Operating System Concepts

Tei-Wei Kuo
ktw@csie.ntu.edu.tw
Dept. of Computer Science and Information Engineering
National Taiwan University

Syllabus

- **授課教授:** 郭大維 @ Room 315.資工系. NTU.TW
- **助教:** 陳雅淑 (yashc@mail2000.com.tw)
  張原豪 (d93944006@ntu.edu.tw)
- **上課時間:** Wednesday 14:20-17:20
- **教室:**資 103
- **教科書：**
  Silberschatz, Galvin, and Gagne, “Operating System Principles,” 7th Edition, John Wiley & Sons, Inc..
- 成績評量：**(**subject to changes.)**:**
  期中考(40%), 期末考(40%), 作業(20%)

Projects – **Nachos 4.0**

- Not Another Completely Heuristic Operating System
- Written by Tom Anderson and his students at UC Berkeley

  http://www.cs.washington.edu/homes/tom/nachos/
- It simulates an MIPS architecture on host systems

  (Unix/Linux/Windows/MacOS X)
- User programs need a cross-compiler (target MIPS)
- Nachos appears as a single threaded process to the host operating system.

Contents

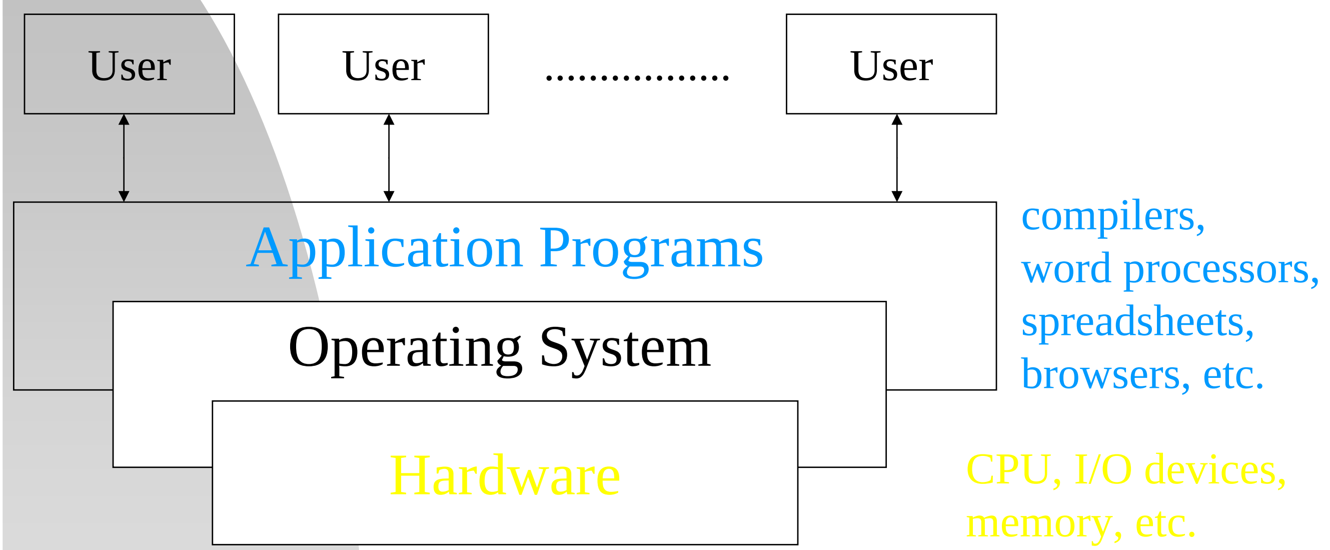
Chapter 1. Introduction

Introduction

- What is an Operating System?
  - A basis for application programs
  - An intermediary between users and hardware
- Amazing variety
  - Mainframe, personal computer (PC), handheld computer, embedded computer without any user view

Convenient vs Efficient

Computer System Components



- OS – a government/environment provider

User View

- The user view of the computer varies by the interface being used!
- Examples:
  - Personal Computer → Ease of use
  - Mainframe or minicomputer → maximization of resource utilization
    - Efficiency and fair share
  - Workstations → compromise between individual usability & resource utilization
  - Handheld computer → individual usability
  - Embedded computer without user view → run without user intervention

