Lecture Note 1.
What is System Programming

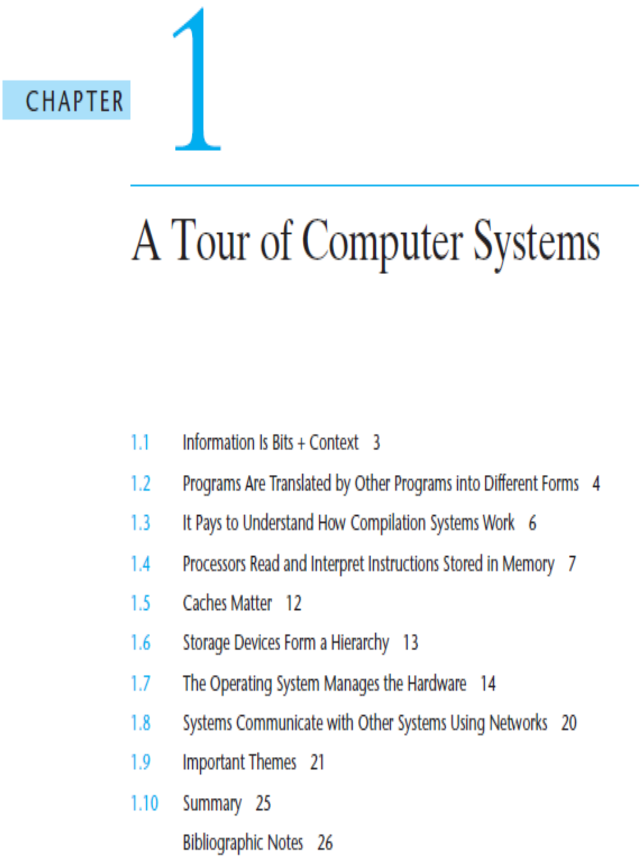
September 6, 2023

Jongmoo Choi
Dept. of Software
Dankook University
http://embedded.dankook.ac.kr/~choijm

Contents

- Understand what is system program
- Identify three types of system program
  - ✓ Compilation system
  - ✓ Operating system
  - ✓ Runtime system
- Discuss Hardware consideration
- Grasp the abstraction concept

- Reference: Chapter 1 in the CSAPP



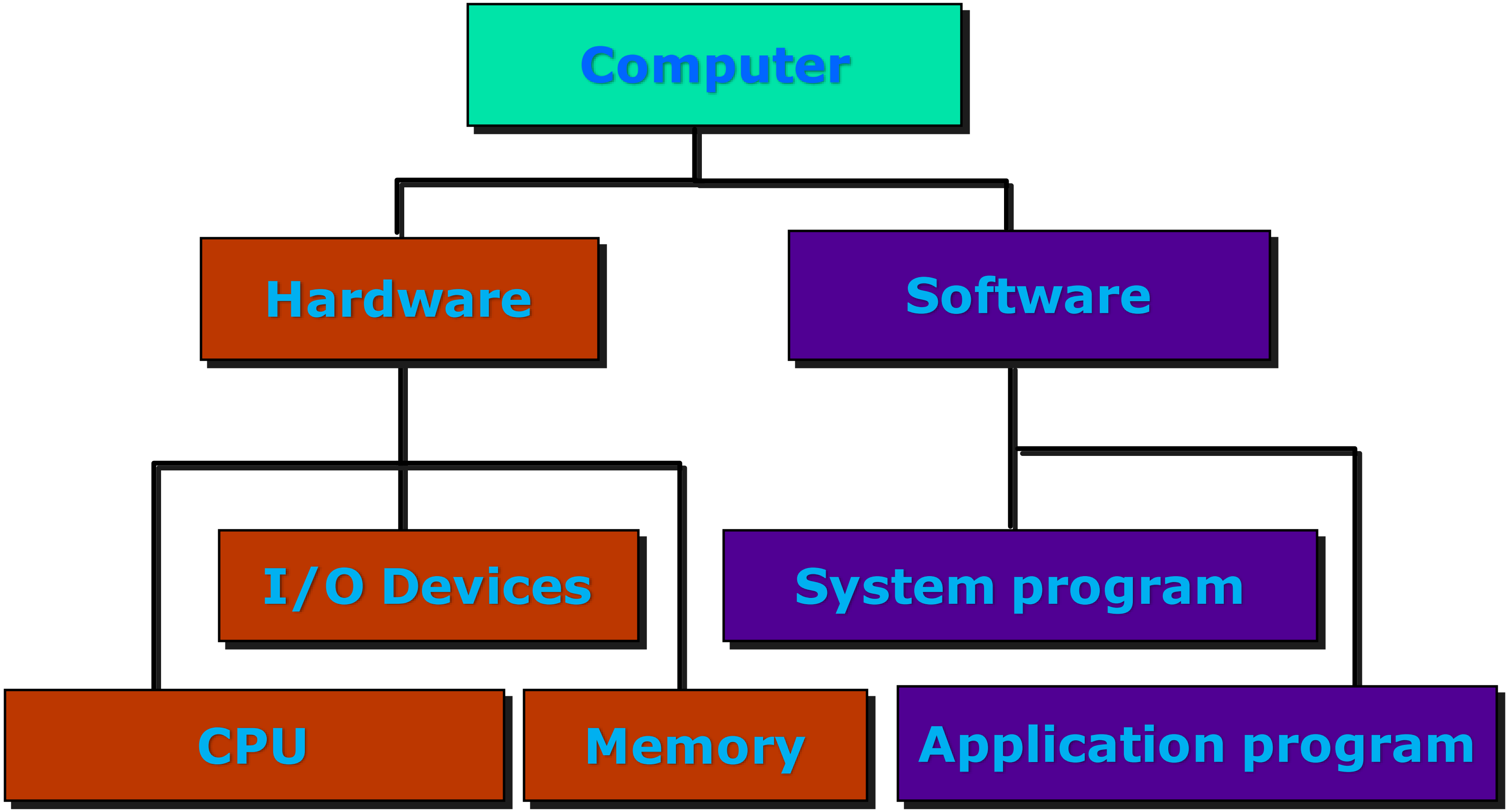
CHAPTER 1

A Tour of Computer Systems

(Source: CSAPP)

Definition of System Program (1/8)

- Computer organization



Computer

Hardware

Software

I/O Devices

System program

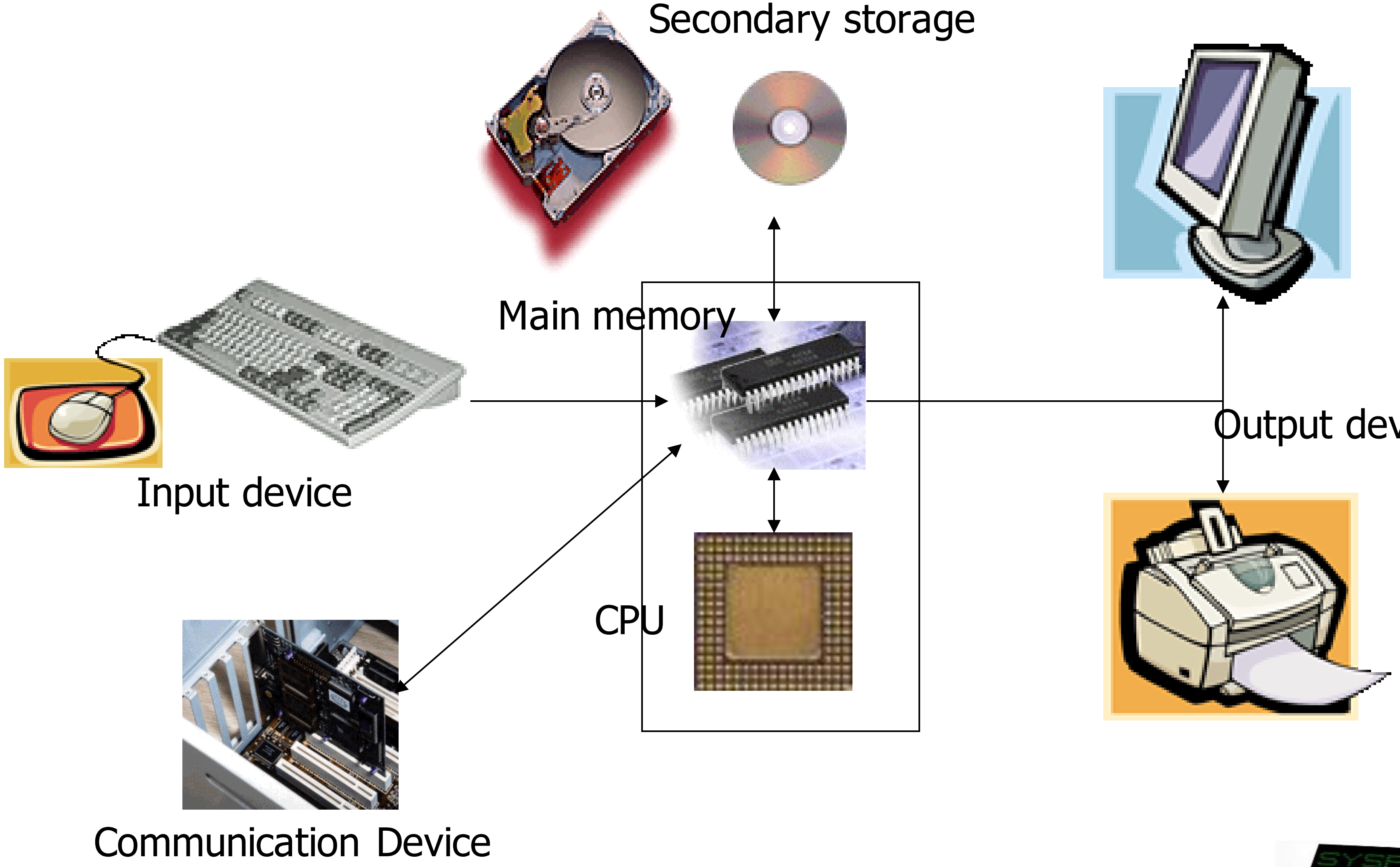
CPU

Memory

Application program

Definition of System Program (2/8)

- Hardware components: PC



Definition of System Program (3/8)

- Hardware components: DRAM vs. Disk
  - ✓ 1. Speed vs. Capacity
    - Memory Hierarchy
  - ✓ 2. Volatility: Volatile vs. Non-volatile
    - Need to write data into disk explicitly for persistency (file I/O)
  - ✓ 3. Interface: Byte-unit interface vs. Sector-unit interface
    - Need to load a program from disk to RAM before execution (loading)

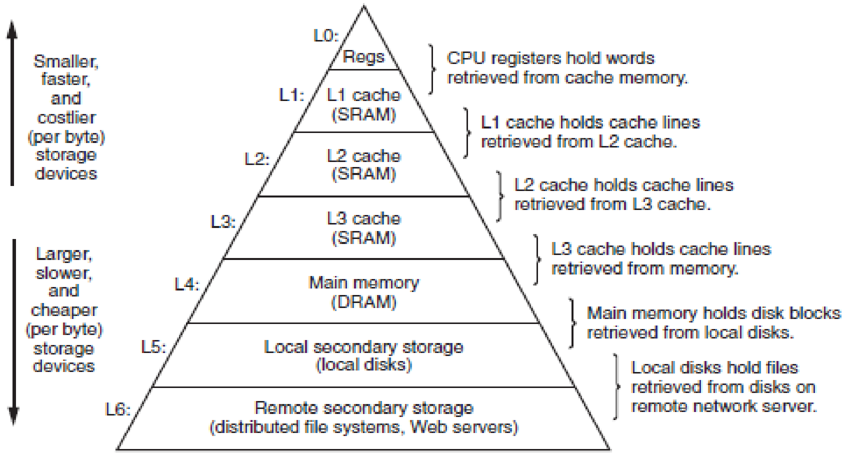
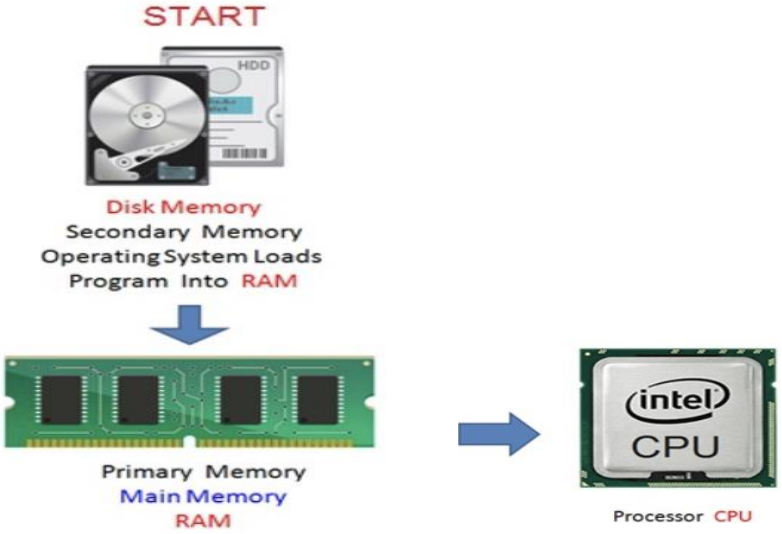

Smaller, faster, and costlier (per byte) storage devices
Larger, slower, and cheaper (per byte) storage devices
L0:
Regs
L1:
L1 cache (SRAM)
L2:
L2 cache (SRAM)
L3:
L3 cache (SRAM)
L4:
Main memory (DRAM)
L5:
Local secondary storage (local disks)
L6:
Remote secondary storage (distributed file systems, Web servers)
CPU registers hold words retrieved from cache memory.
L1 cache holds cache lines retrieved from L2 cache.
L2 cache holds cache lines retrieved from L3 cache.
L3 cache holds cache lines retrieved from memory.
Main memory holds disk blocks retrieved from local disks.
Local disks hold files retrieved from disks on remote network server.

Figure 1.9 An example of a memory hierarchy.

(Source: CSAPP)



(Source: Google Image)

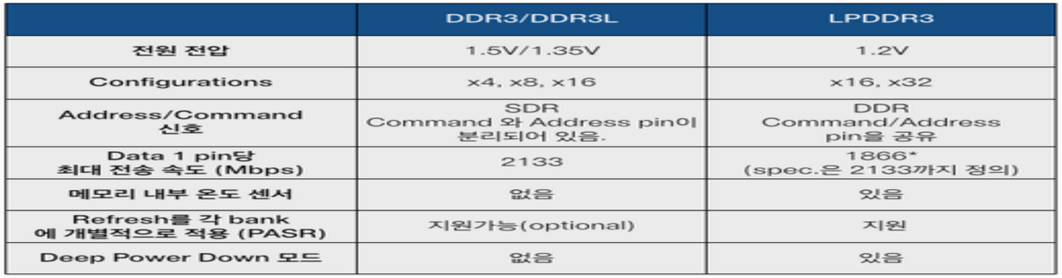
Definition of System Program (4/8)

- Hardware components: Smart Phone
  - ✓ CPU: ARM based Multicore
  - ✓ Memory: LPDDR, SRAM
  - ✓ Storage: NAND flash
  - ✓ Input: Touch Screen, Sensors, Voice, Iris, ...
  - ✓ Output: LCD, LED, Sound, Buzzer, …
  - ✓ Communication
    - WLAN
    - LTE, CDMA, GSM
    - IrDA, Bluetooth, NFC
    - UART, USB
    - …

(Source: Google Image)

Definition of System Program (5/8)

- Hardware components: PC vs. Mobile
  - ✓ Differ according to the requirements for Mobile devices
  - ✓ Power Saving
    - Make use of RICS CPU instead of CISC CPU
      - RISC: Reduced Instruction Set Computing ➔ Small Instructions ➔ Compact CPU internal ➔ Consume less Power
    - Make use of LPDDR (Low-Power DDR) instead of General DRAM
      - LPDDR: Reduce power by using lower voltage and less refreshing
  - ✓ Portability
    - Make use of Flash memory instead of Disk
      - Lightweight, Shock resistance
  - ✓ User friendliness
    - Make use of diverse input, output and communication devices



	DDR3/DDR3L	LPDDR3
전원 전압	1.5V/1.35V	1.2V
Configurations	x4, x8, x16	x16, x32
Address/Command 신호	SDR Command 와 Address pin이 분리되어 있음.	DDR Command/Address pin을 공유
Data 1 pin당 최대 전송 속도 (Mbps)	2133	1866* (spec.은 2133까지 정의)
메모리 내부 온도 센서	없음	있음
Refresh를 각 bank 에 개별적으로 적용 (PASR)	지원가능(optional)	지원
Deep Power Down 모드	없음	있음

(Source: http://egloos.zum.com/donghyun53/v/4125772)

Definition of System Program (6/8)

- Software components
  - ✓ Application program vs. System program
    - Application program: how to do a specific job

```
#include <stdio.h>

int main()
{
    printf(“hello, world₩n”);
}
```

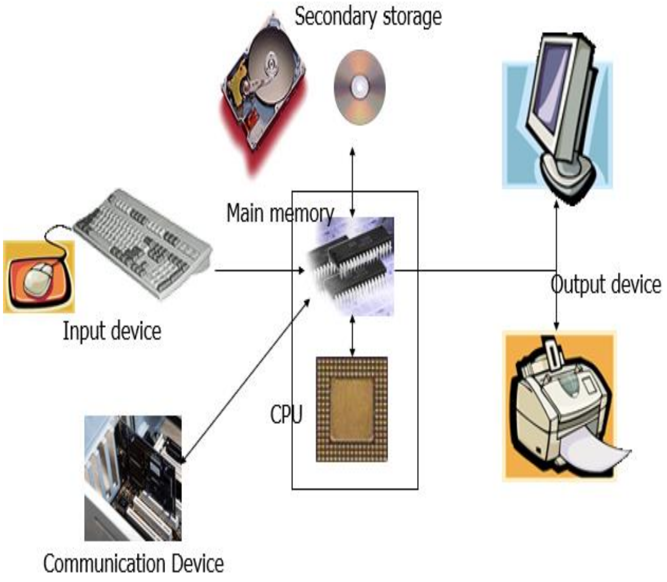
- System program: address the following issues
  - How to run this application program on CPU?
  - What is the role of printf()?
  - How the string is displayed on Monitor?
  - How this program can be executed with other programs concurrently?
  - What are the differences between local and global variables?
  - What kinds of techniques can be applied to enhance the performance of this program?

Definition of System Program (7/8)

- Software components: System program
  - ✓ How to run a program on CPU?
    - object, binary, compiler, assembler, loader, ...
  - ✓ What is the role of printf()?
    - library, linker, ...
  - ✓ How the string is displayed on Monitor?
    - device driver, file system, ...
  - ✓ How a program can be executed with other programs concurrently?
    - process, scheduler, context switch, IPC (Inter process communication), ...
  - ✓ What are the differences between local and global memory?
    - data, stack, heap, virtual memory, buddy system, ...
  - ✓ What kind of techniques can be applied to enhance the performance of a program?
    - compiler optimization (loop unrolling, reordering), CPU optimization (pipeline, superscalar, out-of-order execution), …

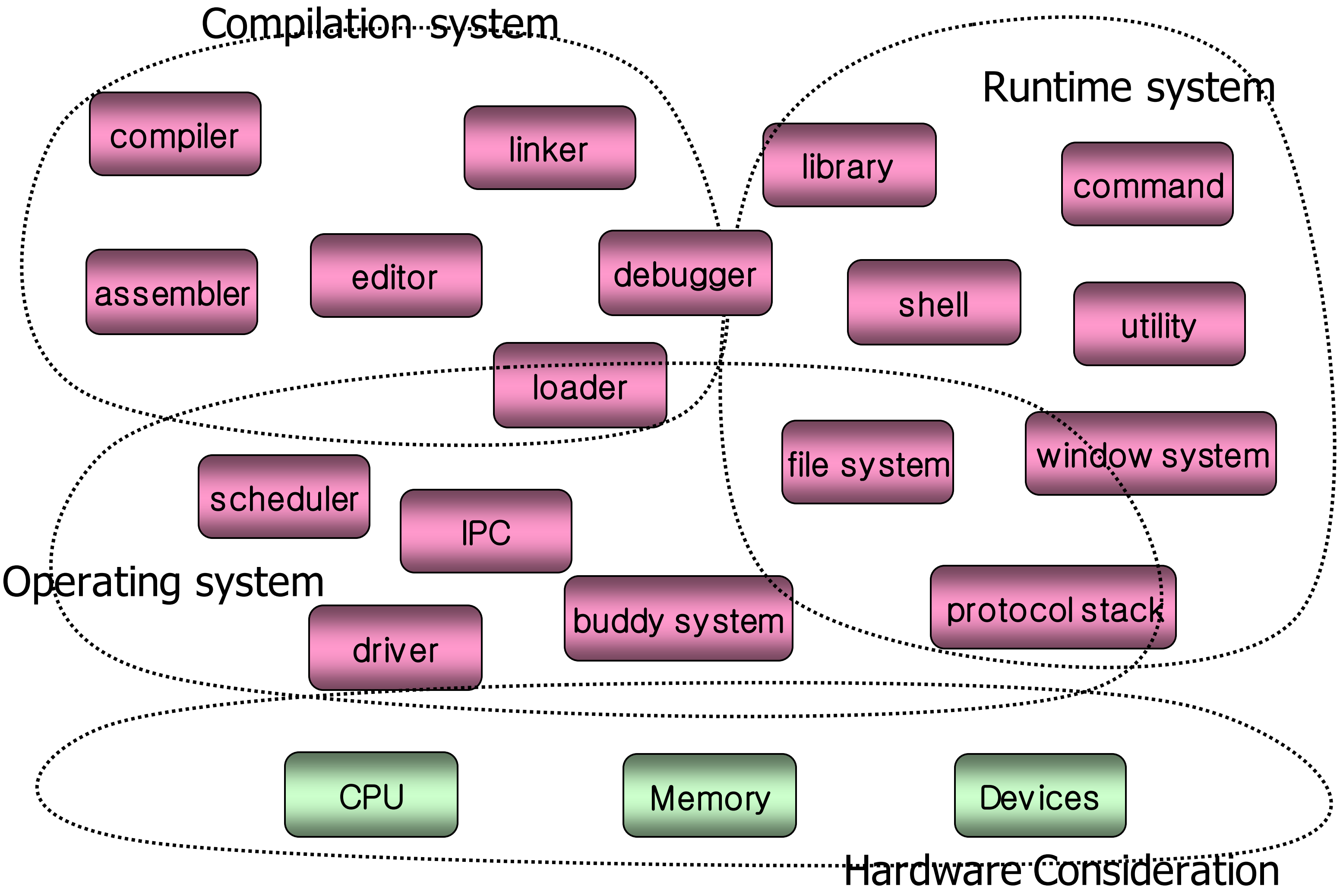
Definition of System Program (8/8)

- Software components: System program
  - ✓ Definition
    - Supporting computing environments for application programs (Support Interfaces such as commands, library functions and system calls)
    - Strongly related to hardware (hardware management)
  - ✓ Support abstraction
    - CPU and Task (Process)
    - DRAM and Virtual memory
    - Storage and File
    - Device and Driver
    - Machine vs. High level language
    - Untrusted and Trusted Domain
    - ...



