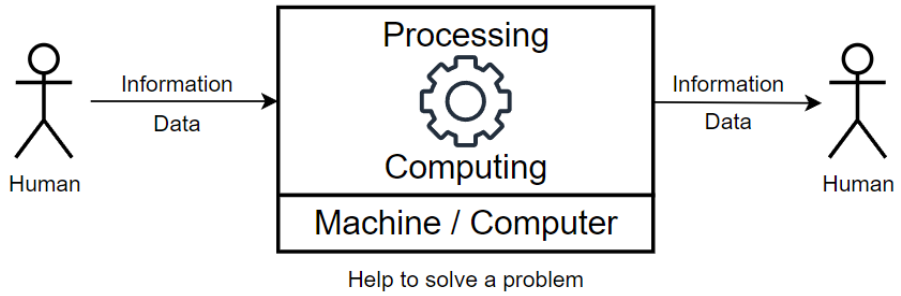
Chapter 1 : Introduction to Computer Science

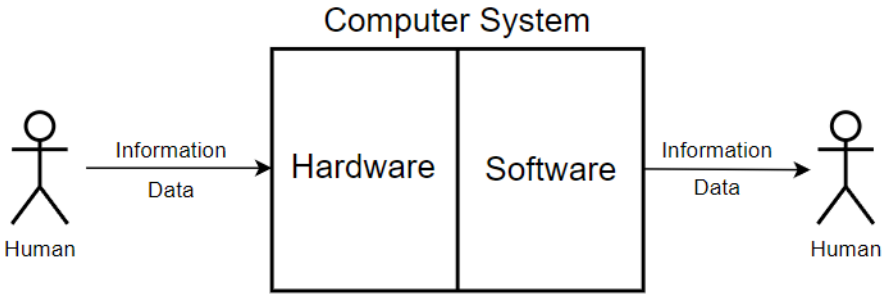
1. Computer Science

- Encompasses the theoretical foundations of information and computation.
- It allows a machine (Computer) to apply automatic processing (computation) on information (data) producing results solving certain kinds of problems.
- Practical techniques are studied for how to use, design, and build computer systems, and how to process, store, and communicate information.



2. Computer System

A computer system is a complete, operational set of hardware and software components working together to perform specific tasks, process data, and enable human interaction.

