Introduction to Software Technology
5. Design Patterns

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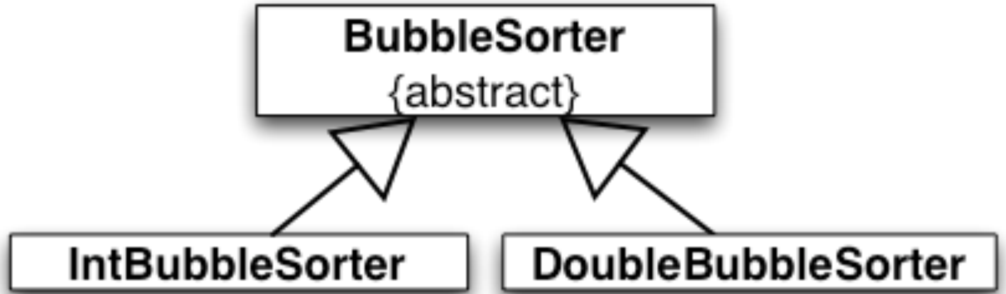
Topics of this Lecture

- Design Patterns
  - Template
  - Strategy
  - Bridge
  - Decorator
- These design patterns are less general than the GRASP patterns
  - They focus on specific design problems
- These are some of the most common and most important classical design patterns in OO design

Template Method Pattern

- The goal is to separate...
  - policies from detailed mechanisms.
  - invariant and variant parts.
- Abstract classes...
  - define interfaces.
  - implement high-level policies.
- Control sub-class extensions.
- Avoid code duplication.
- The Template Method Pattern is at the core of the design of object-oriented frameworks.

Using the Template Method Pattern for Bubble-Sort

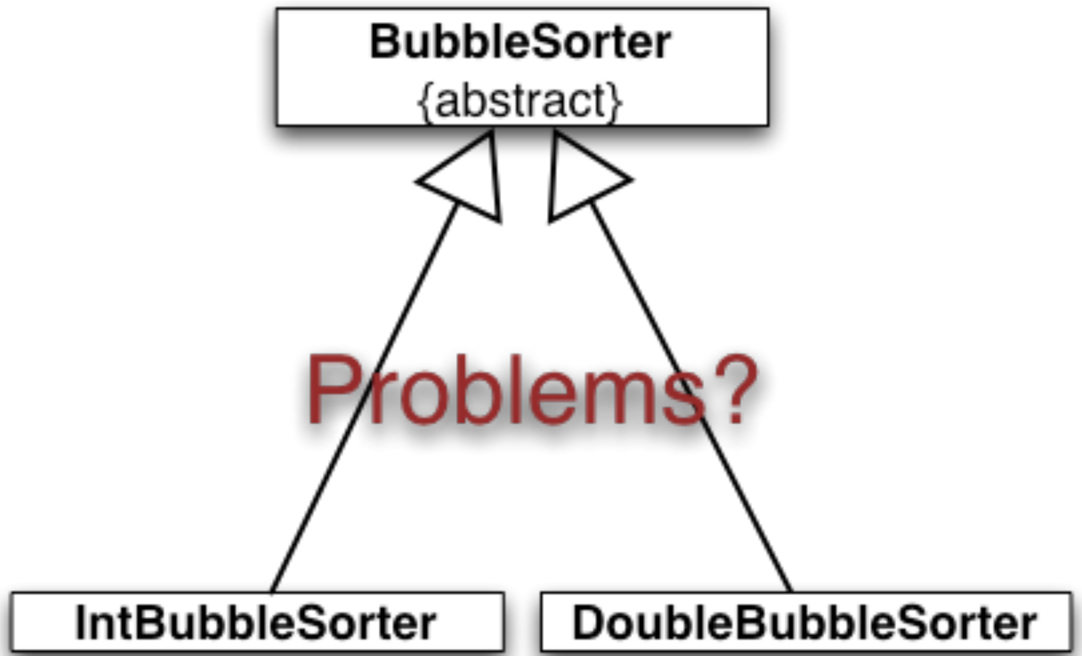



```
public abstract class BubbleSorter{
	protected int length = 0;
	protected void sort() {
		if(length <= 1) return;
		for(int nextToLast= length-2;
			nextToLast>= 0; nextToLast--)
			for(int index = 0;
				index <= nextToLast; index++)
				if(outOfOrder(index)) swap(index);
	}
	protected abstract void swap(int index);
	protected abstract boolean outOfOrder(int index);
}
```

IntBubbleSorter

```
public class IntBubbleSorter extends BubbleSorter{
	private int[] array = null;
	public void sort(int[] theArray) {
		array = theArray;
		length = array.length;
		super.sort();
	}
	protected void swap(int index) {
		int temp = array[index];
		array[index] = array[index+ 1];
		array[index+1] = temp;
	}
	protected boolean outOfOrder(int index) {
		return(array[index] > array[index+ 1]);
	}
}
```

Discussion



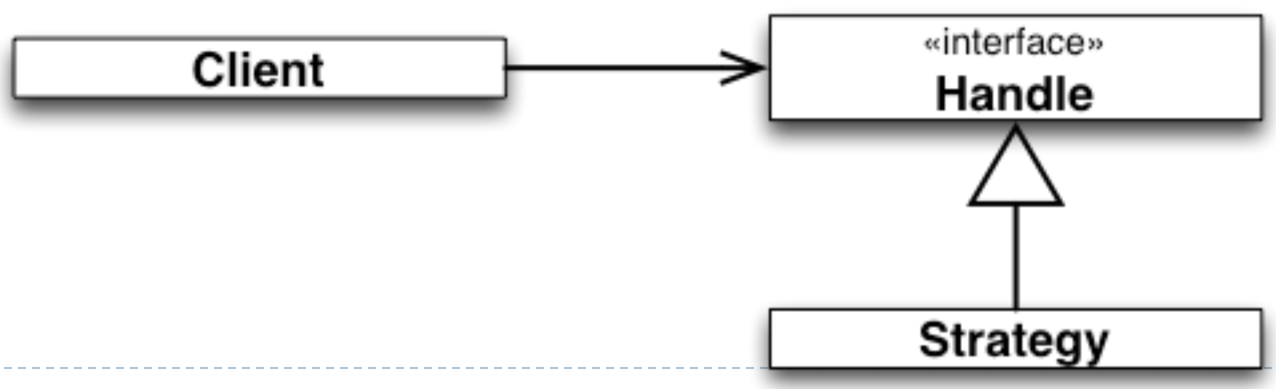
BubbleSorter
{abstract}
Problems?
IntBubbleSorter
DoubleBubbleSorter

