CSE201: Monsoon 2020
Advanced Programming

Lecture 22: Introduction to Design Patterns

Vivek Kumar
Computer Science and Engineering
IIIT Delhi
vivekk@iiitd.ac.in

Today’s Lecture

- One remaining topic in multithreading
  - Deadlocks
- Introduction to design patterns
  - Iterator
  - Singleton
  - Flyweight
  - (Acknowledgement: CSE331, University of Washington)


DEADLOCK
© CanStockPhoto.com - csp50107200

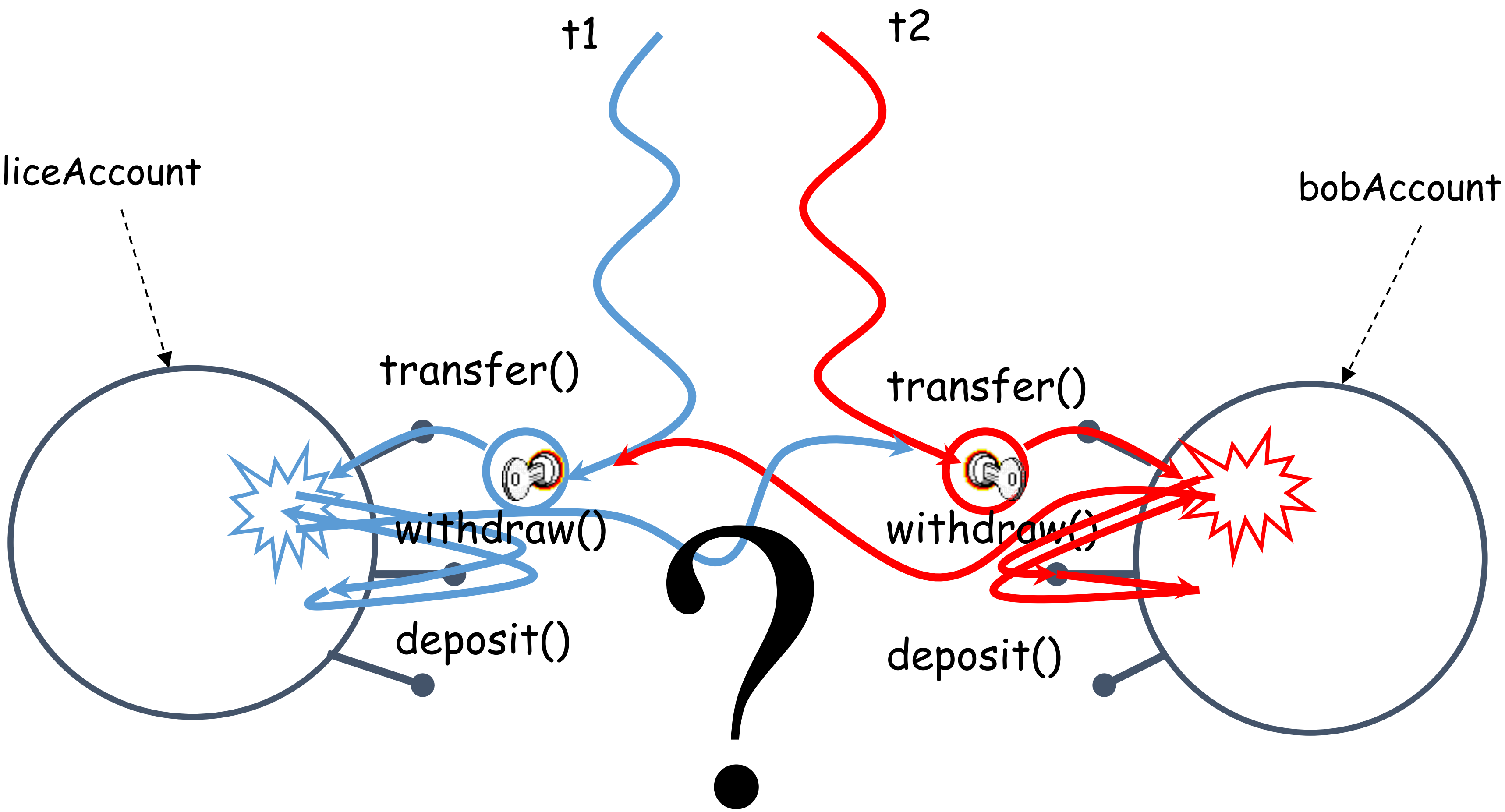
Let's Code a Deadlock

```java
public class BankAccount {

    private volatile float balance;

    public synchronized void deposit(float amount) {
        balance += amount;
    }

    public synchronized void withdraw(float amount) {
        balance -= amount;
    }

    public synchronized void transfer(float amount,
                               BankAccount target) {
        withdraw(amount);
        target.deposit(amount);
    }
}
```

```java
public class MoneyTransfer implements Runnable {
    private BankAccount source, target;
    private float amount;
    public MoneyTransfer(BankAccount from,
                  BankAccount to, float amount) {
        this.source = from;
        this.target = to;
        this.amount = amount;
    }
    public void run() {
        source.transfer(amount, target);
    }
}
```

```java
BankAccount aliceAccount = new BankAccount();
BankAccount bobAccount = new BankAccount();
...
// At one place
Runnable transaction1 = new MoneyTransfer(aliceAccount, bobAccount, 1200);
Thread t1 = new Thread(transaction1);
t1.start();

// At another place
Runnable transaction2 = new MoneyTransfer(bobAccount, aliceAccount, 700);
Thread t2 = new Thread(transaction2);
t2.start();
```

