Lecture 2: What's in a computer?

• logical or functional organization: "architecture"
  – what the pieces are, what they do, how they work
  – how they are connected, how they work together
  – what their functional properties are

• physical structure
  – what they look like, how they are made

• major pieces
  – processor ("central processing unit" or CPU)
    does the work, controls the rest
  – primary memory (RAM = random access memory)
    stores instructions and data while computer is running
  – secondary memory/storage (disk, drive, SSD)
    stores everything even when computer is turned off
  – other devices ("peripherals"), especially wireless
Hardware: tangible devices and gadgets

• **how computers represent and process information**
  – universal digital representation of information:
    everything is represented as numbers
  – bits, bytes, binary numbers

• **a computer is a universal digital processor**
  – it stores data and instructions in the same memory
  – the instructions are numbers
  – it's a general purpose machine:
    change the numbers and it does something different
  – your phone is a computer

• **hardware has been getting smaller, cheaper, faster exponentially for 60+ years**
2023 freshman computer

Apple - MacBook Air 13.3" Laptop with Touch ID - Intel Core i5 - 8GB Memory - 256GB Solid State Drive (Latest Model) - Space Gray

Model: MVFJ2LL/A  SKU: 6356923

- Solid State Drive Capacity: 256 gigabytes
- System Memory (RAM): 8 gigabytes
- Graphics: Intel Iris Plus Graphics 640
- Processor Speed (Base): 2.3 gigahertz
- Processor Model: Intel 7th Generation Core i5
- Processor Model Number: Not Available
- Operating System: Mac OS
- Battery Life: 10 hours
- Battery Type: Lithium-polymer

Price: $1,099.99

Price Match Guarantee
Save $200
Block diagram of a typical laptop computer

- **GHz, cores**
  - processor
  - display/screen
  - keyboard, touchpad, mouse
- **bus**
- **RAM:** GB  
- **disk, SSD:** GB (soon TB)  
- **wi-fi, Bluetooth**  
  - primary memory
  - secondary storage
  - other devices: camera, speakers, microphone, ...
Processor (CPU, or Central Processing Unit)

- can perform a small set of basic operations ("instructions")
  - arithmetic: add, subtract, multiply, divide, …
  - memory access:
    - fetch information from memory, store results back into memory
  - decision making: compare numbers, letters, ...
    - decide what to do next depending on result of previous computations
  - control the rest of the machine
    - tell memory to send data to display; tell disk to read data from network; ...

- operates by performing sequences of simple operations very fast

- instructions to be performed are stored in the same memory as the data is
  - instructions are encoded as numbers: e.g., Add = 1, Subtract = 2, ...

- the processor is a general-purpose device: putting different instructions into the memory makes it do a different task
  - this is what happens when you run different programs
How fast is fast?

- CPU uses an internal "clock" (like a heartbeat) to step through instructions

- 900 MHz, 2.5 GHz, etc., is the number of clock ticks per second
  - 1 Hertz = 1 tick per second; abbreviated 1 Hz
  - mega = million
  - giga = billion
  - 1 MHz = 1 megaHertz = 1 million ticks per second
  - 1 GHz = 1 gigaHertz = 1 billion ticks per second = 1000 MHz

- one instruction (like adding two numbers) might take one, two or several ticks, depending on design of the CPU
  - or it might complete more than one instruction in one tick

- modern processors execute several billion instructions/sec
GPU: graphics processing unit

• specialized processor, originally for graphics
  – many specialized processors working in parallel on simple computations
    drawing things, e.g., for games
    video
    many other computations
    speech, image, motion, ...

• works with, complements the CPU
  – often on the same chip as the CPU
Primary Memory (Random Access Memory = "RAM")

• a place to store information while the computer is running
  – the programs that are running
  – their data
  – the operating system (Windows, MacOS, Unix/Linux, ...)
• volatile: forgets everything when power is turned off
• limited (though large) capacity
• logically, a set of numbered boxes ("pigeonholes"? mailboxes?)
  – each capable of storing one byte = 8 bits of information
    a small number or a single character like A or part of a larger value
  – random access
    CPU can access any location as quickly as any other location

```
0 1 2 ............. 8G
```
What's a bit? What's a byte?

• a bit is the smallest unit of information
• represents one 2-way decision or a choice out of two possibilities
  – yes / no, true / false, on / off, up / down, ...
• abstraction of all of these is represented as 0 or 1
  – enough to tell which of TWO possibilities has been chosen
  – a single digit with one of two values
  – hence "binary digit"
  – hence bit
• binary is used in computers because it's easy to make fast, reliable, small devices that have only two states
  – high voltage(low voltage, current flowing/not flowing (chips)
  – electrical charge present/not present (Flash)
  – magnetized this way or that (disks)
  – light bounces off/doesn't bounce off (CD, DVD)
• all information in a computer is stored and processed as bits
• a byte is 8 bits that are treated as a unit
Disks

- a place to store information when the power is turned off
- was based on magnetic surfaces, rotating machinery
  - today, more often solid-state Flash memory (SSD)
- logical / functional structure: folders (directories) and files
  - your information: papers, mail, music, web page, …
  - programs and their data: Firefox, Word, iTunes, …
  - operating system(s): Windows, MacOS, Unix, Linux, …
  - bookkeeping info: where things are physically located
Wrapup on components

- the logical or functional components of computer hardware
- how they fit together, what the numbers measure
- some Greek/Latin/... prefixes:
  - (...,) nano, micro, milli, kilo, mega, giga, tera, (peta, ...)
- what the basic physical pieces look like
- one logical organization can have different physical forms
- logical organization hasn't changed much in 60+ years
- physical form has changed rapidly for the entire time
  - many tradeoffs among physical forms (size, weight, power, ...)

•
Some numeric prefixes you must know

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<th>Prefix</th>
<th>Exponent</th>
<th>corresponding word</th>
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<td>billionth</td>
</tr>
<tr>
<td>micro</td>
<td>$10^{-6}$</td>
<td>millionth</td>
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<td>milli</td>
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<td>-</td>
<td>$10^0$</td>
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