Data Structures

Lists II

CS284

Structure of this week's classes

- Double-Linked List
- Syntax sugar for iterator
- Operations with SingleLinkedList
- LeetCode problem 1: reverse linked list
- LeetCode problem 2: finding the intersection node of two linked lists
- Exam on Friday: two coding problems on linked list

List

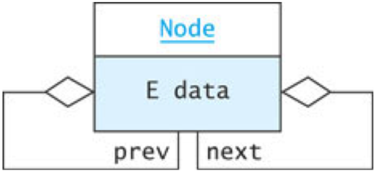
- Last class we introduced lists
- We studied an array based implementation
- We also studied a linked-list based implementation (Single Linked Lists)
- Next we present a double-linked list implementation (Double Linked Lists)
- Also, we present Iterators

Limitations of a single-linked list

- Insertion at the front is O(1); insertion at other positions is O(n)
- Insertion is convenient only after a referenced node
- Removing a node requires a reference to the previous node
- We can traverse the list only in the forward direction
- We can overcome these limitations by:
  - Add a reference in each node to the previous node, creating a double-linked list

Node Class

```
private static class Node<E> {
  private E data;
  private Node<E> next = null;
  private Node<E> prev = null;
  private Node(E dataItem) {
    data = dataItem;
  }
  private Node(E dataItem, Node<E> p, Node<E> n ) {
    data = dataItem;
    prev = p;
    next = n;
  }
}
```



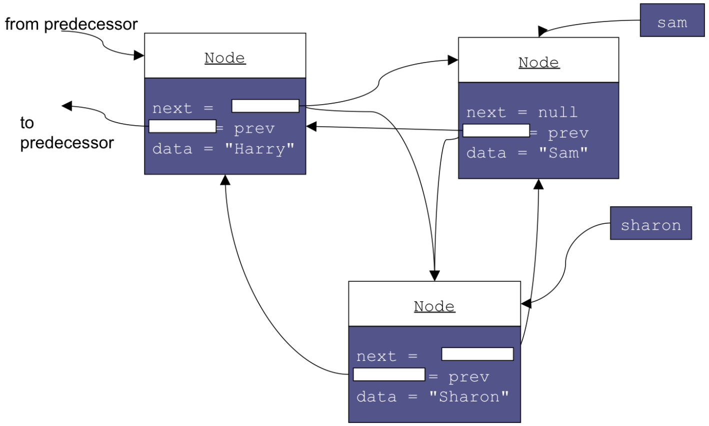
Inserting into a Double-Linked List

```
Node<String> sam = new Node<String>("Sam");
Node<String> harry = new Node<String>("Harry");
harry.next = sam;
sam.prev = harry;
```

- Let's draw a diagram

Inserting into a Double-Linked List

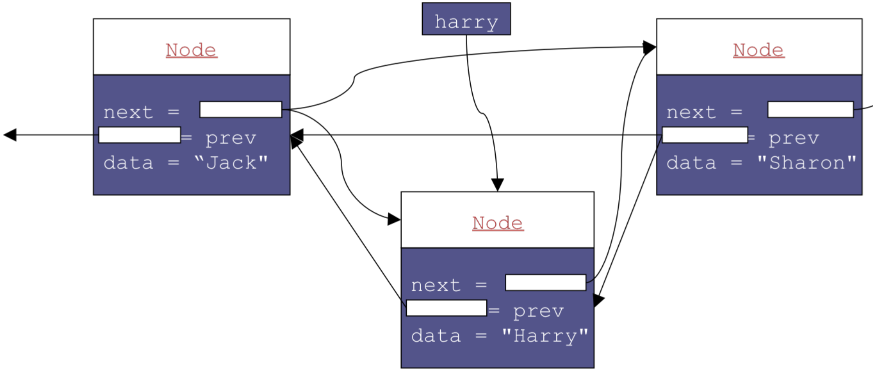
```
Node<String> sharon = new Node<String>("Sharon");
sharon.next = sam;
sharon.prev = sam.prev;
sam.prev.next = sharon;
sam.prev = sharon
```



How do we remove a node?

