Operating system

Part III: Process [进程] & Thread [线程]

Know data structures to maintain the resources needed when executing your program

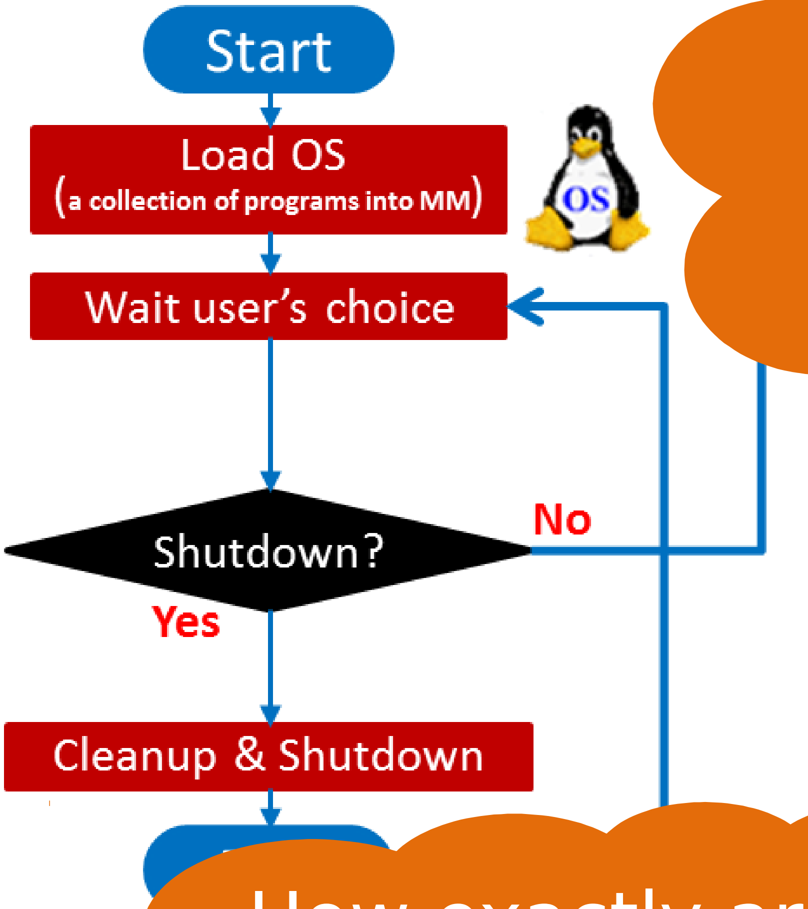
By KONG LingBo (孔令波)

Process

- To understand the execution of your program
  - Process [进程] is the traditional concept
    - The identification to manage the needed information to run one program (**OS' s or user' s**)
      - **PCB** is the data structure to record the necessary information: resources (MM, ownership, security, …), execution stages/states, …
    - Additional data structures and algorithms are needed to manage the concurrent execution of many programs
      - Queues, and schedulers
      - Inter-process communication (IPC)
  - Thread[线程] is the modern concept
    - The idea could be seen as **MULTIPLEX**ing **process,** *namely that your program is constructed to have more than one execution units*
      - CPU is occupied by the process, however the usage of the CPU is shared among the internal execution units (threads)
        - » The resources assigned to the process could be shared by those threads.

We have learned th

OS, prefer to call the collection of necessary resources to execute your program + program itself as **PROCESS[进程]!**


Start

Load OS (a collection of programs into MM)

OS

Wait user's choice

Shutdown?

No

Yes

Cleanup & Shutdown

…ny programs).

During the execut… …gram's task to respond user's input

1:1:M = 1 CPU, 1 MM, Many IO devices

How exactly are those programs controlled by OS?

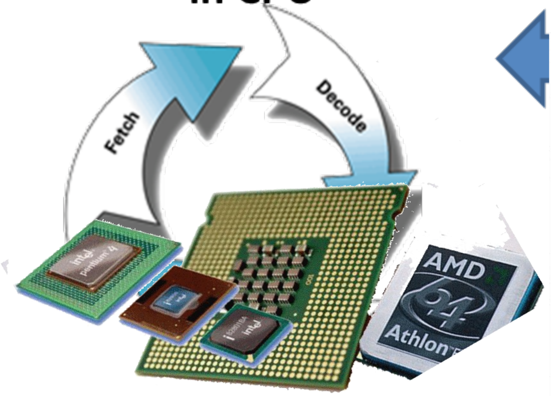
The execution of your program needs some support

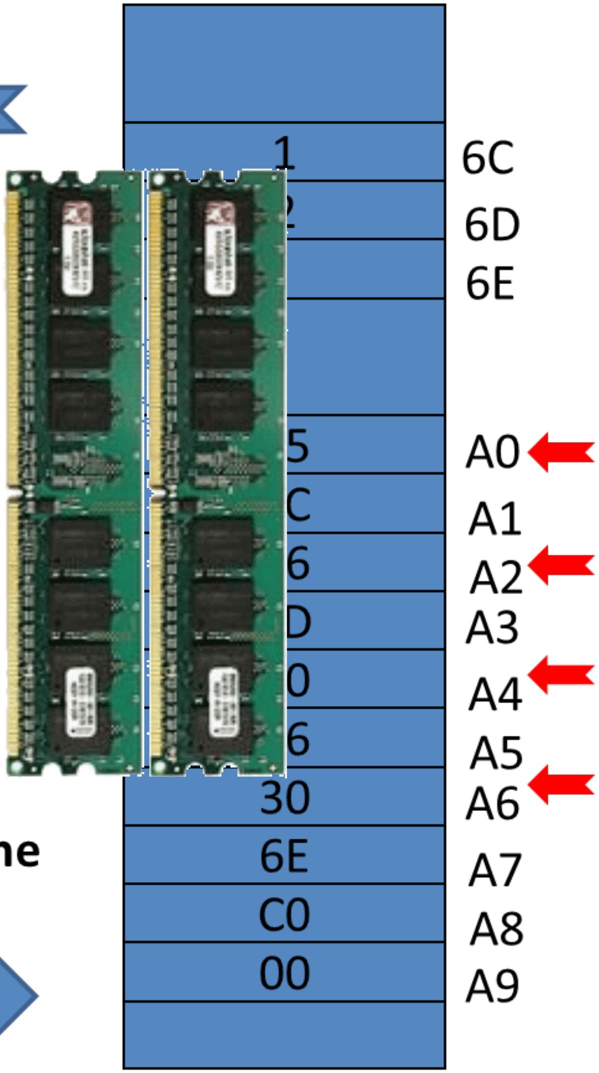
Programs are stored as Files in storage media

Program

X=1;
Y= 2;
Z= X+Y;

execute instructions serially in CPU

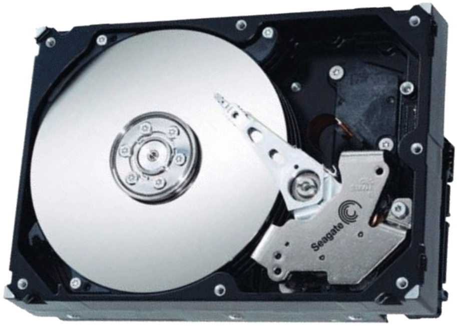




1	6C
2	6D
	6E
5	A0
C	A1
6	A2
D	A3
0	A4
6	A5
30	A6
6E	A7
C0	A8
00	A9

Machine code

156C→0001010101101100
166D→0001011001101101
5056→0101000001010110
306E→0011000001101110
C000→1100000000000000



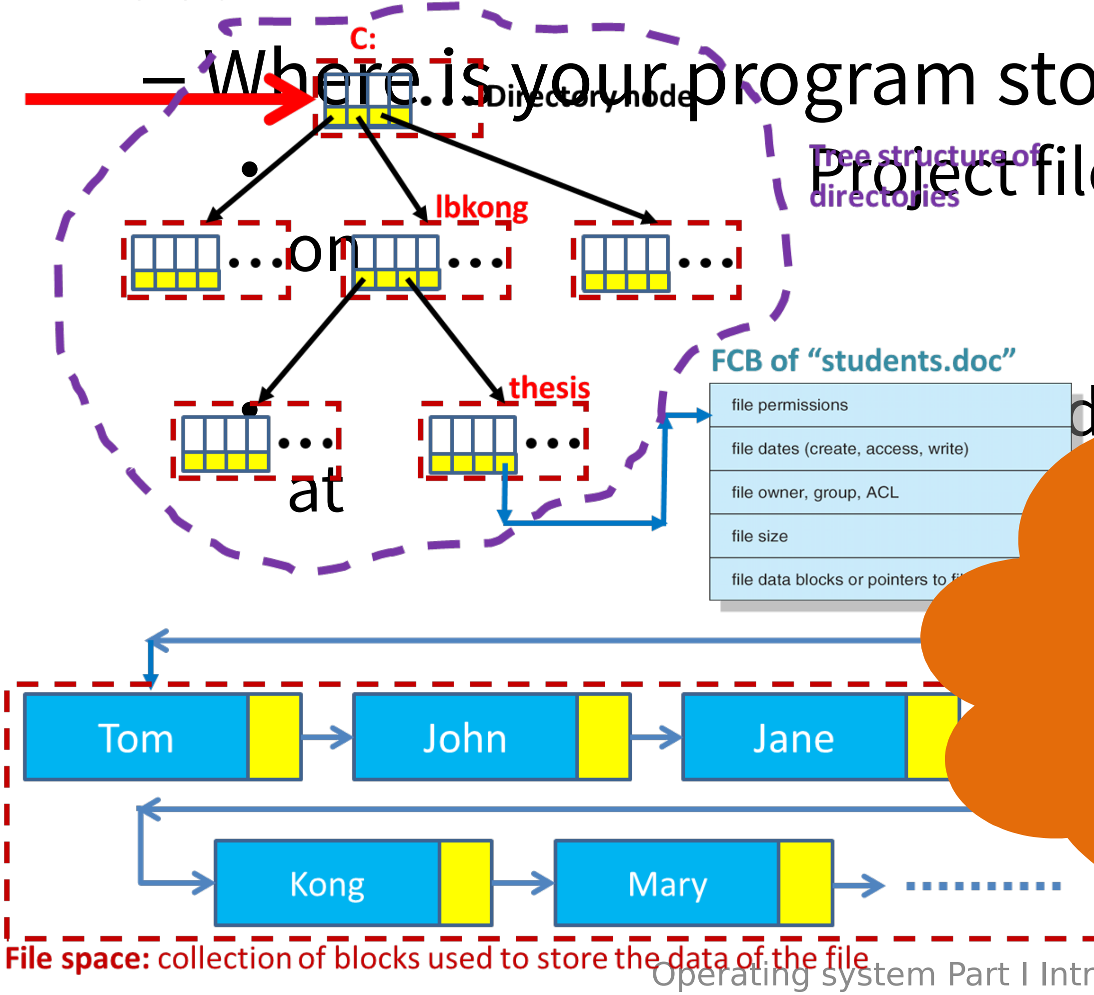
HDD

Put executable codes into the memory of the computer

Instructions are mapped into the address space of memory

- To support the execution of a program, we need to record some information (define so me data structure) – besides the program it self
  - – Where is your program stored in the HDD?
    - Project file contains the organizati on at information.

d inform t

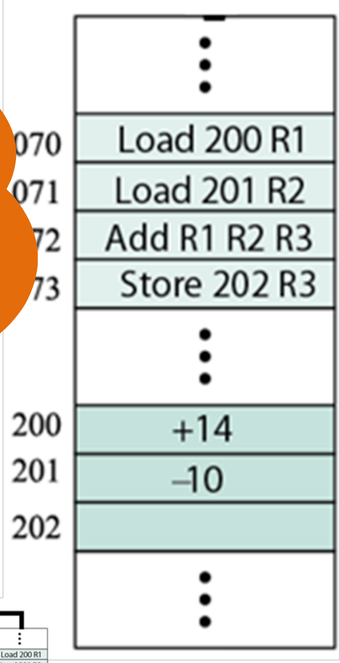

C:
Directory node
Tree structure of directories
lbkong
thesis
FCB of “students.doc”
file permissions
file dates (create, access, write)
file owner, group, ACL
file size
file data blocks or pointers to fi
Tom
John
Jane
Kong
Mary
....
File space: collection of blocks used to store the data of the file

We'll learn this **how** in later chapter: **IO + File**

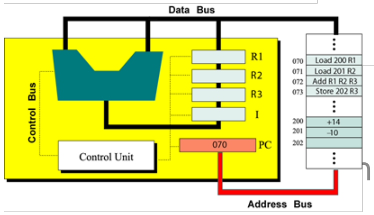
- Where could we copy the program in MM?
  - We need information about the usage of MM first
  - If available, the program is copied into MM
  - We need information to locate the instructions in MM

We'll learn this **how** in later chapter:

MM



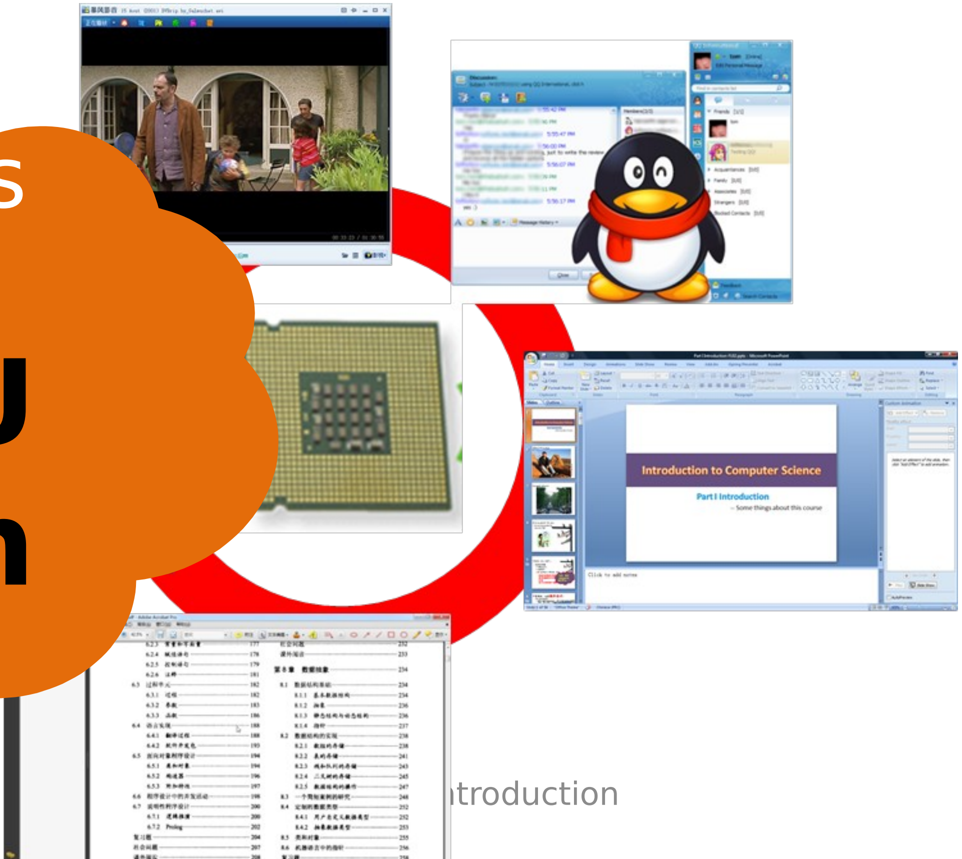
	⋮
070	Load 200 R1
071	Load 201 R2
72	Add R1 R2 R3
73	Store 202 R3
	⋮
200	+14
201	–10
202	
	⋮



Machine code

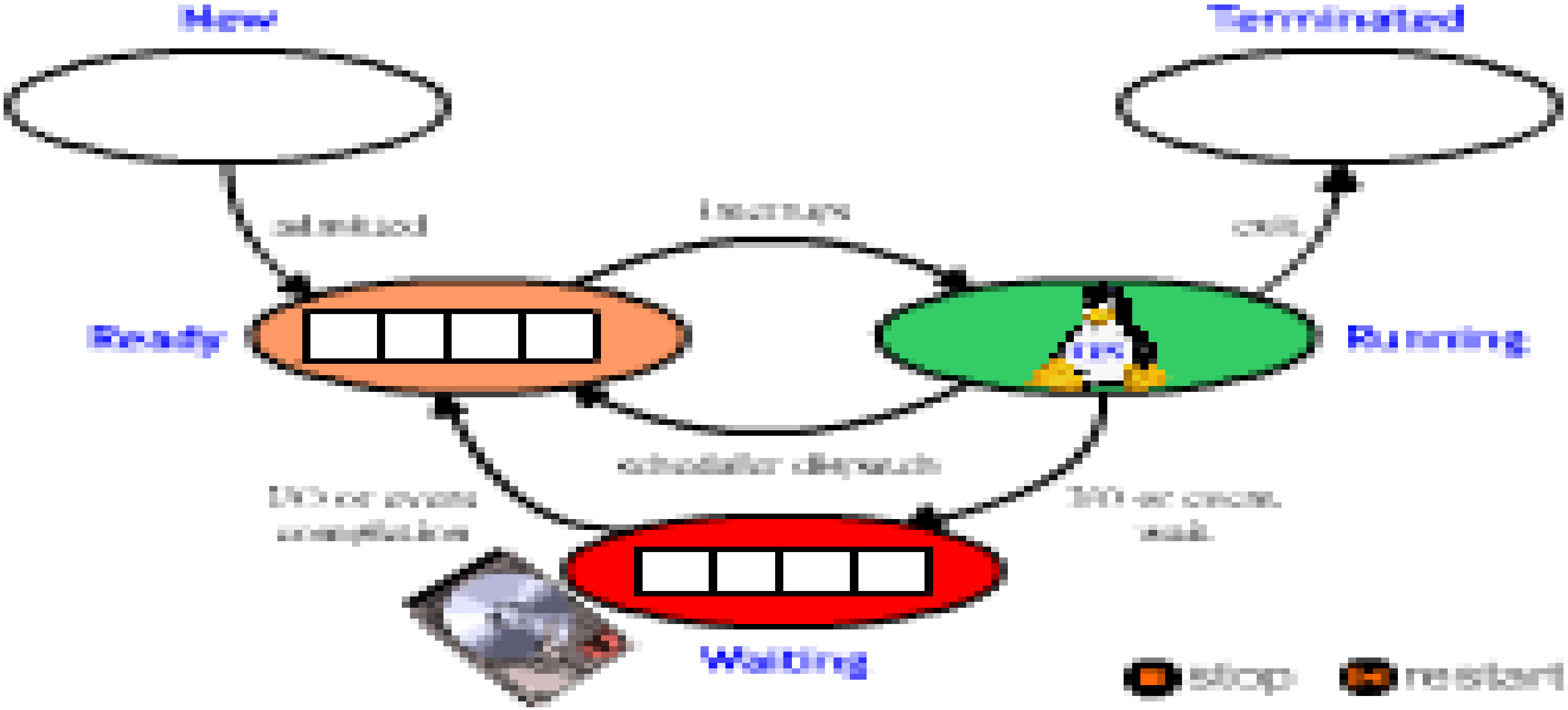
[00] 14 (should be bin)
[01] -10
[02] (used later)
[03] 0001 **00000000**
[04] 0010 **00000001**
[05] 0011
[06] 0100 **00000010**

- We also need to record the information of current instruction for CPU switching
    - The address of the instruction when CPU is switched, like 1031


Introduction to Computer Science
Part I Introduction
– Some things about this course

We'll learn this **how** in later chapter: **CPU Scheduling**

The execution of your program is alive



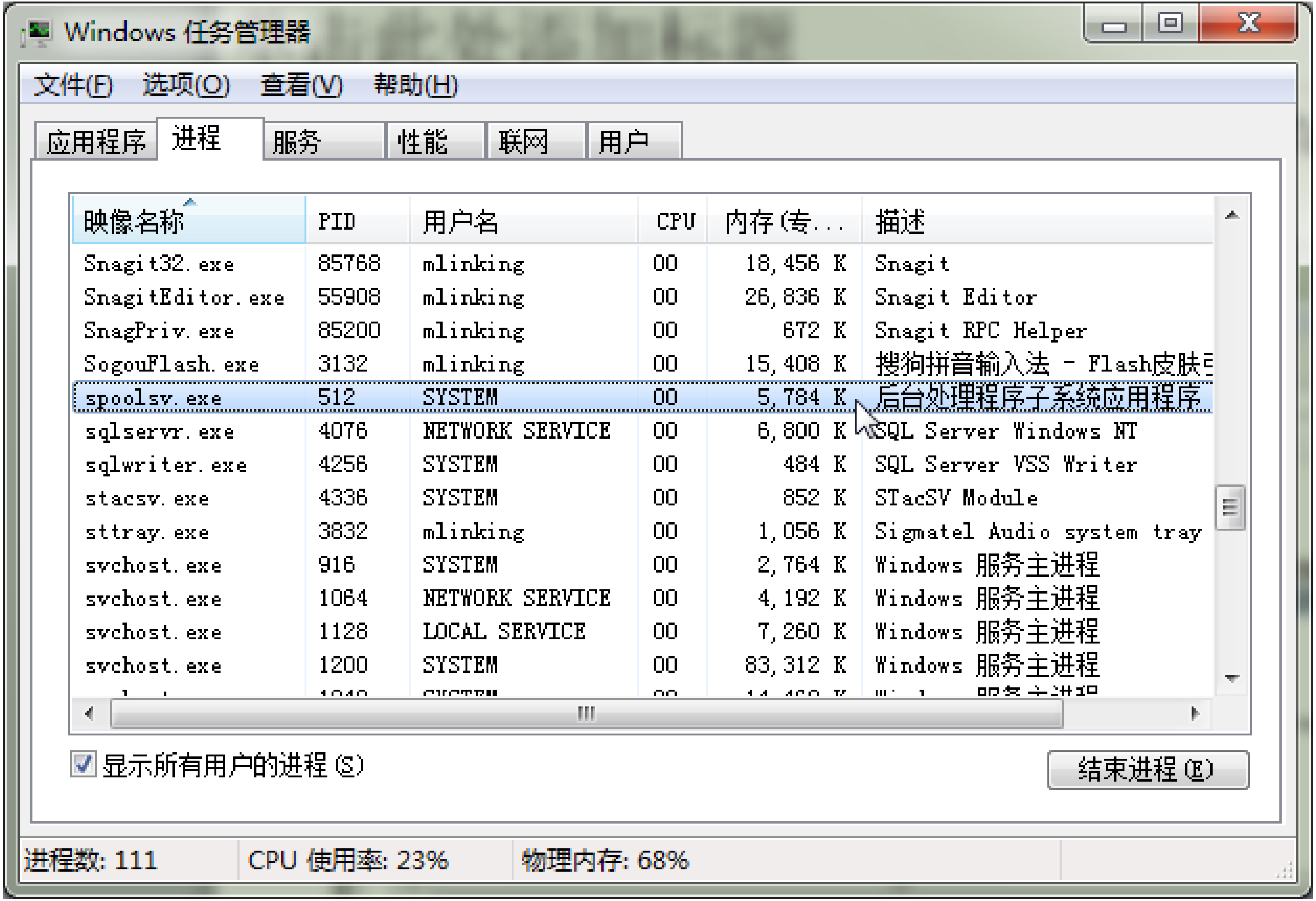
- You have learned how to record that kind of information in **programming**.
  - Design the **data structure**!

- **PCB** (Process Control Block) is the one used/named data structure
  1. Process **location** information
  2. Process **identification** information
  3. Process **state** information
  4. Process **control** information

PCB: Process Location Information

- Process **Location** Information: Each process image in memory
  - may **not** occupy a contiguous range of addresses (depends on memory management scheme used, which will be discussed in later MM part).
    - both a private and shared memory address space can be used.
- Process **Identification** Information: A few numeric identifiers may be used
  - Unique process identifier (PID) –
    - indexes (directly or indirectly) into the process table.
  - User identifier (UID) –
    - the user who is responsible for the job.
  - Identifier of the process that created this process (PPID).

- The process!



