Design Patterns So Far

- Creational patterns: Factories, Prototype, Singleton, Interning
  - Problem: constructors in Java (and other OO languages) are inflexible
    - 1. Can’t return a subtype of the type they belong to. “Factory” patterns address the issue: Factory method (e.g. **`createBicycle()`**), Factory class/object, Prototype
    - 2. Always return a fresh new object, can’t reuse.
      - “Sharing” patterns address the issue: Singleton, Interning

Design Patterns

- FlyWeight
  - Many objects are similar
- Wrappers: Adapter, Decorator, Proxy
  - Structural patterns: when we want to change interface or functionality of an existing class, or restrict access to an object
- Composite
  - A structural pattern: expresses whole-part structures, gives uniform interface to client
- Patterns for traversal of composites: Interpreter, Procedural and Visitor

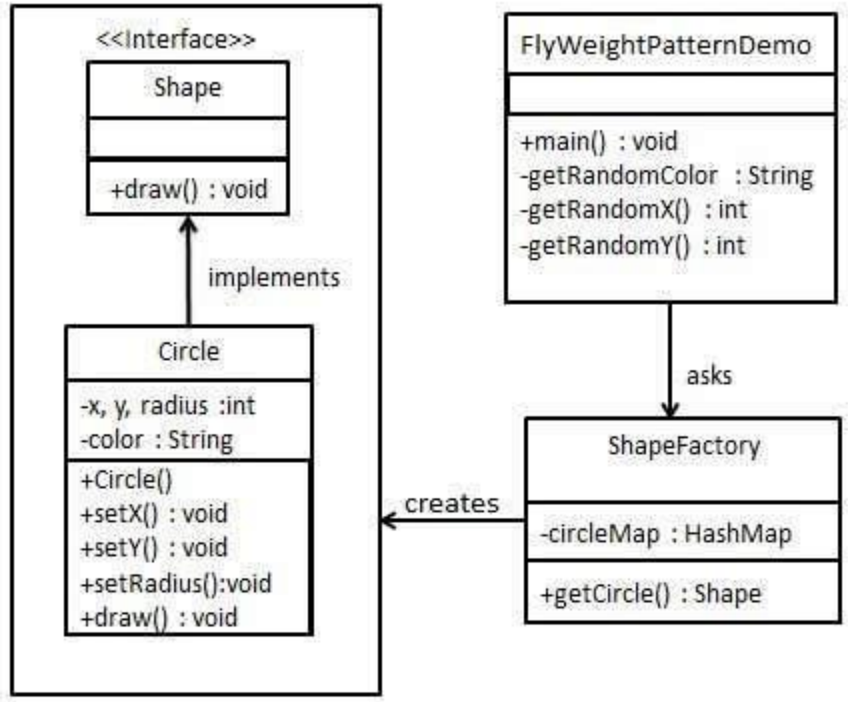
Flyweight Pattern

- Good when many objects are mostly the same
  - Interning works only if objects are completely the same and immutable
- If there is an intrinsic state that is the same across all objects
  - Intern it
- If there is an extrinsic state that is different for different objects
  - Extrinsic - not part of the essential nature of someone or something; coming or operating from outside.
  - Represent it explicitly
  - Or make it implicit
    - Don’t represent it
    - Requires immutability

Flyweight Pattern

- The flyweight pattern is primarily used to reduce the number of objects created
  - decrease memory footprint
  - increase performance
  - decrease object count
  - creates new object when no matching object is found.

Flyweight Example



We will demonstrate this pattern by drawing 20 circles of different locations but we will create only 5 objects. Only 5 colors are available so color property is used to check already existing *Circle* objects.

Similar to memorization.

https://www.tutorialspoint.com/design_pattern/flyweight_pattern.htm

```java
public interface Shape {
  void draw();
}

public class Circle implements Shape {
  private String color;
  private int x;
  private int y;
  private int radius;

  public Circle(String color){
    this.color = color;
  }

  @Override
  public void draw() {
    System.out.println("Circle: Draw() [Color : " + color +
        ", x : " + x + ", y :" + y + ", radius :" + radius);
  }
  …
}
```

```java
public class ShapeFactory {
  private static final HashMap<String, Shape> circleMap = new HashMap();

  public static Shape getCircle(String color) {
    Circle circle = (Circle)circleMap.get(color);

    if(circle == null) {
      circle = new Circle(color);
      circleMap.put(color, circle);
      System.out.println("Creating circle of color : " + color);
    }
    return circle;
  }
}
```

```
public class FlyweightPatternDemo {
  private static final String colors[] = { "Red", "Green", "Blue", "White", "Black" };
  public static void main(String[] args) {

    for(int i=0; i < 20; ++i) {
      Circle circle = (Circle)ShapeFactory.getCircle(getRandomColor());
      circle.setX(getRandomX());
      circle.setY(getRandomY());
      circle.setRadius(100);
      circle.draw();
    }
  }
  private static String getRandomColor() {
    return colors[(int)(Math.random()*colors.length)];
  }
  private static int getRandomX() {
    return (int)(Math.random()*100 );
  }
  private static int getRandomY() {
    return (int)(Math.random()*100);
  }
}
```

```
Creating circle of color : Black
Circle: Draw() [Color : Black, x : 36, y :71, radius :100
Creating circle of color : Green
Circle: Draw() [Color : Green, x : 27, y :27, radius :100
Creating circle of color : White
Circle: Draw() [Color : White, x : 64, y :10, radius :100
Creating circle of color : Red
Circle: Draw() [Color : Red, x : 15, y :44, radius :100
Circle: Draw() [Color : Green, x : 19, y :10, radius :100
Circle: Draw() [Color : Green, x : 94, y :32, radius :100
Circle: Draw() [Color : White, x : 69, y :98, radius :100
Creating circle of color : Blue
Circle: Draw() [Color : Blue, x : 13, y :4, radius :100
Circle: Draw() [Color : Green, x : 21, y :21, radius :100
Circle: Draw() [Color : Blue, x : 55, y :86, radius :100
Circle: Draw() [Color : White, x : 90, y :70, radius :100
Circle: Draw() [Color : Green, x : 78, y :3, radius :100
Circle: Draw() [Color : Green, x : 64, y :89, radius :100
Circle: Draw() [Color : Blue, x : 3, y :91, radius :100
Circle: Draw() [Color : Blue, x : 62, y :82, radius :100
Circle: Draw() [Color : Green, x : 97, y :61, radius :100
Circle: Draw() [Color : Green, x : 86, y :12, radius :100
Circle: Draw() [Color : Green, x : 38, y :93, radius :100
Circle: Draw() [Color : Red, x : 76, y :82, radius :100
Circle: Draw() [Color : Blue, x : 95, y :82, radius :100
```

Example: bicycle spokes

- 32 to 36 spokes per wheel
  - Only 3 varieties per bike model
- In a bike race, hundreds of spoke varieties
  - Thousands of instances

```
class Wheel {
        FullSpoke[] spokes;
        ...
}
class FullSpoke {
        int length;
        int diameter;
        bool tapered;
        Metal material;
        float weight;
        float threading;
        bool crimped;
        int location; // rim and hub holes this is installed in
```

Alternatives to FullSpoke

```
class IntrinsicSpoke {
        int length;
        int diameter;
        boolean tapered;
        Metal material;
        float weight;
        float threading;
        boolean crimped;
}
class InstalledSpokeFull extends IntrinsicSpoke {
    int location;
}
```

Doesn't save space.
Same as FullSpoke

```
class InstalledSpokeWrapper {
        IntrinsicSpoke s; // refer to interned object
        int location;
}
```

Composition - Save space because of interning

Align (true) a Wheel

```
class FullSpoke {
        // Tension the spoke by turning the nipple the
        // specified number of turns.
        void tighten(int turns) {
.               .. location ... // location is a field
        }
}
class Wheel {
        FullSpoke[] spokes;
        void align() {
                while ( wheel is misaligned) {
                        // tension the ith spoke
.                       .. spokes[i].tighten(numturns)
                        ...
                }
        }
}
```

What is value of location in spokes[i]

Flyweight code to true (align) a wheel

```
class IntrinsicSpoke {
        void tighten(int turns, int location) {
                ... location ... // location is a parameter
        }
}
class Wheel {
        IntrinsicSpoke[] spokes;
        void align() {
                while (wheel is misaligned) {
                // tension the ith spoke
                        ... spokes[i].tighten(numturns, i) ...
                }
        }
}
```

Flyweight Pattern

- What if FullSpoke contains a wheel field pointing at the Wheel containing it?
  - Wheel methods pass *this* to the methods that use the wheel field.
- What if Fullspoke contains a boolean indication a broken spoke
  - Add an array of booleans parallel to spokes
- Flyweight used when there are very few mutable (extrinsic) fields
  - Complicates code
  - Use when profiling has determined that space is a serious problem

Wrappers

- A wrapper uses composition/delegation
- A wrapper is a thin layer over an encapsulated class
  - Modify the interface
    - GraphWrapper
  - Extend behavior
  - Restrict access to encapsulated object
- The encapsulated object (delegate) does most work

Structural Patterns

Pattern	Functionality	Interface
Adapter	same	different
Decorator	different	same
Proxy	same	same

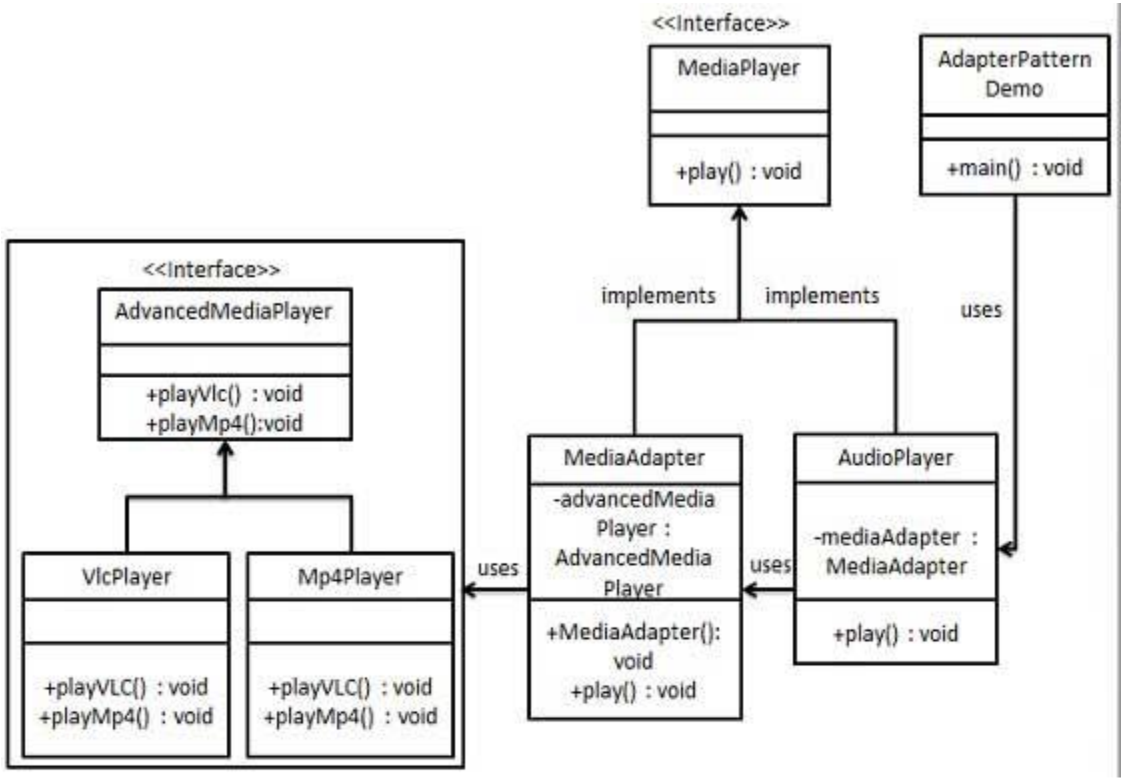
Adapter Pattern

- The purpose of the Adapter is:
  - change an interface, without changing the functionality of the encapsulated class
  - Allows reuse of functionality
  - Protects client from modification
- Reasons
  - Rename methods
  - Convert units
  - Implement a method in terms of another
- Example
  - Angles passed in radians instead of degrees

Adapter Pattern

- bridge between two incompatible interfaces
- single class which is responsible to join functionalities of independent or incompatible interfaces.
  - Example: card reader which acts as an adapter between memory card and a laptop.

