

Objects and classes

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Classes

Definition of object

An object is an entity that you can request to do certain things. These actions are the *methods* and to make these possible the object probably stores data, the *members*.

Objects comes in classes:
similar to variables and datatypes.

When designing a class, first ask yourself: 'what functionality should the objects support'.

Object functionality

Small illustration: vector objects.

Code:

```
Point p(1.,2.); // make point (1,2)
cout << "distance to origin "
      << p.length() << endl;
p.scaleby(2.);
cout << "distance to origin "
      << p.length() << endl
      << "and angle " << p.angle()
      << endl;
```

Output

[object] functionality:

```
distance to origin 2.23607
distance to origin 4.47214
and angle 1.10715
```

Note the 'dot' notation; in a `struct` we use it for the data members; in an object we (also) use it for methods.

Exercise 1

Thought exercise:

What data does the object need to store to do this?

Is there more than one possibility?

The object workflow

Similar to `struct`:

- You have to define what an object looks like by giving a

```
class myobject { /* ... */ };
```

definition, typically before the *main*.

- You create specific objects with a declaration

```
myobject  
    object1( /* .. */ ),  
    object2( /* .. */ );
```

- You let the objects do things:

```
object1.do_this();  
object2.do_that( /* ... */ );
```

Constructor

To create an object belonging to a class: use a constructor: function with same name as the class.

Constructors are typically used to initialize data members.

```
class Point {                                Point v(1.,2.);
private: // members
    double x,y;
public: // methods
    Point( double in_x,
           double in_y ) {
        x = in_x; y = in_y;
    };
};
```

Constructor'

Better mechanism:
use 'initializer lists':

```
class Point {  
private: // members  
    double x,y;  
public: // methods  
    Point( double in_x,  
           double in_y )  
        : x(in_x),y(in_y) {;  
    };  
};
```

The syntax `x(in_x)` copies the argument to the data member.
(You're even allowed to have `x(x).`)

Methods

Class methods

Let's define method *length*.

Definition in the class:

```
double length() {  
    return sqrt(x*x + y*y); };
```

Use in the program:

```
Point pt(5,12);  
double  
    s = pt.length();
```

- Methods look like ordinary functions,
- except that they can use the data members of the class, for instance *x*;
- Methods can only be used on an object with the 'dot' notation. They are not independently defined.

Exercise 2

Add a method *angle* to the *Point* class.

How many parameters does it need?

Exercise 3

Discuss the pros and cons of this design:

```
class Point {  
private:  
    double x,y,alpha;  
public:  
    Point(double x,double y)  
    : x(x),y(y) {  
        alpha = // something trig  
    };  
    double angle() { return alpha; };  
};
```

Member default values

Class members can have default values, just like ordinary variables:

```
class Point {  
private:  
    float x=3., y=.14;  
private:  
    // et cetera  
}
```

Each object will have its members initialized to these values.

Member initialization in the constructor

The members stored can be different from the constructor arguments.

Example: create a vector from x, y cartesian coordinates, but store r, θ polar coordinates:

```
class Point {  
private: // members  
    double r, theta;  
public: // methods  
    Point( double x, double y ) {  
        r = sqrt(x*x+y*y);  
        theta = atan(y/x);  
    }  
}
```

Data access in methods

Data members should not be accessed directly from outside an object, but using them inside a method is proper:

```
class Point {  
private:  
    double x,y;  
public:  
    void flip() {  
        Point flipped;  
        flipped.x = y;  
        flipped.y = x;  
    };  
};
```

Interaction between objects

Exercise 4

Extend the `Point` class of the previous exercise with a method: `distance` that computes the distance between this point and another: if `p,q` are `Point` objects,

`p.distance(q)`

computes the distance between them.

Hint: remember the 'dot' notation for members.

Review quiz 1

T/F?

