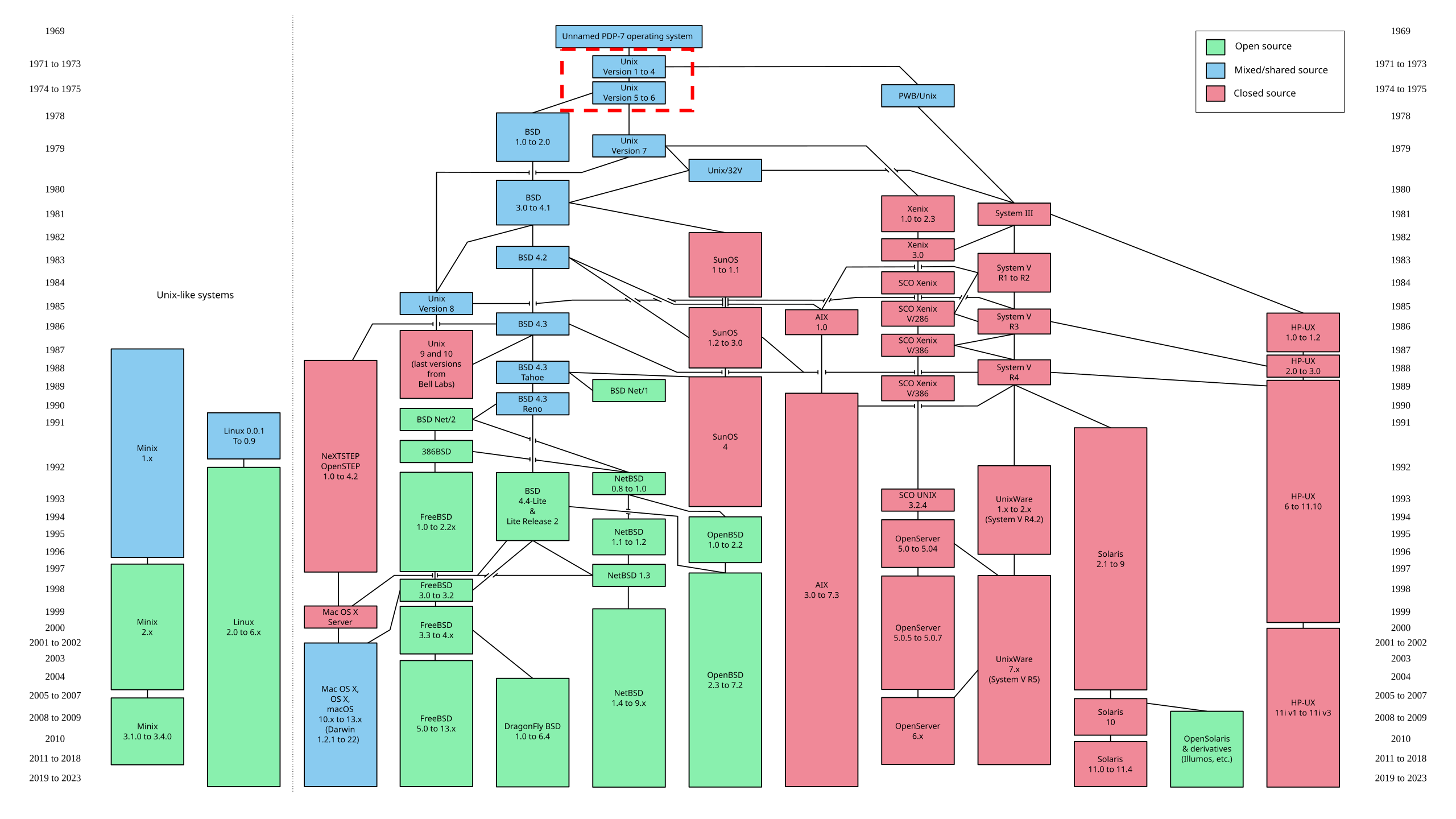
Operating Systems
Lecture 1

Why Learn Operating System? And How?

Prof. Mengwei Xu

What is the most important software that humans ever build?


Unix-like systems
1969
1971 to 1973
1974 to 1975
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001 to 2002
2003
2004
2005 to 2007
2008 to 2009
2010
2011 to 2018
2019 to 2023
Open source
Mixed/shared source
Closed source
Unnamed PDP-7 operating system
Unix Version 1 to 4
Unix Version 5 to 6
Unix Version 7
PWB/Unix
BSD 1.0 to 2.0
Unix/32V
BSD 3.0 to 4.1
BSD 4.2
BSD 4.3
BSD 4.3 Tahoe
BSD 4.3 Reno
Unix Version 8
Unix 9 and 10 (last versions from Bell Labs)
BSD Net/1
BSD Net/2
386BSD
BSD 4.4-Lite & Lite Release 2
FreeBSD 1.0 to 2.2x
FreeBSD 3.0 to 3.2
FreeBSD 3.3 to 4.x
FreeBSD 5.0 to 13.x
NetBSD 0.8 to 1.0
NetBSD 1.1 to 1.2
NetBSD 1.3
NetBSD 1.4 to 9.x
OpenBSD 1.0 to 2.2
OpenBSD 2.3 to 7.2
DragonFly BSD 1.0 to 6.4
Mac OS X Server
Mac OS X, OS X, macOS 10.x to 13.x (Darwin 1.2.1 to 22)
NeXTSTEP OpenSTEP 1.0 to 4.2
SunOS 1 to 1.1
SunOS 1.2 to 3.0
SunOS 4
AIX 1.0
AIX 3.0 to 7.3
Xenix 1.0 to 2.3
Xenix 3.0
SCO Xenix
SCO Xenix V/286
SCO Xenix V/386
SCO UNIX 3.2.4
OpenServer 5.0 to 5.04
OpenServer 5.0.5 to 5.0.7
OpenServer 6.x
System III
System V R1 to R2
System V R3
System V R4
UnixWare 1.x to 2.x (System V R4.2)
UnixWare 7.x (System V R5)
HP-UX 1.0 to 1.2
HP-UX 2.0 to 3.0
HP-UX 6 to 11.10
HP-UX 11i v1 to 11i v3
Solaris 2.1 to 9
Solaris 10
Solaris 11.0 to 11.4
OpenSolaris & derivatives (Illumos, etc.)
Minix 1.x
Minix 2.x
Minix 3.1.0 to 3.4.0
Linux 0.0.1 To 0.9
Linux 2.0 to 6.x

Goals for Today

- About this course
- What is OS?
- Why learn OS?
- Challenges and how to overcome?
- Brief history of OS

- Warmups
  - Computer organization
  - CPU, ISA, assembly, etc
  - Lifetime of a "Hello World" program

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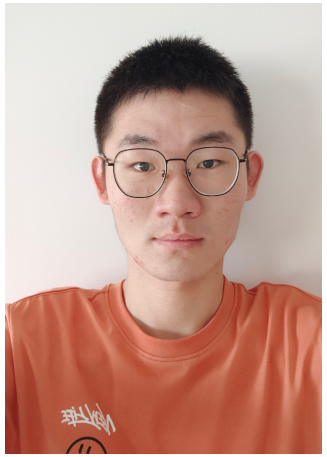
About This Course

- Mengwei XU (徐梦炜）， 副教授，硕/博导师
- Office: 科研楼1107
- BA and PhD from PKU, joined BUPT in 2020
- Personal page: https://xumengwei.github.io/
- System Software, Edge Computing, ML Systems
- TAs:



杜嘉骏

孙子泰

陈银骁

About This Course

- Textbooks
  - <Operating System Principles & Practice> (2nd edition) Thomas Anderson et al
  - <Operating Systems: Three Easy Pieces> (version 1.10) Remzi H. Arpaci-Dusseau and Andrea C. Arpaci-Dusseau
  - <Operating System Concepts> (7th Edition) Abraham Silberschatz et al
- Slides
  - Much of the contents are from Ion Stoica @ Berkeley!
- Course time
  - 8:00-9:35, Monday
  - 8:00-9:35, Wednesday
- Materials
  - There will be a website that holds everything about the course
  - https://buptos.github.io/index.html
- Discipline
  - Ask a question anytime, but do not disturb others from learning.

About This Course

- WeChat Group

About This Course - Grading

- Homework (30%)
  - ❑ <200 lines of code as designed
  - ❑ Reports, code, documents, paper reading, etc.
  - ❑ Including 5 labs
- Final (70%)
- ~~Bonus (5%) – MIT JOS 6.828~~
  - ~~❑ https://pdos.csail.mit.edu/6.828/2018/labs/lab1~~
  - ~~❑ Let TAs know that you take the challenge within 2 weeks.~~
  - ~~❑ There will be face-to-face test at the end of semester~~
- ~~Bonus (1%) – Find error in ChatGPT~~
  - ~~❑ If you find it answers wrongly about OS concepts (in English)~~
  - ~~❑ Report it immediately to TAs – only one student gets credits for the same error~~

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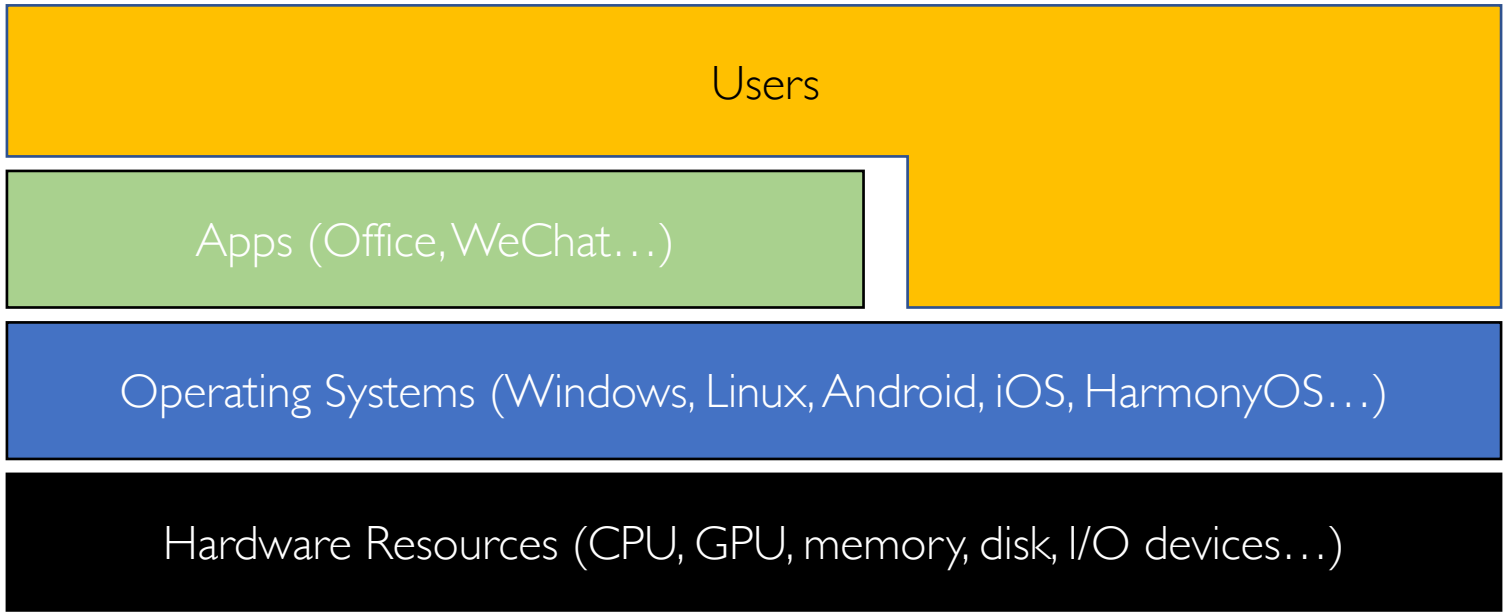
What is OS?

