CS 520

Theory and Practice of Software Engineering
Fall 2020

Object Oriented Design Patterns

September 8, 2020

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

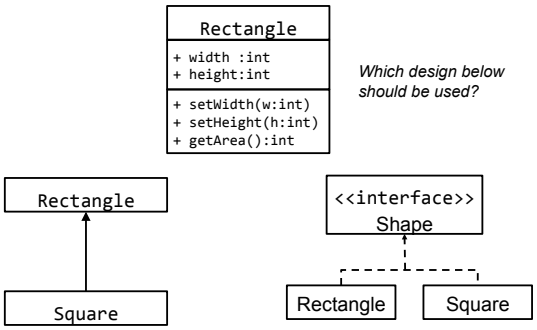
- Information hiding (and encapsulation)
- Open/closed principle
- Liskov substitution principle
- Composition/aggregation over inheritance
  - Can be used to prevent the diamond of death

Recap

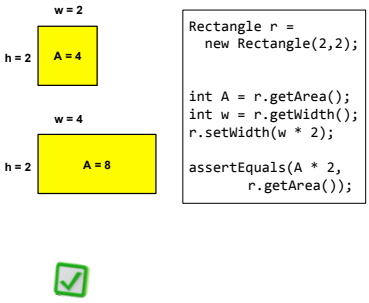
Object oriented design principles

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

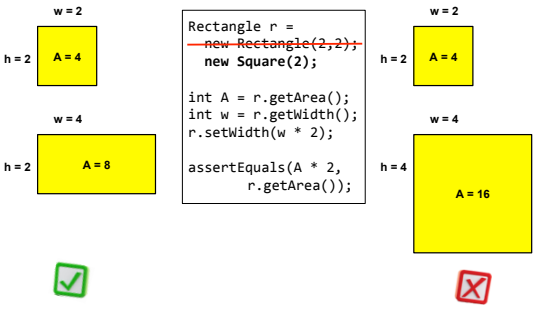
Design principles: Liskov substitution principle



Design principles: Liskov substitution principle



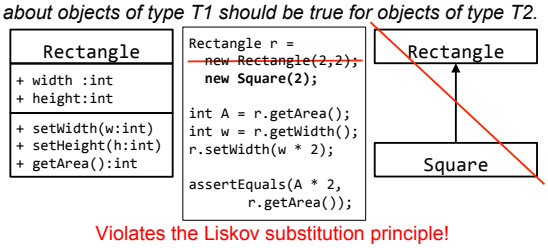
Design principles: Liskov substitution principle



Design principles: 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.

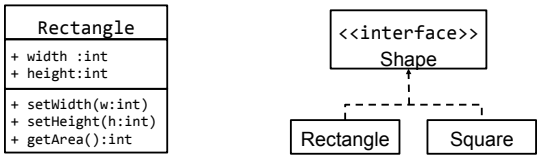


Violates the Liskov substitution principle!

Design principles: 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.



