
# COMP 2012H Honors Object-Oriented Programming and Data Structures

## Topic 18: Stack & Queue

Dr. Desmond Tsoi

Department of Computer Science & Engineering
The Hong Kong University of Science and Technology
Hong Kong SAR, China



## Data Structures

- Computer science is the study of how to process information (data) efficiently using computers.
- A data structure helps store, organize, and manipulate data in a particular way so that they can be processed efficiently by computers.
- Different applications require different data structures.
- Examples: array, linked list, stack, queue, (binary) tree, etc.
- An abstract data type (ADT) is the mathematical model of a data structure that is independent of its implementation. It may be used to analyze the efficiency of algorithms.



## Stack and Queue


Stack and queue let you insert and remove items at the ends only, not in the middle.



# Part I

## Stack




## Stack: How it Works

Consider a pile of cookies.

- more cookies: new cookies are added on top, one at a time.
- fewer cookies: cookies are consumed one at a time, starting at the top.

As an ADT, insertions and removals of items on a stack are based on the *last-in first-out (LIFO)* policy.

It supports:

- Data: an ordered list of data/items.
- Operations (major ones):
  - top : get the value of the top item
  - push : add a new item to the top
  - pop : remove an item from the top



## Stack of int Data — stack.h

```
#include <iostream>     /* File: int-stack.h */
#include <cstdlib>
using namespace std;
const int BUFFER_SIZE = 5;

class int_stack
{
  private:
    int data[BUFFER_SIZE];  // Use an array to store data
    int top_index;          // Starts from 0; -1 when empty

  public:
    // CONSTRUCTOR member functions
    int_stack();            // Default constructor

    // ACCESSOR member functions: const => won't modify data members
    bool empty() const;     // Check if the stack is empty
    bool full() const;      // Check if the stack is full
    int size() const;       // Give the number of data currently stored
    int top() const;        // Retrieve the value of the top item

    // MUTATOR member functions
    void push(int);         // Add a new item to the top of the stack
    void pop();             // Remove the top item from the stack
};
```



## Stack of int Data — Test Program

```
#include "int-stack.h" /* File: int-stack-test.cpp */

void print_stack_info(const int_stack& s)
{
    cout << "No. of data currently on the stack = " << s.size() << "\t";
    if (!s.empty())
        cout << "Top item = " << s.top();
    cout << endl << "Empty: " << boolalpha << s.empty()
         << "\t\t" << "Full: " << boolalpha << s.full() << endl << endl;
}

int main()
{
    int_stack a; print_stack_info(a);
    a.push(4);   print_stack_info(a);
    a.push(15);  print_stack_info(a);
    a.push(26);  print_stack_info(a);
    a.push(37);  print_stack_info(a);
    a.pop();     print_stack_info(a);
    a.push(48);  print_stack_info(a);
    a.push(59);  print_stack_info(a);

    return 0;
} /* compile: g++ -L. -o int-stack-test int-stack-test.cpp -lintstack */
```



## Example: Decimal to Binary Conversion — Illustration

- e.g., $26_{(10)} = 11010_{(2)}$
- Algorithm to convert $N_{(10)} = M_{(2)}$:

Step 1 : divide N by 2 successively

Step 2 : each time push the remainder onto a stack

Step 3 : print the answer by popping the stack successively

```
2 | 26
2 | 13  ...  0
2 | 6   ...  1
2 | 3   ...  0
2 | 1   ...  1
    0   ...  1
```

# Example: Decimal to Binary Conversion

```
#include "int-stack/int-stack.h" /* File: decimal2binary.cpp */

int main()  // Convert +ve decimal number to binary number using an stack
{
    int_stack a;
    int x, number;

    while (cin >> number)
    {   // Conversion: decimal to binary
        for (x = number; x > 0; x /= 2)
            a.push(x % 2);

        // Print a binary that is stored on a stack
        cout << number << "(base 10) = ";
        while (!a.empty())
        {
            cout << a.top();
            a.pop();
        }
        cout << "(base 2)" << endl;
    }

    return 0;
} // Compile: g++ -o decimal2binary -Lint-stack decimal2binary.cpp -lintstack
```



