Generics

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Contents

- Concepts
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issues

- **Basically most of the algorithms** are independent on data types of items (e.g., sorting, searching...)
- **Some data structures** do not depend on data types of items either (e.g., stacks, linked list...)
- How to reuse the same piece of code with different data types?

Solution

Use inheritance?

- **All the classes** are inherited from **Object class**
- Objects are upcasted to **Object**

```
public class MyList {   // items could be objects of any classes
   public void add(Object o) {…}
   public Object getFirst() {…}
   …
}
```

Solution: inheritance

limitation

- Casting is required all the time

```
MyList   myPets = new MyList();// declare a list of type object
…
Animal a = (Animal) myPets.getFirst();
```

- No mechanism for checking errors

```
myPets.add(new Integer(3));
 . . .
Animal a = (Animal) myPets.getFirst(); ();// runtime error
```

Solution

Generics

- Generic class introduced in JDK 5.0
- enables classes to accept parameters when defining them, **much like** the *familiar parameters* used in method declarations
- Defining a type parameter for a class provides a way for you
  - **to re-use** the same code with different inputs
  - The difference is that the **input** to formal parameters are **values,** while the **inputs** to type parameters are **types**

Generics...

- ArrayList use **Generics** to allow you **to specify** the data type of the **elements** you're intending to add into that ArrayList
- The way to do so is by defining that **data type** between **<>** when declaring the ArrayList variable
  - **ArrayList**<String> *listOfString* = **new** ArrayList();

No need for casting

- Generics eliminates the need for casting

- E.g.,

Code without generics	rewrite with generics
List list = **new** ArrayList(); list.add("hello java"); String s= (String) list.get(0);	**List**<String> list = **new** **A**rrayList(); list.add("hello Java"); String s= list.get(0);

Defining a generic type

- You can define your own Generic types
  - by declaring **a generic parameter** when defining your class
  - check the link for more detail

Defining a generic class

```
public class Pair<K>
{
   private K first;
   private K second;

   public Pair() { first= null; second= null; }
   public Pair(K first, K second) { this.first= first; this.second = second;
   }
    public void setFist(K newValue) { first = newValue; }
    public K getFirst() { return first; }

    public void setSecond(K newValue) { second = newValue; }
    public K getSecond() { return second; }


}
```

```
…
Pair<String> o = new Pair<String> ("1st", "2nd");
System.out.println(o.getFirst() + "," + o.getSecond());
```

include more parameter

```
public class Pair<K, V>
{
   private K key;
   private V value;

   public Pair() { key = null; value = null; }
   public Pair(K key, V value)
     { this.key = key; this.value = value; }

   public void setKey(K newValue) { key = newValue; }
   public K getKey() { return key; }

   public void setValue(V newValue) { value = newValue; }
   public V getValue() { return value; }


}
```

```
…
Pair<Integer, String> o = new Pair<Integer, String> (1, “1st");
System.out.println(o.getKey() + "," + o.getValue());
```

Generic methods

- are methods that introduce their own type parameters
  - similar to a generic type, but the type parameter's **scope** is limited to *the methods* there it is declared

- **Syntax** for a generic method
  - includes a list of type parameters inside angle brackets **<>**
  - appear **before** the method's return type

Example

- Assume we have the class **Pair<K,V>**

```
class Util{
   public static <K,V>  boolean compare(Pair<K,V> p1, Pair<K,V> p2)
    {
       return ( p1.getKey().equals p2.getKey() ) &&
                ( p1.getKey().equals p2.getKey());
    }
}
```

```
Pair<Integer, String> p1= new Pair(1, “apple”);
Pair<Integer, String> p2 = new Pair(2, “pineapple”);
boolean same = Util.<Integer, String>compare(p1, p2);
```

This can be left out, *the compiler will refer the type that is needed*

Bounded type parameters

```
class Util {
  public static <T> T min(T[] a)  //finding the smallest element in a
  {
    if (a == null || a.length == 0) return null;

    T smallest = a[0];
    for (int i =1; i < a.length; i++)
      if (smallest > (a[i]) ) //compile error
        smallest = a[i];
    return smallest;
  }
}
```

the operator > applies only primitive types, cannot use it to compare objects!