Types of System Program

- Classification



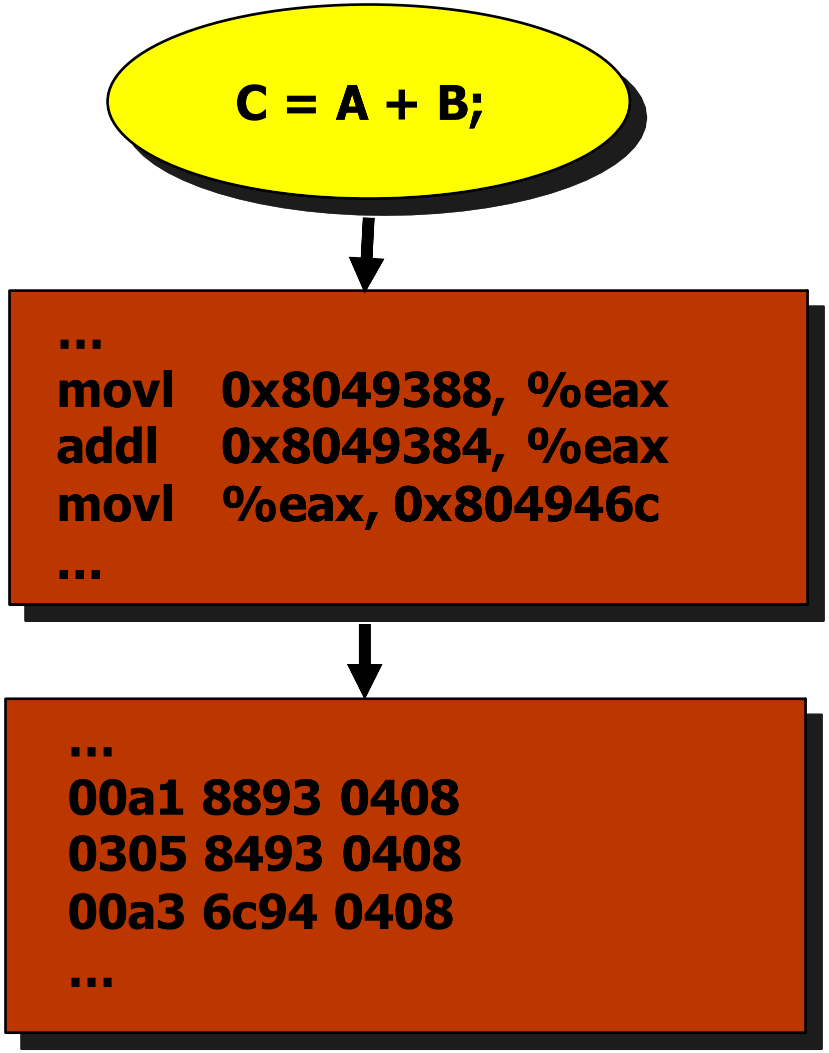
Compilation System (1/5)

- Concept: Language Hierarchy

High-level Language

Assembly Language

Machine Language (Binary code)



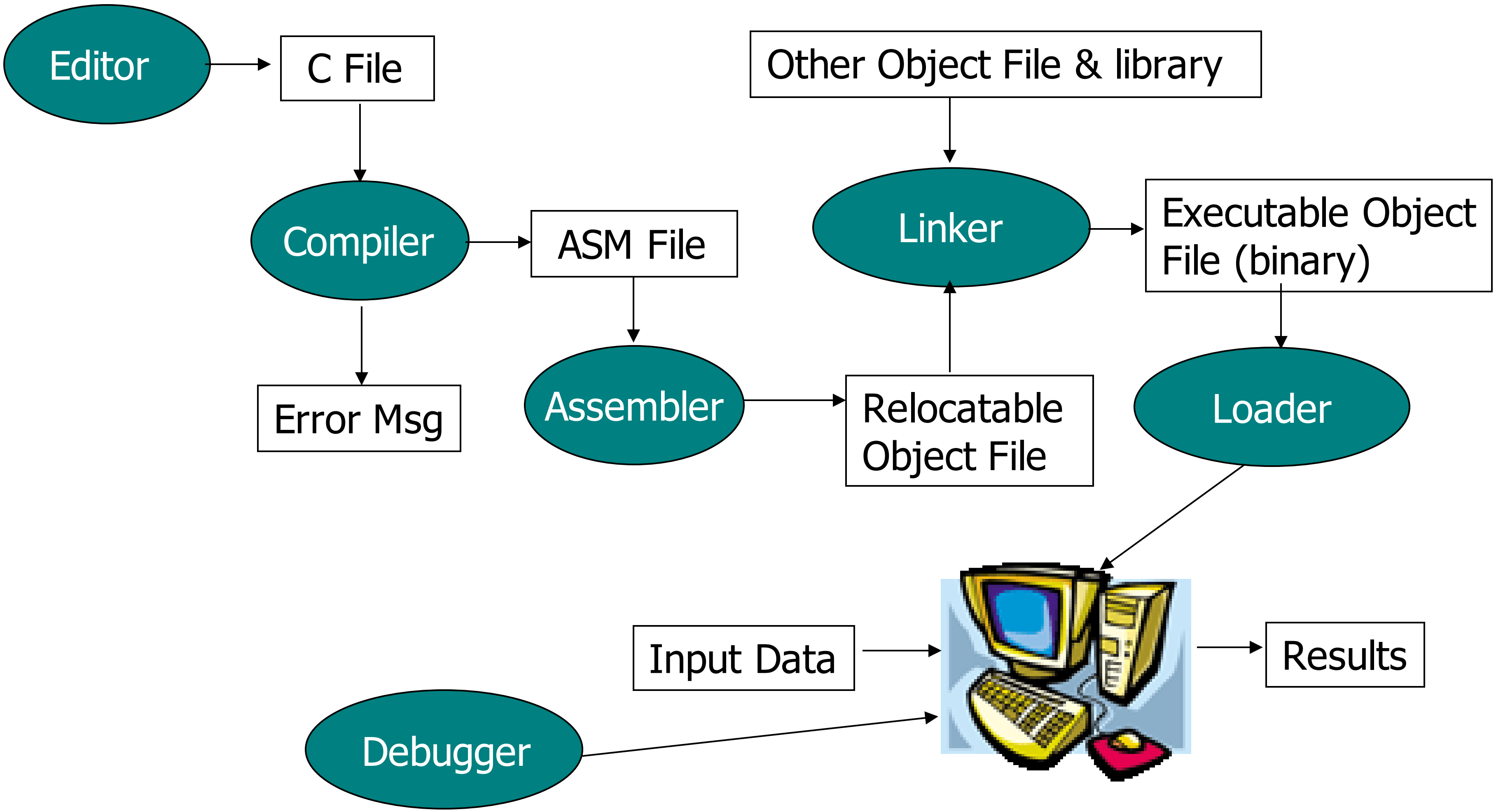
```
C = A + B;
```

```
...
movl   0x8049388, %eax
addl   0x8049384, %eax
movl   %eax, 0x804946c
...
```

```
...
00a1 8893 0408
0305 8493 0408
00a3 6c94 0408
...
```

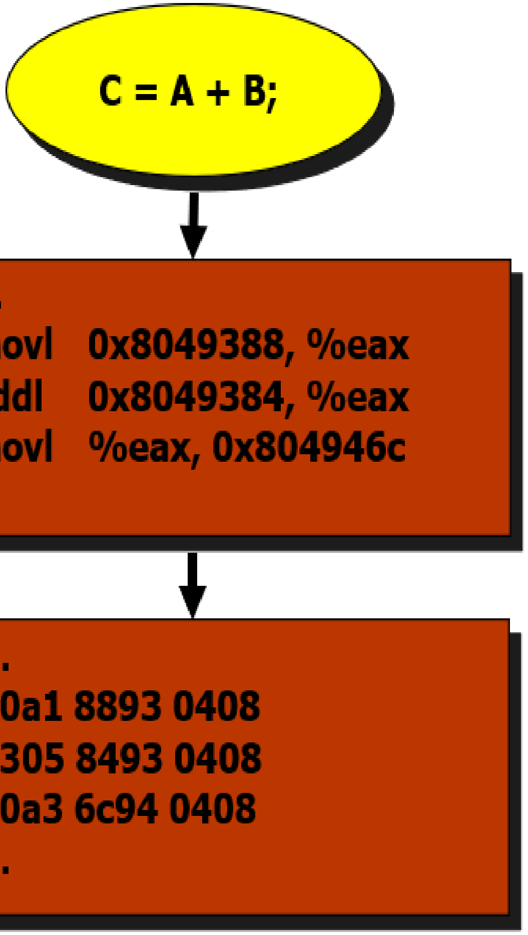
Compilation System (2/5)

- Overall structure
  - ✓ 6 key components



Compilation System (3/5)

- Relation between Language Hierarchy and Overall Structure

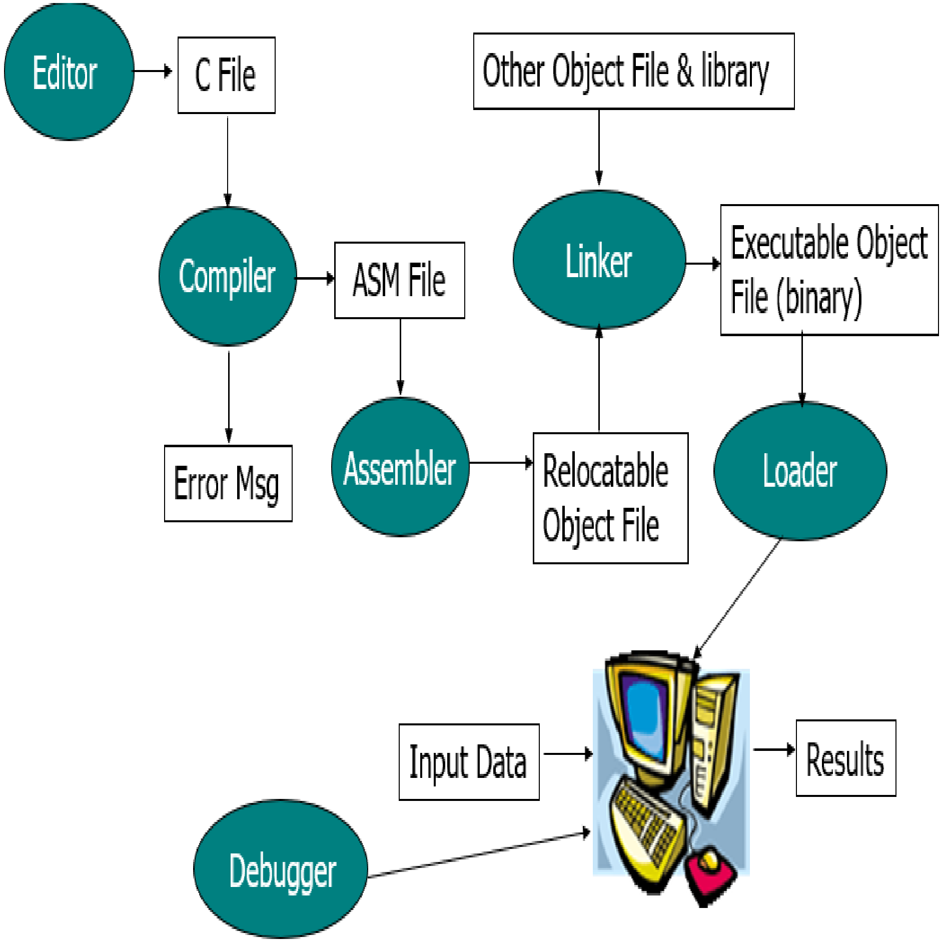


C = A + B;

```
...
movl   0x8049388, %eax
addl   0x8049384, %eax
movl   %eax, 0x804946c
...
```

```
...
00a1 8893 0408
0305 8493 0408
00a3 6c94 0408
...
```

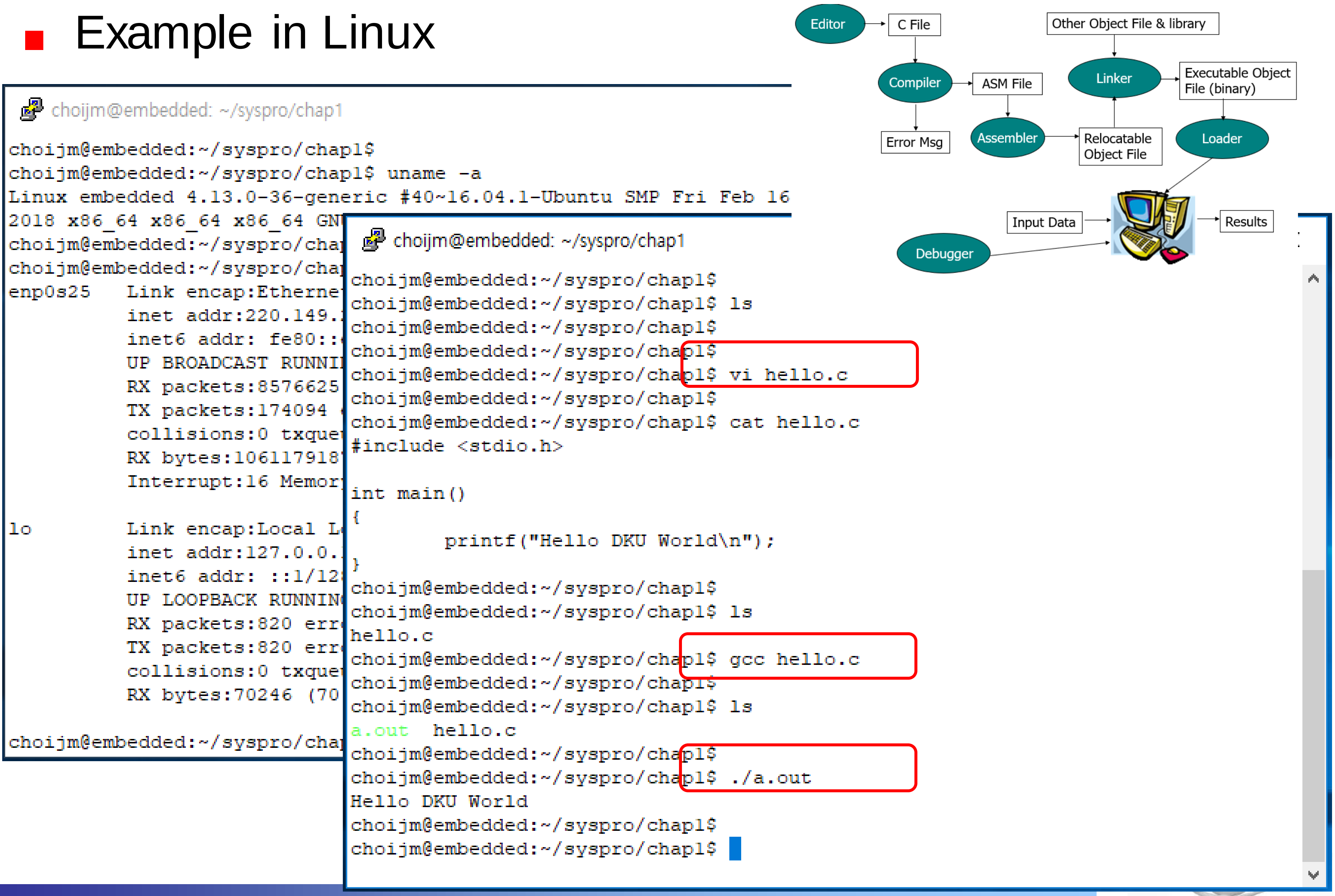
(Language hierarchy)



(Compilation system)

Compilation System (4/5)

- Example in Linux



choijm@embedded: ~/syspro/chap1

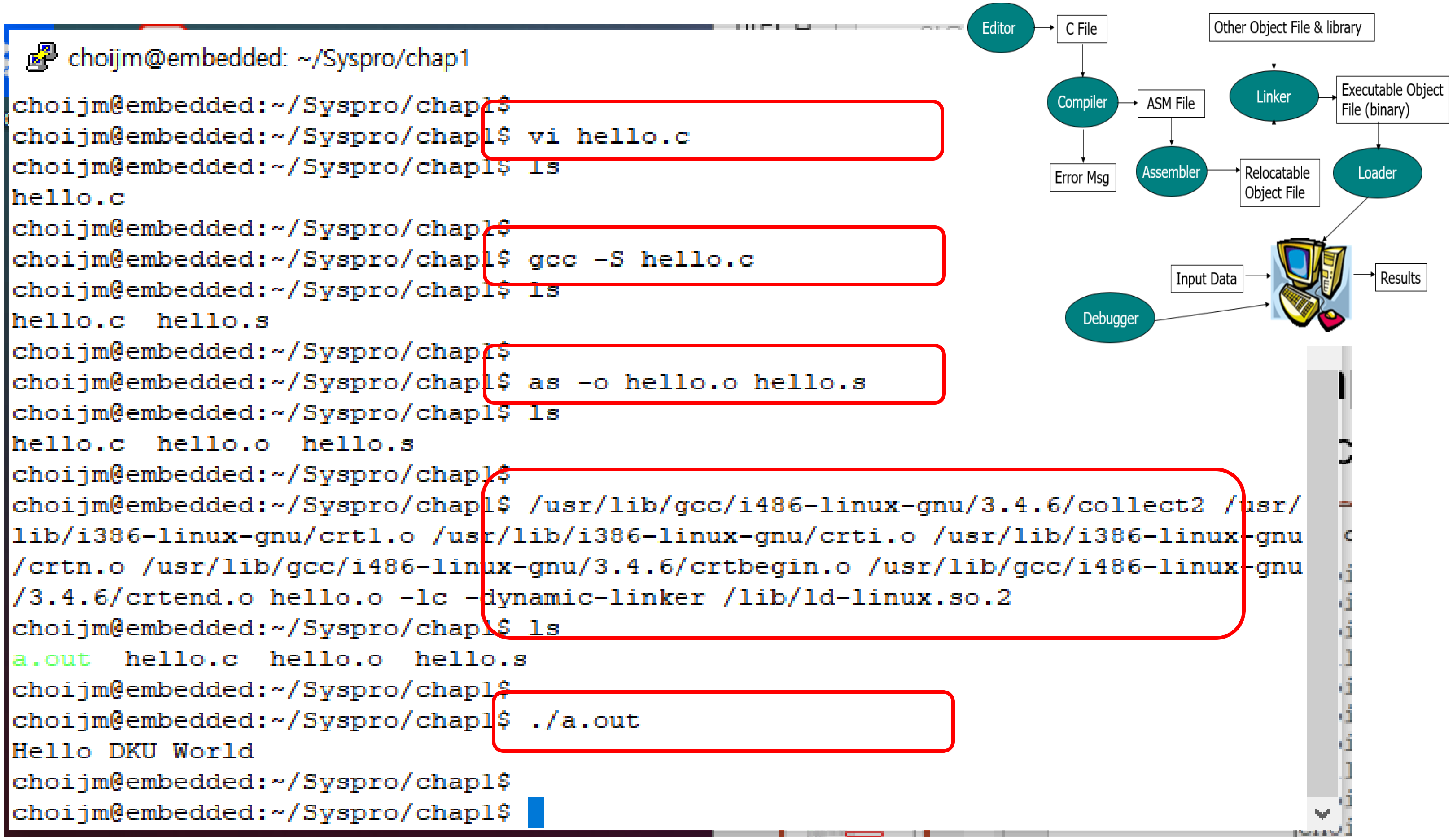
```
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ uname -a
Linux embedded 4.13.0-36-generic #40~16.04.1-Ubuntu SMP Fri Feb 16
2018 x86_64 x86_64 x86_64 GN
choijm@embedded:~/syspro/cha
choijm@embedded:~/syspro/cha
enp0s25   Link encap:Etherne
          inet addr:220.149.
          inet6 addr: fe80::
          UP BROADCAST RUNNI
          RX packets:8576625
          TX packets:174094
          collisions:0 txque
          RX bytes:106117918
          Interrupt:16 Memor

lo        Link encap:Local L
          inet addr:127.0.0.
          inet6 addr: ::1/12
          UP LOOPBACK RUNNIN
          RX packets:820 err
          TX packets:820 err
          collisions:0 txque
          RX bytes:70246 (70

choijm@embedded:~/syspro/cha
```

choijm@embedded: ~/syspro/chap1

```
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ vi hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ cat hello.c
#include <stdio.h>

int main()
{
        printf("Hello DKU World\n");
}
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
hello.c
choijm@embedded:~/syspro/chap1$ gcc hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
a.out  hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ./a.out
Hello DKU World
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$
```

