CSE 331
Software Design & Implementation

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Design Patterns, Part 2

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

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

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`** library 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 the following 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
  ...
}
```

Adapter: Use subclassing

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

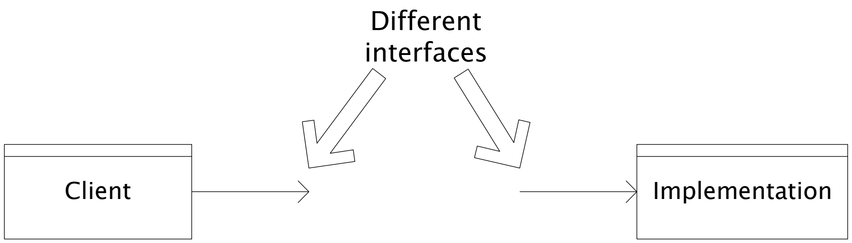
Adapter: use delegation

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) {
    r.setWidth(factor * r.getWidth());
    r.setHeight(factor * r.getHeight());
  }
  float getWidth() { return r.getWidth(); }
  float area() {
     return r.area();
  }
  ...
}
```

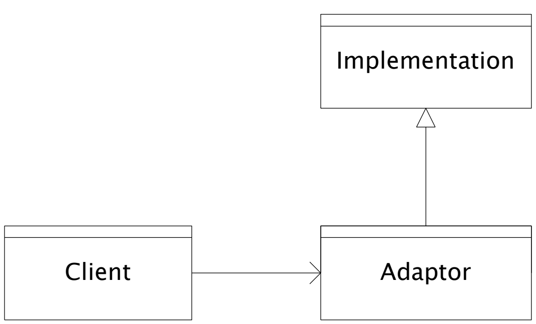
Types of adapter

Goal of adapter:
connect incompatible interfaces

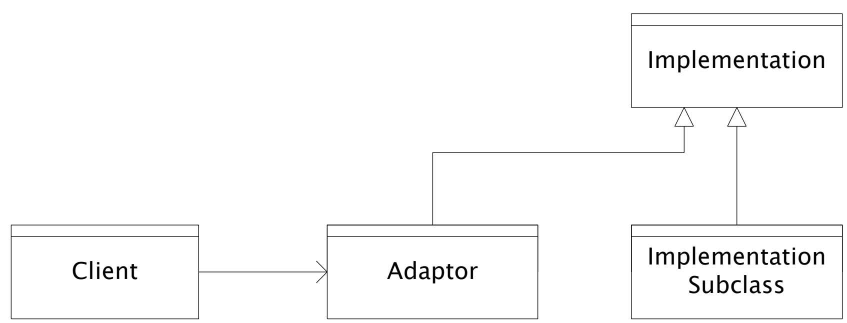


Adapter with delegation

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);
  }
}
```

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, or a window that is both bordered and shaded.

Wrappers can be added and removed dynamically

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`**

  Alternative: Decoration via delegation can create a class with no Java subtyping relationship, which is often desirable when removing functionality (if an interface exists)

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

Subclassing vs. delegation

Subclassing

- automatically gives access to all methods of superclass
- built in to the language (syntax, efficiency)
- If this does what you need, use it

Delegation

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

Delegation vs. *composition*

- Differences are subtle
- For CSE 331, consider them equivalent (?)

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
  - Frame
  - Drivetrain
  - Wheel
    - Skewer
      - Lever
      - Body
      - Cam
      - Rod
    - Hub
    - Spokes
    - Nipples
    - Rim
    - Tape
    - Tube
    - Tire
  - ...

Example 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 ...
  }
}
```

Outline

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✓ Structural patterns (controlling heap layout)

⇒ Behavioral patterns (affecting object semantics)

