Object-Oriented Programming

Amanda Araujo

Abstract

A compilation of the basic concepts of Object-Oriented Programming (OOP) and implementations with the C++ programming language (`.gpp`). The *4dummies* guide I needed to learn this new computing paradigm and language, while keeping my sanity. We ought to be our own best collaborator, and I think the future me would appreciate it. It's an ongoing and continuous process[*].

Contents

[*]Codes available on GitHub in the repository: poo-cpp.

1 Introduction

1.1 Object-Oriented Programming

Object-Oriented Programming (OOP) is a programming paradigm based on the concept of **objects**, which can contain *data* and *code*: data in the form of fields (called *attributes* or properties), and code in the form of procedures (known as *methods*). In OOP, computer programs are designed by making them out of objects that interact with one another.

Figure 1: Let's take a leap into this new paradigm of programming.

1980s - THE RISE OF OBJECT-ORIENTED PROGRAMMING[*]

"In the 1980s, object-oriented programming (OOP) gained prominence with the introduction of languages like Smalltalk and C++. OOP introduced the concept of 'objects'—data structures that combine both data and methods. This shift in programming approach improved code modularity, reusability, and maintenance, setting the stage for the development of more complex and scalable software systems."

1.2 Procedural *vs.* Object-Oriented Programming Languages

So far, what we've seen coming from a background of programming in FORTRAN, C, and focusing on tasks and functions in Python, resume to a way of thinking and designing code to what it is called *Procedural Programming*. It consists of a programming model derived from *structured programming* (programming without the use of `goto`), based on the concept of calling procedures, also known as routines, subroutines

[*]Ref. Coding milestones - Nomical Connecting worlds

or functions. Now the focus is shifted from actions, tasks, *functions* to agents, *objects*.

A key advantage of OOP over procedural programming is that OOP provides a clear structure and allows reusability with less code. The principal differences between them can be seen in (Table 1).

Procedural	*Object-Oriented*
Focus on *processes*	Focus on *objects*
Program divided into small parts called *functions*	Program divided into small parts called *objects*
Top-down approach	*Bottom-up approach*
Function over data	Data over function
Adding new data and functions is not easy	Adding new data and functions is easy
No overloading	Overloading is supported
No access specifier	Has access specifier
No concept of data hiding and inheritance	Concept of data hiding and inheritance used
No proper way of hiding data, *less secure*	Provides data hiding, *more secure*
Designing medium-sized programs	Designing large and complex programs
Concept of procedure abstraction	Concept of data abstraction
Code reusability absent	Code reusability present
FORTRAN, C, BASIC, Pascal	C++, Python, Java, C#, Dart

Table 1: Procedural programming *vs.* Object-Oriented programming.

1.3 Brief History of Programming Languages

Generations in programming languages are related to the evolution of both hardware and software progressing exponentially over the past half-century, thus allowing different levels of conceptual development and capabilities to be accomplished. In Computer Science history, there are five reconized generation languages (GLs):

- First-Generation Programming Languages (1GL)

  The beginning of it all: Machine language 01s

Low-level, no compiler, no assembler

Very fast, inputted directly to the computer

- Second-Generation Programming Languages (2GL)

  Assembly language (1947/1949)

  Alphabetical letters, huge leap from binary

  Low-level, no compiler, assembler to translate it into computer language

- Third-Generation Programming Languages (3GL)

  1st look at high-level: FORTRAN (1957), BASIC (1964), Pascal (1970), C (1972)

  Syntax resembles human languages

  Introduction of variables, constants, loops, flow constrains

  Compiler (1st 1951) to convert to machine language

  Enabled the development of complex software systems

  * "Advanced 3GL": Python, Java, Ruby, C++, C#

- Fourth-Generation Programming Languages (4GL)

  SQL, MATLAB, Octave

  Human language form of thinking and conceptualize

  Many of them based on C code

  Database related, report generation, and data manipulation

- Fifth-Generation Programming Languages (5GL)

  OPS5, Mercury, ICAD, ProLog

  Constrain-based languages (instead of procedural)

  Problem-solving using constrains rather than using an algorithm written by a programmer

  Use of logic and declarative programming paradigms

  Pushed forward the development of AI and complex problem-solving systems

1.4 The DRY Principle

The *DRY principle* stands for: "Don't Repeat Yourself", also known as "duplication is evil", and is a cornerstone of good practices in programming, specially in Software Development. The principle was coined by Andy Hunt and Dave Thomas in their book *The Pragmatic Programmer* (1999) and its powerful idea states:

Every piece of knowledge must have a single, unambiguous, and authoritative representation within a system.

I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code
I will not write any more bad code

Figure 2: "Don't repeat yourself" (DRY) principle.