Compilation System (5/5)

- Example in Linux: details
  - ✓ Location of collect2, crt1.o, … depend on gcc version



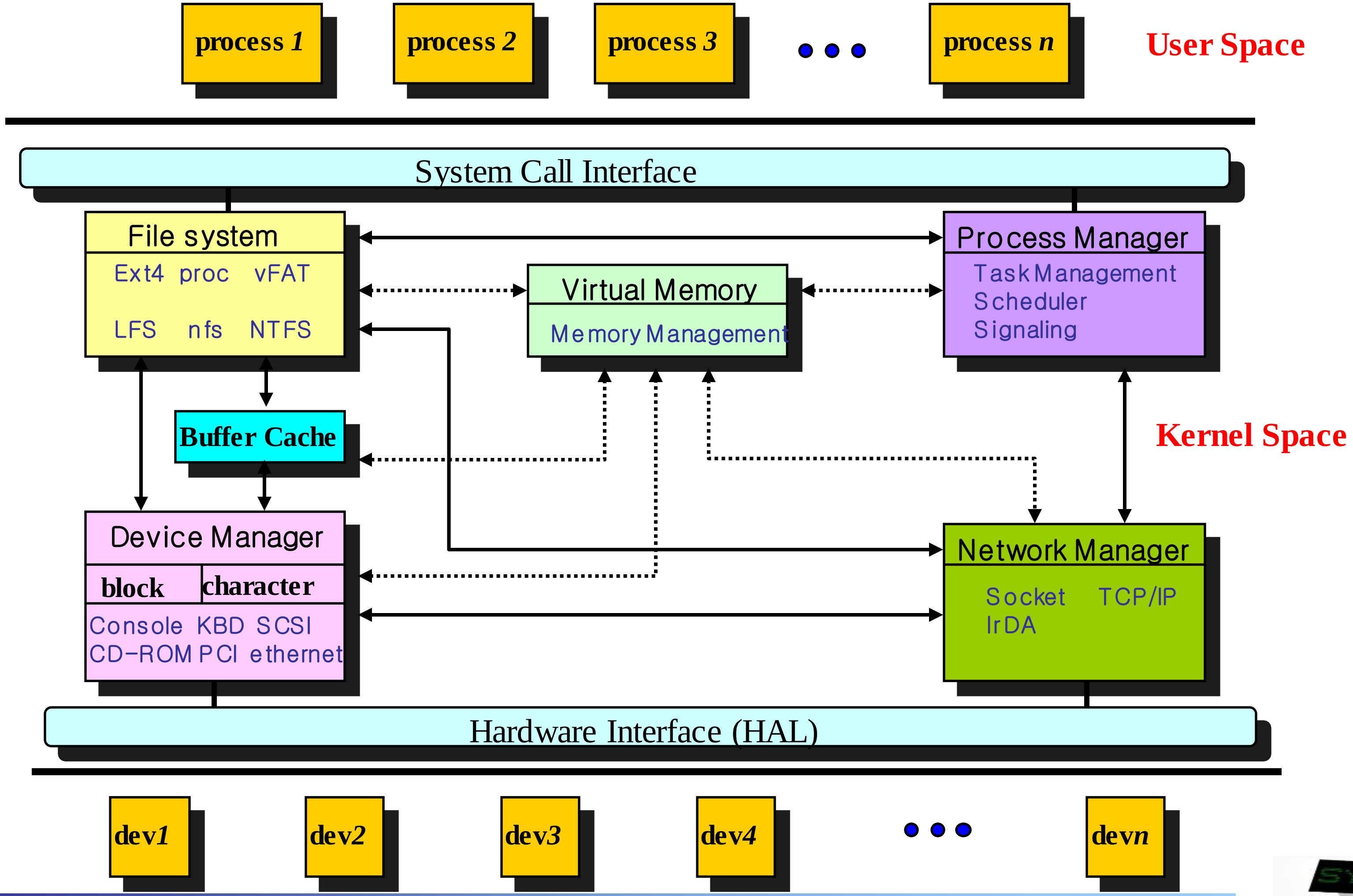
```
choijm@embedded:~/Syspro/chap1$
choijm@embedded:~/Syspro/chap1$ vi hello.c
choijm@embedded:~/Syspro/chap1$ ls
hello.c
choijm@embedded:~/Syspro/chap1$
choijm@embedded:~/Syspro/chap1$ gcc -S hello.c
choijm@embedded:~/Syspro/chap1$ ls
hello.c  hello.s
choijm@embedded:~/Syspro/chap1$
choijm@embedded:~/Syspro/chap1$ as -o hello.o hello.s
choijm@embedded:~/Syspro/chap1$ ls
hello.c  hello.o  hello.s
choijm@embedded:~/Syspro/chap1$
choijm@embedded:~/Syspro/chap1$ /usr/lib/gcc/i486-linux-gnu/3.4.6/collect2 /usr/
lib/i386-linux-gnu/crt1.o /usr/lib/i386-linux-gnu/crti.o /usr/lib/i386-linux-gnu
/crtn.o /usr/lib/gcc/i486-linux-gnu/3.4.6/crtbegin.o /usr/lib/gcc/i486-linux-gnu
/3.4.6/crtend.o hello.o -lc -dynamic-linker /lib/ld-linux.so.2
choijm@embedded:~/Syspro/chap1$ ls
a.out  hello.c  hello.o  hello.s
choijm@embedded:~/Syspro/chap1$
choijm@embedded:~/Syspro/chap1$ ./a.out
Hello DKU World
choijm@embedded:~/Syspro/chap1$
choijm@embedded:~/Syspro/chap1$
```

☞ **What are the differences btw hello.c and hello.s?**

☞ **What are the differences btw hello.o and a.out?**

Operating System (1/15)

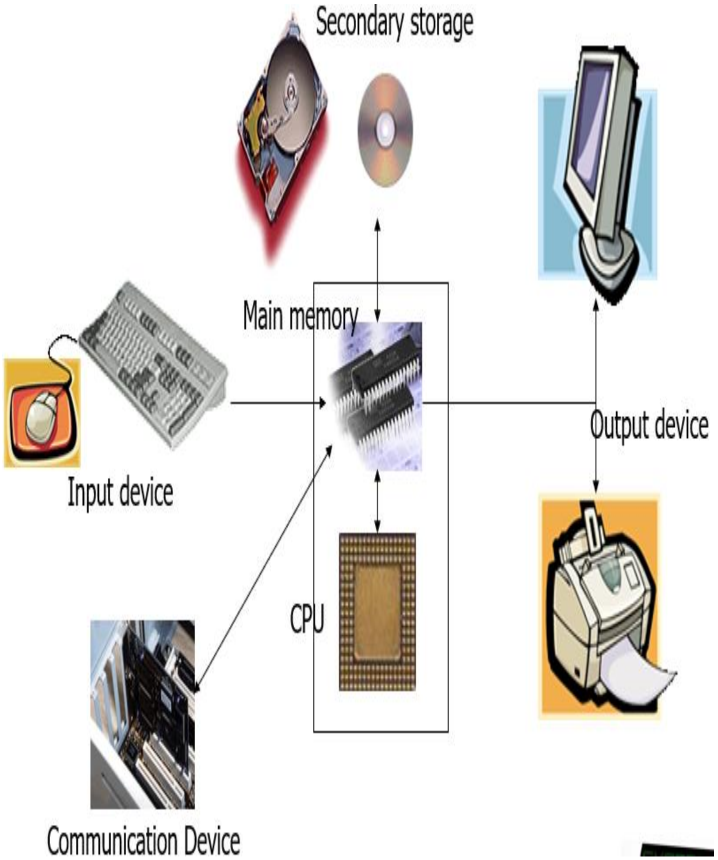
- Overall structure
  - ✓ 7 key components

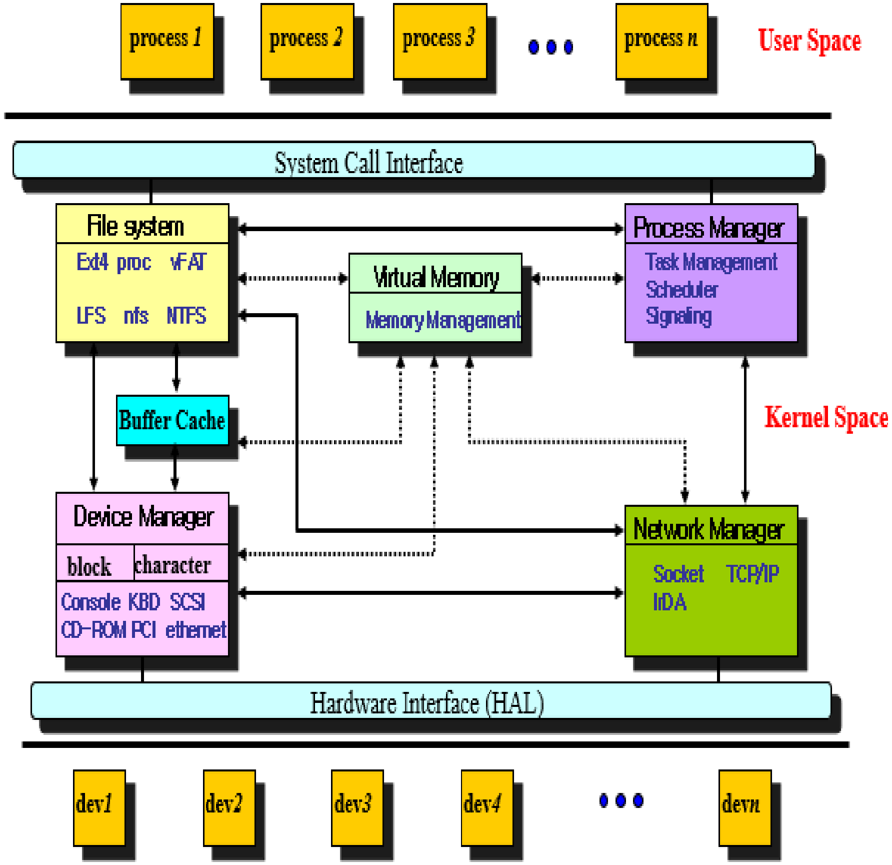


(Source: Linux Kernel Internals)

Operating System (2/15)

- Relation between hardware component and overall structure
  - ✓ OS: a resource manager ➔ abstract HW resources into logical ones



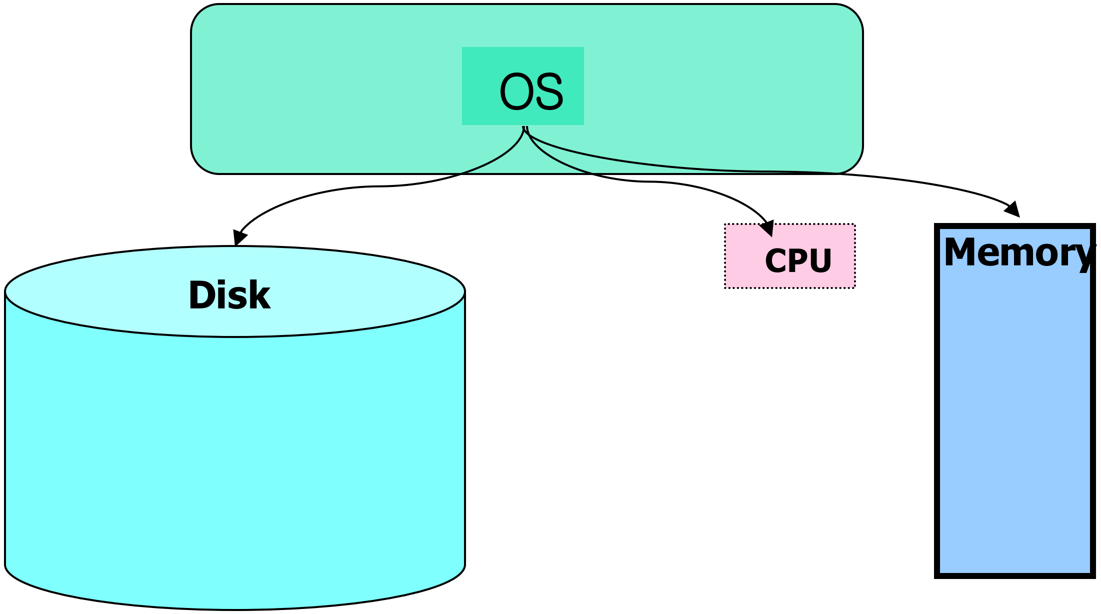


(Physical resources)

(Logical resources)

Operating System (3/15)

- Behaviors: 1) initial state

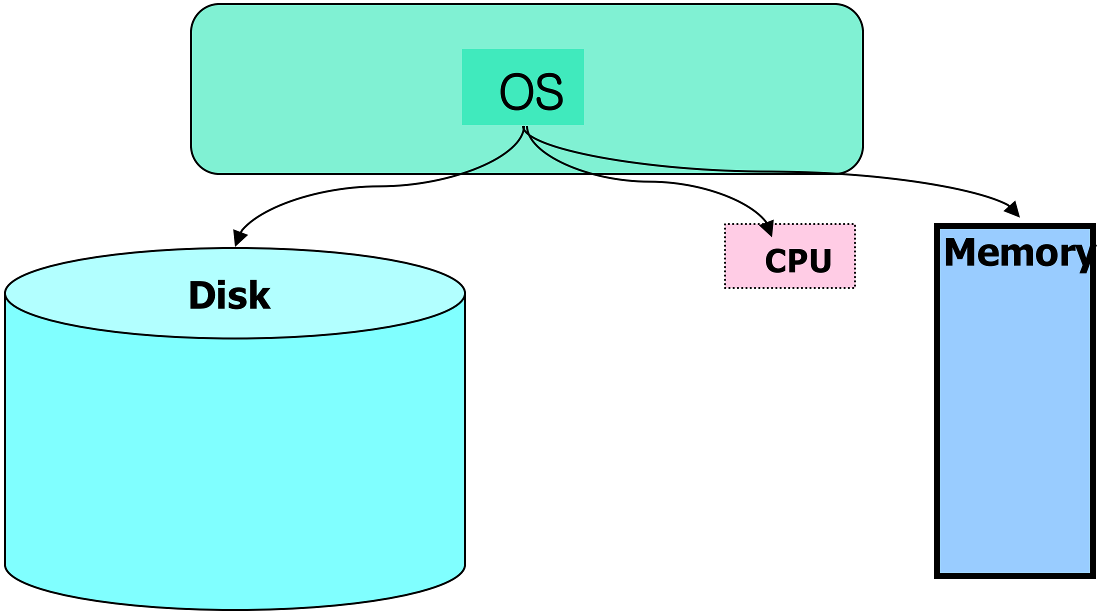


Operating System (4/15)

- Behaviors: 2) create a file (user’s viewpoint)

vi test.c

```
#include <stdio.h>

int main()
{
        printf(“Hello world₩n”);
}
```

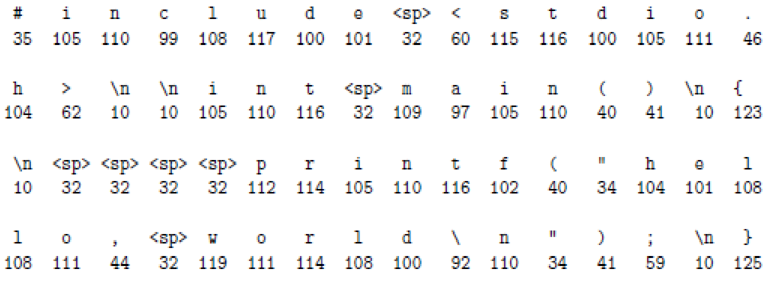


Operating System (5/15)

- Behaviors: 2) create a file (system's viewpoint)

vi test.c

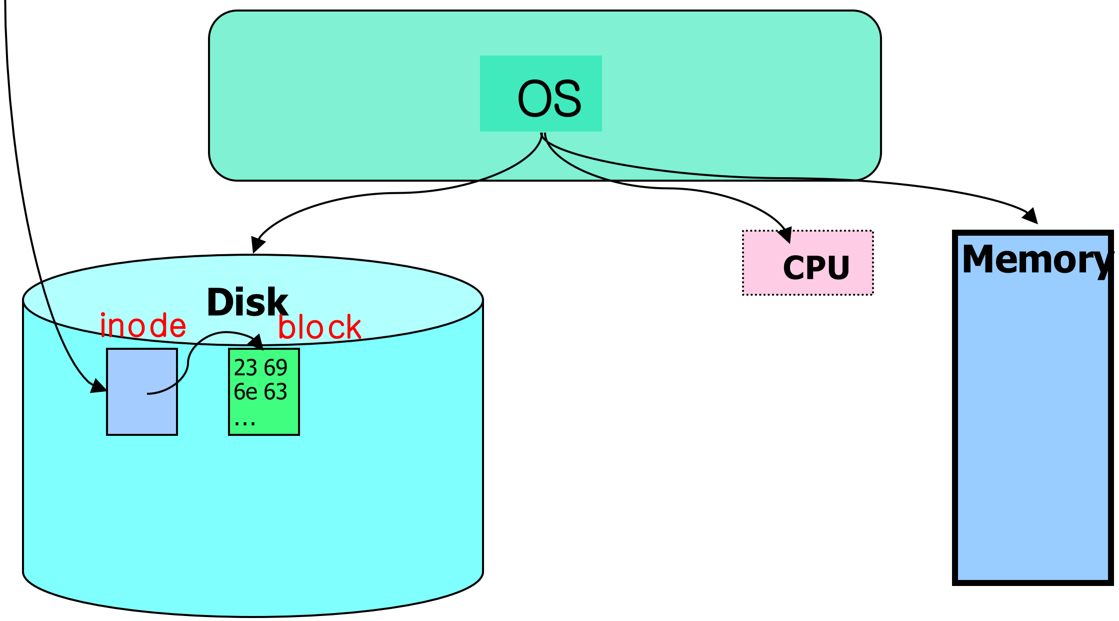
```
#include <stdio.h>

int main()
{
        printf("Hello world₩n");
}
```



```
 #    i    n    c    l    u    d    e  <sp>   <    s    t    d    i    o    .
35  105  110   99  108  117  100  101   32   60  115  116  100  105  111   46

 h    >   \n   \n    i    n    t  <sp>   m    a    i    n    (    )   \n    {
104  62   10   10  105  110  116   32  109   97  105  110   40   41   10  123

\n  <sp> <sp> <sp> <sp>   p    r    i    n    t    f    (    "    h    e    l
10   32   32   32   32  112  114  105  110  116  102   40   34  104  101  108

 l    o    ,  <sp>   w    o    r    l    d    \    n    "    )    ;   \n    }
108 111   44   32  119  111  114  108  100   92  110   34   41   59   10  125
```

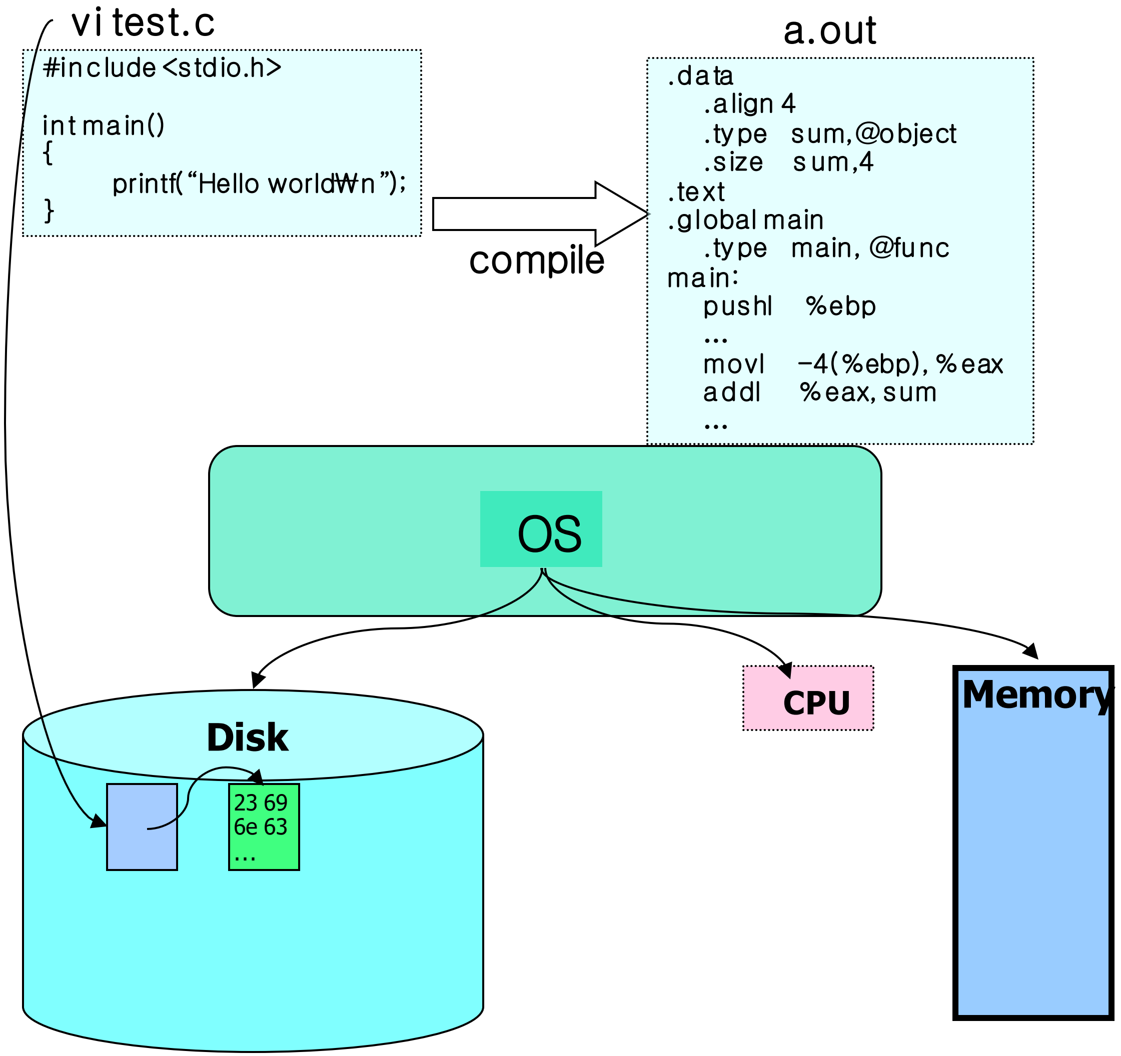
Figure 1.2 The ASCII text representation of hello.c.

