Northeastern University

Lecture 24: More about Generics

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The Interface `Comparable`

- Consider the method `compareTo` for class `String`
- If s and t are strings, `s.compareTo(t)` is
  - » Negative if s comes before t
  - » Zero if s and t are equal
  - » Positive if s comes after t

The Interface `Comparable`

- By invoking `compareTo`, you compare two objects of the class T.
- The interface `java.lang.Comparable`

```
public interface Comparable<T>
{
    public int compareTo(T other);
} // end Comparable
```

The Interface `Comparable`

- Create a class `Circle`, define `compareTo`

```
public class Circle implements Comparable<Circle>, Measurable
{

   private double radius;

   // Definitions of constructors and methods are here.
   // . . .

   public int compareTo(Circle other)
   {
      int result;
      if (this.equals(other))
         result = 0;
      else if (radius < other.radius)
         result = -1;
      else
         result = 1;

      return result;
   } // compareTo

} // end Circle
```

Generic Methods

- Suppose you have a class that does not define a type parameter in its header, but you want to use a generic data type in a method of that class.
- Take following steps:
  - Write a type parameter enclosed in angle brackets in the method's header just before its return type
  - Use the type parameter within the method as you would if it were in a generic class

Generic Methods

Different class types

```
public class Example
{
    public static void main(String args[])
    {
       String[] stringArray = {"apple", "banana", "carrot", "dandelion"};
       System.out.print("stringArray contains ");
       displayArray(stringArray);

       Character[] characterArray = {'a', 'b', 'c', 'd'};
       System.out.print("characterArray contains ");
       displayArray(characterArray);
    } // end main

    public static <T> void displayArray(T[] anArray)
    {
       for (T arrayEntry : anArray)
       {
          System.out.print(arrayEntry);
          System.out.print(' ');
       } // end for
       System.out.println();
    } // end displayArray

} // end Example
```

Bounded Type Parameters

- Consider this simple class of squares:

```
public class Square<T>
{
   private T side;

   public Square(T initialSide)
   {
      side = initialSide;
   } // end constructor

   public T getSide()
   {
      return side;
   } // end getSide
} // end Square
```

- Different types of square objects are possible

```
Square<Integer> intSquare = new Square<>(5);
Square<Double> realSquare = new Square<>(2.1);
Square<String> stringSquare= new Square<>("25");
```

Exercise (L24_E1)

- Please type following code to your Eclipse and fix the error.

```
public class Square<T>
{
   private T side;

   public Square(T initialSide)
   {
      side = initialSide;
   } // end constructor

   public T getSide()
   {
      return side;
   } // end getSide

   public double getArea() {
       double s = side.doubleValue();
       return s*s;
   }
} // end Square
```

Answer

- We want the `side` of a square to be a numeric value.
- We can impose this restriction by making T represent a class that is derived from `Number`, the base class (superclass) of the classes Byte, Double, Float, Integer, Long and Short.
- We bound T by using "`T extends Number`" in `Square's` header.

Answer

```
public class Square<T extends Number>
{
   private T side;

   public Square(T initialSide)
   {
      side = initialSide;
   } // end constructor

   public T getSide()
   {
      return side;
   } // end getSide

   public double getArea() {
       double s = side.doubleValue();
       return s*s;
   }
} // end Square
```

Bounded Type Parameters (cont.)

- Imagine that we want to write a static method that returns the smallest object in an array. Suppose that we wrote our method shown here:

```
public MyClass
{
   // First draft and INCORRECT:
   public static <T> T arrayMinimum(T[] anArray)
   {
      T minimum = anArray[0];
      for (T arrayEntry : anArray)
      {
         if (arrayEntry.compareTo(minimum) < 0)
            minimum = arrayEntry;
      } // end for

      return minimum;
   } // end arrayMinimum
} // end MyClass
```

Bounded Type Parameters

- Header really should be as shown

```
public MyClass
{
   public static <T extends Comparable<T>> T arrayMinimum(T[] anArray)
   {
      T minimum = anArray[0];
      for (T arrayEntry : anArray)
      {
         if (arrayEntry.compareTo(minimum) < 0)
            minimum = arrayEntry;
      } // end for

      return minimum;
   } // end arrayMinimum

   // . . .

} // end MyClass
```

Exercise

- What, if anything, is wrong with the following class?

```
public final class Min {
   public static T smallerOf(T x, T y) {
     if (x < y)
      return x;
     else
      return y;
   }
}
```

Answer

```
public final class Min {
   public static <T extends Comparable<T>> T smallerOf(T x, T y) {
     if (x.compareTo(y) <0)
      return x;
     else
      return y;
   }
}
```

Wildcards

- Question mark, ?, is used to represent an unknown class type
  - » Referred to as a wildcard

- Consider following method and objects

```
public static void displayPair(OrderedPair<?> pair)
{
   System.out.println(pair);
} // end displayPair
```

Wildcards

- Method `displayPair` will accept an argument, a pair of objects, whose data type is any class.

```
OrderedPair<String> aPair = new OrderedPair<>("apple", "banana");
OrderedPair<Integer> anotherPair = new OrderedPair<>(1, 2);

displayPair(aPair);
displayPair(anotherPair);
```

Bounded Wildcards

- Recall the method `arrayMinimum()`

```
public MyClass
{

   public static <T extends Comparable<T>> T arrayMinimum(T[] anArray)
   {
      T minimum = anArray[0];
      for (T arrayEntry : anArray)
      {
         if (arrayEntry.compareTo(minimum) < 0)
            minimum = arrayEntry;
      } // end for

      return minimum;
   } // end arrayMinimum

   // . . .

} // end MyClass
```

Bounded Wildcards (cont.)

