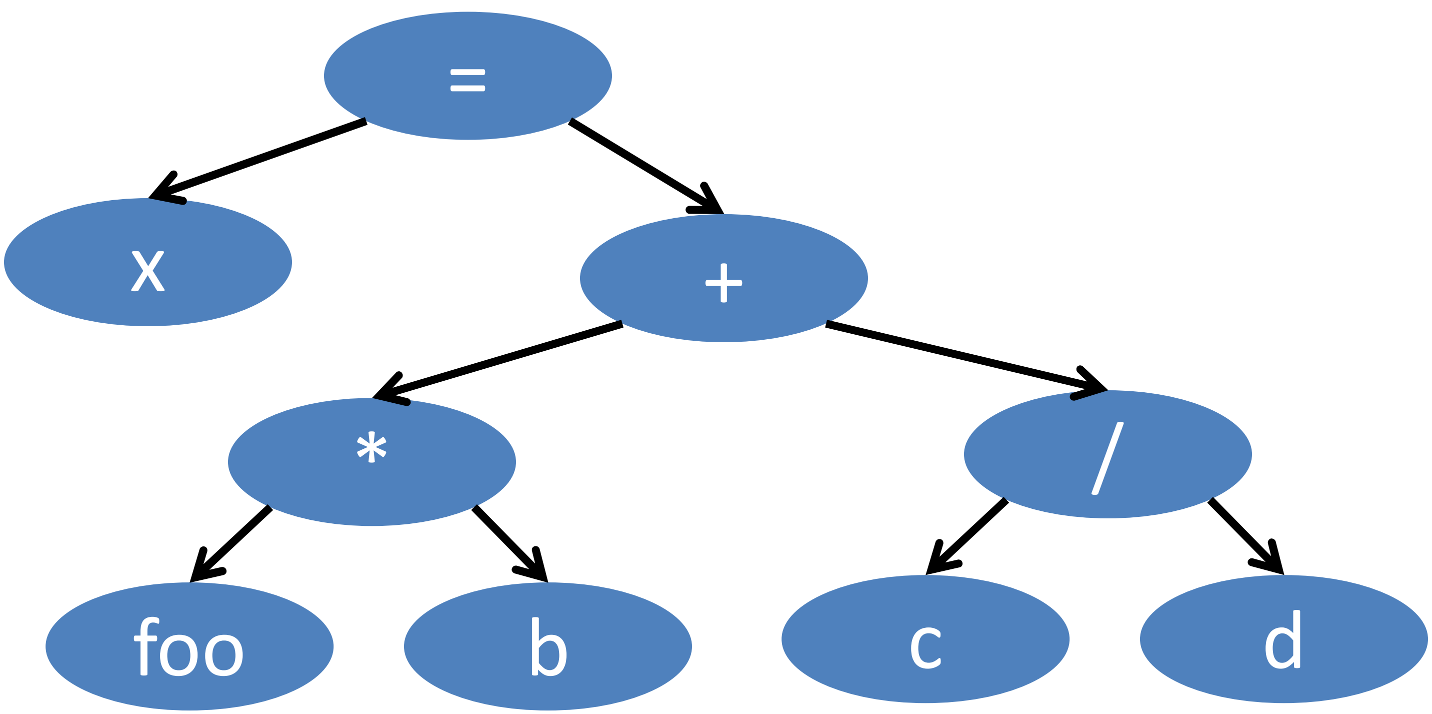
```
interface Text {
  String getText();
}
class Page implements Text {
  String getText() {
    ... return the concatenation of the column texts ...
  }
}
```

Traversing composites

Goal: perform operations on all parts of a composite

Representing Java code

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

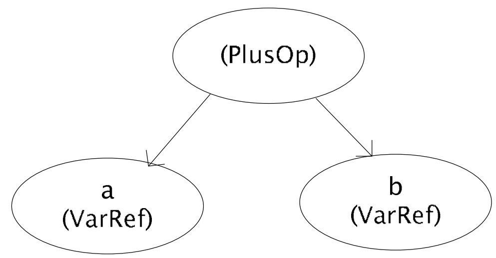


Abstract syntax tree (AST) for Java code

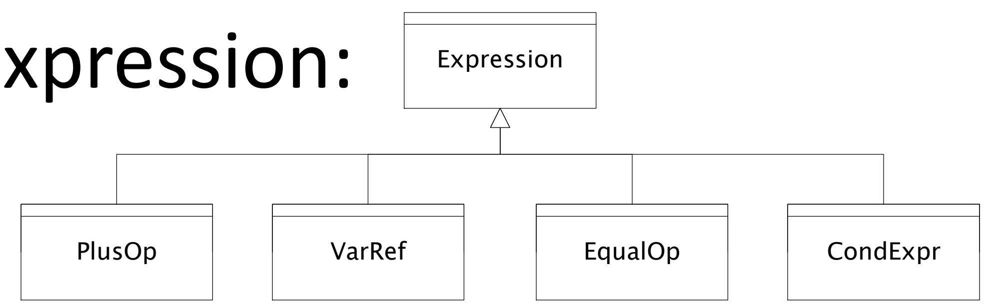
```
class PlusOp extends Expression {    // + operation
  Expression leftExp;
  Expression rightExp;
}
class VarRef extends Expression {    // variable reference
  String varname;
}
class EqualOp extends Expression {  // equality test a==b;
  Expression lvalue;     // left-hand side; "a" in "a==b"
 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

Objects

	CondExpr	EqualOp
typecheck		
pretty-print		

Objects

	CondExpr	EqualOp
typecheck		
pretty-print		

Interpreter pattern

	Objects	
	CondExpr	EqualOp
typecheck		
pretty-print		

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

	Objects	
	CondExpr	EqualOp
typecheck		
pretty-print		

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 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
  }
}
```

`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?

Visitor pattern: example

Objects

```
class EqualsOp extends Expression {
  void accept(Visitor v) {
    for each child of this node {
      child.accept(v);
    }
    v.visit(this);
  }
}


class PlusOp extends Expression {
 void accept(Visitor v) {
    for each child of this node {
      child.accept(v);
    }
    v.visit(this);
  }
}
```

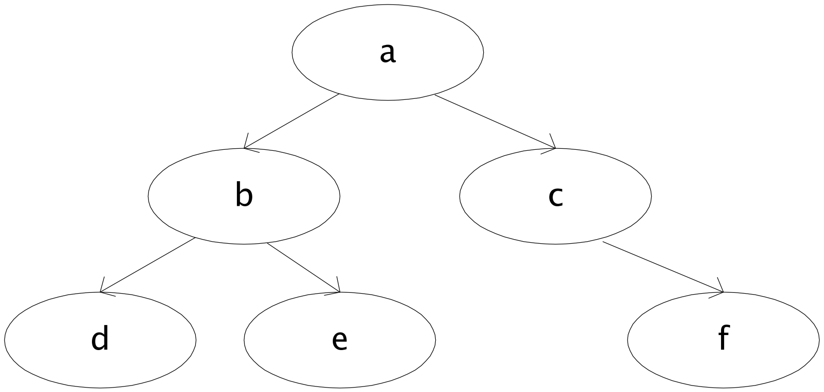
Operations

```
class TypeCheckVisitor implements
   Visitor {
  void visit(EqualsOp e) {
    perform work on n
  }
  void visit(PlusOp e) {
    perform work on n
  }
}


class PrettyPrintVisitor implements
   Visitor {
  void visit(EqualsOp e) {
    perform work on n
  }
  void visit(PlusOp e) {
    perform work on n
  }
}
```

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)