BASIC DATA STRUCTURES

CS062

DATA STRUCTURES AND ADVANCED PROGRAMMING

7: Singly Linked Lists

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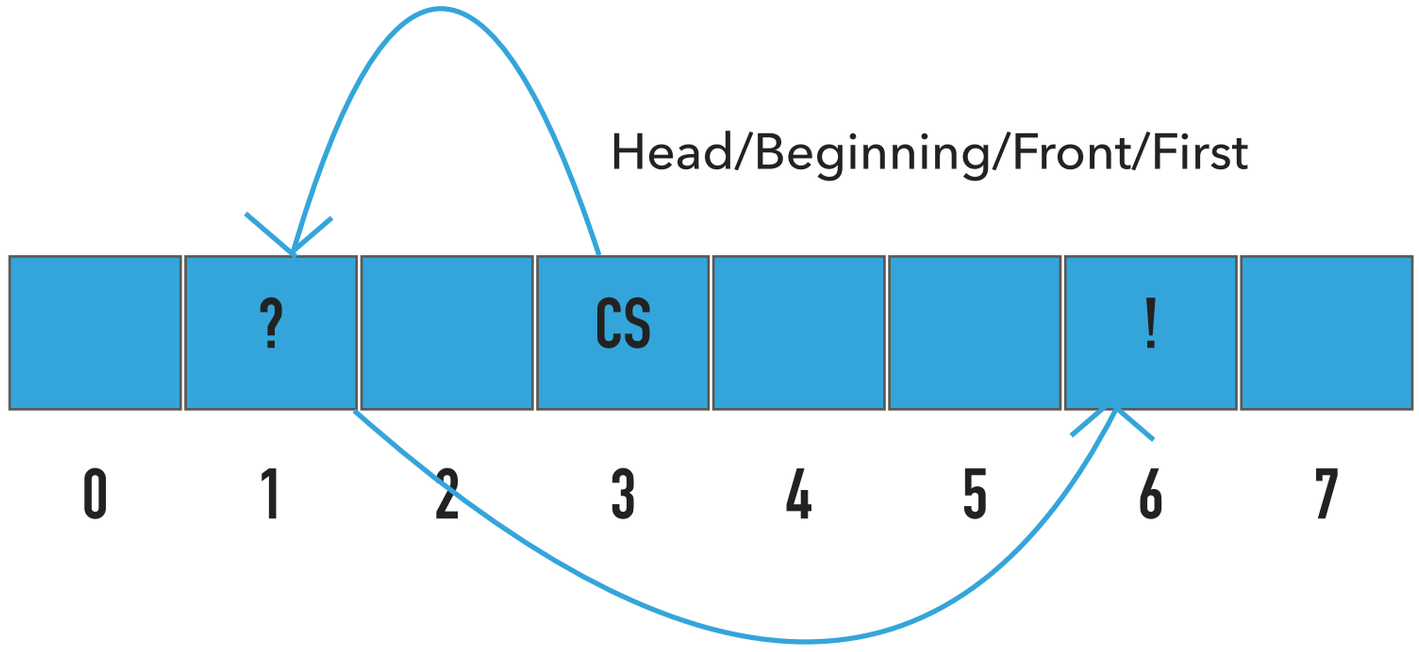
Lecture 7: Singly Linked Lists

