Functional Programming with Java

Notable Enhancements in Java 8

- Lambda expressions
  - Allow you to do *functional programming* in Java
- Static and default methods in interfaces

Lambda Expressions in Java

- Lambda expression
  - A block of code (or a function) that you can pass to a method.
- Before Java 8, methods could receive primitive values and objects only.

```
– public void example(int i, String s, ArrayList<String> list)
```

  - Methods could receive nothing else.
    - You couldn't do like this:

```
– foo.example( [if(Math.random()>0.5){
                    System.out.println(...);}
                 else{
                    System.out.println(...);} ] )
```

How to Define a Lambda Expression?

- A lambda expression consists of
  - A code block
  - A set of parameters to be passed to the code block

```
– (String str) -> str.toUpperCase()

– (StringBuffer first, StringBuffer second)
      -> first.append(second)

– (int first, int second)-> second - first
```

- No need to specify the name of a function.
  - Lambda expression ~ *anonymous* function/method that is not bound to a class/interface
  - `(int first, int second)-> second - first`

  -
    ```
    public int subtract(int first, int second){
        return second - first; }
    ```
- No need to explicitly specify the return value's type.
  - Your Java compiler automatically infers that.
- Single-expression code block
  - Does not use the "return" keyword.

- A lambda expression consists of
  - A code block
  - A set of parameters to be passed to the code block

  -
    ```
    (double threshold)-> {
        if(Math.random() > threshold) return true;
        else return false;
    }
    ```

  -
    ```
    () -> {
        if(Math.random() > 0.5) return true;
        else return false;
    }
    ```

- Single-expression code block
  - Does not use the "return" keyword.
- Multi-expression code block
  - Surrounds expressions with { and }. Use ; in the end of each exp.
  - Needs the "return" keyword in the end of each control flow.
    - Every conditional branch must return a value.

    -
      ```
      () -> {
          if(Math.random() > 0.5) return true;
      //    else return false; ← A compilation error occurs
                                 here if this line is
                                 commented out.
      }
      ```

How to Pass a Lambda Expression?

- A method can receive a lambda expression(s).
  - `foo.example( (int first, int second) -> second-first )`
  - The method receives a lambda expression *as a parameter*.
  - What is the type of that parameter?
    - *Functional interface*!

Functional Interface

- A special type of interface
  - An interface that has a single abstract (or empty) method.
- An example functional interface: `java.util.Comparator`
  - Defines `compare()`, which is the only abstract/empty method.
    - A new annotation is available:

      -
        ```
        @FunctionalInterface
        public interface Comparator<T>
        ```
      - All functional interfaces in Java API have this annotation.
        - » The API documentation says “This is a functional interface and can therefore be used as the assignment target for a lambda expression…”
- `Collections.sort(List, Comparator<T>)`
  - The second parameter can accept a lambda expression.

  -
    ```
    Collections.sort( aList,
                      (Integer first, Integer second)->
                         second.intValue()-first.intValue() );
    ```

