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.

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; 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?

3. 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();
  x = object2.do_that( /* ... */ );
  ```

4. 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 {
private: // members
  double x,y;
public: // methods
  Point( double in_x,
         double in_y ) {
    x = in_x; y = in_y;
  };
};
```

```
Point v(1.,2.);
```

5. 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

6. Class methods

Let's define method *distance*.

Definition in the class:

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

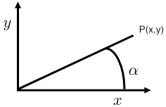
Use in the program:

```
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 2

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 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; };
};
```

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. 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 $r,theta$ 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;
  };
};
```

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 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
```

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 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?

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 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;
```

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 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. Use the `primegenerator` class you developed in exercise 28.

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
```