In practical terms, it means no physical copies of code all over the place! It aims to reduce repetition of information which is likely to change (and it *will*! We are humans and code need to be flexible), replacing it with abstractions[†] that are less likely to change. One of the purposes of the DRY principle is to centralize reusable code. In the context of OOP, we avoid repetition by defining *Classes* and instantiating *objects*.

Keep it *DRY*, don't be *WET*: "write everything twice", "write every time", "we enjoy typing" or "waste everyone's time"!

1.5 Programming Language: C++

Here are the notes of a first contact with Object-Oriented Programming (OOP) through the lens of the C++ programming language. As the previous background relies on C programming, and so many times codes implemented in C/C++ seems interchangeable, it sounds worthy to highlight differences between C and C++.

Starting with the common heard allegations that "C++ is a superset of C" and that C++ is "C with class", nowadays, it is no longer nearly true as it was when originally created (Figure 3). Both languages evolved and developed specific aspects that make them differ. It is not bad nor false to consider:

C++ is mostly a superset of C C adding Object-Oriented Programming, Exception Handling, Templating, and a more extensive standard library.

Aspects of C++ that differ from C:

- C++ supports polymorphism, encapsulation, and inheritance *i.e.* is an OOP language;
- C++ supports both procedural and object-oriented programming paradigms (hybrid language);

[†]In computer science, information hiding is the principle of segregation of the design decisions in a computer program that are most likely to change, thus protecting other parts of the program from extensive modification if the design decision is changed.

- Data and functions encapsulated together in form of an object in C++ against separated in C;
- Functions can be used inside a structure in C++;
- Namespace is used in C++ avoiding name collisions;
- Virtual and friend functions are supported by C++;
- Exception handling is supported by C++;
- Strict type checking in done in C++. So many programs that run well in C compiler will result in many warnings and errors under C++ compiler;
- Named initializers must match the data layout of the struct in C++, instead of may appearing out of order in C;
- ...

Figure 3: Dennis Richie, developer of C (1969 - 1973) and Bjarne Stroustrup, developer of C++ (1979) (*from left to right*).

Practical changes:

Extension	`.c` $\longrightarrow$ `.cpp`
Header	`<stdio.h>` $\longrightarrow$ `<iostream.h>`
Input	`scanf()` $\longrightarrow$ `cin`
Output	`printf()` $\longrightarrow$ `cout`

Regarding dynamic memory, allowed by both, the functions `malloc()` and `free()` are forgotten as C++ provides new memory allocation operator and delete operator for memory de-allocation. Also, less common file extensions in C++ are given by `.c++`, `.cc`, `.cxx`.

Personal comment: Thanks gods of C++, no more dozens of variable specifications just to get input/output (I/O)!

2 Objects

The most fundamental concept in Object-Oriented Programming (as it couldn't be different) is the concept of **Object**. Here is a wide variety of definitions[‡] for *Object*:

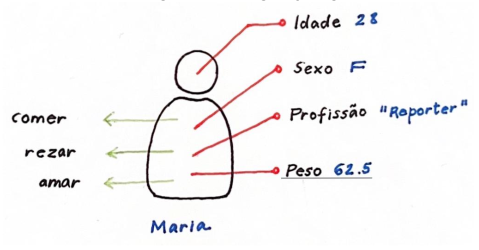
An object is a data structure or abstract data type containing fields (state variables containing data) and methods (subroutines or procedures defining the object's behavior in code).

In software development, an object is an entity that has state, behavior, and identity. An object can model some part of reality or can be an invention of the design process whose collaborations with other such objects serve as the mechanisms that provide some higher-level behavior. Put another way, an object represents an individual, identifiable item, unit, or entity, either real or abstract, with a well-defined role in the problem domain.

Software objects are conceptually similar to real-world objects: they too consist of state and related behavior. An object stores its state in fields (variables in some programming languages) and exposes its behavior through methods (functions in some programming languages).

In object-oriented programming (OOP), objects are the basic entities that actually exists in the memory. Each object is based on a blueprint of attributes and behaviours (variables and functions) defined as Class.

Example of an object



- Identity: Maria (object's name)
- State: `Idade`, `Sexo`, `Profissão`, `Peso` (age, sex, profession, weight) - Contains information about Maria
- Behavior: `comer`, `rezar`, `amar` (eat, pray, love)

3 Classes & Objects

The role of a **class** in C++ is to define a *template* or blueprint for creating **objects**. A class contemplates a family of objects that share a same group of characteristics (*attributes*) and behave/act in a certain manner (*methods*).

