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Homework 5

This homework will teach you a more secure way to encapsulate lists than the method used in Homework 4, and give you practice using it to accomplish tasks quickly. This is an individual assignment; you may not share code with other students.

The list package contains encapsulated DList and SList classes (both of which inherit from an abstract List class). These classes differ from those we have seen before in a critical way: each ListNode knows which List it is in. A new invariant in our Lists is that for every ListNode x in a List l , $x.myList = l$, UNLESS x is the sentinel. For any sentinel node x , $x.myList = null$. Because every ListNode knows its List, we can move some of the methods from the List class to the ListNode class.

Methods of List

```
public boolean isEmpty()
public int length()
public void insertFront(Object item)
public void insertBack(Object item)
public ListNode front()
public ListNode back()
```

Methods of ListNode

```
public Object item()
public void setItem(Object item)
public ListNode next()
public ListNode prev()
public void insertAfter(Object item)
public void insertBefore(Object item)
public void remove()
public boolean isValidNode()
```

One innovation of these classes is the existence of "invalid nodes," which can be identified by the `isValidNode()` method. In Homework 4, the methods `next()` and `prev()` return `null` when there is no node to return. Here in Homework 5, they return an invalid node instead. A node that has been removed from a List is also invalid. With the exception of `isValidNode()`, any method called on an invalid node will throw an `InvalidNodeException`.

The `item` field of `ListNode` is no longer public, to prevent applications from storing items in invalid nodes.

Recall that every `ListNode` knows what List it is in. An invalid node is represented by any `ListNode` whose "myList" field is `null`. In the `DList` implementation, the sentinel is an invalid node, which simplifies the implementations of `front()`, `back()`, `next()`, and `prev()`. (Take a look at the code for `DListNode.isValidNode()`.)

Part I (2 points)

Complete the implementation of the `DList` and `DListNode` classes.

In `DList.java`, you will need to implement `insertFront()`, `insertBack()`, and the `DList()` constructor. You should be able to cut and paste your solutions from Homework 4 with just a small change. The implementations of `front()` and `back()` are already provided; observe that they are simpler than in Homework 4 because we use sentinels as invalid nodes.

In `DListNode.java`, you will need to implement `insertAfter()`, `insertBefore()`, and `remove()`. Your Homework 4 solutions will be a good start, but you'll need to make changes to accommodate these methods' move from `DList` to `DListNode`.

The `main()` method of `list.DList` contains code to help test your work.

Part II (8 points)

Your main assignment is to implement a Set ADT in `Set.java`. Your Set class must use a List to store the elements of the set. Your Sets should behave like mathematical sets, which means they should not contain duplicate items. To make set union and intersection operations run quickly, your Sets will contain only Comparable elements, and you will keep them sorted in order from least to greatest element. (You will want to review the Comparable interface on the Java API Web page.)

You will need to declare some fields and implement the following methods.

<code>public Set()</code>	// Constructs an empty Set.
<code>public int cardinality()</code>	// Number of elements in this Set.
<code>public void insert(Comparable c)</code>	// Insert c into this Set.
<code>public void union(Set s)</code>	// Assign this = (this union s).
<code>public void intersect(Set s)</code>	// Assign this = (this intersect s).
<code>public String toString()</code>	// Express this Set as a String.

Two items o_1 and o_2 are considered duplicates if $o_1.compareTo(o_2) == 0$. By convention, Java classes are supposed to have $o_1.compareTo(o_2) == 0$ if and only if $o_1.equals(o_2)$. (Of course, it's always possible for some idiot to break this convention, so it would be safest not to depend on `equals()` working.)

Unlike most previous assignments, each method comes with prescribed time bounds that you must meet when your Set uses DLists (but not when it uses SLists). For example, `union()` and `intersect()` must run in time proportional to `this.cardinality() + s.cardinality()`. This means you do NOT have time to make a pass through "this" list for every element of s ; that would take time proportional to `this.cardinality() * s.cardinality()`. To achieve this time bound, you must take advantage of the fact that Sets are sorted. This time bound is one reason why Sets may not store duplicate items in their Lists.

On the other hand, `insert()` need not run in constant time. Since each Set uses a sorted representation, `insert()` may need time proportional to the cardinality of the Set to find the right place to insert a new element, and to ensure that the new element doesn't duplicate an old one.

Another constraint is that `union()` and `intersect()` may NOT change the Set s . Furthermore, `intersect()` may not construct any new `ListNodes` (it only needs to remove `ListNodes` from "this" List), and `union()` should reuse all the `ListNodes` in the Set "this", constructing new nodes only for elements of s that "this" List lacks. We will deduct points for failing to meet the time bounds or failing to obey these constraints.

Be sure to declare variables of static type `List` and `ListNode` in `Set.java`, not variables of type `DList`, `DListNode`, `SList`, or `SListNode`. `Set.java` should be able to switch between using DLists and using SLists by changing one constructor call in the `Set()` constructor. (In fact, you can use `SList` to help you debug `Set` if you have trouble getting `DList` working. But be sure to use a `DList` in your final submission unless you can't get it working.)

Do not modify `List.java`, `ListNode.java`, `SList.java`, or `SListNode.java`. Do not modify the prototypes in `Set.java`, `DList.java`, or `DListNode.java`.

Afterthought (for your own introspection only)

If you use SLists instead of DLists, do your `union()` and `intersect()` methods still run within the time bounds? If not, how easy would it be to fix them so that they do?

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Submitting your solution

Make sure that your code compiles and runs. After submitting, if you realize
your solution is flawed, you may fix it and submit again. You may submit as
often as you like. Only the last version you submit before the deadline will
be graded.