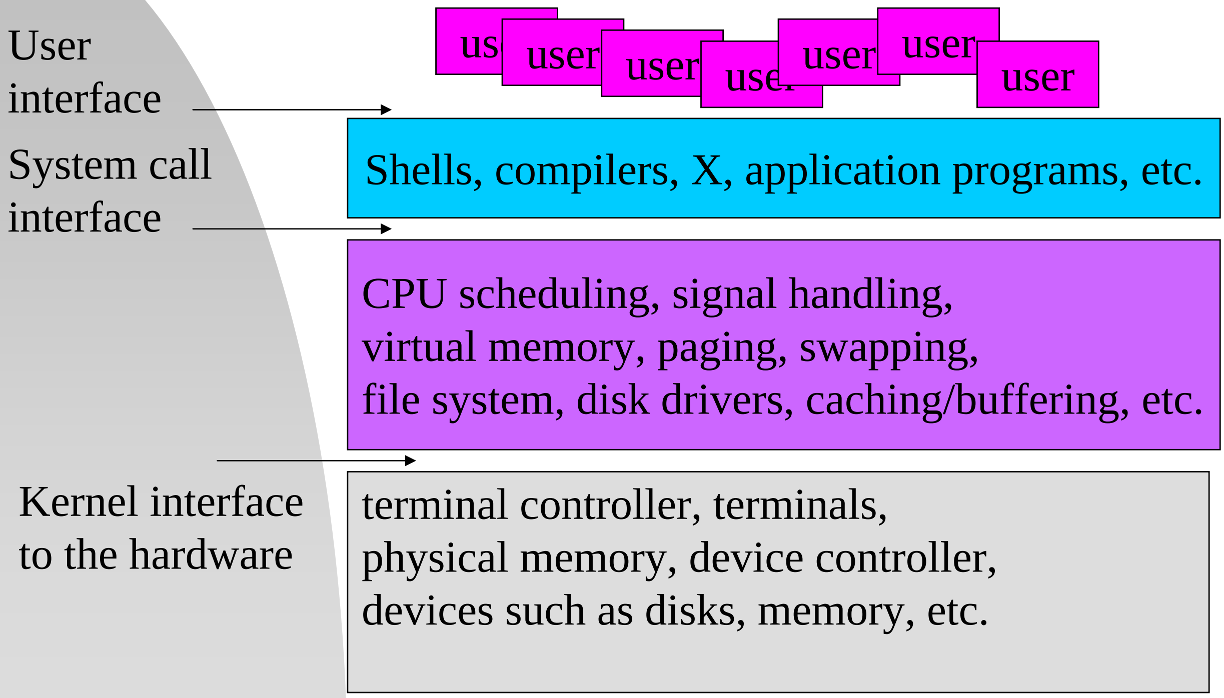
System View

- A Resource Allocator
  - CPU time, Memory Space, File Storage, I/O Devices, Shared Code, Data Structures, and more
- A Control Program
  - Control execution of user programs
  - Prevent errors and misuse
- OS definitions – US Dept.of Justice against Microsoft in 1998
  - The stuff shipped by vendors as an OS
  - Run at all time

System Goals

- Two Conflicting Goals:
  - Convenient for the user!
  - Efficient operation of the computer system!
- We should
  - recognize the influences of operating systems and computer architecture on each other
  - and learn why and how OS's are by tracing their evolution and predicting what they will become!

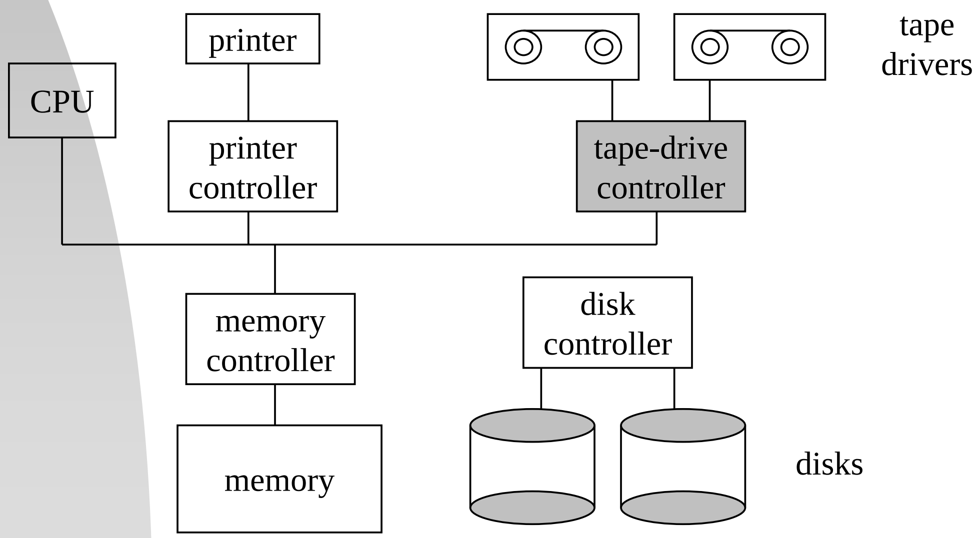
UNIX Architecture



UNIX

Computer-System Structure

- Objective: General knowledge of the structure of a computer system.



- Device controllers: synchronize and manage access to devices.

Booting

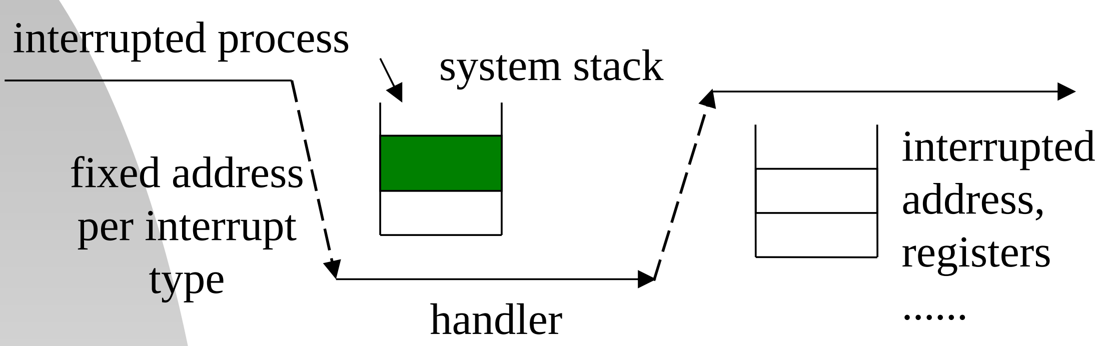
- Bootstrap program:
  - Initialize all aspects of the system, e.g., CPU registers, device controllers, memory, etc.
  - Load and run the OS
- Operating system: run *init* to initialize system processes, e.g., various daemons, login processes, after the kernel has been bootstrapped. (/etc/rc* & init or /sbin/rc* & init)

Interrupt

- Hardware interrupt, e.g. services requests of I/O devices
- Software interrupt, e.g. signals, invalid memory access, division by zero, system calls, etc – (trap)

- Procedures: generic handler or interrupt vector (MS-DOS,UNIX)

