COMP2511

Generics and Collections in Java
Iterator Pattern

Prepared by

Dr. Ashesh Mahidadia

Generics in Java

These lecture notes use material from the website at https://docs.oracle.com/javase/tutorial/java/generics/index.html

Generics in Java: Java Tutorial

- Good introduction at the following web page, Oracle's official Java Tutorial, you must read all the relevant pages!

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

- The following lecture slides cover only some parts of the above tutorial, however, you should read all the relevant sections (pages) in the above tutorial.

Generics in Java

Generics enable types (classes and interfaces) to be parameters when defining:

- classes,
- interfaces and
- methods.

Benefits

- Removes *casting* and offers stronger type checks at compile time.
- Allows implementations of generic algorithms, that work on collections of different types, can be customized, and are type safe.
- Adds stability to your code by making more of your bugs detectable at compile time.

```
List list = new ArrayList();
list.add("hello");
String s = (String) list.get(0);
```

Without Generics

```
List<String> listG = new ArrayList<String>();
listG.add("hello");
String sg = listG.get(0);    // no cast
```

With Generics

Generic Types

- A generic type is a generic class or interface that is parameterized over types.
- A generic class is defined with the following format:

  class name< **T1, T2, ..., Tn** > { /* ... */ }
- The most commonly used type parameter names are:
  - E - Element (used extensively by the Java Collections Framework)
  - K - Key
  - N - Number
  - T - Type
  - V - Value
  - S,U,V etc. - 2nd, 3rd, 4th types
- For example,

  Box<Integer> integerBox = new Box<Integer>();

  OR

  Box<Integer> integerBox = new Box<>();

```
public class Box {
    private Object object;

    public void set(Object object) { this.object = object; }
    public Object get() { return object; }
}
```

```
/**
 * Generic version of the Box class.
 * @param <T> the type of the value being boxed
 */
public class Box<T> {
    // T stands for "Type"
    private T t;

    public void set(T t) { this.t = t; }
    public T get() { return t; }
}
```

Multiple Type Parameters

- A generic class can have multiple type parameters.
- For example, the generic OrderedPair class, which implements the generic Pair interface

```
public interface Pair<K, V> {
    public K getKey();
    public V getValue();
}

public class OrderedPair<K, V> implements Pair<K, V> {

    private K key;
    private V value;

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

    public K getKey()   { return key; }
    public V getValue() { return value; }
}
```

- Usage examples,

```
Pair<String, Integer> p1 = new OrderedPair<String, Integer>("Even", 8);
Pair<String, String>  p2 = new OrderedPair<String, String>("hello", "world");
... ...
OrderedPair<String, Integer> p1 = new OrderedPair<>("Even", 8);
OrderedPair<String, String>  p2 = new OrderedPair<>("hello", "world");
... ...
OrderedPair<String, Box<Integer>> p = new OrderedPair<>("primes", new Box<Integer>(...));
```

Generic Methods

Generic methods are methods that introduce their own type parameters.

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

The complete syntax for invoking this method would be:

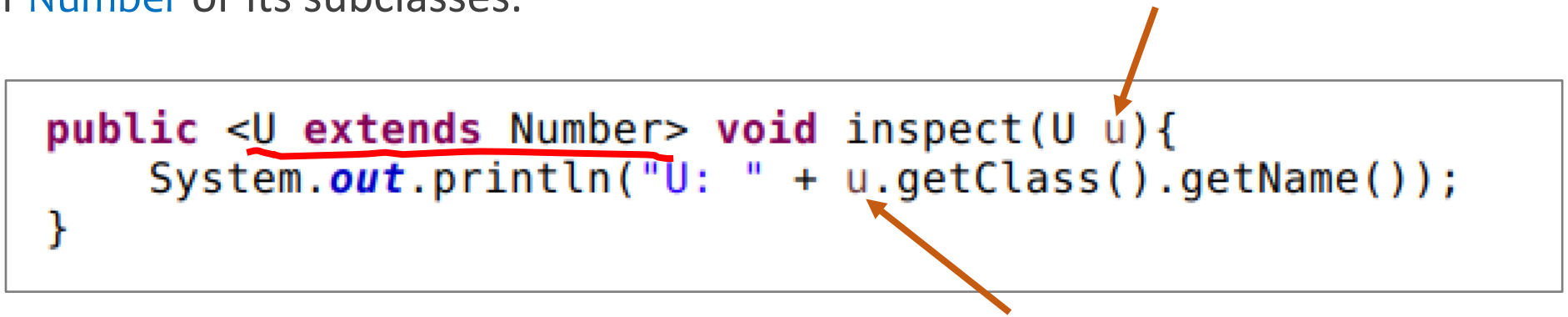
```
Pair<Integer, String> p1 = new Pair<>(1, "apple");
Pair<Integer, String> p2 = new Pair<>(2, "pear");
boolean  same = Util.<Integer, String>compare(p1, p2);
```

The type has been explicitly provided, as shown above.
Generally, this can be left out and the compiler will **infer** the **type** that is needed:

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

Bounded Type Parameters

- There may be times when you want to **restrict the types** that can be used as type arguments in a parameterized type.
- For example, a method that operates on numbers might only want to accept instances of Number or its subclasses.



```
public <U extends Number> void inspect(U u){
    System.out.println("U: " + u.getClass().getName());
}
```

```
public class NaturalNumber<T extends Integer> {
```

Multiple Bounds

- A type parameter can have multiple bounds:

  < T **extends** B1 & B2 & B3 >

- A type variable with multiple bounds is a subtype of all the types listed in the bound.
- Note that B1, B2, B3, etc. in the above refer to interfaces or a class. There can be at most one class (single inheritance), and the rest (or all) will be interfaces.
- If one of the bounds is a class, it must be specified first.

Generic Methods and Bounded Type Parameters

```
public static <T> int countGreaterThan(T[] anArray, T elem) {
    int count = 0;
    for (T e : anArray)
        if (e > elem)  // compiler erro
            ++count;
    return count;
}
```

X - invalid

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

```
public static <T extends Comparable<T>> int countGreaterThan(T[] anArray, T elem)
    int count = 0;
    for (T e : anArray)
        if (e.compareTo(elem) > 0)
            ++count;
    return count;
}
```

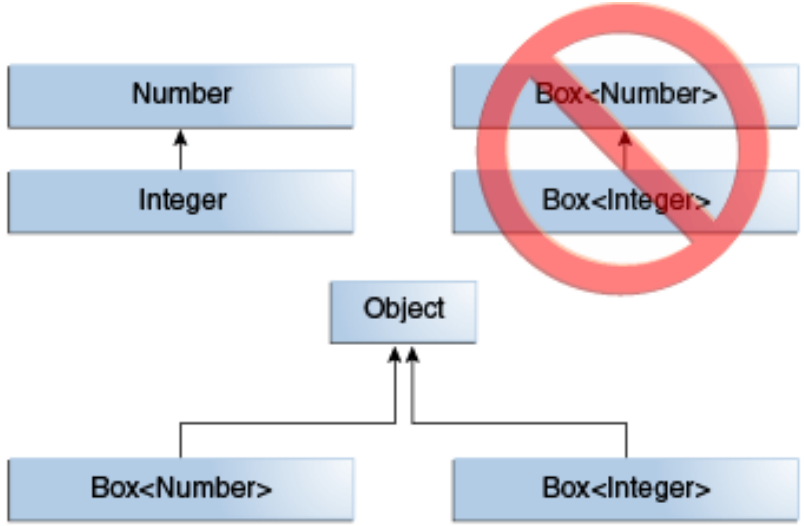
Valid

Generics, Inheritance, and Subtypes

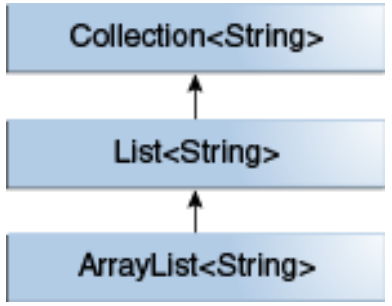
- Consider the following method:

```
public void boxTest( Box<Number> n ) { /* ... */ }
```

- What type of argument does it accept?
- Are you allowed to pass in Box<Integer> or Box<Double> ?
- The answer is "no", because Box<Integer> and Box<Double> are not subtypes of Box<Number>.
- This is a **common misunderstanding** when it comes to programming with generics.



