Operating Systems Overview

Operating System

- A program that controls the execution of application programs
- An interface between applications and hardware
- A set of programs that provides basic functionalities

Operating System Objectives

- Convenience
  - Makes the computer more convenient to use
- Efficiency
  - Allows computer system resources to be used in an efficient manner
- Ability to evolve
  - Permit effective development, testing, and introduction of new system functions without interfering with service

Layers of Computer System

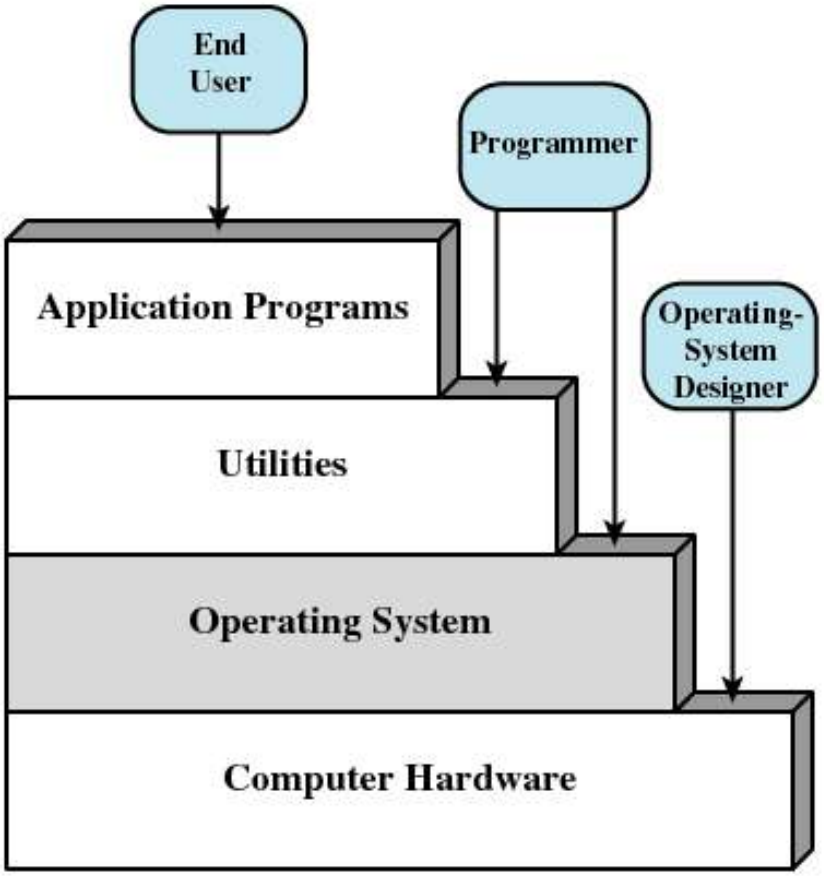
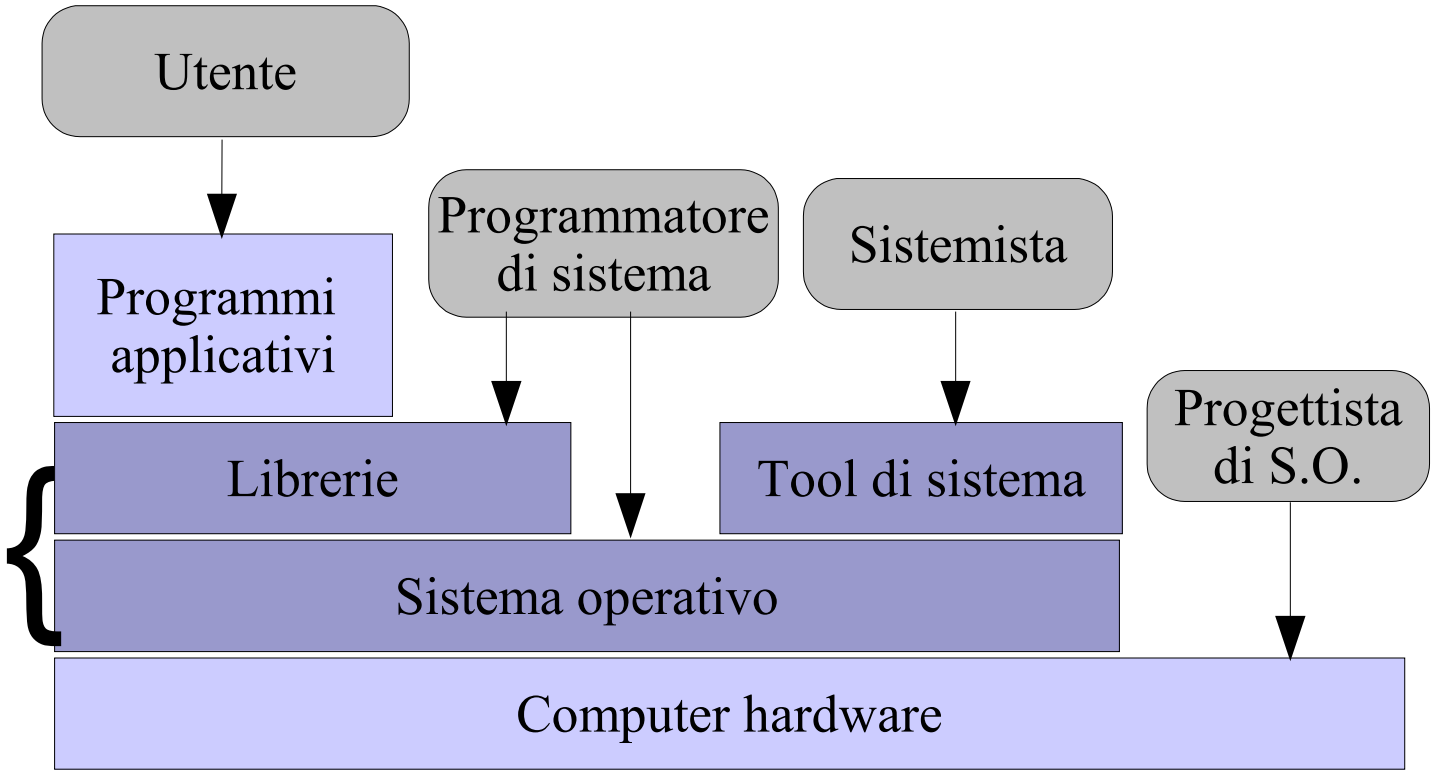


