Adam Blank | Lecture 12a | Autumn 2015

CSE 143X

Accelerated Computer Programming I/II

CSE 143X: Accelerated Computer Programming I/II

Linked Lists I

Outline

1 Learn how `LinkedIntList` is implemented

2 Learn about the different cases to deal with for `LinkedList`s

`LinkedIntList`

1

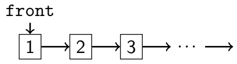
- No generics (only stores ints)
- Fewer methods: `add`(value), `add`(index, value), `get`(index), `set`(index, value), `size`(), `isEmpty`(), `remove`(index), `indexOf`(value), `contains`(value), `toString`()
- This is the same idea as when we implemented `ArrayIntList`!

`LinkedIntList` Fields

2

What fields does our `LinkedIntList` need?

A reference to the front of the list



`LinkedIntList v1`

```
public class LinkedIntList {
   private ListNode front;

   public LinkedIntList() {
                                       front
                                         ↓
      front = null;
   }

   ...
}
```

`LinkedIntList toString()`

3

Buggy `toString()`

```
public String toString() {
   String result = "[";

   ListNode current = this.front;
   while (current != null) {
      result += current.data + ", ";
      current = current.next;
   }

   return result + "]";
}
```

Our `toString()` puts a trailing comma. Fix it by stopping one early:

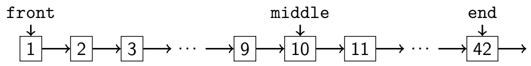
Fixed `toString()`

```
public String toString() {
   String result = "[";

   ListNode current = this.front;
   while (current != null && current.next != null) {
      result += current.data + ", ";
      current = current.next;
   }
   if (current != null) {
      result += current.data;
   }

   return result + "]";
}
```

Modifying LinkedLists

Writing a LinkedList Method

1. Identify cases to consider…
   - Front/Empty
   - Middle
   - End
2. Draw pictures for each case
3. Write each case separately



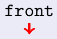
LinkedIntList add() (Empty Case)

Cases to consider:

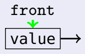
- Add to empty list
- Add to non-empty list

Add To An Empty List

What does an empty list look like?



```
public void add(int value) {
   /* If the list is empty... */
   if (this.front == null) {
      this.front = new ListNode(value);
```

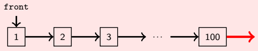


```
   }
   /* Other Cases ... */
}
```

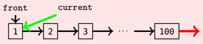
LinkedIntList add() (Non-empty Case)

Add To A Non-Empty List

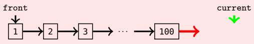
Consider a non-empty list:



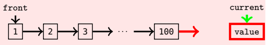
```
/* Idea: We want to change the red arrow.
         Loop until we're at the last node. */
ListNode current = this.front;
```



```
while (current != null) {
   current = current.next;
}
```



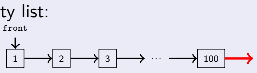
```
current = new ListNode(value);
```



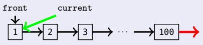
LinkedIntList add() (Non-empty Case)

Add To A Non-Empty List (Fixed)

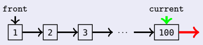
Consider a non-empty list:



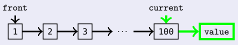
```
/* Idea: We want to change the red arrow.
         Loop until we're at the node before the last node */
ListNode current = this.front;
```



```
while (current.next != null) {
   current = current.next;
}
```



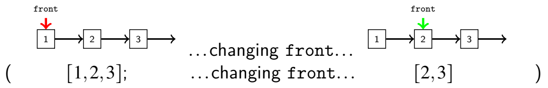
```
current.next = new ListNode(value);
```



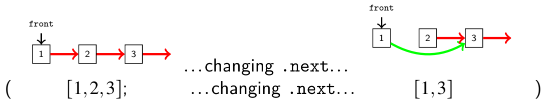
Working with LinkedLists

There are only two ways to modify a LinkedList:

- Change front



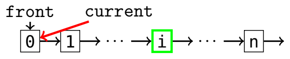
- Change current.next for some ListNode, current



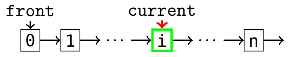
Settting "current" does NOTHING!

LinkedIntList get()

```
// pre: 0 <= index < size
// post: Returns the value in the list at index
public int get(int index) {
   ListNode current = front;
```



```
   for (int i = 0; i < index; i++) {
      current = current.next;
   }
```



```
   return current.data;
}
```

Some `LinkedList` Tips!

- Be able to deal with before-and-after `ListNode` pictures
- Know how to loop through a `LinkedList`
  - Use a `while` loop.
  - Don't forget to create a `ListNode current` variable so we don't destroy the original list.
  - Don't forget to update the `current` variable.
  - They both have the same functionality (`add`,`remove`, etc.)
  - But they're **implemented** differently (array vs. `ListNodes`)
- With `LinkedLists`, you often have to stop **one node before the one you want**.
- DO NOT start coding `LinkedList` problems without drawing pictures first.