Let’s Analyze Our Bank Transaction



Deadlock Avoidance

- **Deadlock occurs when multiple threads need the same set of locks but obtain them in different order**
- Not so easy to avoid deadlocks
- It’s an active research area

Let’s try simple remedies to fix
our Bank Transaction program

Deadlock Avoidance

- Lock ordering
  - Ensure that all locks are taken in same order by any thread
- Lock timeout
  - Put a timeout on lock attempts
    - Not possible with monitor locks
      - You will need java.util.concurrent.ReentrantLock

Now Let’s Resolve the Deadlock

```java
public class BankAccount {

    private volatile float balance;
    final int account_id;

    public BankAccount(int i) { account_id = i; }

    public synchronized void deposit(float amount) {
        balance += amount;
    }

    public synchronized void withdraw(float amount) {
        balance -= amount;
    }

    public synchronized void transfer(float amount,
                              BankAccount target) {
        withdraw(amount);
        target.deposit(amount);
    }
}
```

```java
public class MoneyTransfer implements Runnable {
    private BankAccount source, target;
    private float amount;
    public MoneyTransfer(BankAccount from,
                         BankAccount to, float amount) {
        this.source = from;
        this.target = to;
        this.amount = amount;
    }
    public void run() {
        Object obj1 = null, obj2 = null;
        if(source.account_id > target.account_id) {
            obj1=target; obj2=source;
        }
        else { obj1=source; obj2=target; }
        synchronized(obj1) { synchronized(obj2) {
                source.transfer(amount, target);
        } }
    }
}
```

```java
BankAccount aliceAccount = new BankAccount(1); // account_id = 1;
BankAccount bobAccount = new BankAccount(2);   // account_id = 2;
...
// At one place
Runnable transaction1 = new MoneyTransfer(aliceAccount, bobAccount, 1200);
Thread t1 = new Thread(transaction1);
t1.start();

// At another place
Runnable transaction2 = new MoneyTransfer(bobAccount, aliceAccount, 700);
Thread t2 = new Thread(transaction2);
t2.start();
```

- We are using lock ordering technique here to resolve the deadlock
- Lock on BankAccount objects are taken in run() method as per the ascending order value of the account_id
  - Recall monitor locks are reentrant