To create a new class, we use the command `class`:

```
class MyClass;
```

[‡]Ref. OOP - Objects Wikipedia, Object (computer science) Wikipedia, The Java Tutorials Oracle, What are Objects in Programming? Geeksforgeeks

```cpp
#include <iostream>

// Creation of a Class
class Treco {
    // Body
};
```

Regarding position in the C++ code, the classes are defined above the `main` function to keep the code legible and well-organized (good practices). By common agreement, classes are indicated with upper case.

The creation of an object in OOP is often called *instantiation*[§]. A specific object is an **instance** of the class. To create an object, we use the indication of the class of the object, followed by the object name:

`MyClass myObject;`

```cpp
// Creation of an object
int main(){
    Treco marreco; // Object of class Treco: instantiation

    // Fill the object
    marreco.tam = 10;
    marreco.name = "Marre";

    return 0;
}
```

Objects are created inside the `main` function, and following good practices, objects are indicated with lower case.

It is possible to create as many objects of a class as wanted. And a scenario where we need dozens, hundreds, or even more objects is where we can start to visualize and appreciate the power, economy, and sanity provided by the OOP paradigm. Instead of copying the block of code describing the object characteristics and actions n times the amount of required objects, just one declaration of the Class is needed, followed by the instantiation of the specifics objects in question. It's the DRY principle in action!

3.1 Attributes

Attributes are characteristics of a Class, or the characteristics that a Class can have within the program. Attributes are basically *variables* that belong to the class. An attribute is a "class member". A Class can have multiple attributes, each one presented as a variable declaration, with a certain type of variable and a name associated to it:

[§]**Instantiation**, most simply understood to mean "exemplification," or "the ideal example or representation," is also a more complicated philosophical idea. The "instantiation principle" is essentially the concept that a characteristic or property can't exist unless you can point to a real-world instance of it. Ref.https://www.vocabulary.com/dictionary/instantiation

```
type attribute;
```

Classes in C++ allow for attributes of different `type`. There is no problem in mixing types and using them multiple times, a Class can have inside it `char`, `int`, `double`, `bool`, `string` and even `struct` attributes.

The attributes access of an object in C++ is done using the dot (`.`) operator with the object name:

```
myObject.name;
```

```cpp
#include <iostream>
using namespace std;

// Class definition
class Animal {
    public: // Access specifier
        char zone;        // Attribute (type char)
        int size;         // Attribute (type int)
        double weight;    // Attribute (type double)
        bool carnivorous; // Attribute (type bool)
        string sp;        // Attribute (type string)
};

int main() {
    Animal tiger; // Class instantiation

    tiger.zone = 'a';
    tiger.size = 10;
    tiger.weight = 120.5;
    tiger.carnivorous = true;
    tiger.sp = "Bengala Tiger";

    cout << "Zone: " << tiger.zone << '\n';
    cout << "Size: " << tiger.size << '\n';
    cout << "Weight: " << tiger.weight << '\n';
    cout << "Carnivorous: " << tiger.carnivorous << '\n';
    cout << "Species: " << tiger.sp << '\n';
    return 0;
}
```

3.2 Methods

Methods are basically *functions* that belong to the class in C++. They are related to the actions and behavior of the objects of a particular class. A method is a "class member". A method is defined in C++ in one of the following ways: inside or outside class definition. The subsequent access of the method is done by creating an object of the class and using the dot (`.`) operator (just like accessing attributes).

Example Method defined inside and outside class definition

```cpp
    class Car {
    public: // Access specifier
        // Attributes
        int cc;       // Car engine (cc)
        int tank;     // Capacity (L)
        string name; // Model name
        double price_tank; // Amount to fuel the tank ($)

        // Methods
        // Method defined inside class
        void fuelCar(double price_fuel) {
            price_tank = tank * price_fuel;
        }
        // Method defined outside class
        void moveCar(); // Method declaration
};

// Method definition outside the class
void Car::moveCar() {
    cout << "vrum vrum" << "\n";
    cout << name << " on the highway " << cc << " cc" << "\n";
}
```

3.3 Constructor

Special method called (automatically) when an object of a class is created.

- Always same name as the class;
- Always public;
- Don't have return value!

A constructor is defined in C++ using the class name followed by parentheses:

```cpp
class MyClass {
    public:
      MyClass() {
       cout << "Hello World!";
      }
};
int main() {
    MyClass myObj;
    return 0;
}
```

```cpp
    class Toy { // The class
        public: // Access specifier
            Toy() { // Constructor
                cout << "Toy Story" << endl;
            }
    };
```

It is possible to add parameters to the Constructor (just like regular functions):

```cpp
    class Car { // The class
        public: // Access specifier
            string brand; // Attribute
            string model; // Attribute
            int year;     // Attribute

            // Constructor with parameters
            Car(string x, string y, int z) {
                brand = x;
                model = y;
                year = z;
            }
    };
```

