# Operating Systems

## Introduction to Computer

**Yu-Ting Wu**

*(with some slides borrowed from Prof. Tian-Li Yu)*

# Outline

- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine’s activities
- Handling competition among processes
- Security

# Outline

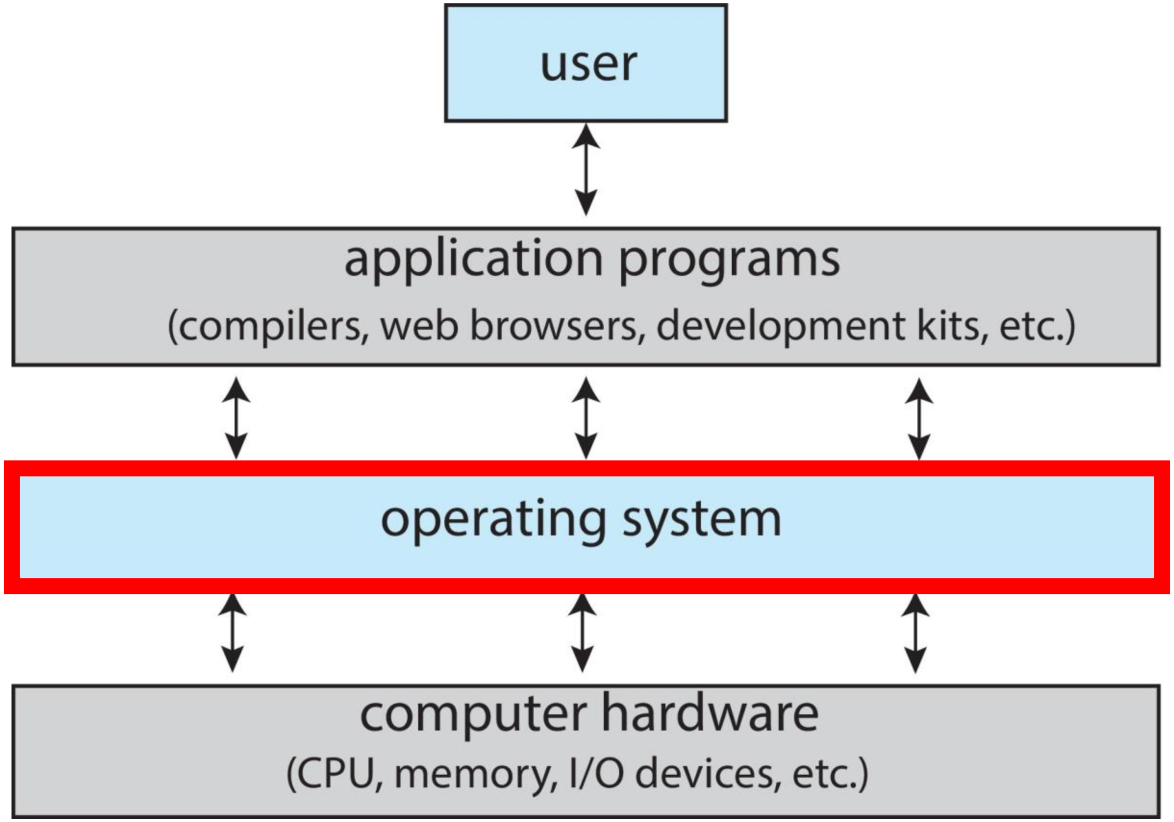
- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine’s activities
- Handling competition among processes
- Security

# What is an Operating System

- An operating system (OS) is a **software program** that acts as an **intermediary** between a user and the computer hardware
  - Execute user programs
  - Make the computer system convenient to use
    - Such that users can focus on their problems
  - Use the computer hardware in an efficient manner

# What is an Operating System (cont.)

- An operating system (OS) can be considered as a government or environment provider



# Features of Operating Systems

- User view: varies by the types of the computers

Personal Computer (PC)

ease of use

Mainframe, Workstation

reliability
efficiency
fair sharing

Handheld Computer

individual usability
battery life

Embedded Computer

run without user intervention

# Features of Operating Systems (cont.)

- System view: a resource allocator and control program

- **Resource allocator**
  - CPU time
  - Memory space
  - File storage
  - I/O devices

- **Control program**
  - Control execution of user programs
  - Prevent errors and misuse

# Examples of Operating Systems

- Windows
- UNIX
- Mac OS
- Solaris
- Linux

- Apple iOS
- Windows phone
- BlackBerry OS
- Nokia Symbian OS
- Google Android

# Free and Open-Source OSes

- OS with available source
  - Otherwise: closed-source OS. E.g., MS Windows, iOS
- Examples: GNU/Linux, BSD, UNIX, etc.
- Arguably issues on bugs, security, support

# Outline

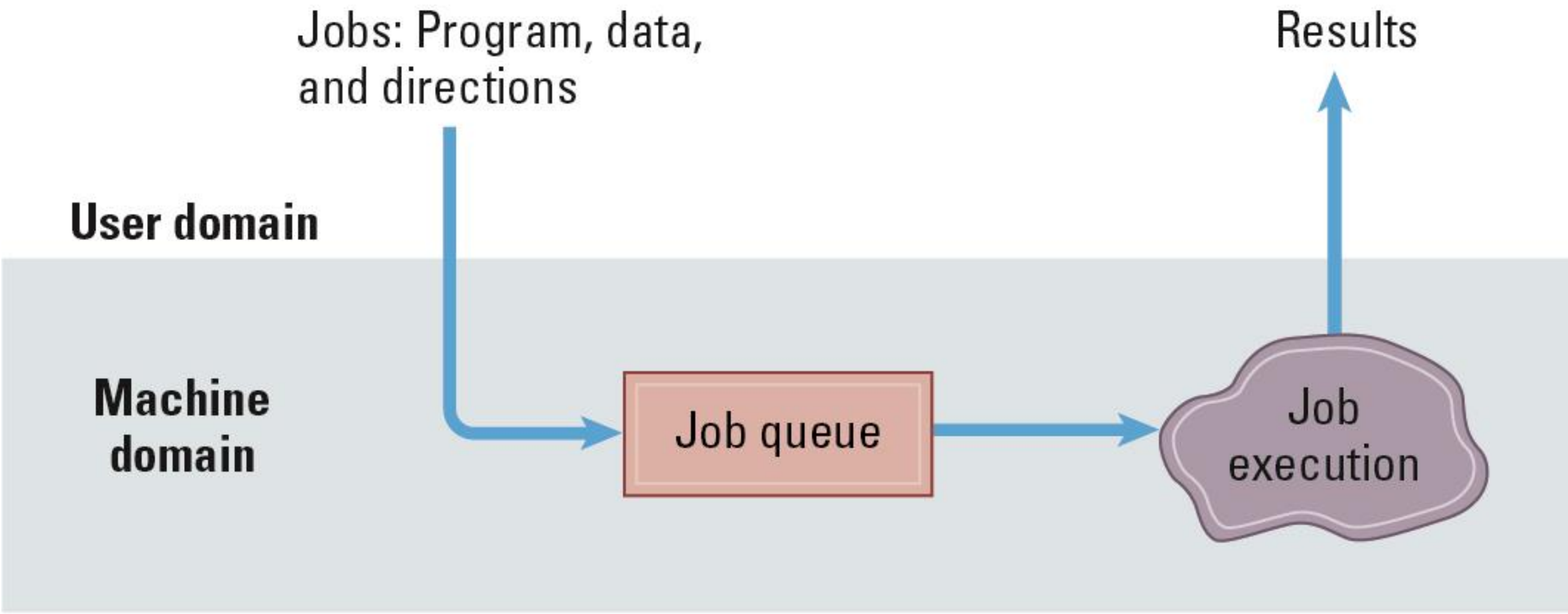
- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine’s activities
- Handling competition among processes
- Security

# History of Operating Systems

- Batch processing (job queue)
- Interactive and (real-time) processing
- Multi-tasking and time-sharing and
- Multiprocessor machines
- Embedded Systems (specific devices)

# Batching Process

- Each program is called a “job”
  - Feed by computer operators
- First-in, first-out (FIFO)