Adapter Example



https://www.tutorialspoint.com/design_pattern/adapter_pattern.htm

```java
public interface MediaPlayer {
  public void play(String audioType, String fileName);
}

public interface AdvancedMediaPlayer {
  public void playVlc(String fileName);
  public void playMp4(String fileName);
}
```

```java
public class VlcPlayer implements AdvancedMediaPlayer{
  @Override
  public void playVlc(String fileName) {
    System.out.println("Playing vlc file. Name: "+ fileName);

  }
  …
  @Override
  public void playMp4(String fileName) {
    //do nothing
  }
}
public class Mp4Player implements AdvancedMediaPlayer{

  @Override
  public void playVlc(String fileName) {
    //do nothing
  }

  @Override
  public void playMp4(String fileName) {
    System.out.println("Playing mp4 file. Name: "+ fileName);
  }
}
```

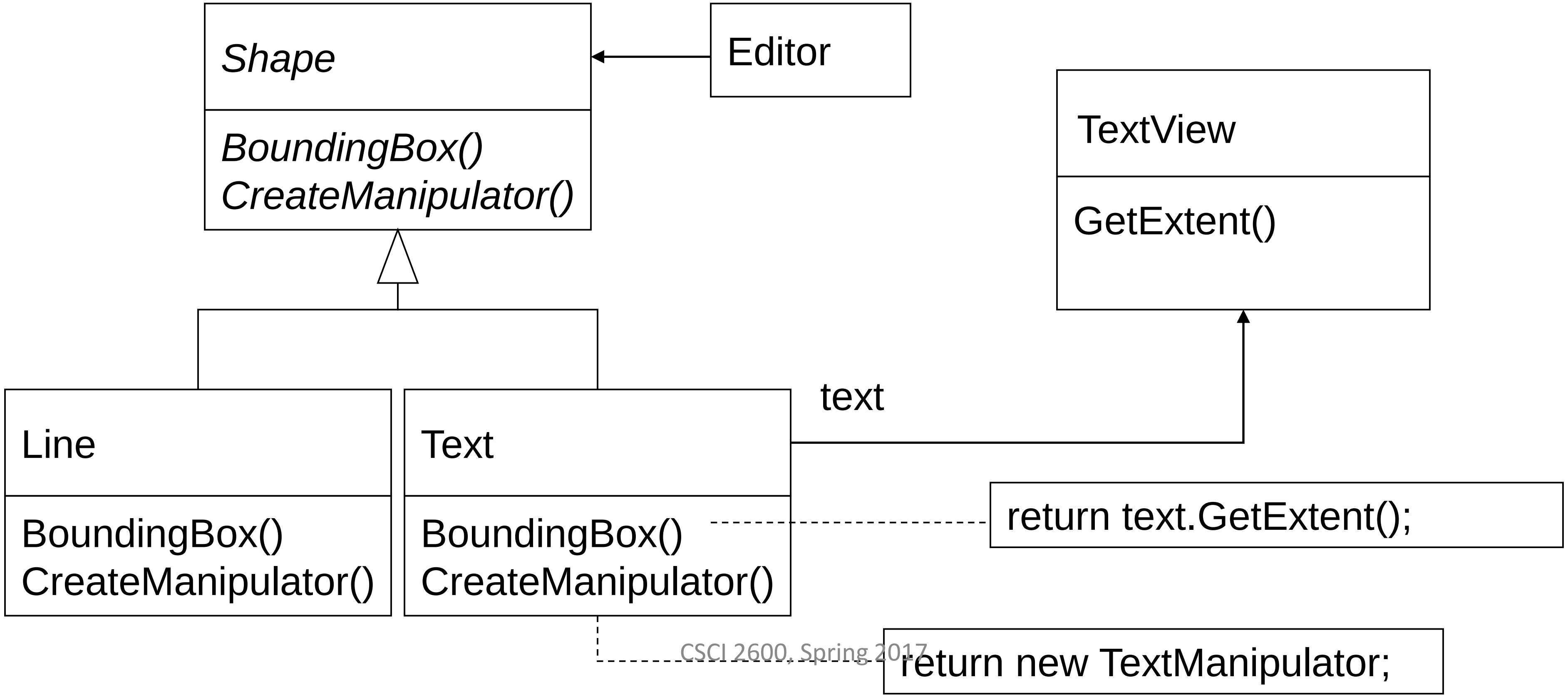
```java
public class MediaAdapter implements MediaPlayer {

   AdvancedMediaPlayer advancedMusicPlayer;

   public MediaAdapter(String audioType){
      if(audioType.equalsIgnoreCase("vlc") ){
         advancedMusicPlayer = new VlcPlayer();

      }else if (audioType.equalsIgnoreCase("mp4")){
         advancedMusicPlayer = new Mp4Player();
      }
   }

   @Override
   public void play(String audioType, String fileName) {
      if(audioType.equalsIgnoreCase("vlc")){
         advancedMusicPlayer.playVlc(fileName);
      }
      else if(audioType.equalsIgnoreCase("mp4")){
         advancedMusicPlayer.playMp4(fileName);
      }
   }
}
```

```
public class AudioPlayer implements MediaPlayer {
   MediaAdapter mediaAdapter;

   @Override
   public void play(String audioType, String fileName) {

      //inbuilt support to play mp3 music files
      if(audioType.equalsIgnoreCase("mp3")){
         System.out.println("Playing mp3 file. Name: " + fileName);
      }

      //mediaAdapter is providing support to play other file formats
      else if(audioType.equalsIgnoreCase("vlc") || audioType.equalsIgnoreCase("mp4")){
         mediaAdapter = new MediaAdapter(audioType);
         mediaAdapter.play(audioType, fileName);
      }

      else{
         System.out.println("Invalid media. " + audioType + " format not supported");
      }
   }
}
```

```
public class AdapterPatternDemo {
   public static void main(String[] args) {
      AudioPlayer audioPlayer = new AudioPlayer();

      audioPlayer.play("mp3", "beyond the horizon.mp3");
      audioPlayer.play("mp4", "alone.mp4");
      audioPlayer.play("vlc", "far far away.vlc");
      audioPlayer.play("avi", "mind me.avi");
   }
}
```

Adapter Pattern

- Motivation: reuse a class with an interface different that the class' interface



Adapter Example: Scaling Rectangles

```
interface Rectangle {
  void scale(int factor); //grow or shrink by factor
  void setWidth();
  float getWidth();
  float area(); …
}
class Client {
  void clientMethod(Rectangle r) {
    … r.scale(2);
  }
}
class NonScalableRectangle {
  void setWidth(); …
  // no scale method!
}
```

Can we use NonScalableRectangle in Client instead?

Class Adapter

- Class adapter adapts via subclassing

```
class ScalableRectangle1
            extends NonScalableRectangle
            implements Rectangle {
   void scale(int factor) {
     setWidth(factor*getWidth());
     setHeight(factor*getHeight());
   }
}
```

Object Adapter

- Object adapter adapts via delegation: it forwards work to delegate

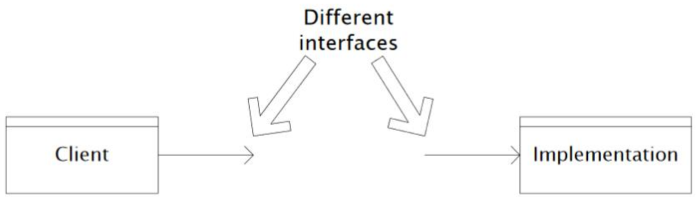
```
class ScalableRectangle2 implements Rectangle {
   NonScalableRectangle r; // delegate
   ScalableRectangle2(NonScalableRectangle r) {
     this.r = r;
   }
   void scale(int factor) {
     setWidth(factor * getWidth());
     setHeight(factor * getHeight());
   }
   float getWidth() { return r.getWidth(); }
   …
}
```

Subclassing Versus Delegation

- Subclassing
  - Automatically gives access to all methods in the superclass
  - More efficient
- Delegation
  - Permits removal of methods
  - Multiple objects can be composed
  - More flexible
- Some wrappers have qualities of adapter, decorator, and proxy
  - Differences are subtle

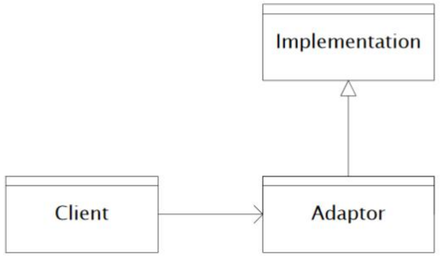
Types of Adapters

Goal of adapter:
connect incompatible interfaces

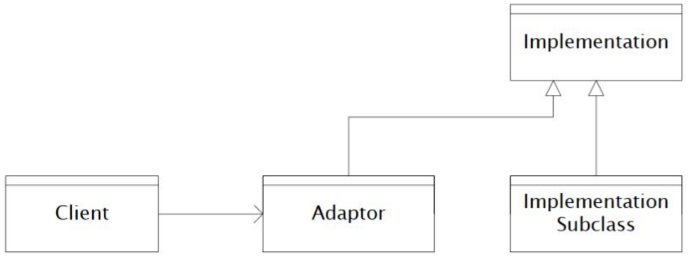


Adapter with delegation

Adapter with subclassing



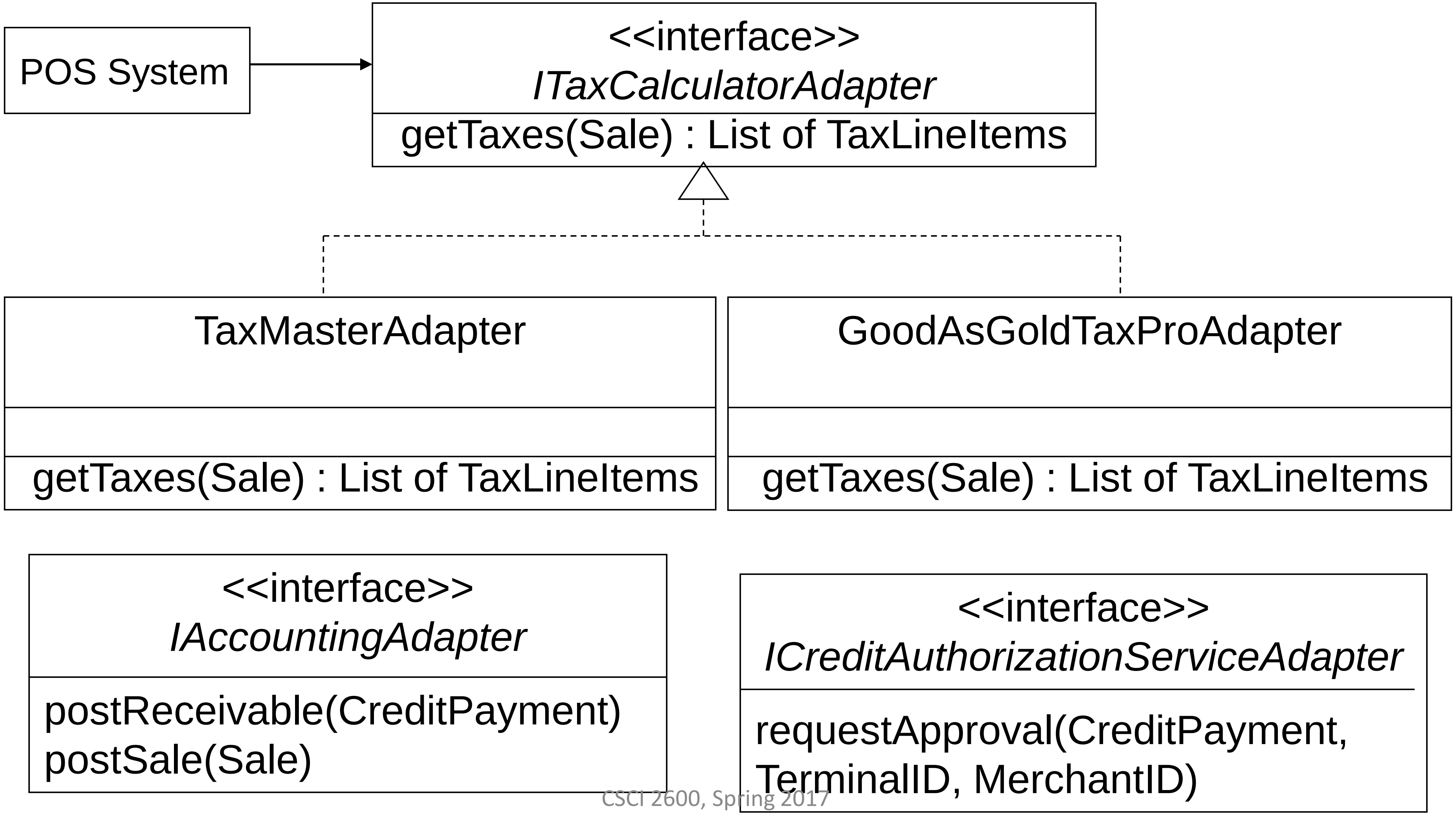
Adapter with subclassing:
no extension is permitted



Example

- A Point-of-Sale system needs to support services from different third-party vendors:
  - Tax calculator service from different vendors
  - Credit authorization service from different vendors
  - Inventory systems from different vendors
  - Accounting systems from different vendors
- Each vendor service has its own API, which can't be changed
- What design pattern helps solve this problem?

The Solution: Object Adapter



Exercise

- Who creates the appropriate adapter object?
  - Is it a good idea to let some domain object from the Point-of-Sale system (e.g., Register, Sale) create the adapters?
    - That would assign responsibility beyond domain object's logic. We would like to keep domain classes focused, so, this is not a good idea
- How to determine what type of adapter object to create? We expect adapters to change.
- What design patterns solve this problem?

The Solution: Factory

ServiceFactory
accountingAdapter : IAccountingAdapter inventoryAdapter : IInventoryAdapter taxCalculatorAdapter : ITaxCalculatorAdapter
getAccountingAdapter() : IAccountingAdapter getInventoryAdapter () : IInventoryAdapter getTaxCalculatorAdapter () : ITaxCalculatorAdapter

Using the Factory

```
public ITaxCalculatorAdapter
                    getTaxCalculatorAdapter() {
  if (taxCalculatorAdapter == null) {
   String className =
     System.getProperty("taxcalculator.classname");
     taxCalculatorAdapter =
      (ITaxCalculatorAdapter)
      Class.forName(className).newInstance();
  }
  return taxCalculatorAdapter;
}
```

- What design pattern(s) do you see here?

Java reflection: creates a brand new object from String className!

Exercise

- Who creates the **`ServiceFactory`**?
- How is it accessed?
- We need a single instance of the **`ServiceFactory`** class
-
- What pattern solves these problems?

The Solution: Singleton

Special UML notation.