Adding parameters to the Constructor makes it specially useful in terms of setting the initial values for the object's attributes, which can be performed right along with the object instantiation:

```cpp
    int main() {
    // Create Car objects + call constructor w/ different values
    Car car1("Fiat Uno", "Mille", 1983);
    Car car2("Ford", "Mustang", 1969);
    //Car uno; // Error: default constructor is missing

    // Print the objects and its attributes
    cout << car1.brand << " " << car1.model << " " << car1.year << endl;
    cout << car2.brand << " " << car2.model << " " << car2.year << endl;
    return 0;
}
```

Example Definition of a constructor outside of a class
→ Use of the `::` operator with the class name

```cpp
class Food { // The class
    public: // Access specifier
        string name;   // Attribute
        bool tasty;    // Attribute
        int stars;     // Attribute
        string status; // Attribute
        // Constructor declaration
        Food(string in_name, bool in_tasty, int in_stars);

        // Methods
        void avaliation() {
            cout << "Food " << name << " avaliation:" << endl;
            cin >> stars;
        }
};

// Constructor definition outside the class
Food::Food(string in_name, bool in_tasty, int in_stars) {
    name = in_name;
    tasty = in_tasty;
    stars = in_stars;
    status = "Not rated yet";
}
```

3.4 Specifier

The specifier element of a Class indicates the *access* each component - attribute or method - has. It's the idea of having credentials in real life to access something. Allows hiding members from the outside world. In C++, there are three *access specifiers*:

- `Public`: accessible from outside the class;
- `Private`: cannot be accessed (or viewed) from outside the class;
- `Protected`: cannot be accessed from outside the class, but can be accessed in inherited classes.

$\longrightarrow$ By **default**, if no access specifier is indicated, all data members and member functions of a class are made `private` by the compiler !

Note that: Private members are not lost. It is possible to access private members from inside the class, *ie.* using a public method inside the same class.

OBS: It is considered good practice to declare class attributes as private (as often as possible). This will reduce the possibility of messing up the code. It is related to the property of C++ of providing data hiding, thus more secure code.

