

# Quick Introduction to C++

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Lecture 11

B3B36PRG – C Programming Language

## Part I

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

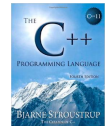
## Overview of the Lecture

- Part 1 – Quick Introduction to C++

### Topics Discussed

## Books

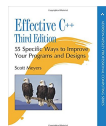
 **The C++ Programming Language,** *Bjarne Stroustrup,* Addison-Wesley Professional, 2013, ISBN 978-0321563842



 **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



## 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

## 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
```

## 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)

## 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)
```

## 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

```
int print(Matrix matrix) Variables are passed by value
{ // 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
}
```

## 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)

## 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
- **Data Fields** – attributes as basic and complex data types and structures (objects)

```
// 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;
};
```

*Instance vs class methods*

*Object composition*

- Instance variables – define the state of the object of the particular class
- Class variables – common for all instances of the particular class

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

## 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 implementation
<pre>class MyClass { public:   // constructor   MyClass(int i);   MyClass(int i, double d);  private:   const int _i;   int _ii;   double _d; };</pre>	<pre>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; }</pre>
<pre>{   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</pre>	

## 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

## 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

## 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	Access	
		Derived Class	“World”
public	✓	✓	✓
protected	✓	✓	x
private	✓	x	x

## 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;
};
```

## 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"*

## 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.*

## Example – Template Function

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

```
template <typename T>
int T const & max(T const &a, T const &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;
```

## 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;
```

## 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/>

## 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;
}
lec11/stl-vector.cc
```

## Topics Discussed

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

## Summary of the Lecture