4 - Class Definitions

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COMP2404

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1. Imperative to Object Oriented
2. Access Specifiers
3. Class Members
4. Code Organization
5. Variable Scope
6. Namespaces

Imperative to Object Oriented

C++ was once known as C with **classes**.

- Classes provide an ***Object Oriented*** way of organizing data and functions related to that data.

We will start by writing the code ***Imperatively***

- C uses ***imperative*** style.
- We will convert it to ***Object Oriented*** code.

Along the way we will show:

- How **classes** and ***Object Oriented*** programming provide a useful way to organize code.
- How to allocate **classes** dynamically

University System

Let's say we want a **University** system

- It will have information about all the `Students` there
- Each `Student` will have a **name**, **student number, major, gpa**.
- We will want to do operations such as
  - print all `Students`, or
  - print all passing `Students`.

We will use arrays to store the `Students` information (simulating a database).

coding example <p1>

University System

We've stored all the information in separate arrays, but it would make sense to do something more convenient

- such as have them all together in memory.

In C we could use a **struct**.

- C++ also has **structs**.

In C++ **structs** and **classes** are the ***same***

- except for the access modifiers.
- We will use ***classes*** in C++.

We will make a `Student` **class** to store all information related to students.

coding example <p2>

University System

Instead of printing all the information separately, it makes sense to have a `print` function for `Students`.

We can make the **print** function a part of the `Student` class

- That way information and the functions that act on them appear together.
- This also gives the functions access to *private* member variables.

coding example <p3>

University System

We are still initializing `Students` in a primitive way.

- C++ gives you a special ***constructor*** function to handle this.
- Since it is a function, it has access to private members.

Now we can ***hide*** or ***encapsulate*** the information.

- `Student` data can only be modified in ways we approve of.

We can also allocate `Students` dynamically if we wish.

- We only allocate memory as we need it.
- We can delete it when we are done.

coding example <p4>

Imperative to Object Oriented

We have shown how **classes** and ***Object Oriented*** programming is a natural way to organize programs.

- The overhead compared to imperative programming is still relatively low.

We have also begun to demonstrate ***encapsulation***.

- We don't give access to information in unnecessary ways.
- Only functions belonging to the **class** had access to ***private*** member variables.

Next we will cover **classes** in more detail.

Access Specifiers

Industrial grade software is typically huge

- Millions of lines of code
- Hundreds of libraries and packages
- Must protect your code from unauthorized changes

Restrict access to unnecessary details, information, access whenever possible

- **Principle of Least Privilege**
- everything should be as close to private as possible
- example – you only want qualified people to access the inner workings of your car

Of course, some (`public`) access is necessary

Class Access Specifiers

Public access

- class member is visible to all objects and global functions

Protected access

- class member is visible by subclasses only
- different from Java
- make use of this only when using inheritance

Private access

- not visible to other classes or global functions
- visible to other members of the **same class**
  - different from Java

Classes in C++

Class Definitions

- `class` keyword followed by class name followed by braces `{}`, followed by semi-colon `;`

In the `class` block are the `class` members

- data members (instance variables)
- member functions (methods)

We can use access specifiers to partition members by access level

- `public`, `private`, `protected`
- default access level for classes is `private`

Classes in C++


```
class Student{

    public:  // start of the public members

        // some functions and/or variables

    private: // start of the private members

        //some functions and/or variables
};
```

Objects in Memory


```
Student casey("100999999","Casey");
Student joe;
```

Observe there is no “new” here. How did we make new objects?

- C++ gives you the option of *statically* or *dynamically* allocating objects.
- If you statically allocate an object as a local variable in a function, then
  - Object is allocated to the **Stack**.
  - Access is fast.
  - When the **stackframe** is popped off, the object is deleted for you.
  - Convenient for temporary objects.

Objects in Memory


```
Student* casey = new Student("100999999","Casey");
Student* joe = new Student;
```

We can also use "new" to allocate objects on the **Heap**.