Discussion

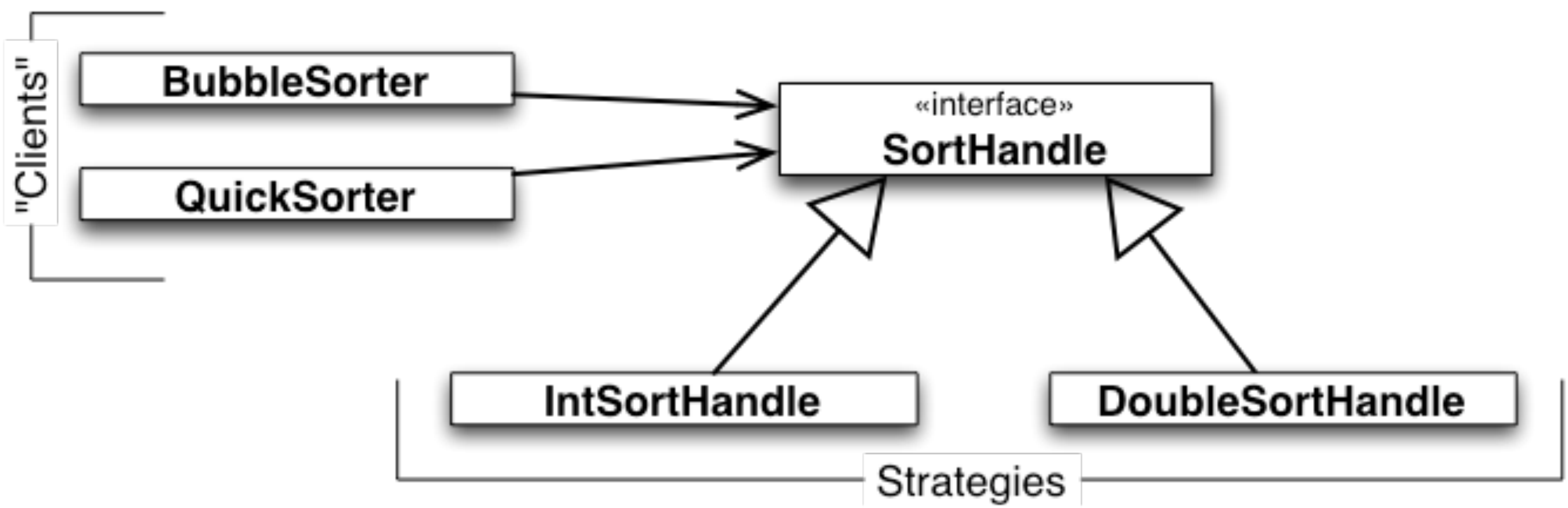
- Template method forces detailed implementations to extend the template class.
- Detailed implementation depend on the template.
- Cannot re-use detailed implementations‘ functionality. (E.g., swap and out-of-order are generally useful.)
- If we want to re-use the handling of integer arrays with other sorting strategies we must remove the dependency
  - this leads us to the Strategy Pattern.

Strategy Pattern

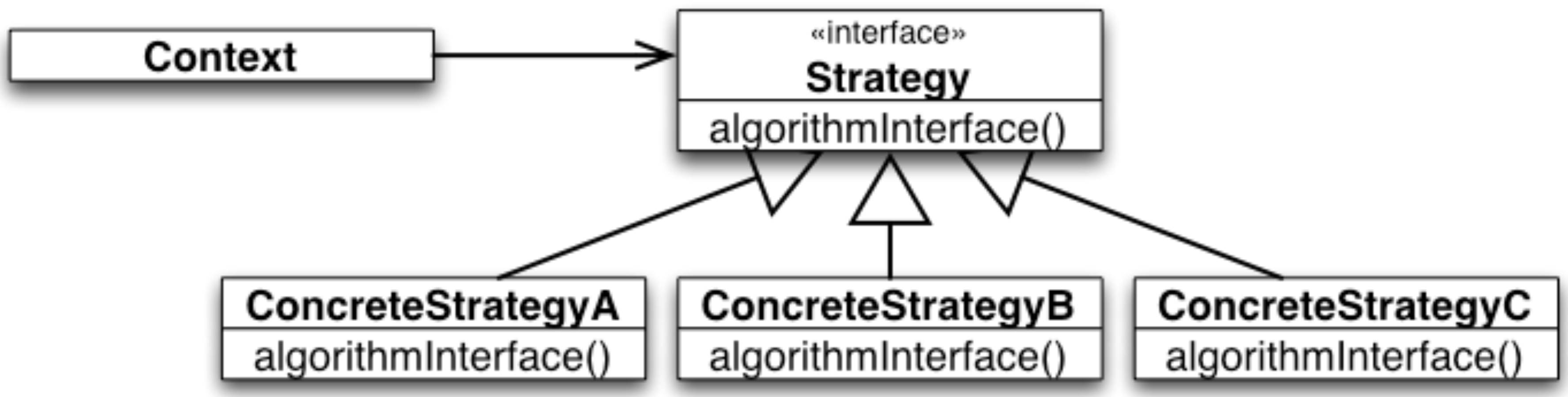
- **Intent**
  - Define a **family of algorithms**, encapsulate each one, and make them **interchangeable**. Strategy lets the algorithm vary independently from clients that use it.
- **Comparison With Template**
  - Using the strategy pattern, both - the template and the detailed implementations - depend on abstractions.
- Basic Structure



Strategy Pattern: Example



Strategy: General Structure



Define a family of algorithms, encapsulate each one, and make them interchangeable

Strategy Pattern: Discussion

- Use if many related classes differ only in their behavior rather than implementing different related abstractions.
  - Strategies allow to configure a class with one of many behaviors.
- Use if you need different variants of an algorithm.
  - Strategies can be used when variants of algorithms are implemented as a class hierarchy.
- Use if a class defines many behaviors that appear as multiple conditional statements in its operations.
  - Move related conditional branches into a strategy

Strategy vs Subclassing

- Sub-classing Context mixes algorithm‘s implementation with that of Context.
  Context harder to understand, maintain, extend.
- When using sub-classing we can't vary the algorithm dynamically.
- Sub-classing results in many related classes.
  Only differ in the algorithm or behavior they employ.
- Encapsulating the algorithm in Strategy...
  - lets you vary the algorithm independently of its context.
  - makes it easier to switch, understand, and extend the algorithm.

