ArrayList

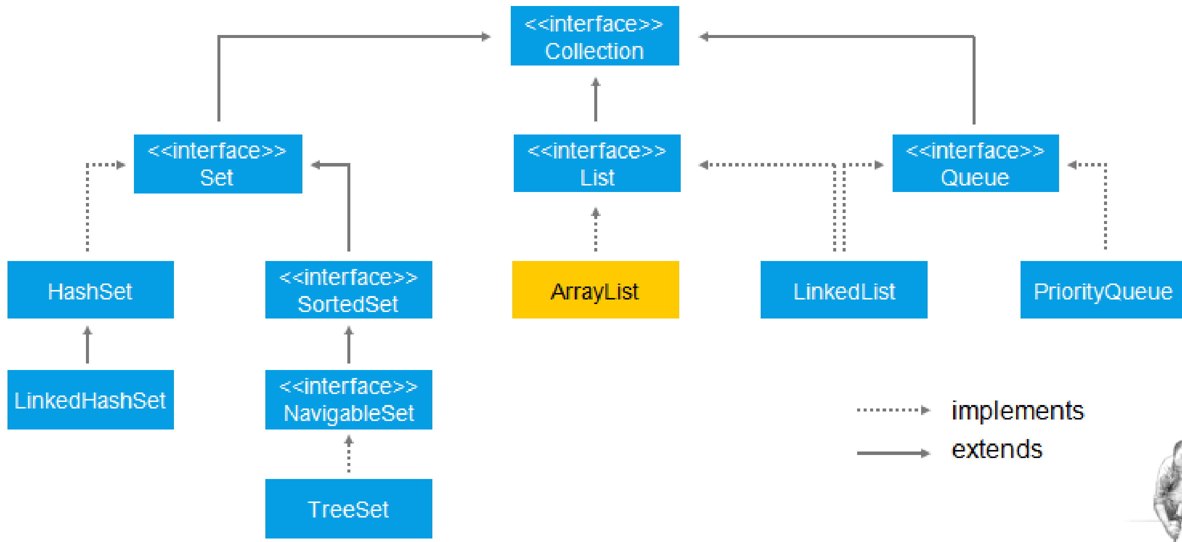
Introduction

In this article from my free Java 8 course, I will be giving you a basic overview of the Java class java.util.ArrayList. I will first explain the meaning of size and capacity of an ArrayList and show you the difference between them. After that, I will explain some ArrayList methods, divided between the interfaces `Collection` and `List` to which the methods belong. I will finish off by giving you a few practical coding examples that will, for instance, show you how to add and remove elements from an `ArrayList`.

java.util.ArrayList

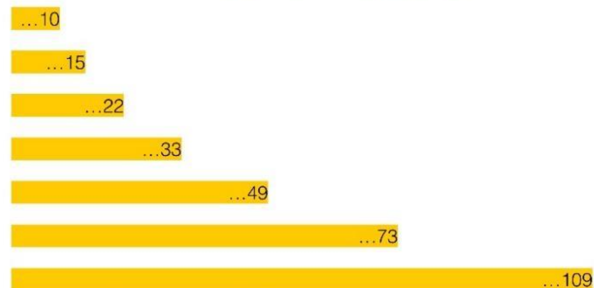
`ArrayList` implements the `List` interface, which again extends the `Collection` interface. As is typical of `List` implementations, we can have duplicate elements in our `ArrayList` and we can go from element to element in the same order as they were inserted. As the name implies, `ArrayList` is based on an array data structure. Therefore, `ArrayList` provides fast access but slow element insertion and removal at arbitrary positions as changes to it require reorganizing the entire list. Fast access, however, is crucial for most applications which is why `ArrayList` is the most commonly used collection. To store data that changes frequently, a better alternative container to use would be a `LinkedList,` for example.