(Source: CSAPP)



Operating System (6/15)

- Behaviors: 3) compile the file (user’s viewpoint)



vi test.c

```
#include <stdio.h>

int main()
{
        printf( “Hello world₩n”);
}
```

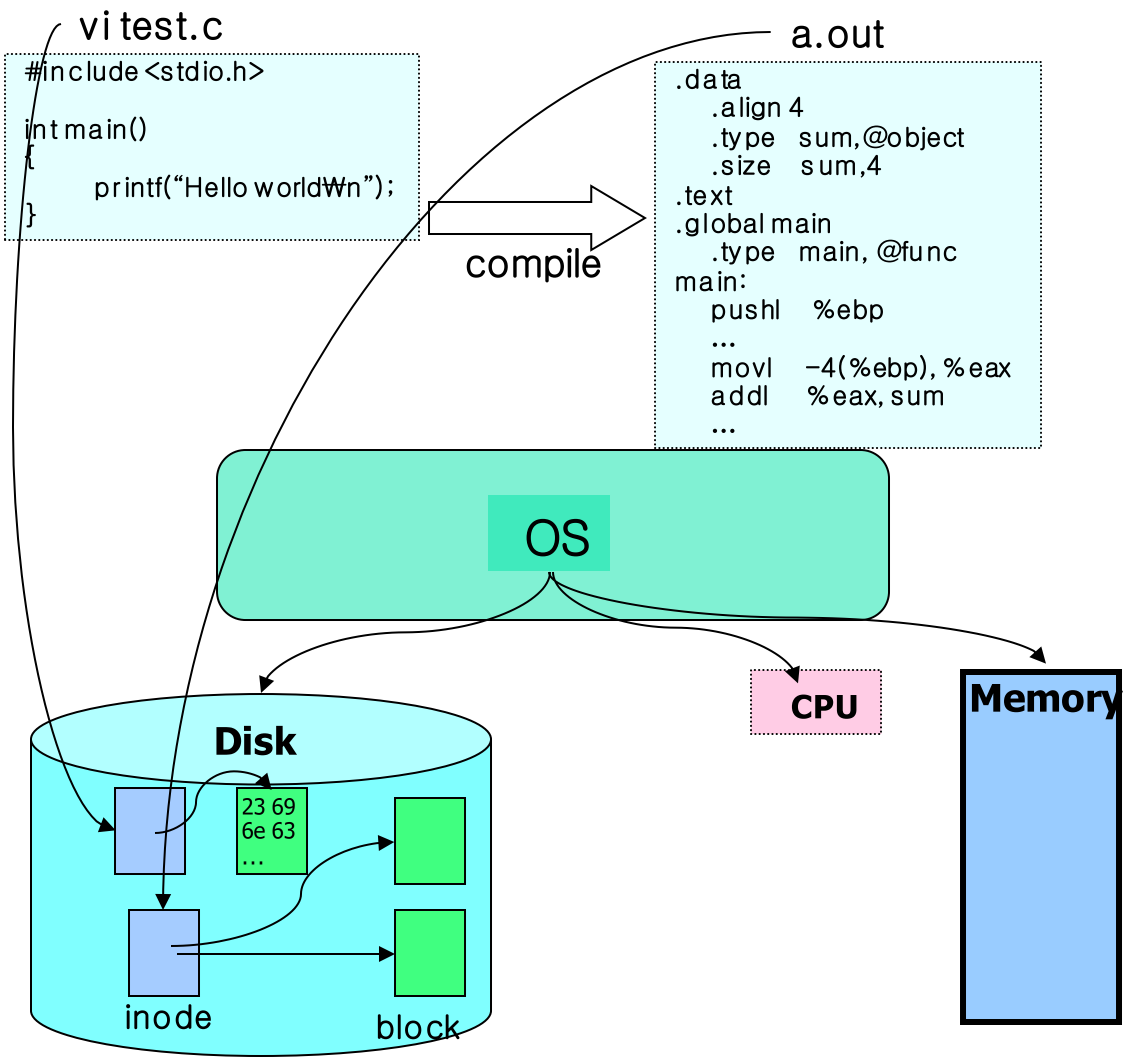
compile

a.out

```
.data
    .align 4
    .type   sum,@object
    .size   sum,4
.text
.global main
    .type   main, @func
main:
    pushl   %ebp
    ...
    movl    -4(%ebp), %eax
    addl    %eax, sum
    ...
```

Operating System (7/15)

- Behaviors: 3) compile the file (system's viewpoint)



vi test.c

```
#include <stdio.h>

int main()
{
        printf("Hello world₩n");
}
```

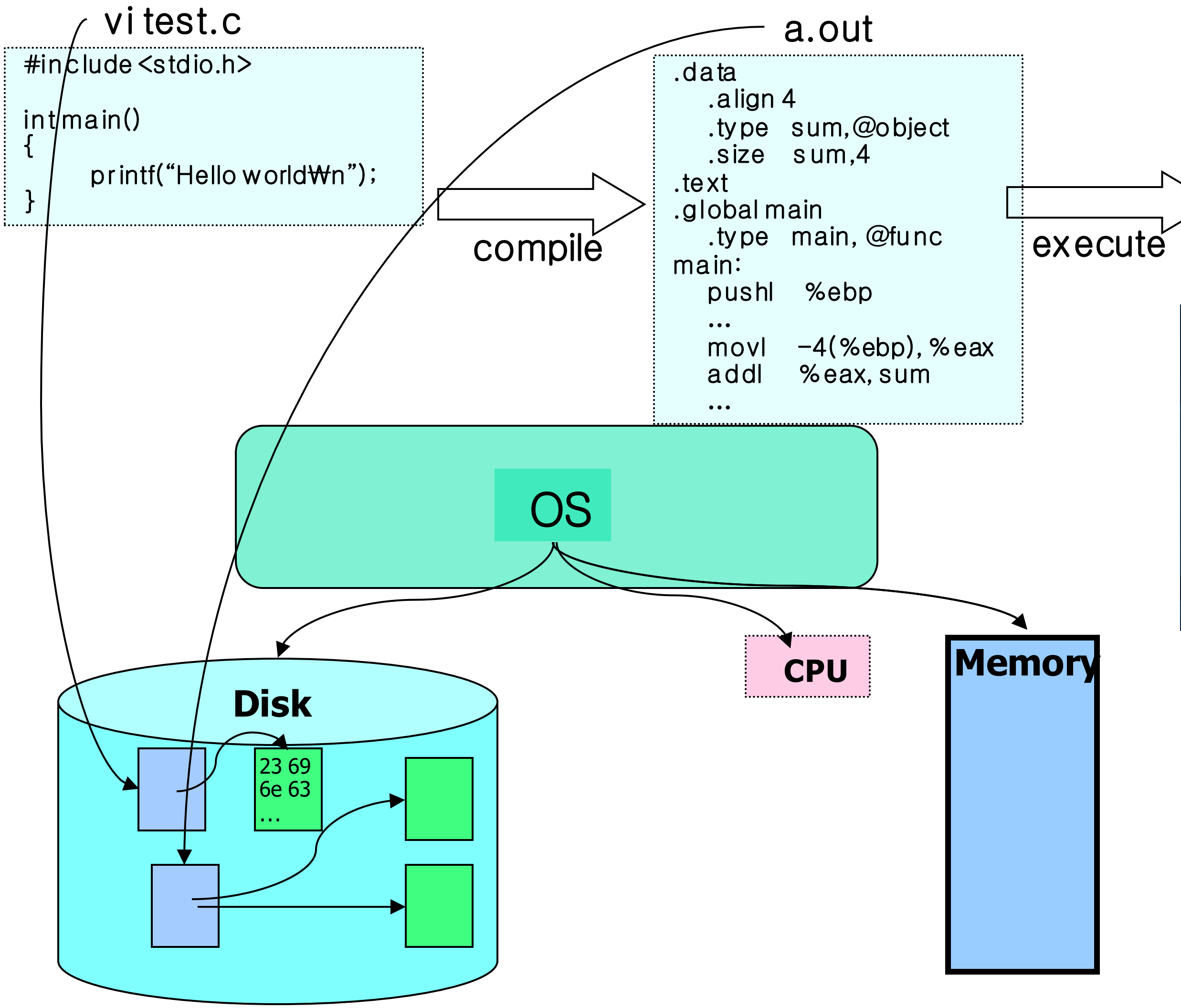
compile

a.out

```
.data
    .align 4
    .type  sum,@object
    .size  sum,4
.text
.global main
    .type  main, @func
main:
    pushl   %ebp
    ...
    movl   -4(%ebp), %eax
    addl    %eax, sum
    ...
```

Operating System (8/15)

- Behaviors: 4) execute the a.out (user's viewpoint)



vi test.c

```
#include <stdio.h>

int main()
{
        printf("Hello world₩n");
}
```

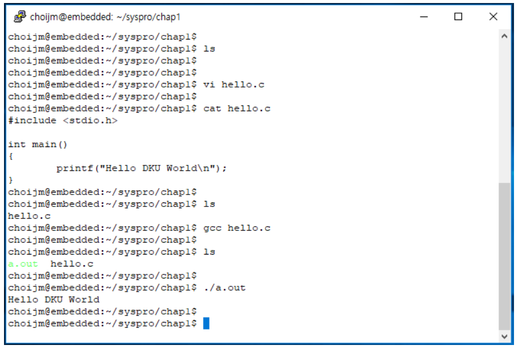
compile

a.out

```
.data
    .align 4
    .type   sum,@object
    .size   sum,4
.text
.global main
    .type   main, @func
main:
    pushl   %ebp
    ...
    movl    -4(%ebp), %eax
    addl    %eax, sum
    ...
```

execute

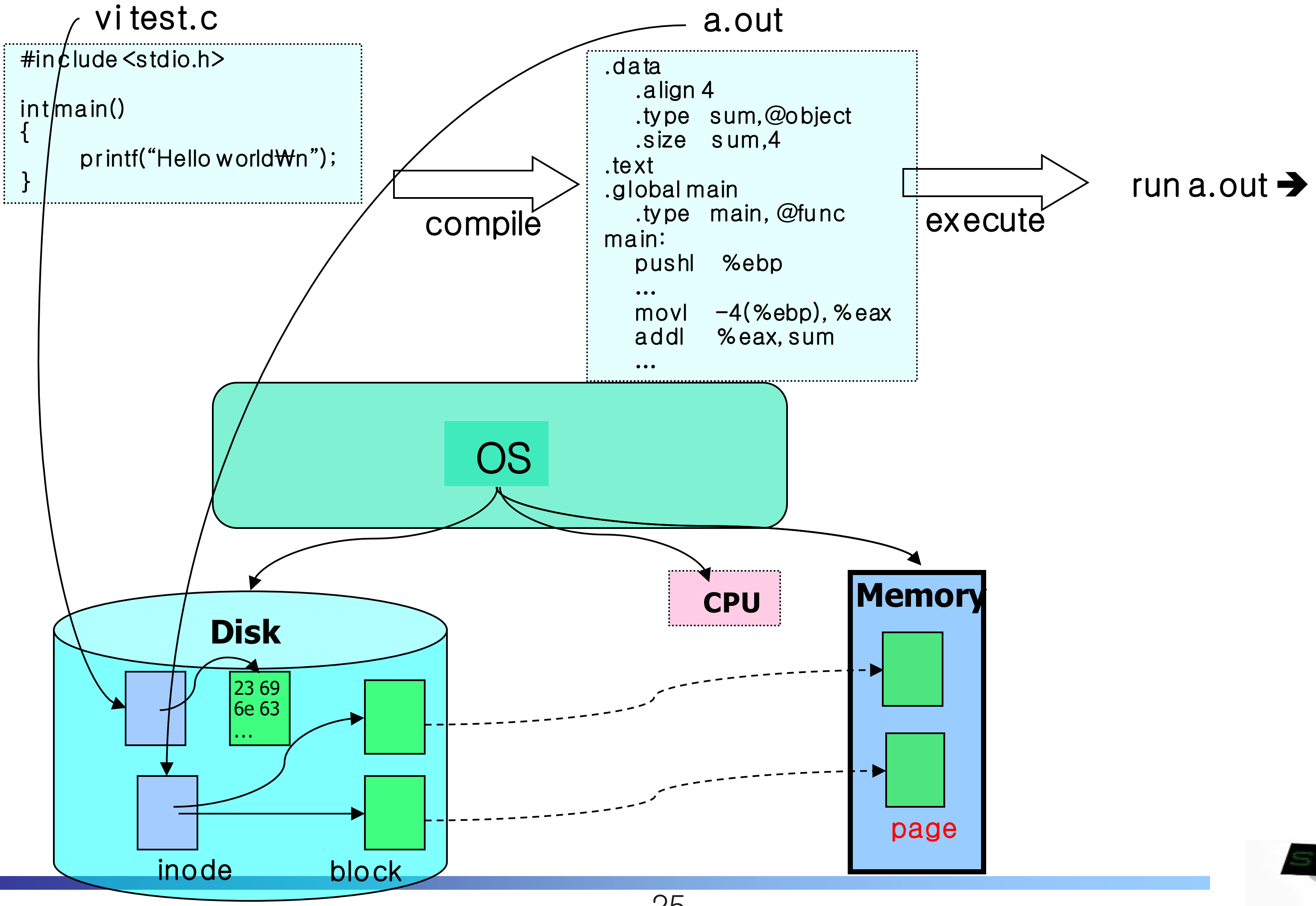
run a.out



```
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ vi hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ cat hello.c
#include <stdio.h>

int main()
{
        printf("Hello DKU World\n");
}
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
hello.c
choijm@embedded:~/syspro/chap1$ gcc hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
a.out  hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ./a.out
Hello DKU World
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$
```

Operating System (9/13)

- Behaviors: 4) execute the a.out (system’s viewpoint)
  - ✓ To run a.out, OS first loads it into memory

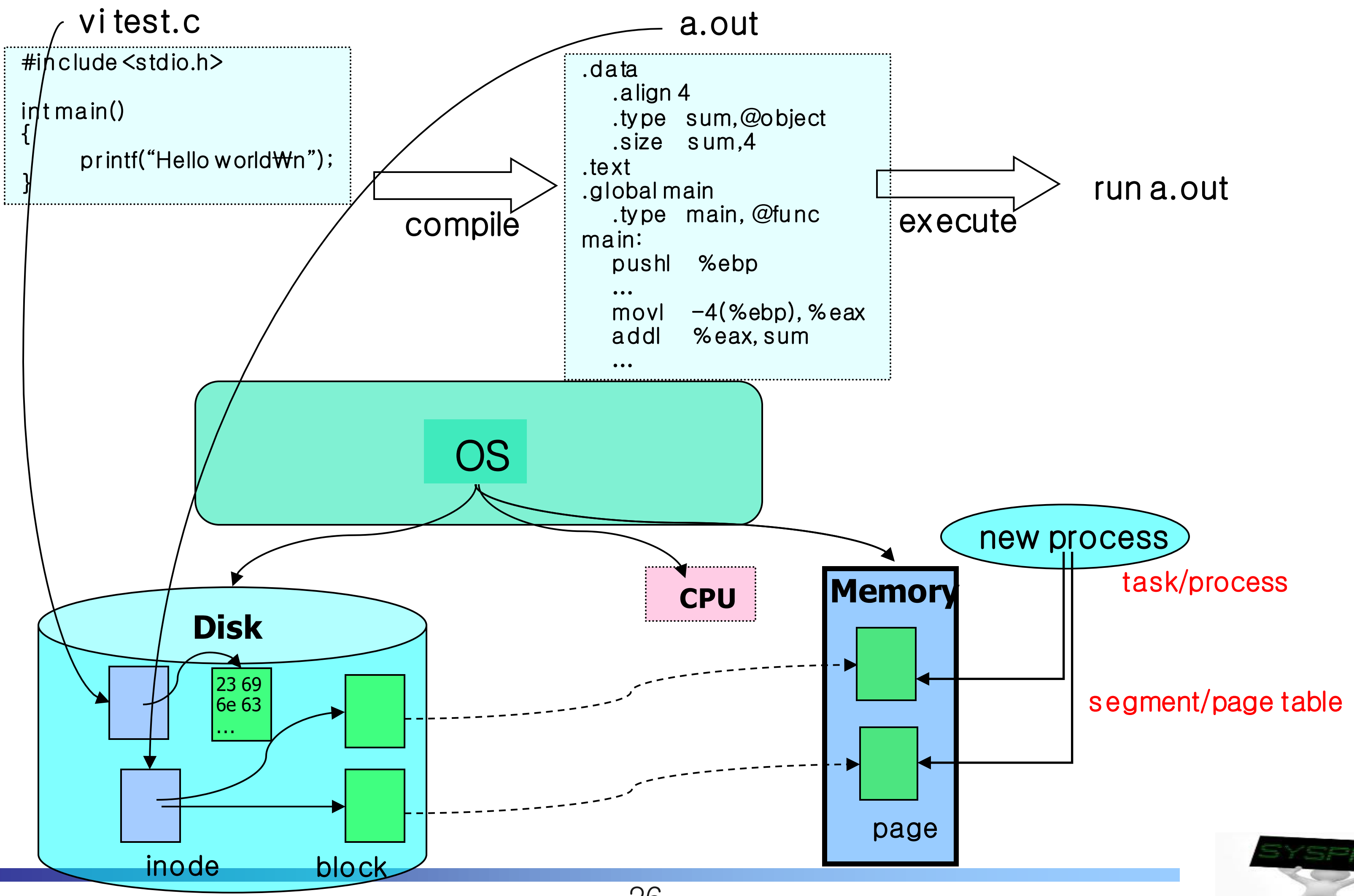


```
#include <stdio.h>

int main()
{
        printf(“Hello world₩n”);
}
```

```
.data
    .align 4
    .type   sum,@object
    .size   sum,4
.text
.global main
    .type   main, @func
main:
    pushl   %ebp
    …
    movl    -4(%ebp), %eax
    addl    %eax, sum
    …
```

Operating System (10/13)

- Behaviors: 4) execute the a.out (system's viewpoint)
  - ✓ Then, OS makes a new process (active object)