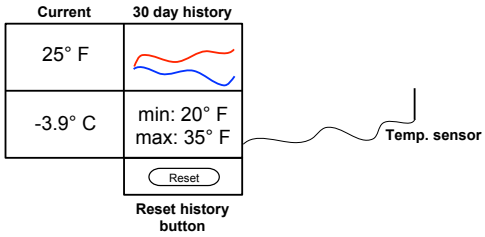
Design patterns

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

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

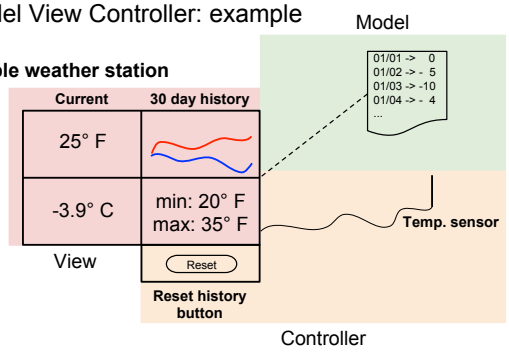
A first design problem

Weather station revisited

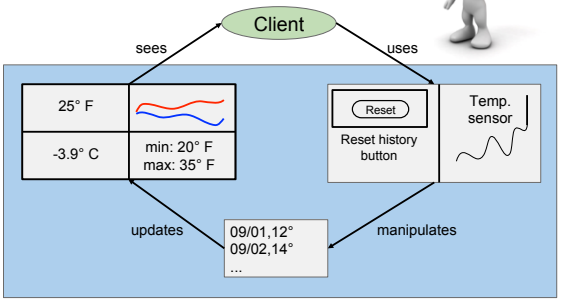


Model View Controller: example

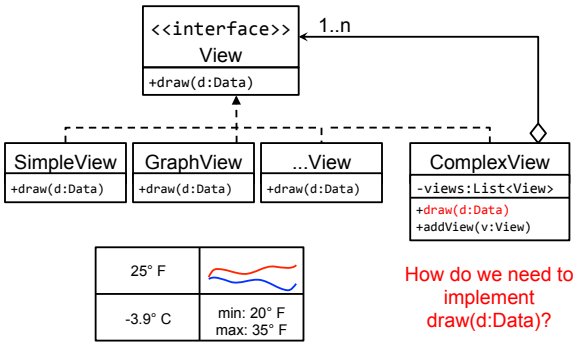
Simple weather station



What's a good design for the view?

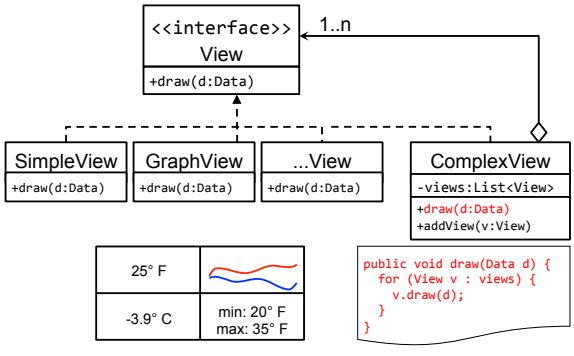


Weather station: view

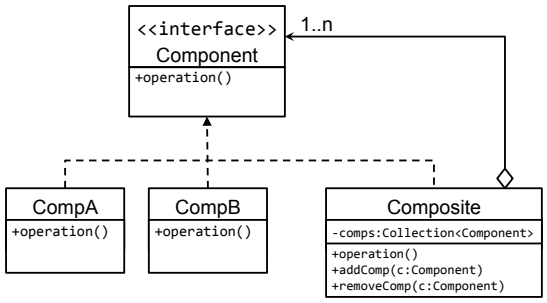


How do we need to implement draw(d:Data)?

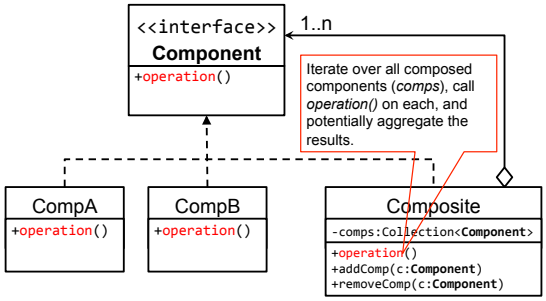
Weather station: view



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

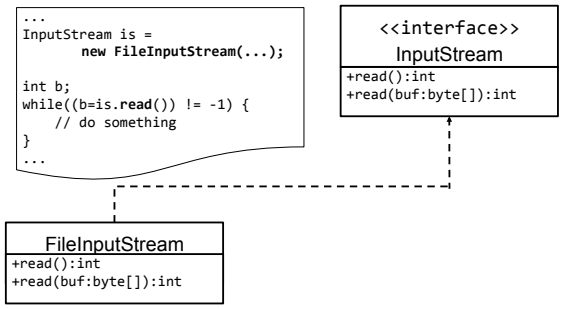
- Risk of over-engineering.
- Potential impact on system performance.