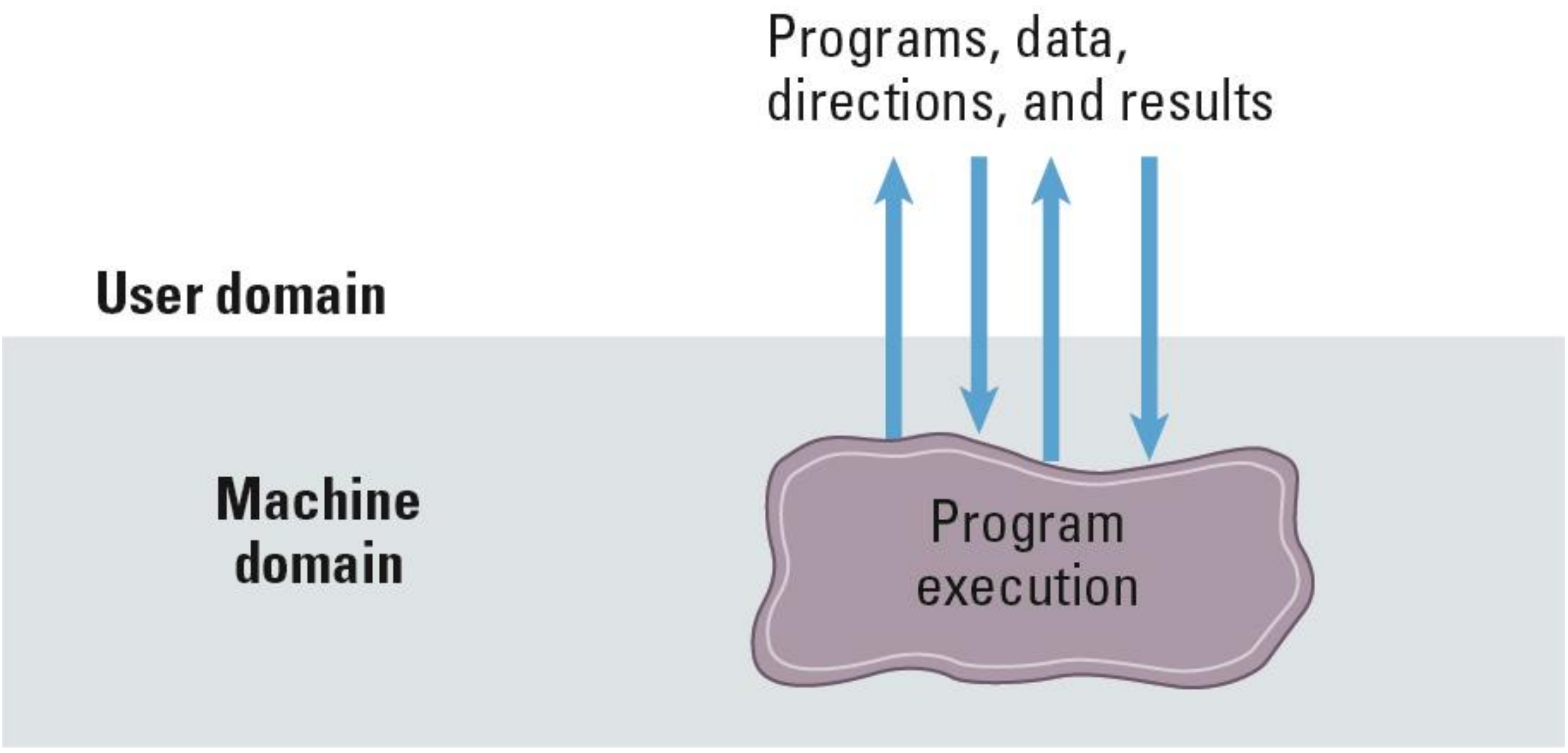


# Batching Process (cont.)


Punch card operator

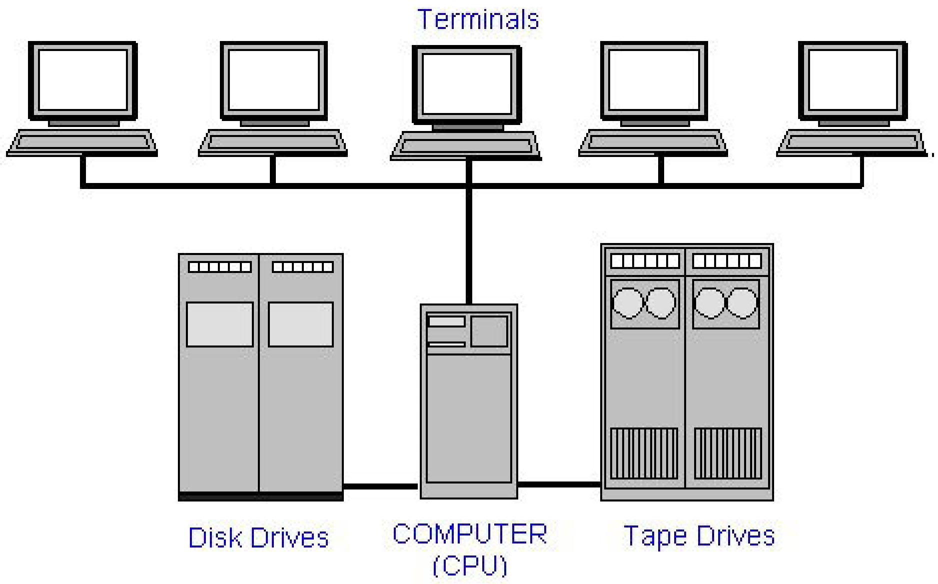
# Interactive Processing

- OS with remote terminals



# Interactive Processing (cont.)

- Terminals




# Real-Time Processing

- Real-time OS has well-defined fixed time constraints
  - **Hard real-time system**
    - Processing **must** be done within the constraint
    - Correct operation only if constraints met
  - **Soft real-time system**
    - Missing a timing is serious but does not necessarily result in failure (ex: multimedia)

- Real-time means **on time**! (not fast)

# Multi-Tasking

- Before multi-tasking, one job at a time
- Example: MS DOS


# Multi-Tasking (cont.)

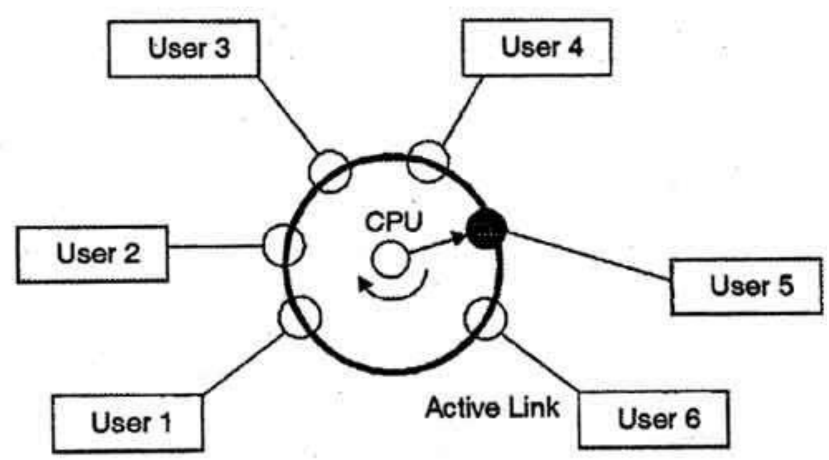
- A single user cannot always keep CPU and I/O devices busy
  - E.g., humans and disk I/O are too slow compared to CPU and memory
- Put multiple programs in memory
- OS organizes jobs so that the CPU always has one to execute
  - When a job has to wait (e.g., for I/O), OS **switches to another job**

➡ Increase CPU utilization

➡ Need job and CPU scheduling

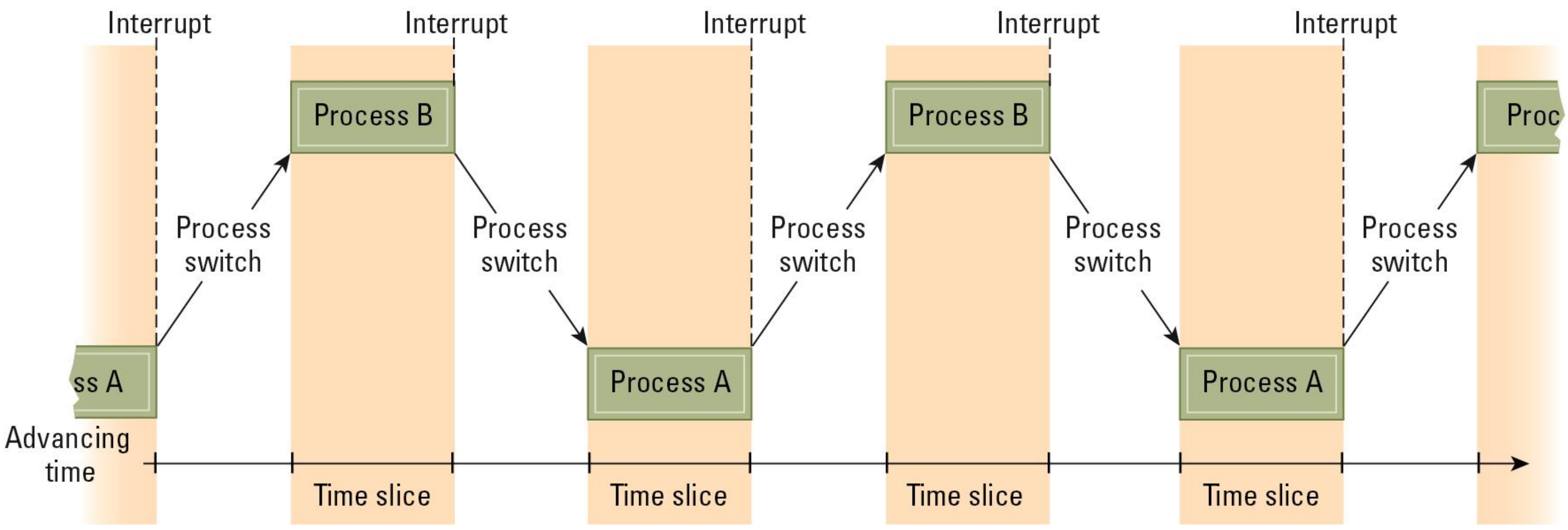
# Multi-Tasking with Time-Sharing

- CPU switches jobs frequently so that users can interact with each job while it is running
  - Only **one** (per core) task is being executed at any given time
  - A logical extension of multi-tasking
  - **Interactivity**!
    - Response time should be less than 1 sec.



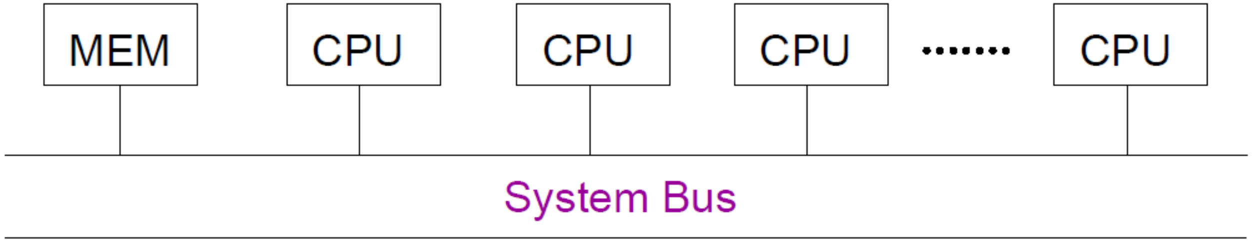
# Context Switch

- Kernel saves the state of the old process and loads the saved state for the new process
- Context switch time is **purely overhead**
- Switch time (about 1 ~ 1000 ms) depends on hardware

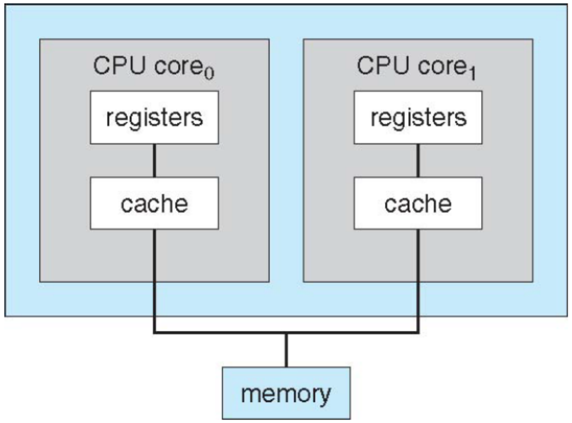


# Multiprocessor

- More than one processor in close communication sharing bus, memory, and peripheral devices




- The recent trend: from a fast single processor to lots of processors
  - **Multiple cores** over a single chip