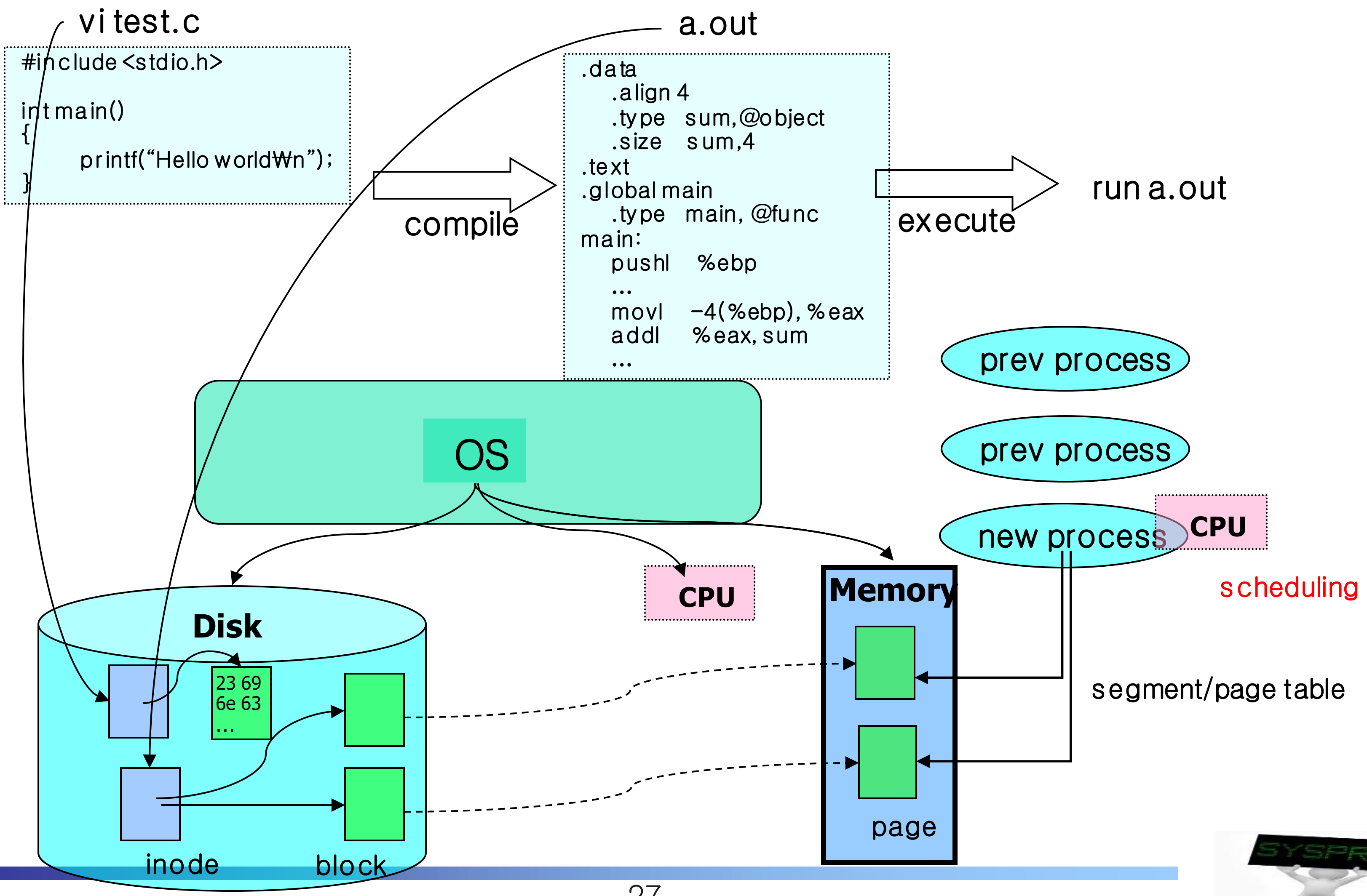


```
#include <stdio.h>

int main()
{
        printf("Hello world₩n");
}
```

```
.data
    .align 4
    .type   sum,@object
    .size   sum,4
.text
.global main
    .type   main, @func
main:
    pushl   %ebp
    ...
    movl    -4(%ebp), %eax
    addl    %eax, sum
    ...
```

Operating System (11/13)

- Behaviors: 4) execute the a.out (system's viewpoint)
  - ✓ Then, OS makes a new process & schedule it

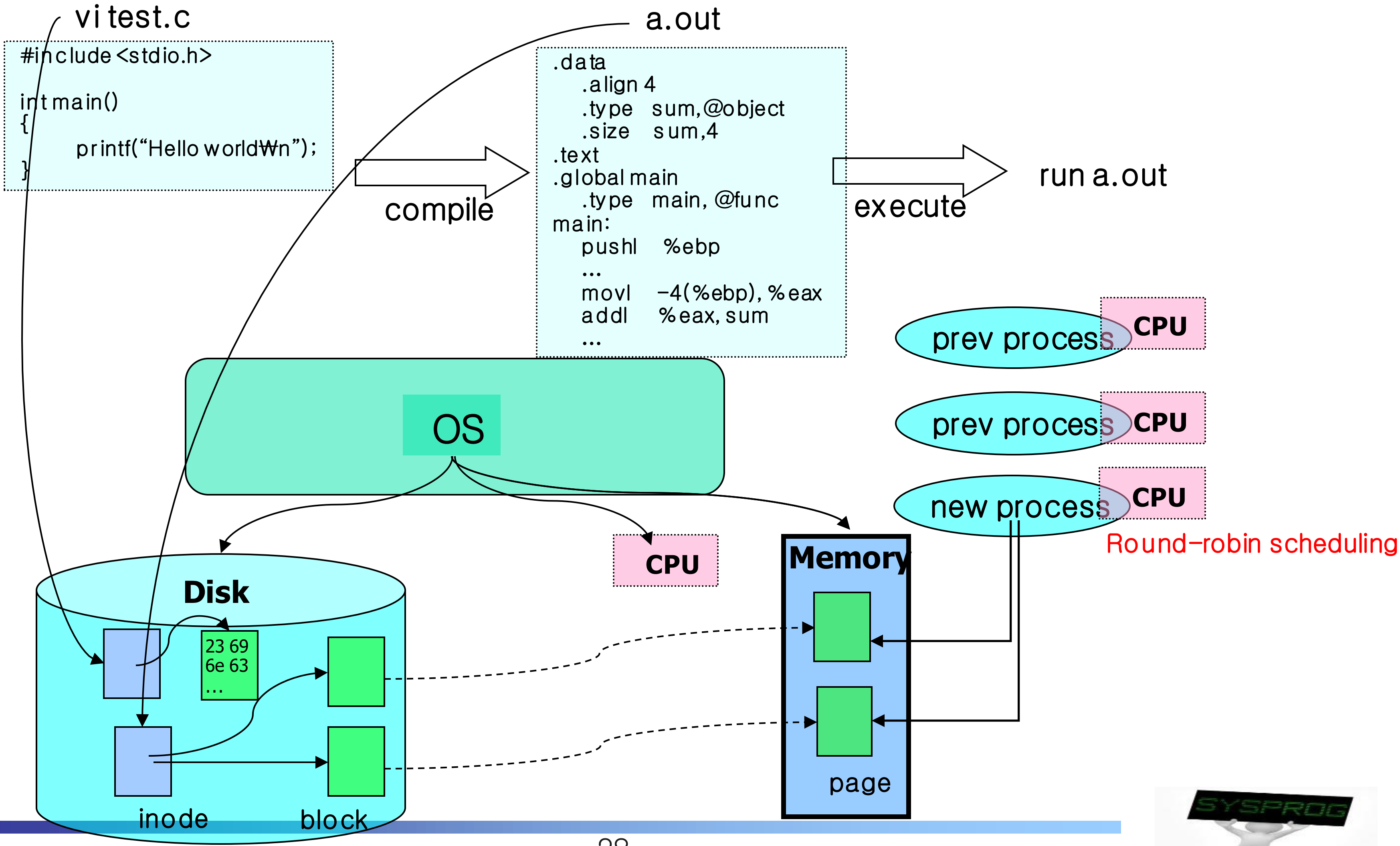


```
#include <stdio.h>

int main()
{
        printf("Hello world₩n");
}
```

```
.data
    .align 4
    .type   sum,@object
    .size   sum,4
.text
.global main
    .type   main, @func
main:
    pushl    %ebp
    ...
    movl     -4(%ebp), %eax
    addl     %eax, sum
    ...
```

Operating System (12/13)

- Behaviors: 4) execute the a.out (system’s viewpoint)
  - ✓ Then, OS makes a new process & schedule it with time-sharing



vi test.c

```
#include <stdio.h>

int main()
{
        printf(“Hello world₩n”);
}
```

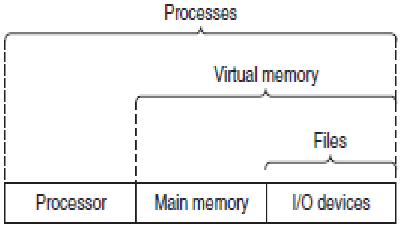
a.out

```
.data
    .align 4
    .type   sum,@object
    .size   sum,4
.text
.global main
    .type   main, @func
main:
    pushl   %ebp
    ...
    movl    -4(%ebp), %eax
    addl    %eax, sum
    ...
```

Operating System (13/13)

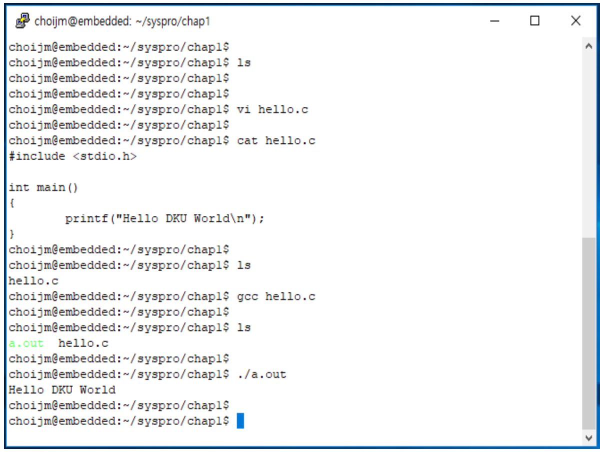
- Operating system: summary
  - ✓ Process manager (Task manager): CPU
    - process manipulation, schedule, IPC, signal, context switch
    - fork, exec, wait, getpid, (pthread_create) , …
  - ✓ Virtual Memory: Main memory
    - page, segment, address translation, buddy, LRU
    - brk, (malloc, free), …
  - ✓ File system: Storage
    - file, directory, disk scheduling, FAT
    - open, read, write, mknod, pipe, (fopen, fwrite, printf), …
  - ✓ Device driver: Device
    - IO port management, interrupt, DMA
    - open, read, write, ioctl, module, …
  - ✓ Network protocol: Network
    - connection, routing, fragmentation
    - socket, bind, listen, send, receive, …

Figure 1.11 Abstractions provided by an operating system.

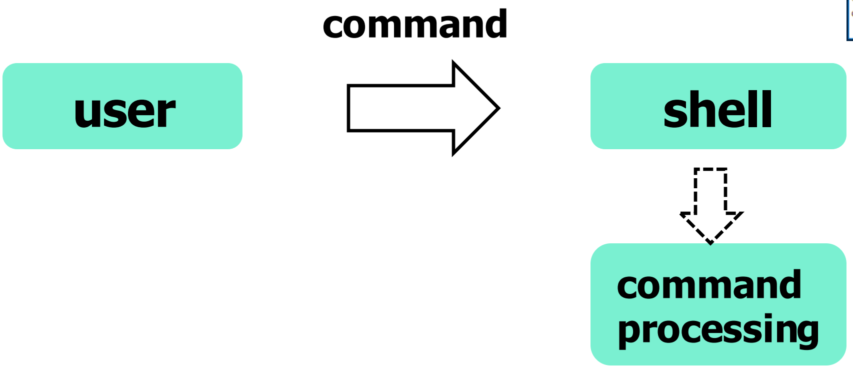


Runtime System (1/5)

- Command
  - ✓ file related: ls, cat, more, cp, mkdir, cd, …
  - ✓ task related: ps, kill, jobs, …
  - ✓ utility: vi, gcc, as, make, tar, patch, debugger, ..
  - ✓ management: adduser, passwd, ifconfig, mount, fsck, shutdown, ..
  - ✓ others: man, file, readelf, grep, wc, …
- shell
  - ✓ command interpreter
  - ✓ pipe, redirection, background processing, ….
  - ✓ shell script programming

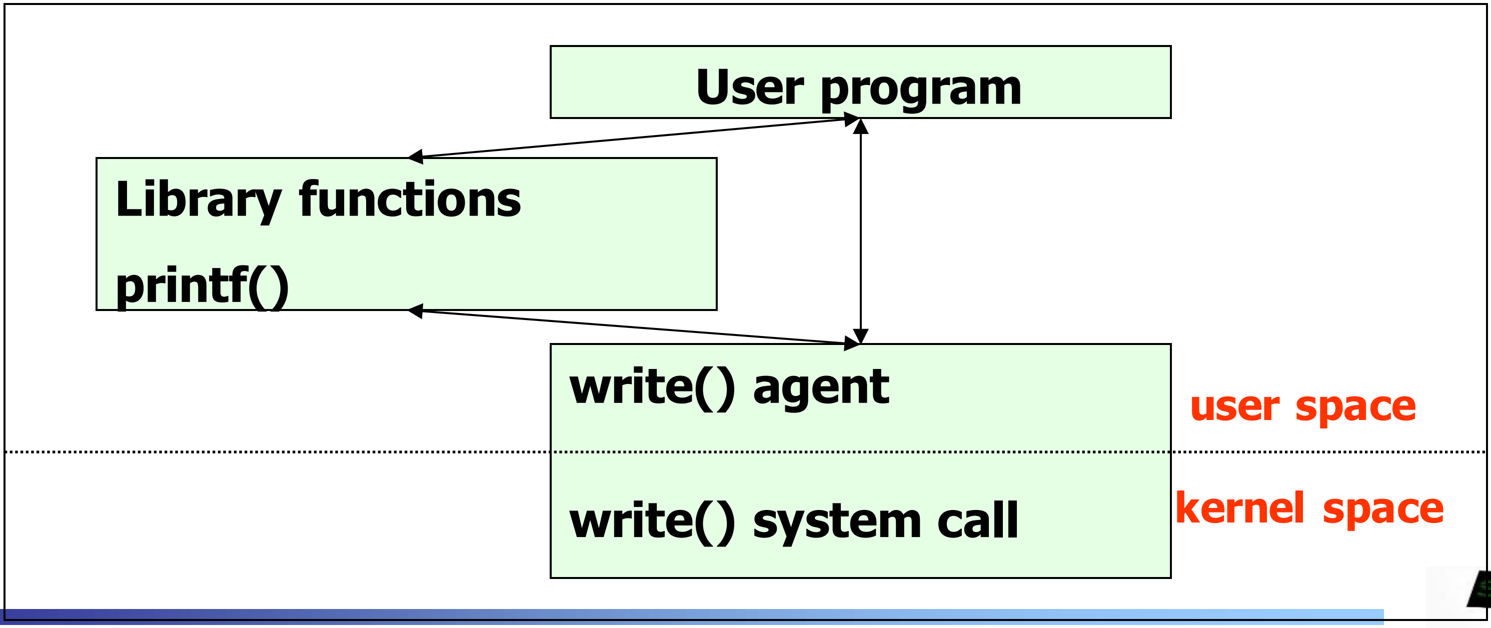


```
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ vi hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ cat hello.c
#include <stdio.h>

int main()
{
        printf("Hello DKU World\n");
}
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
hello.c
choijm@embedded:~/syspro/chap1$ gcc hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ls
a.out  hello.c
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$ ./a.out
Hello DKU World
choijm@embedded:~/syspro/chap1$
choijm@embedded:~/syspro/chap1$
```



Runtime System (2/5)

- library
  - ✓ A collection of functions, invoked frequently by a lot of users
    - Relocatable objects
    - Most languages have standard libraries (also programmers can make their own custom libraries using ar, ranlib and libtool.)
  - ✓ Categories
    - Static: 1).a, 2) statically linked (compile time), 3) simple
    - Shared: 1) .so, 2) dynamically linked (runtime), 3) memory efficient



User program

Library functions

printf()

write() agent

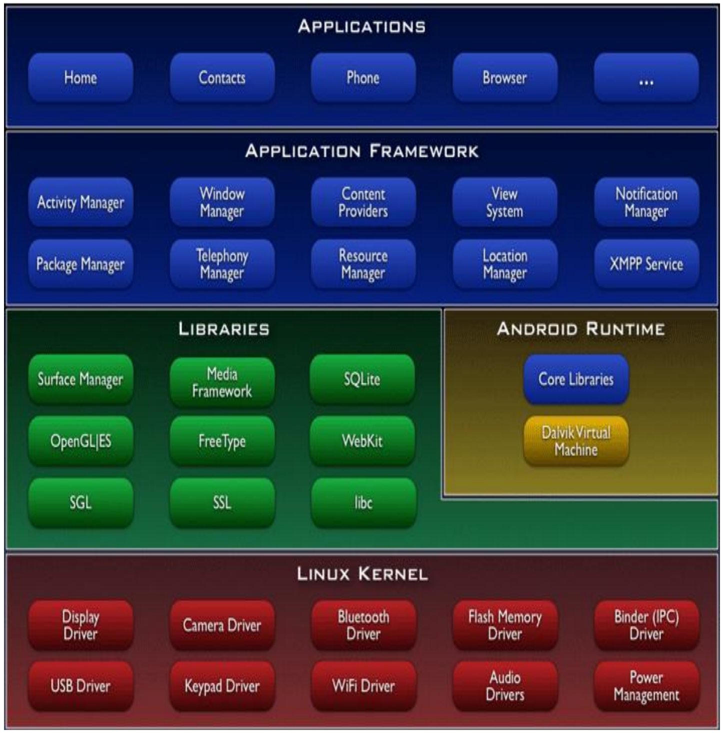
user space

kernel space

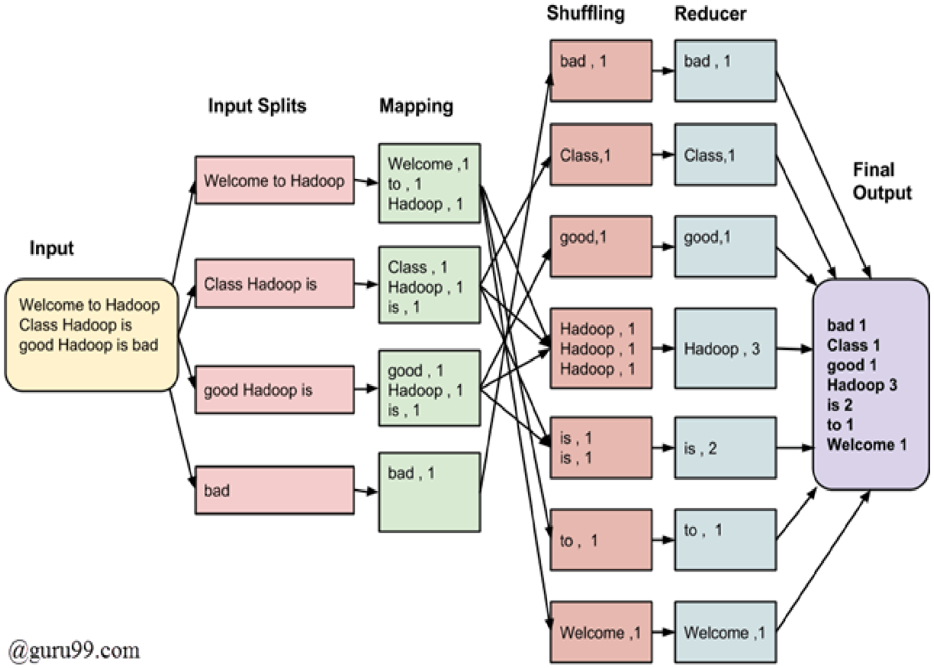
write() system call

Runtime System (3/5)

- Framework (also called as Platform)
  - ✓ A set of functionalities such as windows, database, graphics, multimedia, web, RPC, protocol, ...
  - ✓ Mobile framework (e.g. Android), Machine learning (e.g. Tensorflow) and Bigdata framework (e.g. MapReduce or Hadoop)



(Source: google image)

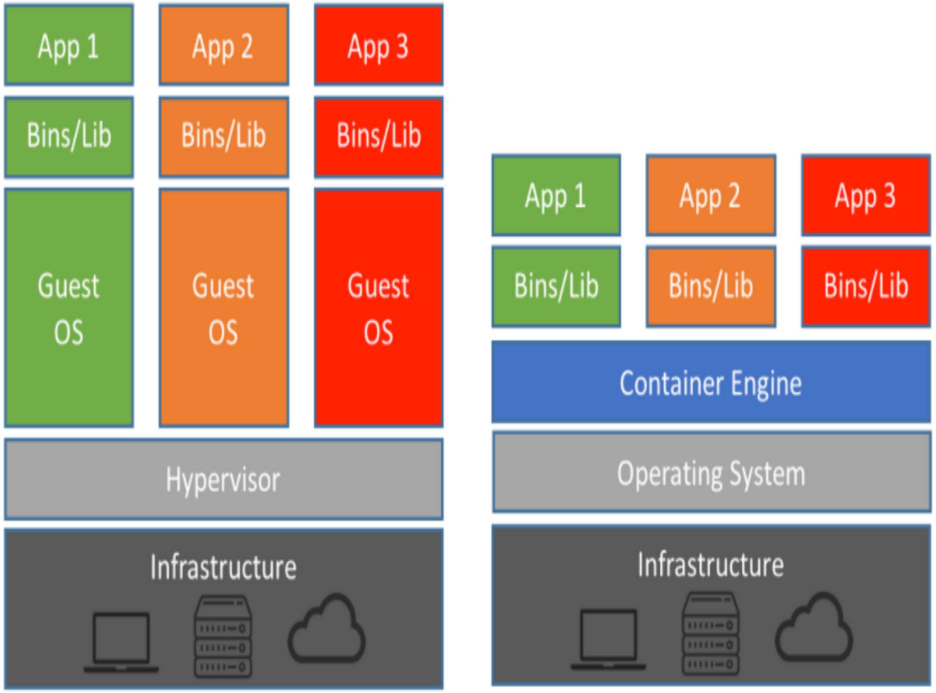


MapReduce Architecture

(Source: https://www.guru99.com/introduction-to-mapreduce.html)

