Programming and Software Development
COMP90041

Lecture 11

Generics

NOTE: Some of the Material in these slides are adopted from
* Lectures Notes prepared by Dr. Peter Schachte, Dr. Rose Williams, and
* the Textbook resources

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- File I/O
- Buffered Reader
- Binary Files

Review: Week 10

- Introduction to Generics & Generic Classes
- Bounds for Type Parameters
- Generic Methods
- Inheritance with Generic Classes

Outline

- Introduction to Generics & Generic Classes
- Bounds for Type Parameters
- Generic Methods
- Inheritance with Generic Classes

Outline

- Beginning with version 5.0, Java allows class and method definitions that include parameters for types
- Such definitions are called *generics*
  - Generic programming with a type parameter enables code to be written that applies to any class

Introduction to Generics

```java
public class SampleInteger
{
  private Integer data;

  public void setData(Integer newData)
  {
    data = newData;
  }

  public Integer getData()
  {
    return data;
  }
}
```

```java
public class SampleDouble
{
  private Double data;

  public void setData(Double newData)
  {
    data = newData;
  }

  public Double getData()
  {
    return data;
  }
}
```

Example

Display 14.4 A Class Definition with a Type Parameter

```
1  public class Sample<T>
2  {
3      private T data;

4      public void setData(T newData)
5      {
6          data = newData;
7      }

8      public T getData()
9      {
10         return data;
11     }
12 }
```

T is a parameter for a type.

Example

- Classes and methods can have a type parameter (a.k.a type variable)
  - A type parameter can have any reference type (i.e., any class type) plugged in for the type parameter
  - When a specific type is plugged in, this produces a specific class type or method
  - Traditionally, a single uppercase letter is used for a type parameter, but any non-keyword identifier may be used
    - A naming convention:
      - E: Element (e.g., ArrayList<E>)
      - K: Key (e.g., HashMap<K, V>)
      - N: Number
      - T: Type
      - V: Value
      - S, U, V, and so on: Second, third, and fourth types

Generics

- A class that is defined with a parameter for a type is called a ***generic class*** or a ***parameterized class***
  - The type parameter is included in angle brackets after the class name in the class definition heading
  - Any non-keyword identifier can be used for the type parameter, but by convention, the parameter starts with an uppercase letter
  - The type parameter can be used like other types used in the definition of a class (e.g., instance variable declarations, method parameters)

Class Definitions with a Type Parameter

- A class definition with a type parameter is stored in a file and compiled just like any other class
- Once a parameterized class is compiled, it can be used like any other class
  - However, the class type plugged in for the type parameter ***must be specified before it can be used in a program***
  - Doing this is said to ***instantiate*** the generic class

```
Sample<Double> object = new Sample<Double>();
```

Generics: Instantiation

- There are many pitfalls that can be encountered when using type parameters
- Compiling with the **`-Xlint`** option will provide more informative diagnostics of any problems or potential problems in the code, including warnings
  javac –Xlint Sample.java

Tip: Compile with the –Xlint Option

Display 14.5 A Generic Ordered Pair Class

```
1  public class Pair<T>
2  {
3      private T first;
4      private T second;

5      public Pair()
6      {
7          first = null;
8          second = null;
9      }

10     public Pair(T firstItem, T secondItem)
11     {
12         first = firstItem;
13         second = secondItem;
14     }
```

Constructor headings do not include the type parameter in angular brackets.

