

Quick Introduction to C++

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Lecture 11

B3B36PRG – C Programming Language

Books

 **The C++ Programming Language**,
Bjarne Stroustrup, Addison-Wesley Professional,
2013, ISBN 978-0321563842



 **Programming: Principles and Practice Using C++**,
Bjarne Stroustrup, Addison-Wesley Professional,
2014, ISBN 978-0321992789



 **Effective C++: 55 Specific Ways to Improve Your Programs and Designs**,
Scott Meyers, Addison-Wesley Professional, 2005, ISBN
978-0321334879



From struct to class

- **struct** defines complex data types for which we can define particular functions, e.g., `allocation()`, `deletion()`, `initialization()`, `sum()`, `print()` etc.
- **class** defines the data and function working on the data including the initialization (**constructor**) and deletion (**destructor**) in a compact form
 - Instance of the class is an object, i.e., a variable of the class type
 - Object

```
typedef struct matrix {
    int rows;
    int cols;
    double *mtx;
} matrix_s;

matrix_s* allocate(int r, int c);
void release(matrix_s **matrix);
void init(matrix_s *matrix);
void print(const matrix_s *matrix);

matrix_s *matrix = allocate(10, 10);
init(matrix);
print(matrix);
release(matrix);

class Matrix {
    const int ROWS;
    const int COLS;
    double *mtx;
public:
    Matrix(int r, int c);
    ~Matrix(); //destructor
    void init(void);
    void print(void) const;
};

Matrix matrix(10, 10);
matrix.init();
matrix.print();
// will call destructor
```

Overview of the Lecture

- Part 1 – Quick Introduction to C++

Resources

Quick Overview How C++ Differs from C

Classes and Objects

Constructor/Destructor

Templates

Standard Template Library (STL)

Objects Oriented Programming (OOP)

OOP is a way how to design a program to fulfill requirements and make the sources easy maintain.

- **Abstraction** – concepts (templates) are organized into classes
 - Objects are instances of the classes
- **Encapsulation**
 - Object has its state hidden and provides **interface** to communicate with other objects by sending messages (function/method calls)
- **Inheritance**
 - Hierarchy (of concepts) with common (general) properties that are further specialized in the derived classes
- **Polymorphism**
 - An object with some interface could replace another object with the same interface

Dynamic allocation

- **malloc()** and **free()** and standard functions to allocate/release memory of the particular size in C

```
matrix_s *matrix = (matrix_s*)malloc(sizeof(matrix_s));
matrix->rows = matrix->cols = 0; //inner matrix is not allocated
print(matrix);
free(matrix);
```

- C++ provides two keywords (operators) for creating and deleting objects (variables at the heap) **new** and **delete**

```
Matrix *matrix = new Matrix(10, 10); // constructor is called
matrix->print();
delete matrix;
```

- **new** and **delete** is similar to **malloc()** and **free()**, but
 - Variables are strictly typed and constructor is called to initialize the object
 - For arrays, explicit calling of **delete[]** is required

```
int *array = new int[100]; // aka (int*)malloc(100 * sizeof(int))
delete[] array; // aka free(array)
```

Part I

Part 1 – Quick Introduction to C++ (for C coders)

C++ for C Programmers

- C++ can be considered as an “extension” of C with additional concepts to create more complex programs in an easier way
- It supports to organize and structure complex programs to be better manageable with easier maintenance
- **Encapsulation** supports “locality” of the code, i.e., provide only public interface and keep details “hidden”
 - Avoid unintentional wrong usage because of unknown side effects
 - Make the implementation of particular functionality compact and easier to maintain
 - Provide relatively complex functionality with simple to use interface
- Support a tighter link between data and functions operating with the data, i.e., classes combine data (properties) with functions (methods)

Reference

- In addition to variable and pointer to a variable, C++ supports references, i.e., a reference to an existing object
- Reference is an **alias** to existing variable, e.g.,

```
int a = 10;
int &r = a; // r is reference (alias) to a
r = 13; // a becomes 13
```

- It allows to pass object (complex data structures) to functions (methods) without copying them