- Then, we called this method with the statement

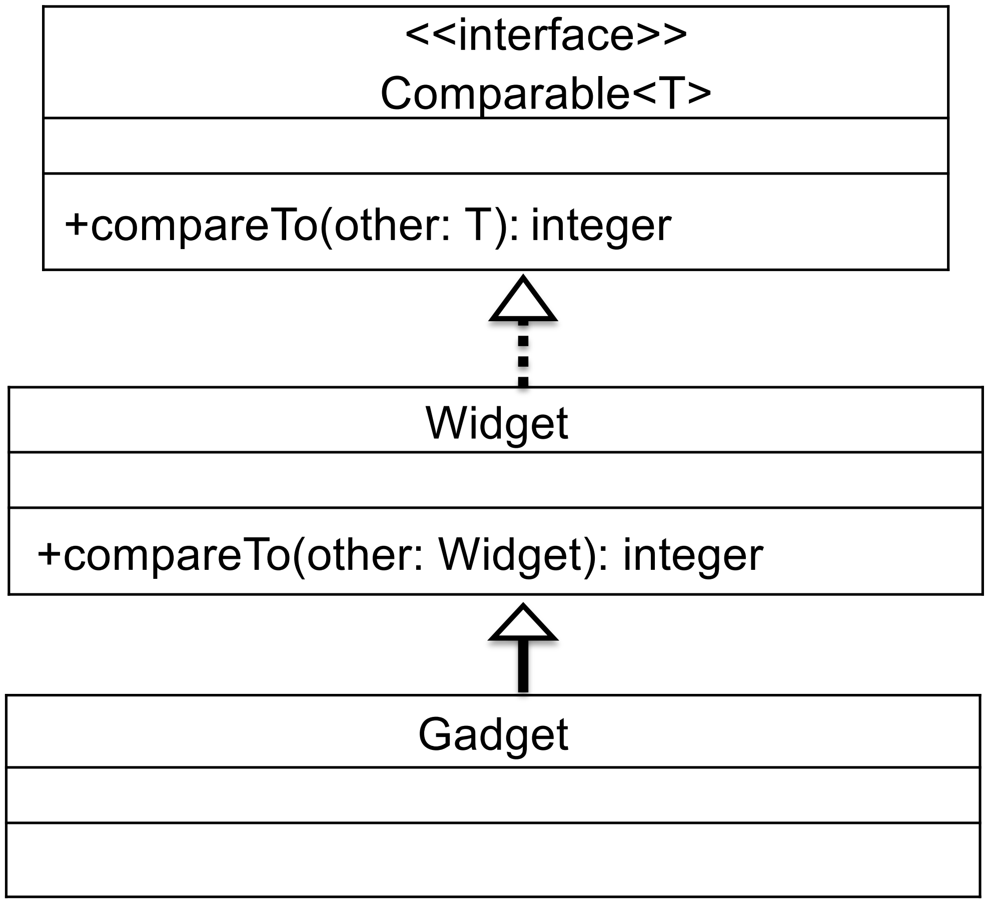
```
Gadget smallestGadget = MyClass.arrayMinimum(myArray);
```

where `myArray` is an array of `Gadget` objects.

- Instead of comparing an object of T only with other objects of T, we can allow comparisons to objects of a superclass of T.

`<T extends Comparable<T>>` ➡ `<T extends Comparable<? super T>>`

Bounded Wildcards (cont.)


<<interface>>
Comparable<T>
+compareTo(other: T): integer
Widget
+compareTo(other: Widget): integer
Gadget

The class `Gadget` is derived from the class `Widget`, which implements the interface `Comparable`

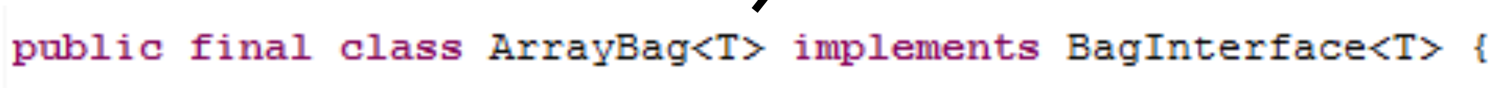
More About Generics

```
public static <T extends Comparable<? super T>>
        void selectionSort(T[] a, int n)
{
```

More About Generics (cont.)

- Generic Methods
  - If you have a class that does not define a type parameter in its header

define a type parameter



```
public final class ArrayBag<T> implements BagInterface<T> {
```

  - But, you want to use a generic data type in a method of that class.

More About Generics (cont.)

```
<T extends Comparable<? super T>>
```

- T represents a class that derived from Comparable, i.e., we bound T by writing `T extends Comparable`.

```
<? super T>
```

- ? : represent an unknown class type and is referred to as a wildcard.
- `? super T` means any superclass of T

More About Generics (cont.)

- Q: Why not use “implements” instead of “extends” in

```
<T extends Comparable<? super T>>
```

- As the official document mentions:

To declare a bounded type parameter, list the type parameter's name, followed by the extends keyword, followed by its upper bound, ... Note that, in this context, extends is used in a general sense to mean either "extends" (as in classes) or "implements" (as in interfaces).

https://docs.oracle.com/javase/tutorial/java/generics/bounded.html