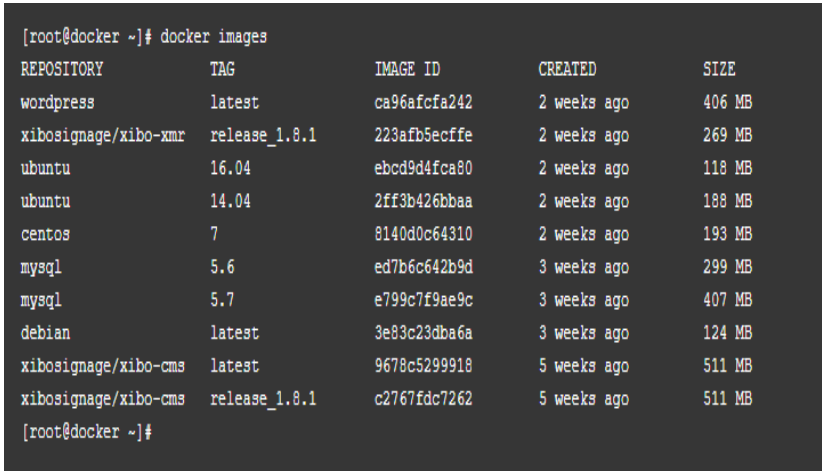
Runtime System (4/5)

- Virtual machine and Docker
  - ✓ Virtual machine: make virtual devices from Hypervisor (or Host OS)
    - Run GuestOS on the virtual devices
  - ✓ Docker: make a container (an isolated environment) using namespace and cgroup
    - Docker commands are quite similar to Linux (UNIX) command

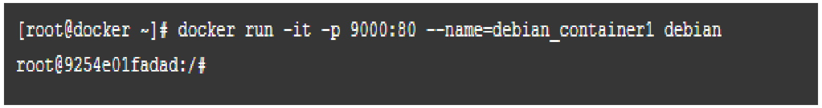


Machine Virtualization

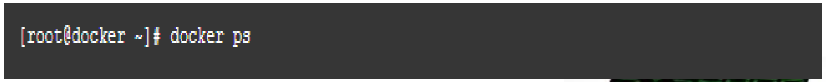
Containers



```
[root@docker ~]# docker images
REPOSITORY               TAG             IMAGE ID        CREATED        SIZE
wordpress                latest          ca96afcfa242    2 weeks ago    406 MB
xibosignage/xibo-xmr     release_1.8.1   223afb5ecffe    2 weeks ago    269 MB
ubuntu                   16.04           ebcd9d4fca80    2 weeks ago    118 MB
ubuntu                   14.04           2ff3b426bbaa    2 weeks ago    188 MB
centos                   7               8140d0c64310    2 weeks ago    193 MB
mysql                    5.6             ed7b6c642b9d    3 weeks ago    299 MB
mysql                    5.7             e799c7f9ae9c    3 weeks ago    407 MB
debian                   latest          3e83c23dba6a    3 weeks ago    124 MB
xibosignage/xibo-cms     latest          9678c5299918    5 weeks ago    511 MB
xibosignage/xibo-cms     release_1.8.1   c2767fdc7262    5 weeks ago    511 MB
[root@docker ~]#
```



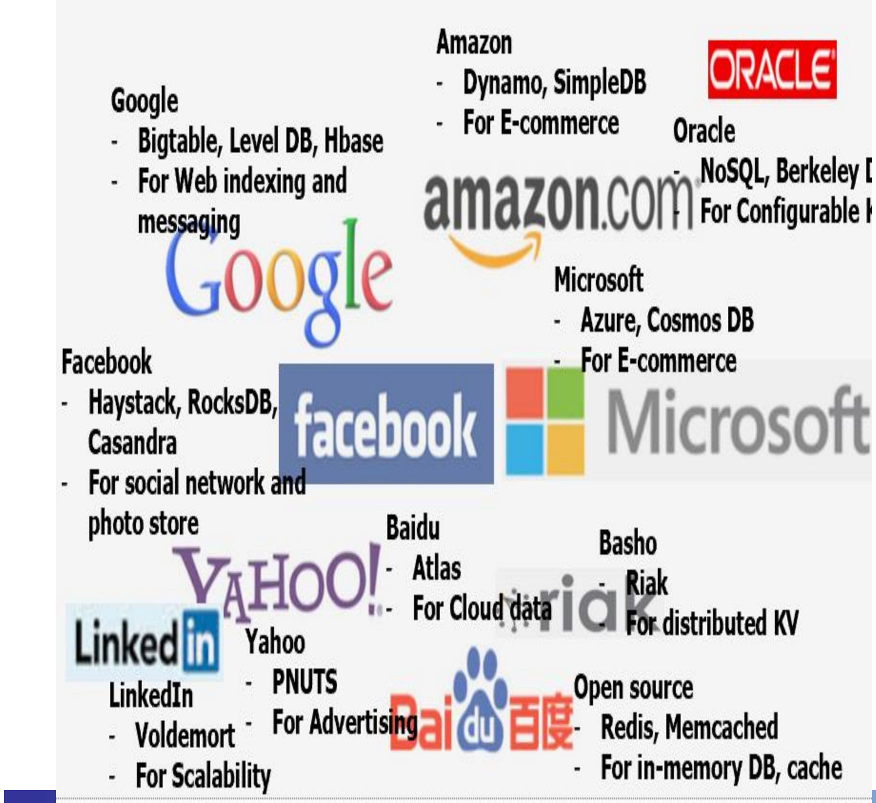
```
[root@docker ~]# docker run -it -p 9000:80 --name=debian_container1 debian
root@9254e01fadad:/#
```



```
[root@docker ~]# docker ps
```

Runtime System (5/5)

- Key-Value Store
  - ✓ Bigdata ➔ un-structured ➔ need new database ➔ Key-value store (or Document store or Graph store)
    - E.g. Google’s LevelDB, Meta’s RocksDB, Amazon’s Dynamo, …
  - ✓ Key data structure: LSM-tree, Skipped-list, Bloom filter, …



Google
- Bigtable, Level DB, Hbase
- For Web indexing and messaging

Amazon
- Dynamo, SimpleDB
- For E-commerce

Oracle
- NoSQL, Berkeley D
- For Configurable K

Microsoft
- Azure, Cosmos DB
- For E-commerce

Facebook
- Haystack, RocksDB, Casandra
- For social network and photo store

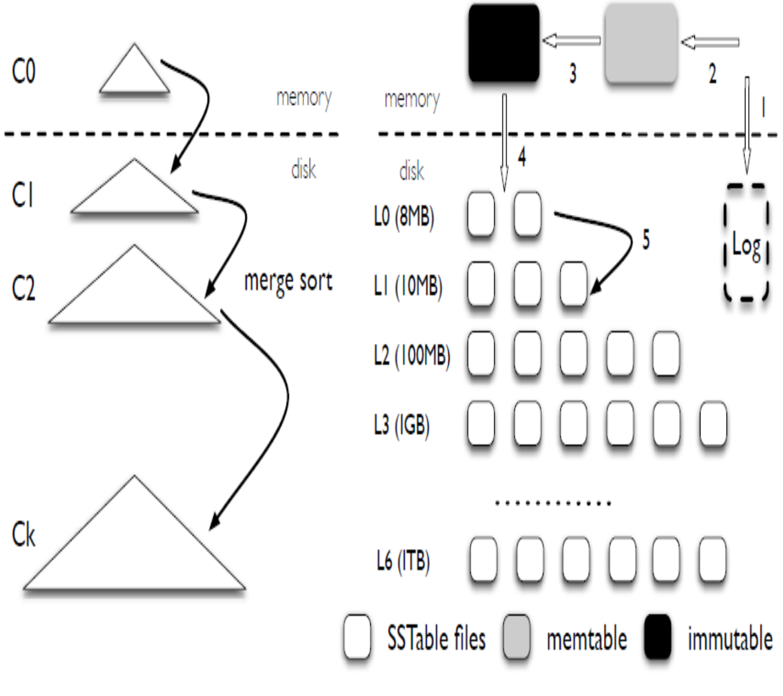
Baidu
- Atlas
- For Cloud data

Basho
- Riak
- For distributed KV

Yahoo
- PNUTS
- For Advertising

LinkedIn
- Voldemort
- For Scalability

Open source
- Redis, Memcached
- For in-memory DB, cache

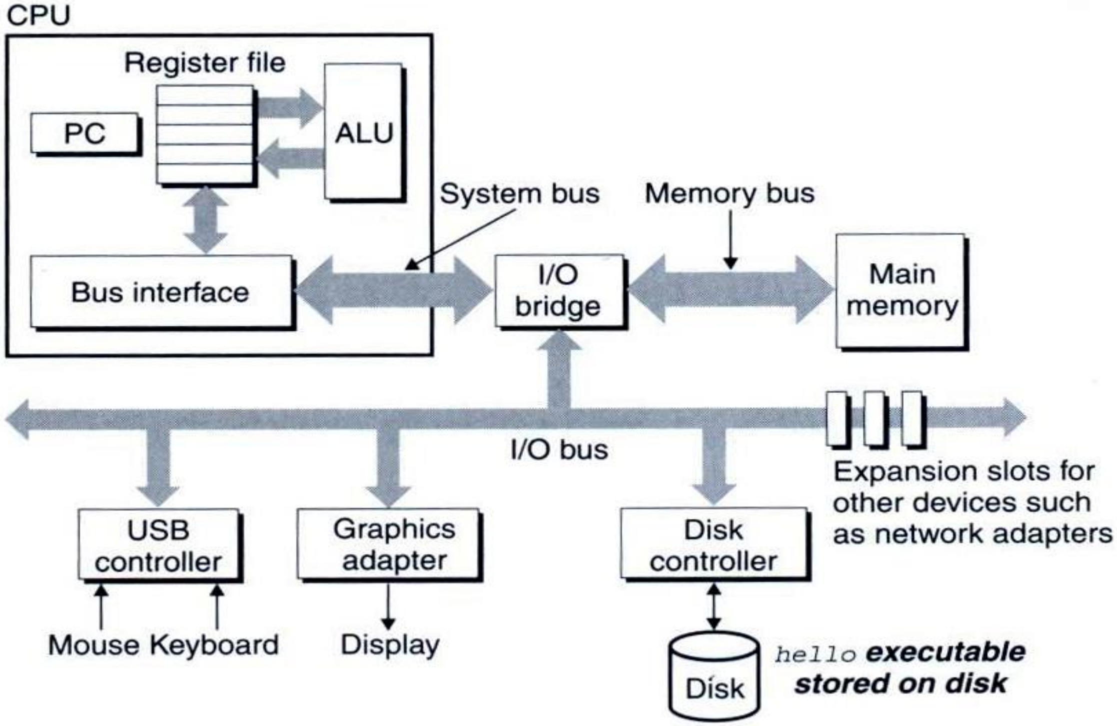


(a) LSM-tree (b) LevelDB

Hardware consideration (1/6)

- Computer organization
  - ✓ CPU: registers (include PC), ALU, cache, …
  - ✓ Memory: “address, content” pair
  - ✓ Device: controller + device itself
  - ✓ Bus: path for data flow, hierarchical

Figure 1.4
Hardware organization of a typical system. CPU: Central Processing Unit, ALU: Arithmetic/Logic Unit, PC: Program Counter, USB: Universal Serial Bus.

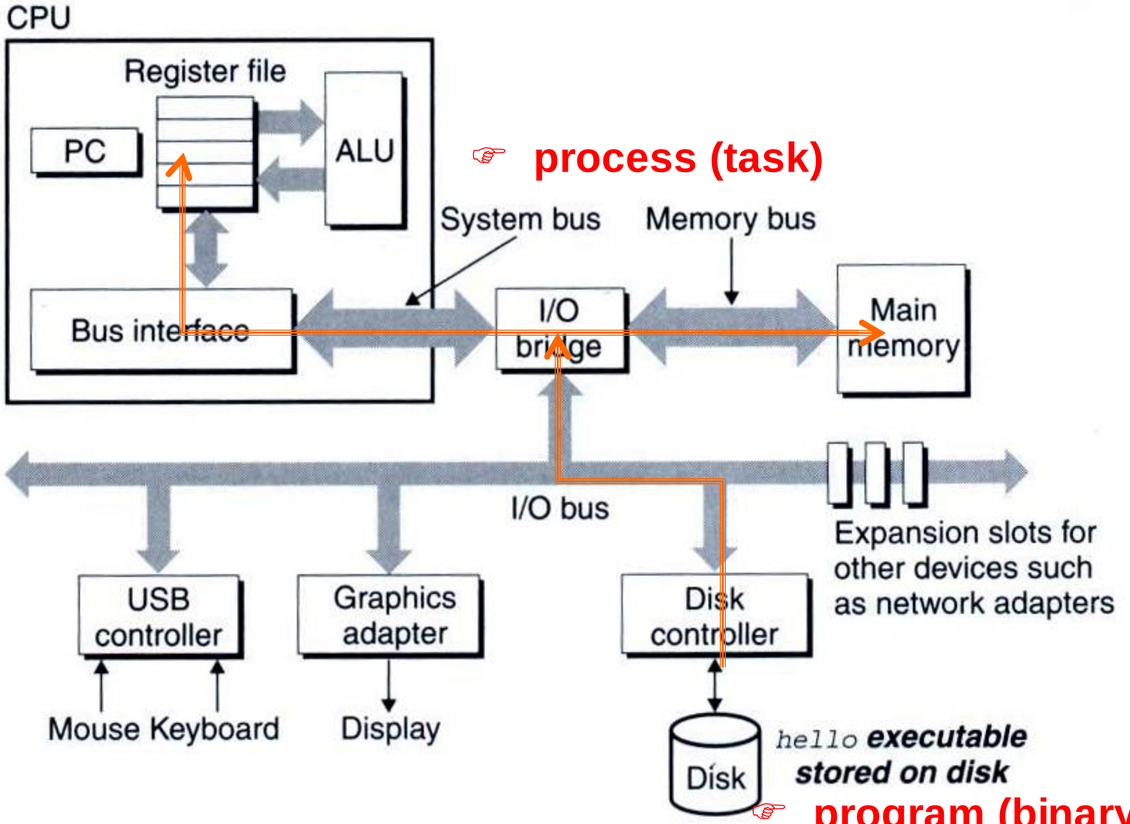


(Source: CSAPP)

Hardware consideration (2/6)

- Computer organization
  - ✓ Revisit the a.out compiled from hello.c
    - When is it loaded,

Figure 1.4 Hardware organization of a typical system. CPU: Central Processing Unit, ALU: Arithmetic/Logic Unit, PC: Program Counter, USB: Universal Serial Bus.



☞ **process (task)**

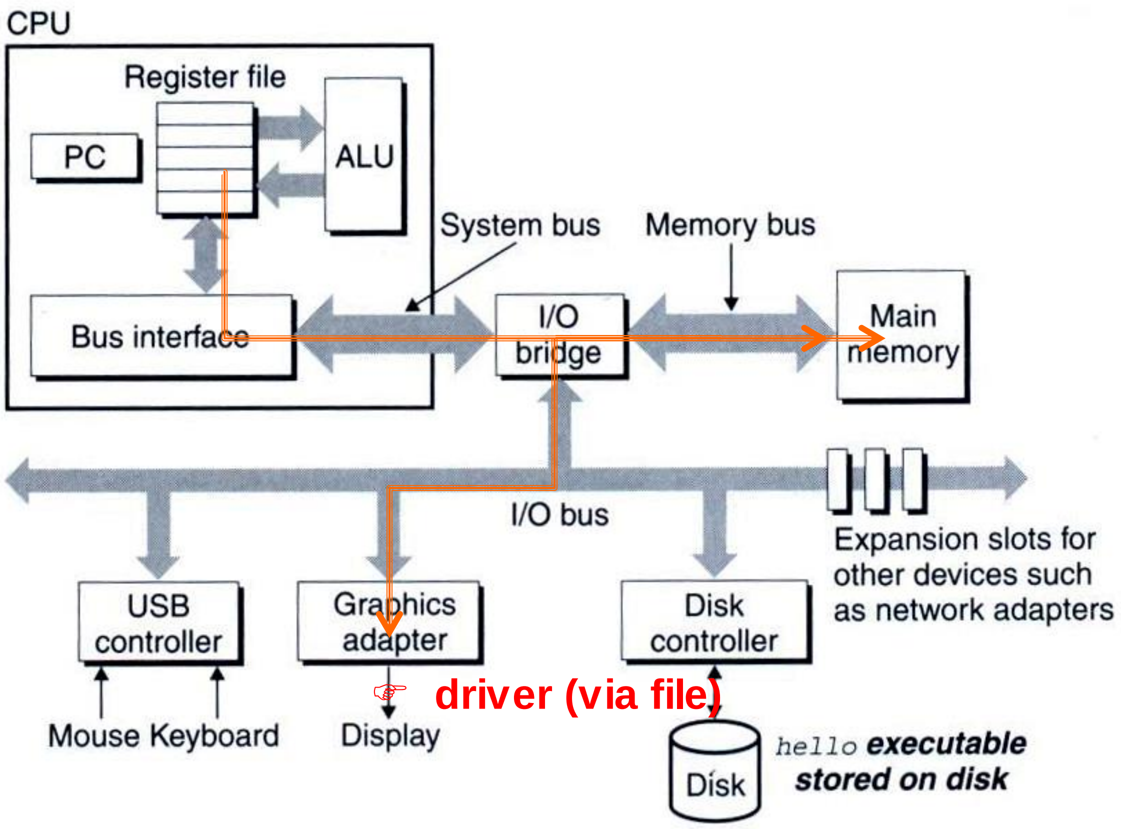
`hello` executable stored on disk

☞ **program (binary)**

Hardware consideration (3/6)

- Computer organization
  - ✓ Revisit the a.out compiled from hello.c
    - When printf(“Hello World\n”) is invoked

Figure 1.4 **Hardware organization of a typical system.** CPU: Central Processing Unit, ALU: Arithmetic/Logic Unit, PC: Program Counter, USB: Universal Serial Bus.



