Definition of classes in C++

Programação (L.EIC009)

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A class named `some_class` is a datatype declared using the `class` keyword.

```
class some_class { ... };
```

We will now see how a class is defined, covering the following notions:

- class declaration;
- `public` and `private` declarations;
- member fields, member functions, constructors and destructors; and
- `static` (global) class fields and functions.

Other topics not covered here: template classes, operator overloading and class inheritance.

Class vs Struct

What is the difference between a class and a struct?

```
class some_class { ... };

struct some_struct { ... };
```

Class vs Struct

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```

In C++, almost none! Struct has been “inherited” from C.

They are essentially the same, with one difference: declarations in a class are `private` by default, and in a struct are `public` by default.

Later in this class we will see what this means.

Class vs instance (or object)

A **class** is defined by a set of attributes (e.g., variable declarations) and behaviours (e.g., function declarations).

An **instance** of a class (or an **object**) represents a particular realization of a given class.

A common analogy is to think of a **class** as the blueprint for a house, and **objects** as the houses that come from that blueprint.

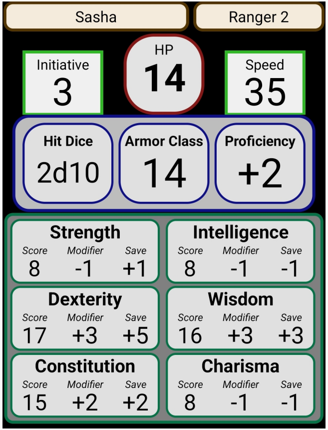
Let's see another example.

Class vs instance (or object)

```
class Ranger {...};
```

```cpp
class Ranger {...};
```


```cpp
Ranger sasha{"Sasha", 3, 14, 35};
```



```
namespace some_namespace {
  class some_class {
    ...
  };
}
```

A class is declared using the `class` keyword. Like other definitions (functions, structs, etc) a class may be declared in the scope of a namespace, e.g. `some_namespace`.

You should *always* declare the class in a header file, e.g. `some_class.h`/`some_class.hpp`, while the implementation resides in a separate file, e.g. `some_class.cpp` (the same is true for other declarations with implementations, such as functions).

We will see later why (*tip*: it has to do with the linker).

U.PORTO

```
// header guard section:
#ifndef __some_class_hpp__
#define __some_class_hpp__
namespace some_namespace {
  class some_class {
    ...
  };
}
#endif // <-- end of section
```

Class declaration (cont.)

```
// header guard section:
#ifndef __some_class_hpp__
#define __some_class_hpp__
namespace some_namespace {
  class some_class {
    ...
  };
}
#endif // <-- end of section
```

Header guards are a standard practice for C/C++ header files, in particular those containing class declarations. They prevent repeated includes of the same file to have any effect.

```
#include <some_class.hpp>
#include <some_class.hpp>
// 2nd line: no effect !
```

Another example

U.PORTO

`fraction.hpp` (1) :

```
#ifndef __fraction_hpp__
#define __fraction_hpp__

namespace leic {
  class fraction { ... };
} ...
#endif
```

`polynomial.hpp` (2):

```
#ifndef __polynomial_hpp__
#define __polynomial_hpp__
#include "fraction.hpp"
namespace leic {
  class polynomial {  ... };
} ...
#endif
```

Another example

U.PORTO

Thanks to header guards, `fraction.hpp` is only included once, even if `some_class.hpp` and `polynomial.hpp` both include it.

`some_class.hpp` (2):

```
#ifndef __some_class_hpp__
#define __some_class_hpp__

#include "polynomial.hpp"
#include "fraction.hpp"

namespace leic {
  class some_class { ... };
} ...
#endif
```

Examples (cont.)

```
class fraction {
  ...
};
```

`fraction`: represents fractions $\frac{n}{d}$ (rational number) in irreducible form, where $n \in \mathbb{Z}$ and $d \in \mathbb{Z}^+$.

```
class polynomial {
  ...
};
```

`polynomial`: represents polynomials $f_0 + f_1 x^1 + f_2 x^2 + \ldots + f_n x^n$ where $f_1, \ldots, f_n$ are `fraction` objects.

