

Stacks and Queues

Week 9

Gaddis: Chapter 18

CS 5301
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Introduction to the Stack

- **Stack**: a data structure that holds a collection of elements of the same type.
 - The elements are accessed according to LIFO order: last in, first out
 - No random access to other elements
- **Examples**:
 - plates in a cafeteria
 - bangles . . .

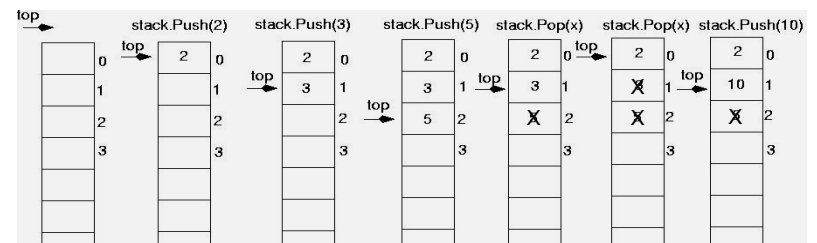
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Stack Operations

- **Operations**:
 - **push**: add a value onto the top of the stack
 - make sure it's not full first.
 - **pop**: remove (and return) the value from the top of the stack
 - make sure it's not empty first.
 - **isFull**: true if the stack is currently full, i.e., has no more space to hold additional elements
 - **isEmpty**: true if the stack currently contains no elements

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Stack illustrated



```
int item;
stack.push(2);
stack.push(3);
stack.push(5);
item = stack.pop(); //item is 5
item = stack.pop(); //item is 3
stack.push(10);
```

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Implementing a Stack Class

- Array implementations:
 - fixed size (static) arrays: size doesn't change
 - dynamic arrays: can resize as needed in push
- Linked List
 - grow and shrink in size as needed
- Templates
 - any of the above can be implemented using templates

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A static stack class

```
class IntStack
{
private:
    const int STACKSIZE = 100; // The stack size
    int stackArray[STACKSIZE]; // The stack array
    int top; // Index to the top of the stack

public:
    // Constructor
    IntStack() { top = -1; } // empty stack

    // Stack operations
    void push(int);
    int pop();
    bool isFull() const;
    bool isEmpty() const;
};
```

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A static stack class: push&pop

```
/**
 * Member function push pushes the argument onto
 * the stack.
 */
```

```
void IntStack::push(int num)
{
    assert(!isFull());

    top++;
    stackArray[top] = num;
}
```

assert will abort the program
if its argument evaluates to false

```
/**
 * Member function pop pops the value at the top
 * of the stack off, and returns it.
 */
```

```
int IntStack::pop()
{
    assert(!isEmpty());

    int num = stackArray[top];
    top--;
    return num;
}
```

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A static stack class: functions

```
/**
 * Member function isFull returns true if the stack
 * is full, or false otherwise.
 */
```

```
bool IntStack::isFull() const
{
    return (top == stackSize - 1);
}
```

```
/**
 * Member function isEmpty returns true if the stack
 * is empty, or false otherwise.
 */
```

```
bool IntStack::isEmpty() const
{
    return (top == -1);
}
```

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A Dynamic Stack Class: Linked List implementation

- Push and pop from the head of the list:

```

/*****
// Member function push pushes the argument onto *
// the stack. *
/*****

```

```

void IntStack2::push(int num)
{
    assert(!isFull());

    Node *temp=new Node;
    temp->data = num;

    //insert at head of list
    temp->next = head;
    head = temp;
}

```

```

private:
    struct Node {
        int data;
        Node* next;
    };
    Node* head; // ptr to top

```

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A Dynamic Stack Class: Linked List implementation

- Push and pop from the head of the list:

```

/*****
// Member function pop pops the value at the top *
// of the stack off, and returns it. *
/*****

```

```

int IntStack2::pop()
{
    assert(!isEmpty());

    int result = head->data;
    Node * temp = head;
    head = head->next;
    delete temp;
    return result;
}