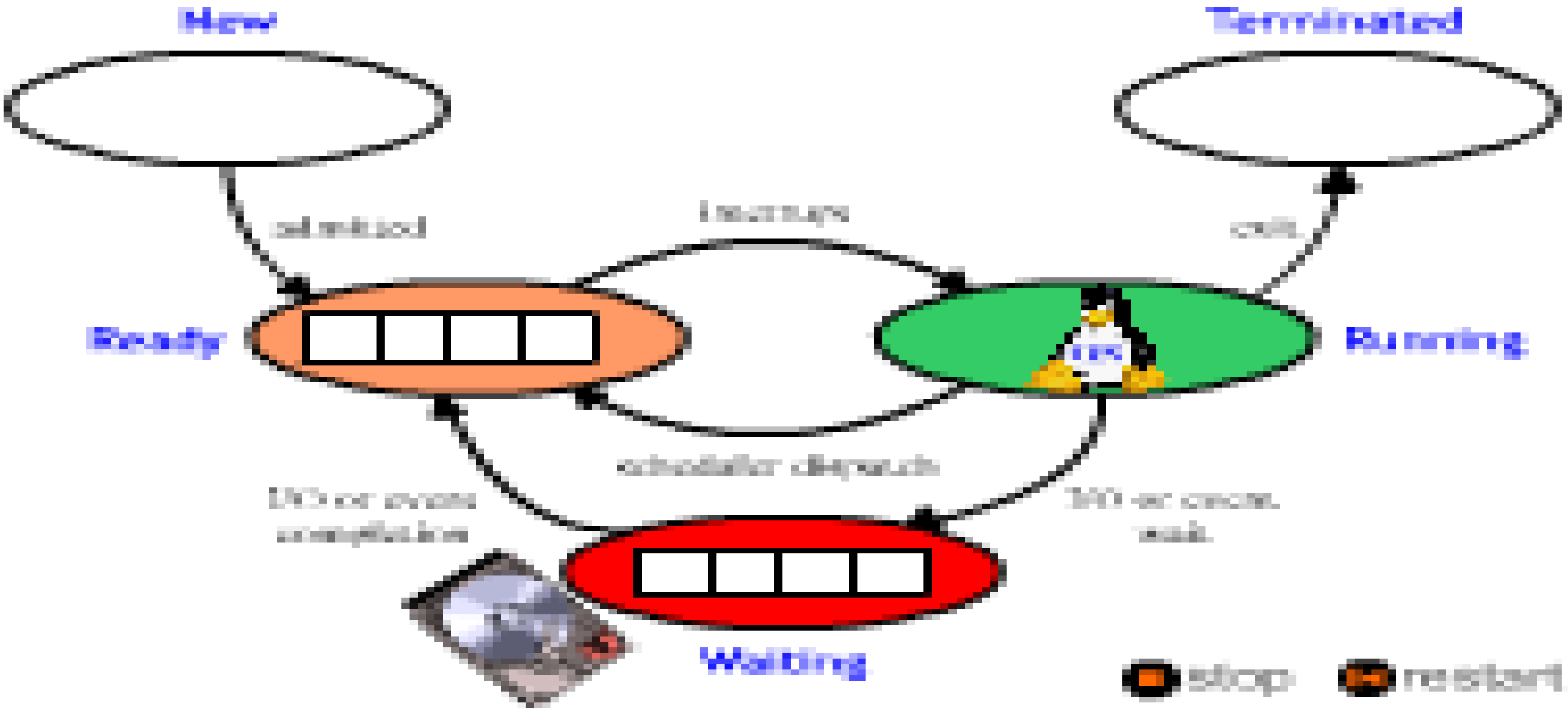
映像名称	PID	用户名	CPU	内存(专...	描述
Snagit32.exe	85768	mlinking	00	18,456 K	Snagit
SnagitEditor.exe	55908	mlinking	00	26,836 K	Snagit Editor
SnagPriv.exe	85200	mlinking	00	672 K	Snagit RPC Helper
SogouFlash.exe	3132	mlinking	00	15,408 K	搜狗拼音输入法 - Flash皮肤引
spoolsv.exe	512	SYSTEM	00	5,784 K	后台处理程序子系统应用程序
sqlservr.exe	4076	NETWORK SERVICE	00	6,800 K	SQL Server Windows NT
sqlwriter.exe	4256	SYSTEM	00	484 K	SQL Server VSS Writer
stacsv.exe	4336	SYSTEM	00	852 K	STacSV Module
sttray.exe	3832	mlinking	00	1,056 K	Sigmatel Audio system tray
svchost.exe	916	SYSTEM	00	2,764 K	Windows 服务主进程
svchost.exe	1064	NETWORK SERVICE	00	4,192 K	Windows 服务主进程
svchost.exe	1128	LOCAL SERVICE	00	7,260 K	Windows 服务主进程
svchost.exe	1200	SYSTEM	00	83,312 K	Windows 服务主进程

进程数: 111　CPU 使用率: 23%　物理内存: 68%

Eh? What's the meaning of "Control" information here? – Because process is alive in OS!

- Processor **State** In
  r registers
  - User-visible regi
  - Control and status re
  - Stack pointers
- Process **Control** Information: Scheduling and stat
  e information
  - Process state (i.e., running, ready, blocked...)
  - Priority of the process
  - Relationship with other processes
    - the process is waiting (if blocked).
    - other PCBs for process queues, parent-child relationships and other structures

The execution of your program is alive



Program execution is dynamic ☾ Process has **states**

- As a process executes, it chan
  - The state of a process is defin activity of that process.
- Each process may be in one s:
  - **New**. The process is being created.
  - **Running**. Instructions are being executed ≈ Get **CPU**.
  - **Waiting**. The process is waiting for some event to occur (such as an I/O completion or reception of a signal).
  - **Ready**. The process is waiting to be assigned to a processor.
  - **Terminated**. The process has finished execution.

We'll learn this **how** in later chapter: **CPU Scheduling**

Process Transitions (1)

- Ready ☾ Running
  - When it is time, the dispatcher selects a new process to run.
- Running ☾ Ready
  - the running process has expired his time slot.
  - the running process gets interrupted because a higher priority process is in the ready state.

Process Transitions (2)

- Running ☾ Waiting
  - When a process requests something for which it must wait:
    - a service that the OS is not ready to perform.
    - an access to a resource not yet available.
    - initiates I/O and must wait for the result.
    - waiting for a process to provide input.
- Waiting ☾ Ready
  - When the event for which it was waiting occurs.

PCB
exampl
e

PCB defined in Linux

- PCB in Linux is defined using a struct **task_struct**
- There are many parameters in Linux’ s PCB
- The size of each PCB is usually a little larger than 1KB

```
struct task_struct{
        …
        unsigned short uid;
        int pid;
        int processor;
        …
        volatile long state;
        long priority;
        unsighed long rt_prority;
        long counter;
        unsigned long flags;
        unsigned long policy;
        …
        Struct task_struct *next_task, *prev_task;
        Struct task_struct *next_run,*prev_run;
        Struct task_struct  *p_opptr, *p_pptr, *p_cptr,
        *pysptr, *p_ptr;
        …
};
```

(2)int pid is the ID of the current process

(3)int processor: the CPU used by the current process. Support multi-processor

(4)volatile long state: corresponds to the states defined as follows：

Running （TASK-RUNING): 可运行状态；

Interruptible state (TASK-IntERRUPTIBLE): 可中断阻塞状态

Uninterruptible state (TASK-UNINTERRUPTIBLE): 不可中断阻塞状态

Zombie (TASK-ZOMBIE): 僵死状态

Stopped (TASK_STOPPED): 暂停态

Swapping (TASK_SWAPPING): 交换态

(5)long priority [**进程的优先级**]

(6)unsigned long rt_priority ［ **实时进程的优先级**，对于普通进程无效]

(7)long counter: a counter for counting the priority

(8)unsigned long policy

scheduling ：

SCHED_OTHER(=0)

优先级轮转法]

SCHED_FIFO(=1) RT

算法]

SCHED_RR(=2) RT Priority algorithm [实时进程优先级轮转法]

Hope you could infer the related operations for PCB data structure. You’ve been trained in DSA course

(9)struct task_struct *next_task,*prev_task: pointers for PCB’s **Double linked lists** [**进程 PCB 双向链表的前后项指针**]

(10)struct task_struct *next_run,*prev_run: pointers for the PCBs in ready queue [**就绪队列双向链表的前后项指针**]

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Five-State Model

may be several processes in these states, some data structures are needed to represent those state-related processes

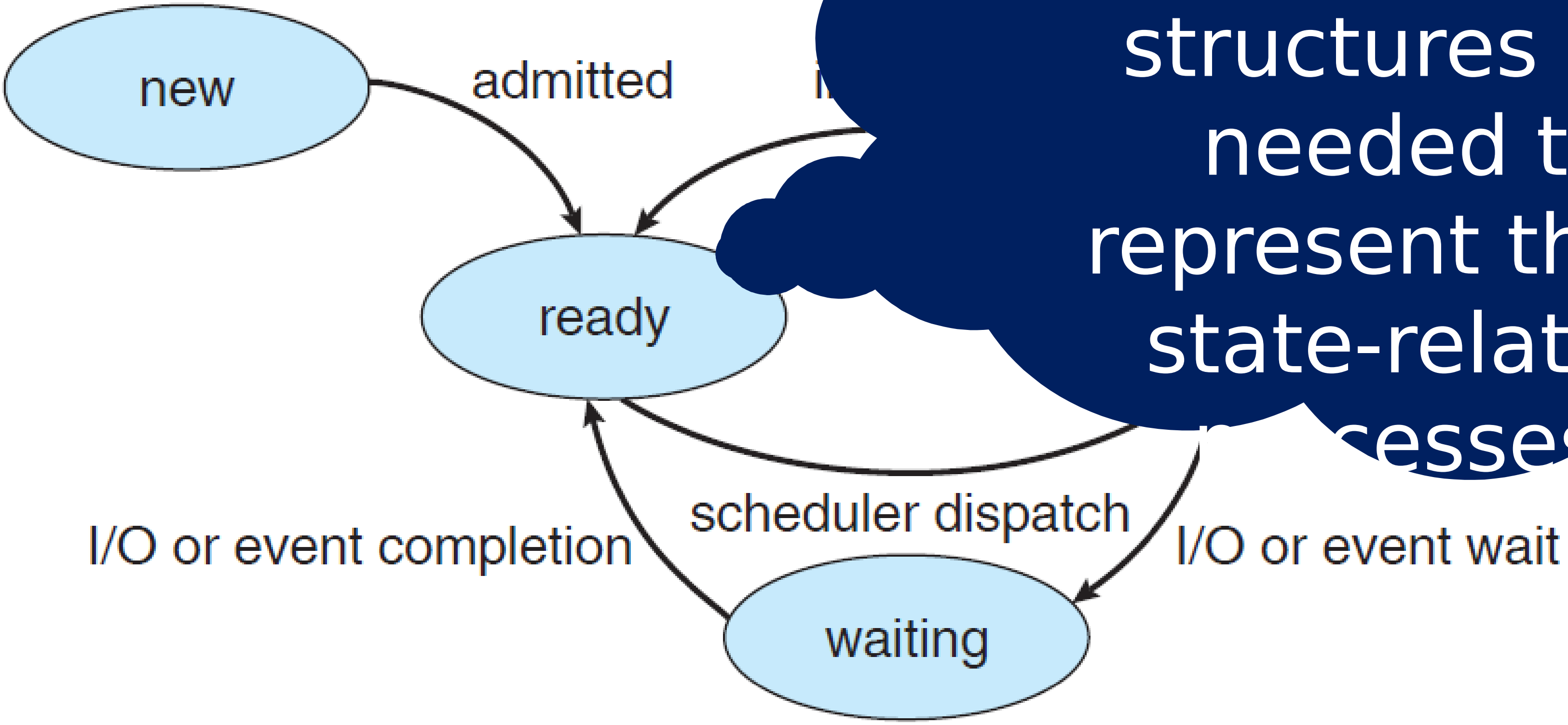


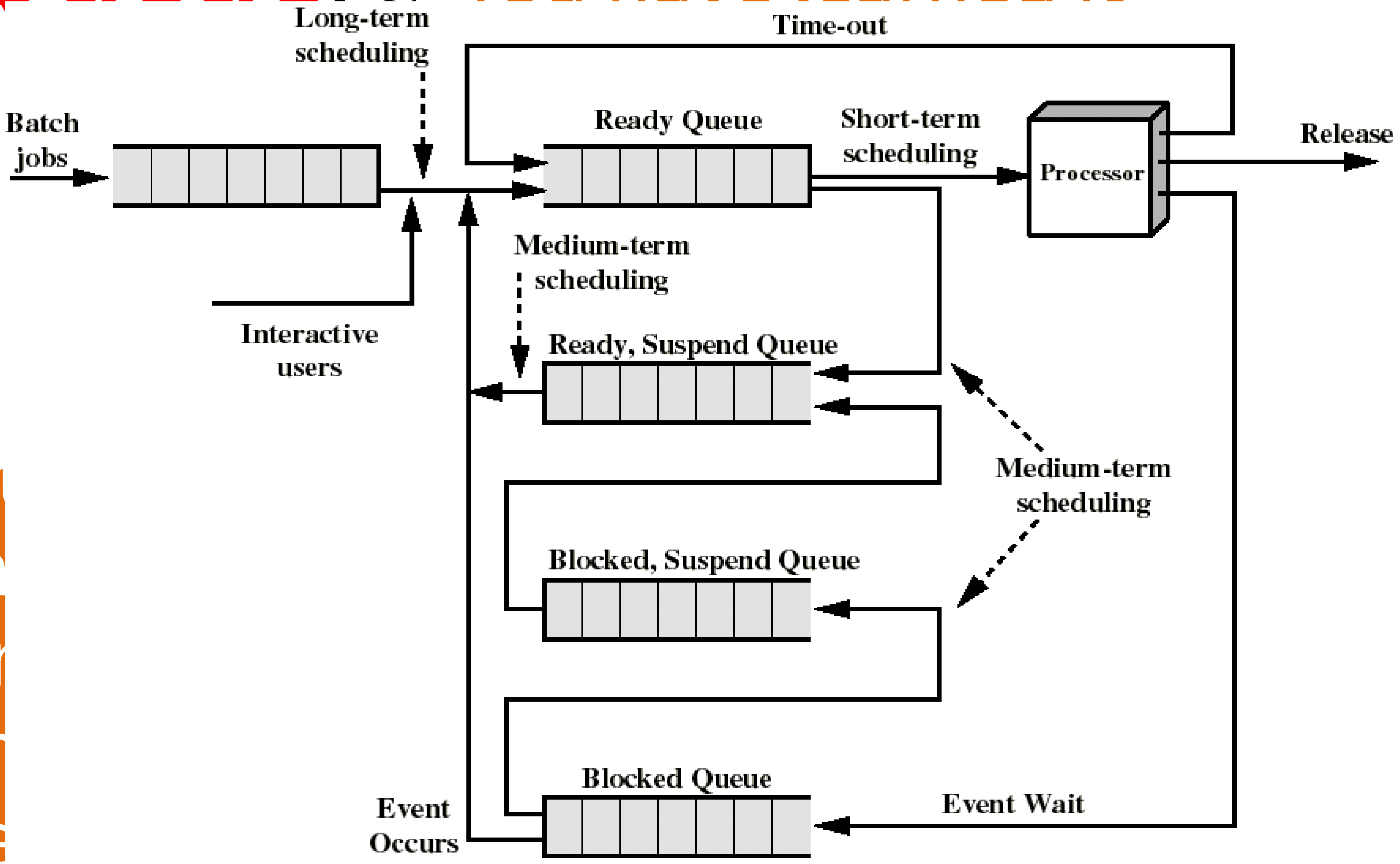
Figure 3.2 Diagram of process state.

