Structural Patterns

Composite

Decorator

Composite

- Intent
  - Compose objects into **tree** structures to represent **part-whole** hierarchy.
  - Lets clients **treat** individual objects and composition objects ***uniformly***
- Applicability
  - Want to represent part-whole hierarchy
  - Want clients to be able **to ignore the difference** between composites and individuals

Example 1: Company Structure

- Organizational hierarchy btw Employees
  - Each worker has a manager
  - Each manager has a manager
    - Unless they are the Head of the company
- Tree structure, let's build a tree
- Not enough…

Example 1: Company Structure

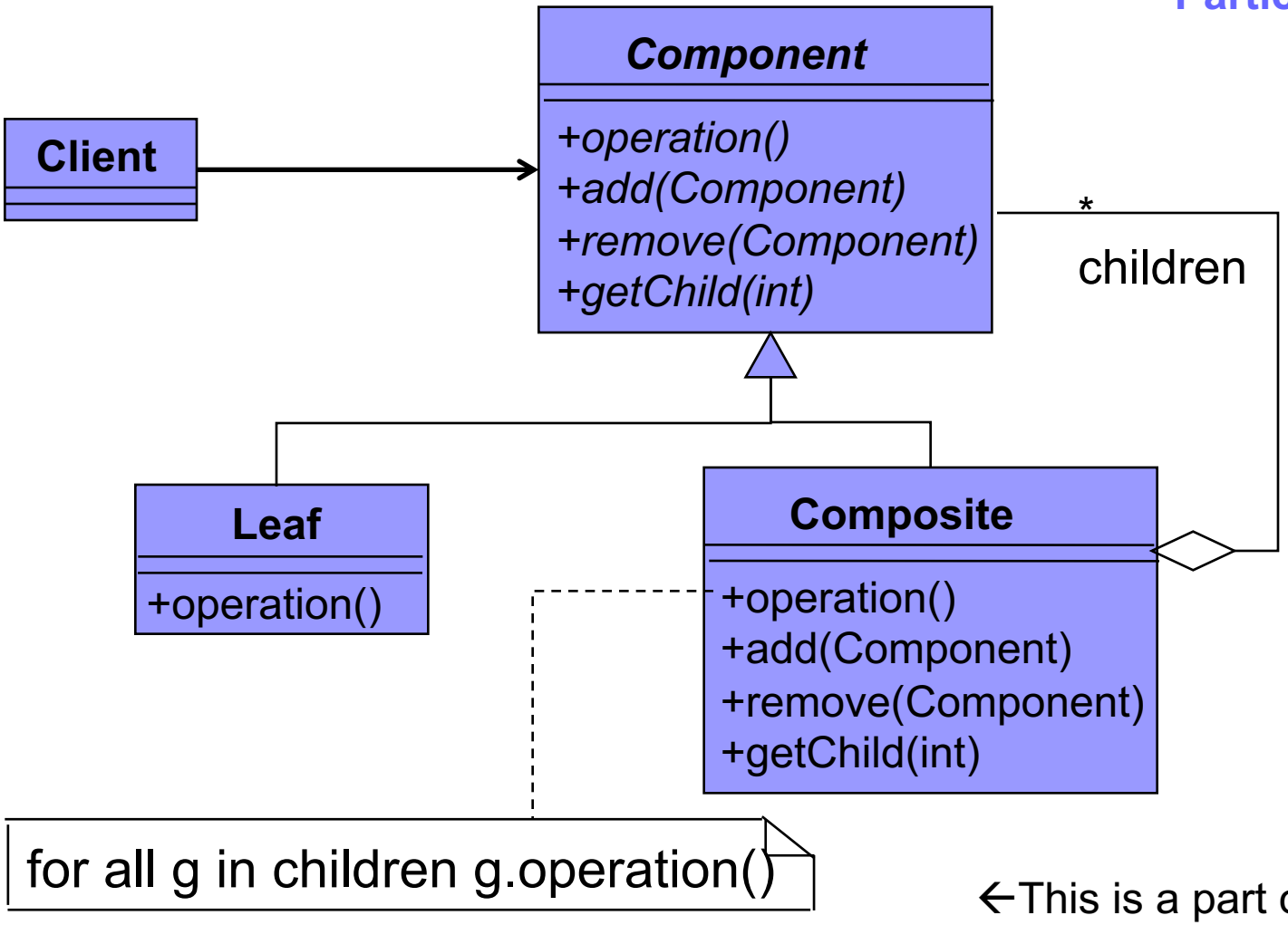
- Organizational hierarchy btw Employees
  - Each worker has a manager
  - Each manager has a manager
- Tree structure, let's build a tree
- Not enough…
- I want to apply the same operations over both composite and individual objects
  - Say "move to 2nd floor" to a worker
  - Say "move to 2nd floor" to a manager to move their people to 2nd floor

Example 1: Company Structure

- Tree structure
  - Node class which as children as other nodes
- Client code should be able to request a leaf or a node uniformly
  - employee.print()
    - prints the subtree if the employee is a manager
    - prints the worker info if the employee is not a manager
  - employee.move()
  - employee.printVacationDays()
- the primitive and composite objects are treated alike

Composite - Structure

Participants?