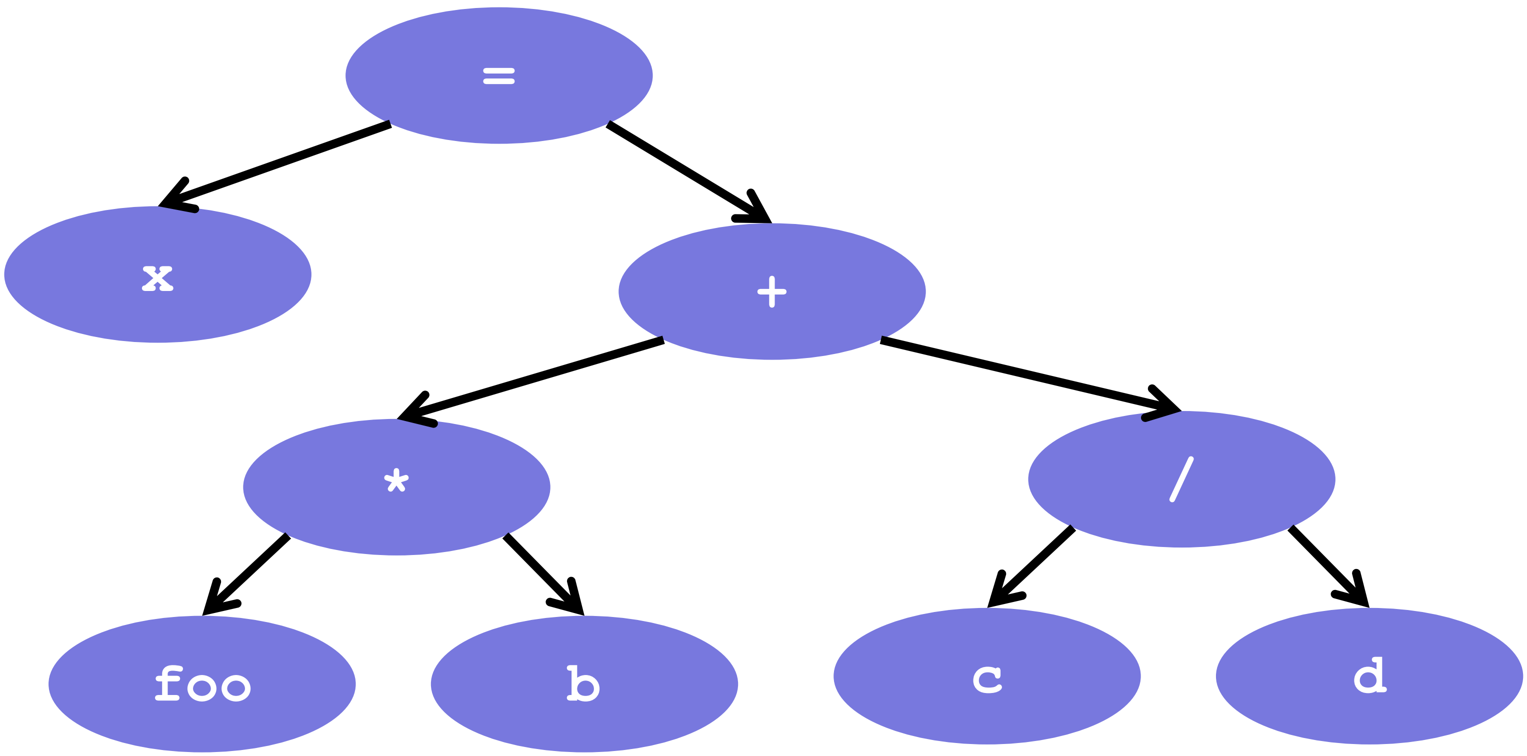
- Already seen: Observer, Iterator, Strategy (graph search algorithms for project!)
- Will look at 2-3 related additional ones

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?