Let’s change gears…

Design Patterns

What is Design Pattern

- It is a solution for a repeatable problem in the software design
- This is not a complete design for a software system that can be directly transformed into code
- It is a description or template for how to solve the problem that can be used in many different situations

Why Study Patterns

- Reuse tried, proven solutions
  - Provides a head start
  - Avoids gotchas later (unanticipated things)
  - No need to reinvent the wheel
- Establish common terminology
  - Design patterns provide a common point of reference
  - Easier to say, “We could use Strategy here.”
- Provide a higher level prospective
  - Frees us from dealing with the details too early

“GoF” (Gang of Four) patterns

- **Creational Patterns** *(abstracting the object-instantiation process)*
  - Factory Method, Abstract Factory, Singleton
  - Builder, Prototype
- **Structural Patterns** *(how objects/classes can be combined)*
  - Adapter, Bridge, Composite
  - Decorator, Facade, Flyweight
  - Proxy
- **Behavioral Patterns** *(communication between objects)*
  - Command, Interpreter, Iterator
  - Mediator, Observer, State
  - Strategy, Chain of Responsibility, Visitor
  - Template Method

In 1990 a group called the Gang of Four or "GoF” (Gamma, Helm, Johnson, Vlissides) compile a catalog of design patterns in the book “Design Patterns: Elements of Reusable Object-Oriented Software”

Pattern: Iterator

objects that traverse collections

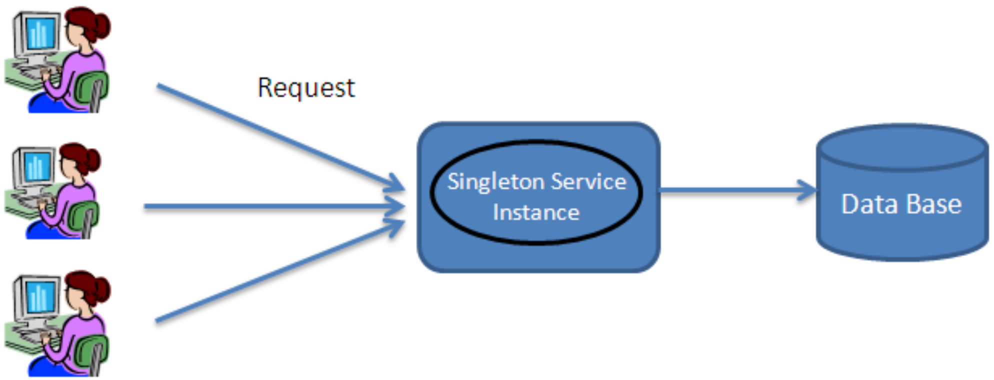
Pattern: Iterator

- Recurring Problem
  - How can you loop over all objects in any collection. You don't want to change client code when the collection changes. Want the same methods
- Solution
  1. Provide a standard *iterator* object supplied by all data structures
  2. The implementation performs traversals, does bookkeeping
  3. The implementation has knowledge about the representation
  4. Results are communicated to clients via a standard interface
- Consequences
  - Can change collection class details without changing code to traverse the collection

