Mixing Static and Non-static

Singleton

Singleton Pattern

- “There can be only one.”

- Connor MacLeod, Highlander

Singleton Pattern

- a singleton is a class that is instantiated exactly once
- singleton is a well-known design pattern that can be used when you need to:
  1. ensure that there is one, and only one*, instance of a class, and
  2. provide a global point of access to the instance
     - any client that imports the package containing the singleton class can access the instance

[notes 3.4]

*or possibly zero

One and Only One

- how do you enforce this?
  - need to prevent clients from creating instances of the singleton class
    - `private` constructors
  - the singleton class should create the one instance of itself
    - note that the singleton class is allowed to call its own `private` constructors
    - need a `static` attribute to hold the instance

A Silly Example: Version 1

uses a public field that all clients can access

```
package xmas;

public class Santa
{
  // whatever fields you want for santa...

  public static final Santa INSTANCE = new Santa();

  private Santa()
  { // initialize attributes here... }

}
```

```
import xmas;

// client code in a method somewhere ...
public void gimme()
{
  Santa.INSTANCE.givePresent();
}
```

A Silly Example: Version 2

uses a private field; how do clients access the field?

```
package xmas;

public class Santa
{
  // whatever fields you want for santa...

  private static final Santa INSTANCE = new Santa();

  private Santa()
  { // initialize attributes here... }

}
```

Global Access

- how do clients access the singleton instance?
  - by using a static method

- note that clients only need to import the package containing the singleton class to get access to the singleton instance
  - any client method can use the singleton instance without mentioning the singleton in the parameter list

A Silly Example (cont)

```
package xmas;

public class Santa {
  private int numPresents;
  private static final Santa INSTANCE = new Santa();

  private Santa()
  { // initialize fields here... }

  public static Santa getInstance()
  { return Santa.INSTANCE; }

  public Present givePresent() {
    Present p = new Present();
    this.numPresents--;
    return p;
  }
}
```

uses a private field; how do clients access the field?

clients use a public static factory method

```
import xmas;

// client code in a method somewhere ...
public void gimme()
{
  Santa.getInstance().givePresent();
}
```

Enumerations

- an enumeration is a special data type that enables for a variable to be a set of predefined constants
- the variable must be equal to one of the values that have been predefined for it
  - e.g., compass directions
    - NORTH, SOUTH, EAST, and WEST
  - days of the week
    - MONDAY, TUESDAY, WEDNESDAY, etc.
  - playing card suits
    - CLUBS, DIAMONDS, HEARTS, SPADES
- useful when you have a fixed set of constants

A Silly Example: Version 3

```
package xmas;

public enum Santa
{
  // whatever fields you want for santa...

  INSTANCE;

  private Santa()
  { // initialize attributes here... }

}
```

singleton as an enumeration

will call the private default constructor same usage as public field (Version 1)

```
import xmas;

// client code in a method somewhere ...
public void gimme()
{
  Santa.INSTANCE.givePresent();
}
```

Singleton as an enumeration

- considered the preferred approach for implementing a singleton
  - for reasons beyond the scope of CSE1030

- all enumerations are subclasses of **`java.lang.Enum`**

Applications

- singletons should be uncommon
- typically used to represent a system component that is intrinsically unique
  - window manager
  - file system
  - logging system

Logging

- when developing a software program it is often useful to log information about the runtime state of your program
  - similar to flight data recorder in an airplane
  - a good log can help you find out what went wrong in your program
- problem: your program may have many classes, each of which needs to know where the single logging object is
  - global point of access to a single object == singleton
- Java logging API is more sophisticated than this
  - but it still uses a singleton to manage logging
  - java.util.logging

Lazy Instantiation

- notice that the previous singleton implementation always creates the singleton instance whenever the class is loaded
  - if no client uses the instance then it was created needlessly
- it is possible to delay creation of the singleton instance until it is needed by using lazy instantiation
  - only works for version 2

Lazy Instantiation as per Notes

```
public class Santa {
  private static Santa INSTANCE = null;

  private Santa()
  { // ... }

  public static Santa getInstance()
  {
    if (Santa.INSTANCE == null) {
      Santa.INSTANCE = new Santa();
    }
    return Santa.INSTANCE;
  }
}
```

