Singleton Pattern: One of a Kind Objects

I tell ya she's ONE OF A KIND. Look at the lines, the curves, the body, the headlights!
You talkin' to me or the car? Oh, and when can I get my oven mitt back?

Singleton Pattern

- **Intent: Ensure that a class only has a single instance (which is accessed over a global point of access)**
  - MP3-File Player should only play one file at a time
    => single instance coordinates play-back
  - Database-Driver has to ensure global invariants
    => single instance coordinates DB access
  - Cache provides fast look-up for often used objects
    => single instance controls cache
  - Only one activity should access the camera
    => single instance coordinates access to the camera instance

Singleton Pattern

- **Example: Registry Class**

```
public class Registry {
   private Map<String, Object> entries =
      Collections.synchronizedMap(new HashMap<>());

   public Registry() { }

   public void register(String name, Object value) {
      ...
   }

   public Object lookup(String name) {
      ...
   }
}
```

  – Goal: One Instance of class `Registry` only, please!

Singleton Pattern

- **Solution 1: Use static methods only**

```
public final class Registry {
   private static Map<String, Object> entries =
      Collections.synchronizedMap(new HashMap<>());

   private Registry() { }

   public static void register(String name, Object value) {
      ...
   }

   public static Object lookup(String name) {
      ...
   }
}
```

Problems with the static Approach

- **Initialization**
  - We may require run-time information to prepare the static class

```
class Registry {
   private static boolean initialized = false;
   public static void init(Properties prop) {
      if(initialized) throw new IllegalStateException();
      ...
      initialized = true;
   }

   public static void register(String name, Object value) {
      if(!initialized) throw new IllegalStateException();
      ...
   }
```

Problems with the static Approach

- **Initialization**
  - Order in which static initializers are called is not statically defined

```
public class Initialization {
   public static void main(String[] args) throws Exception {
      System.out.println("A.x = " + A.x);
      System.out.println("B.x = " + B.x);
   }
}
class A {
   static { System.out.println("A()"); }
   static int x = B.x + 1;
}
class B {
   static { System.out.println("B()"); }
   static int x = A.x + 1;
}
```

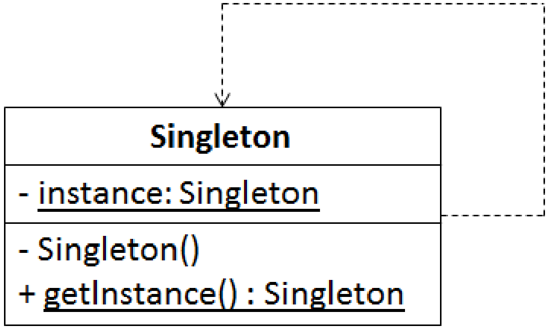
Problems with the static Approach

- **Interface**
  - Static methods cannot implement an interface

- **Generalization**
  - It might be necessary to support *n* singleton instances
    - At most n instances (=> thread pool, front/back camera)
    - Named instances (=> database drivers)

Singleton Pattern

- **Structure**



Singleton

- instance: Singleton

- Singleton()

+ getInstance() : Singleton

- **Code**

```
public final class Singleton {
   private Singleton() { }
   private static Singleton instance = new Singleton();
   public  static Singleton getInstance() {
      return instance;
   }
}
```

  – Private constructor prevents creation of instances outside of the class
  – Prevents creation of instances in subclasses as well => final

Singleton Pattern Example

```
public final class Registry {
   private Map<String, Object> entries =
      Collections.synchronizedMap(new HashMap<>());

   private Registry() { }
   private static Registry instance = new Registry();
   public  static Registry getInstance() {
      return instance;
   }

   public void register(String name, Object value) {
     ...
   }

   public Object lookup(String name) {
     ...
   }
}
```

```
Registry.getInstance().register("one", 1);
```

Singleton Pattern Samples

- java.lang.Runtime Runtime.getRuntime()
  - Every Java application has a single instance of class Runtime that allows the application to interface with the environment in which the application is running.
- java.lang.Class x.getClass()
  - Instances of the class *Class* represent classes and interfaces in a running Java application. Class *Class* has no public constructor; instances are constructed automatically by the JVM
  - Two instances of the same class refer to the same class instance
- java.util.logger.Logger Logger.getLogger(String name)
  - A Logger object is used to log messages for a specific system or application component
- java.awt.Taskbar Taskbar.getTaskbar()
  - The Taskbar class allows a Java application to interact with the system task area (taskbar, Dock, etc.).

