CSCI-1200 Computer Science II — Spring 2006
Lecture 21 Linked Lists — Part II

Review from Lecture 20

- 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`

21.1 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.

21.2 Generalizations of Singly-Linked Lists

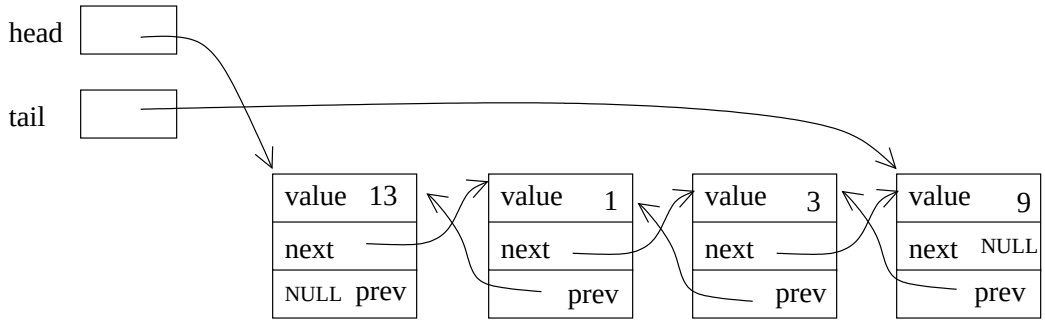
- Three common generalizations:
  - Doubly-linked: allows forward and backward movement through the nodes
  - Circularly linked: simplifies access to the tail, when doubly-linked
  - Dummy header node: simplifies special-case checks
- We will only consider doubly-linked, here

21.3 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;
};
```

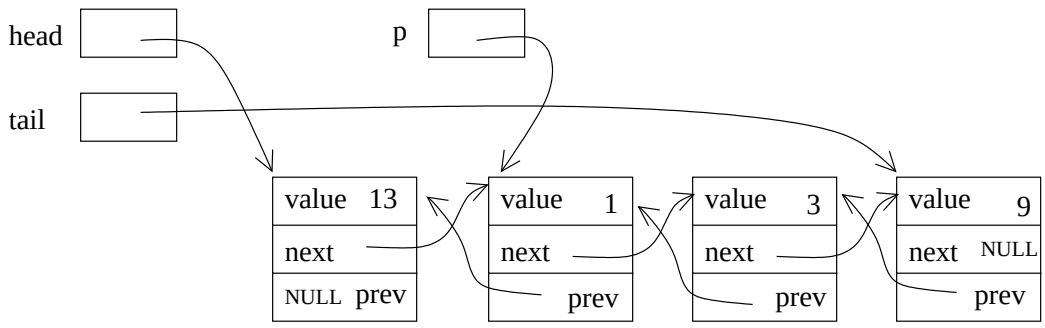
- Here is a picture of a doubly-linked list holding 4 integer values:



- Note that we now assume 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 push-back operations.

21.4 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. 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:



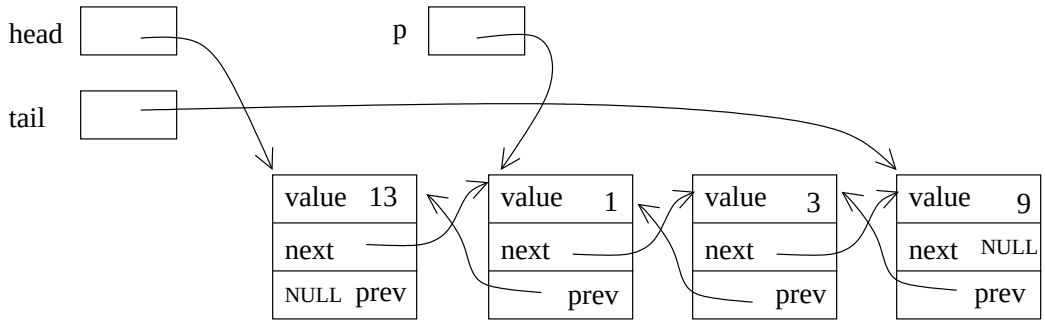
- What must happen?
  - The new node must be created, using another temporary pointer variable to hold its address.
  - Its two pointers must be assigned.
  - Two pointers in the current linked list must be adjusted. Which ones?

  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.

21.5 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.

21.6 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.
- All of these will be built into the `erase` function that we write as part of our `cs2list` class.

21.7 The cs2list Class — Overview

- We will write a templated class called `cs2list` that implements much of the functionality of the `std::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

21.8 The Node Class

- 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 NULL (which is equivalent to the special memory address 0).

