Design Patterns

Design Patterns

- Tested, proven and documented solutions for recurring design problems in given contexts.
- Each design pattern is structured as
  - Pattern name
  - Intent
  - Motivation
  - Applicability
  - Class structure
  - Participants
  - …etc.

Resources

- *Design Patterns: Elements of Reusable Object-Oriented Software*
  - Eric Gamma et al., Addison-Wesley
- *Head First Design Patterns*
  - Elizabeth Freeman et al., O'Reilly
- *Game Programming Patterns*
  - Robert Nystrom, Genever Benning
  - http://gameprogrammingpatterns.com/introduction.html
- Web
  - http://en.wikipedia.org/wiki/Design_patterns_(computer_science)
  - http://sourcemaking.com/design_patterns

Benefits of Design Patterns

- Useful information source to learn and practice good designs
- Useful as a communication tool among developers
  - e.g., Recursion, collection (array, stack, queue, etc.), sorting, buffers, infinite loops

Recap: Brief History to OOD

- In good, old days… programs had no structures.
  - One dimensional code.
    - From the first line to the last line on a line-by-line basis.
    - "Go to" statements to control program flows.
      - Produced a lot of "spaghetti" code
        - » "Go to" statements considered harmful.
  - No notion of structures (or modularity)
    - Modularity: Making a chunk of code (module) self-contained and independent from the other code
      - Improve reusability and maintainability
        - » Higher reusability → higher productivity, less production costs
        - » Higher maintainability → higher productivity and quality, less maintenance costs

Modules in SD and OOD

- Modules in Structured Design (SD)
  - Structure = a set of variables (data fields)
  - Function = a block of code
- Modules in OOD
  - Class = a set of data fields and functions
  - Interface = a set of abstract functions
- Key design questions/challenges:
  - how to define modules
  - how to separate a module from others
  - how to let modules interact with each other

SD v.s. OOD

- OOD
  - Intends coarse-grained modularity
    - The size of each code chuck is often bigger.
  - Extensibility in mind in addition to reusability and maintainability
    - How easy (cost effective) to add and revise existing modules (classes and interfaces) to accommodate new/modified requirements.
    - How to make software more flexible/robust against changes in the future.
  - How to gain reusability, maintainability and extensibility?
    - Design patterns show good examples.

Suggested Read

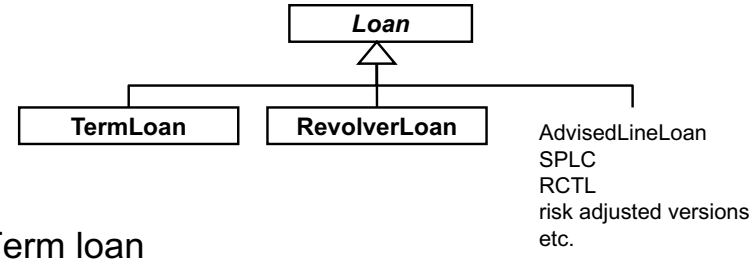
- Chapter 1 (Introduction) of *Game Programming Patterns*
  - http://gameprogrammingpatterns.com/introduction.html

Static Factory Method

Static Factory Method

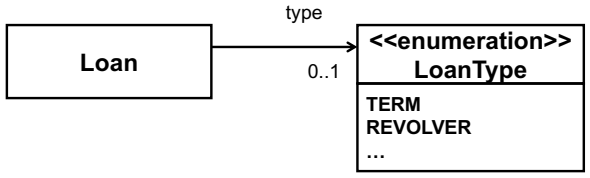
- Intent
  - Define a “communicable” method to instantiate a class
    - Constructors are the methods to instantiate a class.
    - Static factory methods are more “communicable” (or easier to use) than constructors.
- Benefits
  - Static factory methods have names (!).
    - Improve code maintainability.
      - The name can explicitly tell what object to be returned.
      - Client code gets easier to understand.

Recap: This Design is not Good.

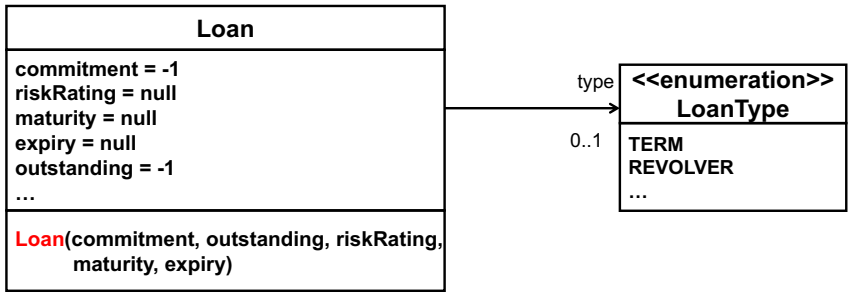


- Term loan
  - Must be fully paid by its maturity date.
- Revolver (e.g. credit card)
  - With a spending limit and expiry date
- Dynamic class change problem
  - A revolver can transform into a term loan when the revolver expires.

