CSCI 262
Data Structures

4 – Linked Lists, part 1

Overview

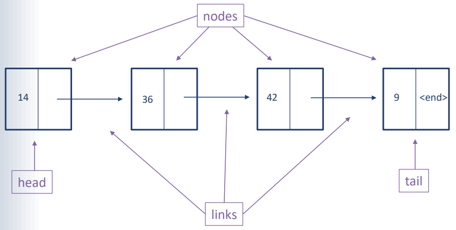
- Our first data structure: Linked List
- Practice some old (or recently new) concepts:
  - Pointers
  - Classes & objects
  - Encapsulation
- Introduces some new concepts at high level:
  - Dynamic memory allocation
  - Analysis of algorithms

We'll describe, create, and analyze a *very* simple linked list class in this lecture sequence.

Linked Lists

- A linked structure composed of *node* objects
  - Each node contains one data value
  - Each node contains a *pointer* to the next node
  - Nodes can be independently created/destroyed
    - …through the use of dynamic allocation – more soon!

Linked Lists Illustrated



This list contains {14,36,42,9}.

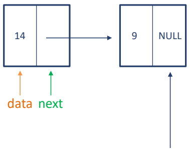
Node Class

Here's a very simple implementation of a node:

```
class node {
public:
    int   data;
    node* next;
};
```

Pointer to node, inside node!

Graphical representation



Note NULL pointer in tail node!
(Should use nullptr, but NULL fit better.)

Creating Nodes

Where do nodes come from…?

Don't worry about *where* just yet, but here's *how* we do it:

```
node* ptr = new node;
```

Declare a pointer variable (of type pointer to node)

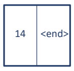
Create (*dynamically allocate*) a node object.

new is a C++ keyword. You can't use it as a variable name, etc.

Make a Linked List

```
class node {
public:
    int   data;
    node* next;
};

int main() {
    node* head;
    head = new node;
    head->data = 14;
    head->next = nullptr;
}
```

We just made this:



CS@Mines

Make a Linked List

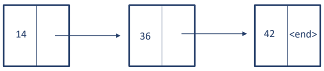
```
class node {
public:
    int   data;
    node* next;
};

int main() {
    node* head;
    head = new node;
    head->data = 14;
    head->next = nullptr;
}
```

The -> operator lets us dereference the pointer head and access the member variables of the node pointed to in one step.
`head->data`
is equivalent to
`(*head).data`

CS@Mines

Making it Longer

```
int main() {
    node* head;
    head = new node;
    head->data = 14;
    head->next = new node;
    head->next->data = 36;
    head->next->next = new node;
    head->next->next->data = 42;
    head->next->next->next = nullptr;
}
```



CS@Mines

Print List

Let's print our list.

Remember, head is a pointer to our first node.

Stopping condition: remember the tail node's next pointer is set to nullptr.

```
…
 for (node* p = head; p != nullptr; p = p->next) {
    cout << p->data << endl;
 }
```

This is how you advance in a linked list. No indexes!

The pointer p moves down the list, pointing to each node in turn.

CS@Mines

Why linked lists?

INTERLUDE

CS@Mines

Why Linked Lists

Seems overly complex: why not just use a vector?

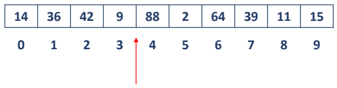
It's all about trade-offs:

- Vectors are built on arrays
  - On the plus side: *random access*!
    - Low cost to get/set values at a particular *index*
  - However:
    - (Relatively) difficult to grow and shrink
    - Insert/remove operations expensive
- Linked lists built on independent nodes
  - Grow/shrink trivial
  - Insert/remove inexpensive-ish
  - However, we lose random access

CS@Mines

Thought Exercise

What is involved in inserting a value at some index in an array?



E.g., insert the value 27 before value 88.

Do you think it is easier or harder with a linked list?

CS@Mines

OPERATIONS

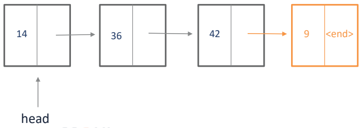
CS@Mines

Linked List Operations: add

Making a linked list like we did a few slides ago seems a bit silly…

Let's do it smarter with a function:

- Start with existing list
- Create new node containing requested value
- Add to end



CS@Mines

Linked List Operations: add

```
void add_to_tail(node* head, int val) {
    // start from head, travel down links to find tail.
    node *ptr = head;
    while (ptr->next != nullptr)
        ptr = ptr->next;

    // ptr now points to tail node
    ptr->next = new node;
    ptr->next->data = val;
    ptr->next->next = nullptr;
}
```

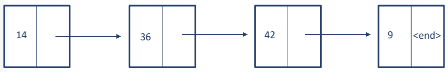
Note the pattern here; like in our previous for loop, `ptr = ptr->next` advances us to the following node. Note this time we stop one step earlier, before ptr = nullptr.