Implementation Remarks

- **equals / hashCode**
  - default implementation is appropriate

- **clone**
  - Return *this* (the singleton instance)

```
    public Object clone() {
        return this;
    }
```

  - *Better Solutions:*
    - *No clone support*
    - *Throw CloneNotSupportedException*

Implementation Remarks

- **Eager initialization**

```
public final class Singleton {
   private Singleton() { }
   private static Singleton instance = new Singleton();
   public  static Singleton getInstance() {
      return instance;
   }
}
```

  - Problem: singleton object is instantiated when the class is first accessed (i.e. initialized)
    - May use much memory which is never freed!
    - Only a problem if the class contains other public static fields or methods (which may trigger initialization of the class)

Implementation Remarks

- **Variant with lazy initialization**

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

  - Method *getInstance* must be declared synchronized, otherwise several instances might be generated
  - Initialization properties might be passed to the constructor (and in addition to the *getInstance* method)

Implementation Remarks

- **Instances cannot be reclaimed by garbage collector**
  - java.lang.ref.Reference<T> might be used
    - WeakReference (removed when not referenced by strong references)
    - SoftReference (removed when system is short of memory)

```java
public final class Singleton {
   private Singleton() { }
   private static SoftReference<Singleton> instance = null;
   public static synchronized Singleton getInstance() {
      Singleton s = instance == null ? null : instance.get();
      if (s == null) {
         s = new Singleton();
         instance = new SoftReference<>(s);
      }
      return s;
   }
}
```

Implementation Remarks

- **Serialization**
  - Deserialization of a serialized singleton instance may lead to several singleton instances

```
import java.lang.ref.*;
public final class Singleton implements Serializable {
   private Singleton() { }
   private static Singleton instance = null;
   public  static synchronized Singleton getInstance() {
      if(instance == null) instance = new Singleton();
      return instance;
   }
   public Object readResolve() {
   // during object input, convert this deserialized
   // singleton into the proper singleton instance
      return getInstance();
   }
}
```

Implementation Remarks

- **Initialization on Demand Holder Idiom**

```
public final class Singleton {
   private static class Holder {
      private static final Singleton INSTANCE = new Singleton();
   }
   private Singleton() { }
   public static Singleton getInstance() {
      return Holder.INSTANCE;
   }
}
```

  - Thread-safe solution (without requiring synchronized or volatile)
  - Instance is created upon first access of `getInstance` (lazy instantiation)
  - Problem: Singleton-constructor must not throw an exception!

Implementation Remarks

- **Enum**
  - Singleton may also be implemented as an enum

```
public enum SingletonDriver implements Driver {
   INSTANCE;
   public String toString() { return "Singleton"; }
   public void playSong(File file) { ... }
}
```

  - Advantages
    - Unique instance (access with `SingletonDriver.INSTANCE`)
    - Provides the serialization machinery for free
    - Interfaces may be implemented
  - Disadvantage
    - Fields are not serialized (only the name of the enum)
    - Cannot be extended to multiple instances

Implementation Remarks

- **Extensibility of singleton (different versions)**
  - If singleton is extensible, then singleton implementation cannot guarantee that only one instance exists, but only that the instance accessed through the `getInstance()` method is unique
  - Implementation
    - Register unique instance using the constructor of base class
      - Eager initialization, instance must not be overwritten
    - Create instance using a factory

```
interface Singleton {
   ...
}

interface SingletonFactory {
   Singleton getInstance();
}
```

Implementation Remarks

```
public final class SingletonRegistry {
   private static SingletonFactory factory = null;
   private static Singleton instance = null;
   public static synchronized Singleton getInstance() {
      if(instance == null) {
         if(factory != null)
            instance = factory.getInstance();
         else
            instance = new DefaultSingletonImplementation();
      }
      return instance;
   }
   public static synchronized void setFactory(
                                         SingletonFactory factory) {
      if(instance != null) throw new IllegalStateException();
      this.factory = factory;
   }
}
```

Singleton and Spring

- **Spring Singleton Beans**
  - By default all Spring beans are Singletons
- **Spring Prototype Beans**
  - Defining a prototype means instead of defining a single bean, one defines a blueprint
  - Bean instances are then created based on this blueprint

```
<bean id="person" class="ch.fhnw.Person" scope="prototype">
   …
</bean>
```

- Every time the `getBean("person")` method is invoked a new instance of Person will be created

Relation with other Patterns

- **State**
  - State instances are often implemented as Singleton instances (could well be implemented using `enums`)
- **Abstract Factory**
  - This pattern can use a Singleton for providing the current factory
- **Façade**
  - The façade objects are often Singletons because only one instance is required

Singleton Pattern: 15 Years Later

- **When discussing which patterns to drop, we found that we still love them all. (Not really—I'm in favor of dropping Singleton. Its use is almost always a design smell.)**
  - Erich Gamma
    Design Patterns 15 Years Later
    http://www.informit.com/articles/article.aspx?p=1404056