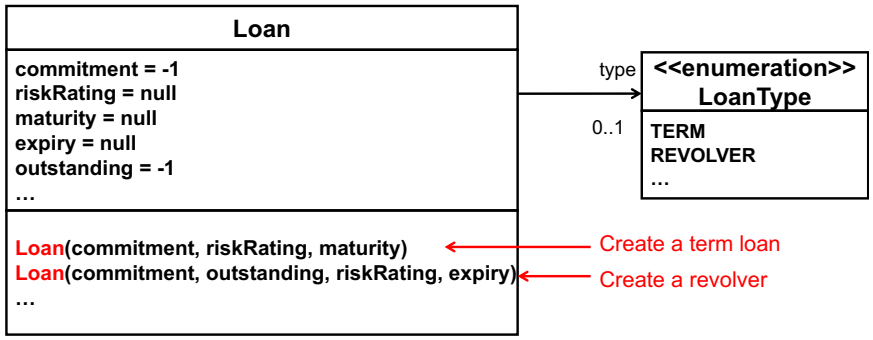
Enumeration-based Design



- A class inheritance should not be used here.

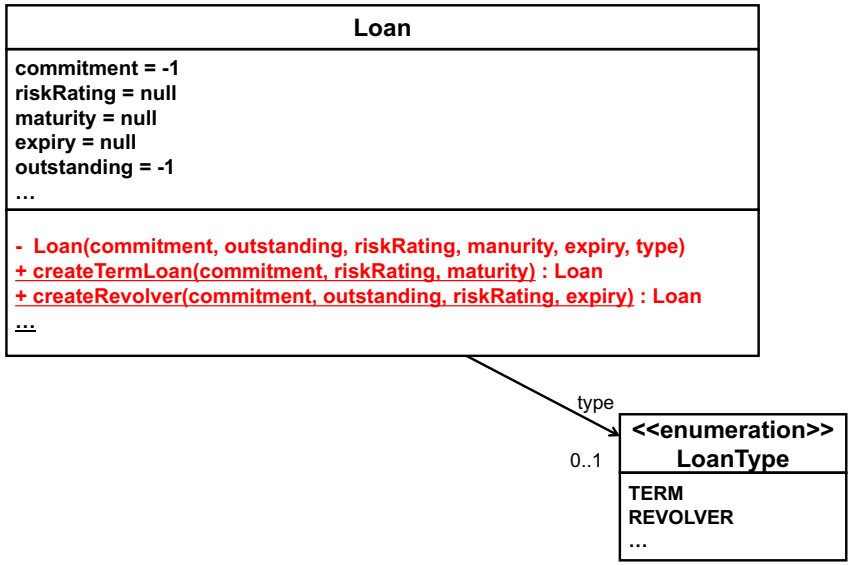


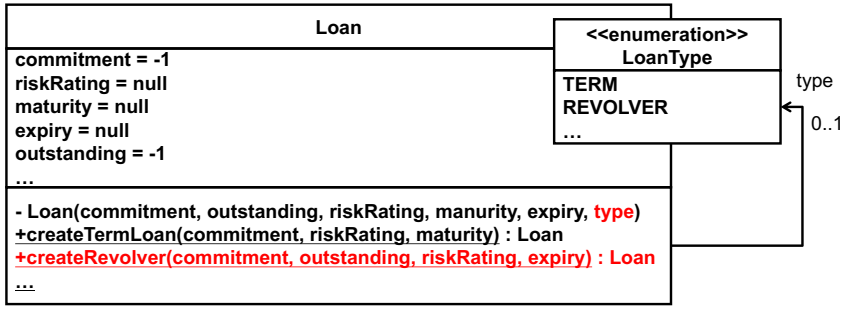
- Different loans need different sets of data to be set up.
  - A term loan needs commitment, risk rating and maturity date.
  - A revolver needs commitment, outstanding debt, risk rating and expiry date.
- The constructor is hard to use and error-prone.
- Client code is hard to understand.
  - `Loan l1 = new Loan(100, -1, 0.9, new Date(…), null);`
    `l1.setLoanType( LoanType.TERM );`
  - `Loan l2 = new Loan(100, 0, 0.7, null, new Date(…));`
    `l2.setLoanType( LoanType.REVOLVER );`



- Multiple constructors to create different types of loans.
- They are less error-prone, but still hard to use.
- Client code is still hard to understand.
  - `Loan l1 = new Loan(100, 0.9, new Date(…));`
    `l1.setLoanType( LoanType.TERM );`
  - `Loan l2 = new Loan(100, 0, 0.7, new Date(…));`
    `l2.setLoanType( LoanType.REVOLVER );`

