AP Computer Science with Data Structures

Lab: List Interface and ArrayList

Background: `List`

A *list* (known in mathematics as a *sequence*) is an ordered, expandable collection of objects. Its elements may be accessed by index, and it may contain the same value at different positions.

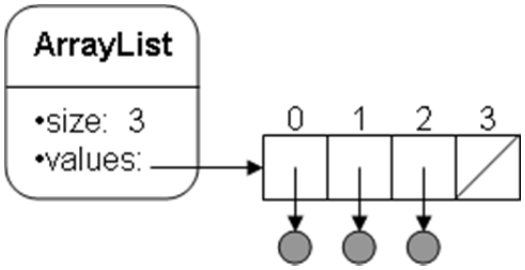
Because a list data structure can be implemented in a variety of ways, `List` has been defined as an interface.

`interface java.util.List<E>`

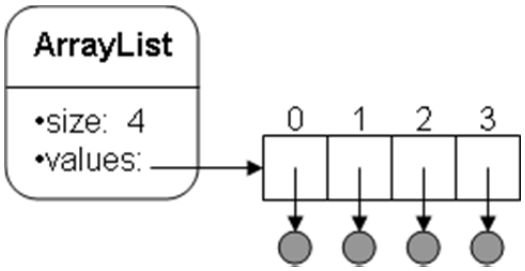
- `int size()`
- `boolean add(E obj)` `// appends obj to end of list; returns true`
- `void add(int index, E obj)` `// inserts obj at position index (0 ≤ index ≤ size),`
  `// moving elements at position index and higher to the`
  `// right (adds 1 to their indices) and adjusts size`
- `E get(int index)`
- `E set(int index, E obj)` `// replaces the element at position index with obj`
  `// returns the element formerly at the specified position`
- `E remove(int index)` `// removes element from position index, moving`
  `// elements at position index + 1 and higher to the`
  `// left (subtracts 1 from their indices) and adjusts size`
  `// returns the element formerly at the specified position`
- `Iterator<E> iterator()`
- `ListIterator<E> listIterator()`

Background: `ArrayList`

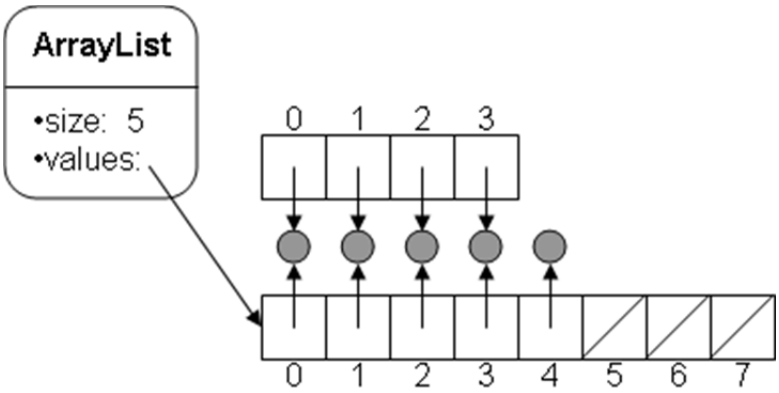
Does the `List` interface look familiar? That's because the `ArrayList` class implements the `List` interface. We know *what* we can do with an `ArrayList`, but we don't know *how* it works. How does `ArrayList` implement the `List` interface? It uses an array! The array will typically be longer than the number of elements in the list, so `ArrayList` also remembers the size of the list.



Usually, when an element is added to the `ArrayList`, a new element is added to the array, and the size is increased.



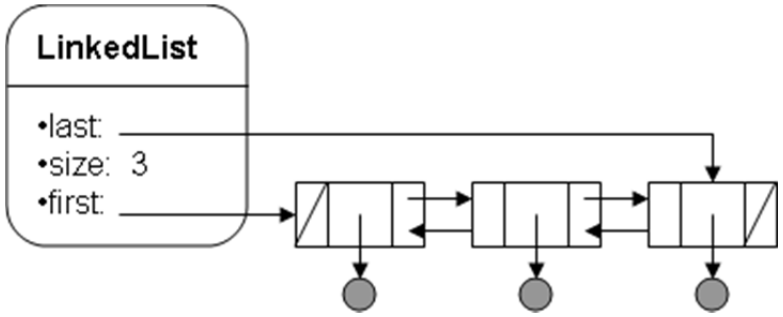
If, however, the array is full when an element is added, `ArrayList` will replace the array with one that is twice as long, and copy all of the old elements into it.



Background: `LinkedList`

Java provides a second implementation of the `List` interface, and it goes by the unfortunate name of `LinkedList`. ***This is not the same as the linked list data structure consisting of a sequence of `ListNode` objects we will investigate later in the course.*** Hence, for the rest of the course, we'll need to be careful to distinguish between "a linked list" and "a `LinkedList`".

Why did Java decide to call this class `LinkedList`? Because internally, just as an `ArrayList` is implemented in terms of an array, a `LinkedList` is implemented in terms of a linked list. Specifically, the `LinkedList` class keeps track of its size, and pointers to the first and last node in a doubly-linked list.



The `LinkedList` class also supports the following methods.

`class java.util.LinkedList<E> implements java.util.List<E>`

- `void addFirst(E obj)`
- `void addLast(E obj)`
- `E getFirst()`
- `E getLast()`
- `E removeFirst()`
- `E removeLast()`

Background: `Iterator`

Typically, we'll declare a list variable to be of the general type `List`, as follows. This gives us the flexibility to switch list implementations later, by changing only a single line of code.

```
List<Bacteria> favorites = new ArrayList<Bacteria>();
```

(Of course, if we're using methods specific to `LinkedList`, then we should declare our variable as a `LinkedList`.)