Representing Java code

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

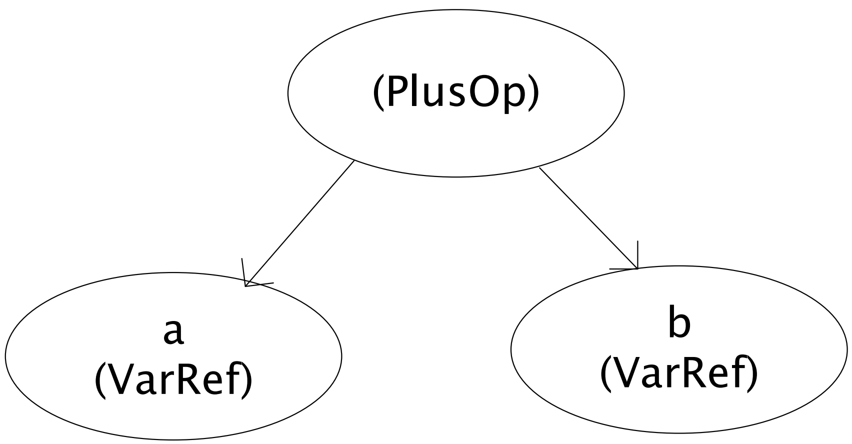


Abstract syntax tree (AST) for Java code

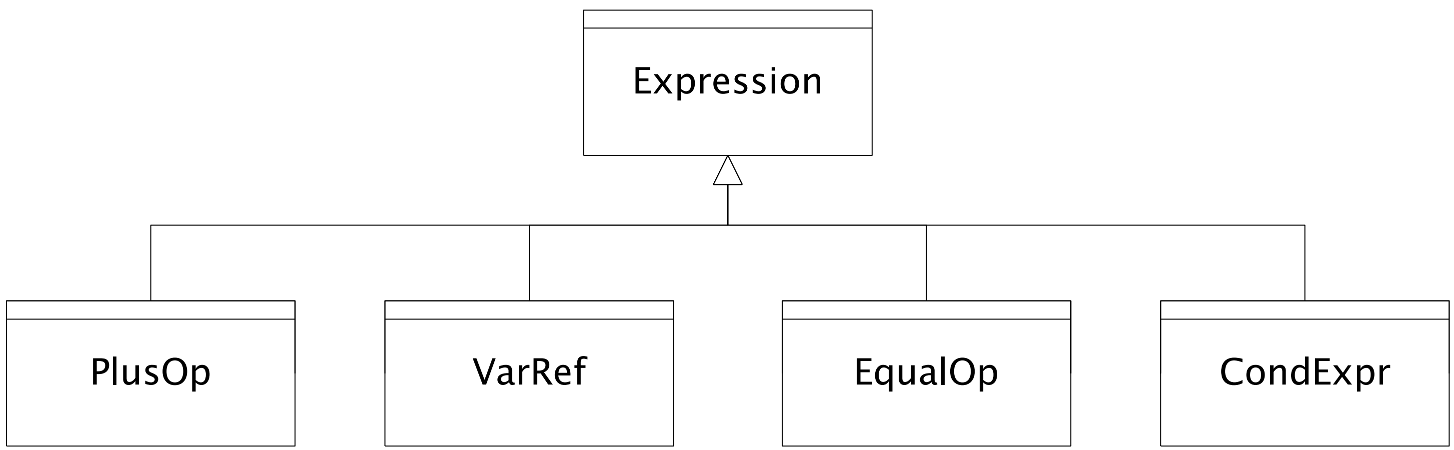
```
class PlusOp extends Expression { // + operation
  Expression leftExp;
  Expression rightExp;
}
class VarRef extends Expression { // variable use
  String varname;
}
class EqualOp extends Expression {  // test a==b;
  Expression leftExp; // left-hand side: a in a==b
  Expression rightExp; // right-hand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

Need to write code for each entry in this table

Types of Objects

Operations		**CondExpr**	**EqualOp**
	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 code into 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 types of 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 types of 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

	Objects	
	CondExpr	EqualOp
typecheck		
print		

Add a method to each class for each supported operation

```
abstract class Expression {
   ...
   Type typecheck();
   String print();
}
class EqualOp extends Expression {
   ...
   Type typecheck() { ... }
   String print() { ... }
}
class CondExpr extends Expression {
   ...
   Type typecheck() { ... }
   String print() { ... }
}
```

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

Overall, type-checker spread across classes

Procedural pattern

	CondExpr	EqualOp
typecheck		
print		

Objects

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 typeCheckEqualOp(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);
    } els
      ret
    } els
    ...
  }
}
```

Maintaining this code is tedious and error-prone

- No help from type-checker to get all the cases (unlike in functional languages)

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 heirarchical data structure
- Nodes (objects in the hierarchy) accept visitors for traversal
- 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

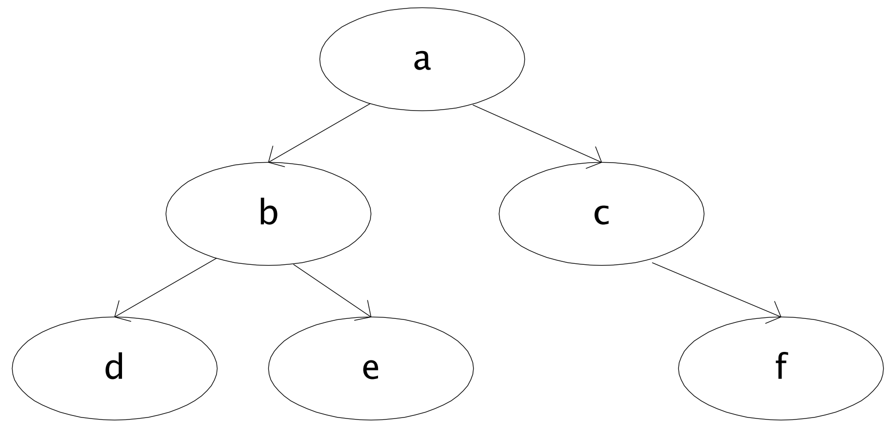
The visitor has a **`visit`** method for each kind of expression, thus picking the right code for this kind of expression

- 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

Design patterns retrospect

A standard solution to a common programming problem

- A design or implementation structure that achieves a particular purpose
- A high-level programming idiom

A technique for making code more flexible

- Reduce coupling among program components

Shorthand description of a software design

- Well-known terminology improves communication / documentation
- Makes it easier to “think to use” a known technique

The basic catalog

Creational Patterns are about the object-creation process

- Factory Method, Abstract Factory, Singleton, Builder, Prototype, …

Structural Patterns are about how objects/classes can be combined

- Adapter, Bridge, Composite, Decorator, Façade, Flyweight, Proxy, …

Behavioral Patterns are about communication among objects

- Command, Interpreter, Iterator, Mediator, Observer, State, Strategy, Chain of Responsibility, Visitor, Template Method, …

Green = ones we've seen/used earlier in the course