Computer Science II — CSci 1200
Lecture 11
Linked Lists, Part 2

Review from Lecture 10

- Introductory example on linked lists.
- Basic linked list operations:
  - Stepping through a list
  - Push back
  - Insert
  - Remove
- Common mistakes

Today's Lecture

- Limitations of singly-linked lists
- Doubly-linked lists:
  - Structure
  - Insert
  - Remove
- Our own version of the `list<T>` class
- `list<T>::iterator`

Limitations of Singly-Linked Lists

- We can only move through it in one direction
- We need 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.

Generalizations of Singly-Linked Lists

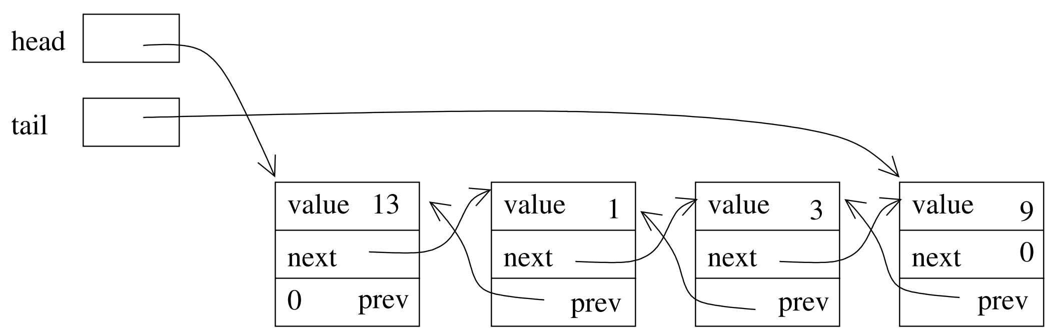
- Three common generalizations:
  - Doubly-linked: allows forward and backward movement through the nodes
  - Circularly linked: simplifies access to the tail, when doubly-linked
  - Dummy header node: simplifies special-case checks
- We will only consider doubly-linked, here

The Structure of Doubly-Linked Lists

- For the next few examples, we will use the simple node class:

```
class Node {
public:
  int value;
  Node* next;
  Node* prev;
};
```

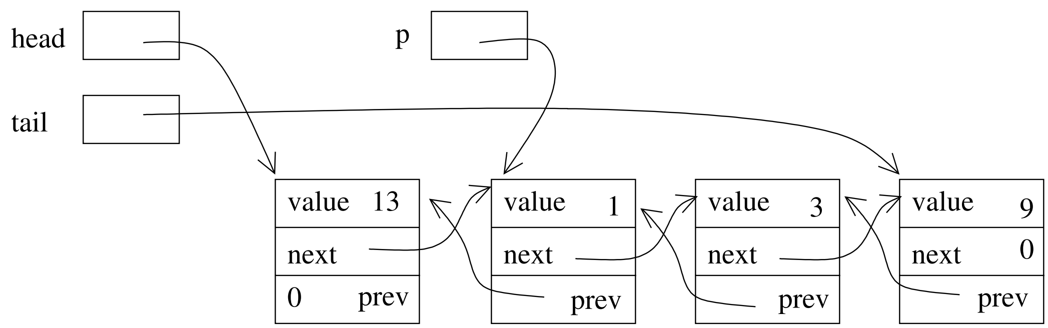
- Here is a picture of a doubly-linked list holding 4 integer values:



- Note that we now assume 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.
  - This is not strictly necessary, but it allows immediate access to the end of the list for push-back operations.

