香港中文大學(深圳)
The Chinese University of Hong Kong, Shenzhen

Introduction to Computer Science: Programming Methodology

Lecture 1 Introduction

Prof. Yunming XIAO

School of Data Science

Outline

- Tuesday
  - Introduction & logistics
  - Overview of modern computers
- Thursday
  - Preliminary knowledge for computer programming

- Boilers for next week
  - Python Basics

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About me

- Background
  - Education: B.Eng. BUPT (2019) & Ph.D. Northwestern U (2024)
  - Work Experience
    - Intern: ByteDance (2019), Bell Labs (2021), HPE Labs (2022), Google (2023)
    - Research Fellow (2024-2025), University of Michigan—Ann Arbor
    - Assistant Professor (2025.7-*Present*), SDS, CUHK-Shenzhen
  - Research: computer systems, networks, and security

- Contact
  - Email: yunmingxiao@cuhk.edu.cn
  - Office: Zhi Xin Building 403a
  - Office Hour: 5pm-6pm Tuesday (except holidays)

Useful materials

- Personal website:
  - https://yunmingxiao.github.io
- Course website: https://yunmingxiao.github.io/courses/csc1001-26fall
- Blackboard: https://bb.cuhk.edu.cn
- Online resources/books:
  - W3School Python Tutorial (https://www.w3schools.com/python/)
  - A Practical Introduction to Python Programming, by Brian Heinold
  - How to think like a Computer Scientist, by Peter Wentworth, Jeffrey Elkner, Allen B. Downey, and Chris Meyers

About this course

- This course is a required course for all SDS students, and we welcome students from other schools

- Need to synchronize between other 4 parallel sessions (schedules, assignments, exams)

Learning objectives

- This course will introduce the key programming concepts using Python language as examples
- Students will learn basic elements of modern computer systems, key programming concepts, problem solving, and basic algorithm design
- If you have a laptop, please bring it to the class; we will write code together on site

Assessment

Activity	Grade
Assignments × 4	5% × 3 (best of 3)
Mid-term quiz	35%
Final exam	50%

Assessment

Assignment Number	(Intended) Start Date	(Intended) Due Date
#1	9.30	10.20
#2	11.5	11.19
#3	12.25	12.10
#4	12.12	12.26

Course components

Activity	Hours/week
Lecture	**90min × 2**
Tutorial	**60min × 1**

A message for freshmen:

- University courses are very different from what you might have been familiar with in your high school
  - Languages
  - Assignments
  - Exams

- In your future university life, there are no more head teachers (班主任)
  - No one is watching you to finish the assignments
  - It is the right time to start being mature and independent
  - Make best use of tutorials (starting next week)
  - Check your emails often
  - Assignments and important course announcements will be sent out via emails
  - Motivation!

Indicative teaching plans

Week	Content/ topic/ activity
1	Introduction to modern computers Preliminary knowledge for computer programming
2	Basic introduction to Python language Data types and operators in Python language Input/output
3	Flow control and loop
4 & 5	Function
6	Basic data structures
7	Review for mid-term quiz
8	Introduction to object-oriented programming, part I
9	Introduction to object-oriented programming, part II
10	Data Structure, part I
11	Data Structure, part II
12	Introduction to algorithm design, part I
13	Introduction to algorithm design, part II
14 & 15	Review for final exam

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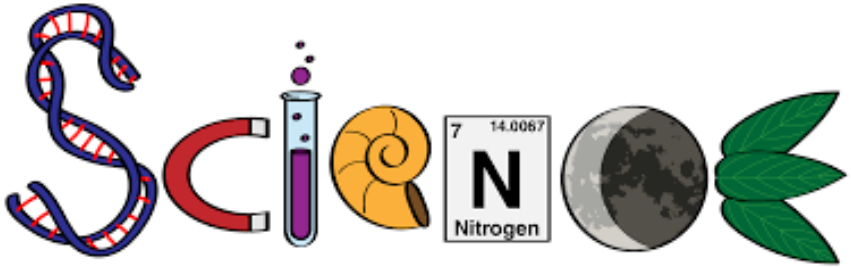
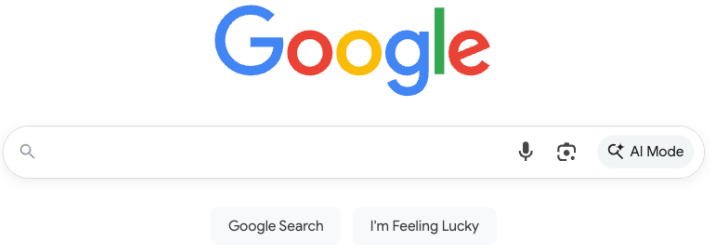
Why learning programming?

- Computers are built to help people solve problems

Input: ABCDE……
Output: SDFQA……





ChatGPT

deepseek

Why learning programming?

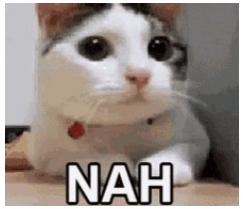
- Computers are built to help people solve problems

- ~~Computers do not understand what we say~~

- ~~We need to communicate with computers using their languages (computer programming language)~~

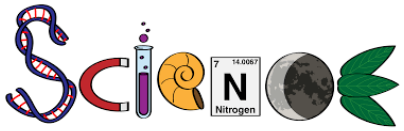
ChatGPT

deepseek



Why learning programming?

- Computers are built to help people solve problems



- Computers might seem to understand what we say, but they still process everything using code under the hood
  - Automation with code is different (and much cheaper) from AI generation
- Understanding programming is key to finding and solving problems
- Programming is a way of thinking

The success of AI imply that human intelligence is computable?

Alan Turing has proved that a computer, in theory, can compute anything that is computable

Why computer science?

- AI, Data Science, Cybersecurity, HCI, etc., all stem from CS
- Without understanding algorithms, systems, and theory, people risk becoming tool users rather than innovators
- Programming and CS aren't just skills but a way of (computational) thinking
- CS evolves: many "hot" fields today may look very different in 10 years, but the core principles of CS remain
- With a CS foundation, you can branch into any area

csrankings.org

Programmer

- Professional programmer writes computer programs and develops software
- Today, per year,
  - A junior programmer gets a salary of 300k+ RMB in an Internet company
  - A CS PhD can earn 1M – 6M RMB in China, or 500K – 1M USD in the US!
  - A senior programmer may earn 5M – 100M+ USD!!
- Software, Internet, and are huge industries

A.I. Researchers Are Negotiating $250 Million Pay Packages. Just Like N.B.A. Stars.

A.I. technologists are approaching the job market as if they were Steph Curry or LeBron James, seeking advice from their entourages and playing hardball with the highest bidders.

