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

Introduction to Computer Science: Programming Methodology

Lecture 1 Introduction

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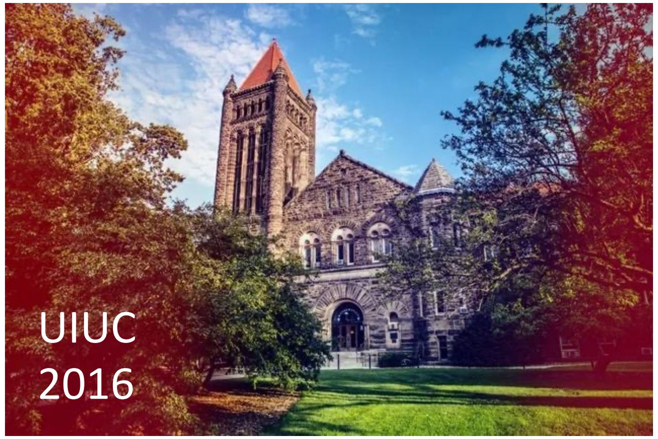
School of Data Science



CUHK Shenzhen
2021-present

Contact

- Email: hepinjia@cuhk.edu.cn
- Office hour: Thu. 10 am – 11 am (Daoyuan 420B)

Go-to Person

- Lectures: Me
- Assignments: TA
  - The corresponding TA name and email will likely be on the assignment.
  - Different assignments have different TAs
- Tutorials: TA
  - Different tutorial sessions have different TAs

Learning Objectives

- This course introduces the basics of computer programming using Python

- Students will learn the basic elements of modern computer systems, key programming concepts, problem solving and basic algorithm design

(Video: computer science basics, hardware and software)

Key Topics

- Introduction to modern computers
- Preliminary knowledge for computer programming
- Basic introduction to Python language
- Data types and operators in Python language
- Input/output
- Flow control and loop
- Function
- List
- Basic data structure
- Introduction to algorithm design
- Introduction to object oriented programming

Assessment

Assignments × 4	10% × 4
Mid-term quiz	20%
Final exam	40%

Course Materials

- All lecture notes and sample code used in classes will be provided to students via Blackboard

- Recommended readings
  - Online resources: https://www.python.org/doc/
  - Learning Python, 5th Edition, by Mark Lutz, Publisher: O'Reilly media

Course Components

Activity	Hours/week
Lecture	75 minutes × 2
Tutorial	50 minutes × 1

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	Function;
5	List;
6	Introduction to object oriented programming, part I
7	Review for mid-term quiz;
8	Introduction to object oriented programming, part II
9	Data Structure, part I;
10	Data Structure, part II;
11	Introduction to algorithm design, part I;
12	Introduction to algorithm design, part II;
13	Introduction to algorithm design, part III;
14	Review for final exam;

Why learn programming?

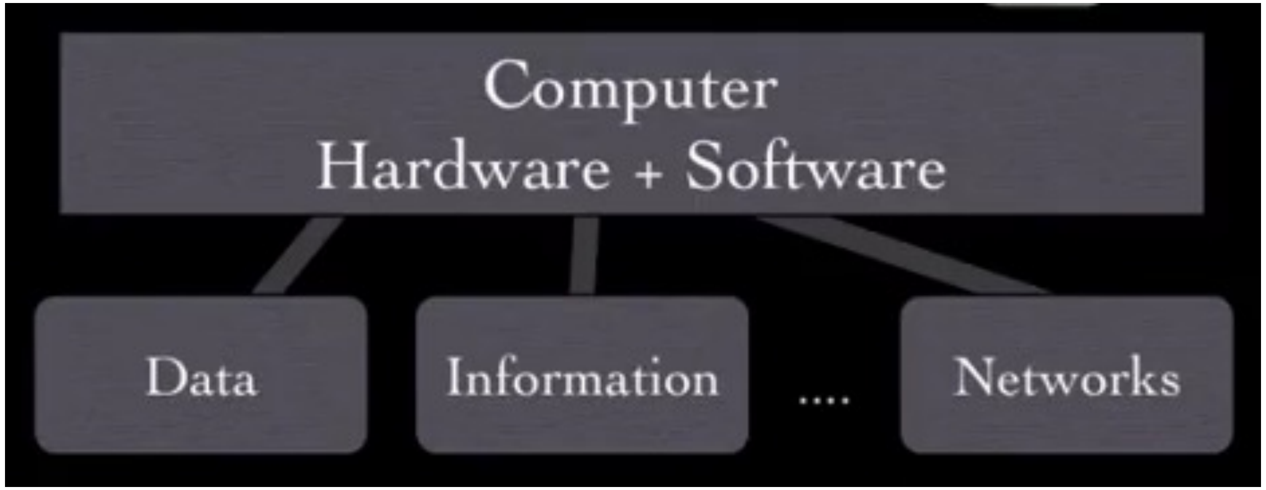
- Computer is built to help people solve problems