It’s also OK to use following 5 states:
Running, Ready, **Blocked**, New, **Exit**

Supplement:

Data structures to manage those state-related process
es

- **Queue**! ≈ You have learned it



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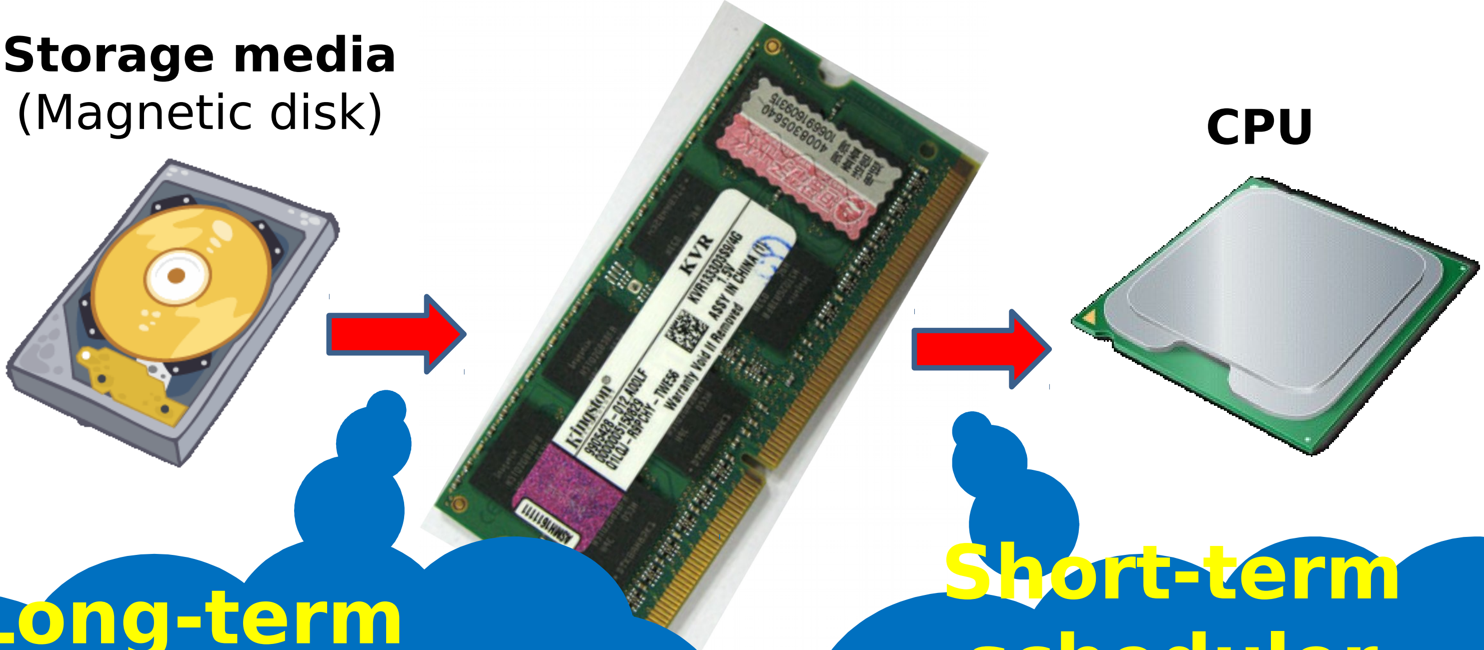
que

Three kinds of schedulers

1. Long-term scheduler (jobs scheduler) – selects which programs/processes should be brought into the **ready queue**.
2. Medium-term scheduler (emergency scheduler) – selects which job/process should be **swapped** out if system is loaded.
3. Short-term scheduler (CPU scheduler) – selects which process should be **executed** next and allocates CPU.

PPTs from others\From Ariel J. Frank\OS381\os3-2.ppt

Those queues are used by
Three kinds of schedulers



Main Memory

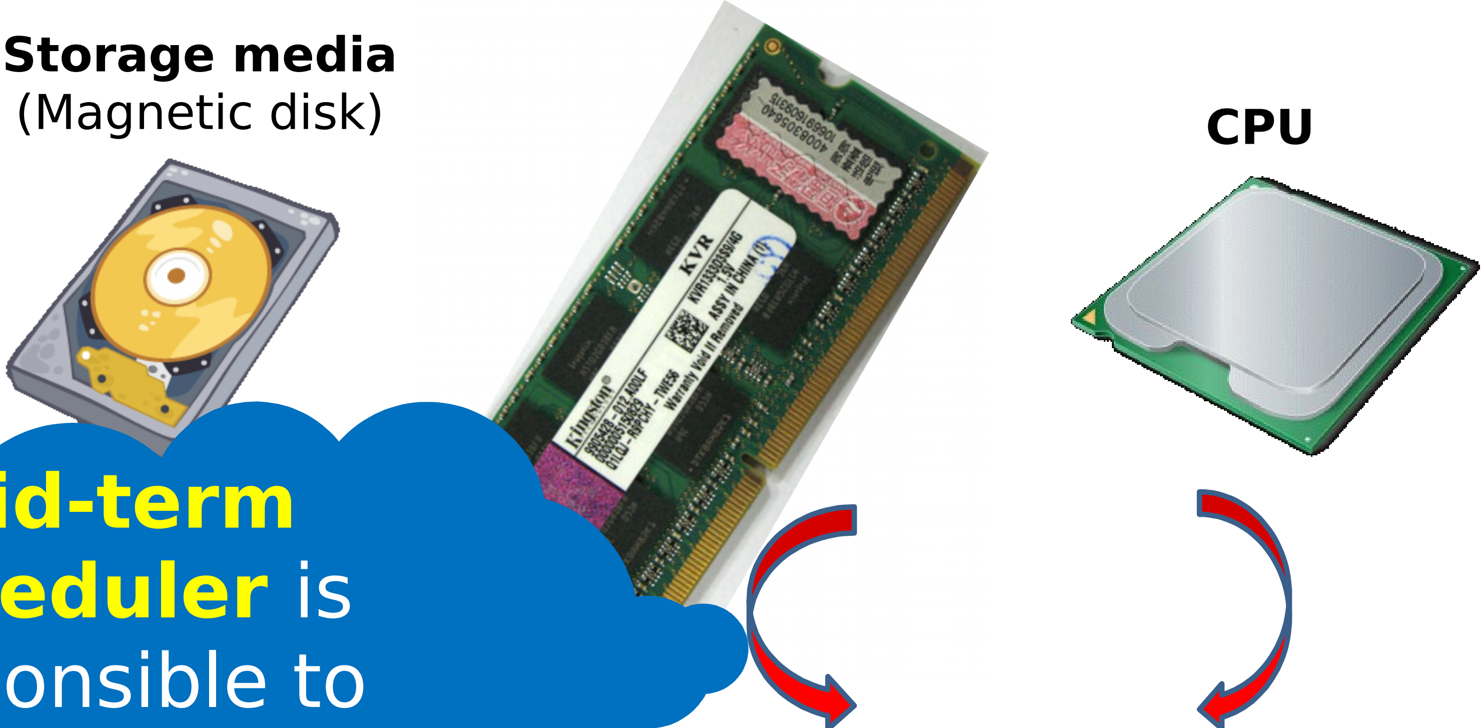
Storage media
(Magnetic disk)

CPU

Long-term scheduler determines which jobs could be transited into main memory

Short-term scheduler determines which processes could get the usage of CPU

Three kinds of schedulers



Main Memory

Storage media
(Magnetic disk)

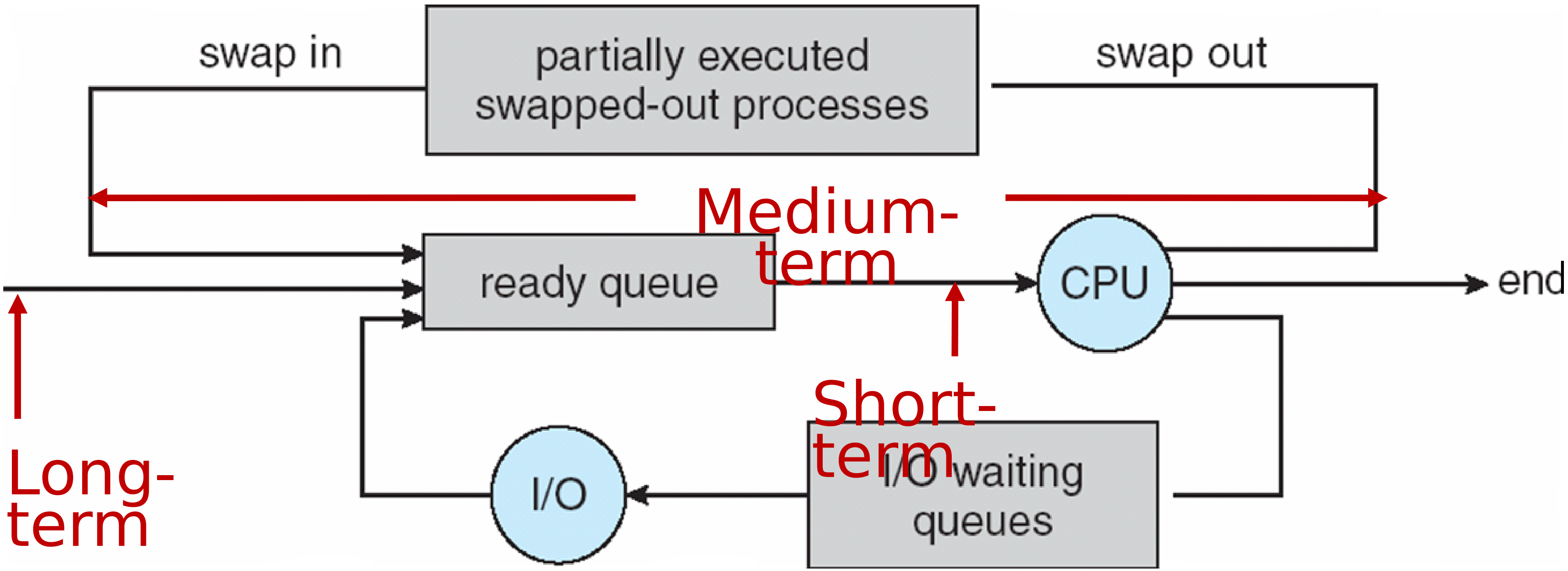
CPU

Mid-term scheduler is responsible to swap some processes out of memory or CPU usage

Data structures to store the swapped out processes

Medium-Term Scheduling

— Addition of Medium Term Scheduling



Medium-term

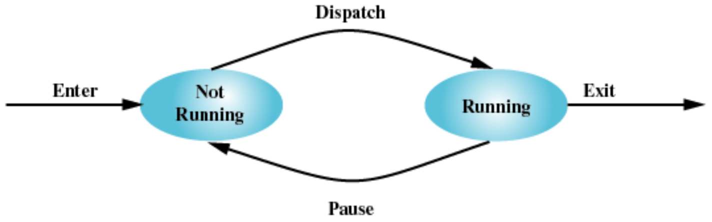
Short-term

Long-term

* **Queueing diagram** : A common representation for discussion for of process scheduling is a queueing diagram

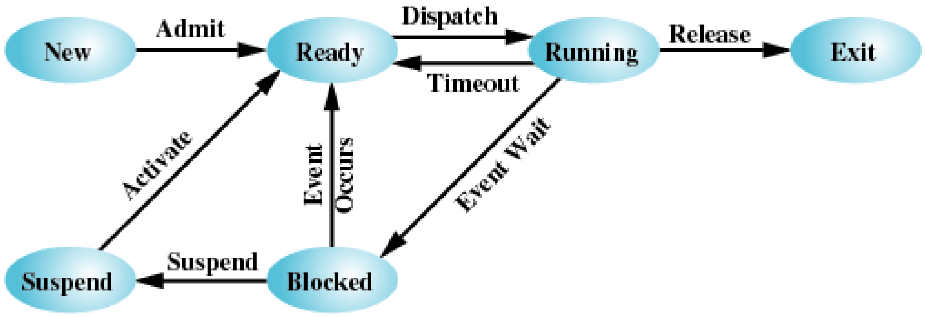
Summary: Sketch of the control for processes

- The execution of a process goes through several states
  - New, Ready, Running, Waiting, Terminated [**Five state model**]
- There are many different models for state transitions
  - **<u>Two state model:</u>**
    - Running, Not-running



