Topic #9: Collections

CSE 413, Autumn 2004
Programming Languages

http://www.cs.washington.edu/education/courses/413/04au/

- If S is a subtype of T, what is S permitted to do with the methods of T?

Typing Rule	Return values	Arguments	Sound?
Contravariant			
Covariant			
Invariant			

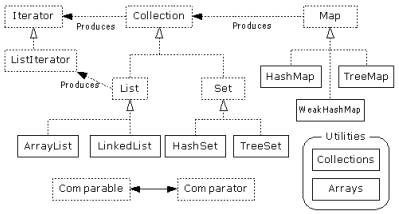
Readings and References

- Reading
- Other References
  - » "Collections", Java tutorial
  - » http://java.sun.com/docs/books/tutorial/collections/index.html

Collections

- A collection is an object that groups multiple elements into a single unit
- A collections framework contains three things
  - » Interfaces
  - » Implementations
  - » Algorithms

Java Collections



•From Thinking in Java, page 462

Collection Interface

- Defines fundamental methods
  - » `int size();`
  - » `boolean isEmpty();`
  - » `boolean contains(Object element);`
  - » `boolean add(Object element);  // Optional`
  - » `boolean remove(Object element); // Optional`
  - » `Iterator iterator();`
- Plus Iterator

Iterator Interface

- Methods
  - `Object next()`
  - `boolean hasNext()`
  - `void remove()`
- An Iterator knows position within collection
- Each call to next() "reads" an element from the collection

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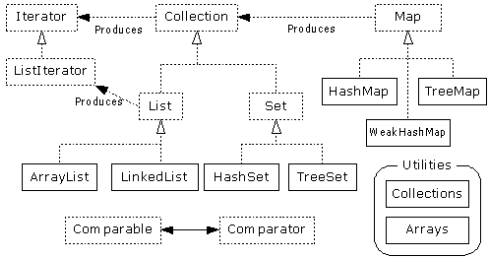
List Interface Context



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List Interface

- The List interface adds the notion of *order* to a collection
- The user of a list has control over where an element is added in the collection
- Lists typically allow *duplicate* elements
- Provides a ListIterator to step through the elements in the list.

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ListIterator Interface

- Extends the Iterator interface
- New methods:
  - `void add(Object o)` - before current position
  - `boolean hasPrevious()`
  - `Object previous()`

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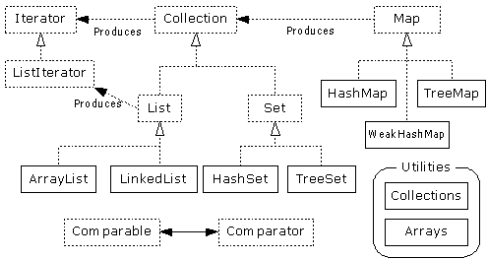
ArrayList and LinkedList Context



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List Implementations

- ArrayList
  - » low cost random access
  - » high cost insert and delete
  - » array that resizes if need be
- LinkedList
  - » sequential access
  - » low cost insert and delete
  - » high cost random access

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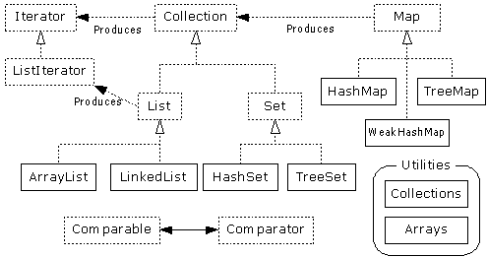
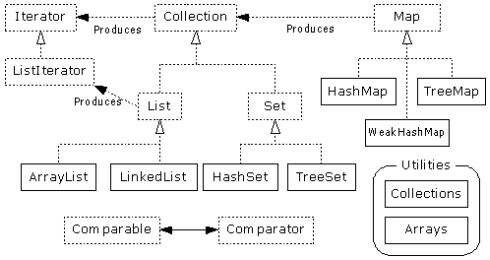
Set Interface Context



Set Interface

- Same methods as Collection but…
- Defines two fundamental methods
  - » **`boolean add(Object o)`** - reject duplicates
  - » **`Iterator iterator()`**
- Iterator to step through the elements in the Set
  - » No guaranteed order in the basic Set interface
  - » There is a SortedSet interface that extends Set

HashSet and TreeSet Context



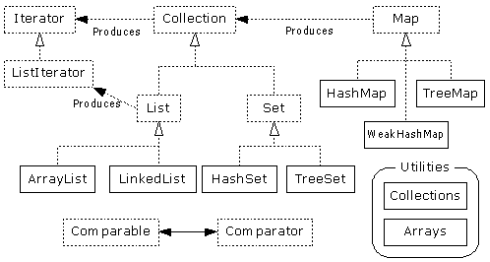
HashSet

- Find and add elements very quickly
- 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
- The **`hashCode()`** method and the **`equals()`** method must be compatible:

TreeSet

- Set with all elements in order
- Elements can be inserted in any order
- The TreeSet stores them in order
- An iterator always presents them in order
- Default order is defined by natural order
  - » objects implement the Comparable interface
  - » TreeSet uses **`compareTo(Object o)`** to sort
- Can use a different Comparator
  - » provide Comparator to the TreeSet constructor

Map Interface Context



Map Interface

- Stores key/value pairs
- Maps from the key to the value
- Keys are unique
  - » keys are stored as a Set
  - » a key can map to only one value
- Values do not have to be unique

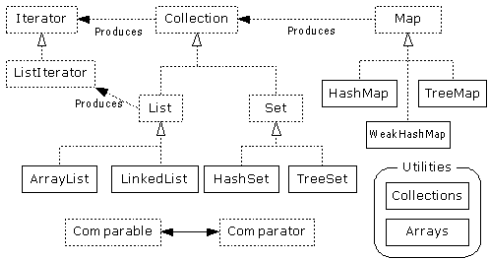
Map methods

```
Object put(Object key, Object value)
Object get(Object key)
Object remove(Object key)
boolean containsKey(Object key)
boolean containsValue(Object value)
int size()
boolean isEmpty()
```


Map views

- A means of iterating over the keys and values in a Map
- **`Set keySet()`**
  - » returns the Set of keys contained in the Map
- **`Collection values()`**
  - » returns the Collection of values contained in the Map.
- **`Set entrySet()`**
  - » returns the Set of key-value pairs contained in the Map. See docs.

HashMap and TreeMap Context



HashMap and TreeMap

- HashMap
  - » The keys are stored in a HashSet
  - » Fast
  - » No implicit key ordering
- TreeMap
  - » The keys are stored in a TreeSet
  - » Same options for ordering as a TreeSet
    - *Natural order (Comparable, compareTo(Object))*
    - *Special order (Comparator, compare(Object, Object))*

Utilities

- The Collections class provides a number of static methods for fundamental algorithms
- Most operate on Lists, some on all Collections
  - » Sort, Search, Shuffle
  - » Reverse, fill, copy
  - » Min, max
- Wrappers
  - » synchronized Collections, Lists, Sets, etc
  - » unmodifiable Collections, Lists, Sets, etc

Appendix

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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)`
- Indexed add and remove are provided, but can be costly if used frequently
  - `void add(int index, Object element)`
  - `Object remove(int index)`
- May want to resize in one shot if adding many elements
  - `void ensureCapacity(int minCapacity)`

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Example – Using Iterator

```
public class SimpleCollection  {
   public static void main(String[] args) {
    Collection c;
    c = new ArrayList();
    System.out.println(c.getClass().getName());
    for (int i=1; i <= 10; i++) {
          c.add(i + " * " + i + " = "+i*i);
    }
    Iterator iter = c.iterator();
    while (iter.hasNext())
          System.out.println(iter.next());
   }
}
```

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LinkedList overview

- Stores each element in a node
- Each node stores a link to the next and previous nodes
- 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

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LinkedList entries

```
private static class Entry {
   Object element;
   Entry next;
   Entry previous;

   Entry(Object element, Entry next, Entry previous) {
       this.element = element;
       this.next = next;
       this.previous = previous;
   }
}

private Entry header = new Entry(null, null, null);

public LinkedList() {
   header.next = header.previous = header;
}
```

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LinkedList methods

- The list is sequential, so access it that way
  - `ListIterator listIterator()`
- ListIterator knows about position
  - use `add()` from ListIterator to add at a position
  - use `remove()` from ListIterator to remove at a position
- LinkedList knows a few things too
  - `void addFirst(Object o), void addLast(Object o)`
  - `Object getFirst(), Object getLast()`
  - `Object removeFirst(), Object removeLast()`

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Bulk Operations

- In addition to the basic operations, a Collection may provide "bulk" operations

```
boolean containsAll(Collection c);
boolean addAll(Collection c);    // Optional
boolean removeAll(Collection c); // Optional
boolean retainAll(Collection c); // Optional
void clear();                    // Optional
Object[] toArray();
Object[] toArray(Object a[]);
```

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Legacy classes

- Still available
- Don't use for new development
- Retrofitted into Collections framework
- Hashtable
  - » use HashMap
- Enumeration
  - » use Collections and Iterators
  - » if needed, can get an Enumeration with Collections.enumeration(Collection c)

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More Legacy classes

- Vector
  - » use ArrayList
- Stack
  - » use LinkedList
- BitSet
  - » use ArrayList of boolean, unless you can't stand the thought of the wasted space
- Properties
  - » legacies are sometimes hard to walk away from …
  - » see next few pages

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Properties class

- Located in java.util package
- Special case of Hashtable
  - » Keys and values are Strings
  - » Tables can be saved to/loaded from file

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System properties

- Java VM maintains set of properties that define system environment
  - » Set when VM is initialized
  - » Includes information about current user, VM version, Java environment, and OS configuration

```
Properties prop = System.getProperties();
Enumeration e = prop.propertyNames();
while (e.hasMoreElements()) {
   String key = (String) e.nextElement();
   System.out.println(key + " value is " +
       prop.getProperty(key));
}
```

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