Figure 2.1 Layers and Views of a Computer System

Layers of Computer System



Services Provided by the Operating System

- Program execution
- Access to I/O devices
- Controlled access to files
- System access
- Support for program development

Services Provided by the Operating System

- Error detection and response
  - Internal and external hardware errors
    - Memory error
    - Device failure
  - Software errors
    - Arithmetic overflow
    - Access forbidden memory locations
  - Operating system cannot grant request of application

Services Provided by the Operating System

- Accounting
  - Collect usage statistics
  - Monitor performance
  - Used to anticipate future enhancements
  - Used for billing purposes

Operating System as a Resource Manager

- It manages
  - cpu time
    - even if it is executed by the same CPU!
  - I/O devices
  - memory
  - etc.

Operating System as Resource Manager

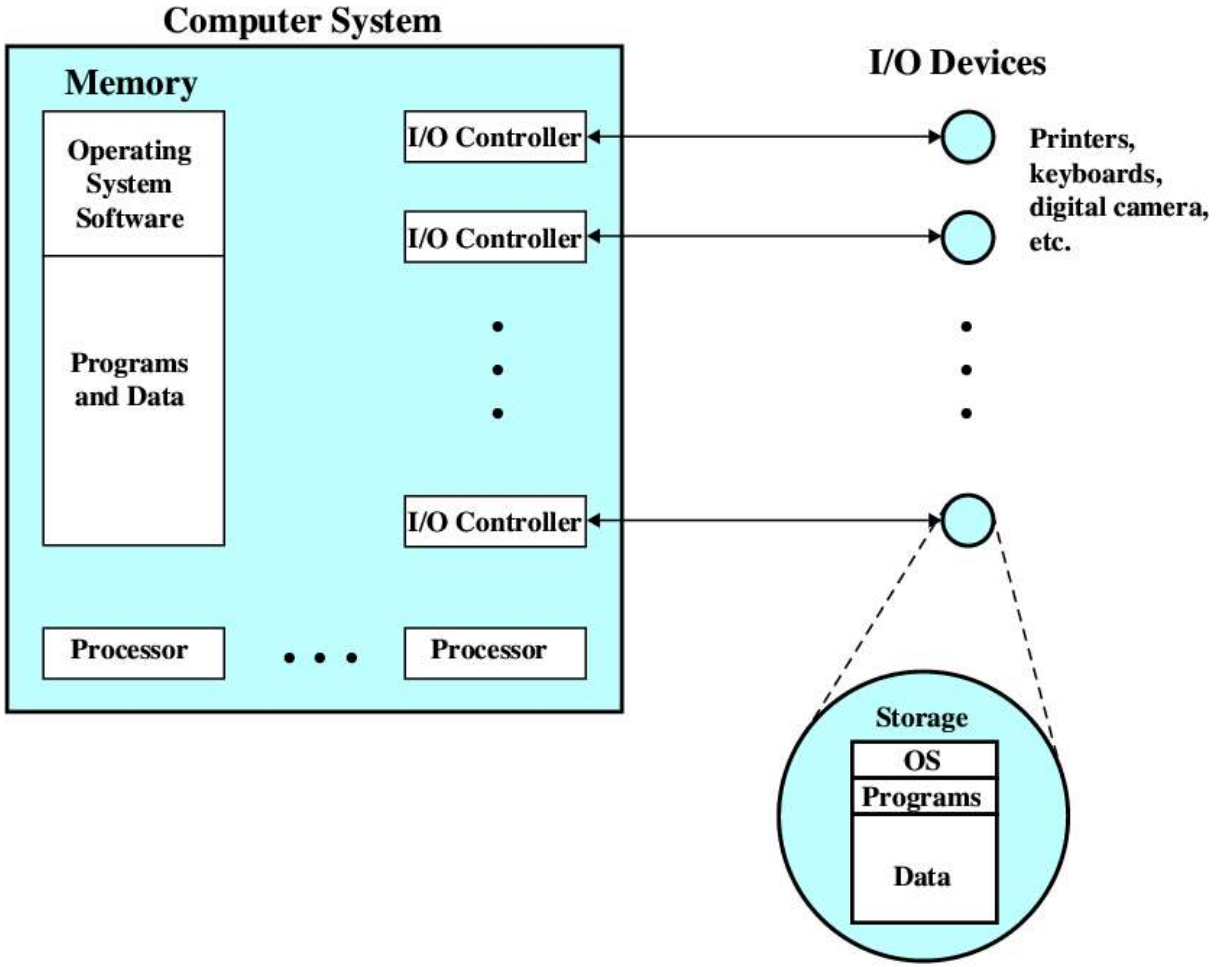


Figure 2.2 The Operating System as Resource Manager

Kernel

- Portion of operating system that is in main memory
- Contains most frequently used functions
- Also called “nucleus”

User/Kernel mode

- User program executes in **user mode**
  - Certain *privileged* instructions may not be executed
  - only a ristricted part of main memory can be accessed (user space)
- Kernel executes in **system mode**
  - a.k.a. **kernel mode** or **supervisor mode**
  - Privileged instructions can be executed
  - Protected areas of memory may be accessed (kernel space)

