

# Composite objects: `structs` and `classes`

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## Declaration and definition of `structs`

In C/C++ all variables must be “declared” before being used;  
`structs` need also being “defined”

**Declaration:** a name is simply stated as identifying a `struct`.  
It can be repeated.

```
// Point declaration
struct Point;
Point* pp;
```

**Definition:** all the members of the `struct` must be specified.  
**One and only one** definition must exist in each translation unit using it.  
A definition is also a declaration.

```
// Point definition
struct Point {
    float x;
    float y;
};
Point p;
```

- To create a `struct` the definition is necessary
- To create a pointer the declaration is enough



## Access to members

structs can be initialized with a list.

When a struct has been created,  
its member are accessed with their names.

```
Point p={2.35,6.71};
std::cout << p.x << " " << p.y << std::endl;
```

The members of a struct can be accessed  
starting from a pointer, too

```
Point p;
Point* pp=&p;
(*pp).x=4.59; // parentheses are needed
pp->y=-12.86; // equivalent to(*pp).y=-12.86
```

## Nested structs

A struct can be defined inside the definition of another one

```
struct Outer {  
    ...  
    struct Inner {  
        float x;  
        ...  
    };  
    Inner i;  
    ...  
};  
...  
Outer o;  
o.i.x=13.6;
```



## Memory sharing: unions

In a `struct` the members are stored in memory sequentially;  
in an `union` the members share the same memory locations.

All the objects are stored  
starting from the same  
memory location

```
union Misc {  
    float x;  
    int i;  
    char* p;  
};  
Misc m;
```

- The size of the `union` is the size of the largest object
- Only one object can be stored at once
- Undefined results are obtained when writing one object (e.g. `m.x`) and reading another one (e.g. `m.i`)

## structs and classes

`class`: the main improvement of C++ versus plain C

A `class` is essentially an evolution of a `struct`

Plain-C `structs` contain only variables or other objects,

C++ `classes` provide several new functionalities:

- constructor(s) and destructor,
- functions handling data members,
- access specifiers to control access to data.

The standard extended to `structs` the properties of `classes`

## class “interface”

The definition of a `class`, with all its functions, is also called “interface”

```
class Point {
public: // accessible by all functions
    Point(float x, float y); // constructor
    ~Point(); // destructor
    float getX() const; // member functions
    float getY() const;
    float dist(const Point& p) const;
private: // accessible only by the class
    float xp; // member data
    float yp;
};
```

- `struct` : members are `public` by default
- `class` : members are `private` by default





## Constructor and destructor

The “constructor” and “destructor” of a class are executed when an object is created or destroyed

```
Point::Point(float x, float y):
    xp(x),
    yp(y) {
}
Point::~~Point() {
}
```

- Data members are **initialized** in the order **they're declared** in the class definition, **not as they're listed** in the constructor: important when a member is initialized using another one.
- Destructor is often empty; typical operations are:
  - `delete` dynamic objects used by the class
  - close files opened and used by the object
  - free other resources allocated by the object

## Object destruction

An object can be destroyed in different circumstances

- An automatic object is destroyed when it goes out of scope,
- A `static` object is destroyed at the execution end,
- A dynamic object is destroyed when a `delete` instruction is executed.

If an object is created with `new`  
and it is not destroyed with `delete`  
the destructor is NOT run.

Any resource allocated by the object is simply released  
by the operating system at the execution end.

## Function members

Function members (sometimes called "methods") have direct access to member data of the object

```
float Point::getX() const {
    return xp;
}
float Point::getY() const {
    return yp;
}
float Point::dist(const Point& p) const {
    return sqrt(pow(xp-p.xp, 2)+pow(yp-p.yp, 2));
}
```

Functions are declared `const` when they do not modify any member of the object; only `const` function can be called for `const` objects.

## const and mutable members

### Members declared `const`

- they cannot be modified during the object life
- they must be initialized in the constructor

### Members declared `mutable`

- they can be modified also by functions declared `const` or through pointers to `const`
- they're to be used for members not affecting the “externally visible state” of an object.

## Member initialization at declaration

C++11 only

Class members can be initialized in the definition.

```
class Pippo {
public:
    Pippo();
    Pippo(int i);
    ~Pippo();

    ...
private:
    int x = 1;
};
Pippo() { // x=1
}
Pippo(int i): x(i) { // x=i
}
```

## Constructor types

### Default constructor

The default constructor allows the creation of an object with no arguments:

- declared with no arguments
- declared with arguments all having a default value

### Copy constructor

The copy constructor takes one single argument, of the same class. It's used any time an object is copied, e.g.:

- when an object is passed to a function by value
- when an object is returned by a function

User-defined constructor:  
any constructor declared by the user  
(including default and copy)

## Defaulted constructor and destructor

### Implicit declaration

If the definitions of a class does not contain any constructor and/or destructor, “defaulted” (i.e. implicitly declared) ones are automatically provided by the compiler itself.