- Computer does not understand what we say
- We need to communicate with computers using their languages (computer programming language)

- Assembly, C, C++, Java and Python

User

Interface



Programmer

- Programmers solve problems like data, information, networks on behalf of users

Programmer

- Professional programmer writes computer programs and develops software

- A junior programmer gets a salary of 10-20k RMB in an INTERNET company like Tencent

- A programmer can earn up to 500k – 1m USD in Google!!

- Software and INTERNET are huge industries.

Why be a programmer?

- Programming is pervasive in your life, even if you are NOT in the IT industry
  - ➢ Electrical/electronic engineer – control program
  - ➢ Economist – mathematical modeling
  - ➢ Salesman – analyzing sales data
  - ➢ …

(Video: Should I learn to code?)

What is Code? Software? Program?

- A sequence of instructions
- Computers take the instructions and execute them
- It is a little piece of our intelligence in the computer
- Intelligence is re-usable

Programs for human

- Right hand around your head
- Left hand around your belly
- Straighten out right hand
- Left hand rests on your hip
- One step to the right while straighten out left hand
- Keep down and swing your ham
- ……

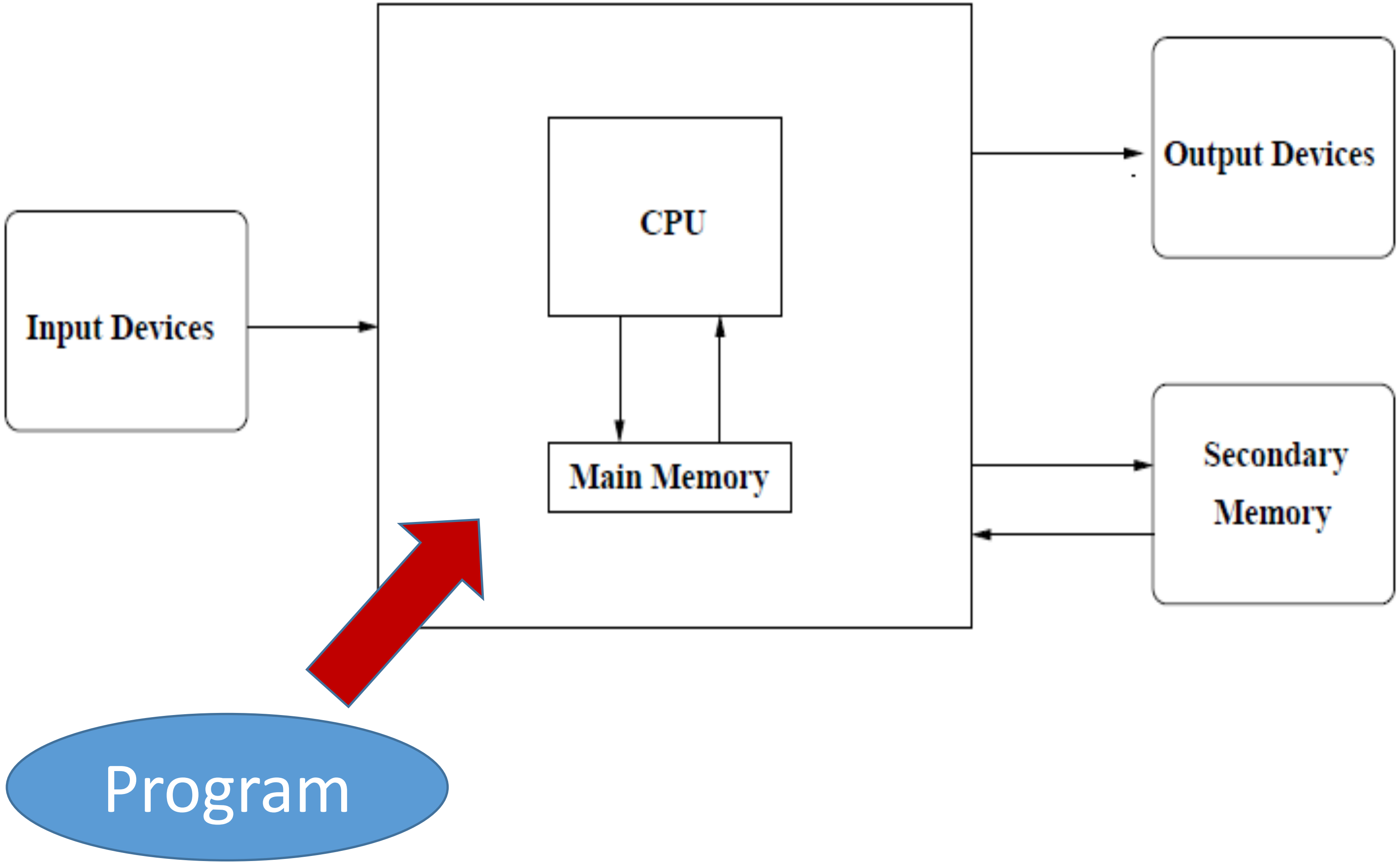
(Video: Algorithms)

