CSC 143 Java

Collections

Collections

- Most programs need to store and access collections of data
- Collections are worth studying because...
  - They are widely useful in programming
  - They provide examples of the OO approach to design and implementation
    - identify common patterns
      - regularize interface to increase commonality
    - factor them out into common interfaces, abstract classes
  - Their implementation will raise issues previously swept under the rug: efficiency

Goals for Next Several Lectures

- Survey different kinds of collections, focusing on their *interfaces*
  - Lists, sets, maps
  - Iterators over collections
- Then look at different possible *implementations*
  - Arrays, linked lists, hash tables, trees
  - Mix-and-match implementations to interfaces
- Compare implementations for efficiency
  - How do we measure efficiency?
  - Implementation tradeoffs

Java Collection Interfaces

- Key interfaces in Java :
  - **Collection** – a collection of objects
  - **List** extends Collection – ordered sequence of objects (first, second, third, …); duplicates allowed
  - **Set** extends Collection – unordered collection of objects; duplicates suppressed
  - **Map** – collection of <key, value> pairs; each key may appear only once in the collection; item lookup is via key values
    (Think of pairs like <word, definition>, <id#, student record>, <book ISBN number, book catalog description>, etc.)
  - **Iterator** – provides element-by-element access to collection items

Java 2 Collection Implementations

- Main concrete implementations of these interfaces:
  - **ArrayList** implements List (using arrays underneath)
  - **LinkedList** implements List (using linked lists)
  - **HashSet** implements Set (using hash tables)
  - **TreeSet** implements Set (using trees)
  - **HashMap** implements Map (using hash tables)
  - **TreeMap** implements Map (using trees)

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Java Generics

- Before Java 5.0, the static type of the elements of a Collection or of the keys and values of a Map was Object
  - Yields unattractive code

```
ArrayList a = new ArrayList();
a.add("First element"); // a string
String s = (String) a.get(0); // need a cast
```

- In Java 5.0, a Collection (or a Map) specifies the static type of its elements
  - Better code

```
ArrayList<String> a = new ArrayList<String>();
a.add("First element");
String s = a.get(0); // no cast
```

- With Generics, the compiler can do some type checking.

```
ArrayList<String> a = new ArrayList<String>();
a.add(new Oval()); // doesn't compile
```

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Java Boxing

- Before Java 5.0, a primitive type could not be put directly in a collection

```
ArrayList a = new ArrayList();
int i = 3;
a.add(i);// NO!
a.add(new Integer(i)); // OK
```

- The distinction between primitive and reference types is still present in Java 5.0. But, the details are hidden from the programmer.

```
ArrayList<Integer> a = new ArrayList<Integer>();
int i = 3;
a.add(i);// OK: i is boxed into an Integer object
int k = a.get(0); // OK: the arraylist element is unboxed
```

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interface Collection<E>

- Basic methods available on most collections (E is the generic type of the collection):
  - int **size**( ) – # of items currently in the collection
  - boolean **isEmpty**( ) – (size( ) == 0)
  - boolean **contains**(Object o) – true if o is in the collection
    [how to compare o with the elements already in the collection?]
  - boolean **add**(E o) – ensure that o is in the collection, possibly adding it;
    return true if collection altered; false if not. [leaves a lot unspecified….]
  - boolean **addAll**(Collection<E> other) – add all elements in the other collection (actually not the exact signature…)
  - boolean **remove**(Object o) – remove one o from the collection, if present;
    return true if something was actually removed
  - void **clear**( ) – remove all elements
  - Iterator<E> **iterator**( ) – return an iterator object for this collection

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interface Iterator<E>

- Provides access to elements of any collection one-by-one, even if the collection has no natural ordering (sets, maps)

```
boolean hasNext( ) – true if the iteration has more elements
E next( ) – next element in the iteration; precondition: hasNext( ) == true
void remove( ) – remove from the underlying collection the element last returned
    by the iteration. [Optional; some collections don't support this.]
```


Standard Iterator<E> Loop Pattern

```
Collection<E> c = …;
Iterator<E> iter = c.iterator( );
while (iter.hasNext( )) {
  E elem = iter.next( );
  // do something with elem
}
```

- Note similarity to generic file/stream processing loop:

```
open stream -- perhaps from file
while not at end of stream {
  read/write next data item, do something with it
}
```


Iterators vs. Counter Loops

- A related pattern is the *counting loop*:

```
ArrayList<E> list = …;
for (int i = 0; i < list.size( ); i ++) {
    E elem = list.get(i);
    // do something with elem
}
```

- The iterator pattern is generally preferable because it...
  - works over any collection, even those without a get(int) operation
  - encapsulates the tedious details of iterating, indexing

Still more abstraction: for(:)