Static Factory Methods





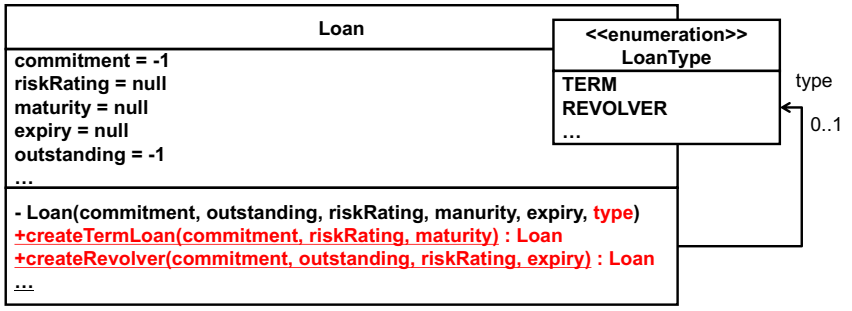
- Client/user of Loan
  - `Loan loan = Loan.createRevolver(1000,0,…,…);`

```
Public class Loan{
  private LoanType type = null;
  ……
  private Loan(…,…,…,…,…,…){ … }
  public static Loan createRevolver( commitment, outstanding,
                                     riskRating, expiry ){
    return new Loan( commitment, outstanding, riskRating, null,
                     expiry, LoanType.REVOLVER );
  }
```

- Benefits of *Static Factory Method*
  - Static factory methods have names (!).
    - Improve code maintainability.
      - The name can explicitly tell what object to be returned.
      - Client code gets easier to understand.

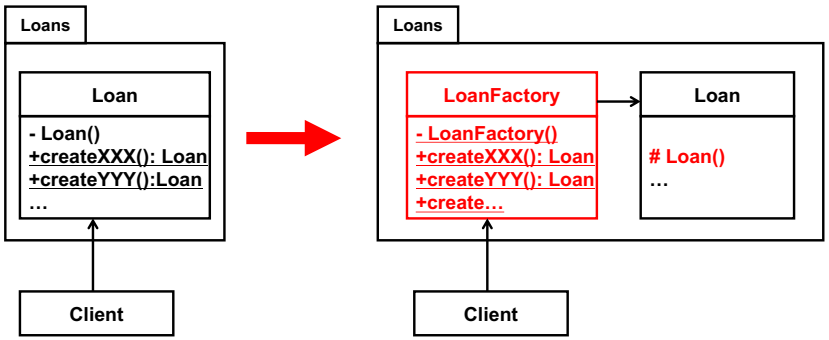
```
Loan l1 = new Loan(100, 0.9, new Date(…));
Loan l2 = Loan.createTermLoan(100, 0.9, new Date(…));
```


A Potential Issue



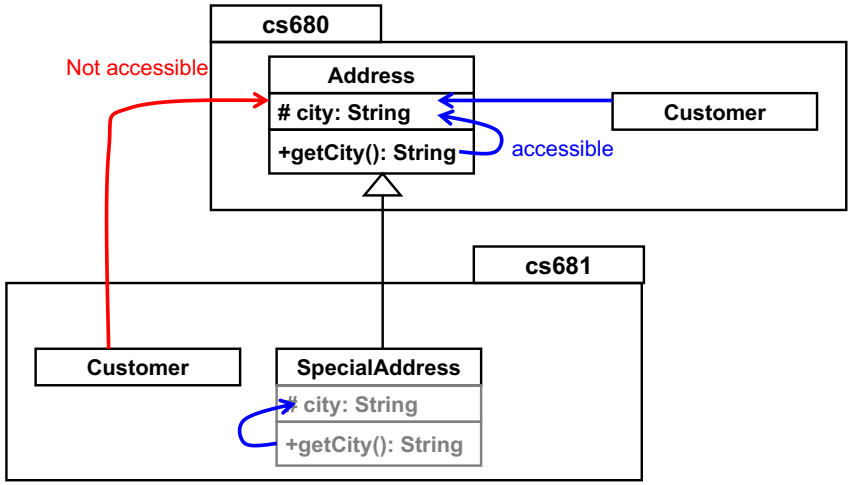
- Too many (static) factory methods in a class may obscure its primary responsibility/functionality.
  - They may dominate the class's public methods.
  - Loan may no longer strongly communicate it's primary (i.e., loan-related) responsibility/functionality.

Alternative: Factory Class



- Factory class
  - A class that encapsulates static factory methods and isolate instantiation logic from other classes.
- Loan can now directly/strongly communicate its primary responsibility/functionality.

