

Programming in C (+ +) and R, MATH10017

Song Liu (song.liu@bristol.ac.uk)

GA 18, Fry Building,

Microsoft Teams (search "song liu").

Twitter: songandylIU

When and Where

Type	Time	Location
Lectures	10-11AM, Mondays	FRY BLDG G.10 LT
Labs*	10-12AM, 4-6PM Tuesday,	FRY BLDG LG.21 PC
Tutorials	Every two weeks	See Timetable

[https://www.bristol.ac.uk/timetables/html.html?
unit=MATH10017](https://www.bristol.ac.uk/timetables/html.html?unit=MATH10017)

*Labs and tutorials and will have attendance checking.

*For international students, these are your visa checkpoints.

Key Objectives

Upon completion of this unit you should:

1. *Understand* the workflow of computer programming and appreciate computer as a data processing tool.
2. *Program, debug, document* and *test* basic algorithms in C(++) and R, with appropriate coding paradigms.
3. *Decide* which programming language to use when faced with a computing task.

How This Unit is Structured?

- TB1: C Programming Language
- TB2:
 - Some aspects of C++ Programming Language.
 - R Programming Language.

What are the Assessments?

- Written Exam (50%) at the end of TB2.
- Four Programming Coursework (12.5% X 4).
 - **TWO** per TB.
 - In TB1, submit by 6th Nov, 15th Dec
- Non-assessed homework each week after lecture.
 - **Do not skip homework.**
 - These homework are designed to build up skills required for the coursework.
 - Reuse some of the code you've written for these homework, to make your coursework easier.

Your Week

- **Monday:** Attend lecture.
 - Think about your homework
- **Tuesday:** Go to lab.
 - Convert your thoughts into actual C/R code.
 - Get help from TA/me on your homework.
 - Help each other.
- **Pre-Tutorial Day:**
 - Read/Watch pre-tutorial materials (If any).
- **Tutorial Day:**
 - Work on your tutorial tasks (If any)
 - Discuss feedback of your homework with TA/me.

Plagiarism and Collusion

- Read [this guideline](#) on Plagiarism very carefully.
- Read [this guideline](#) on Collusion very carefully.
- They are serious academic offences.
- **Tips:**
 - Never copy and paste from the internet/CHATGPT.
 - Learn from other people's idea, rather than copy it.
 - We encourage discussion but you should do your homework independently.
 - Do NOT ask other people to test your code. It is your own duty to make sure your code works.
- We have many ways to detect Plagiarism and we caught several incidences in the past.

Q: Why do I need to learn programming?

Data Science = Statistics + Computing,

- Programming is an important computing skill.

Q: But I am already good at programming...

- This course is designed to be the foundation for all students.
 - We understand students' background may vary.
- **If you are confident** that you can get good score in assessments, you are free to spend more time on math courses.
- **Do follow along**, as we may introduce topics that are specifically designed for data science students.

Q: But can't AI/ChatGPT write code nowadays?

- AI cannot do general programming yet (although it may soon).
- You still need to be proficient at programming in order to use AI assisted programming tools.
- **Although we have self-driving cars now, you still need to take driving lessons.**

Using ChatGPT

- ChatGPT is an advanced AI assistant.



Why does the compiler complain "missing;"?

```
#include<iostream>
```

```
void main(){  
    printf("hello!")  
}
```



The reason the compiler complains about a "missing;" is because you forgot to add a semicolon at the end of the `printf` statement.