(continued)

A Generic Ordered Pair Class (Part 1 of 4)

Display 14.5 A Generic Ordered Pair Class

```
15      public void setFirst(T newFirst)
16      {
17          first = newFirst;
18      }

19      public void setSecond(T newSecond)
20      {
21          second = newSecond;
22      }

23      public T getFirst()
24      {
25          return first;
26      }
```

(continued)

A Generic Ordered Pair Class (Part 2 of 4)

Display 14.5 **A Generic Ordered Pair Class**

```
27      public T getSecond()
28      {
29          return second;
30      }

31      public String toString()
32      {
33          return ( "first: " + first.toString() + "\n"
34                   + "second: " + second.toString() );
35      }
36
```

(continued)

A Generic Ordered Pair Class (Part 3 of 4)

Display 14.5 **A Generic Ordered Pair Class**

```
37      public boolean equals(Object otherObject)
38      {
39          if (otherObject == null)
40              return false;
41          else if (getClass() != otherObject.getClass())
42              return false;
43          else
44          {
45              Pair<T> otherPair = (Pair<T>)otherObject;
46              return (first.equals(otherPair.first)
47                  && second.equals(otherPair.second));
48          }
49      }
50  }
```

A Generic Ordered Pair Class (Part 4 of 4)

Display 14.6 **Using Our Ordered Pair Class**

```
1  import java.util.Scanner;

2  public class GenericPairDemo
3  {
4     public static void main(String[] args)
5     {
6          Pair<String> secretPair =
7               new Pair<String>("Happy", "Day");
8
9          Scanner keyboard = new Scanner(System.in);
10         System.out.println("Enter two words:");
11         String word1 = keyboard.next();
12         String word2 = keyboard.next();
13         Pair<String> inputPair =
14             new Pair<String>(word1, word2);
```

(continued)

Using Our Ordered Pair Class (Part 1 of 3)

Display 14.6 Using Our Ordered Pair Class

```
15          if (inputPair.equals(secretPair))
16          {
17              System.out.println("You guessed the secret words");
18              System.out.println("in the correct order!");
19          }
20          else
21          {
22              System.out.println("You guessed incorrectly.");
23              System.out.println("You guessed");
24              System.out.println(inputPair);
25              System.out.println("The secret words are");
26              System.out.println(secretPair);
27          }
28      }
29  }
```

(continued)

Using Our Ordered Pair Class (Part 2 of 3)

Display 14.6 **Using Our Ordered Pair Class**

SAMPLE DIALOGUE

```
Enter two words:
two words
You guessed incorrectly.
You guessed
first: two
second: words
The secret words are
first: Happy
second: Day
```

Using Our Ordered Pair Class (Part 3 of 3)

- The type plugged in for a type parameter must always be a reference type
  - It cannot be a primitive type such as **`int`**, **`double`**, or **`char`**
  - However, now that Java has automatic boxing, this is not a big restriction
  - Note: reference types can include arrays

Pitfall: A Primitive Type Cannot be Plugged in for a Type Parameter

Display 14.7 Using Our Ordered Pair Class and Automatic Boxing

```
1  import java.util.Scanner;

2  public class GenericPairDemo2
3  {
4     public static void main(String[] args)
5     {
6          Pair<Integer> secretPair =
7               new Pair<Integer>(42, 24);
8
9          Scanner keyboard = new Scanner(System.in);
10         System.out.println("Enter two numbers:");
11         int n1 = keyboard.nextInt();
12         int n2 = keyboard.nextInt();
13         Pair<Integer> inputPair =
14             new Pair<Integer>(n1, n2);
```

Automatic boxing allows you to use an `int` *argument for an* `Integer` *parameter.*

(continued)

Using Ordered Pair Class and Automatic Boxing (Part 1 of 2)

Display 14.7 Using Our Ordered Pair Class and Automatic Boxing

```
15          if (inputPair.equals(secretPair))
16          {
17              System.out.println("You guessed the secret numbers");
18              System.out.println("in the correct order!");
19          }
20          else
21          {
22              System.out.println("You guessed incorrectly.");
23              System.out.println("You guessed");
24              System.out.println(inputPair);
25              System.out.println("The secret numbers are");
26              System.out.println(secretPair);
27          }
28      }
```

Display 14.7 Using Our Ordered Pair Class and Automatic Boxing

SAMPLE DIALOGUE

```
Enter two numbers:
42 24
You guessed the secret numbers
in the correct order!
```

Using Ordered Pair Class and Automatic Boxing (Part 2 of 2)

