

# Linked Lists

Week 8

Gaddis: Chapter 17

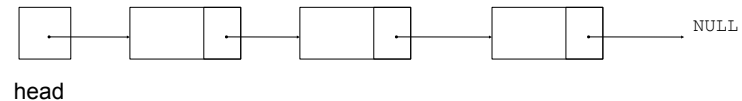
CS 5301  
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1

# Introduction to Linked Lists

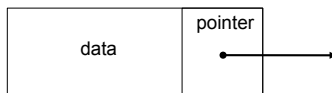
- A data structure representing a list
- A series of **dynamically allocated** nodes chained together in sequence
  - Each node points to one other node.
- A separate pointer (the head) points to the first item in the list.
- The last element points to nothing (NULL)



2

# Node Organization

- Each node contains:
  - data field – may be a structure, an object, etc.
  - a pointer – that can point to another node



- We use a struct to define the node type:

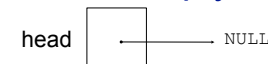
```
struct ListNode {  
    double value;  
    ListNode *next;  
};
```
- `next` can hold the address of a `ListNode`.
  - it can also be NULL

3

# Defining the Linked List variable

- Define a pointer for the head of the list:

```
ListNode *head = NULL; //NULL specifies end of list
```
- Now we have an empty linked list:
- NULL is equivalent to address 0
- to test a pointer for NULL (these are equivalent):



```
while (p) ... <==> while (p != NULL) ...
```

```
if (!p) ... <==> if (p == NULL) ...
```

Note: If you try to dereference a pointer whose value is NULL, you will get a runtime error. For example: `head->next` Check before you do this.

4

## Linked List operations

- Basic operations:
  - **create** a new, empty list
  - **append** a node to the end of the list
  - **insert** a node within the list
  - **delete** a node
  - **display** the linked list
  - **delete/destroy** the list

5

## Linked List class declaration

```
#include <cstddef> // for NULL
using namespace std;
class NumberList
{
private:
    struct ListNode // the node data type
    {
        double value; // data
        ListNode *next; // ptr to next node
    };
    ListNode *head; // the list head

public:
    NumberList() = { head = NULL; } //create empty list
    ~NumberList();

    void appendNode(double);
    void insertNode(double);
    void deleteNode(double);
    void displayList();
};
```

6

## Operation: append node to end of list

- appendNode: adds new node to end of list
- Algorithm:

Create a new node and store the data in it  
If the list has no nodes (it's empty)

Make head point to the new node.

Else

Find the last node in the list

Make the last node point to the new node

When defining list operations, always consider special cases:

- Empty list
- First element, front of the list (when head pointer is involved)

7

## appendNode: find last elem

- How to find the last node in the list?
- Algorithm:

Make a pointer p point to the first element  
while the node p points to has a NEXT node  
make p point to that node (the NEXT node of  
the node p currently points to)

- In C++:

```
ListNode *p = head;
while ((*p).next != NULL)
    p = (*p).next;
```

<==>

```
ListNode *p = head;
while (p->next)
    p = p->next;
```

p=p->next is like i++<sup>8</sup>

8

```

void NumberList::appendNode(double num) { in NumberList.cpp
    ListNode *newNode; // To point to the new node

    // Create a new node and store the data in it
    newNode = new ListNode;
    newNode->value = num;
    newNode->next = NULL;

    // If empty, make head point to new node
    if (head==NULL)
        head = newNode;

    else {
        ListNode *p; // To move through the list
        p = head; // initialize to start of list

        // traverse list to find last node
        while (p->next) //it's not last
            p = p->next; //make it pt to next

        // now p pts to last node
        // make last node point to newNode
        p->next = newNode;
    }
}

```

9

## Traversing a Linked List

- Visit each node in a linked list, to
  - display contents, sum data, test data, etc.
- Basic process:

set a pointer to point to what head points to  
 while pointer is not NULL  
     process data of current node  
     go to the next node by setting the pointer to  
         the next field of the current node  
 end while

