

Objects and classes

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Classes

1. 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*.

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

Objects come in classes. A class is like a datatype: you can make objects of a class like variables of a datatype.

Exercise 1

Thought exercise: what are some of the actions that a point object should be capable of?

2. Object functionality

Small illustration: vector objects.

Code:

```
Point p(1.,2.); // make point (1,2)
cout << "distance to origin "
      << p.distance_to_origin() << endl
      ;
p.scaleby(2.);
cout << "distance to origin "
      << p.distance_to_origin() << 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. Pronounce with 'apostrophe-ess':
'p's distance' et cetera.

Exercise 2

Thought exercise:

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

Is there more than one possibility?

3. The object workflow

- First define the class, with data and function members:

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

(details later) typically before the *main*.

- You create specific objects with a declaration

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

- You let the objects do things:

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

4. Constructor and data initialization

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;
    };
};
```


5. (more sophisticated approach to initialization)

Better mechanism:

use 'member initializers':

```
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

6. Class methods

Let's define method *distance*.

Definition in the class:

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

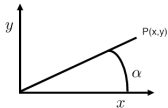
Use in the program:

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

- 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 3

Add a method *angle* to the *Point* class. How many parameters does it need?



Hint: use the function *atan* or *atan2*.

You can base this off the file `pointclass`

Exercise 4

Make a class *GridPoint* which can have only integer coordinates. Implement a function *manhattan_distance* which gives the distance to the origin counting how many steps horizontal plus vertical it takes to reach that point.

Exercise 5

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; };  
};
```

7. 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.

8. Food for thought: initialization vs storage

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:

```
#include <cmath>
class Point {
private: // members
    double r, theta;
public: // methods
    Point( double x, double y ) {
        r = sqrt(x*x+y*y);
        theta = atan2(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;  
    };  
};
```

Exercise 6

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 the design of the class data, you need to change the constructor call.
`/poll "Change data, change constructor proto too" "T" "F"`

9. Methods that alter the object

For instance, you may want to scale a vector by some amount:

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

Interaction between objects

10. Methods that create a new object

Code:

```
class Point {  
    /* ... */  
    Point scale( double 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

11. Anonymous objects

Two ways of returning the scaled point:

Naive:

```
Point Point::scale( double a )
{
    Point scaledpoint =
        Point( x*a, y*a );
    return scaledpoint;
};
```

No copy involved:

```
Point Point::scale( double a )
{
    return Point( x*a, y*a );
};
```

Optional exercise 7

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?

12. 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()'
```

13. 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) {};
```

14. 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 8

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;
```

15. 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 9

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 10

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. Use the `primegenerator` class you developed in exercise 30.

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_goldbach 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_goldbach -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_goldbach -i yourprogram.cc`

Other object stuff

16. String an object

1. Define a function that yields a string representing the object, and
2. redefine the less-less operator to use this.

```
#include <sstream>
using std::stringstream;
#include <string>
using std::string;
/* ... */
string as_string() {
    stringstream ss;
    ss << "(" << x << "," << y
    << ")";
    return ss.str();
};
/* ... */
```

```
std::ostream& operator<<
    (std::ostream &out, Point &p
    ) {
    out << p.as_string(); return
    out;
};
/* ... */
Point p1(1.,2.);
cout << "p1 " << p1
    << " has length "
    << p1.length() << endl
    ;
```

17. 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

18. Copy constructor

- Default defined copy and 'copy assignment' constructors:

```
some_object x(data);  
some_object y = x;  
some_object z(x);
```

- 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; };  
};
```

19. 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
```

20. 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

21. 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.

22. 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;  
    };  
};
```

23. 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