Collection Interface Hierarchy



Size and Capacity

There are two different terms which are important to understand in the context of an `ArrayList` – **size** and **capacity**. Size is the number of elements the `ArrayList` currently holds. For every element added to or removed from the list, the size grows and shrinks by one respectively. Capacity, on the other hand, is the number of elements the underlying array can hold. The



`ArrayList` starts with an initial capacity which grows in intervals. Every time you exceed the capacity of the array, the `ArrayList` copies data over to a new array that is about 50% larger than the previous one. Let's say you want to add 100 elements to an `ArrayList` with an initial capacity of 10. After all the elements are added, it will have created six more arrays to take the place of the first. More specifically, the first array is replaced with a new array that can hold 15

elements, then a second one which can hold 22 elements, then arrays with capacities of 33, 49, 73 and finally, 109 elements – all of this to hold the growing list as pictured on Figure 1. Inherently, these restructuring arrangements can negatively impact performance.

You can instantly create an array of the correct size to minimize these rearrangements by defining the correct capacity at instantiation. In case you don't know the final size of the `ArrayList` before creating it, make the best guess possible. Choosing too large of a capacity can backfire, so choose this value carefully. In addition, it is advisable to always explicitly set the capacity at creation time as it documents your intentions. For most projects, you won't have to worry about optimizing performance on very powerful hardware, but that doesn't excuse sloppy design and poor implementation.

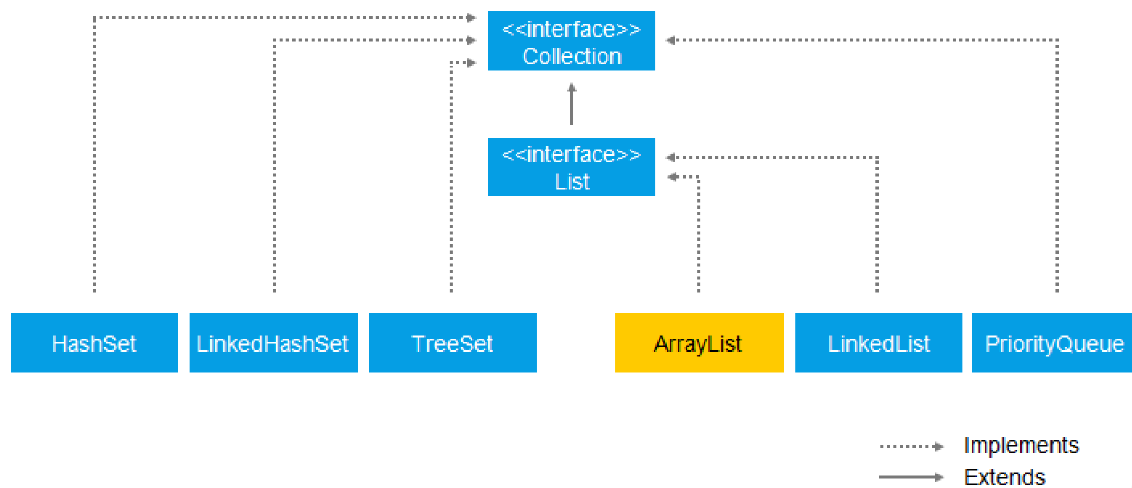
Figure 2 shows a very simplified excerpt of `ArrayList`. As you can see, it is just a class anyone could have written given enough time and knowledge. You can find the actual source code online. However, don't rely too much on source code internals as they may change any time if they are not defined in the Java language specification. `DEFAULT_CAPACITY` is the initial size of the array when you don't specify it as recommended before. `elementData` is the array used to store the elements of the `ArrayList`. `size` is the number of elements the `ArrayList` currently holds. `get`, `add` and `remove` are some of the many functions `ArrayList` provides and we will be taking a closer look at them.

```java
package java.util;

public class ArrayList<E> {
  private static final int DEFAULT_CAPACITY = 10;
  private Object[] elementData;
  private int size;

  public E get(int index) {
      /* Implementation omitted ... */
  }

  public boolean add(E e){
      /* Implementation omitted ... */
  }

  /* Other methods omitted ... */
}
```

Figure 2

`ArrayList`'s Methods

For convenience, we break up the overview into methods that belong to the `java.util.Collection` and `java.util.List` interfaces.