I/O Devices are Slow

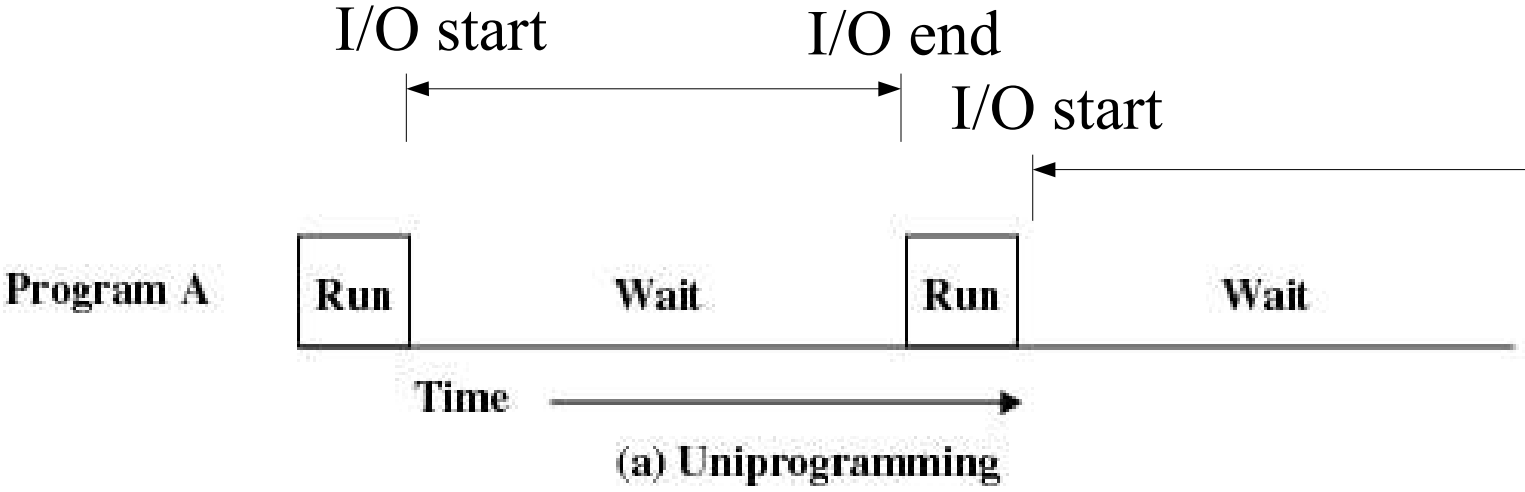
Read one record from file	15 µs
Execute 100 instructions	1 µs
Write one record to file	15 µs
TOTAL	31 µs

