Topic #9: Collections
CSE 413, Autumn 2004
Programming Languages

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

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

<table>
<thead>
<tr>
<th>Typing Rule</th>
<th>Return values</th>
<th>Arguments</th>
<th>Sound?</th>
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<tbody>
<tr>
<td>Contravariant</td>
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<td>Covariant</td>
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<td>Invariant</td>
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Readings and References

- Reading
  - “Collections”, Java tutorial

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

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

List Interface Context

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.

ListIterator Interface

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

ArrayList and LinkedList Context

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
Set Interface Context

- 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

- 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(Comparable 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**
  - 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

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)`

Example – Using Iterator

```java
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());
    }
}
```

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

LinkedList entries

```java
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;
}
```

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()`
Bulk Operations

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

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

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)

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

Properties class

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

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

```java
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));
}
```