CSE201: Monsoon 2024
Advanced Programming

Lecture 10: Collection Framework

Dr. Arun Balaji Buduru

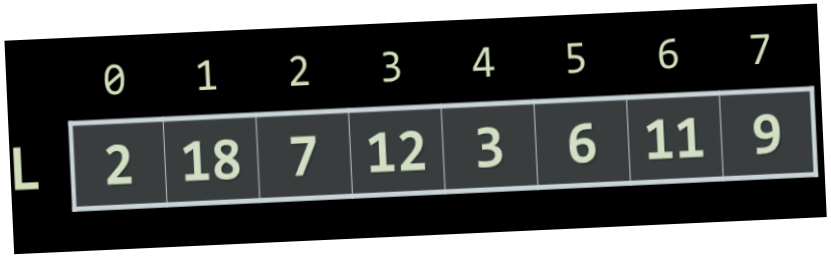
Head, Center of Technology in Policing

Founding Head, Usable Security Group (USG)

Associate Professor, Dept. of CSE | HCD

IIIT-Delhi, India

How is your Experience using Arrays?

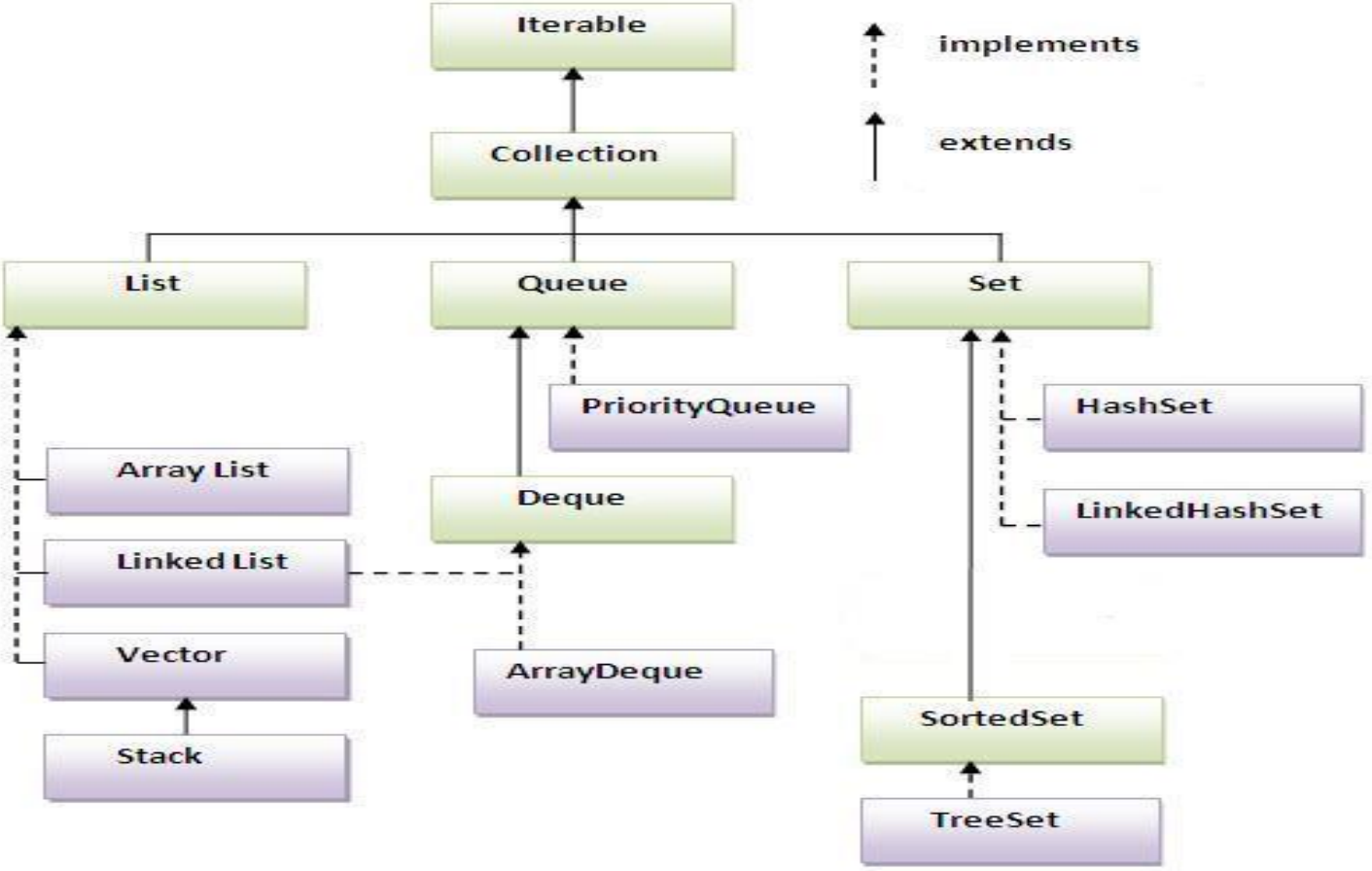


- Has fixed size (**`length`**)
  - Can you do it programmatically?
  - Memory wastage?
- Deleting an element
  - Can you do it programmatically?
- Comparing two arrays
  - Can you use “==“ or equals()?
- Can you assign one array to other?
  - int a[], b[]; a=b

Java Collection Framework

- Unified architecture for representing and manipulating collections
  - A collection (sometimes called a *container*) is simply an object that groups multiple elements into a single unit
  - Very useful
    - store, retrieve and manipulate data
    - transmit data from one method to another
- Collection framework contains three things
  - Interfaces
  - Implementations
  - Algorithms
- This group of collection classes/interfaces are referred to as Java Collection Framework (JCF)
  - The classes in JCF are found in package "`java.util`".

Collection Hierarchy



Interface Can Extend Another Interface (1/2)

```
public interface Moveable {
    public void move_left();
    public void move_right();
}
```

```
public interface Flyable {
    public void fly_up();
    public void fly_down();
    public void move_left();
    public void move_right();
}
```

```
public class Car
         implements Moveable {
    ...
    public void move_left() {
      // move left
    }
    public void move_right() {
      // move right
    }
    // more methods elided
}
```

```
public class Airplane
