CSCI 136
Data Structures & Advanced Programming

Lecture 10

Spring 2018

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Administrative Details

- Lab 1
  - Feedback on GitHub as a “Pull Request”
    - In a separate `TA-feedback` branch
  - `//$` and `/*$     */` comments are from TAs/instructors.
  - Comment on any of the PR lines if you have any questions!
- Lab 4
  - Optional partners again: please fill out form whether working alone or in pairs!

Last Time

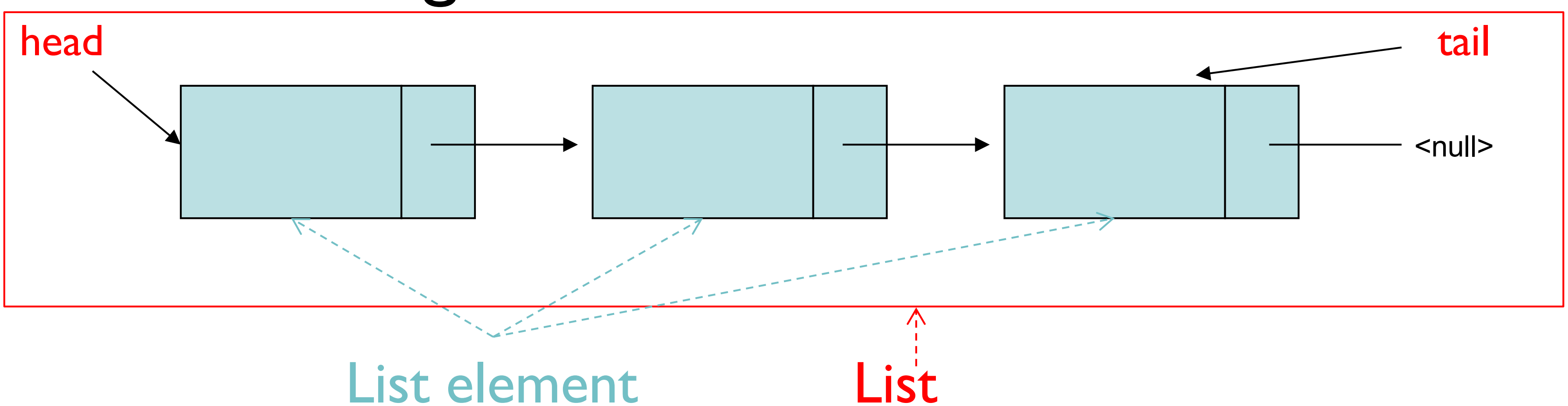
- Induction
- List: A general-purpose interface
- Implementing Lists with linked structures
  - Singly Linked Lists

Today

- Implementing Lists with linked structures
  - Singly Linked Lists – methods and implementation
  - Circularly Linked Lists (more details in book)
  - Doubly Linked Lists – Lab 4

Linked List Basics

- There are two key aspects of Lists
  - Elements of the list
    - Store data, point to the "next" element
  - The list itself
    - Includes `head` (sometimes `tail`) member variable
- Visualizing lists

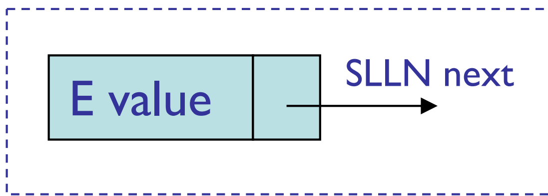


Linked List Basics

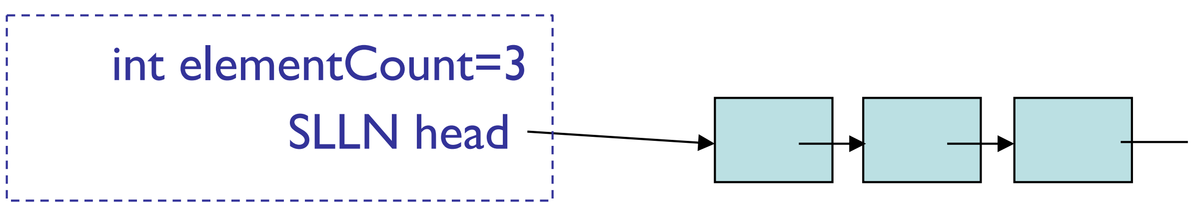
- List nodes are recursive data structures
- Each "node" has:
  - A data value
  - A next variable that identifies the next element in the list
  - Can also have "previous" that identifies the previous element ("doubly-linked" lists)
- What methods does the `Node` class need?
  - `next()`, `setNext()`, `value()`, `setValue()`

SinglyLinkedLists

- How would we implement `SinglyLinkedListNode`?
  - `SinglyLinkedListNode` = SLLN in my notes
  - SLLN = `Node` in the book (in Ch 9)