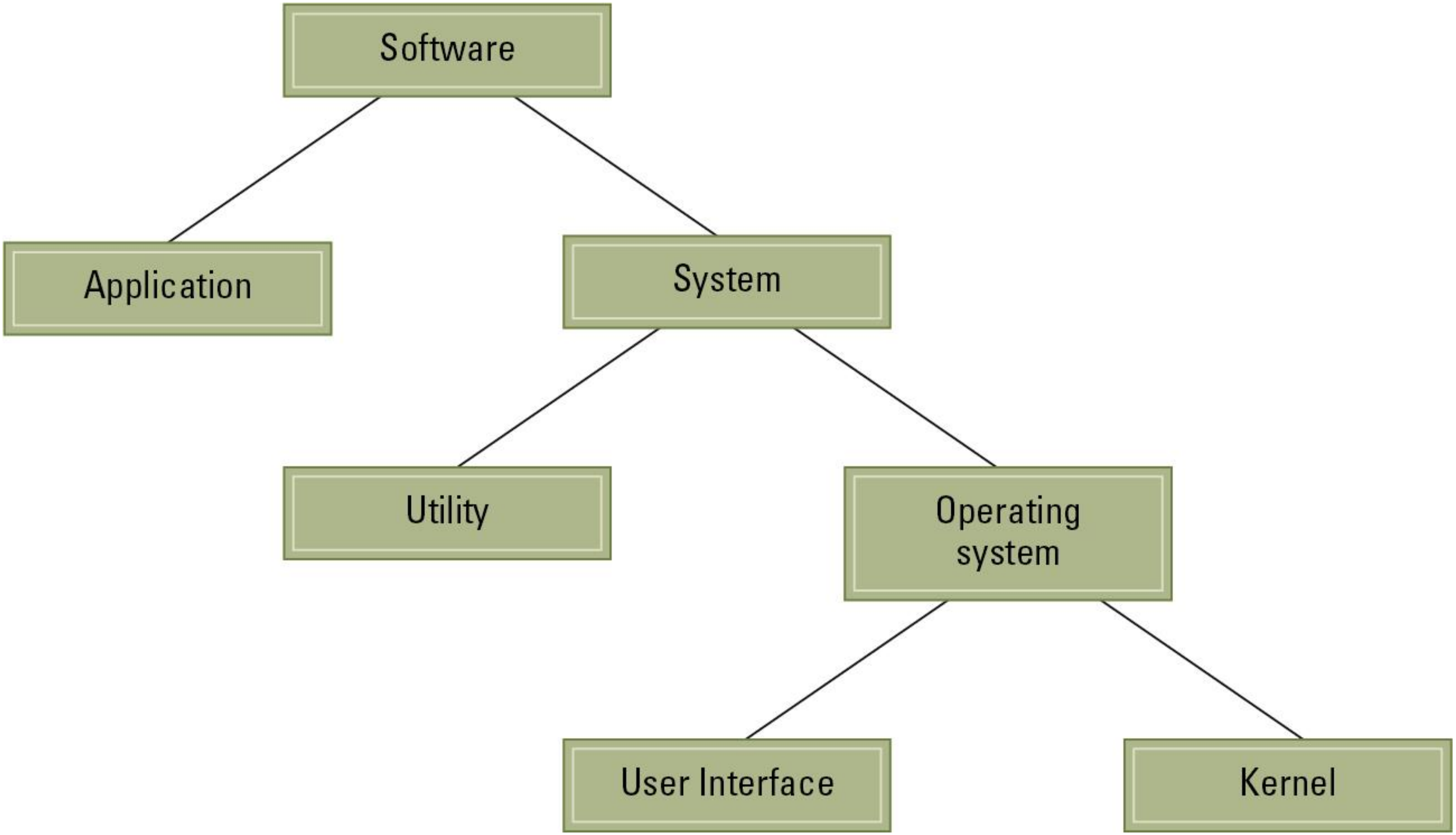
# Outline

- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine’s activities
- Handling competition among processes
- Security

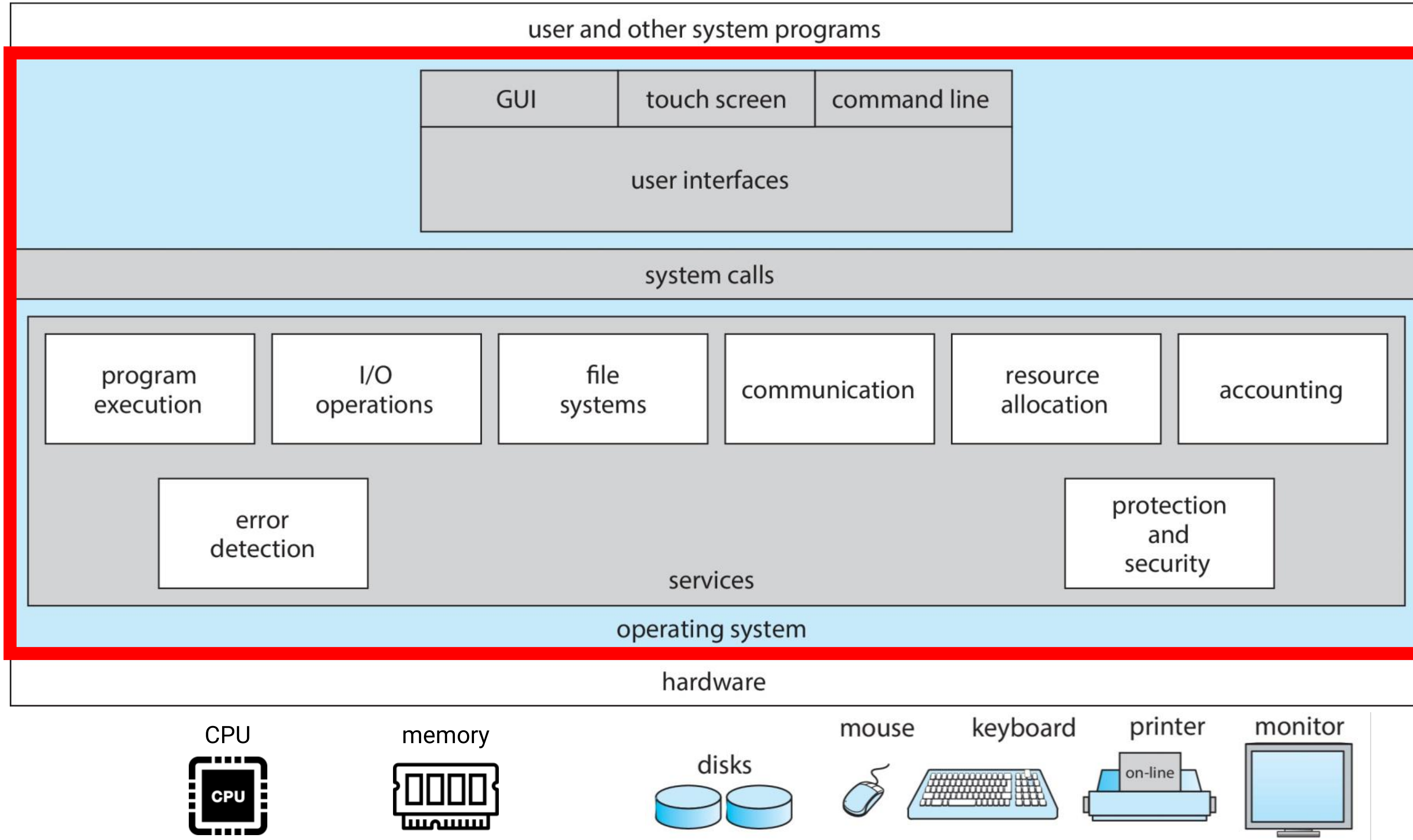
# Software Classification

- **Application software**
  - Performs specific tasks for users (productivity, games, software development)
- **System software**
  - Provides infrastructure for application software
  - Consists of operating system and utility software

# Software Classification (cont.)

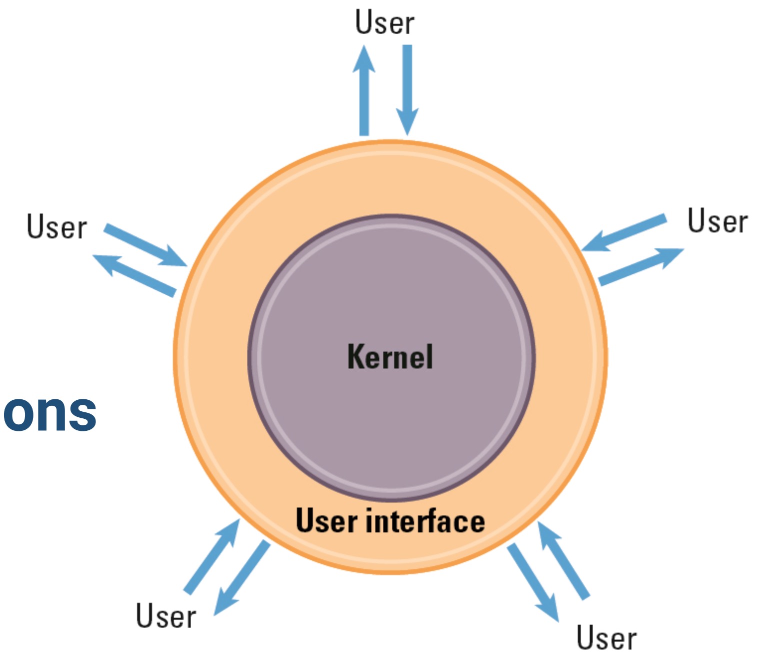


# Operating System Components

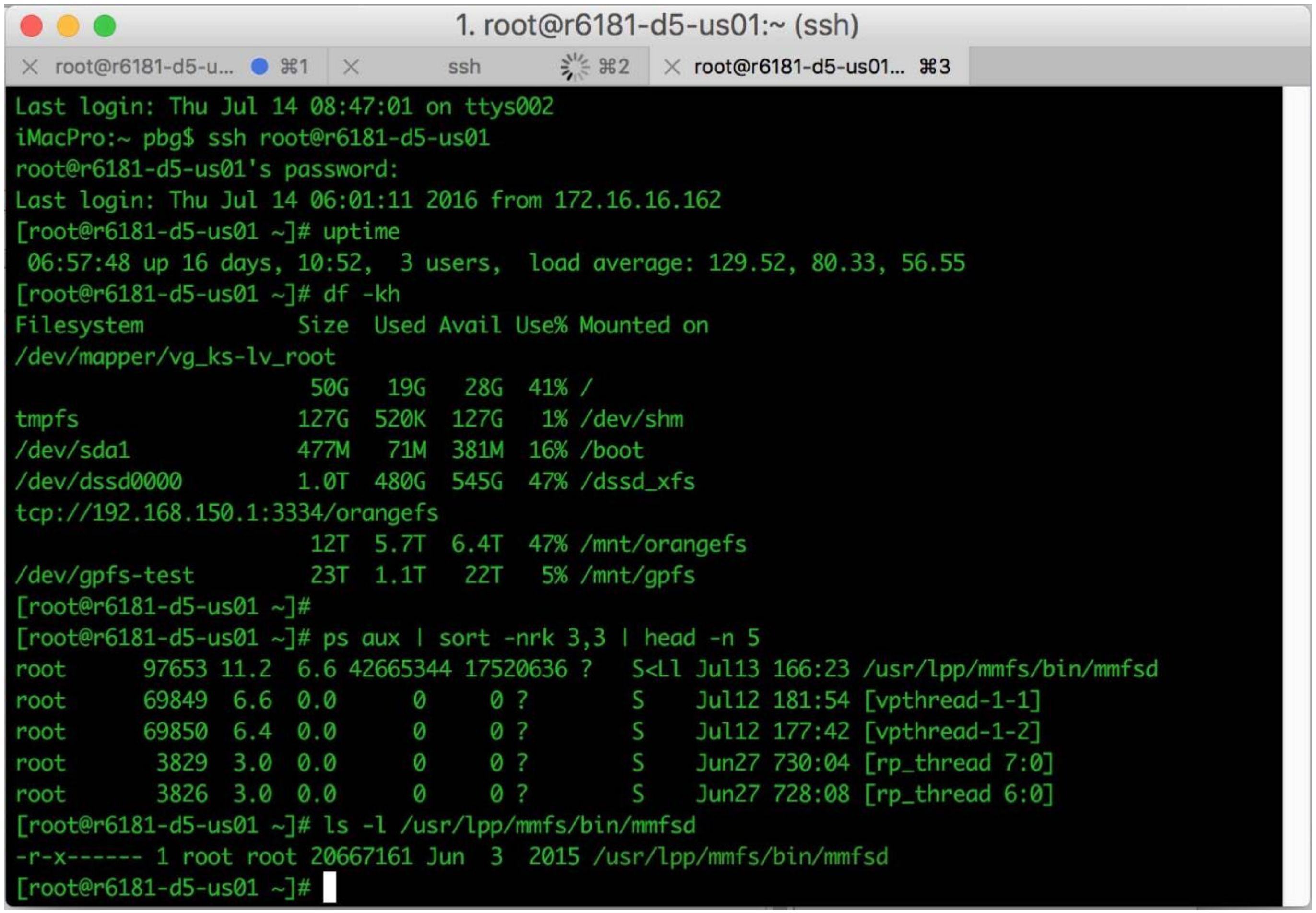


# Operating System Components (cont.)

- **User interface:**
  - **Communicates with users**
    - Text-based (Shell)
    - Graphical user interface (GUI)
- **Kernel:**
  - **Performs basic required functions**
    - File manager
    - Device drivers
    - Memory manager
    - Scheduler
    - Dispatcher