ServiceFactory 1
- instance: ServiceFactory - accountingAdapter : IAccountingAdapter - inventoryAdapter : IInventoryAdapter - taxCalculatorAdapter : ITaxCalculatorAdapter
+ getInstance() : ServiceFactory + getAccountingAdapter() : IAccountingAdapter + getInventoryAdapter() : IInventoryAdapter + getTaxCalculatorAdapter() : ITaxCalculatorAdapter

In UML, - means private, + means public. All (shown) fields in **`ServiceFactory`** are private and all methods are public. underline means static. **`instance`** and **`getInstance`** are static. Single instance of **`ServiceFactory`** ensures single instance of adapter objects.

Composite Pattern

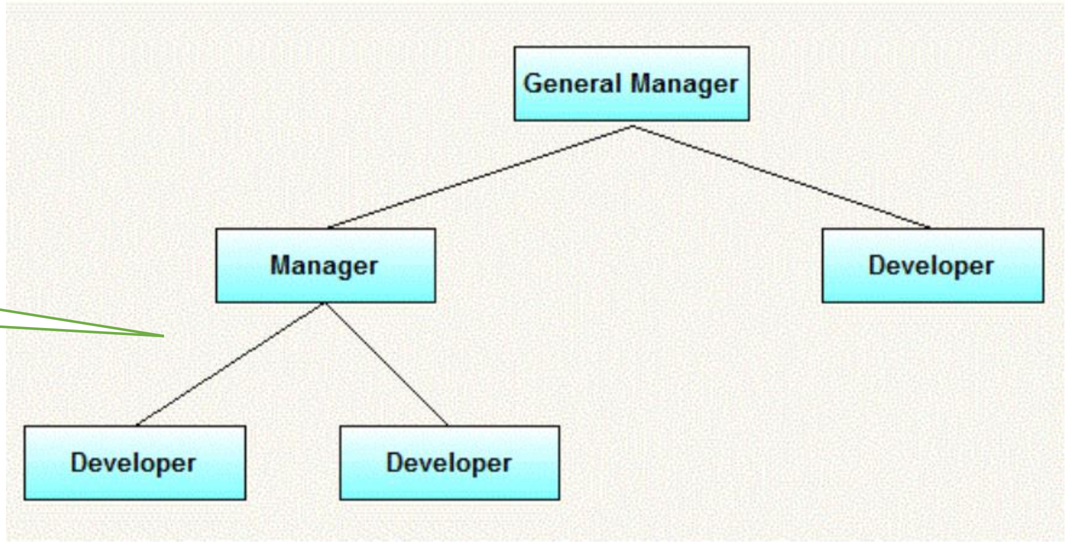
- Client treats a composite object (a collection of objects) the same as a simple object (an atomic unit)

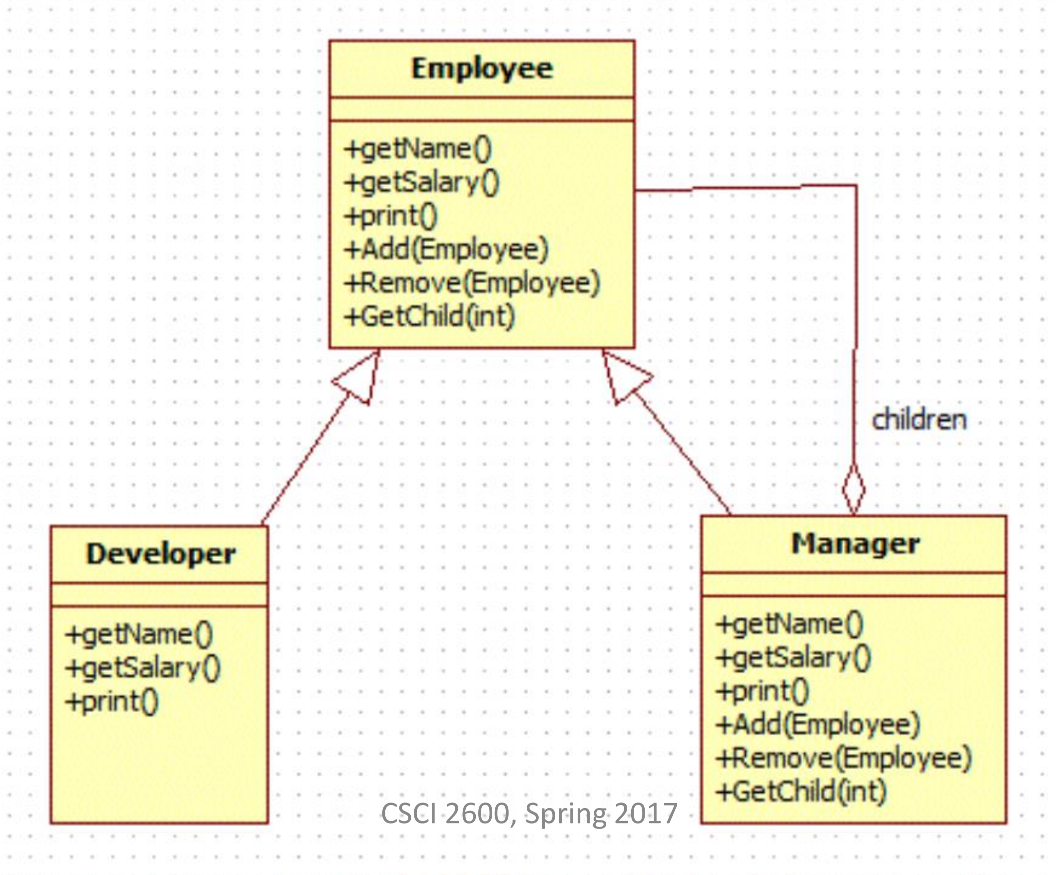
- Good for part-whole relationships
  - Can represent arbitrarily complex objects

Composite Pattern

- Composite pattern composes objects in term of a tree structure to represent the part as well as the whole hierarchy.
- This pattern creates a class that contains a group objects.
- The class provides ways to modify its group of objects.

Organization Chart





```java
public interface Employee {

  public void add(Employee employee);
  public void remove(Employee employee);
  public Employee getChild(int i);
  public String getName();
  public double getSalary();
  public void print();
}
```

```java
public class Manager implements Employee{

 private String name;
 private double salary;

 public Manager(String name,double salary){
  this.name = name;
  this.salary = salary;
 }

 List<Employee> employees = new ArrayList<Employee>();
 public void add(Employee employee) {
   employees.add(employee);
 }

 public Employee getChild(int i) {
  return employees.get(i);
 }
 …// implements print
}
```

```java
public class Developer implements Employee{

  private String name;
  private double salary;

  public Developer(String name,double salary){
    this.name = name;
    this.salary = salary;
  }
  public void add(Employee employee) {
    //this is leaf node so this method is not applicable to this class.
  }

  public Employee getChild(int i) {
    //this is leaf node so this method is not applicable to this class.
    return null;
  }
  …
}
```

```java
public static void main(String[] args) {
  Employee emp1=new Developer("John", 10000);
  Employee emp2=new Developer("David", 15000);
  Employee manager1=new Manager("Daniel",25000);
  manager1.add(emp1);
  manager1.add(emp2);
  Employee emp3=new Developer("Michael", 20000);
  Manager generalManager=new Manager("Mark", 50000);
  generalManager.add(emp3);
  generalManager.add(manager1);
  generalManager.print();
 }
}
```

Example: Bicycle

- Bicycle
  - Wheel
    - Skewer
      - Lever
      - Body
      - Cam
      - Rod
      - Acorn nut
    - Hub
    - Spokes
    - …
  - Frame
  - …

Example: Methods on Components

```
abstract class BicycleComponent {
   …
   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()+… }
}
```

Skewer is an atomic unit

Wheel is a collection of objects

Even Better

```
abstract class BicycleComponent {
   …
   float cost();
}
class Skewer extends BicycleComponent {
   float price;
   float cost() { return price; }
}
class Wheel extends BicycleComponent {
   float assemblyCost;
   BicycleComponent skewer;
   BicycleComponent hub;
   …
   float cost() { return assemblyCost+
                           skewer.cost()+hub.cost()+… }
}
```

The skewer and hub are BicycleCompoenents, so we can use BicycleComponent!

Another Example: Boolean Expressions

- A boolean expression can be
  - Variable (e.g., **`x`**)
  - Boolean constant: **`true, false`**
  - Or expression (e.g., **`x or true`**)
  - And expression (e.g., **`(x or true) and y`**)
  - Not expression (e.g., **`not x, not (x or y)`**)
- And, Or, Not: collections of expressions
- Variable and Constant: atomic units

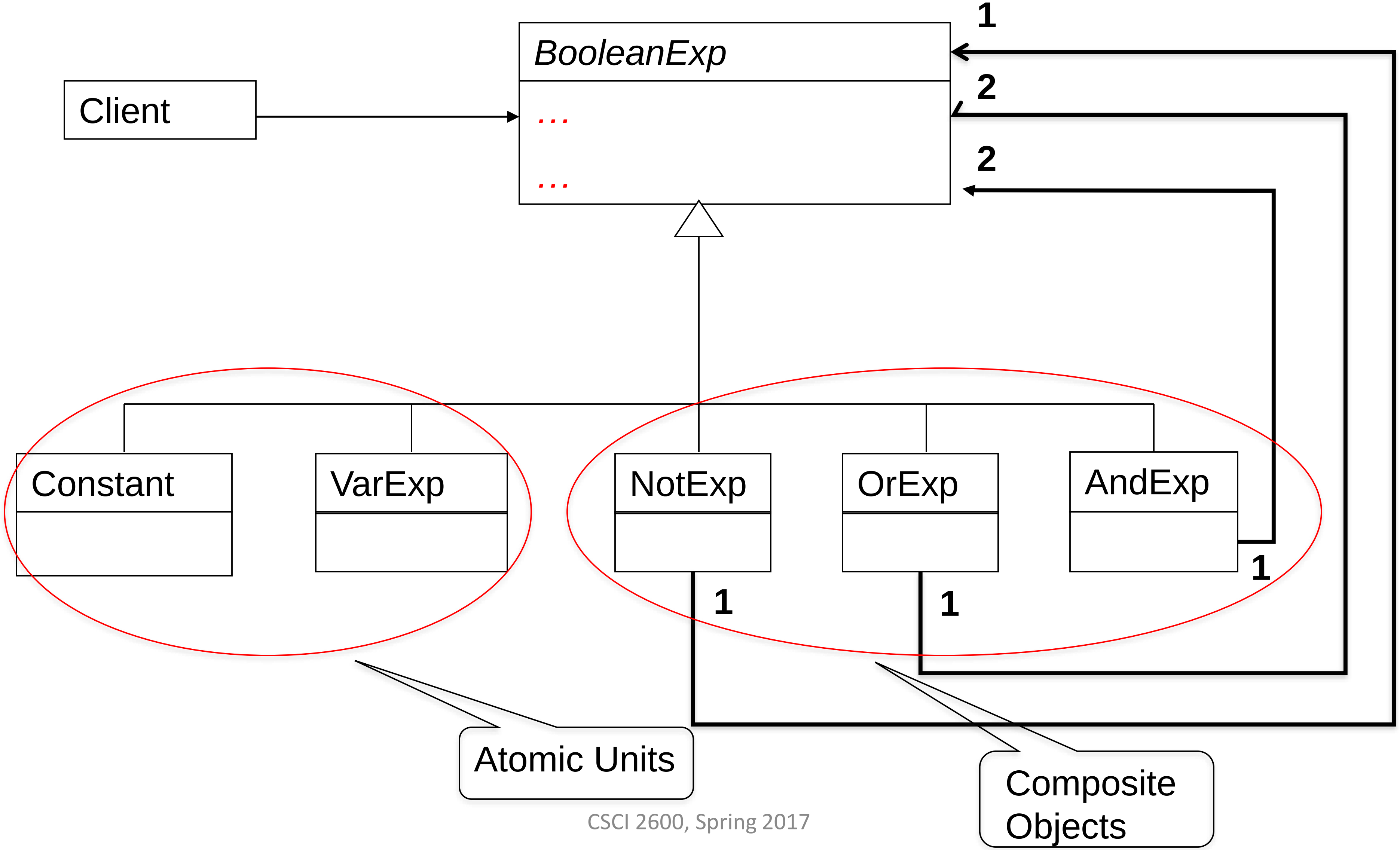
Using Composite to Represent Boolean Expressions

```
abstract class BooleanExp {
  boolean eval(Context c);
}
class Constant extends BooleanExp {
  private boolean const;
  Constant(boolean const) { this.const=const; }
  boolean eval(Context c) { return const; }
}
class VarExp extends BooleanExp {
  String varname;
  VarExp(String var) { varname = var; }
  boolean eval(Context c) {
    return c.lookup(varname);
  }
}
```

Using Composite to Represent Boolean Expressions

```
class AndExp extends BooleanExp {
  private BooleanExp leftExp;
  private BooleanExp rightExp;
  AndExp(BooleanExp left, BooleanExp right) {
   leftExp = left;
   rightExp = right;
  }
  boolean eval(Context c) {
   return leftExp.eval(c) && rightExp.eval(c);
  }
}

// analogous definitions for OrExp and NotExp
```

