Lab: Circular Lists
CSC 207, “Algorithms and Object-Oriented Design”
Department of Computer Science
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Setting Up

The goal of this lab is to see how far we can get with Exercise 17.16 in the textbook, “Implement a circularly and doubly linked list.”

1. Open a new project in Eclipse and creat two new classes: a CircularList class and a CircularListTester class for testing the methods that you implement in CircularList. Write the header for the definition of the CircularList class, making it a generic class that extends the AbstractCollection class.

Designing the Implementation

Figure 17.18 of the textbook is a box-and-pointer diagram for a circular, doubly-linked list with four elements. It indicates that the class will need at least one field, called first, which will be a reference to one of the nodes in the list.

2. In order to declare the first field, you’ll need to provide a definition of the Node class. Inside the definition of the CircularList class, define a private, static class Node with a data field and (for double linking) prev and next fields that will contain references to adjacent nodes. Provide a three-argument constructor that simply initializes the three fields from the arguments supplied. This class should be generic in the same way as the CircularList class itself.

   Nesting the definition of Node inside the definition of CircularList ensures that objects of the Node class cannot be created or used outside of the definition of the CircularList class. As a result, it’s kind of pointless to make the fields of the Node class private and to supply accessor and mutator methods, but you can do so if you like.

3. Add a declaration of the first field to the definition of the CircularList class.

4. How will an empty CircularList be implemented? Define an isEmpty method that tests the appropriate condition and returns the appropriate boolean value.

Implementing the Methods

In order to have CircularList extend the AbstractCollection class, as promised in the header, we have to define the abstract methods from that class, which are size and iterator.

   The Java 9 API recommends that we also supply two constructors, one with no arguments that creates an empty CircularList and one that takes as argument any object that implements the Collection interface and creates a CircularList that contains the same elements as the given Collection.

   Because we want to be able to add elements to instances of CircularList, we’ll also want to override the add method, which in the AbstractCollection class itself is implemented as a method that always throws an UnsupportedOperationException.

5. Add a field to the definition of the CircularList class that keeps track of the number of elements that the list currently stores. Add a size method that acts as an accessor to this field.


7. Implement the add method. It would be a good idea to insert the new element so that it immediately precedes the first node, if there is one. This could be regarded either as insertion at the beginning of the list (if you adjust the value of first after the insertion) or insertion at the
end (if you don’t change first). Note that you will have to treat an empty list as a special case. An insertion into an empty list should result in the first field containing a reference to a single node in which the prev and the next fields both contain references to that very same node.

8. With the help of the add method, define the one-argument constructor for CircularList. (Hint: The hardest part is probably figuring out how to declare the parameter. The textbook’s implementation of the corresponding constructor for LinkedList provides a useful example.)

Extracting and Removing Elements

We also want to be able to remove elements from instances of CircularList, so we’ll need a remove method.

In the AbstractCollection class itself, remove is implemented as a method that takes one argument, an Object, and uses the collection’s iterator to search through the elements of the collection. When and if an element that is equal to the argument is encountered, the iterator’s remove method is used to delete it from the collection, and the AbstractCollection’s remove method returns a boolean that indicates whether the search was successful. (If the iterator doesn’t have its own remove method, it throws an UnsupportedOperationException.)

One straightforward way for us to handle this situation is for the CircularList class to support two remove methods: (a) a private method that takes a Node as argument, splices it out of the CircularList that contains it, and returns the element in the node’s data field, and (b) a public method that takes an Object as argument, overriding the implementation that AbstractCollection provides, and conducts its own search for the element to be removed. If the search succeeds, method (b) uses method (a) to splice out the node and returns true; otherwise, method (b) leaves the list unchanged and returns false.

We can then use method (a) to help implement other variants of remove, such as removal from the beginning of the list, or from the end, or from a designated position within the list, and eventually to provide the iterator with its own remove method.

9. Implement the two remove methods.

Implementing an Iterator

Extending the AbstractCollection class requires us to provide an iterator method that, when invoked, constructs and returns an object that can be used to iterate over the elements of a circular list. For this purpose, we can define an inner class called CircularListIterator inside the definition of the CircularList class. Our CircularListIterator objects will implement the Iterator interface in a straightforward way.