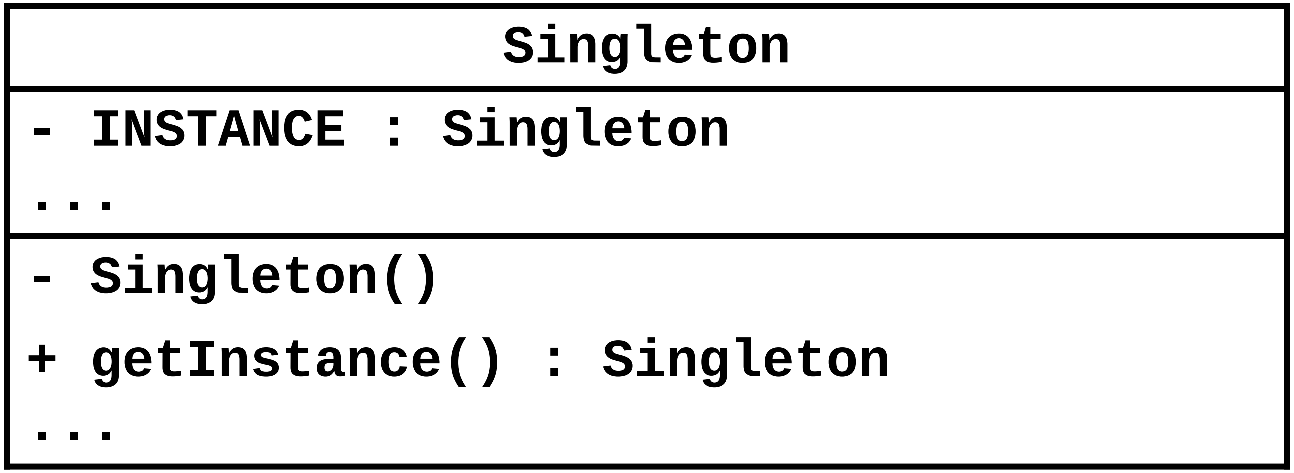
Mixing Static and Non-static

Multiton

Goals for Today

- Multiton
- review maps
- static factory methods

Singleton UML Class Diagram



```
                 Singleton
- INSTANCE : Singleton
...
- Singleton()
+ getInstance() : Singleton
...
```

One Instance per State

- the Java language specification guarantees that identical **`String`** literals are not duplicated

```
// client code somewhere

String s1 = "xyz";
String s2 = "xyz";

// how many String instances are there?
System.out.println("same object? " + (s1 == s2) );
```

  - prints: **`same object? true`**
- the compiler ensures that identical **`String`** literals all refer to the same object
  - a single instance per unique state

[notes 3.5]

