# CS 520

Theory and Practice of Software Engineering
Fall 2021

**Object Oriented Design Patterns**

September 30, 2021

# Today

- Recap: Object oriented design principles
- Design problems & potential solutions
- Design patterns:
  - What is a design pattern?
  - Categories of design patterns
  - Structural design patterns

# Recap

**Object oriented design principles**

- Open/closed principle
- Information hiding (and encapsulation)
- Liskov substitution principle
- Composition/Aggregation over inheritance
    - Can be used to prevent the diamond of death

# Inheritance and polymorphism

**Example:**
https://docs.oracle.com/en/java/javase/15/docs/api/java.base/java/util/Stack.html

1) For the Java inheritance, what are the is-a relationships for the Stack class?

2) What kinds of polymorphism are being used by this class?

- Ad-hoc
- Subtype
- Parametric

# Open/Closed and information hiding principles

3) What is a Stack field that is open only for extensions?

4) What is a Stack method that is open only for extensions?

# Liskov substitution principle

**Subtype requirement**

*Let object x be of type T1 and object y be of type T2. Further, let T2 be a subtype of T1 (T2 <: T1). Any provable property about objects of type T1 should be true for objects of type T2.*

- Supertype T1 is Vector // It is a List.
- Subtype T2 is Stack
- One key property of a List is that the List is represented as an ordered sequence of elements.
- Is this principle: satisfied or violated?

# Composition/Aggregation over inheritance

**Another example:**
https://docs.oracle.com/javase/8/docs/api/java/util/LinkedHashMap.html

- From this class name, the two parts of the functionality are providing Map access and Linked access.

- How is the class implementing the Map access?

- How is the class implementing the Linked access?

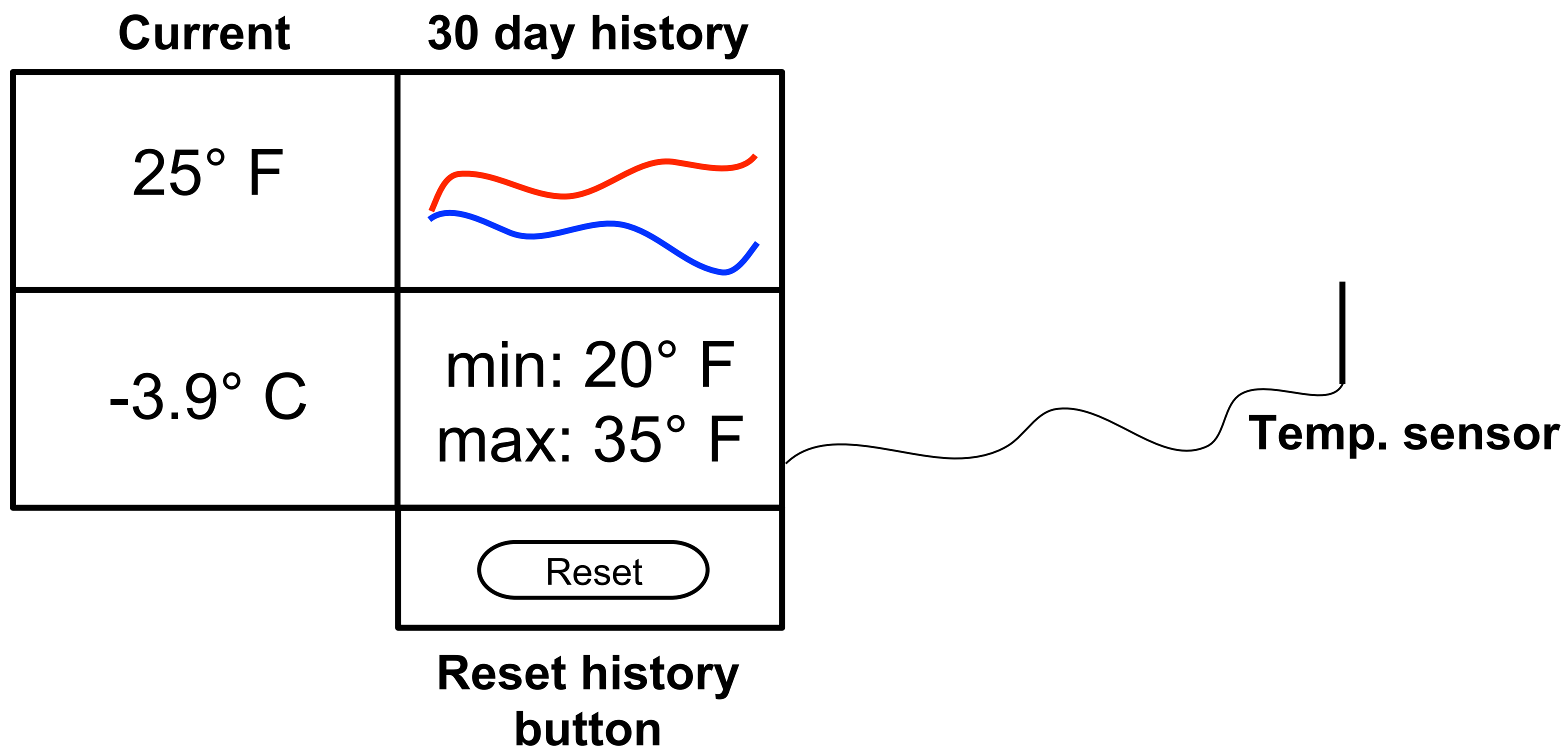
# Design patterns

- What is a design pattern?
- Categories of design patterns
- Structural design patterns