- Within the definition of a parameterized class definition, there are places where an ordinary class name would be allowed, but a type parameter is not allowed
- In particular, the type parameter cannot be used in simple expressions using new to create a new object
  - For instance, the type parameter cannot be used as a constructor name or like a constructor:

```
T object = new T();
T[] a = new T[10];
```

Pitfall: A Type Parameter Cannot Be Used Everywhere a Type Name Can Be Used

- Arrays such as the following are illegal:

```
Pair<String>[] a =
  new Pair<String>[10];
```

  - Although this is a reasonable thing we want to do, it is not allowed given the way that Java implements generic classes

Pitfall: An Instantiation of a Generic Class Cannot be an Array Base Type

- It is not permitted to create a generic class with **`Exception`**, **`Error`**, **`Throwable`**, or any descendent class of **`Throwable`**
  - A generic class cannot be created whose objects are throwable

    public class GEx<T> extends Exception
  - The above example will generate a compiler error message

Pitfall: A Generic Class Cannot Be an Exception Class

- A generic class definition can have any number of type parameters
  - Multiple type parameters are listed in angle brackets just as in the single type parameter case, but are separated by commas

Tip: A Class Definition Can Have More Than One Type Parameter/Type Variable

Display 14.8 Multiple Type Parameters

```
1  public class TwoTypePair<T1, T2>
2  {
3      private T1 first;
4      private T2 second;

5      public TwoTypePair()
6      {
7          first = null;
8          second = null;
9      }

10     public TwoTypePair(T1 firstItem, T2 secondItem)
11     {
12         first = firstItem;
13         second = secondItem;
14     }
```

(continued)

Multiple Type Parameters (Part 1 of 4)

Display 14.8 **Multiple Type Parameters**

```
15      public void setFirst(T1 newFirst)
16      {
17          first = newFirst;
18      }

19      public void setSecond(T2 newSecond)
20      {
21          second = newSecond;
22      }

23      public T1 getFirst()
24      {
25          return first;
26      }
```

(continued)

Multiple Type Parameters (Part 2 of 4)

Display 14.8 **Multiple Type Parameters**

```
27      public T2 getSecond()
28      {
29          return second;
30      }

31      public String toString()
32      {
33          return ( "first: " + first.toString() + "\n"
34                   + "second: " + second.toString() );
35      }
36
```

(continued)

Multiple Type Parameters (Part 3 of 4)

Display 14.8 **Multiple Type Parameters**

```
37      public boolean equals(Object otherObject)
38      {
39          if (otherObject == null)
40              return false;
41          else if (getClass() != otherObject.getClass())
42              return false;
43          else
44          {
45              TwoTypePair<T1, T2> otherPair =
46                                  (TwoTypePair<T1, T2>)otherObject;
47              return (first.equals(otherPair.first)
48                  && second.equals(otherPair.second));
49          }
50      }
51  }
```

The first `equals` *is the* `equals` *of the type* `T1`*. The second* `equals` *is the* `equals` *of the type* `T2`*.*

Multiple Type Parameters (Part 4 of 4)

Display 14.9 Using a Generic Class with Two Type Parameters

```
1  import java.util.Scanner;

2  public class TwoTypePairDemo
3  {
4     public static void main(String[] args)
5     {
6          TwoTypePair<String, Integer> rating =
7               new TwoTypePair<String, Integer>("The Car Guys", 8);

8          Scanner keyboard = new Scanner(System.in);
9          System.out.println(
10                      "Our current rating for " + rating.getFirst());
11         System.out.println(" is " + rating.getSecond());

12         System.out.println("How would you rate them?");
13         int score = keyboard.nextInt();
14         rating.setSecond(score);
```

(continued)

Using a Generic Class with Two Type Parameters (Part 1 of 2)

Display 14.9 Using a Generic Class with Two Type Parameters

```
15          System.out.println(
16                      "Our new rating for " + rating.getFirst());
17          System.out.println(" is " + rating.getSecond());
18      }
19  }
```