However, there are several other issues in your code:

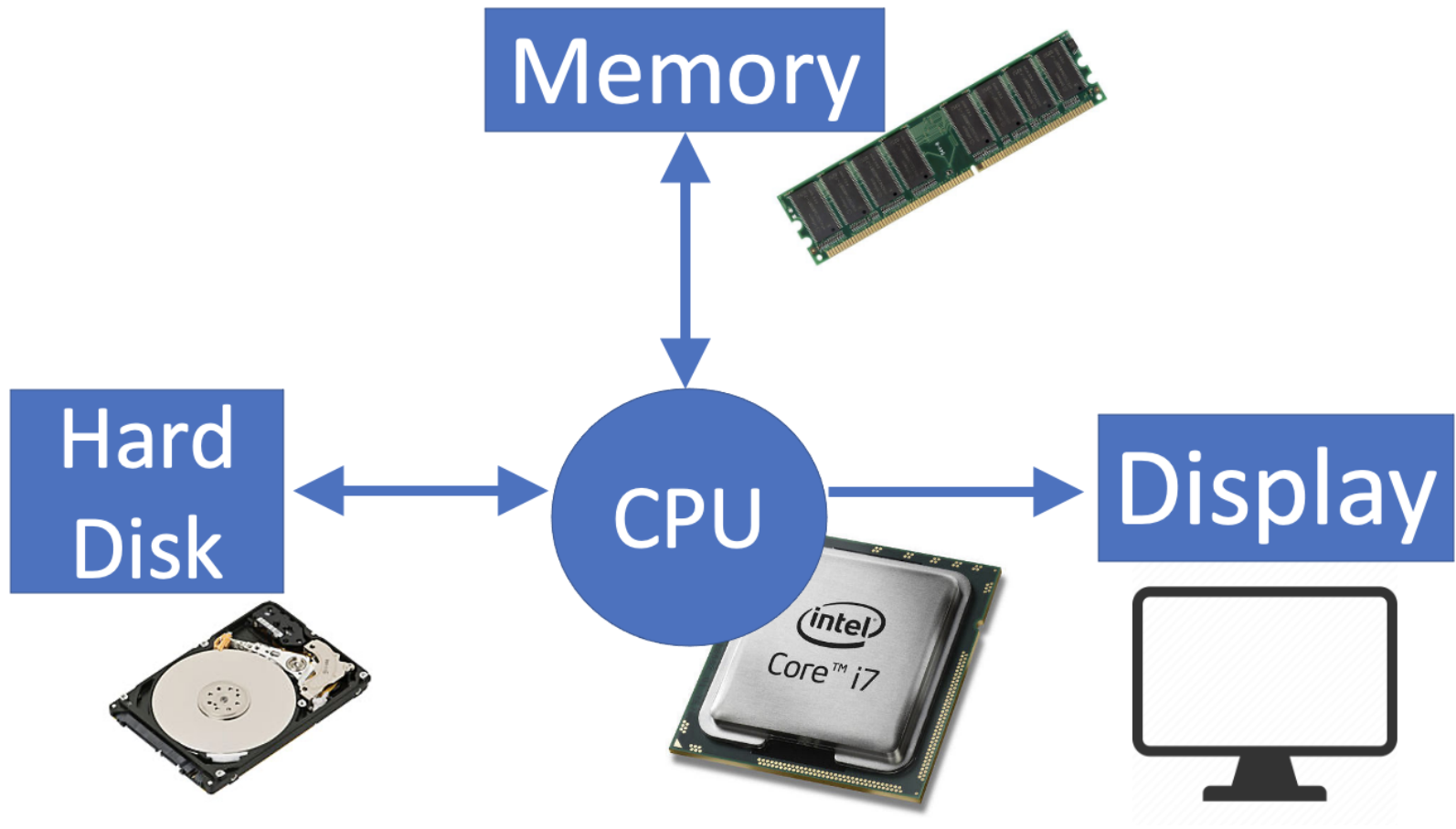
1. The `printf` function is not defined in the `<iostream>` header. It is a C function and is defined in the `<cstdio>` (or `<stdio.h>` in older code) header.
2. You're not using any namespace specification. If you were to use C++'s `std::cout`, you'd need the `std::` prefix unless you use a `using` directive or declaration.
3. The proper return type for the `main` function in C++ is `int`, not `void`.

