Stacks and Queues

Week 9
Gaddis: Chapter 18

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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

```java
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 static 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

void IntStack::push(int num)
{
  assert(!isFull());
  top++;
  stackArray[top] = num;
}

A static stack class: functions

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

bool IntStack::isEmpty() const
{
  return (top == -1);
}
A Dynamic Stack Class:
Linked List implementation

• Push and pop from the head of the list:

```cpp
void DynIntStack::push(int num) {
    assert(!isFull());
    Node *temp = new Node;
    temp->data = num;
    //insert at head of list
    temp->next = head;
    head = temp;
}
```

private:
```cpp
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:

```cpp
int DynIntStack::pop() {
    assert(!isEmpty());
    int result = head->data;
    Node * temp = head;
    head = head->next;
    delete temp;
    return result;
}
```

private:
```cpp
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

```
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: Array

- 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

```
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: Array

- When is it full? \((\text{rear}+1)\%\text{queueSize}==\text{front}\)
  
<table>
<thead>
<tr>
<th>3</th>
<th>4</th>
<th>5</th>
<th>2</th>
<th>1</th>
<th>7</th>
<th>9</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>rear</td>
<td>front</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- When is it empty? \((\text{rear}+1)\%\text{queueSize}==\text{front}\)
  
  One element left:
  
<table>
<thead>
<tr>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>front</td>
</tr>
<tr>
<td>rear</td>
</tr>
</tbody>
</table>

  No elements left, front passes rear:
  
<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>rear</td>
<td>front</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

A static queue class

```cpp
class IntQueue {
private:
  const static int QUEUESIZE = 100;  // capacity of 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

```cpp
//****************************************************
// 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

```cpp
//****************************************************
// 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:

```
+-- front <- Node <- Node <- Node +
    |                     |           |
    |                     v     NULL
    |                        +
    |     rear
```

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

```cpp
void DynIntQueue::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;
    }
}
```

```cpp
int DynIntQueue::dequeue() {
    assert(!isEmpty());
    int value = front->data;
    // remove the first node (front)
    Node *temp = front;
    front = front->next;
    delete temp;
    if (front == NULL) rear = NULL;
    return value;
}
```