https://en.wikipedia.org/wiki/Design_Patterns

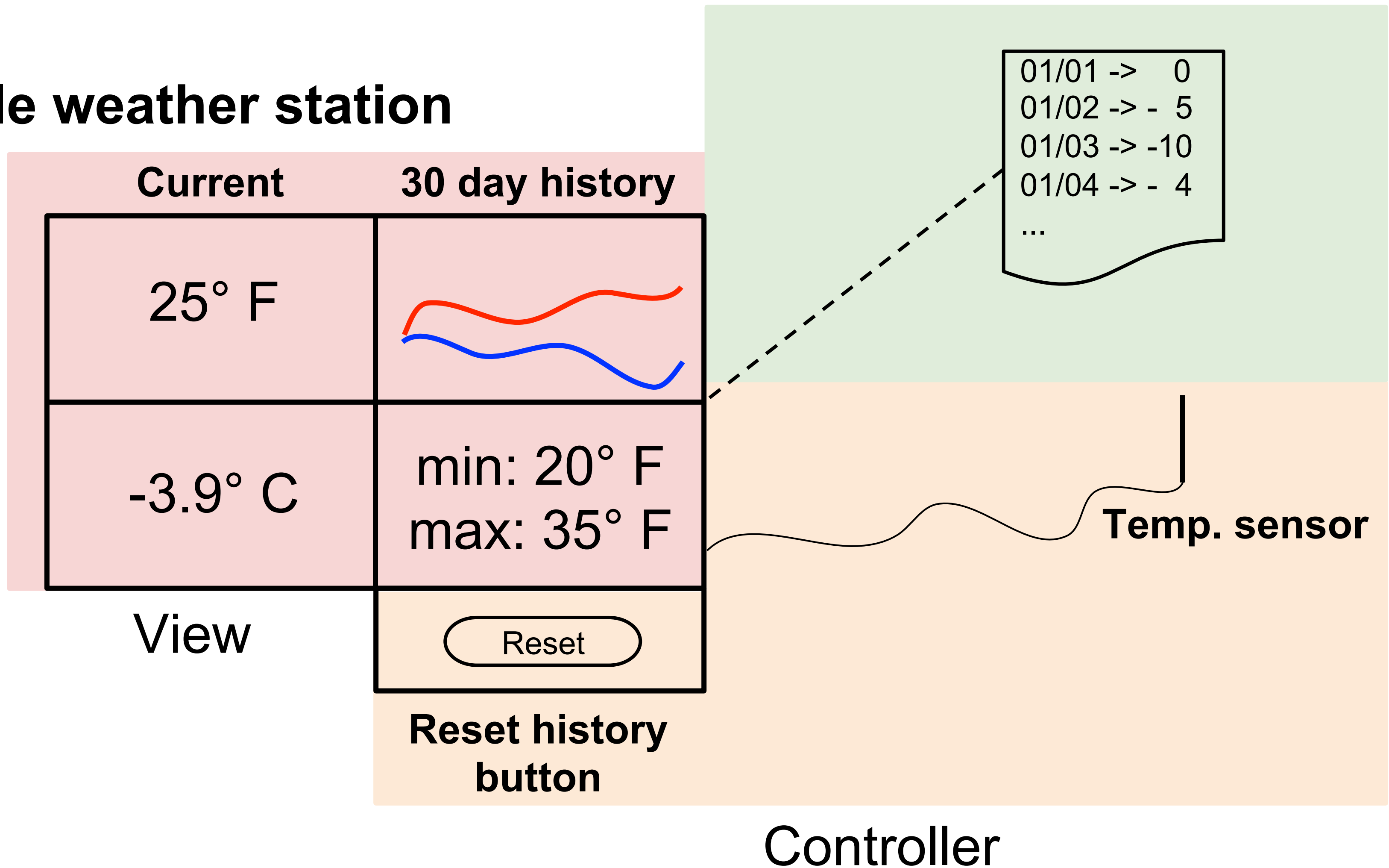
# A first design problem

## Weather station revisited



# Model View Controller: example

**Simple weather station**



# What's a good design for the view?

Client

sees

uses

| 25° F | |
| --- | --- |
| -3.9° C | min: 20° F<br>max: 35° F |

Reset

Reset history button

Temp. sensor

updates

manipulates

09/01,12°
09/02,14°
...

# Weather station: view

<<interface>>
View
+draw(d:Data)

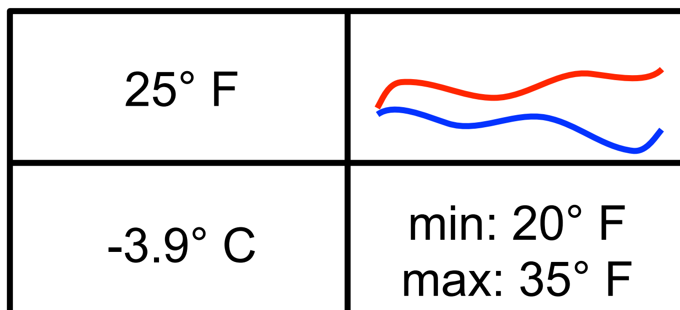
1..n

SimpleView
+draw(d:Data)

GraphView
+draw(d:Data)

...View
+draw(d:Data)

ComplexView
-views:List<View>
+draw(d:Data)
+addView(v:View)




How do we need to implement draw(d:Data)?

# Weather station: view

<<interface>>
View

+draw(d:Data)

1..n

SimpleView
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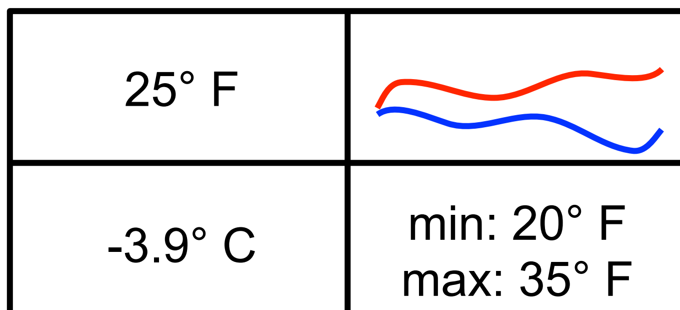
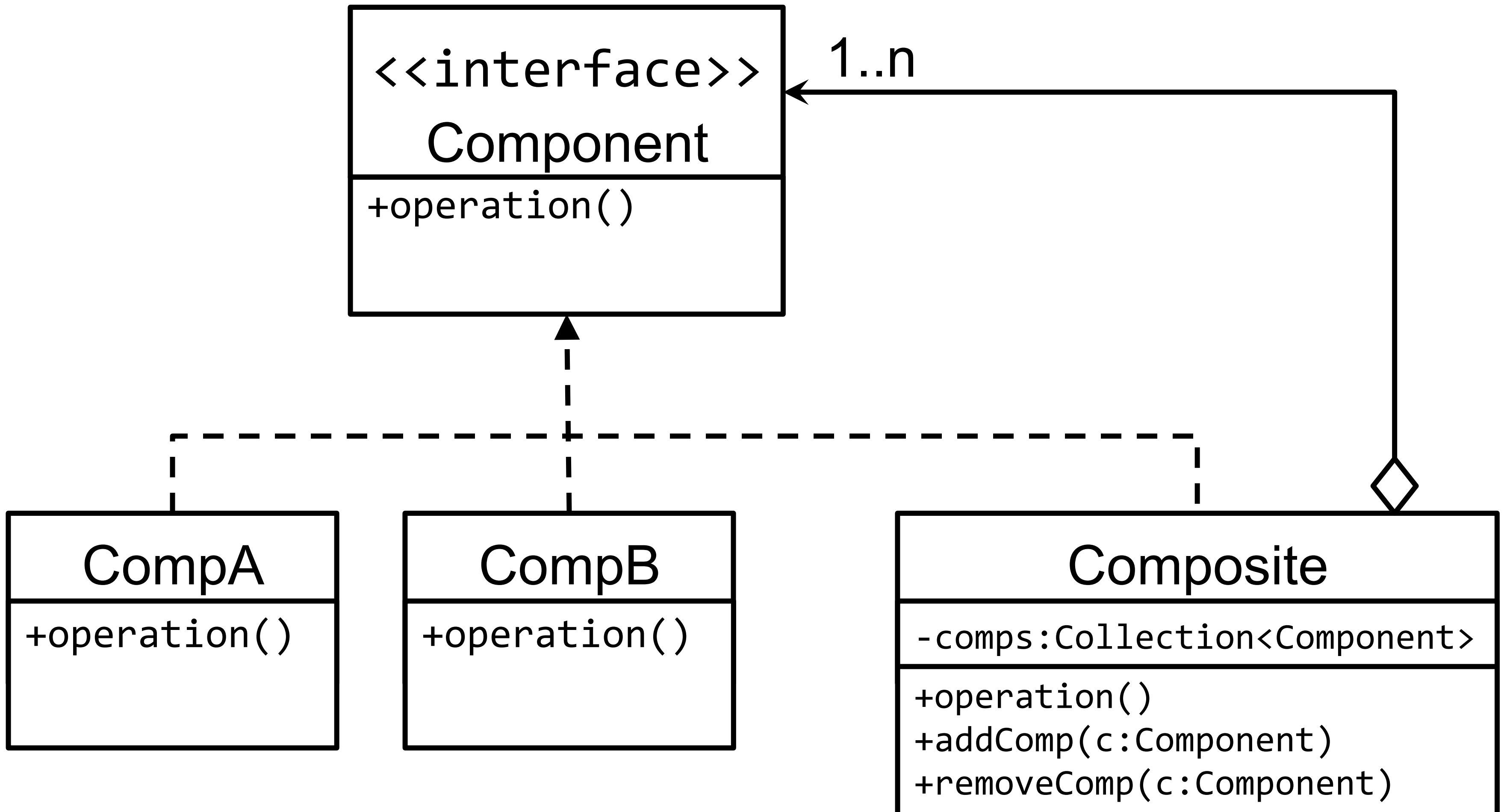
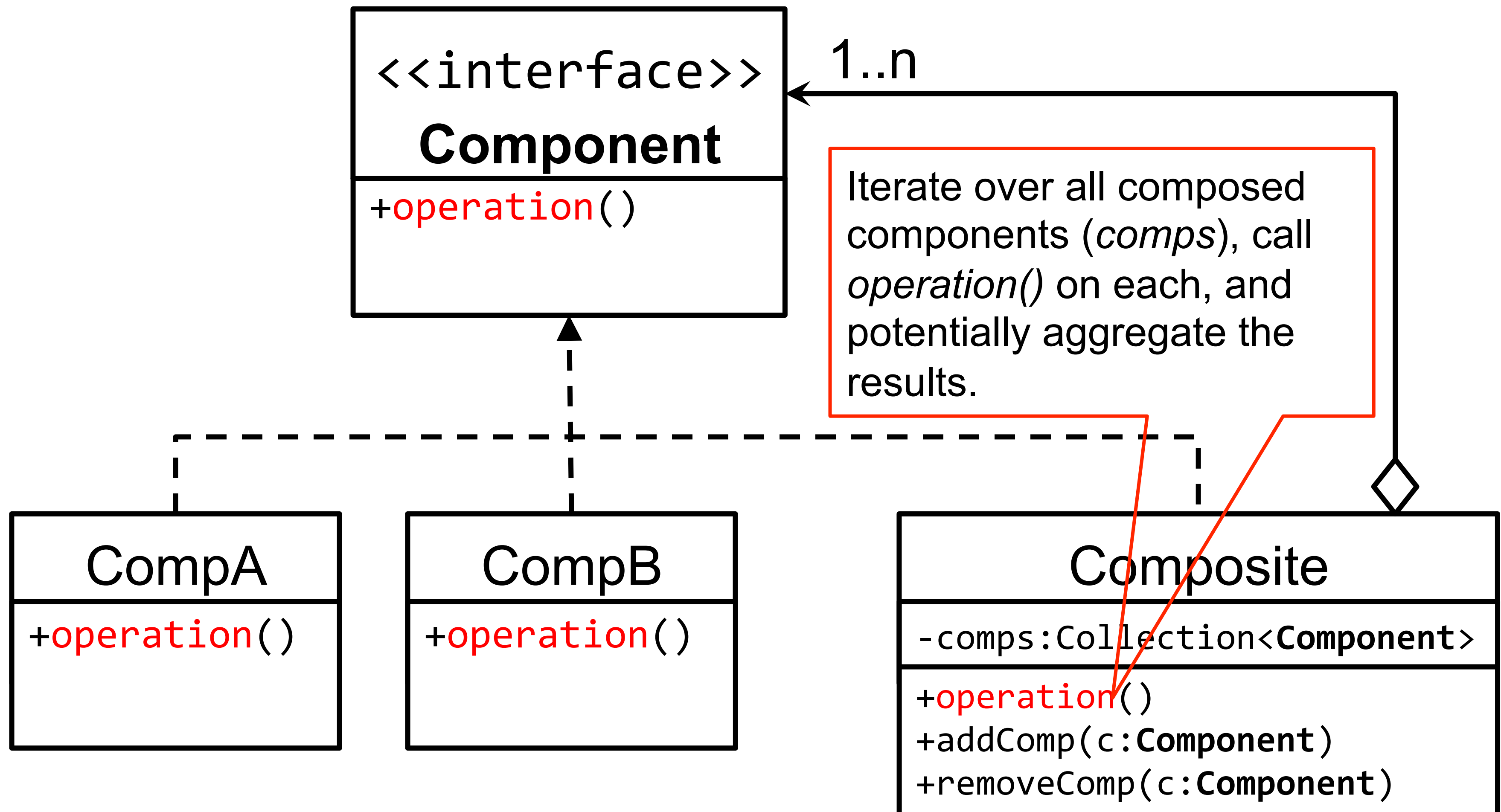



```
public void draw(Data d) {
  for (View v : views) {
    v.draw(d);
  }
}
```