- **Singletons are often used as a justification for global state. Easy to add / difficult to remove**
  - Erich Gamma
    Design Patterns: Past, Present and Future
    FOSE (The Future of Software Engineering Symposium) 2010
    http://fose.ethz.ch/slides/gamma.pdf

Singleton Disadvantages

- **Hidden coupling from potentially everywhere!**
  - Singleton provides a global access point to a service, but this coupling not visible by examining the interfaces of the classes that use the Singleton
- **Violation of the Single Responsibility Principle**
  - A Singleton allows to limit the creation of objects, which means that two responsibilities are mixed together into one class:
    - Its own singularity
    - Its functionality
  - http://c2.com/cgi/wiki?SingleResponsibilityPrinciple

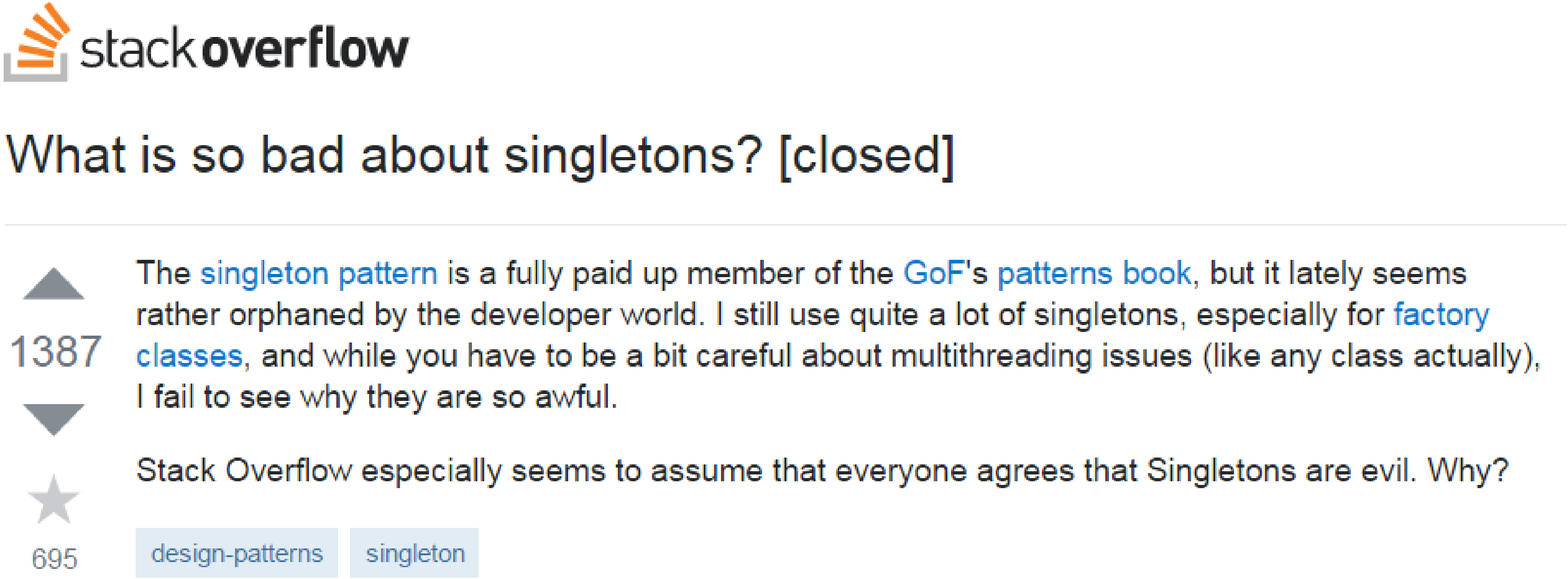
Singleton Disadvantages

- **A Singleton promotes tight coupling between classes**
  - Problem: testing. A Singleton object prevents the polymorphic substitution of another, simpler object (mock object)
  - A better solution is (once more) to delegate the creation of the object to, e.g., a simple Factory.
  - Or: Base your code onto the principle of Dependency Injection and use Spring, some other DI-framework or provide your own mechanism.

- **Singletons carry state**
  - Problem: testing,
    - Singleton object is created before the first test uses it
    - The *same* Singleton is reused all over the time in any other test, being perhaps in some weird state!

Discussion and Comments

- **What is so bad about Singletons?**



What is so bad about singletons? [closed]

The singleton pattern is a fully paid up member of the GoF's patterns book, but it lately seems rather orphaned by the developer world. I still use quite a lot of singletons, especially for factory classes, and while you have to be a bit careful about multithreading issues (like any class actually), I fail to see why they are so awful.

Stack Overflow especially seems to assume that everyone agrees that Singletons are evil. Why?

  - 36 Answers can be found at http://stackoverflow.com/questions/137975/what-is-so-bad-about-singletons