$$\text{Percent CPU Utilization} = \frac{1}{31} = 0.032 = 3.2\%$$

Figure 2.4 System Utilization Example

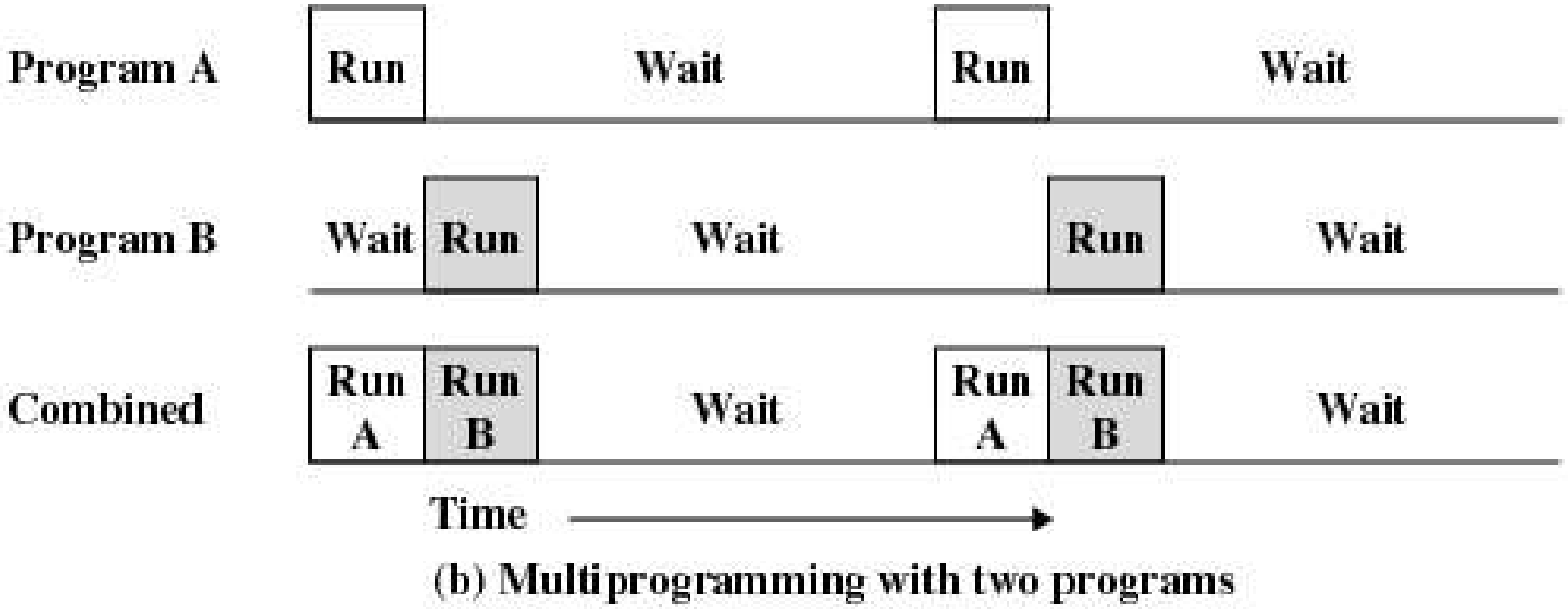
Uniprogramming

- Processor must wait for I/O instruction to complete before preceding



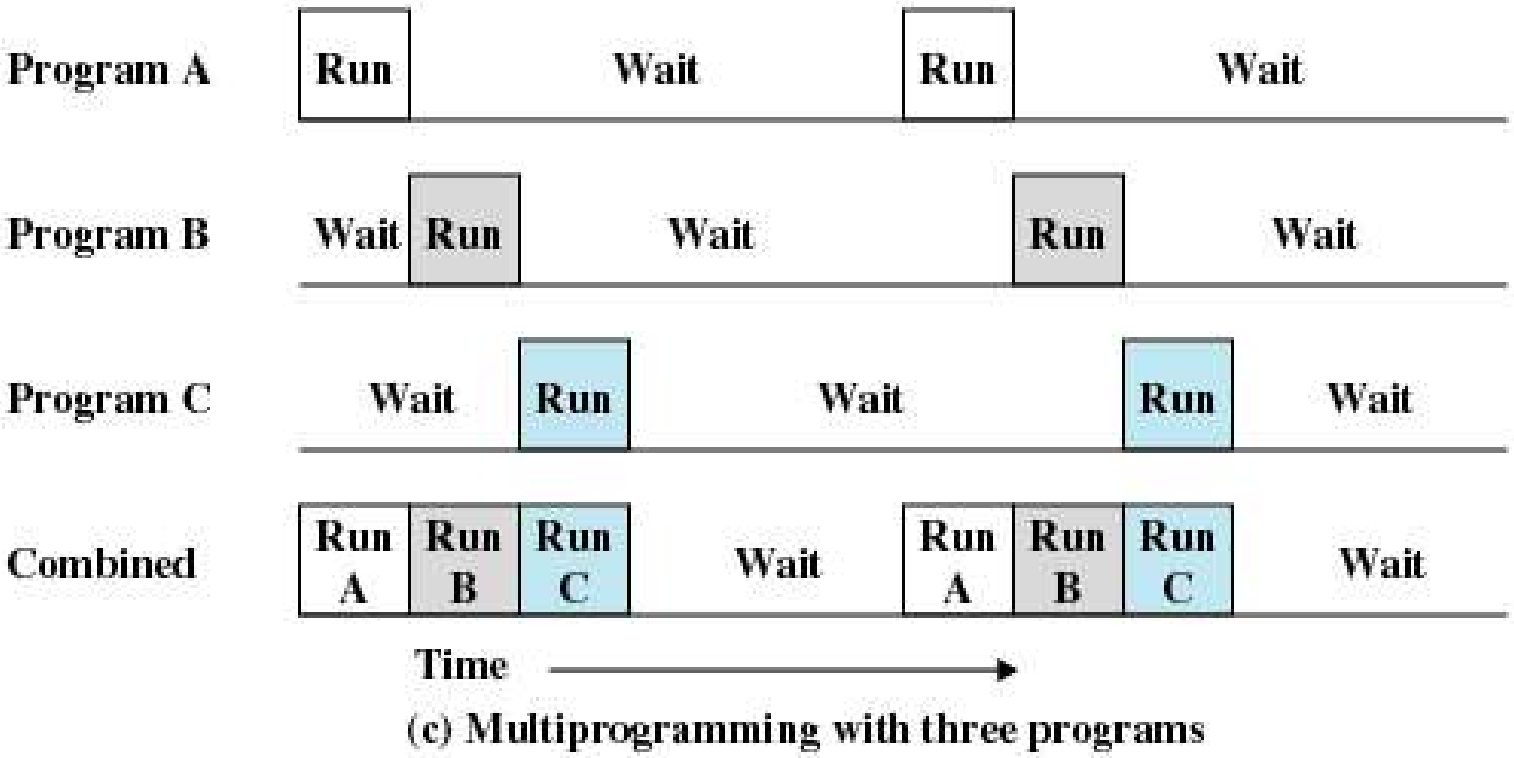
Multiprogramming

- When one job needs to wait for I/O, the processor can switch to the other job



(b) Multiprogramming with two programs

Multiprogramming

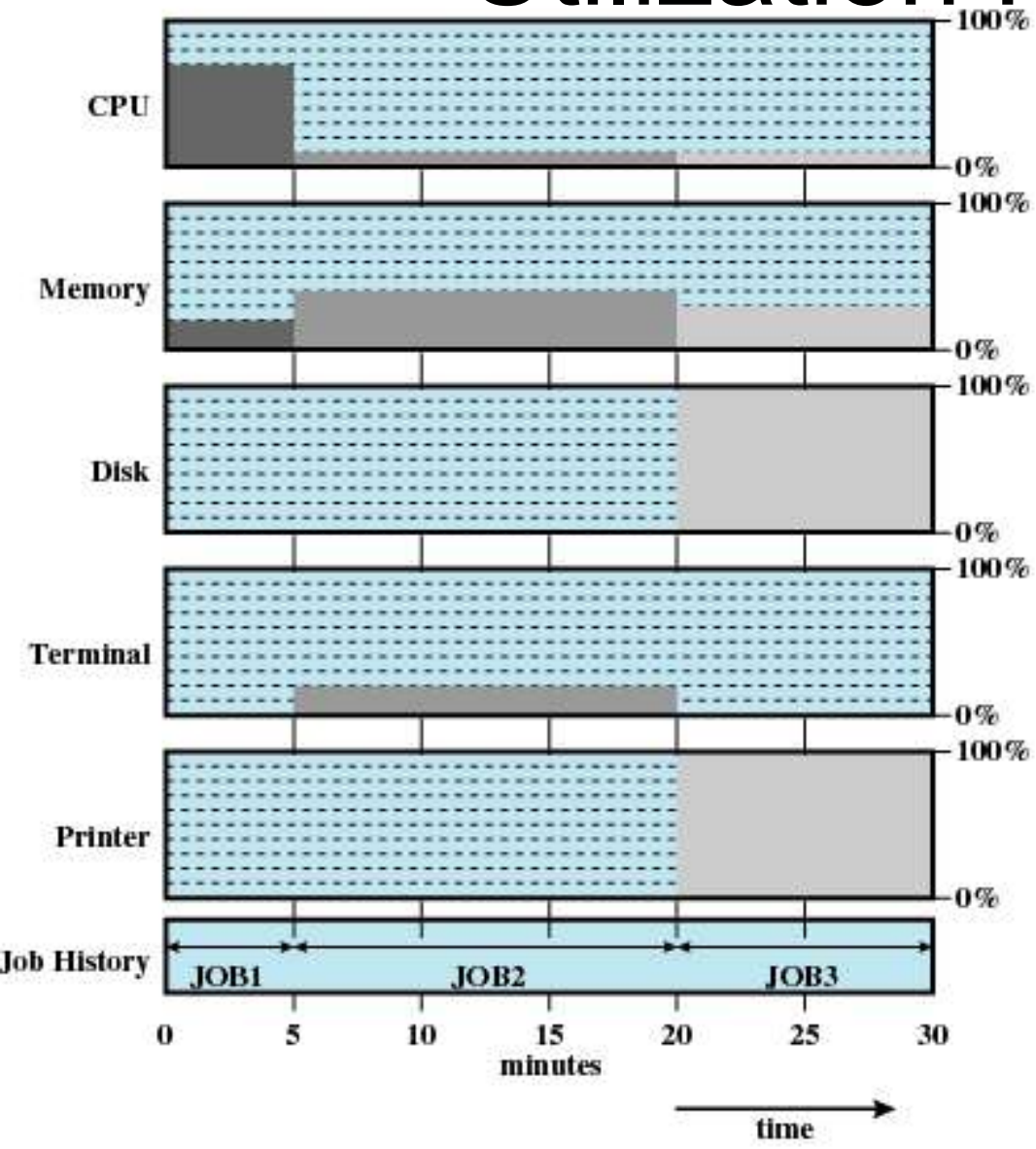


(c) Multiprogramming with three programs

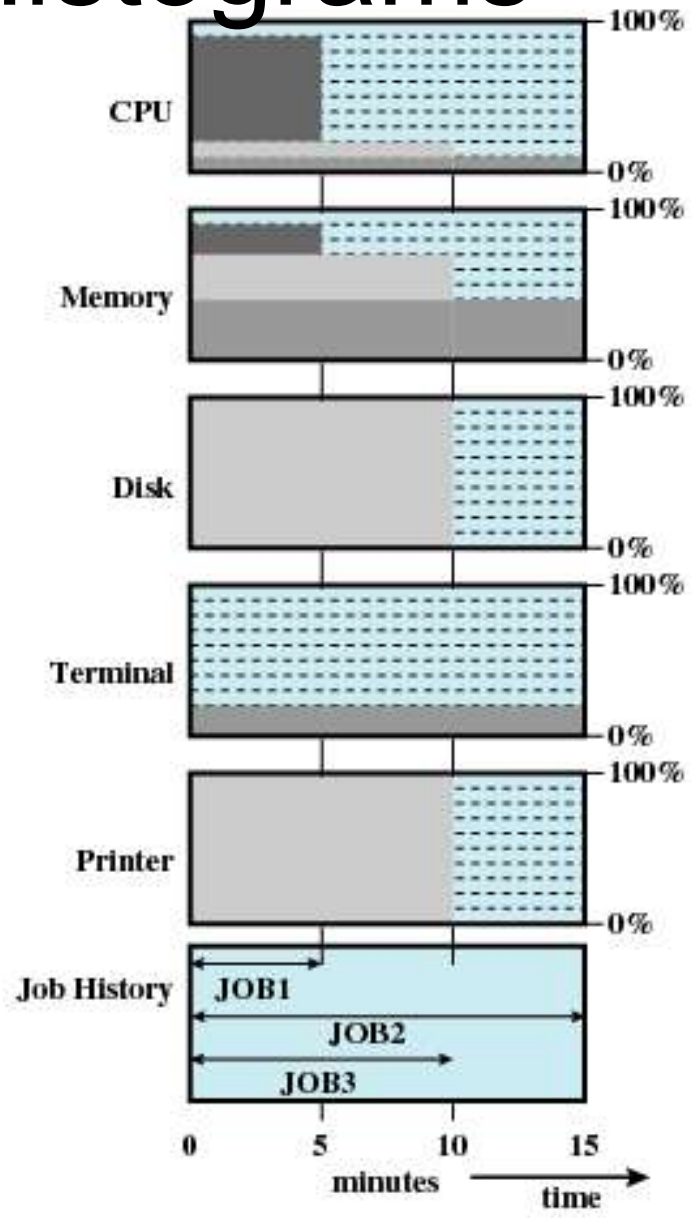
Example (multiple batch jobs)

	JOB1	JOB2	JOB3
Type of job	Heavy compute	Heavy I/O	Heavy I/O
Duration	5 min	15 min	10 min
Memory required	50 M	100 M	75 M
Need disk?	No	No	Yes
Need terminal?	No	Yes	No
Need printer?	No	No	Yes
	CPU bound	I/O bound	I/O bound

Utilization Histograms



(a) Uniprogramming



(b) Multiprogramming

Time Sharing

- Using multiprogramming to handle **multiple interactive jobs**
- Processor's time is shared among multiple users
- Multiple users simultaneously access the system through terminals

Major Achievements of Modern OSes

- Processes
- Memory Management
- Information protection and security
- Scheduling and resource management
- System structure

Processes

- A program in execution (running) on a computer
- The entity that can be assigned to and executed on a processor
- A unit of activity characterized by
  - at least one sequential thread
  - an associated set of system resources
  - a current state of CPU