Variables are passed by value

```
int print(Matrix matrix)
// new local variable matrix is allocated
// and content of the passed variable is copied
int print(Matrix *matrix) // pointer is passed
{
    matrix->print();
}
int print(Matrix &matrix)
{
    // reference is passed - similar to passing pointer
    matrix.print(); //but it is not pointer and . is used
}
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```

Class

Describes a set of objects – it is a model of the objects and defines:

- Interface – parts that are accessible from outside
 - public, protected, private
- Body – implementation of the interface (methods) that determine the ability of the objects of the class
 - Instance vs class methods
- Data Fields – attributes as basic and complex data types and structures (objects)
 - Object composition
 - Instance variables – define the state of the object of the particular class
 - Class variables – common for all instances of the particular class

```
// header file - definition of the class type
class MyClass {
public:
    // public read only
    int getValue(void) const;
private:
    // hidden data field
    // it is object variable
    int myData;
};

// source file - implementation of the methods
int MyClass::getValue(void) const
{
    return myData;
}
```

Object Structure

- The value of the object is structured, i.e., it consists of particular values of the object data fields which can be of different data type
 - Heterogeneous data structure unlike an array
- Object is an abstraction of the memory where particular values are stored
 - Data fields are called attributes or instance variables
- Data fields have their names and can be marked as hidden or accessible in the class definition
 - Following the encapsulation they are usually hidden

Object:

- Instance of the class – can be created as a variable declaration or by dynamic allocation using the new operator
- Access to the attributes or methods is using . or -> (for pointers to an object)

Creating an Object – Class Constructor

- A class instance (object) is created by calling a constructor to initialize values of the instance variables
 - Implicit/default one exists if not specified
- The name of the constructor is identical to the name of the class

```
Class definition
class MyClass {
public:
    // constructor
    MyClass(int i);
    MyClass(int i, double d);
private:
    const int _i;
    int _ii;
    double _d;
};

Class implementation
MyClass::MyClass(int i) : _i(i)
{
    _ii = i * i;
    _d = 0.0;
}
// overloading constructor
MyClass::MyClass(int i, double d) : _i(i)
{
    _ii = i * i;
    _d = d;
}

MyClass myObject(10); //create an object as an instance of MyClass
} // at the end of the block, the object is destroyed
MyClass *myObject = new MyClass(20, 2.3); //dynamic object creation
delete myObject; //dynamic object has to be explicitly destroyed
```

Relationship between Objects

- Objects may contain other objects
- Object aggregation / composition
- Class definition can be based on an existing class definition – so, there is a relationship between classes
 - Base class (super class) and the derived class
 - The relationship is transferred to the respective objects as instances of the classes
 - By that, we can cast objects of the derived class to class instances of ancestor
- Objects communicate between each other using methods (interface) that is accessible to them

Access Modifiers

- Access modifiers allow to implement encapsulation (information hiding) by specifying which class members are private and which are public:
 - public: – any class can refer to the field or call the method
 - protected: – only the current class and subclasses (derived classes) of this class have access to the field or method
 - private: – only the current class has the access to the field or method

Modifier	Class	Derived Class	“World”
public	✓	✓	✓
protected	✓	✓	x
private	✓	x	x

Constructor and Destructor

- Constructor provides the way how to initialize the object, i.e., allocate resources
 - Programming idiom – Resource acquisition is initialization (RAII)
- Destructor is called at the end of the object life
 - It is responsible for a proper cleanup of the object
 - Releasing resources, e.g., freeing allocated memory, closing files
- Destructor is a method specified by a programmer similarly to a constructor
 - However, unlike constructor, only single destructor can be specified
 - The name of the destructor is the same as the name of the class but it starts with the character ~ as a prefix

Constructor Overloading

- An example of constructor for creating an instance of the complex number
- In an object initialization, we may specify only real part or both the real and imaginary part

```
class Complex {
public:
    Complex(double r)
    {
        re = r;
    }
    Complex(double r, double i)
    {
        re = r;
        im = i;
    }
    ~Complex() { /* nothing to do in destructor */ }
private:
    double re;
    double im;
};

