COMP110: Principles of Computing

11: Further C++

DEADLINES

Representing numbers

Powers of 10

$$10^6 = 1\underbrace{000000}_{\text{6 zeroes}}$$

$$10^1 = 10$$

$$10^0 = 1$$

$$10^{-1} = 0.1$$

$$10^{-6} = 0.\underbrace{00000}_{\text{5 zeroes}}1$$

Scientific notation

- A way of writing **very large** and **very small** numbers
- $a \times 10^b$, where
  - a ($1 \leq |a| < 10$) is the **mantissa**
  - (a is a positive or negative number with a single non-zero digit before the decimal point)
  - b (an integer) is the **exponent**
- E.g. 1 light year = 9.461×10^{15} metres
- E.g. Planck's constant = 6.626×10^{-34} joules
- Socrative `FALCOMPED`

Scientific notation in C++

Instead of writing $\times 10$, write `e`

```
double lightYear = 9.461e15;
double plancksConstant = 6.626e-34;
```

This also works in Python and many other programming languages

Floating point numbers

- Similar to scientific notation, but **base 2** (binary)
- $\pm \text{mantissa} \times 2^{\text{exponent}}$
- Sign is stored as a single bit: $0 = +$, $1 = -$
- Mantissa is a binary number with a 1 before the point; only the digits after the point are stored
- Exponent is a signed integer, stored with a **bias**

IEEE 754 floating point formats

Type	Sign	Exponent	Mantissa	Total
`float`	1 bit	8 bits	23 bits	32 bits
`double`	1 bit	11 bits	52 bits	64 bits

Exponent is stored with a **bias**:

- Single precision: store exponent $+$ 127
- Double precision: store exponent $+$ 1023

Example

`0 10000001 10100000000000000000000`

- Exponent: $129 - 127 = 2$
- Mantissa: binary 1.101
- $1 + \frac{1}{2} + \frac{1}{8} = 1.625$
- $1.625 \times 2^2 = 6.5$
- Alternatively: $1.101 \times 2^2 = 110.1$
- $= 4 + 2 + \frac{1}{2} = 6.5$

Socrative `FALCOMPED`

What is the value of this number expressed in IEEE 754 single precision format?

```
0 01111100 10011000000000000000000
```

You have **5 minutes**, and you **may** use a calculator!

Floating point numbers

- Similar to scientific notation, but **base 2** (binary)
- $\pm \text{mantissa} \times 2^{\text{exponent}}$
- Sign is stored as a single bit: $0 = +$, $1 = -$
- Mantissa is a binary number with a 1 before the point; only the digits after the point are stored
- Exponent is a signed integer, stored with a **bias**

Limitations of floating point numbers

- Precision **varies** by **magnitude**: numbers near 0 can be stored more accurately than numbers further from 0.
  - Why? Socrative `FALCOMPED`
- Many numbers cannot be represented exactly, e.g. $\frac{1}{5}$
  - Similar to how decimal notation cannot exactly represent $\frac{1}{3} = 0.3333333\ldots$
- This can lead to **rounding errors** with some calculations
  - E.g. according to Python,

    ```
    0.1 + 0.2 == 0.30000000000000004
    ```

Testing for equality

- Due to rounding errors, using `==` or `!=` with floating point numbers is almost always a bad idea
- E.g. in Python, `0.1 + 0.2 == 0.3` evaluates to `False`
- Better to check for **approximate equality**: calculate the difference between the numbers, and check that it's smaller than some threshold

Modular program design

Modular program design

- We saw previously that **splitting your code into several files** is generally a good idea
- Python makes it easy: any .py file can be `import`ed on demand
- C++ is a little trickier...

Definitions and declarations

A function **definition** specifies its name, return type, parameters, and the code it contains:

```
double average(double n1, double n2)
{
    return (n1 + n2) / 2.0;
}
```

A function **declaration** specifies everything **except** the code:

```
double average(double n1, double n2);
```

A declaration tells the compiler that this function exists, but is defined **elsewhere**

Sources and headers

- A C++ project contains two main types of file
- **Source files** (.cpp) usually contain **definitions**
- **Header files** (.h) usually contain **declarations**
- For example, `myfile.cpp` may contain some function definitions, and `myfile.h` may contain the declarations for those functions
- (Yep, that means you have to type the same thing twice in two different files...)

Example

words.cpp

```
void readWords()
{
    // code omitted
}

std::string chooseRandomWord()
{
    // code omitted
}
```