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

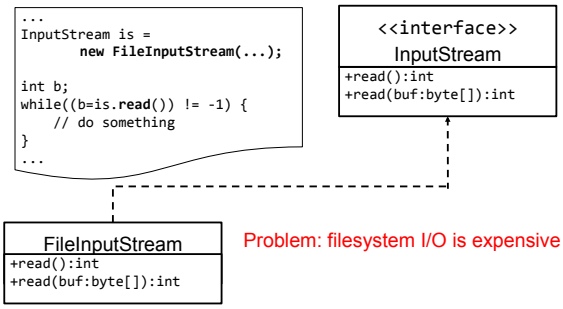
Design patterns: categories

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

Another design problem: I/O streams

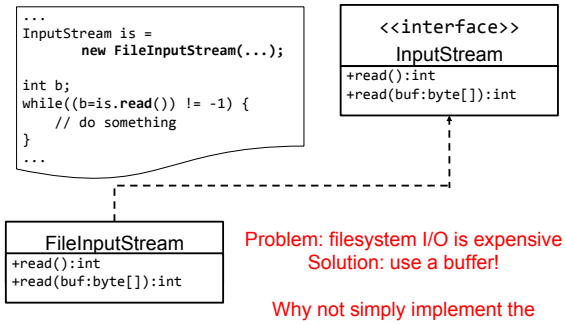


Another design problem: I/O streams



Problem: filesystem I/O is expensive

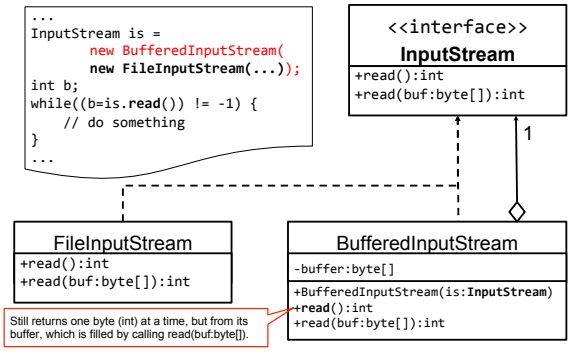
Another design problem: I/O streams



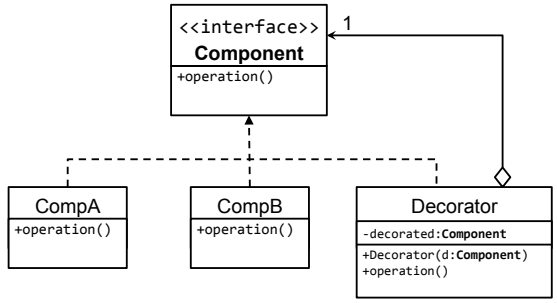
Problem: filesystem I/O is expensive
Solution: use a buffer!