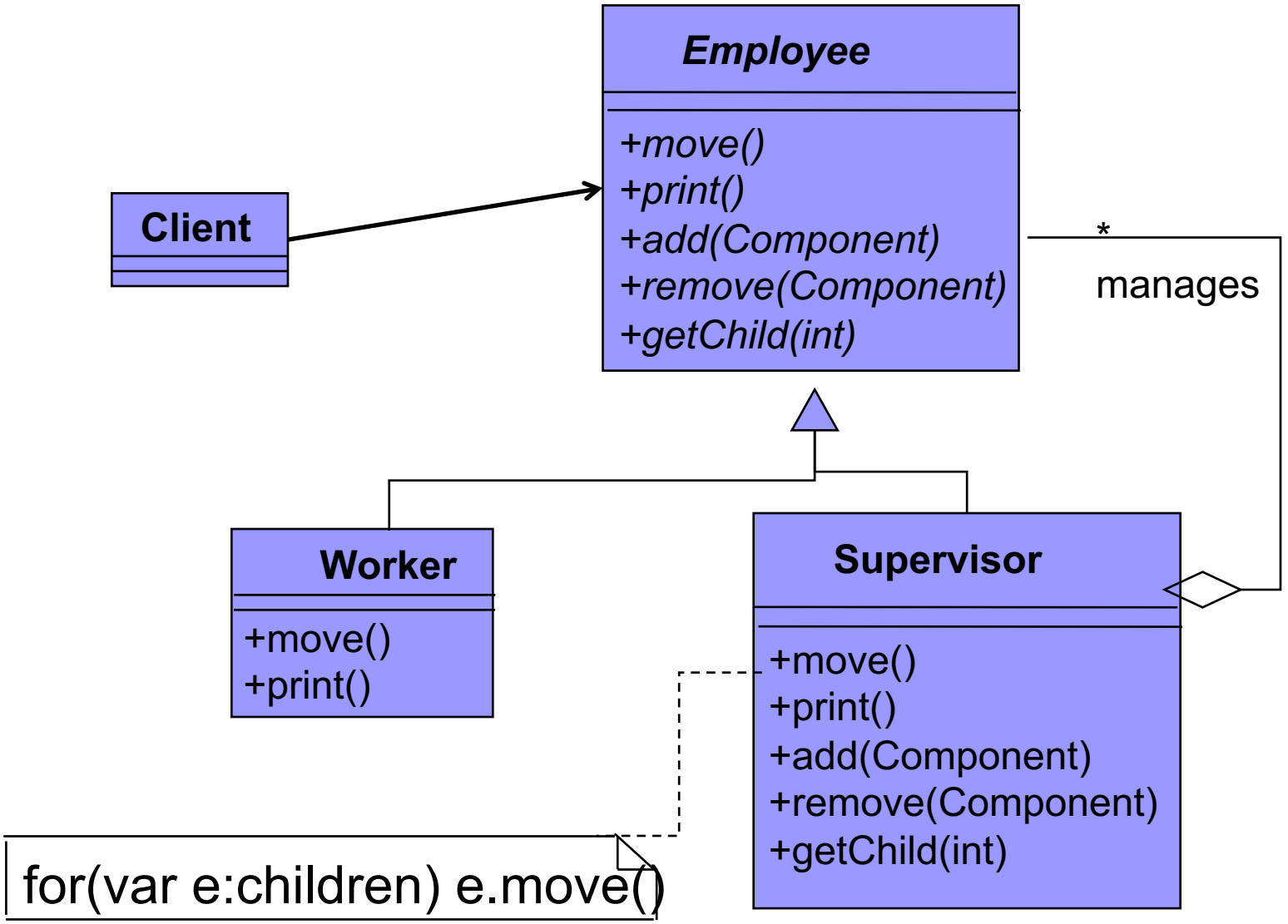


←This is a part of the pattern

Collaboration & Participants

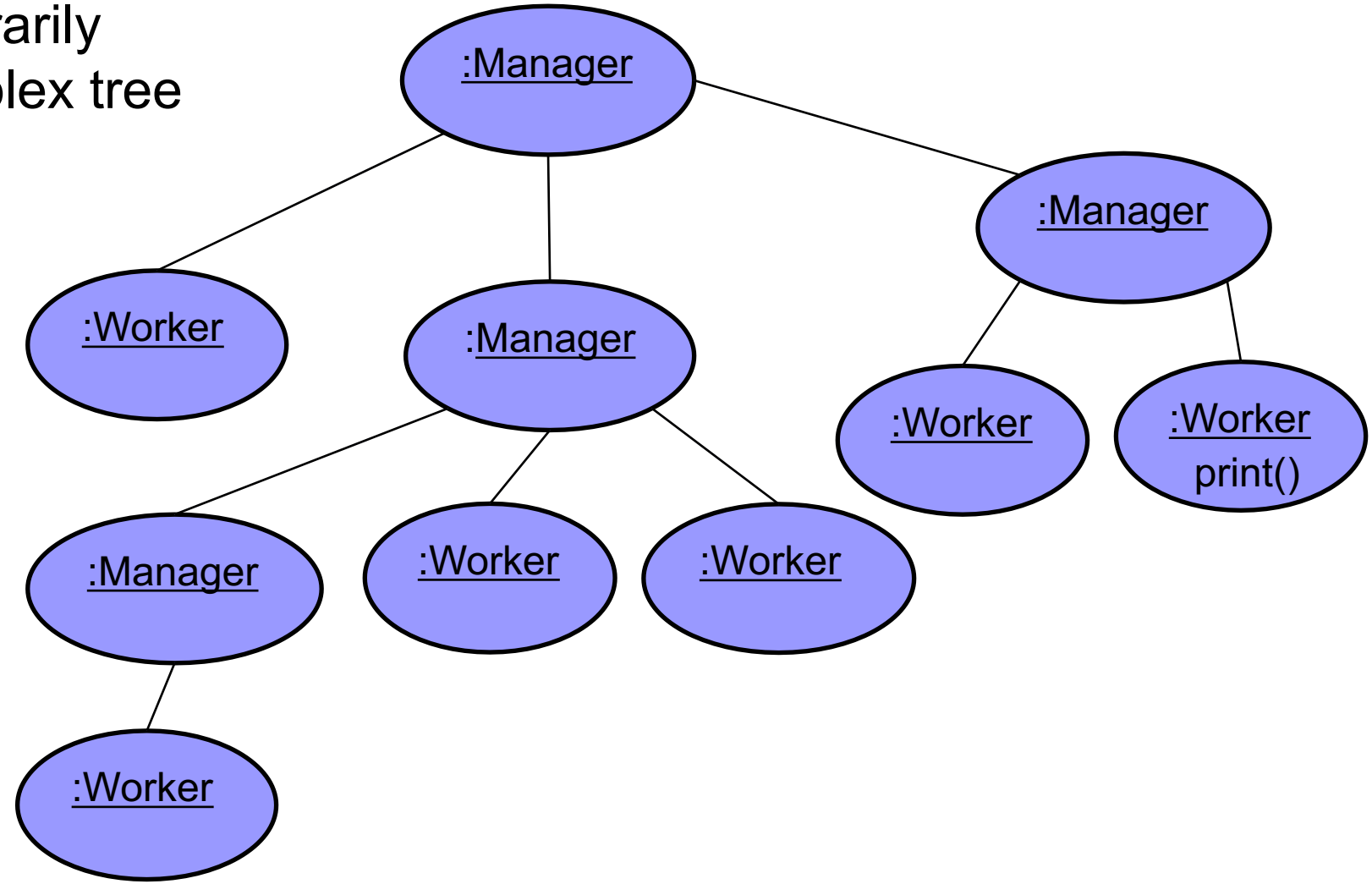
- Clients use the Component class interface to interact with objects in the composite structure.
- If the recipient is a Leaf, then the request is handled directly.
- If the recipient is a Composite, then it usually forwards requests to its child components, possibly performing additional operations before and/or after forwarding.

Composite Company



Composite company

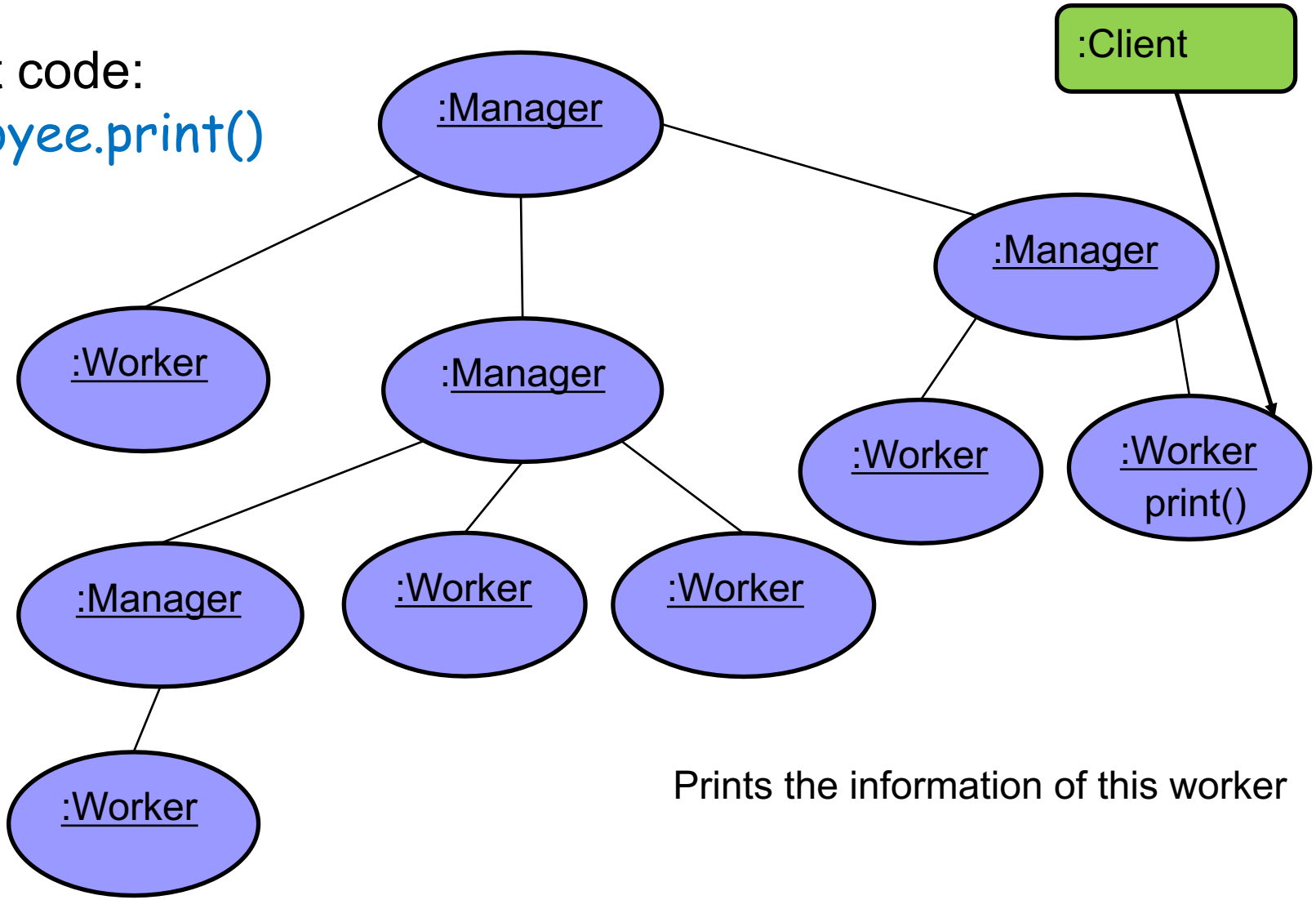
Arbitrarily complex tree



Composite company

Client code:

employee.print()

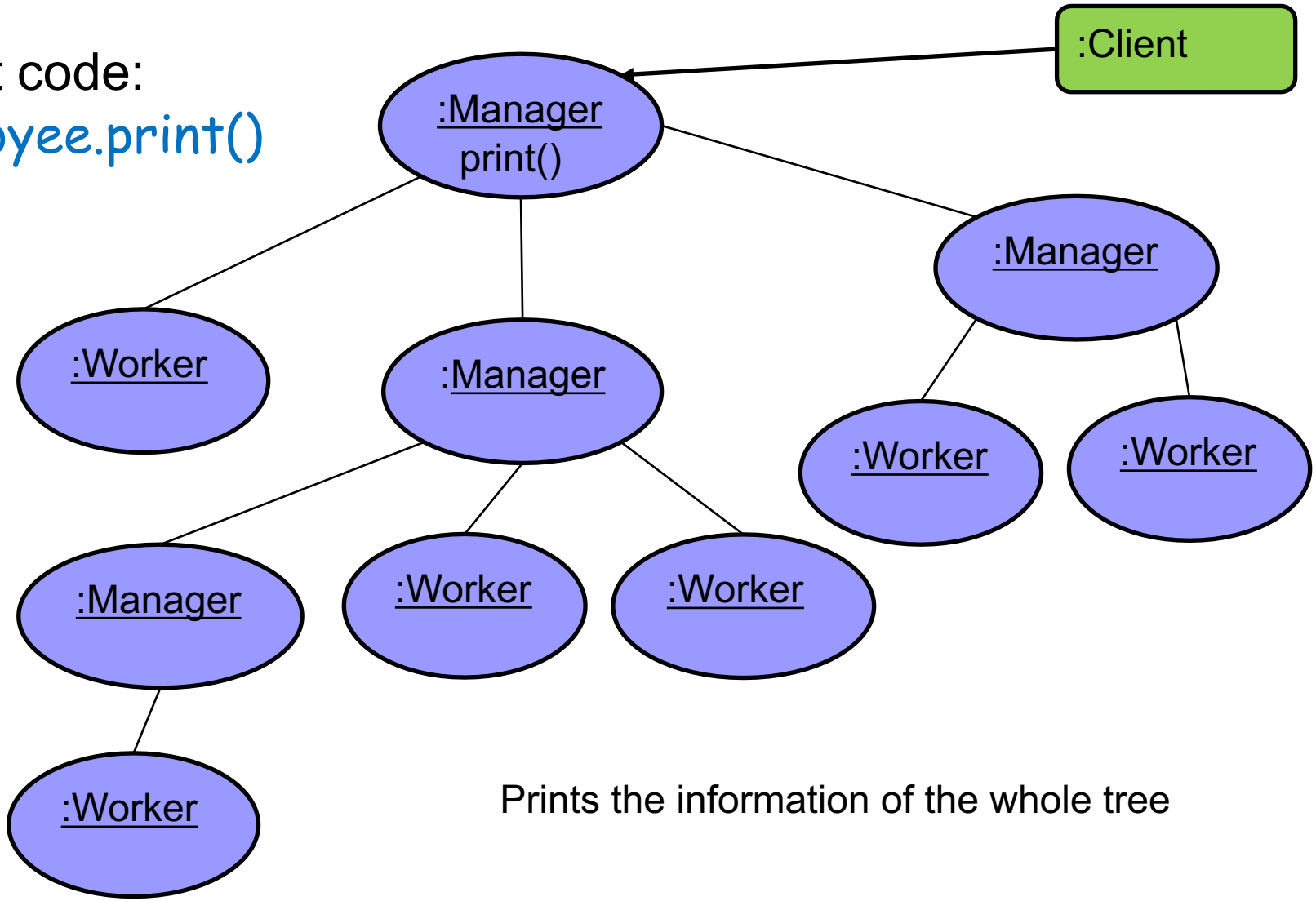


Prints the information of this worker

Composite company

Client code:

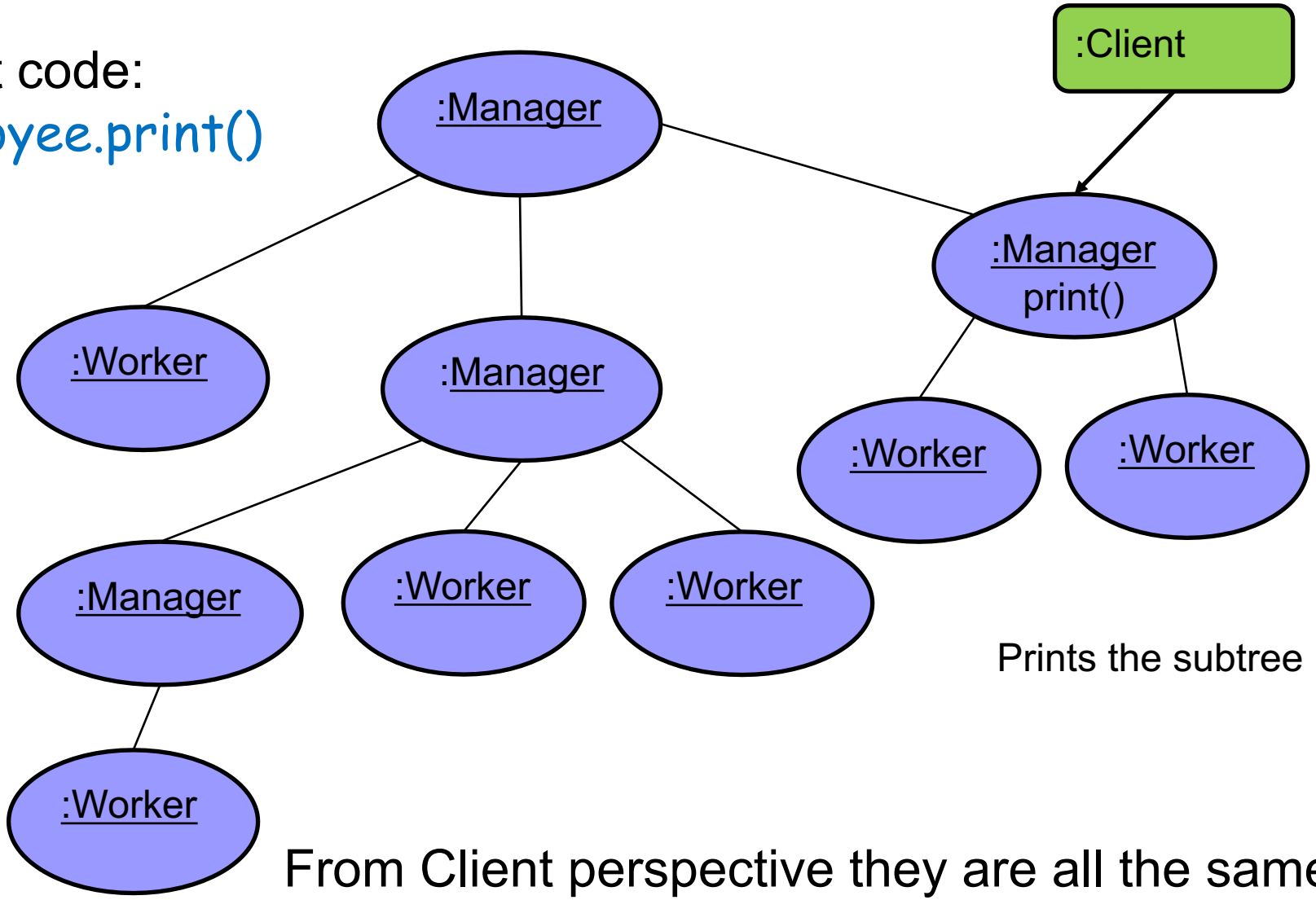
employee.print()



Prints the information of the whole tree

Composite company

Client code:
employee.print()



Prints the subtree

From Client perspective they are all the same

Sample code

```
abstract class Employee{
   abstract void print();
   void add(Component) {
        //throw exception};
   void remove(Component) {..};
   Component get(int){….};
}
class Worker extends Employee{
   private int data;
   public void print(){
        System.out.println(value);}
   public Worker(int v){ data=v;}
}
```

```
class Manager extends Employee{
   List<Employee> children;
   void add (Employee  c){
        children.add(c);}
   void remove(Employee c){
         children.remove(c);}
   Employee get(int i){
        return children.get(i);}
   void print(){
        //…print own data first, then
        for(Component c: children)
              c.print();
   }
  public Manager(int v) {data=v;/*..*/};
  private int data;
}
```

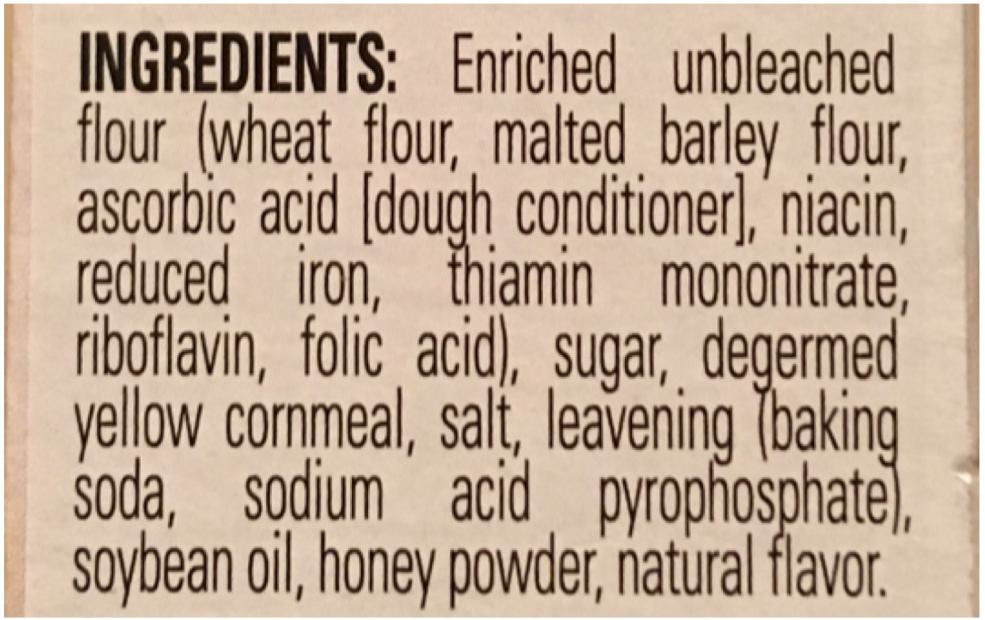
Sample client code

```
Employee example=new Manager(10);
example.add(new Worker(3));
example.add( new Manager(5).add(new Worker(2));
Employee another=new Manager();
…..
example.add(another);
….
example.print(); //print the whole structure

example.get(1).print(); //prints the whole subtree
```

A recurring problem…

- Any organizational hierarchy
- Organizing files and folders
  - Is it different to move a file from move a folder?
- Even printing ingredients☺
- Graphical User Interface frameworks



Example 2: Scenario

- A GUI system has window objects which can contain various GUI components (widgets) such as, buttons and text areas.
- A window can also contain widget container objects which can hold other widgets.
- We want to update the window and all its content for some user interactions
- Problem:
  - How to represent these widgets?
  - Update one widget or whole window
    - E.g. change the theme

Example2: Solution 1

```
public class Window {
   Button[] buttons;
   Menu[] menus;
   TextArea[] textAreas;
   WidgetContainer[] containers;
   public void update() {
      if (buttons != null)
        for (int k = 0; k < buttons.length;
              k++) buttons[k].draw();
      if (menus != null)
         for (int k = 0; k < menus.length;
              k++) menus[k].refresh();
      // Other widgets handled similarly.
     if (containers != null)
       for (int k = 0; k<containers.length;
      k++)containers[k].updateWidgets();
}
...
```

- Solution 1: Design all the widgets with different interfaces for "updating" the screen.
  - a Window update() method
- A bad solution
- violates the Open-Closed Principle.
  - If we want to add a new kind of widget, we have tomodify the update() method of Window to handle it.

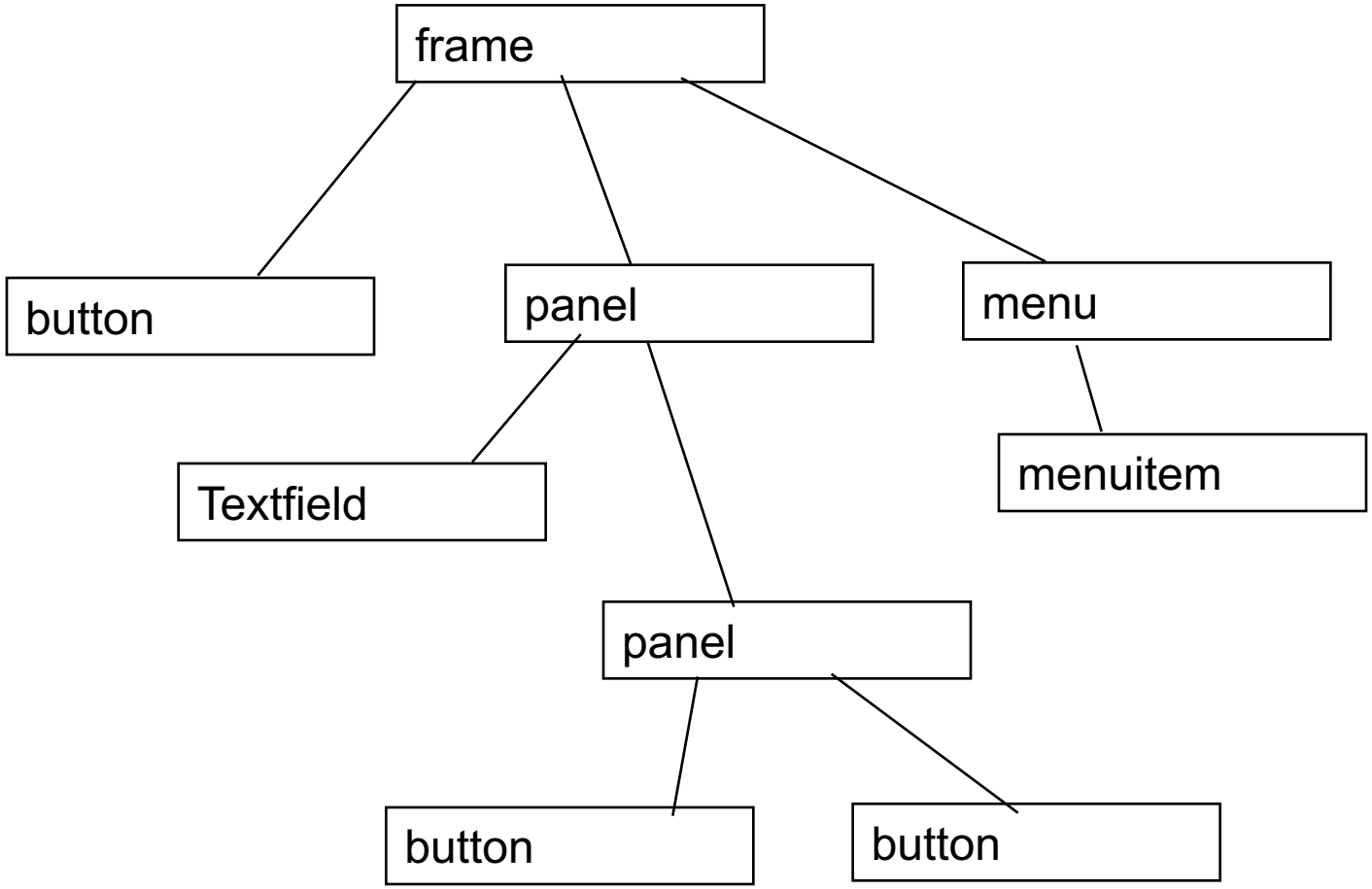
Example2: Solution 2

- Try to program to an interface. All widgets support the Widget interface,
  - subclasses of a Widget class