Google

ByteDance

Alibaba Group 阿里巴巴集团

Tencent 腾讯

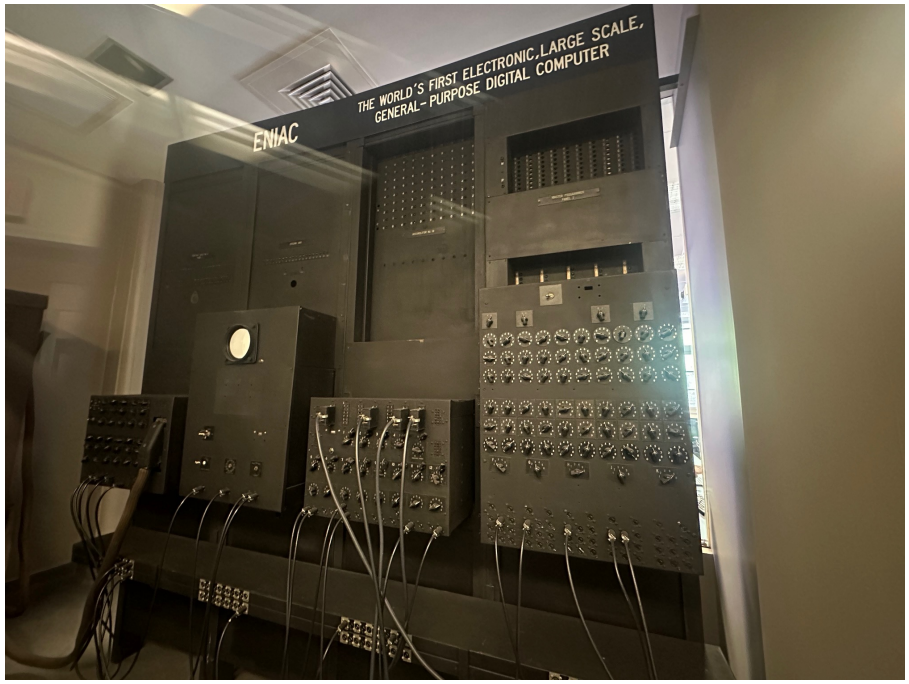
NVIDIA

.....

Non-programmer

- Even if you are NOT in the IT industry, programming is pervasive in your life,
  - Electrical/electronic engineer – control program
  - Finance/economist – mathematical modeling
  - Salesman – analyzing sales data
  - …
- Programming is becoming a foundation of the world today. Learning programming allows you to understand one of the foundation of the world

Modern computers



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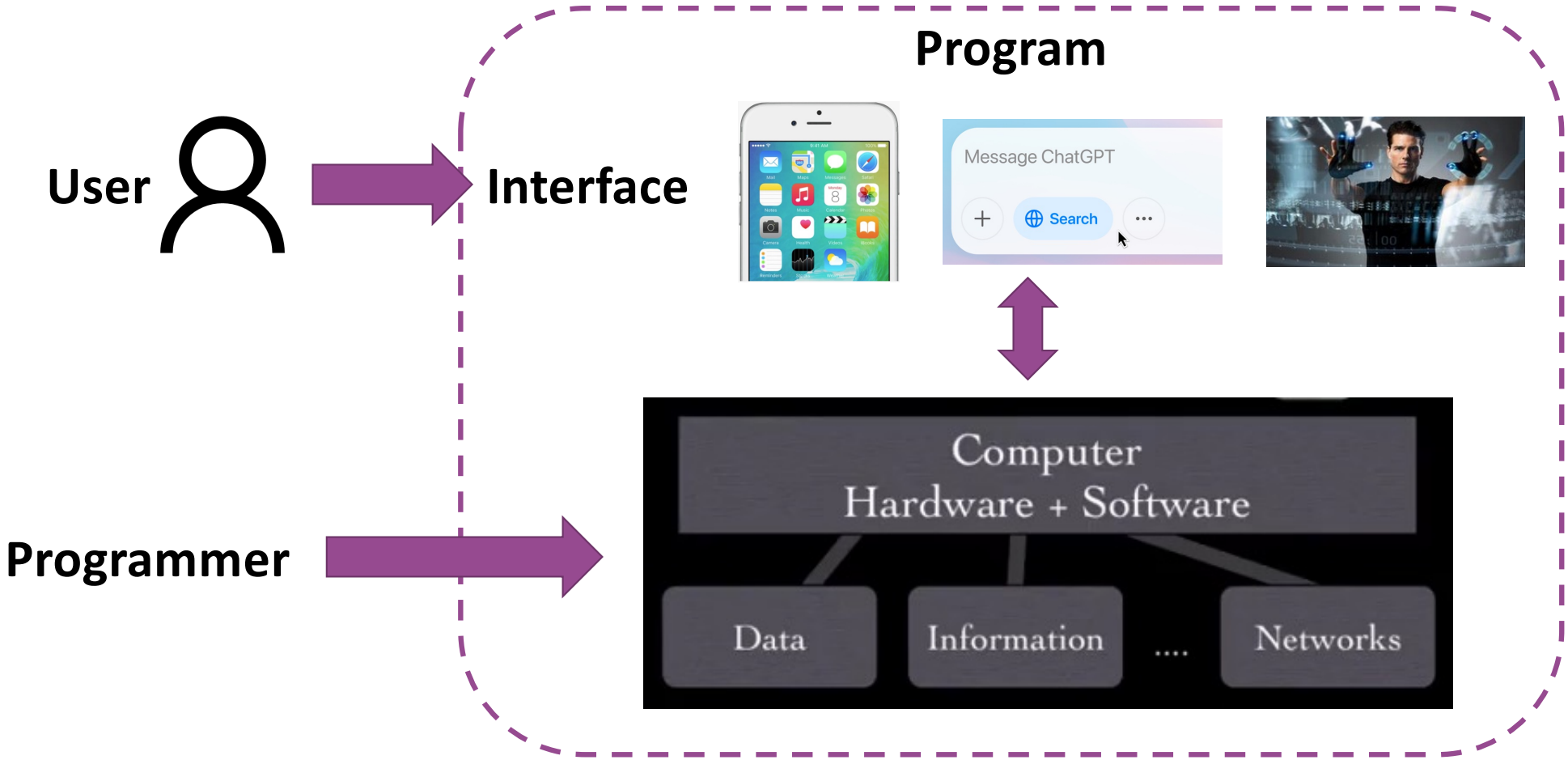
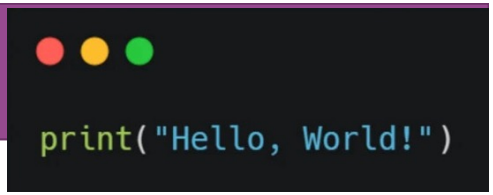
Digital world



What is code, program, and software?

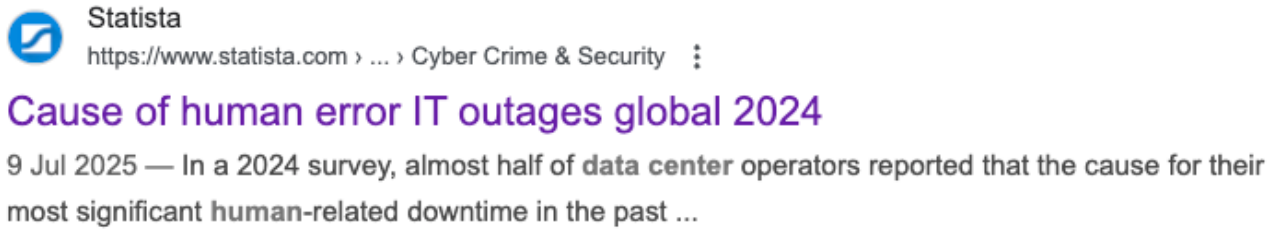


- Code (sentence): text written by humans in a programming language (e.g., Python, Java) to tell the computer what to do
- Program (recipe of one dish): a set of code that performs a specific task at runtime (code with purpose)
- Software (cookbook): a collection of programs and data

- Software is compiled into instructions and executed by computers
- It is a little piece of our intelligence in the computer
- Intelligence that is re-usable

Computers are good at following instructions

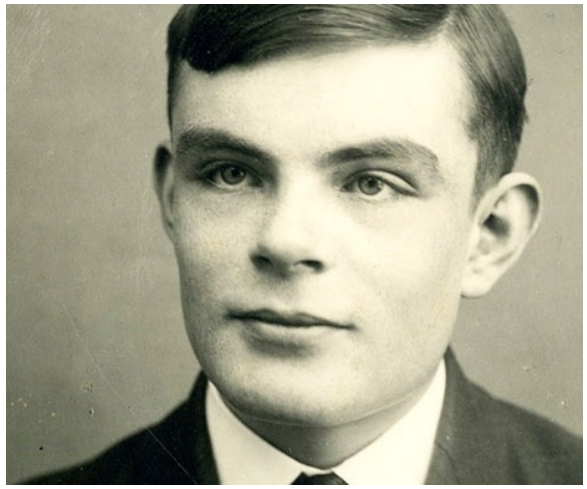
- Humans can easily make mistakes when following a set of instructions
- On the contrary, computers (almost) do not make mistakes, regardless of they are given 10 or 10 billion instructions!!