# Design pattern: Composite



# Design pattern: Composite



# What is a design pattern?

- Addresses a recurring, common design problem.
- Provides a generalizable solution.
- Provides a common terminology.

# What is a design pattern?

- Addresses a recurring, common design problem.
- Provides a generalizable solution.
- Provides a common terminology.

**Pros**
- Improves communication and documentation.
- “Toolbox” for novice developers.

**Cons**
- Risk of over-engineering.
- Potential impact on system performance.

More than just a name for common sense and best practices.

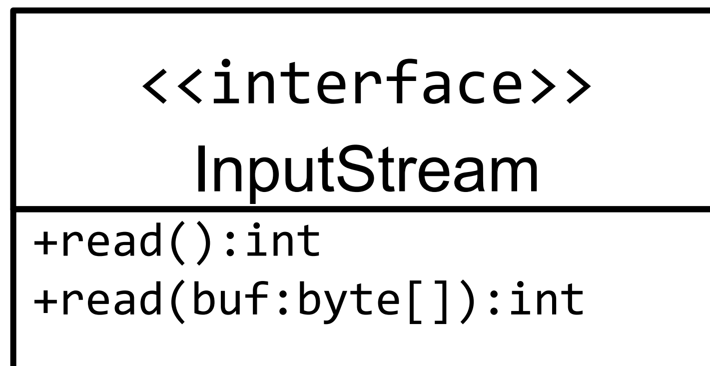
# Design patterns: categories

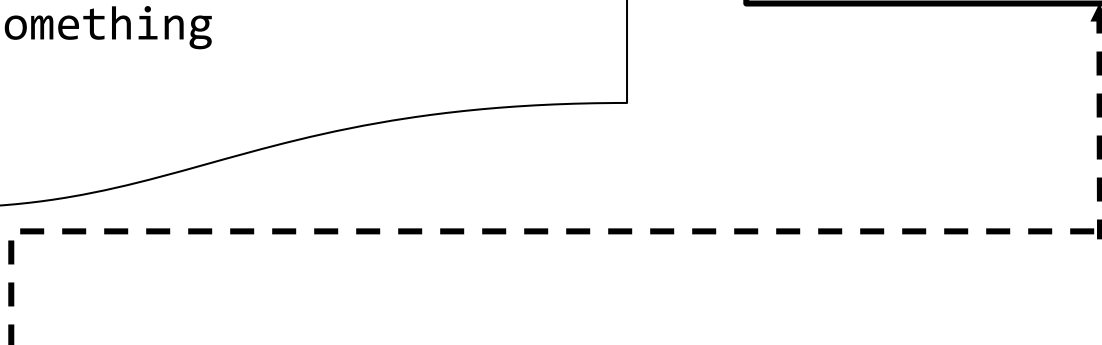
1. Structural
   - Composite
   - Decorator
   - ...
2. Behavioral
   - Template method
   - Visitor
   - ...
3. Creational
   - Singleton
   - Factory (method)
   - ...