☞ **driver (via file)**

Hardware consideration (4/6)

- Memory matters
  - ✓ array programming example

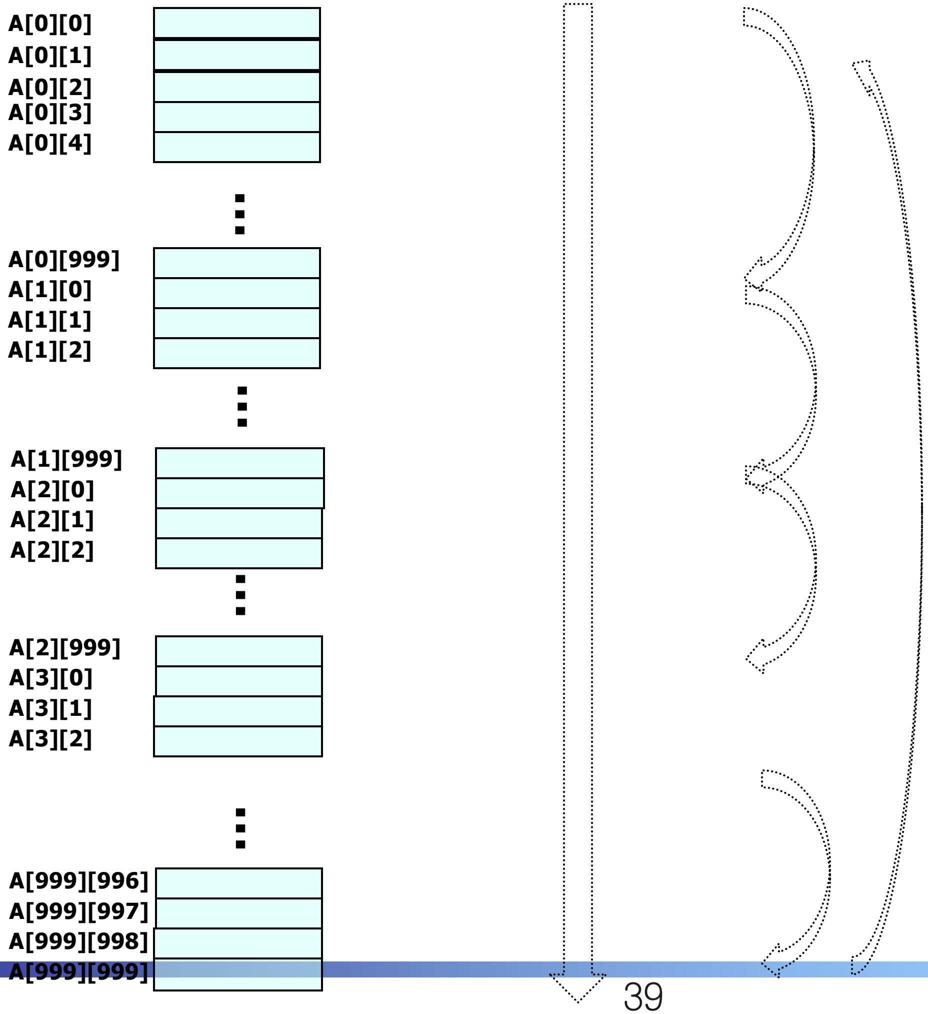
```
/* program A */
int a[1000][1000];
int i, j;
....

for (i=0; i<1000; i++)
    for (j=0; j<1000; j++)
        a[i][j] ++;
```

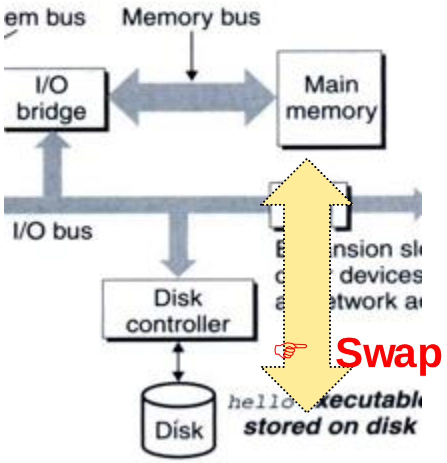
VS

```
/* program B */
int a[1000][1000];
int i, j;
....

for (i=0; i<1000; i++)
    for (j=0; j<1000; j++)
        a[j][i] ++;
```

Hardware consideration (5/6)

- Memory matters
  - ✓ Memory layout of the array programming example
  - ✓ Note that, in limited memory, some data are swapped out and in





Hardware consideration (6/6)

- CPU also matters
  - ✓ Loop unrolling example
    - Two programs show different resource utilization in CPU (➔ See Chapter 5 in CSAPP)

```
void combine4(vec_ptr v, data_t *dest)
{
   int i;
   int length = vec_length(v);
   data_t *data = get_vec_start(v);
   data_t x = 0;

   for (i = 0; i < length; i++) {
      x = x + data[i];
   }
   *dest = x;
}
```

VS

```
void combine5(vec_ptr v, data_t *dest)
{
   int i;
   int length = vec_length(v);
   data_t *data = get_vec_start(v);
   data_t x = 0;
   int limit = length – 2;

   for (i = 0; i < limit; i += 3) {
       x = x + data[i] + data[i+1] + data[i+2];
   }

   for ( ; i < length; i++) {
       x = x + data[i];
   }
   *dest = x;
}
```

(Source: Chapter 5 in CSAPP)

Abstraction (1/9)

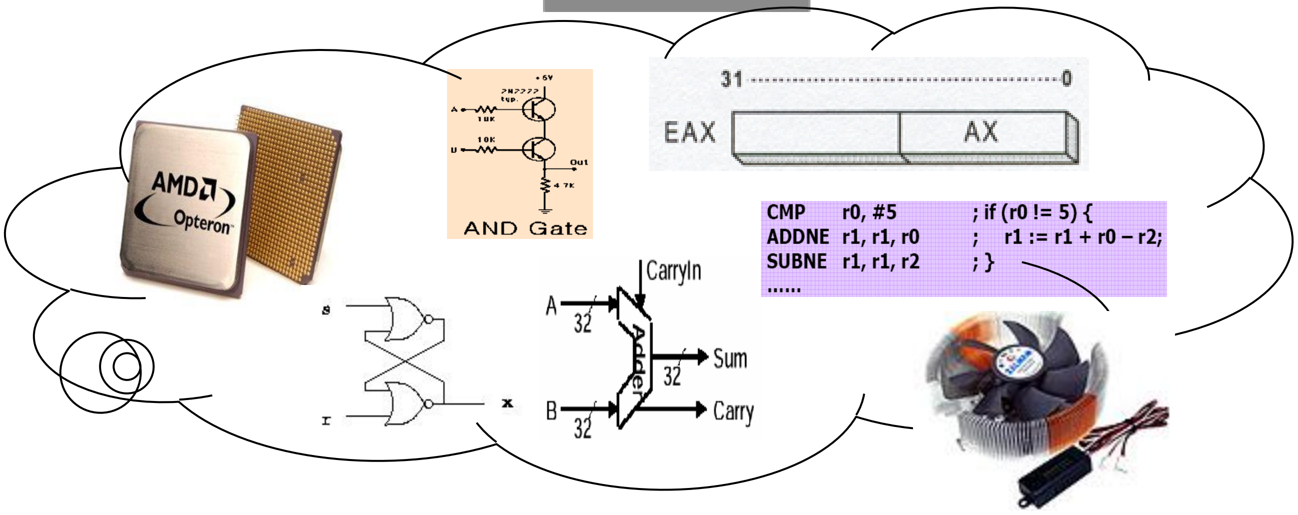
- Key of System Program: Abstraction
  - ✓ **Abstraction** is the process of generalization by reducing the information content of a concept or an observable phenomenon, typically in order to retain only information which is relevant for a particular purpose.
  - ✓ In computer science, abstraction tries to reduce and factor out details so that the programmer can focus on a few concepts at a time. A system can have several abstraction layers whereby different meanings and amounts of detail are exposed to the programmer.

Abstraction (2/9)

- CPU

Human-Friendly High Level Language
(ISA: Instruction Set Architecture)

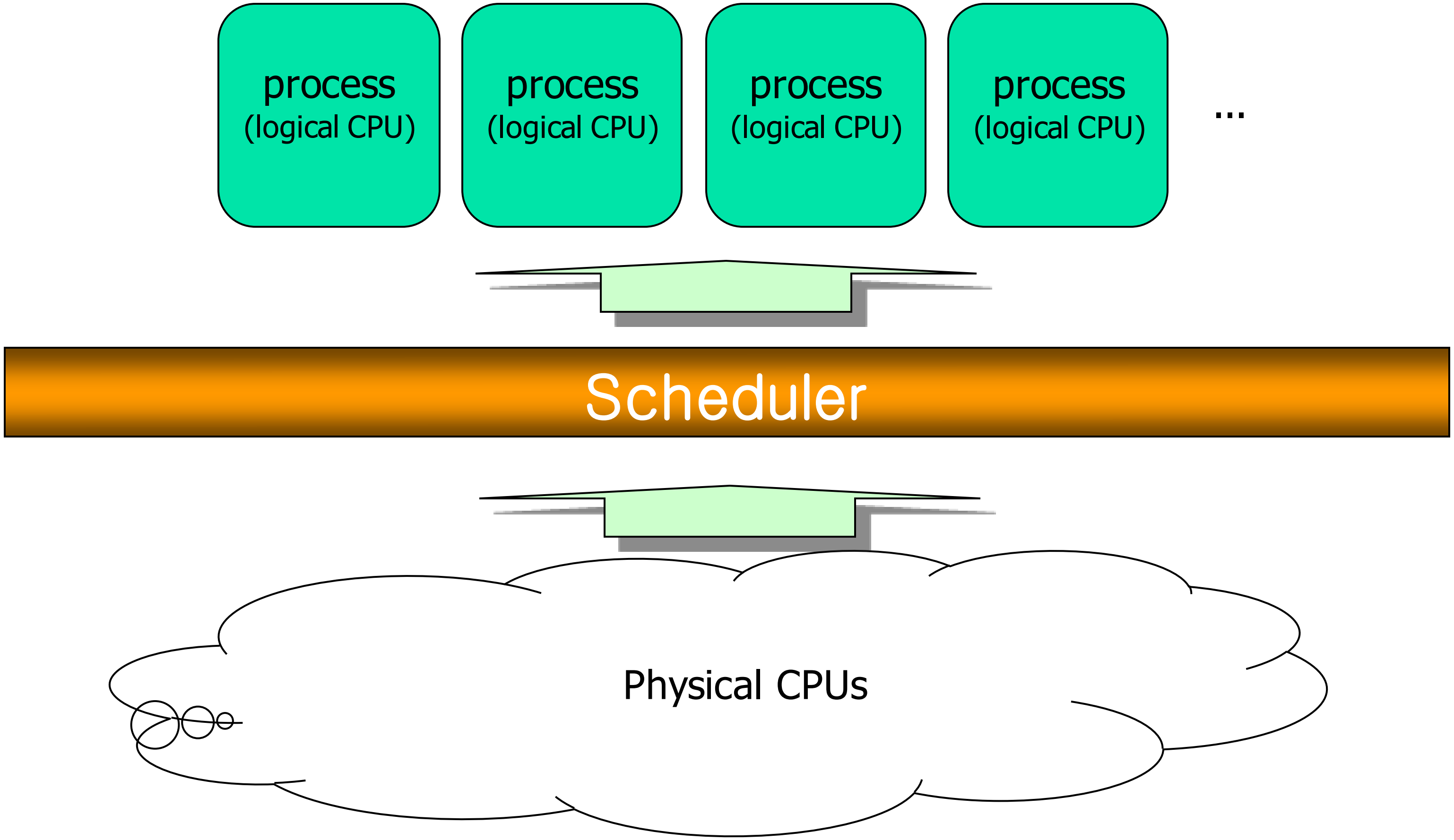
Compilation system



```
CMP     r0, #5          ; if (r0 != 5) {
ADDNE   r1, r1, r0      ;    r1 := r1 + r0 – r2;
SUBNE   r1, r1, r2      ; }
……
```

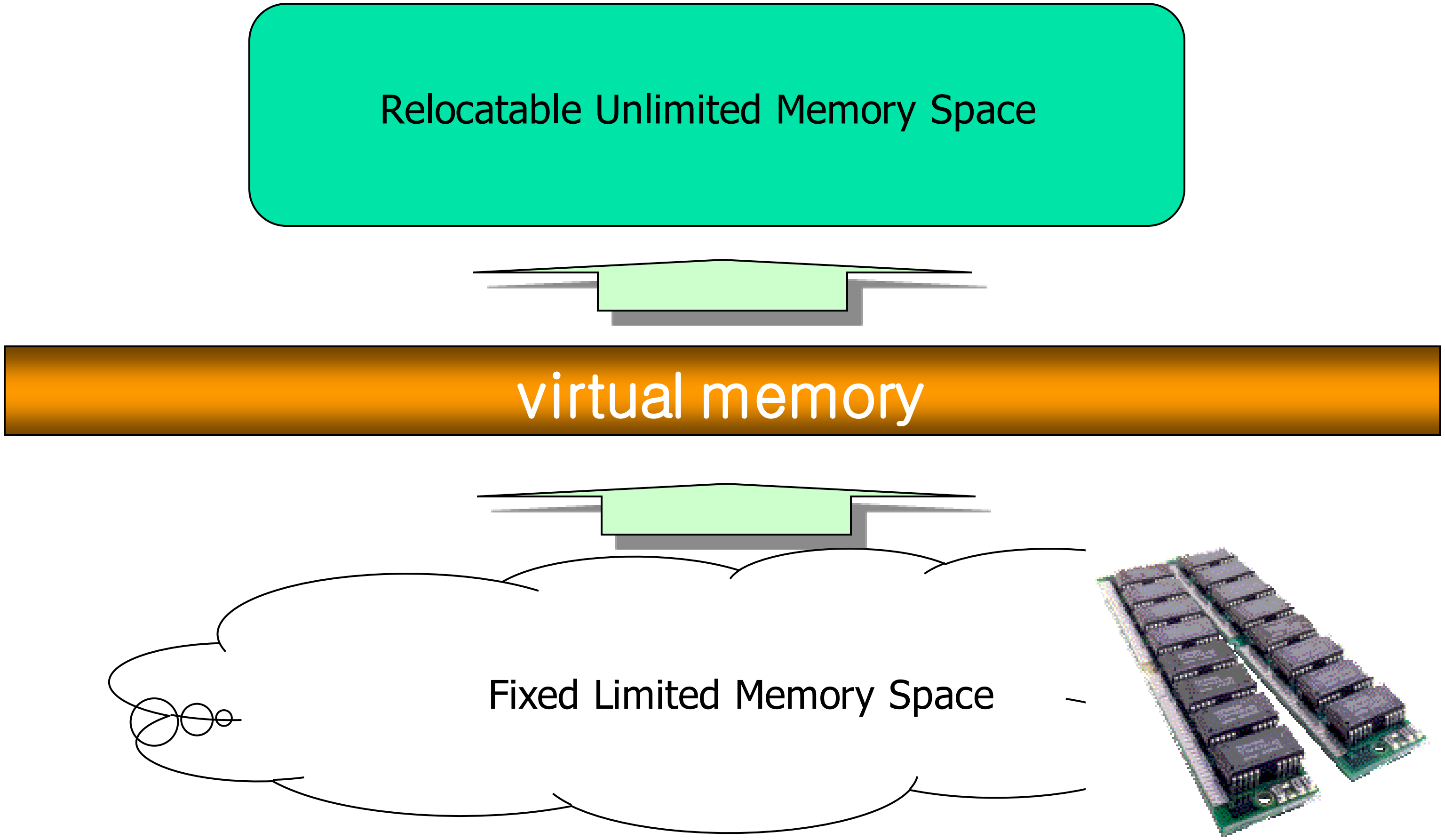
Abstraction (3/9)

- Multitasking



Abstraction (4/9)

- Memory management



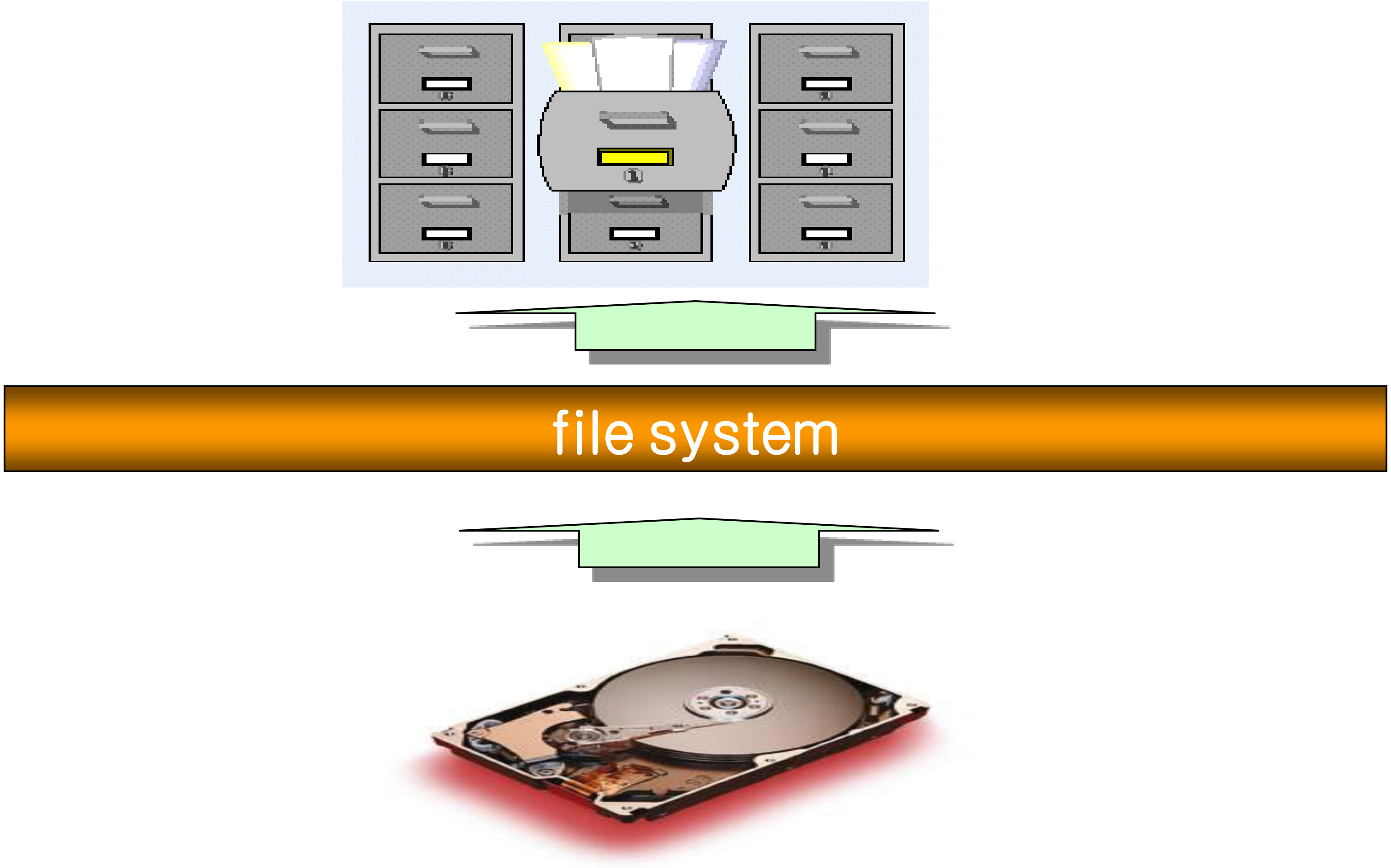
Relocatable Unlimited Memory Space

virtual memory

Fixed Limited Memory Space

Abstraction (5/9)

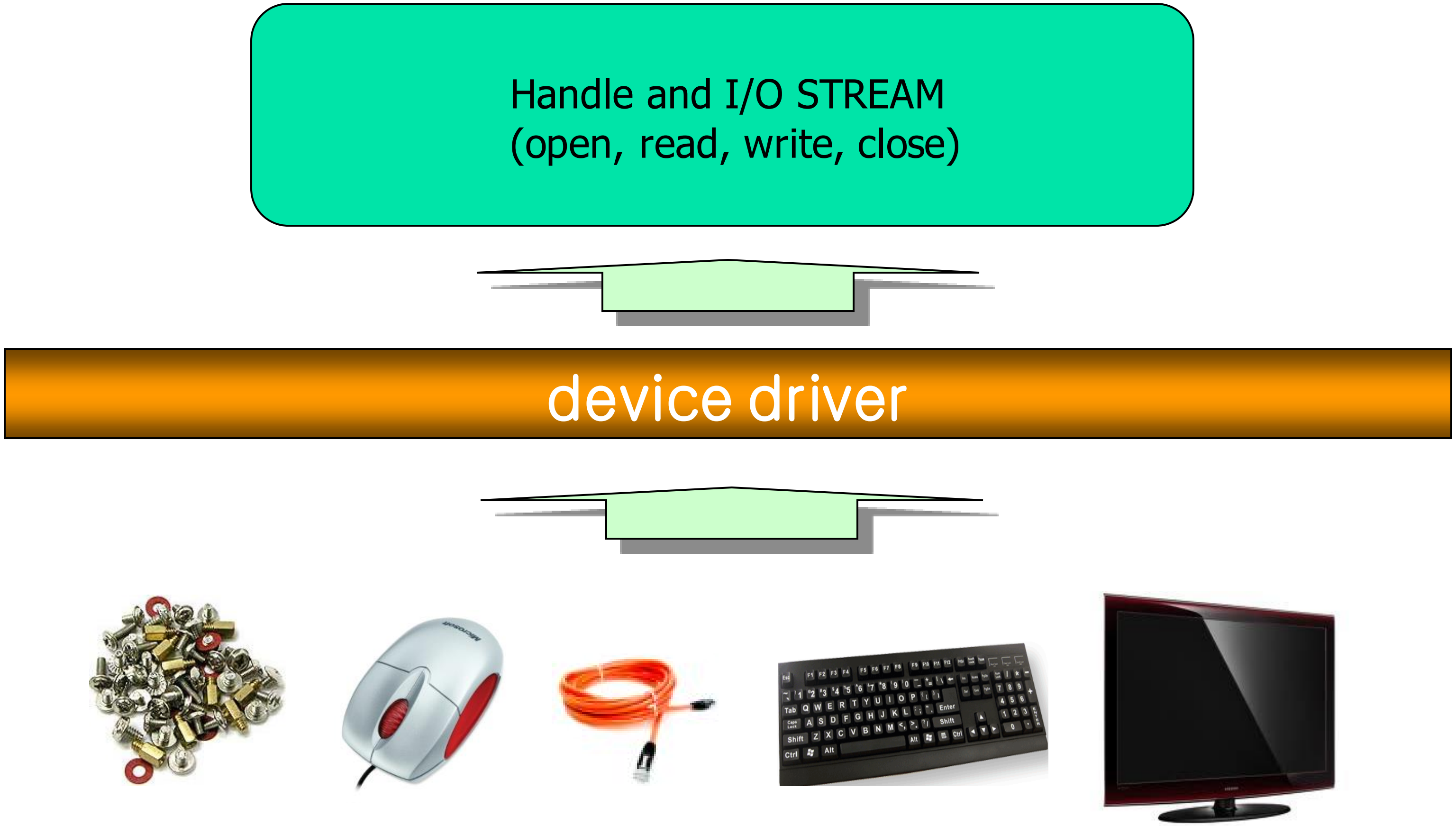
- File system



file system

Abstraction (6/9)