Interrupt Handling Procedure

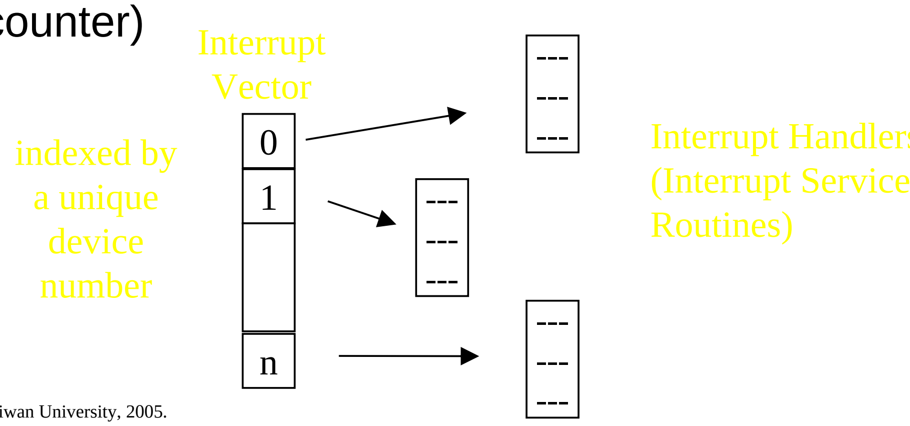


- Saving of the address of the interrupted instruction: fixed locations or stacks
- Interrupt disabling or enabling issues: lost interrupt?!

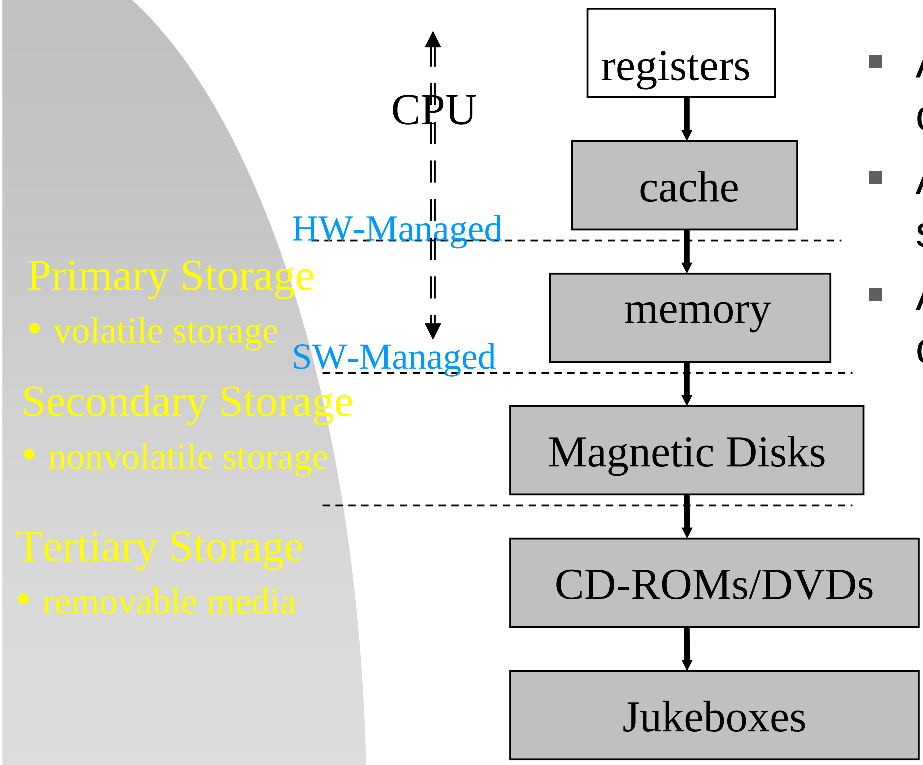
  prioritized interrupts → masking

Interrupt Handling Procedure

- Interrupt Handling
  - ➔ Save interrupt information
  - ➔ OS determine the interrupt type (by polling)
  - ➔ Call the corresponding handlers
  - ➔ Return to the interrupted job by the restoring important information (e.g., saved return addr. → program counter)



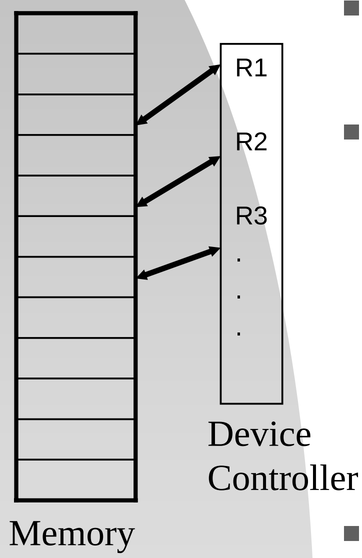
Storage Structure



- Access time: a cycle
- Access time: several cycles
- Access time: many cycles

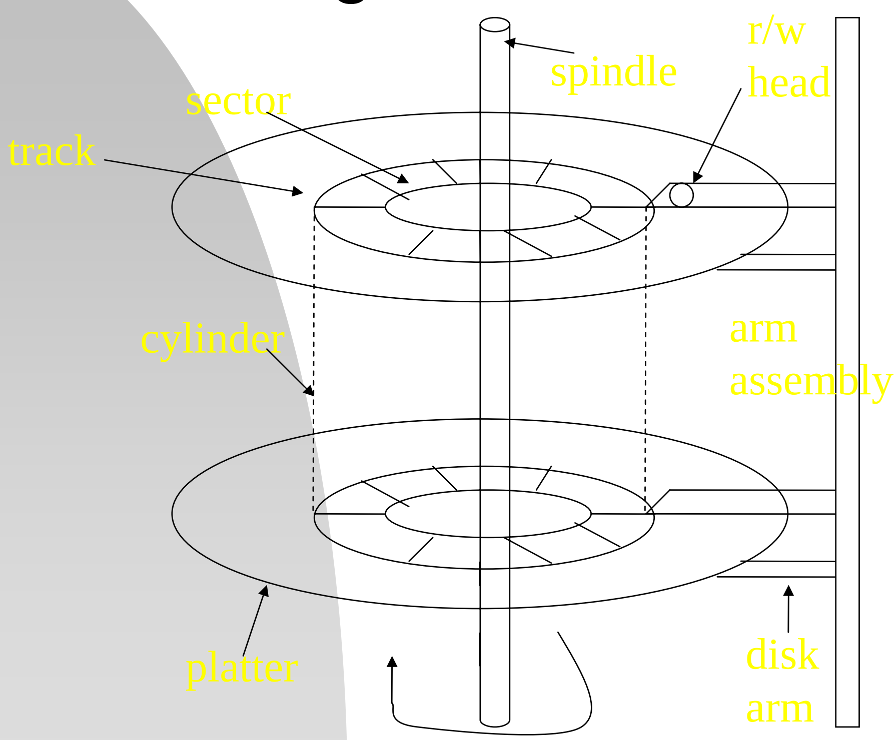
* Differences: Size, Cost, Speed, Volatility