SAMPLE DIALOGUE

```
Our current rating for The Car Guys
is 8
How would you rate them?
10
Our new rating for The Car Guys
is 10
```

Using a Generic Class with Two Type Parameters (Part 2 of 2)

- Introduction to Generics & Generic Classes
- Bounds for Type Parameters
- Generic Methods
- Inheritance with Generic Classes

Outline

Bounds for Type Parameters

- Sometimes it makes sense to ***restrict the possible types*** that can be plugged in for a type parameter `T`
  - For instance, to ensure that only classes that implement the `Comparable` interface are plugged in for `T`, define a class as follows:

```
public class RClass<T extends Comparable>
```

  - "`extends Comparable`" serves as a *bound* on the type parameter `T`
  - Any attempt to plug in a type for `T` which does not implement the `Comparable` interface will result in a compiler error message

Bounds for Type Parameters

- A bound on a type may be a class name (rather than an interface name)
  - Then only descendent classes of the bounding class may be plugged in for the type parameters

```
public class ExClass<T extends Class1>
```

- A bounds expression may contain ***multiple interfaces and up to one class***
- If there is more than one type parameter, the syntax is as follows:

```
public class Two<T1 extends Class1, T2 extends Class2 & Comparable>
```

Display 14.10 **A Bounded Type Parameter**

```
1   public class Pair<T extends Comparable>
2   {
3       private T first;
4       private T second;

5       public T max()
6       {
7           if (first.compareTo(second) <= 0)
8               return first;
9           else
10              return second;
11      }

    <All the constructors and methods given in Display 14.5
            are also included as part of this generic class definition>

12  }
```

A Bounded Type Parameter

- An interface can have one or more type parameters
- The details and notation are the same as they are for classes with type parameters

Tip: Generic Interfaces

- Introduction to Generics & Generic Classes
- Bounds for Type Parameters
- Generic Methods
- Inheritance with Generic Classes

Outline

- When a generic class is defined, the type parameter can be used in the definitions of the methods for that generic class
- In addition, a generic method can be defined that has its own type parameter that is not the type parameter of any class
  - A generic method can be a member of an ordinary class or a member of a generic class that has some other type parameter
  - The type parameter of a generic method is ***local*** to that method, not to the class

Generic Methods (advanced)

- The type parameter must be placed (in angle brackets) after all the modifiers, and before the returned type

```
public static <T> T genMethod(T[] a)
```

- When one of these generic methods is invoked, the method name is prefaced with the type to be plugged in, enclosed in angle brackets

```
String s = NonG.<String>genMethod(c);
```

Generic Methods

```java
public class Utility
{
  public static <T> T getMidPoint(T[] a)
  {
    return a[a.length/2];
  }

  public static <T> T getFirst(T[] a)
  {
    return a[0];
  }

  public static <T1, T2> boolean isSameClass(T1 a, T2 b)
  {
    return (a.getClass() == b.getClass());
  }
}
```

Example

- Introduction to Generics & Generic Classes
- Bounds for Type Parameters
- Generic Methods
- Inheritance with Generic Classes

Outline

- A generic class can be defined as a derived class of an ordinary class or of another generic class
  - As in ordinary classes, an object of the subclass type would also be of the superclass type

Inheritance with Generic Classes

Display 14.11 A Derived Generic Class

```
1  public class UnorderedPair<T> extends Pair<T>
2  {
3      public UnorderedPair()
4      {
5          setFirst(null);
6          setSecond(null);
7      }

8      public UnorderedPair(T firstItem, T secondItem)
9      {
10         setFirst(firstItem);
11         setSecond(secondItem);
12     }
```

(continued)

A Derived Generic Class (Part 1 of 2)

Display 14.11 **A Derived Generic Class**

```
13      public boolean equals(Object otherObject)
14      {
15          if (otherObject == null)
16              return false;
17          else if (getClass() != otherObject.getClass())
18              return false;
19          else
20          {
21              UnorderedPair<T> otherPair =
22                                  (UnorderedPair<T>)otherObject;
23              return (getFirst().equals(otherPair.getFirst())
24                 && getSecond().equals(otherPair.getSecond()))
25                 ||
26                     (getFirst().equals(otherPair.getSecond())
27                 && getSecond().equals(otherPair.getFirst()));
28          }
29      }
30  }
```