- Implicitly-declared default constructor:  
the default constructor for each member is called
- Implicitly-declared destructor:  
the destructor for each member is called
- Implicitly-declared copy and assignment:  
each member is simply copied

If any user-defined constructor is declared, with or without parameters, there's no default constructor implicit declaration.

## Defaulted constructor and destructor recovery or drop

### C++11 only

Defaulted constructor and destructor can be explicitly declared or removed.

```
class Point {
public:
    Point() = default; // allow d.c.
    Point(float x, float y);
    ...
};
class Line {
public:
    Line() = delete; // remove d.c.
    Line(const Point& p1, const Point& p2);
    ...
};
```

## Implicitly declared members summary

A **default constructor** is **implicitly declared** if:

- no user-defined (**generic**) **constructor** is declared
- OR it's declared with the specification = `default` .

A **default constructor** is **NOT implicitly declared** if:

- at least one user-defined constructor is declared
- OR it's declared with the specification = `delete` .

A **copy constructor** is **implicitly declared** if:

- no user-defined **copy constructor** is declared
- OR it's declared with the specification = `default` .

A **copy constructor** is **NOT implicitly declared** if:

- an user-defined one is declared and implemented
- OR it's declared with the specification = `delete` .

A copy constructor (user-defined or implicitly declared)  
is always present, unless explicitly `deleted`.

## Delegated constructor

C++11 only

A constructor can delegate to another one.

```
class Point {
public:
    Point(float d);
    Point(float x, float y);
    ...
};
Point::Point(float d):
    Point(d,d) { // delegate to other constructor
}
```

## Shared members declaration

Each “instance” of a `class` contains its own members, e.g.  
each `Point` contains its `x` and `y`

A member shared by all the instances of a class can be declared by using the keyword `static`

```
class Line { // ax+by+c=0
public:
    Line(const Point& p1, const Point& p2);
    ~Line();
    Point intersect(const Line& l) const;
private:
    static float tolerance;
    float a;
    float b;
    float c;
};
```

## Shared members initialization

Shared (`static`) data members are not bound to any specific instance of a class

- They are created at the execution start (or when loading dynamic libraries), even if no instance is created
- They must be initialized, only once, outside any function

```
float Line::tolerance=1.0e-05;
Point Line::intersect(const Line& l) const {
    float det=(a*l.b)-(b*l.a);
    float chk=pow( a,2)+pow( b,2)+
              pow(l.a,2)+pow(l.b,2);
    if(fabs(det/chk)<tolerance)
        return Point(FLT_MAX,FLT_MAX);
    return Point(((b*l.c)-(c*l.b))/det,
                ((c*l.a)-(a*l.c))/det);
}
```

## Shared members functions

Shared (`static`) member functions, not bound to any specific instance of a class, can be declared as well

- They can be called using the “scope resolution” (`::`) operator
- They can access only `static` data members
- They cannot access `non-static` data members, but for specific objects they may have access to (e.g. passed as parameters, or global objects)

```
class Pippo {
public:
    static int count();
    ...
};
...
int j=Pippo::count();
```

## Cross references among classes

Two (or more) classes may exist, each one using the other as argument of its own functions: both must know about the other

```
class Line;
class Point {
    ...
    float dist(const Line& l) const;
    ...
};
```

```
class Point;
class Line {
    ...
    float dist(const Point& p) const;
    ...
};
```

## Self reference

Each instance can obtain the pointer to itself from `this`

- It can be used as parameter when calling functions
- It can be returned by member functions
- It can be dereferenced to obtain the object instance

```
float Line::dist(const Point& p) const {  
    return fabs((a*p.getX())+(b*p.getY()+c)/  
               sqrt((a*a)+(b*b)));  
};
```

```
float Point::dist(const Line& l) const {  
    return l.dist(*this);  
};
```

## friend functions and classes

A class can declare friend functions and classes, allowed to access its private members (use sparingly!).

```
class Point {
    friend class Line;
    // all functions of "Line" can access
    // private members of "Point"
    ...
};
class Line {
    friend
    float Point::dist(const Point& p) const;
    // only the function "dist" of "Point"
    // can access private members of "Line"
    ...
};
```

## Operator members

Not only functions but also operators can be defined for classes

```
class Vector2D {
public:
    Vector2D(float x, float y);
    ~Vector2D();
    float getX() const;
    float getY() const;
    Vector2D operator+(const Vector2D& v);
    Vector2D& operator*=(float f);
private:
    float xv;
    float yv;
};
```

- Operators are defined as other functions.
- Assignment operators return a “\*this”.

