Operating Systems

Lecture Course in Autumn Term 2015
University of Birmingham

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Course Details

- Lecture notes and resources:
  `http://www.cs.bham.ac.uk/exr/teaching/lectures/opsys/15_16`
- use canvas for discussions
- Recommended Course Books
  - OS Concepts (8th Edition) Silberchatz *et al.*
  - Linux Kernel Development. Robert Love.
  - The C Programming Language (2nd Edition) Kernighan and Ritchie

Course Details

- Assessment:
  - 80% exam, 20% coursework
  - Description of coursework and assessment criteria will be made available on the website.
  - There will be 4 pieces of challenging coursework over the term that will put you through your paces, ultimately to give you a firm grasp on the subject.
  - Students on the extended module (check your registration status with the school office if you are unsure of this) will be given an additional piece of coursework.
  - Make use of the labs (two hours per week) to work on the coursework problems.

Prerequisites for this module

Good C programming skills are essential prerequisite for this module
Familiarity with pointers and explicit memory management expected
See `http://www.cs.bham.ac.uk/~exr/teaching/lectures/opsys/13_14/exercises/ex1.pdf` for the level of C programming skills expected.

What is an Operating System?

- A program that acts as an intermediary between a user of a computer and the computer hardware
- Operating system goals:
  - Execute user programs and make solving user problems easier
  - Make the computer system convenient to use
  - Use the computer hardware in an efficient manner

Two Popular Definitions of an OS

OS as a resource allocator: Manages all resources and decides between conflicting requests for efficient and fair resource use (*e.g.* accessing disk or other devices)

OS as a control system: Controls execution of programs to prevent errors and improper use of the computer (*e.g.* protects one user process from crashing another)

Computer System Structure

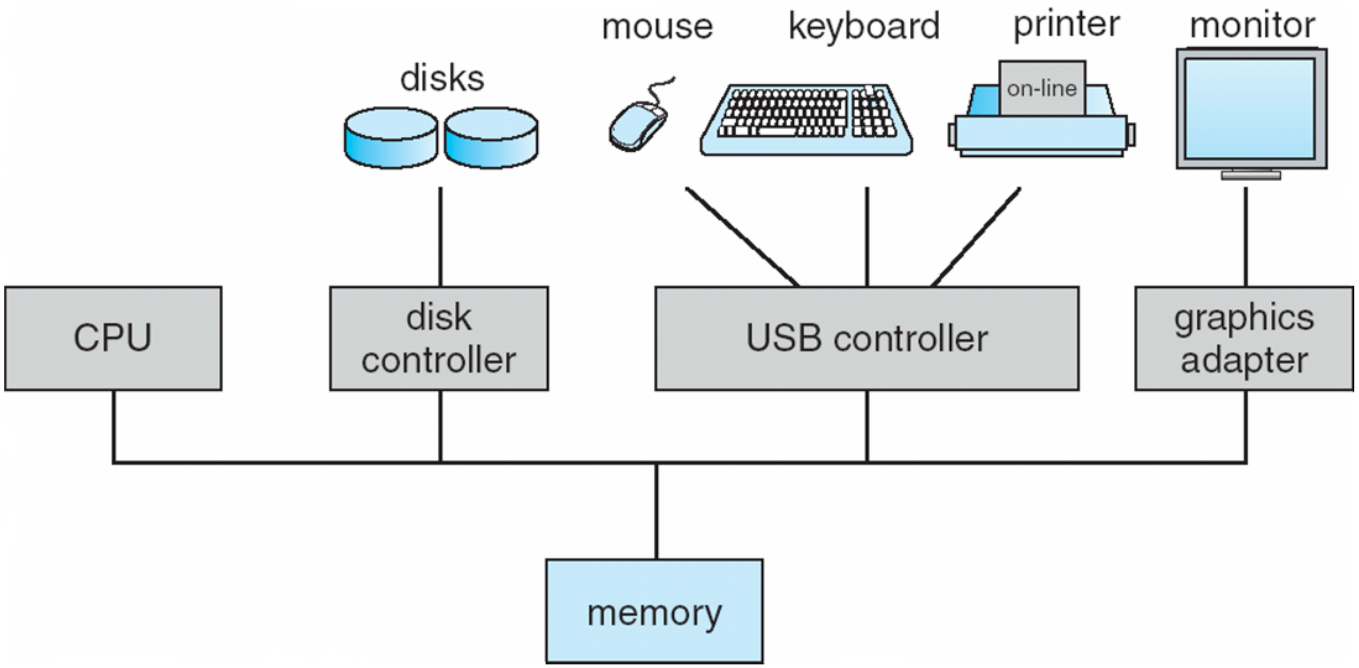
Computer system can be divided into four components:

- Hardware: provides basic computing resources CPU, memory, I/O devices
- Operating system: Controls and coordinates use of hardware among various applications and users
- Application programs: define the ways in which the system resources are used to solve the computing problems of the users Word processors, compilers, web browsers, database systems, video games
- Users: People, machines, other computers

Bootstrapping of the OS

- Small bootstrap program is loaded at power-up or reboot
  - Typically stored in ROM or EPROM, generally known as firmware (*e.g.* BIOS)
- Initializes all aspects of the system (*e.g.* detects connected devices, checks memory for errors, *etc.*)
- Loads operating system kernel and starts its execution

