Java Collections

CSE 403, Winter 2003
Software Engineering

http://www.cs.washington.edu/education/courses/403/03wi/
Readings and References

• References
  » "Collections", Java tutorial
  » http://java.sun.com/docs/books/tutorial/collections/index.html
Java 2 Collections

- A collection is an object that groups multiple elements into a single unit
- Very useful
  - store, retrieve and manipulate data
  - transmit data from one method to another
  - data structures and methods written by hotshots in the field
    - Joshua Bloch, who also wrote the Collections tutorial
Collections Framework

- Unified architecture for representing and manipulating collections.
- A collections framework contains three things
  - Interfaces
  - Implementations
  - Algorithms
Collections Framework Diagram

- Interfaces, Implementations, and Algorithms
- 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();

• These methods are enough to define the basic behavior of a collection

• Provides an Iterator to step through the elements in the Collection
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
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());
        }
    }
}
List Interface Context

- `Collection` produces `Map`
- `List` produces `ListIterator`
- `List` produces `Comparable`
- `List` produces `Comparator`
- `List` produces `ArrayList`
- `List` produces `LinkedList`
- `List` produces `HashSet`
- `List` produces `TreeSet`
- `List` produces `Utils`:
  - `Collections`
  - `Arrays`
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
- 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
- A ListIterator knows position within list
Iterator Position - `next()`, `previous()`

Figure 2–3: Advancing an iterator
ArrayList and LinkedList Context

- Collection
- List
- Map
- Iterator
- ListIterator
- Comparable
- Comparator
- ArrayList
- LinkedList
- HashMap
- TreeMap
- WeakHashMap
- HashSet
- TreeSet
- Collections
- Arrays
- Utilities
List Implementations

- **Array List**
  - low cost random access
  - high cost insert and delete
  - array that resizes if need be

- **Linked List**
  - sequential access
  - low cost insert and delete
  - high cost random access
ArrayList overview

- Constant time positional access (it’s an array)
- One tuning parameter, the initial capacity

```java
public ArrayList(int initialCapacity) {
    super();
    if (initialCapacity < 0)
        throw new IllegalArgumentException(
            "Illegal Capacity: "+initialCapacity);
    this.elementData = new Object[initialCapacity];
}
```
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)`
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

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()
Set Interface Context
Set Interface

- Same methods as Collection
  - different contract - no duplicate entries
- Defines two fundamental methods
  - `boolean add(Object o)` - reject duplicates
  - `Iterator iterator()`
- Provides an 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

Collection

HashSet

TreeSet

List

Set

Iterator

ListIterator

Map

HashMap

TreeMap

WeakHashMap

ArrayList

LinkedList

Comparable

Comparator

Collections

Arrays
HashSet

- Find and add elements very quickly
  - uses hashing implementation in HashMap
- 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
  - if two objects are equal, they must have the same `hashCode()` value
TreeSet

- Elements can be inserted in any order
- The TreeSet stores them in order
  - Red-Black Trees out of Cormen-Leiserson-Rivest
- 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
  - a single key only appears once in the Map
  - 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. This Collection is not a Set, as multiple keys can map to the same value.
- Set `entrySet()`
  - returns the Set of key-value pairs contained in the Map. The Map interface provides a small nested interface called `Map.Entry` that is the type of the elements in this Set.
HashMap and TreeMap Context

Iterator \rightarrow Collection \rightarrow \textbf{Map}

ListIterator \rightarrow List \rightleftharpoons Set

HashMap, TreeMap

Utilities

Comparable \rightarrow Comparator

ArrayList, LinkedList, HashSet, TreeSet

WeakHashMap

Collections, Arrays
HashMap and TreeMap

- **HashMap**
  - The keys are a set - unique, unordered
  - Fast

- **TreeMap**
  - The keys are a set - unique, ordered
  - Same options for ordering as a TreeSet
    - **Natural order** (*Comparable*, `compareTo(Object)`)
    - **Special order** (*Comparator*, `compare(Object, Object)`)
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
boolean retainAll(Collection c); // Optional
void clear();                  // Optional
Object[] toArray();
Object[] toArray(Object a[]);  
```
Utilities Context
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
Legacy classes

- Still available
- Don’t use for new development
  » unless you have to, eg, J2ME, J2EE in some cases
- 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));
}
```