Computers are good at following instructions

- Humans can easily make mistakes when following a set of instructions

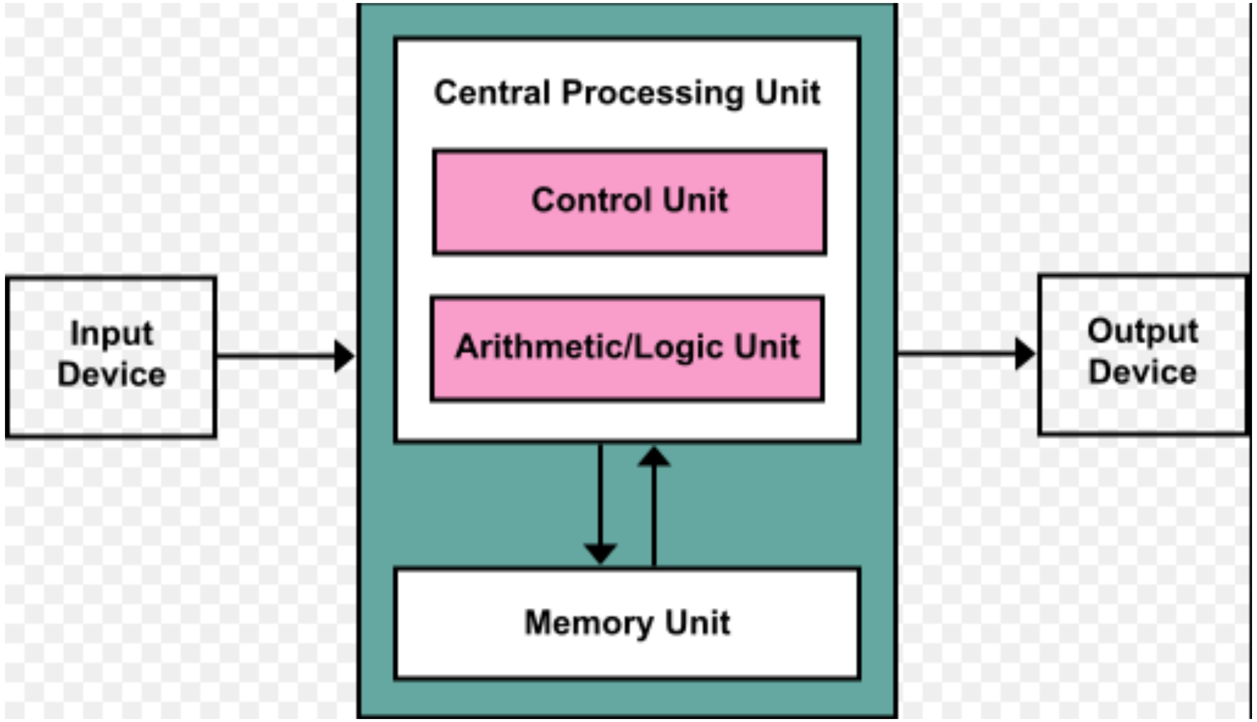
- On the contrary, computers (usually) won’t make mistakes, regardless of they are given 10 or 10 billion instructions !!