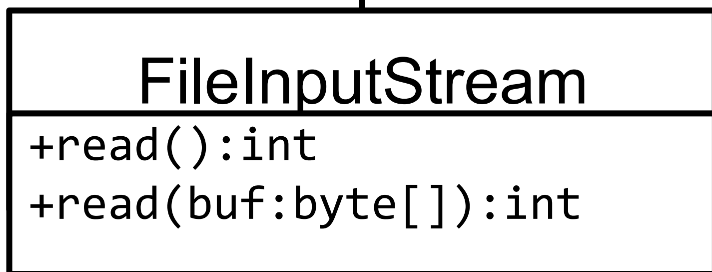
# Another design problem: I/O streams

```
...
InputStream is =
       new FileInputStream(...);

int b;
while((b=is.read()) != -1) {
    // do something
}
...
```





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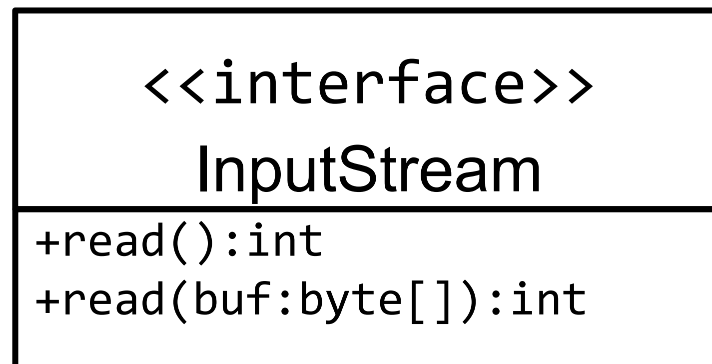


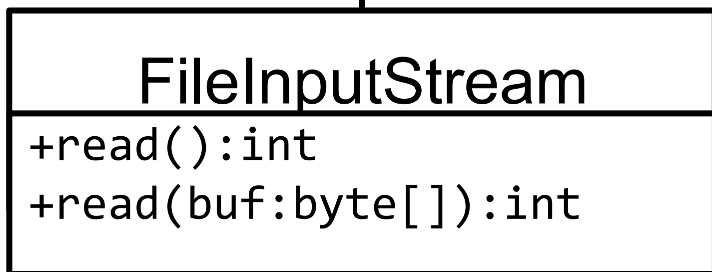


Problem: filesystem I/O is expensive

# Another design problem: I/O streams

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InputStream is =
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int b;
while((b=is.read()) != -1) {
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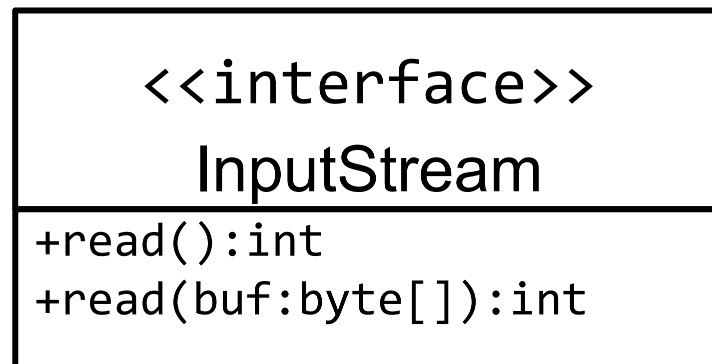
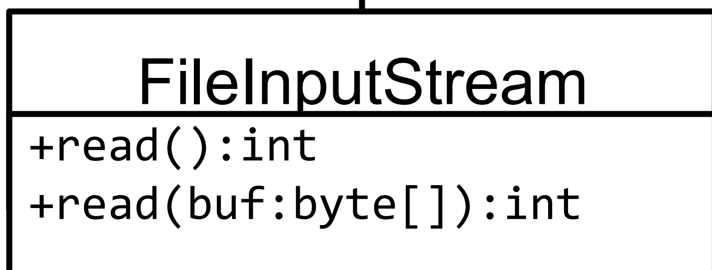
```



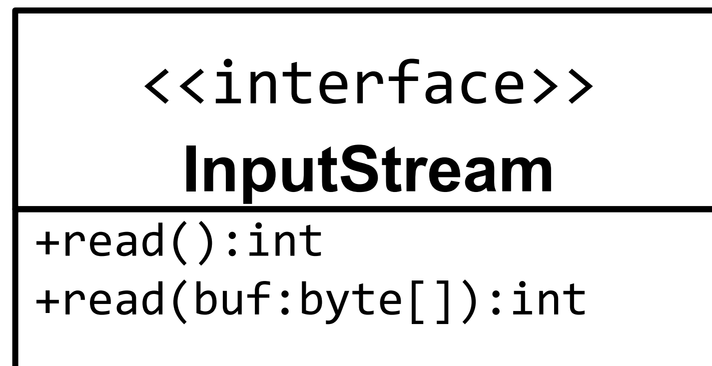

Problem: filesystem I/O is expensive

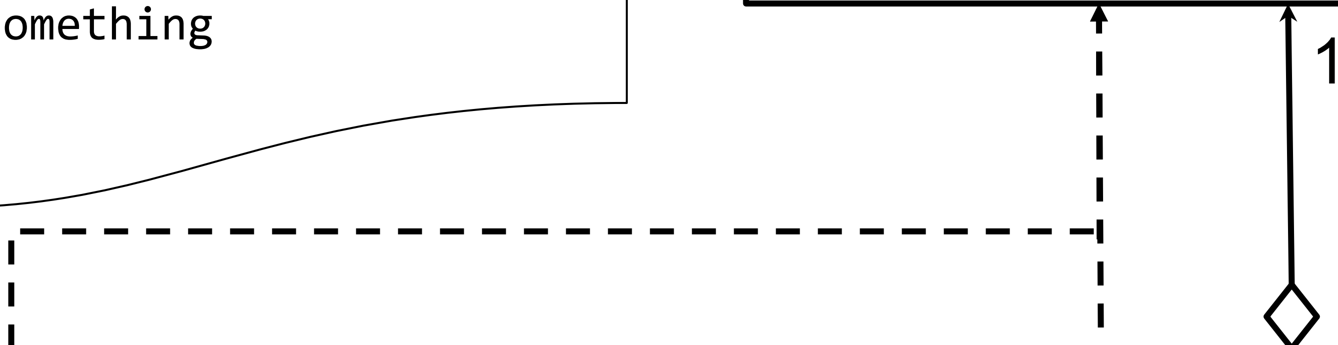
Solution: use a buffer!

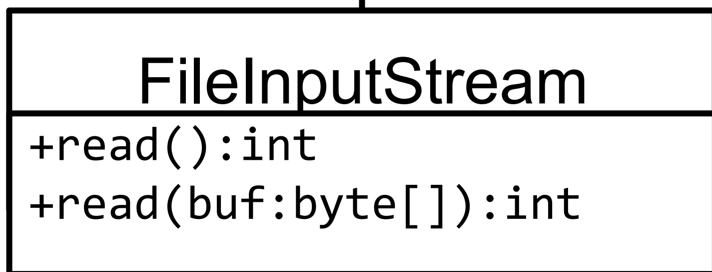
Why not simply implement the buffering in the client or subclass?

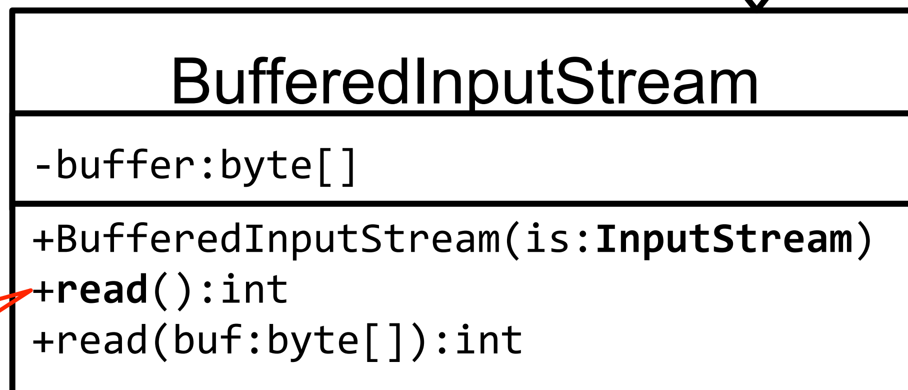
# Another design problem: I/O streams