Passing Context Information to Strategy

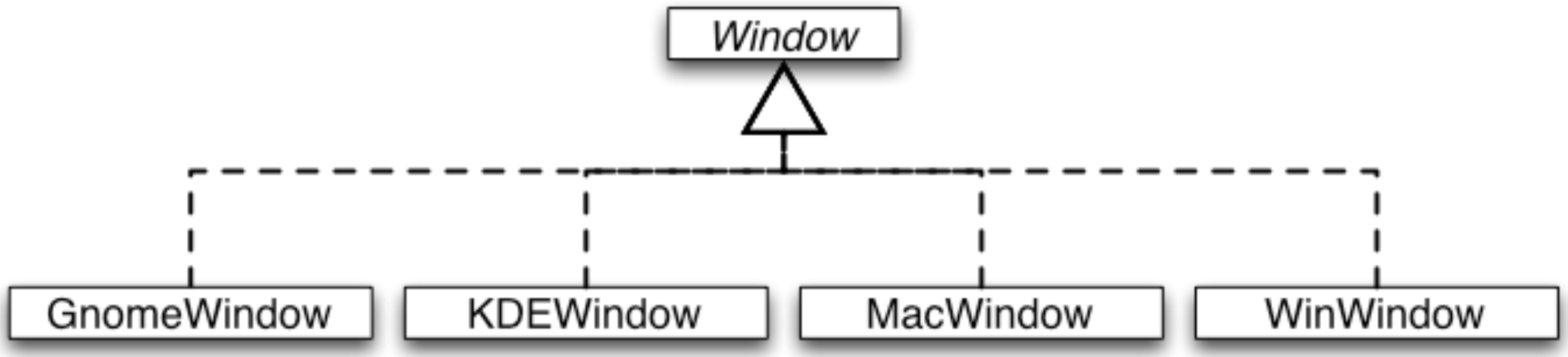
- The Strategy interface is shared by all concrete Strategy classes whether the algorithms they implement are trivial or complex.
- Some concrete strategies won't use all the information passed to them
  - Simple concrete strategies may use none of it.
  - Context creates/initializes parameters that never get used.
- If this is an issue use a tighter coupling between Strategy and Context; let Strategy know about Context

Passing Context Information to Strategy

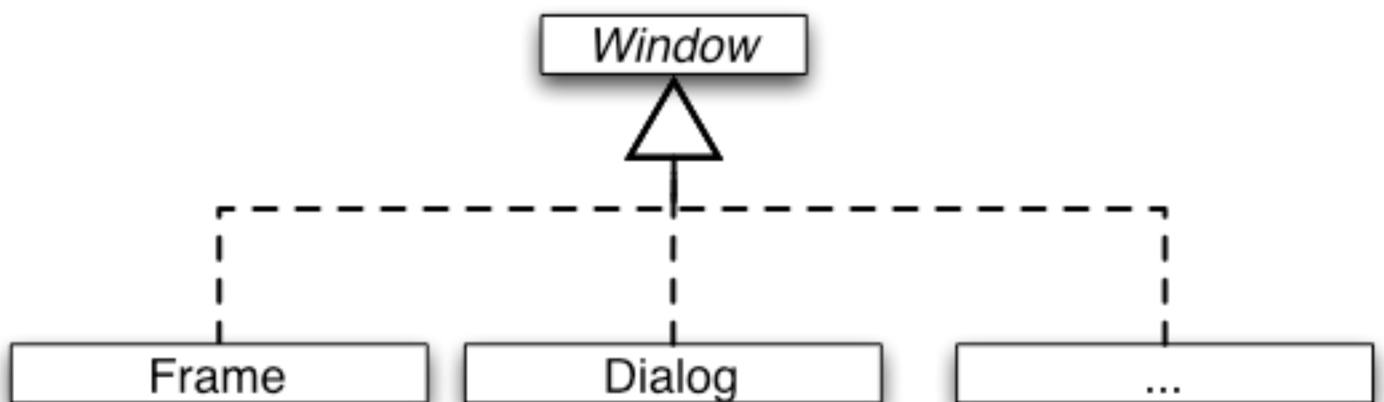
- Two possible strategies:
  - Pass the needed information as a parameter.
    - Context and Strategy decoupled
    - Communication overhead
    - Algorithm can’t be adapted to specific needs of context
  - Context passes itself as a parameter or Strategy has a reference to its Context.
    - Reduced communication overhead
    - Context must define a more elaborate interface to its data
    - Closer coupling of Strategy and Context.
    - Avoid closer coupling by defining an explicit interface for retrieving context, which is implemented by the context

Bridge Pattern: Motivation

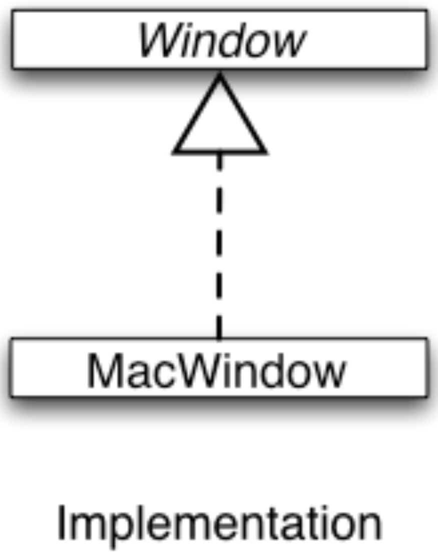
We want to support multiple operating systems...

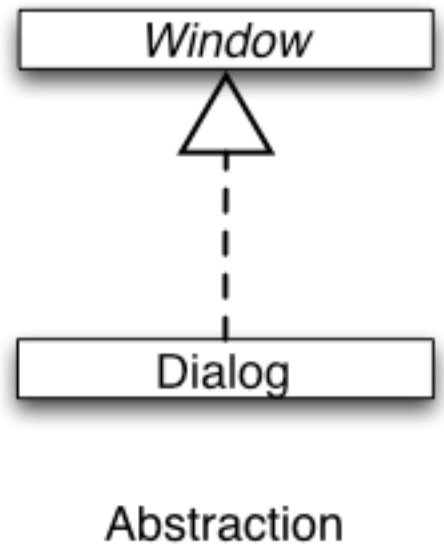


We want to provide different types of windows...