- A bridge between hardware and apps/users.
- Or, a special software layer that provides and manages the access from apps/users to hardware resources (CPU, memory, disk, etc).
  - *"We can solve any problem by introducing an extra level of indirection" – David Wheeler*



The Role of OS

- OS as referee
- OS as illusionist
- OS as glue

The Role of OS

- OS as referee
- OS as illusionist
- OS as glue

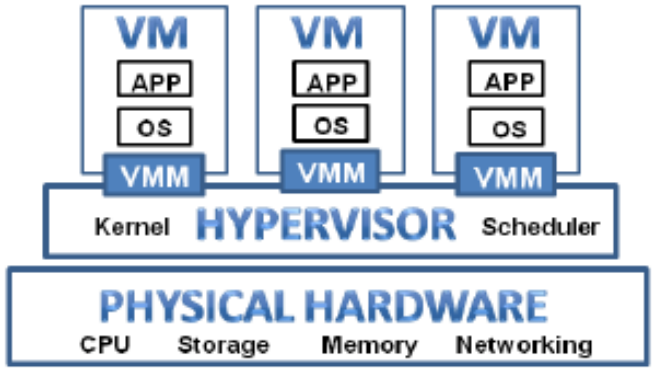
- Resource allocation
  - Multitasks on constrained resources
  - What if there is an infinite loop?
- Isolation
  - Fault in one app shall not disrupt others
  - Prevent malicious attackers
- Communication
  - Reliable, safe, and fast

The Role of OS

- OS as referee
- **OS as illusionist**
- OS as glue

- Illusion of resources not physically present
  - Processor, memory, screen, disk..
  - Ease of debugging, portability, isolation

- A step further: virtual machine



The Role of OS

- OS as referee
- OS as illusionist
- OS as glue

- Providing common services to facilitate resource sharing
  - read/write files
  - share memory
  - pass messages
  - UI
- Decouple HW and app development
  - As an interoperability layer for portability
  - Most applications can evolve independently with OS, unless those require very low-level programming such as databases

Code Example: CPU Virtualization

```
1  #include <stdio.h>
2  #include <stdlib.h>
3  #include <sys/time.h>
4  #include <assert.h>
5  #include "common.h"
6
7  int
8  main(int argc, char *argv[])
9  {
10     if (argc != 2) {
11         fprintf(stderr, "usage: cpu <string>\n");
12         exit(1);
13     }
14     char *str = argv[1];
15     while (1) {
16         Spin(1);
17         printf("%s\n", str);
18     }
19     return 0;
20 }
```

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15     while (1) {
16         Spin(1);
17         printf("%s\n", str);
18     }
19     return 0;
20 }
```

```
prompt> gcc -o cpu cpu.c -Wall
prompt> ./cpu "A"
A
A
A
A
^C
```

Code Example: CPU Virtualization

```c
#include <stdio.h>
#include <stdlib.h>
#include <sys/time.h>
#include <assert.h>
#include "common.h"

int
main(int argc, char *argv[])
{
    if (argc != 2) {
        fprintf(stderr, "usage: cpu
        exit(1);
    }
    char *str = argv[1];
    while (1) {
        Spin(1);
        printf("%s\n", str);
    }
    return 0;
}
```

```
prompt> gcc -o cpu cpu.c -Wall
prompt> ./cpu "A"
A
A
A
A
^C
```

```
prompt> ./cpu A & ./cpu B & ./cpu C & ./cpu D &
[1] 7353
[2] 7354
[3] 7355
[4] 7356
A
B
D
C
A
B
D
C
A
...
```

Code Example: Memory Virtualization

```
1  #include <unistd.h>
2  #include <stdio.h>
3  #include <stdlib.h>
4  #include "common.h"
5
6  int
7  main(int argc, char *argv[])
8  {
9      int *p = malloc(sizeof(int));                    // a1
10     assert(p != NULL);
11     printf("(%d) address pointed to by p: %p\n",
12            getpid(), p);                             // a2
13     *p = 0;                                          // a3
14     while (1) {
15         Spin(1);
16         *p = *p + 1;
17         printf("(%d) p: %d\n", getpid(), *p);       // a4
18     }
19     return 0;
20 }
```

Code Example: Memory Virtualization

```
1  #include <unistd.h>
2  #include <stdio.h>
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12            getpid(), p);                             // a2
13     *p = 0;                                          // a3
14     while (1) {
15         Spin(1);
16         *p = *p + 1;
17         printf("(%d) p: %d\n", getpid(), *p);        // a4
18     }
19     return 0;
20 }
```

```
prompt> ./mem
(2134) address pointed to by p: 0x200000
(2134) p: 1
(2134) p: 2
(2134) p: 3
(2134) p: 4
(2134) p: 5
^C
```

Code Example: Memory Virtualization

```
1  #include <unistd.h>
2  #include <stdio.h>
3  #include <stdlib.h>
4  #include "common.h"
5
6  int
7  main(int argc, char *argv[])
8  {
9      int *p = malloc(sizeof(int));
10     assert(p != NULL);
11     printf("(%d) address pointed to
12             getpid(), p);
13     *p = 0;
14     while (1) {
15         Spin(1);
16         *p = *p + 1;
17         printf("(%d) p: %d\n", getp
18     }
19     return 0;
20 }
```

```
prompt> ./mem
(2134) address pointed to by p: 0x200000
(2134) p: 1
(2134) p: 2
(2134) p: 3
(2134) p: 4
(2134) p: 5
^C
```

```
prompt> ./mem & ./mem &
[1] 24113
[2] 24114
(24113) address pointed to by p: 0x200000
(24114) address pointed to by p: 0x200000
(24113) p: 1
(24114) p: 1
(24114) p: 2
(24113) p: 2
(24113) p: 3
(24114) p: 3
(24113) p: 4
(24114) p: 4
...
```

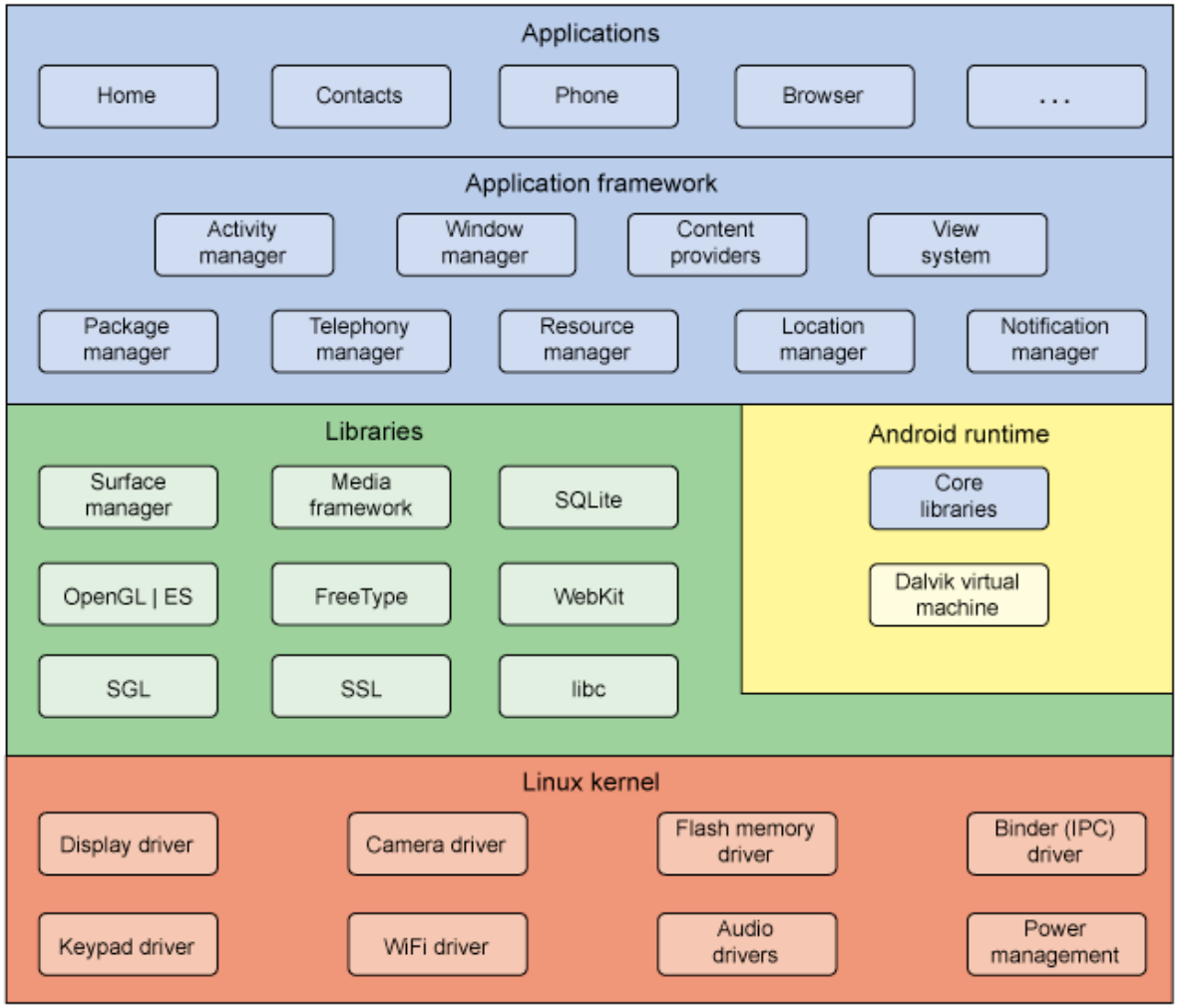
Why not 1,2,3,4..?

The Goal of OS

- Managing hardware resources
  - Allocating resources to concurrent tasks, who gets more?
  - Determining hardware status: CPU frequency, I/O device on/off, etc.
- Facilitate app developers
  - Illusion of resources not physically present
    - Large memory size
  - Isolation of apps
    - so a bug does not cause the machine down
  - Cross-apps communication
    - Without
- Facilitate users
  - UI components and rendering

The OS concept is expanding

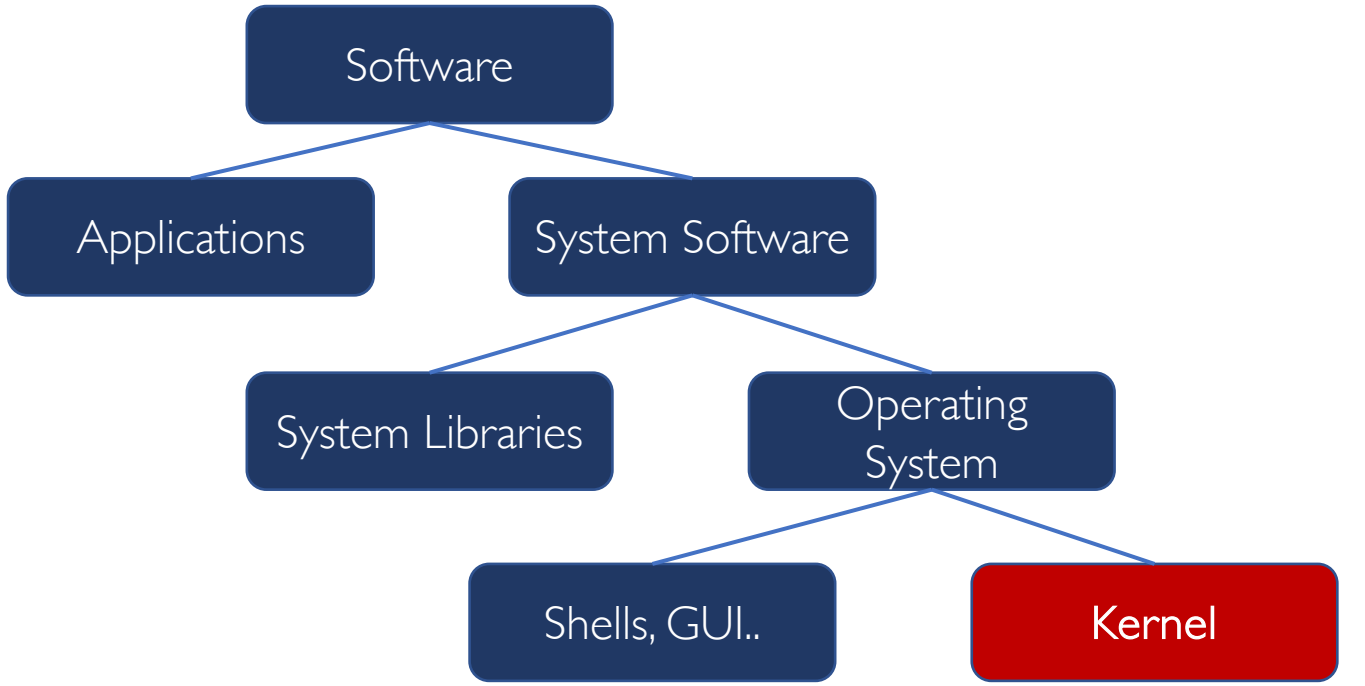
- Android/TensorFlow/WeChat
- OS vs. kernel (内核)



(The focus of this course)

The OS concept is expanding

- Android/TensorFlow/WeChat
- OS vs. kernel (内核)



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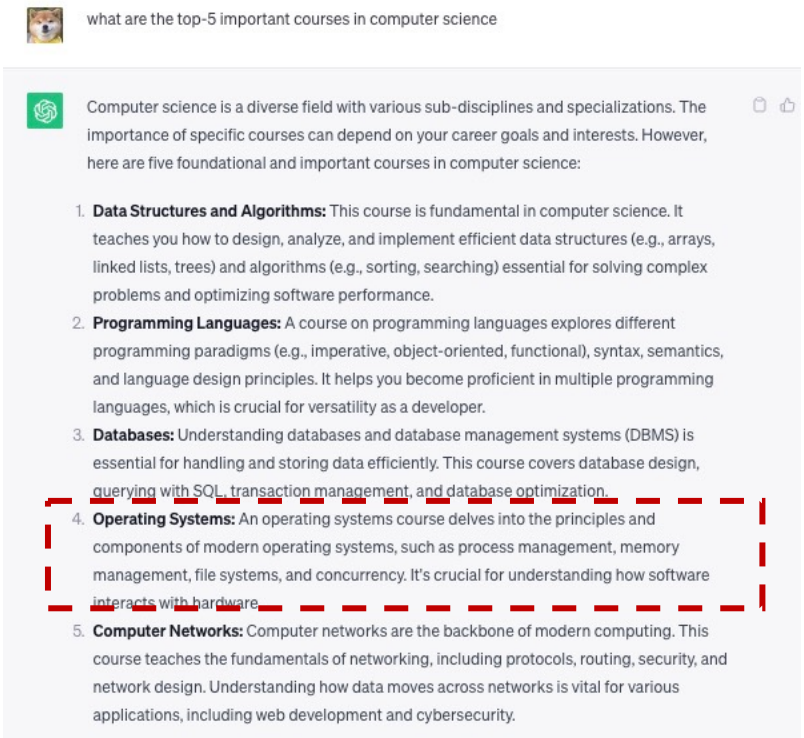
Why Study OS? (1/3)

- OS is a fundamental piece of computer science.
  - It's everywhere and will be long-standing.
  - It extensively adopts the most important concepts in CS.
  - It extensively interacts with hardware, compiler, PLs, runtime, etc.



what are the top-5 important courses in computer science

Computer science is a diverse field with various sub-disciplines and specializations. The importance of specific courses can depend on your career goals and interests. However, here are five foundational and important courses in computer science:

1. **Data Structures and Algorithms:** This course is fundamental in computer science. It teaches you how to design, analyze, and implement efficient data structures (e.g., arrays, linked lists, trees) and algorithms (e.g., sorting, searching) essential for solving complex problems and optimizing software performance.
2. **Programming Languages:** A course on programming languages explores different programming paradigms (e.g., imperative, object-oriented, functional), syntax, semantics, and language design principles. It helps you become proficient in multiple programming languages, which is crucial for versatility as a developer.
3. **Databases:** Understanding databases and database management systems (DBMS) is essential for handling and storing data efficiently. This course covers database design, querying with SQL, transaction management, and database optimization.
4. **Operating Systems:** An operating systems course delves into the principles and components of modern operating systems, such as process management, memory management, file systems, and concurrency. It's crucial for understanding how software interacts with hardware.
5. **Computer Networks:** Computer networks are the backbone of modern computing. This course teaches the fundamentals of networking, including protocols, routing, security, and network design. Understanding how data moves across networks is vital for various applications, including web development and cybersecurity.

然后，我觉得计算机专业最重要的5门课是：

1、数据结构与算法

2、计算机组成原理

3、操作系统

4、计算机网络

5、数据库

之所以把这五个作为最重要的课，其实包含一点功利之心，因为校招面试大厂的时候，这五门基础课问的最多的，至于其他的编译原理、汇编语言、数学基础课程不是说不重要，只是相对于校招面试这些课程问题的比较少。

接下来，我就跟大家分享下，**我看过数据结构与算法、计算机组成、操作系统、计算机网络、数据库这些课程的书和视频，都是从入门再到进阶的路线。**

这里推荐下我当初自学的书籍和视频。

▲ 赞同 2095 ▼ 30 条评论 分享 收藏 喜欢 ··· 收起

Why Study OS? (2/3)

- OS is useful
  - Whatever you work at correlates to OS
    - HPC, mobile/edge/cloud computing, ML/AI, security, etc..
  - Helps you understand why your program does not work well
  - Helps you to get a good job