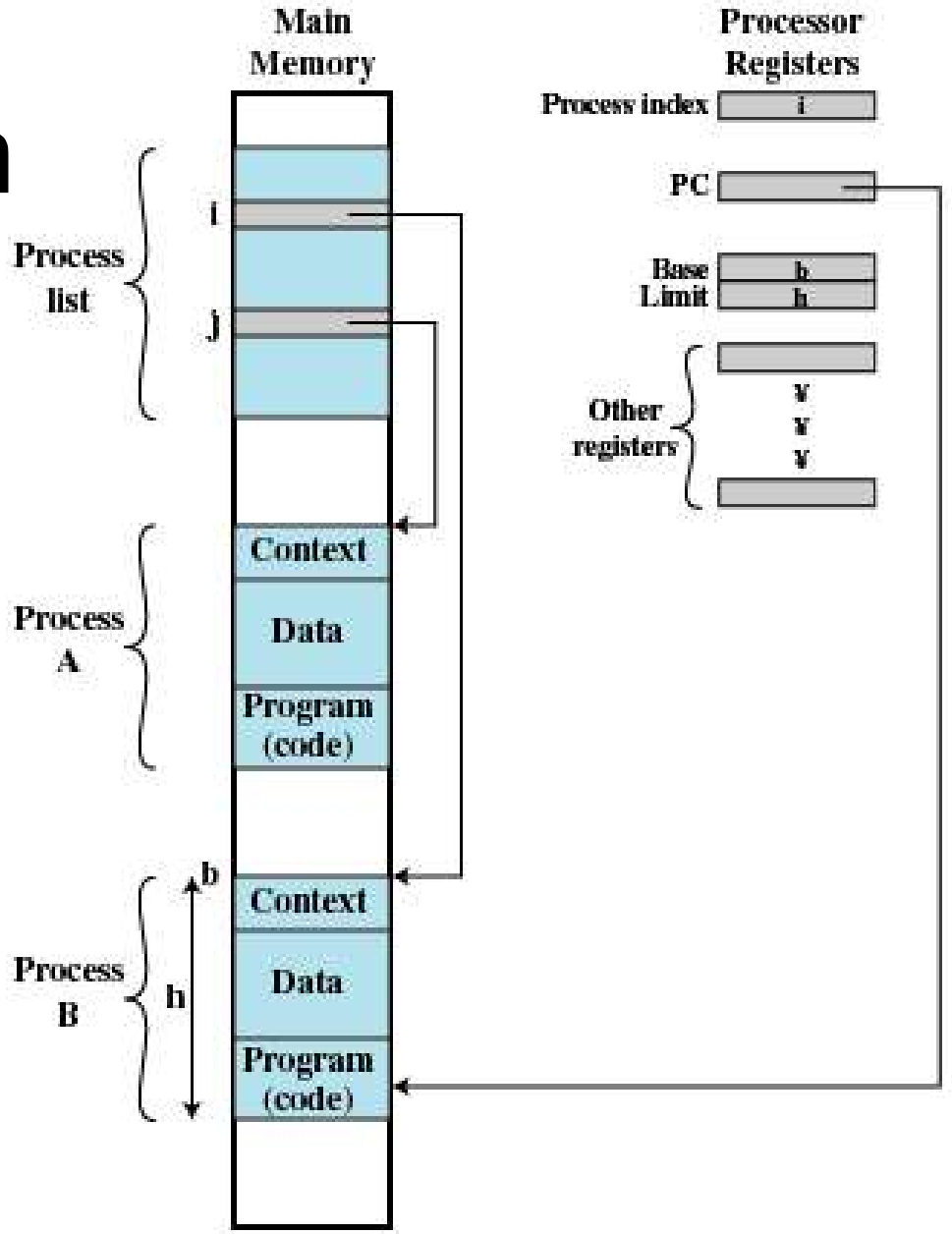
Process

- A process may be described by...
  - An executable program
  - Associated data needed by the program
  - Execution context of the program
    - a.k.a. process state
    - includes
      - all information the operating system needs to manage the process
      - all informatin the cpu needs to execute the process

execution context

- cpu registers
- priority of the process
- is the process waiting for I/O? on which device?
- etc.
- etc.
- etc.
- etc.
- ...

Processes Representation



Memory Management

- Process isolation
- Automatic allocation and management
- Support of modular programming
- Protection and access control
- Long-term storage

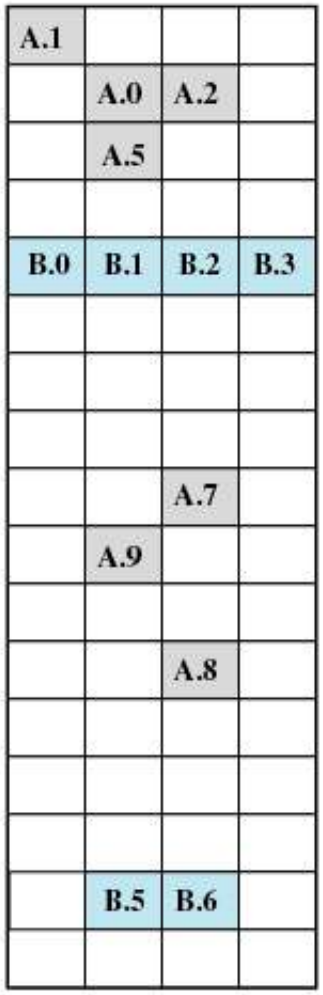
Virtual Memory

- Allows programmers to address memory from a logical point of view
- Virtual memory is much larger than Real Memory
  - processes see a large virtual address space
- Real Memory is used only for processes that are in execution