4 Graphic Representation - Class Diagram UML

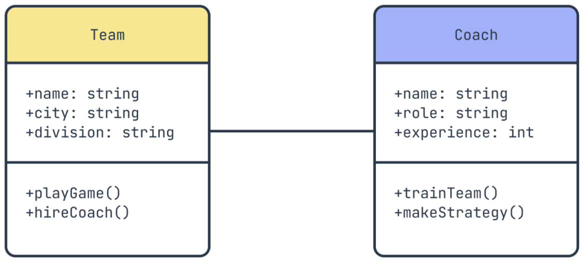


Figure 4: UML Class Diagram representation

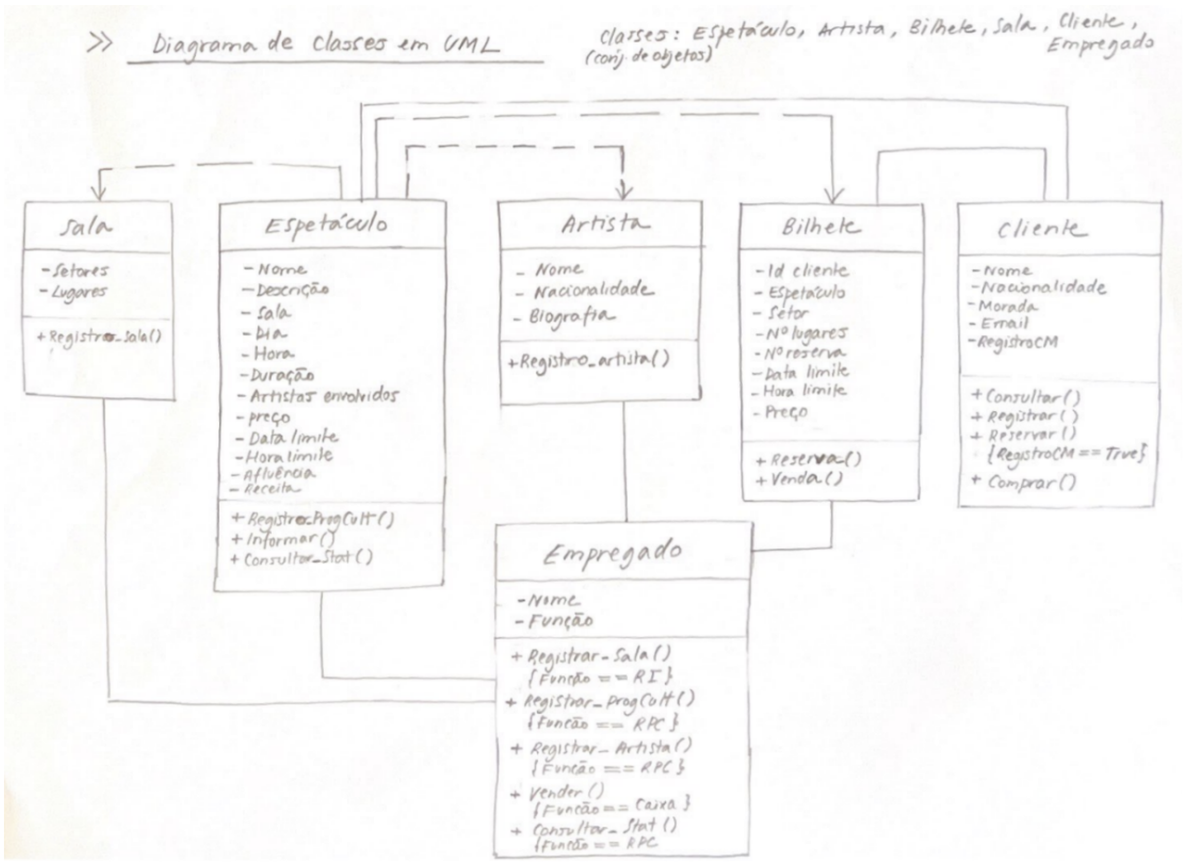


Figure 5: Example of a Class Diagram in UML - Casa da Música

5 Encapsulation

The idea of **encapsulation** is strongly connected to the concept of *hiding information*. Encapsulation is a language mechanism for restricting direct access to some of the object's components. Languages as C++ allows it (not possible in C), and it is implemented using *classes* and *access modifiers*, done by declaring class members, attributes or methods, as `private`.

Encapsulation $\longrightarrow$ Hide members at declaration; access specifier `private`

Access $\longrightarrow$ Provision of public methods ("`set`" and "`get`")

As access specifiers limits access in terms of external routines, a `private` member is restricted for the public eyes, not from the object itself. To access a private attribute in a class, it is possible by using public *setter* and *getter* methods.

Getter method: Has the role to return the value of a private attribute;
Setter method: Assigns value to a private attribute.

Good practice to keep code readable and organized is to create getter and setter methods using the prefix `get` or `set`, respectively, conserving with upper letter the name of the attribute they are going to act on:

Private attribute	`private:`	`type secret;`
Getter method	`public:`	`getSecret()`
Setter method	`public:`	`setSecret()`

Example Setter and Getter methods

```
class Housing {
    private:
        string address; // Attribute private

    public:
        // Methods
        // Setter
        void setAddress(string a) {
            address = a;
        }
        // Getter
        string getAddress() {
            return address;
        }
        string wantAddress() { // Also works as getter method
            return address;
        }
    /*Good practices: use prefixes 'set' and 'get' + private
    member name*/
};

```

```cpp
int main() {
    Housing house;
    house.setAddress("R. Goncalo Cristovao");
    cout << house.getAddress() << endl;
    cout << house.wantAddress() << endl;
    return 0;
}
```

The main purpose of encapsulation in C++ is to ensure that sensitive data is hidden from users, thus it is considered good practice to declare class attributes as privates as it allows better control of data and increases security. Encapsulation allows us to modify parts of the code without affecting other parts.

OBS: Encapsulation is supported in all object-oriented programming (OOP) systems support. Programming languages such as C++, C#, Java, PHP, Swift, and Delphi offer ways to restrict access to data fields, but encapsulation is not unique to OO languages, it is also possible in non-object-oriented languages.

6 Inheritance

Inheritance in C++ is a way to inherit attributes and methods from one class to another. There is the **derived class**, *i.e.* the class that inherits from another class, the "kid", and the **base class** or **parent class**, the "mother/father".

Inheritance is useful in programming as it enables code reusability by reusing attributes and methods from existing classes. The symbol : is used to indicate inheritance in C++.

```cpp
// Defining classes
// Base class
class UPStudent {
    private: // Access specifier
        int personal; // Attribute

    public: // Access specifier
        string name;   // Attribute
        void party() { // Method
            cout << "Queima de fitas! \n";
        }
        void setPersonal(int p) { // Setter method
            personal = p;
        }
        int getPersonal() { // Getter method
            return personal;
        }
};

```

```
// Derived class
class FEUPStudent: public UPStudent{ // New class, takes other
    public:
        string engineering;
};

int main() {
    FEUPStudent student;          // Obj. instant. derived class
    student.name = "Joao";        // Attr. from base class
    student.engineering = "EIC"; // Attr. from derived class
    student.party();              // Method from base class
    cout << student.name + " " + student.engineering << endl;

    // Accessing private attributes from base class
    student.setPersonal(10);                  // Setter base class
    cout << student.getPersonal() << "\n"; // Getter base class
    return 0;
}
```