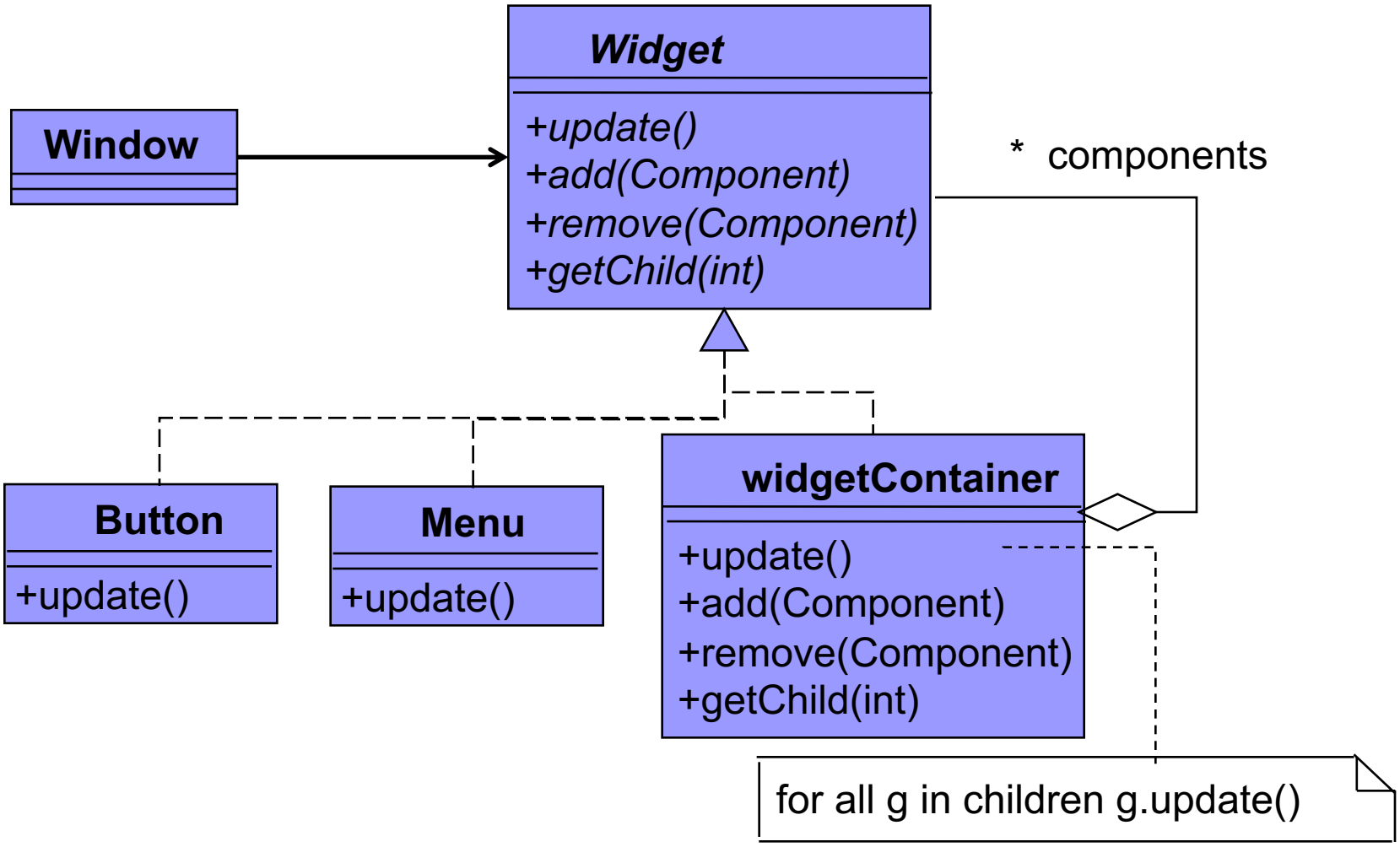
```
public class Window {
   Widget[] widgets;
   WidgetContainer[] containers;
   public void update() {
     if (widgets != null)
       for (int k = 0; k < widgets.length; k++) widgets[k].update();
     if (containers != null)
       for (int k = 0; k < containers.length; k++ )
            containers[k].updateWidgets();
}}
```

still distinguishing between widgets and widget containers

The tree of widgets and containers



Applying the Composite



Example 2 –Composite pattern soln

```
abstract class Widget{
   abstract void update();
   void add(Component) {
         //throw exception};
   void remove(Component) {..};
   Component get(int){….};
}
class Button extends Widget{
   public void update(){
         //updating this button
   }
   /*…other methods*/
}
```

```
class WidgetContainer extends Widget{
   List<Widget> children;
   void add (Widget  c){
         children.add(c);}
   void remove(Widget c){
          children.remove(c);}
   Widget get(int i){
         return children.get(i);}
   void update(){
         for(Widget c: children)
               c.update();
   }
  /*…other operations and fields*/
}
```

Sample client code

```
public class Window{
   private Widget root;
   void initialize(){….}
   /*….*/
  public void update() {
    root.update(); // updates itself and all its children
  }
}
```

Example 3: Navigation menu

- How a navigation menu looks (a sitemap)

Root
——Folder1
————————-File11
————————-File12
——Folder2
————————-File21
————————-Folder21
————————————File211
————————-Folder22
————————-Folder23
————————————File231
——Folder3

- We only want to show those links to user which he is authorized to view.
- if all the links in a category are not visible then the category itself will not be visible.
- Operations: isAuthorized() and display()

Draw a class diagram…

http://www.zapbuild.com/bitsntricks/composite-design-pattern/

Component responsibilities

1. Its own responsibility
   - i.e. leaf operations
   - e.g. employee methods
2. Child management
   - add(), remove(), getChild()

- Trading *single responsibility* for uniform access

Implementation issues-1

- Where should the child management methods (add(), remove(), getChild()) be declared?
  - In the Component class: Gives transparency, since all components can be treated the same. But it's **not safe**, since clients can try to do meaningless things to (add, remove) leaf components at run-time.
    - Add/remove fail by default, the composite overrides them
    - Add/remove does nothing, the composite overrides them
  - In the Composite class: Gives safety, since any attempt to perform a child operation on a leaf component will be caught at compile-time. But we **lose transparency**, since now leaf and composite components have different interfaces.

Implementation issues-1

- In the Component class
  - Interpret the leaves as components with 0 child.
  - If we view a Leaf as a Component that *never* has children, then we can define a default operation for child access in the Component class that never returns any children.
  - Leaf classes can use the default implementation,
    - Throw exception by default
    - Do nothing by default
    - Return null or false
  - Composite classes will reimplement it to return their children, add or remove children

Implementation issues-1

- In the Composite class
  - Leaf and composite components have different interfaces
  - Requires the client to check the type of every object before making a call so the object can be cast correctly.
    - Uniformity is traded for safety

Implementation issues-2

- Should components maintain a reference to their parent component?
  - Depends on application
  - If needed, put the parent reference in the *Component* class
    - Add and Remove operations handle the parent reference
  - Suppose we have a reference to a child and need to delete it.
    - We must get the parent to remove the child.
    - Having the parent reference makes that easier.
  - Having parent references supports the Chain of Responsibility pattern (later)

Composite Pattern with Parent: C++

```
class Component{
 public:
  virtual ~Component() {}
  virtual void add(Component *component) {}
  virtual void remove(Component *component) {}
  virtual Component *get(int i) const {return 0;}
  void setParent(Component *parent) {
      this->parent_ = parent;  }
  Component *getParent() const {
      return this->parent_;
  }
 virtual std::string operation() const = 0;
 protected:  Component *parent_;
};
```

```
class Leaf : public Component {
 public:
  string operation() const override {
     return "Leaf";  }
};
```

Composite Pattern with Parent: C++

```
class Composite : public Component {
protected:   std::vector<Component *> children_;
public:
  void add(Component *component) override {
      this->children_.push_back(component);
      component->setParent(this);}
void remove(Component *component) override {
    children_.remove(component);
    component->setParent(0);   } //assuming no sharing
std::string operation() const override {
    std::string result;
    for (const Component *c : children_) {
       result += c->operation() + " ";      }
     return result;}
  };
```