A Derived Generic Class (Part 2 of 2)

Display 14.12 **Using UnorderedPair**

```
1  public class UnorderedPairDemo
2  {
3     public static void main(String[] args)
4     {
5          UnorderedPair<String> p1 =
6               new UnorderedPair<String>("peanuts", "beer");
7          UnorderedPair<String> p2 =
8               new UnorderedPair<String>("beer", "peanuts");
```

(continued)

Using UnorderedPair (Part 1 of 2)

Display 14.12 **Using UnorderedPair**

```
 9            if (p1.equals(p2))
10            {
11                System.out.println(p1.getFirst() + " and " +
12                          p1.getSecond() + " is the same as");
13                System.out.println(p2.getFirst() + " and "
14                                   + p2.getSecond());
15            }
16        }
17    }
```

SAMPLE DIALOGUE[2]

```
peanuts and beer is the same as
beer and peanuts
```

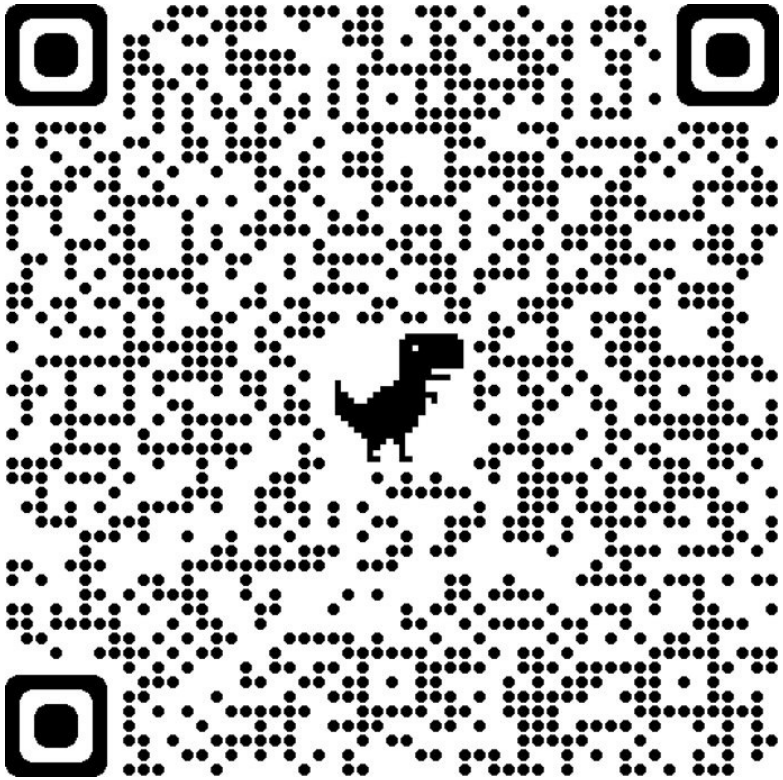
Using UnorderedPair (Part 2 of 2)

- Given two classes: **A** and **B**, and given **G**: a generic class, there is no relationship between **G<A>** and **G<B>**
  - This is true regardless of the relationship between class **A** and **B**, e.g., if class **B** is a subclass of class **A**
- Example:
  - Suppose HourlyEmployee is a derived class of the class Employee, there is no relationship between **G<HourlyEmployee>** and **G<Employee>**

Pitfall: Inheritance with Generic Classes

- Which moment or experience from COMP90041 this week was significant or important to you?
- Why do you think this experience was significant
  - Examine your experience. Why do you care?)
- What insights have you had?
  - What can you learn from the experience?)
- How is this experience going to help you in the future?
- What questions have come up for you?

Class Reflections



http://go.unimelb.edu.au/5o8i.

Class Reflections