⇒ Use a type parameter bounded by the Comparable<T> **interface**

```
public interface Comparable<T>{
      public int CompareTo(T o);
}
```

```
public static <T extends Comparable<T>> T min(T[] a){
  …
   smallest > a[i]    is replaced with smallest.compareTo(a[i]) > 0
  //The others are the same as before
}
```

Bounded type

- Syntax: <**T** extends BoundingType>

- **T** and BoundingType can be either **interface** or **class**
- **T** is *a subtype* of BoundingType

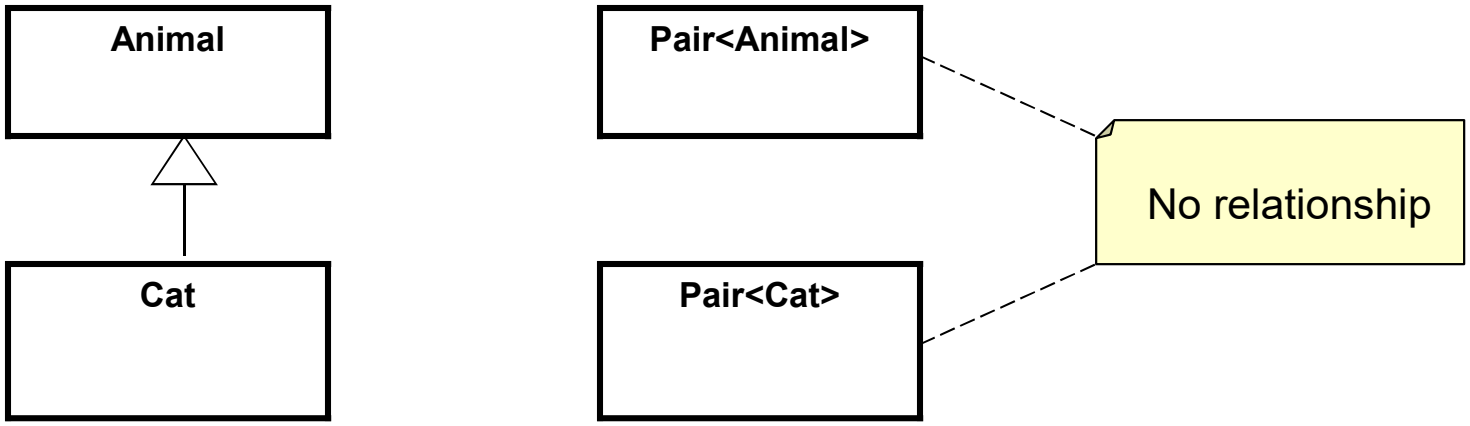
- can include multiple BoundingTypes
  - <T extends **superClassName** & **Interface**>
  - We can't have more than one class in multiple bounds
  - e.g., <**T** **extends** Comparable & Serializable>

```
class ArrayAlg {
   /**      Gets the minimum and maximum of an array of objects of type T.
     @param a an array of objects of type T
     @return a pair with the min and max value,
      or null if a is null or empty
   */
   public static <T extends Comparable<T>> Pair<T> minmax(T[] a)
   {
      if (a == null || a.length == 0) return null;
      T min = a[0];
      T max = a[0];
      for (int i = 1; i < a.length; i++)
      {
         if (min.compareTo(a[i]) > 0) min = a[i];
         if (max.compareTo(a[i]) < 0) max = a[i];
      }
      return new Pair<T>(min, max);
   }
}
```

```
...
String[] words = { "Mary", "had", "a", "little", "lamb" };
Pair<String> o = ArrayAlg.minmax(words);
System.out.println("min = " + o.getFirst());
System.out.println("max = " + o.getSecond());
```

Inheritance and generics

- There's no inheritance relationship in generics



How to make generic class/method with **Pair<Animal>** accept **Pair<Cat>** ?

wildcards

- Create a type **Pair** to be able to work with a subtype of Animal as follows
  - **Pair**<? **extends** Animal> *aPair* = …;