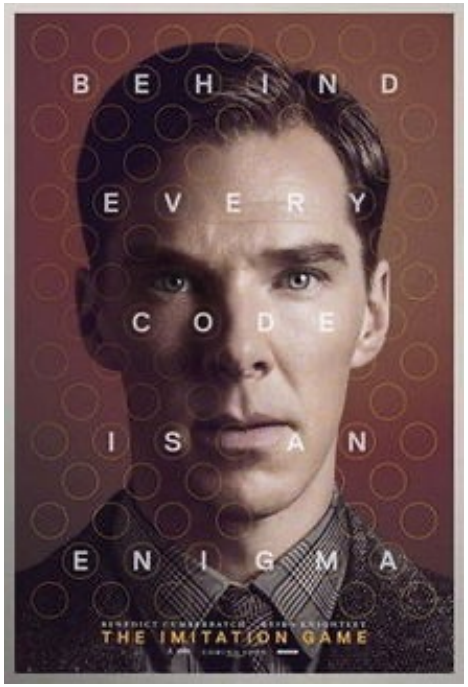
"Humans are the weakest link in any security system"
– *The Art of Deception,* by Kevin Mitnick

Theoretical foundation of CS

- The theoretical foundation of computer science are built by Alan Turing
- Father of theoretical computer science and artificial intelligence
- Computability theory and Turing test
- ACM Turing Award is the highest honour in computer science



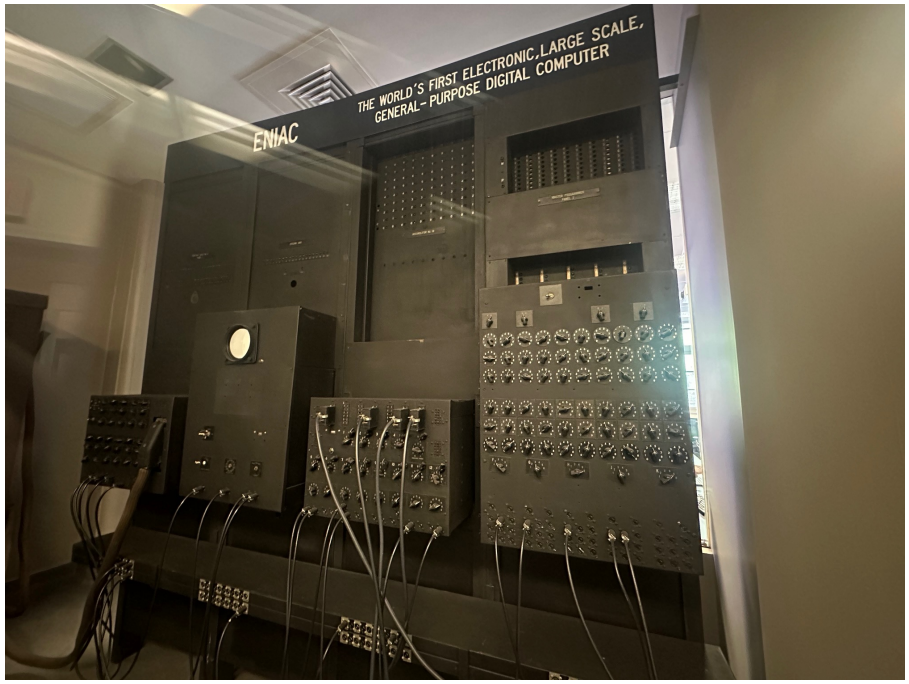
A movie about Turing



模仿遊戲

The Imitation Game

What is common in them?



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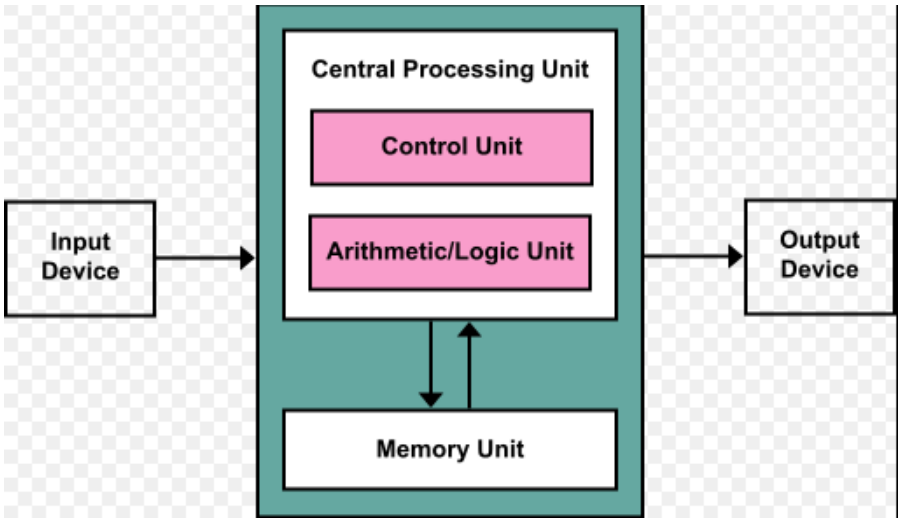
Von Neumann architecture

- The modern computer architecture is proposed by John Von Neumann
- It is one possibility to build computer defined by Turing (aka Turing machine)



A side note

SDS Dean Jim Dai Awarded 2024 INFORMS John von Neumann Theory Prize

October 30, 2024 Research Development

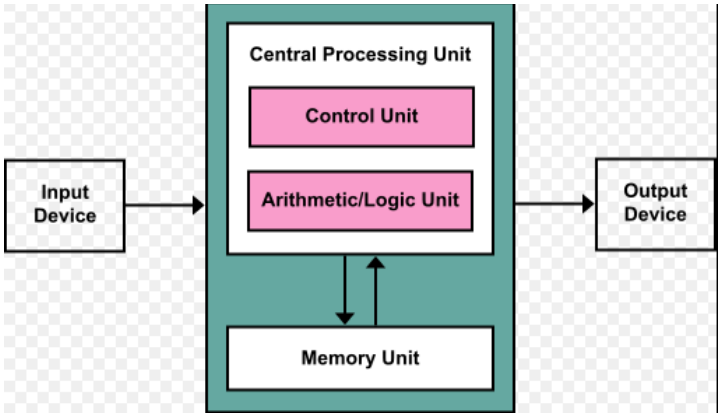
Professor Jim Dai, Dean of the School of Data Science at The Chinese University of Hong Kong, Shenzhen (CUHK-Shenzhen), has been awarded the 2024 John von Neumann Theory Prize at the INFORMS Annual Meeting in Seattle, USA. The prize recognizes his fundamental and sustained contributions to stochastic systems theory, particularly his seminal work on stochastic network stability and heavy traffic diffusion approximations.

