COMP110: Principles of Computing

Transition to C++ I

Learning outcomes

By the end of this session you will

- Understand a thing
- Understand another thing
- Be convinced that LaTeX makes better-looking slides than PowerPoint

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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**
- When asked about source control, click **Cancel**

The code

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

#include "stdafx.h"

int main()
{
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```

- Add the following line to the end of `stdafx.h`:

```
#include <iostream>
```

- Click **Debug** → **Start Without Debugging**, or press **Ctrl + F5**

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 <iostream>
```

- `#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`
- `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 line breaks)
- ... but whitespace is important for readability, so use it anyway

Writing to the console

```
std::cout << "Hello, world!" << std::endl;
```

- Equivalent of Python's `print` statement
- `std` is the **namespace** containing most of the C++ standard library
- `std::cout` is the console output stream
- `std::endl` is the end-of-line character
- To use `std::cout` and `std::endl`, it is necessary to `#include <iostream>`
- `<<` is the **insertion operator** — used to write values to a stream

Exit code

```
    return 0;
```

- Returning 0 from `main` tells the OS that the program completed successfully

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Variables and types

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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
```

Basic data types

- `int`: an integer (whole number)

```
7      136      -74965      0
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```

- `bool`: a boolean value

```
true     false
```

- `char`: an ASCII character

```
'Q'     '7'     '@'     ' '     '\n'
```

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

Strings

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  - `char*` or `char[]`: low-level array of ASCII characters (more on arrays next week)
  - `std::string`: high-level string class

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- Add `#include <string>` to `stdafx.h`

```
std::string name = "Ed";
std::string message = "Hello " + name + "!";
std::cout << message << std::endl;
```

Enumerations

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Direction playerDirection = dirUp;
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```
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

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```
const int x = 7;
std::cout << x << std::endl; // 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";
```

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- 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

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```
int x = 7;
if (x > 5)
{
    int y = x * 2;
    std::cout << x << std::endl; // OK
    std::cout << y << std::endl; // OK
}
std::cout << x << std::endl; // OK
std::cout << y << std::endl; // Error
```

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Control structures

If statement

```
if (x > 0)
{
    std::cout << "x is positive" << std::endl;
}
else if (x < 0)
{
    std::cout << "x is negative" << std::endl;
}
else
{
    std::cout << "x is neither positive nor negative"
        << std::endl;
}
```

If statement

```
if (x > 0)
{
    std::cout << "x is positive" << std::endl;
}
else if (x < 0)
{
    std::cout << "x is negative" << std::endl;
}
else
{
    std::cout << "x is neither positive nor negative"
        << std::endl;
}
```

- Condition is always in parentheses ( )

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))
{
    std::cout << "Point is in rectangle" << std::endl;
}
```

Single-statement blocks

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

```
if (x > 0)
    std::cout << "x is positive" << std::endl;
else if (x < 0)
    std::cout << "x is negative" << std::endl;
else
    std::cout << "x is neither positive nor negative"
        << std::endl;
```

- Careful though! This can lead to obscure bugs

```
// This code is wrong!
if (z == 0)
    x = 0; y = 0;
```

Switch statement

```
switch (x)
{
case 0:
    std::cout << "zero" << std::endl;
    break;
case 1:
    std::cout << "one" << std::endl;
    break;
case 2:
    std::cout << "two" << std::endl;
    break;
default:
    std::cout << "something else" << std::endl;
    break;
}
```

While loop

```
while (x > 0)
{
    std::cout << x << std::endl;
    x--;
}
```

Do-while loop

```
do
{
    std::cout << x << std::endl;
    x--;
} while (x > 0);
```

Do-while loop

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do
{
    std::cout << x << std::endl;
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- `while` loop checks the condition **before** executing the loop body

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do
{
    std::cout << x << std::endl;
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```

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- `do-while` loop checks the condition **after** executing the loop body

Do-while loop

```
do
{
    std::cout << x << std::endl;
    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 each (int x in numbers)
{
    std::cout << x << std::endl;
}
```

For-each loop

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

for each (int x in numbers)
{
    std::cout << x << std::endl;
}
```

- This works like the `for` loop in Python
- Used for iterating over data structures

For loop

```
for (int i = 0; i < 10; i++)
{
    std::cout << i << std::endl;
}
```

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    std::cout << i << std::endl;
}
```

- The `for` loop has three parts:

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- The **initialiser** `int i = 0`
  - This is executed at the start of the loop

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for (int i = 0; i < 10; i++)
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- The **initialiser** `int i = 0`
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- 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

For loops and while loops

```
for (int i = 0; i < 10; i++)
{
    std::cout << i << std::endl;
}
```

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

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for (int i = 0; i < 10; i++)
{
    std::cout << i << std::endl;
}
```

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

```
int i = 0;
while (i < 10)
{
    std::cout << i << std::endl;
    i++;
}
```

For loops in C++ and Python

```cpp
for (int i = 0; i < 10; i++)
{
    std::cout << i << std::endl;
}
```

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

```python
for i in range(10):
    print i
```

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Variables and types

Function definitions

- We have already seen an example of a function definition

```
int main()
{
    std::cout << "Hello, world!" << std::endl;
    return 0;
}
```

- The function `main` takes no parameters, and returns a value of type `int`

Function signatures

- The **signature** of a function defines its return type, name, and parameters

```
double foo(std::string x, int y, bool z)
```

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double foo(std::string x, int y, bool z)
```

- This function takes three parameters: `x` of type `std::string`, `y` of type `int`, and `z` of type `bool`
- It returns a value of type `double`

Functions without return values

- It is possible to define a function which does not return a value, using the `void` keyword in place of its return type

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- It is possible to define a function which does not return a value, using the `void` keyword in place of its return type

```
void printNumber(int n)
{
    std::cout << n << std::endl;
}
```

Pass by value

- Function parameters are passed **by value**: the function receives **copies** of the original variables

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```
void changeName(std::string name)
{
    name = "Ed";
}

int main()
{
    std::string name = "Mike";
    std::cout << name << std::endl;
    changeName();
    std::cout << name << std::endl;
}
```

Pass by reference

- Parameters can be passed **by reference** using the `&`, allowing the function to modify them

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```
void changeName(std::string& name)
{
    name = "Ed";
}

int main()
{
    std::string name = "Mike";
    std::cout << name << std::endl;
    changeName();
    std::cout << name << std::endl;
}
```

Constant references

```
void greet(std::string name)
{
    std::cout << "Hi " << name << std::endl;
}
```

- Pass by value — the string will be copied in order to be passed in
- More efficient to pass a reference, and mark it `const` to prevent accidental modification

```
void greet(const std::string& name)
{
    std::cout << "Hi " << name << std::endl;
}
```

- (this is only worthwhile for large data structures like strings and vectors, not for basic data types)