- How about `SinglyLinkedList`?
  - `SinglyLinkedList` = SLL in my notes



Let's Draw and Implement

- In SinglyLinkedListNode:
  - public SLLN(E v, SLLN<E> next)
  - SLLN<E> next(),
    void setNext(SLLN<E> next)
  - E value(), setValue(E value)
- In SinglyLinkedList:
  - public SLL()
  - public void addFirst(E value),
    public E getFirst()
  - public void addLast(E value),
    public E getLast()

More SLL Methods

- How would we implement:
  - `get(int index)`, `set(E d, int index)`
  - `add(E d, int index)`, `remove(int index)`
    - `removeLast()` is just `remove(size() - 1)`
    - `removeFirst()` is just `remove(0)`
- Left as an exercise:
  - `contains(E d)`
  - `clear()`
- Note: `E` is value type (generic)

Get and Set

```
//pre: index < size() – 1, size() > 0
public E get(int index) {
   SLLN finger = head;
   for (int i=0; i<index; i++){
        finger = finger.next();
   }
   return finger.value();
}

//pre: index < size() – 1, size() > 0
public E set(E d, int index) {
   SLLN finger = head;
   for (int i=0; i<index; i++){
        finger = finger.next();
   }
   E old = finger.value();
   finger.setValue(d);
   return old;
}
```

We should add error-checking in our functions. Preconditions aren't enforced by the Java language!

Add

```
public void add(E d, int index) {
   if(index > size()) retur;
   E old;

   if (index==0) { addFirst(d); }

   else if (index==size()) { addLast(d); }

   else {
        SLLN finger = head;
        SLLN previous = null;
        for (int i=0; i<index; i++) {
            previous = finger;
            finger = finger.next();
        }
        SLLN elem = new SLLN(d, finger);
        previous.setNext(elem); // new “ith” item added after i-1
        count++;
   }
}
```

Remove

```
public E remove(int index) {
   if(index >= size()) return null;

   E old;

   if (index==0) {              // Special case: remove from head
         old = head.value();
         head = head.next();
         count--;
         return old;
   }

   else {
         SLLN finger = head;
         for (int i=0; i < index-1; i++) { //stop one before index
               finger = finger.next();
         }
         old = finger.next.value();
         finger.setNext(finger.next().next());
         count--;
         return old;
   }
}
```

Linked Lists Summary

- Recursive data structures used for storing data
- More control over space use than Vectors
- Easy to add objects to front of list
- Components of SLL (`SinglyLinkedList`)
  - `SLLN<E> head`, `int elementCount`
- Components of SLLN (`Node`):
  - `SLLN<E> next`, `SLLN<E> value`

Vectors vs. SLL

- Compare performance of:
  - `size()`
  - `addLast()`, `removeLast()`, `getLast()`
  - `addFirst()`, `removeFirst()`, `getFirst()`
  - `get(int index), set(E d, int index)`
  - `remove(int index)`
  - `contains(E d)`
  - `remove(E d)`

Vectors vs. SLL

Operation	Vector	SLL
size	O(1)	O(1)
addLast	O(1) or O(n)(if resize)	O(n)
removeLast	O(1)	O(n)
getLast	O(1)	O(n)
addFirst	O(n)	O(1)
removeFirst	O(n)	O(1)
getFirst	O(1)	O(1)
get(i)	O(1)	O(n)
set(i)	O(1)	O(n)
remove(i)	O(n)	O(n)
contains	O(n)	O(n)
remove(o)	O(n)	O(n)

SLL Summary

- SLLs provide methods for efficiently modifying front of list
  - Modifying tail/middle of list is not quite as efficient
- SLL runtimes are consistent
  - No hidden costs like `Vector.ensureCapacity()`
  - Avg and worst case are always the same
- Space usage
  - No empty slots like vectors
  - But keep extra reference for each value
    - overhead proportional to list length
      - (but this is constant and predictable)