The John von Neumann Theory Prize, the highest honour in operations research and management science, celebrates scholars who have made foundational and sustained contributions to the field.

Professor Jim Dai (centre) with INFORMS President Julie Swann (left) and INFORMS Executive Director Elena Gerstmann (right) at the award ceremony

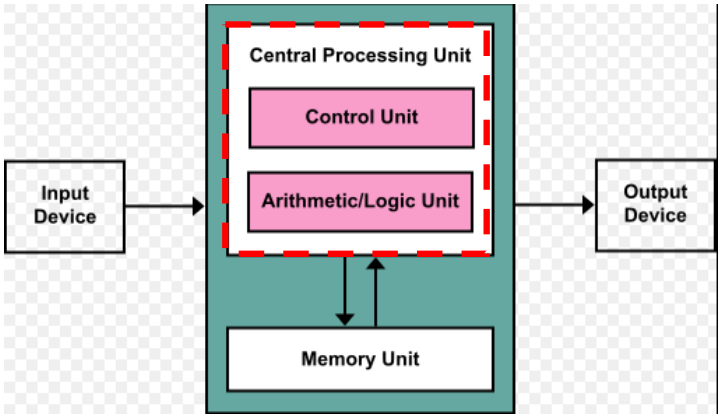
Key hardware components in a computer

- Central processing unit (CPU): program execution
- Memory unit: store instructions and data
- Input device: take inputs from users or other devices
- Output device: output information to users or other devices

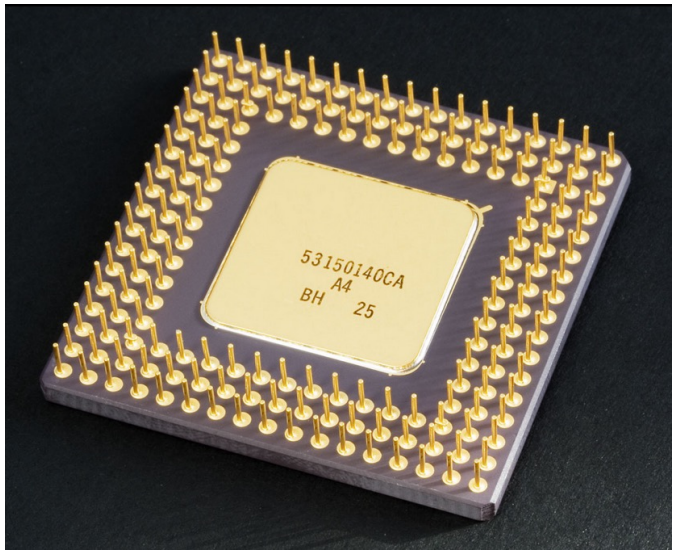


Central Processing Unit (CPU)

- A processor contains two units, a control unit (CU) and an arithmetic/logic unit (ALU)
- Control Unit (CU) is used to fetch commands from the memory
- Arithmetic/Logic Unit (ALU) contains the electric circuits which can execute commands



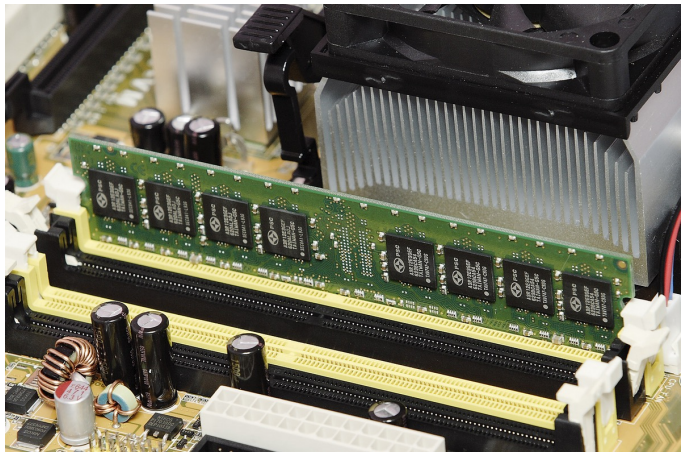
Central Processing Unit (CPU)



- Processor manufacturer: Intel, AMD, ARM, etc

Memory/Storage

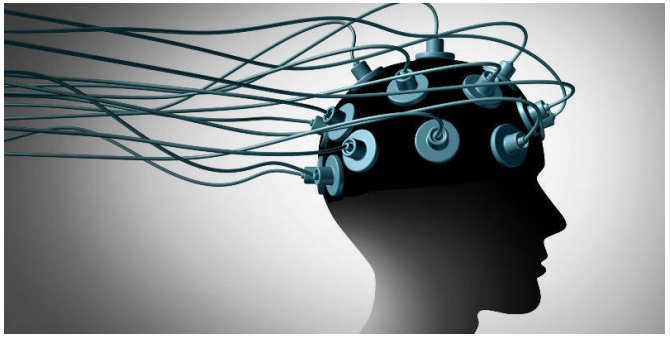
- High-speed cache (~36MB)
- RAM (16GB)
- ROM (N/A)
- Flash (2TB SSD)
- Hard disk (N/A)



Input/output devices

- Input devices: mouse, keyboard, panel, touch screen, audio input, mind reading, etc
- Output devices: screen, audio output, etc
- Research field
  - human-machine interaction (HCI)

Any other input devices?



Any other output devices?

VR/AR/MR/XR

Holographic projection

How the hard disk works

http://v.youku.com/v_show/id_XNjA4NzMxNDk2.html?from=s1.8-1-1.2

What can a computer actually understand?

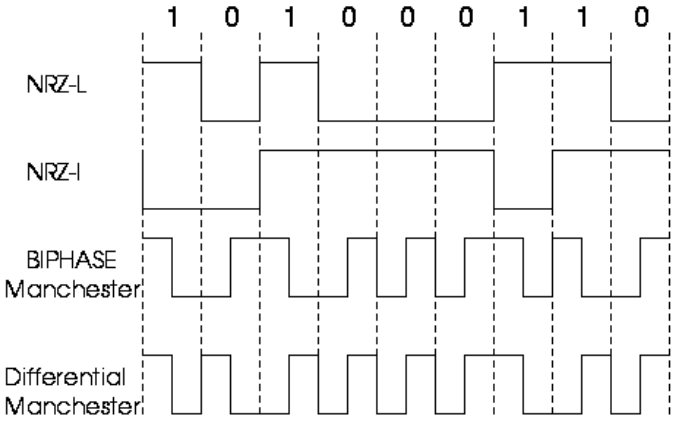
- The computers used nowadays can understand only binary number (i.e., 0 and 1)
- Computers use voltage levels to represent 0 and 1
- NRZL and NRZI coding
- The instructions expressed in binary code is called machine language