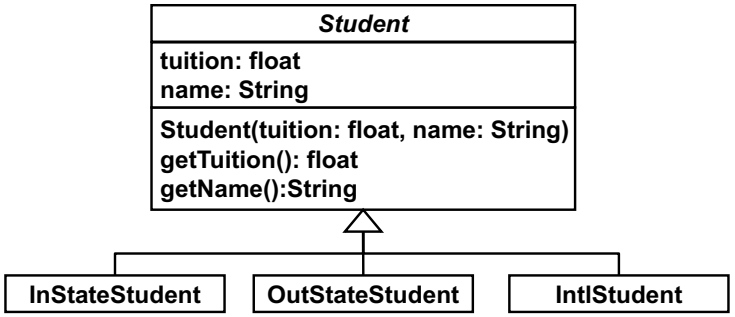
Recap: "Protected" Visibility



Design Tradeoffs

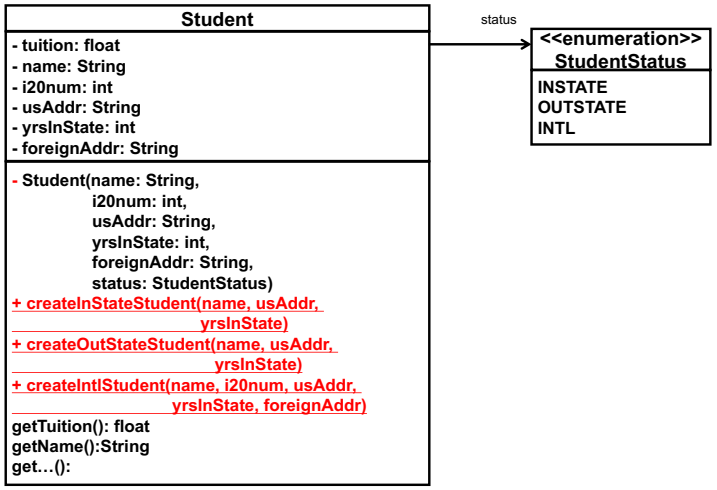
- Class inheritance
  - Pros: Straightforward.
  - Cons: Dynamic class change is hard (virtually impossible) to implement.
- Static factory method
  - Pros: Can avoid dynamic class change problem.
  - Cons: Potentially too many factory methods in a single class
- Factory class
  - Pros: Separates a class's primary logic and its instantiation logic
  - Cons: Non-factory classes in the same package can call protected constructors.
    - Could violate the encapsulation principle.
    - Consider an inner class (e.g., Loan as an inner class of LoanFactory)

Recap: This Design is not Good.



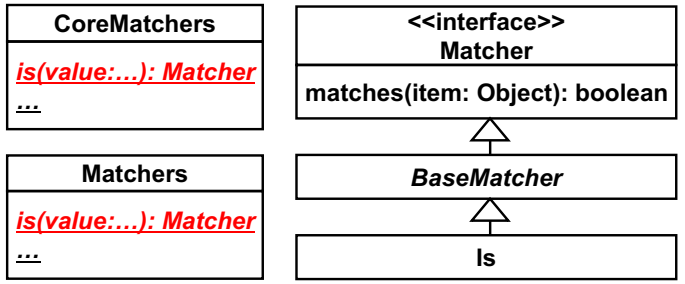
- Alternative designs
  - Use an enumeration
  - Use *Static Factory Method* and an enumeration

Design Improvement w/ *Static Factory Method*



Another Example: Matchers in hamcrest-all.jar

- `org.hamcrest.CoreMatchers`
- `org.hamcrest.Matchers`
  - Contains static methods, each returning a matcher object that performs matching logic.
  - `Matchers` is a superset of `CoreMatchers`.
- `is()` is a static factory method that creates an instance of `Is`.



Suggested Read

- Chapter 2 (Creating and destroying Objects) of *Effective Java*
  - Joshua Bloch, Addison
  - http://bit.ly/2ydblp8

Singleton Design Pattern

Singleton

- Intent
  - Guarantee that a class has only one instance.

```
public class Singleton{
    private Singleton(){};
    private static Singleton instance = null;

    public static Singleton getInstance(){
          if(instance==null)
                instance = new Singleton ();
          return instance;
    }
}
```

- You should not define public constructors.
- If you do not define constructors...


```
Singleton instance = Singleton.getInstance();
instance.hashCode();
Singleton instance = Singleton.getInstance();
instance.hashCode();
```

- hashCode() returns a unique ID for each instance.
  - Different instances of a class have different IDs.
- *Singleton* is an application of *Static Factory Method*.
  - getInstance() is a static factory method.
  - *Singleton* focuses on a requirement to have a class keep only one instance.

What Can be a Singleton?

- Object pools
- Logger
- Plugin manager
- Access counter
- Game loop
- …, etc.

Alternative Implementation with Null Checking API in Java 7

- java.util.Objects, extending java.lang.Object
  - A utility class (i.e., a set of static methods) for the instances of java.lang.Object and its subclasses.
  - ```
    class Foo{
        private String str;
        public Foo()(String str){
            this.str = Objects.requireNonNull(str);
        } }
    ```
    - `requireNonNull()` throws a `NullPointerException` if `str==null`. Otherwise, it simply returns `str`.
  - ```
    class Foo{
        private String str;
        public Foo()(String str){
            this.str = Objects.requireNonNull(
                            str, "str must be non-null!!!");
        } }
    ```
    - `requireNonNull()` can accept an error message, which is to be contained in a `NullPointerException`.

- Traditional null checking
  - ```
    if(str == null)
        throw new NullPointerException();
    this.str = str;
    ```
- With `Objects.requireNonNull()`
  - ```
    this.str = Objects.requireNonNull(str);
    ```
- Can eliminate an explicit conditional statement and make code simpler.