```
for i in xrange(4096):
  for j in xrange(4096):
    for k in xrange(4096):
      C[i][j] += A[i][k] * B[k][j]
```

Version	Implementation	Running time (s)	GFLOPS	Absolute speedup
1	Python	25,552.48	0.005	1
2	Java	2,372.68	0.058	11
3	C	542.67	0.253	47
4	Parallel loops	69.80	1.969	366
5	Parallel divide and conquer	3.80	36.180	6,727
6	plus vectorization	1.10	124.914	23,224
7	plus AVX intrinsics	0.41	337.812	62,806

Charles E Leiserson, Neil C Thompson, Joel S Emer, Bradley C Kuszmaul, ButlerW Lampson, Daniel Sanchez, and Tao B Schardl. There's plenty of room at the top: What will drive computer performance after moore's law? Science, 368(6495), 2020.

Why Study OS? (3/3)

- OS is cool
  - Probably the most complex software you will deal with
  - The critical path to understand how computer *really* works

Who Cares OS?

- Academia: USENIX/ACM/IEEE
  - Conferences: SOSP/OSDI/USENIX ATC/EuroSys/ApSys..
- Companies
  - (direct) Microsoft, Google, Apple, Huawei..
  - (indirect) NVIDIA, Intel, Meta, Alibaba..
  - Hardware and OS always co-evolve!

- Developers who benefit from OS knowledge: everyone!

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  - Lifetime of a "Hello World" program

Challenges

- Complexity
  - Windows 10 has roughly 10,000,000 lines of code.
- OS directly deals with hardware
  - OS crash means…
- OS manages concurrency (并发)
  - A major source of software bugs
- OS cares many metrics
  - Reliability, availability, performance, energy, etc…
- Gap between concepts and code
- There are historical baggage

```
// Shared variable
int counter = 0;