10

## Operation: display the list

```

void NumberList::displayList() { in NumberList.cpp
    ListNode *p; //ptr to traverse the list

    // start p at the head of the list
    p = head;

    // while p pts to something (not NULL), continue
    while (p) {
        //Display the value in the current node
        cout << p->value << " ";

        //Move to the next node
        p = p->next;
    }
    cout << endl;
}

```

Or the short version:

```

void NumberList::displayList() {
    for (ListNode *p = head; p; p = p->next)
        cout << p->value << " ";
    cout << endl;
}

```

11

## Destroying a Linked List: destructor

- The destructor must “delete” (deallocate) all nodes used in the list
- To do this, use list traversal to visit each node:
  - save the address of the next node in a pointer
  - delete the node

```

NumberList::~NumberList() { in NumberList.cpp
    ListNode *p; // traversal ptr
    ListNode *n; // saves the next node

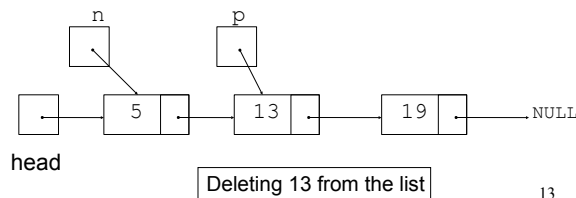
    p = head; //start at head of list
    while (p) {
        n = p->next; // save the next
        delete p; // delete current
        p = n; // advance ptr
    }
}

```

12

## Operation: delete a node from the list

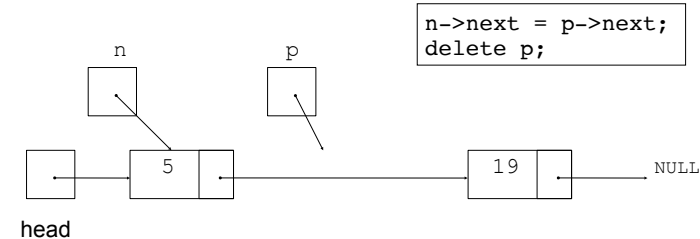
- deleteNode: removes node from list, and deletes (deallocates) the removed node.
- Requires two extra pointers:
  - one to point to the node to be deleted
  - one to point to the node before the node to be deleted.



13

## Deleting a node

- Change the pointer of the previous node to point to the node after the one to be deleted.
- Then just “delete” the p node



14

## Delete Node Algorithm

- Delete the node containing num

use p to traverse the list, until it points to num or NULL  
--as p is advancing, make n point to the node before it

if (p is not NULL) //found!

if (p==head) //it's the first node, and n is garbage  
make head point to the second element  
delete p's node (the first node)

else

make n's node point to what p's node points to  
delete p's node

else: . . . p is NULL, not found do nothing

15

## Linked List functions: deleteNode

```
void NumberList::deleteNode(double num) { in NumberList.cpp
    ListNode *p = head; // to traverse the list
    ListNode *n; // trailing node pointer (previous)

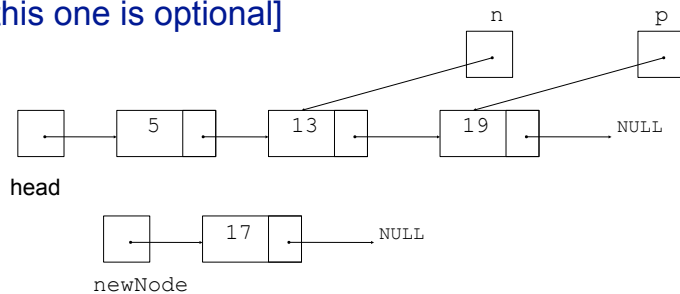
    // skip nodes not equal to num, stop at last
    while (p && p->value!=num) {
        n = p; // save it!
        p = p->next; // advance it
    }

    // p not null: num is found, set links + delete
    if (p) {
        if (p==head) { // p points to the first elem, n is garb
            head = p->next;
            delete p;
        } else { // n points to the predecessor
            n->next = p->next;
            delete p;
        }
    }
}
```