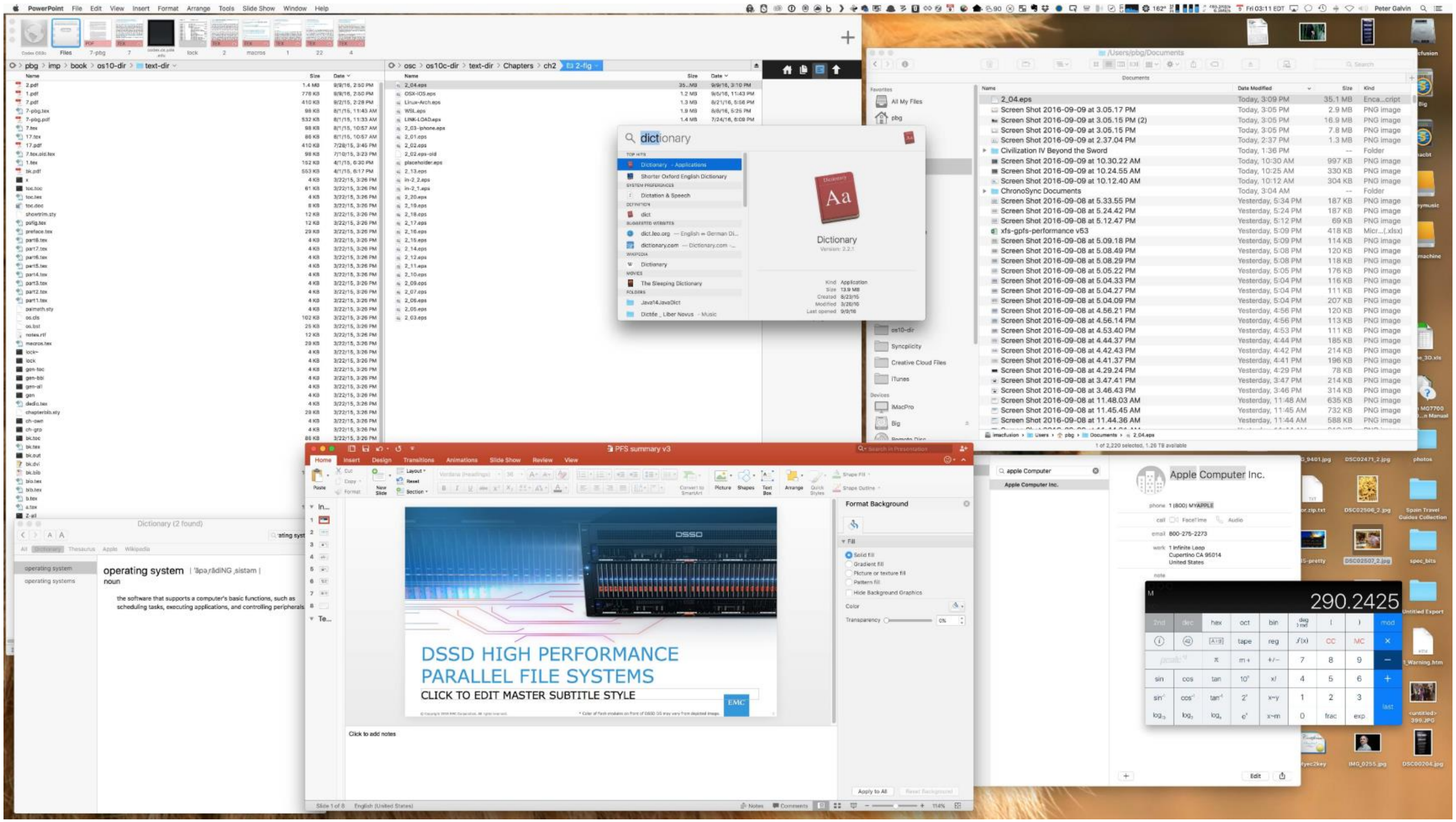


# User Interface: Shell




Bourne Shell (default shell of UNIX ver. 7)

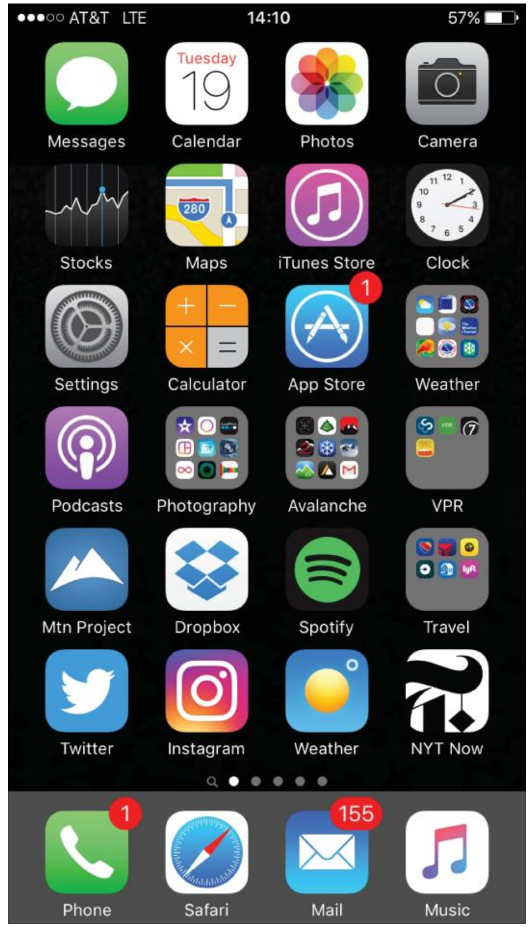
# User Interface: GUI

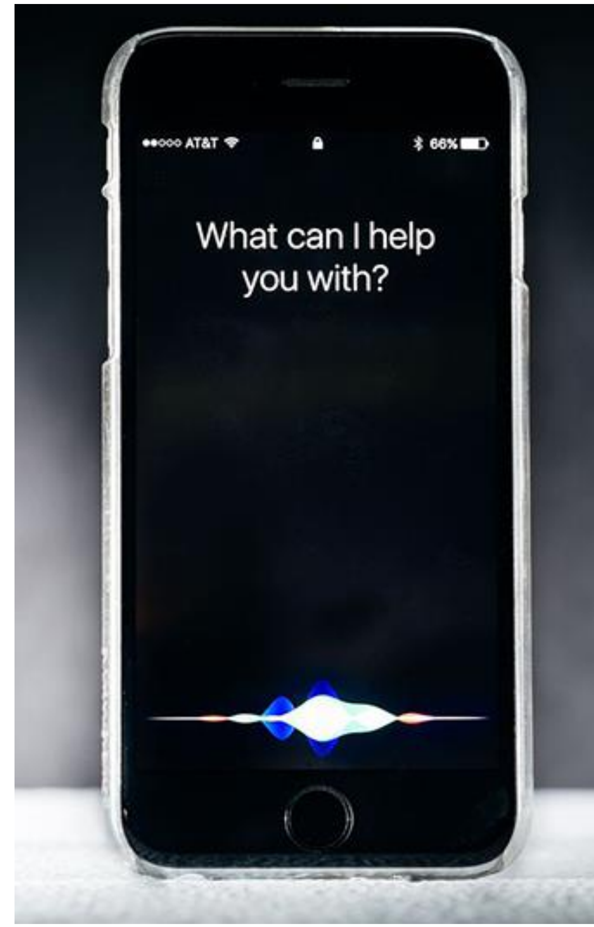



Mac OS X GUI

# User Interface: Others

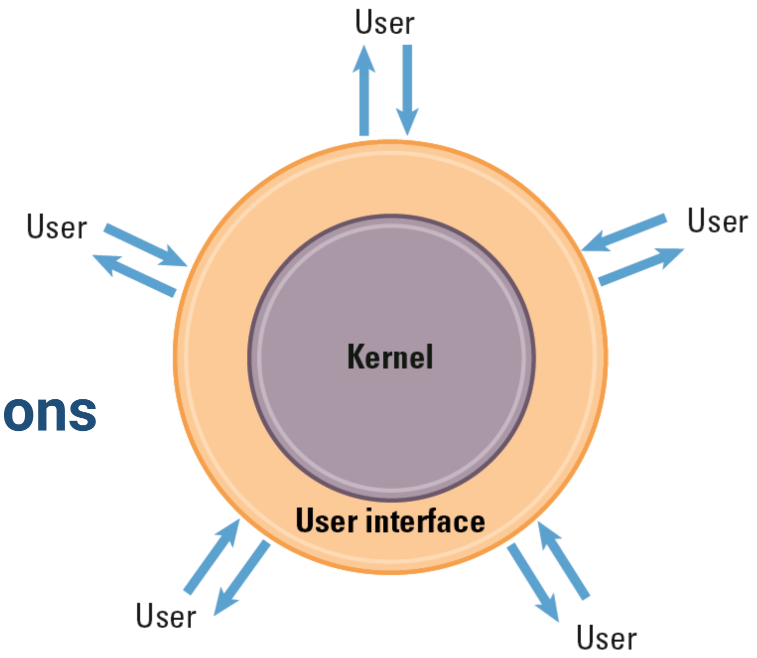
- Touch-screen
- Voice control



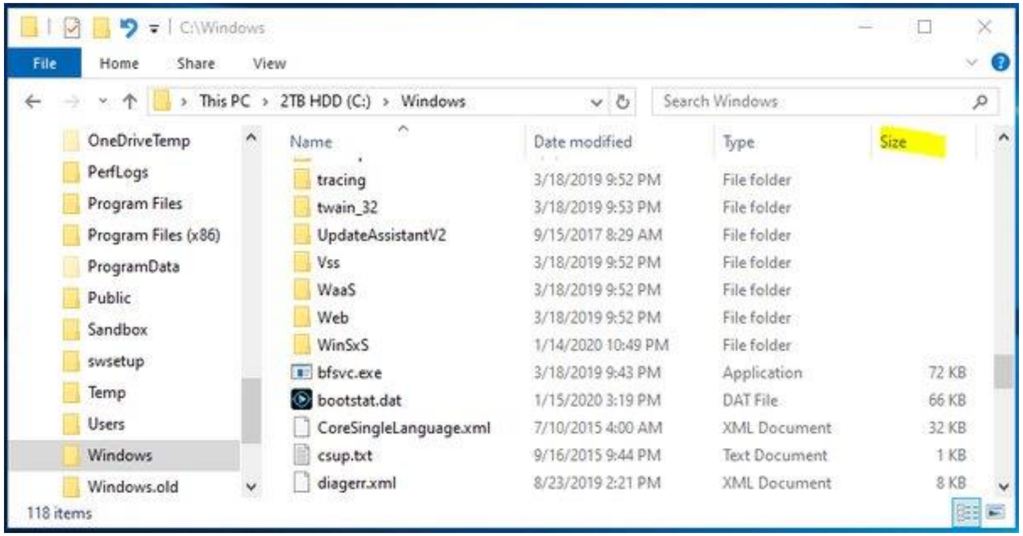
# Operating System Components

- **User interface:**
  - **Communicates with users**
    - Text-based (Shell)
    - Graphical user interface (GUI)
- **Kernel:**
  - **Performs basic required functions**
    - File manager
    - Device drivers
    - Memory manager
    - Scheduler
    - Dispatcher