Bridge Pattern

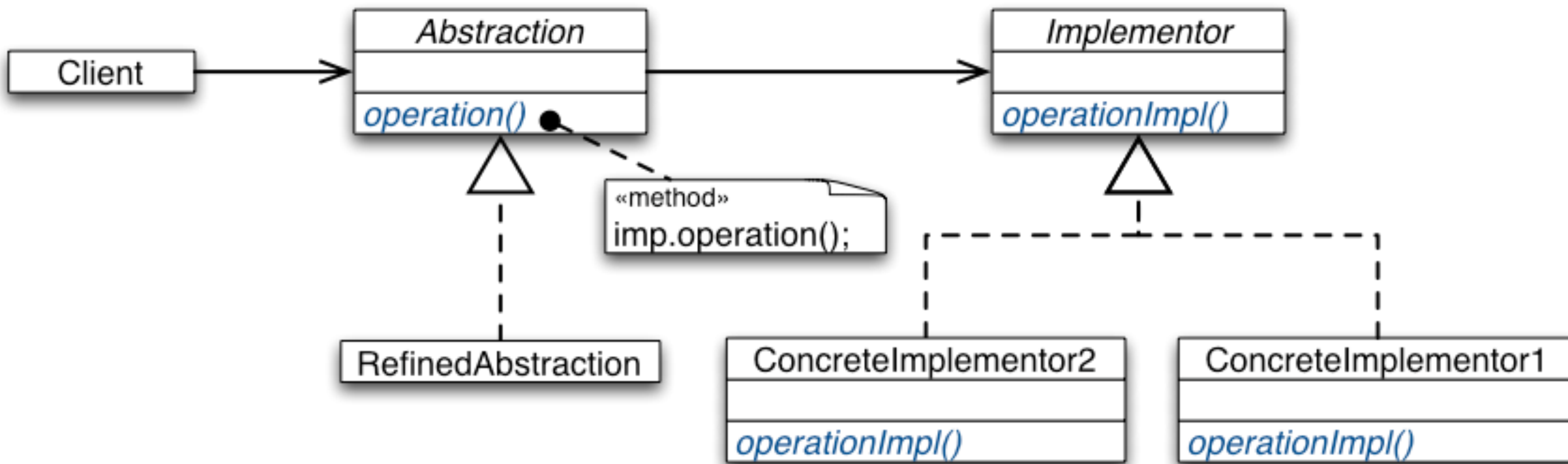




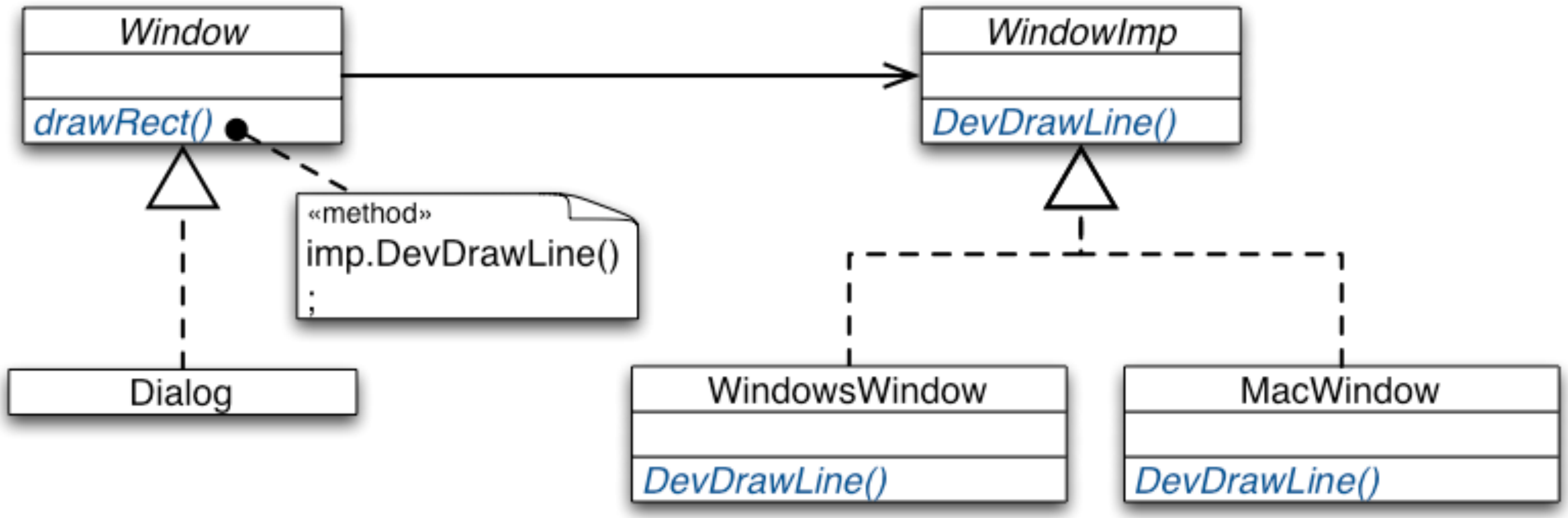
- Which alternative would be better represented using inheritance?
- What technique can we use to provide both types of classifications?

Bridge Pattern

- **Intent**
  - Decouple an abstraction from its implementation so that the two can vary independently.
- **Structure**



Bridge Pattern: Example



- By encapsulating the concept that varies we can avoid problems with inheritance conflicts.
- This is very similar to the technique used in the Strategy pattern

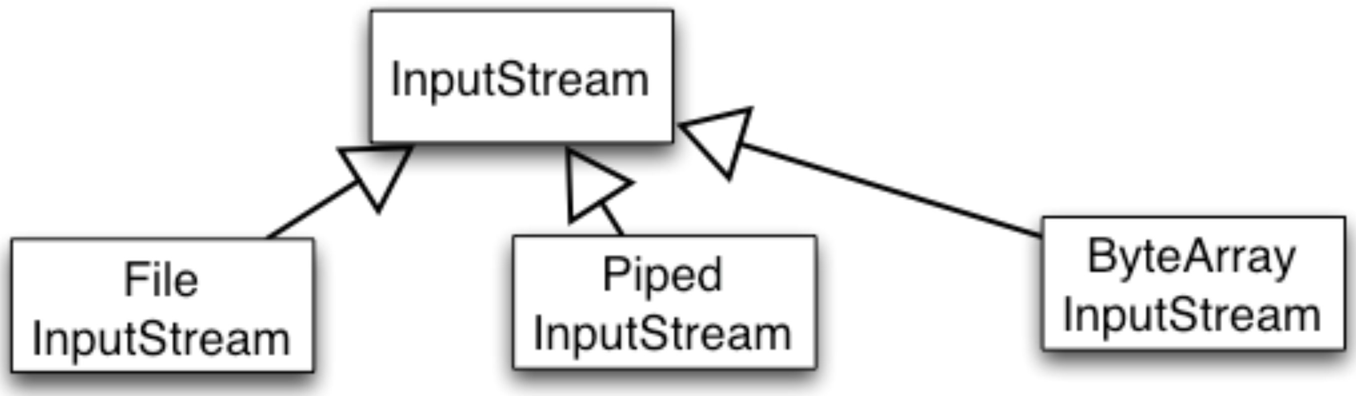
Bridge Pattern: Discussion

- **Decoupling interface and implementation**:
  - Implementation can be configured at run-time.
  - Implementation being used is hidden inside abstraction.
- **Improved extensibility**
  Abstraction and Implementer hierarchies can be extended independently.
- **Issues**
  - Most languages do not support parallel hierarchies very well
    - Type safety problems