Thread 1: counter++;
Thread 2: counter++;
```

How to Overcome?

- Think more and ask why
  - What's the benefit? What if.. ?
- Be interactive
  - In and after course
- Be patient
  - Too many abstractions and indirections
- Get your hands dirty

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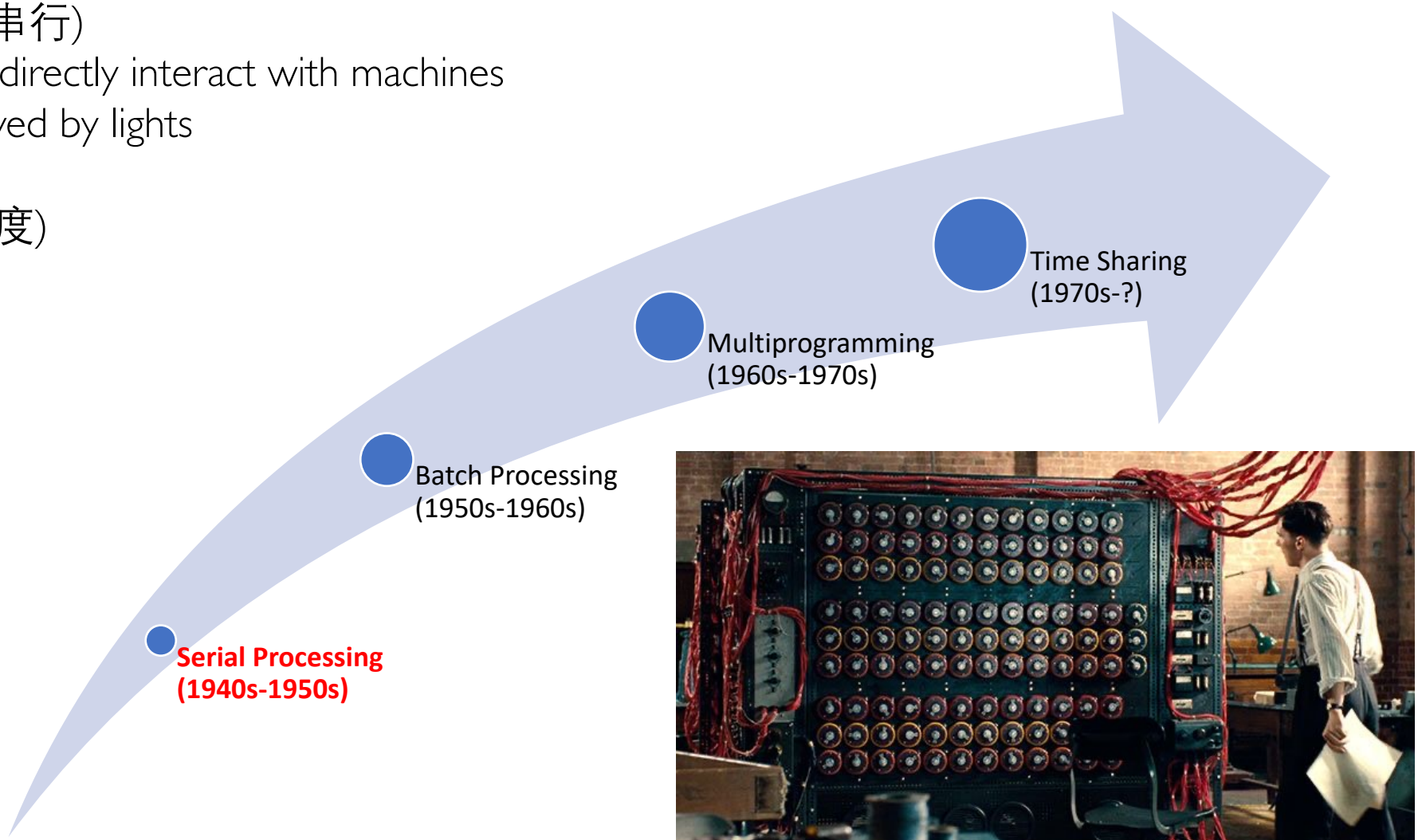
OS history

- Serial Processing (串行)
  - No OS, users directly interact with machines
  - Output displayed by lights

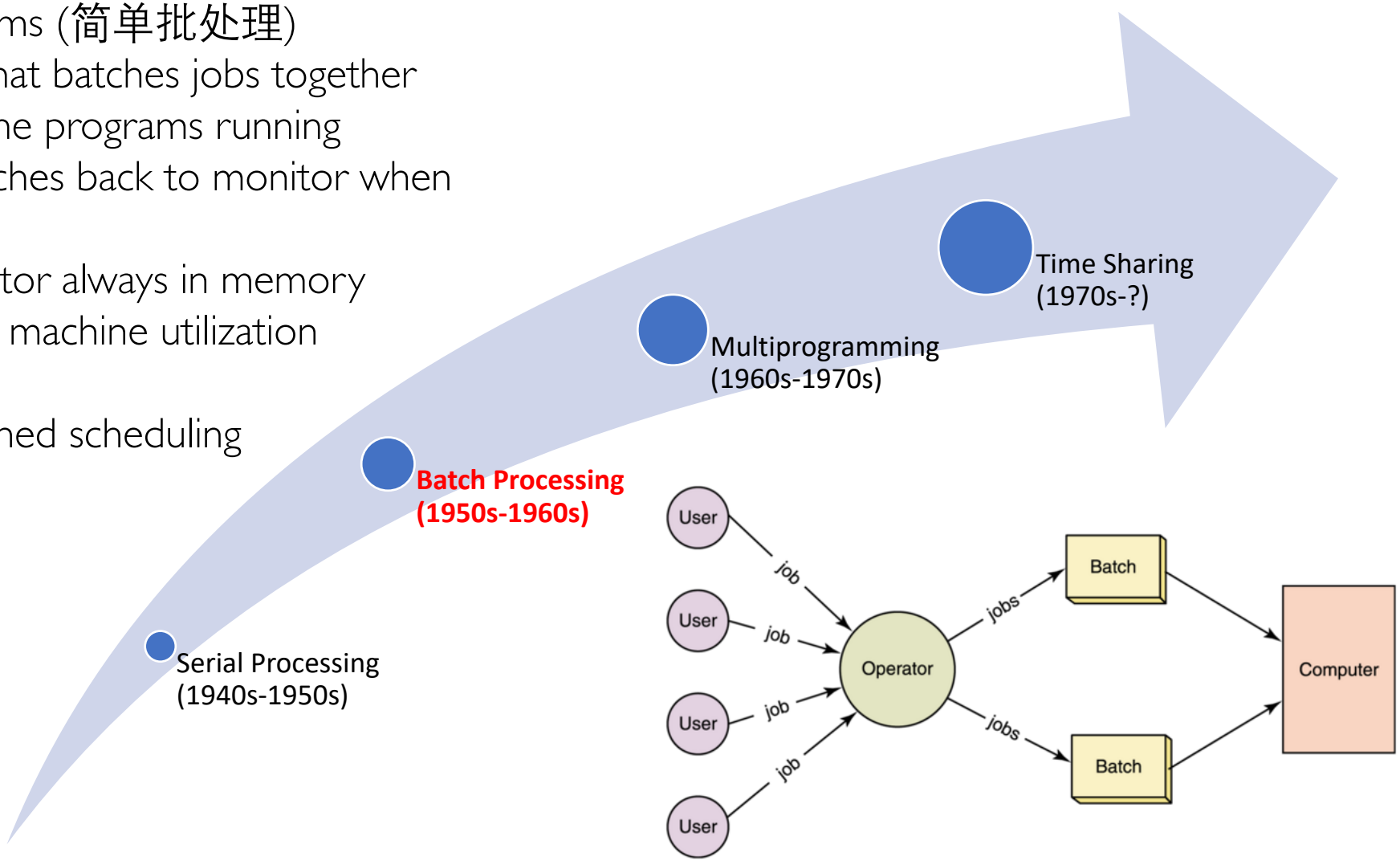
- No scheduling (调度)
- Huge setup time



OS history

- Simple Batch Systems (简单批处理)
  - A "monitor" that batches jobs together and controls the programs running
  - Program branches back to monitor when finished
  - (part of) Monitor always in memory
  - Maximizes the machine utilization

- Simple, coarse-grained scheduling
- Uniprogramming



OS history

- Multiprogrammed Batch Systems (多道批处理)
  - Processor can switch among different jobs when they are running (waiting for I/O)
  - Memory management, scheduling, save and restore
  - Optimized for job <u>throughput</u> (vs. speed)

- Not enough for user interactions

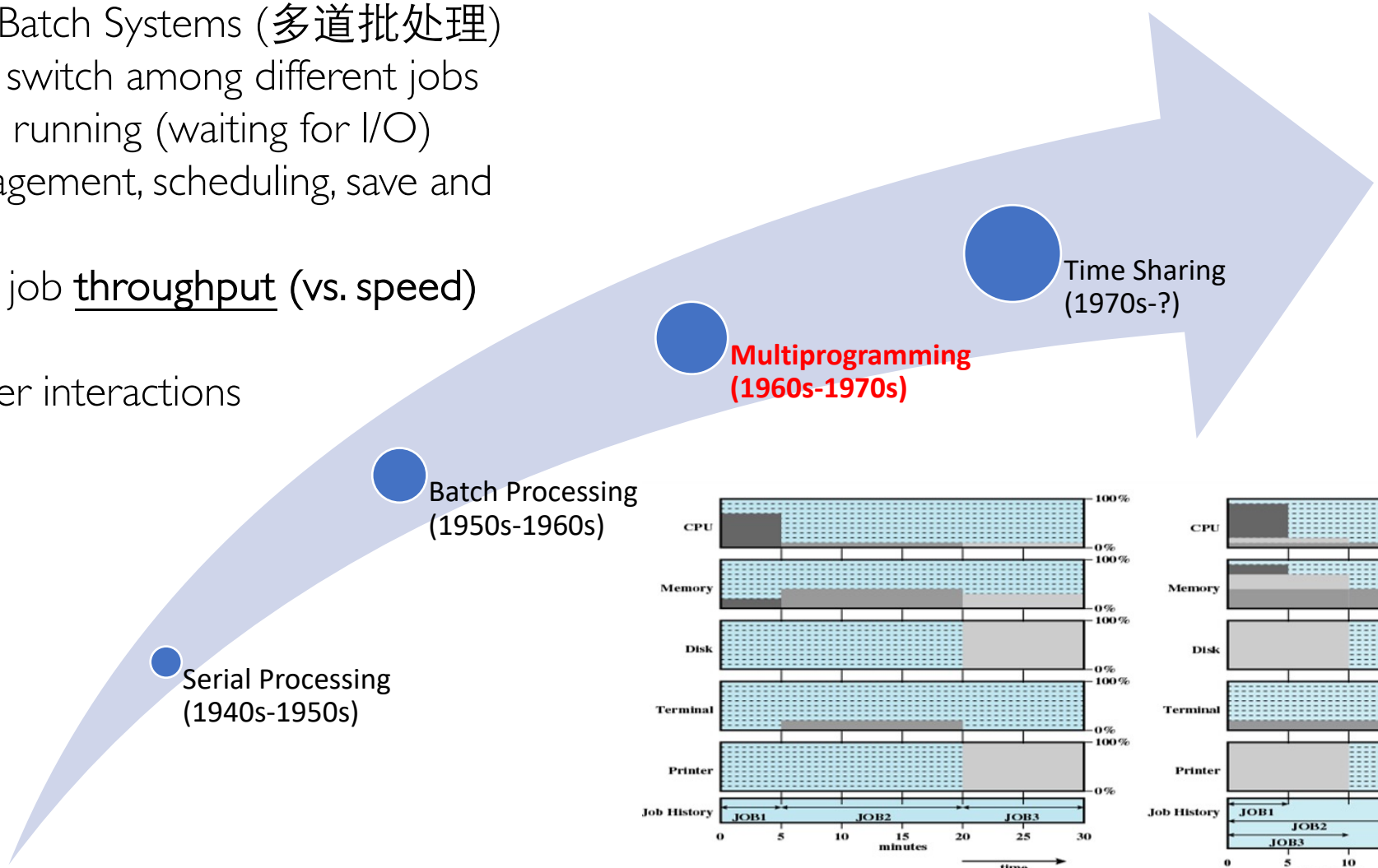
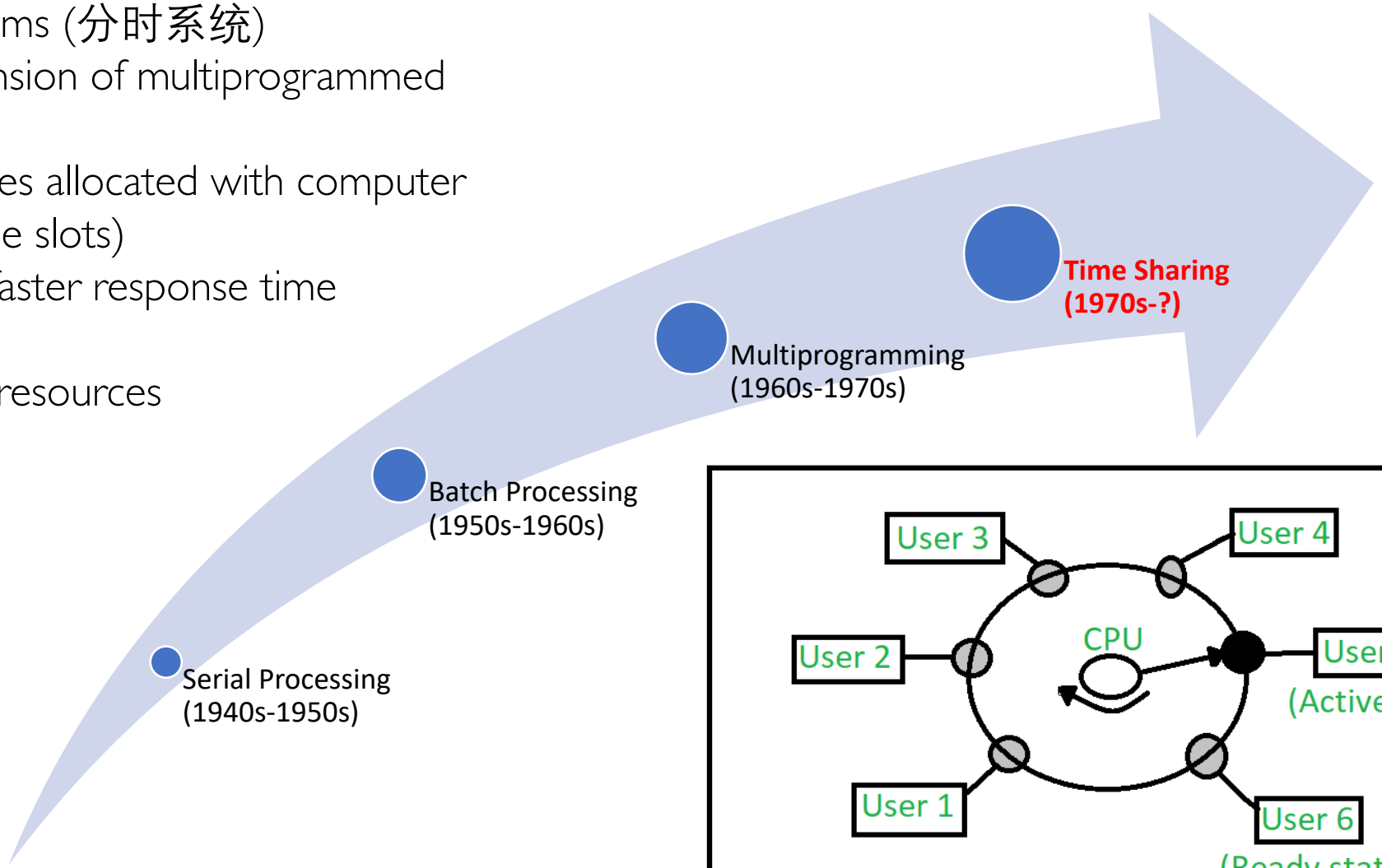


Figure 2.6 Utilization Histograms

OS history

- Time Sharing Systems (分时系统)
  - A logical extension of multiprogrammed systems
  - Users/processes allocated with computer resources (time slots)
  - Designed for faster response time

- It consumes many resources



Other OS types

- Real-time OS (实时操作系统)
  - vs. General-purpose OS (通用操作系统)
  - Used in robots, satellites, airplanes, etc..
- Distributed OS (分布式操作系统)
  - Could be atop traditional OS
  - C/S, P2P
- Microkernel
  - vs. Monolithic kernels
  - Small size: moving drivers, filesystems, etc to user space
  - Securer, but slower
  - Many OSes are hybrid (Mac OS)

Summary of OS Evolution

- Adapting to new hardware
  - Multi-core CPU, GPU, NPU, NVM, RDMA..
- Adapting to new workloads
  - Machine learning serving/training, distributed programs, AR/VR..
- Adapting to new user demands
  - Faster, more responsive, lower power..

- Hardware is cheaper, yet humans are more expensive
  - So OS (like many other software) trades off efficiency for usability

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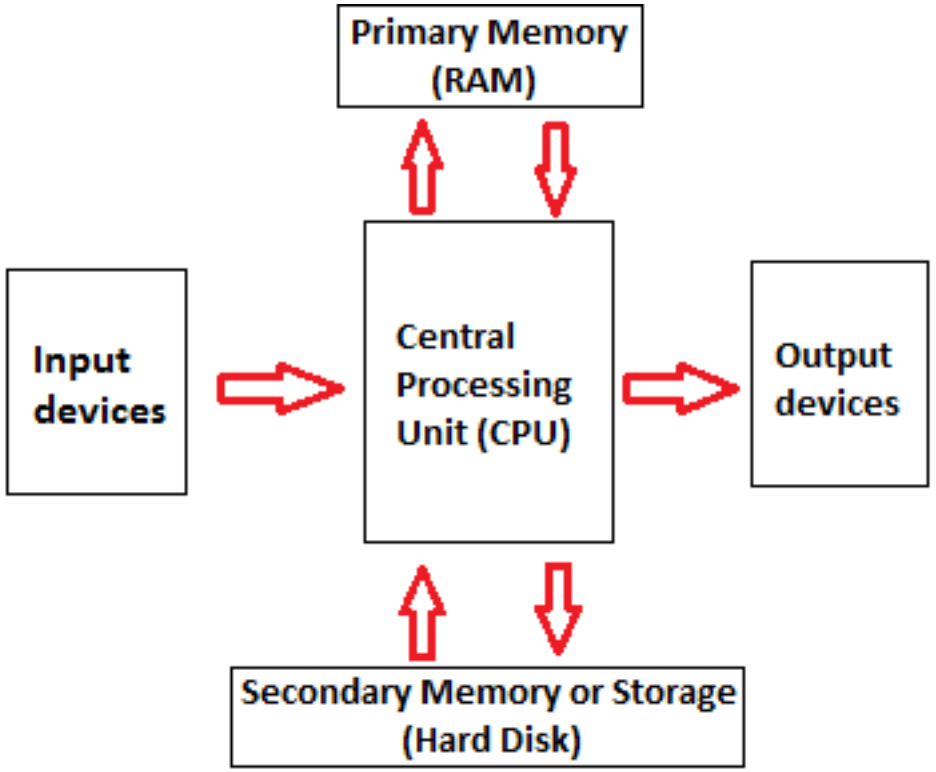
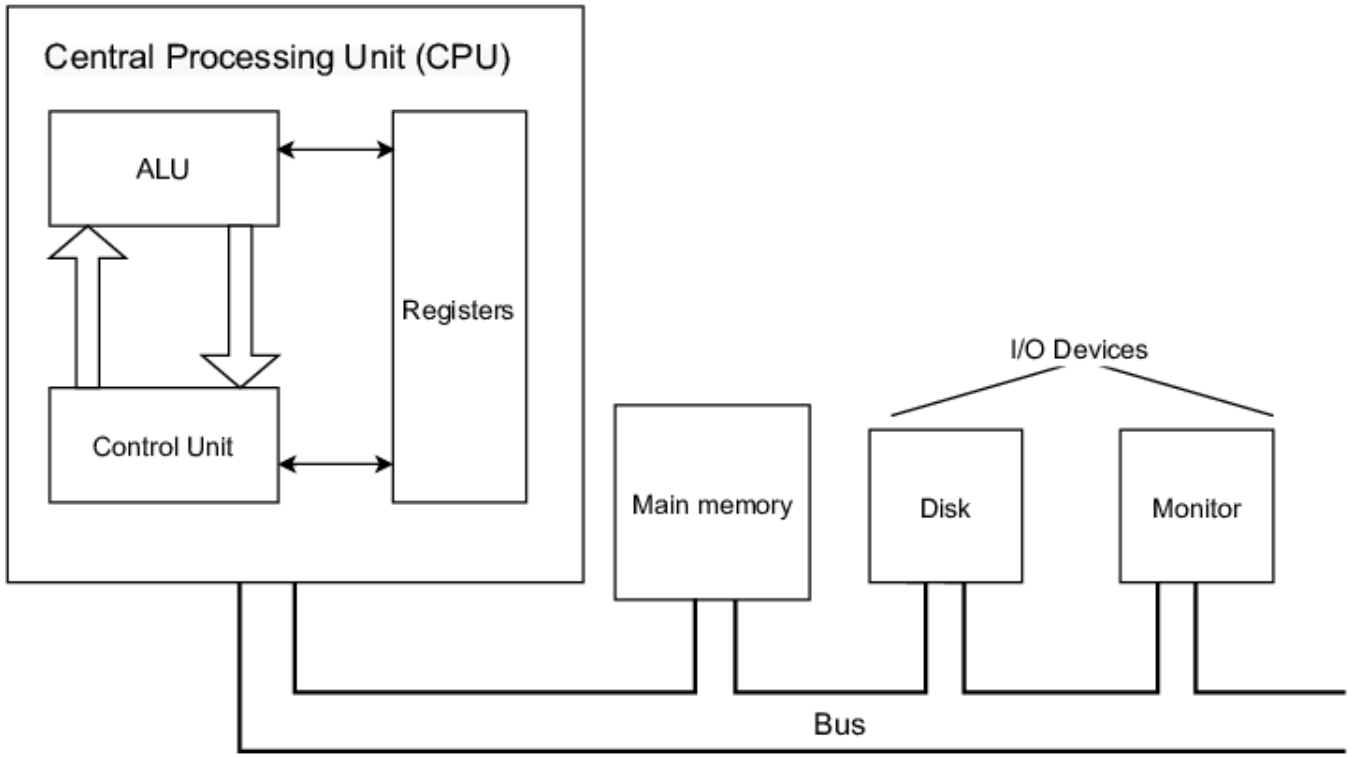
Computer Components

- CPU, Memory, Disk, Input devices, Output devices
  - This is a very rough understanding



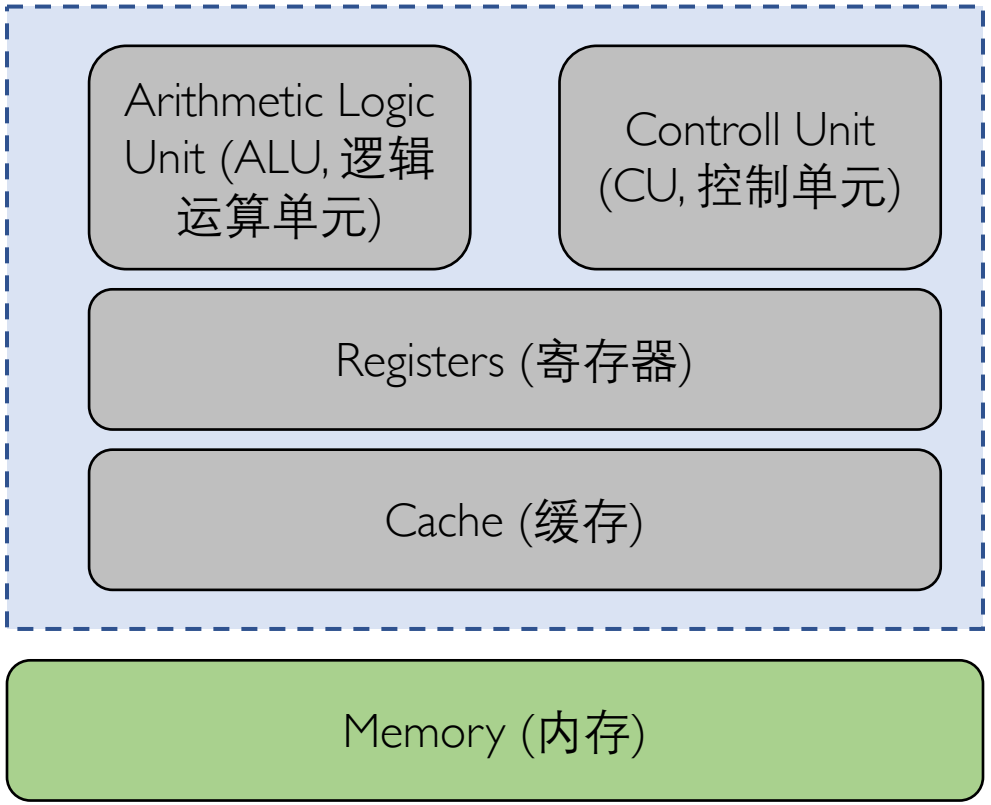
Computer Architecture

- Direct Memory Access (DMA, 直接存储器访问)
- CPU directly accesses data in cache and memory, but not disk.



CPU

- ALU operates on registers
- CU loads/saves data from/to memory



CPU

- In x86-64 CPUs, there are 16 64-bit general-purpose registers and many other special purpose registers

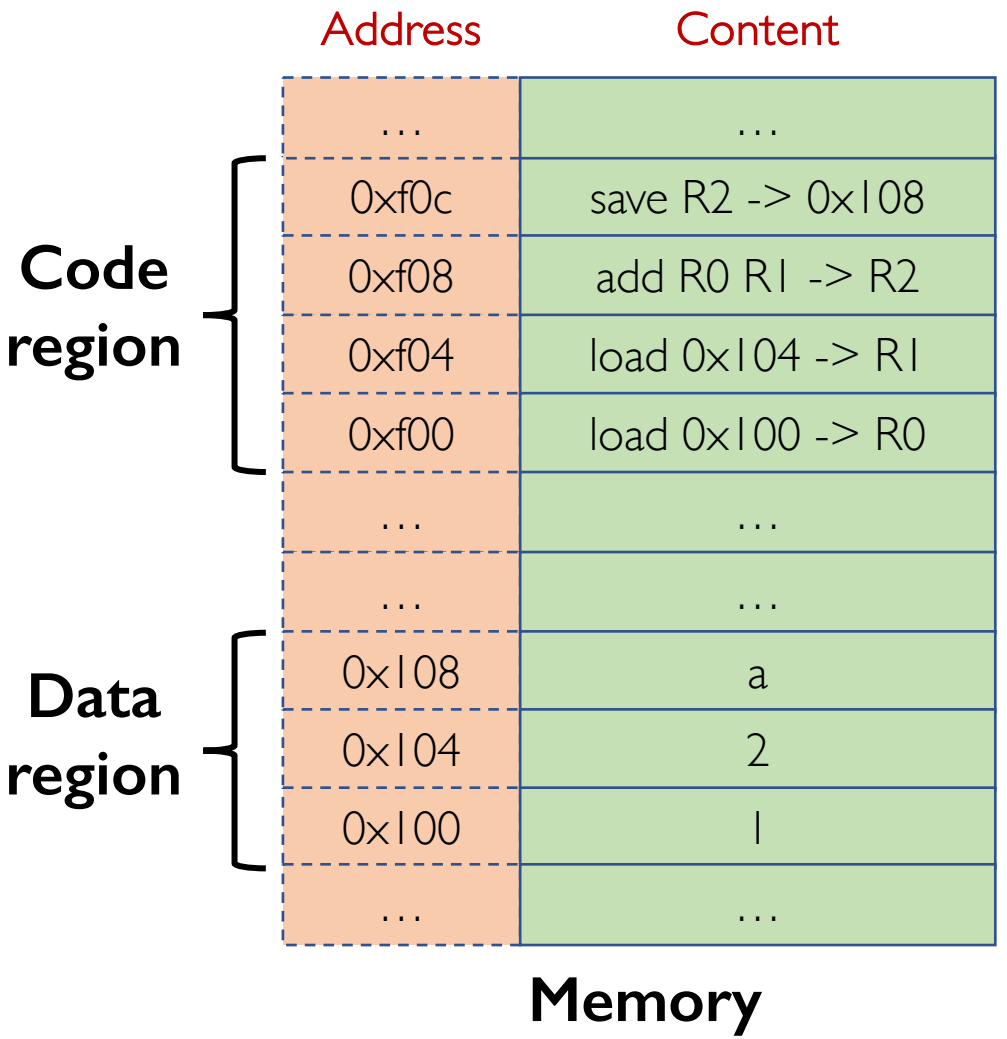
64-bit	32-bit	16-bit	8-bit (low)
RAX	EAX	AX	AL
RBX	EBX	BX	BL
RCX	ECX	CX	CL
RDX	EDX	DX	DL
RSI	ESI	SI	SIL
RDI	EDI	DI	DIL
RBP	EBP	BP	BPL
RSP	ESP	SP	SPL
R8	R8D	R8W	R8B
R9	R9D	R9W	R9B
R10	R10D	R10W	R10B
R11	R11D	R11W	R11B
R12	R12D	R12W	R12B
R13	R13D	R13W	R13B
R14	R14D	R14W	R14B
R15	R15D	R15W	R15B

- Instruction pointer (EIP/IP)
- Status register (RFLAGS)