0 0 0 1 numerical value 2^0

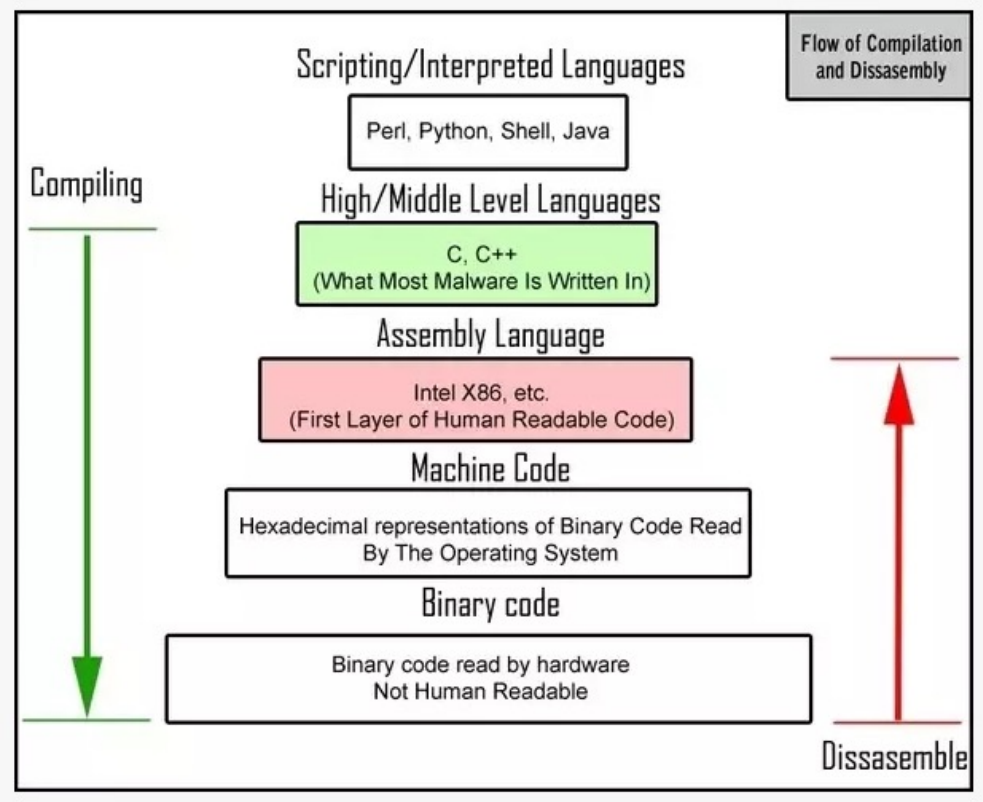
0 0 1 0 numerical value 2^1

0 1 0 0 numerical value 2^2

1 0 0 0 numerical value 2^3



Programing language



https://www.quora.com/I-am-an-11th-grader-I-find-it-quite-difficult-to-write-C++-code-especially-when-the-only-way-to-practice-is-to-solve-maths-problems-Should-I-keep-learning-C++-or-drop-it-for-C

Low-level language – Assembly language

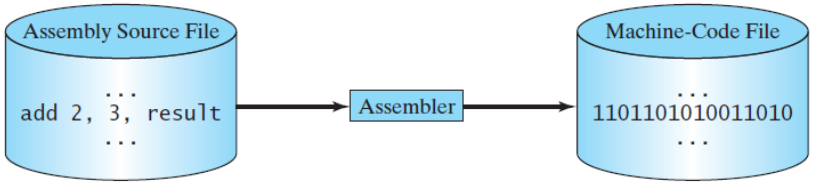
- An assembly language is a low-level programming language, in which there is a very strong (generally one-to-one) correspondence between the language and machine code instructions.

- Each assembly language is specific to a particular computer architecture

- Assembly language is converted into executable machine code by a utility program referred to as an assembler

```
                        ****************************************
                        * FUNCTION: INHEX - INPUT HEX DIGIT
                        * INPUT: none
                        * OUTPUT: Digit in acc A
                        * CALLS: INCH
                        * DESTROYS: acc A
                        * Returns to monitor if not HEX input
C01E 8D F0      INHEX   BSR     INCH        GET A CHAR
C020 81 30              CMP A   #'0         ZERO
C022 2B 11              BMI     HEXERR      NOT HEX
C024 81 39              CMP A   #'9         NINE
C026 2F 0A              BLE     HEXRTS      GOOD HEX
C028 81 41              CMP A   #'A
C02A 2B 09              BMI     HEXERR      NOT HEX
C02C 81 46              CMP A   #'F
C02E 2E 05              BGT     HEXERR
C030 80 07              SUB A   #7          FIX A-F
C032 84 0F      HEXRTS  AND A   #$0F        CONVERT ASCII TO DIGIT
C034 39                 RTS

C035 7E C0 AF   HEXERR  JMP     CTRL        RETURN TO CONTROL LOOP
```



C language (1969 - 1973)

- C was developed by Dennis Ritchie between 1969 and 1973 at Bell Labs
- One of the early high-level programming language
- Somewhere between assembly and other high-level languages
- Provide powerful functionalities for low level memory manipulations
- Have the highest efficiency within high level languages
- Very widely used in low level applications, such as operating systems, embedded programming, super computers, etc

C++ language (1979)

- C++ was developed by Bjarne Stroustrup at Bell Labs since 1979
- Inherent major features of C
- An object-oriented programming language, supporting code reuse
- High efficiency and powerful in low level memory manipulation
- Still platform dependent

Java language (1995)

- Java was developed by James Gosling at Sun Microsystems (which has since been acquired by Oracle Corporation) and released in 1995
- A new generation of general-purpose object-oriented programming language
- Platform independent, “write once, run anywhere” (WORA)
- Java is one of the most popular programming languages currently in use

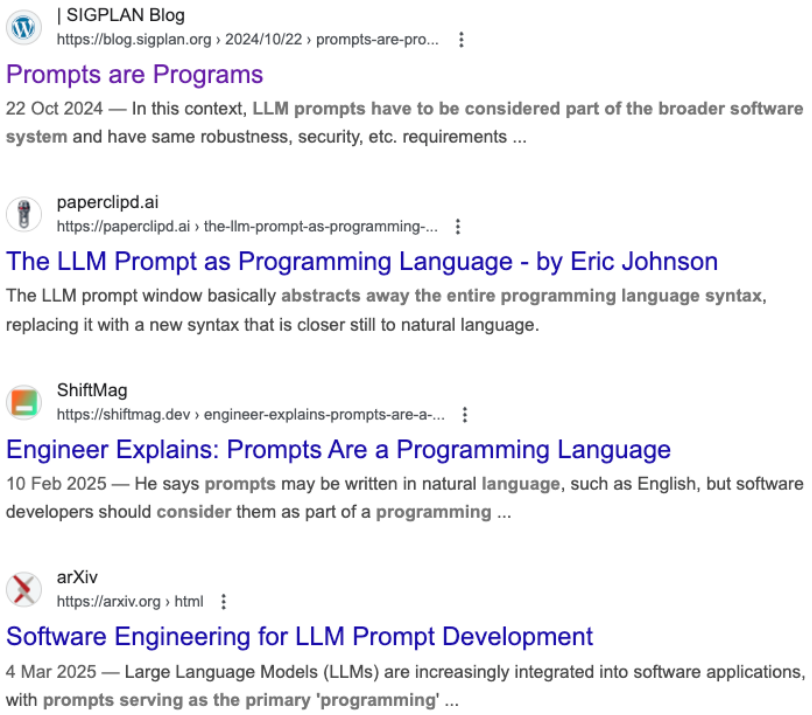
Python language (1991)

- Developed by Guido van Rossum in 1989, and formally released in 1991
- An open source, object-oriented programming language
- Powerful libraries
- Powerful interfaces to integrate other programming languages (C/C++, Java, and many other languages)
- In AI research, people mainly use Python

AI model prompt? (2022)

- Whether AI model prompt is programming language is debatable

- Primary issues:
  - Lack of formal grammar
  - Non-deterministic execution
  - Low abstraction and formal verification
  - ……



Language efficiency v.s. development efficiency

- High-level languages cannot be executed directly
- High-level languages must be converted into low-level languages first
- Lower-level languages have higher language efficiency (they are faster to run on a computer)
- Higher-level languages have higher development efficiency (it is easier to write programs in these languages)