Decorator Pattern

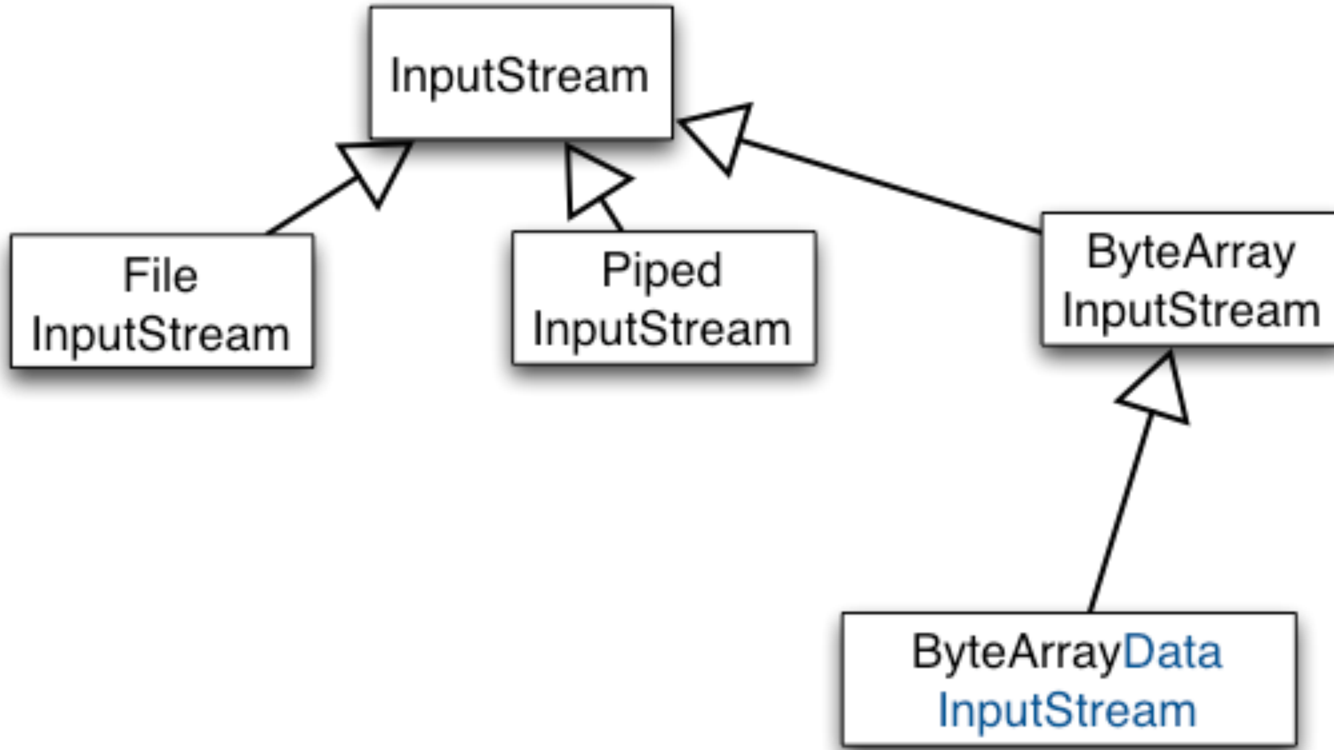
- **Intent**
  - We need to add responsibilities to existing individual objects
  - … dynamically and transparently, without affecting other objects.
  - … responsibilities can be withdrawn dynamically.
- **Problem:** Extension by subclassing is not practical:
  - Large number of independent extensions are possible.
  - Would produce an explosion of subclasses to support every combination.
  - No support for dynamic adaptation.
  - A class definition may be hidden or otherwise unavailable for subclassing
  - Cannot change all constructor calls to the class whose object are to be extended

Limitations of Inheritance: Example



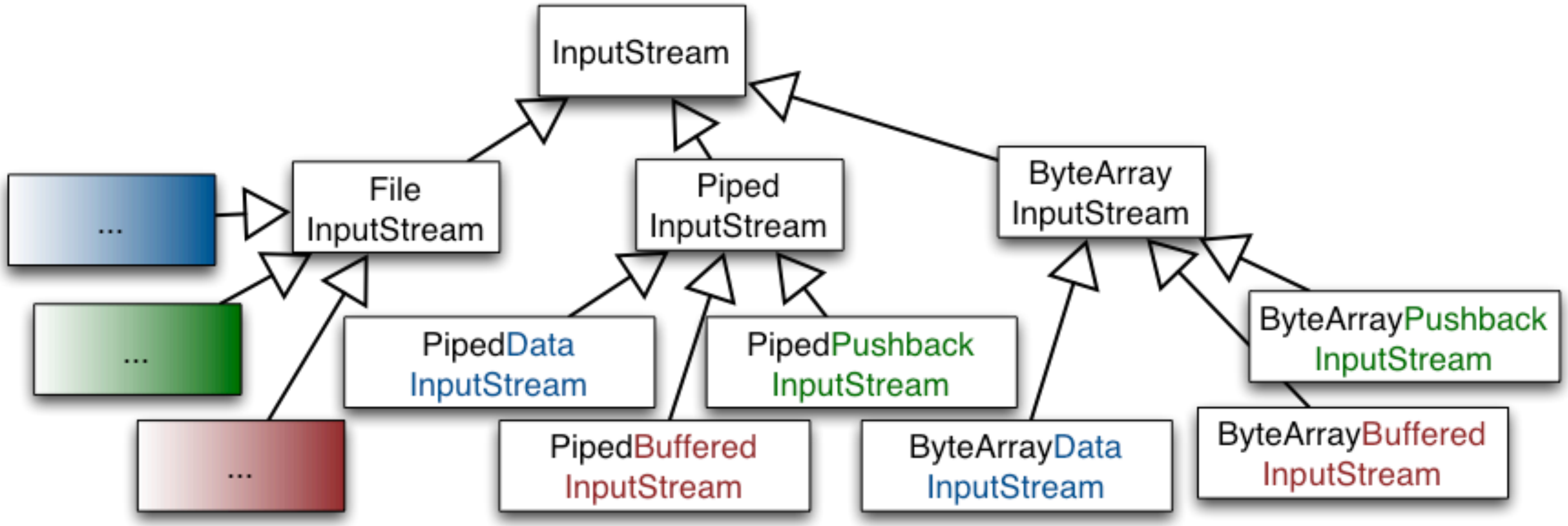
Evolution:
Adding functionality to a ByteArrayInputStream to read whole sentences and not just single bytes.