Paging

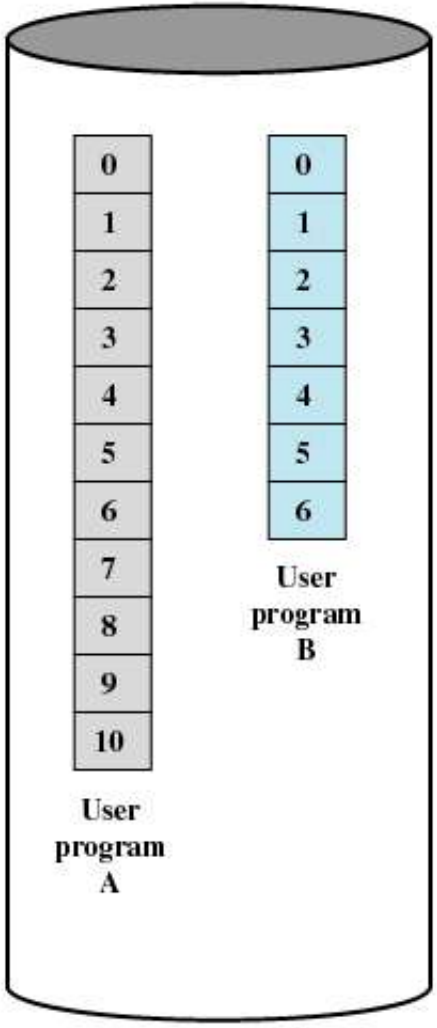
- Allows process to be comprised of a number of fixed-size blocks, called pages
- Virtual address is a page number and an offset within the page
- Each page may be located any where in main memory
- Real address or physical address in main memory are managed only by the kernel

Virtual Memory and Main Memory



Main Memory

Main memory consists of a number of fixed-length frames, each equal to the size of a page. For a program to execute, some or all of its pages must be in main memory.

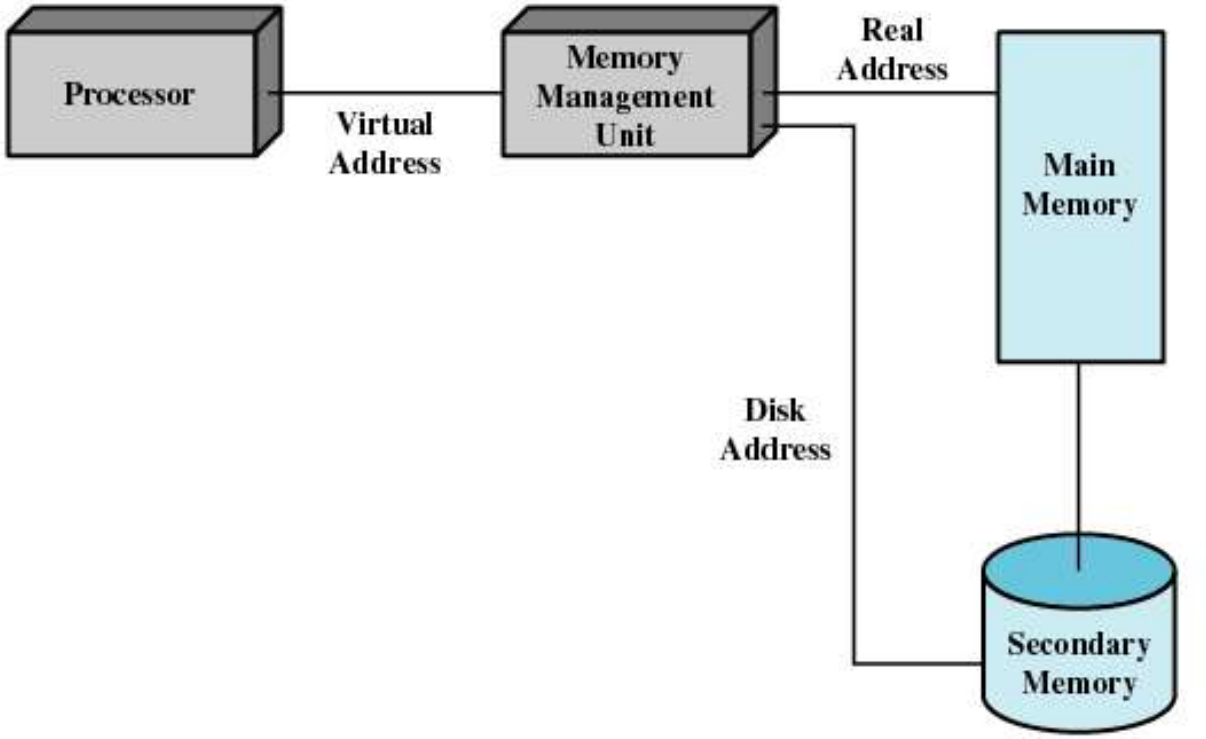


Disk

Secondary memory (disk) can hold many fixed-length pages. A user program consists of some number of pages. Pages for all programs plus the operating system are on disk, as are files.

Virtual Memory Addressing

- Virtual is managed by
  - a Memory Management Unit
  - ...and the kernel



Information Protection and Security

- Availability
  - Concerned with protecting the system against interruption
- Confidentiality
  - Assuring that users cannot read data for which access is unauthorized

Information Protection and Security

- Data integrity
  - Protection of data from unauthorized modification
- Authenticity
  - Concerned with the proper verification of the identity of users and the validity of messages or data

Scheduling and Resource Management

- Fairness
  - Give equal and fair access to resources
- Differential responsiveness
  - Discriminate among different classes of jobs
- Efficiency
  - Maximize throughput, minimize response time, and accommodate as many uses as possible