           implements Flyable {
    ...
    public void move_left() {
      // move left
    }
    public void move_right() {
      // move right
    }
    public void fly_up() {
      // fly up
    }
    public void fly_down() {
      // fly down
    }
}
```

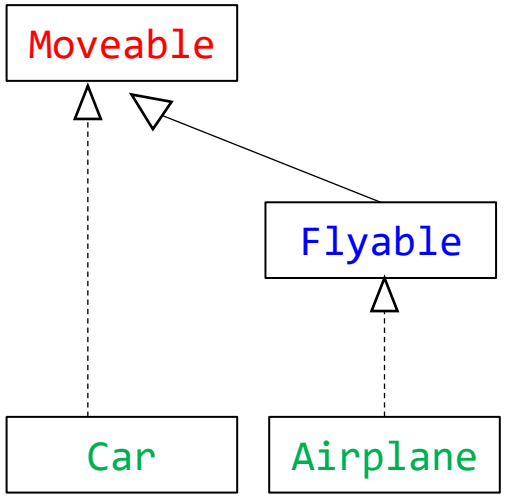
Interface Can Extend Another Interface (2/2)

```
public interface Moveable {
    public void move_left();
    public void move_right();
}
```

```
public interface Flyable
            extends Moveable {
    public void fly_up();
    public void fly_down();
}
```

```
public class Car
         implements Moveable {
    ...
    public void move_left() {
      // move left
    }
    public void move_right() {
      // move right
    }
    // more methods elided
}
```

```
public class Airplane
           implements Flyable {
    ...
    public void move_left() {
      // move left
    }
    public void move_right() {
      // move right
    }
    public void fly_up() {
      // fly up
    }
    public void fly_down() {
      // fly down
    }
}
```



Iterable Interface Source Code

```
package java.lang;
public interface Iterable<E> {
    Iterator<E> iterator();
}
```

- Just one method in this interface
- Objects of all classes that implements this interface can be the target of foreach statement
- Iterators allow iterating over the entire collection. It also allows element removal from collection during iteration

Iterator Interface

- Defines three fundamental methods
  - `Object next()`
  - `boolean hasNext()`
  - `void remove()`
- These three methods provide access to the contents of the collection
- An Iterator knows position within collection
- Each call to next() “reads” an element from the collection
  - Then you can use it or remove it