(a) State transition diagram

  - Three state model:
    - Ready, Running, blocke
  - Five state model
  - **<u>Six state model</u>**
  - Other models



(a) With One Suspend State

Suspended Processes

- Processor is faster than I/O so all processes could be waiting for I/O
- **Swap** these processes **to disk** to free up more memory
- Blocked state bec es su n **swapped to disk**
- Two new states
  - Blocked/Susp
  - Ready/Suspend

strategy to select which process is swapped out, corresponds to the **midterm scheduling**「中期调度」

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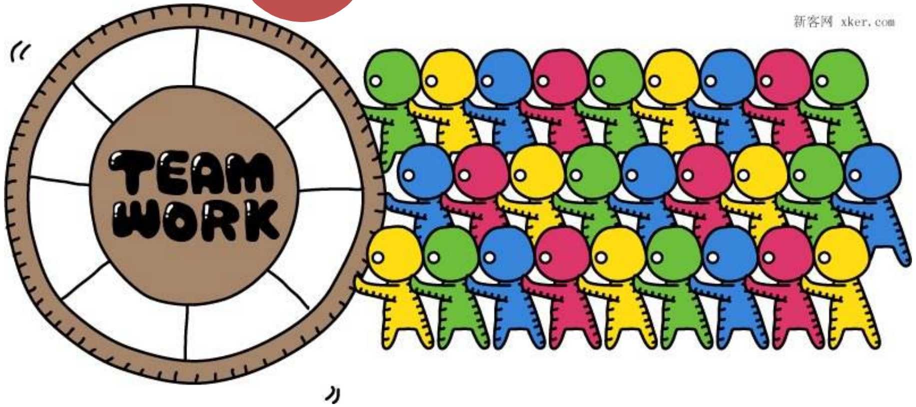
Concurrency OF COURSE b

- Concurrent process
  stem allows for th
  ally or destructively)
  - The simplest exa
    wo processes are

This is of course not FREE! The cooperation leads to complexity – deadlock and data inconsistency in later chapters

- Reasons for cooperating p
  - Several processes may need to ac the same data (such as stored in a file)
  - Information sharing
  - Computation speed-up
  - Modularity
  - Convenience

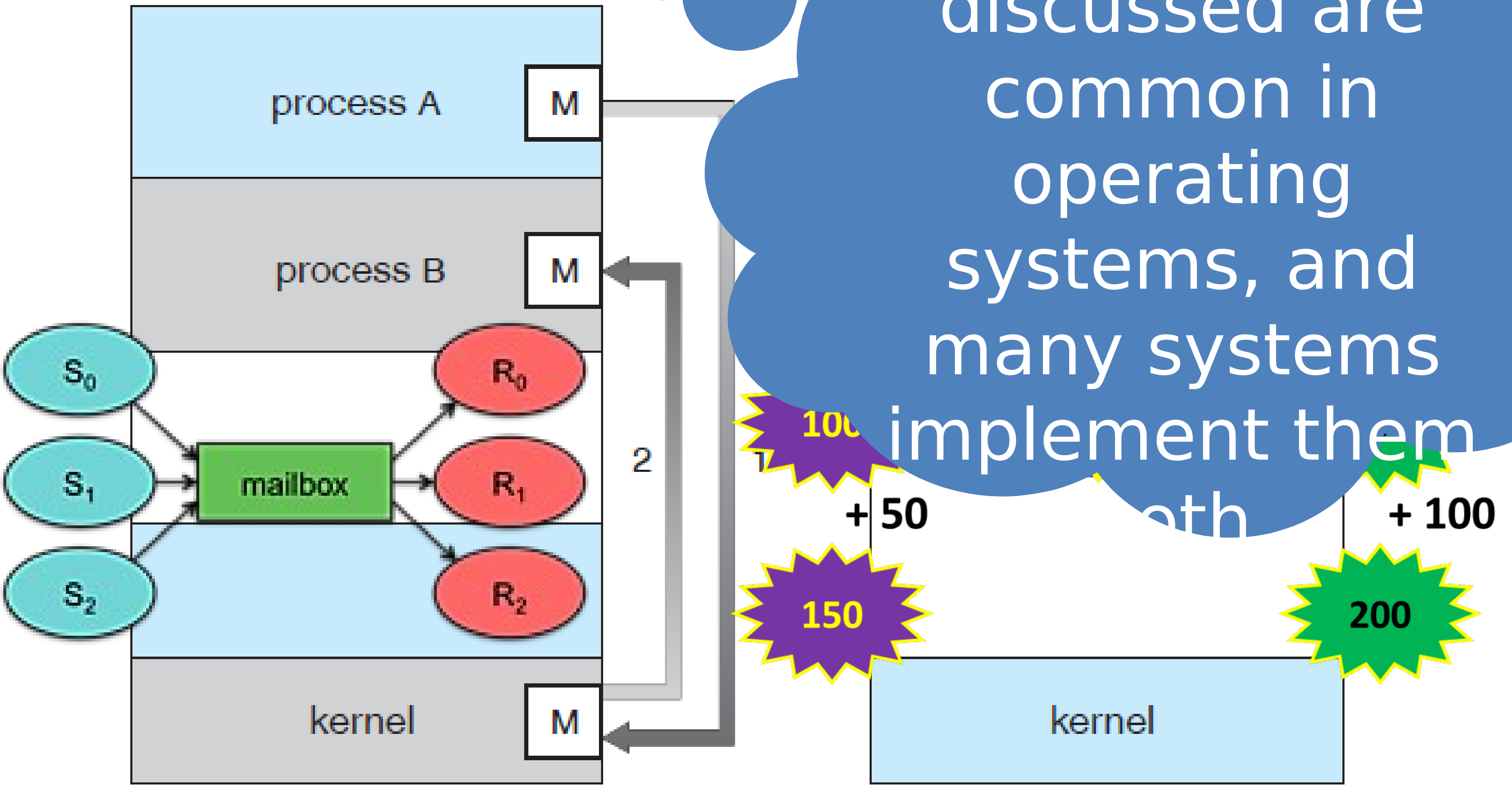


IPC: Inter-Process Communication

- Cooperating processes require an inter-process communication (IPC) mechanism that will allow them to exchange data and information.
- There are two fundamental models of inter-process communication:
  - **Shared memory**
  - **Message passing**
    - message passing interfaces, mailboxes and message queues
    - sockets, STREAMS, pipes

IPC: two fundamental types

models just discussed are common in operating systems, and many systems implement them
oth



(a) (b)

Figure 3.13 Communications models. (a) Message passing. (b) Shared memory.

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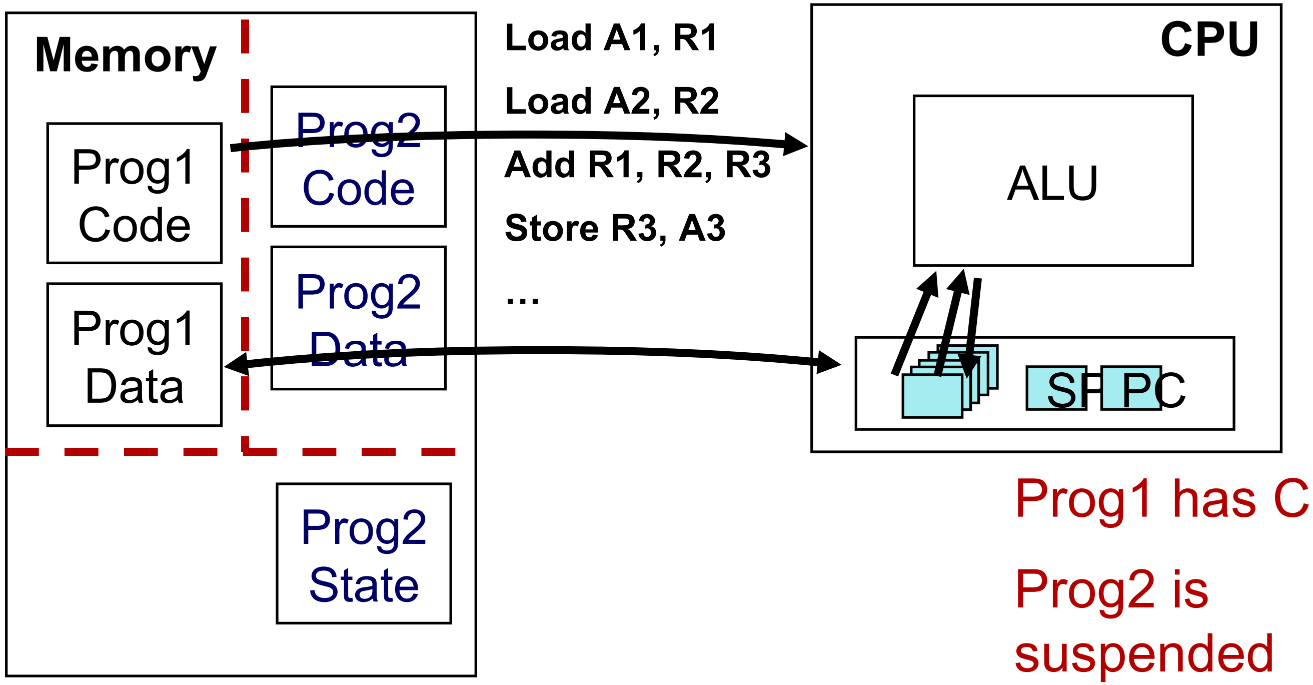
Process switching is EXPENSIVE!

Context Switching

- Program instructions operate on operands in memory and (temporarily) in registers