Limitations of Inheritance: Example



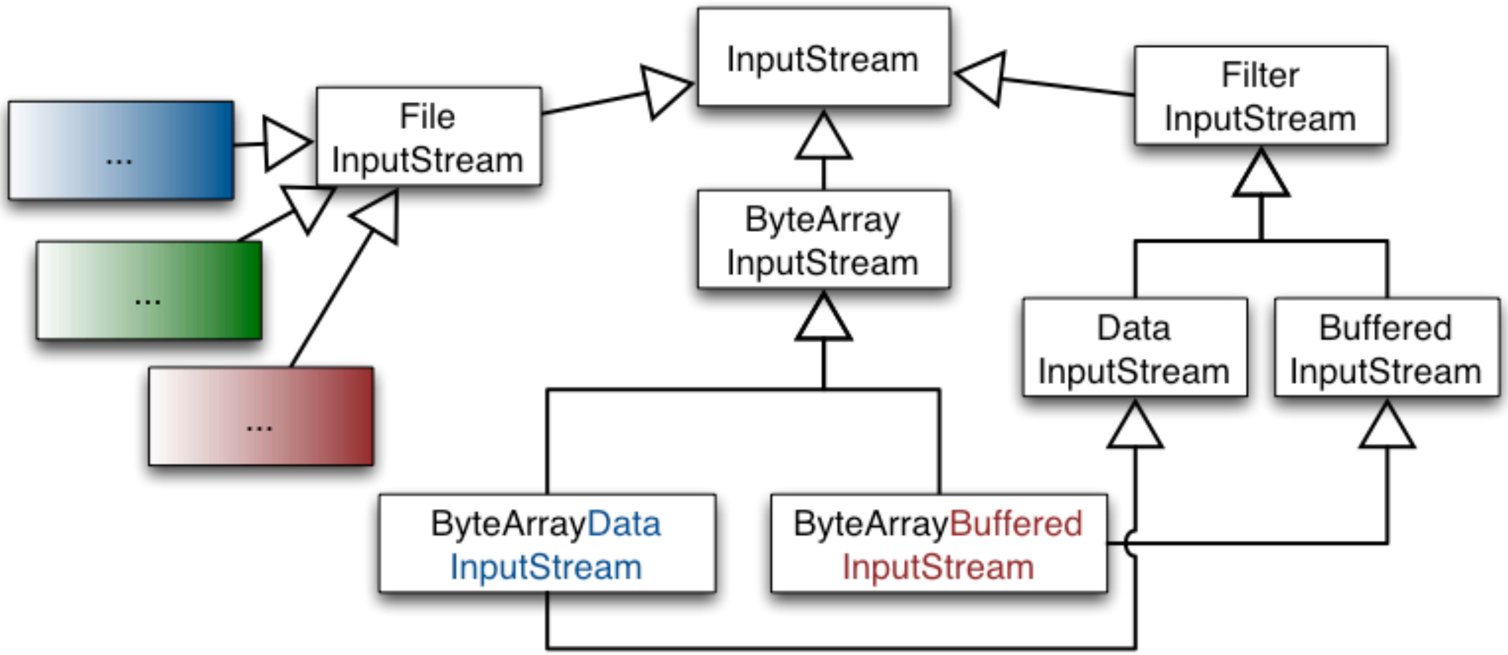
Evolution:
We also want to have the possibility to read whole sentences using FileInputStreams...

After the n-th iteration…



- Problems:
  - … a new class for each responsibility.
  - responsibility mix fixed statically.
    (How about PipedDataBufferedInputStream?)
  - non-reusable extensions; code duplication;
  - maintenance nightmare: exponential growth of number of classes

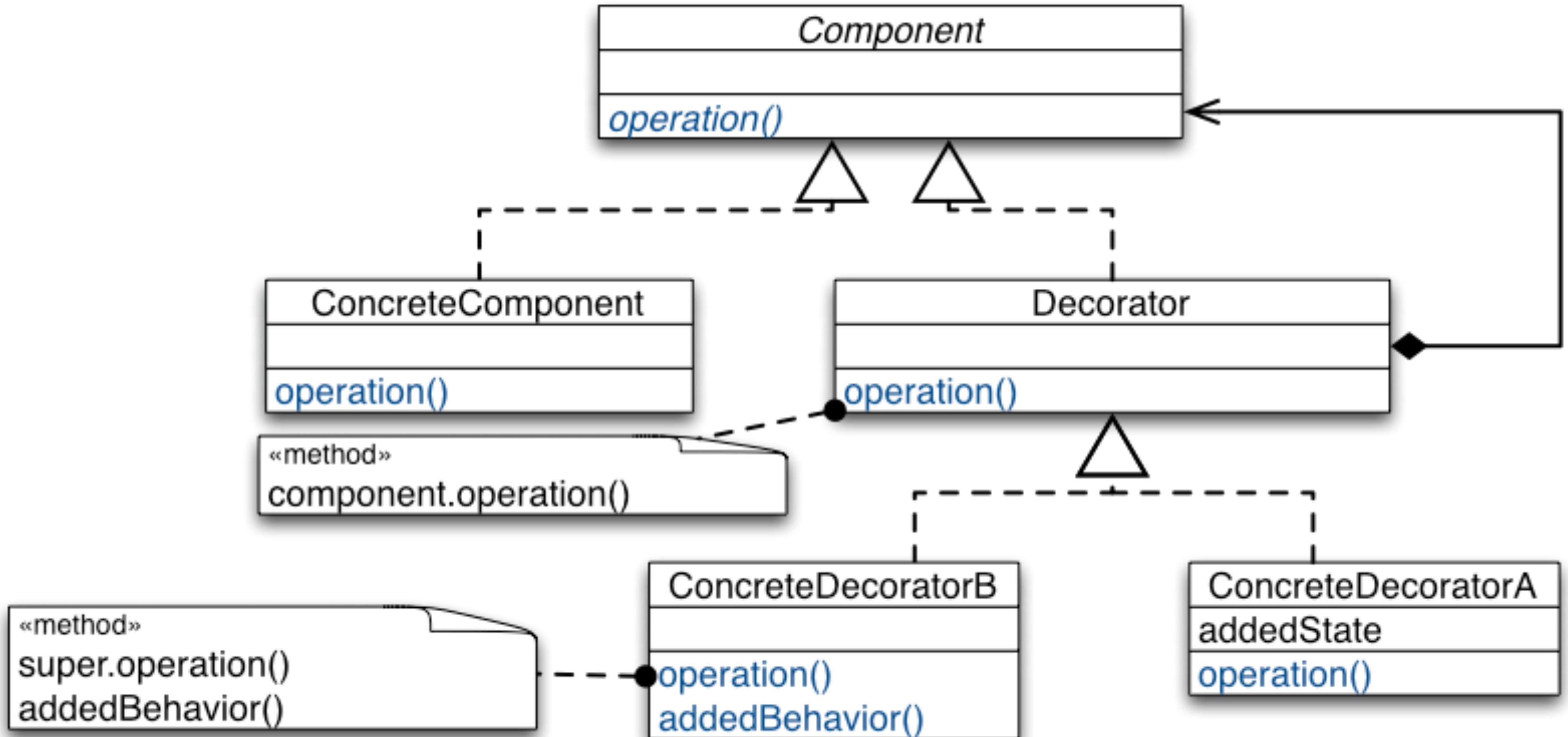
Multiple Inheritance is no Solution Either