Using ChatGPT

- You can use it to **get feedback**.
- but you **cannot ask it to generate code for you** and submit it as your work.
- In the exam, you will be asked to program using pen and paper, and ChatGPT will not be available.
- ChatGPT may sound confident, but may give you **wrong answers**.

The foundation of computing

An Idealized Computer



von Neumann Architecture

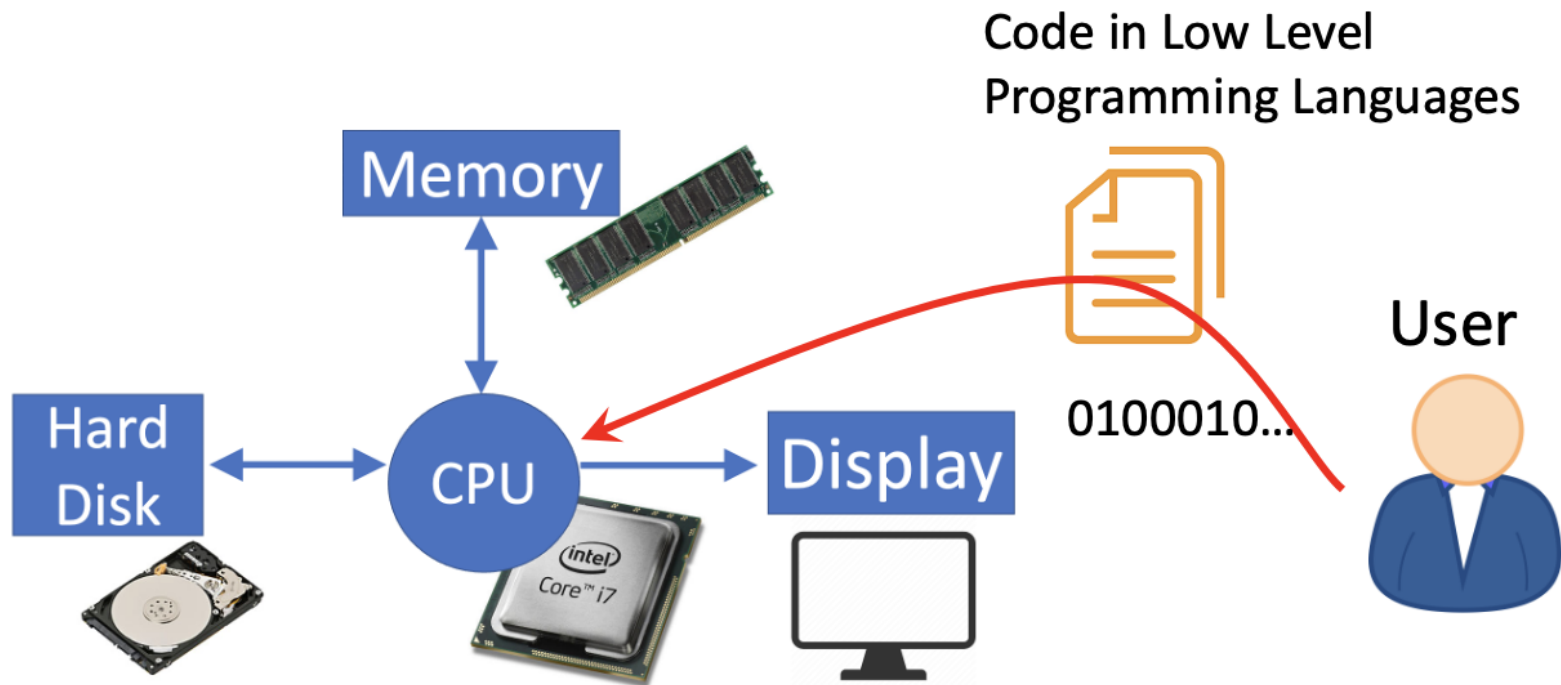
- **Central Processing Unit (CPU)**
 - Performs computational tasks.
 - Controls Input/Output (IO) devices.
 - Maintains data stored in the memory.
- **Memory**
 - Stores program/data being used by CPU temporarily.
- **IO Devices**
 - Hard disk
 - Display
 - Camera
 - Touch Screen, etc.