`public` and `private` visibility

A class may contain sections of `public` and `private` declarations:

```
class some_class {
public:
  // public declarations
  ...
private:
  // private declarations
  ...
};
```

`public` and `private` are keywords called **access specifiers**.

Declarations in a `public` section are accessible outside the class without restrictions.

Declarations in a `private` section are accessible by the class only.

Two complementary mechanisms to be seen later: (1) `friend` classes and functions may access private declarations too; and (2) `protected` is another type of access specifier (not covered in these slides), allowing declarations to be acessed by derived classes through inheritance.

```
class fraction {
  ...
private:
  int num, den;
  ...
};
```

```
class polynomial {
  ...
private:
  vector<fraction> coeff;
  ...
};
```

A class may declare **member fields**, also called instance fields. Each object that instantiates the class will have values for each of the member fields.

Above: `num` and `den` defined for `fraction`; `coeffs` for `polynomial`.

```
class fraction {
  ...
private:
  int num, den;
  ...
};
```

Fields work as in the case of `struct` types. However, unlike `struct`s, in `class`es they are `private` by default, and can only be manipulated directly by code inside the class. The purpose of a `private` visibility is to “hide” the internal state of objects, and allow their manipulation only indirectly through `public` constructors and member functions.

Member fields (cont.)

U.PORTO

Access to `private` member fields from outside the class are not allowed by the compiler:

```
class fraction {
  ...
private:
  int num, den;
  ...
};
...
int main() {
  fraction f;
  f.num = 123; // NOT ALLOWED!
}
```

Access to `private` member fields from outside the class are not allowed by the compiler:

```
class fraction {
  ...
private:
  int num, den;
  ...
};
...
int main() {
  fraction f;
  f.num = 123; // NOT ALLOWED!
}
```

```
error: ‘int leic::fraction::num’ is private
within this context
...   f.num = 123;
```

Constructors and member functions

```
class fraction {
public:
  // constructors
  fraction(int n, int d=1) { ... }
  fraction() {  ... }
  fraction(const fraction& f) { ... }
  ...
private:
  int num, den;
  ...
};
```

Constructors allow an object to be created and initialized. They are typically `public`.

```
fraction a(1,2), b(3), c, d(c);
```

Constructors

```
fraction(int n, int d=1) {
  num = n;
  den = d;
  reduce(); // convert to irreducible form (check the code for details)
}
fraction() {
  num = 0;
  den = 1;
}
```

```
fraction(const fraction& f) {
  num = f.num;
  den = f.den;
}
```

Constructors define the **initial state** of an object by assigning values to member fields.

Constructors (cont.)

Field initialisation in constructors can be expressed alternatively through **member initializer lists**. The generic syntax is as follows:

```
class_name(...) : field_1(value_1), ..., field_n(value_n) {
  // constructor body (may be empty!)
  ...
}
```

For `fraction` the previous constructors can be rewritten using initializer lists as follows:

```
fraction(int n, int d)  : num(n), den(d) { reduce(); }
fraction() : num(0), den(1) { }
fraction(const fraction& f) : num(f.num), den(f.den) { }
```

Constructors (cont.)

```
fraction(int n, int d=1)  : num(n), den(d) { reduce();}

// Delegating constructors call the first one -->
fraction() : fraction(0) { }
fraction(const fraction& f) : fraction(f.num, f.den) { }
```

Member initializer lists can also be used to call other constructors, a mechanism called **constructor delegation**. This is shown above for `fraction`.

The purpose is usually that one of the constructors provides the base functionality for initialisation, while other constructors that call it, called **delegating constructors**, just offer the conveniency of distinct types of object construction.