- static responsibility mix
- naming conflicts
- hard to dispatch super calls correctly

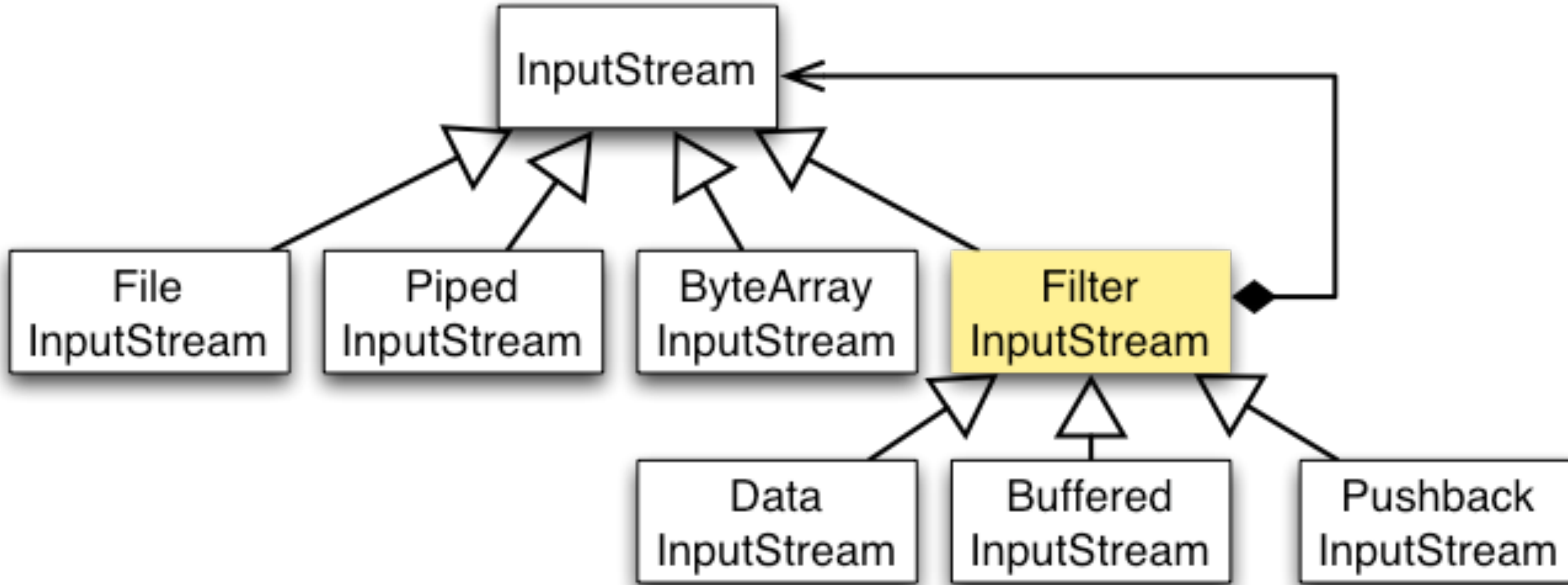
> "Multiple inheritance is good, but there is no good way to do it."
> A. SYNDER

Structure of the Decorator Pattern



Intent: We need to add responsibilities to existing individual objects dynamically and transparently, without affecting other

Example: Decorator in java.io



- java.io abstracts various data sources and destinations, as well as processing algorithms:
  - Programs **operate on stream objects** ...
  - **independently of** ultimate data source / destination / shape of data.

Decorator Pattern: Discussion

- Decorator enables more flexibility than inheritance:
- Responsibilities can be added / removed at run-time.
- Different Decorator classes for a specific Component class enable to mix and match responsibilities.
- Easy to add a responsibility twice; e.g., for a double border, attach two BorderDecorators
- Decorator avoids incoherent classes:
  - feature-laden classes high up in the hierarchy
    pay-as-you-go approach: don't bloat, but extend using fine-grained Decorator classes
    - functionality can be composed from simple pieces.
    - an application does not need to pay for features it doesn't use.

Decorator: Problems

- Lots of little objects
  - A design that uses Decorator often results in systems composed of lots of little objects that all look alike.
  - Objects differ only in the way they are interconnected, not in their class or in the value of their variables.
    Imagine a class to draw a border around a component..
  - Such systems are easy to customize by those who understand them, but can be hard to learn and debug.
- Object identity
  - A decorator and its component aren't identical.
    From an object identity point of view, a decorated component is not identical to the component itself.
  - You shouldn't rely on object identity when you use decorators