Implementation issues-3

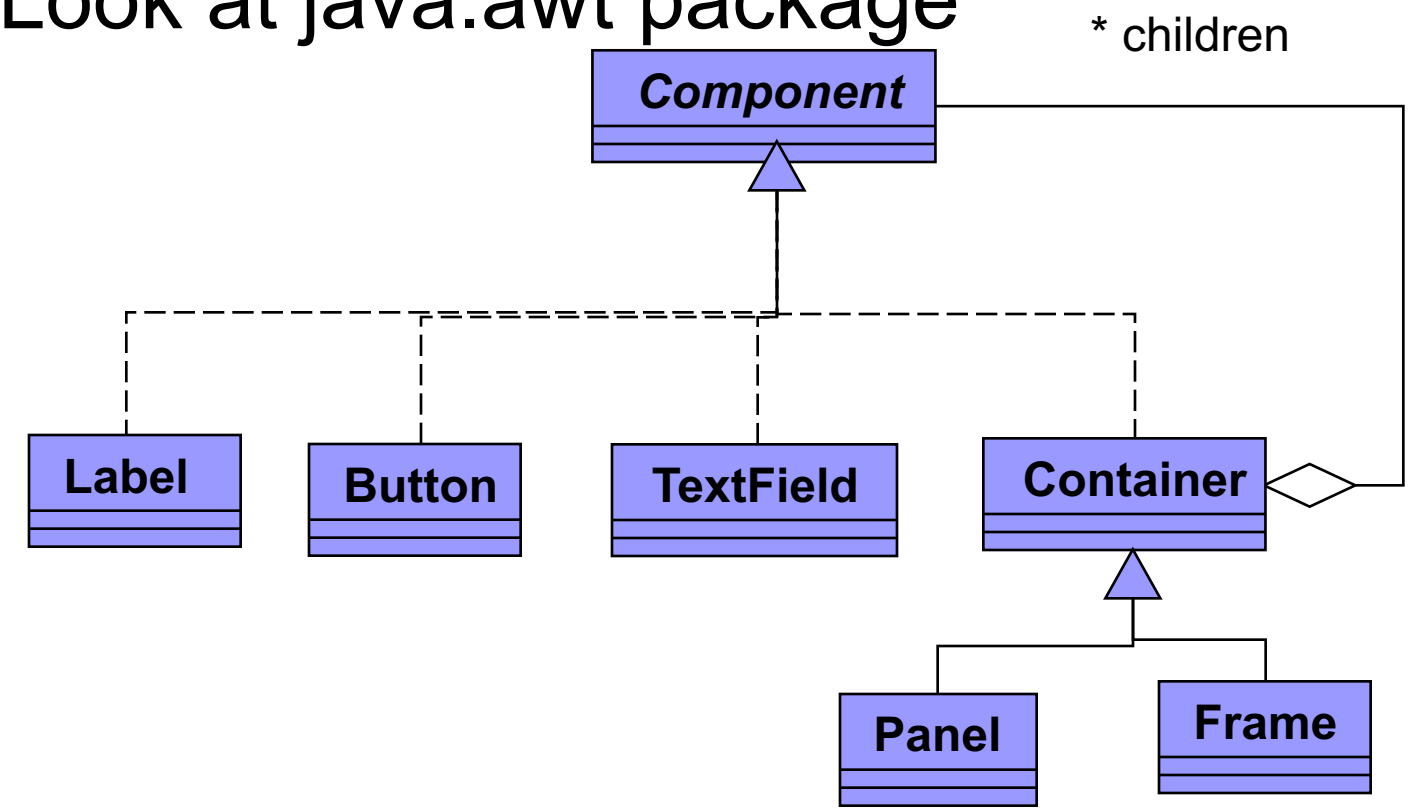
- Should Component maintain the list of components that will be used by a composite object?
  - Should children list be an instance variable of Component rather than Composite class?
  - Better to keep this part of Composite and avoid wasting the space in every Leaf object
- Is child ordering important?
  - Depends on application:
    - parse tree, graphics front-to-back order

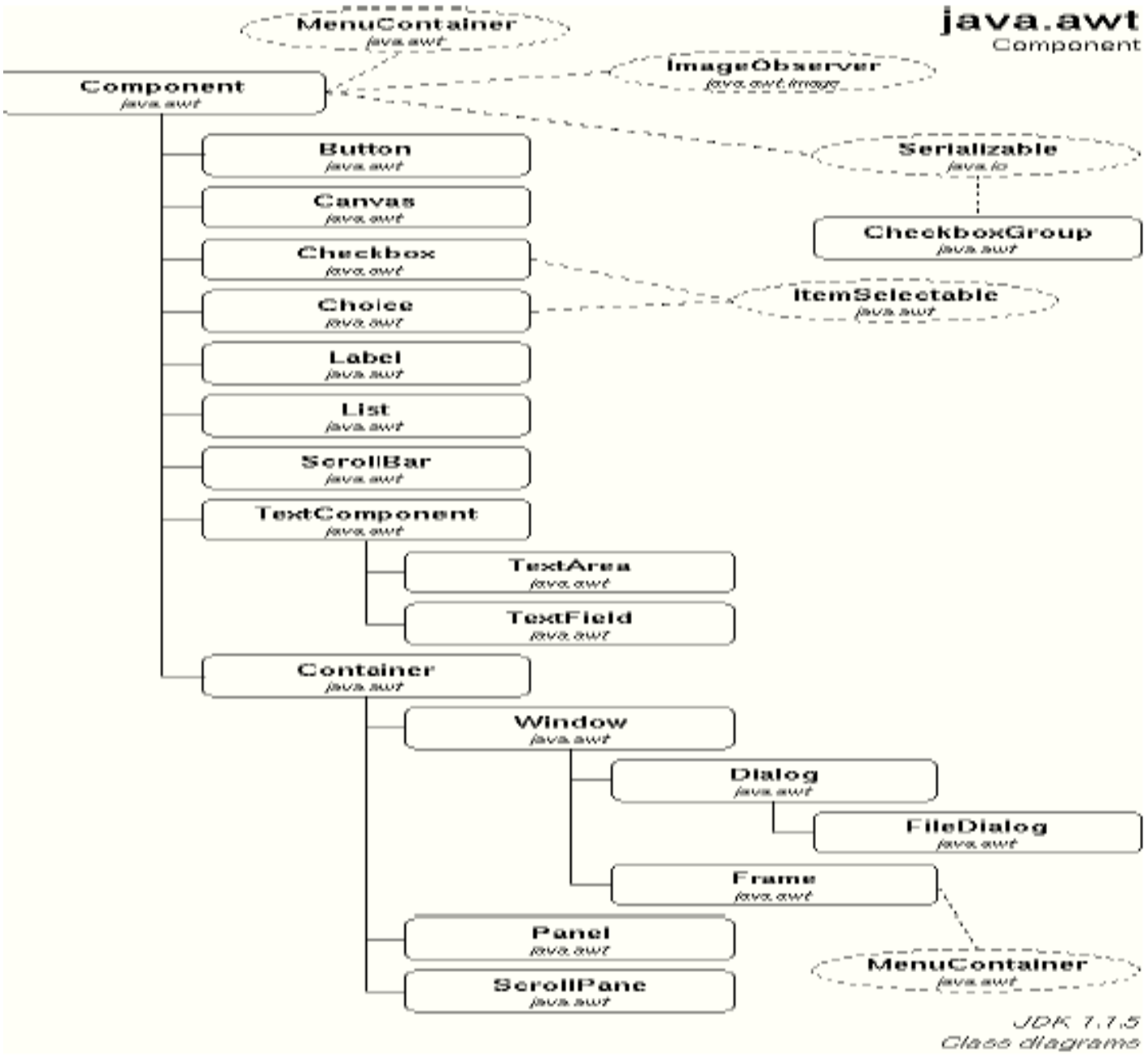
Implementation issues-4

- Sharing components to remove redundancy
  - When components have reference to their parents, it gets tricky
- Who should delete a component?
  - If there is garbage collection, like Java, this is not an issue
  - Composite deletes its children when destroyed
    - Destructor of Composite calls destruct for all children
  - Careful when components are shared by multiple composites

Composite –Known uses

- GUI frameworks
- Web page layouts
- Look at java.awt package




java.awt
Component
MenuContainer
java.awt
Component
java.awt
ImageObserver
java.awt.image
Serializable
java.io
Button
java.awt
Canvas
java.awt
Checkbox
java.awt
CheckboxGroup
java.awt
Choice
java.awt
ItemSelectable
java.awt
Label
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List
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TextComponent
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TextArea
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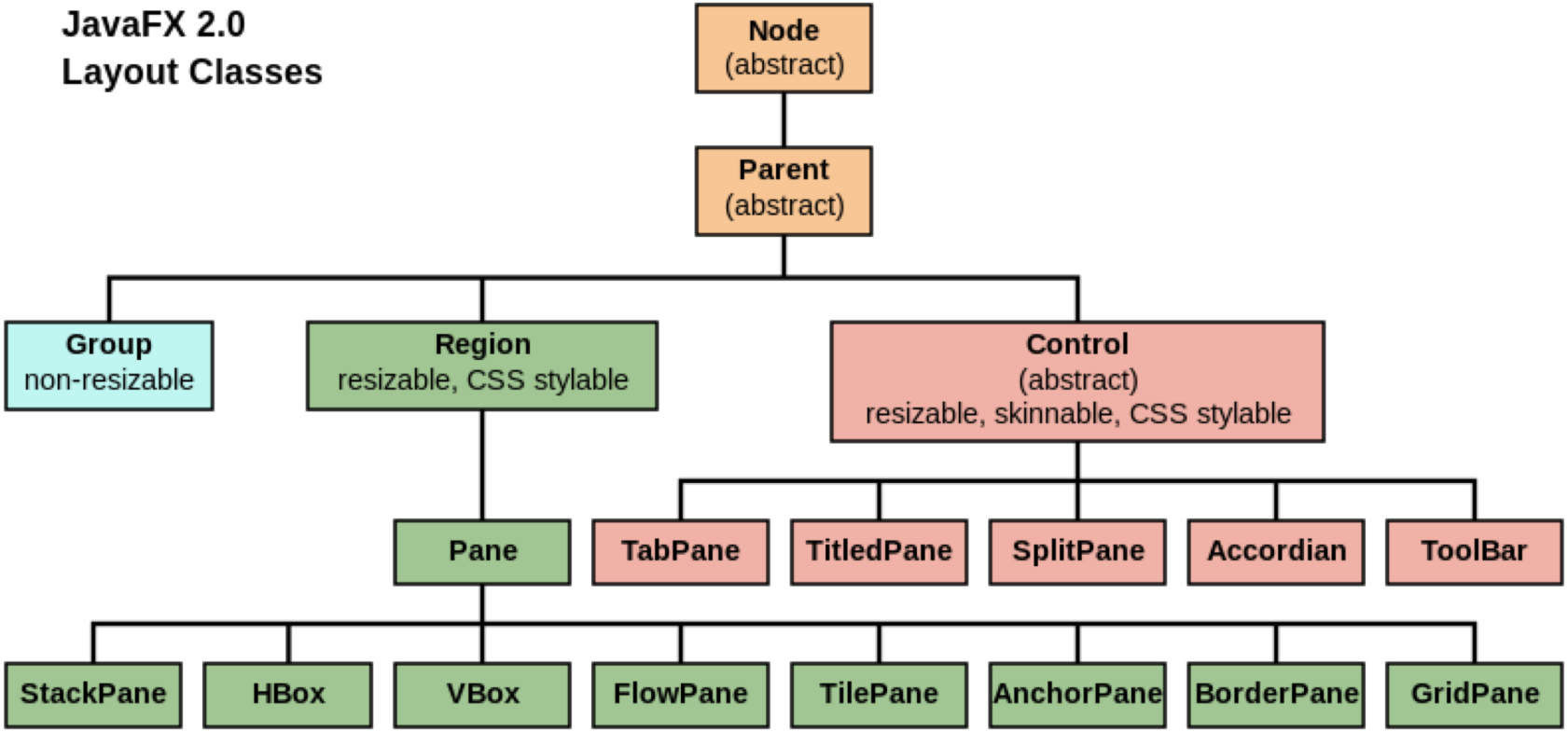
TextField
java.awt
Container
java.awt
Window
java.awt
Dialog
java.awt
FileDialog
java.awt
Frame
java.awt
Panel
java.awt
ScrollPane
java.awt
MenuContainer
java.awt
JDK 1.1.5
Class diagrams