What is Programming?

- Programming = writing a list of instructions to be executed on the CPU.
- The list of instructions is called the "code".
- Programming is also called "coding".
- Programmer is also called "coder".
- The language used to write the code is called programming language.

Low-level Programming Language

- Coder can program in **machine code**.
- Then the code can be **directly executed** on the CPU requiring no (or very little) translation.
- Machine code (and its more human friendly variants) are referred to as "Low-Level Programming Languages".



Low-level Programming Language

- **Advantages** of Low-level Programming Language:
 - gives coder total control of hardware.
 - can be efficient since it needs no translation (You talk to the computer using its native language!).
- **Disadvantages** of Low-level Programming Language:
 - can damage the hardware if the coder is not careful.
 - is difficult to learn and read (machine instructions are usually very different from human languages).
 - only works on a specific cpu architecture (e.g. x86 or ARM). Thus the code is not "portable".

Low-level Programming Language

Example code printing a message "Hello, World" on display on x86 CPUs

```
global start
section .text
start:
    mov     rax, 0x02000004
    mov     rdi, 1
    mov     rsi, message
    mov     rdx, 13
    syscall
    mov     rax, 0x02000001
    xor     rdi, rdi
    syscall
section .data
message:
    db      "Hello, World", 10
```

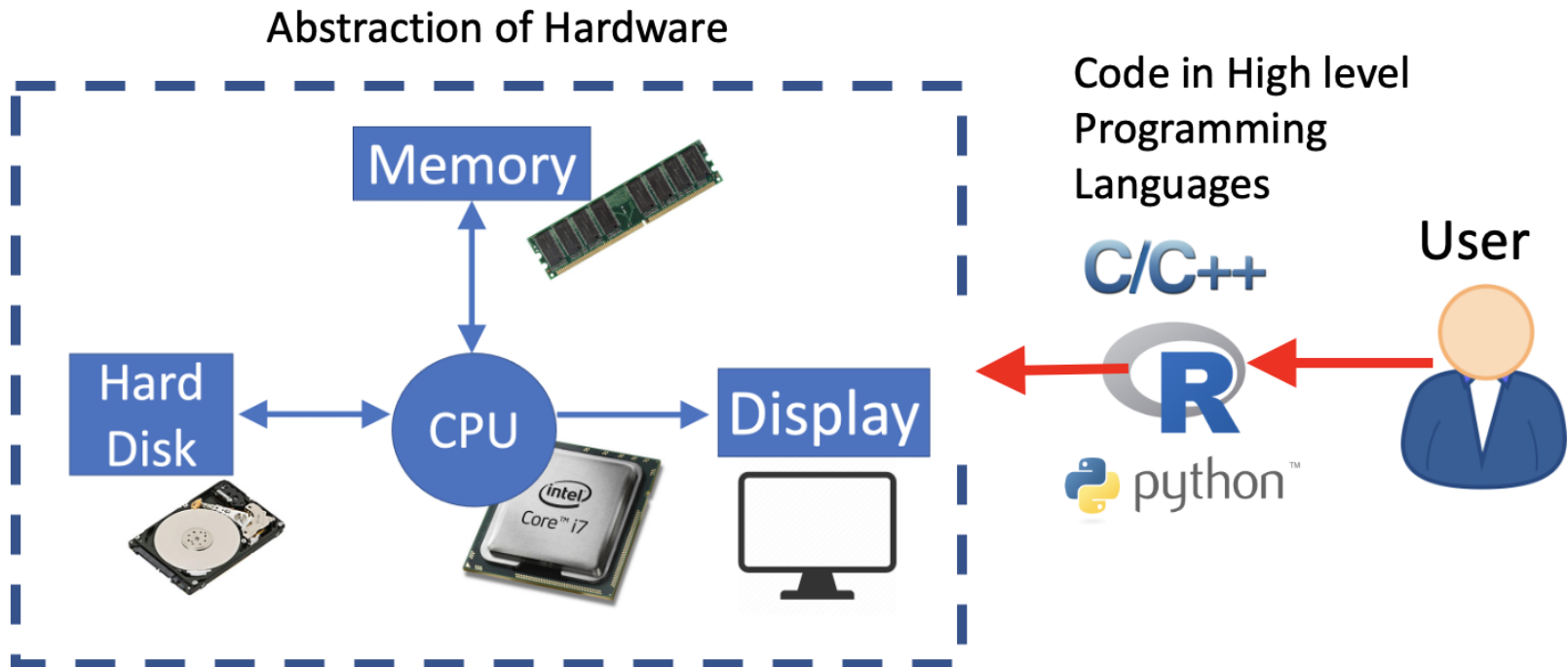
[Source](#)