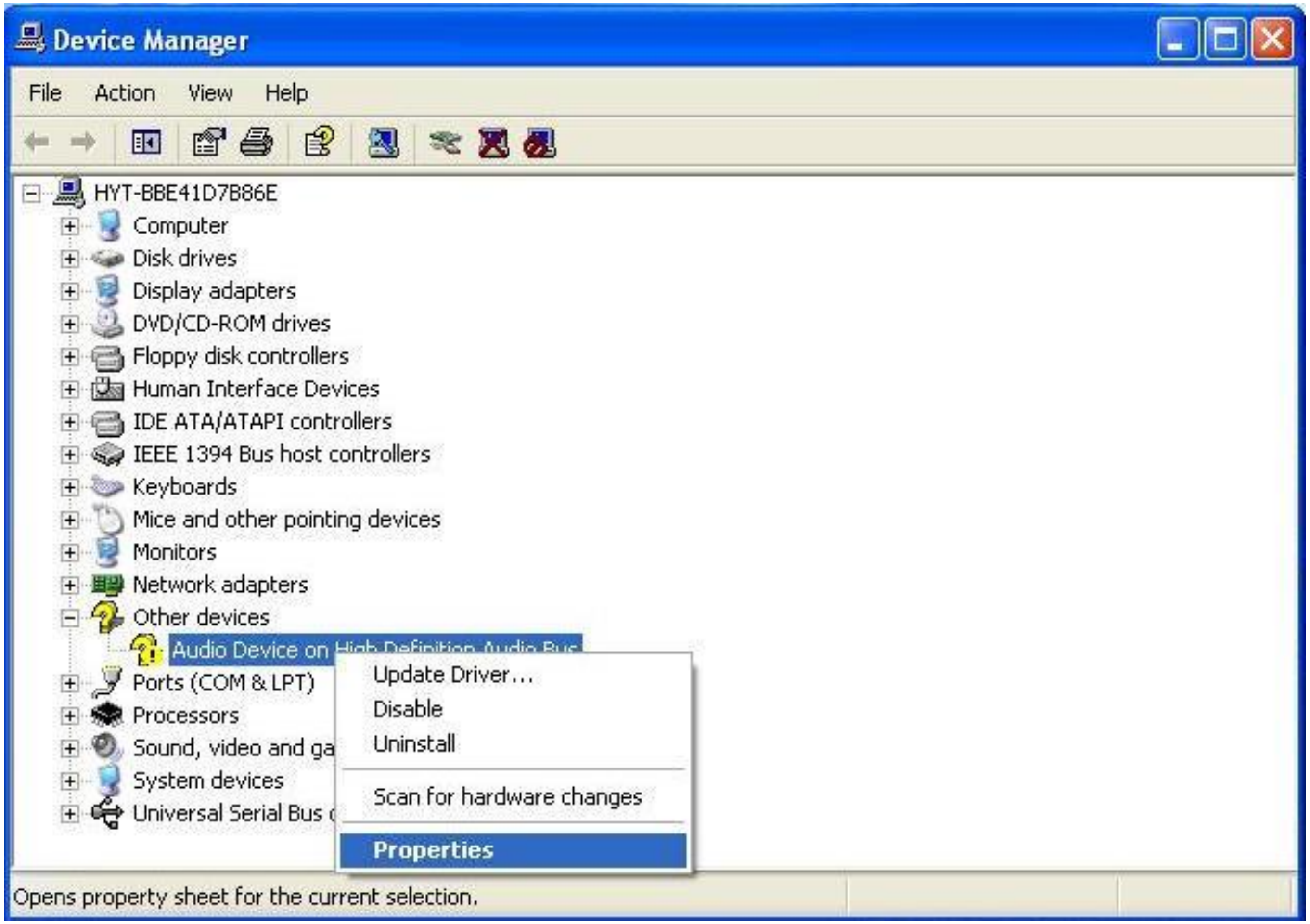


# Kernel: File Manager

- Directory (or folder)
  - A user-created bundle of files and other directories (subdirectories)
- Directory path
  - A sequence of directories within directories

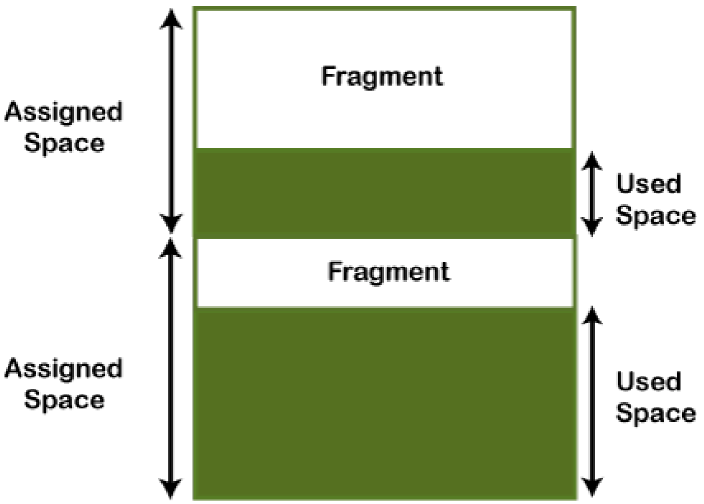


# Kernel: Device Drivers



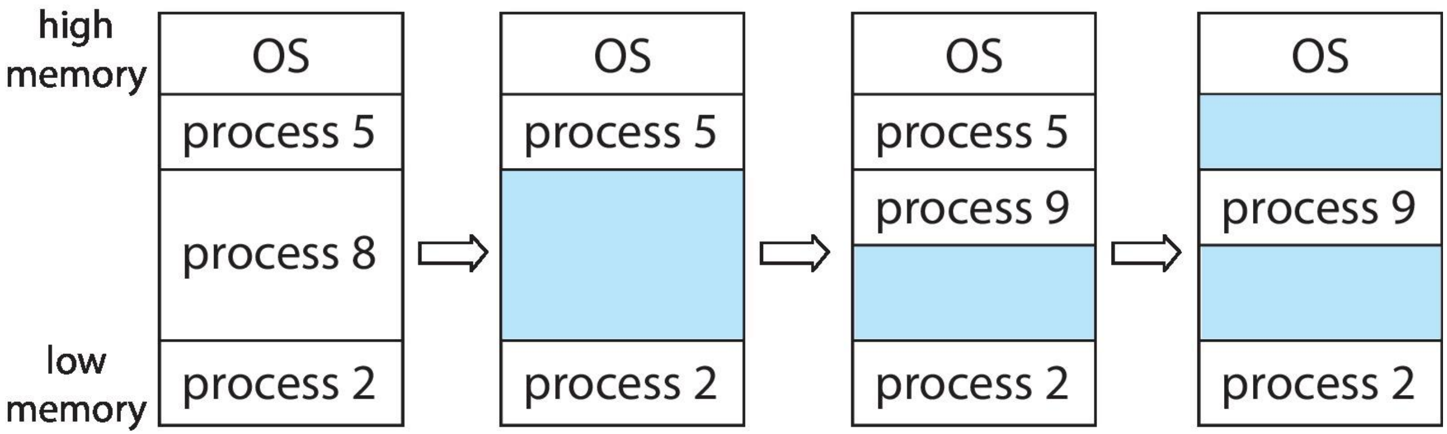
# Kernel: Memory Manager

- Allocating space in the main memory
- **Contiguous allocation: fixed-partition allocation**
  - Each process loads into one partition of fixed-size
  - **Degree of multi-programming** is bounded by the number of partitions
  - Result in **internal fragmentation**
    - Memory that is internal to a partition but is not being used



# Kernel: Memory Manager (cont.)

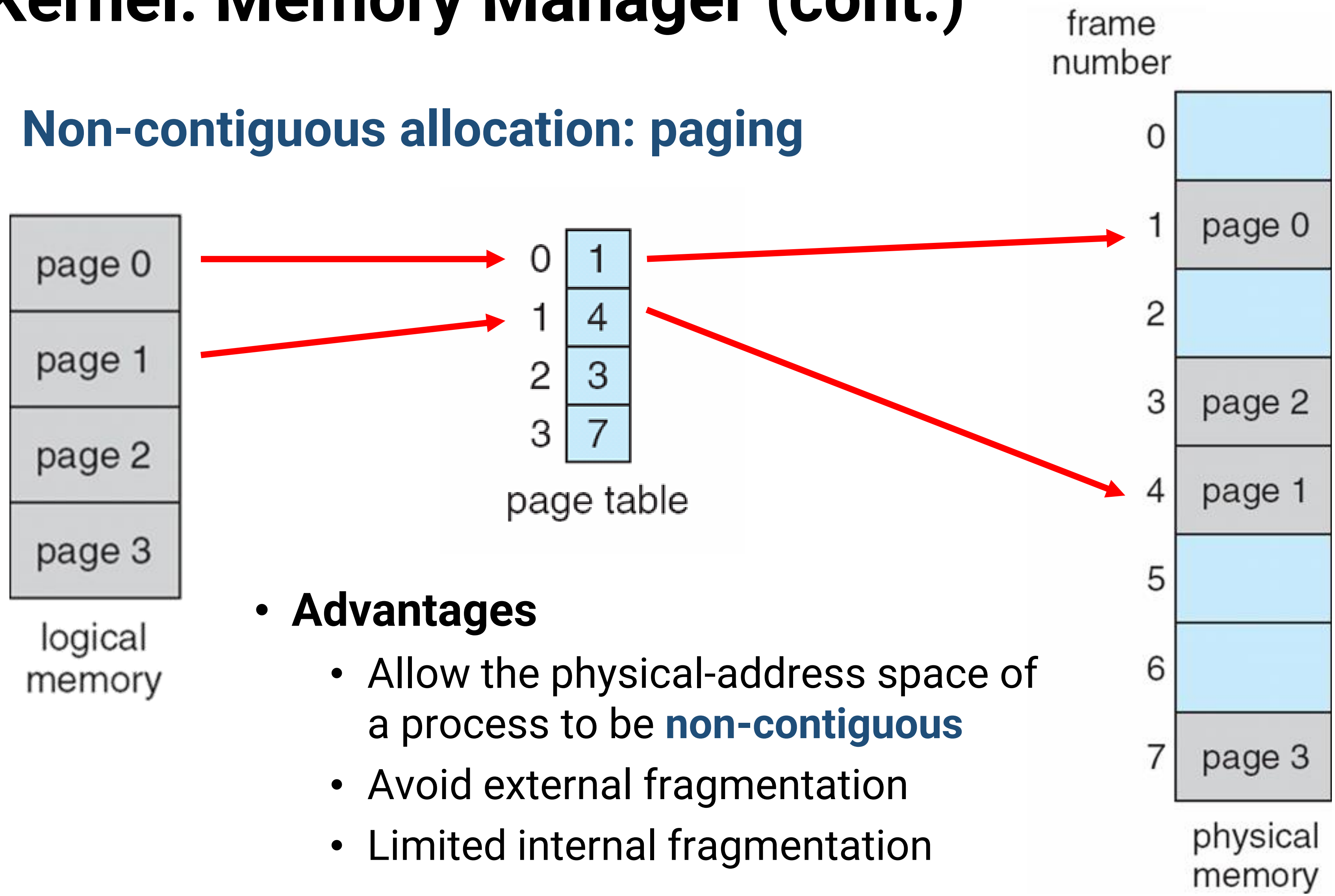
- Allocating space in the main memory
- **Contiguous allocation: variable-size partition**