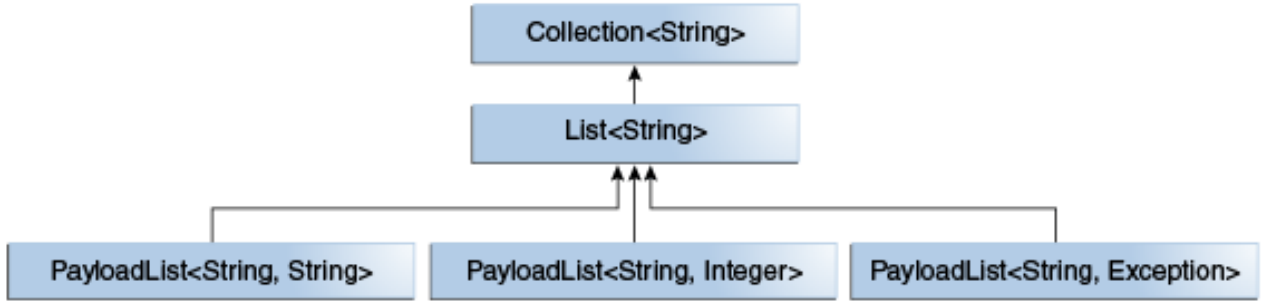
Generic Classes and Subtyping



- You can subtype a generic class or interface by extending or implementing it.
- The relationship between the type parameters of one class or interface and the type parameters of another are determined by the **extends** and **implements** clauses.
- ArrayList<E> implements List<E>, and List<E> extends Collection<E>.
- So ArrayList<String> is a subtype of List<String>, which is a subtype of Collection<String>.
- So long as you do not vary the type argument, the subtyping relationship is preserved between the types.

```
interface PayloadList<E,P> extends List<E> {
  void setPayload(int index, P val);
  ...
}
```

```
PayloadList<String,String>
PayloadList<String,Integer>
PayloadList<String,Exception>
```



Wildcards: Upper bounded

- In generic code, the question mark (**?**), called the **wildcard**, represents an unknown type.
- The wildcard can be used in a variety of situations: as the type of a parameter, field, or local variable; sometimes as a return type.
- The **upper bounded wildcard**, < **?** **extends** Foo >, where Foo is any type, matches Foo and any subtype of Foo .
- You can specify an upper bound for a wildcard, or you can specify a lower bound, but you cannot specify both.

```
public static void process(List<? extends Foo> list) {
    for (Foo elem : list) {
        // ...
    }
}
```

```
public static double sumOfList(List<? extends Number> list) {
    double s = 0.0;
    for (Number n : list)
        s += n.doubleValue();
    return s;
}
```

Wildcards: Unbounded

- The **unbounded wildcard** type is specified using the wildcard character (?), for example, List< ? >. This is called a list of unknown type.

```
public static void printList(List<Object> list) {
    for (Object elem : list)
        System.out.println(elem + " ");
    System.out.println();
}
```

It prints only a list of Object instances; it cannot print List<Integer>, List<String>, List<Double>, and so on

```
public static void printList(List<?> list) {
    for (Object elem: list)
        System.out.print(elem + " ");
    System.out.println();
}
```