```

```

private:
    struct Node {
        int data;
        Node* next;
    };
    Node* head; // ptr to top

```

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Introduction to the Queue

- Queue: a data structure that holds a collection of elements of the same type.
 - The elements are accessed according to FIFO order: first in, first out
 - No random access to other elements
- Examples:
 - people in line at a theatre box office
 - restocking perishable inventory

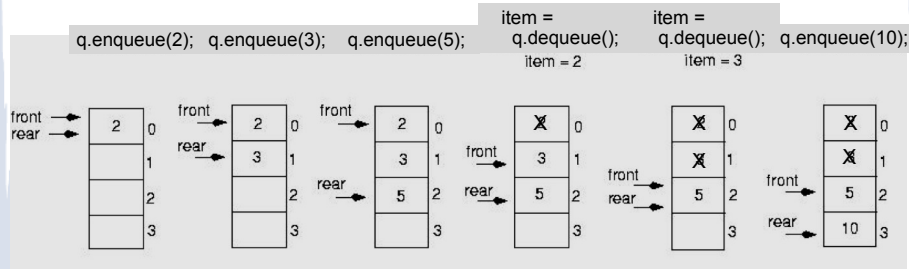
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Queue Operations

- Operations:
 - enqueue: add a value onto the rear of the queue (the end of the line)
 - make sure it's not full first.
 - dequeue: remove a value from the front of the queue (the front of the line) "Next!"
 - make sure it's not empty first.
 - isFull: true if the queue is currently full, i.e., has no more space to hold additional elements
 - isEmpty: true if the queue currently contains no elements

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Queue illustrated



Note: front and rear are variables used by the implementation to carry out the operations

```
int item;
q.enqueue(2);
q.enqueue(3);
q.enqueue(5);
item = q.dequeue(); //item is 2
item = q.dequeue(); //item is 3
q.enqueue(10);
```

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Implementing a Queue Class

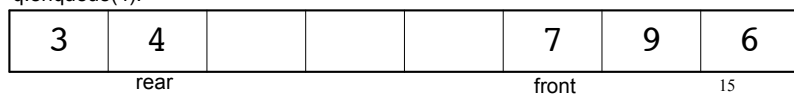
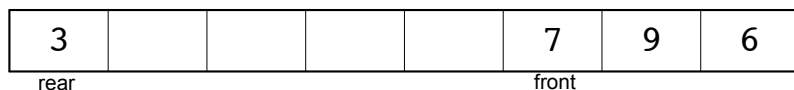
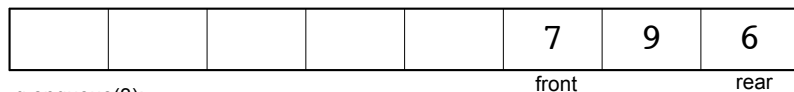
Same as for Stacks:

- Array implementations:
 - fixed size (static) arrays: size doesn't change
 - dynamic arrays: can resize as needed in enqueue
- Linked List
 - grow and shrink in size as needed
- Templates
 - any of the above can be implemented using templates

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Implementing a Queue Class

- When front and rear indices move in the array:
 - problem: rear hits end of array quickly
 - solution: wrap index around to front of array



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Implementing a Queue Class

- To "wrap" the rear index back to the front of the array, you can use this code to increment rear during enqueue:

```
if (rear == queueSize-1)
    rear = 0;
else
    rear = rear+1;
```

- The following code is equivalent, but shorter (assuming $0 \leq \text{rear} < \text{queueSize}$):

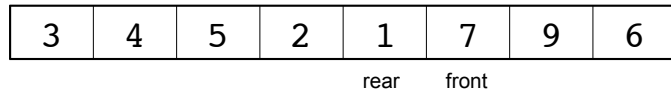
```
rear = (rear + 1) % queueSize;
```

- Do the same for advancing the front index.