High-level Programming Language

- Coder can program in a more natural language, which is then **translated** into machine code.
- This translation process is called "compilation" and the software that performs this translation is called "**complier**".
- This kind of languages are called "High-level Programming Languages". For example,
 - C, C++
 - Python
 - Java
 - MATLAB
 - R...

Abstraction of Hardware

- Since your code is not executed on the CPU "as is", high-level language provides an **abstraction of hardware**.
- Coder interfaces with this abstraction rather than directly program for the underlying CPU and hardware.



Abstraction of Hardware

- Not allowing the user to directly program for the hardware sounds restrictive but also has many advantages:
 - The code is "portable", i.e., the coder needs not to rewrite their code for different CPU architectures, as all CPU architectures share the same abstraction.
 - The abstraction hides many cumbersome details of hardware management, so the coder can focus on their computational task.
 - Not allowing the program to have direct access to the hardware would enhance the security of the system.

Abstraction of Hardware

- However, different programming languages may provide different levels of abstraction.
- Some high-level programming language allows you to directly manage computational resources to some extent.
- Therefore, you can again categorize high-level programming languages into "relatively high-level" and "relatively low-level".
 - C/C++ is regarded as "relatively low-level".
 - Python/R/MATLAB are regarded as "relative high-level".

Stack Exchange: Why do some programmers categorize C, Python, C++ differently?

High-level Programming Language

- **Advantages** of High-level Programming Languages
 - Close to human language, easy to learn/read.
 - CPU architecture independent, a.k.a., "Portable".
- **Disadvantages** of High-level Programming Languages
 - Less efficient as the code requires "translation" before it can be executed on CPU.
 - Cannot directly communicate with hardware: the coder has to interface with *the abstraction*.

Example Code: C

Example C code for printing "Hello World!" on your screen.

```
//filename: main.c
#include <stdio.h>

void main(){
    printf("Hello World!\n");
}
```

Compilation (in command line):

```
gcc main.c -o main.exe
```

Execution (in command line):

```
./main.exe
Hello World!
```

Dissecting C Code

```
//filename: main.c
#include <stdio.h>

void main(){
    printf("Hello World!\n");
}
```

- `//filename: main.c` : **Comments**. Readable explanations or annotations in the source code. It is ignored by compiler.
- `#include <stdio.h>` : **Preprocessing command**. Instructs the compiler to perform pre-processing before the actual compilation.
- `void main(){...}` : **Function**. Contains list of statements.
- `printf("Hello World!\n");` : **Statement**. The actual command to be carried out by the CPU.

The `gcc` Compiler

```
gcc main.c -o main.exe
```

- `gcc` : [GNU C Compiler](#). An [open-source](#) C programming compiler, available on Linux and MacOS.
- `main.c` C code file, as the input.
- `-o main.exe` "main.exe" as the output executable file (a file contains machine code, ready to be executed by CPU).