```
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_;
};
```

21.9 The Iterator Class — Desired Functionality

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

21.10 The Iterator Class — Implementation

- (See attached code)
- 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.
  - `cs2list<T>` is a friend class to allow access to the pointer for `cs2list<T>` member functions such as `erase` and `insert`.
- `operator*` dereferences the pointer and gives access to the contents of a node.
- Stepping through the chain of the linked-list is implemented by the increment and decrement operators.
- `operator==` and `operator!=` are defined, but no other comparison operators are allowed.

21.11 The cs2list Class — Overview

- 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
- 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`.

21.12 The cs2list class — Implementation 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.

21.13 Exercises

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

```
#ifndef cs2list_h_
#define cs2list_h_
// A simplified implementation of a generic list container class,
// including the iterator, but not the const_iterators.  Three
// separate classes are defined: a Node class, an iterator class, and
// the actual list class.  The underlying list is doubly-linked, but
// there is no dummy head node and the list is not circular.

// ----------------------------------------------------------------
// NODE CLASS
template <class T>
class Node {
public:
  Node() : next_(NULL), prev_(NULL) {}
  Node(const T& v) : value_(v), next_(NULL), prev_(NULL) {}

  // REPRESENTATION
  T value_;
  Node<T>* next_;
  Node<T>* prev_;
};

// A "forward declaration" of this class is needed
template <class T> class cs2list;

// ----------------------------------------------------------------
// LIST ITERATOR
template <class T>
class list_iterator {
public:
  list_iterator() : ptr_(NULL) {}
  list_iterator(Node<T>* p) : ptr_(p) {}
  list_iterator(list_iterator<T> const& old) : ptr_(old.ptr_) {}
  ~list_iterator() {}

  list_iterator<T> & operator=(const list_iterator<T> & old) {
    ptr_ = old.ptr_;  return *this; }

  // dereferencing operator gives access to the value at the pointer
  T& operator*()  { return ptr_->value_;  }

  // increment & decrement operators
  list_iterator<T> & operator++() {
    ptr_ = ptr_->next_;
    return *this;
  }
  list_iterator<T> operator++(int) {
    list_iterator<T> temp(*this);
    ptr_ = ptr_->next_;
    return temp;
  }
  list_iterator<T> & operator--() {
    ptr_ = ptr_->prev_;
    return *this;
  }
  list_iterator<T> operator--(int) {
    list_iterator<T> temp(*this);
    ptr_ = ptr_->prev;
    return temp;
  }

  friend class cs2list<T>;

  // Comparions operators are straightforward
  friend bool operator==(const list_iterator<T>& l, const list_iterator<T>& r) {
    return l.ptr_ == r.ptr_; }
  friend bool operator!=(const list_iterator<T>& l, const list_iterator<T>& r) {
    return l.ptr_ != r.ptr_; }

private:
  // REPRESENTATION
  Node<T>* ptr_;    // ptr to node in the list

};

// ----------------------------------------------------------------
// LIST CLASS DECLARATION
// Note that it explicitly maintains the size of the list.
template <class T>
class cs2list {
public:
  cs2list() : head_(NULL), tail_(NULL), size_(0) {}
  cs2list(const cs2list<T>& old) { this->copy_list(old); }
  ~cs2list() { this->destroy_list(); }
  cs2list& operator= (const cs2list<T>& old);

  int size() const { return size_; }
  bool empty() const { return head_ == NULL; }
  void clear() { this->destroy_list(); }

  void push_front(const T& v);
  void pop_front();
  void push_back(const T& v);
  void pop_back();

  const T& front() const { return head_->value_;  }
  T& front() { return head_->value_; }
  const T& back() const { return tail_->value_; }
  T& back() { return tail_->value_; }

  typedef list_iterator<T> iterator;
  iterator erase(iterator itr);
  iterator insert(iterator itr, T const& v);
  iterator begin() { return iterator(head_); }
  iterator end() { return iterator(NULL); }

private:
  void copy_list(cs2list<T> const & old);
  void destroy_list();

  //REPRESENTATION
  Node<T>* head_;
  Node<T>* tail_;
  int size_;
};
```

```
// ----------------------------------------------------------------
// LIST CLASS IMPLEMENTATION
template <class T>
cs2list<T>& cs2list<T>::operator= (const cs2list<T>& old) {
  if (&old != this) {
    this->destroy_list();
    this->copy_list(old);
  }
  return *this;
}

template <class T>
void cs2list<T>::push_back(const T& v) {









}

template <class T>
void cs2list<T>::push_front(const T& v) {









}

template <class T>
void cs2list<T>::pop_back() {









}

template <class T>
void cs2list<T>::pop_front() {









}

template <class T>
typename cs2list<T>::iterator cs2list<T>::erase(iterator itr) {









}

template <class T>
typename cs2list<T>::iterator cs2list<T>::insert(iterator itr, T const& v) {









}

template <class T>
void cs2list<T>::copy_list(cs2list<T> const & old) {









}

template <class T>
void cs2list<T>::destroy_list() {









}

#endif
```