  - When a process arrives, it is allocated a hole **large enough** to accommodate it
  - Result in **external fragmentation**

# Kernel: Memory Manager (cont.)

- **Non-contiguous allocation: paging**



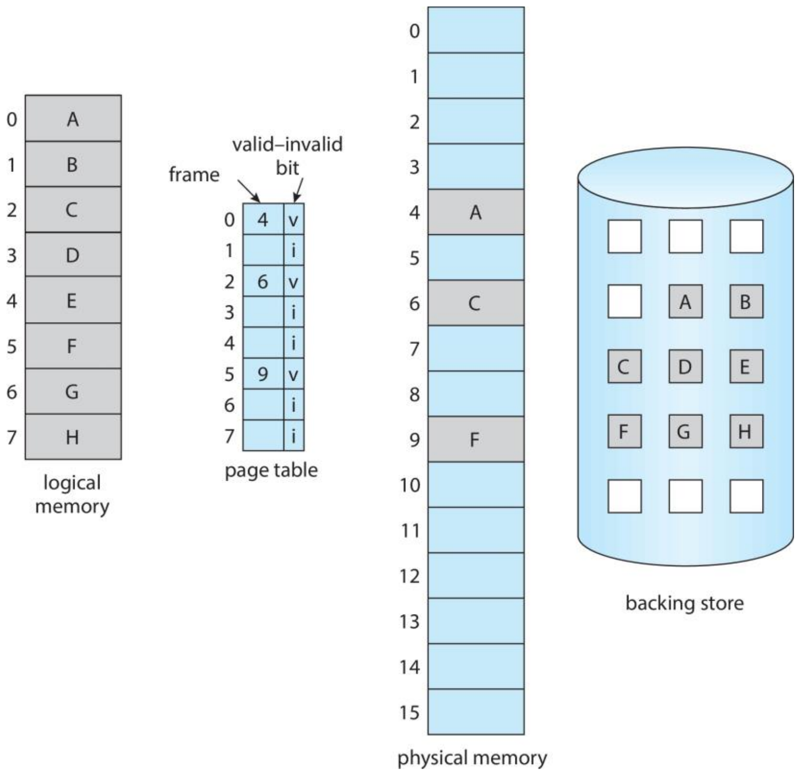

- **Advantages**
  - Allow the physical-address space of a process to be **non-contiguous**
  - Avoid external fragmentation
  - Limited internal fragmentation

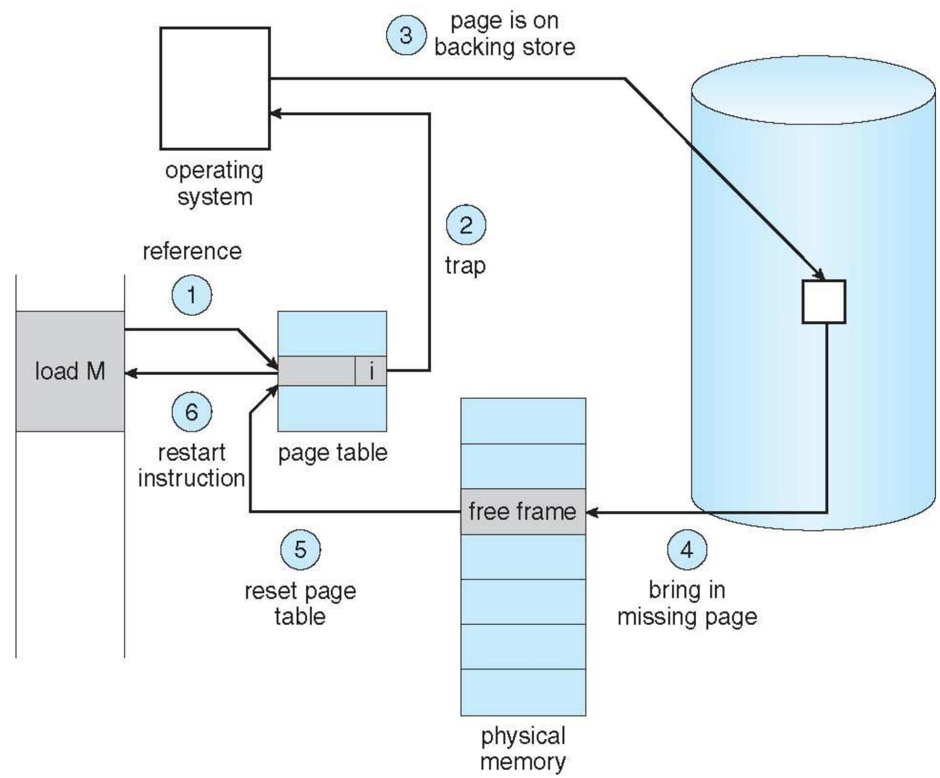
# Kernel: Memory Manager (cont.)

- **Paging**
  - Divide **physical memory** into fixed-size blocks called **frames**
  - Divide **logical address** space into blocks of the **same size** called **pages**
  - To run a program of *n* pages, need to find *n* free frames and load the program
  - **Must keep track of free frames**
  - Set up a **page table** to translate logical to physical addresses

# Kernel: Memory Manager

- **Virtual memory**
  - A process can be swapped out of memory to a **backing store**, and later brought back into memory for continuous execution



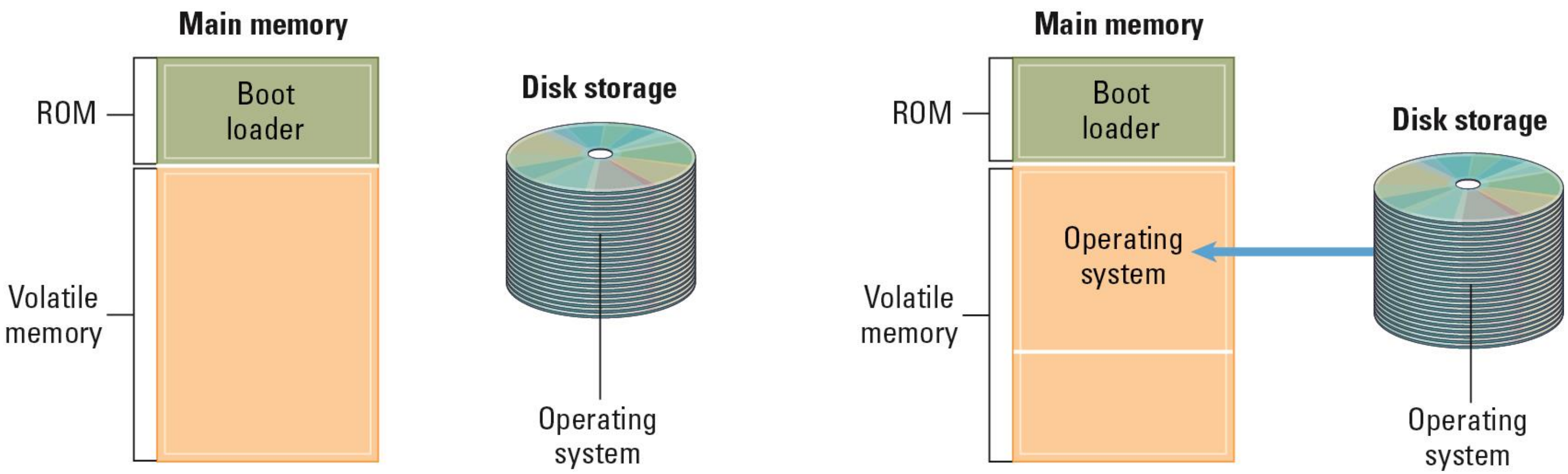



# Kernel: Memory Manager

- **Virtual memory**
  - To run an **extremely large process**
    - Logical address space can be much larger than physical address space
  - To increase **CPU/resource utilization**
    - Higher degree of multi-tasking
    - Avoid putting rarely used data and codes in memory
  - To **launch** programs **faster**
    - Less I/O would be needed to load or swap

# Bootstrapping / Booting

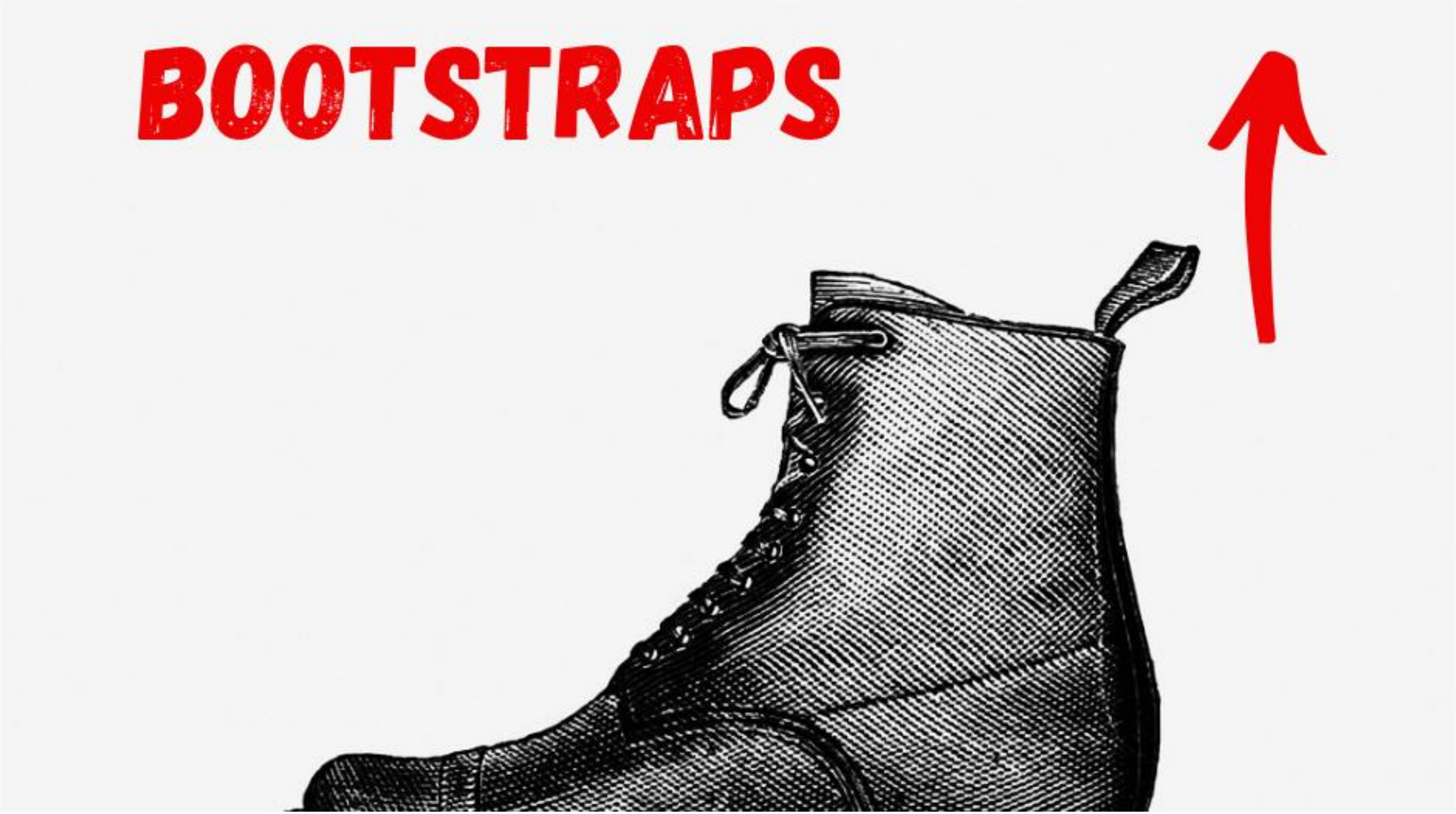
- **Boot loader:** program in ROM (read-only memory)
  - Run by the CPU when power is turned on
  - Transfers operating system from mass storage to main memory
  - Executes jump to the operating system




**Step 1:** Machine starts by executing the boot loader program already in memory. Operating system is stored in mass storage.