Operating system

- The operating system (OS) is a low-level program, which provides all basic services for managing and controlling a computer's activities

- Applications are programs which are built based upon an OS

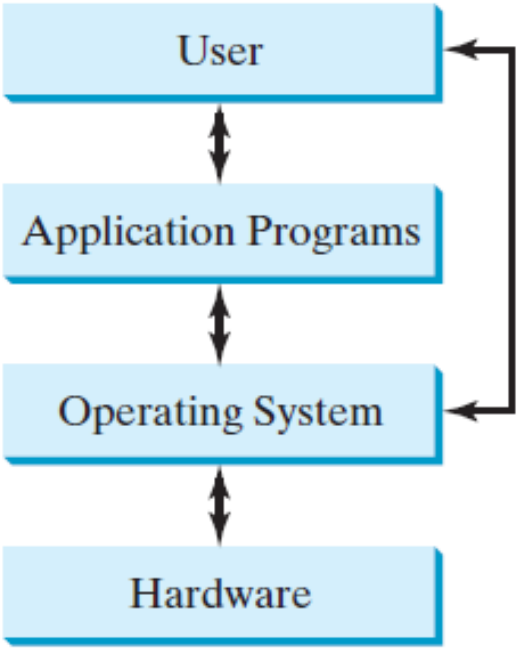
- Main functions of an OS:

✓ Controlling and monitoring system activities

✓ Allocating and assigning system resources

✓ Scheduling operations

- Popular OS: Windows, Mac OS, Linux, iOS, Android…



Learn more at CSC3150 (which I teach)!

Break

Slogan for Python

Life is short, use Python!

Review of last lecture

- Why programming and CS
- Von Neumann Architecture
- CPU and memory
- Input/output devices
- Programming language
- Operating system

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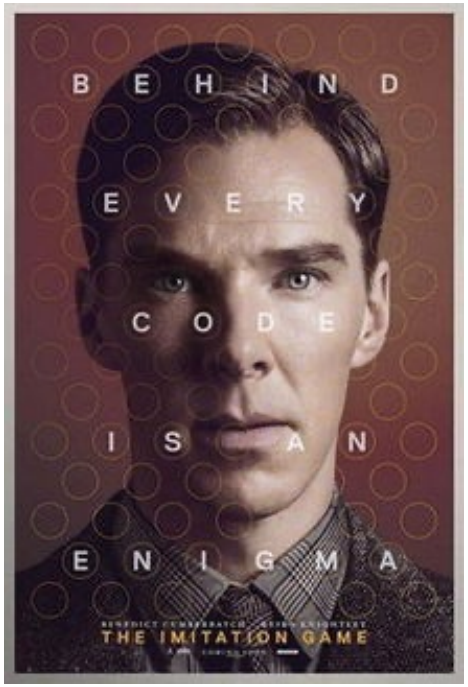
How do you like the movie?



模仿遊戲

The Imitation Game

Data representation and conversion

- We use positional notation (进位记数法) to represent or encode numbers in a computer
- Data are stored essentially as binary numbers in a computer
- In practice, we usually represent data using either binary (二进制), decimal (十进制), octal (八进制) or hexadecimal (十六进制) number systems
- We may need to convert data between different number systems

The basic idea of positional notation

- Each positional number system contains two elements, a base (基数) and a set of symbols
- Using the decimal system (十进制系统) as an example, its base is 10, and the symbols are {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
- When a number “hits” 9, the next number will not be a different symbol, but a “1” followed by a “0” (逢十进一)

Decimal number system

- In the decimal number system, the base is 10, the symbols include 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

- Every number can be decomposed into the sum of a series of numbers, each is represented by a positional value times a weight

- $N = a_n \times 10^n + a_{n-1} \times 10^{n-1} + a_{n-2} \times 10^{n-2} \ \ldots\ldots + a_0 \times 10^0 + a_{-1} \times 10^{-1} + a_{-2} \times 10^{-2} \ \ldots$

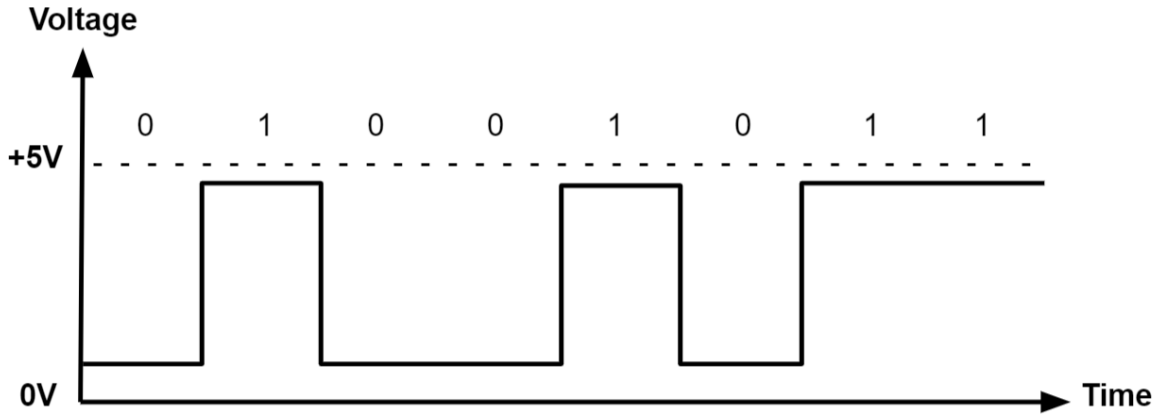
- a_n is the positional value (ranging from 0 to 9), while 10^n represents the weight

Binary number system

- In the binary system, the base is 2, we use only two symbols 0 and 1
- "10" is used when we hit 2 (逢二进一)
- $N = a_n \times 2^n + a_{n-1} \times 2^{n-1} + a_{n-2} \times 2^{n-2} \ \ldots\ldots + a_0 \times 2^0 + a_{-1} \times 2^{-1} + a_{-2} \times 2^{-2} \ldots$
- a_n is the positional value (ranging from 0 to 1), while 2^n represents the weight

Why use binary number?

- Easy to implement physically
- Simple calculation rules
- Easy to combine arithmetic and logic operations

