Introduction to the C programming language
From C to C++: Stack and Queue

Giuseppe Lipari
http://retis.sssup.it/~lipari

Scuola Superiore Sant’Anna – Pisa

February 23, 2010
Outline

1. From struct to classes
2. First data structure: stack
3. Queue
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1. From struct to classes
2. First data structure: stack
3. Queue
An important concept in programming is the *Abstract Data Type* (ADT)

An abstract data type is a user-defined type, that can be used similarly to built-in data types

An ADT defines
- What kind of values the data type can assume (*domain*)
- What operations we can perform on the data type

How the data and the operations are implemented is *hidden* to the user, and it is part of the implementation
ADT in C

- ADT are a general concept that can be supported in any language, including Assembler, Basic, C

- Example of ADT in C

```c
struct point {
    double x, y;
    int z;
};

void point_read(ifstream &in, point *p);
void point_save(ofstream &out, point *p);
void point_print(point *p);
```

- The structure defines the domain (i.e. how the data is composed by three components)
  The three functions define the operations we can do on the data

- It is not very nice to program ADT in C, because there is little support from the language. ADT are well supported in Object Oriented (OO) languages
Example in C++

- C++ is the OO version of C
- It maintains a similar syntax, adding new keywords and constructs
- How the previous class can be expressed in C++?

```cpp
class Point {
    double x, y;
    int z;
public:
    Point(double x1, double y1);
    Point();
    void read(ifstream &in);
    void save(ofstream &out);
    void print();
    double get_x();
};
```
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new keyword class instead of struct
this data is `private`, i.e. can only be used from the functions defined in the class
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keyword `public` indicated that the following data and functions are public, i.e. that can be used by any other function

This is the constructor: it is used to initialize an `object` with proper data values
**Example in C++**

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- There can be more than one constructor (many different ways to construct the same object)
Example in C++

- C++ is the OO version of C
- It maintains a similar syntax, adding new keywords and constructs
- How the previous class can be expressed in C++?

```cpp
class Point {
    double x, y;
    int z;

public:
    Point(double x1, double y1);
    Point();
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    void save(ofstream &out);
    void print();
    double get_x();
};
```

- new keyword class instead of struct
- this data is *private*, i.e. can only be used from the functions defined in the class
- keyword public indicated that the following data and functions are public, i.e. that can be used by another function
- This is the constructor: it is used to initialize an *object* with proper data values
- There can be more than one constructor (many different ways to construct the same object)
- this function is part of the class, i.e. it can access all private data of the class
This is an example of how the class Point can be used in a program.

```c
int main()
{
    Point p(2,0);
    Point q;

    p.print();

    p.x;
}
```
This is an example of how the class Point can be used in a program.

```c
int main()
{
    Point p(2,0);
    Point q;
    p.print();
    p.x;
}
```

Declares, defines and initialize a object of type Point. The constructor is invoked.
This is an example of how the class Point can be used in a program.

```c
int main()
{
    Point p(2,0);
    Point q;

    p.print();

    p.x;
}
```

- Declares, defines and initialize a object of type Point. The constructor is invoked.
- The default constructor is invoked.
This is an example of how the class `Point` can be used in a program.

```c++
int main()
{
    Point p(2, 0);
    Point q;
    p.print();
    p.x;
}
```

- Declares, defines and initialize a object of type `Point`. The constructor is invoked.
- The default constructor is invoked.
- Access a `public member` of class `Point` on the object `p`. In this specific case, invoked the function `print()` of class `Point` on object `p`. 
This is an example of how the class Point can be used in a program.

```c
int main()
{
    Point p(2,0);
    Point q;
    p.print();
    p.x;
}
```

- Declares, defines and initialize a object of type Point. The constructor is invoked
- The default constructor is invoked
- Access a `public member` of class Point on the object p. In this specific case, invoked the function `print()` of class Point on object p.
- This is a compilation error: x is a private member of Point and cannot be accessed from the other parts of the program.
Implementation

- Implementation usually goes into a separate class `point.cpp`

```cpp
#include <iostream>
#include "point.hpp"

Point::Point() : x(0), y(0), z(0)
{
}

Point::Point(double x1, double y1) :
   x(x1), y(y1), z(0)
{
}

void Point::print()
{
    cout << "(" << x << "," << y << ")";
}

void Point::read(ifstream &if)
{
    in >> x >> y >> z;
}

void Point::save(ofstream &out)
{
    out << x << " " << y << " "
        << z << endl;
}

double Point::get_x()
{
    return x;
}
```

- Notice how we specify the functions, and how we access the member variables (i.e. variables defined inside the class).
Dynamic memory allocation

C language

```c
int *p = (int *)malloc(sizeof(int));
int *a = (int *)malloc(10*sizeof(int));
...
free(p);
free(a);
```

C++ language

```cpp
int *p = new int(0);
int *a = new [10] int;
...
delete p;
delete a;
```

- C++ uses the special keyword new, and a more automatic syntax (you can specify the type, and there is no need to specify the size)
Is that all?