Pattern: Singleton

A class that has only a single instance

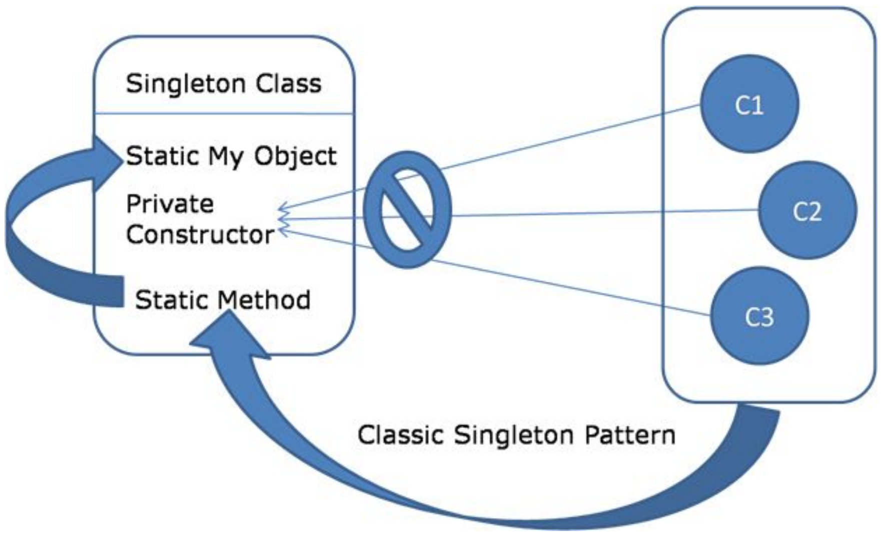
Pattern: Singleton



- Recurring problem
  - Sometimes we only ever need one instance of a particular class
  - It should be illegal to have another instance of the same class
- Solution
  - Singleton pattern – ensuring that a class has at most one instance
  - Providing global access to that instance

Fig. source: https://rajneekanth.wordpress.com/2014/04/11/what-are-design-patterns/

Implementing Singleton



1. Make constructor private so that no client is able to call it from outside
2. Declare a single private static instance of the class
3. Write a getInstance() method (or similar) that allows access to the single instance
   - Ensure thread safety in case multiple threads can access this method

Singleton Example

```
public class RandomGenerator {
    private static RandomGenerator gen = null;
    public static RandomGenerator getInstance()
    {
        if (gen == null) {
            gen = new RandomGenerator();
        }
        return gen;
    }
    private RandomGenerator() {}
    ...
}
```

- Creates a new random generator
- Clients will not use the constructor directly but will instead call getInstance to obtain
  a RandomGenerator obect that is shared by all classes in the application
- Lazy initialization
  - Can wait until client asks for the instance to create it
  - How to ensure thread safety?

Singleton Comparator

```
public class LengthComparator
                implements Comparator<String> {

    private static LengthComparator comp = null;

    public static LengthComparator getInstance()
    {
        if (comp == null) {
            comp = new LengthComparator();
        }
        return comp;
    }

    private LengthComparator() {}

    public int compare(String s1, String s2) {
        return s1.length() - s2.length();
    }
}
```

- Comparators make great singletons because they have no state
- Saves memory by not allowing the creation of more than one object

Pattern: Flyweight

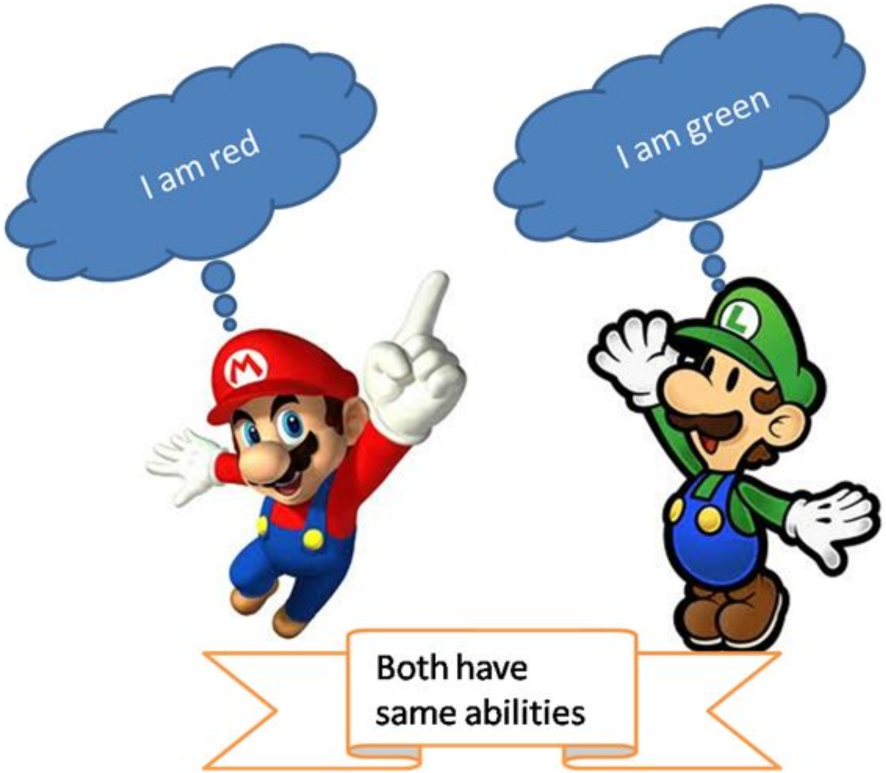
a class that has only one instance for each unique state