```
...
InputStream is =
        new BufferedInputStream(
        new FileInputStream(...));
int b;
while((b=is.read()) != -1) {
    // do something
}
...
```



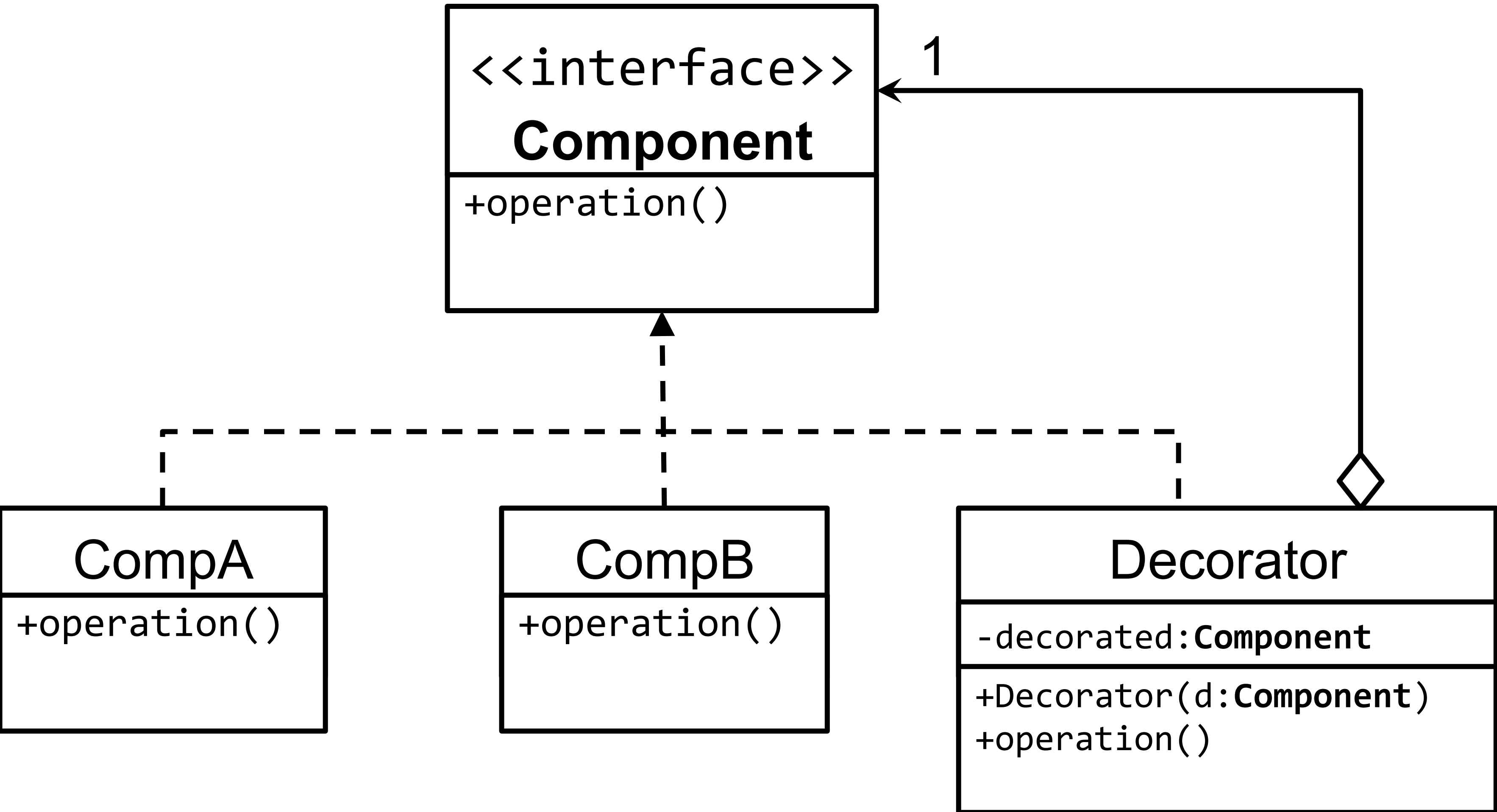



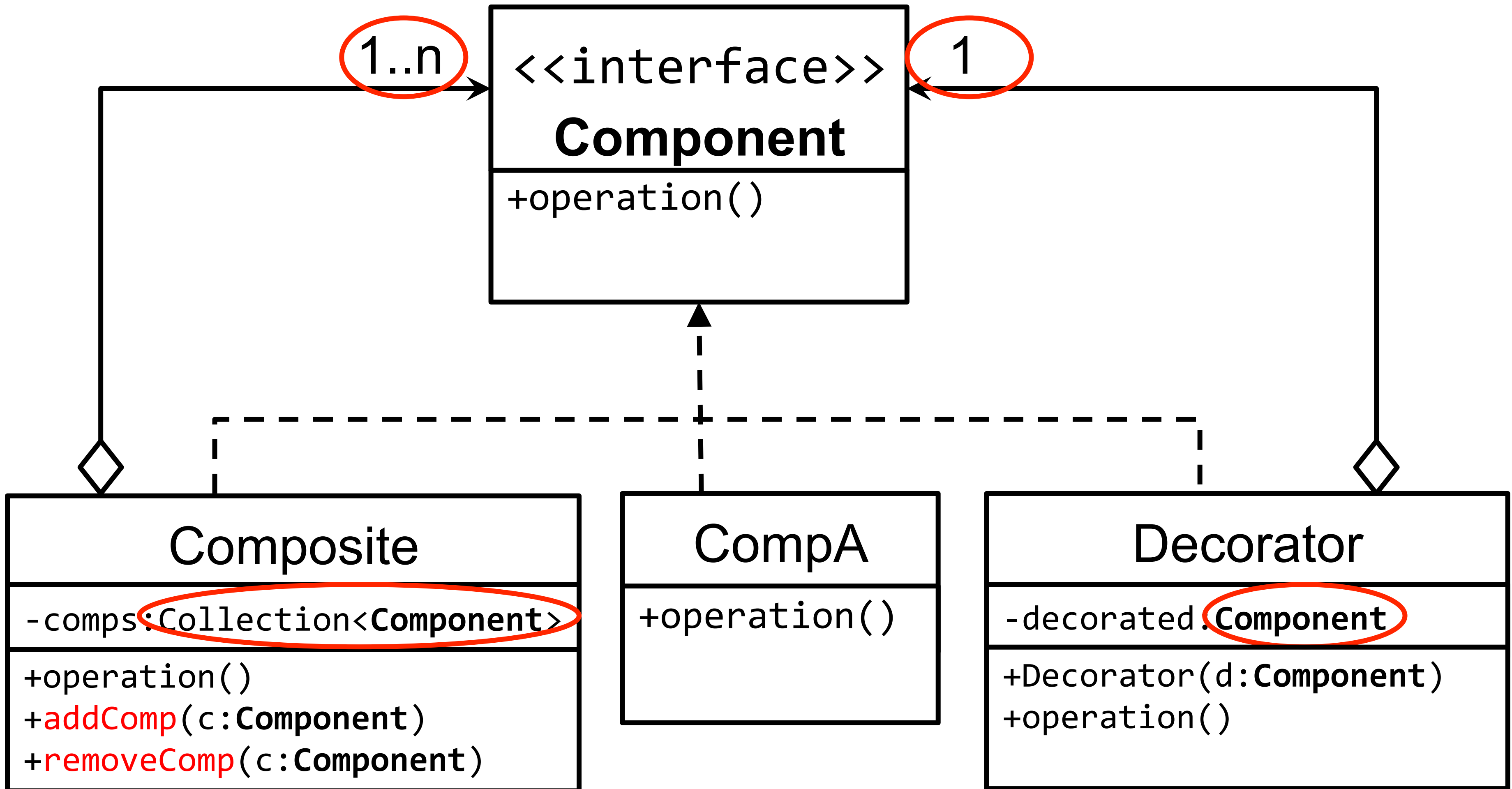




Still returns one byte (int) at a time, but from its buffer, which is filled by calling read(buf:byte[]).

# Design pattern: Decorator



# Composite vs. Decorator



# Find the median in an array of doubles

Examples:

- median([1, 2, 3, 4, 5]) = ???
- median([1, 2, 3, 4]) = ???

# Find the median in an array of doubles

Examples:

- median([1, 2, 3, 4, 5]) = 3
- median([1, 2, 3, 4]) = 2.5

**Algorithm**

**Input**: *array* of length *n* **Output**: median

# Find the median in an array of doubles

Examples:

- median([1, 2, 3, 4, 5]) = 3
- median([1, 2, 3, 4])     = 2.5

**Algorithm**

**Input**: *array* of length *n*     **Output**: median

1. Sort *array*
2. if *n* is *odd* return (*(n+1)/2)*th element
   *otherwise* return arithmetic mean of
   *(n/2)*th element and *((n/2)+1)*th element

# Median computation: naive solution