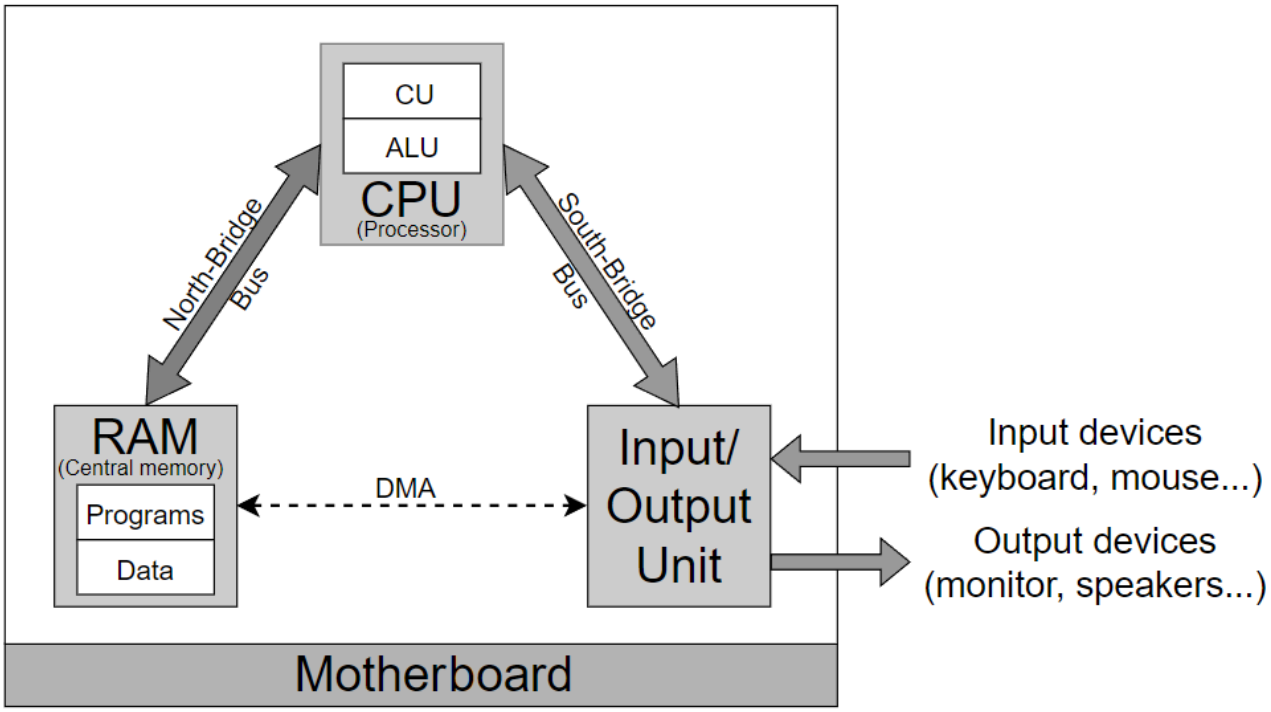


2.1. Hardware

- Hardware is generally what we call the Computer or the Machine.
- It refers to the physical, tangible components of a computer system that we can see and touch.
- It is the electronic and physical parts that enable the computer to function, process data, and interact with the world.
- It is the *body* of the Computer System.
- Such as PC tower, screen, keyboard, mouse, speakers…etc.

2.1. Von Neumann architecture

The hardware is naturally organized following an architecture, the most well-known for Personal Computers (PCs) is the Van Neumann architecture, described in the schematic below :



- The Motherboard supports the 3 principal interconnected components, the CPU, the RAM, and Input/Output unit (I/O Unit).
- The Motherboard is the main electronic board inside the PC tower, it is approximately about the size of 30x25 cm.
- The CPU (for Central Processing Unit, or the processor) is the engine of the architecture. It executes programs, process information, and controls the entire architecture.
- The CPU contains 2 distinguishable entities: The Control Unit (CU), responsible for the control of the CPU and the architecture, and the Arithmetic and Logic Unit (ALU) in charge of arithmetic and logic operations, like, addition, subtraction, division, logic AND, OR, NOT…etc.
- The RAM (for Random Access Memory) is considered the central memory storage of the architecture. Its job is it to save and store information processed by the CPU.
- It is the computer's short-term working memory, it holds information the CPU needs right now to work quickly, but forgets it when the power is off.
- Two kinds of information are stored in the RAM: Data and Programs. Data is raw information that should be processed by the CPU. Programs are succession of instructions describing for the CPU the way it should compute data.

- The I/O Unit is the interface of the architecture with the outer world. Many devices are connected and used to import and export information.
- The North Bridge manages the data transfer between the CPU and the RAM. And the South Bridge manages the data transfer between the CPU and the I/O Unit. They are called Chipset.
- In the modern PCs, the North Bridge is integrated inside the CPU and the South Bridge is now the only Chipset on the Motherboard that also integrates many I/O chips.
- Theoretically, the CPU should perform all the data transfer between the RAM and the I/O Unit, but for optimization, the DMA (Direct Memory Access) was invented to discharge the CPU for this cumbersome task.

Remark 1 : The diagram shown above doesn't follow exactly the original Von Neumann model. The reason is that when the model was first proposed, the CPU was not invented yet, leading to the necessity to adapt the model to the modern architectures.

Remark 2 : At this point, the terms 'information' and 'data' are used interchangeably, but in reality they are different. To put it simply, 'data' means a bunch of unstructured binary values without meaning. And the opposite, 'information' consists of binary values structured to provide meaning and context (like an image file, for instance).

2.2. Input / Output devices

Component Name	Description	Type (Category)	Examples/Common Models/Brands
Central Processing Unit (CPU)	The "brain" of the computer; it executes instructions, performs calculations, and manages the flow of data.	Processing	Intel Core i7/i9, AMD Ryzen 7/9, Apple M1/M2/M3
Random Access Memory (RAM)	Volatile short-term memory that stores data and program instructions currently being used by the CPU for quick access.	Primary Memory	DDR4/DDR5 RAM sticks, Brands: Crucial, Corsair, Kingston, G.Skill
Hard Disk Drive (HDD)	Non-volatile storage device that stores large amounts of data (OS, programs, files) using spinning magnetic platters.	Secondary Storage / (I/O) device	Western Digital (WD) Blue/Black, Seagate Barracuda
Solid State Drive (SSD)	Non-volatile storage device that stores data using flash memory, offering much faster read/write speeds than HDDs.	Secondary Storage / (I/O) device	Samsung 970/980/990 Pro, Crucial P5 Plus, WD Black SN770
Motherboard	The main circuit board that connects and allows communication between all other hardware components of the computer.	System Board / Interconnect	ASUS ROG, MSI PRO, Gigabyte AORUS, ASRock
Graphics Processing Unit (GPU)	Specialised processor designed to rapidly render images, videos, and animations, crucial for gaming and visual tasks.	Processing / Output Unit	NVIDIA GeForce RTX 4090, AMD Radeon RX 7900 XT, Intel Arc A770
Power Supply Unit (PSU)	Converts AC power from the wall outlet into DC power that the computer's components can use.	Power	Corsair RMx Series, Seasonic Focus, EVGA SuperNOVA
Keyboard	An input device that allows users to enter text, characters, and other commands into the computer.	Input Device	Logitech K-Series, Razer BlackWidow, Apple Magic Keyboard
Mouse / Trackpad	An input device used to control a cursor on the screen, select items, and interact with graphical interfaces.	Input Device	Logitech MX Master, Apple Magic Mouse/Trackpad, Razer DeathAdder