- Singly Linked Lists

Some slides adopted from Algorithms 4th Edition and Oracle tutorials

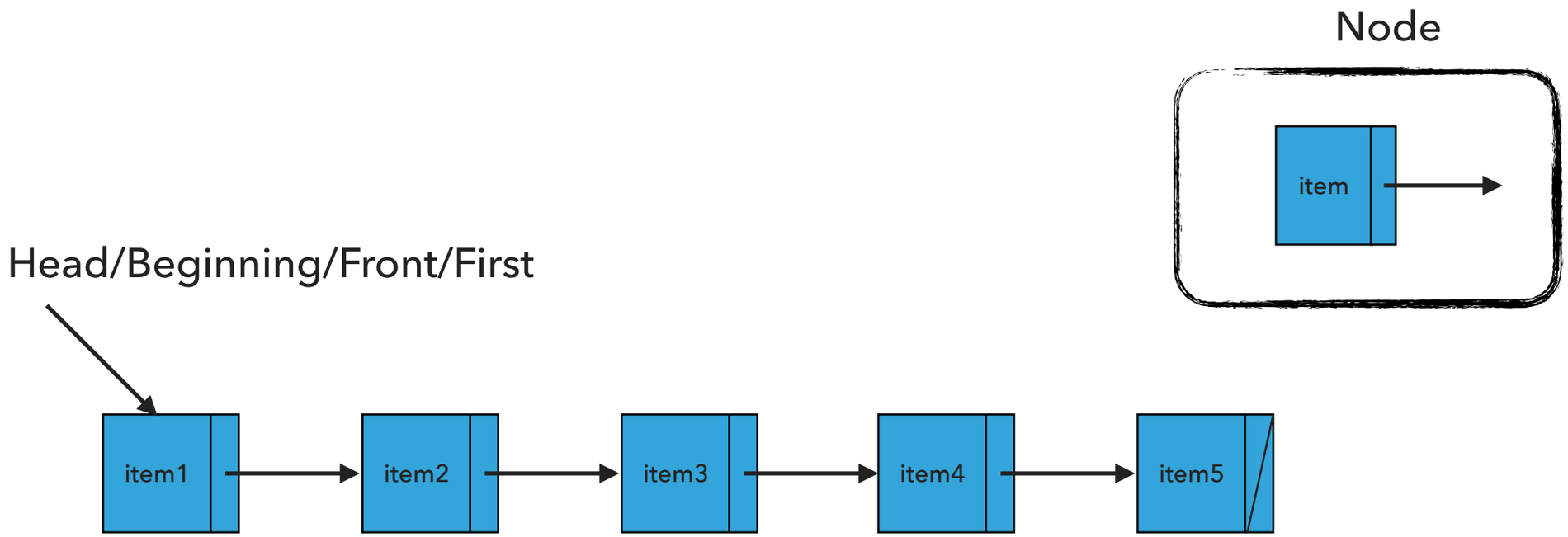
Singly Linked Lists

- Dynamic linear data structures.
- In contrast to sequential data structures, linked data structures use pointers/links/references from one object to another.



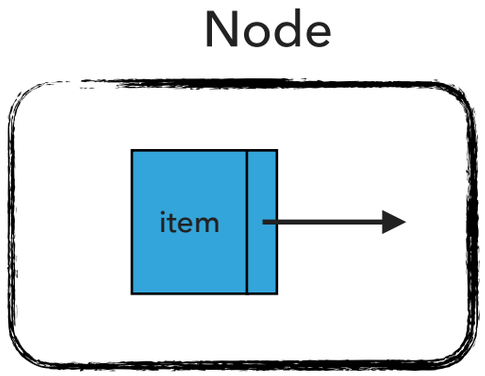
Recursive Definition of Singly Linked Lists

- A singly linked list is either empty (null) or a node having a reference to a singly linked list.
- Node: is a data type that holds any kind of data and a reference to a node.



Node

```
private class Node {
    Item item;
    Node next;
}
```



Standard Operations

- `SinglyLinkedList()`: Constructs an empty singly linked list.
- `isEmpty()`:Returns true if the singly linked list does not contain any item.
- `size()`: Returns the number of items in the singly linked list.
- `Item get(int index)`: Returns the item at the specified index.
- `add(Item item)`: Inserts the specified item at the head of the singly linked list.
- `add(int index, Item item)`: Inserts the specified item at the specified index.
- `Item remove()`: Removes and returns the head of the singly linked list.
- `Item remove(int index)`: Removes and returns the item at the specified index.

`SinglyLinkedList()`: Constructs an empty SLL

first = ?

n = ?