The time it takes to perform an operation on our list will depend on which implementation of `List` we choose. Consider the following code.

```
for (int i = 0; i < mooses.size(); i++)
     System.out.println(mooses.get(i));
```

This code will be extremely inefficient for one implementation of `List`. (Which one?) Therefore, we prefer to rewrite the code in terms of an `Iterator`. Java's `Iterator` interface lets you repeatedly ask for the next element of a collection. (`Iterator`s will be invaluable to us later in the course when we study `Set`s and `Map`s, whose elements cannot be accessed by

index). Iterators are often useful for solving free response questions on the AP Exam, however they are not explicitly tested.

interface java.util.Iterator<E>

- `boolean hasNext()`
- `E next()`
- `void remove()` `//` removes the last element that was returned by `next`

Thus, we can rewrite our code as:

```
Iterator<Moose> it = mooses.iterator();
while (it.hasNext())
     System.out.println(it.next());
```

Calling the `List`'s `iterator` method will create a new instance of some class that implements the `Iterator` interface. The first call to the `next` method will return the first element in the list. The second call will return the one after that, and so on. You should never call `next` unless `hasNext` returns `true`.

Each of the following code segments exhibits a common error in using `Iterator`s. Can you identify and explain each of these mistakes?

```
while (mooses.iterator().hasNext())
     System.out.println(mooses.iterator().next());

Iterator<Moose> it = mooses.iterator();
Moose moose = it.next();
while (moose != null)
{
     System.out.println(moose);
     moose = it.next();
}

Iterator<Moose> it = mooses.iterator();
while (it.hasNext())
{
     if (it.next() != secretValue)
          System.out.println(it.next());
}
```

Although we'll usually just use an `Iterator` to traverse a collection, an `Iterator` can also be used to remove elements *from the original collection*.

```
Iterator<Mooose> it = mooses.iterator();
while (it.hasNext())
     if (it.next().hasBittenMe())
          it.remove();
```

Note that the `remove` method will remove the value that `next` has already returned.

Java's `ListIterator` interface extends the `Iterator` interface to include a couple of extra methods. (Yes, you can extend an interface!) We might not use the `ListIterator` interface in this course and it will not appear on the AP test.

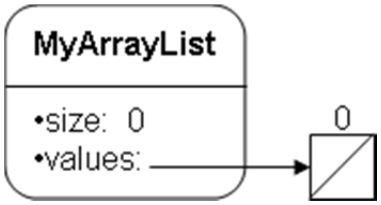
`interface java.util.ListIterator<E> extends java.util.Iterator<E>`

- `void add(E obj)` `//` adds `obj` before the element that will be returned by `next`
- `void set(E obj)` `//` replaces the last element returned by `next` with `obj`

Download MyArrayList.java. Unlike the real `ArrayList<E>` class, `MyArrayList<E>` will not implement the `List<E>` interface (because there are many more methods in Java's `List<E>` interface than the ones that appear in the AP Java subset). `MyArrayList<E>` has two instance variables: `size` and `values`. Do *not* add any others!

This is the first time we're implementing an `<E>` class (something we thankfully do *not* need to know how to do for the AP exam). `MyArrayList<E>` stores its values in an array of type `Object[]`(because Java stubbornly refuses to let us make a new array of type `E[]`.) So, whenever you need to return one of those values, you'll need to promise it's of type `E` using an explicit type cast (and ignore Java's warning message).

`MyArrayList<E>`'s constructor has already been written for you. A new `MyArrayList<E>` is initially empty, and `values` points to a 1-element array.



Exercise: `MyArrayList<E>`'s Capacity

Complete the `doubleCapacity` helper method, which you will call whenever you need to add an element and `values` is full.

```
//postcondition:  replaces the array with one that is
//                twice as long, and copies all of the
//                old elements into it
private void doubleCapacity()
```

Complete the `getCapacity` method, which will be used to test that the capacity changes appropriately.

```
//postcondition:  returns the length of the array
public int getCapacity()
```

Exercise: `MyArrayList<E>`'s Capabilities

Now go ahead and complete the following methods. Be sure to call `doubleCapacity` whenever you need to add an element and the array is full. (When you've finished the lab, you may decide to go back and complete the other methods you see listed in `MyArrayList<E>` for additional credit.)

- `int size()`
- `Object get(int index)`
- `Object set(int index, Object obj)`
  `// replaces the element at position index with obj`
  `// returns the element formerly at the specified position`
- `boolean add(Object obj)` `// appends obj to end of list; returns true`
- `Object remove(int index)` `// removes element from position index, moving`
  `// elements at position index + 1 and higher to the`
  `// left (subtracts 1 from their indices) and adjusts size`
  `// returns the element formerly at the specified position`

Exercise: `MyArrayListTester`

Download MyArrayListTester.java, which you may run to test and debug your `MyArrayList<E>` code. The tester performs random operations on both your `MyArrayList<E>` and on the real `ArrayList<E>` class. When the tester's `DEBUG` variable is set to `true`, you'll see it print out what operation is being performed and the contents of "your" list and the "real" list. The tester is great for debugging obscure errors and for showing your teacher that your code works. On the other hand, you may be better off writing your own simple test cases to do a first pass at debugging. In the end, though, your code must past the tester to get checked off.

Additional Credit

In order to receive additional credit above 95%, you must write your own test cases to demonstrate that your code works.

- (3 points) Complete all of the "additional credit" methods in MyArrayList.java including the `Iterator`s.

- (1 point) Implement the `listIterator` method for `MyArrayList`. An interface will come in handy here since you will be making a private inner class. Also, if you try to extend your iterator, you will have trouble with the state (which should be private).

- (1 point) Modify your `Iterator`'s `next` method so that it throws an exception if the list has been modified since the `Iterator` was constructed.