Stacks and Queues

Week 9

Gaddis: Chapter 18

CS 5301
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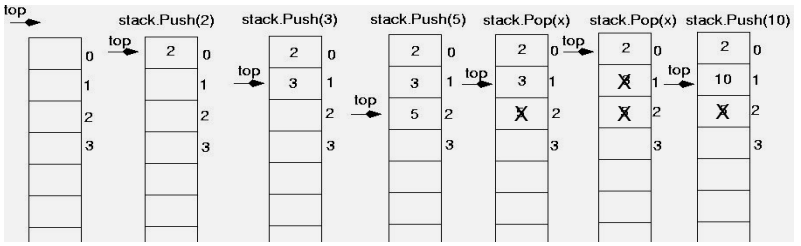
Introduction to the Stack

- 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 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
- 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()  {  top = -1; }  // empty stack

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


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;
}

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

assert will abort the program if its argument evaluates to false

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:

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


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
```

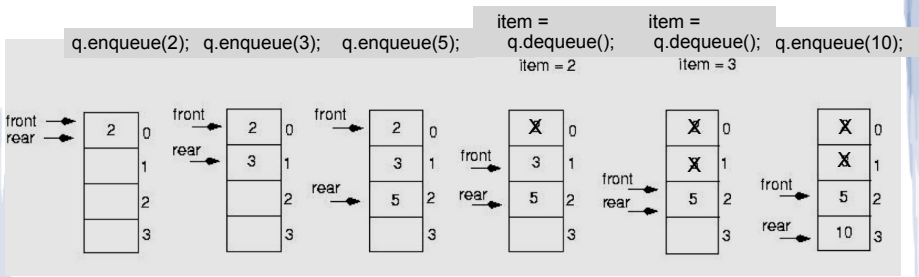

Introduction to the Queue

- 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);
```

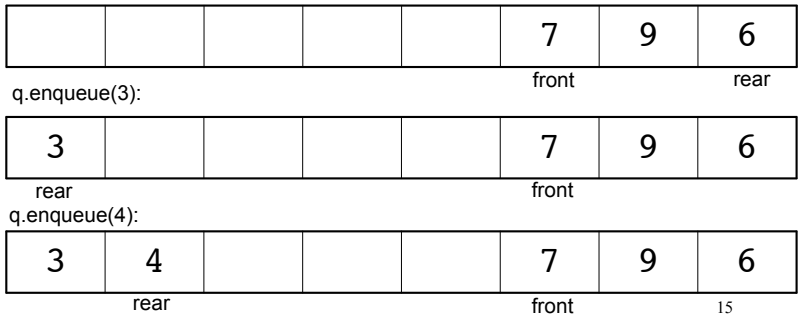

Implementing a Queue Class

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

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



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;
```

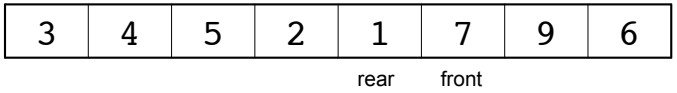
- The following code is equivalent, but shorter (assuming 0 <= rear < queueSize):

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

- Do the same for advancing the front index.

Implementing a Queue Class

- When is it full? (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!!

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() { front = 0;  rear = -1;  numItems = 0;  }

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


A static queue: enqueue/dequeue

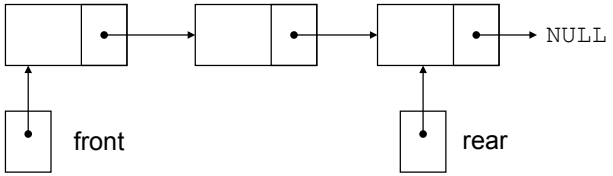
```
//*********************************************************
// Enqueue inserts a value at the rear of the queue.    *
//*********************************************************

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

    rear = (rear + 1) % queueSize;
    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) % queueSize;
    numItems--;
    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:

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

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


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
```


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.