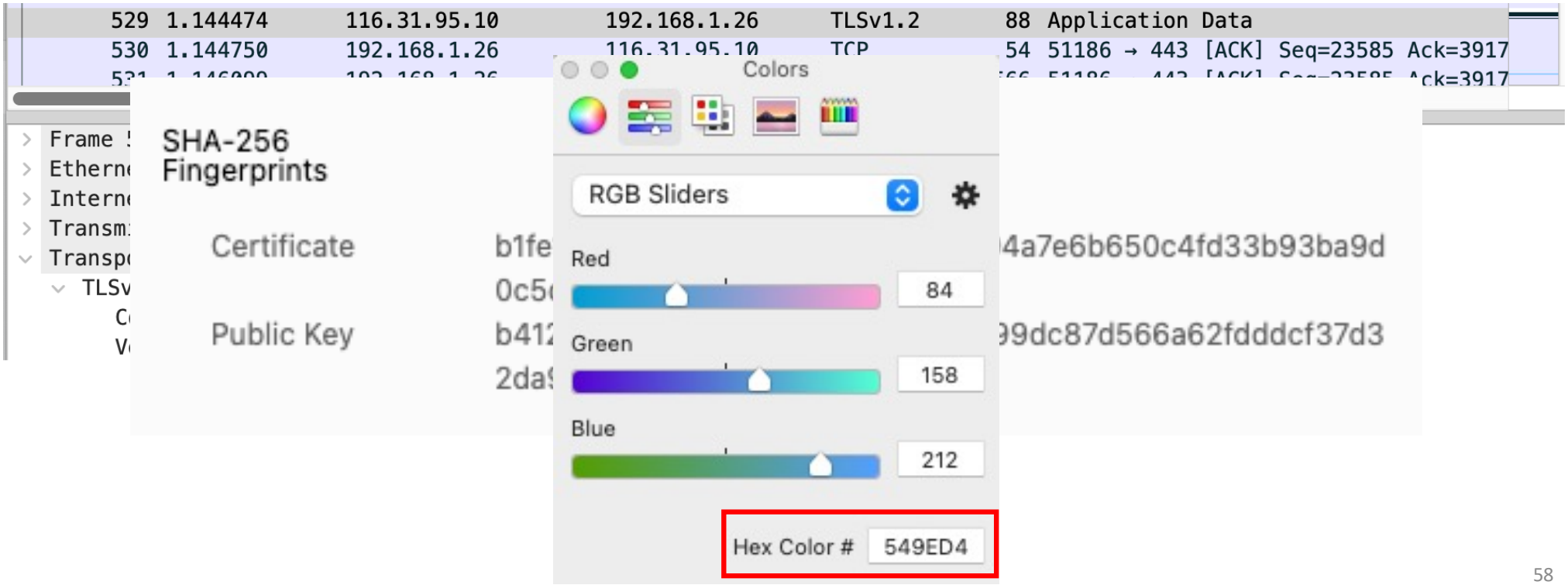


Hexadecimal number system

- In the hexadecimal system, the base is 16, we use 16 symbols {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b, c, d, e, f}
- "10" is used when we hit 16 (逢十六进一)
- $N = a_n \times 16^n + a_{n-1} \times 16^{n-1} + a_{n-2} \times 16^{n-2}$ …… + $a_0 \times 16^0 + a_{-1} \times 16^{-1} + a_{-2} \times 16^{-2}$ …
- a_n is the positional value (ranging from 0 to 15), while 16^n represents the weight

Why hexadecimal?

- More compressed than binary so commonly used in various scenarios



Octal number system

Converting binary number into decimal number

Example $(1101.01)_2$

$=(1\times2^3+1\times2^2+0\times2^1+1\times2^0+0\times2^{-1}+1\times2^{-2})_{10}$

$=(13.25)_{10}$

Practice $(10110.11)_2=(?)_{10}$

Converting binary number into decimal number

Answer

(10110.11)

$=(1\times2^4+0\times2^3+1\times2^2+1\times2^1+0\times2^0+1\times2^{-1}+1\times2^{-2})_{10}=(22.75)_{10}$.

Converting octal number into decimal number

Example $(24.67)_8=(2\times8^1+4\times8^0+6\times8^{-1}+7\times8^{-2})_{10}$

$=(20.859375)_{10}$

Practice $(35.7)_8=(?)_{10}$

Converting octal number into decimal number

Answer

$$(35.7)_8=(3\times8^1+5\times8^0+7\times8^{-1})_{10}$$
$$=(29.875)_{10}$$

Converting hexadecimal -> decimal

Example $(2AB.C)_{16}$

$=(2\times16^{2}+10\times16^{1}+11\times16^{0}+12\times16^{-1})_{10}$

$=(683.75)_{10}$

Practice $(A7D.E)_{16}=(?)_{10}$

Converting hexadecimal -> decimal

Answer

$$(A7D.E)_{16}=(10\times16^{2}+7\times16^{1}+13\times16^{0}+14\times16^{-1})_{10}$$
$$=(2685.875)_{10}$$

Converting other number system into decimal system

- Other number system can also be converted into decimal system in a similar way

- We just need to change the corresponding base

Tests: converting into decimal system

- $(110110)\_2 = (?)\_10$
- $(101011.11)\_2 = (?)\_10$
- $(120)\_8 = (?)\_10$
- $(34.01)\_8 = (?)\_10$
- $(BCA)\_16 = (?)\_10$
- $(E05.C)\_16 = (?)\_10$

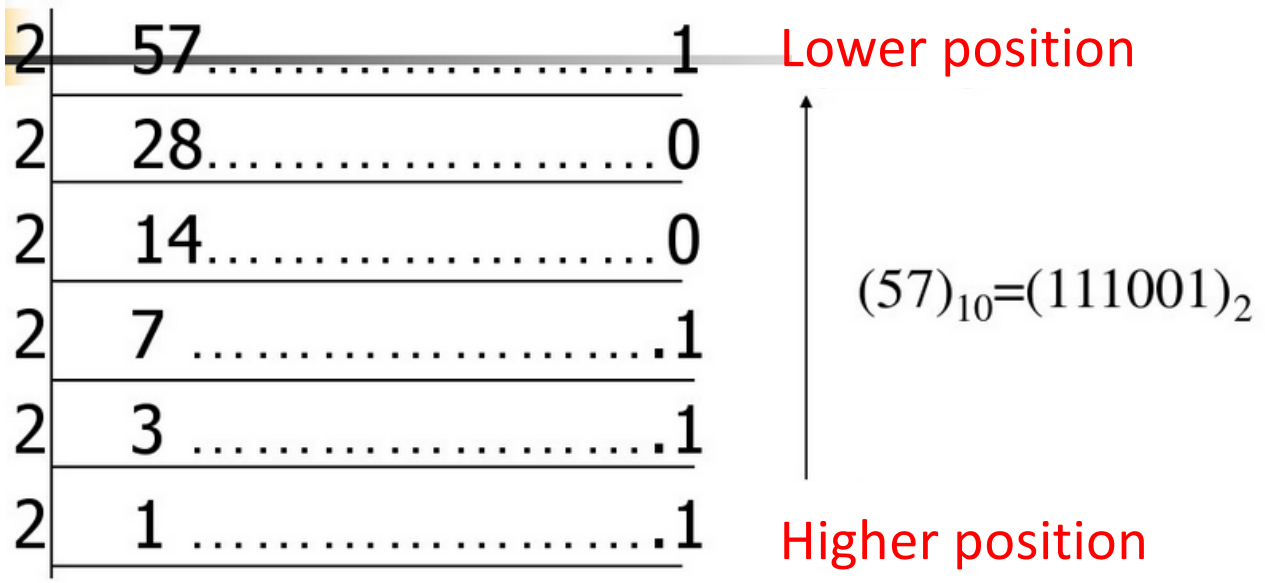
Tests: converting into decimal system

- $(110110)\_2 = (\mathbf{54})\_10$
- $(101011.11)\_2 = (\mathbf{43.75})\_10$
- $(120)\_8 = (\mathbf{80})\_10$
- $(34.01)\_8 = (\mathbf{28.015625})\_10$
- $(\mathrm{BCA})\_16 = (\mathbf{3018})\_10$
- $(\mathrm{E05.C})\_16 = (\mathbf{3589.75})\_10$

https://www.rapidtables.com/convert/number/hex-to-decimal.html

Converting decimal integer into binary integer

Example: $(57)_{10} = (?)_2$



Converting decimal fraction into binary fraction

Example: $(0.875)_{10} = (?)_2$

Higher position

$0.875 \times 2 = \mathbf{1}.75$ Integer part: **1**

$0.75 \times 2 = \mathbf{1}.5$ Integer part: **1**

$0.5 \times 2 = \mathbf{1}$ Integer part: **1**

Lower position

Answer: $(0.875)_{10} = (0.111)_2$

Practice: $(0.6875)_{10} = (?)_2$

Converting decimal fraction into binary fraction

Answer:

$0.6875 \times 2 = \mathbf{1}.375$ Integer part: **1**

$0.375 \times 2 = \mathbf{0}.75$ Integer part: **0**

$0.75 \times 2 = \mathbf{1}.5$ Integer part: **1**

$0.5 \times 2 = \mathbf{1}$ Integer part: **1**

Higher position

Lower position

So, $(0.6875)_{10} = (0.1011)_2$

Converting decimal fraction into binary fraction

- For a decimal number that has both integer and fractional parts
- Convert the integer and fractional parts separately
- Example: $(215.3125)_{10} = (?)_2$

Converting decimal fraction into binary fraction

Answer:

$$(215)_{10} = (11010111)_2$$
$$(0.3125)_{10} = (0.0101)_2$$
$$(215.3125)_{10} = (11010111.0101)_2$$

The one-to-one relationship between binary and octal numbers

There is a “one-to-one” relationship between three digits binary number and one-digit octal number

$$(0)_8 = (000)_2$$
$$(1)_8 = (001)_2$$
$$(2)_8 = (010)_2$$
$$(3)_8 = (011)_2$$
$$(4)_8 = (100)_2$$
$$(5)_8 = (101)_2$$
$$(6)_8 = (110)_2$$
$$(7)_8 = (111)_2$$

Converting octal number into binary number

- Convert each octal digit into binary number of three digits
- Keep the digit order unchanged
- Example: $(0.754)_8 = (\underline{000}.\underline{111}\ \underline{101}\ \underline{100})_2$
  $= (0.1111011)_2$
- Practice: $(16.327)_8 = (?)_2$

Converting octal number into binary number

Answer:

$$(16.327)_8$$
$$= (\underline{001\ 110}.\ \underline{011\ 010\ 111})_2$$
$$= (1110.011010111)_2$$

Converting hexadecimal number into binary number

- Convert each hexadecimal digit into binary number of four digits
- Keep the digit order unchanged

- Example: $(4C.2E)_{16} = (\underline{0100}\ \underline{1100}.\underline{0010}\ \underline{1110})_2$
  $= (1001100.0010111)_2$

- Practice: $(AD.7F)_{16} = (?)_2$

Converting hexadecimal number into binary number

Answer:

$$(AD.7F)_{16}$$
$$= (\underline{1010}\ \underline{1101}.\underline{0111}\ \underline{1111})_2$$
$$= (10101101.01111111)_2$$

Converting binary number into octal number

- Starting from lower positions, convert every three digits of the integer part into an octal digit
- When there is not enough higher positions in the integer part, fill with 0
- Starting from higher positions, convert every three digits of the fractional part into an octal digit
- When there is not enough lower positions in the fractional part, fill with 0
- Keep the digit order unchanged

Converting binary number into octal number

Example:

$(0.10111)_2 = (\underline{000}.\ \underline{101}\ \underline{110})_2 = (0.56)_8$

$(11101.01)_2 = (\underline{011}\ \underline{101}.\ \underline{010})_2 = (35.2)_8$

Practice:

$(1101101.011)_2$

Converting binary number into octal number

Answer:

$$(1101101.011)_2 = (\underline{001}\ \underline{101}\ \underline{101}.\ \underline{011})_2$$
$$= (155.3)_8$$

The one-to-one relationship between binary and hexadecimal numbers

There is a “one-to-one” relationship between four digits binary number and one-digit hexadecimal number

$$
\begin{array}{ll}
(0)_{16} = (0000)_2 & (8)_{16} = (1000)_2 \\
(1)_{16} = (0001)_2 & (9)_{16} = (1001)_2 \\
(2)_{16} = (0010)_2 & (A)_{16} = (1010)_2 \\
(3)_{16} = (0011)_2 & (B)_{16} = (1011)_2 \\
(4)_{16} = (0100)_2 & (C)_{16} = (1100)_2 \\
(5)_{16} = (0101)_2 & (D)_{16} = (1101)_2 \\
(6)_{16} = (0110)_2 & (E)_{16} = (1110)_2 \\
(7)_{16} = (0111)_2 & (F)_{16} = (1111)_2
\end{array}
$$

Converting binary number into hexadecimal number

- Starting from lower positions, convert every four digits of the integer part into an octal digit
- When there is not enough higher positions in the integer part, fill with 0
- Starting from higher positions, convert every three digits of the fractional part into an octal digit
- When there is not enough lower positions in the fractional part, fill with 0
- Keep the digit order unchanged

Converting binary number into hexadecimal number

Example:

$$(11101.01)_2 = (\underline{0001}\ \underline{1101}.\ \underline{0100})_2$$
$$= (1D.4)_{16}$$

The units of information (data)

- Bit: a binary digit which takes either 0 or 1
- Bit is the smallest information unit in computer programming
- Byte: 1 byte = 8 bits, every English character is represented by 1 byte
- Kilobyte (KB): 1 KB = 2^10 B = 1024 B
- Megabyte (MB): 1MB = 2^20 B = 1024 KB
- Gigabyte (GB): 1GB = 2^30 B = 1024 MB
- Terabyte (TB): 1TB = 2^40 B = 1024 GB

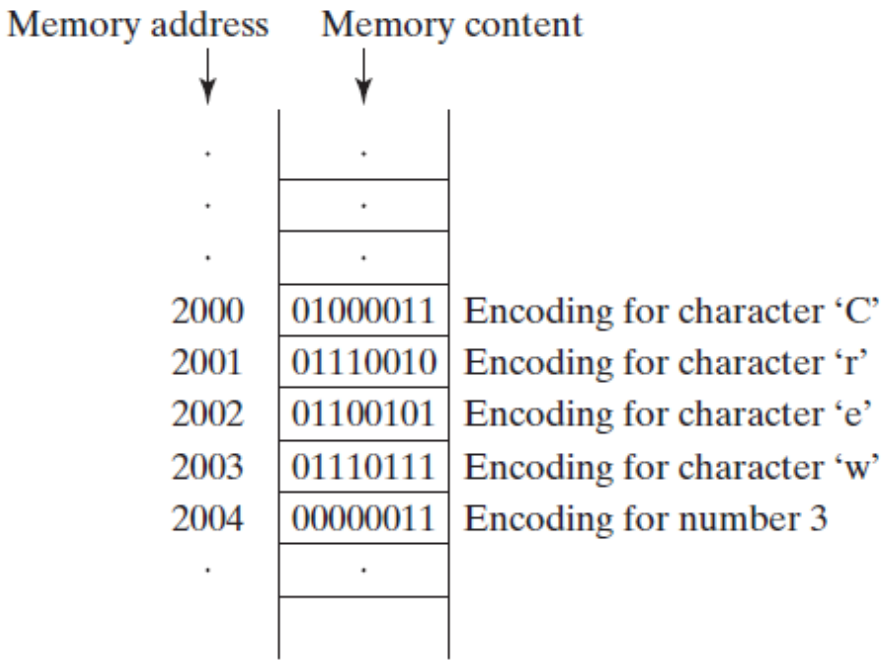
Note:
In computation, 2^10 is often used to represent 1K because computers operate in binary.

However, in storage and networking, 1K = 1000 (based on the metric system, SI units).

Memory and addressing

- A computer's memory consists of an ordered sequence of bytes for storing data
- Every location in the memory has a unique address
- The key difference between high- and low-level programming languages is whether programmer has to deal with memory addressing directly

  (e.g., the concept of "pointer" in C language)



Thanks