Constructors and member functions

```
class fraction {
public:
  // constructors
  ...
  // member functions
  int numerator() const { ... }
  int denominator() const { ... }
  void add(const fraction& f) { ... }
  void mul(const fraction& f) { ... }
  ...
};
```

After construction, member functions can be invoked on an object.

```
fraction a(1,2), b(2,3), c(1);
a.mul(b); // 1/2 * 2/3 = 1/3
a.add(c); // 1/3 + 1 = 4/3
cout << a.numerator() << ' '
     << a.denominator() << '\n';
  // ^--> 4 3
```

```
int numerator() const { return num; }
int denominator() const { return den; }
```

```
void add(const fraction& f) {
  num = num * f.den + f.num * den;
  den = den * f.den;
  reduce();
}
```

```
void mul(const fraction& f) {
  num = num * f.num;
  den = den * f.den;
  reduce();
}
```

Member functions allow an objet state to be queried or modified. Above: `numerator()` and `denominator()` just return the values of member fields without changing them; `add()` and `mul()` change the member fields' values.

U.PORTO

```
int numerator()   const { return num; }
int denominator() const { return den; }
```

The `const` modifier reflects that the member function does not change member fields.

Changes to a member field within a `const` member function yield compilation errors.

```
// Alternative definition ...
int numerator() const {
  num++; // NOT ALLOWED BY THE COMPILER!
  return num;
}
```

```
error: increment of member ‘leic::fraction::num’ in read-only object
```

Separate declaration and implementation

Functions are declared within a class, and their implementation should appear separately in a different source code file. For example, one could have `fraction` defined as follows:

```
// Only declarations!
class fraction {
public:
  fraction(int num, int den=1);
  ...
  int numerator() const;
  int denominator() const;
  ...
};
```

```
// Implementation
fraction::fraction(int n, int d) :
  num(n), den(d) { }
int fraction::numerator() const {
  return num;
}
int fraction::denominator() const {
  return den;
}
...
```

“What is `this` ?”

`this` designates a pointer to the object instance in context in a constructor or other member function.

For instance, within `fraction` ...

```
int numerator() const { return this->num; }
```

or

```
int numerator() const { return (*this).num; }
```

are both equivalent to

```
int numerator() const { return num; }
```

The use of `this` is relevant only when there is a need for disambiguation between the names of fields and other variables, and in some other special cases.

“What is `this` ?” (cont.)

In the following constructor of `fraction`, arguments are named exactly like the `num` and `den` field names. The constructor body uses the `this` pointer to disambiguate between fields and arguments.

```
fraction(int num, int den) {
  this -> num = num; // field = argument
  this -> den = den;
  reduce();
}
```

Class composition

```cpp
class polynomial {
  ...
private:
  // Fraction coefficients.
  // Position i in the vector
  // refers to the
  // coefficient of degree i.
  std::vector<fraction> coeff;
  ...
};
```

Class composition happens when one or more member fields of a class are objects of other classes.

Above: `polynomial` is defined through the use of a `std::vector` field.

Moreover, `std::vector` (a template class) is parameterised in this case with the `fraction` class type.

Class composition (cont.)

```
class polynomial {
public:
  polynomial(const
  std::vector<fraction>& c)
  : coeffs(c) {
    reduce();
  }
  ...
private:
  std::vector<fraction> coeffs;
  ...
};
```

The initialisation of `coeffs` through `coeffs(c)` in the member initialiser list means that the `vector` copy constructor is called.

Member initializer lists are specially relevant in the case of object member fields, since they ensure an adequate constructor invocation.

Through class composition, we can combine the functionality of several classes for meaningful code.

```
class polynomial {
public:
  // the maximum exponenent
  int degree() const {
```

Class composition (cont.)

Through class composition, we can combine the functionality of several classes for meaningful code.

```
class polynomial {
public:
  // the maximum exponenent
  int degree() const {
    return coeffs.size() - 1;
  }
```

Class composition (cont.)

Through class composition, we can combine the functionality of several classes for meaningful code.

```
class polynomial {
public:
  // add another polynomial
  void add(const polynomial& p) {
```

Class composition (cont.)

