CS61B Lecture #15

Administrative:

- Test Review Session
- Reminder: auto-grader run sometime tonight.

Today:

- Asymptotic complexity (from last time)
- Iterators, ListIterators
- Containers and maps in the abstract
- Views

Readings for Today: *Data Structures*, Chapter 2.

Readings for next Topic: *Data Structures*, Chapter 3.

Some Intuition on Meaning of Growth

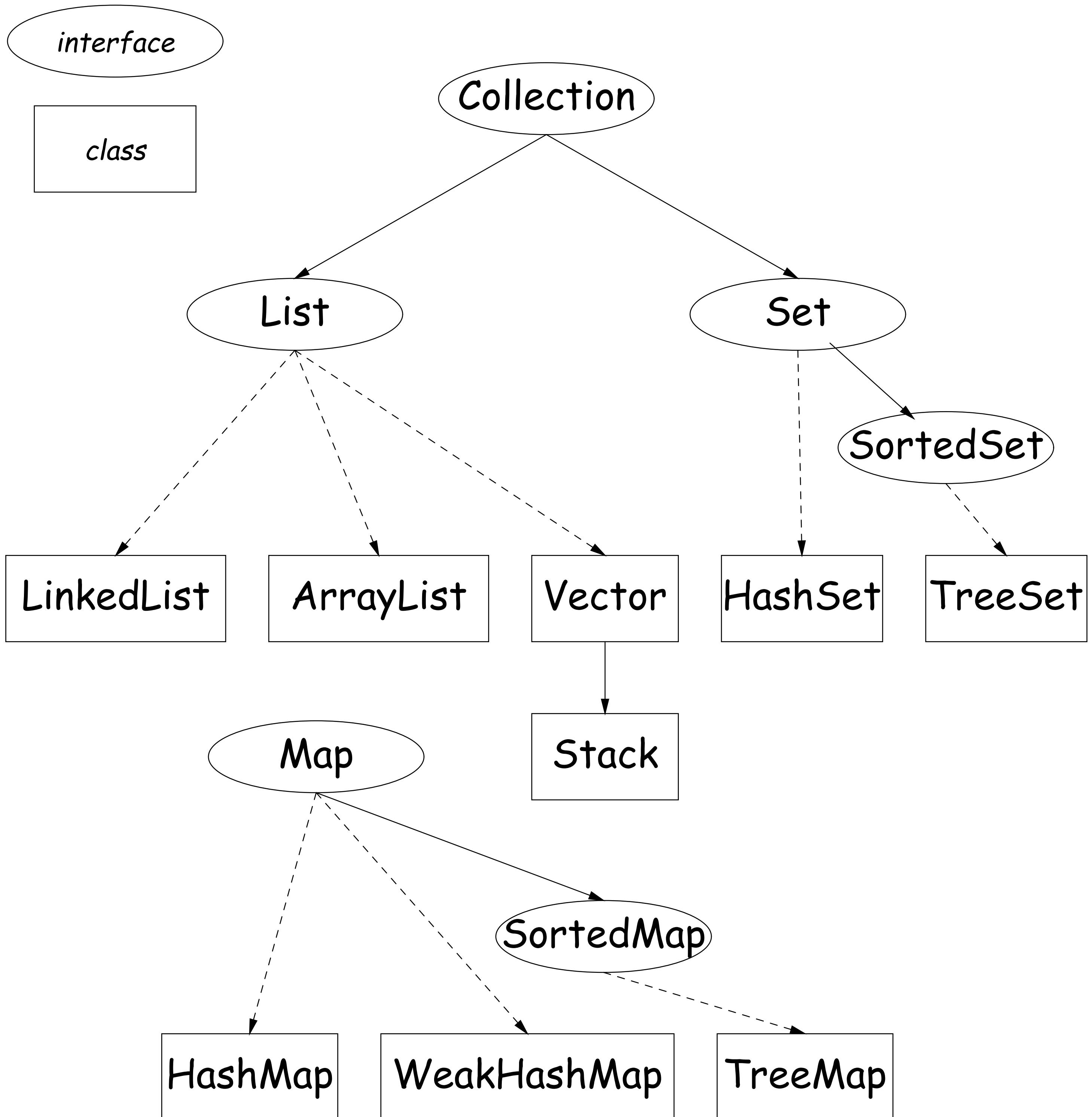
- How big a problem can you solve in a given time?
- In the following table, left column shows time in microseconds to solve a given problem as a function of problem size N.
- Entries show the *size of problem* that can be solved in a second, hour, month (31 days), and century, for various relationships between time required and problem size.
- $N =$ problem size

Time (μsec)	Max N Possible in			
	1 second	1 hour	1 month	1 century
$\lg N$	10^{300000}	10^{10^9}	$10^{8\cdot 10^{11}}$	$10^{9\cdot 10^{14}}$
N	10^6	$3.6 \cdot 10^9$	$2.7 \cdot 10^{12}$	$3.2 \cdot 10^{15}$
$N \lg N$	63000	$1.3 \cdot 10^8$	$7.4 \cdot 10^{10}$	$6.9 \cdot 10^{13}$
N^2	1000	60000	$1.6 \cdot 10^6$	$5.6 \cdot 10^7$
N^3	100	1500	14000	150000
2^N	20	32	41	51

Data Types in the Abstract

- Most of the time, should *not* worry about implementation of data structures, search, etc.
- What they do for us—their specification—is important.
- Java has several standard types (in `java.util`) to represent collections of objects
  - Six interfaces:
    - `Collection`: General collections of items.
    - `List`: Sequences with duplication
    - `Set`, `SortedSet`: Collections without duplication
    - `Map`, `SortedMap`: Dictionaries (key $\mapsto$ value)
  - Concrete classes that provide actual instances: `LinkedList`, `ArrayList`, `HashSet`, `TreeSet`.
  - To make change easier, purists would use the concrete types only for **new**, interfaces for parameter types, local variables.