Consider the execution of the following additional lines

```
harry.prev.next = harry.next
harry.next.prev = harry.prev
```



The class DLList<E>

```
public class DLList<E> {

    private class Node<E> {
          /* As defined above */
          ...
    }
    /** The first element in the list */
    private Node<E> head;
    /** The last element in the list */
    private Node<E> tail;
    /** The size of the list */
    private int size = 0;

  // Operations should follow
}
```

Implement `public void add(E item)`

- This operation should add the item in a new node at the beginning of the list

Double-Linked List

- So far we have worked only with internal nodes
- As with the single-linked class, it is best to access the internal nodes with a double-linked list object
- A double-linked list object has data fields:
  - `head` (a reference to the first list Node)
  - `tail` (a reference to the last list Node)
  - `size`
- Insertion at either end is $\mathcal{O}(1)$; insertion elsewhere is still $\mathcal{O}(n)$

Circular lists

- Circular double-linked list:
  - Link last node to the first node, and
  - Link first node to the last node
- We can also build singly-linked circular lists:
  - Traverse in forward direction only
- Advantages:
  - Continue to traverse even after passing the first or last node
  - Visit all elements from any starting point
  - Never fall off the end of a list
- Disadvantage: Code must avoid an infinite loop!

Iterators

- An iterator can be viewed as a moving place marker that keeps track of the current position in a particular linked list
- An Iterator object for a list starts at the list head
- The programmer can move the Iterator by calling its next method
- The Iterator stays on its current list item until it is needed
- An Iterator traverses in $\mathcal{O}(n)$ while a list traversal using `get()` calls in a linked list is $\mathcal{O}(n^2)$

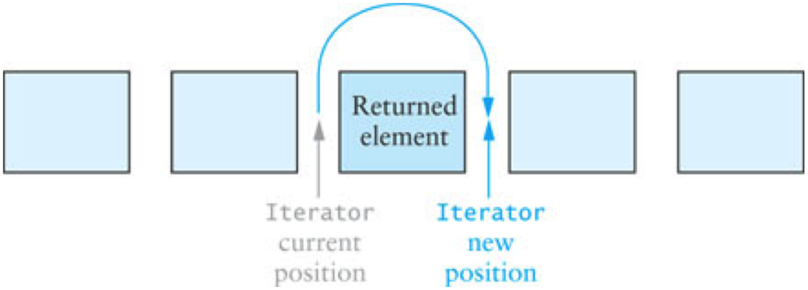
Iterator interface

- The Iterator interface is defined in java.util
- The List interface declares the method `iterator()` which returns an Iterator object that iterates over the elements of that list

Method	**Behavior**
`boolean hasNext()`	Returns true if the next method returns a value
`E next()`	Returns the next value. If there are now more elements, throws the `NoSuchElementException`
`void remove()`	Removes the last element returned by the next method

Iterator interface

An Iterator is conceptually between elements; it does not refer to a particular object at any given time



Iterator interface

In the following loop, we process all items in `List<Integer>` through an Iterator

```java
Iterator<Integer> iter = aList.iterator();
while (iter.hasNext()) {
  int value = iter.next();
  // Do something with value
  ...
}
```

Syntax Suger for Iterator

- Java 5.0 introduced a syntax suger for iterator
- The enhanced for statement creates an Iterator object and implicitly calls its hasNext and next methods.
- The following code counts the number of times target occurs in `myList` (type `LinkedList<String>`)

```
count = 0;
for (String nextStr : myList) {
  if (target.equals(nextStr)) {
    count++;
  }
}
```

Syntax Suger for Iterator

The enhanced for statement can also be used with arrays, in this case, chars or type char[]

```
for (char nextCh : chars) {
  System.out.println(nextCh);
  }
```

Demo: SingleLinkedList

```
    /**
     * @return a boolean indicating whether all the
     elements in the list are non-null
     */
    public SingleLinkedList<E> clone() {
        if (this.head != null) {
            Node<E> previous = new Node<E>(head.data);
            Node<E> head_2 = previous;
            Node<E> node = this.head;
            while (node.next != null) {
                node = node.next;
                Node<E> node_2 = new Node<E>(node.data);
                previous.next = node_2;
                previous = node_2;
            }
            return new SingleLinkedList<E>(head_2);
        }
        else {
            return null;
        }
    }
```

Demo: SingleLinkedList

```
/**
 *
 * @return appends the two lists
 */
public void append(SingleLinkedList<E> l2){
    if (this.head != null) {
        Node<E> node = this.head;
        while (node.next != null) {
            node = node.next;
        }
        node.next = l2.head;
    }
    else {
        this.head = l2.head;
    }
}
```

Reverse a linked list

For example, given input sam, bill, harry, return harry, bill, sam.