**Step 2:** Boot loader program directs the transfer of the operating system into main memory and then transfers control to it.

# Bootstrapping / Booting (cont.)



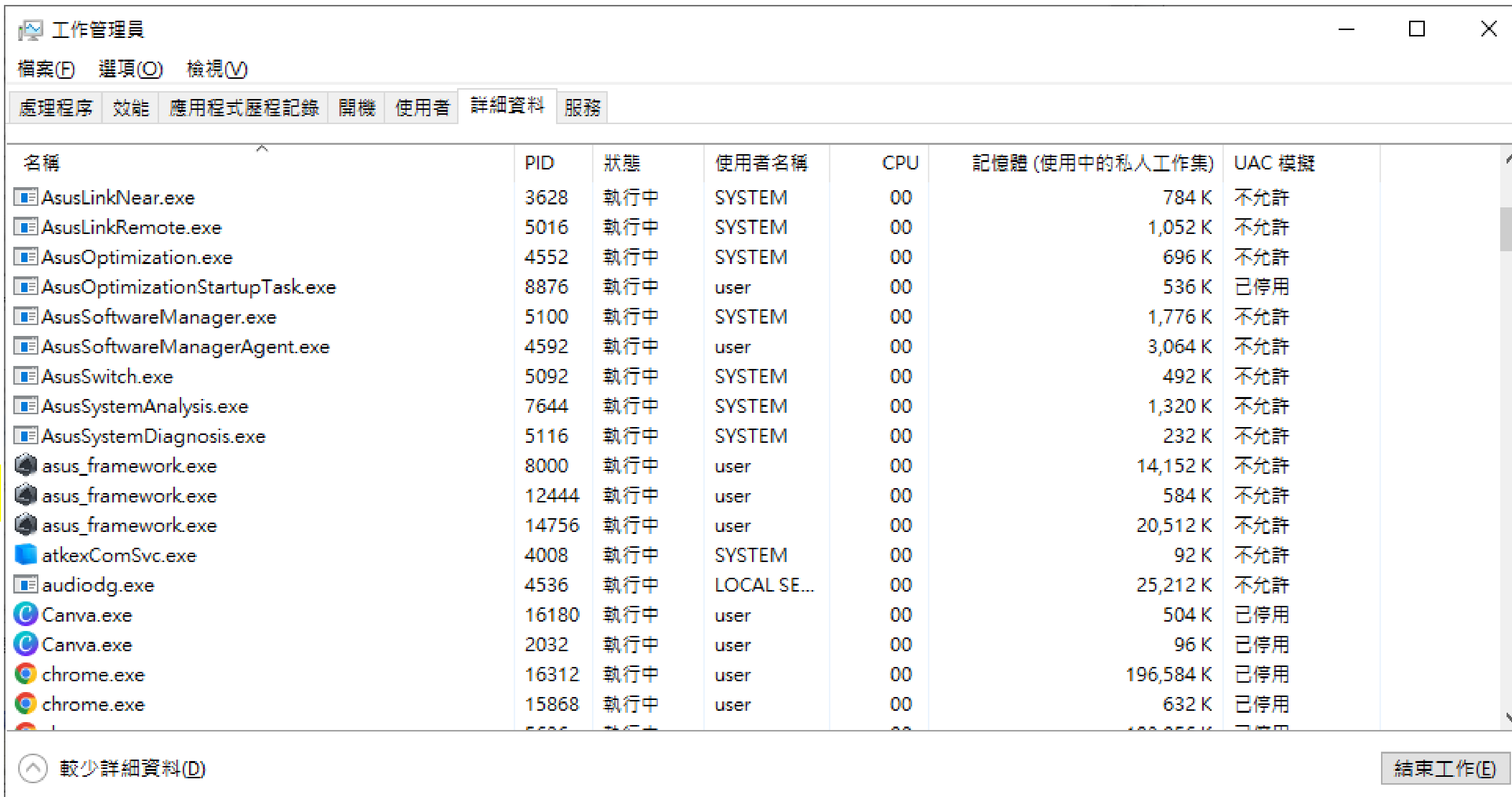
# Outline

- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine's activities
- Handling competition among processes
- Security

# Coordinating the Machine's Activities

- An operating system coordinates the execution of application software, utility software, and units within the operating system itself

Processes



工作管理員

檔案(F) 選項(O) 檢視(V)

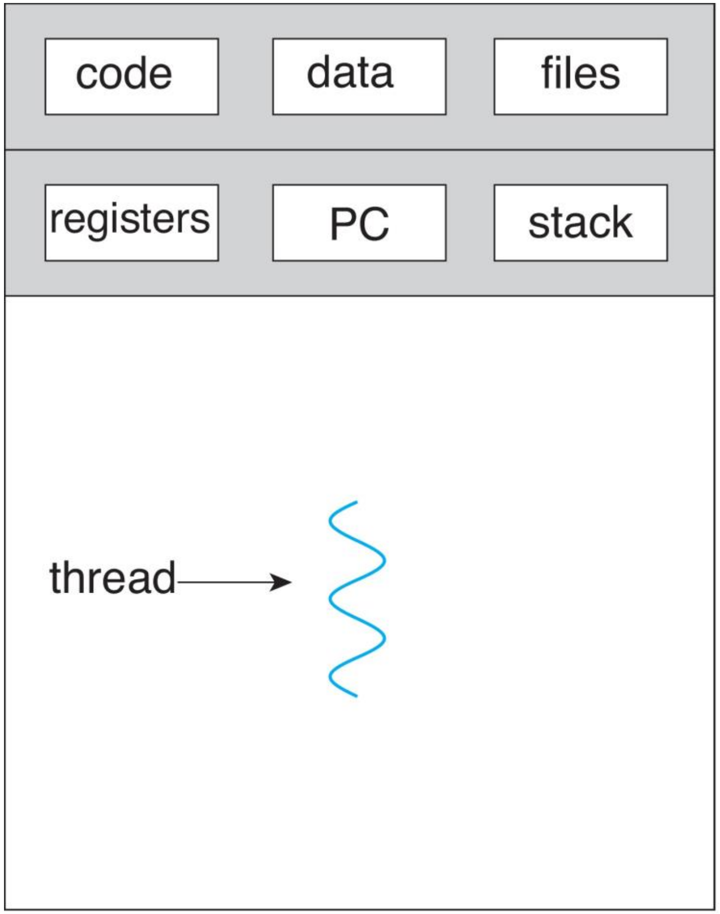
處理程序 | 效能 | 應用程式歷程記錄 | 開機 | 使用者 | 詳細資料 | 服務

| 名稱 | PID | 狀態 | 使用者名稱 | CPU | 記憶體 (使用中的私人工作集) | UAC 模擬 |
|---|---|---|---|---|---|---|
| AsusLinkNear.exe | 3628 | 執行中 | SYSTEM | 00 | 784 K | 不允許 |
| AsusLinkRemote.exe | 5016 | 執行中 | SYSTEM | 00 | 1,052 K | 不允許 |
| AsusOptimization.exe | 4552 | 執行中 | SYSTEM | 00 | 696 K | 不允許 |
| AsusOptimizationStartupTask.exe | 8876 | 執行中 | user | 00 | 536 K | 已停用 |
| AsusSoftwareManager.exe | 5100 | 執行中 | SYSTEM | 00 | 1,776 K | 不允許 |
| AsusSoftwareManagerAgent.exe | 4592 | 執行中 | user | 00 | 3,064 K | 不允許 |
| AsusSwitch.exe | 5092 | 執行中 | SYSTEM | 00 | 492 K | 不允許 |
| AsusSystemAnalysis.exe | 7644 | 執行中 | SYSTEM | 00 | 1,320 K | 不允許 |
| AsusSystemDiagnosis.exe | 5116 | 執行中 | SYSTEM | 00 | 232 K | 不允許 |
| asus_framework.exe | 8000 | 執行中 | user | 00 | 14,152 K | 不允許 |
| asus_framework.exe | 12444 | 執行中 | user | 00 | 584 K | 不允許 |
| asus_framework.exe | 14756 | 執行中 | user | 00 | 20,512 K | 不允許 |
| atkexComSvc.exe | 4008 | 執行中 | SYSTEM | 00 | 92 K | 不允許 |
| audiodg.exe | 4536 | 執行中 | LOCAL SE... | 00 | 25,212 K | 不允許 |
| Canva.exe | 16180 | 執行中 | user | 00 | 504 K | 已停用 |
| Canva.exe | 2032 | 執行中 | user | 00 | 96 K | 已停用 |
| chrome.exe | 16312 | 執行中 | user | 00 | 196,584 K | 已停用 |
| chrome.exe | 15868 | 執行中 | user | 00 | 632 K | 已停用 |

較少詳細資料(D) 結束工作(E)

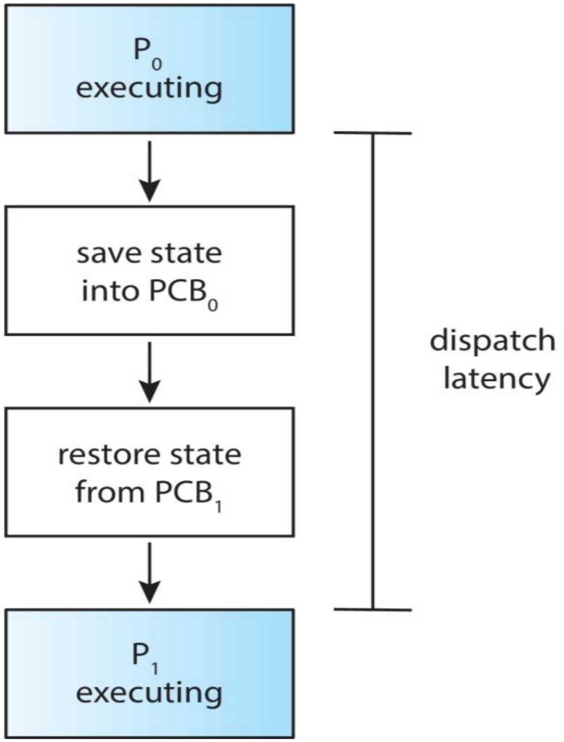
# The Concept of a Process

- **Process**
  - The activity of executing a program
- **Process state**
  - Current status of the activity
    - Program counter
    - General purpose registers
    - Related portion of main memory
  - Managed by a process table (**Process Control Block, PCB**)
  - Save/load during a **context switch**