To write a generic printList method, use **List<?>**

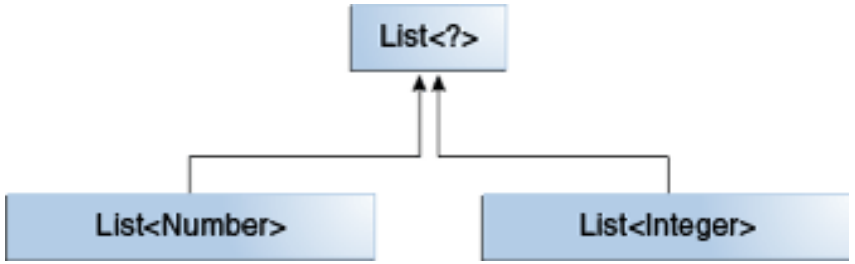
Wildcards: Lower Bounded

- An upper bounded wildcard restricts the unknown type to be a specific type or a subtype of that type and is represented using the **extends** keyword.
- A **lower bounded wildcard** is expressed using the wildcard character ('?'), following by the **super** keyword, followed by its lower bound: < ? **super** A >.
- To write the method that works on lists of Integer and the super types of Integer, such as Integer, Number, and Object, you would specify List<? **Super** Integer>.
- The term List<Integer> is more restrictive than List<? **super** Integer>.

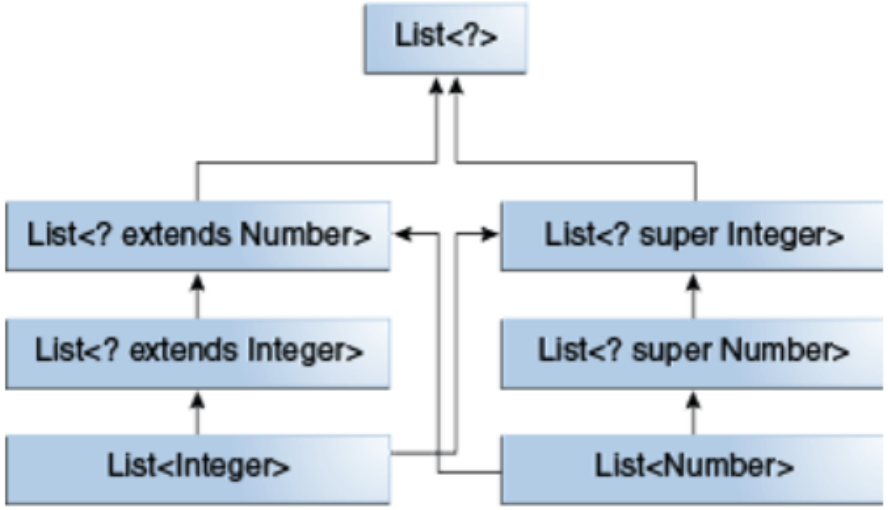
```
public static void addNumbers(List<? super Integer> list) {
    for (int i = 1; i <= 10; i++) {
        list.add(i);
    }
}
```

Wildcards and Subtyping

- Although Integer is a subtype of Number, List<Integer> is **not** a subtype of List<Number> and, these two types are not related.



- The **common parent** of List<Number> and List<Integer> is **List<?>.**



A hierarchy of several generic `List` class declarations.