words.h

```
#pragma once

void readWords();
std::string chooseRandomWord();
```

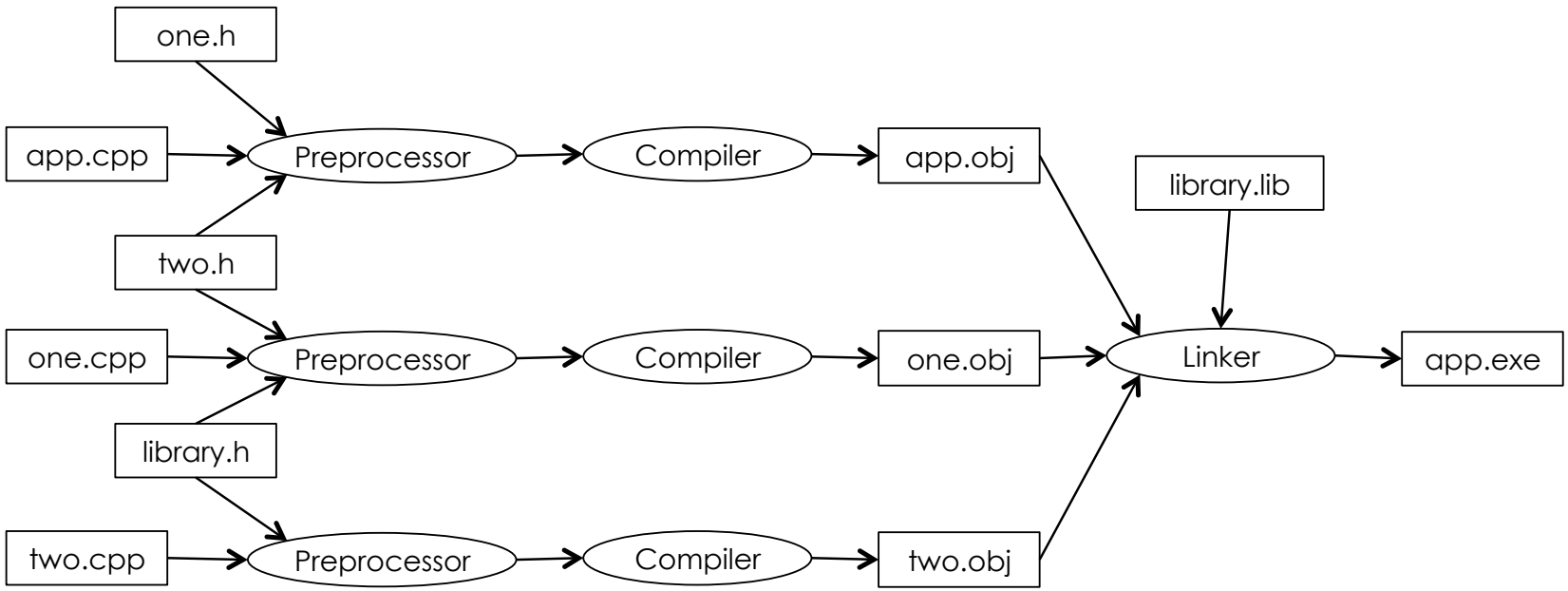
Example from last week

- `readWords()` and `chooseRandomWord()` are **defined** in `words.cpp`
- `readWords()` and `chooseRandomWord()` are **declared** in `words.h`
- Any file which does **`#include`** `"words.h"` can call these functions as if they were declared in that file

How #include works

- **`#include`** works **exactly** as if the **`#include`**d file were copied and pasted at the point where the **`#include`** directive appears
- All header files should start with **`#pragma`** `once` — otherwise, **`#include`**ing the same file more than once will result in duplicate declaration errors
- Putting an **`#include`** directive in the wrong place (e.g. inside a function) will result in weird compile errors

The C++ build process



Pointers

Pointers

- A **pointer** is the address of a memory location
- If `T` is a type, `T*` is the type "pointer to `T`"
- `&` is the **address-of** operator: gets a pointer to something
- `*` is the **dereference** operator: gets the thing the pointer points to

Classes in C++

```
class MyClass
{
public:
    MyClass() { /* constructor */ }
    ~MyClass() { /* destructor */ }

    void myMethod();
    int anotherMethod(float foo);

    int myField;
    bool anotherField
};
```

Allocating objects on the stack

```
// Calls a parameterless constructor
MyClass instance;

// Calls a constructor with parameters
MyClass otherInstance(1, 2, 3);
```

Beware though — these instances are **destroyed** when the variable goes out of scope!

Allocating objects on the heap

- Objects can be allocated on the heap using the **`new`** keyword
- **`new`** gives a pointer to the new instance

```
// To use a parameterless constructor
MyClass* myInstance = new MyClass;

// To use a constructor with parameters
MyClass* myOtherInstance = new MyClass(1, 2, 3);
```

Deleting objects from the heap

- Objects instantiated with **`new`** must be deleted using **`delete`**

```
delete myInstance;
```

- Forgetting to do this is a **memory leak**
- Deleting something **twice** is bad
- Trying to **dereference a deleted pointer** is bad
- Key concept is **ownership**: you're responsible for deleting it **if and only if** you own it

Addressing and dereferencing

```
int a = 7;

// Address-of operator
int* b = &a;

// Dereferencing
int c = *b;
```

- `&` gets the **address** of a variable, i.e. a pointer to it
- `*` **dereferences** the pointer, i.e. looks up the thing it points to

Socrative FALCOMPED

```
int a = 7;
int* b = &a;
int c = *b;
```

Suppose that the variables are assigned to the following memory addresses:

Variable	a	b	c
Address	1000	1004	1008

1. What is the value of `a`?
2. What is the value of `b`?
3. What is the value of `c`?

Null pointer

- Pointers can have a special value **`nullptr`**
- This signifies the pointer doesn't point to anything

```
MyClass* notAnInstance = nullptr;
```

- Similar to `None` in Python
- You may also see `NULL` used instead of **`nullptr`** — the meaning is the same