Computer Hardware

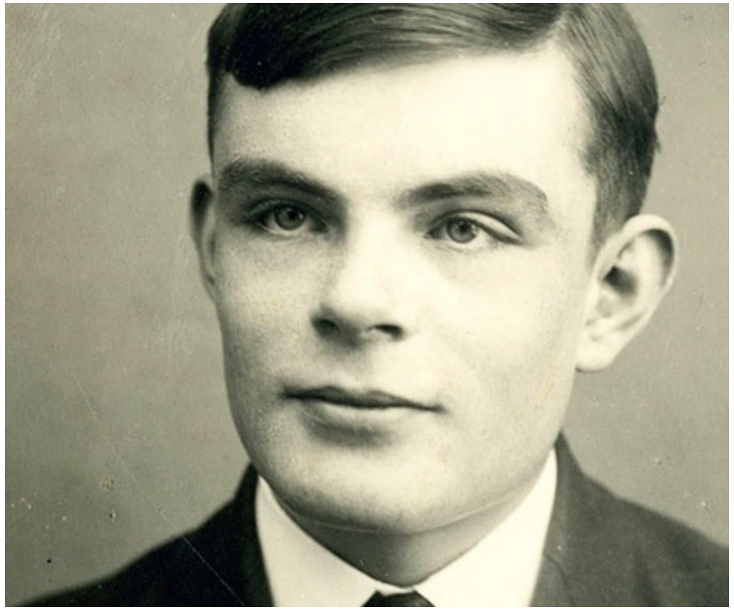


Von Neumann Architecture

- The modern computer architecture is proposed by John Von Neumann



The theoretical foundation of computer science



- The theoretical foundation of computer science are built by Alan Turing
- Father of theoretical computer science and artificial intelligence
- Computability theory and Turing test

Key components in a computer

- Central processing unit (CPU): execute your program. Similar to human brain, very fast but not that smart
- Input device: take inputs from users or other devices
- Output device: output information to users or other devices
- Main memory: store data, fast and temporary storage
- Secondary memory: slower but large size, permanent storage

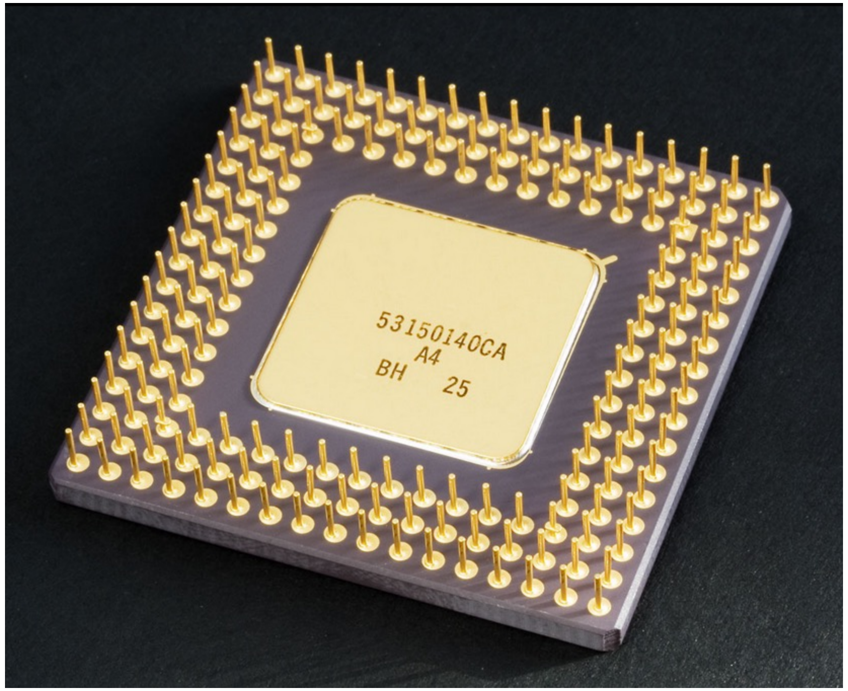
Central Processing Unit

- A processor contains two units, a control unit (CU) and an arithmetic/logic unit (ALU)