# Stack of int Data — Constructors, Assessors

```
#include "int-stack.h"  /* File: int-stack1.cpp */

          /***** Default CONSTRUCTOR member function *****/
int_stack::int_stack() { top_index = -1; } // Create an empty stack

          /***** ACCESSOR member functions *****/
// Check if the int_stack is empty
bool int_stack::empty() const { return (top_index == -1); }

// Check if the int_stack is full
bool int_stack::full() const { return (top_index == BUFFER_SIZE-1); }

// Give the number of data currently stored
int int_stack::size() const { return top_index + 1; }

// Retrieve the value of the top item
int int_stack::top() const
{
    if (!empty())
        return data[top_index];

    cerr << "Warning: Stack is empty; can't retrieve any data!" << endl;
    exit(-1);
}
```



# Stack of int Data — Mutators

```
#include "int-stack.h"  /* File: int-stack2.cpp */

        /***** MUTATOR member functions *****/
void int_stack::push(int x) // Add a new item to the top of the stack
{
    if (!full())
        data[++top_index] = x;
    else
    {
        cerr << "Error: Stack is full; can't add (" << x << ")!" << endl;
        exit(-1);
    }
}

void int_stack::pop()       // Remove the top item from the stack
{
    if (!empty())
        --top_index;
    else
    {
        cerr << "Error: Stack is empty; can't remove any data!" << endl;
        exit(-1);
    }
}
```



# Part II

# Queue

## Queue: How it Works

Consider the case when people line up for tickets.

- more people: new customers join the back of a queue, one at a time.
- fewer people: the customer at the front buys a ticket and leaves the queue.

As an ADT, insertions and removals of items on a queue are based on a *first-in first-out (FIFO)* policy.

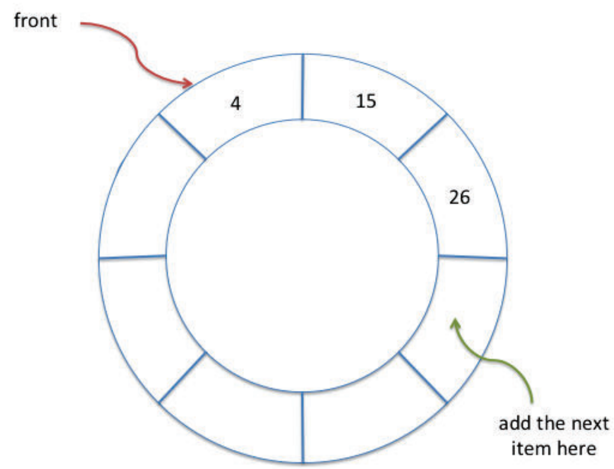
It supports:

- Data: an ordered list of data/items.
- Operations (major ones):

front : get the value of the front item
enqueue : add a new item to the back
dequeue : remove an item from the front



## Circular Queue of int Data — Illustration






## Circular Queue of int Data — queue.h

```
#include <iostream>     /* File: int-queue.h */
#include <cstdlib>
using namespace std;
const int BUFFER_SIZE = 5;

class int_queue // Circular queue
{
  private:
    int data[BUFFER_SIZE]; // Use an array to store data
    int num_items;         // Number of items on the queue
    int first;             // Index of the first item; start from 0

  public:
    // CONSTRUCTOR member functions
    int_queue();           // Default constructor

    // ACCESSOR member functions: const => won't modify data members
    bool empty() const;    // Check if the queue is empty
    bool full() const;     // Check if the queue is full
    int size() const;      // Give the number of data currently stored
    int front() const;     // Retrieve the value of the front item
    // MUTATOR member functions
    void enqueue(int);     // Add a new item to the back of the queue
    void dequeue();        // Remove the front item from the queue
};
```



## Circular Queue of int Data — Test Program

```
#include "int-queue.h" /* File: int-queue-test.cpp */

void print_queue_info(const int_queue& a) {
    cout << "No. of data currently on the queue = " << a.size() << "\t";
    if (!a.empty()) cout << "Front item = " << a.front();
    cout << endl << "Empty: " << boolalpha << a.empty();
    cout << "\t\t" << "Full: " << boolalpha << a.full() << endl << endl;
}

int main() {
    int_queue a;    print_queue_info(a);
    a.enqueue(4);   print_queue_info(a);
    a.enqueue(15);  print_queue_info(a);
    a.enqueue(26);  print_queue_info(a);
    a.enqueue(37);  print_queue_info(a);
    a.dequeue();    print_queue_info(a);
    a.enqueue(48);  print_queue_info(a);
    a.enqueue(59);  print_queue_info(a);
    a.dequeue();    print_queue_info(a);
    a.dequeue();    print_queue_info(a);
    a.dequeue();    print_queue_info(a);
    a.dequeue();    print_queue_info(a);
    a.dequeue();    print_queue_info(a);
    return 0;
} /* compile: g++ -L. -o int-queue-test int-queue-test.cpp -lintqueue */
```