- A class is primately determined by the data it stores
/poll "Class determined by its data" "T" "F"
- A class is primarily determing by its methods
/poll "Class determined by its methods" "T" "F"
- If you change class data, you need to change the constructor call
/poll "Change data, change constructor proto too" "T" "F"

Methods that alter the object

Code:

```
class Point {  
    /* ... */  
    void scaleby( double a ) {  
        vx *= a; vy *= a; };  
    /* ... */  
};  
  
/* ... */  
Point p1(1.,2.);  
cout << "p1 to origin "  
      << p1.length() << endl;  
p1.scaleby(2.);  
cout << "p1 to origin "  
      << p1.length() << endl;
```

Output

[geom] pointscaleby:

p1 to origin 2.23607
p1 to origin 4.47214

Methods that create a new object

Code:

```
class Point {  
    /* ... */  
    Point scale( double a ) {  
        return Point( vx*a, vy*a ); };  
    /* ... */  
    cout << "p1 to origin "  
        << p1.length() << endl;  
    Point p2 = p1.scale(2.);  
    cout << "p2 to origin "  
        << p2.length() << endl;
```

Output

[geom] pointscale:

```
p1 to origin 2.23607  
p2 to origin 4.47214
```

Anonymous objects

(also known as 'move semantics') Instead of

```
Point scale( double a ) {  
    return Point( vx*a, vy*a ); };
```

we could have written:

```
Point scale( double a ) {  
    Point new_point( vx*a, vy*a );  
    return new_point;  
};
```

However, that may involve an extra copy.
(Depends on standard version.)

Optional exercise 5

Write a method `halfway_point` that, given two `Point` objects `p`, `q`, construct the `Point` halfway, that is, $(p + q)/2$:

```
Point p(1,2.2), q(3.4,5.6);  
Point h = p.halfway(q);
```

You can write this function directly, or you could write functions `Add` and `Scale` and combine these.

(Later you will learn about operator overloading.)

How would you print out a `Point` to make sure you compute the halfway point correctly?

Default constructor

Consider this code that looks like variable declaration, but for objects:

```
Point p1(1.5, 2.3);  
Point p2;  
p2 = p1.scaleby(3.1);
```

Compiling gives (g++; different for intel):

```
pointdefault.cxx: In function 'int main()':  
pointdefault.cxx:32:21: error: no matching function for call to  
      'Point::Point()'
```

Default constructor

The problem is with *p2*:

```
Point p1(1.5, 2.3);
```

```
Point p2;
```

- *p1* is created with the constructor;
- *p2* uses the default constructor:

```
Point() {};
```

- as soon as you define a constructor, the default constructor goes away;
- you need to redefine the default constructor:

```
Point() {};
```

```
Point( double x,double y )  
    : x(x),y(y) {};
```


Public versus private

- Interface: `public` functions that determine the functionality of the object; effect on data members is secondary.
- Implementation: data members, keep `private`: they only support the functionality.

This separation is a Good Thing:

- Protect yourself against inadvertant changes of object data.
- Possible to change implementation without rewriting calling code.

Exercise 6

Make a class `LinearFunction` with a constructor:

```
LinearFunction( Point input_p1,Point input_p2 );
```

and a member function

```
float evaluate_at( float x );
```

which you can use as:

```
LinearFunction line(p1,p2);  
cout << "Value at 4.0: " << line.evaluate_at(4.0) << endl;
```

Classes for abstract objects

Objects can model fairly abstract things:

Code:

```
class Stream {
private:
    int last_result{0};
public:
    int next() {
        return last_result++; };
};

int main() {
    Stream ints;
    cout << "Next: "
         << ints.next() << endl;
    cout << "Next: "
         << ints.next() << endl;
    cout << "Next: "
         << ints.next() << endl;
```

Output

[object] stream:

```
Next: 0
Next: 1
Next: 2
```

Project Exercise 7

Write a class `primegenerator` that contains

- members `how_many_primes_found` and `last_number_tested`,
- a method `nextprime`;
- Also write a function `isprime` that does not need to be in the class.

