Programming with C++

COMP2011: Data Structures — Stack & Queue

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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, (binary) tree, stack, queue, etc.

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 = 20;

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
};
```

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:

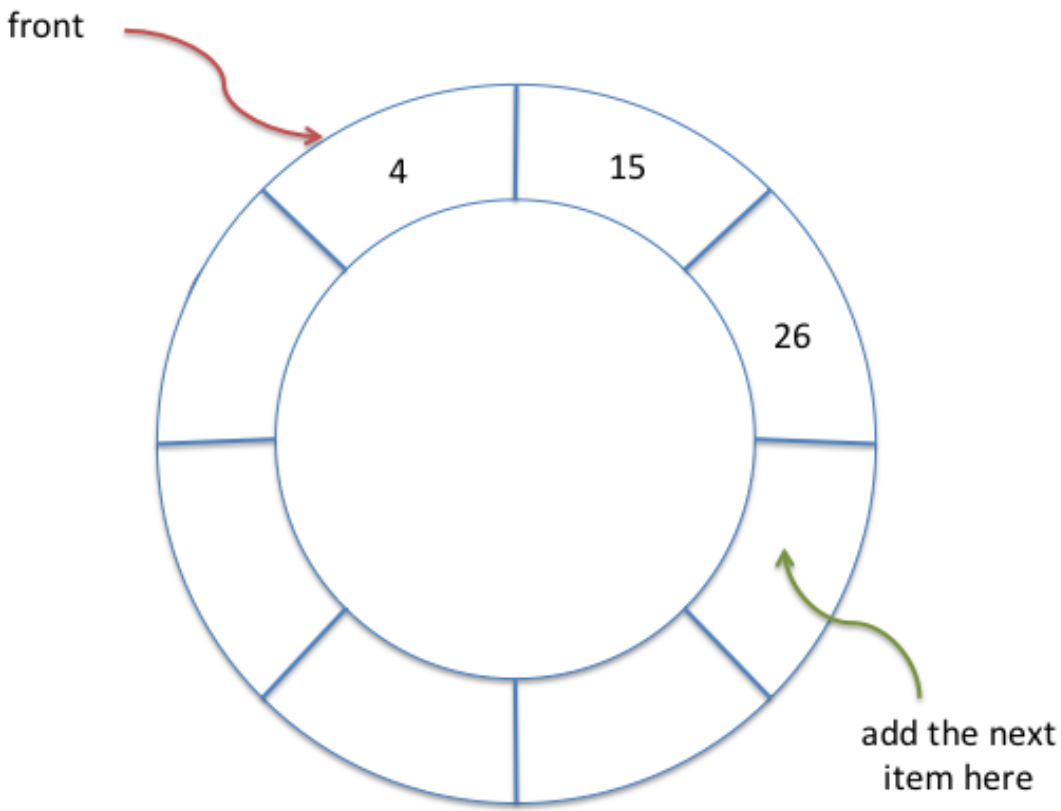
- Data: an ordered list of data/items.
- Operations (major ones):

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);
    }
}
```