Memory



- Processor can have direct access!
- Intermediate storage for data in the registers of device controllers
- Memory-Mapped I/O (PC & Mac)
  (1) Frequently used devices
  (2) Devices must be fast, such as video controller, or special I/O instructions is used to move data between memory & device controller registers
- Programmed I/O – polling
  - or interrupt-driven handling

Magnetic disks

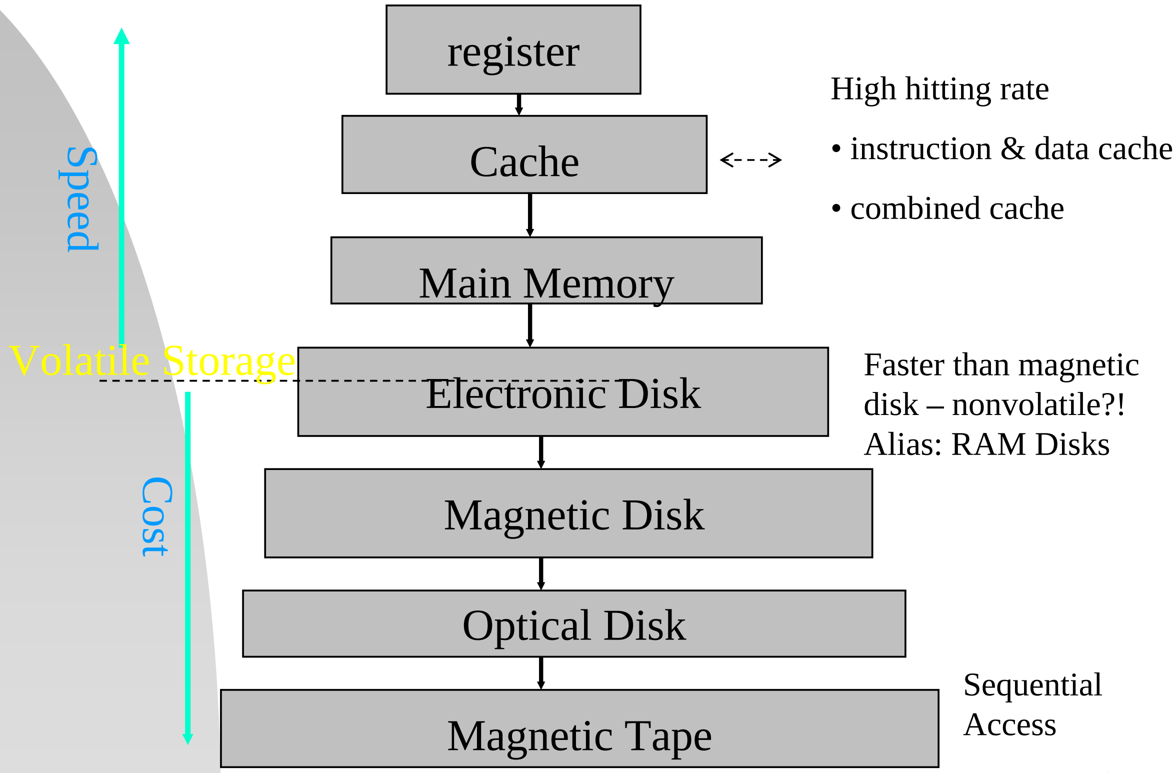


- Transfer Rate
- Random-Access Time
  - Seek time in *x* ms
  - Rotational latency in *y* ms
    - 60~200 times/sec

Magnetic Disks

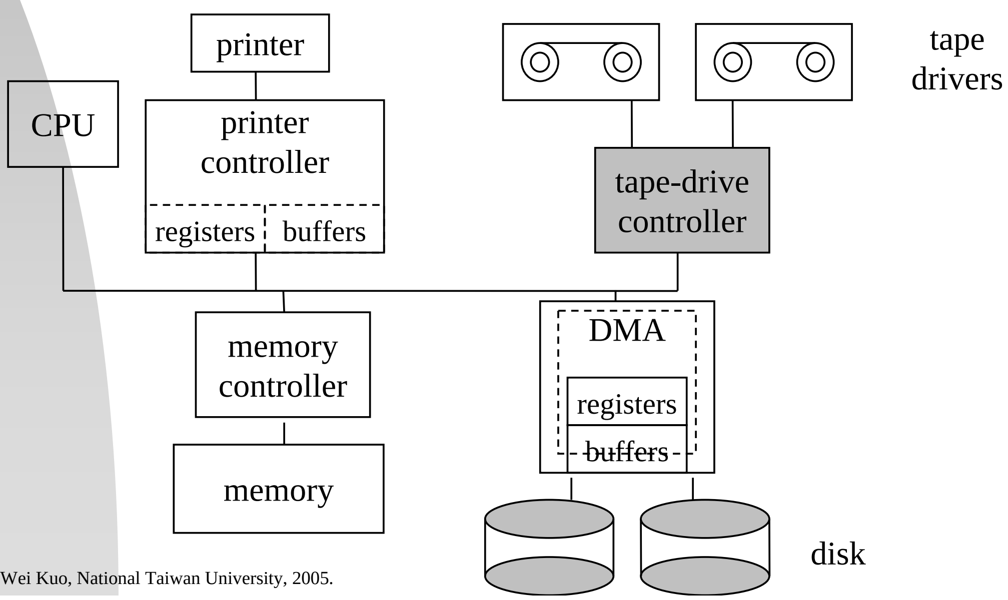
- Disks
  - Fixed-head disks:
    - More r/w heads v.s. fast track switching
  - Moving-head disks (hard disk)
  - Primary concerns:
    - Cost, Size, Speed
  - Computer → host controller → disk controller → disk drives (cache ←→ disks)
- Floppy disk
  - slow rotation, low capacity, low density, but less expensive
- Tapes: backup or data transfer bet machines