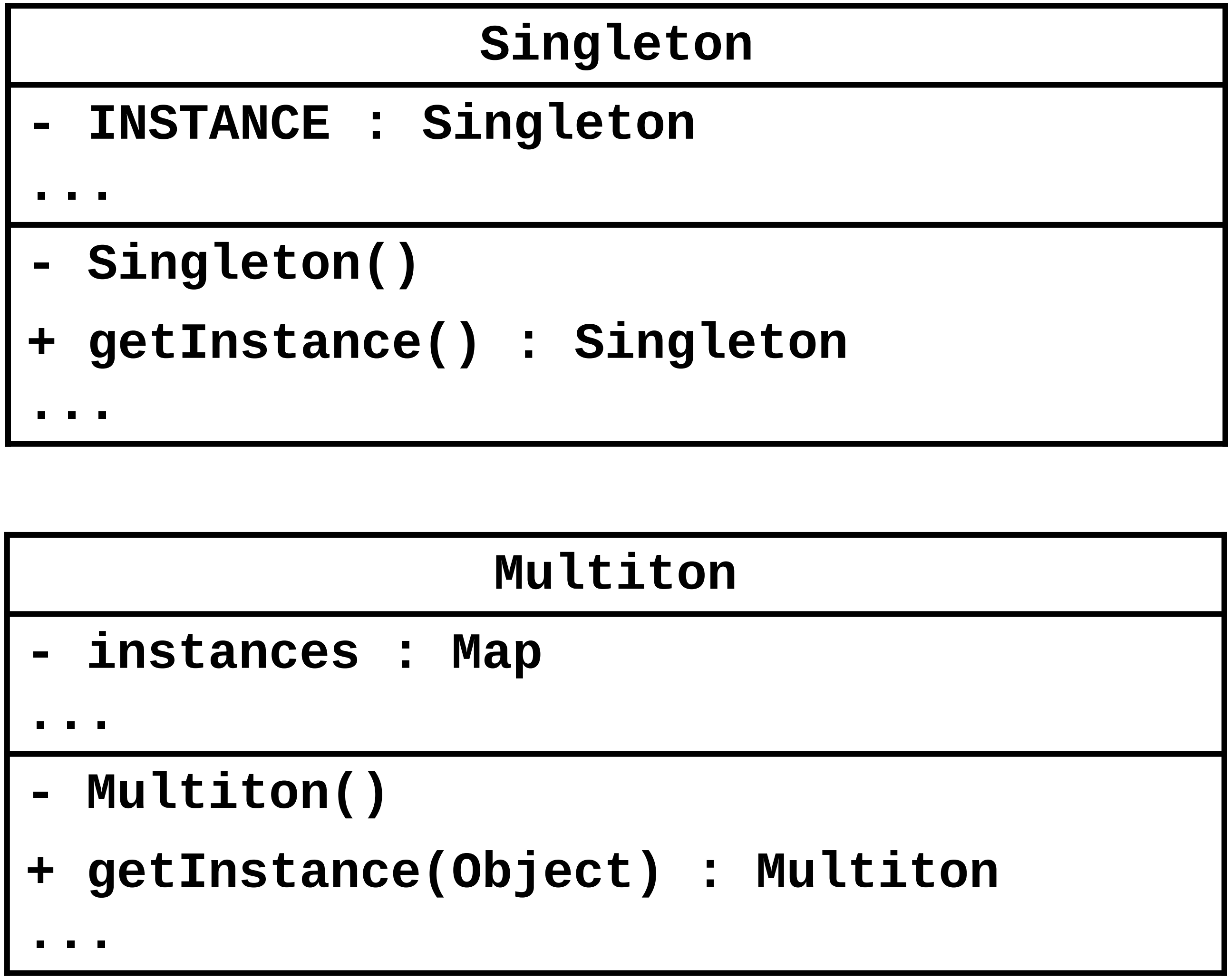
Multiton

- a *singleton* class manages a single instance of the class
- a *multiton* class manages multiple instances of the class

- what do you need to manage multiple instances?
  - a collection of some sort

- how does the client request an instance with a particular state?
  - it needs to pass the desired state as arguments to a method

Singleton vs Multiton UML Diagram



```
Singleton
- INSTANCE : Singleton
...
- Singleton()
+ getInstance() : Singleton
...
```

```
Multiton
- instances : Map
...
- Multiton()
+ getInstance(Object) : Multiton
...
```

Singleton vs Multiton

- Singleton
  - one instance

```
private static final Santa INSTANCE = new Santa();
```

  - zero-parameter accessor

```
public static Santa getInstance()
```

Singleton vs Multiton

- Multiton
  - multiple instances (each with unique state)

```
private static final Map<String, PhoneNumber>
  instances = new TreeMap<String, PhoneNumber>();
```

  - accessor needs to provide state information

```
public static PhoneNumber getInstance(int areaCode,
                                      int exchangeCode,
                                      int stationCode)
```

Map

- a map stores key-value pairs

```
Map<String, PhoneNumber>
```

key type value type

- values are put into the map using the key

```
// client code somewhere
Map<String, PhoneNumber> m =
                      new TreeMap<String, PhoneNumber>;

PhoneNumber ago = new PhoneNumber(416, 979, 6648);
String key = "4169796648"

m.put(key, ago);
```

[AJ 16.2]

- values can be retrieved from the map using only the key
  - if the key is not in the map the value returned is **`null`**

```
// client code somewhere
Map<String, PhoneNumber> m =
                      new TreeMap<String, PhoneNumber>;

PhoneNumber ago = new PhoneNumber(416, 979, 6648);
String key = "4169796648";

m.put(key, ago);

PhoneNumber gallery = m.get(key);            // == ago
PhoneNumber art = m.get("4169796648");       // == ago

PhoneNumber pizza = m.get("4169671111");     // == null
```

- a map is not allowed to hold duplicate keys
  - if you re-use a key to insert a new object, the existing object corresponding to the key is removed and the new object inserted

```
// client code somewhere
Map<String, PhoneNumber> m = new TreeMap<String, PhoneNumber>;

PhoneNumber ago = new PhoneNumber(416, 979, 6648);
String key = "4169796648";

m.put(key, ago);                               // add ago
System.out.println(m);

m.put(key, new PhoneNumber(905, 760, 1911));   // replaces ago
System.out.println(m);
```

prints

```
{4169796648=(416) 979-6648}
{4169796648=(905) 760-1911}
```

Mutable Keys

- from **http://docs.oracle.com/javase/7/docs/api/java/util/Map.html**
  - Note: great care must be exercised if mutable objects are used as map keys. The behavior of a map is not specified if the value of an object is changed in a manner that affects equals comparisons while the object is a key in the map.

```
public class MutableKey
{
  public static void main(String[] args)
  {
    Map<Date, String> m = new TreeMap<Date, String>();
    Date d1 = new Date(100, 0, 1);
    Date d2 = new Date(100, 0, 2);
    Date d3 = new Date(100, 0, 3);
    m.put(d1, "Jan 1, 2000");
    m.put(d2, "Jan 2, 2000");
    m.put(d3, "Jan 3, 2000");
    d2.setYear(101);           // mutator
    System.out.println("d1 " + m.get(d1));  // d1 Jan 1, 2000
    System.out.println("d2 " + m.get(d2));  // d2 Jan 2, 2000
    System.out.println("d3 " + m.get(d3));  // d3 null
  }
}
```

don't mutate keys;
bad things will happen

change TreeMap to HashMap and see what happens

Making **PhoneNumber** a Multiton

1. multiple instances (each with unique state)

```
private static final Map<String, PhoneNumber>
    instances = new TreeMap<String, PhoneNumber>();
```