Both constructors shared the duplicate code, which we like to avoid!
```

Example – Constructor Calling 1/3

- We can create a dedicated initialization method that is called from different constructors

```
class Complex {
public:
    Complex(double r, double i) { init(r, i); }
    Complex(double r) { init(r, 0.0); }
    Complex() { init(0.0, 0.0); }
private:
    void init(double r, double i)
    {
        re = r;
        im = i;
    }
private:
    double re;
    double im;
};
```

Example – Constructor Calling 2/3

- Or we can utilize default values of the arguments that are combined with initializer list here

```
class Complex {
public:
    Complex(double r = 0.0, double i = 0.0) : re(r), im(i) {}
private:
    double re;
    double im;
};

int main(void)
{
    Complex c1;
    Complex c2(1.);
    Complex c3(1., -1.);
    return 0;
}
```

Example – Constructor Calling 3/3

- Alternatively, in C++11, we can use [delegating constructor](#)

```
class Complex {
public:
    Complex(double r, double i)
    {
        re = r;
        im = i;
    }
    Complex(double r) : Complex(r, 0.0) {}
    Complex() : Complex(0.0, 0.0) {}

private:
    double re;
    double im;
};
```

Example – Template Class

- The template class is defined by the [template](#) keyword with specification of the type name

```
template <typename T>
class Stack {
public:
    bool push(T *data);
    T* pop(void);
};
```

- An object of the template class is declared with the specified particular type

```
Stack<int> intStack;
Stack<double> doubleStack;
```

std::vector – Dynamic "C" like array

- One of the very useful data containers in STL is [vector](#) which behaves like C array but allows to add and remove elements

```
#include <iostream>
#include <vector>

int main(void)
{
    std::vector<int> a;
    for (int i = 0; i < 10; ++i) {
        a.push_back(i);
    }

    for (int i = 0; i < a.size(); ++i) {
        std::cout << "a[" << i << "] = " << a[i] << std::endl;
    }

    std::cout << "Add one more element" << std::endl;
    a.push_back(0);

    for (int i = 5; i < a.size(); ++i) {
        std::cout << "a[" << i << "] = " << a[i] << std::endl;
    }
    return 0;
}
```

Constructor Summary

- The name is identical to the class name
- The constructor does not have return value
 - Not even void*
- Its execution can be prematurely terminated by calling [return](#)
- It can have parameters similarly as any other method (function)
- We can call other functions, but they should not rely on initialized object that is being done in the constructor
- [Constructor is usually public](#)
- ([private](#)) constructor can be used, e.g., for:
 - Classes with only class methods
 - Prohibition to instantiate class*
 - Classes with only constants
 - The so called singletons
 - E.g., "object factories"*

Example – Template Function

- Templates can also be used for functions to specify particular type and use type safety and typed operators

```
template <typename T>
const T & max(const T &a, const T &b)
{
    return a < b ? b : a;
}

double da, db;
int ia, ib;

std::cout << "max double: " << max(da, db) << std::endl;
std::cout << "max int: " << max(ia, ib) << std::endl;
//not allowed such a function is not defined
std::cout << "max mixed " << max(da, ib) << std::endl;
```

Topics Discussed

Summary of the Lecture

Templates

- Class definition may contain specific data fields of a particular type
- The data type itself does not change the behavior of the object, e.g., typically as in
 - Linked list or double linked list
 - Queue, Stack, etc.
 - data containers*
- Definition of the class for specific type would be identical except the data type
- We can use [templates](#) for later specification of the particular data type, when the instance of the class is created
- Templates provides [compile-time polymorphism](#)
 - In contrast to the run-time polymorphism realized by virtual methods.*

STL

- Standard Template Library (STL) is a library of the standard C++ that provides efficient implementations of the data [containers](#), algorithms, functions, and iterators
- High efficiency of the implementation is achieved by templates with compile-type polymorphism
- Standard Template Library Programmer's Guide – <https://www.sgi.com/tech/stl/>

Topics Discussed

- Classes and objects
- Constructor/destructor
- Templates and STL
- Next: C++ constructs (polymorphism, inheritance, and virtual methods, etc.) in examples