Storage Hierarchy



I/O Structure

- Device controllers are responsible of moving data between the peripheral devices and their local buffer storages.



I/O Structure

- I/O operation
  a. CPU sets up specific controller registers within the controller.
  b. Read: devices → controller buffers → memory

     Write: memory → controller buffers → devices
  c. Notify the completion of the operation by triggering an interrupt

DMA

- Goal: Release CPU from handling excessive interrupts!
  - E.g. 9600-baud terminal

    2-microsecond service / 1000 microseconds

    High-speed device:

    2-microsecond service / 4 microseconds
- Procedure
  - Execute the device driver to set up the registers of the DMA controller.
  - DMA moves blocks of data between the memory and its own buffers.
  - Transfer from its buffers to its devices.
  - Interrupt the CPU when the job is done.

Single-Processor Systems

- Characteristics: One Main CPU
  - Special-Purpose Processors, e.g., Disk-Controller Microprocessors.
- Examples:
  - Personal Computers (Since 1970's), Mainframes.
- Operating Systems
  - Batching → Multiprogramming → Time-Sharing

Parallel Systems

- Tightly coupled: have more than one processor in close communication sharing computer bus, clock, and sometimes memory and peripheral devices
- Loosely coupled: otherwise
- Advantages
  - Speedup – Throughput
  - Lower cost – Economy of Scale
  - More reliable – Graceful Degradation → Fail Soft (detection, diagnosis, correction)
    - A Tandem or HP-NonStop fault-tolerance solution

Parallel Systems

- Symmetric multiprocessing model: each processor runs an identical copy of the OS
- Asymmetric multiprocessing model: a master-slave relationship
  - ~ Dynamically allocate or pre-allocate tasks
  - ~ Commonly seen in extremely large systems
  - ~ Hardware and software make a difference?
- Trend: the dropping of microporcessor cost

  ➔ OS functions are offloaded to slave processors (back-ends)

Parallel Systems

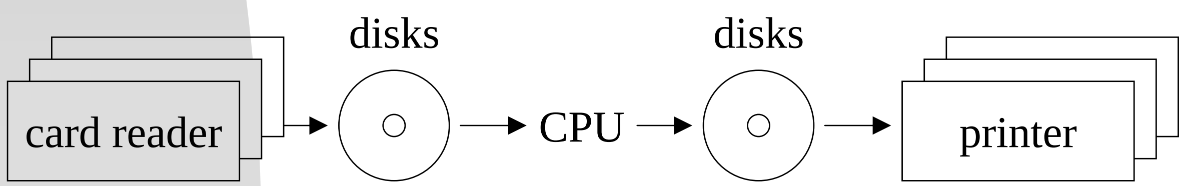
- The Recent Trend:
  - Hyperthreading Processors
  - Multiple Cores over a Single Chip
    - N Standard Processors!
- Loosely-Coupled Systems
  - Processors do not share memory or a clock
  - Blade Servers
    - Each blade-processor board boots independently and runs its own OS.

Clustered Systems

- Definition: Clustered computers which share storage and are closely linked via LAN networking.
- Advantages: high availability, performance improvement, etc.
- Types
  - Asymmetric/symmetric clustering
  - Parallel clustering – multiple hosts that access the same data on the shared storage.
- Distributed Lock Manager (DLM)
  - Oracle

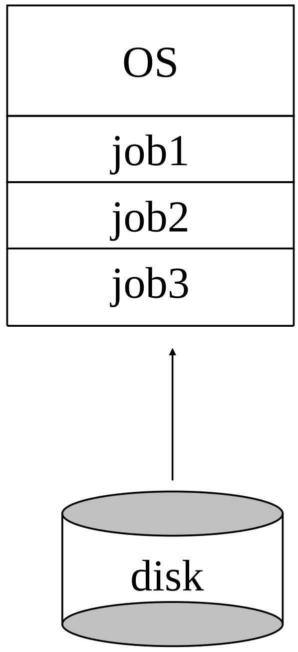
Operating-System Structure

- Simple batch systems
  - Resident monitor – Automatically transfer control from one job to the next
- Spooling (Simultaneous Peripheral Operation On-Line)
  - Replace sequential-access devices with random-access device



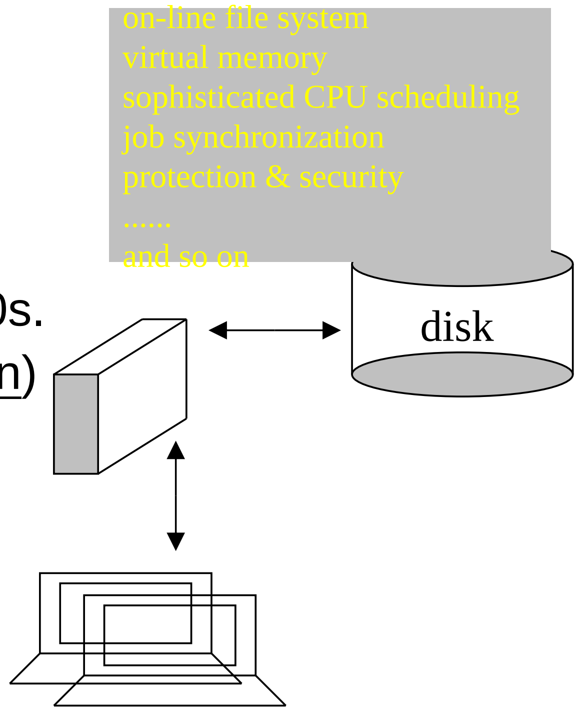
Operating-System Structure

- Multiprogramming increases CPU utilization by organizing jobs so that the CPU always has one to execute – Early 1960
  - Job scheduling and CPU scheduling
  - Goal : efficient use of scare resources