Example Code: R

Example R code for printing "Hello World!" on all platforms that run R programming language.

```
#filename: hello.R  
print("Hello World!")
```

To execute, in command line, run

```
RScript hello.R  
  
[1] "Hello World!"
```

There is no explicit complication. R command line (RScript) tool reads the R code line by line and automatically translates them into executable codes in real time.

More on R in the Next TB.

Development Environment

Development environment refers to the collection of software you need to write, debug (more on this later) and test your code.

To do C programming, you need two things at least:

- **Text Editor:** As C code are text files, you need a text editor to write and organize these code files.
- `gcc` : The compiler to translate your C code into machine code. It comes with most Linux installations.

This unit recommends using [Visual Studio Code](#) as your code editor. It comes with many useful features for beginners (such as syntax highlighting, code autocomplete, etc.).

Resources about C Programming

Download the slides from Github before clicking the links!

1. [The C Programming Language](#), Brian Kernighan and Dennis Ritchie (The creators of C). The Bible.
 - i. [An interview of Brian](#) on the history of C.
2. [Wikibooks: C Programming](#), for quick references.
3. [COMS10008: Imperative Programming](#)
 - i. An excellent unit used to be taught by Dr. Ian Holyer in Computer Science department.
4. [CS50](#) is Harvard University's introductory course to computer science and the art of programming.
5. [C Programming under 4 hours](#) is a youtube video crash course designed for beginners.

Conclusion

1. Programming = **writing a list of instructions to be executed on the CPU.**
2. There are two types of programming language: High level programming and low level programming.
 - i. Pros and cons.
3. Two things you need for C programming: Text editor + Compiler!

A Pre-configured Development Environment for Fry PC Lab

- Download the [Lab Pack](#) and unzip.
- Double click "lab0.bat".
- Visual Studio Code should open. You should be presented with a "hello, world" C code example.

Homework 1.1, Hello World

- Set up your Development Environment.
- **Compile** the provided "hello world" program.
 - Press `ctrl` + `'` to bring out the command line.
 - Use `gcc` to compile the code, as shown in the slides.
 - Hint: You can hide the command line by pressing `ctrl` + `'` again.
- **Execute** and Observe the program output.

Homework 1.2, Hello World

- Change the C code in Visual Studio Code, so that it prints out your information, not mine.
 - Your student ID is the stuff before your Bristol email address, should be something like "ab231234".

For example,

```
My name is [YOUR NAME].  
I am from [YOUR NATIONALITY].  
My student ID is [STUDENT ID].  
My favourite food is [YOUR FAVOURITE FOOD].
```

- **Re-compile, execute** and observe the output.
- Does the program output change?

Homework 1.3, Hello World

- Modify the C code in Visual Studio Code, so that it prints out your information in the following order:
 - NAME
 - STUDENT ID
 - FAVOURITE FOOD
 - NATIONALITY
- Make sure your code compiles, runs and produces intended output.

Homework 1.3, Hello World

- Write a short comment in your code, listing
 - Pros and Cons of high level programming language
 - Three key components of von Neumann Architecture
 - Hint, you can use

```
/*  
to write multi-line  
comments.  
*/
```

- **Make sure your code compiles, runs before submission!**
- Submit the C code (`YOUR_STUDENT_ID.c`) [here](#).
 - Your student ID should be something like "ab231234".

printf function

- `printf` will replace all "format specifiers" in the `FORMAT_STRING` with supplied `VARIABLE` before display.
 - `printf("My name is %s %s. \n", "Song", "Liu");`
 - Prints out `My name is Song Liu.`
 - `"%s"`: string specifier, tells computer to expect "string" type variable at this location.
 - `"\n"`: [ASCII code](#) for "new line".
- [Read this manual](#) for a list of all possible "format specifiers" and simple examples.