COMP110: Principles of Computing

10: Transition to C++

Learning outcomes

- **Recall** the key differences between Python and C++
- **Use** the Visual Studio IDE to compile and run your first C++ program
- **Write** basic programs in C++

Worksheets — final submission

Recommended method:

- Go to your fork of the `COMP110-worksheets` repo
- "Clone or download" → "Download zip"
- **Check** that the zip contains **five subfolders**, named `worksheet_A` to `worksheet_E`
- **Check** that the zip contains **all** material for your worksheet submissions (especially images not hosted on GitHub)
- **Rename** the zip to `COMP110_1_1600000.zip`, replacing `1600000` with your **student number**
- **Upload** the zip to the submission queue on LearningSpace

Your first C++ program

Project setup

- Open **Visual Studio 2015** from the Start menu
- Click **New Project**
- Choose **Templates** $\rightarrow$ **Visual C++** $\rightarrow$ **Win32** $\rightarrow$ **Win32 Console Application**
- Choose an appropriate name and location, and click **OK**
- Click **Finish**
- If asked about source control, click **Cancel**

The code

- Edit ⟨`YourApplicationName`⟩`.cpp` to match the following:

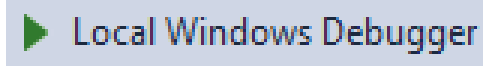
```
// YourApplicationName.cpp : Defines the entry point for the console application.

#include "stdafx.h"

int main()
{
    printf("Hello, world!\n");
    return 0;
}
```

Running it

- Click 

, or press **F5**
- It worked, but the window disappeared before we could see it!
- Solution 1: click **Debug** $\rightarrow$ **Start Without Debugging**, or press **Ctrl + F5**
- Solution 2: click in the left margin next to the `return 0;` line to set a **breakpoint** — a red circle should appear. Then click 

Comments

```
// ConsoleApplication1.cpp : Defines the entry point ↩
    for the console application.
```

- `//` denotes a single-line comment
- Equivalent of `#` in Python
- ↩ denotes a line too long to fit on the slide — in your program this should be a single line
- Multi-line comments, delimited by `/**/`, are also available

```
/* This is an example of a multi-line comment
   More comment text
   Even more comment text */
```

The #include directive

```
#include "stdafx.h"
```

- **`#include`** imports definitions from a **header file**
- Similar to **`import`** in Python
- **`#include "..."`** (quotes) is used for headers in the current project
- **`#include`** `<...>` (angle brackets) is used for external libraries
- `stdafx.h` is the **precompiled header** file — for faster compilation, external library headers should be included here rather than in the main `.cpp` file

Entry point

```
int main()
```

- **All code** must be inside a **function**
- The **entry point** of an application is (almost) always named `main`
  - Some types of Windows GUI application use a different name for the entry point
  - A game engine (e.g. Unreal) takes care of the entry point for you
- `int` means the function **returns** a value of integer type
- `()` means the function takes **no parameters**

Blocks and semicolons

```
{
    ...;
    ...;
}
```

- Curly braces are used to denote **blocks**
- All statements in C++ end with a semicolon `;`
- Unlike Python, C++ ignores whitespace (indentation and usually line breaks)
- ... but whitespace is important for readability, so use it anyway

Writing to the console

```
printf("Hello, world!\n");
```

- Equivalent of Python's **`print`** statement
- `printf` is a function, part of the **standard library**
- In Unreal, can use `UE_LOG` for the same purpose
- `"\n"` is the **new line character**
- Most online tutorials will recommend using `std::cout` to write to console, but `printf` is easier for now

Formatted printing

- The string passed to `printf` can include **placeholders**
- Pass further arguments to `printf`, one for each placeholder

```
printf("%d plus %d equals %d\n", 3, 4, 3+4);
```

- Placeholder **must** match the type of the argument
- `"%d"` or `"%i"`: integer
- `"%f"`: floating point
- `"%s"`: string

Exit code

```
    return 0;
```

- Returning 0 from `main` tells the OS that the program completed successfully
- Mainly useful for writing tools to be used in DOS/Windows batch scripts or Linux shell scripts — for our purposes, `main` will almost always return 0