- The **Heap** is slower to allocate objects,
  - but the objects last as long as we like
- These objects are never deleted until we call "delete"
  - We should consider when to do this in our design.
- More on this later

Member Function Implementations

A Class in C++ should consist of 2 files:

- A header file (using the `.h` extension) contains the class definition.
  - Data member declarations.

    ```
    string name;
    string id;
    ```
    etc.

  - Member function prototypes (usually not the code!)

    ```
    void print();
    bool isPassing();
    ```

- A source file (using the `.cc` extension)
  - This contains the member function implementation (the actual code)
  - Static data member initializations
  - Related global functions

Member Function Implementations

A function implementation is the code for a function.

- Written in the .cc file.
- Has scope resolution operator, the function definition, and the code.

```
void Student::print(){
     cout<<"Name: "<<name<<endl;
     cout<<"Id:   "<<id<<endl;
}
```

Member Function Implementations

For very small programs, we may include implementation in the class definition

- Getters for example
- This gets messy quickly – discouraged for larger programs

For all other programs, the implementation should be separate

- There are a couple of reasons:
  - Principle of Least Privilege
  - Can help avoid circular `#includes` between your files

Standard Member Functions: Constructors

Job of a constructor to ***initialize all data members***

- There are a few ways to initialize data members
- We will start with the most conventional
  - assignment operators

Constructor with no arguments – **default constructor**

- can be very important for things like arrays
- we decide if there is a default constructor

C++ classes can have multiple constructors

- cannot call "super" as with Java to make use of multiple constructors
- C++ can leverage other constructors, but uses a different syntax

Standard Member Functions: Constructors

Prototype (in the header file):

```
class Student{
    public:
        Student();
        Student(string, string);
};
```

Implementation (in source file):

```
Student::Student(){
    name = "unknown";
    id   = "unknown";
}
```

Other Standard Functions

There is no `toString()` function in C++

- initially we will use `print()` functions
- later we will see how to overload the stream insertion operator `<<`
  - C++ equivalent to `toString()`

Example <**p4**> from previous slides is bad – body of functions are within the class definition.

- against C++ conventions (though the compiler is fine with it)
- Keeping headers and source separate has actual advantages:
  - Compiler only needs the function prototype (header) to report usage errors
  - Header can be `#include`-d, and the source still compiled separately and linked.
  - Can help mitigate circular references.

programming example <p1>

Allocating Classes

Like primitive variables, we have choice in how to allocate classes.

- Statically allocated means memory is allocated where it is declared.
- Dynamically allocated means allocated on the Heap.

There is an extra complication using **classes** with **arrays**.

For now we will ***statically allocate*** arrays, but we still have 2 choices in the type of array:

- Array of objects, or
- array of object ***pointers***.
- Arrays of **objects** automatically call the **default constructor** of the **class**.

programming example <p2>

Compiler

The C++ compiler is (deliberately) primitive

- It does not organize the code for you (like Java)

Consider the command: `g++ -c Date.cc`

- The compiler starts reading `Date.cc`.
- When it sees `#include "Date.h"` it jumps to that file and continues reading.
- Think of all `#include`-d files as one large file, in order.
  - If the compiler reads it top to bottom, will it make sense?
  - What information does the compiler need to ensure no errors?
  - What are the potential pitfalls?

Class Interface

A **Class Interface** is *not* the same as a Java interface.

The **Interface** refers to the part of the class that can be accessed and used by other classes. It consists of

- class name and
- public members.

This defines how the user interacts with your class.

In C++, this is contained in the header file.

- Though there are also private and protected members in the header.

Class Interface

To use a class, you `#include` the header file.

- This contains the public interface.
- This is enough information for the compiler to ensure that you use the class correctly.
- It is exactly like forward referencing your functions.

To make an executable using this class, you then must link your code to the object code.

- I.e., the implementation.