## Circular Queue of int Data — Constructors, Assessors

```
#include "int-queue.h"  /* File: int-queue1.cpp */

          /***** Default CONSTRUCTOR member function *****/
// Create an empty queue
int_queue::int_queue() { first = 0; num_items = 0; }

          /***** ACCESSOR member functions *****/
// Check if the int_queue is empty
bool int_queue::empty() const { return (num_items == 0); }

// Check if the int_queue is full
bool int_queue::full() const { return (num_items == BUFFER_SIZE); }

// Give the number of data currently stored
int int_queue::size() const { return num_items; }

// Retrieve the value of the front item
int int_queue::front() const
{
    if (!empty())
        return data[first];

    cerr << "Warning: Queue is empty; can't retrieve any data!" << endl;
    exit(-1);
}
```



## Circular Queue of int Data — Mutators

```
#include "int-queue.h" /* File: int-queue2.cpp */

void int_queue::enqueue(int x)  // Add a new item to the back of the queue
{
    if (!full())
    {
        data[(first+num_items) % BUFFER_SIZE] = x;
        ++num_items;
    } else {
        cerr << "Error: Queue is full; can't add (" << x << ")!" << endl;
        exit(-1);
    }
}

void int_queue::dequeue()       // Remove the front item from the queue
{
    if (!empty())
    {
        first = (first+1) % BUFFER_SIZE;
        --num_items;
    } else {
        cerr << "Error: Queue is empty; can't remove any data!" << endl;
        exit(-1);
    }
}
```



## That's all!

## Any questions?




## Further Reading

## Stack Application: Balanced Parentheses — Illustration

- e.g., [()][()()]() is balanced but [(]) is not.
- Algorithm to check balanced parentheses:

Step 1 : Scan the given character expression from left to right.

Step 2 : If a left paranthesis is read, push it onto a stack.

Step 3 : If a right paranthesis is read, check if its matching left parenthesis is on the top of the stack.

Step 4 : If Step 3 is true, pop the stack and continue.

Step 5 : If Step 3 is false, return false and stop.

Step 6 : If the end of the expression is reached, check if the stack is empty.

Step 7 : If Step 6 is true, return true otherwise false.



## Stack Application: Balanced Parentheses I

```
#include "char-stack/char-stack.h" /* File: balanced-paren.cpp */
const char L_PAREN    = '('; const char R_PAREN    = ')';
const char L_BRACE    = '{'; const char R_BRACE    = '}';
const char L_BRACKET  = '['; const char R_BRACKET  = ']';

bool balanced_paren(const char* expr);

int main()  // To check if a string has balanced parantheses
{
    char expr[1024];
    cout << "Input an expression containing parentheses: ";
    cin >> expr;

    cout << boolalpha << balanced_paren(expr) << endl;
    return 0;
} /* Compile: g++ -Lchar-stack -o balanced-parenstack balanced-paren.cpp
              -lcharstack */

bool check_char_stack(char_stack& a, char c)
{
    if (a.empty()) return false;
    if (a.top() != c) return false;
    a.pop(); return true;
}
```



## Stack Application: Balanced Parentheses II

```
bool balanced_paren(const char* expr)
{
    char_stack a;
    for (const char* s = expr; *s != '\0'; ++s)
        switch (*s)
        {
            case L_PAREN: case L_BRACE: case L_BRACKET:
                a.push(*s); break;

            case R_PAREN:
                if (!check_char_stack(a, L_PAREN)) return false;
                break;
            case R_BRACE:
                if (!check_char_stack(a, L_BRACE)) return false;
                break;
            case R_BRACKET:
                if (!check_char_stack(a, L_BRACKET)) return false;
                break;

            default: break;
        }

    return a.empty();
}
```