Singleton Implimentaion with `Objects.requireNonNull()`

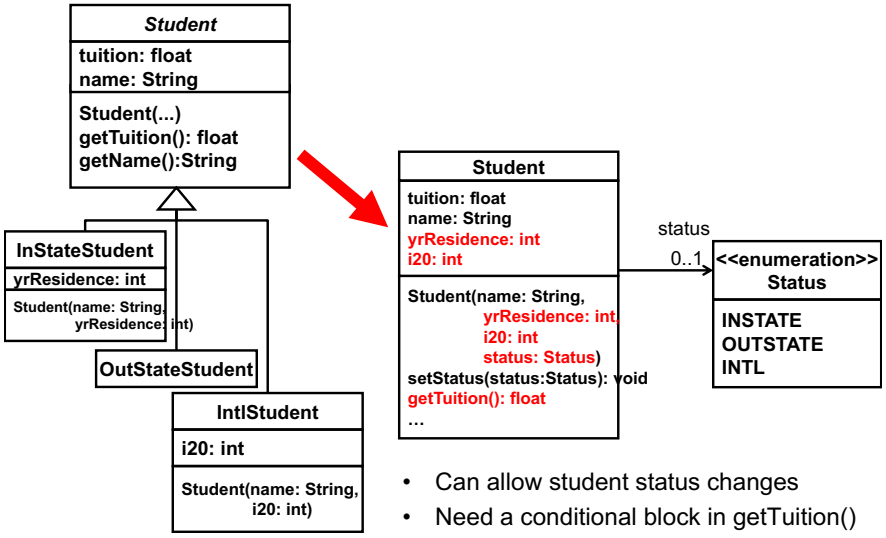
- ```
  public class SingletonNullCheckingJava7{
      private SingletonNullCheckingJava7(){};
      private static SingletonNullCheckingJava7 instance = null;

      public static SingletonNullCheckingJava7 getInstance(){
        try{
            return Objects.requireNonNull(instance);
        }
        catch(NullPointerException ex){
            instance = new SingletonNullCheckingJava7();
            return instance;
      } }
  ```
- ```
  public class Singleton{
      private Singleton(){};
      private static Singleton instance = null;

      public static Singleton getInstance(){
             if(instance==null)
                    instance = new Singleton ();
             return instance;
      } }
  ```

State Design Pattern

State

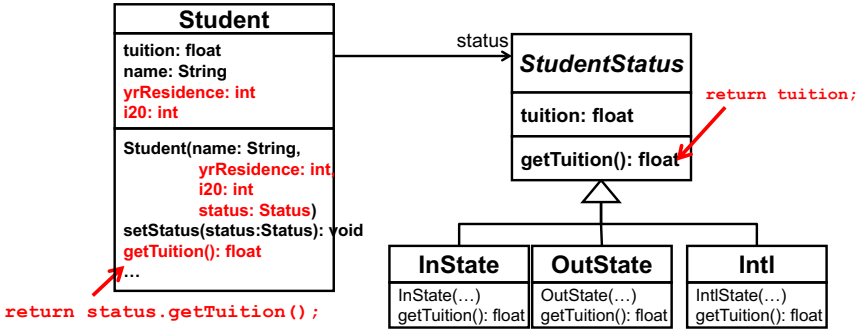
- Intent
  - Allow an object to change its behavior according to its state.

Eliminating Class Inheritance



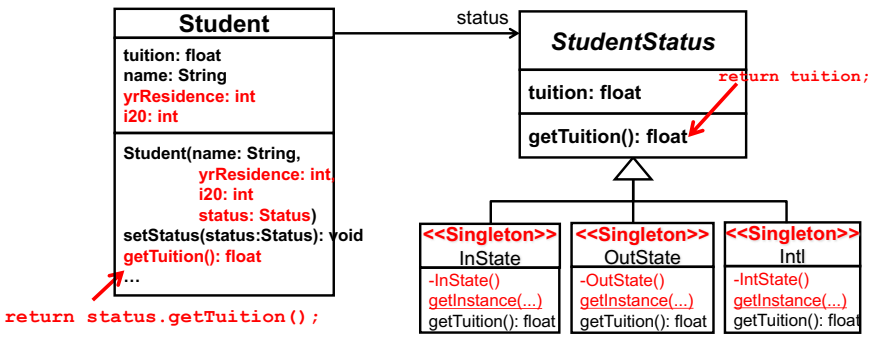
- Can allow student status changes
- Need a conditional block in getTuition()
  - Can remove the conditional with *State*.

