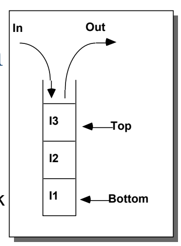
CS 1704

Introduction to Data Structures and Software Engineering

Stacks

- Restricted list structure
  - Dynamic LIFO Storage Structure
    - Size and Contents can change during execution of program
    - Last In First Out (lifo)
- Elements are added to the top and removed from the top
- How do you implement one?
  - What about a dynamic array?
  - What about a linked list?
  - What about a string?

Stack Implementation



- Has two main operations
  - Push
    - adds element to top of stack
  - Pop
    - removes elements from top of stack
  - Both should return a bool to indicate success or failure

More Ideas

- Also nice to include some maintenance functions:
  - **Stack** ( ) ;
    - set Stack to be empty
  - bool **Empty** ( ) const;
    - check if stack is empty
  - bool **Full** ( ) const;
    - check if stack is full
  - bool **Push** (const ItemType& item) ;
    - insert item onto the stack
  - Item **Pop** ( ) ;
    - remove & return the item at the top of the stack

More Ideas

- Some implementations define:
  - Item Top( ) ;
    - Returns top item in the stack, but does not remove it.
  - Pop() ;
    - In this case removes the top item in the stack, but does not return it.

Implementations

- String Representation
  - Empty Stack == Empty String
  - Top of Stack == End of String
  - String operations are used to implement stack operations
    - Enforces stack behavior on strings of type stack
    - Maps one data structure, (stack), onto another, (string)
- Linked-List Representation
  - top is fixed at the head (tail) of the list
  - Push & Pop operate only on the head (tail) of the list

String Implementation

```
#include <string>
typedef char Item;

class Stack {
private:
   string stk;
public:
   bool Empty( ) const;
   bool Full ( ) const;
   bool Push (const Item& Item);
   Item Pop( ) ;
};
```

String Implementation

```
#include "Stack.h"
using namespace std;

bool Stack::Empty( ) const {
  return ( stk.empty() );
}

bool Stack::Full( ) const {
  return( stk.length() == stk.max_size()
  );
}
```

String Implementation

```
bool Stack::Push(const Item& Item) {
   stk = stk + Item;
   return ( Full() );
}

Item Stack::Pop( ) {
   Item temp;
   int i;

   i = stk.length();
   temp = stk.at(i-1);
   stk.erase(i-1, 1);
   return( temp );
}
```

String Implementation

```
//if top() was to be implemented:

Item Stack::Top( ) {
  Item temp;
  int i;

  i = stk.length();
  temp = stk.at(i-1);
  return( temp );
}
```

Linked List Implementation

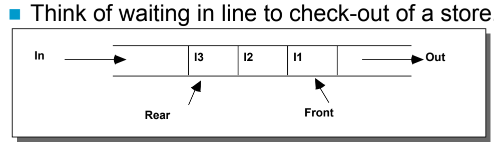
```
#include "LinkList.h"
//typedef   arbitrary Itemtype;
#include "Item.h"

class Stack {
private:
   LinkList stk;

public:
   Stack();
   bool Empty( ) const;
   bool Full ( ) const;
   bool Push (const Itemtype& Item);
   Item Pop( ) ;
};
```

Queues

- Restricted (two-tailed) list structure
- Dynamic FIFO Storage Structure
  - Size and Contents can change during execution of program
  - First in First Out
  - Elements are inserted (enqueue) into the rear and retrieved (dequeue) from front.
- Think of waiting in line to check-out of a store.



Queue Implementation

- **Queue** ( ) ;
  - † set queue to be empty
- bool **Empty** ( ) ;
  - † check if queue is empty
- bool **Full** ( ) ;
  - † check if queue is full
- **Enqueue** (const Item& item) ;
  - † *Insert* item into the queue
- Item **Dequeue** ( ) ;
  - † *Remove* & return the item at the front of the queue

What about a Front()?

- Some implementations define:
  - Item Front( ) ;
- Returns first item in the queue, but does not remove it.
  - bool Dequeue() ;
- In this case removes the first item in the queue, but does not return it.
- What about a Clear()?

Implementation Details

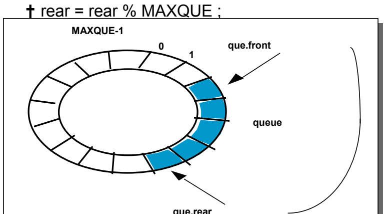
- Linear Array: not as easy to implement as it seems.
  - Front or Rear must be fixed at one end of the array
    - Enqueing or Dequeing requires inefficient array shifting.
  - OR if not fixed
    - The head and tail move causing problems.

Linear Array Solution

- Make the queue circular.
  - The problem now becomes when is the queue empty and full?
- Solution
  - Leave one cell empty.
  - The trade-off is one empty cell for processing time.

Whaaaaaaat?

- Code operations to force array indices to 'wrap-around'
  - † front = front % MAXQUE ;
  - † rear = rear % MAXQUE ;



States of the Queue

- front and rear indicies delimit the bounds of the queue contents
- Enqueue
  - † Move the que.rear pointer 1 position clockwise & write the element in that position.
- Dequeue
  - † Return element at que.front and move que.front one position clockwise
- Count (queue size) is stored and maintained or boolean full status flag maintained.