Monitor / Display	An output device that visually presents information processed by the computer to the user.	Output Device	Dell UltraSharp, LG UltraGear, Samsung Odyssey, ASUS ROG
Webcam	An input device that captures video and still images, typically used for video conferencing and streaming.	Input Device	Logitech C920, Razer Kiyo, Microsoft LifeCam
Microphone	An input device that converts sound waves into electrical signals, allowing audio to be processed or transmitted.	Input Device	Blue Yeti, Rode NT-USB, HyperX QuadCast
Speakers / Headphones	Output devices that convert electrical audio signals into sound waves for the user to hear.	Output Device	Bose QuietComfort, Sony WH-1000XM, Logitech Z-series, JBL
Network Interface Card (NIC)	A hardware component that allows a computer to connect to a network, either wired (Ethernet) or wirelessly (Wi-Fi).	Input/Output (I/O) Device	Intel Ethernet Adapters, Realtek, Killer Wi-Fi
Optical Drive	A device that uses a laser to read or write data from/to optical discs like CDs, DVDs, and Blu-ray discs. (Less common now)	Input/Output (I/O) Device	LG Blu-ray Drive, ASUS DVD Writer
Printer	An output device that produces hard copies of electronic documents on physical media, typically paper.	Output Device	HP LaserJet, Epson EcoTank, Canon PIXMA
Scanner	An input device that converts physical documents or images into digital format.	Input Device	Epson Perfection, Canon CanoScan, Fujitsu ScanSnap

Remark 3: The examples shown in the above tables are not intended to be memorized, they are just a glimpse of the computer equipment market.

Remark 4: In the table above, CPU, RAM, motherboard, and PSU, are not really I/O devices, they added just to get a global view of the market of computer equipment.

2.2. Software

- It refers to the intangible set of instructions (program), including data, that tell computer hardware what to do and how to perform specific tasks.
- Unlike hardware, you cannot physically touch software, it exists as code and data stored electronically inside the computer.
- Think of it as the logic, instructions, or scripts that guide the hardware's actions. Without software, hardware is just a set of inert components.
- It is the *brain* or the *mind* that gives life to the physical machine.
- We can distinguish 2 kinds of software: System software and Application software.

2.2.1. System software

- Also often referred as the Operating System (OS).
- It is a critical and essential backbone of the computer system.
- Its purpose is to manage and control the computer's hardware and provides a platform for Application software to run.

- It manages memory, programs, hardware devices, and provides a user interface.
- Examples: Windows, macOS, Linux, Android, iOS.

2.2.2. Application software

- Designed for end-users to perform specific tasks or activities. These are the programs you typically interact with daily.

The following table contains some well-known Application software exemples :

Category	Description	Examples
Productivity Suites	Tools designed to help users create documents, manage data tables, and give presentations efficiently.	Microsoft Office (Word, Excel, PowerPoint), Google Workspace (Docs, Sheets, Slides), LibreOffice
Web Browsers	Software applications for accessing, retrieving, and viewing information on the World Wide Web (WWW).	Google Chrome, Mozilla Firefox, Apple Safari, Microsoft Edge, Brave
Email Clients	Programs used to access, manage, send, and receive email messages.	Microsoft Outlook, Mozilla Thunderbird, Apple Mail, Gmail (web-based clients also exist)
Media Players & Streaming	Applications for playing audio and video files, or streaming content online.	VLC Media Player, Spotify, Netflix App, YouTube App, Windows Media Player
Graphics & Design Software	Programs used for creating, editing, and manipulating images, illustrations, and visual designs.	Adobe Photoshop, GIMP, Adobe Illustrator, Canva, AutoCAD, SketchUp
Video Games	Interactive software applications designed for entertainment, played on computers, consoles, or mobile devices.	Fortnite, Minecraft, Call of Duty, The Sims, League of Legends, Candy Crush
Communication Apps	Software facilitating real-time text, voice, and video conversations between individuals or groups.	Zoom, Microsoft Teams, Slack, WhatsApp, Telegram, Discord.
Financial/ Accounting Software	Applications for managing personal or business finances, tracking expenses, and preparing taxes.	QuickBooks, Mint, TurboTax, Xero, SAP ERP
Educational Software	Programs designed to assist with learning, teaching, or training in various subjects.	Duolingo, Khan Academy, Quizlet, Rosetta Stone, Blackboard/Canvas (LMS)
Development Tools	Software used by programmers and developers to write, test, and debug other software.	Visual Studio Code, Eclipse, GitHub Desktop, Sublime Text, Docker
Operating System Utilities	Tools that perform specific tasks to maintain, optimize, or secure the computer system.	Antivirus Software (Norton, Avast), Disk Defragmenters, File Compression (WinZip), Backup Software

