Programming in C (++) and R, MATH10017

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When and Where

Type	Time	Location
Lectures	3PM - 5PM, Mon	G44, PHYS
Labs	Tue 1PM - 3PM	FRY BLDG LG.21 PC
Tutorials	Friday	FRY BLDG LG.21 PC

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, first half: C Programming Language
- TB1, second half: R Programming Language.

What are the Assessments?

- Written Exam (50%) at the end of TB1.
- Two Programming Coursework (25% X 2).
  - CW1, 3 NOV
  - CW2, 8 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.

Plagiarism and Collusion

- Read this guideline on Plagiarism very carefully.
- Read this guideline on Collusion very carefully.
- They are serious academic offenses.
- **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.
- We have many ways to detect Plagiarism and we caught several incidences in the past.

Policy of AI Use

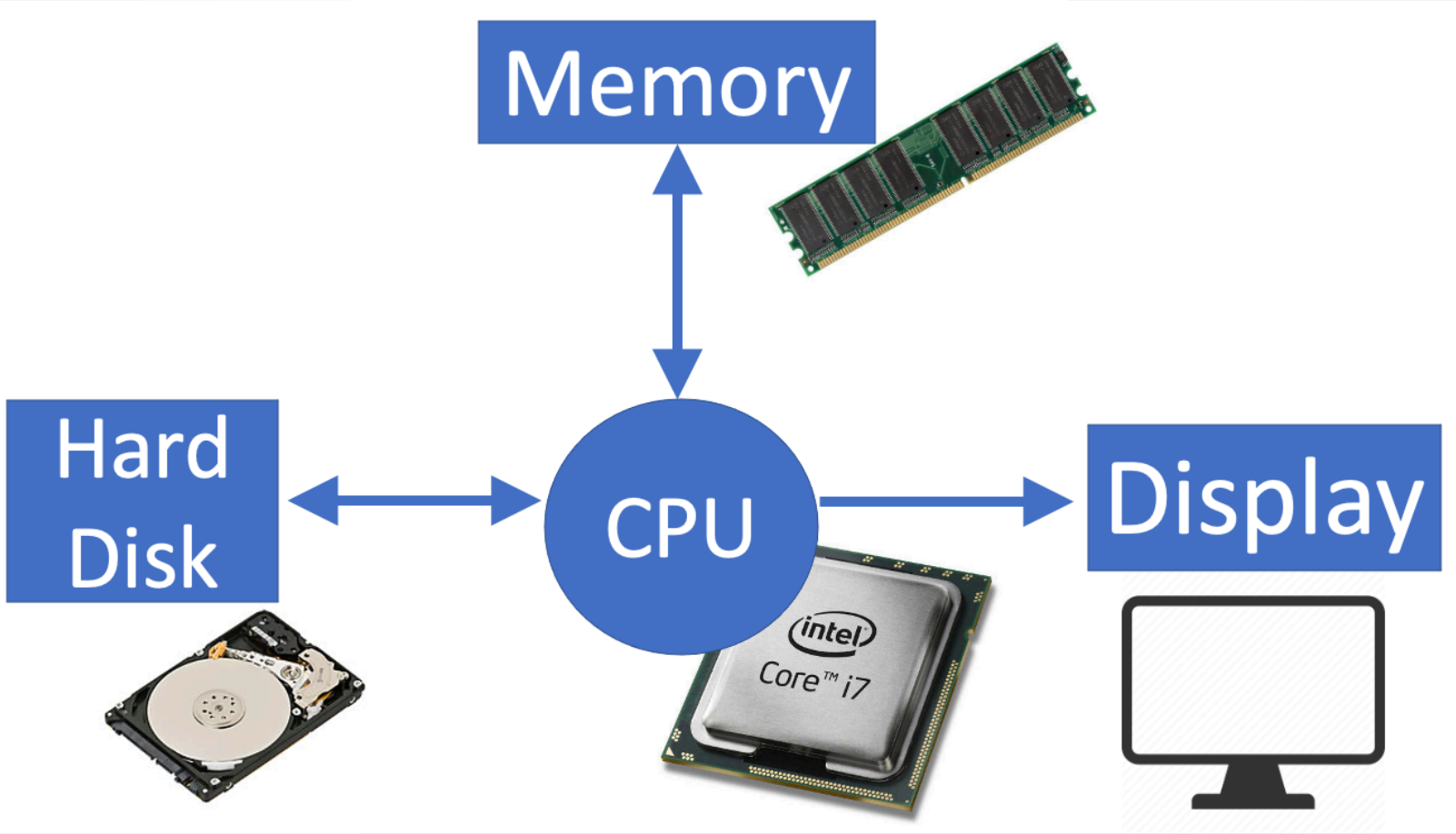
Read the Policy of AI Use.