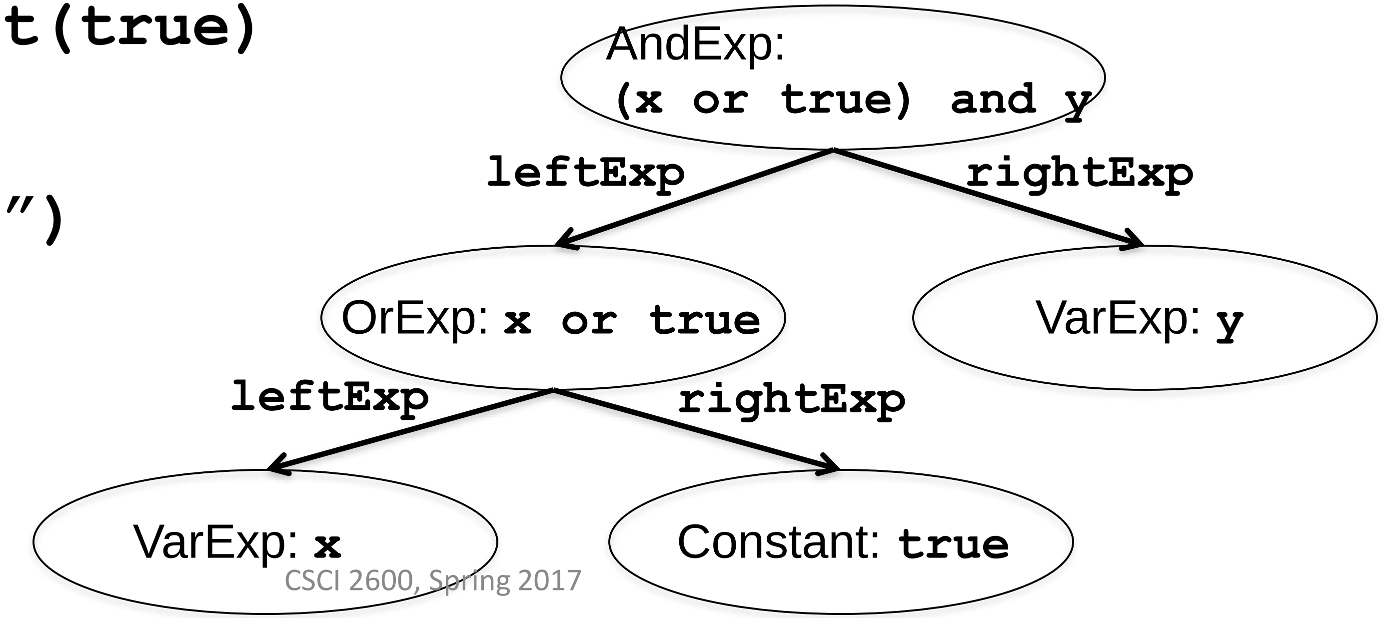
Composite Pattern: Class diagram



Object Structure versus Class Diagram

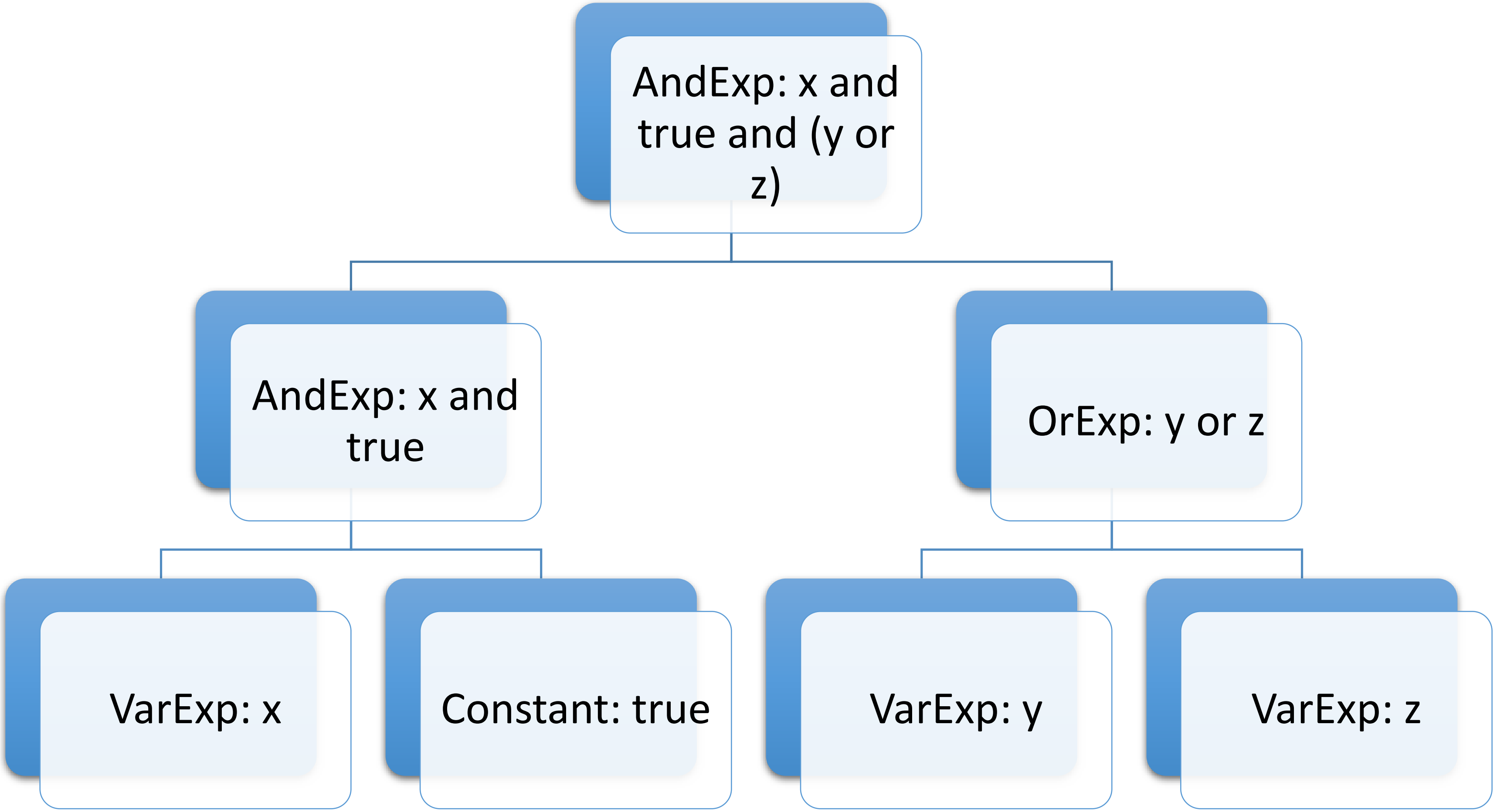
- Expression **`(x or true) and y`**

```
new AndExp(
    new OrExp(
      new VarExp(“x”),
      new Constant(true)
    ),
    new VarExp(“y”)
)
```

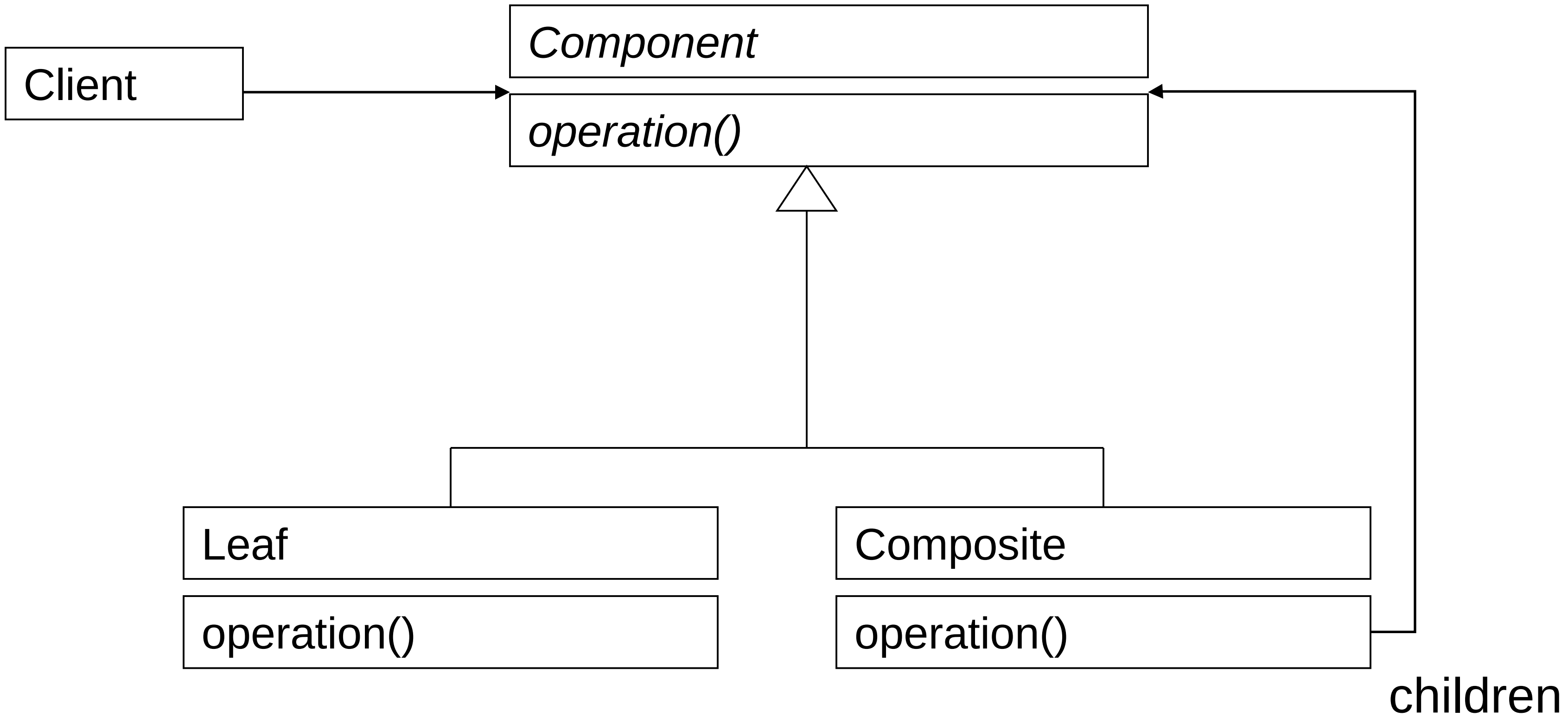


Exercise: Object Structure

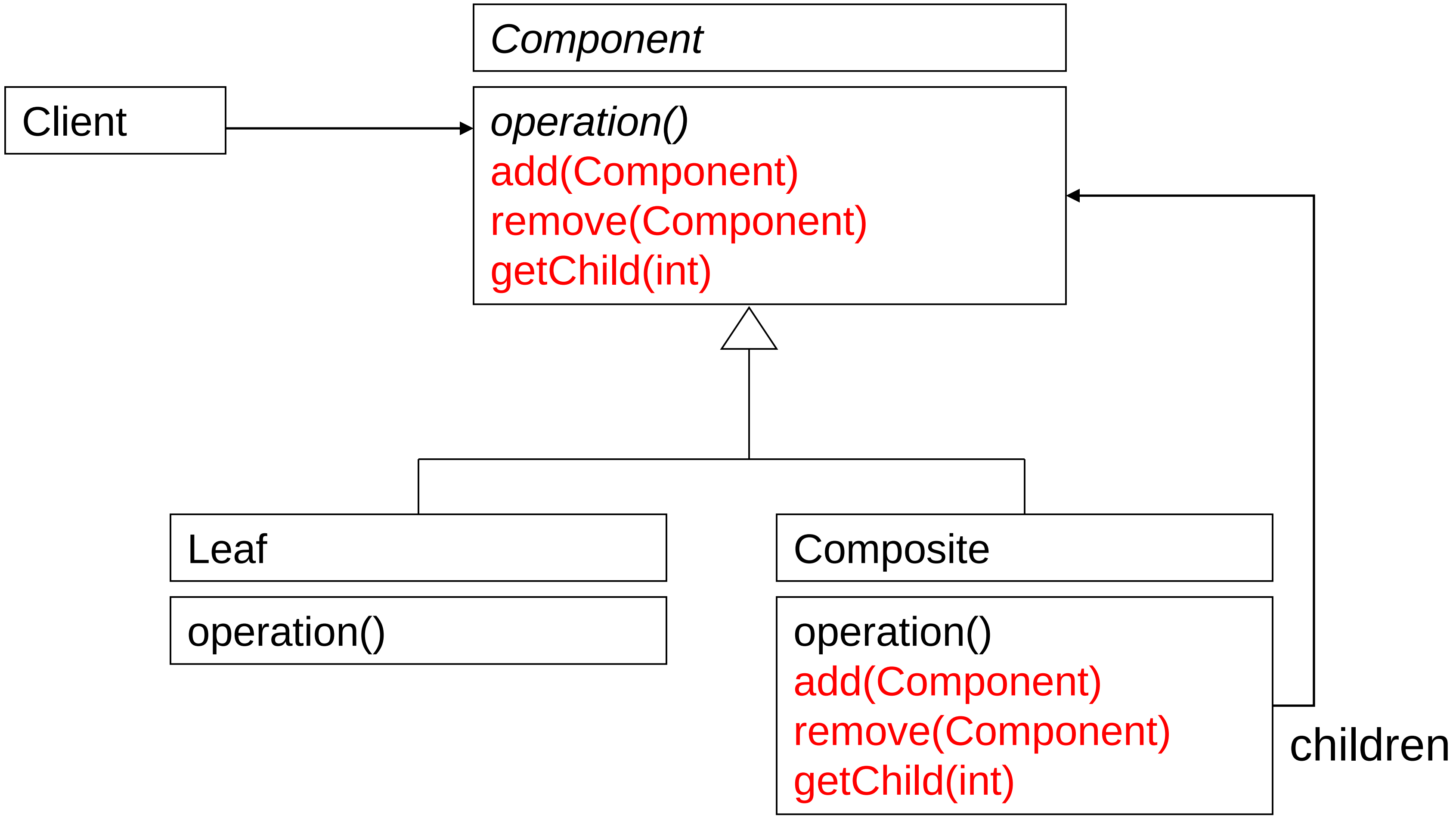
- Draw the object structure (a tree!) for expression **`x and true and (y or z)`** new AndExp(new AndExp(new VarExp(“x”) new Constant(true)), new OrExp(new VarExp(“y”), new VarExp(“z”)))