3. Binary representation of information

Problem statement: Information is an abstract concept, only meaningful for the human mind and entirely impalpable (intangible) in the physical world. The problem is how to represent information in the real world to allow its use by the machine.

Solution statement: Using electrical signals to represent numbers. Numbers are the keystone for the representation of any type of information, including numbers, text, images, video, voice, sound, 3D scenes…etc. Two technological solutions were proposed: Analog and Binary (called also *Digital*)

- The first solution is called Analog representation, where the voltage intensity represents values. For example, 8 volts on a wire could represent the number 8.
- Although well established in the '80s and '90s for multimedia applications, like TV, radio, VHS, cassette tape. This technology faced many flaws.
- Its major flaws include voltage imprecision, noise influence, slowness for transmission, difficulty in storage.
- An answer to those flaws was the Binary or Digital system.
- It is more precise, more robust, faster in transmission, and easier to save, and most of all it aligns with the mathematical Boolean algebra.
- The idea is to use only 2 digits, 0 and 1, to represent any number. For example, 8 is represented by $(1000)_b$.
- Referring to Boolean algebra, 0 and 1 are often called logical 0 and logical 1.
- One digit (0 or 1), is called a *bit*, the smallest possible unit of informaiton, and the portmanteau of "Binary Digit".
- Physically it is implemented by an "On state" and "Off state" in electricity. For example, 0 volts represent logical 0, and 5 volts represent logical 1.
- Unlike Analog electronics, in Digital systems, except the 2 logical values, the other voltages are not allowed by the hardware.

4. Data quantification

To measure a quantity of data, a system of quantification is established allowing the measurement of the size on storage devices like USB sticks or hard drivers. Or to measure the data flow through networks and Internet connection.

The Unit table is as follows :

Unit	Abbreviation	Size	Approximation
Bit	b	1 bit (0 or 1)	-
Byte	B	8 bits	-
Kilobyte	KB	1024 B = 2^{10} B	10^3 B
Megabyte	MB	1024 KB = 2^{20} B	10^6 B
Gigabyte	GB	1024 MB = 2^{30} B	10^9 B
Terabyte	TB	1024 GB = 2^{40} B	10^{12} B
Petabyte	PB	1024 TB = 2^{50} B	10^{15} B
Exabyte	EB	1024 PB = 2^{60} B	10^{18} B
Zettabyte	ZB	1024 EB = 2^{70} B	10^{21} B
Yottabyte	YB	1024 YB = 2^{80} B	10^{24} B

5. Some complementary definitions

- **Analog:** Refers to information represented by continuous, varying physical quantities, generally fluctuating voltage.
- **Digital:** Refers to information represented by discrete (separate, distinct) values, such as binary 0s and 1s. This is in contrast to analog.
- **Algorithm:** A step-by-step set of well-defined, unambiguous instructions for solving a problem or accomplishing a specific task.
- **Program:** A collection of algorithms and data, expressed in a specific programming language, that a computer can understand and execute to perform a particular task. It's the implementation of an algorithm.

- **Instruction:** A single, elementary command that a computer's CPU can understand and execute. Programs are composed of many individual instructions.
- **Programming Language:** A formal language (like Python, Java, C++) used to write instructions (programs) that a computer can execute.
- **ROM (Read-Only Memory):** is a type of non-volatile computer memory that stores data permanently and cannot be easily modified or erased. It's primarily used to store the firmware and the BIOS.
- **Flash memory:** is a non-volatile computer storage medium that can be electrically erased and reprogrammed. It is widely used in USB flash drives, solid-state drives (SSDs), and memory cards.
- **BIOS (Basic Input/Output System):** is a type of firmware stored on a ROM chip on the motherboard that initializes and tests hardware components, and then loads the operating system when a computer is turned on (in the boot sequence).
- **Firmware:** is a specific class of software that provides low-level control for a device's specific hardware. It is responsible for basic functions, allowing the hardware to operate and communicate with other software like an operating system.
- **CMOS (Complementary Metal-Oxide-Semiconductor):** is a small, volatile memory chip on the motherboard that stores BIOS settings, such as date, time, and hardware configurations. It requires a small battery to retain this information when the computer is turned off.