2. accessor needs to provide state information

```
public static PhoneNumber getInstance(int areaCode,
                                      int exchangeCode,
                                      int stationCode)
```

- **`getInstance()`** will get an instance from **`instances`** if the instance is in the map; otherwise, it will create the new instance and put it in the map

Making **`PhoneNumber`** a Multiton

3. require private constructors
    - to prevent clients from creating instances on their own
        - clients should use **`getInstance()`**

4. require immutability of **`PhoneNumber`**s
    - to prevent clients from modifying state, thus making the keys inconsistent with the **`PhoneNumber`**s stored in the map
    - recall the recipe for immutability…

```
public class PhoneNumber implements Comparable<PhoneNumber>
{
  private static final Map<String, PhoneNumber> instances =
                         new TreeMap<String, PhoneNumber>();

  private final short areaCode;
  private final short exchangeCode;
  private final short stationCode;

  private PhoneNumber(int areaCode,
                      int exchangeCode,
                      int stationCode)
  { // identical to previous versions }
```

why is validation not needed?

```
public static PhoneNumber getInstance(int areaCode,
                                      int exchangeCode,
                                      int stationCode)
{
  String key = "" + areaCode + exchangeCode + stationCode;
  PhoneNumber n = PhoneNumber.instances.get(key);
  if (n == null)
  {
    n = new PhoneNumber(areaCode, exchangeCode, stationCode);
    PhoneNumber.instances.put(key, n);
  }
  return n;
}
// remainder of PhoneNumber class ...
```

```
public class PhoneNumberClient {

  public static void main(String[] args)
  {
    PhoneNumber x = PhoneNumber.getInstance(416, 736, 2100);
    PhoneNumber y = PhoneNumber.getInstance(416, 736, 2100);
    PhoneNumber z = PhoneNumber.getInstance(905, 867, 5309);

    System.out.println("x equals y: " + x.equals(y) +
                      " and x == y: " + (x == y));

    System.out.println("x equals z: " + x.equals(z) +
                      " and x == z: " + (x == z));
  }
}
```

```
x equals y: true and x == y: true
x equals z: false and x == z: false
```

Bonus Content

- notice that Singleton and Multiton use a static method to return an instance of a class
- a static method that returns an instance of a class is called a *static factory method*
  - factory because, as far as the client is concerned, the method creates an instance
    - similar to a constructor

Static Factory Methods

- many examples
  - `java.lang.Integer`

    ```
    public static Integer valueOf(int i)
    ```
    - Returns a **`Integer`** instance representing the specified **`int`** value.

  - `java.util.Arrays`

    ```
    public static int[] copyOf(int[] original, int newLength)
    ```
    - Copies the specified array, truncating or padding with zeros (if necessary) so the copy has the specified length.

Java API Static Factory Methods

- `java.lang.String`

  ```
  public static String format(String format, Object... args)
  ```

  - Returns a formatted string using the specified format string and arguments.

- `cse1030.math.Complex`

  ```
  public static Complex fromPolar(double mag, double angle)
  ```

  - Returns a reference to a new complex number given its polar form.

- you can give meaningful names to static factory methods (unlike constructors)

```
public class Person {
  private String name;
  private int age;
  private int weight;

  public Person(String name, int age, int weight) { // ... }

  public Person(String name, int age) { // ... }

  public Person(String name, int weight) { // ... }
  // ...
}
```

illegal overload: same signature

```
public class Person {  // modified from PEx's
  // attributes ...

  public Person(String name, int age, int weight) { // ... }

  public static Person withAge(String name, int age) {
    return new Person(name, age, DEFAULT_WEIGHT);
  }

  public static Person withWeight(String name, int weight) {
    return new Person(name, DEFAULT_AGE, weight);
  }
}
```

A Singleton Puzzle: What is Printed?

```
public class Elvis {
  public static final Elvis INSTANCE = new Elvis();
  private final int beltSize;
  private static final int CURRENT_YEAR =
    Calendar.getInstance().get(Calendar.YEAR);

  private Elvis() { this.beltSize = CURRENT_YEAR – 1930; }

  public int getBeltSize() { return this.beltSize; }

  public static void main(String[] args) {
    System.out.println("Elvis has a belt size of " +
                        INSTANCE.getBeltSize());
  }
}
```

from Java Puzzlers by Joshua Bloch and Neal Gafter