Collections in Java

Collections in Java

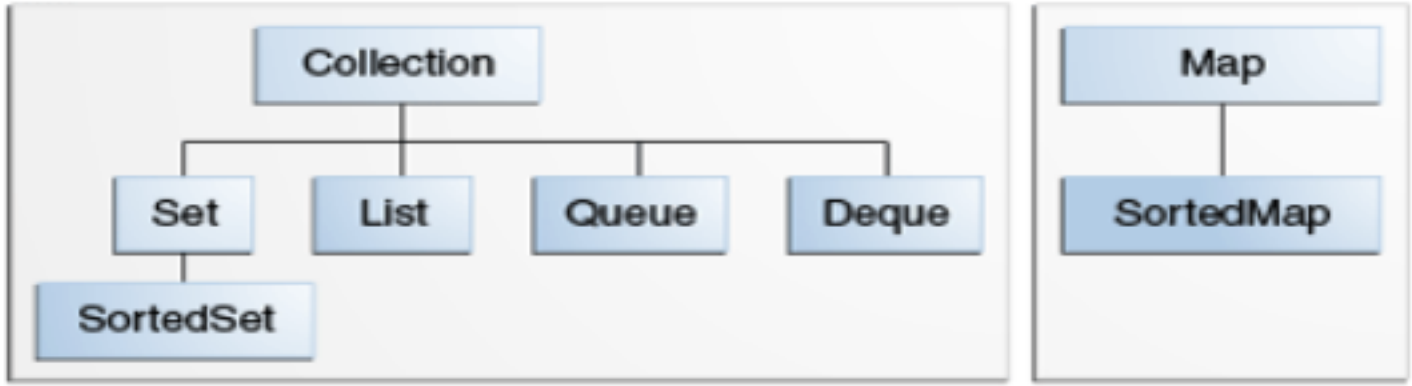
A collections framework is a unified architecture for representing and manipulating collections. A collection is simply an object that groups multiple elements into a single unit.

All collections frameworks contain the following:

- *Interfaces*: allows collections to be manipulated independently of the details of their representation.
- *Implementations*: concrete implementations of the collection interfaces.
- *Algorithms*: the methods that perform useful computations, such as searching and sorting, on objects that implement collection interfaces.
  - The algorithms are said to be polymorphic: that is, the same method can be used on many different implementations of the appropriate collection interface.

Core Collection Interfaces:

- The core collection interfaces encapsulate different types of collections
- The interfaces allow collections to be manipulated independently of the details of their representation.



The core collection interfaces.

The Collection Interface

- A Collection represents a group of objects known as its elements.
- The Collection interface is used to pass around collections of objects where maximum generality is desired.
- For example, by convention all general-purpose collection implementations have a constructor that takes a Collection argument.
- The Collection interface contains methods that perform basic operations, such as
  - int **size**(),
  - boolean **isEmpty**(),
  - boolean **contains**(Object element),
  - boolean **add**(E element),
  - boolean **remove**(Object element),
  - Iterator<E> **iterator**(),
  - … …**many more** …

More at : https://docs.oracle.com/javase/tutorial/collections/**interfaces/collection.html**

Collection Implementations

- The general purpose implementations are summarized in the following table:

Interface	Hash Table	Resizable Array	Balanced Tree	Linked List	Hash Table + Linked List
Set	HashSet		TreeSet		LinkedHashSet
List		ArrayList		LinkedList	
Deque		ArrayDeque		LinkedList	
Map	HashMap		TreeMap		LinkedHashMap

Implemented Classes in the Java Collection, Read their APIs.

- Overview of the *Collections Framework* at the following page:

https://docs.oracle.com/javase/8/docs/technotes/guides/**collections/overview.html**

Wrappers for the Collection classes

- https://docs.oracle.com/javase/tutorial/collections/implementations/wrapper.html

Demo: Collections Framework

Demo …

Iterator Pattern

Iterator Pattern: Intent and Motivation

- The intent of the Iterator design pattern is to:

  "*Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.*" [GoF]

- Exposing representation details of an aggregate breaks its encapsulation.