JavaFX 2.0
Layout Classes



Composite - Consequences

- Defines class hierarchies consisting of primitive and composite objects
- Clients can treat composite structures and individual objects uniformly
  - Simpler clients, no case-based handling
  - Client can make one method call and execute an operation over an entire structure.
- Easier to **add** new kinds of components
- Makes it **harder** to restrict the components of a composite.You have to check the constraints on runtime

DECORATOR

Motivation

- Sometimes we want to add responsibilities to individual objects, not to an entire class
  - E.g. I want to add scrollbar to a TextArea
- We can do this with inheritance, but it limits our flexibility.
  - How to add and withdraw scrollbar whenever necessary?
  - Change the type of the object at runtime?
  - Later, I want to add border to some TextArea objects
  - Too many subclasses!
- A better way is to use object composition!

Question

- What if I put flags for each add-on
  - isScroolbar, isBorder,…..
  - Loosing advantage of object orientation
  - Violates which principle?
- No more class explosion
- I can withdraw scrollbar by setting the flag to false
- Not a good idea

Object composition

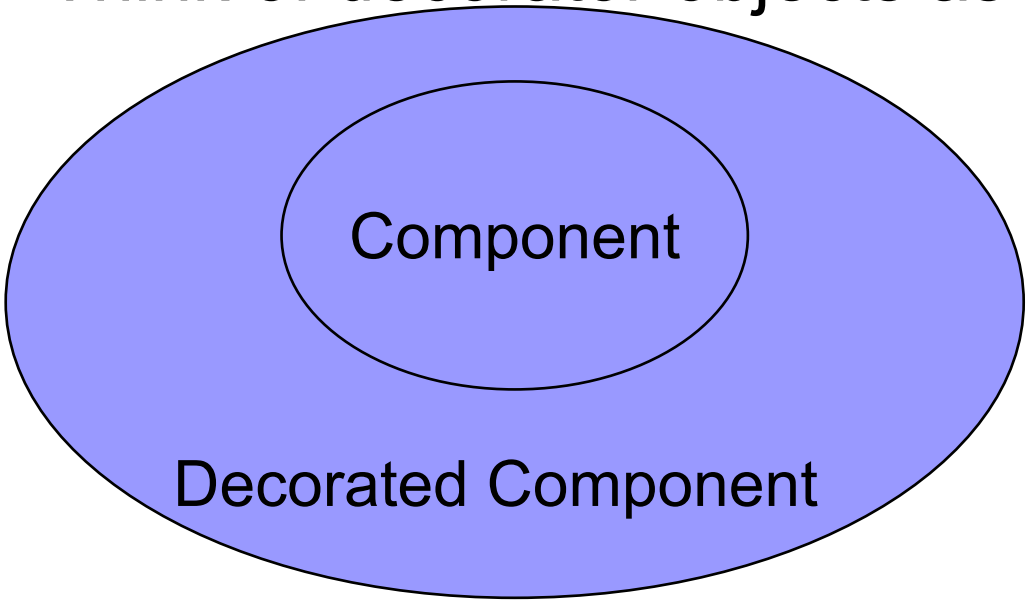
- TextArea and Border. Who composes whom?
  - TextArea contains Border
    - Must modify subclasses, if any, to make it aware of the border.
  - Border contains TextArea
    - keeps the border-drawing code entirely in the Border class, leaving other classes alone.
- What does the Border class look like?
  - Clients should not care whether TextArea objects have borders or not.
  - Border and TextArea have the same interface
- Border is decorating the TextArea

Decorator

- Intent
  - Attach additional responsibilities to an object dynamically
  - a.k.a. Wrapper
- You'll be able to give objects new responsibilities without changing the client code

Decorator is a Wrapper

Think of decorator objects as “wrappers.”

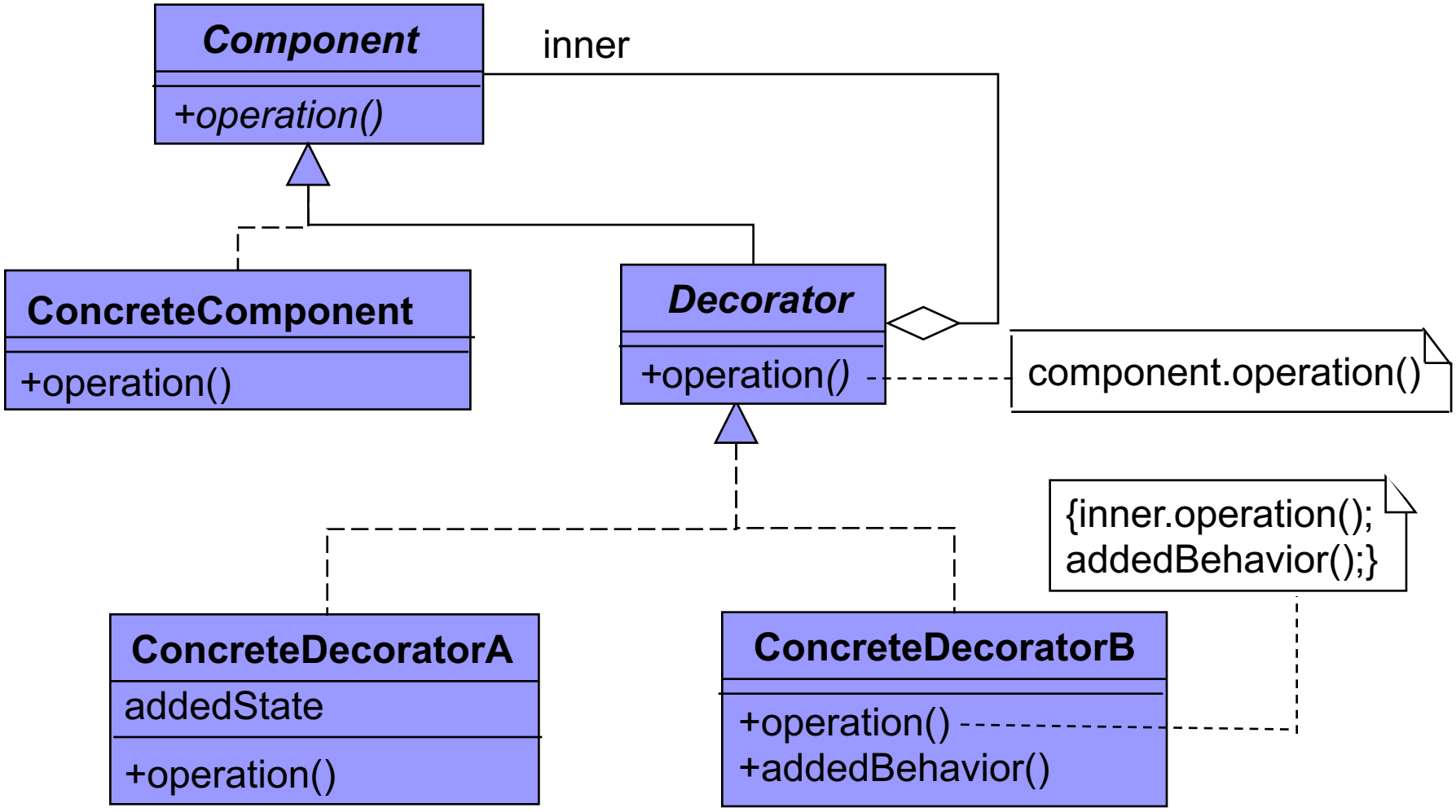


Wrapping additional responsibility

Wrapping with composition

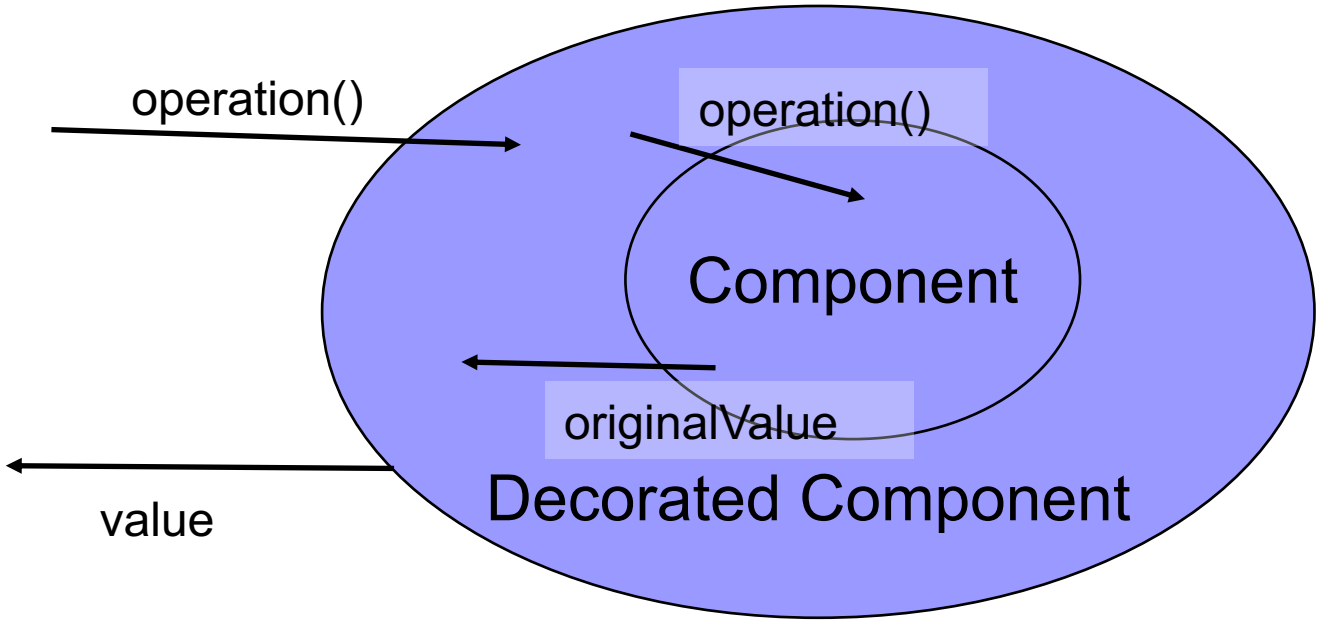
Decorator -Structure

Participants?