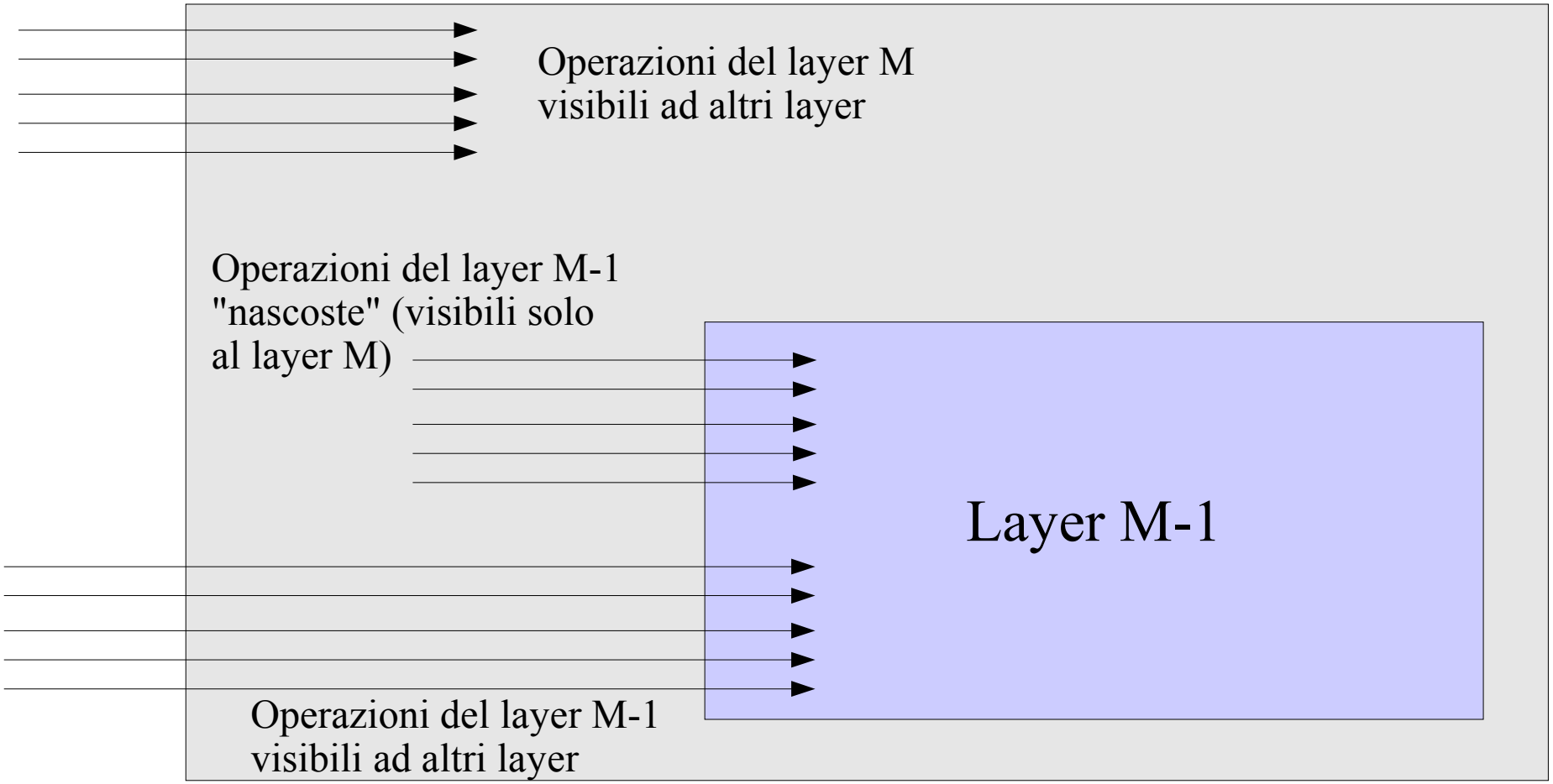
Scheduling Elements

- queues
  - at least one for each resource
- CPU
  - short term
    - contains processes in main memory and ready to run
    - short term scheduler / dispatcher
      - simple approach: round robin (circular queue)
  - long term
    - new jobs waiting for the processor
    - long term scheduler
- I/O
  - at least queue for each device
  - interrupts

System Structure

- View the system as a series of levels
- Each level performs a related subset of functions
- Each level relies on the next lower level to perform more primitive functions
- This decomposes a problem into a number of more manageable subproblems

Layered Systems



System Structure
Hardware Levels

- Level 1
  - Electronic circuits
  - Objects are registers, memory cells, and logic gates
  - Operations are clearing a register or reading a memory location
- Level 2
  - Processor's instruction set
  - Operations such as add, subtract, load, and store

System Structure
Hardware Levels

- Level 3
  - Adds the concept of a procedure or subroutine, plus call/return operations
- Level 4
  - Interrupts

System Structure
Basic Multiprogramming and Memory Management

- Level 5
  - Process management from the point of view of CPU (no I/O support)
  - Suspend and resume processes
- Level 6
  - Secondary storage devices
  - Transfer of blocks of data
- Level 7
  - Creates logical address space for processes
  - Organizes virtual address space into blocks

System Structure

Process comunication, I/O, and Inter Process Comunication

- Level 8
  - Communication of information and messages between processes
- Level 9
  - Supports long-term storage of named files
- Level 10
  - Provides access to external devices using standardized interfaces

System Structure

Process comunication, I/O, and Inter Process Comunication

- Level 11
  - Responsible for maintaining the association between the external and internal identifiers
- Level 12
  - Provides full-featured facility for the support of processes

System Structure
User Interface

- Level 13
  - Provides an interface to the operating system for the user (shell)

Modern Operating Systems

- Microkernel architecture
  - Assigns only a few essential functions to the kernel
    - Address spaces
    - Interprocess communication (IPC)
    - Basic scheduling

Modern Operating Systems

- Multithreading
  - Process is divided into threads that can run concurrently
    - Thread
      - Dispatchable unit of work
      - executes sequentially and is interruptable
    - Process is a collection of one or more threads

Modern Operating Systems

- Symmetric multiprocessing (SMP)
  - There are multiple processors
  - These processors share same main memory and I/O facilities
  - All processors can perform the same functions