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

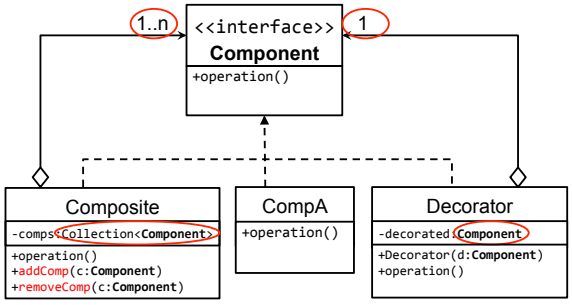
Another design problem: I/O streams



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

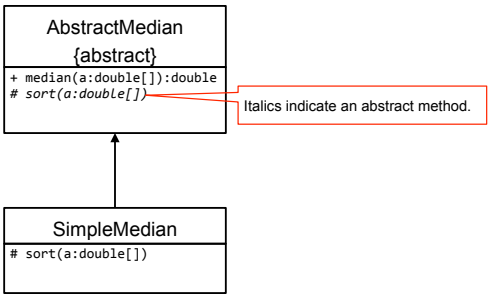
```
public static void main(String ... args) {
        System.out.println(median(1,2,3,4,5));
}

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?

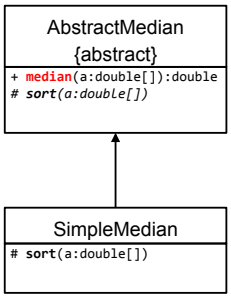
Ways to improve

- 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

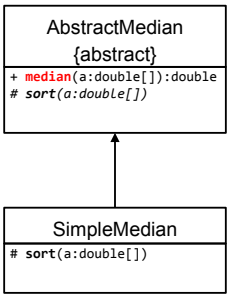


One possible solution: template method pattern



- 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**.

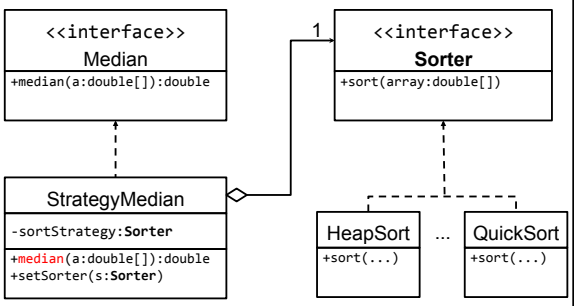
One possible solution: template method pattern



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

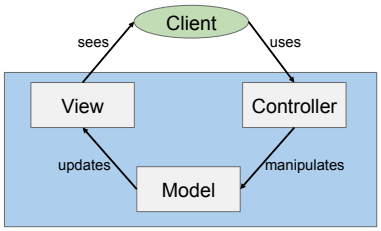
- Behavior selected at compile time.
- Template method is usually final.

Strategy

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

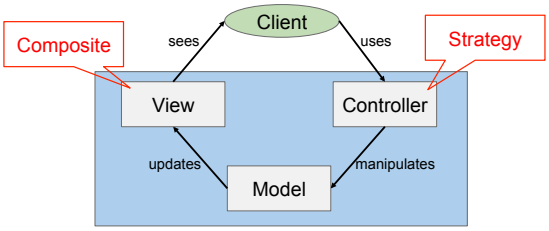
Model-View-Controller revisited

Design patterns in a MVC architecture



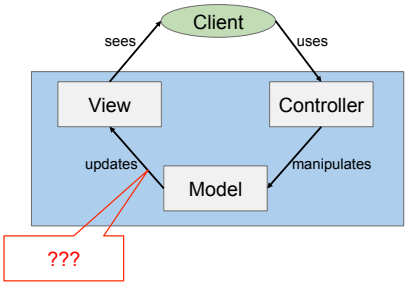
Model-View-Controller revisited

Design patterns in a MVC architecture



Model-View-Controller revisited

Design patterns in a MVC architecture



Observer pattern

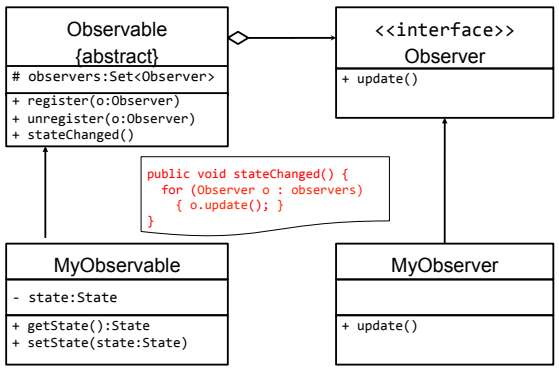
Observer pattern

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

- **Which is the Observable?** Model or View
- **Which is the Observer?** Model or View
- **Which class should use the setState method?** Model, View, or Controller

Example: Observer pattern for MVC

- **Which is the Observable?** Model or View
- **Which is the Observer?** Model or View
- **Which class should use the setState method?** Model, View, or Controller

Model-View-Controller revisited

Design patterns in a MVC architecture