Structure of Composite



Another Option: Add Operations to Manage Composites



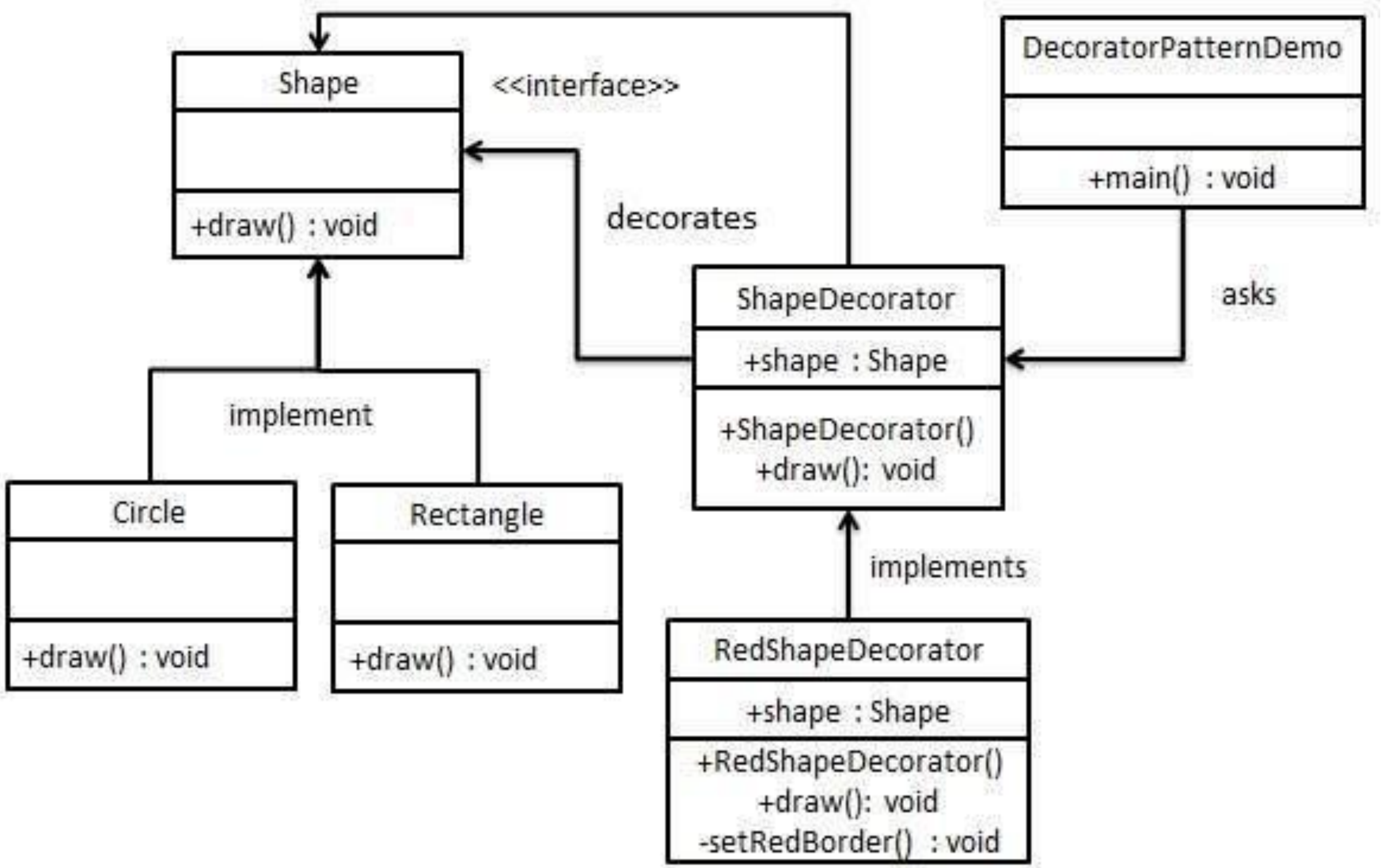
Decorators

- A wrapper pattern
  - Adapter is a wrapper
  - Composite is not
- Decorators add functionality without changing the interface
- When to use
  - Add to existing method to do something in addition while preserving the interface and spec
- Similar to subclassing
  - Not all subclassing is decoration

Decorators

- The decorator pattern allows a user to add new functionality to an existing object without altering its structure.
- This pattern creates a decorator class which wraps the original class and provides additional functionality keeping class method's signatures intact.

Example



https://www.tutorialspoint.com/design_pattern/decorator_pattern.htm

```java
public interface Shape {
   void draw();
}

public class Rectangle implements Shape {

   @Override
   public void draw() {
      System.out.println("Shape: Rectangle");
   }
}

public class Circle implements Shape {

   @Override
   public void draw() {
      System.out.println("Shape: Circle");
   }
}
```

```java
public abstract class ShapeDecorator implements Shape {
   protected Shape decoratedShape;
   public ShapeDecorator(Shape decoratedShape){
      this.decoratedShape = decoratedShape;
   }
   public void draw(){
      decoratedShape.draw();
   }
}
public class RedShapeDecorator extends ShapeDecorator {
   public RedShapeDecorator(Shape decoratedShape) {
      super(decoratedShape);
   }
   @Override
   public void draw() {
      decoratedShape.draw();
      setRedBorder(decoratedShape);
   }
   private void setRedBorder(Shape decoratedShape){
      System.out.println("Border Color: Red");
   }
}
```

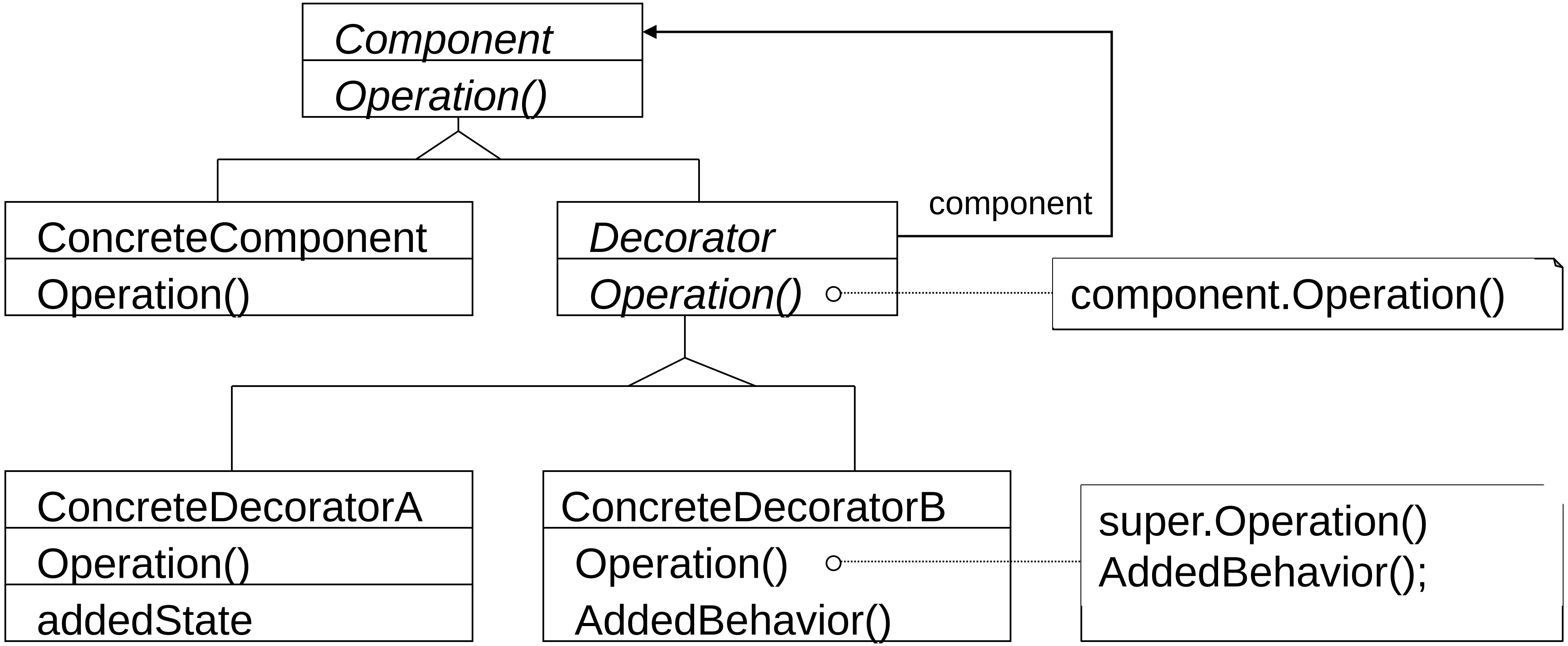
```
public class DecoratorPatternDemo {
  public static void main(String[] args) {

    Shape circle = new Circle();

    Shape redCircle = new RedShapeDecorator(new Circle());

    Shape redRectangle = new RedShapeDecorator(new Rectangle());
    System.out.println("Circle with normal border");
    circle.draw();

    System.out.println("\nCircle of red border");
    redCircle.draw();

    System.out.println("\nRectangle of red border");
    redRectangle.draw();
  }
}
```

Output:

```
Circle with normal border
Shape: Circle

Circle of red border
Shape: Circle
Border Color: Red

Rectangle of red border
Shape: Rectangle
Border Color: Red
```

Structure of Decorator

- Motivation: add small chunks of functionality without changing the interface



Example

```
abstract class Component { void draw(); }
class TextView extends Component {
  public void draw() {
     // Draw the TextView
   }
}
abstract class Decorator extends Component {
  private Component component;
  public Decorator(Component c) {
    this.component = c;
   }
  public void draw() {
    component.draw();
    … // additional functionality
   }
}
```

Example: Bordered Windows

Adds a border to the text view

```
class BorderDecorator extends Decorator {
  public BorderDecorator(Component c,
                         int borderwidth) {
     super(c);
     …
   }
  private void drawBorder() { … }
  public void draw() {
      super.draw();
     drawBorder();
   }
}
class ScrollDecorator extends Decorator {
   …
}
```

Calls **Decorator.draw** which redirects work to the enclosed component

Adds a scroll bar to the text view

Example

```
public class Client {
   public static void main(String[] args) {
      TextView textView = new TextView();
      Component decoratedComponent =
           new BorderDecorator(
              new ScrollDecorator(textView),1);
      }
      …
      decoratedComponent.draw();
      …
}
```

Bordered Windows: Another Version

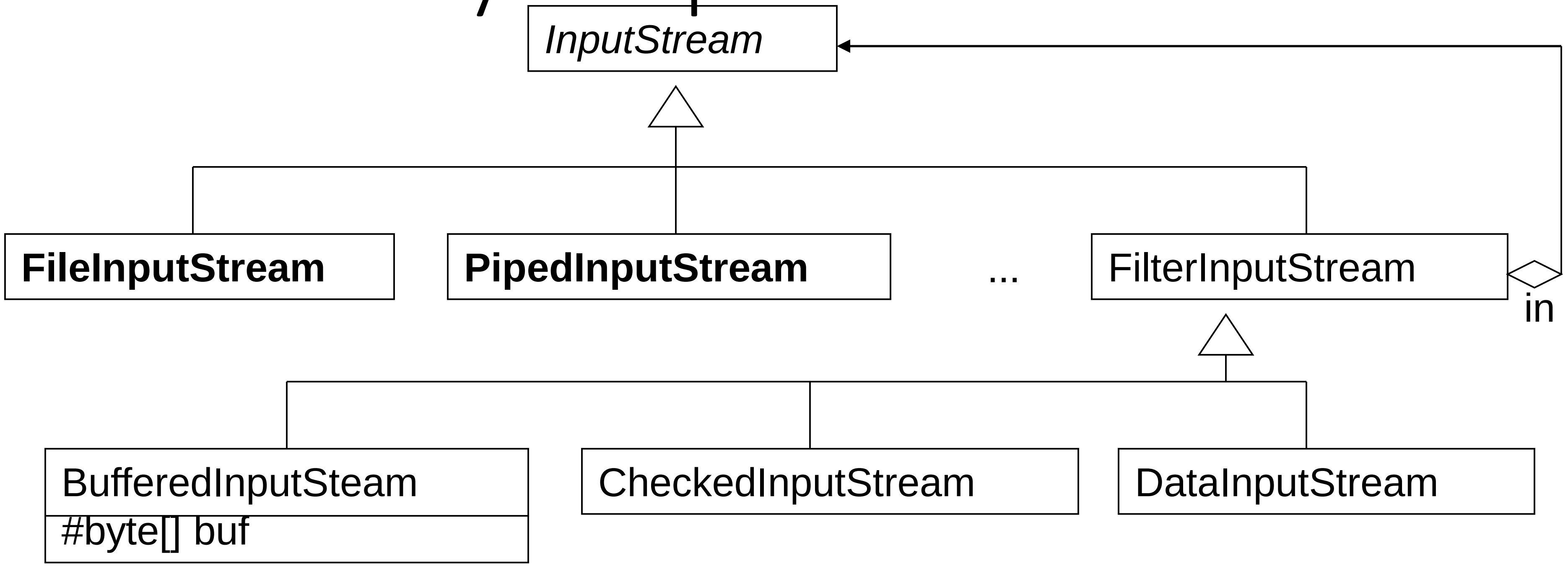
```
Interface Window {
        // rectangle bounding the window
        Rectangle bounds();
        // draw this on the specified screen
        Void draw(Screen s);
        ...
}
Class WindowImpl implements Window {
        ...
}
```