Computer System Organisation



- One or more CPUs, device controllers connect through common bus providing access to shared memory
- CPU(s) and devices compete for memory cycles (*i.e.* to read and write memory addresses)

Computer System Operation

- I/O devices and the CPU can execute concurrently
- Each device controller (*e.g.* controller chip) is in charge of a particular device type
- Each device controller has a local buffer (*i.e.* memory store for general data and/or control registers)
- CPU moves data from/to main memory to/from controller buffers (*e.g.* write this data to the screen, read coordinates from the mouse, *etc.*)
- I/O is from the device to local buffer of controller
- Device controller informs CPU that it has finished its operation by causing an *interrupt*

Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the interrupt vector, which contains the addresses of all the service routines
- Interrupt architecture must save the address of the interrupted instruction so original processing may be resumed
- Incoming interrupts are disabled while another interrupt is being processed to prevent a lost interrupt
- A trap is a software-generated interrupt caused either by an error or a user request

Storage Structure

- Main memory - only large storage media that the CPU can access directly
- Secondary storage - extension of main memory that provides large non-volatile storage capacity
- Magnetic disks - rigid metal or glass platters covered with magnetic recording material
  - Disk surface is logically divided into tracks, which are subdivided into sectors
  - The disk controller determines the logical interaction between the device and the computer

Caching

- Important optimisation principle, performed at many levels in a computer (in hardware, operating system, software)
- Information in use copied from slower to faster storage temporarily
- Faster storage (cache) checked first to determine if information is there
  - If it is, information used directly from the cache (fast)
  - If not, data copied to cache and used there
- Cache often smaller than storage being cached
- Cache management is an important design problem
  - Determining cache size and replacement policy

Multiprocessors

- Most systems use a single general-purpose processor
- Multiprocessor systems growing in use and importance
  - Also known as parallel systems, tightly-coupled systems
- Advantages include
  - Increased throughput
  - Economy of scale
  - Increased reliability - graceful degradation or fault tolerance
- Two architectures
  - Asymmetric Multiprocessing - CPUs have different roles, usually one is the master of the others
  - Symmetric Multiprocessing - CPUs have identical roles, sharing process queues to service *ready* processes.

Fault Handling and Protection

- Software error or request creates exception or trap, which are essentially handled as special interrupts
  - Division by zero, request for operating system service
- Other process problems include infinite loop, processes modifying each others' or the operating system's code
- Dual-mode operation allows OS to protect itself and other system components
  - User mode and kernel mode
  - Mode bit provided by hardware
    - Provides ability to distinguish when system is running user code or kernel code
    - Some instructions designated as privileged, only executable in kernel mode
    - System call changes mode to kernel, return from call resets it to user
    - Otherwise, a user process could manipulate hardware directly, leading to chaos.

Process Management

- A process is a program in execution. It is a unit of work within the system. Program is a passive entity (*e.g.* the stored code), process is an active entity.
- Process needs resources to accomplish its task
  - CPU, memory, I/O, files, initialization data
- Process termination requires reclamation of any reusable resources
- Single-threaded process has one program counter, specifying location of next instruction to execute
  - Process executes instructions sequentially, one at a time, until completion
- Multi-threaded process has one program counter per thread
- Concurrency of systems achieved by multiplexing the CPUs among the processes/threads

Process Management Activities

The operating system is responsible for the following activities in connection with process management:

- Creating and deleting both user and system processes
- Suspending and resuming processes
- Providing mechanisms for process synchronization
- Providing mechanisms for process communication
- Providing mechanisms for deadlock handling

Memory Management

- All data must be in memory before and after processing
- All instructions must be in memory in order to be executed
- Memory management determines what is in memory and when
  - Optimizing CPU utilization and computer response to users (*e.g.* avoiding excessive swapping of data between disk and memory)
- Memory management activities
  - Keeping track of which parts of memory are currently being used and by whom
  - Deciding which processes (or parts thereof) and data to move into and out of memory (*e.g.* to and from the disk - virtual memory)
  - Allocating and deallocating memory space as needed

Storage Management

- OS provides uniform, logical view of information storage
  - Abstracts physical properties to logical storage units: file and directories
- Each medium is controlled by device (*e.g.* disk drive, tape drive)
  - Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)
- File-System management
  - Access control on most systems to determine who can access what
  - OS activities include
    - Creating and deleting files and directories
    - Primitives (*i.e.* standardised functions) to manipulate files and directories
    - Mapping files within memory onto secondary storage

I/O Subsystems

- One purpose of OS is to hide peculiarities of hardware devices from the user
- I/O subsystem responsible for:
  - Memory management of I/O, including buffering (storing data temporarily while it is being transferred), caching (storing parts of data in faster storage for performance), spooling (the overlapping of output of one job with input of other jobs)
  - Abstract device-driver interface, so driver developers know how to interface their code with the OS (*e.g.* network cards, storage devices for different hardware use common interfaces).
  - Drivers for specific hardware devices

Protection and Security

- **Protection** - any mechanism for controlling access of processes or users to resources defined by the OS
- **Security** - defense of the system against internal and external attacks
  - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- Systems generally first distinguish among users, to determine who can do what
  - User identities (user IDs, security IDs) include name and associated number, one per user
  - User ID then associated with all files, processes of that user to determine access control
  - Group identifier (group ID) allows set of users to be defined and controls managed, then also associated with each process, file
  - Privilege escalation allows user to change to effective ID with more rights