What should happen?

```
SinglyLinkedList<String> sll = new SinglyLinkedList<String>();
```

`SinglyLinkedList()`: Constructs an empty SLL

```
SinglyLinkedList<String> sll = new SinglyLinkedList<String>();
```

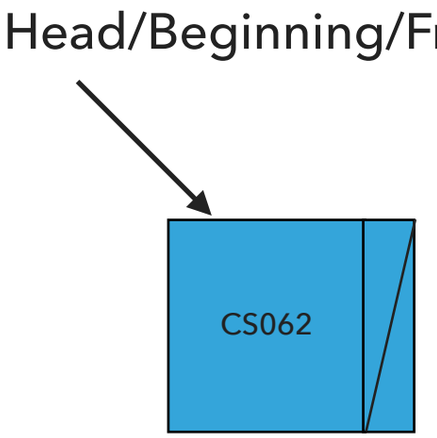
first = null

n = 0

What should happen?

```
sll.add("CS062");
```

`add(Item item)`: Inserts the specified item at the head of the singly linked list



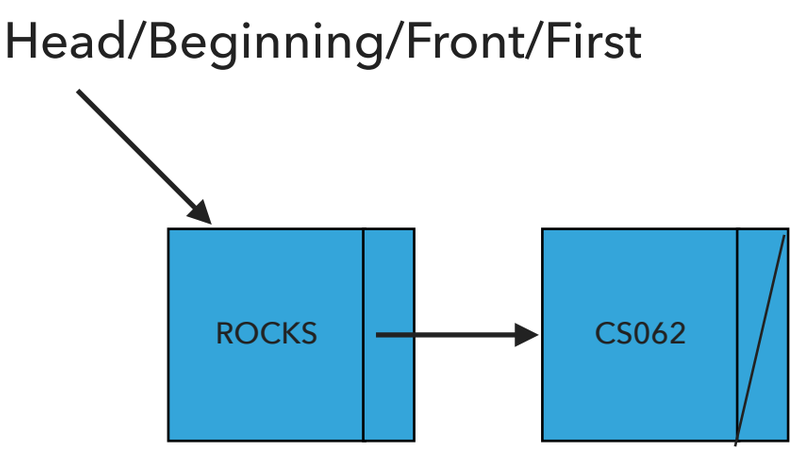

```
sll.add("CS062")

n=1
```

What should happen?

```
sll.add("ROCKS");
```

`add(Item item)`: Inserts the specified item at the head of the singly linked list



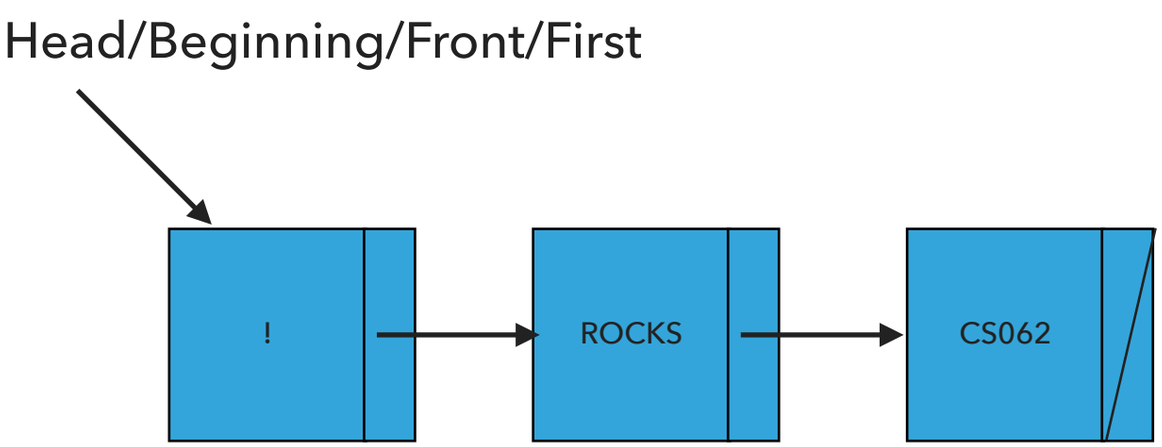

```
sll.add("ROCKS")

n=2
```

What should happen?

```
sll.add("!");
```

`add(Item item)`: Inserts the specified item at the head of the singly linked list