- Segment registers (CS, SS, DS, ES, FS, GS)
- Control registers (CR0-CR15)
  - Last bit of CR0 indicates if CPU is in protected mode or real mode
  - 31st bit of CR0 indicates if paging is enabled
  - CR2 indicates the page fault address
- SIMD and FP registers (AVX..)
- Etc..

- Those special registers determine how CPU operates

CPU

- An example of "a=1+2"
  - Von Neumann architecture (冯诺依曼架构)
  - Program Counter (PC, 程序计数器)
    - Also known as instruction pointer (IP)
  - Assembly code (汇编程序)



CPU

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    - Also known as instruction pointer (IP)
  - Assembly code (汇编程序)

http://ref.x86asm.net/coder32.html

Instruction set for a Relatively Simple CPU

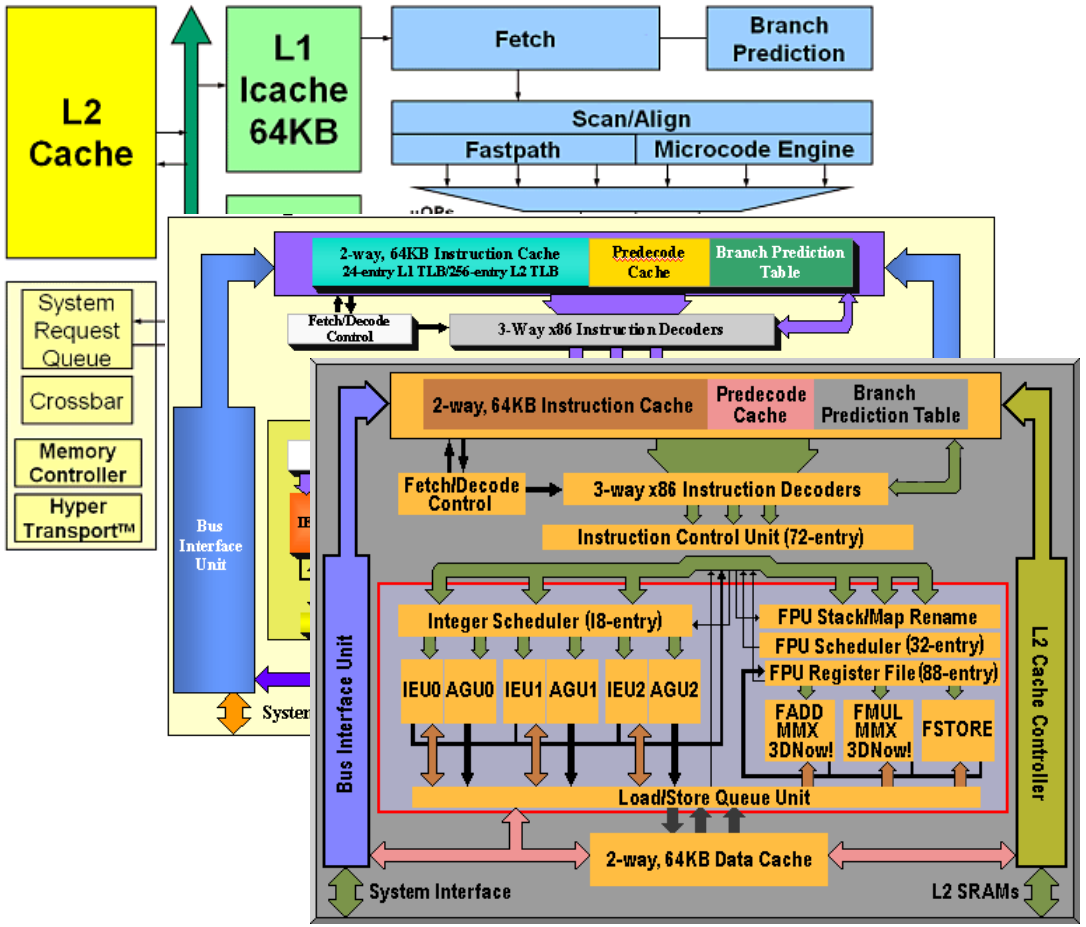
Instruction	Instruction Code	Operation
NOP	0000 0000	No operation
LDAC	0000 0001 Γ	*AC*←M[Γ]
STAC	0000 0010 Γ	M[Γ]←*AC*
MVAC	0000 0011	*R*←*AC*
MOVR	0000 0100	*AC*←*R*
JUMP	0000 0101 Γ	GOTO Γ
JMPZ	0000 0110 Γ	IF (Z=1) THEN GOTO Γ
JPNZ	0000 0111 Γ	IF (Z=0) THEN GOTO Γ
ADD	0000 1000	*AC*←*AC* + *R*, IF (*AC* + *R* = 0) THEN *Z*←1 ELSE *Z*←0
SUB	0000 1001	*AC*←*AC* − *R*, IF (*AC* − *R* = 0) THEN *Z*←1 ELSE *Z*←0
INAC	0000 1010	*AC*←*AC* + 1, IF (*AC* + 1 = 0) THEN *Z*←1 ELSE *Z*←0
CLAC	0000 1011	*AC*←0, *Z*←1
AND	0000 1100	*AC*←*AC* ∧ *R*, IF (*AC* ∧ *R* = 0) THEN *Z*←1 ELSE *Z*←0
OR	0000 1101	*AC*←*AC* ∨ *R*, IF (*AC* ∨ *R* = 0) THEN *Z*←1 ELSE *Z*←0
XOR	0000 1110	*AC*←*AC* ⊕ *R*, IF (*AC* ⊕ *R* = 0) THEN *Z*←1 ELSE *Z*←0
NOT	0000 1111	*AC*←*AC'*, IF (*AC'* = 0) THEN *Z*←1 ELSE *Z*←0

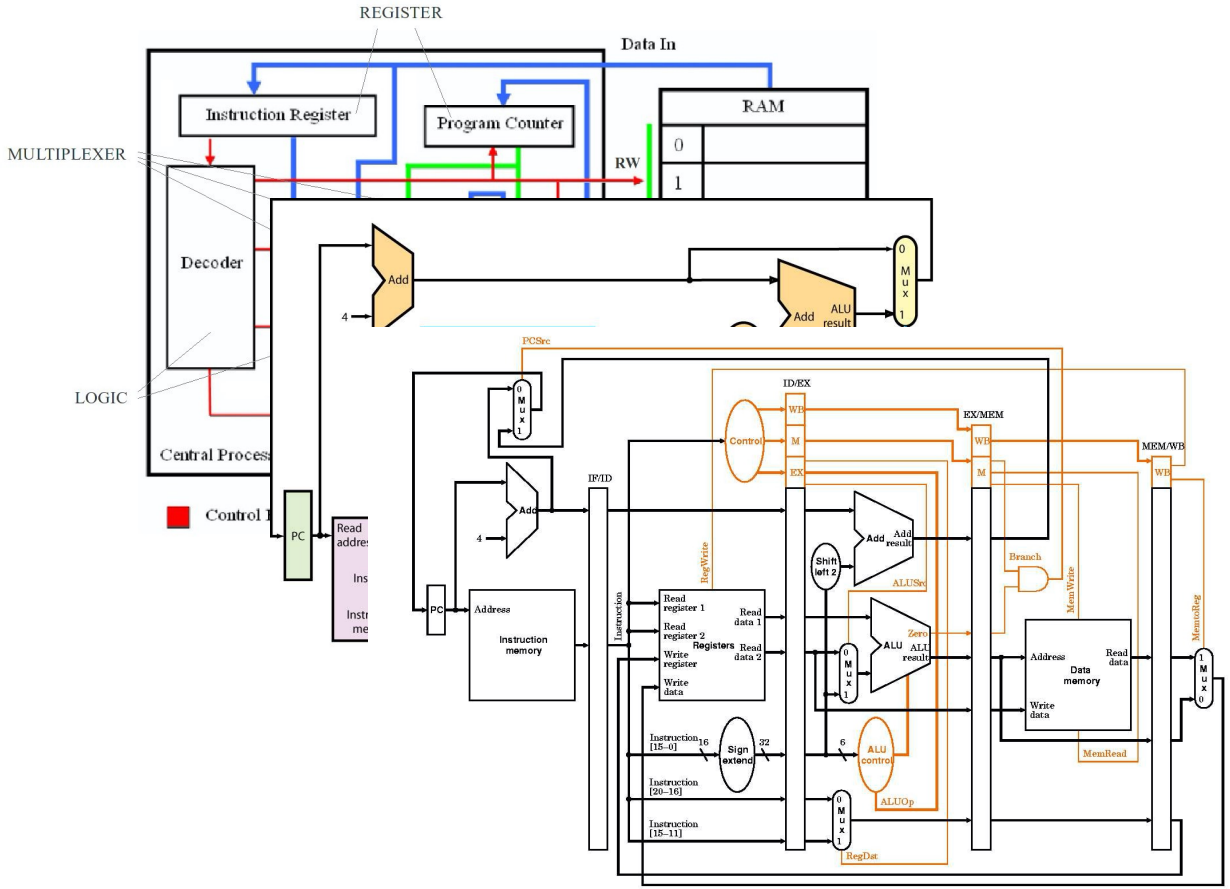
- How CPU understands (decodes) instructions?
  - Opcode (操作码), Operands (操作数)
  - Instruction Set Architecture (ISA, 指令集架构)
    - How many you know?

Opcode	Operands/Address
add	R0 R1 R2

CPU

- Internally, it's about circuit and very complex





CPU

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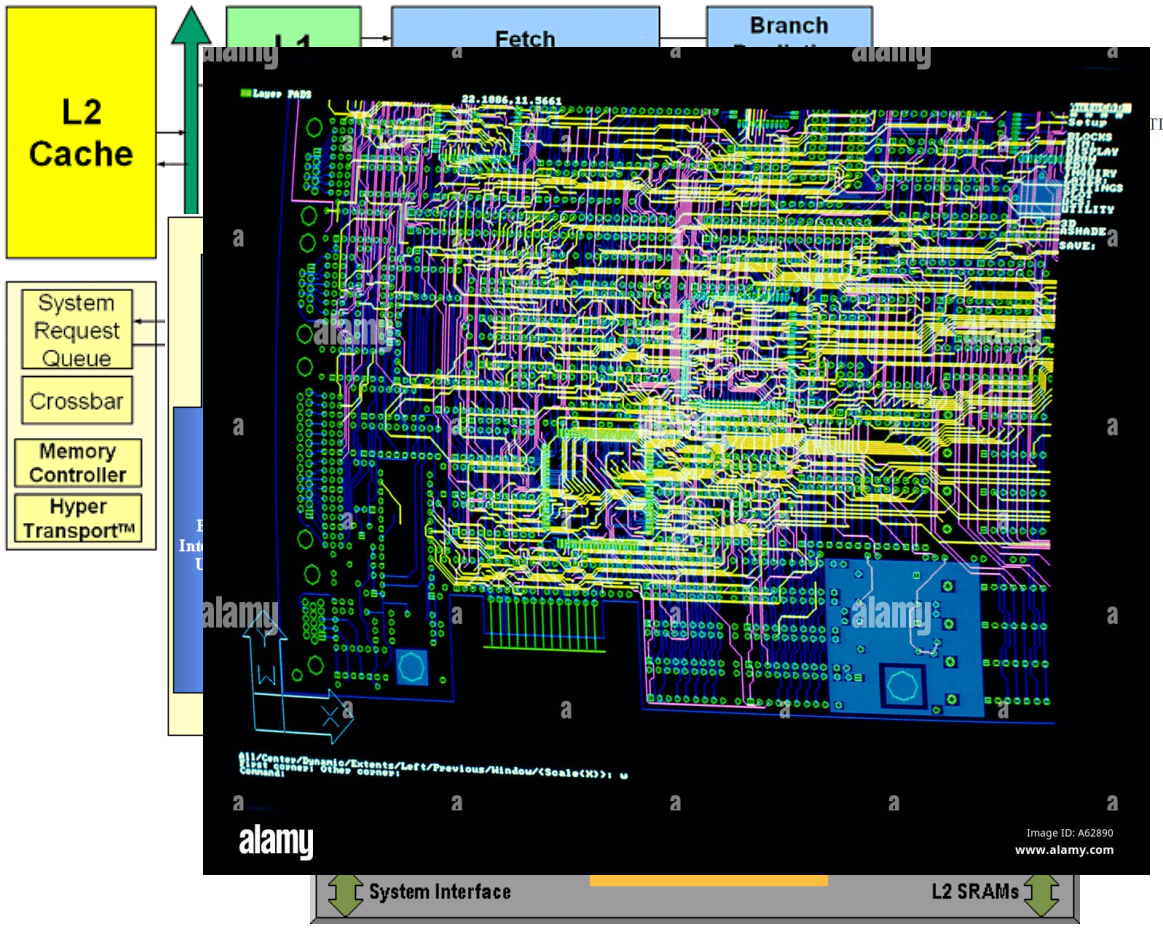
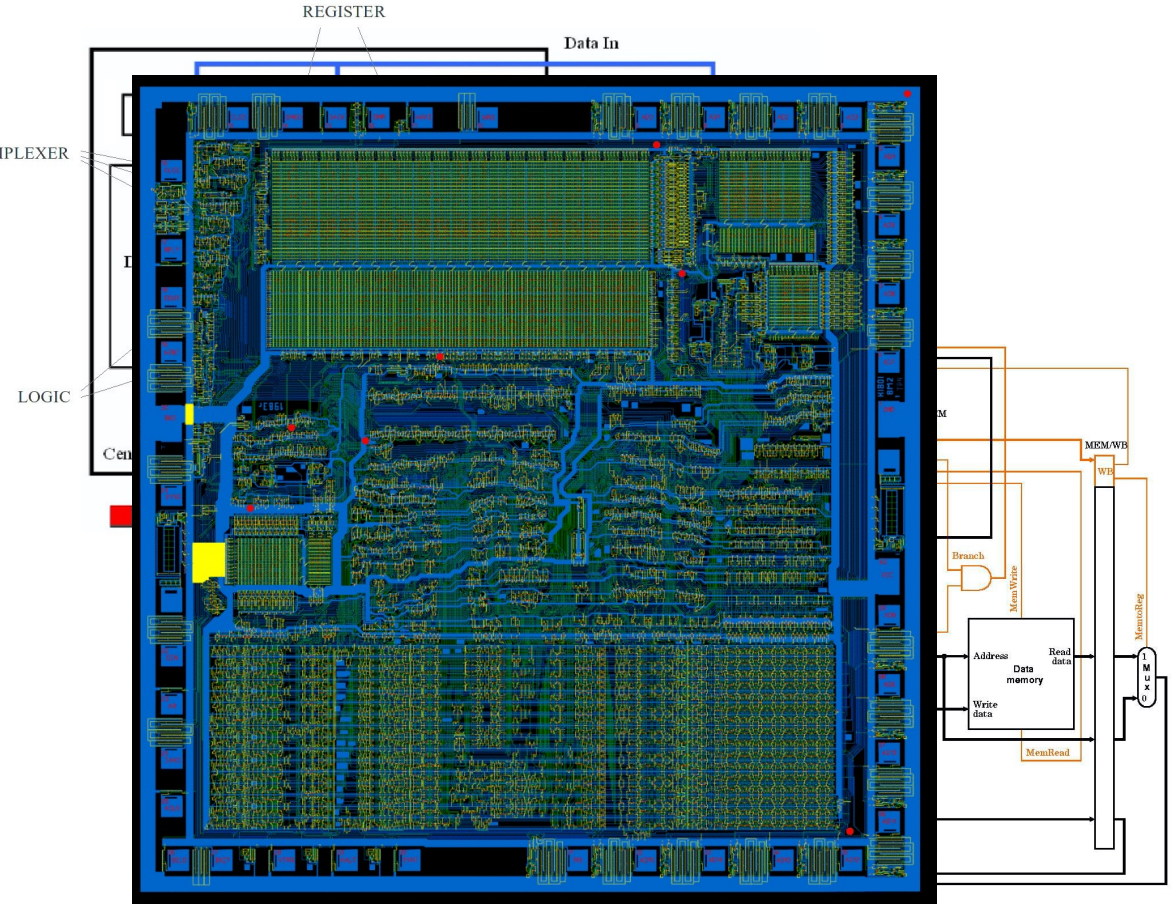
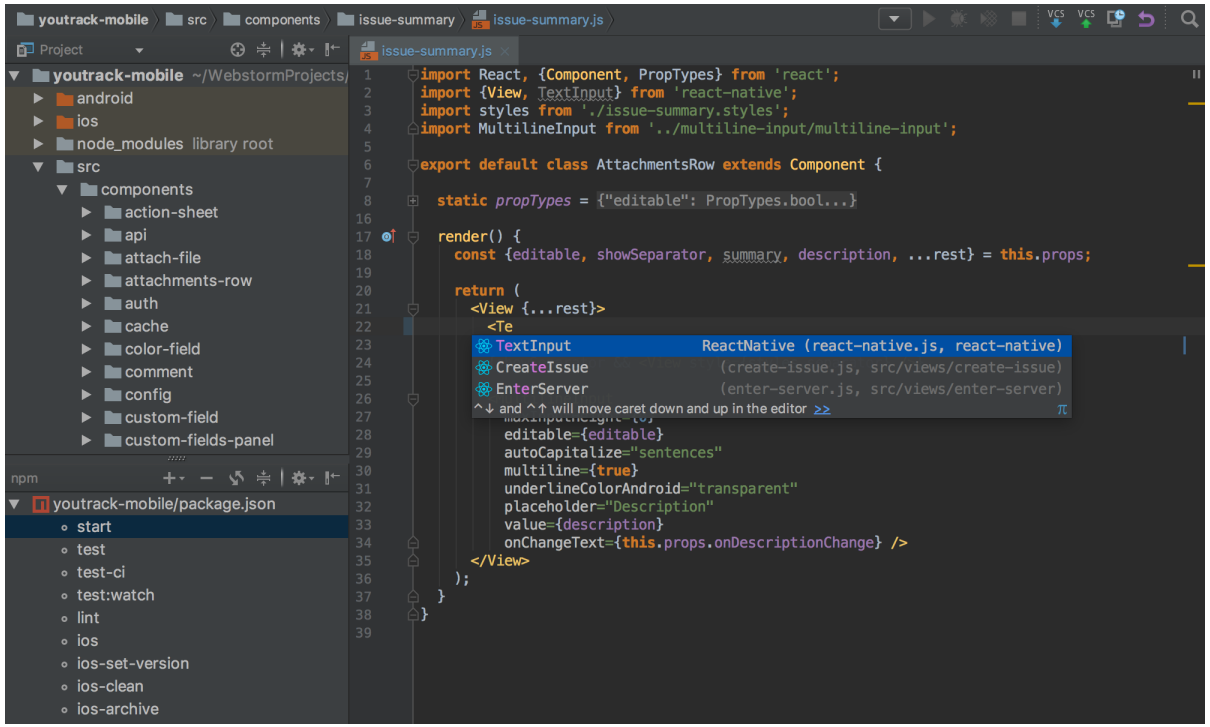




Lifetime of Hello World

1. Coded with PL and IDE
   - By developers
2. Compiled to assembly
   - By compilers like GCC/G++/LLVM
3. Linked to other libs
   - By linkers like ld
4. Loaded to memory
   - By OS
   - Allocated with memory at right position
5. Executed
   - By OS
   - See previous slide
6. Terminated
   - By OS with *return* command
   - Memory released



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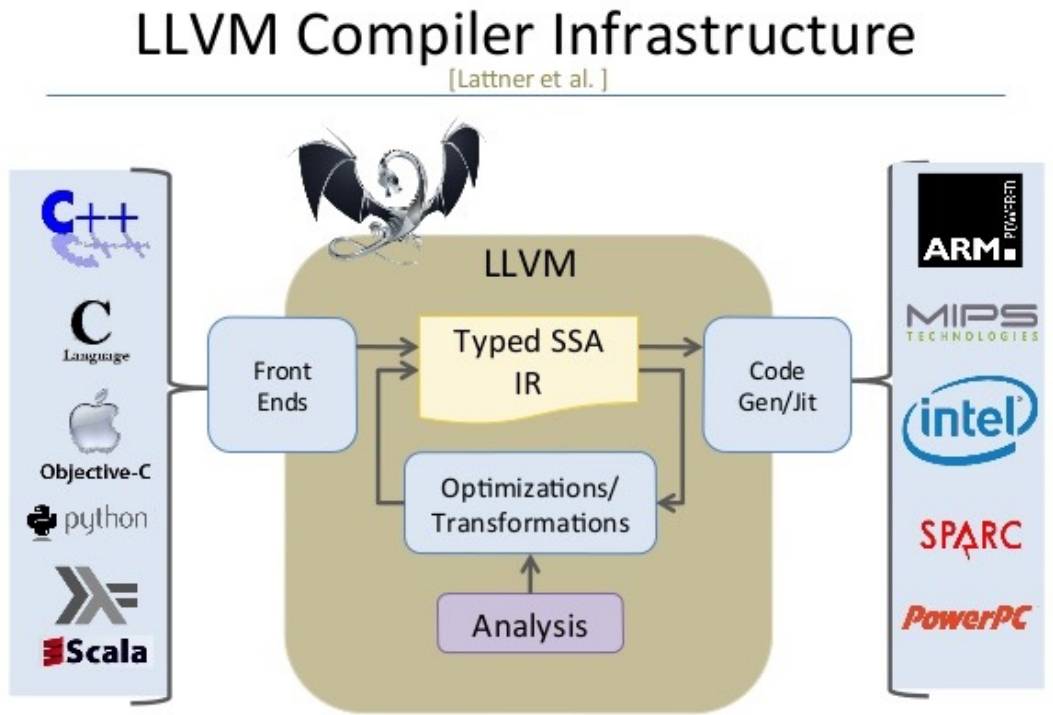

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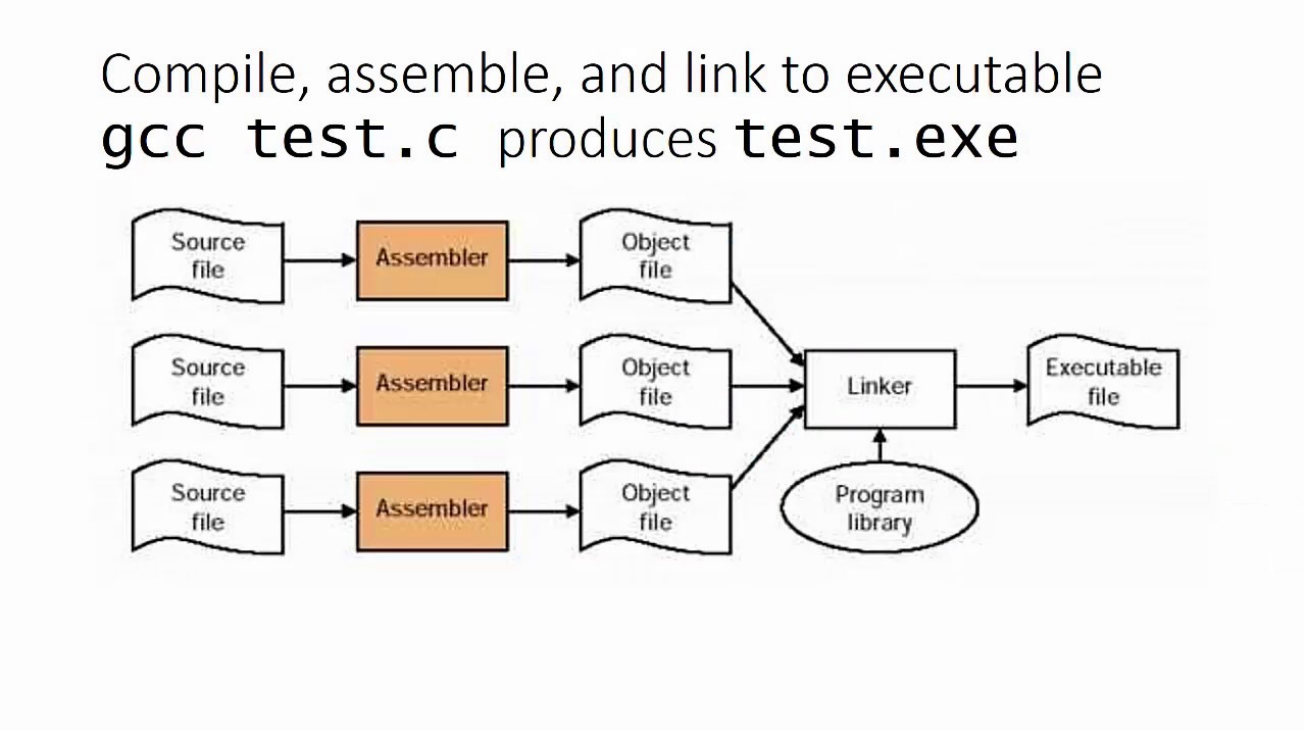

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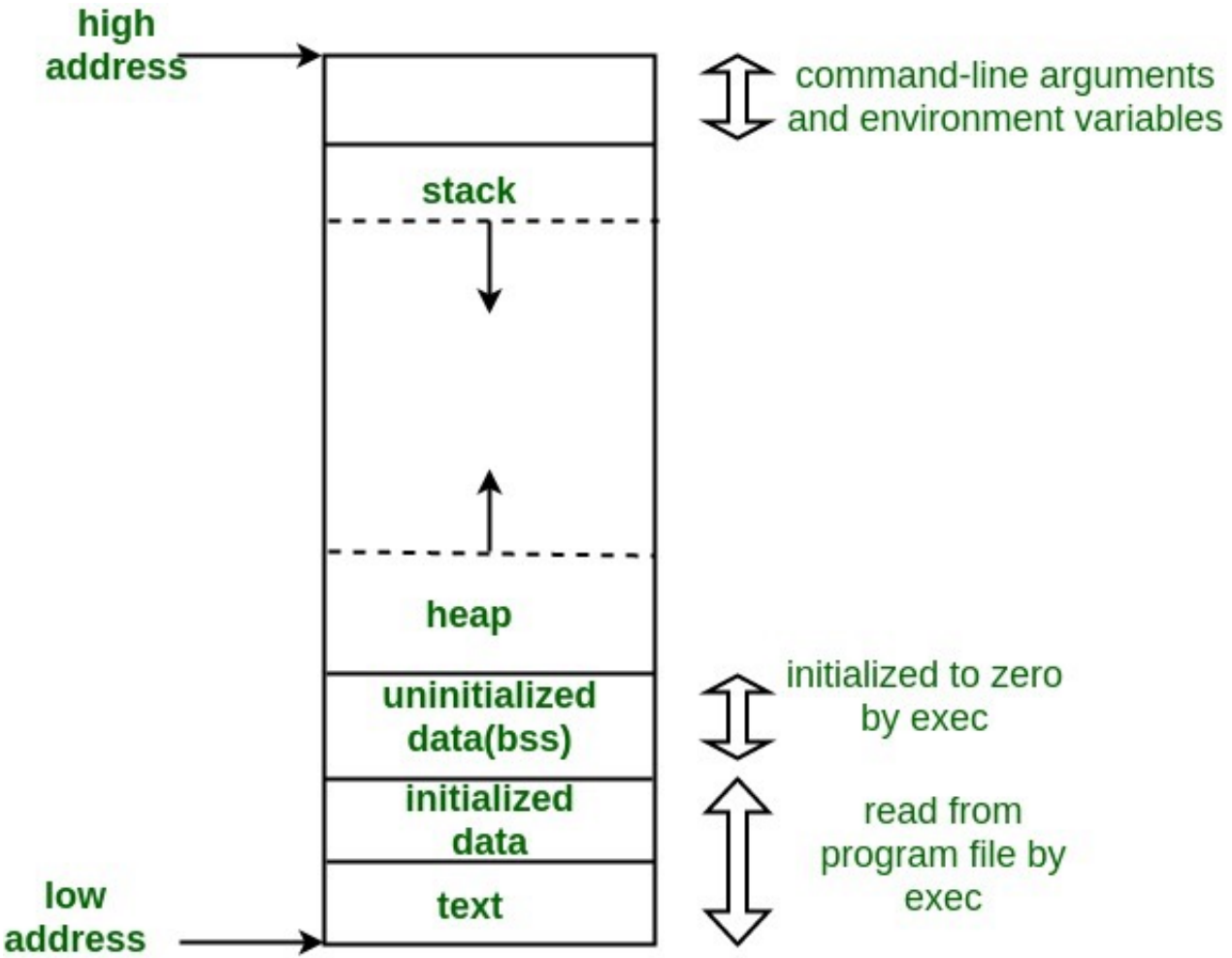
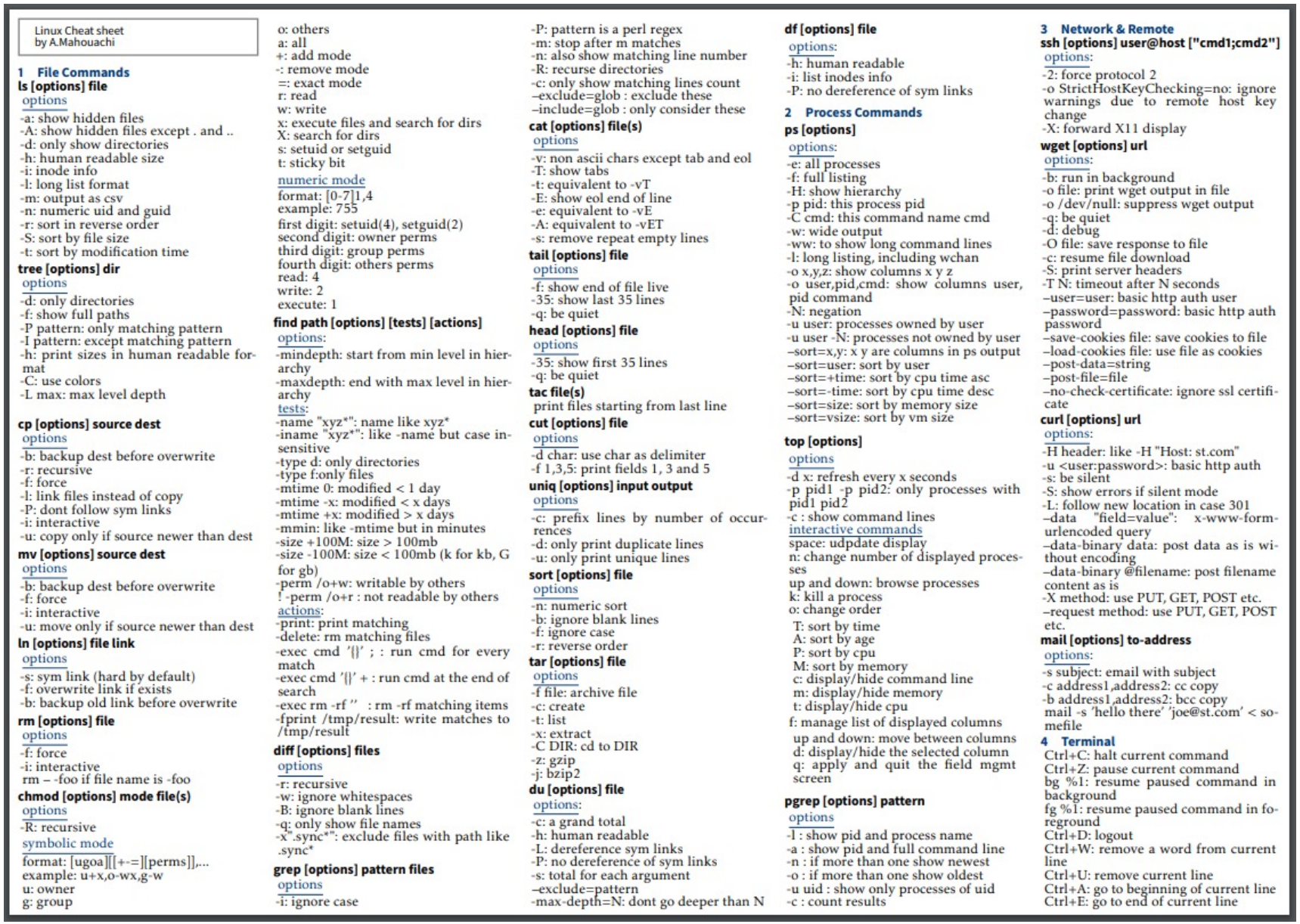


Linux Command-Line Interfaces



Linux Cheat sheet
by A.Mahouachi

1 File Commands

ls [options] file
options
-a: show hidden files
-A: show hidden files except . and ..
-d: only show directories
-h: human readable size
-i: inode info
-l: long list format
-m: output as csv
-n: numeric uid and guid
-r: sort in reverse order
-S: sort by file size
-t: sort by modification time

tree [options] dir
options
-d: only directories
-f: show full paths
-P pattern: only matching pattern
-I pattern: except matching pattern