Array Interface

```
const int MAXQUE = 100;
//typedef   arbitrary Itemtype;
#include "Item.h"

class Queue {
 private:
  int        Front;
  int        Rear;
  Item       Items[MAXQUE];
 public:
  Queue();
  bool Empty();
  bool Full();
  void Enqueue (const Item& item);
  Item Dequeue ();
};
```

Array Math

- Distinct States
  - Full Queue:
    ```
    (que.rear + 1) % MAXQUE
          == que.front //% MAXQUE
    ```
  - Empty Queue:
    ```
    (que.rear == que.front )
    ```
  - One-element Queue:
    ```
    (que.front + 1) % MAXQUE
           == que.rear //% MAXQUE
    ```

```
#include "Queue.h"
Queue::Queue() {
  Front = 0;
  Rear  = 0;
}
bool Queue::Empty ( ) {
  return ( Front == Rear );
}
bool Queue::Full  ( ) {
  return ( ((Rear+1) % MAXQUE) == Front );
}
void Queue::Enqueue(const Item& item ) {
  Rear = (Rear + 1) % MAXQUE;
  Items[Rear] = item;
}
Item Queue::Dequeue( ) {
     Front = (Front + 1) % MAXQUE;
     return( Items[Front] );
}
```

Linked-List Representation

- Queue is a structure containing two pointers:
  - front: points to the head of the list
  - rear: points to the end of the list (last node)
- Enque operates upon the rear pointer, inserting after (before) the last (first) node.
- Deque operates upon the front pointer, always removing the head (tail) of the list.
- Empty queue is represented by NULL front & rear pointers

Linked List Interface

```
#include "LinkList.h"
//typedef arbitrary Item
#include "Item.h"

class Queue {
private:
  LinkList que;
public:
  Queue(); //LinkList constructor
  bool Empty();
  bool Full();
  void Enqueue (const Item& Item);
  Item Dequeue ();
};
```

Drop-Out Stack (dos)

"Bottomless" Stack

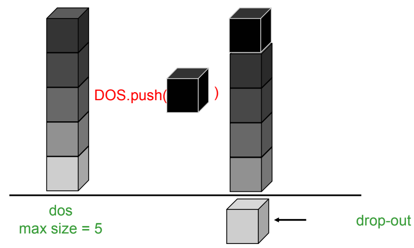
- Variation of a regular stack.
  - No fullstack operation (i.e. a **dos** can never become full).
- "Drop-Out" Stack of size N has following behavior:

  Let the integers 1 , 2 ... be the first elements PUSHed onto the stack respectively.

  After the N^{th} integer element is PUSH'ed, integer 1 is at the "bottom" of the stack, with 2 immediately above it.

  After the N+1 integer is PUSHed, 1 **Drops-Out** of the bottom and integer 2 is now at the bottom of the stack.
- Note: any element that Drops-Out of the stack never **reenters** the stack automatically from the bottom due to POPs being performed.

DOS



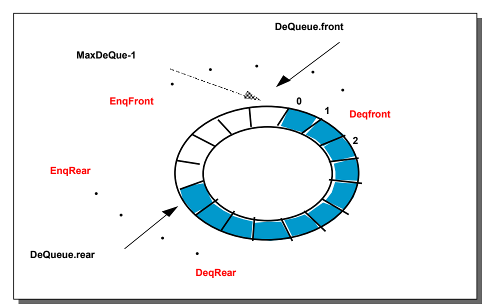
Efficiency

- Implementation

"Double-Ended" Queue

- variation of a regular queue.
- elements can be added and removed at either the rear or front of the queue, but nowhere else in the queue.
- operations:
  Deque(), Empty(), Full(), EnqRear(), EnqFront(), DeqFront(), DeqRear()
- generalization of both a stack and a queue.

Circular Array



New-Style Header Files

- In general, old-style C++ header files are replaced by new-style headers whose names omit the ".h" suffix. Some headers, such as math.h, were inherited from the C language. In those cases, the new-style headers prefix a "c" to the name and omit the ".h".

Old style:
- `iostream.h`
- `fstream.h`
- `string.h`
- `math.h`
- `stdlib.h`

New style:
- `iostream`
- `fstream`
- `string`
- `cmath`
- `cstdlib`

Some differences

`iostream.h` — standard stream stuff	`iostream` — same type names, but some subtle differences in implementation
`fstream.h` — file stream stuff; includes iostream.h	`fstream` — file stream stuff; does NOT include iostream.h
`string.h` — C-style char arrays	`string` — string object library

Observations

- The new-style headers offer enhanced functionality.
- There are some S/E advantages incorporated into the new-style implementation.
- Therefore, use the new-style approach whenever possible.
- Never, ever, mix old- and new-style headers in the same compilation unit. If possible don't mix them in the same program.

Namespaces

A namespace is a scope with a name attached. That is:

```
namespace FooSpace {

   typedef struct {
      string Message;
      int    Target;
   } Foo;
   const int MaxFoo = 1000;
   int numFoo;
   Foo List[MaxFoo];

};
```

Using namespaces

```
. . .
cout <<
  FooSpace::numFoo;
. . .
```

```
using namespace FooSpace;
cout << numFoo;
cout << List[0].Message;
```

```
using FooSpace::numFoo;
cout << numFoo;
cout << List[0].Message;
```

Error. List[ ] is not declared in the present scope.

using namespace std;

- The new-style C++ header files are all wrapped in a single namespace, called std:
- Namespaces may be composed; that is, two with the same name are automatically concatenated by the preprocessor.

```
// foobar
#ifndef FOOBAR
#define FOOBAR
namespace std {
  // declarations
}
#endif
```

Benefits

```
int Stupid = 0;
void F( ) {
  int Stupid = 10;
  cout << Stupid;
  // local
  cout << ::Stupid;
  // global
}
```

- Modulization
- You could wrap all those tempting globals into a namespace to protect them
- global scope is itself considered a namespace, with no name