- CU is used to fetch commands from the memory

- ALU contains the electric circuits which can execute commands

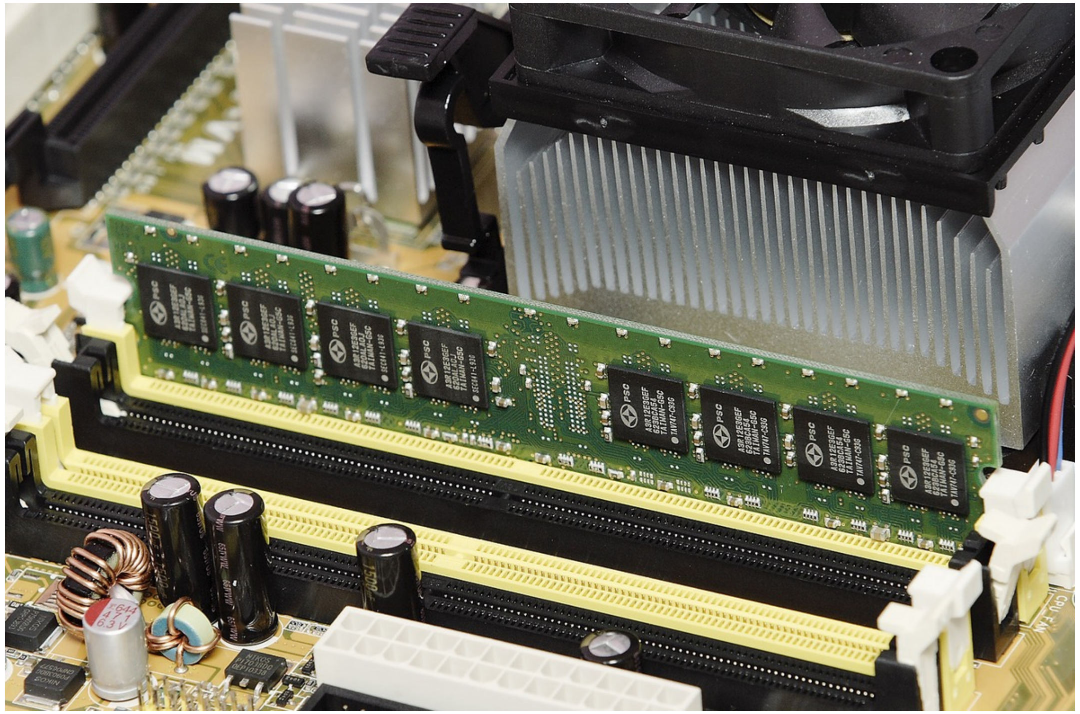
Central Processing Unit



- Processor manufacturer: Intel, AMD, ARM, etc

Memory/Storage

- High speed cache
- Internal RAM
- Internal ROM
- External RAM
- Flash
- Hard disk



Input/output devices

- Input devices: mouse, keyboard, panel, touch screen, audio input, mind reading, etc

- Output devices: screen, audio output, etc

How the hard disk works

What can a computer actually understand?

- How can a computer understand a number (e.g., 8)?