```
public static void main(String ... args) {
        System.out.println(median(1,2,3,4,5));
}

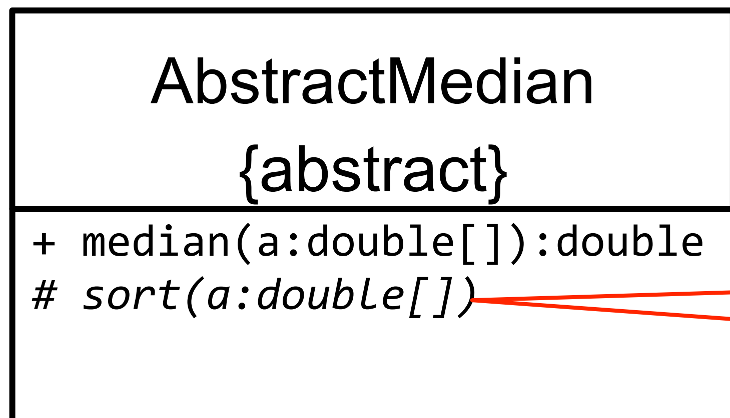
public static double median(double ... numbers) {
    int n = numbers.length;
        boolean swapped = true;
    while(swapped) {
        swapped = false;
        for (int i = 1; i<n; ++i) {
                if (numbers[i-1] > numbers[i]) {
                                ...
                        swapped = true;
                        }
        }
    }
    if (n%2 == 0) {
        return (numbers[(n/2) - 1] + numbers[n/2]) / 2;
    } else {
        return numbers[n/2];
    }
}
```

What's wrong with this design?
How can we improve it?

# Ways to improve

- 1: Monolithic version, static context.
- 2: Extracted sorting method, non-static context.
- 3: Proper package structure and visibility, extracted main method.
- 4: Proper testing infrastructure and build system.

# One possible solution: template method pattern

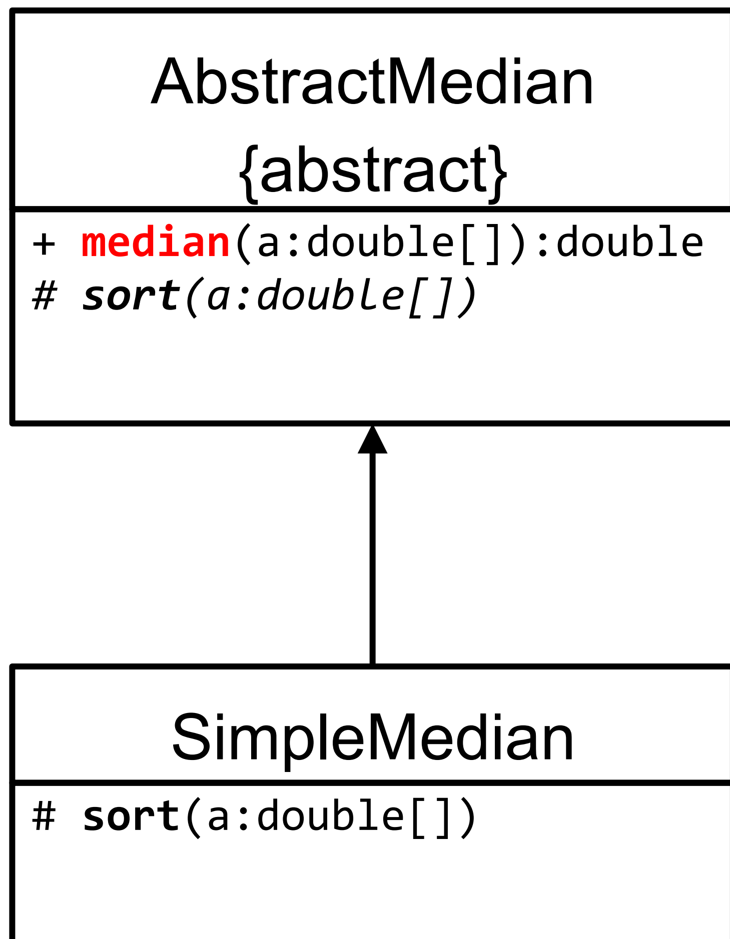



Italics indicate an abstract method.

SimpleMedian

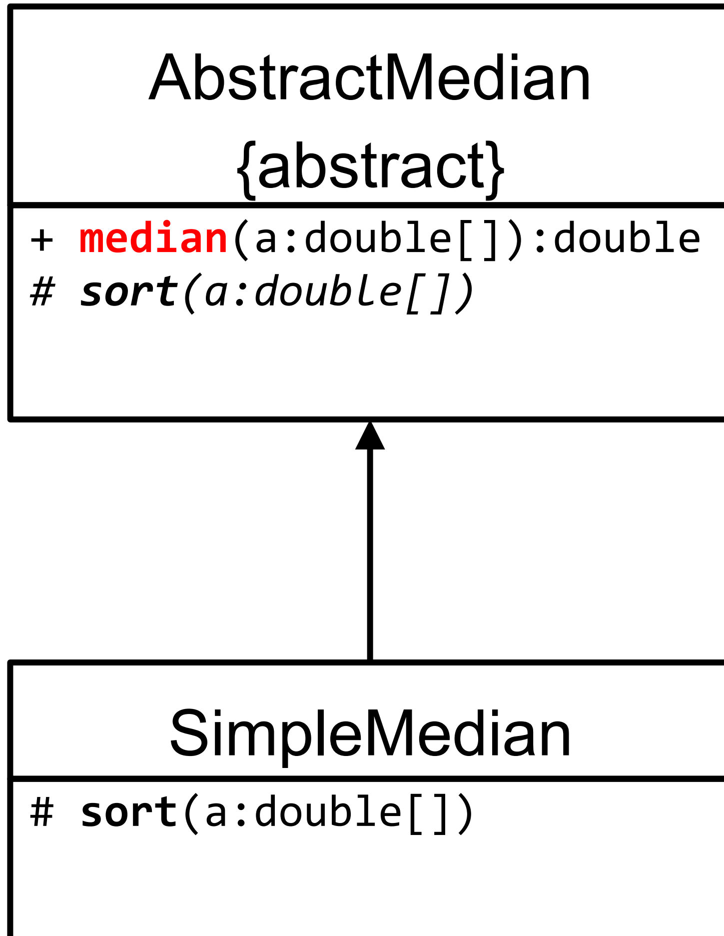
# sort(a:double[])

# One possible solution: template method pattern




- The template method (**median**) implements the algorithm but leaves the **sorting** of the array undefined.