Your main program should look as follows:

```
cin >> nprimes;
primegenerator sequence;
while (sequence.number_of_primes_found() < nprimes) {
    int number = sequence.nextprime();
    cout << "Number " << number << " is prime" << endl;
}
```

Project Exercise 8

The Goldbach conjecture says that every even number, from 4 on, is the sum of two primes $p + q$. Write a program to test this for the even numbers up to a bound that you read in.

This is a great exercise for a top-down approach!

1. Make an outer loop over the even numbers e .
2. For each e , generate all primes p .
3. From $p + q = e$, it follows that $q = e - p$ is prime: test if that q is prime.

For each even number e then print e, p, q , for instance:

The number 10 is 3+7

If multiple possibilities exist, only print the first one you find.

Turn it in!

- If you have compiled your program, do:

```
coe_gold yourprogram.cc
```

where 'yourprogram.cc' stands for the name of your source file.

- Is it reporting that your program is correct? If so, do:

```
coe_gold -s yourprogram.cc
```

where the -s flag stands for 'submit'.

- If you don't manage to get your code working correctly, you can submit as incomplete with

```
coe_gold -i yourprogram.cc
```

Other object stuff

Class prototypes

Header file:

```
class something {  
private:  
    int i;  
public:  
    double dosomething( int i, char c );  
};
```

Implementation file:

```
double something::dosomething( int i, char c ) {  
    // do something with i,c  
};
```


Advanced stuff about constructors

Copy constructor

- Several default copy constructors are defined
- They copy an object:
 - simple data, including pointers
 - included objects recursively.
- You can redefine them as needed.

```
class has_int {  
private:  
    int mine{1};  
public:  
    has_int(int v) {  
        cout << "set: " << v <<  
        endl;  
        mine = v; };  
    has_int( has_int &h ) {  
        auto v = h.mine;  
        cout << "copy: " << v <<  
        endl;  
        mine = v; };  
    void printme() { cout  
        << "I have: " << mine <<  
        endl; };  
};
```

Copy constructor in action

Code:

```
has_int an_int(5);  
has_int other_int(an_int);  
an_int.printme();  
other_int.printme();
```

Output

[object] copyscalar:

```
set: 5  
copy: 5  
I have: 5  
I have: 5
```

Copying is recursive

Class with a vector:

```
class has_vector {  
private:  
    vector<int> myvector;  
public:  
    has_vector(int v) { myvector.push_back(v); };  
    void set(int v) { myvector.at(0) = v; };  
    void printme() { cout  
        << "I have: " << myvector.at(0) << endl; };  
};
```

Copying is recursive, so the copy has its own vector:

Code:

```
has_vector a_vector(5);  
has_vector other_vector(a_vector);  
a_vector.set(3);  
a_vector.printme();  
other_vector.printme();
```

Output

[object] copyvector:

```
I have: 3  
I have: 5
```

Destructor

- Every class *myclass* has a *destructor* *~myclass* defined by default.
- The default destructor does nothing:

```
~myclass() {};
```

- A destructor is called when the object goes out of scope.
Great way to prevent memory leaks: dynamic data can be released in the destructor. Also: closing files.

Destructor example

Just for tracing, constructor and destructor do `cout`:

```
class SomeObject {  
public:  
    SomeObject() {  
        cout << "calling the constructor"  
              << endl;  
    };  
    ~SomeObject() {  
        cout << "calling the destructor"  
              << endl;  
    };  
};
```

Destructor example

Destructor called implicitly:

Code:

```
cout << "Before the nested scope"
      << endl;
{
    SomeObject obj;
    cout << "Inside the nested scope"
          << endl;
}
cout << "After the nested scope"
      << endl;
```

Output

[object] destructor:

Before the nested scope
calling the constructor
Inside the nested scope
calling the destructor
After the nested scope