Design Improvement with *State*



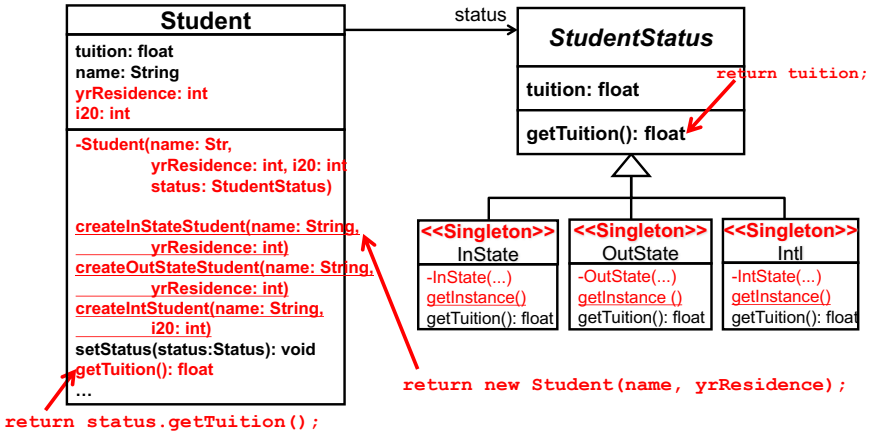

```
Student s1 = new Student( ..., new InState(...) );
s1.getTuition();
```

State Classes as *Singleton*




```
Student s1 = new Student( ..., InState.getInstance(...) );
s1.getTuition();
```


Adding *Static Factory Methods*




```
Student s1 = Student.createInStateStudent( "John Smith", 18 );
s1.getTuition();
```


Another Example: DVD Player

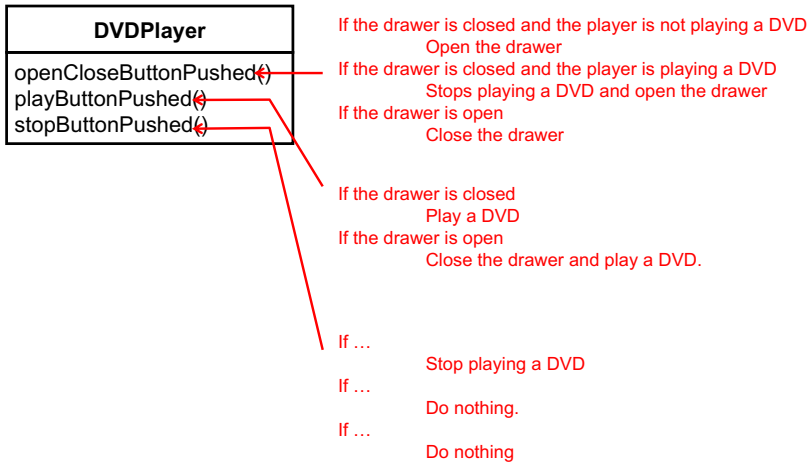
- Imagine you implement a firmware of DVD players
  - Focus on a player's ***behaviors*** upon ***events***.
  - Events
    - The "Open/Close" button is pushed.
    - The "Play" button is pushed.
    - The "Stop" button is pushed.

  - The player behaves upon a certain event differently depending on its current state.
    - State-dependent behaviors

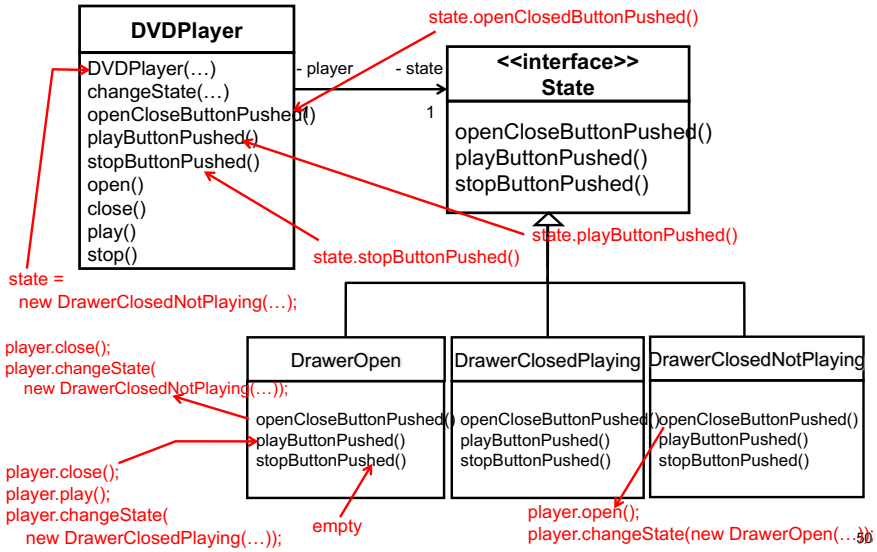
State-Dependent Behaviors

- When the "open/close" button pushed,
  - Opens the drawer
    - If the drawer is closed and the player is not playing a DVD.
  - Stops playing a DVD and opens the drawer
    - if the drawer is closed and the player is playing a DVD.
  - Closes the drawer
    - if the drawer is open.
- When the "play" button pushed,
  - Plays a DVD
    - If the drawer is closed.
      - Displays an error message if the drawer is empty.
  - Closes the drawer and plays a DVD
    - If the drawer is open.
      - Displays an error message if the drawer is empty.