Variables and types

Variables

In Python, variables exist the moment they are assigned to:

```
a = 10
b = 20
```

Variables can hold values of any type:

```
a = 10
a = 3.14159
a = "Hello"
```

In C++, variables must be **declared** before use, and must be given a **type**:

```
int a = 10;
int b = 20;
```

Variables can only hold values of the correct type:

```
int a = 10;
a = 17;       // OK
a = "Hello"; // Error
```

Integers

- **`int`** is the basic data type for integers (whole numbers)

```
int a = 42;
int b = -74965;
int c = 0;
int d = 0x19FD; // Hexadecimal
```

- On Windows (32 and 64 bit), **`int`** can store numbers from -2^{31} to $2^{31} - 1 \approx \pm 2$ billion
- **`unsigned int`** stores **nonnegative** integers, from 0 to $2^{32} \approx 4$ billion
- Other integer types exist, for example **`long long`** is a 64 bit integer

Floating point numbers

- **`float`** and **`double`** can store floating point numbers (numbers with a fractional part)

```
double a = 3.14159;
double b = -42;
double c = 3.0e8; // Scientific notation
float d = 123.456f; // Note the 'f' suffix for float
```

- **`float`** uses less space, and can be slightly faster, but is less precise
- Generally **`double`** is the better choice

Characters

- **`char`** stores a single ASCII character

```
char foo = 'Q';
char bar = '7';
char baz = '@';
char space = ' ';
char newLine = '\n'; // Escape sequence
```

- **`char`** can also be thought of as an 8-bit integer, i.e. an integer between -128 and 127 — C++ makes no distinction between ASCII characters and their numerical codes

Booleans

- **`bool`** stores a boolean (true or false) value

```
bool isAlive = true;
bool isDead = false;
```

Vectors

- **Vectors** are the C++ equivalent of lists in Python
- Add `#include <vector>` to `stdafx.h`
- `std::vector<T>` is a vector with elements of type `T`

```
std::vector<int> numbers = { 1, 4, 9, 16 };
numbers.push_back(25);
```

- NB: in Unreal, it is recommended to use `TArray` instead of `std::vector`

Strings

- C++ has two main data types for strings:
  - **`char`**`*` or **`char`**`[]`: low-level array of ASCII characters (more on arrays next week)
  - `std::string`: high-level string class
- Add **`#include`** `<string>` to `stdafx.h`

```
std::string name = "Ed";
std::string message = "Hello " + name + "!\n";
printf(message.c_str()); // printf expects a character ↩
     array, so use c_str to convert
```

- NB: Unreal has its own string types that should be used instead of `std::string`

Enumerations

- An **enumeration** is a set of named values

```
enum Direction { dirUp, dirRight, dirDown, dirLeft };

Direction playerDirection = dirUp;
```

- This is equivalent to using an **`int`** with 0=up, 1=right etc, but is more readable

Constants

- The **`const`** keyword can be used to define a "variable" whose value cannot change, i.e. read only

```
const int x = 7;
int y = x * 3; // OK
x = 12; // Error
```

Declaring variables

- A variable declaration must specify a **type**, and one or more **variable names**:

```
int i, j, k;
bool isDead;
std::string playerName;
```

- A variable declaration can optionally specify an **initial value**:

```
int i = 0, j = 1, k = 2;
bool isDead = false;
std::string playerName = "Ed";
```

Initial values

- If the initial value is omitted, what happens depends on the type:
- Basic data types (**`int`**, **`double`**, **`bool`**, **`char`** etc): the value is undefined — whatever data happened to be in that memory location already
  - Your code should **never** read an uninitialised variable — doing so is **always** a bug
- Object types (`std::vector`, `std::string` etc): depends on the type (consult the documentation)
  - `std::vector` and `std::string` are both initialised to empty

Scope

- The **scope** of a variable is the region of the program where it exists
- Generally the scope of a variable begins when it is declared, and ends when the block in which it is declared ends

```
int x = 7;
if (x > 5)
{
    int y = x * 2;
    printf("%d\n", x); // OK
    printf("%d\n", y); // OK
}
printf("%d\n", x); // OK
printf("%d\n", y); // Error
```

