ADTs: 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 . . .

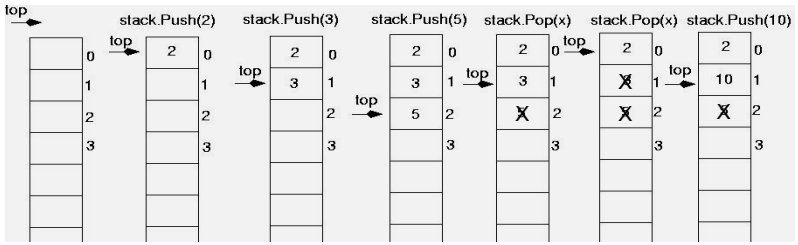
Stack Operations

- 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

Stack Terms

- Stack overflow:
  - trying to push an item onto a full stack
- Stack underflow.
  - trying to pop an item from an empty stack

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);
```


Stack Applications

- Easily reverse the order of a list of items.
  - push all the items, then pop while not empty.
- Evaluate an expression in postfix notation.
  - 4 5 + 7 2 - * is equivalent to (4+5)*(7-2)
  - push numbers, when operator encountered, pop top two values, apply operator, push result.
- Matching brackets in a text file
  - if (x==list.getCurrent()) { z[i] = x; count++; }
- Implement nested function calls and returns.

Implementing a Stack Class

- Array implementations:
  - fixed size 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

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();

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

A static stack class: functions

```
//*********************************************
// Constructor                                *
// This constructor creates an empty stack.   *
//*********************************************

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


//no need to initialize the static array stackArray
```


A static stack class: push

```
//*********************************************
// 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

A static stack class: pop

```
//*************************************************
// 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;
}
```


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);
}
```

A Dynamic Stack Class:
Linked List implementation

- Push and pop from the head of the list, for example:

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

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

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

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

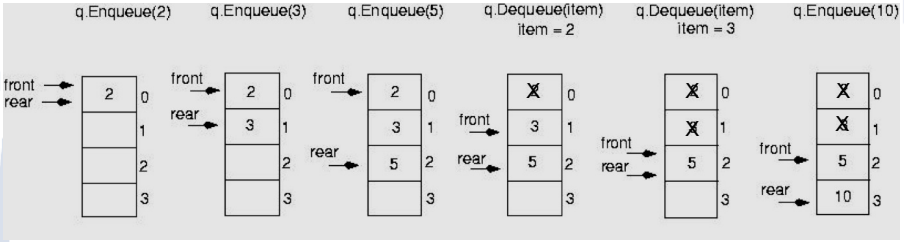

Introduction to the Queue

- 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

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);
```

Queue Applications

- The best applications of queues involve multiple processes.
- For example, imagine the print queue for a computer lab.
- Any computer can add a new print job to the queue (enqueue).
- The printer performs the dequeue operation and starts printing that job.
- While it is printing, more jobs are added to the Q
- When the printer finishes, it pulls the next job from the Q, continuing until the Q is empty

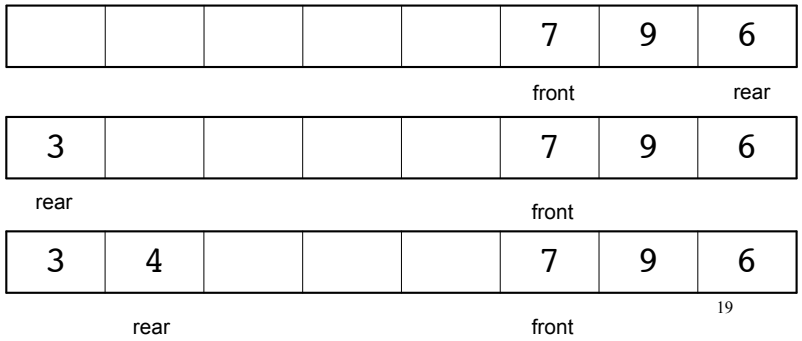
Queue implemented

- Just like stacks, queues can be implemented using arrays (fixed size, or resizing dynamic arrays) or linked lists (dynamic queues).
- 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 in the array.

Queue implemented

problem: end of the array

- When front and rear indices move in the array:
  - problem: rear hits end of array quickly
  - solution: 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;
```

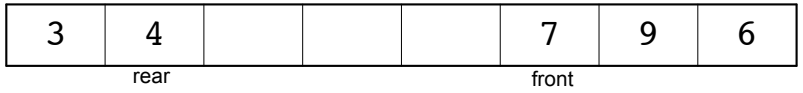
- The following code is equivalent, but shorter (assuming 0 <= rear < queueSize):

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

- Do the same for advancing the front index.

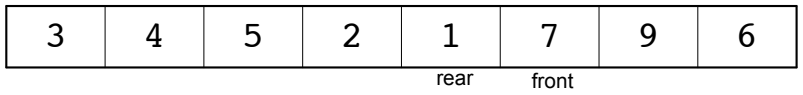
Implementing a Queue Class

- When is it full?




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

Note: enqueue increments rear



- It's full:

(rear+1)%queueSize==front

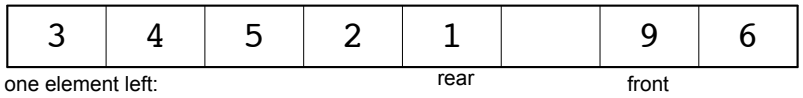
Implementing a Queue Class

- When is it empty?

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

Note: dequeue increments front

after the first one:



one element left:

no elements left, front passes rear:

- 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

A static queue class

```
class IntQueue
{
private:
   const int QUEUESIZE = 100;  // capacity of the queue
   int queueArray[QUEUESIZE];  // 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();

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

A static queue class: functions

```
//*****************************************************
// Creates an empty queue of a specified size.        *
//*****************************************************

IntQueue::IntQueue()
{
   front = 0;              // set up bookkeeping
   rear = -1;
   numItems = 0;
}
```


A static queue class: enqueue

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

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

    // Calculate the new rear position
    rear = (rear + 1) % queueSize;

    // Insert new item
    queueArray[rear] = num;

    // Update item count
    numItems++;
}
```


A static queue class: dequeue

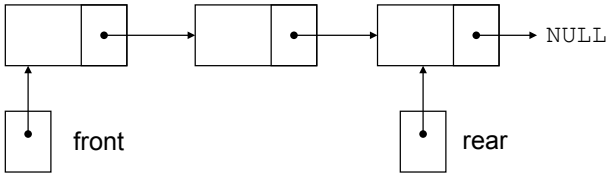
```
//*****************************************************
// Dequeue removes the value at the front of the      *
// queue and returns the value.                       *
//*****************************************************

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

    //save the result to return
    int result = queueArray[front];

    // Advance front
    front = (front + 1) % queueSize;

    // Update item count
    numItems--;

    // Return the front item
    return result;
}
```


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 == queueSize);
}
```

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

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

    int value = front->data;

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

    return value;
}
```