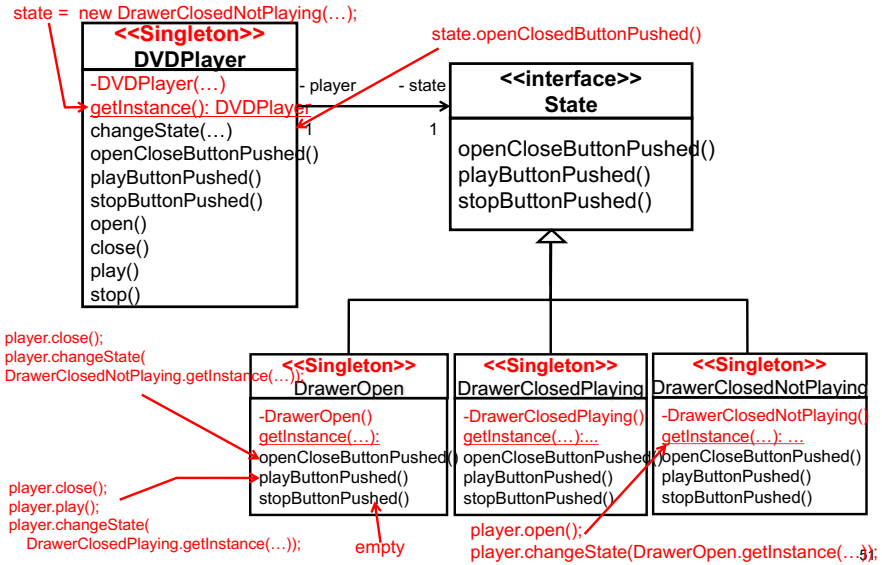
- When the "stop" button pushed
  - Stops playing a DVD
    - If the drawer is closed and the player is playing a DVD
  - Does nothing.
    - If the drawer is closed and the player is not playing a DVD.
  - Does nothing
    - If the drawer is open.



Defining States as Classes



State Classes as *Singleton*



State

- Intent
  - Allow an object to change its behavior according to its state.
  - Can implement state-dependent behaviors without conditionals.

HW 2

- Implement the design in Slide 51.
- Write and run at least one test case for every single method.

- **FIRM** Deadline: October 26 (Thu) midnight

- Use <batchtest> to have Ant search test classes in your project directory and run all of them (DVDPlayerTest, etc.).
  - <junit …>
    …
    <batchtest …>
    ...
    </batchtest>
    ...
    </junit>

  - c.f. JUnit documentation

HW Submission

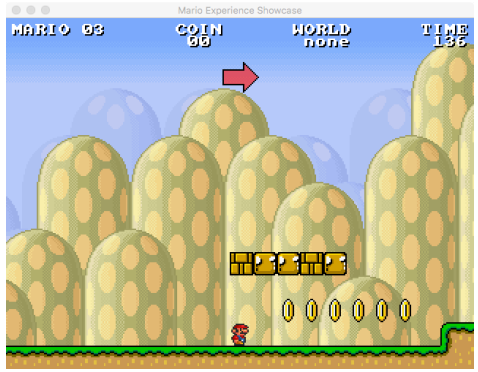
- Submit me an archive file (.rar, .tar.gz, .7z, etc.) that contains
  - build.xml
  - "src" sub-directory
  - "test/src" sub-directory

  - DO NOT send me binary files (.class and .jar files)
  - Avoid a .zip file. (Gmail often removes attached .zip files.)

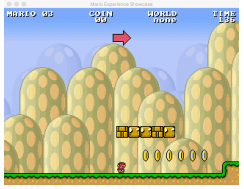
  - Send the archive file to **umasscs680@gmail.com** from **your "primary" email address**
  - Or, place it somewhere online (e.g. at G Drive) and email me a link to it.

One More Example: A Simple 2D Game

- Imagine a simple 2D game like Super Mario
  - http://www.marioai.org/
  - http://www.platformersai.com



Handling User Inputs



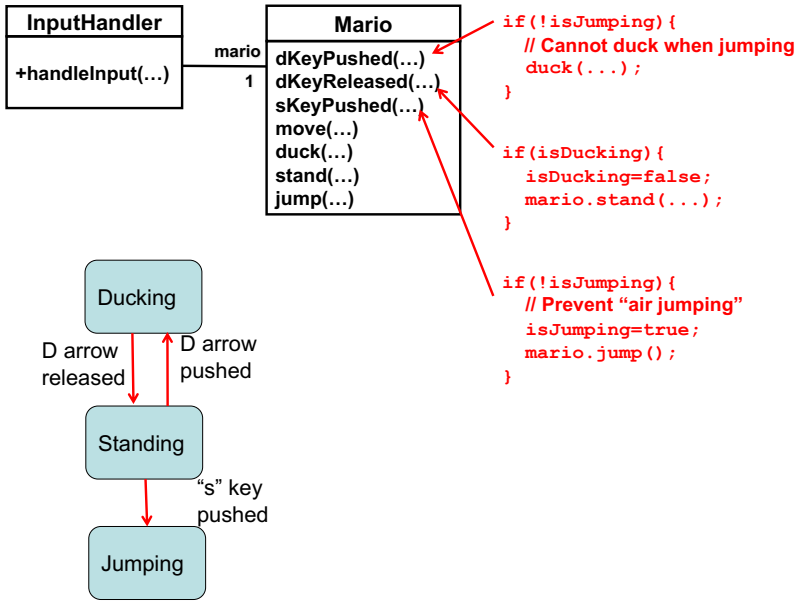
Detect inputs from the user
→ Call InputHandler.handleInput()