- Can even use an iterator without asking for one

```
ArrayList<E> list = …;
for (E elem : list) {
    // do something with elem
}
```

- CSC143 style rule: use the iterator pattern (with an actual iterator or in the form of the above for loop). It is a good illustration of the concept of abstraction.
  - Unless there are compelling reasons to use a counting loop (e.g. initialization)
- Note: the for(:) statement works for arrays as well (anything that is Iterable)

```
int a = new int [10];
for ( int k : a) { // do something with k }
```

Lists as Collections

- In some collections, there is no natural order
  - Leaves on a tree, grocery items in a bag, grains of sand on the beach
- In other collections, the order of elements is natural and important
  - Chapters of a book, floors in a building, people camping out to buy *Starwars* tickets
- Lists are collections where the elements have an order
  - Each element has a definite position (first, second, third, …)
  - positions are generally numbered from 0

interface List<E> extends Collection<E>

- Following are included in all Java Lists (and some other Collection types):

  E **get**(int pos) – return element at position pos

  boolean **set**(int pos, E elem) – store elem at position pos

  boolean **add**(int pos, E elem) – store elem at position pos; slide elements at position pos to size( )-1 up one position to the right

  E **remove**(int pos) – remove item at given position; shift remaining elements to the left to fill the gap; return the removed element

  int **indexOf**(Object o) – return position of first occurrence of o in the list, or -1 if not found

  - Precondition for most of these is 0 <= pos < size( )

interface ListIterator<E> extends Iterator<E>

- The iterator( ) method for a List returns an instance of ListIterator
  - Can also send **listIterator**(int pos) to get a ListIterator starting at the given position in the list
- ListIterator returns objects in the list collection in the order they appear in the collection
- Supports additional methods:

  hasPrevious( ), **previous**( ) – for iterating backwards through a list

  set(E o) – to replace the current element with something else

  add(E o) – to insert an element after the current element

List Implementations

- **ArrayList<E>** – internal data structure is an array
  - Fast iterating
  - Fast access to individual elements (using get(int), set(int, E))
  - Slow add/remove, particularly in the middle of the list
- **LinkedList<E>** – internal data structure is a linked list
  - Fast iterating
  - Slow access to individual elements (using get(int), set(int, E))
  - Fast add/remove, even in the middle of the list if via iterator
- A bit later in the course we'll dissect both forms of implementation

interface **Set<E>** extends Collection<E>

- As in math, a Set is an unordered collection, with no duplicate elements
  - attempting to add an element already in the set does not change the set
- Interface is same as Collection, but refines the specifications
  - The specs are in the form of comments
- interface **SortedSet<E>** extends Set<E>
  - Same as Set, but iterators will always return set elements in a specified order
  - Requires that elements be Comparable: implement the **compareTo**(E o) method, returning a negative, 0, or positive number to mean <=, ==, or >=, respectively
    or that elements be comparable with a Comparator.

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interface **Map<K, V>**

- Collections of <key, value> pairs
  - keys are unique, but values need not be
- Doesn't extend Collection, but does provide similar methods
  size( ), **isEmpty**( ), **clear**( )
- Basic methods for dealing with <key, value> pairs:
  V **put**(K key, V value) – add <key, value> to the map, replacing the previous <key, value> mapping if one exists
  void **putAll**(Map<K, V> other) – put all <key, value> pairs from other into this map
  V **get**(K key) – return the value associated with the given key, or null if key is not present
  V **remove**(K key) – remove any mapping for the given key
  boolean **containsKey**(Object key) – true if key appears in a <key, value> pair
  boolean **containsValue**(Object value) – true if value appears in a <key, value>

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Maps and Iteration

- Map provides methods to view contents of a map as a collection:
  Set<K> keySet( ) – return a Set whose elements are the keys of this map
  Collection<V> values( ) – return a Collection whose elements are the values contained in this map
  [why is one a set and the other a collection?]
- To iterate through the keys or values or both, grab one of these collections, and then iterate through that

```
Map<K, V> map = ...;
Set<K> keys = map.keySet( );
for (K key : keys) {
    V value = map.get(key);
    // do something with key and value
}
```

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interface **SortedMap<K, V>** extends Map

- SortedMap can be used for maps where we want to store key/value pairs in order of their keys
  - Requires keys to be Comparable, using compareTo, or comparable with a Comparator.
- Sorting affects the order in which keys and values are iterated through
  - keySet( ) returns a SortedSet<K>
  - values( ) returns an ordered Collection<V>

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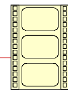
Preview of Coming Attractions



1. Study ways to implement these interfaces
   - Array-based vs. link-list-based vs. hash-table-based vs. tree-based
2. Compare implementations
   - What does it mean to say one implementation is “faster” than another?
   - Basic complexity theory – O( ) notation
3. Use these and other data structures in our programming

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