AIMS Embedded Systems Programming
MT 2017
Object-Oriented Programming with C++

Daniel Kroening

University of Oxford, Computer Science Department

Version 1.0, 2014
Outline

Classes and Objects

Constructors and Destructors

References

Function, Method and Operator Overloading

Virtual Methods

Exceptions

Templates
Idea: an object is an *instance* of class

- John is an instance of a person

- Peter is also in instance of a person, but he is not John

We’ll call John and Peter objects, and say that “person” is a class.
Idea: objects have attributes

- John’s name is “John”. His gender is MALE. His age is 43.

- Peter’s name is “Peter”. His gender is MALE. His age is 13.

These attributes apply to all persons, and we don’t want to re-do the list for each object.
class Person {
    string name;
    enum { MALE, FEMALE } gender;
    unsigned age;
};

This is much like a struct in C, but we can omit the aggregate key when using the type.
Idea: we often want to specialise or extend a class with further information.

- All students are persons, but not all persons are students. There is a student number to be stored.

- There are also teachers, who are persons as well. We want to store a list of courses taught.
```cpp
class Student : public Person {
    string student_number;
};

class Teacher : public Person {
    list<Course> courses_taught;
};
```
Type Hierarchies

Note that we can use any Student or Teacher as a Person.

Student John;
Teacher Mike;

Person someone1=John;
Person someone2=Mike;

The opposite does not work.
Member Functions

Code should be linked to the data it operates on.

Thus, don’t do this:

```cpp
class Person {
    string name;
    enum { MALE, FEMALE } gender;
    unsigned age;
};

void birthday(Person *p) {
    p->age += 1;
}
```
class Person {
    string name;
    enum { MALE, FEMALE } gender;
    unsigned age;

    void birthday();
};

void Person::birthday()
{
    age+=1;
}
Member Functions

- Member functions are implicitly given a pointer to the object
- The pointer is accessible with the keyword `this`
- The pointer can be made a pointer to a constant object by adding `const` after the method parameters

```cpp
class Person {
    string name;
    enum { MALE, FEMALE } gender;
    unsigned age;
    bool is_cool() const { return age<20; }
};
```
Access Protection

- Members of classes can be public, private or protected

- public: Anyone can access
- private: Only the member functions of the class can access
- protected: Only the member functions of the class or derived classes can access

- The default in a class is protected

- You can also declare other classes to be friends
 Constructors

- Constructors contain “set up” or “initialization” code for a class

- They do not return a value, not even `void`

- Constructors can have parameters, and if there is exactly one, then the compiler will use the constructor implicitly

- If this is potentially confusing, add the keyword `explicit`
Constructors

class Person {
public:
    Person(string s) {
        name = s;
    }

private:
    string name;
};
Constructors

Alternatively:

```cpp
class Person {
public:
    Person(string s):name(s) {
    }

private:
    string name;
};
```
Let's use it:

```cpp
int main()
{
    Person Mike("Mike");
    Person John("John");

    string name="Pete";
    Person someone=name;
}
```
Default Constructors

- If you don’t define a constructor, the compiler will make one for you.

- The default constructor will call the default constructors for all base classes and all member objects.

- It also creates a copy constructor, which takes one parameter that has the same type as the class. It copies all members.
Destructors

There is sometimes clean-up work to do.

class temporary_file {
public:
    temporary_file();
    ~temporary_file();

private:
    string file_name;
};

temporary_file::~temporary_file()
{
    // Delete the temporary file we have made
    unlink(file_name.c_str());
}
Destructors

The destructor is called automatically when the object “dies”

```c
void some_function() {
    temporary_file temp_file1;
    i++;

    if(some_condition) return;

    {
        temporary_file temp_file2;
        i++
    }

    i++;
}
```

Huge benefit: you won’t forget to clean up!
C offers pointers, which serve a range of purposes:

- Pass large arguments to functions without copying
- Return multiple values from a function
- Efficiently return a value from a function that is partially modified
- Iterators over arrays
- Dynamic memory allocation

Pointers are difficult to deal with. Some of the above are made more robust with *references*. 


References

```c
int var;
int &ref=var;  // read: int *ref=&var;

ref=ref+1;     // read: *ref=*ref+1;

void my_function(const Person &person) {
    ...
}
...

my_function(John);
```
But:

- You can’t change the address behind the reference
- No address arithmetic; thus no iteration
- References can’t be NULL
- Be careful not to destroy the object the reference refers to
std::vector<Person> persons;

persons.push_back(John);
Person &John_ref=persons[0];

person.push_back(Jack);
Person &Jack_ref=persons[1];
Function Overloading

- In C, many functions exist in variants for different parameter types
- E.g.: abs, cabs, fabs, labs, llabs, fabsl, fabsf
- They all have the same intent but require separate implementations
- We don’t usually benefit from the reminder about the argument type, and it’s extra work to keep this in sync
- Wouldn’t it be nice if we could just write abs(x)? And have the compiler figure out which implementation to use?
int my_abs(int);
long int my_abs(long int);
float my_abs(float);
double my_abs(double);
...

int my_power(int x, int p);
float my_power(float x, float p);
...
Function Overloading

- Recall which basic types are really different
- If there is no perfect match, the compiler will use a scoring system
- Sorry, you can’t make the distinction using the return value
- Overloading works with methods just as well
Operator Overloading

Certain operators can be overloaded:

MyMatrix operator+(MyMatrix, MyMatrix);
MyMatrix operator-(MyMatrix, MyMatrix);
MyMatrix operator*(MyMatrix, MyMatrix);
...

MyMatrix A, B, C;

A = B * C;

For instance, this enables transparent implementation of complex numbers.
class base {
    void my_method() { std::cout << "BASE!\n"; }
};

class derived: public base {
    void my_method() { std::cout << "DERIVED!\n"; }
};

void do_something(base &b) {
    b.my_method();
}

int main() {
    derived D;
    do_something(D);
}
Virtual Methods

➤ The fix is to add the keyword `virtual` to the method declaration

➤ The primary purpose of virtual methods is typing for APIs

➤ Typically realised with function pointers, but all done for you
Virtual Destructors

- Virtual constructors don’t make sense. Why?

- Virtual destructors make so much sense that compilers will warn if you don’t add one, even if blank.

Why?
 Exceptions

- Run-time error handling is a very common idiom

- Usually done via `if(something bad) return -1;` or the like

- It’s easy to forget, clutters code, and means that we have to have “normal data” and “error data”

- Instead, throw an exception!
class my_error:public exception {
    virtual const char* what() const {
        return "my_error message";
    }
};

... if(something bad) throw my_error();

Neat thing: cleans up any objects on the stack
Exceptions

```java
try {
    ...
}
```

```java
catch(exception e) {
    // deal with it!
}
```
Templates

- We have seen templates, e.g., `std::string` or `std::vector`.

- These are built using *templates*, which allow parameterizing classes, functions and typedefs with types.

- The primary purpose is library construction. Before engaging, check whether someone has already built that library you are thinking about.