CS 103 Unit 15

Doubly-Linked Lists and Deques

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Singly-Linked List Review

- Used structures/classes and pointers to make ‘linked’ data structures
- Singly-Linked Lists dynamically allocates each item when the user decides to add it.
- Each item includes a 'next' pointer holding the address of the following Item object
- **Traversal and iteration is only easily achieved in one direction**

```cpp
#include <iostream>
using namespace std;

struct Item {
    int val;
    Item* next;
};

class List {
    public:
        List();
        ~List();
        void push_back(int v); ...
    private:
        Item* head;
};
```

Given temp...could you ever recover the address of the previous item?

No!!!
Doubly-Linked Lists

- Includes a previous pointer in each item so that we can traverse/iterate backwards or forward
- First item's previous field should be NULL
- Last item's next field should be NULL

```cpp
#include<iostream>
using namespace std;

struct DLItem {
    int val;
    DLItem* prev;
    DLItem* next;
};

class DLList {
public:
    DLList();
    ~DLList();
    void push_back(int v);
private:
    DLItem* head;
};
```
Doubly-Linked List Add Front

- Adding to the front requires you to update...
- ...Answer
  - Head
  - New front's next & previous
  - Old front's previous
Doubly-Linked List Add Front

- Adding to the front requires you to update...
  - Head
  - New front's next & previous
  - Old front's previous
Doubly-Linked List Add Middle

• Adding to the middle requires you to update...
  – Previous item's next field
  – Next item's previous field
  – New item's next field
  – New item's previous field
Doubly-Linked List Add Middle

- Adding to the middle requires you to update...
  - Previous item's next field
  - Next item's previous field
  - New item's next field
  - New item's previous field
Doubly-Linked List Remove Middle

- Removing from the middle requires you to update...
  - Previous item's next field
  - Next item's previous field
  - Delete the item object
Doubly-Linked List Remove Middle

- Removing from the middle requires you to update...
  - Previous item's next field
  - Next item's previous field
  - Delete the item object
DEQUES AND THEIR IMPLEMENTATION
Understanding Performance

- Recall vectors are good at some things and worse at others in terms of performance.
  - **The Good:**
    - Fast access for random access (i.e. indexed access such as myvec[6])
    - Allows for ‘fast’ addition or removal of items at the back of the vector.
  - **The Bad:**
    - Erasing / removing item at the front or in the middle (it will have to copy all items behind the removed item to the previous slot).
    - Adding too many items (vector allocates more memory that needed to be used for additional push_back()’s…but when you exceed that size it will be forced to allocate a whole new block of memory and copy over every item.

![Diagram showing vector operations](vector-diagram.png)
Deque Class

• Double-ended queues (like their name sounds) allow for efficient (fast) additions and removals from either 'end' (*front or back*) of the list/queue

• Performance:
  – Slightly slower at random access (i.e. array style indexing access such as: `data[3]`) than vector
  – Fast at adding or removing items at *front or back*
Deque Class

- Similar to vector but allows for `push_front()` and `pop_front()` options
- Useful when we want to put things in one end of the list and take them out of the other

```cpp
#include <iostream>
#include <deque>
using namespace std;

int main()
{
    deque<int> my_deq;
    for(int i=0; i < 5; i++){
        my_deq.push_back(i+50);
    }
    cout << "At index 2 is: " << my_deq[2] ;
    cout << endl;

    for(int i=0; i < 5; i++){
        int x = my_deq.front();
        my_deq.push_back(x+10);
        my_deq.pop_front();
    }
    while( !my_deq.empty() ){
        cout << my_deq.front() << " ";
        my_deq.pop_front();
    }
    cout << endl;
}
```
Deque Implementation

• Let's consider how we can implement a deque
• Could we use a singly-linked list and still get fast [i.e. O(1)] insertion/removal from both front and back?
Singly-Linked List Deque

• Recall a deque should allow for fast [i.e. \(O(1)\)] addition and removal from front or back
• In our current singly-linked list we only know where the front is and would have to traverse the list to find the end (tail)
Option 1: Singly-Linked List + Tail Pointer

• We might think of adding a tail pointer data member to our list class
  – How fast could we add an item to the end?
Option 1: Singly-Linked List + Tail Pointer

- We might think of adding a tail pointer data member to our list class
  - How fast could we add an item to the end? \( O(1) \)
  - How fast could we remove the tail item?
Option 1: Singly-Linked List + Tail Pointer

- We might think of adding a tail pointer data member to our list class
  - How fast could we add an item to the end? O(1)
  - How fast could we remove the tail item? O(n)
- Would have to walk to the 2\textsuperscript{nd} to last item
Option 2: Tail Pointer + Double-Linked List

- We might think of adding a tail pointer data member to our list class
  - How fast could we add an item to the end?
Option 2: Tail Pointer + Double-Linked List

- We might think of adding a tail pointer data member to our list class
  - How fast could we add an item to the end? $O(1)$
  - How fast could we remove the tail item?
Option 2: Tail Pointer + Double-Linked List

• We might think of adding a tail pointer data member to our list class
  – How fast could we add an item to the end? O(1)
  – How fast could we remove the tail item? O(1)

• We use the PREVIOUS pointer to update tail
Option 2: Tail Pointer + Double-Linked List

• We might think of adding a tail pointer data member to our list class
  – How fast could we add an item to the end? O(1)
  – How fast could we remove the tail item? O(1)
• We use the PREVIOUS pointer to update tail
Option 3: Circular Double-Linked List

- Make first and last item point at each other to form a circular list
  - We know which one is first via the 'head' pointer
Option 3: Circular Double-Linked List

- Make first and last item point at each other to form a circular list
  - We know which one is first via the 'head' pointer
  - What expression would yield the tail item?

```
head
0x148
```

```
prev  val  next
0x210 3  0x1c0
```
```
prev  val  next
0x148 9  0x210
```
```
prev  val  next
0x1c0 6  0x148
```
Option 3: Circular Double-Linked List

- Make first and last item point at each other to form a circular list
  - We know which one is first via the 'head' pointer
  - What expression would yield the tail item?
    - head->prev
One Last Point

• Can this kind of deque implementation support $O(1)$ access to element $i$?
  – i.e. Can you access list[$i$] quickly for any $i$?
• No!!! Still need to traverse the list
• You can use a "circular" array based deque implementation to get fast random access
  – This is similar to what the actual C++ deque<T> class does
  – More to come in CS 104!
Activity: Write a 'delist' class

• Write a 'double-ended list' class to store integers that mimics a deque
• Support the following methods
  – size()
  – empty()
  – push_back() and pop_back()
  – push_front() and pop_front()
  – back() and front()  [returns back or front integer]