`java.util.Collection`

The contract of the `Collection` interface does not guarantee any particular order, implying it does not provide any index or order-related methods. The first set of methods, namely:

```
boolean add (E e)
boolean add All (Collection<? extends E> c)
boolean remove (Object o)
boolean removeAll(Collection<?> c)
```

are all part of the `Collection` interface. Note that a lot of what is said here about these methods does not only apply to `ArrayList` but also to all classes that implement the `Collection` interface. The method `add` appends the element to the end of the collection. For `ArrayList`, the end is the next empty cell of the underlying array. `addAll` appends all given elements to the end of the `Collection`.

The stuff in the angle brackets is related to generics. In short, it ensures that no one can call such a method with the wrong arguments. `remove` removes the first occurrence of the element you specify from the `Collection`. `removeAll` removes the given elements from the `Collection`.

We now look at the second set of methods, namely:

```
Iterator iterator(E e)
int size()
boolean contains(Object o)
```

The `iterator` method returns an object you usually use in a loop to go through a `Collection` one element at a time, from one element to the next. We say we iterate over the `Collection` hence the name `iterator`. `size` returns the current number of elements in our `Collection`. `contains` returns `true` if the `Collection` contains at least one instance of the element you specify.

Lastly, we look at our third set of methods, namely:

```
void clear()
boolean isEmpty()
T[] toArray(T[] a)
```

`clear` removes all elements from the `Collection`. `isEmpty` returns true if the `Collection` contains no elements. `toArray` returns a raw array containing all of the elements of the collection.

java.util.List

`ArrayList` also implements the `List` interface.

```
boolean addAll(int index, E element)
E remove(int index)
E get(int index)
int indexOf(E o)
int lastIndexOf(Object o)
List subList(int fromIndex, int toIndex)
int lastIndexOf(Object o)
```

The methods are similar in part to the `Collection` methods we've just looked at but differ in that they require an ordering on the elements of the list. Again, we note that everything we say about these methods typically applies not only to `ArrayList` but for most classes that implement `List`. The `add` method with an index parameter actually acts like an insertion method. It allows you to insert an element at any index position in the list, instead of just adding the element to the end of the list. In the process, the elements of the backing array for `ArrayList` will be shifted to the right and migrated to a larger array if necessary.

The `remove` method allows removing an element from any index position of the list. Similar to `ArrayList`'s `add` method, it might require shifting the remaining elements of the underlying array to the left. The `get` by index method returns an element from any given position of the list. The `indexOf` method takes an object and returns the index of the first occurrence of the element in the list or `-1` if the element is not found. `lastIndexOf` returns the index of the last occurrence of the element in the list and as before, `-1` if the element is not found. `subList` returns a subset of the list starting with the position specified by `fromIndex`, ending one position before the position `toIndex`. Last but not the least, `sort` sorts the list following the order of the given comparator.

Declaring a `Collection` While Instantiating an `ArrayList`

Later on, we will be going through several code examples demonstrating `ArrayList`'s methods. In many of our code examples to follow, we create an instance of `ArrayList` and assign it to a reference variable of type `Collection` like the one shown on the line of code below.

```
Collection<String> elements = new ArrayList<>(INITIAL_CAPACITY);
```

This might be a bit counterintuitive at first as we would expect our `ArrayList` instance to be assigned to an `ArrayList` or at least a `List` reference variable. There is a reasoning behind this and to cite Robert Martin, *"A good architecture is one that maximizes the number of decisions not made or the number of decisions deferred."* We can infer that in many situations, by assigning to a `Collection` reference variable, we can forward it to other methods and/or other objects and end up not being limited to passing an `ArrayList` for instance. This is good for us because business requirements usually change very fast and if there were a new requirement stating `elements` cannot have duplicates, we could just change only one place in the code to instantiate a `HashSet` instead without having to touch the code that uses our `Collection` variable. If we were to use a `List` or an `ArrayList` everywhere in the code, it would be very difficult to change our mind later on. We would have to touch a lot of code, which is a very dangerous thing to do. Of course, using `Collection` limits the number of methods we can use as it has less methods than the `List` interface, but we will come to learn that having access only to the methods we need to use is actually better for us. Later on, we will eventually switch to a `List` interface to show more methods `List` brings to the table on top of `Collection`'s.