In short, in the assessment, the use of AI is prohibited.

In the exam, you will write code on the paper.

The foundation of computing

An Idealized Computer



von Neumann Architecture

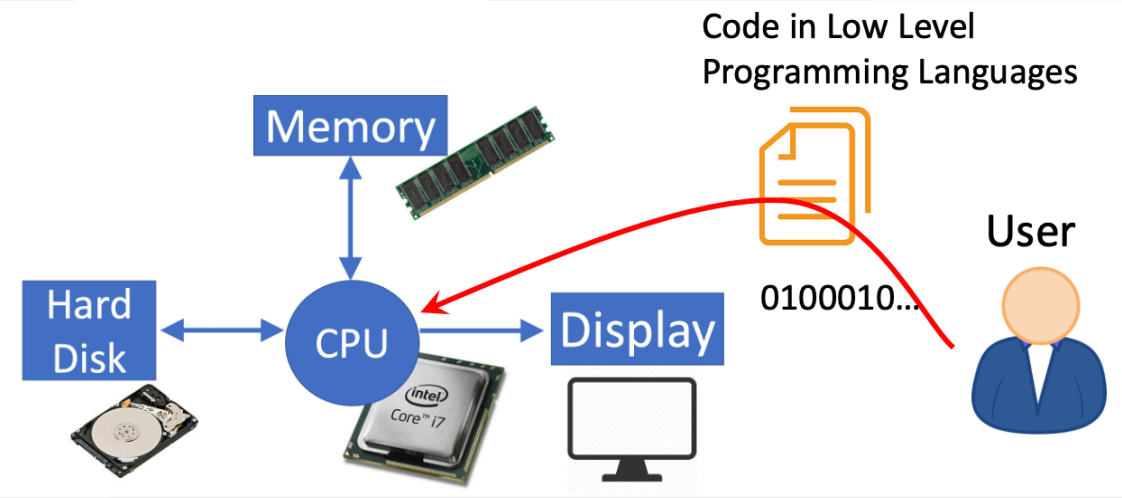
- **Central Processing Unit (CPU)**
  - Performs computational tasks.
  - Controls Input/Output (IO) devices.
  - Maintains data stored in the memory.
- **Memory**
  - Stores program/data being used by CPU temporarily.
- **IO Devices**
  - Hard disk
  - Display
  - Camera
  - Touch Screen, etc.