Demo: SingleLinkedList

```
/**
 * reverse the linked list
 */
public void reverse() {
    if (this.head != null) {
        Node<E> new_current_head = this.head;
        Node<E> current = new_current_head.next;
        new_current_head.next = null;
        while (current != null) {
            Node<E> tmp = current.next;
            current.next = new_current_head;
            new_current_head = current;
            current = tmp;
        }
        this.head = new_current_head;
    }
}
```

Demo: SingleLinkedList

```
/**
 * returns a new list in which n copies of the
 original list have been juxtaposed
 * @param n
 */
public void repeatLN(int n){
    SingleLinkedList<E> sll_clone = this.clone();
    for (int i = 0; i < n - 1; i ++)
        this.append(sll_clone);
}
```

Demo: SingleLinkedList

```java
    /**
     * repeats each element in the list n times
     * @param n
     */
    public void stutterNL(int n){
        if (this.head != null) {
            Node<E> node = this.head;
            Node<E> node_next = node.next;
            ArrayList<Node<E>> sub_list = this.sub_copy(node,
            Node<E> all_head = sub_list.get(0);
            Node<E> new_tail = sub_list.get(1);
            while (node_next != null) {
                node = node_next;
                node_next = node.next;
                sub_list = this.sub_copy(node, n);
                Node<E> new_head = sub_list.get(0);
                new_tail.next = new_head;
                new_tail = sub_list.get(1);
            }
            this.head = all_head;
        }
    }
```

Demo: SingleLinkedList

```
    public ArrayList<Node<E>> sub_copy(Node<E> node, int n) {
        Node<E> head = node;
        for (int j = 0; j < n - 1; j ++) {
            Node<E> copy_node = new Node<E>(node.data);
            node.next = copy_node;
            node = copy_node;
        }
        ArrayList<Node<E>> ret_array = new ArrayList<Node<E>>(
        ret_array.add(head);
        ret_array.add(node);
        return ret_array;
    }
```

Demo: SingleLinkedList

```
    /**
     * removing the adjacent duplicate items
     */
    public void removeAdjacentDuplicates() {
        if (this.head != null) {
            Node<E> node = this.head;
            Node<E> new_head = node;
            Node<E> current_node = node;
            E prev_Data = node.data;
            while (node.next != null) {
                node = node.next;
                if (node.data.equals(prev_Data) == false) {
                    current_node.next = node;
                    current_node = node;
                }
                prev_Data = node.data;
            }
            this.head = new_head;
        }
    }
```

Demo: SingleLinkedList

```
    /**
     * Provide a solution in which a new list is constructed
     * @param l2
     */
    public void zipL(SingleLinkedList<E> l2){
        if (this.head != null) {
            Node<E> node = this.head;
            Node<E> new_head = node;
            Node<E> node_2 = l2.head;
            Node<E> node_next = node.next;
            Node<E> node_next_2 = node_2.next;

            while (node_next != null) {
                node.next = node_2;
                node_2.next = node_next;

                node = node_next;
                node_2 = node_next_2;

                node_next = node.next;
                node_next_2 = node_2.next;
            }
```

Reversing Linked List II

Reverse a linked list from position m to n. Do it in one-pass. For example:

- given input tom, bill, harry, sam, marry, $m = 1, n = 3$, return tom, harry, bill, sam, marry.
- given input tom, bill, harry, sam, marry, $m = 0, n = 3$, return harry, bill, tom, sam, marry.

Reversing Linked List II

Questions to consider: how many cases of m, n should we consider? How to assign the pointers and how many pointers do we need?

Different Cases of m, n

- $m > 0$ vs. $m = 0$;
  - If $m = 0$, need one more pointer;
- $n = m + 1$ vs. $n > m + 1$;
  - If $n = m + 1$, no reverse will happen;
- $n < length$ vs. $n = length$;
  - If $n < length$, need one more pointer;

Algorithms

- For the 0-th thru m-th element, traverse the list, find the pointer n_1 to the $m-1$-th item (if $m > 0$);
- For the m-th thru $n-1$-th element, execute the reverse module, get new head n_2 and new tail n_3;
- Point n_1 to n_2;
- Point n_3 to the n-th element;

Traversing

Traverse 0-th thru *m*-th element:

```
    /**
     * reverse the linked list from m to n-th position
     * @throws Exception
     */
    public void reverse(int m, int n) throws Exception {
        if (m < 0)
            throw new Exception("illegal input");
        if (this.head != null) {
            Node<E> new_current_head = this.head;
            Node<E> current = this.head;
            for (int i = 0; i < m - 1; i ++) {
                current = current.next;
            }
```

Finding Pointers

Find the pointer to the *m*-th element:

```
    Node<E> last_node = null;
    Node<E> prev_node = null;
    if (m > 0) {
        last_node = current; //pointer to the $m-1$-
        th element
        current = current.next; // pointers for reversing
        $m$-th thru $n-1$-th item
        prev_node = current;
    }
```

Handling Boundary Case

Detecting whether $m = length$:

```
if (current == null) {
        this.head = new_current_head;
        return;
    }
    else {
        Node<E> next_node = current.next;
        if (next_node == null) {
            this.head = new_current_head;
            return;
        }
        else {
```