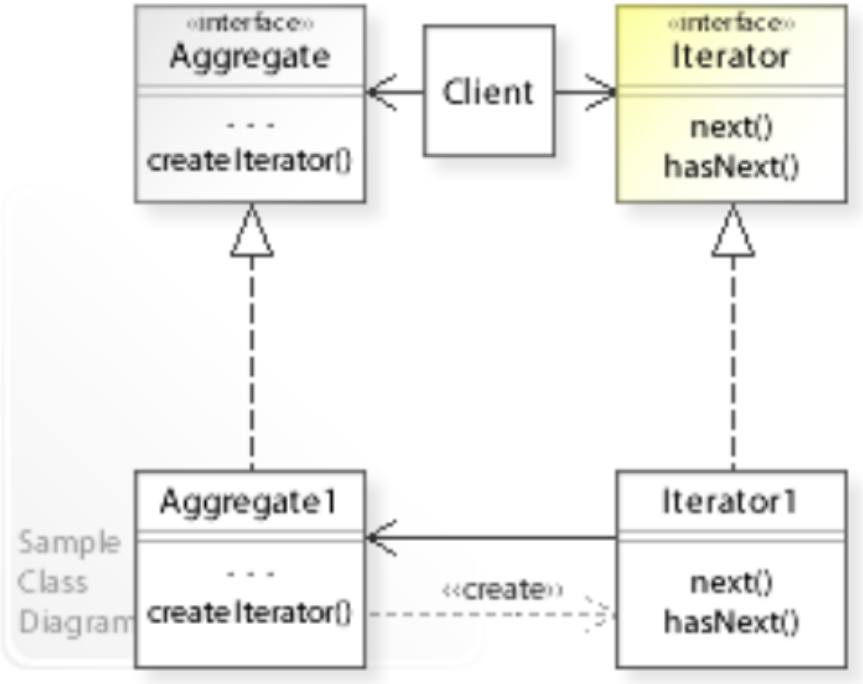
- Problem to address:

  How can the elements of an aggregate object be accessed and traversed without exposing its underlying representation?

- "But you probably don't want to bloat the List [Aggregate] interface with operations for different traversals, even if you could anticipate the ones you will need." [GoF, p257]

Iterator Pattern: Possible Solution

- Encapsulate the access and traversal of an aggregate in a separate Iterator object.
- Clients request an Iterator object from an aggregate (say by calling createIterator()) and use it to access and traverse the aggregate.
- Define an interface for accessing and traversing the elements of an aggregate object (next(), hasNext()).
- Define classes (Iterator1,...) that implement the Iterator interface.



Iterator Pattern: Possible Solution

- An iterator is usually implemented as inner class of an aggregate class. This enables the iterator to access the internal data structures of the aggregate.
- New access and traversal operations can be added by defining new iterators.
  For example, traversing back-to-front: previous(), hasPrevious().
- An aggregate provides an interface for creating an iterator (createIterator()).
- Clients can use different Iterator objects to access and traverse an aggregate object in different ways.
- Multiple traversals can be in progress on the same aggregate object (simultaneous traversals). However, need to consider concurrent usage issues!

Iterator Pattern: Java Collection Framework

The Java Collections Framework provides,

- a general purpose *iterator*

  next(), hasNext(), remove()

- an extended *listIterator*

  next(), hasNext(), previous(), hasPrevious(), remove(), ...

Example: Custom Iterator

```
Hashtable<String, MenuItem> menuItems =
        new Hashtable<String, MenuItem>();
```

```
public Iterator<MenuItem> createIterator() {
    return menuItems.values().iterator();
}
```

Using or forwarding an **iterator** method from a collection (i.e. Hashtable, ArrayList, etc.)

Implement **Iterator** interface, and provide the required methods (and more if required).

```
public class DinerMenuIterator implements Iterator<MenuItem> {
    MenuItem[] list;
    int position = 0;

    public DinerMenuIterator(MenuItem[] list) {
        this.list = list;
    }

    public MenuItem next() {
        MenuItem menuItem = list[position];
        position = position + 1;
        return menuItem;
    }

    public boolean hasNext() {
        if (position >= list.length || list[position] == null) {
            return false;
        } else {
            return true;
        }
    }

    public void remove() {
        if (position <= 0) {
            throw new IllegalStateException
                ("You can't remove an item until you've done at least one next()");
        }
        if (list[position-1] != null) {
            for (int i = position-1; i < (list.length-1); i++) {
                list[i] = list[i+1];
            }
            list[list.length-1] = null;
        }
    }
}
```

Read the example code discussed/developed in the lectures, and also provided for this week

Demo: Iterator Pattern

Demo …

End