6.1 Multilevel Inheritance

History and family: genealogical tree and inheritance. A class can be derived from one class, which is already derived from a class and all the way back... Multilevel inheritance in C++ is a class that is derived from another derived class.

```
class UPStudent {
    private: // Access specifier
        int personal; // Attribute

    public: // Access specifier
        string name;   // Attribute
        UPStudent() { // Constructor
            std::cout << "UP student" << endl;
        }
        void party() { // Method
            cout << "Queima de fitas! \n";
        }
        void setPersonal(int p) {
            personal = p;
        }
        int getPersonal() {
            return personal;
        }
};

// Derived class
class FEUPStudent: public UPStudent{};
class FCUPStudent: public UPStudent{};
```

```cpp

// Derived class from derived class
class AEFEUPStudent: public FEUPStudent { // Multilevel inherit.
    public:
        int AEFEUPnum;
        AEFEUPStudent() { // Construct
            std::cout << "AEFEUP Student" << endl;
        };
};
```

Note that a derived class is not obligated to have any attribute or method to be defined. It can rely solely on what it inherits. A benefit of multilevel inheritance is code reusability and access to methods from multiple levels.

6.2 Multiple Inheritance

Not only of eggs is a cake made! Neither does Brazil, which is a fruit of several cultures, so that its citizens are heirs of multiple inheritance. Italian mother with Spanish father, Japanese father and Lebanese mother and so go on, with classes in C++ being able to be derived from more than one class, using a **comma-separated list** (,):

```
class ClassName:  public BaseClass1, public BaseClass2
```

Example Multiple Inheritance

```cpp
#include <iostream>
using namespace std;

class Physics { // Base class (father)
    public:
        int physics;
};

class Mathematics { // Another base class (mother)
    public:
        int math;
};

// Derived class (child)
class Engineering: public Mathematics, public Physics {};

int main() {
    Engineering engineer;
    engineer.math = 10;
    engineer.physics = 1000;
    cout << engineer.math + engineer.physics << endl;
    return 0;
}
```

```
1010
```

Example Multiple Inheritance (3+ classes)

Multiple inheritance in C++ is not limited to only a "mother" and a "father" class; it supports inheritance from a multitude of different base classes.

```cpp
#include <iostream>
using namespace std;

class Physics { // Base class (father)
    public:
        int physics;
};

class Mathematics { // Another base class (mother)
    public:
        int math;
};

class Chemistry { // One more base class
    public:
        int chemistry;
};

class Science: public Mathematics, public Physics,
               public Chemistry {};

int main() {
    Science science;
    science.math = 1;
    science.physics = 2;
    science.chemistry = 3;
    cout << science.math + science.physics + science.chemistry
    << endl;
    return 0;
}
```

```
6
```

Example Multiple Inheritance + Multilevel Inheritance (Fig. 6)

Sometimes beyond being a heir of multiples classes (*multiple inheritance*), the base classes from where it derives are also derived from others classes (multilevel inheritance) as well. C++ allows for a combination of all of it for the definition of a new class.

```cpp
class USPStudent {
    public:
        int USPnum;
};
class ICMCStudent: public USPStudent {
    public:
        ICMCStudent() {
            cout << "ICMC student: 'Raca CAASO' " << endl;
        }
};
class ERASMUSStudent: public FEUPStudent, public ICMCStudent {};

int main() {
    // Multiple Inheritance
    ERASMUSStudent student4;
    student4.name = "Amanda";
    cout << student4.name << endl;
}
```

```
UP student
FEUP student
ICMC student:  'Raça CAASO'
Amanda
```

→ *Note that* the object `student4` instantiated of the class `ERASMUSStudent` were able to inherit attributes and methods from both classes `FEUPStudent` and `ICMCStudent`, as we can see by the messages `UP student`, `FEUP student`, and `ICMC student:  'Raça CAASO'`. We also see that the attribute `name` from the base class `UPStudent`, from which `FEUPStudent` is derived, was also accessible. Thus, C++ allows us to perform multiple inheritance along with multilevel inheritance.

OBS: Atention Multiple Inheritance - Simple mistake

```cpp
class ERASMUSStudent: public FEUPStudent, ICMCStudent {};

int main() {
    // Multiple Inheritance
    ERASMUSStudent student4;
    student4.name = "Amanda";
    student4.USPnum = 10260441;
    student4.UPnum = 202411286;
    cout << student4.name + " N USP: " + student4.USPnum +
    " N UP: " + student4.UPnum << endl;
}
```

```
error:  'int USPStudent::USPnum' is inaccessible within this context 17 |
student4.USPnum = 10260441;
```

→ *Note that* trying to create a derived class `ERASMUSStudent` combining multiple classes **without** the access specifier `public` before the name of the second class led to an error.

