Stacks and Queues

Unit 6

Chapter 18

CS 2308
Fall 2016

Jill Seaman

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)

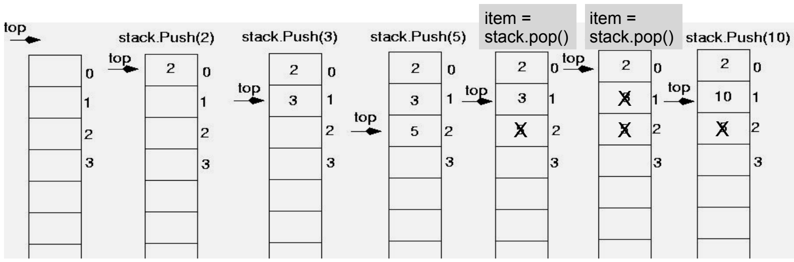
Introduction to the Stack

- 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 . . .

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

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);
```


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

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;
};
```


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.

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.

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);
}
```


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?

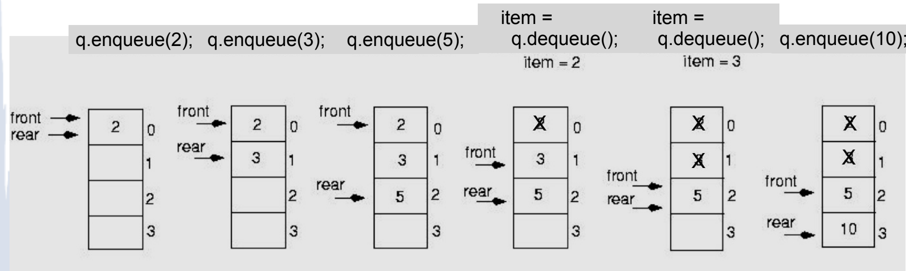
Introduction to the Queue

- 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

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

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);
```


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

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.

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

					7	9	6
					front		rear

q.enqueue(3):

3					7	9	6
rear					front		

q.enqueue(4):

3	4				7	9	6
	rear				front		

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 <= rear < queueSize):

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

- Do the same for advancing the front index.

Implementing a Queue Class

- When is it full?

3	4				7	9	6
	rear				front		

```
q.enqueue(5);
q.enqueue(2);
q.enqueue(1);
```

Note: enqueue increments rear

3	4	5	2	1	7	9	6
				rear	front		

- It's full:

  (rear+1)%queueSize==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:

3	4	5	2	1		9	6
				rear		front	

one element left:

				1			
				front rear			

no elements left, front passes rear:

				rear	front		

- It's empty:

  (rear+1)%queueSize==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

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).

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) % QUEUESIZE;  //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) % QUEUESIZE; //calc new position
    numItems—;                       //update count
    return result;
}
```


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);
}
```

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?

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

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;
}
```


A Dynamic Stack Class:
Linked List implementation

- Push and pop from the head of the list:

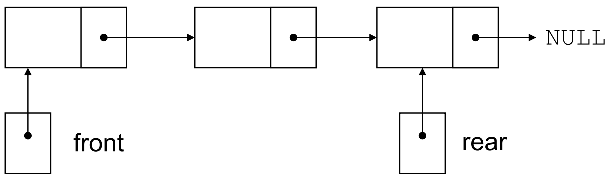
```
//*******************************************************
// Member function pop pops the value at the top       *
// of the stack off, and returns it.                   *
//*******************************************************

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;
}
```

A Dynamic Queue Class:
Linked List implementation

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



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; }
};
```


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
    }
}
```


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;
}
```