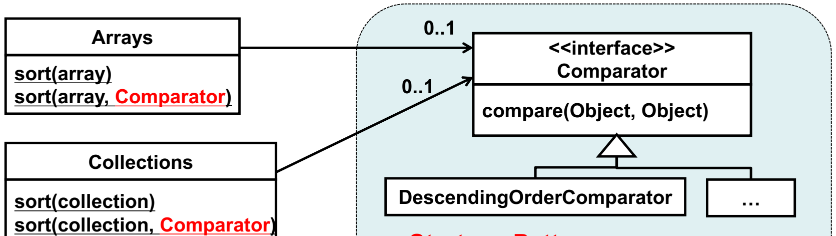
Recap: Comparators

- Sorting collection elements:

  -
    ```
    ArrayList<Integer> years2 = new ArrayList<Integer>();
    years2.add(new Integer(2010));
    years2.add(new Integer(2000));
    years2.add(new Integer(1997));
    years2.add(new Integer(2006));
    Collections.sort(years2);
    for(Integer y: years2)
        System.out.println(y);
    ```
  - `java.util.Collections`: a utility class (i.e., a set of static methods) to process collections and collection elements
  - sort() orders collection elements in an ascending order.
    - 1997 -> 2000 -> 2006 -> 2010

Comparison/Ordering Policies

- What if you want to sort array/collection elements in a descending order or any specialized (user-defined) order?
  - `Arrays.sort()` and `Collections.sort()` implement ascending ordering only.
    - They do not implement any other policies.
- Define a custom comparator by implementing `java.util.Comparator`



Strategy Pattern: Comparison/ordering policies/algorithms are “strategized.”

- Arrays.sort() and Collections.sort() are defined to sort array/collection elements from “smaller” to “bigger” elements.
  - By default, “smaller” elements mean the elements that have *lower* numbers.
- A descending ordering can be implemented by treating “smaller” elements as the elements that have *higher* numbers.
- compare() in comparator classes can define (or re-define) what “small” means and what’s “big” means.
  - Returns a negative integer, zero, or a positive integer as the first argument is “smaller” than, “equal to,” or “bigger” than the second.

-
  ```
  public class DescendingOrderComparator implements Comparator{
    public int compare(Object o1, Object o2){
      return ((Integer)o2).intValue()-((Integer) o1).intValue();
    }
  }
  ```

Sorting Collection Elements with a Custom Comparator

```
– ArrayList<Integer> years = new ArrayList<Integer>();
  years.add(new Integer(2010)); years.add(new Integer(2000));
  years.add(new Integer(1997)); years.add(new Integer(2006));
  Collections.sort(years);
  for(Integer y: years)
      System.out.println(y);
  Collections.sort(years, new DescendingOrderComparator());
  for(Integer y: years)
      System.out.println(y);
```

– 1997 -> 2000 -> 2006 -> 2010

– 2010 -> 2006 -> 2000 -> 1997

```
• public class DescendingOrderComparator implements Comparator{
    public int compare(Object o1, Object o2){
      return ((Integer)o2).intValue()-((Integer) o1).intValue();
    }
  }
```

- A more type-safe option is available/recommended:

```
• public class DescendingOrderComparator<Integer>{
    implements Comparator<Integer>{
      public int compare(Integer o1, Integer o2){
        return o2.intValue()-o1.intValue();
      }
  }
```

Okay, so What’s the Point?

- Without a lambda expression

```
– public class DescendingOrderComparator<Integer>{
    implements Comparator<Integer>{
      public int compare(Integer o1, Integer o2){
        return o2.intValue()-o1.intValue();
      }
  }
  Collections.sort(years, new DescendingOrderComparator());
```

- With a lambda expression

```
– Collections.sort(years,(Integer o1, Integer o2)->
                             o2.intValue()-o1.intValue());
```

- Code gets more concise (shorter and simpler).
  - The lambda expression defines `DescendingOrderComparator`’s `compare()` in a concise way.
  - More readable and less ugly than the code based on an anonymous class.
- The LE version is a *syntactic sugar* for the non-LE version.
  - Your compiler does program transformation at compilation time.

FYI: Anonymous Class

- The most expressive (default) version

```
– public class DescendingOrderComparator<Integer>{
    implements Comparator<Integer>{
      public int compare(Integer o1, Integer o2){
        return o2.intValue()-o1.intValue();
      }
  }
  Collections.sort(years, new DescendingOrderComparator());
```

- With an anonymous class

```
– Collections.sort(years,
                    new Comparator<Integer>(){
                      @Override
                      public int compare(Integer o1, Integer o2){
                        return o2.intValue()-o1.intValue();
                      }
                    } );
```

- With a lambda expression

```
– Collections.sort(years,(Integer o1, Integer o2)->
                             o2.intValue()-o1.intValue());
```

How Do You Know Where You can Use a Lambda Expression?

- You are trying to use `Collections.sort(List, Comparator<T>)`
- Check out `Comparator` in the API doc.
- Notice that `Comparator` is a functional interface.