Iterator Position

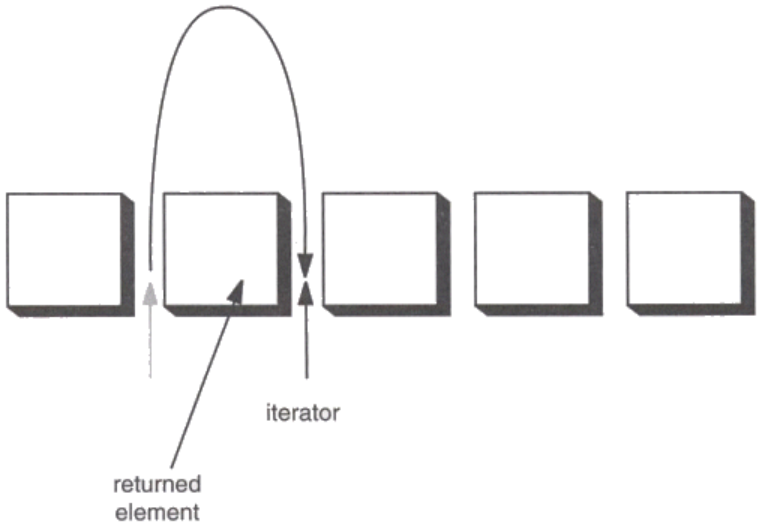


Figure 2–3: Advancing an iterator

Collection Interface Source Code

```
package java.util;
public interface Collection<E> extends Iterable<E>
{
    int size();
    boolean isEmpty();
    contains(Object o);
    boolean add(E e);
    boolean remove(Object o);
    equals(Object o);
    ........
    ........
}
```

- Defines fundamental methods that are enough to define the basic behavior of a collection
- Inherit the method from Iterable interface

Example - SimpleCollection

```
public class SimpleCollection  {
    public static void main(String[] args) {
     Collection c = new ArrayList();
     for (int i=0; i < 10; i++) {
              c.add(i);
     }
     Iterator iter = c.iterator();
     while (iter.hasNext())
              System.out.println(iter.next());
    }
}
```

List Interface

- Recall in Java, arrays have fixed length
  - Cannot add / remove / insert elements
- Lists are like resizable arrays
  - Allow add / remove / insert of elements
- List **interface** is defined through the **`ArrayList<E>`** class
  - Where **`E`** is the type of the list, e.g. **`String`** or **`Integer`**

List Interface Source Code

```
package java.util;
public interface List<E> extends Collection<E> {
    E get(int index);
    E set(int index);
    void add(int index, E element);
    E remove(int index);
    ListIterator<E> listIterator();
    ........
    ........
}
```

- Observe that List interface has two different iterators
  - `Iterator<E> iterator();`
  - `ListIterator<E> listIterator();`

ListIterator Interface

- Extends the Iterator interface
- Defines three fundamental methods
  - `void add(Object o)` - before current position
  - `boolean hasPrevious()`
  - `Object previous()`
- The addition of these three methods defines the basic behavior of an ordered list
- Iterator v/s ListIterator
  - Unlike Iterator, a ListIterator knows position within list (obtain indexes)
  - Iterator allows traversal only in forward direction but ListIterator allows list traversal in both forward and backward directions
  - ListIterator can be used to traverse a List only

List Implementations

- ArrayList
  - low cost random access (at an index)
  - high cost insert and delete
  - array that resizes if need be
- LinkedList
  - sequential access but high cost random access (at an index)
  - low cost insert and delete

ArrayList overview

- Constant time positional access (it's an array)
- One tuning parameter, the initial capacity to constructor
- Constructors
  - `ArrayList()`
    - Build an empty ArrayList (of initial size 10)
  - `ArrayList(Collection c)`
    - Build an ArrayList initialized with the elements of the collection c
  - `ArrayList(int initialCapacity)`
    - Build with the specified initial capacity

ArrayList Methods

- The indexed get and set methods of the List interface are appropriate to use since ArrayLists are backed by an array
  - `Object get(int index)`
  - `Object set(int index, Object element)`
  - `May throw IndexOutOfBoundsException`
- Indexed add and remove are provided, but can be costly if used frequently
  - `void add(int index, Object element)`
  - `Object remove(int index)`
  - `May throw IndexOutOfBoundsException`
- May want to resize in one shot if adding many elements
  - `void ensureCapacity(int minCapacity)`
- ArrayList allows adding duplicate elements