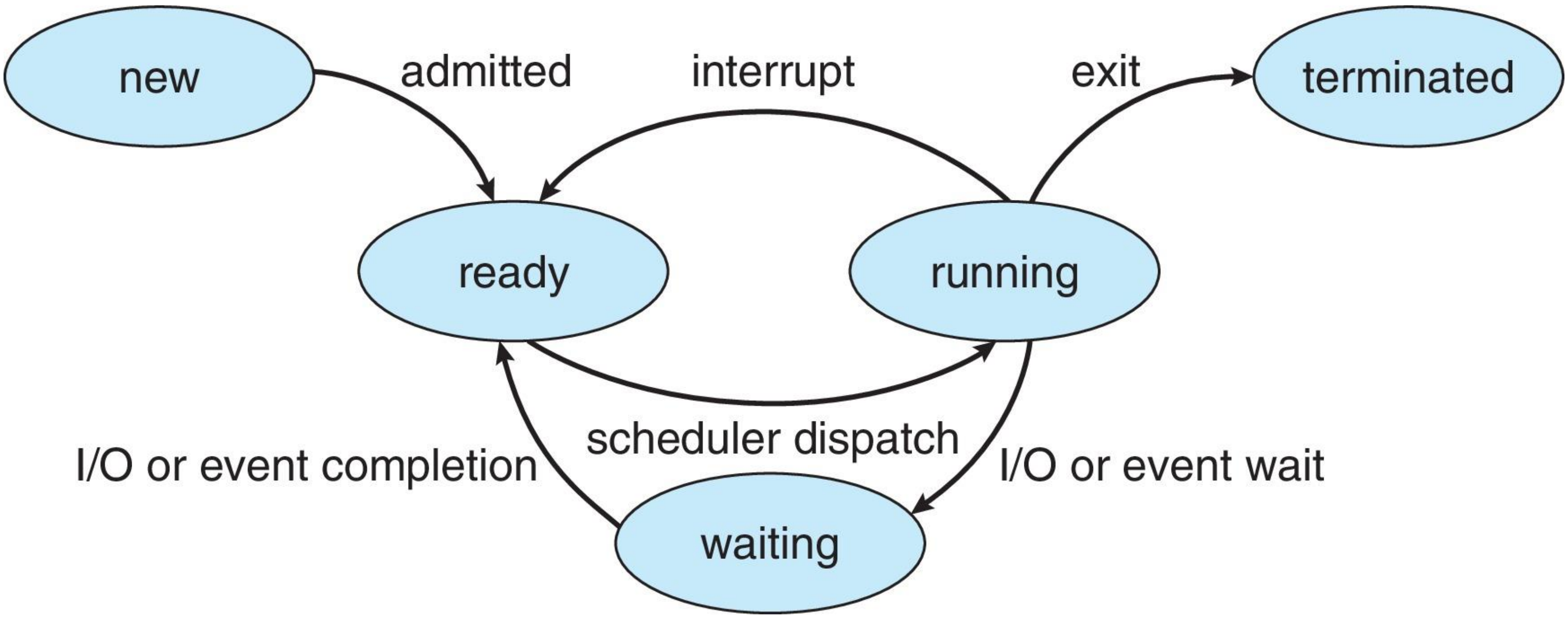


# Process Administration

- **Scheduler**
  - Maintain the process table
    - Introduce new processes
    - Remove completed processes
    - Decide whether a process is ready or waiting
- **Dispatcher**
  - Really execute the program
    - Control the allocation of time slices to the processes
    - Switch processes (**context switch**)



# Process State




**Only one** process is running on any processor at any instant

However, many processes may be ready or waiting (put into a queue)

# Scheduling Criteria

- **CPU utilization**
  - Theoretically 0% ~ 100%
  - Real systems: 40% (light) ~ 90% (heavy)
- **Throughput**
  - Number of completed processes per time unit
- **Turnaround time**
  - Submission ~ completion
- **Waiting time**
  - Total waiting time in the ready queue
- **Response time**
  - Submission ~ the first response is produced

system view

single job view

# Scheduling Criteria (cont.)

- **Max** CPU utilization
- **Max** Throughput
- **Min** Turnaround time
- **Min** Waiting time
- **Min** Response time

# Scheduling Algorithms

- First-Come, First-Served (FCFS) scheduling
- Shortest-Job-First (SJF) scheduling
- Priority scheduling
- Round-Robin scheduling
- Multi-level queue scheduling
- Multi-level feedback queue scheduling

# Starvation

- Process cannot get the resources needed for a long time because the resources are being allocated to other processes

- **Aging**
    - Add an aging factor to the priority of each request

# Outline

- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine's activities
- Handling competition among processes
- Security

# Data Consistency

- **Concurrent access** to **shared data** may result in **data inconsistency**

- Maintaining data consistency requires a mechanism to ensure the **orderly execution** of cooperating processes

# Example: Consumer & Producer Problem

- **Producer** process produces information that is consumed by a **Consumer** process, both operating on a fixed-size buffer

```
/* Producer */
while (true) {
	// produce an item in next produced.
	while (counter == BUFFER_SIZE);
		// do nothing.
	buffer[in] = next_produced;
	in = (in + 1) % BUFFER_SIZE;
	counter++;
}
```

```
/* Consumer */
while (true) {
	while (counter == 0);
		// do nothing.
	next_consumed = buffer[out];
	out = (out + 1) % BUFFER_SIZE;
	counter--;
	// consume the item in next consumed.
}
```

# Concurrent Operations on Counter

- The statement "counter++" may be implemented in machine language as

  *move R1, counter*

  *add R1, 1*

  *move counter, R1*

- The statement "counter--" may be implemented as

  *move R2, counter*

  *sub R2, 1*

  *move counter, R2*

# Instruction Interleaving

- Assume the counter is initially 5. One interleaving of statement is

| | |
|---|---|
| *producer: move R1, counter* | ➔ R1 = 5 |
| *producer: add R1, 1* | ➔ R1 = 6 |
| *context switch* | |
| *consumer: move R2, counter* | ➔ R2 = 5 |
| *consumer: sub R2, 1* | ➔ R2 = 4 |
| *context switch* | |
| *producer: move counter, R1* | ➔ counter = 6 |
| *context switch* | |
| *consumer: move counter, R2* | ➔ counter = 4 |

# Handling Competition among Processes

- **Critical Region**
  - A **protocol** for processes to cooperate
  - A group of instructions that should be executed by only one process at a time
- **Mutual exclusion**
  - Requirement that **only one** process at a time be allowed to execute a critical region

*do {*
    **entry section** → get **entry permission**
        *critical section* → modified **shared data**
    **exit section** → release **entry permission**
        *remainder section*
*} while (1);*

# Semaphore

- A tool to generalize the synchronization problem
  - Can be achieved by hardware or software solutions
- Hardware support: **atomic instructions** (uninterruptible)

```
bool TestAndSet (bool &lock) {
    bool value = lock;
    lock = true;
    return value;
}
```

execute atomically:
**return the value** of “lock” and **set** “lock” to true

```
shared data: bool lock; // initially lock = false
```

```
// P0
do {
    while (TestAndSet (lock));
    critical section
    lock = false;
    remainder section
} while (1);
```

```
// P1
do {
    while (TestAndSet (lock));
    critical section
    lock = false;
    remainder section
} while (1);
```

# Deadlock

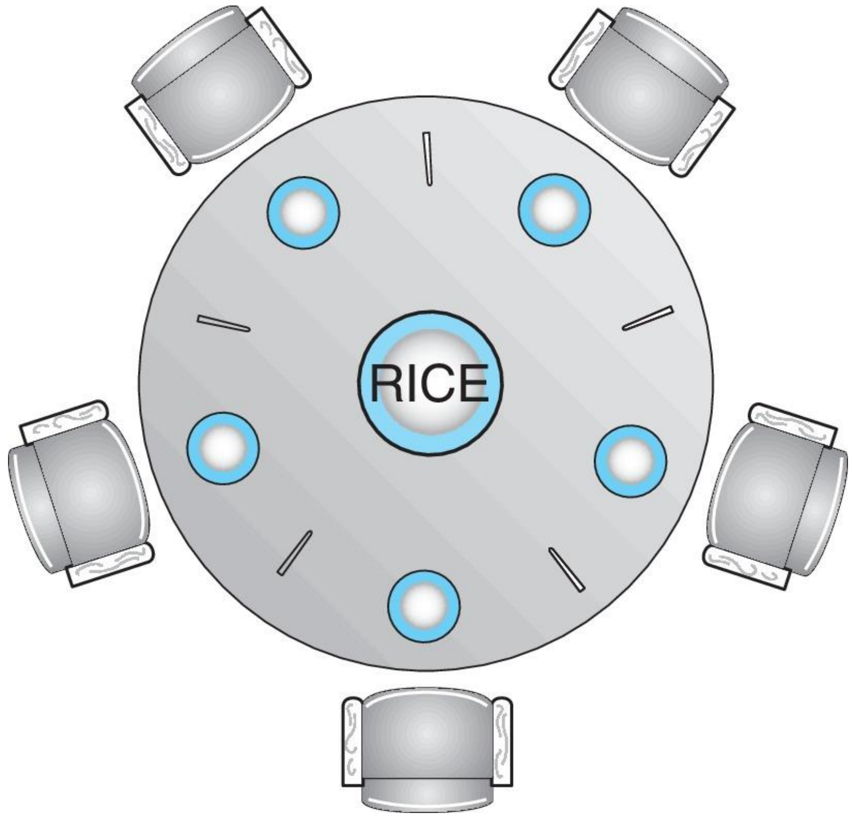
- Processes block each other from continuing because each is waiting for a resource that is allocated to another
- Example
  - 2 processes
    - $P_1$ holds resource B and waits for resource A
    - $P_2$ holds resource A and waits for resource B

# Deadlock (cont.)

- Conditions required for deadlock
  - Competition for non-sharable resources (**mutual exclusion**)
    - Only one process at a time can use a resource
  - Resources requested on a partial basis (**hold and wait**)
    - A process holding some resources and is waiting for another resource
  - An allocated resource can not be forcibly retrieved (**no preemption**)
    - A resource can be only released by a process **voluntarily**
  - **Circular wait**
    - There exists a set $\{P_0, P_1, \ldots, P_n\}$ of waiting processes such that $P_0 \rightarrow P_1 \rightarrow P_2 \rightarrow \ldots \rightarrow P_n \rightarrow P_0$

# Deadlock (cont.)

- Dining-philosophers problem



# Handling Deadlocks

- Ensure the system will **never** enter a deadlock state
  - **Deadlock prevention**: ensure that at least one of the **four necessary conditions** cannot hold
  - **Deadlock avoidance**: **dynamically** examines the resource-allocation state before allocation
- Allow to **enter a deadlock state** and then **recover**
  - **Deadlock detection**
  - **Deadlock recovery**
- **Ignore the problem** and pretend that deadlocks never occur in the system
  - **Used by most operating systems, including UNIX**

# Outline

- What is an operating system
- The history of operating systems
- Operating system architecture
- Coordinating the machine's activities
- Handling competition among processes
- Security

# Security

- **Goals**
  - Prevent error and misuse
  - Resources are only allowed to be accessed by authorized processes
- **Attacks from outside**
  - Problems
    - Insecure passwords and **bad habits**
    - Sniffing software
    - Virus, worms, Trojan horses
  - Counter measures
    - Auditing software (record and analyze activities)
    - Antivirus software

# Security (cont.)

- **Attacks from within**
  - Problem
    - Process that gains access to memory outside its designated area
  - Counter measures
    - Control process activities via **privilege levels** and **privileged instructions**

# Any Questions?