## Operators definition

Operator members are to be defined as member functions

```
Vector2D Vector2D::operator+(const
                               Vector2D& v) {
    return Vector2D(xv+v.xv, yv+v.yv);
}
Vector2D& Vector2D::operator*=(float f) {
    xv*=f;
    yv*=f;
    return *this;
};
```

Class operators can be used as the built-in ones,  
or through explicit function calls

```
Vector2D u( 2.3, 4.5);
Vector2D v(-1.6, 6.9);
Vector2D s=u+v;
u*=3; // equivalent to u.operator*=(3)
```

## Operator functions

Operators can be defined also as global functions, where at least an argument must be a `class`

```
Vector2D operator+(const Vector2D& vl,
                  const Vector2D& vr) {
    return Vector2D(vl.getX()+vr.getX(),
                  vl.getY()+vr.getY());
}
Vector2D& operator*=(Vector2D& v, float f) {
    v = Vector2D(v.getX()*f, v.getY()*f);
    return v;
}
```

- Both implementations can be present
- The compiler flags as an error any ambiguous call
  - `u.operator+(v)` calls the operator member
  - `operator+(u, v)` calls the operator function

# Functors

Objects usable as functions are called “functors”.

```
class Func {
public:
    Func(int n):f(n) {};
    float operator()(float x) {return f*x;}
private:
    int f;
};
int main() {
    // create a Funct setting it at 3
    Func m(3);
    // call the Funct with 5.3
    cout << m(5.3) << endl;
    return 0;
}
```

## I/O Operators

**Operator functions can be defined to write/read objects**

```
std::ostream& operator<<(std::ostream& os,
                        const Vector2D& v) {
    os << v.getX() << " " << v.getY();
    return os;
};

std::istream& operator>>(std::istream& is,
                        Vector2D& v) {

    float x,y;
    is >> x >> y;
    v=Vector2D(x,y);
    return is;
};
```

**I/O operator functions take  
a `std::istream&` or `std::ostream&` as argument,  
and return the same at the end**

## Operators limitations

Operators must be defined and implemented as global function when:

- The left operand has built-in type (e.g. `int`, `float`, ...)
- The left operand type is a non modifiable `class` (e.g. `istream`)

Only existing operators (e.g. `+`, `-`, `*`, `/`, `=`, ...) can be redefined `classes`, no new ones can be created (e.g. `**` for exponentiation)

## Nested classes

A class can be defined inside the definition of another one  
(being visible outside or not  
if it's `public` or `private` respectively)

```
class Outer {
public:
    ...
    class InnerPub {
        ...
    };
private:
    class InnerPri {
        ...
    };
    ...
};
```

A public nested class can be accessed by using the scope resolution operator `::`:  
`Outer::InnerPub`.

Examples will be shown in the following.

Having several classes nested inside the same enclosing one emphasizes the relations among them.



## Type conversions by operator

### Implicit type conversions

Conversion to other types can be defined with operators.

```
class Pippo {
public:
    operator int();
};

void f(int i);
```

```
...
Pippo p;
f(p);
...
```

### C++11 only

An explicit operator prevents implicit type conversions.

```
class Pluto {
public:
    explicit
    operator int();
};
```

```
...
Pluto p;
f(static_cast<int>(p));
...
```

## Name conflicts

Names of `classes` must be unique throughout the whole program (libraries included): conflicts could arise.

Functions  
and `classes` can be  
declared and defined  
inside “namespaces”

Classes defined inside  
namespaces can be  
accessed by mean of  
the “scope” operator `::`

```
namespace Geom {
    class Line;
    class Point {
        ...
    };
};
```

```
...
int main() {
    Geom::Point p(1.2, 7.4);
    ...
    return 0;
};
```

## Default namespaces

Adding namespace to a `class` name produces a long name...

- A `typedef` can be used
- An `using` declaration or directive can be added

```
typedef Geom::Point point;  
// define "point" as a short name
```

```
using Geom::Point;  
// declaration: makes "Point"  
// visible without namespace resolution
```

```
using namespace Geom;  
// directive: makes all names in "Geom"  
// visible without namespace resolution
```

**An `using` declaration or directive affects all the following code in the same translation unit:  
avoid including “`using`” directives in header files**



## Exception objects

Any object can be (in principle) used as exception

```
class MathException {
public:
    enum errorType {divByZero, sqrNeg};
    MathException(errorType e) {error=e;}
    ~MathException() {}
    errorType get() const {return error;}
private:
    errorType error;
};
```

```
float x;
int i;
...
if(i==0) throw
    MathException(MathException::divByZero);
x/=i;
```

## Exception catching

Exceptions are handled by mean of “try” and “catch” blocks

```
try {
    ... // any code that could possibly
    ... // throw a "MathException"
}
catch (MathException& e) {
    if(e.get() == MathException::divByZero)
        cout << "division by zero" << endl;
}
```

When an exception is thrown  
all the calling functions are immediately terminated  
going back until a “catch” clause is found.

Several “catch” blocks can exist,  
handling exceptions of different type.

## Exception blocking

C++11 only

A function can be declared “`noexcept`” to prevent it transmitting any unhandled exception.

```
void f(int i, float x) noexcept;
```