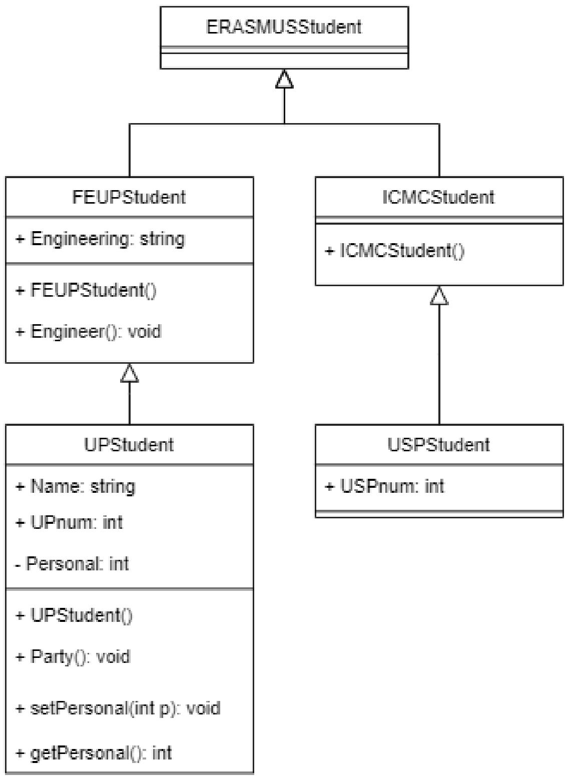


Figure 6: Class diagram UML representation relations in the multiple and multilevel inheritance. Access specifier `public` indicated by + and `private` by −.

6.3 The Diamond Problem

The **Diamond Problem** or the "Deadly Diamond of Death" is a typical problem in Object-Oriented programming languages.

It consists in *ambiguity* arising due to a new multiple inherited class (Child) inheriting from "mother" classes (Parent 1 and Parent 2) both deriving from a common base class (Base). In other words, the diamond problem occurs when two superclasses of a class have a common base class. Or even, deadly diamond of death is simply the problem of *repeated inheritance*.

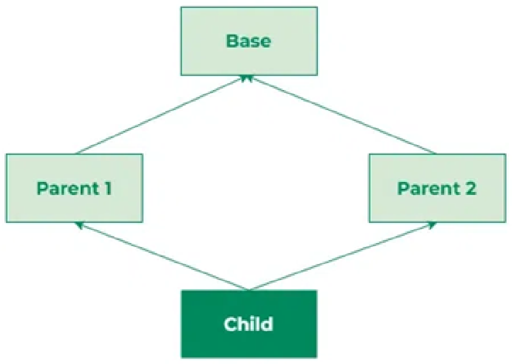


Figure 7: The Diamond Problem

Example Diamond Problem Error

```
#include <iostream>
```

```cpp
using namespace std;

class Animal {
    public:
        string name;
        int weight;
};

class Mammal: public Animal {
    public: int age;
};

class Flying: public Animal {
    public: int velocity;
};

class Bat: public Mammal, public Flying {};

int main () {
    Bat batman;
    batman.age = 40;
    batman.velocity = 100;
    batman.name = "Bruce";
    return 0;
}
```

```
error:  request for member ‘name’ is ambiguous 24 | batman.name = "Bruce";
```

→ *Note that* in this case we have the class `Animal` as Base. `Mammal` and `Flying` as Parent 1 and Parent 2 both inherit from `Animal`, and `Bat` inherits from both `Mammal` and `Flying`. This results in `Bat` having two separate copies of `Animal`'s members (`name` and `weight`), leading to ambiguity when trying to access `name` from an instance of `Bat`. Thus, giving up the error of repeated inheritance: which version of the attribute does `Bat` inherit: that of `Mammal`, or that of `Flying`? >> Error!

Nevertheless, not all OO languages face this problem: “Languages that allow only *single inheritance*, where a class can only derive from one base class, do not have the diamond problem. The reason for this is that such languages have at most one implementation of any method at any level in the inheritance chain regardless of the repetition or placement of methods. Typically these languages allow classes to implement multiple protocols, called interfaces in Java. These protocols define methods but do not provide concrete implementations. This strategy has been used by ActionScript, C#, D, Java, Nemerle, Object Pascal, Objective-C, Smalltalk, Swift and PHP¶.”