Pattern: Flyweight

- Problem
  - **Redundant objects** can bog down the system
    - Many objects have the same state
  - Example: `File` objects that represent the same file on disk
    - `new File("chatlog.txt")`
    - `new File("chatlog.txt")`
    - `new File("chatlog.txt")`

      `...`
    - `new File("notes.txt")`
  - Example: Date objects that represent the same date of the year
    - `new Date(4, 18)`
    - `new Date(4, 18)`

Pattern: Flyweight



- An assurance that no more than one instance of a class will have identical state
  - Achieved by caching identical instances of objects.
  - Similar to singleton, but one instance for each unique object state
  - Useful when there are many instances, but many are equivalent

Fig source: http://www.c-sharpcorner.com/UploadFile/SukeshMarla/learn-design-pattern-flyweight-pattern/

Implementing a Flyweight (1/2)

```
public class Flyweighted {
    private static Map<KeyType, Flyweighted> instances
              = new HashMap<KeyType, Flyweighted>();

    private Flyweighted(...) { ... }

    public static Flyweighted getInstance(KeyType key) {
        if (!instances.contains(key)) {
            instances.put(key, new Flyweighted(key));
        }
        return instances.get(key);
    }
}
```

Implementing a Flyweight (2/2)

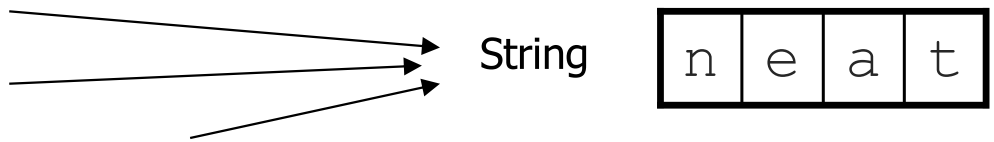
```
public class Point {
    private int x, y;

    public Point(int x, int y) {
        this.x = x;
        this.y = y;
    }

    public int getX() { return x; }
    public int getY() { return y; }

    public String toString() {
        return "(" + x + ", " + y + ")";
    }
}
```

```
public class Point {

    private static Map<String, Point> instances =
        new HashMap<String, Point>();

    public static Point getInstance(int x, int y)
    {
        String key = x + ", " + y;
        if (!instances.containsKey(key)) {
            instances.put(key, new Point(x, y));
        }
        return instances.get(key);
    }

    private final int x, y;   // immutable

    private Point(int x, int y) {
        this.x = x;
        this.y = y;
    }
    public int getX() { return x; }
    public int getY() { return y; }
    public String toString() {
        return "(" + x + ", " + y + ")";
    }
}
```

Flyweighting in String by JVM

- The possible combinations for Strings is close to infinite, hence JVM maintains a cache for strings, called the **string constant pool**
  - It is empty at startup and is filled constantly during the lifecycle of the JVM
- Java String objects are automatically flyweighted by the JVM **whenever** possible
  - If you declare two string variables that point to the same literal.
  - If you concatenate two string literals to match another literal

```
String a = "neat";
String b = "neat";
String c = "n" +
"eat";
```



Next Lecture

- More design patterns