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

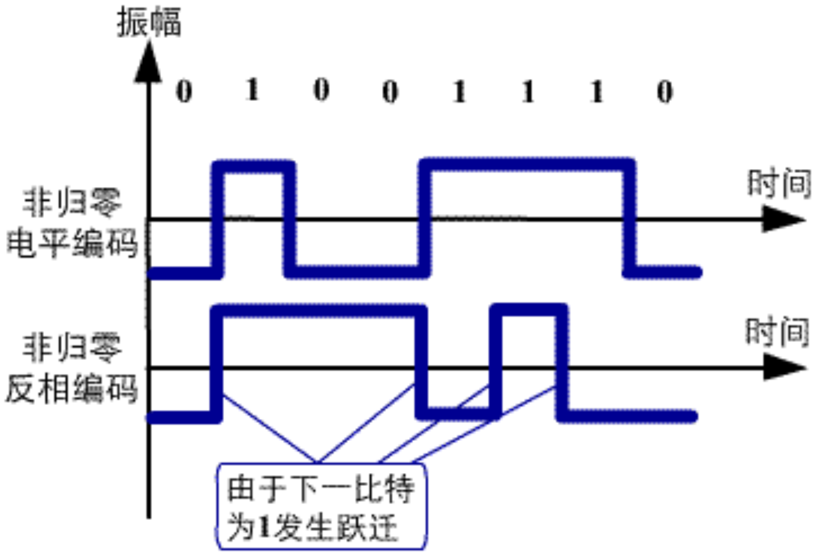
(Video: Programming Languages)

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



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.

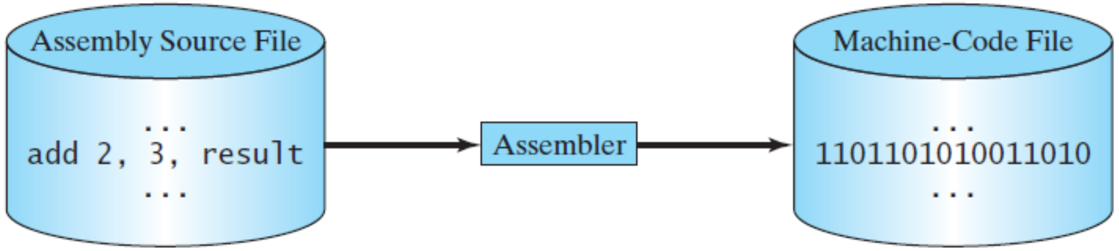
- Each assembly language is specific to a particular computer architecture

- 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 AT&T 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 (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)
- Programming language of the year 2010

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 Systems

- 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:

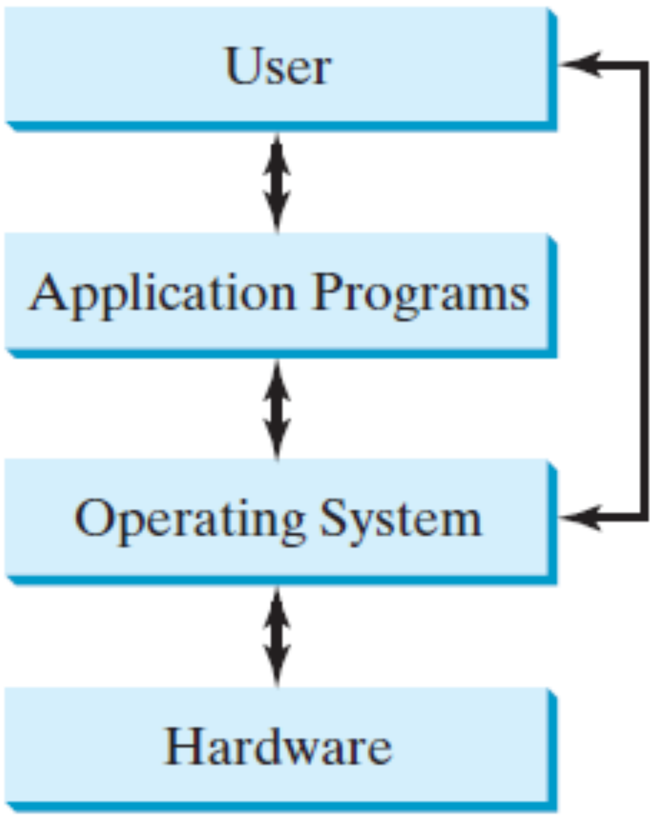
✓ Controlling and monitoring system activities

✓ Allocating and assigning system resources

✓ Scheduling operations

(Demo: mac terminal)

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



(Video: Operating System)

Abstraction

- Machine language -> Assembly -> C -> Python
- Hardware -> OS -> Apps/Software applications
- Binary digits -> Primitive data types -> Data structures

Data Representation and Conversion

- We use positional notation (进位记数法) to represent or encode numbers in a computer

  1 0

- 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

(Video: Binary)

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

$$9_{(10)} = 1\times2^3 + 0\times2^2 + 0\times2^1 + 1\times2^0 = 1001_{(2)}$$

- a_n is the positional value (ranging from 0 to 1), while 2^n represents the weight

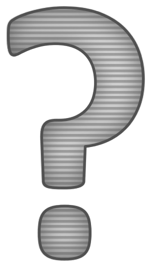
Why use binary number?