Bordered Windows

```
// 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);
        }
}
```

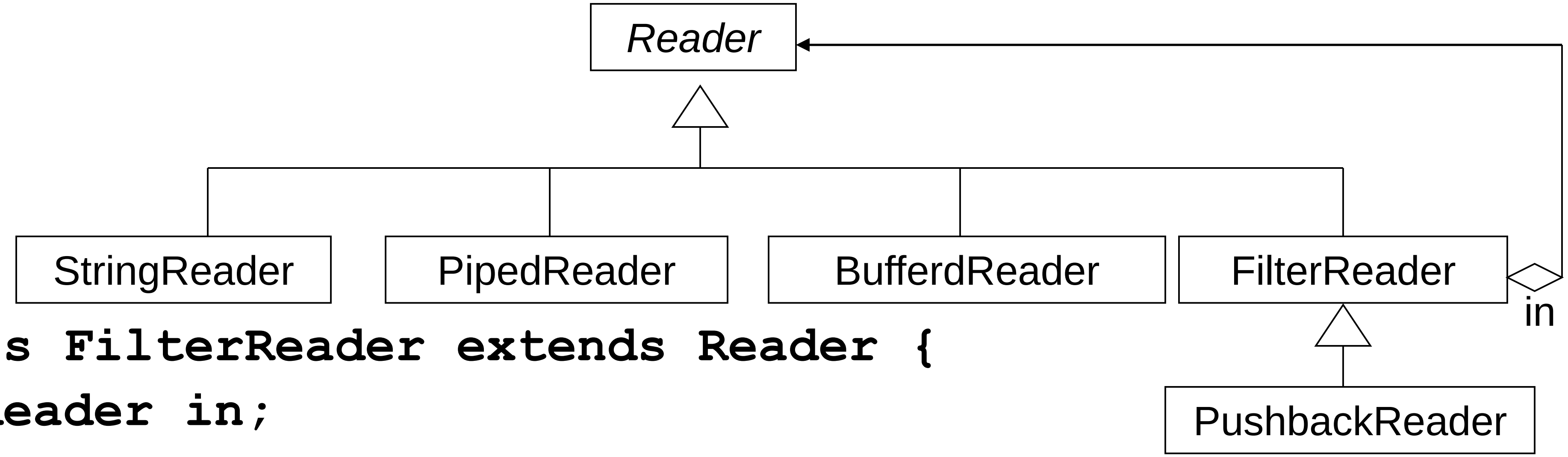
Delegation permits multiple borders on a window, or a window that is both bordered and shaded (or either one of those)

Java I/O Package
InputStream: byte input streams



- FilterInputStream is a Decorator. Enables the “chaining” of streams
- Each FilterInputStream redirects input action to the enclosed InputStream

Readers: character input streams




```
Class FilterReader extends Reader {
   Reader in;
   int read() {
     return in.read();
   }
   …
}
```

Another Decorator Example

```
public class UppercaseConvertor extends
                                FilterReader {
  public UppercaseConvertor(Reader in) {
    super(in);
  }

  public int read() throws IOException {
    int c = super.read();
    return ( c==-1 ? c :
            Character.toUpperCase((char)c));
  }

}
```

We also have **`LowercaseConverter extends FilterReader`**, which (surprise!) converts to lowercase

Another Decorator Example

```
public static void main(String[] args)  {
  Reader f =
          new UppercaseConverter(
            new LowercaseConvertor(
               new StringReader(args[0])));
   int c;
  while ((c = f.read()) != -1)
      System.out.print((char)c);
  System.out.println();
}
```

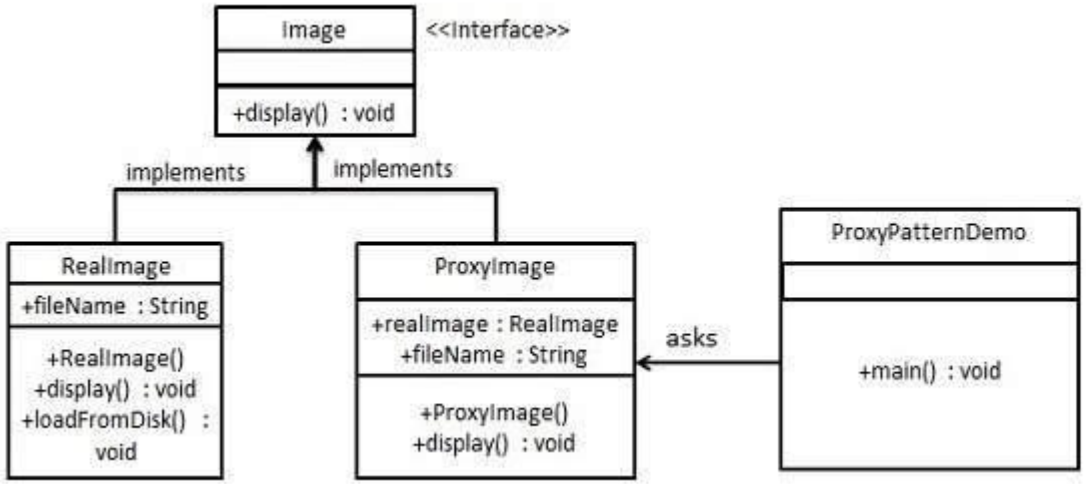
What is the object structure of **`f`**?

What does this code do?

Proxy Pattern

- Same interface and functionality as the enclosed class
- Control access to enclosed object
  - 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 never used

Recap: Simple Proxy Example



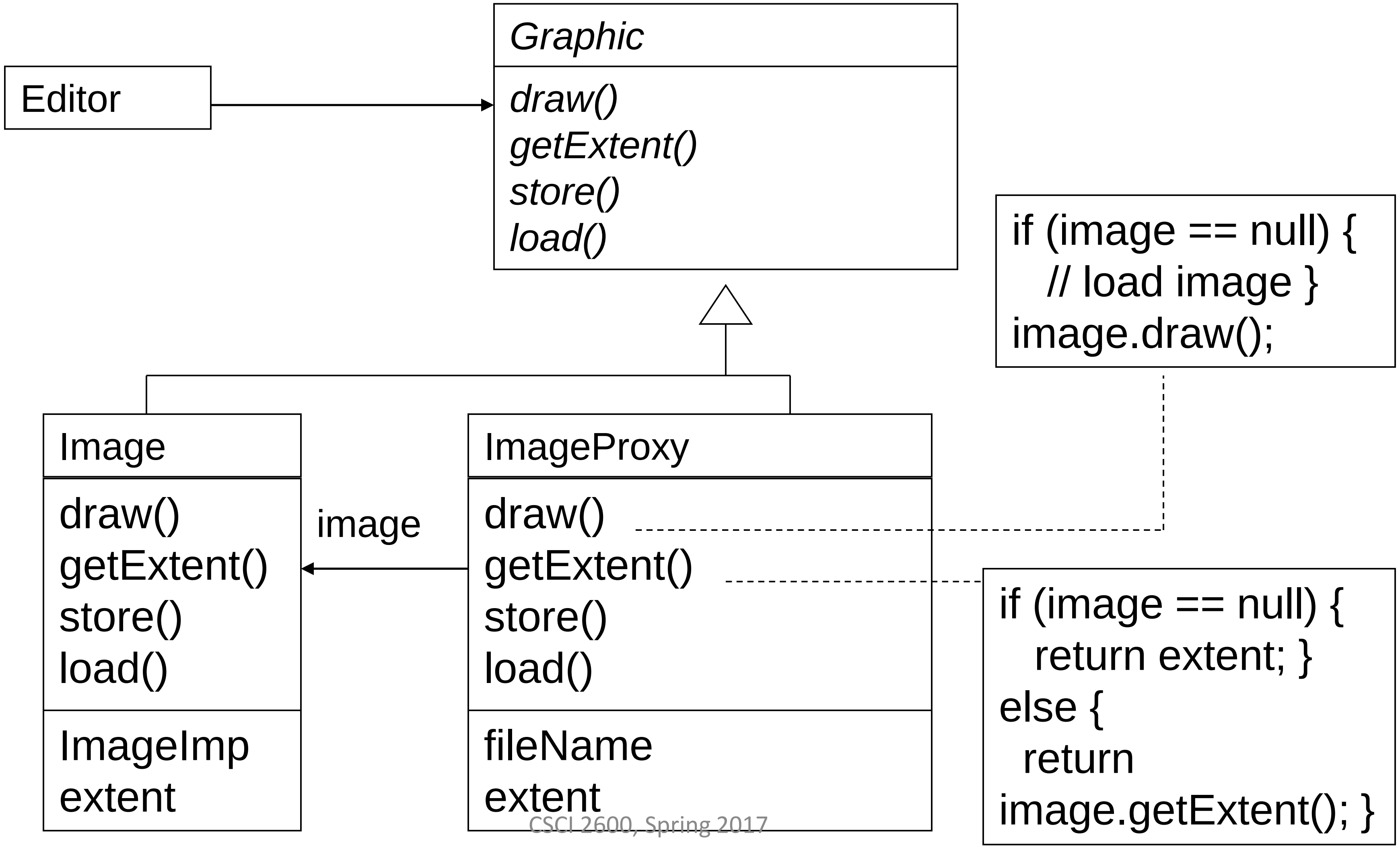
https://www.tutorialspoint.com/design_pattern/proxy_pattern.htm

```java
public interface Image {
   void display();
}

public class RealImage implements Image {

   private String fileName;

   public RealImage(String fileName){
      this.fileName = fileName;
      loadFromDisk(fileName);
   }

   @Override
   public void display() {
      System.out.println("Displaying " + fileName);
   }

   private void loadFromDisk(String fileName){
      System.out.println("Loading " + fileName);
   }
}
```

```java
public class ProxyImage implements Image{
   // delegation
   private RealImage realImage;
   private String fileName;

   public ProxyImage(String fileName){
      this.fileName = fileName;
   }

   @Override
   public void display() {
      if(realImage == null){
         realImage = new RealImage(fileName);
      }
      realImage.display();
   }
}
```

```java
public class ProxyPatternDemo {

  public static void main(String[] args) {
    Image image = new ProxyImage("test_10mb.jpg");

    //image will be loaded from disk
    image.display();
    System.out.println("");

    //image will not be loaded from disk
    image.display();
  }
}
```

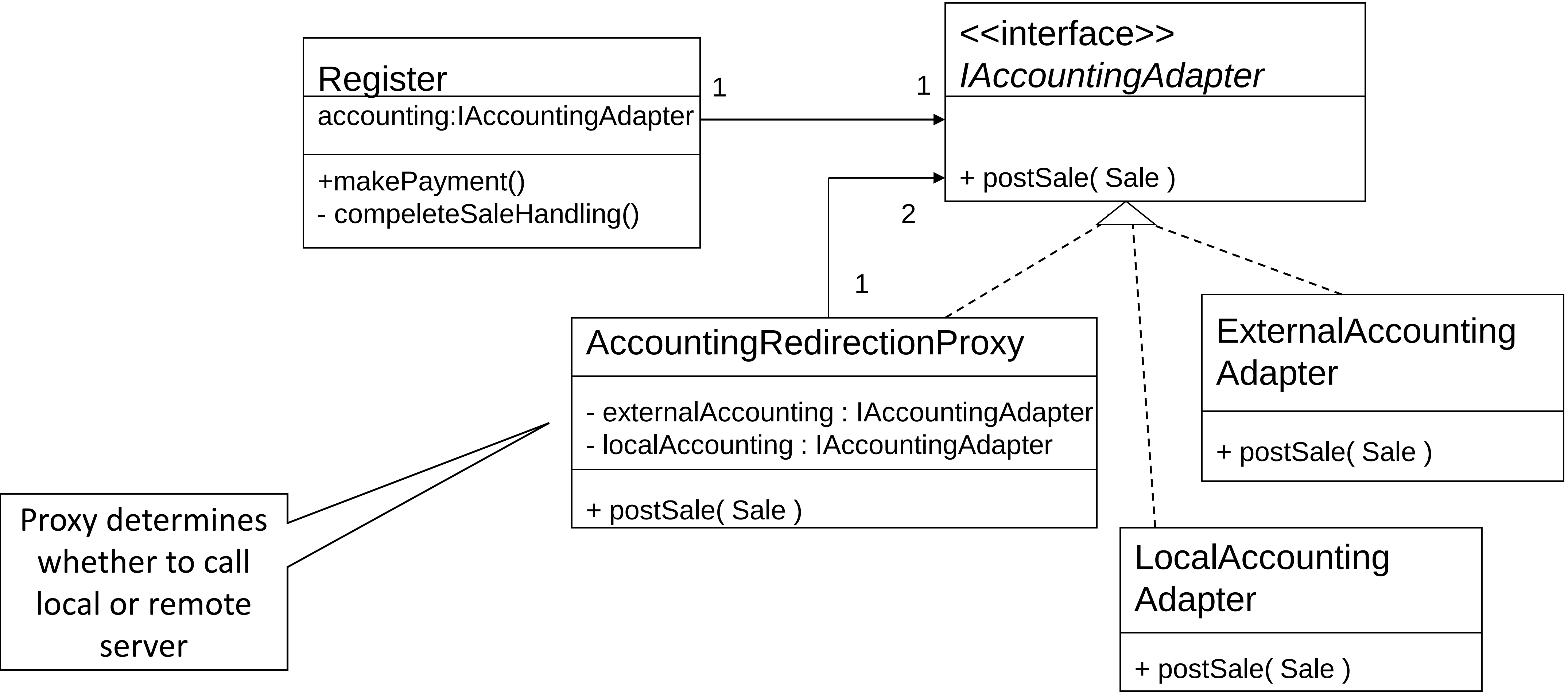
Proxy Example: Manage Creation of Expensive Object