- The concrete subclass only needs to implement the actual **sorting**.

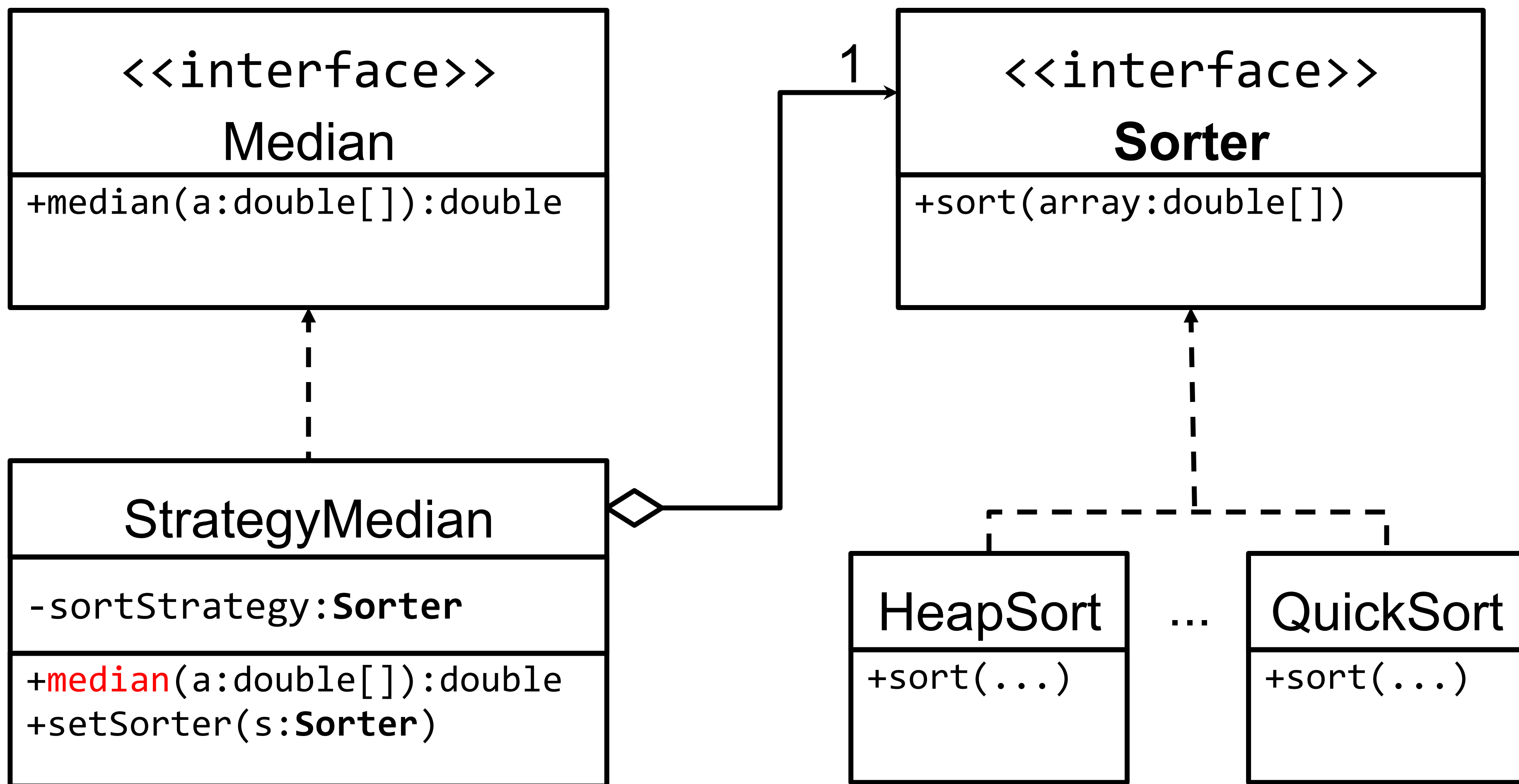
# One possible solution: template method pattern




Should the median method be final?

- The template method (**median**) implements the algorithm but leaves the **sorting** of the array undefined.
- The concrete subclass only needs to implement the actual **sorting**.

# Another solution: strategy pattern




"median" delegates the sorting of the array to a "sortStrategy"

# Template method pattern vs. strategy pattern

**Two solutions to the same problem**

What are the differences, pros, and cons?

# Template method pattern vs. strategy pattern

**Two solutions to the same problem**

**Template method**

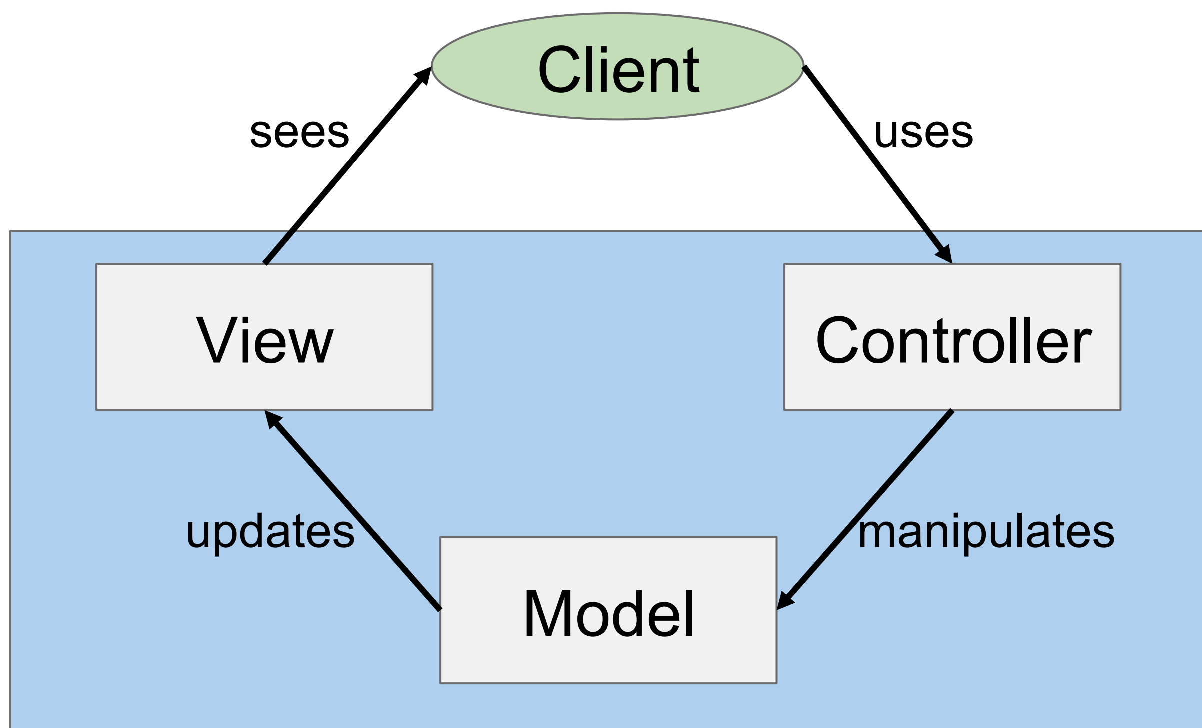
- Behavior selected at compile time.
- Template method is usually final.

**Strategy**

- Behavior selected at runtime.
- Composition/aggregation over inheritance.

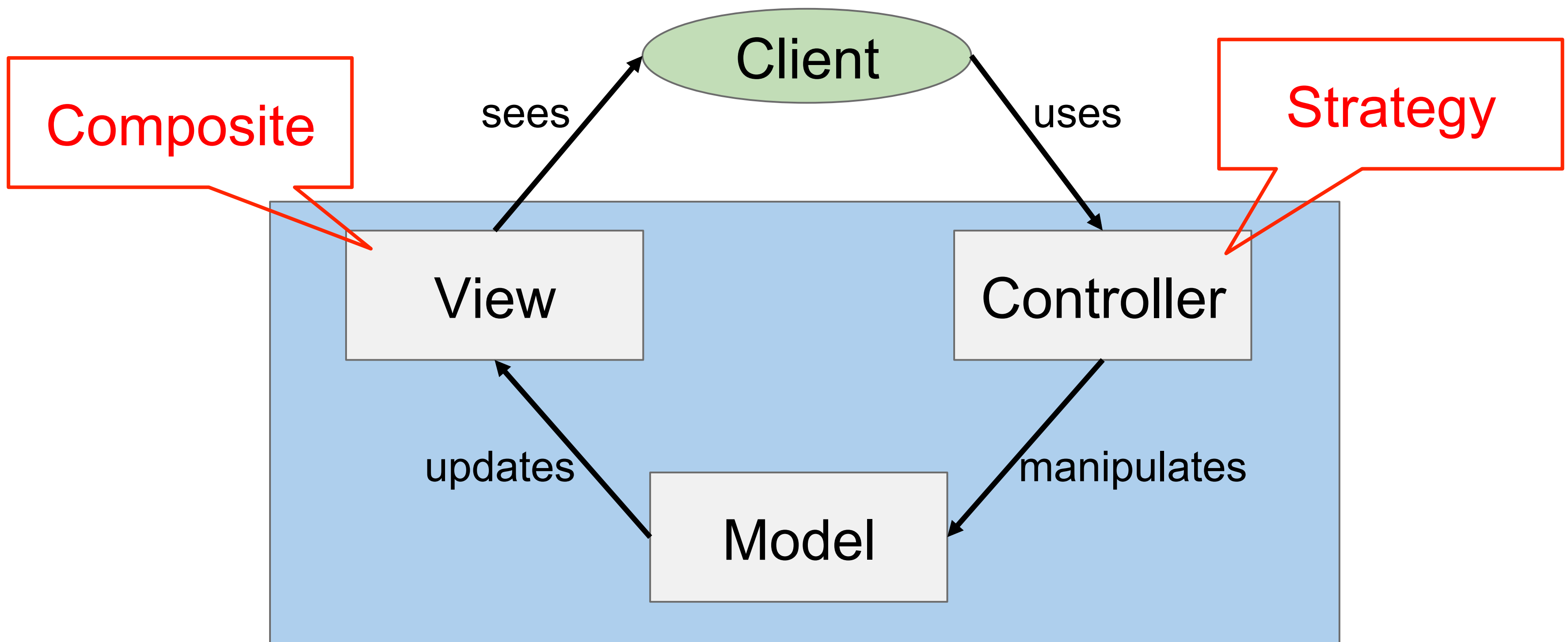
# Model-View-Controller revisited

## Design patterns in a MVC architecture



# Model-View-Controller revisited

## Design patterns in a MVC architecture



# Model-View-Controller revisited

**Design patterns in a MVC architecture**

Client

sees

uses

View

Controller

updates

manipulates

Model

???