Key points

- Decorator forwards requests to its Component object.
- A concrete decorator executes its behavior **before or after** the call to the parent method
  - which always delegates to the wrapped object



Decorator is a **Wrapper**

Key points

- Decorator forwards requests to its Component object.
- A concrete decorator executes its behavior **before or after** the call to the parent method
  - which always delegates to the wrapped object

- We can pass around a decorated object in place of the original (wrapped) object.
  - Decorators have the same supertype as the objects they decorate.
- Objects can be decorated at any time
  - We can decorate objects dynamically at runtime with as **many** decorators as we like

Key points

- We can use one or more decorators to wrap an object.

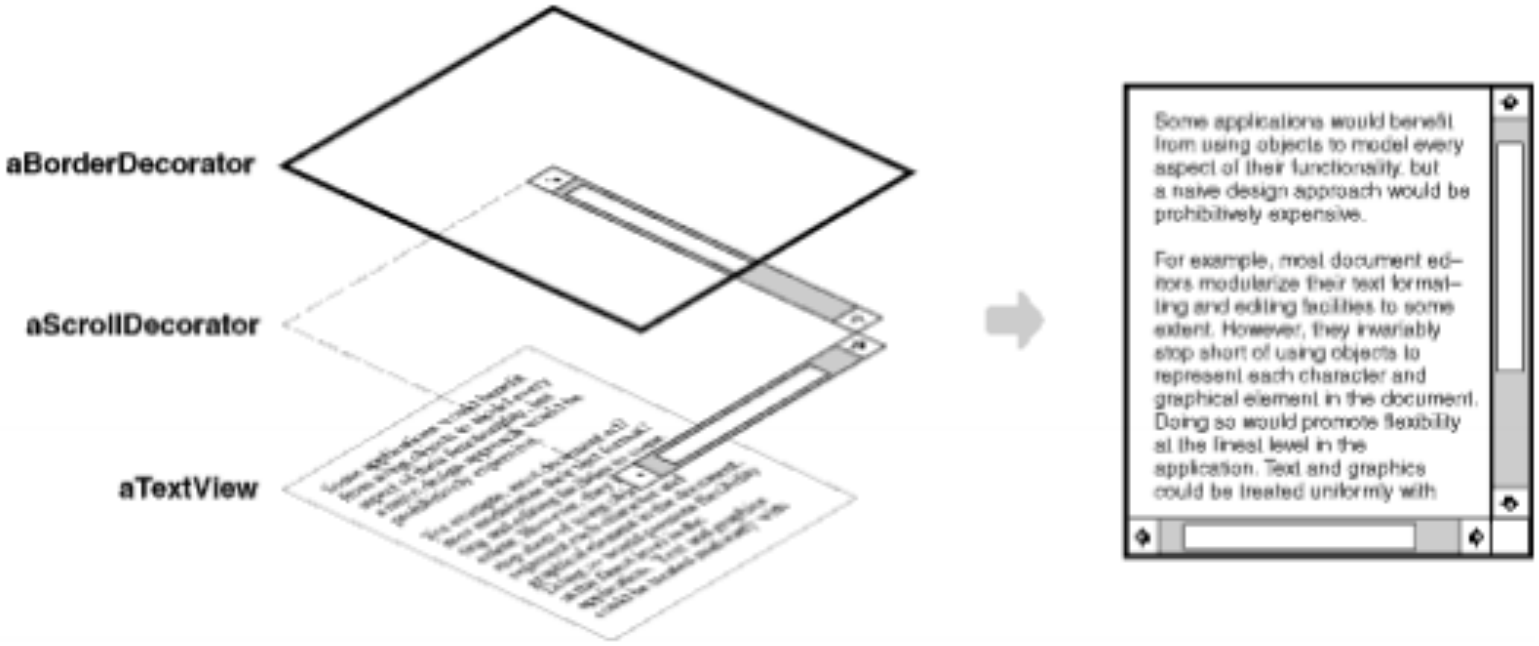
- Chaining decorators is like layering logic
  - We can structure the business logic into layers,
  - create a decorator for each layer and compose objects with various combinations of this logic at runtime.
  - The client code can treat all these objects in the same way, since they all follow a common interface.

Decorator

- Intent
  - Attach additional responsibilities to an object dynamically.
- Applicability
  - Need to add responsibility to individual objects ***dynamically*** and without affecting others
  - Need to add responsibilities ***that can be withdrawn***
  - Allow behavior to extend **without modifying or** breaking the code that uses these objects.
  - When extension by subclassing is impractical
    - Class definition may be hidden
    - Large number of independent extension will result subclass explosion

Example 2: Decorating with borders and scrollbars

- Scrollbar will be added whenever necessary



Draw a class diagram

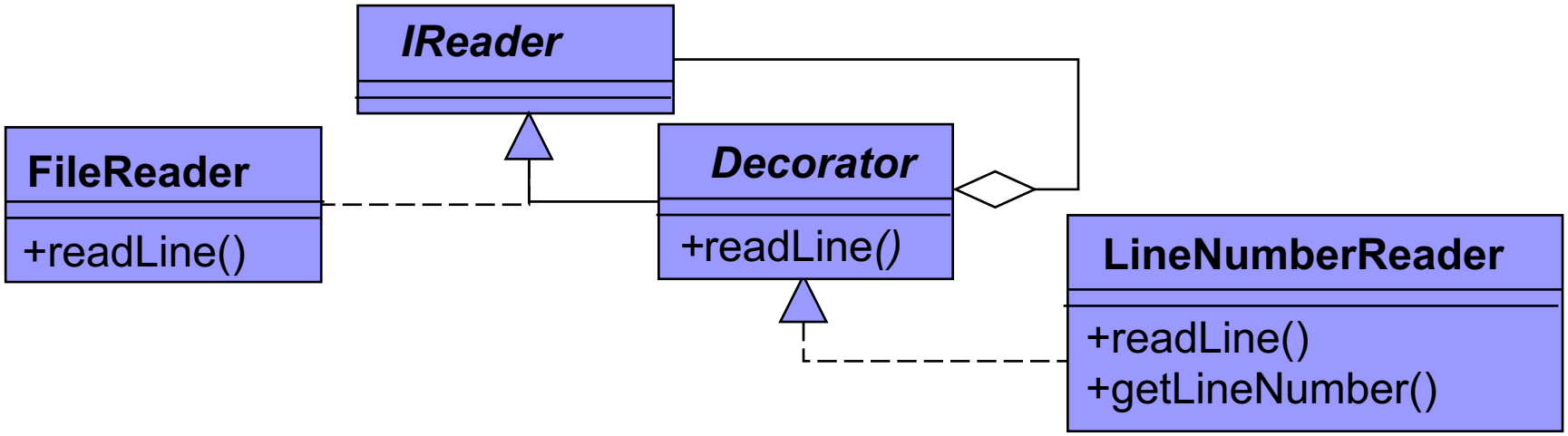
```
class Widget{
  public: virtual void draw() = 0;
};
class TextView: public Widget{
    int width, height;
  public:
    TextView(int w, int h)
            :width(w),height(h){}
    virtual void draw(){/*actual draw*/   }
};
class Decorator: public Widget {
    Widget *wid;
  public:
    Decorator(Widget *w): wid(w){}
    virtual void draw(){
       wid->draw(); //  Delegation
    }
};
```

```
class BorderDecorator: public Decorator{
  public:
    BorderDecorator(Widget *w): Decorator(w){}
    void draw(){
       Decorator::draw();
       cout << “after--BorderDecorator" << '\n';
    }
};

class ScrollDecorator: public Decorator{
  public:
   ScrollDecorator(Widget *w): Decorator(w){}
   void draw(){
      cout << " before-- ScrollDecorator" << '\n';
      Decorator::draw();
      }
};
```

Write a client that builds a double bordered textview with a scrollbar.

Example 3:

- We have a FileReader implementing a Reader interface
- but sometimes we want to read the number of lines in a file
- Decorate FileReader with LineNumberReader



Example 3: LineNumberReader

```
abstract class Decorator implements Reader{
   private Reader innerObject;
   public Decorator(Reader r){innerObject=r;}
   public String  readline(){ innerObject.readLine();}
}
class LineNumberReader extends Decorator{
   int counter;
   public LineNumberReader(Reader inner){ super(inner);}
   public String  readline(){ super.readLine(); counter++;}
   public int getLineNumber(){return ccounter;}
}
```

- Client code

```
FileReader fr=new FileReader(filename);
LineNumberReader lrdr = new LineNumberReader(fr);
```