- 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

Octal number system



Converting binary number into decimal number

Example $(1101.01)_2$

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

$=(13.25)_{10}$

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

Converting binary number into decimal number

Answer

(10110.11)

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

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

$$(35.7)_8 = (3 \times 8^1 + 5 \times 8^0 + 7 \times 8^{-1})_{10}$$
$$= (29.875)_{10}$$

Converting hexadecimal number into decimal number

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 number into decimal number

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

Converting decimal integer into binary integer

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

2	57	1	Lower position
2	28	0	
2	14	0	
2	7	1	
2	3	1	
2	1	1	Higher position

(Video: decimal to binary)

Converting decimal fraction into binary fraction

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

Higher position

$0.875 \times 2 = 1.75$ Integer part: 1

$0.75 \times 2 = 1.5$ Integer part: 1

$0.5 \times 2 = 1$ Integer part: 1

Lower position

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

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

Converting decimal fraction into binary fraction

Answer:

Higher position

$0.6875 \times 2 = 1.375$ Integer part: 1

$0.375 \times 2 = 0.75$ Integer part: 0

$0.75 \times 2 = 1.5$ Integer part: 1

$0.5 \times 2 = 1$ Integer part: 1

Lower position

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

Converting decimal number into binary number

- For a decimal number that has both integer and fractional parts
- Convert the integer and fractional parts separately
- Example: $(215.6875)_{10} = (?)_2$

Converting decimal number into binary number

Answer:

$$(215)_{10}=(11010111)_2$$
$$(0.675)_{10}=(0.1011)_2$$
$$(215.675)_{10}=(11010111.1011)_2$$

Correction: should be 6875

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

There is a “one-to-one” (一一对应) relationship between three digits binary number and one digit octal number

$$
\begin{aligned}
(0)_8 &= (000)_2 \\
(1)_8 &= (001)_2 \\
(2)_8 &= (010)_2 \\
(3)_8 &= (011)_2 \\
(4)_8 &= (100)_2 \\
(5)_8 &= (101)_2 \\
(6)_8 &= (110)_2 \\
(7)_8 &= (111)_2
\end{aligned}
$$

Converting octal number into binary number

- Convert each octal digit into binary number of three digits
- Keep the digit order unchanged
- Example: $(0.754)_8 = (?)_2$

$$(0.754)_8 = (\underline{000}.\underline{111}\ \underline{101}\ \underline{100})_2$$
$$= (0.1111011)_2$$

- Practice: $(16.327)_8 = (?)_2$

Converting octal number into binary number

Answer:

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

Converting hexadecimal number into binary number

- Convert each hexadecimal digit into binary number of four digits
- Keep the digit order unchanged
- Example: $(4C.2E)_{16} = (?)_2$

$$
\begin{aligned}
&(4C.2E)_{16} \\
&= (\underline{0100}\ \underline{1100}.\underline{0010}\ \underline{1110})_2 \\
&= (1001100.0010111)_2
\end{aligned}
$$

- 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 a 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 a 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:

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

Converting binary number into hexadecimal number

- Starting from lower positions, convert every four digits of the integer part into a octal digit
- When there is not enough higher positions in the integer part, fill with 0
- Starting from higher positions, convert every four digits of the fractional part into a 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 (比特/位): a binary digit which takes either 0 or 1

- Bit is the smallest information unit in computer programming

- Byte (字节): 1 byte = 8 bits, every English character is represented by 1 byte

- KB (千字节)： 1 KB = 2^10 B = 1024 B
- MB (兆字节)： 1MB = 2^20 B = 1024 KB
- GB (千兆字节)： 1GB = 2^30 B = 1024 MB
- TB (兆兆字节)： 1TB = 2^40 B = 1024 GB

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