How ArrayList Store Objects in Heap?

```
public boolean add(E e) {
    ensureCapacity(size+1);
    elementData[size++] = e;
    return true;
}
```

```
// Increase the capacity if necessary to ensure that it can
// hold atleast the minCapacity number of elements
public void ensureCapacity(int minCapacity) {
    .....
    int oldCapacity = elementData.length;
    if(minCapacity > oldCapacity) {
        ......
        int newCapacity = ........
        elementData = Arrays.copyOf(elementData, newCapacity);
    }
}
```

- ArrayList stores objects in an Object array
  - `private Object[] elementData;`
- Resizable array implementation

LinkedList Overview (1/2)

- Stores each element in a node
- Each node stores a link to the next and previous nodes
  - Doubly linked list
- Insertion and removal are inexpensive
  - just update the links in the surrounding nodes
- Linear traversal is inexpensive
- Random access is expensive
  - Start from beginning or end and traverse each node while counting

LinkedList Overview (2/2)

- Constructors
  - LinkedList()
    - Build an empty LinkedList
  - LinkedList(Collection c)
    - Construct a list containing the elements of the specified collection, in the order they are returned by the collection's iterator

LinkedList Methods

- ListIterator knows about position
  - use **`add()`** to add at a position
  - use **`remove()`** to remove at a position
- Few other methods
  - **`void addFirst(Object o), void addLast(Object o)`**
  - **`Object getFirst(), Object getLast()`**
  - **`Object removeFirst(), Object removeLast()`**

Example: LinkedList

```
import java.util.*;
public class Book {
    private String name;
    private int pages;
    public Book(int p, String s) { ..... }
    @Override
    public String toString() { ..... }
    public static void main(String[] args) {
        List<Book> list = new LinkedList<Book>();

        list.add(new Book(100, “ABC”));
        list.add(new Book(200, “DEF”));
        list.add(new Book(300, “GHI”));

        for(Book b:list) {
            System.out.println(b);
        }
    }
}
```

Sets

- Sets keep unique elements only
  - Like lists but no duplicates
- HashSet<E>
  - Keeps a set of elements in a hash tables
  - The elements are randomly ordered by their hash code
- TreeSet<E>
  - Keeps a set of elements in a red-black ordered search tree
  - The elements are ordered incrementally

Set Interface

- Same methods as Collection
  - different contract - no duplicate entries
    - How?
- Provides an Iterator to step through the elements in the Set
  - No guaranteed order in the basic Set interface

HashSet

- Find and add elements very quickly
  - uses hashing
- Hashing uses an array of linked lists
  - The **`hashCode()`** is used to index into the array
  - Then **`equals()`** is used to determine if element is in the (short) list of elements at that index
- No order imposed on elements

TreeSet

- Elements can be inserted in any order
  - The TreeSet stores them in order
- Default order is defined by natural order
  - Objects implement the Comparable interface
  - TreeSet uses **`compareTo(Object o)`** to sort

Example: TreeSet

```
import java.util.*;
public class Book implement Comparable<Book> {
    private String name;
    private int pages;
    public Book(int p, String s) { ..... }
    @Override
    public String toString() { ..... }
    public int compareTo(Book b) {
        if(this.page>b.getpage()) return 1;
        else if(this.page<b.getpage()) return -1;
        else return 0;
    }
    public static void main(String[] args) {
        Set<Book> set = new TreeSet<Book>();

        set.add(new Book(100, “ABC”));
        set.add(new Book(200, “DEF”));
        for(Book b:set) { // you can also use iterator
            System.out.println(b);
        }
    }
}
```

- The elements in TreeSet must be of Comparable type
- You need to add compareTo in user defined classes

Maps

- Maps keep unique <key, value> pairs
- HashMap<K, V>
  - Keeps a map of elements in a hash table
  - The elements are randomly ordered using their hash code
- TreeMap<K, V>
  - Keep a set of elements in a red-black ordered search tree
  - The elements are ordered incrementally by their key

Map Interface

- Stores unique key/value pairs
- Maps from the key to the value
- Keys are unique
  - a single key only appears once in the Map
  - a key can map to only one value
- Values do not have to be unique

Example: HashMap

```
import java.util.*;
public class Book {
    private String name;
    private int pages;
    public Book(int p, String s) { ..... }
    @Override
    public String toString() { ..... }
    public static void main(String[] args) {
        Map<Integer, Book> map = new HashMap<Integer, Book>();

        map.add(1, new Book(100, “ABC”));
        map.add(2, new Book(200, “DEF”));
        for(Map.Entry e:map.entrySet()) {
            System.out.println(e.getKey() + “:” + e.getValue());
        }
    }
}
```