Through class composition, we can combine the functionality of several classes for meaningful code.

```
class polynomial {
public:
  // add another polynomial
  void add(const polynomial& p) {

    size_t n = std::min(coeffs.size(), p.coeffs.size());
    for (size_t i = 0; i < n; i++)
      coeffs[i].add(p.coeffs[i]);
    for (size_t i = coeffs.size(); i < p.coeffs.size(); i++)
      coeffs.push_back(p.coeffs[i]);
    reduce(); }
```

Destructors

U.PORTO

```
class fraction {
public:
   ...
   ~fraction() { }
   ...
};
```

A **destructor** frees up resources used by an object when the lifetime of an object ends.

Above: `~fraction()` has an empty body, hence it can be alternatively omitted; an empty destructor is defined by default if the implementation omitted.

Destructors (cont.)

```
class polynomial {
public:
  ...
  ~polynomial() { }
private:
  std::vector<fraction> coeffs;
  ...
};
```

As in `fraction`, `polynomial` has an empty destructor, thus again the destructor could be omitted.

In any case, `~vector()` (the destructor of `vector`) is invoked automatically for `coeffs` in the `polynomial` class. This always happens for object fields in a class, when a class destructor is called.

Destructors (cont.)

```
class polynomial {
public:
  polynomial(
    const vector<fraction>& c) {
    coeffs = new fraction[c.size()];
    for (size_t i = 0; i < c.size();
    i++) coeffs[i] = c[i];
  }
  ~polynomial() {delete [] coeffs;}
  ...
private:
  fraction* coeffs;
};
```

Now suppose `polynomial` used a dynamically allocated array for the coefficients instead of a `vector` object …

In this case, the memory of the array would have to be released explicitly by `~polynomial()`.

```
class fraction {
  // class function (static)
  static int gcd(int a, int b) {
    while (b != 0) {
      int tmp = a; a = b; b = tmp % b; }
    return a;
  }
  // member function (non-static)
  void reduce() {
    int g = gcd(num, den);  num /= g; den /= g;
    if (den < 0) { num = -num; den = -den; }
  } ...
};
```

The `static` modifier indicates that a function is global to the class, called a **class function**. When the function is invoked, there is no association to any particular object. **this** cannot be used inside `static` functions (there is no object!).

static class members (cont.)

```
class fraction {
  ...
  static const fraction ZERO;
  ...
};
// outside the class declaration
const fraction fraction::ZERO(0, 1);
```

We can also have **class fields** declared with `static`.

These fields are global to the class.

Quite often, `static` class fields are used to represent constants as in the example above for the `ZERO` fraction object; note that `ZERO` also has the `const` modifier.

Initialisation of `static` fields must be stated outside the class declaration (it counts as an implementation!).

static class members (cont.)

Given that ZERO is declared as const, it is a class constant. It refers to an immutable object that cannot have its internal state modified after construction.

For instance, it is valid to invoke const member functions over ZERO ...

```
cout << fraction::ZERO.numerator() << ' '
     << fraction::ZERO.denominator() << '\n';
```

but not state-changing member functions ...

```
fraction a(1,2);
fraction::ZERO.add(a); // NOT ALLOWED!
```

```
error: passing 'const leic::fraction' as 'this' argument
discards qualifiers ... fraction::ZERO.add(a);
```

`static` class members (cont.)

The scoping operator `::` must be used to access `static` members outside the class

`class_name::declaration_name`

e.g., `Fraction::ZERO` as in the previous slide, or `Fraction::gcd` for the gcd function.

friend declarations

`friend` declarations in a class identify other external classes or functions with access to private declarations in the class. In this example, `friend` access is granted to the `polynomial` class and an implementation of the << operator (an example of operator overloading, a topic to be covered in detail later).

```
class fraction {
  ...
  friend class polynomial;
  friend std::ostream& operator<<(std::ostream& s, fraction& f);
};
```

`friend` declarations (cont.)

```
std::ostream& operator<<(std::ostream& out, const fraction& f) {
  out << f.num;   // direct access to fields is allowed!
  if (f.den != 1) out << '/' << f.den;
  return out;
}
```