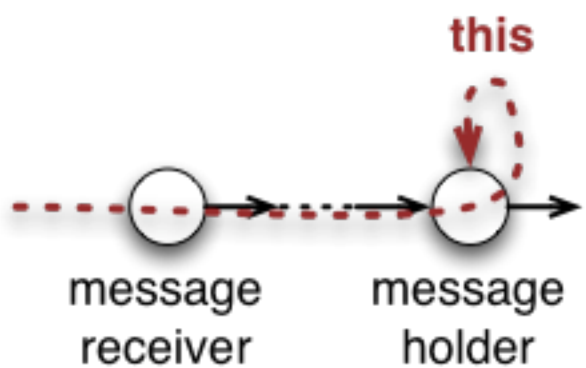
Example: Streams in java.io

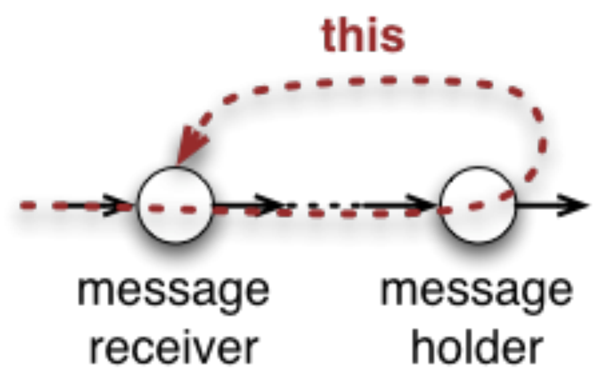
- A stream is normally addressed via the outermost Decorator.
- Sometimes, a reference to one of the internal objects is maintained and operated on
  - operation shouldn't include actual reads or writes
  - good style: all read() operations are performed only to the head decorator in the composite stream object
- Reading from an internal object breaks the illusion of a single object accessed via a single reference, and makes the code more difficult to understand.

```
FileInputStream fin = new FileInputStream("a.txt");
BufferedInputStream din = new
BufferedInputStream(fin);
fin.read();
```

Decorator: Problems

- ***No late binding***
  - ***DELEGATION VERSUS FORWARD SEMANTICS***

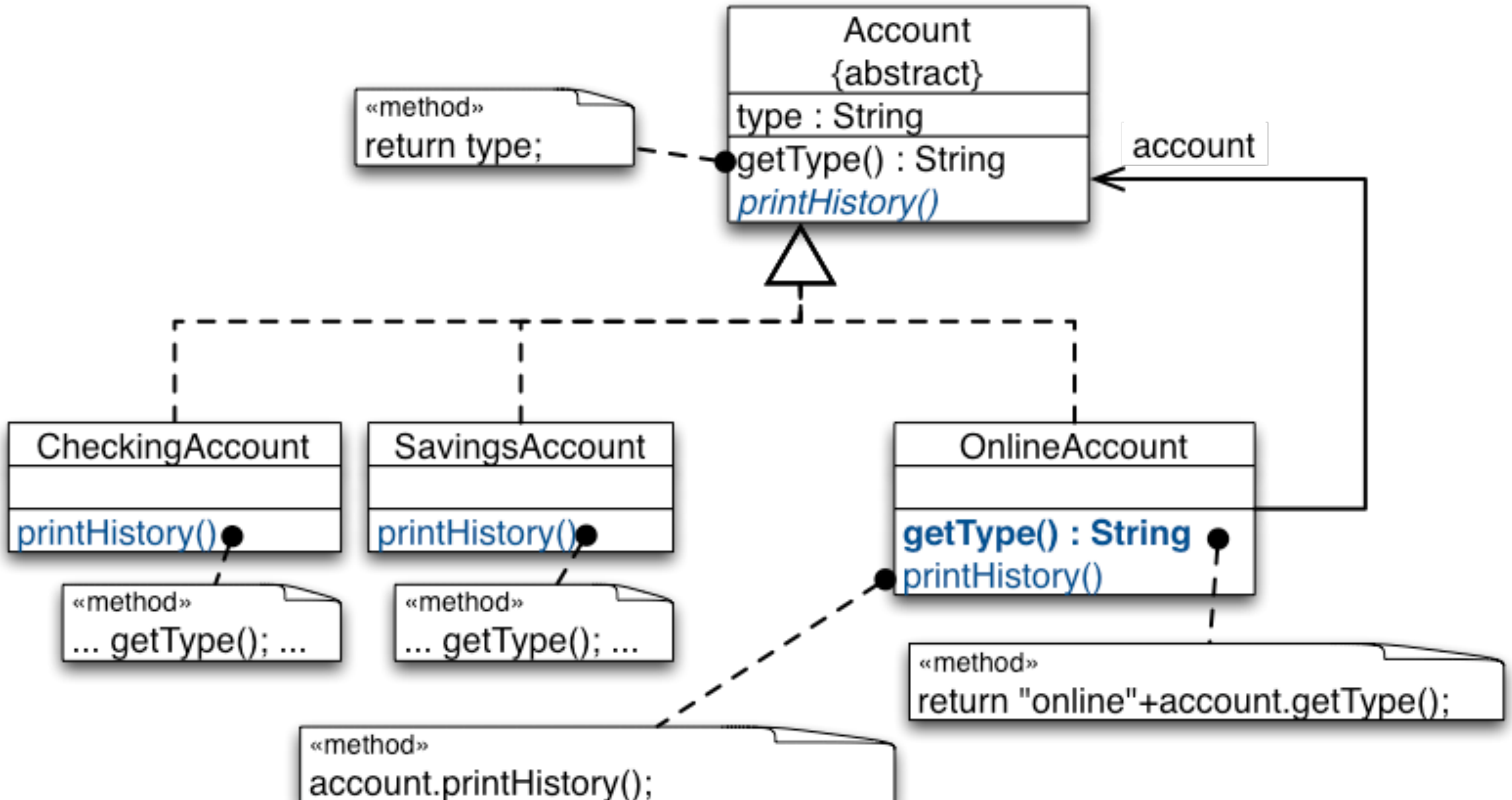




Forwarding with binding of this to method holder; "ask" an **object to do something on its own**.

Binding of this to message receiver: “ask” an object to **do something on behalf of the message receiver**.

No Late Binding: Example



Decorator: Problems

- Need to implement forwarding methods for those methods not relevant to the decorator
  - A lot of repetitive programming work
  - A maintenance problem: What if the decorated class changes
    - Adding new methods or removing methods that are irrelevant to the decorators
    - Decorator classes need to change as well
    - This is a variant of the so-called “fragile base class problem”

Decorator: Issues

- Keep the common class (Component) lightweight:
  - it should focus on defining an interface (e.g. implemented as interface).
  - defer defining data representation to subclasses.
  - otherwise the complexity of Component might make the decorators too heavyweight to use in quantity.
- Putting a lot of functionality into Component makes it likely that subclasses will pay for features they don't need.
- These issues require pre-planning.
  - Difficult to apply decorator pattern to 3rd-party component class.

Literature

- A. Shalloway, J.R. Trott. *Design Patterns Explained.* Addison-Wesley, 2005.
  - Chap. 9,14,15,18