Adam Blank | Lecture 12b | Autumn 2015

CSE 143X

Accelerated Computer Programming I/II

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Linked Lists II

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You love computers and play with them..
then you went college learn many... things.
you learn that programming is a state of the mind...
finally you learn the language that every programmer in knows: blasphemy..
Work you piece of $#!&;;!!
Vlad Bazan (c) 2004

What Are We Doing Again?

What Are We Doing. . . ?

We're building an alternative data structure to an `ArrayList` with different efficiencies.

Today's Main Goals:

- Get more familiarity with `LinkedList`s
- Write more `LinkedList` methods
- Learn how to "protect" against `NullPointerException`s

A New `LinkedList` Constructor

New Constructor

Create a constructor

`public LinkedIntList(int n)`

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

$\boxed{1} \to \boxed{2} \to \boxed{3} \to \cdots \to \boxed{n} \to$

What kind of loop should we use?

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

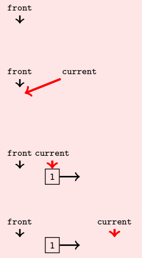
What cases should we worry about?

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

A New `LinkedList` Constructor

First Attempt

```
public LinkedList(int n) {
                                      /* Current State */

   ListNode current = this.front;

   for (int i = 1; i <= n; i++) {
      current = new ListNode(i);

      current = current.next;

   }
}
```



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

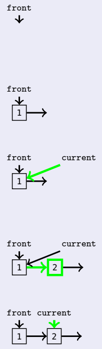
- `front`, or
- `node.next` (for some `ListNode node`)

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

A New `LinkedList` Constructor

Second Attempt

```
public LinkedList(int n) {
                                                /* Current State */

   if (n > 0) {
      //n is at least 1...
      this.front = new ListNode(1);

      ListNode current = this.front;

      for (int i = 1; i <= n; i++) {
         current.next = new ListNode(i);

         current = current.next;

      }
   }
}
```

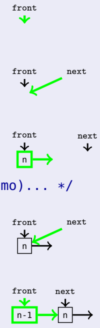


A New LinkedList Constructor: Another Solution

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

Different Solution!

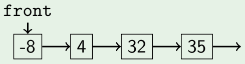
```
public LinkedList(int n) {
                                                  /* Current State */

    for (int i = n; i > 0; i--) {
       ListNode next = this.front;

       this.front = new ListNode(i, next);

    } /* Second time through the loop (for demo)... */
       //ListNode next = this.front;

       //this.front = new ListNode(i, next);

}
```



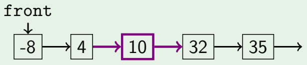
Implementing addSorted

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:



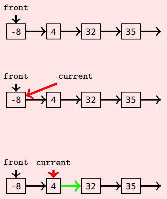
As always, we should approach this by considering the separate cases (and then drawing pictures):

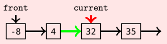
- We're supposed to insert at the front
- We're supposed to insert in the middle
- We're supposed to insert at the back

Case: Middle

An Incorrect Solution

```
public void addSorted(int value) { //Say value = 10...

   ListNode current = this.front;

   while (current.data < value) {
      current = current.next;

   }
                                    ...the while loop continues...

}
```



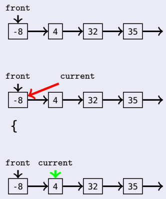


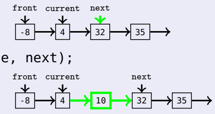
Uh Oh! We went too far! We needed the next field BEFORE us.

Case: Middle

Fixing the Problem

```
public void addSorted(int value) { //Say value = 10...

   ListNode current = this.front;

   while (current.next.data < value) {
      current = current.next;

   }
                                    ...the while loop STOPS now...
   ListNode next = current.next;

   current.next = new ListNode(value, next);

}
```



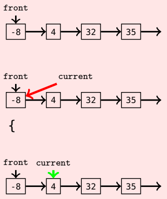


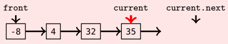
Does this cover all the cases?

Case: End

Adding At The End?

```
public void addSorted(int value) { //Say value = 40...

   ListNode current = this.front;

   while (current.next.data < value) {
      current = current.next;

   }
                                    ...the while loop continues...

                                    ...AND IT KEEPS ON GOING...
                        current.next.data → NullPointerException!!!
}
```





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!

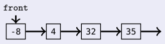
```
public void addSorted(int value) {
   ListNode current = this.front;
   while (current.next != null && current.next.data < value) {
      current = current.next;
   }
}
```

Case: Beginning

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

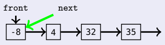
Adding At The Beginning?

```
public void addSorted(int value) { //Say value = −10...
```

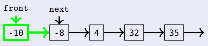


```
   if (value < front.data) {
      ListNode next = front;
```

$-10 < -8 \rightarrow$ `true`



```
      front = new ListNode(value, next);
```



```
   }
   else {
      ...
   }
}
```

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?

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

      ListNode next = current.next;
      current.next = new ListNode(value, next);
   }
}
```

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!

```
public void addSorted(int value) {
   if (front == null || value < front.data) {
      ListNode next = front;
      front = new ListNode(value, next);
   }
   else {
      while (current.next != null && current.next.data < value) {
         current = current.next;
      }

      ListNode next = current.next;
      current.next = new ListNode(value, next);
   }
}
```

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.