Implementation issues

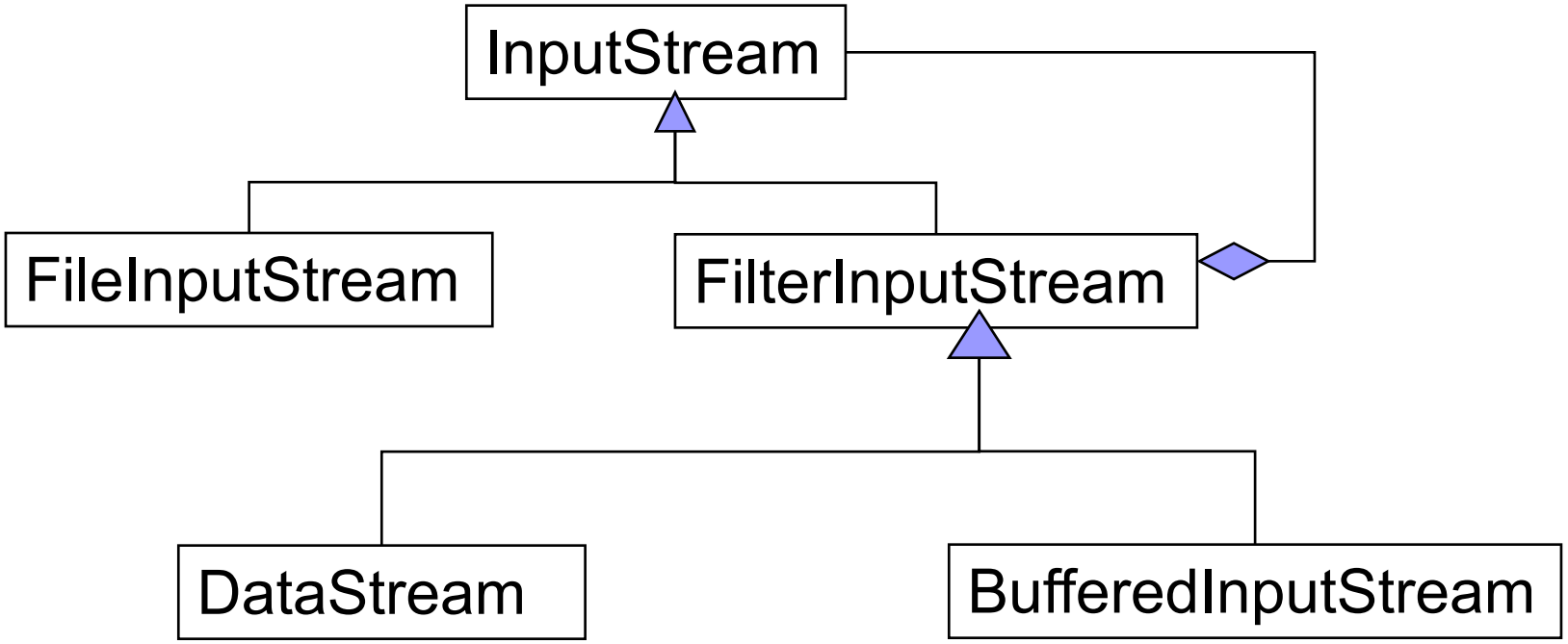
- Keep Component lightweight
  - Java interface, C++ pure virtual
  - concrete class should not pay for features they do not need
  - Intrinsically heavyweight Component makes the Decorator pattern too costly to apply.
- Adding only one responsibility, abstract decorator may be overkill
  - Forwarding the request is in the concrete one
- Decoration order do matter

Known Uses

- X Window use Decorators to add a title bar, border, and scroll bars to a window
- The java.io package
  - FileInputStream is wrapped with BufferedInputStream
  - Further wrapped with LineNumberInputStream
  - Both wrappers extend FilterInputStream (abstract decorator)

Know use

- java.io.InputStream structure



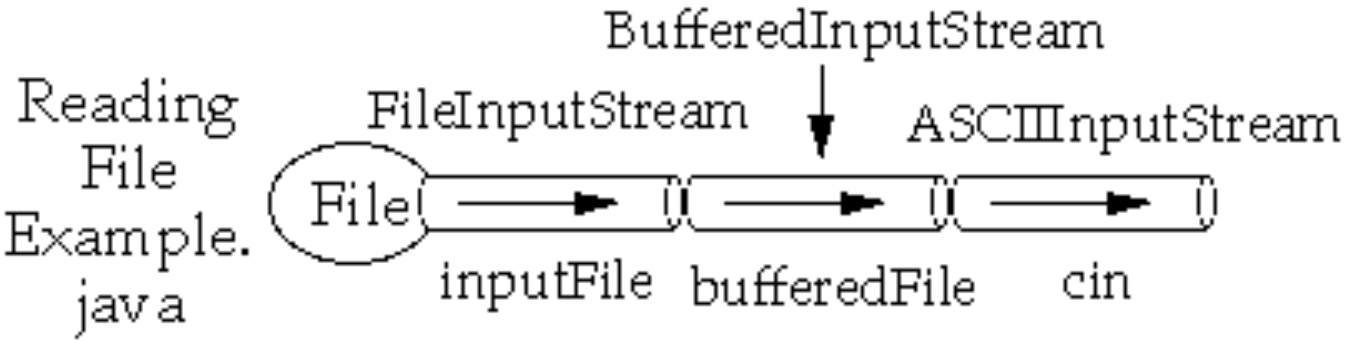
Known use: java.io package

- The basic I/O classes are InputStream, OutputStream, Reader and Writer
- Decorations:
  - Buffered Stream - adds buffering for the stream
  - Data Stream - allows I/O of primitive Java data types
  - Pushback Stream - allows undo operation

Example decoration chaining

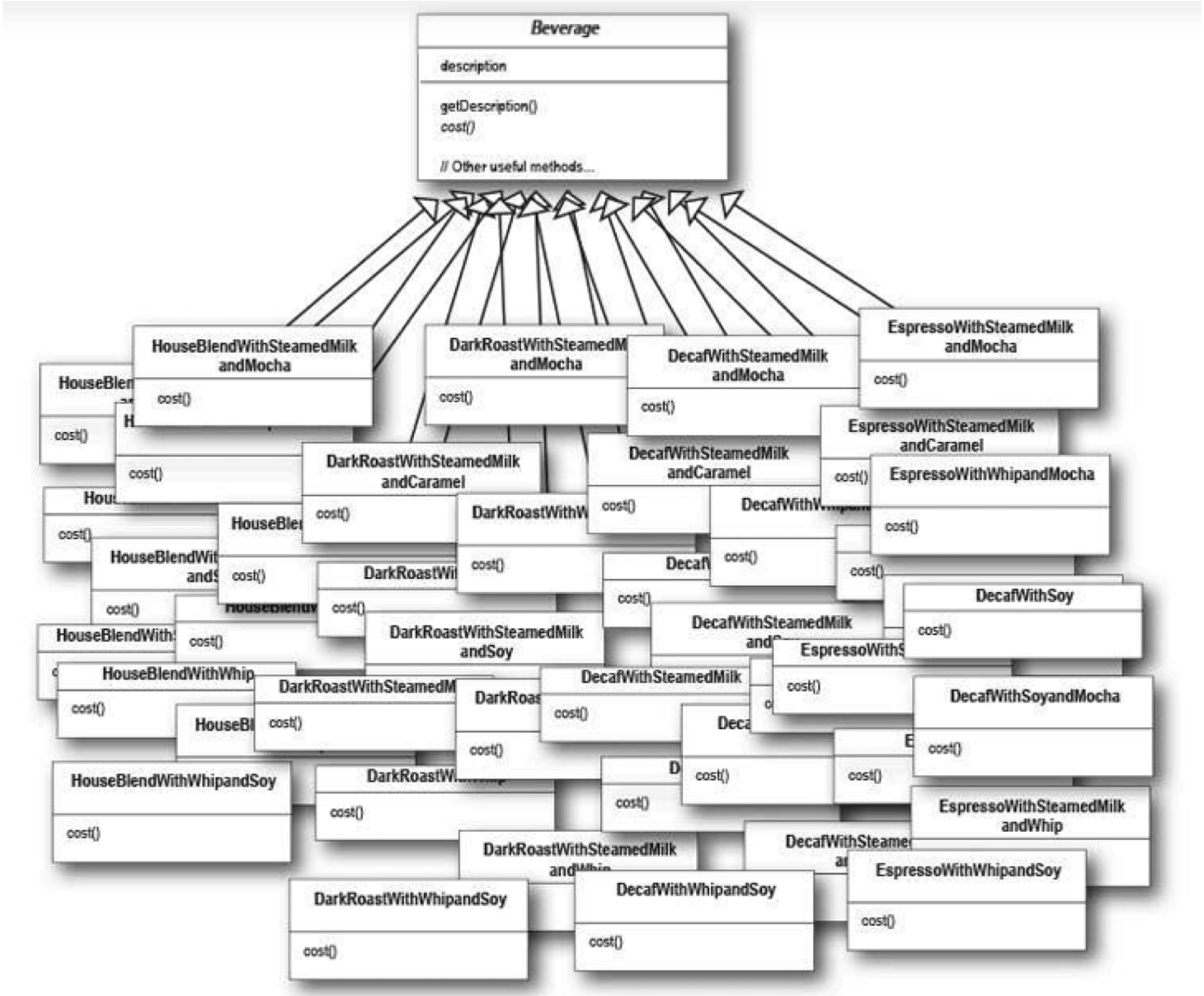
```
public class JavaIO {
 public static void main(String[] args) {
    // Open an InputStream.
    FileInputStream in = new FileInputStream("test.dat");
   // Create a buffered InputStream.
     BufferedInputStream bin = new BufferedInputStream(in);
    // Create a buffered, data InputStream.
    DataInputStream dbin = new DataInputStream(bin);
    // Create an unbuffered, data InputStream.
    DataInputStream din = new DataInputStream(in);
    // Create a buffered, pushback, data InputStream.
     PushbackInputStream pbdbin = new PushbackInputStream(dbin);


   }
 }
```

```
class  ReadingFileExample     {
  public  static  void  main( String  args[]  ) throws Exception
{

      ASCIIInputStream  cin =new ASCIIInputStream(
            new BufferedInputStream (
              new FileInputStream( "ReadingFileExample.java" );

       System.out.println(  cin.readWord()  );
       for  ( int  k = 1 ; k< 4;k++ ) System.out.println(
cin.readLine()  );
    }
 }
```



Decorator – Consequences: Pro

- Flexible **alternative** to **inheritance** for extending functionality
  - Adding/removing responsibility at runtime
  - Mix and match responsibilities
  - Decorators are simple and stackable
  - Avoid class explosion due to inheritance



Source: Head First Design Patterns. Reading this chapter is advised

Decorator – Consequences: Pro

- Flexible alternative to inheritance for extending functionality
  - Adding/removing responsibility at runtime
  - Mix and match responsibilities
  - Decorators are simple and stackable
- Avoids complex classes high up in the hierarchy
  - Keep base simple, Add functionality incrementally
    - a client need not pay for features it does not use.
  - Easy to extend, no need to crowd the base
    - Extending a complex class tends to expose details unrelated to the responsibilities being adding.
- Enables Single Responsibility
  - divide a monolithic implementing many possible variants of behavior into several smaller ones.

Decorator – Consequences: Cons

- Do not rely on identity check
  - They have the same interface, but decorated object is not identical to the object itself.
- Lots of little objects that all look alike
  - Differ only the way they are connected
  - Hard to understand the design and hard to debug
  - Be cautious!
- Initial configuration is ugly ☺
  - See Java I/O

Decorator-Related Patterns

- **Adapter** *modifies* an objects interface.
  - Decorator only alters an objects behaviors while maintaining the interface.
- **Composite:** Decorator looks like a degenerate composite, but the intention is different
  - Object aggregation vs adding responsibilit
- **Proxy**: wrapping objects for different Intent
- Strategy : Change the skin vs change its guts

(later)