- Device driver

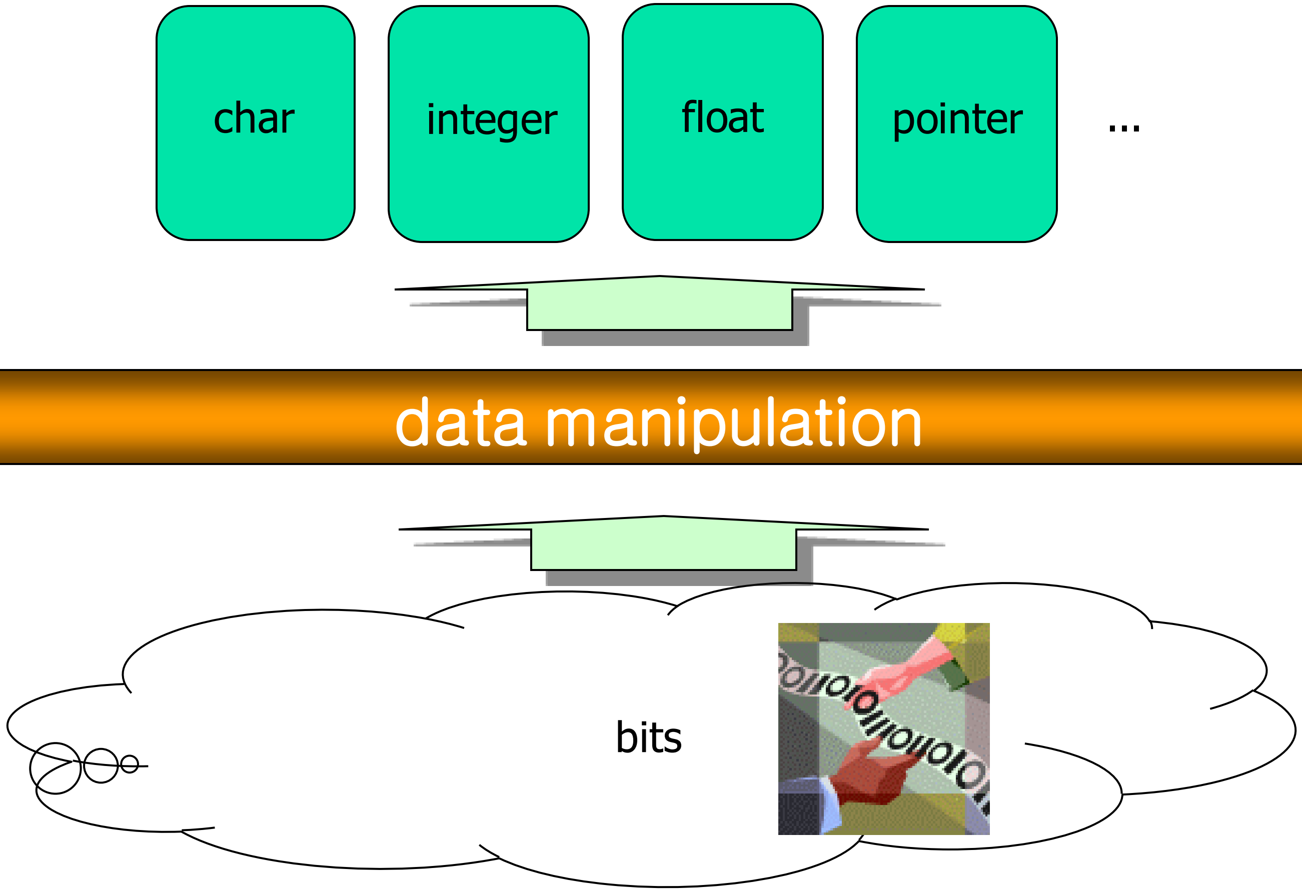


Handle and I/O STREAM
(open, read, write, close)

device driver

Abstraction (7/9)

- Data representation



char

integer

float

pointer

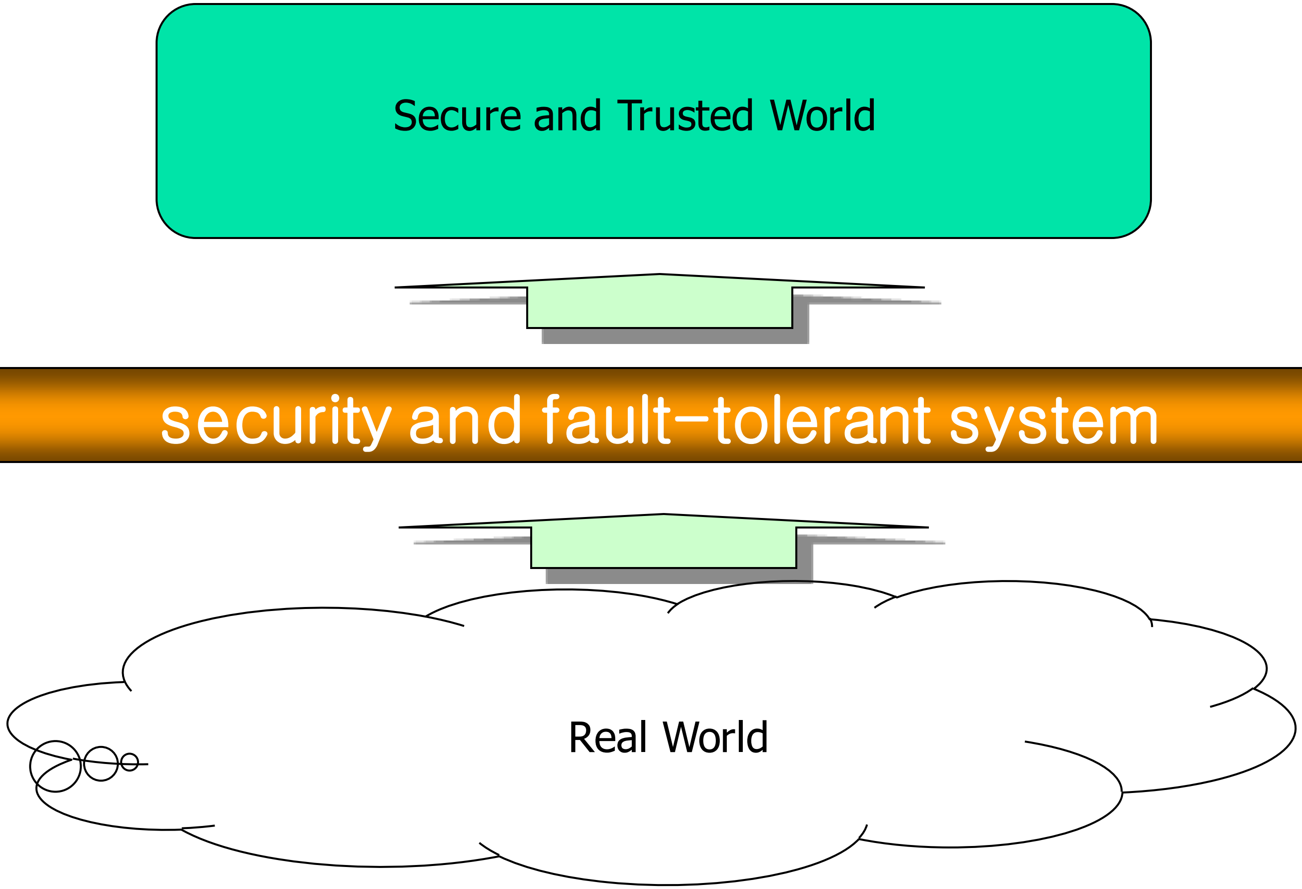
…

data manipulation

bits

Abstraction (8/9)

- Security and reliability



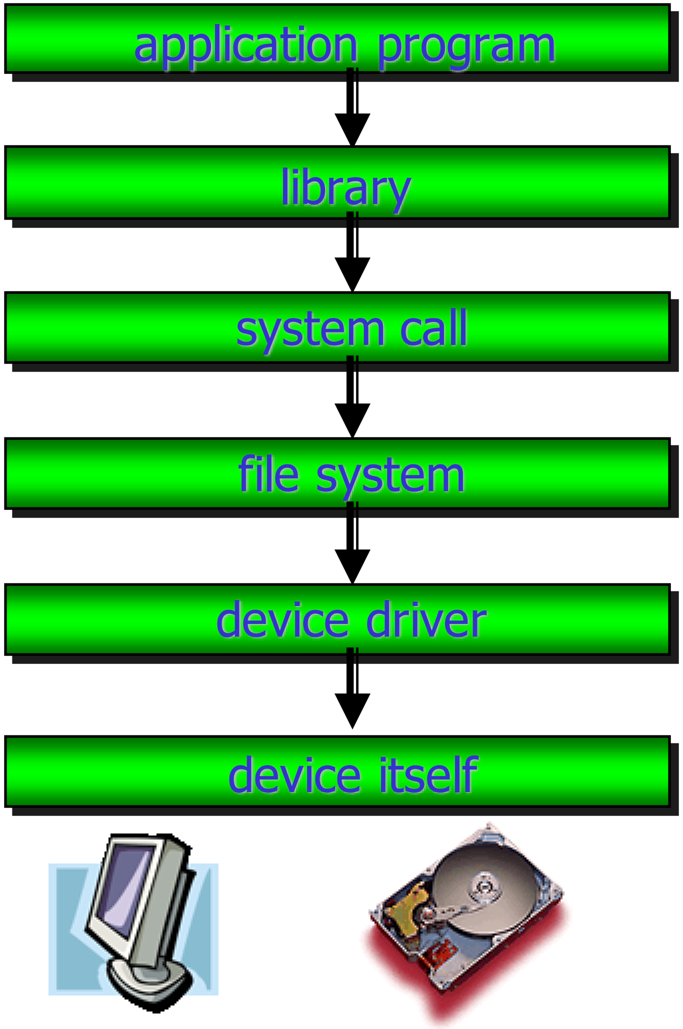
Secure and Trusted World

security and fault-tolerant system

Real World

Abstraction (9/9)

- Software layers (Layered architecture)



application program

library

system call

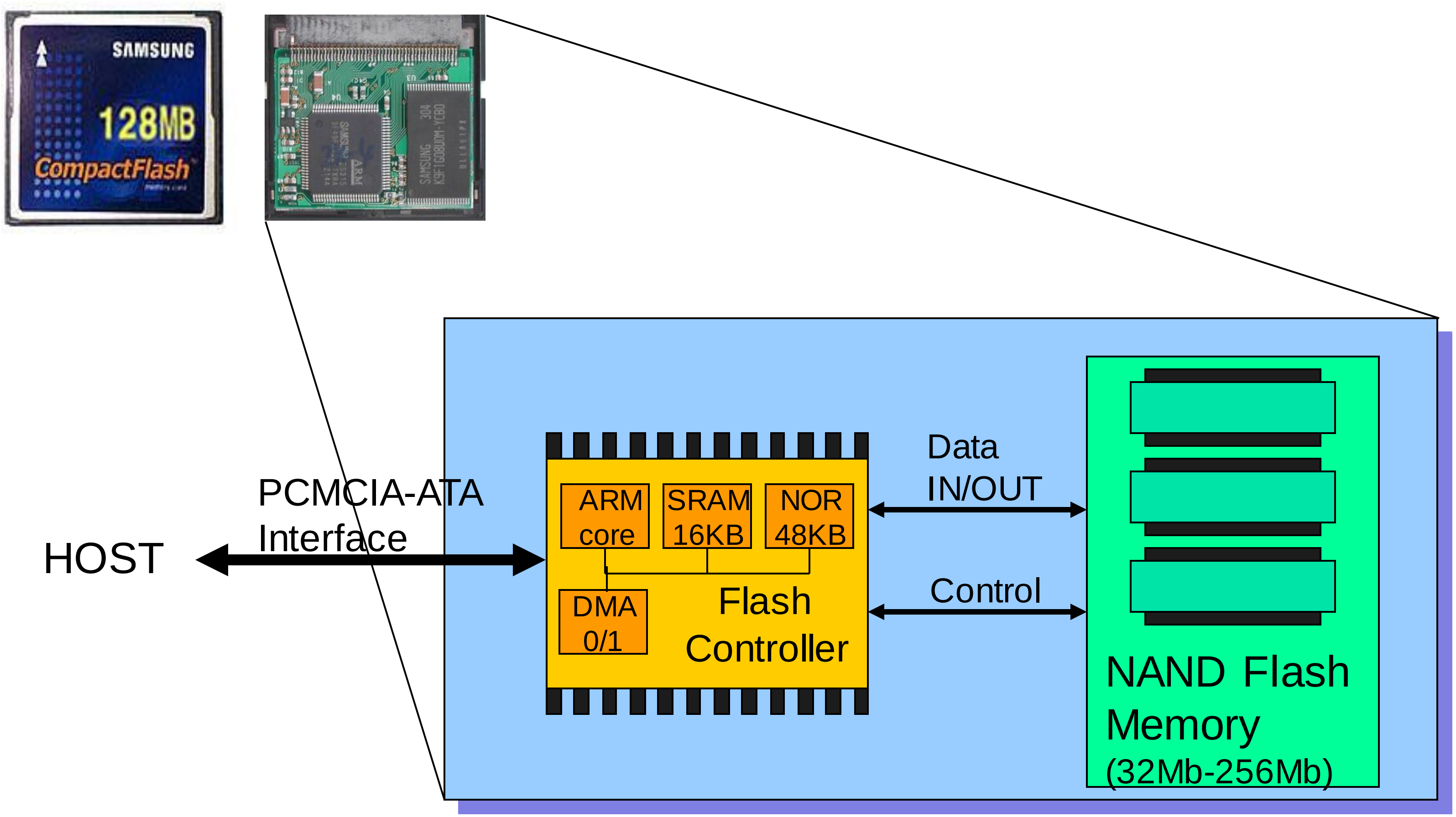
file system

device driver

device itself

Importance of System Program

- Compact Flash Storage Card Internals



☞ **Knowledge about how HW and SW are cooperated becomes indispensable in recent computing industry (HW/SW Co-design)**

Summary

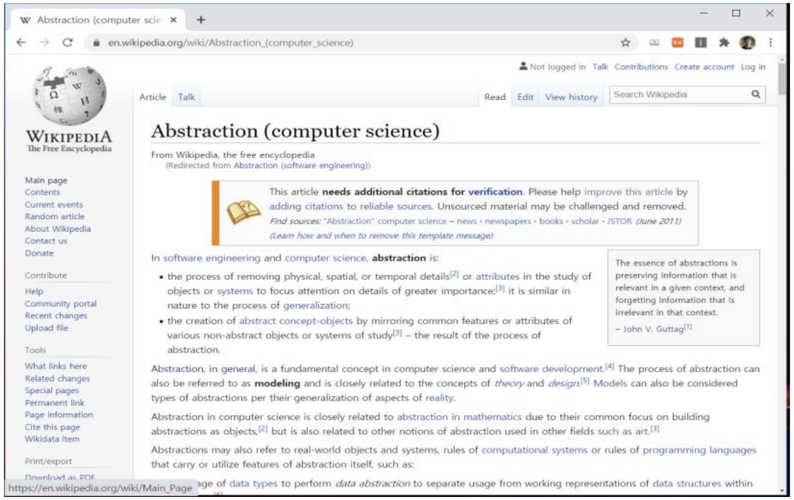
- Definition of System Program
  - ✓ Supporting computing environments
  - ✓ Managing hardware directly
- 3 Types of System Program
  - ✓ Compilation system, operating system, runtime system
  - ✓ Hardware consideration
- Concept of Abstraction
  - ✓ Information hiding
  - ✓ Layered architecture

☞ **Homework 1: Summarize Chapter 1, “A Tour of Computer Systems” in CSAPP.**

- ✓ **Requirement: 1) From the beginning to the Section 1.7 (not include 1.8, 1.9 and 1.10), 2) What is the purpose of studying System Programming?**
- ✓ **Pages: 1) 1~10 pages, 2) 1~2 pages**
- ✓ **Deadline: Two weeks later**
- ✓ **Caution: Do not copy!!**

Quiz for this Lecture

- 1. Explain why loader is required in a computer system. (hint: using the difference between Disk and DRAM).
- 2. Discuss why the hardware components of Smartphone are different from those of PC even though they are same with the viewpoint of computer architecture (3 reasons).
- 3. What are the names of Linux command for editor, compiler, assembler, linker and loader (5 names).
- 4. Describe an example of abstraction in your life and discuss the features of abstraction in your chosen example (e.g. information hiding, focusing on what you are interested in).



Abstraction (computer science)

From Wikipedia, the free encyclopedia
(Redirected from Abstraction (software engineering))

This article **needs additional citations for verification**. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.
Find sources: "Abstraction" computer science – news · newspapers · books · scholar · JSTOR *(June 2011)*
(Learn how and when to remove this template message)

In software engineering and computer science, **abstraction** is:

- the process of removing physical, spatial, or temporal details[2] or attributes in the study of objects or systems to focus attention on details of greater importance;[3] it is similar in nature to the process of generalization;
- the creation of abstract concept-objects by mirroring common features or attributes of various non-abstract objects or systems of study[3] – the result of the process of abstraction.

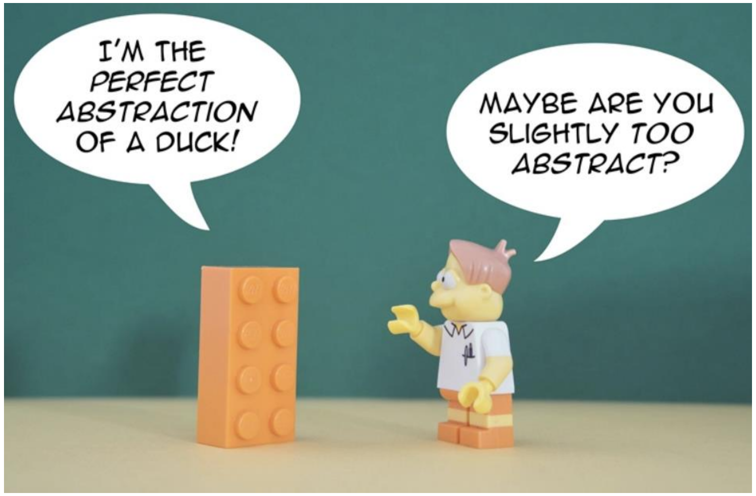
> The essence of abstractions is preserving information that is relevant in a given context, and forgetting information that is irrelevant in that context.
> – John V. Guttag[1]

Abstraction, in general, is a fundamental concept in computer science and software development.[4] The process of abstraction can also be referred to as **modeling** and is closely related to the concepts of *theory* and *design*.[5] Models can also be considered types of abstractions per their generalization of aspects of reality.

Abstraction in computer science is closely related to abstraction in mathematics due to their common focus on building abstractions as objects,[2] but is also related to other notions of abstraction used in other fields such as art.[3]

Abstractions may also refer to real-world objects and systems, rules of computational systems or rules of programming languages that carry or utilize features of abstraction itself, such as:

age of data types to perform *data abstraction* to separate usage from working representations of data structures within


I'M THE PERFECT ABSTRACTION OF A DUCK!
MAYBE ARE YOU SLIGHTLY TOO ABSTRACT?

(Source: https://thevaluable.dev/abstraction-type-software-example/)

Appendix

- RISC vs. CISC
  - ✓ assembly language example: look RISC takes longer
    - a = b + c;

```
load      b, eax
add       c, eax
store     eax, a
```

VS

```
add       b, c, a
```

  - ✓ Instruction execution: but, they can be pipelined

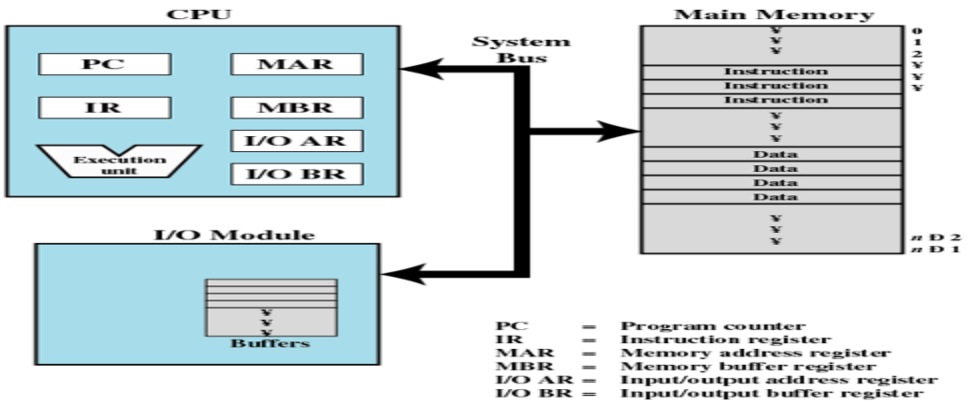


Figure 1.1 Computer Components: Top-Level View

(Source: W. Stalling, "Operating Systems: Internals and Design Principles")