Users of your class do not need to see the source code.

- The interface and documentation give enough information for other developers to use your class.

Code Organization

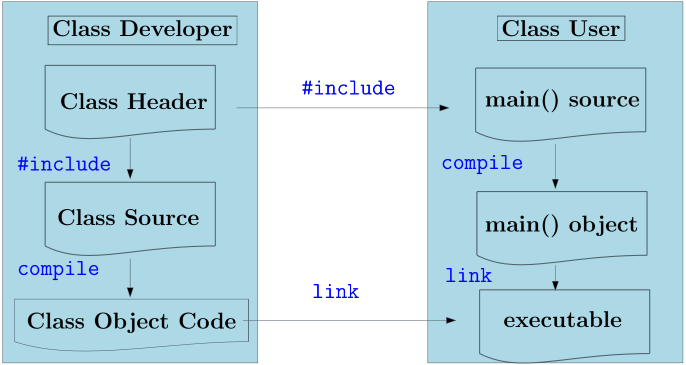
Who will be using your class?

- Mostly other developers
- Even when writing end user code, you may want API's or other developers to contribute.

Other developers need to know:

- Class name,
- public members,
- descriptions of functions where appropriate, and
- (sometimes) protected members.

Class Interface



- If we change our source code, we can recompile this separately from applications that use it.
- User only needs to re-link this source, not re-compile.

Class Header File

Make sure to include the ***header guards***.

- These guard against multiple `#include`-s.

`#include`-ing source code is inefficient.

- Unnecessarily forces recompilation of all code.
- This is frowned upon…mostly.
- **Source** file should `#include` the **header**, not vice-versa.

Understand what belongs in the header file (essentially your class API) vs the source file

- All source files should be compiled separately.
- Class users will only have to **relink** your code (for bug fixes, etc), which is fast.

Source Files

Source files contain:

- All class related source code
  - (i.e., member function implementations).

- By default, all functions you write are global!
- Use the **scope resolution operator** of the ***class*** to inform the compiler of what is a class member.
  - This lets the compiler resolve the visibility of variables and other functions from the class definition (`public, protected, private`).
  - Or to identify static data member initializations...
    - ...more on this later.

Variable Scope

Variable scope refers to where in the program a variable is visible.

- Block scope
  - including Class blocks.
- File scope
  - is outside of any block.
- Function scope for labels (we don't cover labels).
- Function prototype scope for parameters (we won't cover this either).
  - `int foo(int n, int x[n])`

Block Scope

A variable declared within a block has **block scope**.

- Visible within that block and all inner blocks (unless shadowed).
- Once we exit the block, the variable disappears and its value is discarded.
- Variables in inner blocks can hide variables in outer blocks.
  - Shadowing.
- If variables in nested blocks have the same name, the innermost block variable is the one used.
  - Try to avoid this - use unique identifiers when possible.
- Can always use the unary resolution operator to access a global value.
  - Other shadowed variables remain invisible, unless blocks are ***namespaces***.
  - Coming soon.

File Scope

A variable in File scope:

- Is declared outside of all blocks
- Visible everywhere in that file.
  - Global variables, or
  - global functions.

Such a variable can be accessed from another file using the `extern` keyword.

- Without `extern` the compiler will think it is a new variable declaration.

Coding example <p3>

Namespaces

What is a **Namespace**?

- Not a class! Not a package! Has properties of both.
- Closest equivalent is Java ***package***, but more flexible.
- It is the definition of a (named) scope.

To use an element from a **namespace** you must scope it in by either

- using the `using` keyword
- use the ***scope resolution operator*** `::`

Namespaces

A **namespace** may be unnamed, then it is automatically scoped in.

- Has only ***internal*** linkage.
- Visible only to the current ***translation unit***
  - Current source and #include-d headers.
  - I.e., everything that makes this object file.

This is like a global variable, but only for a select group of files.

programming example <p4> - see Makefile for ***variables***.