¶Ref. Multiple Inheritance - *Wikipedia*

6.3.1 Fixing the Diamond Problem: Virtual Inheritance

OBS: Not to dive into the theme, but to bring a solution for the giving problem and not leaving it open, with the help of the "entity" ChatGPT we get a quick solution: **Virtual Inheritance**. The use of virtual inheritance ensures that `Bat` has only one shared instance of `Animal` instead of two separate copies.

```cpp
#include <iostream>
using namespace std;

class Animal {
    public:
        string name;
        int weight;
};

class Mammal: virtual public Animal { // Use virtual inheritance
    public: int age;
};

class Flying: virtual public Animal { // Use virtual inheritance
    public: int velocity;
};

class Bat: public Mammal, public Flying {};

int main () {
    Bat batman;
    batman.age = 40;
    batman.velocity = 100;
    batman.name = "Bruce"; // No ambiguity, single instance of Animal
    batman.weight = 20;    // Also no ambiguity

    cout << "Bat Name: " << batman.name << endl;
    cout << "Bat Weight: " << batman.weight << endl;
    cout << "Bat Age: " << batman.age << endl;
    cout << "Bat Velocity: " << batman.velocity << endl;
    return 0;
}
```

Why Virtual Inheritance works?

1. *Prevents duplicate* instances of `Animal` in `Bat`;
2. Ensures a *single shared base class* for all derived classes;
3. *Resolves ambiguity* when accessing members of `Animal`.

6.4 Inheritance Access

Returning to the topic of *Access Specifiers* (Sec. 3.4), so far, we used and played with `public` and `private` attributes and methods. Now, in the context of inheritance, it's time for the `protected` access specifier to come to the sunlight.

```cpp
#include <iostream>
using namespace std;

class Gradma { // Base class
    public: int age;
    protected: int fortune = 1000000;
};
class Mother: public Gradma { // Derived class
    public:
        int children;
        void setFortune(int f) { // Setter method
            fortune = f;
        }
        int getFortune() { // Getter method
            return fortune;
        }
};

int main () {
    Mother mother;
    mother.children = 3;
    mother.age = 45;
    cout << mother.children << endl;
    cout << mother.age << endl;
    //mother.fortune = 10;
    /*error: 'int Gradma::fortune' is protected within
    this context*/

    cout << "Gradma fortune: " << mother.getFortune() << endl;
    mother.setFortune(100);
    cout << "Gradma fortune after mother : " <<
    mother.getFortune() << endl;
    return 0;
}
```

```
Mother children:  3
Mother age:  45
Gradma fortune:  1000000
Gradma fortune after mother :  100
```

The purpose of the protected access specifier in C++ is to allow access within the class and in derived classes. Protected members of a class cannot be accessed directly from outside the class, similar to private access.

7 Polymorphism

Polymorphism in C++ means many forms and is related to methods that are implemented in multiple classes. Its main purpose is to allow the performance of a single action in different ways.

- Polymorphism allows derived classes to provide their *own implementation of base class methods*;
- It is useful as it allows for code reusability;
- Provides *flexibility* in how methods are implemented in derived classes.

```cpp
#include <iostream>
using namespace std;

class Blood { // Base class
    public:
        int bloodNumber;
        void bloodFlow() {
            cout << "Blood Flow" << endl;
        };
};

class TypeA: public Blood { // Derived class
    public:
        void bloodFlow() {
            cout << "Blood Flow A" << endl;
        };
};

class TypeB: public Blood { // Derived class
public:
    void bloodFlow() {
        cout << "Blood Flow B" << endl;
    };
};

class TypeO: public Blood { // Derived class
public:
    void bloodFlow() {
        cout << "Blood Flow O" << endl;
    };
};

int main () {
    TypeA typeA;
    TypeB typeB;
    TypeO typeO;
    typeA.bloodFlow();
    typeB.bloodFlow();
    typeO.bloodFlow();
    return 0;
}
```

```
Blood Flow
Blood Flow A
Blood Flow B
Blood Flow O
```

Referências

1. "C++ Classes", *W3Schools*, https://www.w3schools.com/cpp/cpp_oop.asp
2. "Object-oriented programming", *Wikipedia*, https://en.wikipedia.org/wiki/Object-oriented_programming#cite_note-2
3. "Coding milestones: a journey through the history of programming", *Nomical Connecting Worlds*, https://nomical.com/news/coding-milestones
4. "The Generations of Programming Languages — Computer Science History", ForrestKnight, *YouTube*, https://www.youtube.com/watch?v=ZFIeEV2HfPQ&ab_channel=ForrestKnight
5. "Programming languages generations", Steve Yonkeu, https://dev.to/yokwejuste/programming-languages-generations-2o6p
6. "OO in One Sentence: Keep It DRY, Shy, and Tell the Other Guy", Andy Hunt and Dave Thomas, *IEEE Software* (2004) https://media.pragprog.com/articles/may_04_oo1.pdf
7. "Multiple Inheritance", *Wikipedia*, https://en.wikipedia.org/wiki/Multiple_inheritance

Index