For this class, we need, at the very least, a zero-argument constructor and methods called hasNext and next. The simplest possible iterator starts with the node to which first refers and follows the next reference in each node to advance to the node that follows it. Let’s implement this design.

10. Write the header for the definition of the CircularListIterator class.

11. The iterator will keep track of its progress through the list by updating a field called current containing a reference to the node containing the element that will be returned on the next call to the iterator’s next method. Add a declaration for this field to the definition of the CircularListIterator class, and write a zero-argument constructor for this class that appropriately initializes this field.

12. In a circular list, which has no end markers, how will the iterator know when it is finished? Define the hasNext method so that it detects this condition and returns false when it is met. Remember also to handle the special case in which the circular list is empty.

If a remove operation is performed in the middle of the iterator’s traversal of a circular list, it can invalidate the iteration. (Specifically, the iterator’s current field may contain a reference
to the deleted node.) Weiss’s implementation of the LinkedList class manages this problem by maintaining a modCount field, initialized to 0 and incremented each time a node is removed from the list. When the iterator is created, it stores the current value of modCount in a field of its own (expectedModCount). The hasNext method can then compare modCount to expectedModCount to determine whether a deletion has occurred since the iterator was created, in which case it throws a ConcurrentModificationException.

13. Add this check, along with the necessary infrastructure, to the CircularList and CircularListIterator classes.


15. Add an iterator method to the definition of CircularList. It should simply construct and return an instance of CircularListIterator.

Tests

At this point, our implementation is sufficiently far along that we can start adding tests to the CircularListTester class.

16. Write and run a test to confirm that the zero-argument constructor for CircularList creates an empty circular list.

17. Create an empty circular list of Integer objects and add 5, 7, and 13 to it. Confirm that its size is 0 before the insertions and 3 afterwards.

18. Write a static method in the CircularListTester class that prints out all of the elements in a given CircularList. Use it to confirm that the list you created in the previous exercise does indeed contain 5, 7, and 13.

19. Remove 7 from the circular list and print it to confirm that 7 has been removed.

20. Call the remove method, giving it an argument that is not an element of the circular list. Print the circular list afterward and confirm that it has not changed.

21. Create an ArrayList containing the elements 16, 21, and 42, then call the one-argument constructor to create a CircularList containing the same elements. Print the resulting circular list to make sure that its contents are correct.

22. Call the iterator method to obtain an iterator for the circular list you created in the last exercise. Call the iterator’s next procedure once — it should return 16 — and then remove 21 from the circular list and call the iterator’s next procedure again. (This should cause an exception to be thrown, so you may want to enclose the second call to next in a try-block with a catch-clause that handles the expected exception.)

Extensions

23. So far, the implementation doesn’t make any significant use of the circularity of the list. Add another inner class, UnboundedIterator, also implementing the Iterator interface, that wraps around instead of stopping when all of the elements have been produced. The hasNext method should still raise an exception if an element has been removed and should return false if the circular list is empty, but should always return true otherwise. The next method should raise an exception if the circular list is empty but otherwise return the element in the node to which current refers and assign current.next to current.

An iterator of this kind will return values forever so long as the circular list is not empty and nothing is removed from it.

Add a cycle method to the definition of CircularList that returns an UnboundedIterator for the list.
24. So far, the implementation doesn’t make use of the double linking of the nodes. Add another inner class, `ReverseIterator`, also implementing the `Iterator` interface, that iterates through the circular list starting from its last node (the one to which `first.prev` refers) and following the `prev` references until all of the elements have been produced. Add a `reverseIterator` method to the definition of `CircularList`.

25. Add a `get` method to the definition of `CircularList`. It takes any `int` value as argument and returns the element at the specified position in the list, counting `first` as the element in position 0. It should throw a `NoSuchElementException` if the circular list is empty, but otherwise `get` method should return a value even when given an argument less than 0 or greater than or equal to the number of elements in the list. When the argument `n` is negative, `get` should start from `first`, follow `prev` references `−n` times, and return the value in the `data` field of the node that it reaches. Similarly, when `n` is positive, `get` should start from `first` and follow `next` references `n` times, even if in doing so it wraps around the list once or more.