Control structures

If statement

```
if (x > 0)
{
    printf("x is positive\n");
}
else if (x < 0)
{
    printf("x is negative\n");
}
else
{
    printf("x is neither positive nor negative\n");
}
```

If statement

- Works just like the `if` statement in Python
- There can be zero, one or many `else if` clauses
- The `else` clause is optional, but if present then there can only be one

Conditions

- Numerical comparison operators work just like Python:
  `== != < > <= >=`
- Boolean logic operators look a little different

Python uses **`and, or, not`**

```
if not (x < 0 or x > 100) and not (y < 0 or y > 100):
    print "Point is in rectangle"
```

C++ uses `&&, ||, !`

```
if (!(x < 0 || x > 100) && !(y < 0 || y > 100))
{
    printf("Point is in rectangle\n");
}
```

Single-statement blocks

- In many cases, if a block contains only a single statement then the curly braces can be omitted

```
if (x > 0)
    printf("x is positive\n");
else if (x < 0)
    printf("x is negative\n");
else
    printf("x is neither positive nor negative\n");
```

Single-statement blocks

- Careful though! This can lead to obscure bugs

```
if (z == 0)
    x = 0; y = 0;
```

Socrative `FALCOMPED`: what's wrong with this?

While loop

```
while (x > 0)
{
    printf("%d\n", x);
    x--;
}
```

- Same as Python

Do-while loop

```
do
{
    printf("%d\n", x);
    x--;
} while (x > 0);
```

- **`while`** loop checks the condition **before** executing the loop body
- **`do-while`** loop checks the condition **after** executing the loop body
- e.g. if `x == 0` to begin with, the **`while`** body does not execute, the **`do-while`** body executes once

For-each loop

```
std::vector<int> numbers { 1, 3, 5, 7, 9 };

for (int x : numbers)
{
    printf("%d\n", x);
}
```

- This works like the **`for`** loop in Python
- Used for iterating over data structures
- For iterating over ranges of numbers, C++ has something different...

For loop

```
for (int i = 0; i < 10; i++)
{
    printf("%d\n", i);
}
```

- The `for` loop has three parts:
- The **initialiser** `int i = 0`
  - This is executed at the start of the loop
- The **condition** `i < 10`
  - The loop executes while this evaluates to `true`
- The **loop statement** `i++`
  - This is executed at the end of each iteration of the loop
  - `i++` means "increment `i`" — this is shorthand for `i = i + 1`

For loops and while loops

```
for (int i = 0; i < 10; i++)
{
    printf("%d\n", i);
}
```

- Any **`for`** loop can easily be rewritten as a **`while`** loop

```
int i = 0;
while (i < 10)
{
    printf("%d\n", i);
    i++;
}
```

For loops in C++ and Python

```
for (int i = 0; i < 10; i++)
{
    printf("%d\n", i);
}
```

- In Python, this would be written as a for-each loop, first using the **`xrange`** function to construct the range of numbers $0, 1, 2, \ldots, 9$:

```
for i in xrange(10):
    print i
```

- The C++ way doesn't require construction of an iterable object, so is more efficient

Socrative FALCOMPED

What would the first code fragment print?

```
for (int i = 0; i < 10; i++)
    printf("%d ", i);
```

Socrative FALCOMPED

What would the second code fragment print?

```
for (int i = 0; i <= 10; i++)
    printf("%d ", i);
```

Socrative FALCOMPED

What would the third code fragment print?

```
for (int i = 0; i < 10; i += 2)
    printf("%d ", i);
```

Socrative FALCOMPED

What would the fourth code fragment print?

```
for (int i = 10; i < 0; i++)
    printf("%d ", i);
```

Socrative FALCOMPED

What would the fifth code fragment print?

```
for (int i = 10; i > 0; i++)
    printf("%d ", i);
```

Socrative FALCOMPED

What would the sixth code fragment print?

```
for (int i = 10; i > 0; i--)
    printf("%d ", i);
```