-h: print sizes in human readable format
-C: use colors
-L max: max level depth

cp [options] source dest
options
-b: backup dest before overwrite
-r: recursive
-f: force
-l: link files instead of copy
-P: dont follow sym links
-i: interactive
-u: copy only if source newer than dest

mv [options] source dest
options
-b: backup dest before overwrite
-f: force
-i: interactive
-u: move only if source newer than dest

ln [options] file link
options
-s: sym link (hard by default)
-f: overwrite link if exists
-b: backup old link before overwrite

rm [options] file
options
-f: force
-i: interactive
rm – -foo if file name is -foo

chmod [options] mode file(s)
options
-R: recursive
symbolic mode
format: [ugoa][[+-=][perms]],...
example: u+x,o-wx,g-w
u: owner
g: group
o: others
a: all
+: add mode
-: remove mode
=: exact mode
r: read
w: write
x: execute files and search for dirs
X: search for dirs
s: setuid or setguid
t: sticky bit
numeric mode
format: [0-7]1,4
example: 755
first digit: setuid(4), setguid(2)
second digit: owner perms
third digit: group perms
fourth digit: others perms
read: 4
write: 2
execute: 1

find path [options] [tests] [actions]
options:
-mindepth: start from min level in hierarchy
-maxdepth: end with max level in hierarchy
tests:
-name "xyz*": name like xyz*
-iname "xyz*": like -name but case insensitive
-type d: only directories
-type f:only files
-mtime 0: modified < 1 day
-mtime -x: modified < x days
-mtime +x: modified > x days
-mmin: like -mtime but in minutes
-size +100M: size > 100mb
-size -100M: size < 100mb (k for kb, G for gb)
-perm /o+w: writable by others
! -perm /o+r : not readable by others
actions:
-print: print matching
-delete: rm matching files
-exec cmd '{}' ; : run cmd for every match
-exec cmd '{}' + : run cmd at the end of search
-exec rm -rf '' : rm -rf matching items
-fprint /tmp/result: write matches to /tmp/result

diff [options] files
options
-r: recursive
-w: ignore whitespaces
-B: ignore blank lines
-q: only show file names
-x".sync*": exclude files with path like .sync*

grep [options] pattern files
options
-i: ignore case
-P: pattern is a perl regex
-m: stop after m matches
-n: also show matching line number
-R: recurse directories
-c: only show matching lines count
–exclude=glob : exclude these
–include=glob : only consider these

cat [options] file(s)
options
-v: non ascii chars except tab and eol
-T: show tabs
-t: equivalent to -vT
-E: show eol end of line
-e: equivalent to -vE
-A: equivalent to -vET
-s: remove repeat empty lines

tail [options] file
options
-f: show end of file live
-35: show last 35 lines
-q: be quiet

head [options] file
options
-35: show first 35 lines
-q: be quiet

tac file(s)
print files starting from last line

cut [options] file
options
-d char: use char as delimiter
-f 1,3,5: print fields 1, 3 and 5

uniq [options] input output
options
-c: prefix lines by number of occurrences
-d: only print duplicate lines
-u: only print unique lines

sort [options] file
options
-n: numeric sort
-b: ignore blank lines
-f: ignore case
-r: reverse order

tar [options] file
options
-f file: archive file
-c: create
-t: list
-x: extract
-C DIR: cd to DIR
-z: gzip
-j: bzip2

du [options] file
options:
-c: a grand total
-h: human readable
-L: dereference sym links
-P: no dereference of sym links
-s: total for each argument
–exclude=pattern
-max-depth=N: dont go deeper than N

df [options] file
options:
-h: human readable
-i: list inodes info
-P: no dereference of sym links

2 Process Commands

ps [options]
options:
-e: all processes
-f: full listing
-H: show hierarchy
-p pid: this process pid
-C cmd: this command name cmd
-w: wide output
-ww: to show long command lines
-l: long listing, including wchan
-o x,y,z: show columns x y z
-o user,pid,cmd: show columns user, pid command
-N: negation
-u user: processes owned by user
-u user -N: processes not owned by user
–sort=x,y: x y are columns in ps output
–sort=user: sort by user
–sort=+time: sort by cpu time asc
–sort=-time: sort by cpu time desc
–sort=size: sort by memory size
–sort=vsize: sort by vm size

top [options]
options
-d x: refresh every x seconds
-p pid1 -p pid2: only processes with pid1 pid2
-c : show command lines
interactive commands
space: udpdate display
n: change number of displayed processes
up and down: browse processes
k: kill a process
o: change order
T: sort by time
A: sort by age
P: sort by cpu
M: sort by memory
c: display/hide command line
m: display/hide memory
t: display/hide cpu
f: manage list of displayed columns
up and down: move between columns
d: display/hide the selected column
q: apply and quit the field mgmt screen

pgrep [options] pattern
options
-l : show pid and process name
-a : show pid and full command line
-n : if more than one show newest
-o : if more than one show oldest
-u uid : show only processes of uid
-c : count results

3 Network & Remote

ssh [options] user@host ["cmd1;cmd2"]
options:
-2: force protocol 2
-o StrictHostKeyChecking=no: ignore warnings due to remote host key change
-X: forward X11 display

wget [options] url
options:
-b: run in background
-o file: print wget output in file
-o /dev/null: suppress wget output
-q: be quiet
-d: debug
-O file: save response to file
-c: resume file download
-S: print server headers
-T N: timeout after N seconds
–user=user: basic http auth user
–password=password: basic http auth password
–save-cookies file: save cookies to file
–load-cookies file: use file as cookies
–post-data=string
–post-file=file
–no-check-certificate: ignore ssl certificate

curl [options] url
options:
-H header: like -H "Host: st.com"
-u <user:password>: basic http auth
-s: be silent
-S: show errors if silent mode
-L: follow new location in case 301
–data "field=value": x-www-form-urlencoded query
–data-binary data: post data as is without encoding
–data-binary @filename: post filename content as is
-X method: use PUT, GET, POST etc.
–request method: use PUT, GET, POST etc.

mail [options] to-address
options:
-s subject: email with subject
-c address1,address2: cc copy
-b address1,address2: bcc copy
mail -s 'hello there' 'joe@st.com' < somefile

4 Terminal

Ctrl+C: halt current command
Ctrl+Z: pause current command
bg %1: resume paused command in background
fg %1: resume paused command in foreground
Ctrl+D: logout
Ctrl+W: remove a word from current line
Ctrl+U: remove current line
Ctrl+A: go to beginning of current line
Ctrl+E: go to end of current line