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 dispaly on x86 CPUs

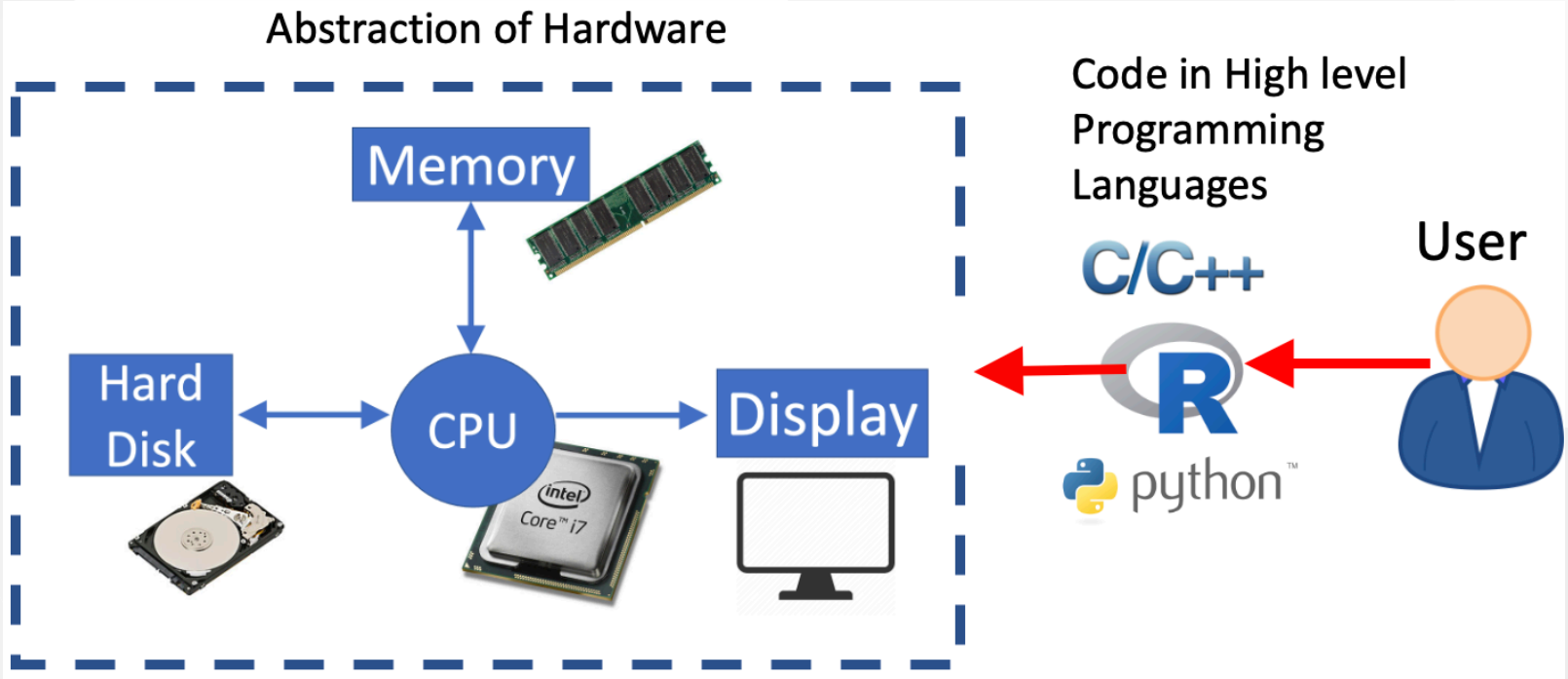
```
    global    start
    section   .text
start:
    mov       rax, 0x02000004
    mov       rdi, 1
    mov       rsi, message
    mov       rdx, 13
    syscall
    mov       rax, 0x02000001
    xor       rdi, rdi
    syscall
    section   .data
message:
    db        "Hello, World", 10
```

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.

```c
//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