  -
    ```
    @FunctionalInterface
    public interface Comparator<T>
    ```
    - The API doc says “This is a functional interface and can therefore be used as the assignment target for a lambda expression…”
  - This means you can pass a lambda expression to `sort()`.
- Find out which method is the only abstract/empty (i.e., non-static, non-default) method.
  - `public int compare(T o1, T o2)`
- Define a lambda expression to represent the method body of `compare()` and pass it to `sort()`.

  -
    ```
    Collections.sort( aList,
                      (Integer first, Integer second)->
                         second.intValue()-first.intValue())
    ```

Assignment of a LE to a Functional Interface

- `Comparator` is a functional interface.

  -
    ```
    @FunctionalInterface
    public interface Comparator<T>
    ```
    - The API doc says “This is a functional interface and can therefore be used as the assignment target for a lambda expression…”
- A lambda expression can be assigned to a variable that is typed with a functional interface.

  -
    ```
    Comparator<Integer> comparator =
        (Integer o1, Integer o2)-> o2.intValue()-o1.intValue();
    Collections.sort(years, comparator);
    ```
- Parameter types can be omitted thru type inference.

  -
    ```
    Comparator<Integer> comparator =
        (o1, o2)-> o2.intValue()-o1.intValue()
    ```
  - C.f. Type inference with the diamond operator (introduced in Java 7).

What does Collections.sort() do?

-
  ```
  class Collections
      static ... sort(List<T> list, Comparator<T> c){
          for each pair (o1 and o2) of elements in list{
              int result = c.compare(o1, o2);
              if(result < 0){
                  ...
              }else if(result > 0){
                  ...
              }else if(result==0){
                  ...
         } } }
  ```
- C.f. Run this two-line code.

  -
    ```
    Comparator<Integer> comparator =
        (Integer o1, Integer o2)-> o2.intValue()-o1.intValue();
    comparator.compare(1, 10);
    ```
  - compare() returns 9 (10 - 1).

Some Notes

- A lambda expression can be assigned to a functional interface.

  -
    ```
    public interface Comparator<T>{
        public int compare(T o1, T o2)
    }
    Comparator<Integer> comparator =
        (Integer o1, Integer o2)-> o2.intValue()-o1.intValue()
    ```
  - `Collections.sort(years, comparator);`
- It cannot be assigned to `Object`.

  -
    ```
    Object comparator =
        (Integer o1, Integer o2)-> o2.intValue()-o1.intValue()
    ```

- Without a lambda expression

```
– public class DescendingOrderComparator<Integer>{
    implements Comparator<Integer>{
      public int compare(Integer o1, Integer o2){
        return o2.intValue()-o1.intValue();
      }
  }
  Collections.sort(years, new DescendingOrderComparator());
```

- With a lambda expression

```
– Collections.sort(years,(Integer o1, Integer o2)->
                             o2.intValue()-o1.intValue());
```

- A type mismatch results in a compilation error.

```
– Collections.sort(years,(Integer o1, Integer o2)->
                           o2.floatValue()-o1.floatValue());
```

  - The return value type must be int, not float.
    - compare() is expected to return an int value.

- A lambda expression cannot throw an exception
  - if its corresponding functional interface does not specify that for the abstract/empty method.

- Not good (Compilation fails.)

```
– public interface Comparator<T>{
      public int compare(T o1, T o2)
  }
– Collections.sort(years,(Integer o1, Integer o2)->{
                          if(...) throw new XYZException;
                         else return ... );
```

- Good

```
– public interface Comparator<T>{
      public int compare(T o1, T o2) throws ZYZException
  }
– Collections.sort(years,(Integer o1, Integer o2)->{
                          if(...) throw new XYZException;
                         else return ... );
```

LEs make Your Code Concise, but…

- You still need to clearly understand
  - the Strategy design pattern
    - Comparator and its implementation classes
    - What `compare()` is meant to do
  - How `Collection.sort()` calls `compare()`.

- Using or not using LEs just impact how to *express* your code.
  - This does not impact how to *design* your code.

A Benefit of Using Lambda Expressions

- Your code gets more concise.
  - This may or may not mean “easier to understand” depending on how much you are familiar with lambda expressions.