As an aside, notice on the same line of code the use of "<>" or the **diamond operator** that was introduced with Java 7. Since we declare and instantiate `elements` on the same statement, the compiler infers that our `ArrayList` is typed to `String`. This makes our code a bit shorter and reads better. Last but not the least, notice the initial capacity which is a constant previously defined as follows: `private final int INITIAL_CAPACITY = 5`. We could have easily just directly typed `5` as our initial capacity but we would be writing a "magic number". This makes it much harder for the next developer reading our code (which often ends up being us) to know what the 5 actually means in this context. We want to explicitly state that we have set an initial capacity for our `ArrayList` so it is highly recommended to use a named value in order to document our intentions.

Code Examples

`Collection` Methods

We will be looking at some examples to have a better grasp on what `ArrayList` is about. We are starting off with the `Collection` interface method **add** shown on Figure 3 from lines 3-7. Seeing as `elements` is a `Collection` of type `String`, we can add the `Strings` into our `ArrayList`. Although our variable is a `Collection`, note that the fact that we instantiated an `ArrayList` allows us to add duplicate elements, e.g. "`A`" and "`E`" twice. Recall earlier that the constant `INITIAL_CAPACITY`, set to 5, is also set as the initial capacity for our `ArrayList`. On line 8, adding the second "`E`" will cause our list's underlying array to create a new array of a larger size, taking all the existing data to a new array with it along with the second "`E`". Despite cases like adding the second "`E`" taking much more time to finish, averaging over thousands or even millions of added elements, each add to an `ArrayList` will take almost no time at all.

```
Collection<String> elements = new ArrayList<>(INITIAL_CAPACITY);

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");
elements.add("E");
elements.add("E");

for (String str : elements) {
   System.out.print(str + " ");
}
// A B A C E E
```

Figure 3

Printing an `ArrayList`

Here are two different ways to print out an ArrayList. We can use its toString method, which println calls when we use it as follows: System.out.println(elements). Lines 10-11 in Figure 3 show another slightly more complicated way. This is because we want to look at how we can iterate over an ArrayList as a consequence of implementing Collection which in turn implements the Iterable interface. Because ArrayList ultimately implements Iterable, we can write Line 10 without worrying about the details required to iterate over this Collection. This is all done for us by the compiler internally. We can use the ArrayList in the *for-each* loop and print out each element separately, giving us more flexibility. Notice that the Collection is printed out in the same order as the elements were added, i.e. as "A B A C E E ". Had our Collection been instantiated to some instance of Set, we would not have been guaranteed the same iteration order as is the case with List.

Removing from an `ArrayList`

We can also just as easily remove elements from an ArrayList. Since we have a Collection variable, we cannot remove by index. The only way would be to remove by specifying the object which internally uses the equals method. In our example, it goes over each element and checks for a match using String's equals. The first match it finds is removed from the Collection.

```
Collection<String> elements = new ArrayList<>(INITIAL_CAPACITY);

elements.add("A");
elements.add("B");
elements.add("A");

elements.remove("A");

System.out.println(elements);

// [B, A]
```

Figure 4

You might also notice that we have two "A"s. It is interesting to note that only the first "A" is removed. How do we know for sure? Whenever you come across such questions, a good idea would be to look for a book, a video tutorial, or the API. However, the quickest way to be sure is to write some simple test code by yourself. Because the code doesn't lie, you will be assured that it behaves as you wrote it. Going by our Figure 4 example, only the first A is removed, leaving elements with only "B" and "A".