Operating-System Structure

- Time sharing (or multitasking) is a logical extension of multiprogramming!
  - Started in 1960s and become common in 1970s.
  - An interactive (or hand-on) computer system
  - Multics, IBM OS/360
- Virtual Memory
  - Physical Address



Operating-System Operations

- An Interrupt-Driven Architecture for Modern OS's
  - Events are almost always signaled by the occurrence of an interrupt or a trap (or an exception).
- Protection of User Programs and OS
  - Multiprogramming
  - Sharing of Hardware and Software

Hardware Protection

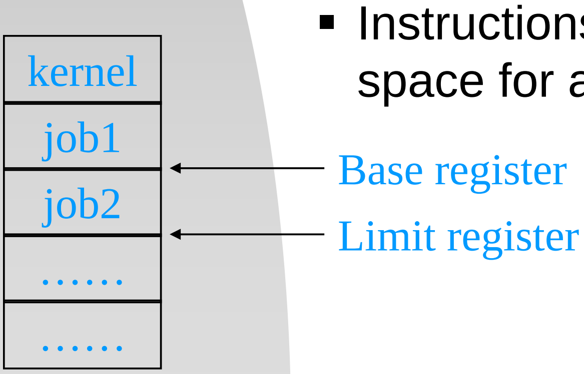
- Goal:
  - Prevent errors and misuse!
    - E.g., input errors of a program in a simple batch operating system
    - E.g., the modifications of data and code segments of another process or OS
- Dual-Mode Operations – a mode bit
  - User-mode executions except those after a trap or an interrupt occurs.
  - Monitor-mode (system mode, privileged mode, supervisor mode)
    - Privileged instruction:machine instructions that may cause harm

Hardware Protection

- System Calls – trap to OS for executing privileged instructions.
- Resources to protect
  - I/O devices, Memory, CPU
- I/O Protection (I/O devices are scare resources!)
  - I/O instructions are privileged.
    - User programs must issue I/O through OS
    - User programs can never gain control over the computer in the system mode.

Hardware Protection

- Memory Protection
  - Goal: Prevent a user program from modifying the code or data structures of either the OS or other users!
  - Instructions to modify the memory space for a process are privileged.



⇔ Check for every memory address by hardware

Hardware Protection

- CPU Protection
  - Goal
    - Prevent user programs from sucking up CPU power!
  - Use a timer to implement time-sharing or to compute the current time.
    - Instructions that modify timers are privileged.
  - Computer control is turned over to OS for every time-slice of time!
    - Terms: time-sharing, context switch

System Components – Process Management

- Process Management
  - Process: An Active Entity
    - Physical and Logical Resources
      - Memory, I/O buffers, data, etc.
    - Data Structures Representing Current Activities:

Program (code) +

Program Counter
Stack
Data Section
CPU Registers
….
And More

System Components – Process Management

- Services
  - Process creation and deletion
  - Process suspension and resumption
  - Process synchronization
  - Process communication
  - Deadlock handling

System Components – Main-Memory Management

- Memory: a large array of words or bytes, where each has its own address
- OS must keep several programs in memory to improve CPU utilization and user response time
- Management algorithms depend on the hardware support
- Services
  - Memory usage and availability
  - Decision of memory assignment
  - Memory allocation and deallocation

System Components – File-System Management

- Goal:
  - A uniform logical view of information storage
  - Each medium controlled by a device
    - Magnetic tapes, magnetic disks, optical disks, etc.
- OS provides a logical storage unit: File
  - Formats:
    - Free form or being formatted rigidly.
  - General Views:
    - A sequence of bits, bytes, lines, records

System Components – File-System Management

- Services
  - File creation and deletion
  - Directory creation and deletion
  - Primitives for file and directory manipulation
  - Mapping of files onto secondary storage
  - File Backup

* Privileges for file access control

System Components – Secondary-Storage Management

- Goal:
  - On-line storage medium for programs & data
    - Backup of main memory
- Services for Disk Management
  - Free-space management
  - Storage allocation, e.g., continuous allocation
  - Disk scheduling, e.g., FCFS

