

Stacks and Queues

Unit 6

Chapter 18

CS 2308
Spring 2017

Jill Seaman

1

Abstract Data Type

- A data type for which:
 - only the properties of the data and the operations to be performed on the data are specific,
 - how the data will be represented or how the operations will be implemented is unspecified.
- An ADT may be implemented using various specific data types or data structures, in many ways and in many programming languages.
- Examples:
 - NumberList (implemented using linked list **or** array)
 - string class (not sure how it's implemented) ²

Introduction to the Stack

- Stack: an abstract data type 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 or trays in a cafeteria
 - bangles . . .

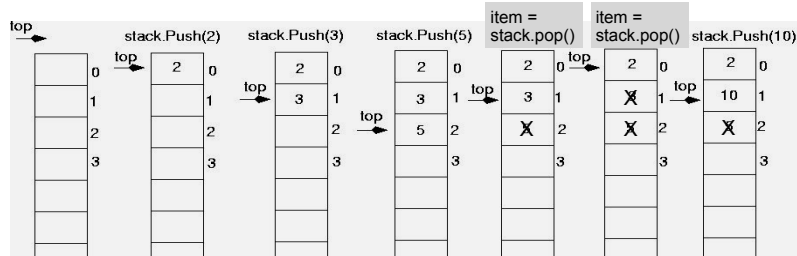
3

Stack Operations

- Operations:
 - push: add a value onto the top of the stack
 - make sure it's not full first.
 - pop: remove a 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

4

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);
```

5

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

6

IntStack: A stack class

```
class IntStack
{
private:
    static const int STACK_SIZE = 100; // The stack size
    int stackArray[STACK_SIZE]; // 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;
};
```

7

IntStack: push

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

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

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

Stack Overflow: attempting to push onto a full stack.

assert will abort the program if its argument evaluates to false. it requires `#include <cassert>`

The driver should ensure that the assert condition is always true before push is called.

8

IntStack: pop

```
//*****  
// Member function pop pops the value at the top *  
// of the stack off, and returns it as the result. *  
//*****  
  
int IntStack::pop()  
{  
    assert (!isEmpty());  
  
    int num = stackArray[top];  
    top--;  
    return num;  
}
```

Stack Underflow: attempting to pop from an empty stack.

The driver should ensure that the assert condition is always true before pop is called.

9

IntStack: test functions

```
//*****  
// Member function isFull returns true if the stack *  
// is full, or false otherwise. *  
//*****  
  
bool IntStack::isFull() const  
{  
    return (top == STACK_SIZE - 1);  
}  
  
//*****  
// Member function isEmpty returns true if the stack *  
// is empty, or false otherwise. *  
//*****  
  
bool IntStack::isEmpty() const  
{  
    return (top == -1);  
}
```

10

IntStack: driver

```
#include<iostream>  
using namespace std;  
  
#include "IntStack.h"  
  
int main() {  
  
    // set up the stack  
    IntStack stack;  
    stack.push(2);  
    stack.push(3);  
    stack.push(5);  
    int x;  
    x = stack.pop();  
    x = stack.pop();  
    stack.push(10);  
    cout << x << endl;  
  
}
```

What is output?

What is left on the stack when the driver is done?

11

Introduction to the Queue

- **Queue:** an abstract data type 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
 - print jobs sent to a (shared) printer

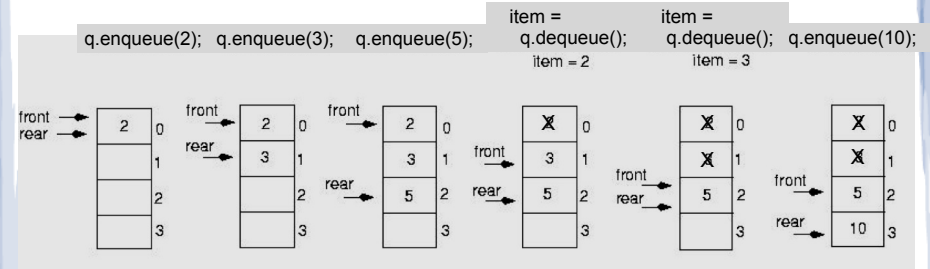
12

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

13

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);
```

14

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

15

Implementing a Queue class

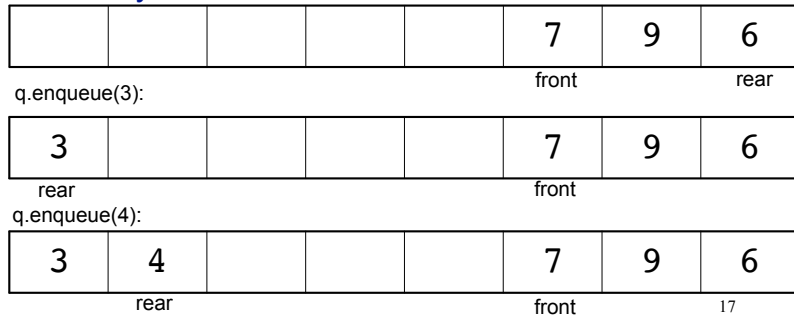
issues using a fixed length array

- The previous illustration assumed we were using an array to implement the queue
- When an item was dequeued, the items were NOT shifted up to fill the slot vacated by dequeued item
 - why not?
- Instead, both front and rear indices move through the array.