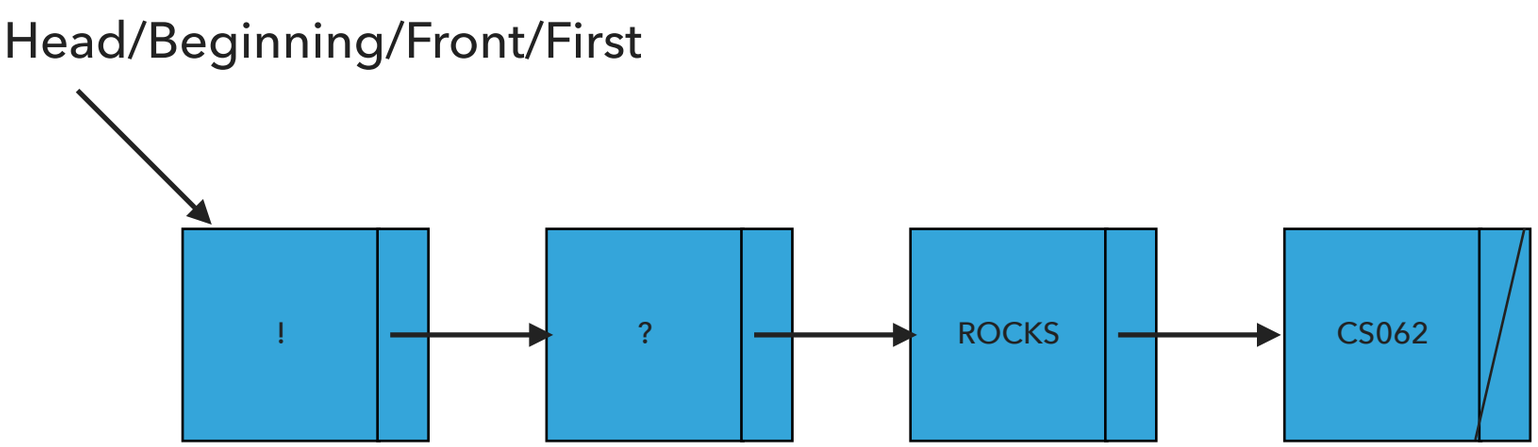

```
sll.add("!")

n=3
```

What should happen?

```
sll.add(1,"?");
```

`add(int index, Item item)`: Adds item at the specified index



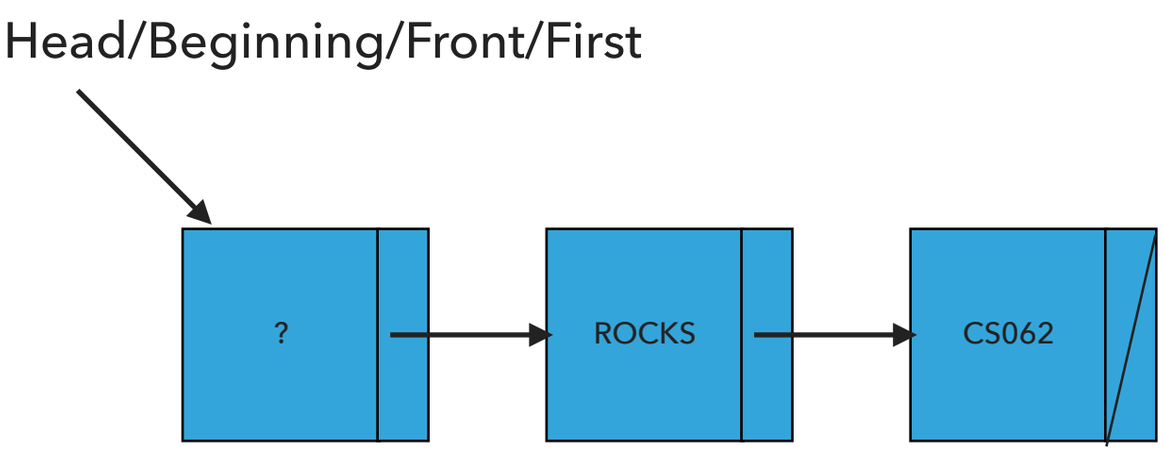

```
sll.add(1,“?”)

n=4
```

What should happen?

```
sll.remove();
```

`remove()`: Retrieves and removes the head of the singly linked list



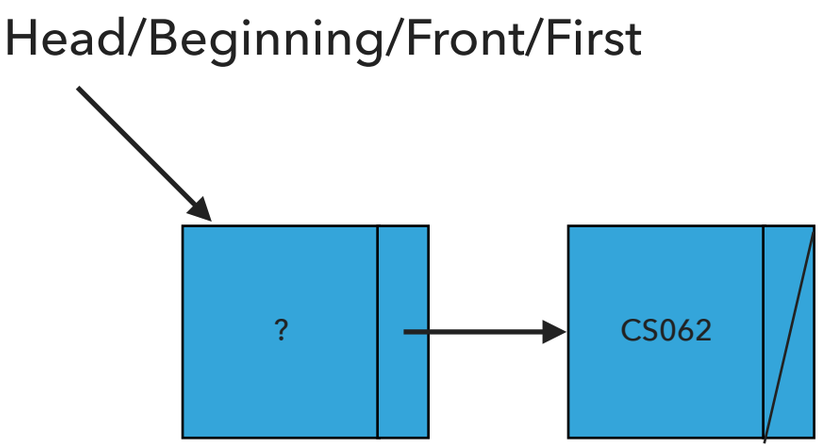

```
sll.remove()

n=3
```

What should happen?

```
sll.remove(1);
```

`remove(int index)`: Retrieves and removes the item at the specified index




```
sll.remove(1)

n=2
```

Our own implementation of Singly Linked Lists

- We will follow the textbook style.
  - It does not offer a class for this so we will build our own.
- We will work with generics because we don't want to offer multiple implementations.
- We will use an inner class Node and we will keep track of how many elements we have in our singly linked list.

Instance variables and inner class

```
public class SinglyLinkedList<Item> implements Iterable<Item> {
   private Node first; // head of the singly linked list
   private int n; // number of nodes in the singly linked list

   /**
    * This nested class defines the nodes in the singly linked list with a
value
    * and pointer to the next node they are connected.
    */
   private class Node {
      Item item;
      Node next;
   }
```

Check if is empty and how many items

```
/**
 * Returns true if the singly linked list does not contain any item.
 *
 * @return true if the singly linked list does not contain any item
 */
public boolean isEmpty() {
    return first == null; // return size() == 0;