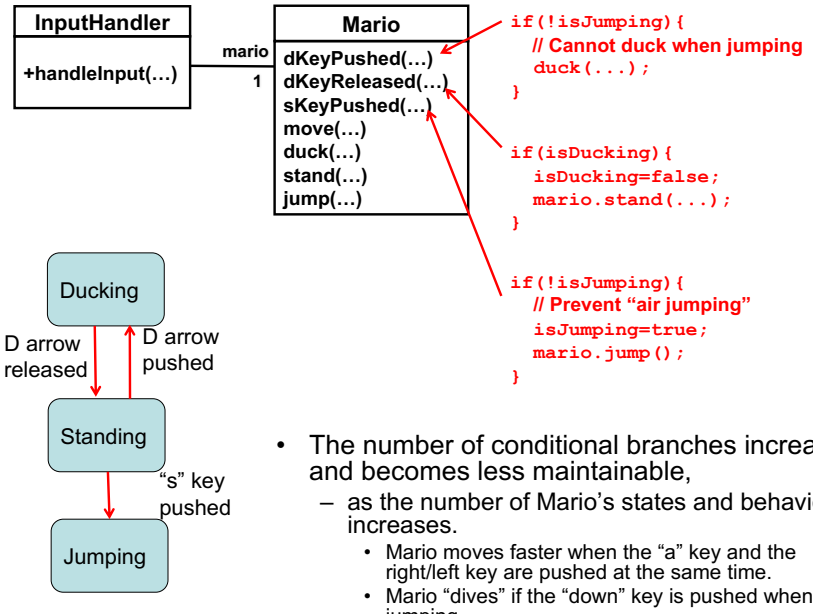
Update the scene (game world)

Render the game world

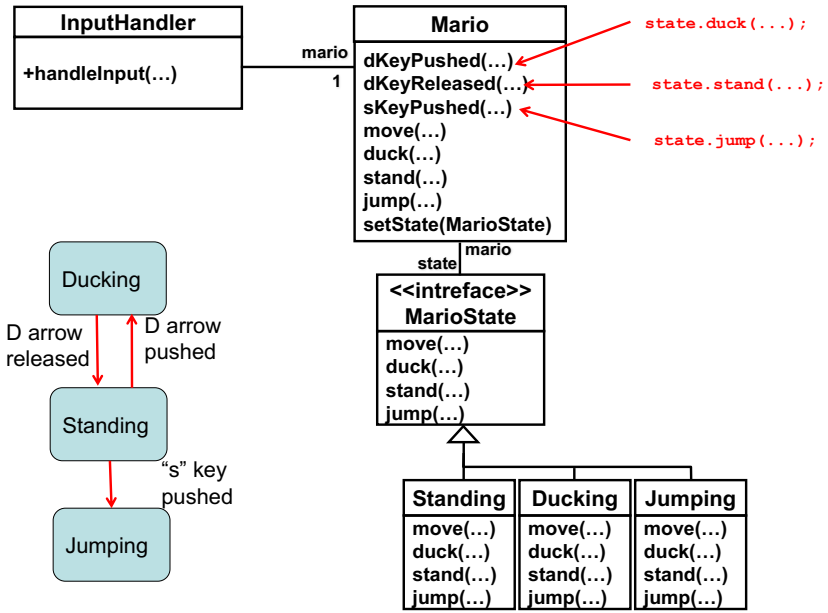
```
InputHandler ih = new InputHandler(...);
while(true){
  ih.handleInput(...);
  ...
}
```

- 5 types of inputs
  - The user pushes the right arrow, left arrow, down arrow and "s" keys.
    - R arrow to move right
    - L arrow to move left
    - D arrow to duck
    - "s" to jump
  - The user releases the D arrow to stand up.
- InputHandler
  - handleInput()
    - identifies a keyboard input since the last game loop iteration (i.e. since the last frame).
    - 60 frames/s (FPS): One input per frame (i.e. during 1.6 msec)





- The number of conditional branches increases and becomes less maintainable,
  - as the number of Mario's states and behaviors increases.
    - Mario moves faster when the "a" key and the right/left key are pushed at the same time.
    - Mario "dives" if the "down" key is pushed when jumping.



HW 3

- Explain how each state class's methods should be implemented.

- **FIRM** Deadline: October 26 (Thu) midnight