`Collection` Size

We can also check for the current size of an `ArrayList` as well as check if it's empty. On Figure 5, Line 3, we directly print out the size of our `Collection` after instantiating it. As expected, `0` is printed out since we have zero elements. Thanks to our example, we can rule out the possibility of Line 3 throwing an `Exception`. On Line 10, after adding 4 `String`s, we print out the size again and get 4.

```
Collection<String> elements = new ArrayList<>(INITIAL_CAPACITY);

System.out.println(elements.size()); // 0

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");

elements.remove("A");

System.out.println(elements.size()); // 4
```

Figure 5

Conveniently, we can check if our `Collection` is empty, i.e its size is `0`. We get `true` on Figure 6, Line 3 after instantiating to an empty `ArrayList` and get false on Line 5 after having added "A" to list.

```
Collection<String> elements = new ArrayList<>(INITIAL_CAPACITY);

System.out.println(elements.isEmpty()); // true

elements.add("A");

System.out.println(elements.isEmpty()); // false
```

Figure 6

`List` Interface Methods

From here on in, we switch over to the `List` interface in most of our examples, i.e. we will now have a reference variable of type `List`, giving us access to all of the `Collection` interface's methods and `List`'s on top of that.

Inserting `List` Elements

We can insert an element by specifying where to place it using an index. Figure 7, Lines 7-8 show how we can add, say, "T" to the start of our list at index 0 and "S" at index 2 – which ends up being right between "A" and "B" after inserting "T". Both insertions shift all other elements to the right of the specified index whereas removing elements by index does the opposite, shifting all other elements to the left. Printing it out as shown on Line 10, we get the output `[T, A, S, B, A, C]`.

```
List<String> elements = new ArrayList<>(INITIAL_CAPACITY);

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");
elements.add(0, "T");
elements.add(2, "S");

System.out.println(elements);

// [T, A, S, B, A, C]
```

Figure 7

Removing `List` Elements

Let's say we want to remove the second element from our list. As Figure 8, Line 7 shows, we do this by calling `remove` with index `1`. This removes "B" from our list, leaving us with the elements `[A, A, C]`. However, you will find that you rarely need to use these index-based methods and can instead opt to use `Collection`'s.

```
List<String> elements = new ArrayList<>(INITIAL_CAPACITY);

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");
elements.remove(1);

System.out.println(elements);

// [A, A, C]
```

Figure 8

`List` Size

Our Figure 9 example starts off with declaring an `initialCapacity` of `100`. The example shows the difference between the capacity and the size of an `ArrayList`. Recall that *size* is the current number of list elements while *capacity* is the length of the list's backing array. In our example, our list is initially set to a capacity of 100 elements. After adding four elements, if you fire up a debugger and break the execution by stepping into the `ArrayList` class before running Line 11, you will see that the internal array `elementData` still has a length of 100 while our size grows to 4.

```
int initialCapacity = 100;
// backing array starts at length of 100
List<String> elements = new ArrayList<>(initialCapacity);

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");

System.out.println(elements.size());
// size is 4, not 100!
```

Figure 9

Getting Element Indices from a `List`

Sometimes, you will want to ask for the index of a certain element in a `List`. The `List` interface gives us two methods to do that – `indexOf` and `lastIndexOf`. Since `List`s allow for duplicate elements, to get the first index of an element, we would use `indexOf`. If we call `indexOf` with "`A`", we get the first index, `0`. To get the last index of "`A`", we would call `lastIndexOf`, which returns 2. You can see all of this in action in Figure 10.

```
int initialCapacity = 100;
// backing array starts at length of 100
List<String> elements = new ArrayList<>(initialCapacity);

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");

System.out.println(elements.indexOf("A")); // 0
System.out.println(elements.lastIndexOf("A")); // 2
```

Figure 10

Clearing a Collection

To remove all the elements from a Collection, we use the clear method. It will empty the list so that if we call isEmpty on a list with elements, true is returned. This is demonstrated on the code excerpt in Figure 11. Interestingly enough, on Line 11, we learn that printing out an empty list doesn't throw an Exception. Instead, it only prints out a pair of square brackets, "[]".

```
List<String> elements = new ArrayList<>(INITIAL_CAPACITY);

elements.add("A");
elements.add("B");
elements.add("A");
elements.add("C");

System.out.println(elements.isEmpty()); // false

elements.clear();

System.out.println(elements.isEmpty()); // true
System.out.println(elements); // []
```

Figure 11

Thanks for reading!

© 2017, Marcus Biel, Software Craftsman
https://cleancodeacademy.com/
All rights reserved. No part of this article may be reproduced or shared in any manner whatsoever without prior written permission from the author