# Observer pattern

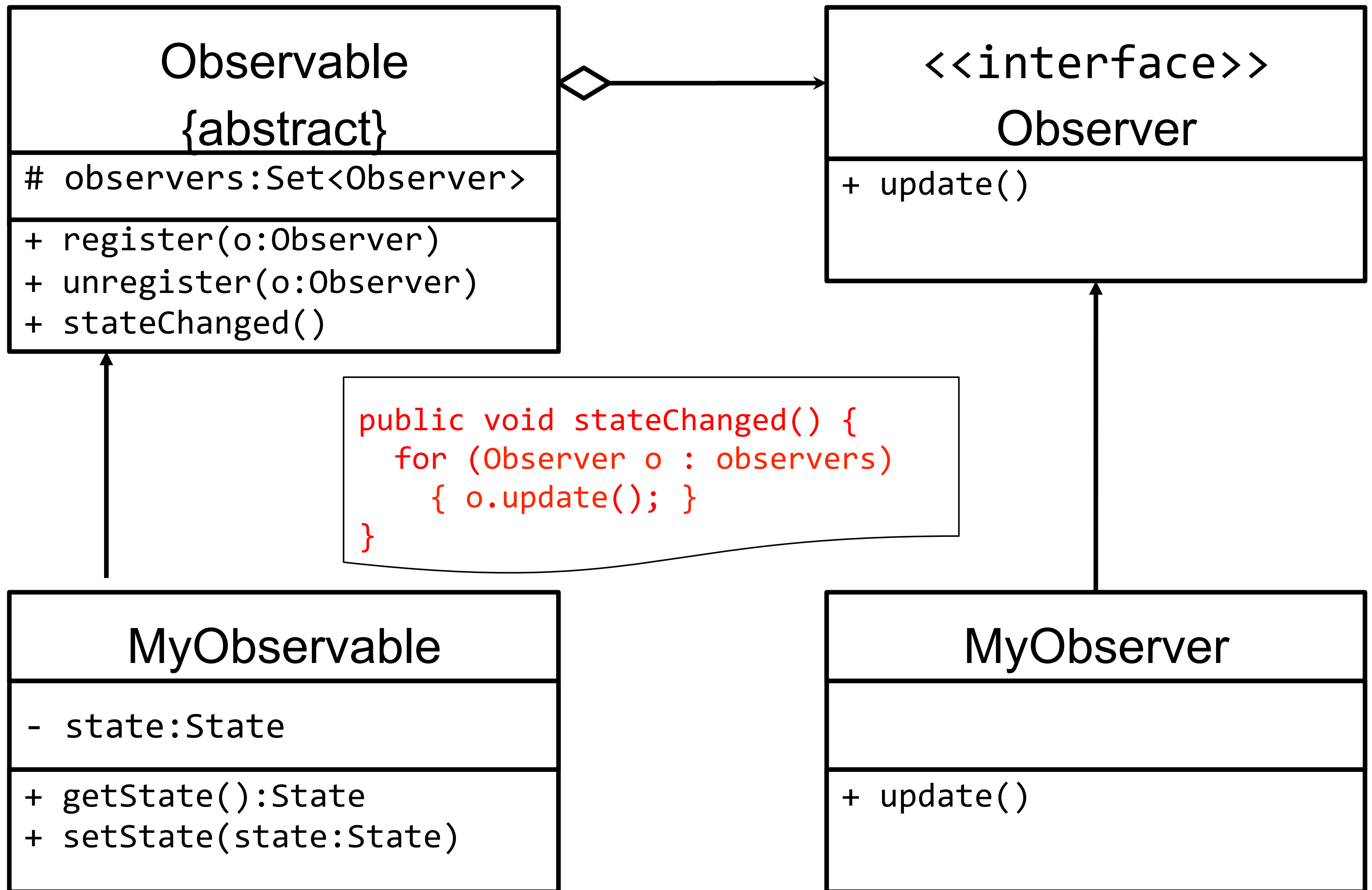
## Observer pattern

From Wikipedia, the free encyclopedia

The **observer pattern** is a software design pattern in which an object, called the **subject**, maintains a list of its dependents, called **observers**, and notifies them automatically of any state changes, usually by calling one of their methods.

- Problem solved:
  - A one-to-many dependency between objects should be defined without making the objects tightly coupled.
  - When one object changes state,
    an open-ended number of dependent objects are updated automatically.
  - One object can notify an open-ended number of other objects.

# Observer pattern




*// For the setState method, use the stateChanged method*

# Variations of the Observer update method

- update(state:State)
  - Alternatively, could decompose the State into pieces
- update(observable:Observable)
  - Use the Observable getState method(s)

# Example: Observer pattern for MVC

1) **Which is the Observable?** Model or View

2) **Which is the Observer?** Model or View

3) **Which class should use the getState method**
   Model, View, or Controller

4) **Which class should use the setState method?**
   Model, View, or Controller

# Model-View-Controller revisited

**Design patterns in a MVC architecture**