Load A1, R1

Load A2, R2

Add R1, R2, R3

Store R3, A3

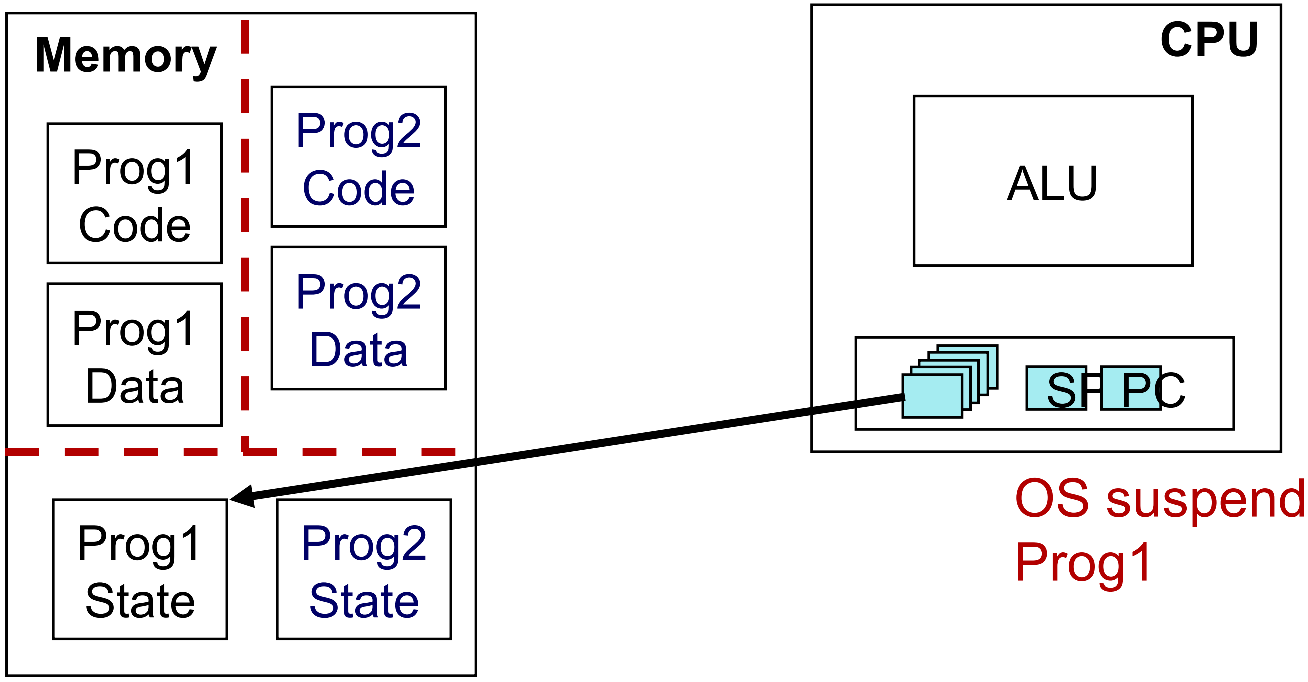
…

Prog1 has CPU

Prog2 is suspended

Context Switching

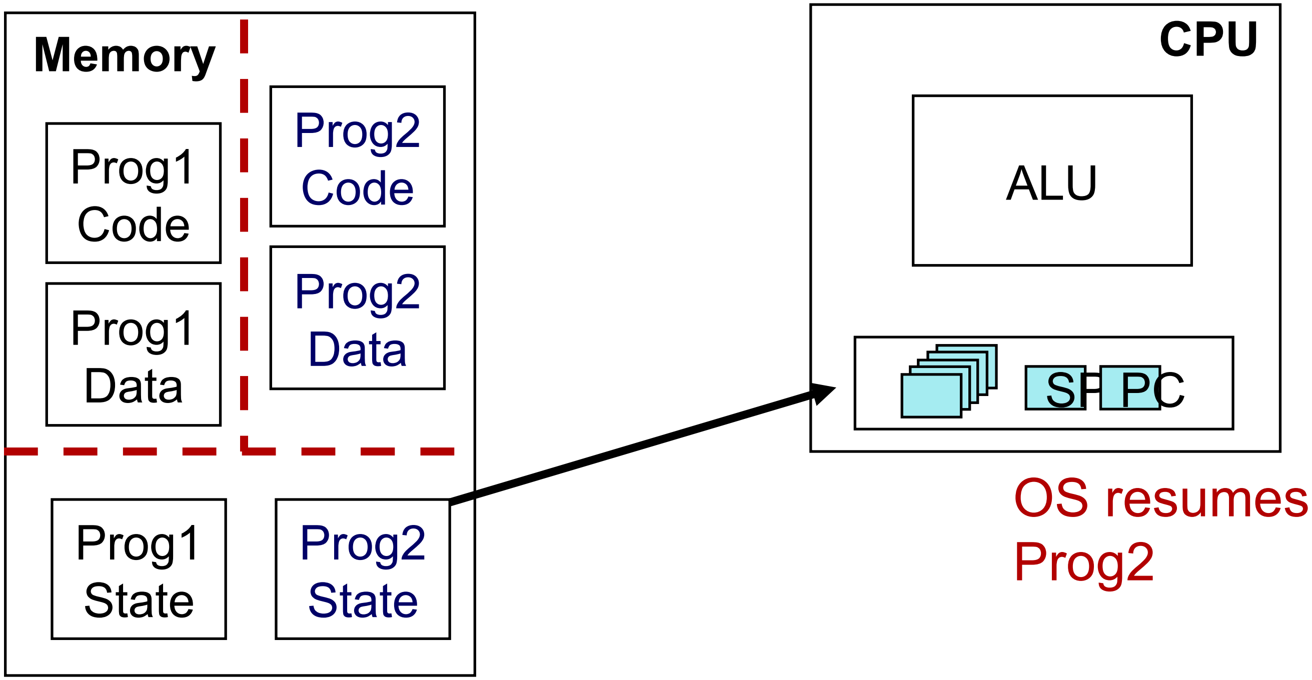
- Saving all the information about a process allows a process to be temporarily suspended and later resumed from the same point



OS suspends Prog1

Context Switching

- Saving all the information about a process allows a process to be temporarily suspended and later resumed



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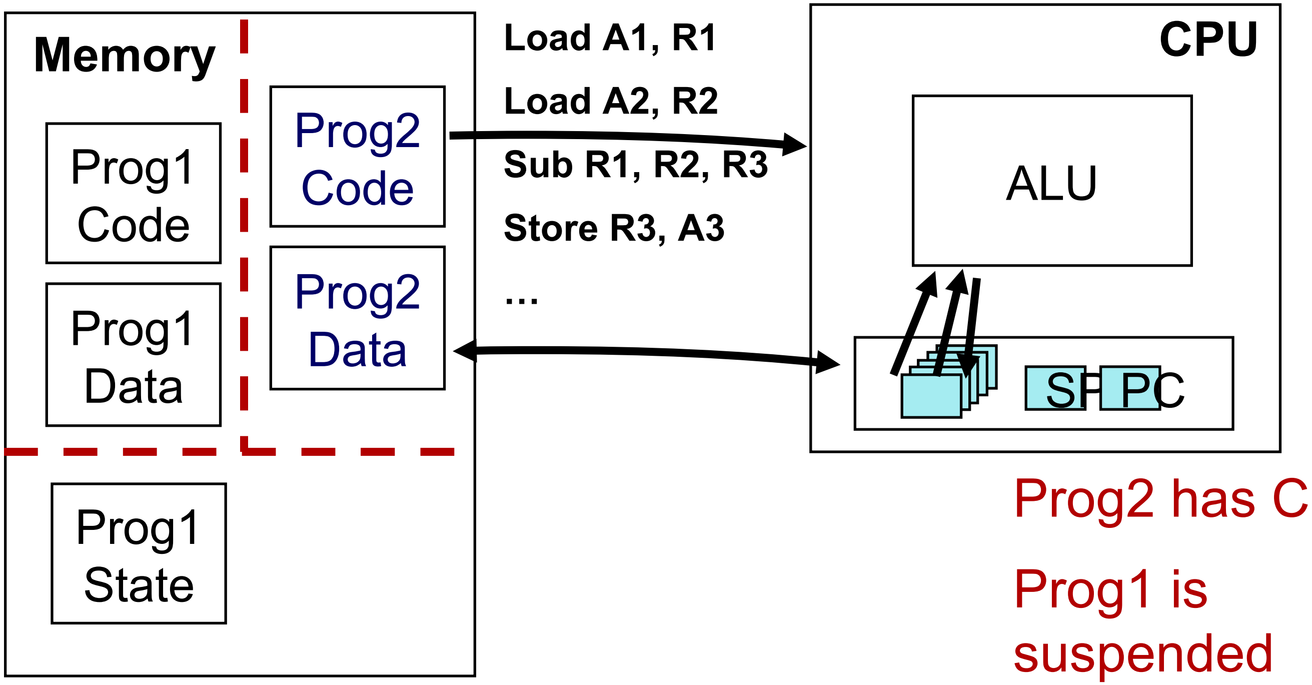
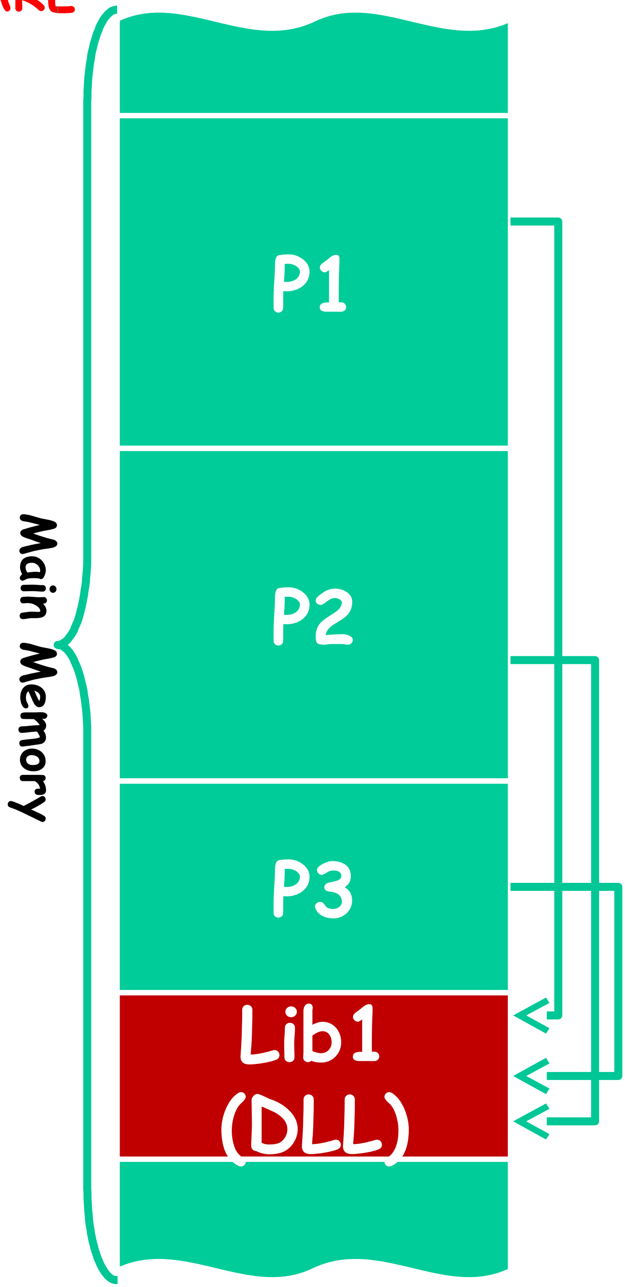


Prog2 has CPU

Prog1 is suspended

How to overcome the cost? SHARE
- Analogous with DLL

- ❑ Three programs (P1, P2, P3) share same DLL (lib1)
- ❑ Namely, there is only a copy of the functions defined in lib1 in the MM
- ❑ And, those programs may access different function in lib1
  - Ⓟ So, each program should remember some information of the target functions (called CONTEXT[上下文]) in lib1



SHARE + CONTEXT: multiple services in one program

- We can use **1** CPU + **1** MM space + **1** HD to support **MULTIPROGRAMMING** – the basis of modern OSs, namely concurrently running many processes
- How about providing multiple services with one program? (**MULTISERVING**?)
  - If so, there is only one copy of the instructions of those server programs or MS Word in MM, which can provide services for many users/requests
    - This is obviously **economical** and **efficient** way!

Here comes **thread**

- Concept of Process has two facets.
- A Process is:
  - A Unit of resource ownership – process is allocated:
    - a virtual address space for the process image
    - control of some resources (files, I/O devices...)
  - A Unit of execution/dispatching - process is an execution path through one or more programs (functions, code segments)
    - may be interleaved with other processes
    - execution state (Ready, Running, Blocked...) and dispatching priority

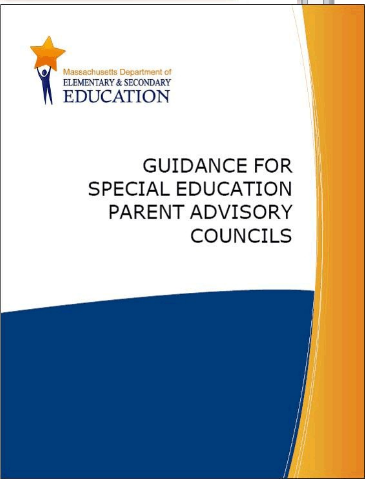
- These two characteristics are treated separately by some recent operating systems:
  - The unit of **resource ownership** is referred to as a **Task** or (for historical reasons) also as a **Process**.
  - **The unit of dispatching** is referred to a **Thread**.

Ⓟ A thread is an execution unit inside a process/program, which could be scheduled directly for CPU (this depends on the OS)

  - Several threads can exist as services in the same task/process.

You’ ve experienced THREAD

- MS Word
  - If you want to edit **M** documents, it is definitely too expensive to run **M** MS Words for those documents!
  - They can **SHARE** the instructions of MS Word!



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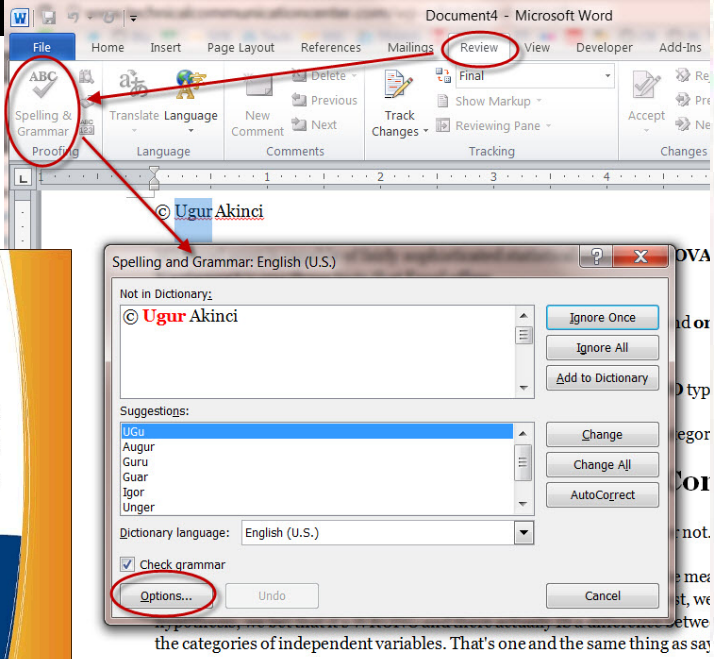

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Unger

Change | Change All | AutoCorrect

Dictionary language: English (U.S.)