}
```

```
/**
 * Returns the number of items in the singly linked list.
 *
 * @return the number of items in the singly linked list
 */
public int size() {
    return n;
}
```

Check if index is >=0 and <n

```
/**
 * A helper method to check if an index is in range 0<=index<n
 *
 * @param index
 *            the index to check
 */
private void rangeCheck(int index) {
    if (index > n || index < 0)
        throw new IndexOutOfBoundsException("Index " + index + " out of bounds");
}
```

Retrieve item from specified index

```
    /**
     * Returns item at the specified index.
     *
     * @param index
     *            the index of the item to be returned
     * @return the item at specified index
     */
    public Item get(int index) {
        // check whether index is valid
        rangeCheck(index);
        // set a temporary pointer to the head
        Node finger = first;
        // search for index-th element or end of list
        while (index > 0) {
            finger = finger.next;
            index--;
        }
        // return the item stored in the node that the temporary pointer points to
        return finger.item;
    }
```

Insert item at head of singly linked list

```
 /**
 * Inserts the specified item at the head of the singly linked list.
 *
 * @param item
 *            the item to be inserted
 */
public void add(Item item) {
    // Create a pointer to head
    Node oldfirst = first;

    // Make a new node that will hold the item and assign it to head.
    first = new Node();
    first.item = item;
    // fix pointers
    first.next = oldfirst;
    // increase number of nodes
    n++;
}
```

