CSE 143

Computer Programming II

Linked Lists II

Outline

`ListNode` Fields are `public`? 1

ListNode Class

```
1 public class ListNode {
2    public int data;
3    public ListNode next;
4 }
```

This is our ONLY exception to the "make all fields private" rule

Why is this okay?

- Do we **need** them to be public?
  Yes; we access `data` and `next` directly from `LinkedIntList`.
- Will our **client** be using `ListNode`?
  The point of `LinkedIntList` is to handle manipulation of `ListNodes` **for** our client. Likely, they won't touch `ListNode`.

A client of a `LinkedList` already knows that it's made of `ListNodes`.
We don't expect them to use `ListNode`, but it's okay if they do.

A New `LinkedList` Constructor 2

New Constructor

Create a constructor

`public LinkedIntList(int n)`

which creates the following `LinkedIntList`, when given n:

What kind of loop should we use?

A `for` loop, because we have numbers we want to put in the list.

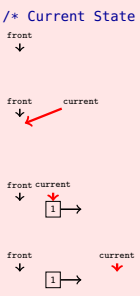
What cases should we worry about?

We're creating the list; so, there aren't really "cases".

A New `LinkedList` Constructor 3

First Attempt

```
1  public LinkedList(int n) {
2
3
4     ListNode current = this.front;
5
6     for (int i = 1; i <= n; i++) {
7        current = new ListNode(i);
8
9        current = current.next;
10
11    }
12 }
```



Remember, to edit a `LinkedList`, we **MUST** edit one of the following:

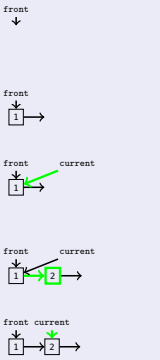
- `front`, or
- `node.next` (for some `ListNode node`)

In our code above, we edit `current`, which is neither.

A New `LinkedList` Constructor

Second Attempt

```
1  public LinkedList(int n) {
2                                                  /* Current State */
3     if (n > 0) {
4        //n is at least 1...
5        this.front = new ListNode(1);
6
7        ListNode current = this.front;
8
9        for (int i = 1; i <= n; i++) {
10          current.next = new ListNode(i);
11
12          current = current.next;
13
14       }
15    }
16 }
```

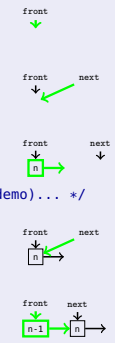


A New `LinkedList` Constructor: Another Solution

This other solution works by going backwards. Before, we were editing the `next` fields. Here, we edit the `front` field instead:

Different Solution!

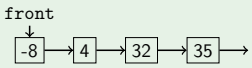
```
1  public LinkedList(int n) {
2                                                  /* Current State */
3        for (int i = n; i > 0; i--) {
4           ListNode next = this.front;
5
6           this.front = new ListNode(i, next);
7
8        } /* Second time through the loop (for demo)... */
9           //ListNode next = this.front;
10
11          //this.front = new ListNode(i, next);
12
13 }
```



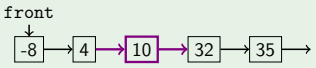
Implementing `addSorted`

`addSorted`

Write a method `addSorted(int value)` that adds `value` to a sorted `LinkedIntList` and **keeps it sorted**. For example, if we call `addSorted(10)` on the following `LinkedIntList`,



We would get:



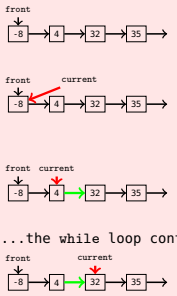
As always, we should approach this by considering the separate cases (and then drawing pictures):

- We're supposed to insert at the front
- We're supposed to insert in the middle
- We're supposed to insert at the back

Case: Middle

An Incorrect Solution

```
1  public void addSorted(int value) { //Say value = 10...
2
3     ListNode current = this.front;
4
5     while (current.data < value) {
6        current = current.next;
7
8     }
9                                                  ...the while loop continues...
10
11 }
```

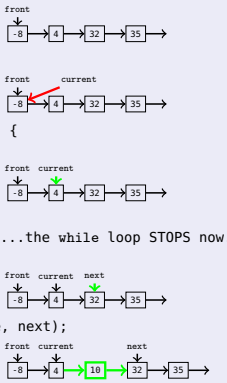


Uh Oh! We went too far! We needed the `next` field BEFORE us.