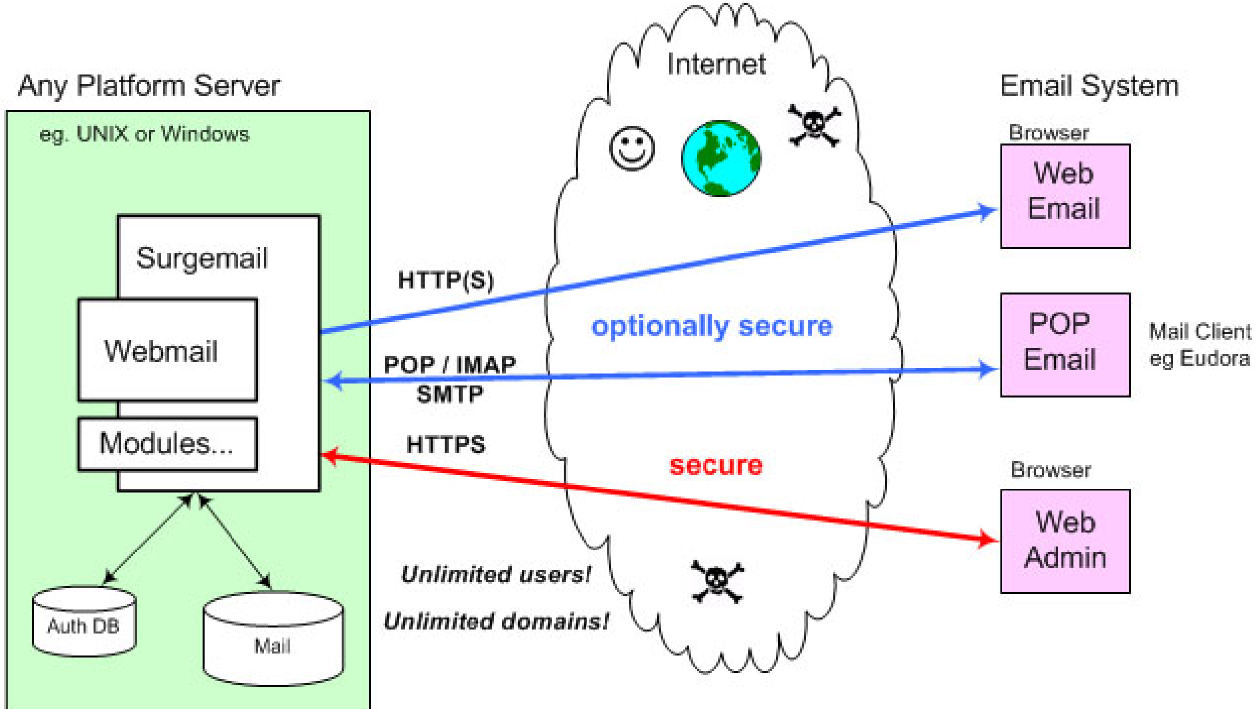
☑ Check grammar

Options... | Undo | Cancel

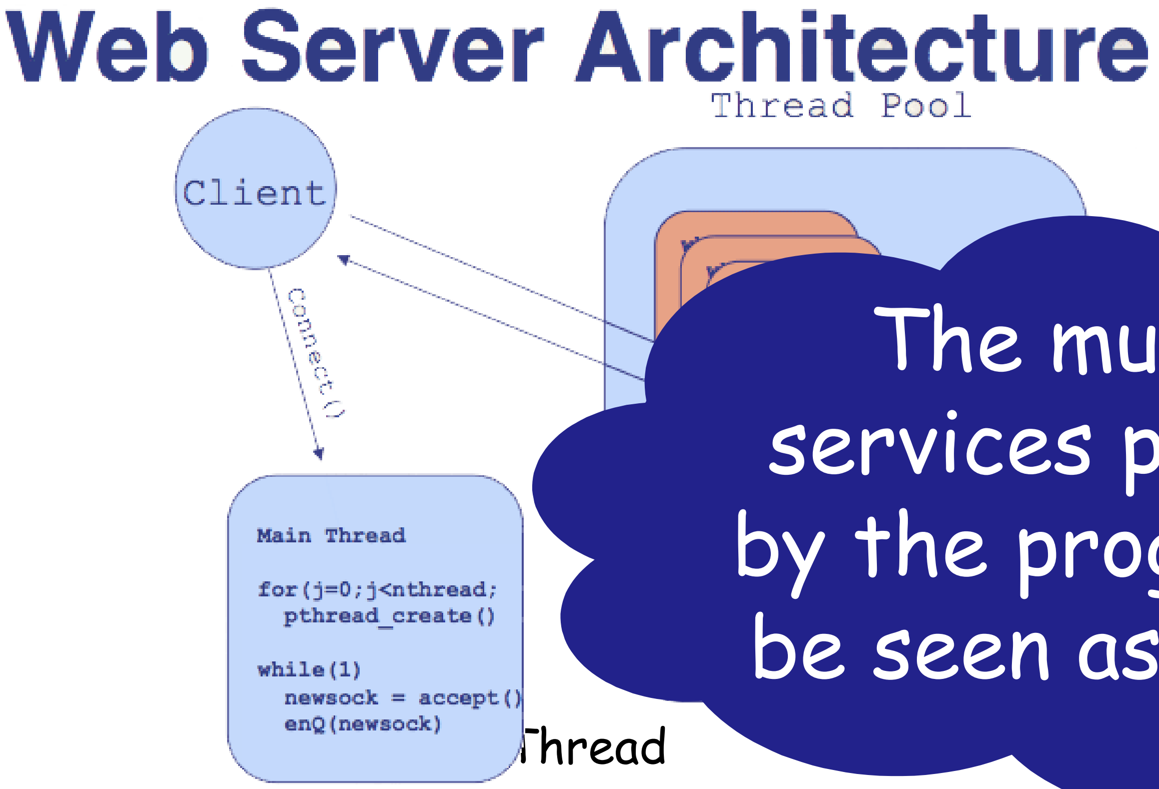
the categories of independent variables. That's one and the same thing as say

Thread now is popular, especially for high performance servers

- Web server, FTP server, DBMS server, e-mail server, …
  - **N** users access those servers, and if we prepare **N** server processes for each user.
    - It’ s definitely too expensive to create many servers to respond those users
  - They can **SHARE** the instructions of the server



- Here is a sketch of Web server architecture
  - Web server runs as a daemon ['di:mən] program
  - When a client connects the server, the server provides the service for the client

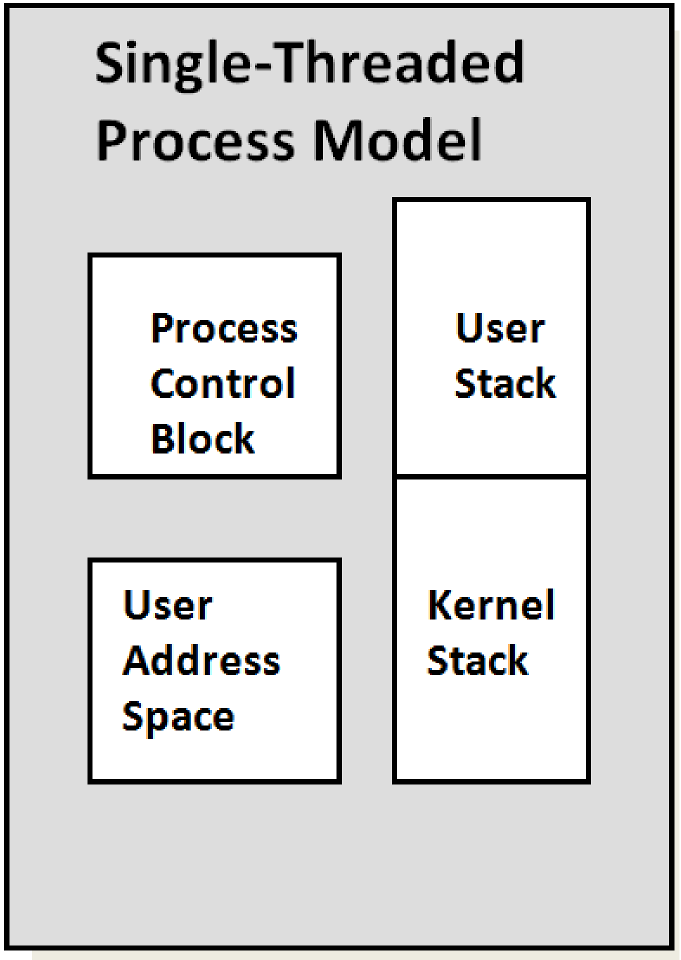


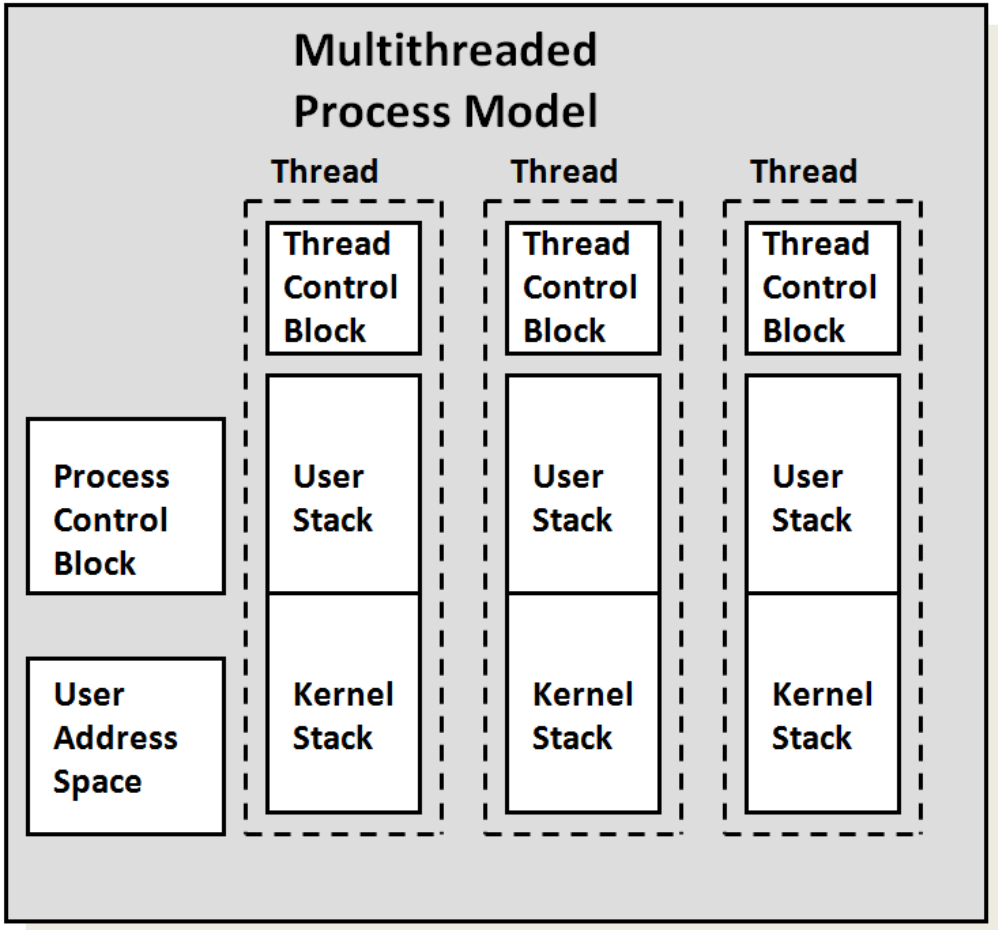
```
Main Thread

for(j=0;j<nthread;
  pthread_create()

while(1)
  newsock = accept()
  enQ(newsock)
```

Thread

The multiple services provided by the program can be seen as Thread

Single Threaded and Multithreaded Process Models

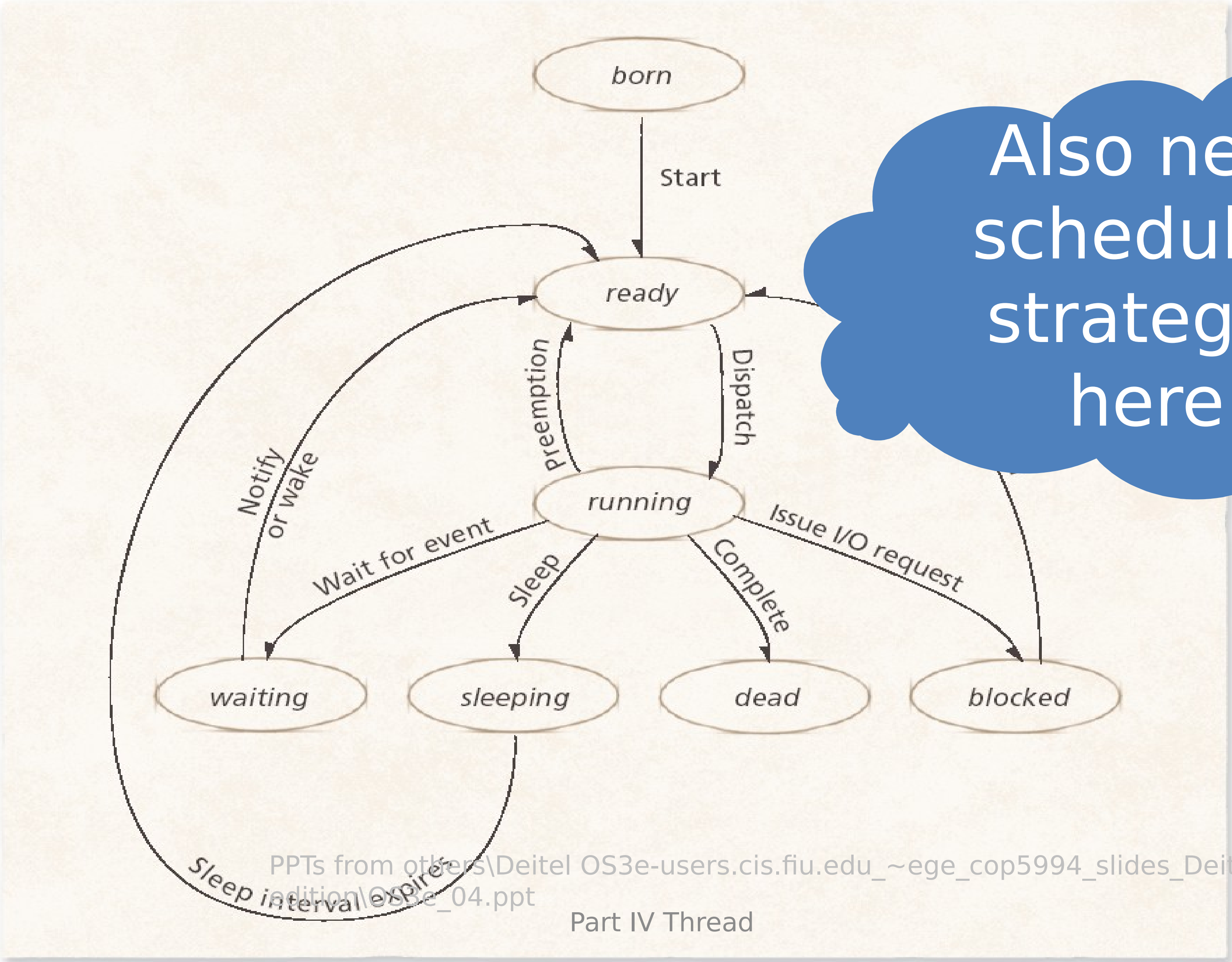




Thread Control Block (TCB) contains a register image, thread priority and thread state information

PPTs from others\Operating Systems\Processes.ppt

Thread States: Life Cycle of a Thread



Also need scheduling strategies here!