16

Implementing a Queue Class

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



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;
```

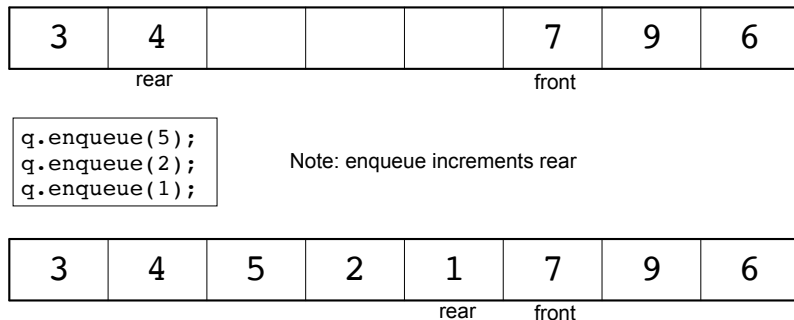
- The following code is equivalent, but shorter (assuming $0 \leq \text{rear} < \text{queueSize}$):

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

- Do the same for advancing the front index.

Implementing a Queue Class

- When is it full?



- It's full:

$$(\text{rear}+1)\% \text{queueSize} == \text{front}$$

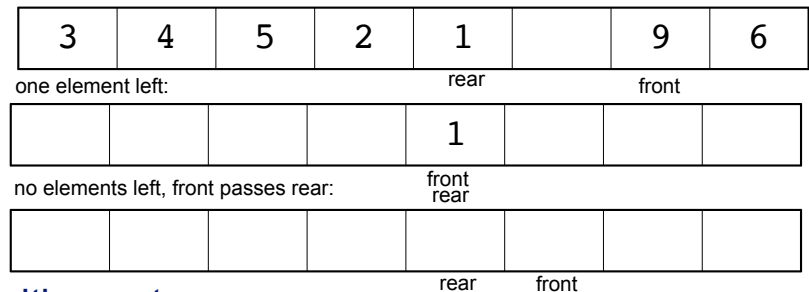
Implementing a Queue Class

- When is it empty?

```
int x;
for (int i=0; i<queueSize;i++)
    x = q.dequeue();
```

Note: dequeue increments front

after the first one:



- It's empty:

$$(\text{rear}+1)\% \text{queueSize} == \text{front}$$

Implementing a Queue Class

- When is it full? $(rear+1)\%queueSize==front$
- When is it empty? $(rear+1)\%queueSize==front$
- How do we define isFull and isEmpty?
 - Use a counter variable, numItems, to keep track of the total number of items in the queue.
- enqueue: numItems++
- dequeue: numItems--
- isEmpty is true when numItems == 0
- isFull is true when numItems == queueSize

21

IntQueue: a queue class

```
class IntQueue
{
private:
    static const int QUEUE_SIZE = 100; //The queue size
    int queueArray[QUEUE_SIZE]; // The queue array
    int front; // Subscript of the front elem
    int rear; // Subscript of the rear elem
    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();
    bool isFull();
};
```

Why front=0; rear=-1;?

The first enqueue increments rear and puts element at position 0 (now front==rear==0). The first dequeue removes element at front (position 0).

22

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; //calc new position
    queueArray[rear] = num; //insert new item
    numItems++; //update count
}

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

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

    int result = queueArray[front]; //retrieve front item
    front = (front + 1) % QUEUE_SIZE; //calc new position
    numItems--; //update count
    return result;
}
```

23

IntQueue: test functions

```
//*****
// isEmpty returns true if the queue is empty, *
// otherwise false. *
//*****

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

//*****
// isFull returns true if the queue is full, otherwise *
// false. *
//*****

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

24

IntQueue: driver

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

#include "IntQueue.h"

int main() {

    // set up the queue
    IntQueue q;
    int item;
    q.enqueue(2);
    q.enqueue(3);
    q.enqueue(5);
    item = q.dequeue();
    item = q.dequeue();
    q.enqueue(10);
    cout << item << endl;

}
```

What is output?

What is left on the queue when the driver is done?

25

A Dynamic Stack Class: Linked List implementation

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

public:
    // Constructor
    DynIntStack() { head = NULL; } // empty stack

    // Stack operations
    void push(int);
    int pop();
    bool isFull() const { return false; }
    bool isEmpty() const { return head == NULL; }
};
```

head points to top element.
add and remove at front of list

26

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 DynIntStack::push(int num)
{
    assert(!isFull());

    Node *temp = new Node; //allocate new node
    temp->data = num;

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

27

A Dynamic Stack Class: Linked List implementation

- Push and pop from the head of the list:

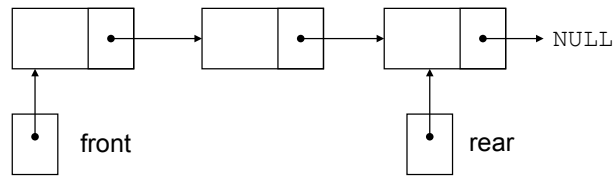
```
/**
// Member function pop pops the value at the top *
// of the stack off, and returns it.
**
int DynIntStack::pop()
{
    assert(!isEmpty());

    int result = head->data; //retrieve front item
    Node * temp = head;
    head = head->next; //head points to second item
    delete temp; //deallocate front item
    return result;
}
```

28

A Dynamic Queue Class: Linked List implementation

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



29

A Dynamic Queue Class: Linked List implementation

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

public:
    // Constructor
    DynIntQueue() { front = NULL; rear = NULL; }

    // Queue operations
    void enqueue(int);
    int dequeue();
    bool isFull() const { return false; }
    bool isEmpty() const { return front == NULL; }
};
```

30

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 DynIntQueue::enqueue(int num)
{
    assert(!isFull());

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

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

31

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 DynIntQueue::dequeue()
{
    assert(!isEmpty());

    int value = front->data;    //retrieve front item

    Node *temp = front;
    front = front->next;    //front points to 2nd item
    delete temp;            //deallocate removed item

    return value;
}
```

32