Example 1

```
public class TestAnimal{
    static void makeASymphony( ArrayList<Animal> a){
        for( Animal anAnimal: a){
            anAnimal.makeNoise();
        }
    }
    public static void main(String [] args){
        ArrayList<Animal> pets = new ArrayList<Animal>();
        pets.add(new Dog()); pets.add(new Cat());
        makeASymphony(pets);
    }
}
```

```
class Animal{
    void makeNoise(){
        System.out.println("Make noise…");
    }
}
```

```
class Dog extends Animal{
    void makeNoise(){
        System.out.println("Woof…");
    }
}
```

```
class Cat extends Animal{
    void makeNoise(){
        System.out.println("Meow")
    }
}
```

Example 2

```
public class TestAnimal{
    static void makeASymphony( ArrayList<Animal> a){
        ...
    }
    public static void main(String [] args){
        ArrayList<Dog> dogs = new ArrayList<Dog>();
        dogs.add(new Dog()); dogs.add(new Dog());
        makeASymphony(dogs);
    }
}
```

types don't match

ArrayList<Animal> cannot changed to ArrayList<Dog> because in Generics there's no such inheritance

```
% javac TestAnimal.java
TestAnimal.java:44: cannot find symbol
symbol  : method
makeASymphony(java.util.ArrayList<Dog>)
location: class TestAnimal
        makeASymphony(dogs);
        ^
1 error
```

Using Upper bounded wildcards

```
static void makeASymphony( ArrayList<? extends Animal> a){
    for( Animal anAnimal: a){
        anAnimal.makeNoise();
    }
}
```

- Upper bounded wildcard is used **to relax** the restrictions on a variable
  - E.g., to write a method that works on List<Integer>, List<Double>, List<Number>, we can achieve this using *an upper bounded wildcard*
- To declare an upper bounded card, use the wildcard character "**?**" followed by the keyword "extends", followed by its upper bound
  - e.g., List<? extends Number>

Example

```
public class Test {
    static public void main(String args[]) {

        Stack<Integer> s1 = new Stack<Integer>();

        s1.push(new Integer(0));

        Integer x = s1.pop();

        s1.push(new Long(0)); //error;

    }
}
```

List & Iterator interface in java

```
public interface List <E>{
    void add(E x);
    Iterator<E> iterator();
}

public interface Iterator<E>{
    E next();
    boolean hasNext();
}
```

Example 1

```
void printList(List<Object> list) { //goals is to print a list of any type,
                                    //but fail
    Iterator it = list.iterator();
    while (it.hasNext())
        System.out.println(it.next());
}
```

```
List<String> list_1 = new LinkedList<String>();

List<Object> list_2 = list_1; //error


printList(list_1); //error , trying to print list of String not Object
```

use Unbounded wildcards

```
void printList(List<?> lst) { //allow to  print a list of any type
    Iterator it = lst.iterator();
    while (it.hasNext())
        System.out.println(it.next());
}
```

```
List<Integer> l1 = Arrays.asList(1, 2, 3);
List<String> l2 = Arrays.asList("one", "two", "three");

printList(l1);
printList(l2);
```

Unbounded wildcards

- The unbounded wildcard type is specified
  - using *the wildcard character* "?"
  - e.g., List<?>

- **2 Scenarios** where an unbounded wildcard is a useful approach

1. if you're writing *a method* that can be implemented using **functionality** provided in the **Object class**
2. When **the code** is using **methods** in **the generic class** that **don't** depend on the type parameter
   - E.g, List.size(). List.clear()
   - In fact, Class<?> is so often used because most of the methods in **Class<?>** don't depend on **T**

Lower bounded wildcards

- Lower bounded wildcard **restricts** the unknown type to be **a =a super type** of that type
- It is expressed using
  - The wildcard character "**?**", followed by the **super** keyword, followed by its lower bound
- E.g., to write a method that puts Integer objects into a list
  - to maximize flexibility, you would like the method to work on List<Integer>, List<Number>, List<Object>
  - You would specify **List**<**?** **super** Integer>

THE END