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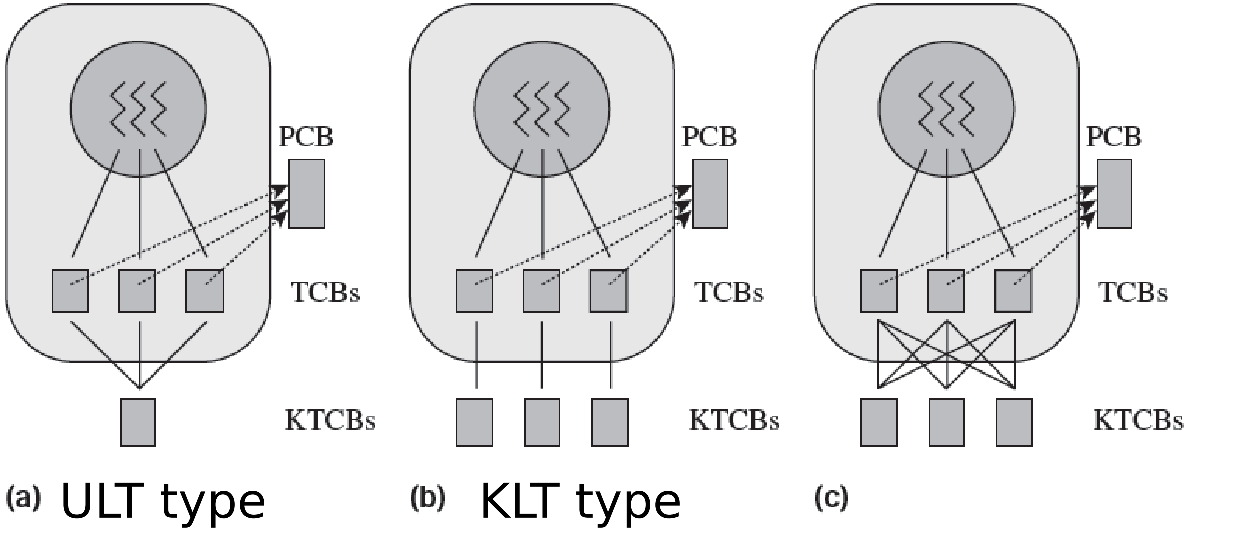
Thread Operations

- Threads and processes have common operations
  - **Create**, **Exit** (terminate), **Suspend**, **Resume**, **Sleep**, **Wake**
- Thread operations do not correspond precisely to process operations
  - Cancel
    - Indicates that a thread should be terminated, but does not guarantee that the thread will be terminated
    - Threads can mask the cancellation signal
  - Join
    - A primary thread can wait for all other threads to exit by joining them
    - The joining thread blocks until the thread it joined exits

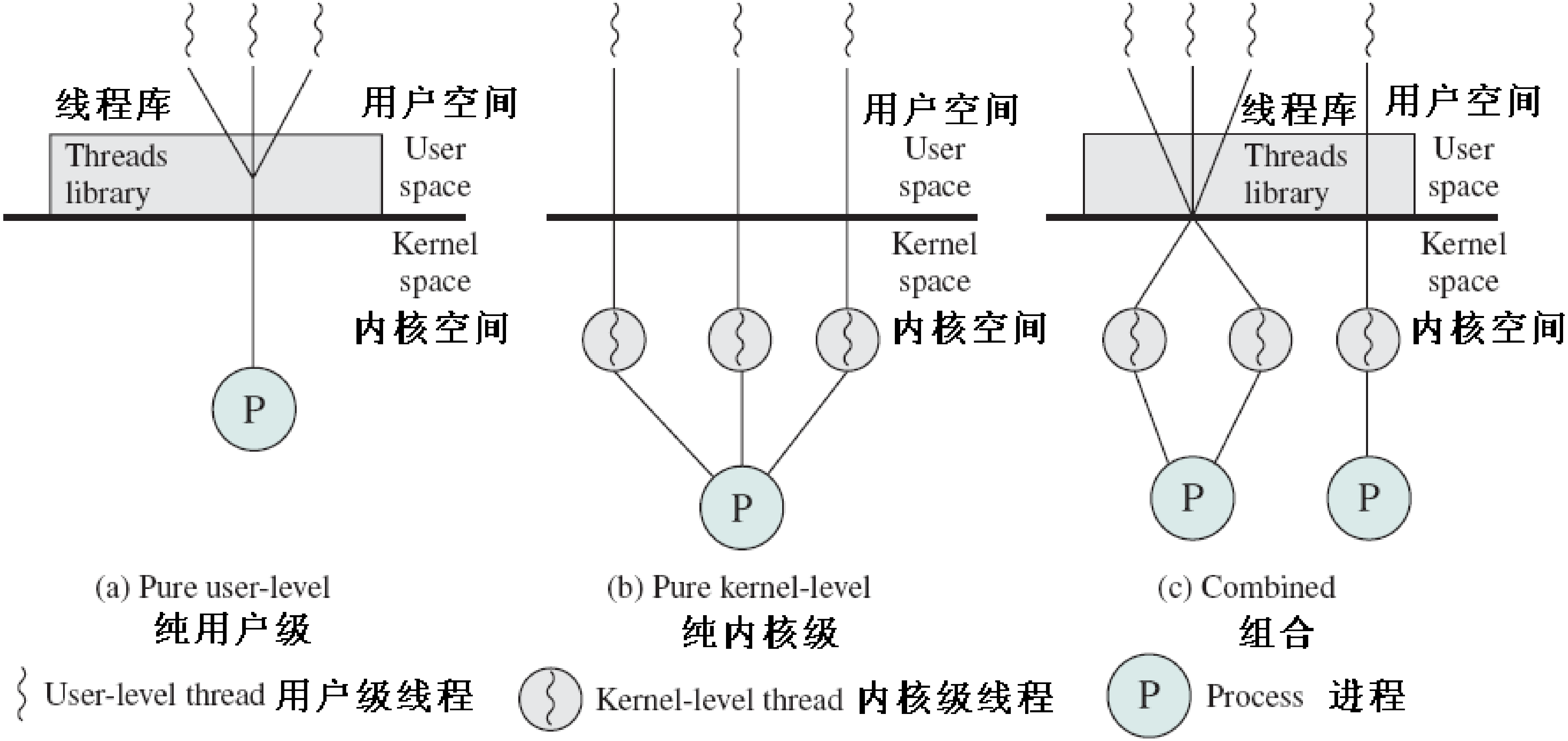
Thread libraries

- To implement threads, a threading library (either in **user space** or **kernel space**) is responsible for handling the saving and switching of the execution context from one thread to another.
  - We have ULT (User-Level Thread) and KLT (Kernel-Level Thread).
- Multithreaded application



(a) ULT type (b) KLT type (c)

Figure 5.17 (a) Many-to-one; (b) one-to-one; (c) many-to-many associations in hybrid threads.



User-Level and Kernel-Level Threads

用户级与内核级线程

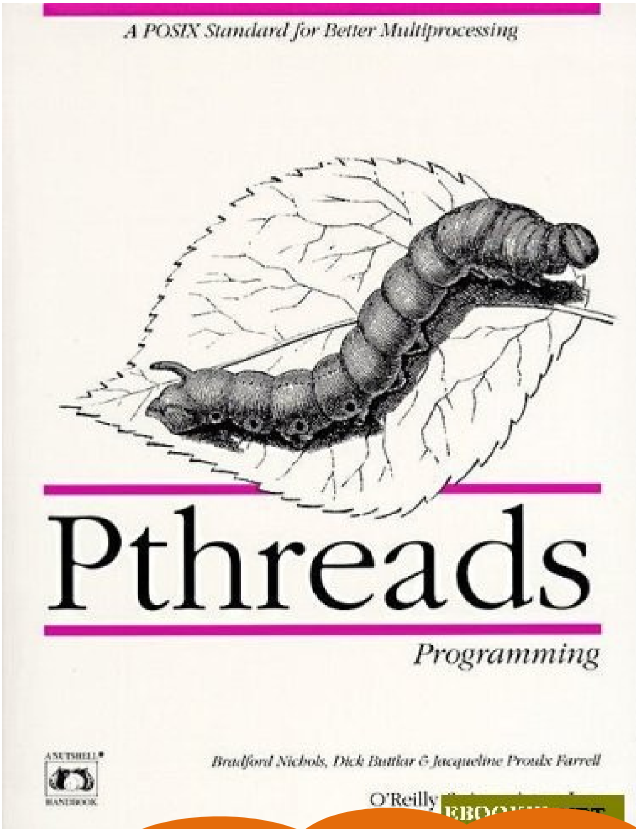
Threads library

- Contains code for:
  - creating and destroying threads
  - passing messages and data between threads
  - scheduling thread execution
    - pass control from one thread to another
  - saving and restoring thread contexts

- ULT can be implemented on any Operating Sys tem, because no kernel services are required t o support them
  - POSIX Pthreads, Mach C-threads, Solaris UI-threads

POSIX and Pthreads

- **Pthreads**, the threads extension of the POSIX standard, may be provided as either a user- or kernel-level library
  - POSIX states that processor registers, stack and signal mask are maintained individually for each thread
  - POSIX specifies how operating systems should deliver signals to Pthreads in addition to specifying several thread-cancellation mo


A POSIX Standard for Better Multiprocessing
Pthreads
Programming
Bradford Nichols, Dick Buttlar & Jacqueline Proulx Farrell
O'Reilly

We've seen Java thread

Win32 Threads (Windows XP)

- The **Win32** thread library is a kernel-level library available on Windows systems
  - Actual unit of execution dispatched to a processor
  - Execute a piece of the process’s code in the process’s context, using the process’s resources
  - Execution context contains
    - Runtime stack
    - State of the machine’s registers
    - Several attributes

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Java Threads

- Java allows the application programmer to create threads that can port to many c omputing platforms
- Threads
  - Created by class `Thread`
  - Execute code specified in a `Runnable` objec t’ s `run` method
- Java supports operations such as namin g, starting and joining threads

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- The **Java** thread API allows threads to be created and managed directly in Java programs
  - However, because inmost instances the JVM is running on top of a host operating system, the Java thread API is generally implemented using a thread library available on the host system.

    - This means that on Windows systems, Java threads are typically implemented using the Win32 API; UNIX and Linux systems often use Pthreads

Java Threads

- Example showing interleaved thread execution :

```
    class SimpleThread extends Thread {
            public SimpleThread (String str) {              // superclass constructor
                    super (str);
            }
            public void run () {
                    for (int i=0; i<10; i++) {
                            System.out.println (i +   “   “ + getName() );
                            try { sleep ((int) (Math.random
() * 1000));
                            catch (InterruptedException e) {
                    }
                    System.out.println (  “Finished   “ +
            }
        }

        class TwoThreadsTest {
            public static void main (String[ ] args) {
                    new SimpleThread (  “Edinburgh”   ).start ();
                    new SimpleThread (  “Glasgow”  ).start ();
```

– main method starts two threads by calling the start method

- output something like :

```
    0 Edinburgh
0       Glasgow
1       Glasgow
1       Edinburgh
2 Edinburgh
3       Edinburgh
2       Glasgow
3       Glasgow
4       Glasgow
4 Edinburgh
5       Glasgow
5 Edinburgh
6 Glasgow
7       Glasgow
8       Glasgow
6       Edinburgh
7       Edinburgh
8       Edinburgh
9       Edinburgh
Finished Edinburgh
9       Glasgow
Finished Glasgow
```

You can use the experiment framework of this course to simulate this , right?