Reversing

Reversing $m - 1$ through n-th element:

```
    current.next = null;
    Node<E> tmp = next_node;
    for (int i = m; i < n - 1; i ++) {
        tmp = next_node.next;
        next_node.next = current;
        current = next_node;
        next_node = tmp;
        if (tmp == null) {
            break;
        }
    }
```

Set the Pointers

```
if (m > 0) {
    last_node.next = current;
    // set n1.next = n_2
    prev_node.next = tmp;
    // set n_3.next = n-th element
    this.head = new_current_head;
    // set the head as the old head
}
```

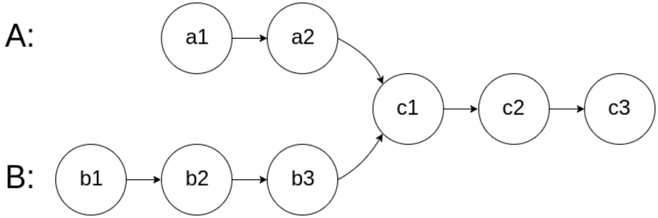
Handling $m = 0$

Handling the case where $m = 0$ differently:

```
else {
    new_current_head.next = tmp;
    // set n_3.next = n-th element
    this.head = current;
    // set the head as n_2
}
```

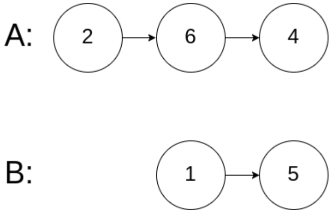
Finding Intersection of Two Lists

Write a program to find the node at which the intersection of two singly linked lists begins.
For example, the following two linked lists:



Finding Intersection of Two Lists (Non-Overlap)

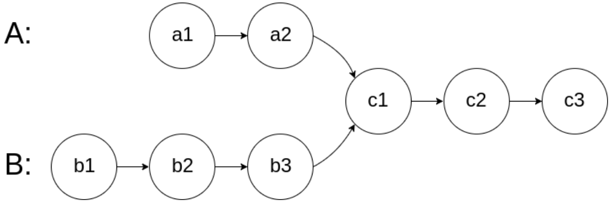
Write a program to find the node at which the intersection of two singly linked lists begins.
For example, the following two linked lists:



Ideas and Thoughts

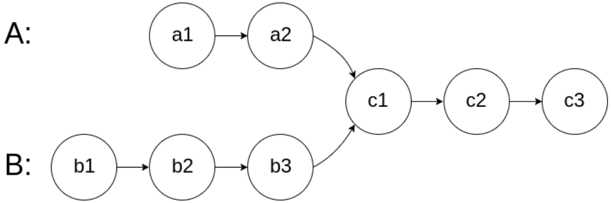
Linear time complexity is necessary:

- The list is only singly linked;
- In the worst case, have to traverse the entire lists to reach the intersection;
- We can traverse the linked list for constant number of times;



Ideas and Thoughts

- The problem with a single linked list is we don't know how far the pointer is to the intersection node;
- Sychronized two pointers: make the pointer the same distance to the intersection, and they will meet;
- Idea: move the pointer for list B for n positions, where $n = B.length - A.length$;



Algorithms

Steps:

- For each list, traverse and get $A.length$ and $B.length$;
- If $A.length > B.length$, move pointer of list A for n positions, where $n = A.length - B.length$;
- Otherwise, move pointer of list B for n positions, where $n = B.length - A.length$;
- Make synchronized move for list A and B;
- If they meet somewhere, return that node; otherwise, return null;

Implementation

Traverse and get the lengths:

```
    /**
     * get the intersection node between list starting
     with head1 and head2
     * @param head1
     * @param head2
     * @return
     */
    public Node<E> getIntersectionNode(Node<E> head1,
    Node<E> head2) {
        if (head1 == null || head2 == null)
            return null;
        Node<E> node1 = head1;
        Node<E> node2 = head2;
        int len1 = len2 = 0;
        while (node1 != null) {
            node1 = node1.next;
            len1 ++;}
        while (node2 != null) {
            node2 = node2.next;
            len2 ++;}
```

Implementation

Shift the pointers:

```
node1 = head1;
node2 = head2;

if (len1 > len2) {
    // shift node1 for len1 - len2 times;
    int steps = len1 - len2;

    for (int i = 0; i < steps; i ++)
        node1 = node1.next;
}
else if (len2 > len1){
    int steps = len2 - len1;

    for (int i = 0; i < steps; i ++)
        node2 = node2.next;
}
```

Implementation

Make synchronized moves:

```
        // now make sync move for node 1 and node2

        while (node1 != null) {
            if (node1.equals(node2) == true)
                return node1;
            node1 = node1.next;
            node2 = node2.next;
        }

        return null;
    }
```