Case: Middle

Fixing the Problem

```
1  public void addSorted(int value) { //Say value = 10...
2
3     ListNode current = this.front;
4
5     while (current.next.data < value) {
6        current = current.next;
7
8     }
9                                                  ...the while loop STOPS now...
10    ListNode next = current.next;
11
12    current.next = new ListNode(value, next);
13
14 }
```

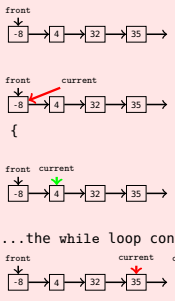


Does this cover all the cases?

Case: End

Adding At The End?

```
1  public void addSorted(int value) { //Say value = 40...
2
3     ListNode current = this.front;
4
5     while (current.next.data < value) {
6        current = current.next;
7
8     }
9                                                  ...the while loop continues...
10
11                                                 ...AND IT KEEPS ON GOING...
12                                 current.next.data → NullPointerException!!!
13 }
```



We fell off the end of the `LinkedList`.
Idea: Make sure `current.next` exists.

Case: End

Adding At The End?

```
public void addSorted(int value) {
   ListNode current = this.front;
   /* If we are making a check for current.next, we must
    * be sure that current is not null. */
   while (current.next.data < value) {
      /* Since we want to keep on going here,
       * the check must be made in the while loop.
      current = current.next;
   }
}
```

A Fix?

```
public void addSorted(int value) {
   ListNode current = this.front;
   /* The extra check here is useless...we've already checked
    * current.next by the time we get to it. */
   while (current.next.data < value && current.next != null) {
      current = current.next;
   }
}
```

A Real Fix!

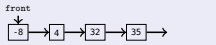
```
public void addSorted(int value) {
   ListNode current = this.front;
   while (current.next != null && current.next.data < value) {
      current = current.next;
   }
}
```

Case: Beginning

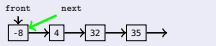
Our current code only sets `current` to a new `ListNode`. Importantly, this never updates `front`; so, we lose the new node.

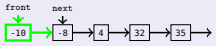
Adding At The Beginning?

```
1  public void addSorted(int value) { //Say value = -10...
2
3     if (value < front.data) {
4        ListNode next = front;
5
6        front = new ListNode(value, next);
7
8     }
9     else {
10       ...
11    }
12 }
```



$-10 < -8 \rightarrow$ true





Have we covered all of our cases now?

Protecting Our Tests!

With `LinkedList` code, every time we make a test (`if`, `while`, etc.), we need to make sure we're protected. Our current code is:

Working Code?

```
1  public void addSorted(int value) {
2     if (value < front.data) {
3        ListNode next = front;
4        front = new ListNode(value, next);
5     }
6     else {
7        while (current.next != null && current.next.data < value) {
8           current = current.next;
9        }
10
11       ListNode next = current.next;
12       current.next = new ListNode(value, next);
13    }
14 }
```

We're "protected" if we know we won't get a `NullPointerException` when trying the test. So, consider our tests:

- `value < front.data`
- `current.next != null && current.next.data < value`

So, Are We Protected?

Protecting Our Tests!

Nope! What happens if `front == null`? We try to get the value of `front.data`, and get a `NullPointerException`. The fix:

Working Code!

```
1  public void addSorted(int value) {
2     if (front == null || value < front.data) {
3        ListNode next = front;
4        front = new ListNode(value, next);
5     }
6     else {
7        while (current.next != null && current.next.data < value) {
8           current = current.next;
9        }
10
11       ListNode next = current.next;
12       current.next = new ListNode(value, next);
13    }
14 }
```

Helpfully, this fix actually handles the empty list case correctly!

Some `LinkedList` Tips!

- Make sure to try all the cases:
  - Empty List
  - Front of Non-empty List
  - Middle of Non-empty List
  - Back of Non-empty List
- To Edit a `LinkedList`, the assignment must look like:
  - `this.front = <something>;`, or
  - `node.next = <something>;` (for some `ListNode node` in the list)
- Protect All Of Your Conditionals! Make sure that nothing can accidentally be `null`.
- When protecting your conditionals, make sure the less complicated check goes first.