Collection Structures in `java.util`



The Collection Interface

- Collection interface. Main functions promised:
  - Membership tests: `contains` ($\in$), `containsAll` ($\subseteq$)
  - Other queries: `size`, `isEmpty`
  - Retrieval: `iterator`, `toArray`
  - *Optional* modifiers: `add`, `addAll`, `clear`, `remove`, `removeAll` (set difference), `retainAll` (intersect)
- Design point: Optional operations may throw

  `UnsupportedOperationException`

  Why not separate interfaces?
- Answer: avoid proliferation of lower types, interfaces (Vector, readonly Vector, add-only remove Vector).

Problem: How to Retrieve?

- Collections don't always have an order—no first, no n^{th}
- So how to *get* things out?
- Even for types of Collection that *do* have an ordering, indexing (as for arrays) not always best (fastest) way to *get* elements.
- Abstraction to the rescue: define retrieval interface:

```
package java.util;
public interface Iterator {
  /** True iff there's more. */
  boolean hasNext ();
  /** Return next item and then move on. */
  Object next ();
  /** Remove last item returned by next() from underlying
   *  Collection. May throw exception if unsupported.  */
  void remove ();
}
```

- Iterator is a kind of "moving finger" through a Collection.

The List Interface

- Extends `Collection`
- Intended to represent *indexed sequences* (like arrays, but more general).
- Adds new methods to those of `Collection`:
  - Membership tests: `indexOf`, `lastIndexOf`.
  - Retrieval: `get(`i`)`, `listIterator`, `sublist(`B, E`)`.
  - Modifiers: `add` and `addAll` with additional index to say *where* to add. Likewise for removal operations. `set` operation to go with `get`.
- Type `ListIterator` extends `Iterator`:
  - Adds `previous` and `hasPrevious`.
  - `nextIndex` gives position in list.
  - `add`, `remove`, and `set` allow one to iterate through a list, inserting, removing, or changing as you go.

Examples of Use I: Linear Search

Problem: Find an element in list satisfying predicate.

- Assume following definition:

```
/** A one-argument predicate (true/false valued).
 * Calling 'test' applies the predicate. */
interface Predicate {
   /** True iff ARG passes the test. */
   boolean test (Object arg);
}
```

- Solution I:

```
/** The first element of L that satisfies P,
 *  or null if none. */
static Object exists (List L, Predicate P) {
   for (int i = 0; i < L.size (); i += 1)
      if (P.test (L.get (i))) return L.get (i);
   return null;
}
```

- **Disadvantage:** On some Lists, `get`(k) can be a $\Theta(k)$ operation, leading to $\Theta(N^2)$ algorithm, for lists of size N.

Faster Linear Search

- The `iterator` method is intended to return an iterator that is tuned to the data structure, and generally $O(1)$ in time.
- With ordered collection (like `List`), iterator is also ordered.

```
// [NOTE: Changed from the paper version
//  handed out in lecture.]
/** The first element of L that satisfies P,
 *  or null if none. */
static Object exists (List L, Predicate P) {
   for (Iterator i = L.iterator ();
        i.hasNext (); ) {
      Object obj = i.next ();
      if (P.test (obj))
        return obj;
   }
   return null;
}
```

Example of Use II: Inserting New Elements

Problem: After first instance of one object, insert a new object.

```
/** Insert OBJ after AFTER in L. */
static void insertAfter (List L, Object obj, Object after)
{
  for (ListIterator i = L.listIterator ();  i.hasNext (); ) {
    Object x = i.next ();
    if (after.equals (x)) {
      i.add (obj);
      break;
    }
  }
}
```

Sublists and Views

Problem: Delete items $K, K+1, \ldots, M$ from List L.

- The `sublist` operation is supposed to yield a "view of" part of an existing list.
- A *view* is an alternative presentation of (interface to) an existing object.
- Changes in original list reflected in sublist view, and vice-versa.
- For example, could solve problem like this:

```
L.sublist (K, M+1).clear ();
```

  which modifies `L` by removing the elements in the sublist consisting of items `K` through `M+1`.
- Another example of a view: a `Map` is a kind of modifiable function:

```
Object get (Object key);  // Value at KEY.
Object put (Object key, Object value);
                              // Set get(KEY) -> VALUE
```

- Provides three views, which change as the Map changes:

```
Set keySet ();  // The set of all keys
Collection values (); // The multiset of mapped-to values
Set entrySet (); // The set of all (key, value) pairs
```