```
the command "help"

help gives you information about
commands that comes with T-UI. click
on the input area on the bottom of
the screen and type "help".

$ help

A
about airplane alias aliasfile apps
B
...


"help" has also an other important
feature: it works like Linux's man,
therefore it tells you how to use a
command. For example:

$ help search

will prints this:

Search something somewhere
Usage:
search [option] something

[option] can be:
-g -> (Google Search)
-p -> (Google Play Store)
-f -> (Files)
-y -> (YouTube)

Example:
>>search -p T-UI


      <--              -->
```

Linux Command-Line Interfaces

- CLI vs GUI (graphical user interface)

Graphical User Interface (GUI)

- Most common interface
  - Windows, OS X, some versions of Linux and Unix
- Frees you from memorizing and typing text commands
- Uses a mouse to control objects
- Shortcuts open programs or documents

Command Line Interface

- Older interface
  - DOS, Linux, UNIX
- With a command-line interface, a user uses the keyboard to enter data and instructions
- User types commands at a prompt
- User must remember all commands
- Included in all GUIs

Linux Command-Line Interfaces

- Can large language models (LLMs) help?

convert the following instruction to linux command line instructions: move the file named "XX.cpp" to my home folder, change its permission to executable, and execute it with output dumped to YY.out

To accomplish the stated tasks, you can use the following Linux command line instructions:

1. **Move the file "XX.cpp" to your home folder**: Assuming you are in the directory containing "XX.cpp", you can use the `mv` command to move it to your home folder.

```bash
mv XX.cpp ~/
```

2. **Change its permission to executable**: Once the file is in your home directory, you can change its permissions to make it executable using the `chmod` command.

```bash
chmod +x ~/XX.cpp
```

3. **Execute it with output dumped to "YY.out"**: You can execute the file and redirect its output to a file named "YY.out" in your home directory using the following command:

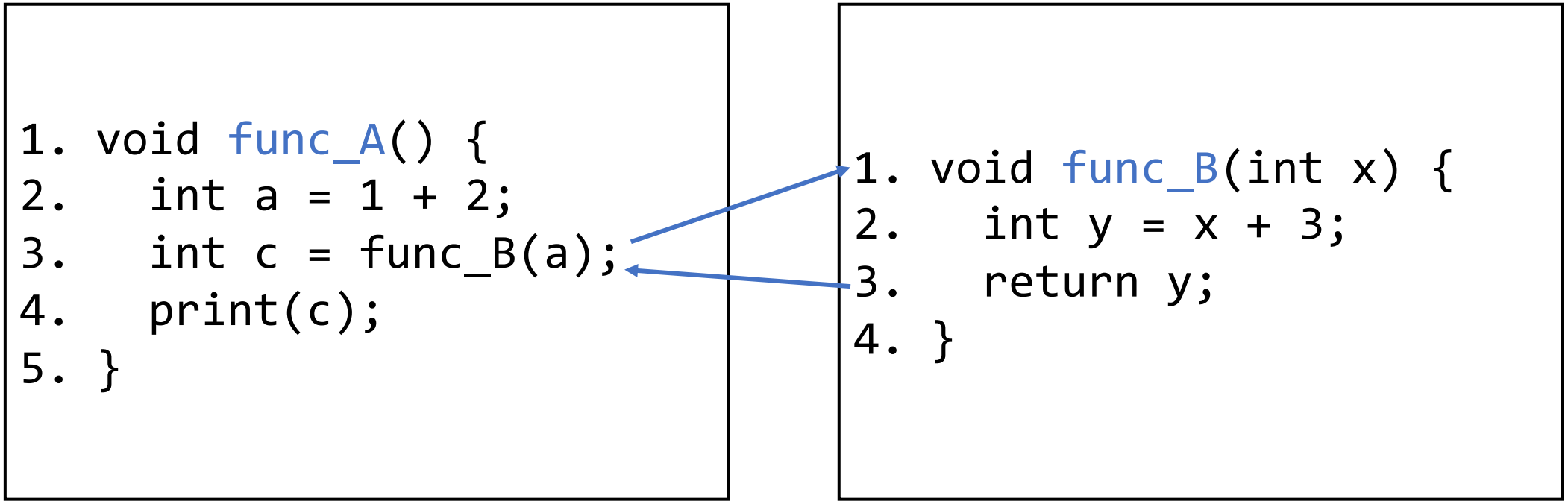
```bash
~/XX.cpp > ~/YY.out
```

Putting it all together, you can run these commands one after another in the same terminal session:

```bash
mv XX.cpp ~/
chmod +x ~/XX.cpp
~/XX.cpp > ~/YY.out
```

This sequence of commands will move the file "XX.cpp" to your home folder, make it executable, and then execute it, redirecting the output to a file named "YY.out" in your home directory.

Calling Conventions



- How does func_A goes to func_B?
- How does func_B return correctly back to func_A?

} stack

Search for “calling conventions” and try to understand what happens at assembly/instruction level

Misc

- Many OS features need architecture support
- Byte, bit, word
- C/C++ pointers

Homework

- The first homework – using large language models (LLMs) to build a command line tool helper
  - DDL: two weeks before the last course
  - Local LLMs (LLaMA 2) or remote (ChatGPT or 豆包), you chose
  - Add if-else if needed
  - Chinese support is cool and useful!
  - Test with a clean environment (VM, docker) so it won't mess up your computers

- Submission: code + detailed documents + testing results
  - The best ones will be demonstrated in the last course
  - Don't copy from other projects!