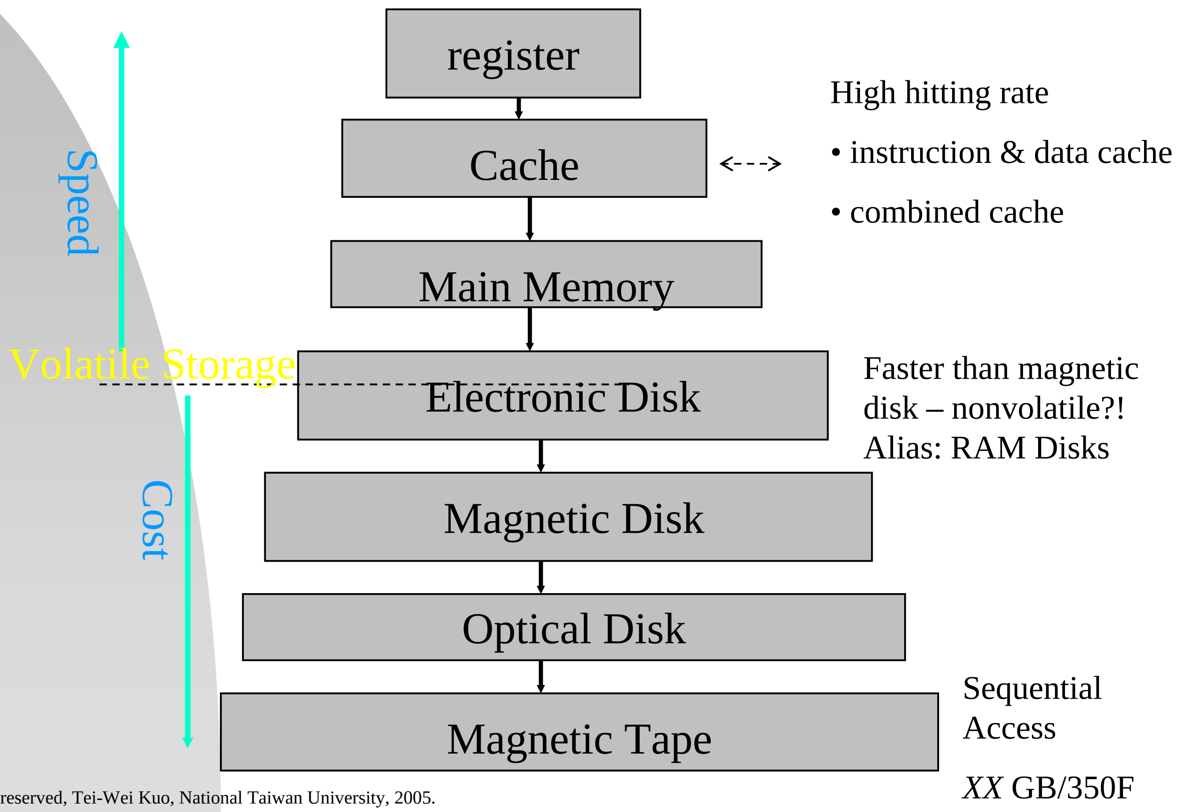
System Components –Tertiary Storage Devices

- Goals:
  - Backups of disk data, seldom-used data, and long-term archival storage
- Examples:
  - Magnetic tape drives and their tapes, CD & DVD drives and platters.
- Services – OS Supports or Applications' Duty
  - Device mounting and unmounting
  - Exclusive allocation and freeing
  - Data transfers from tertiary devices to secondary storage devices.

System Components – I/O System Management

- Goal:
  - Hide the peculiarities of specific hardware devices from users
- Components of an I/O System
  - A buffering, caching, and spooling system
  - A general device-driver interface
  - Drivers

Caching



Caching

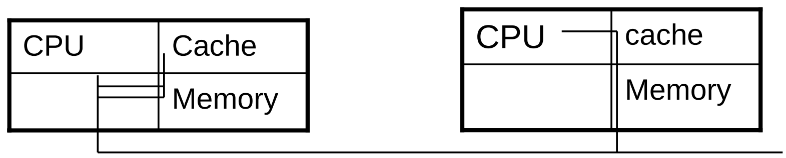
Level	1	2	3	4
Name	Registers	Cache	Memory	Disk
Typical Size	< 1KB	> 16MB	> 16GB	> 100GB
Implementation Strategy	Custom memory with multiple ports, CMOS	On-chip or off-chip CMOS SRAM	CMOS DRAM	Magnetic Disks
Access Time (ns)	0.25 – 0.5	0.5 – 2.5	80 – 250	5,000,000
Bandwidth (MB/s)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	Compiler	Hardware	OS	OS
Backup by	Cache	Memory	Disk	CD/Tape

Caching

- Caching
  - Information is copied to a faster storage system on a temporary basis
  - Assumption: Data will be used again soon.
    - Programmable registers, instr. cache, etc.
- Cache Management
  - Cache Size and the Replacement Policy
- Movement of Information Between Hierarchy
  - Hardware Design & Controlling Operating Systems

Caching

- Coherency and Consistency
  - Among several storage levels (vertical)
    - Multitasking vs unitasking
  - Among units of the same storage level , (horizontal), e.g. cache coherency
    - Multiprocessor or distributed systems



Protection and Security

- Goal
  - Resources are only allowed to be accessed by authorized processes.
- Definitions:
  - Protection – any mechanism for controlling the access of processes or users to the resources defined by the computer system.
  - Security – Defense of a system from external and internal attacks, e.g., viruses, denial of services, etc.

Protection and Security

- Protected Resources
  - Files, CPU, memory space, etc.
- Protection Services
  - Detection & controlling mechanisms
  - Specification mechanisms
- Distinguishing of Users
  - User names and ID's
  - Group names and GID's
  - Privilege Escalating, e.g., Setuid in Unix
    - To gain extra permissions for an activity.
- Remark: Reliability!

Distributed Systems

- Definition: Loosely-Coupled Systems – processors do not share memory or a clock
  - Heterogeneous vs Homogeneous
- Advantages or Reasons
  - Resource sharing: computation power, peripheral devices, specialized hardware
  - Computation speedup: distribute the computation among various sites – load sharing
  - Reliability: redundancy → reliability
  - Communication: X-window, email