Hm, this would be even easier if we kept a pointer to the *tail* node as well as the head node…

CS@Mines

Making a Linked List (Do-over)

```
int main() {
    node* head = new node;
    head->data = 14;
    head->next = nullptr;

    add_to_tail(head, 36);
    add_to_tail(head, 42);
    add_to_tail(head, 9);
}
```



CS@Mines

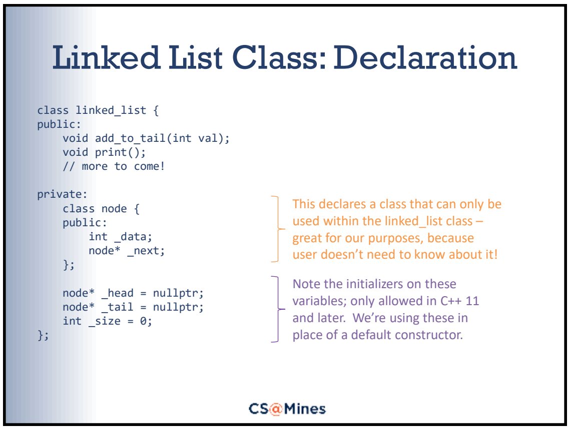
Encapsulating Linked List

Before we add more operations, we should probably make a class.

Advantages:

- Keep track of head/tail pointers so user doesn't have to
- Prevent user from accidentally messing up list structure
- Keep useful metadata (e.g., size)
- *Encapsulate* data with operations on the data

CS@Mines

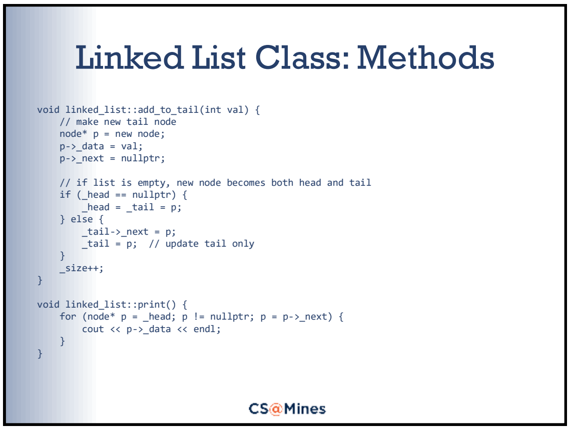


Linked List Class: Declaration

```
class linked_list {
public:
    void add_to_tail(int val);
    void print();
    // more to come!

private:
    class node {
    public:
        int _data;
        node* _next;
    };

    node* _head = nullptr;
    node* _tail = nullptr;
    int _size = 0;
};
```

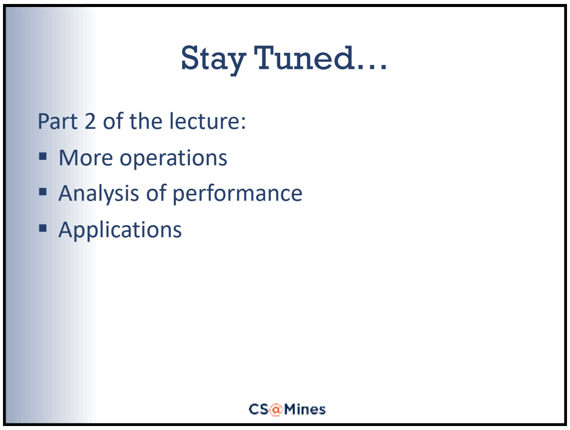
This declares a class that can only be used within the linked_list class – great for our purposes, because user doesn’t need to know about it!

Note the initializers on these variables; only allowed in C++ 11 and later. We’re using these in place of a default constructor.



Linked List Class: Methods

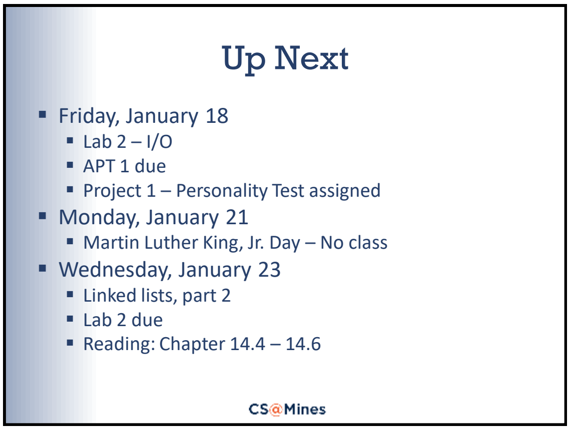
```
void linked_list::add_to_tail(int val) {
    // make new tail node
    node* p = new node;
    p->_data = val;
    p->_next = nullptr;

    // if list is empty, new node becomes both head and tail
    if (_head == nullptr) {
        _head = _tail = p;
    } else {
        _tail->_next = p;
        _tail = p;  // update tail only
    }
    _size++;
}

void linked_list::print() {
    for (node* p = _head; p != nullptr; p = p->_next) {
        cout << p->_data << endl;
    }
}
```



Stay Tuned…

Part 2 of the lecture:

- More operations
- Analysis of performance
- Applications



Up Next

- Friday, January 18
  - Lab 2 – I/O
  - APT 1 due
  - Project 1 – Personality Test assigned
- Monday, January 21
  - Martin Luther King, Jr. Day – No class
- Wednesday, January 23
  - Linked lists, part 2
  - Lab 2 due
  - Reading: Chapter 14.4 – 14.6