DoublyLinkedLists

- Nodes keep reference/links in **both** directions
- DLL keeps `head` and `tail` references
- `DoublyLinkedListNode` instance variables:
  - ```
    DLLN<E> next;
    DLLN<E> prev;
    E value;
    ```

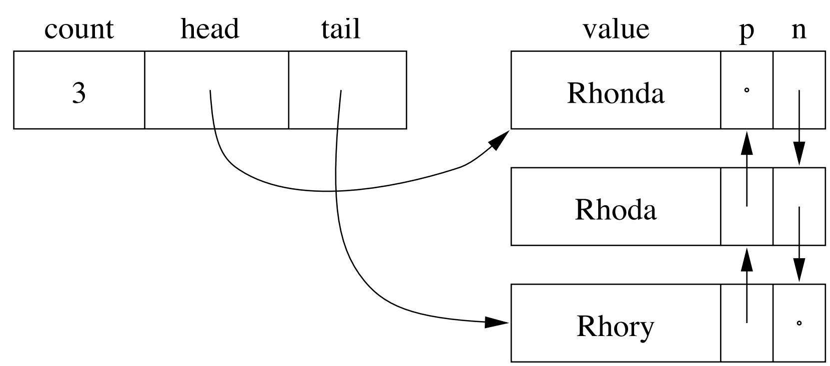


Figure 9.7,
Bailey pg. 202
    ```

DoublyLinkedLists

- Space overhead is proportional to number of elements
  - Still O(n) like SLL and Vector
- <u>ALL</u> operations on tail (including removeLast) are fast!
- Additional complexity in each list operation
  - Example: `add(E d, int index)`
    - Four cases to consider now:
      - empty list
      - add to front
      - add to tail
      - add in middle

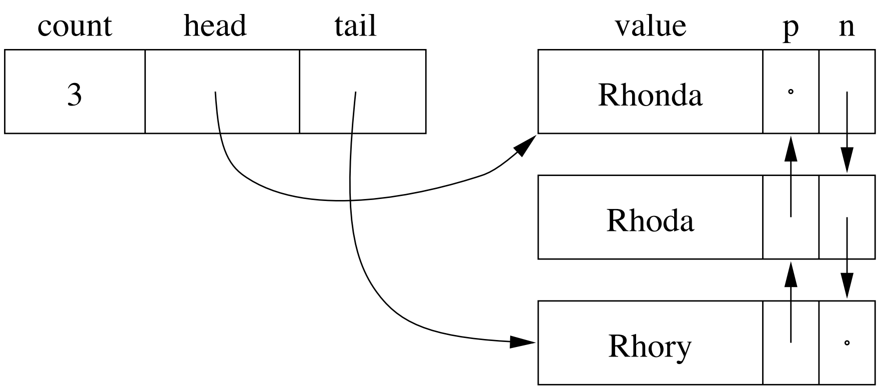
```java
public class DoublyLinkedNode<E> {
        protected E data;
        protected DoublyLinkedNode<E> nextElement;
        protected DoublyLinkedNode<E> previousElement;

// Constructor inserts new node between existing nodes
public DoublyLinkedNode(E v,
                DoublyLinkedNode<E> next,
                DoublyLinkedNode<E> previous)
{
        data = v;
        nextElement = next;
        if (nextElement != null)
                nextElement.previousElement = this;
        previousElement = previous;
        if (previousElement != null)
                previousElement.nextElement = this;
}
```

DoublyLinkedList

- We will implement a modified version of DLL in Lab 4
- See `LinkedList.java` on course webpage
- What is the purpose of the lab?

Lab 4: Dummy Nodes



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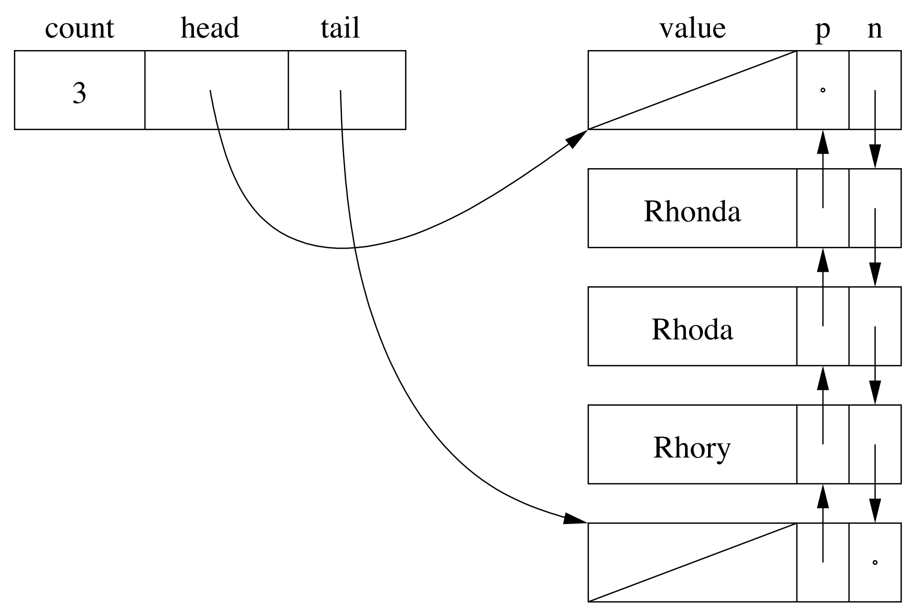

Bailey pg. 215

- Lab Question: What are the advantages of adding dummy nodes?