Inserting in 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.
- Suppose also that 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:



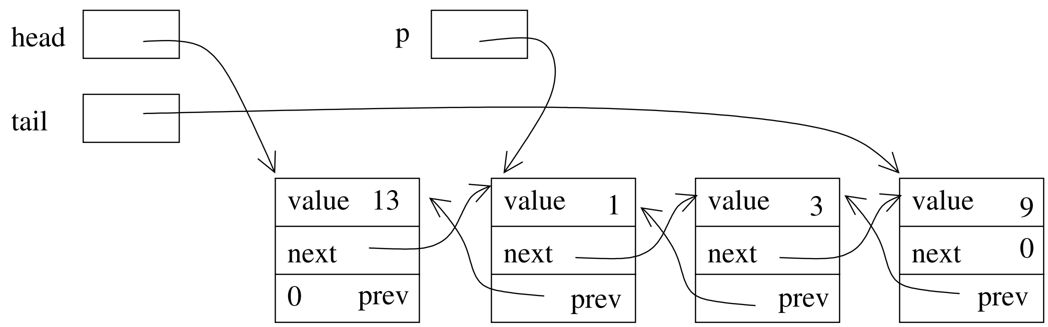
- What must happen?
  - The new node must be created, using another temporary pointer variable to hold its address.
  - Its two pointers must be assigned.
  - Two pointers in the current linked list must be adjusted. Which ones?

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

- At this point, we are ignoring the possibility that the linked list is empty or that `p` points to the tail node (`p` pointing to the head node doesn't cause any problems).
- **Exercise:** write the code as just described.

Removing from the Middle of a Doubly-Linked List

- Suppose now instead of inserting a value 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:** write this code.

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 0.
- 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.
- All of these will be built into the `erase` function that we write as part of our `cs2list` class.

The cs2list Class — Overview

- We will write a templated class called `cs2list` that implements much of the functionality of the `list<T>` container and uses a doubly-linked list as its internal, low-level data structure.
- Three classes are involved:
  - The node class
  - The iterator class
  - The cs2list class itself

The Node Class

- Here's the definition:

```
template <class T>
class Node {
public:
```

```
  Node( ) : next_(0), prev_(0) {}
  Node( const T& v ) : value_(v), next_(0), prev_(0) {}
  T value_;
  Node<T>* next_;
  Node<T>* prev_;
};
```

- It is ok to make all members public because individual nodes are never seen outside the list class.
- Note that the constructors all initialize the pointers to 0 (null).

The Iterator Class — Desired Functionality

- Increment and decrement operators — operations on pointers
- Dereferencing to access contents of a node in a list
- Two comparison operations only: `operator==` and `operator!=`.

The Iterator Class — Implementation

See code attached to the handout:

- Separate class
- Stores a pointer to a node in a linked list
- Constructors initialize the pointer — they will be called from the `cs2list<T>` class member functions.
- This requires that `cs2list<T>` be a **friend class** of `list_iterator<T>`.
  - When a class `A` states that another class `B` is a `friend`, this means that when any member function in `B` is working with an object of type `A`, the `B` member function has access to `A`'s private member variables and functions.
  - In our case, this means `cs2list<T>` member functions have direct access to the private member variables of `list_iterator<T>` objects — the `Node<T>` pointers.
  - This is especially important for the `erase` and `insert` functions.
  - Note that friendship is granted, not claimed!

  Now back to the details of `list_iterator<T>`...

- `operator*` dereferences the pointer and gives access to the contents of a node.
- The mechanision of stepping through the chain of the linked list is implemented by the increment and decrement operators.
- `operator==` and `operator!=` are defined and quite important. No other comparison operators are allowed.

The cs2list class — Overview and Prototype

- Job:
  - Manages the actions of the iterator and node classes
  - Maintains the head and tail pointers and the size of the list
  - Manages the overall structure of the class through member functions
- Three member variables: head_, tail_, size_
- Typedef for the iterator name.
  - This means that the name list_iterator<T> is not used outside the function.
- Prototypes for member functions, which are equivalent to the std::list<T> member functions
- Some things are missing, most notably const_iterator and reverse_iterator.

The cs2list class — Some Member Function Details

- Many short functions are in-lined
- Clearly, it must contain the "big 3": copy constructor, operator=, and destructor.
  - The details of these are realized through the private copy_list and destroy_list member functions. You will write one of these during lab.

Exercises

1. Write cs2list<T>::push_front
2. Write cs2list<T>::erase