- C++ is a complex language, and we have just seen a few very basic concepts
- We have no time to present C++ in details. However, these very basic things should be necessary to start reasoning on data structures
- We will see more features as we go on.
Outline

1. From struct to classes
2. First data structure: stack
3. Queue
A stack is a very simple data structure.

A stack can hold a set of uniform data, like an array (for example, integers)

Data is ordered according to the LIFO (Last-In-First-Out) strategy

Two main operations are defined on the data structure:

- **Push**: a new data is inserted in the stack
- **Pop**: data is extracted from the stack

Usually, we can also read the element at the top of the stack with a Top operation
Stack interface

- Let’s start by defining a stack of integers of fixed size
- Initially, we will allow only a maximum number of elements in the stack

```cpp
#include <iostream>

class Stack {
    int array[10];
    int top;

public:
    Stack();
    void push(int elem);
    int pop();
    int query();
    void print();
};
```

```cpp
#ifndef __STACK_HPP__
define __STACK_HPP__

class Stack {
    int array[10];
    int top;

public:
    Stack();
    void push(int elem);
    int pop();
    int query();
    void print();
};
#endif
```
Stack implementation

- Here is the implementation

c-cplusplus/stack.cpp

```cpp
#include <iostream>
#include "stack.hpp"

using namespace std;

Stack::Stack() : top(0)
{
}

void Stack::push(int elem)
{
    if (top < 10) array[top++] = elem;
    else cerr << "Stack is full, push operation failed" << endl;
}

int Stack::pop()
{
    if (top > 0) return array[--top];
    else cerr << "Stack::pop() : is empty" << endl;
}
int Stack::query()
{
    if (top > 0) return array[top-1];
    else cerr << "Stack::query() : is empty" << endl;
}

void Stack::print()
{
    int i;
    cout << "[";
    for (i=0; i<top; i++) cout << array[i] << ",";
    cout << "]" << endl;
}
Usage

- This is only an example of how to use the Stack class.

```cpp
#include "stackdyn.hpp"
#include <iostream>

using namespace std;

int main()
{
    Stack s;
    int i;

    s.push(5);
    for (i=0; i<12; i++) s.push(2*i);

    s.print();

    for (i=0; i<5; i++) cout << s.pop() << endl;
}
```
Stack: unlimited size

- Let’s remove the limitation on the size
  - We want a stack that enlarges itself dynamically

```c-cplusplus
#include <new>

c-cplusplus/stackdyn.hpp

#ifndef __STACKDYN_HPP__
#define __STACKDYN_HPP__

class Stack {
    int *array;
    int cursize;
    int top;

public:
    Stack();
    ~Stack();
    void push(int elem);
    int pop();
    int query();
    void print();
};

#endif
```
Destructor

- The function \texttt{~Stack()} is called destructor.
- It is automatically called when an object of type stack is destroyed.
- As we will see in the implementation, in our case we need to deallocate the memory allocated by new with a corresponding delete.
Constructor and Destructor in stackdyn

c-cplusplus/stackdyn.cpp

```cpp
#include <iostream>
#include "stackdyn.hpp"

using namespace std;

#define INC_SIZE 5

Stack::Stack() : top(0), cursize(INC_SIZE)
{
    array = new int[INC_SIZE];
}

Stack::~Stack()
{
    delete array;
}
```
Dynamic size stack implementation

c-cplusplus/stackdyn.cpp

```cpp
void Stack::push(int elem)
{
    if (top >= cursize) {
        int i;
        int *temp = new int[cursize + INC_SIZE];
        for (i=0; i<top; i++) temp[i] = array[i];
        delete array;
        array = temp;
        cursize += INC_SIZE;
    }
    array[top++] = elem;
}

int Stack::pop()
{
    if (top > 0) return array[--top];
    else cerr << "Stack::pop() : is empty" << endl;
}
```
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Queue

Let us now implement a queue of integers.

The policy for inserting / extracting elements is FIFO (First-In-First-Out).

Two operations:

- enqueue inserts a new element in the queue.
- dequeue extracts an element from the queue.
Circular array

Let’s start again from a fixed size array

c-cplusplus/queue.hpp

```cpp
#ifndef __QUEUE_HPP__
#define __QUEUE_HPP__

class Queue {
    int array[10];
    int head;
    int tail;
    int num;
public:
    Queue();
    void enqueue(int elem);
    int dequeue();
    void print();
};

#endif
```
Queue implementation

```cpp
#include "queue.hpp"
#include <iostream>

using namespace std;

Queue::Queue() : head(0), tail(0), num(0) {
}

void Queue::enqueue(int elem) {
    if (num < 10) {
        array[head] = elem;
        head = (head + 1) % 10;
        num++;
    }
}
```
int Queue::dequeue()
{
    int ret = 0;
    if (num > 0) {
        ret = array[tail];
        tail = (tail + 1) % 10;
        num--;
    }
    else cerr << "Queue::dequeue() : queue is empty" << endl;
Queue implementation - 3

c-cplusplus/queue.cpp

```cpp
void Queue::print()
{
    int i;
    cout << "[";
    for (i=0; i<num; i++) cout << array[(tail + i)%10] << ",";
    cout << "]" << endl;
}
```