Insert item at a specified index

```
/**
 * Inserts the specified item at the specified index.
 *
 * @param index
 *            the index to insert the node
 * @param item
 *            the item to insert
 */
public void add(int index, Item item) {
      // check that index is within range
       rangeCheck(index);
      // if index is 0, then call one-argument add
       if (index == 0) {
             add(item);
      // else
       } else {
             // make two pointers, previous and finger. Point previous to null and finger to head
             Node previous = null;
             Node finger = first;
             // search for index-th position by pointing previous to finger and advancing finger
             while (index > 0) {
                   previous = finger;
                   finger = finger.next;
                   index--;
             }
             // create new node to insert in correct position. Set its pointers and contents
             Node current = new Node();
             current.next = finger;
             current.item = item;
             // make previous point to newly created node.
             previous.next = current;
             // increase number of nodes
             n++;
       }
}
```

Retrieve and remove head

```
/**
     * Retrieves and removes the head of the singly linked list.
     *
     * @return the head of the singly linked list.
     */
    public Item remove() {
        // Make a temporary pointer to head
        Node temp = first;
        // Move head one to the right
        first = first.next;
        // Decrease number of nodes
        n--;
        // Return item held in the temporary pointer
        return temp.item;
    }
```

Retrieve and remove element from a specific index

```
/**
 * Retrieves and removes the item at the specified index.
 *
 * @param index
 *            the index of the item to be removed
 * @return the item previously at the specified index
 */
public Item remove(int index) {
     // check that index is within range
      rangeCheck(index);
     // if index is 0, then call remove
      if (index == 0) {
            return remove();
     // else
      } else {
     // make two pointers, previous and finger. Point previous to null and finger to head
            Node previous = null;
            Node finger = first;
            // search for index-th position by pointing previous to finger and advancing finger
            while (index > 0) {
                  previous = finger;
                  finger = finger.next;
                  index--;
            }
            // make previous point to finger's next
            previous.next = finger.next;
            // reduce number of items
            n--;
            // return finger's item
            return finger.item;
      }

}
```

add() in singly linked lists is $O(1)$ for worst case

```
public void add(Item item) {
    // Save the old node
    Node oldfirst = first;

    // Make a new node and assign it to head. Fix pointers.
    first = new Node();
    first.item = item;
    first.next = oldfirst;

    n++; // increase number of nodes in singly linked list.
}
```

get() in singly linked lists is $O(n)$ for worst case

```
public Item get(int index) {
    rangeCheck(index);

    Node finger = first;
    // search for index-th element or end of list
    while (index > 0) {
        finger = finger.next;
        index--;
    }
    return finger.item;
}
```

`add(int index, Item item)` in singly linked lists is $O(n)$ for worst case

```
public void add(int index, Item item) {
        rangeCheck(index);

        if (index == 0) {
            add(item);
        } else {

            Node previous = null;
            Node finger = first;
            // search for index-th position
            while (index > 0) {
                previous = finger;
                finger = finger.next;
                index--;
            }
            // create new value to insert in correct position.
            Node current = new Node();
            current.next = finger;
            current.item = item;
            // make previous value point to new value.
            previous.next = current;

            n++;
        }
    }
```

remove() in singly linked lists is $O(1)$ for worst case

```
public Item remove() {
    Node temp = first;
    // Fix pointers.
    first = first.next;

    n--;
    return temp.item;
}
```

`remove(int index)` in singly linked lists is $O(n)$ for worst case

```
public Item remove(int index) {
    rangeCheck(index);

    if (index == 0) {
        return remove();
    } else {
        Node previous = null;
        Node finger = first;
        // search for value indexed, keep track of previous
        while (index > 0) {
            previous = finger;
            finger = finger.next;
            index--;
        }
        previous.next = finger.next;

        n--;
        // finger's value is old value, return it
        return finger.item;
    }

}
```

Lecture 7: Singly Linked Lists

- Singly Linked Lists

Readings:

- Textbook:
  - Chapter 1.3 (Page 142–146)
- Textbook Website:
  - Linked Lists: https://algs4.cs.princeton.edu/13stacks/

Practice Problems:

- 1.3.18–1.3.27