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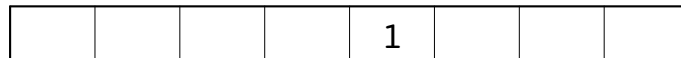
Implementing a Queue Class

- When is it full? $(rear+1)\%queueSize==front$

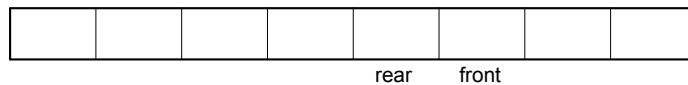


- When is it empty? $(rear+1)\%queueSize==front$

one element left:



no elements left, front passes rear:



- Don't use rear and front to determine if the queue is full or empty!!

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A static queue class

```
class IntQueue
{
private:
    const int QUEUE_SIZE = 100; // capacity of the queue
    int queueArray[QUEUE_SIZE]; // The queue array
    int front; // Subscript of the queue front
    int rear; // Subscript of the queue rear
    int numItems; // Number of items in the queue
public:
    // Constructor
    IntQueue() { front = 0; rear = -1; numItems = 0; }

    // Queue operations
    void enqueue(int);
    int dequeue();
    bool isEmpty() const;
    bool isFull() const;
};
```

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A static queue: enqueue/dequeue

```

//*****
// Enqueue inserts a value at the rear of the queue. *
//*****

void IntQueue::enqueue(int num)
{
    assert(!isFull());

    rear = (rear + 1) % QUEUE_SIZE;
    queueArray[rear] = num;
    numItems++;
}

//*****
// Dequeue removes the value at the front of the *
// queue and returns the value. *
//*****

int IntQueue::dequeue()
{
    assert(!isEmpty());

    int result = queueArray[front];
    front = (front + 1) % QUEUE_SIZE;
    numItems--;
    return result;
}
```

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A static queue class: functions

```

//*****
// isEmpty returns true if the queue is empty *
//*****

bool IntQueue::isEmpty() const {
    return (numItems == 0);
}

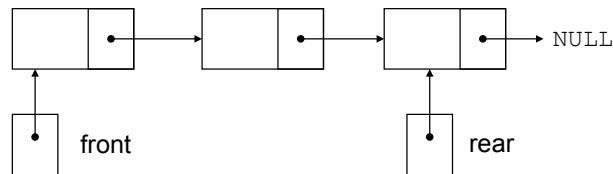
//*****
// isFull returns true if the queue is full *
//*****

bool IntQueue::isFull() const {
    return (numItems == QUEUE_SIZE);
}
```

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A Dynamic Queue Class: Linked List implementation

- Use pointers `front` and `rear` to point to first and last elements of the list:



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A Dynamic Queue Class: Linked List implementation

- Enqueue at the rear of the list, dequeue from the front:

```

//*****
// Enqueue inserts a value at the rear of the queue. *
//*****

void IntQueue2::enqueue(int num)
{
    assert(!isFull());

    Node *temp=new Node;
    temp->data = num;
    temp->next = NULL;

    //append to rear of list, reset rear
    if (isEmpty())
        front = rear = temp;
    else {
        rear->next = temp;
        rear = temp;
    }
}
    
```

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A Dynamic Queue Class: Linked List implementation

- Enqueue at the rear of the list, dequeue from the front:

```

//*****
// Dequeue removes the value at the front of the *
// queue and returns the value. *
//*****

int IntQueue2::dequeue()
{
    assert(!isEmpty());

    int value = front->data;

    // remove the first node (front)
    Node *temp = front;
    front = front->next;
    delete temp;

    return value;
}
    
```

```

private:
    struct Node {
        int data;
        Node* next;
    };
    Node* front; // ptr to first
    Node* rear; // ptr to last
    
```

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Sample Problems

Stack Copy Constructor : Modify the `DynIntStack` from the textbook (or your answer to Programming Challenge 2, Dynamic Stack Template) to add a copy constructor.

Queue Copy Constructor : Modify the `DynIntQueue` from the textbook (or your answer to Programming Challenge 4, Dynamic Queue Template) to add a copy constructor.

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