Proxy Example: Manage Details When Dealing with Remote Object

- Recovery from remote service failure in the Point-Of-Sale system
  - When `postSale` is sent to an accounting service (remember, an `AccountingAdapter`), if connection cannot be established, failover to a local service
  - Failover should be transparent to `Register`
    - I.e., it should not know whether `postSale` was sent to the accounting service or to some special object that will redirect to a local service in case of failure

Proxy Example: Manage Details When Dealing with Remote Object



Traversing Composites

- Question: How to perform operations on all parts of a composite?
  - E.g., evaluate a boolean expression, print a boolean expression

Perform Operations on boolean expressions

- Need to write code for each Operation/Object pair
- Question: do we group together (in a class) the code for a particular operation or the code for a particular object

Objects

Operations

	VarExp	Constant	AndExp	OrExp	NotExp
evaluate					
pretty-print					

Interpreter and Procedural Patterns

- Interpreter: groups code per object, spreads apart code for similar operations

- Procedural: groups code per operation, spreads apart code for similar objects

	VarExp	AndExp
evaluate		
pretty-print		

	VarExp	AndExp
evaluate		
pretty-print		

Interpeter Pattern

	VarExp	AndExp
evaluate		
pretty-print		

```
abstract class BooleanExp {
  abstract boolean eval(Context c);
  abstract String prettyPrint();
}

class VarExp extends BooleanExp {
  …
  boolean eval(Context c);
  String prettyPrint();
}

class AndExp extends BooleanExp {
  boolean eval(Context c);
  String prettyPrint();
}
```

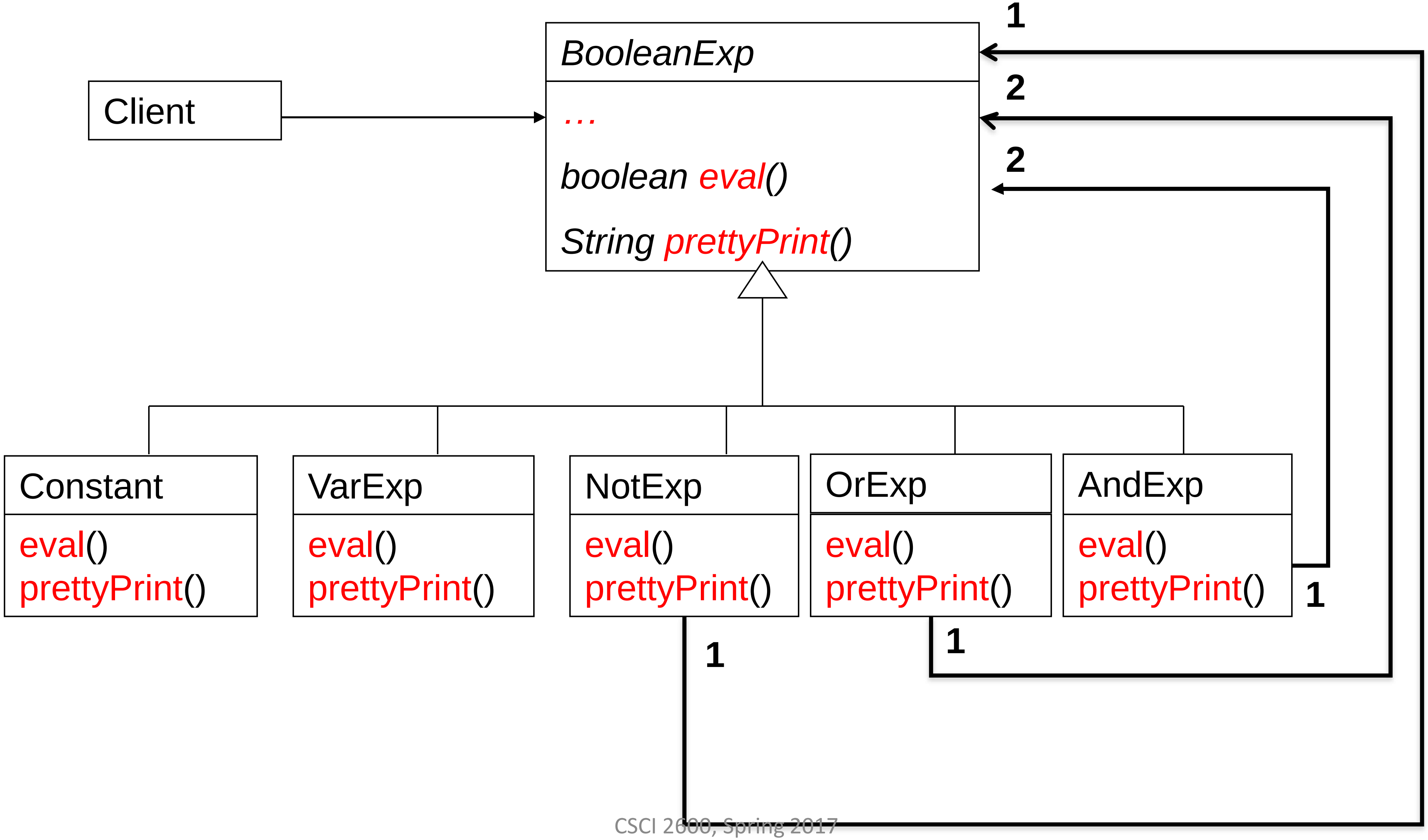
Add a method to each class for each supported operation

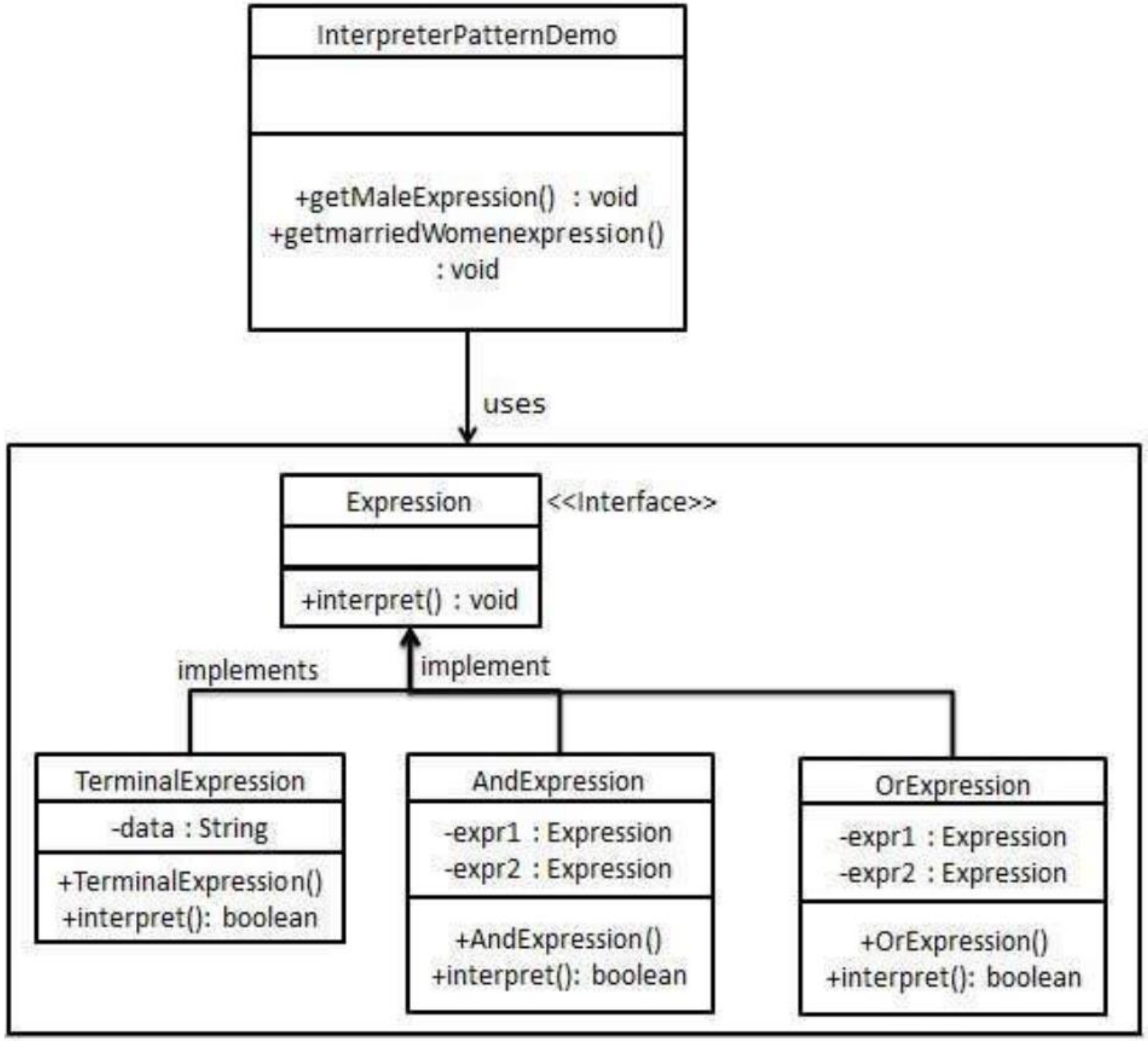
Dynamic dispatch chooses right implementation at call `myExpr.eval(c);`

Interpreter Pattern

```
class AndExp extends BooleanExp {
  private BooleanExp leftExp;
  private BooleanExp rightExp;
  AndExp(BooleanExp left, BooleanExp right) {
   leftExp = left;
   rightExp = right;
  }
  boolean eval(Context c) {
   return leftExp.eval(c) && rightExp.eval(c);
  }
}

// analogous definitions for OrExp and NotExp
```

Interpreter Pattern





https://www.tutorialspoint.com/design_pattern/interpreter_pattern.htm

```java
public interface Expression {
  public boolean interpret(String context);
}


public class TerminalExpression implements Expression {

  private String data;

  public TerminalExpression(String data){
    this.data = data;
  }

  @Override
  public boolean interpret(String context) {

    if(context.contains(data)){
      return true;
    }
    return false;
  }
}
```

```java
public class OrExpression implements Expression {

  private Expression expr1 = null;
  private Expression expr2 = null;

  public OrExpression(Expression expr1, Expression expr2) {
    this.expr1 = expr1;
    this.expr2 = expr2;
  }

  @Override
  public boolean interpret(String context) {
    return expr1.interpret(context) || expr2.interpret(context);
  }
}
```

```java
public class AndExpression implements Expression {

  private Expression expr1 = null;
  private Expression expr2 = null;

  public AndExpression(Expression expr1,
                       Expression expr2) {
    this.expr1 = expr1;
    this.expr2 = expr2;
  }

  @Override
  public boolean interpret(String context) {

    return expr1.interpret(context) &&
             expr2.interpret(context);
  }
}
```

```java
public class InterpreterPatternDemo {

  //Rule: Robert and John are male
  public static Expression getMaleExpression(){
    Expression robert = new TerminalExpression("Robert");
    Expression john = new TerminalExpression("John");
    return new OrExpression(robert, john);
  }

  //Rule: Julie is a married women
  public static Expression getMarriedWomanExpression(){
    Expression julie = new TerminalExpression("Julie");
    Expression married = new TerminalExpression("Married");
    return new AndExpression(julie, married);
  }

  public static void main(String[] args) {
    Expression isMale = getMaleExpression();
    Expression isMarriedWoman = getMarriedWomanExpression();

    System.out.println("John is male? " + isMale.interpret("John"));
    System.out.println("Julie is a married women? " +
        isMarriedWoman.interpret("Married Julie"));
  }
}
```

Procedural pattern

	VarExp	AndExp
evaluate		
pretty print		

```
// Classes for expressions don't have eval

class Evaluate {
  boolean evalConstExp(Constant c) {
    c.value(); // returns value of constant
  }

  boolean evalAndExp(AndExp e) {
    BooleanExp leftExp = e.leftExp;
    BooleanExp rightExp = e.rightExp;

    //Problem: How to invoke the right
    //implementation for leftExp and rightExp?
  }
}
```

Procedural pattern

	VarExp	AndExp
evaluate		
pretty print		

```
// Classes for expressions don't have eval

class Evaluate {
  Context c;
  …
  boolean evalExp(BooleanExp e) {
    if (e instanceof VarExp)
      return evalVarExp((VarExp) e);
    else if (e instanceof Constant)
      return evalConstExp((VarExp) e);
    else if (e instanceof OrExp)
      return evalOrExp((OrExp)e);
    else …
  }
}
```

What is the problem with this code?