```c
//filename: main.c
#include <stdio.h>
void main(){
  printf("Hello World!\n");
}
```

- `//filename: main.c` : **Comments**. Readable explanations of the source code. Ignored by complier.
- `#include <stdio.h>` : **Preprocessing**. Instructs the compiler to perform tasks before 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 most platforms.
- `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 compilation. R command line (RScript) tool reads the R code line by line and automatically translates them into executable codes in real time.

Development Environment

Development environment refers to the collection of software 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!

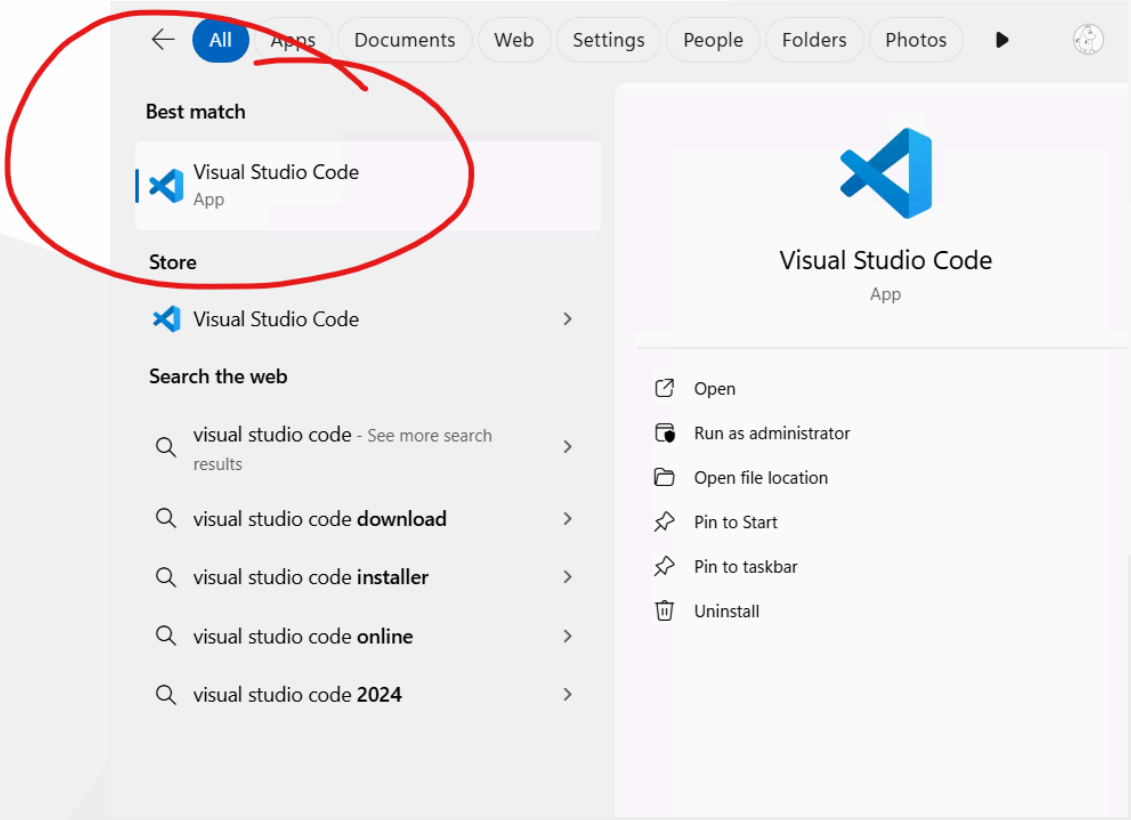
1. The C Programming Language, Brian Kernighan and Dennis Ritchie (The creators of C). The Bible.
    i. An interview of Brian on the history of C.
2. Wikibooks: C Programming, for quick references.
3. COMS10008: Imperative Programming
    i. An excellent unit use to be taught by Dr. Ian Holyer in Computer Science department.
4. CS50 is Harvard University's introductory course to computer science and the art of programming.

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

- In our unit, we use "Visual Studio Code".



A Pre-configured Development Environment for Fry PC Lab

- We cannot provide support for running VSCode on your own computer, due to limited time in lab.
  - If you want to use your own computer, set up VScode before the lab.
  - Note, this set up is a complicated procedure on Windows and Macs.

Homework 0.1, Hello World

- Download the provided code for the lab (See the Github page) and save it to a personal folder.
- Open Visual Studio Code, "open folder", select the folder which contains the file you have just downloaded.
- **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` + `'` agin.
- **Execute** and Observe the program output.

Homework 0.2, 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 HOMETOWN].
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 0.3, Hello World

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

Homework 0.4, Hello World

- Write a short comment in your code, listing
  - Pros and Cons of high level programming language
  - Three key compoments 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.