16

## Operation: insert a node into a linked list

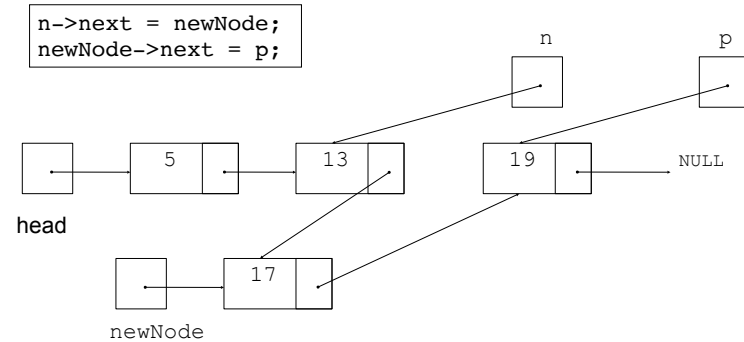
- Inserts a new node into the middle of a list.
- Uses two extra pointers:
  - one to point to node before the insertion point
  - one to point to the node after the insertion point [this one is optional]



17

## Inserting a Node into a Linked List

- Insertion completed:



18

## Insert Node Algorithm

- Insert node in a certain position

Create the new node, store the data in it

Use pointer p to traverse the list,

until it points to: node after insertion point or NULL

--as p is advancing, make n point to the node before

if p points to first node (p is head, n was not set)

make head point to new node

make new node point to p's node

else

make n's node point to new node

make new node point to p's node

Note: we will assume our list is sorted, so the insertion point is immediately before the first node that is larger than the number being inserted.

19

## insertNode code

```
void NumberList::insertNode(double num) {
    ListNode *newNode; // ptr to new node
    ListNode *p;       // ptr to traverse list
    ListNode *n;       // node previous to p
    //allocate new node
    newNode = new ListNode;
    newNode->value = num;

    // skip all nodes less than num
    p = head;
    while (p && p->value < num) {
        n = p; // save
        p = p->next; // advance
    }

    if (p == head) { //insert before first, or empty list
        head = newNode;
        newNode->next = p;
    }
    else { //insert after n
        n->next = newNode;
        newNode->next = p;
    }
}
```

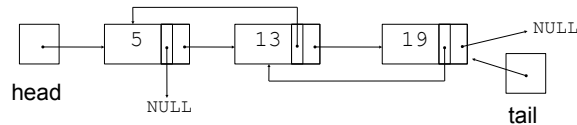
What if num is bigger than all items in the list?

20

## Linked List variations

- Doubly linked list
  - each node has two pointers, one to the next node and one to the previous node
  - head points to first element, tail points to last.

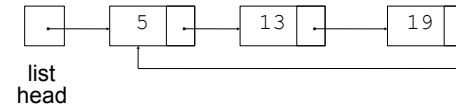
```
private:
// Structure for nodes
struct Node {
    int value; // Value in the node
    Node *prev; // Pointer to the previous node
    Node *next; // Pointer to the next node
};
Node *head; // Pointer to the first element
Node *tail; // Pointer to the last element
```



21

## Linked List variations

- Circular linked list
  - last cell's next pointer points to the first element.
  - no null pointers
  - every node has a successor



22

## Linked lists vs Arrays (pros and cons)

- A linked list can easily grow or shrink in size.
  - No maximum capacity required
  - No need to resize+copy when list reaches max size.
- When a value is inserted into or deleted from a linked list, no other nodes have to be moved.
- Arrays allow random access to elements: array[i] (linked lists require traversal to get i'th element).
- Arrays do not require extra storage for "links" (linked lists are impractical when the pointer value is bigger than data value).

23