Visitor Pattern, a variant of the Procedural pattern

- Visitor helps traverse a hierarchical structure
- Nodes (objects in the hierarchy) accept visitors
- Visitors visit nodes (objects)

```
class SomeBooleanExp extends BooleanExp {
  void accept(Visitor v) {
    for each child of this node {
      child.accept(v);
    }
    v.visit(this);
  }
}
class Visitor {
  void visit(SomeBooleanExp e) { do work on e }
}
```

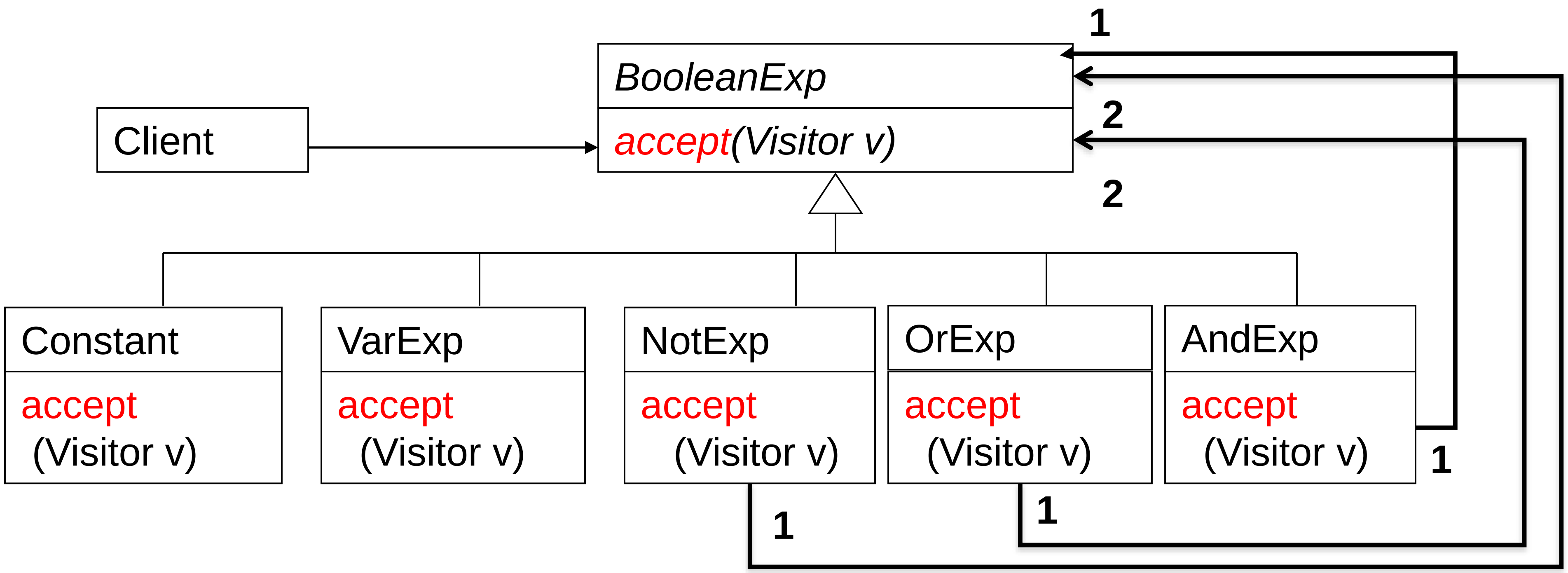
n.accept(v) traverses the structure root at **n**, performing **v**’s operation on every element

Visitor Pattern

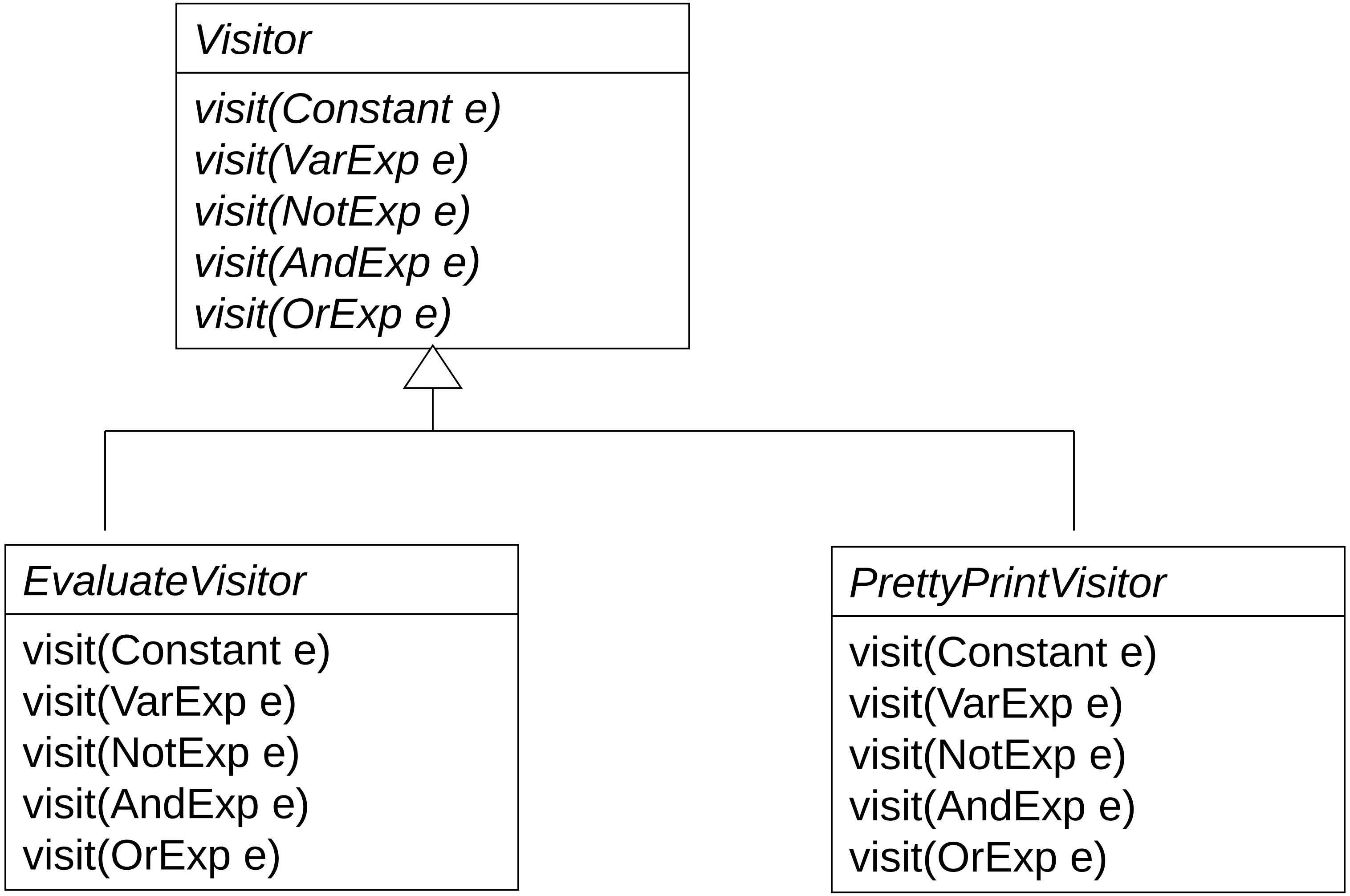
```
class VarExp extends
          BooleanExp {
 void accept(Visitor v) {
  v.visit(this);
 }
}
class AndExp extends
           BooleanExp {
 BooleanExp leftExp;
 BooleanExp rightExp;
 void accept(Visitor v) {
  leftExp.accept(v);
  rightExp.accept(v);
  v.visit(this);
 }
}
```

```
class Evaluate
  implements Visitor {
 void visit(VarExp e)
 {
  //evaluate var exp
 }
 void visit(AndExp e)
 {
  //evaluate And exp
 }
}
class PrettyPrint
  implements Visitor {
…
}
```

The Visitor Pattern



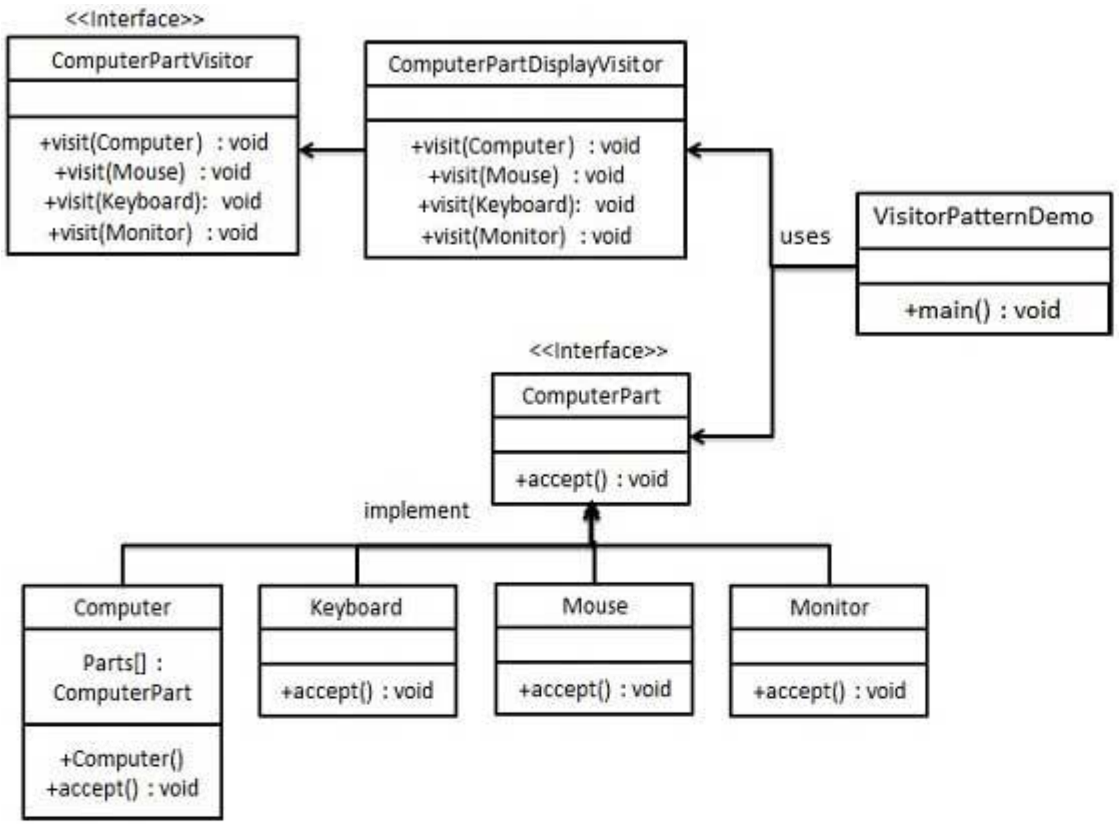
The Visitor Pattern



Visitor Pattern

- Must add definitions of visit (in Visitor hierarchy) and accept (in Object hierarchy)
- visit may do many different things: evaluate, count nodes, pretty print, etc.
- It is easy to add operations (a new Visitor class), hard to add nodes (must modify entire hierarchy of Visitors)
- Visitors are similar to iterators but different because they have knowledge of structure not just sequence

Visitor Example



https://www.tutorialspoint.com/design_pattern/visitor_pattern.htm

```java
public interface ComputerPartVisitor {
		public void visit(Computer computer);
		public void visit(Mouse mouse);
		public void visit(Keyboard keyboard);
		public void visit(Monitor monitor);
}
```

```java
public class ComputerPartDisplayVisitor
		implements ComputerPartVisitor {

  @Override
  public void visit(Computer computer) {
    System.out.println("Displaying Computer.");
  }

  @Override
  public void visit(Mouse mouse) {
    System.out.println("Displaying Mouse.");
  }

  @Override
  public void visit(Keyboard keyboard) {
    System.out.println("Displaying Keyboard.");
  }

  @Override
  public void visit(Monitor monitor) {
    System.out.println("Displaying Monitor.");
  }
}
```

```java
public interface ComputerPart {
  public void accept(ComputerPartVisitor computerPartVisitor);
}


public class Keyboard implements ComputerPart {

  @Override
  public void accept(ComputerPartVisitor computerPartVisitor) {
    computerPartVisitor.visit(this);
  }
}
// similar for monitor, mouse etc.
```

```java
public class Computer implements ComputerPart {

  ComputerPart[] parts;

  public Computer(){
    parts = new ComputerPart[] {new Mouse(),
                                new Keyboard(), new Monitor()};
  }


  @Override
  public void accept(ComputerPartVisitor computerPartVisitor) {
    for (int i = 0; i < parts.length; i++) {
      // visits each item
      parts[i].accept(computerPartVisitor);
    }
    computerPartVisitor.visit(this);
  }
```

```
public class VisitorPatternDemo {
  public static void main(String[] args) {

     ComputerPart computer = new Computer();
     computer.accept(new ComputerPartDisplayVisitor());
  }
}
```

```
Output:
Displaying Mouse.
Displaying Keyboard.
Displaying Monitor.
Displaying Computer.
```

Visitor Pattern's Double Dispatch

	VarExp	AndExp
evaluate		
pretty-print		

`myExp.accept(v)`: we want to choose the right operation

```
myExp.accept(v) // dynamically dispatch the right
  // implementation of accept, e.g., AndExp.accept
class AndExp {
    void accept(Visitor v) {
        …
        v.visit(this); // at compile-time, chooses the
    }// method family: visit(AndExp). At
}      // runtime, dispatches the right implementation of
       // visit(AndExp), e.g.,
       // EvaluateVisitor.visit(AndExp)
```

Design Patterns Summary so Far

- Factory method, Factory class, Prototype
  - Creational patterns: address problem that constructors can't return subtypes
- Singleton, Interning
  - Creational patterns: address problem that constructors always return a new instance of class
- Wrappers: Adapter, Decorator, Proxy
  - Structural patterns: when we want to change interface or functionality of an existing class, or restrict access to an object

Design Patterns Summary so Far

- Composite
  - A structural pattern: expresses whole-part structures, gives uniform interface to client
- Interpreter, Procedural, Visitor
  - Behavioral patterns: address the problem of how to traverse composite structures