CSCI-1200 Data Structures — Spring 2018
Lecture 11 — Doubly-Linked Lists

Today's Lecture

- Limitations of singly-linked lists
- Doubly-linked lists: Structure, Insert, & Remove

11.1 Inserting a Node into a Singly-Linked List

- With a singly-linked list, we'll need a pointer to the node *before* the spot where we wish to insert the new item.
- If `p` is a pointer to this node, and `x` holds the value to be inserted, then the following code will do the insertion. Draw a picture to illustrate what is happening.

```
Node<T> * q = new Node<T>; //  create a new node
q -> value = x;            //  store x in this node
q -> next = p -> next;     //  make its successor be the current successor of p
p -> next = q;             //  make p's successor be this new node
```

- Note: This code will not work if you want to insert `x` in a new node at the *front* of the linked list. Why not?

11.2 Removing a Node from a Singly-Linked List

- The remove operation itself requires a pointer to the node *before* the node to be removed.
- Suppose `p` points to a node that should be removed from a linked list, `q` points to the node before `p`, and `head` points to the first node in the linked list. Note: Removing the first node is an important special case.
- Write code to remove `p`, making sure that if `p` points to the first node that `head` points to what was the second node and now is the first after `p` is removed. Draw a picture of each scenario.

11.3 Exercise: Singly-Linked List Copy

Write a *recursive* function to copy all nodes in a linked list to form an new linked list of nodes with identical structure and values. Here's the function prototype:

```
template <class T> void CopyAll(Node<T>* old_head,  Node<T>*& new_head) {
```

11.4 Exercise: Singly-Linked List Remove All

Write a *recursive* function to delete all nodes in a linked list. Here's the function prototype:

```
template <class T> void RemoveAll(Node<T>*& head) {
```

11.5 Basic Linked Lists Mechanisms: Common Mistakes

Here is a summary of common mistakes. Read these carefully, and read them again when you have problem that you need to solve.

- Allocating a new node to step through the linked list; only a pointer variable is needed.
- Confusing the `.` and the `->` operators.
- Not setting the pointer from the last node to NULL.
- Not considering special cases of inserting / removing at the beginning or the end of the linked list.
- Applying the `delete` operator to a node (calling the operator on a pointer to the node) before it is appropriately disconnected from the list. Delete should be done after all pointer manipulations are completed.
- Pointer manipulations that are out of order. These can ruin the structure of the linked list.
- Trying to use STL iterators to visit elements of a "home made" linked list chain of nodes. (And the reverse.... trying to use `->next` and `->prev` with STL list iterators.)

11.6 Limitations of Singly-Linked Lists

- We can only move through it in one direction
- We need a pointer to the node *before* the spot where we want to insert and a pointer to the node *before* the node that needs to be deleted.
- Appending a value at the end requires that we step through the entire list to reach the end.

11.7 Generalizations of Singly-Linked Lists

- Three common generalizations (can be used separately or in combination):
  - Doubly-linked: allows forward and backward movement through the nodes
  - Circularly linked: simplifies access to the tail, when doubly-linked
  - Dummy header node: simplifies special-case checks
- Today we will explore and implement a doubly-linked structure.

11.8 Transition to a Doubly-Linked List Structure

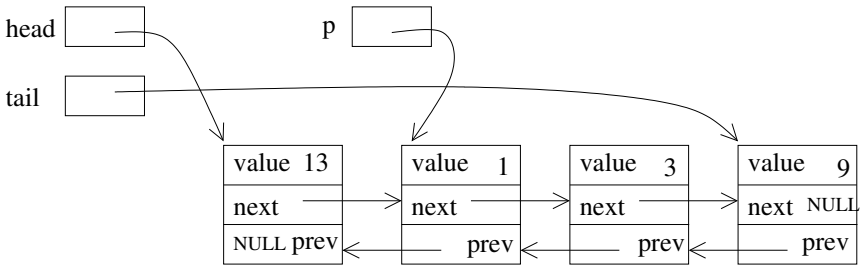
- The revised `Node` class has two pointers, one going "forward" to the successor in the linked list and one going "backward" to the predecessor in the linked list. We will have a `head` pointer to the beginning *and* a `tail` pointer to the end of the list.

```
template <class T> class Node {
public:
    Node() : next_(NULL), prev_(NULL) {}
    Node(const T& v) : value_(v), next_(NULL), prev_(NULL) {}
    T value_;
    Node<T>* next_;
    Node<T>* prev_;
};
```

- Note that we now assume that we have both a `head` pointer, as before and a `tail` pointer variable, which stores the address of the last node in the linked list.
- The tail pointer is not strictly necessary, but it allows immediate access to the end of the list for efficient push-back operations.

11.9 Inserting a Node into the Middle of a Doubly-Linked List

- Suppose we want to insert a new node containing the value 15 following the node containing the value 1. We have a temporary pointer variable, `p`, that stores the address of the node containing the value 1. Here's a picture of the state of affairs:



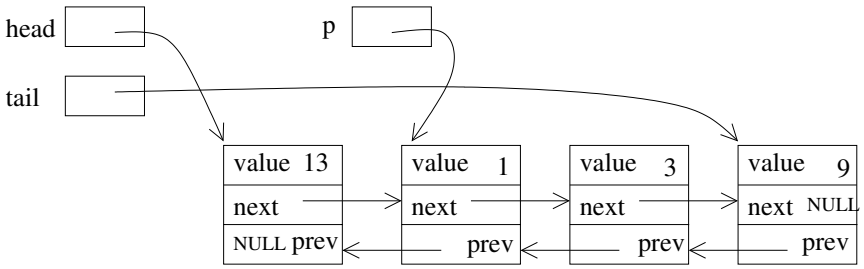
- What must happen? Editing the diagram above...
  - The new node must be created, using another temporary pointer variable to hold its address.
  - Its two pointers must be assigned.
  - Two pointers in the current linked list must be adjusted. Which ones?

  Assigning the pointers for the new node MUST occur before changing the pointers for the current linked list nodes!

- **Exercise:** Write the code as just described. Focus first on the general case: Inserting a new into the middle of a list that already contains at least 2 nodes.

11.10 Removing a Node from the Middle of a Doubly-Linked List

- Now instead of inserting a value, suppose we want to remove the node pointed to by `p` (the node whose address is stored in the pointer variable `p`)



- Two pointers need to change before the node is deleted! All of them can be accessed through the pointer variable `p`.
- **Exercise:** Edit the diagram above, and then write this code.

11.11 Special Cases of Remove

- If `p==head` and `p==tail`, the single node in the list must be removed and both the `head` and `tail` pointer variables must be assigned the value `NULL`.
- If `p==head` or `p==tail`, then the pointer adjustment code we just wrote needs to be specialized to removing the first or last node.