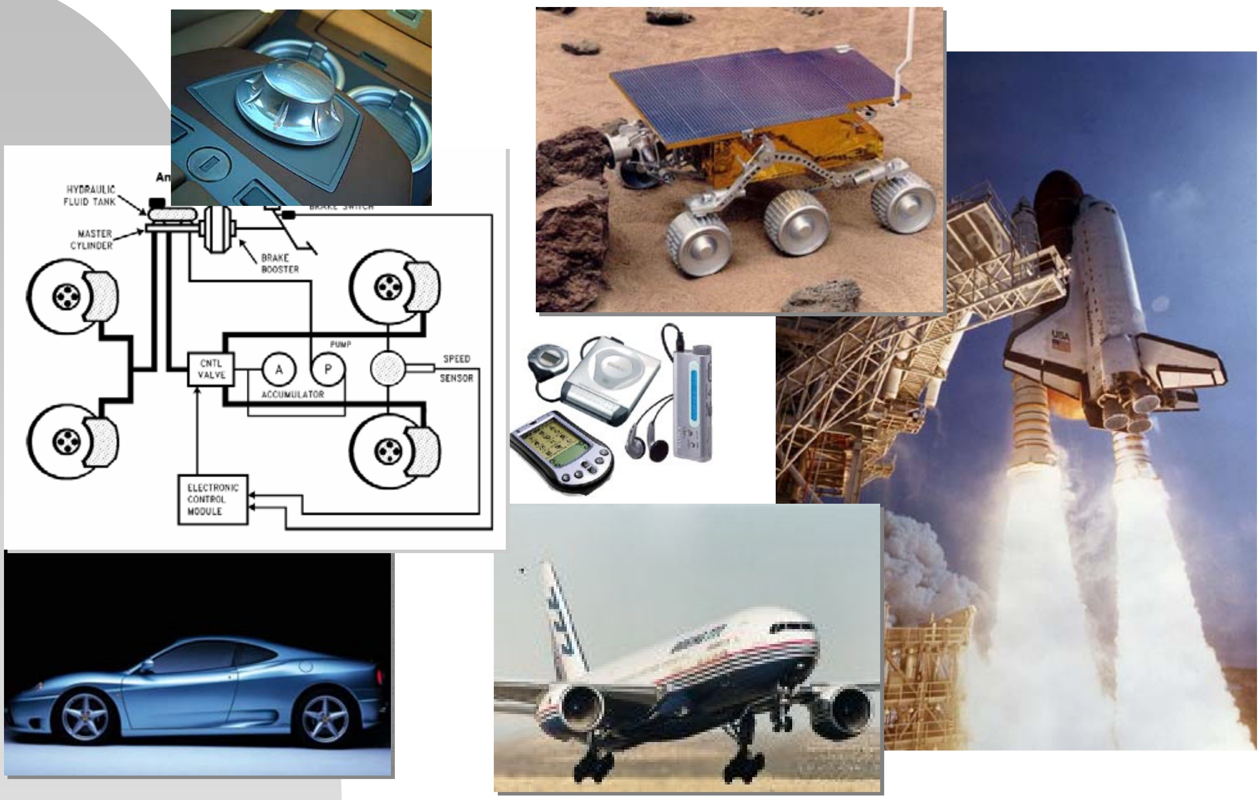
Distributed Systems

- Distributed systems depend on networking for their functionality.
  - Networks vary by the protocols used.
    - TCP/IP, ATM, etc.
  - Types – distance
    - Local-area network (LAN)
    - Wide-area network (WAN)
    - Metropolitan-area network (MAN)
    - Small-area network – distance of few feet
  - Media – copper wires, fiber strands, satellite wireless transmission, infrared communication,etc.

Real-Time Embedded Systems

- Embedded Computers – Most Prevalent Form of Computers
  - Have a wide variety ranged from car engines to VCR's.
    - General-purpose computers with standard OS's, HW devices with or without embedded OS's
    - Standalone units or members of networks and the Web
  - Tend to have specific tasks and almost always run real-time operating systems.

Real-Time Embedded Systems



Real-Time Embedded Systems

- Definition: A real-time system is a computer system where a timely response by the computer to external stimuli is vital!
- Hard real-time system: The system has failed if a timing constraint, e.g. deadline, is not met.
  - All delays in the system must be bounded.
  - Many advanced features are absent.

Real-Time Embedded Systems

- Soft real-time system: Missing a timing constraint is serious, but does not necessarily result in a failure unless it is excessive
  - A critical task has a higher priority.
  - Supported in most commercial OS.
- Real-time means on-time instead of fast

Multimedia Systems

- Multimedia Data
  - Audio and video files and conventional files
  - Multimedia data must be delivered according to certain time restrictions (e.g., 30 frames per second)
- Variety on Platforms
  - Desktop personal computers, Personal Digital Assistant (PDA), cellular telephones, etc.

Handheld Systems

- Handheld Systems
  - E.g., Personal Digital Assistant (PDA) and cellular phones.
- New Challenges – convenience vs portability
  - Limited Size and Weight
  - Small Memory Size (e.g., 512KB ~ 128MB)
    - No Virtual Memory
  - Slow Processor
    - Battery Power
  - Small display screen
    - Web-clipping

Computing Environments

- Evolving Environments
  - Transition from the period of scarce resources to the period of ubiquitous access!
  - In the past, portability is achieved by laptops!
    - Remote access is supported in a limited way. Mainframes are prevalent!
  - Now, PC's, PDA, and various equipments are connected!
    - High speed networks are available at home and office! Web-computing is popular (e.g.,portals).

Computing Environments

- Client-Server Systems
  - Trend: The functionality of clients is improved in the past decades.
  - Categories:
    - Compute-server systems
    - File-server systems
- Network Operating Systems
  - Autonomous computers
  - A distributed operating system – a single OS controlling the network.

Computing Environments

- Peer-to-Peer Systems
  - Characteristics: Client and server roles depend on whether who is requesting or providing a service.
  - Network connectivity is an essential component.
  - Service Availability and Discovery
    - Registration of services: a centralized lookup service or not
    - A discovery protocol
  - Issues:
    - Legal problems in exchanging files.

Computing Environments

- Web-Based Computing
  - Web Technology
    - Portals, network computers, etc.
  - Network connectivity
  - New categories of devices
    - Load balancers
- Embedded Computing
  - Car engines, robots, VCR’s, home automation
  - Embedded OS’s often have limited features.