Introduction

CS 4410
Operating Systems

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What an OS does

• OS is an intermediary between programs and hardware.

• OS creates an environment to execute programs in a convenient and efficient manner:
  - allocates resources (CPU, storage, ...)
  - controls programs
    • cooperation (sharing and synchronization)
    • isolation (protection and resource management)
Ways to view an OS

- **Services** it provides to programs
- **Components** implementing those services
  - internal design and implementation
  - Real hardware is difficult to use directly
Why Study OS?

Learn solutions to problems arising in all systems:

- Resource sharing (scheduling)
- Cooperation (concurrent programming: communication, synchronization)
- System structure (abstractions, interfaces)
Systems vs Programs (I)

How designing an OS differs from designing a program

- **Measure of success**: OS concerned with extensibility, security, reliability, …
- **External interface**: OS more complicated and subject to change. E.g. I/O devices
- **Structuring techniques**: OS employs
  - modules, layers, client-server, event-handler, transaction
Systems vs Programs (II)

How designing an OS differs from designing a program

**OS must bridge mismatched performance characteristics**

- Registers vs RAM vs Disk
- Phone vs Laptop vs Server
What makes systems complex?

Emergent properties: Evident only when components are combined.

Example: Millennium Bridge (London)
What makes systems complex?

**Propagation of Effects:** When small changes have disproportionate effects

Examples:

- Power failures in power grid
- Change auto tire size from 13” to 15”
  - kills suspension
- Boeing 737 max 8 design
  - 4th generation of 737
  - larger engines, mounted further forward and higher
  - pushes up nose of jet
  - compensated by sensors and software…
What makes systems complex?

**Incommensurate Scaling:** Different parts follow different scaling rules

Examples:

- Height limits on skyscrapers
- Size limits on cargo ships
  - Horizon distance is linear in size of object
  - Stopping distance is proportional to object volume
- Giant in Jack and the Beanstalk
How to Manage Complexity

• **Modularity**: Good modularity minimizes connections between components

• **Abstraction**: Separate interface from internals; separate specification from implementation

• **Hierarchy**: Constrains interactions so easier to understand
OS has many roles

Referee
• Manages shared resources: CPU, memory, disks, networks, displays, cameras, etc.

Illusionist
• Look! Infinite memory! Your own private processor!

Glue
• Offers set of common services
• Separates apps from I/O devices
OS as Referee

Resource allocation
• Multiple concurrent tasks, how does OS decide who gets how much?

Isolation
• A faulty app should not disrupt other apps or OS
• OS must export less than full power of underlying hardware

Communication/Coordination
• Apps need to share state
**Virtualization**: Resources seem present but aren’t
- processor, memory, screen space, disk, network
- the entire computer (*virtual machine)*:
  - fooling the illusionist itself!
  - ease of debugging, portability, isolation

![Diagram of Operating System (VMM) stack](Image)
OS as Illusionist (2)

**Abstraction**: Enables new assumptions for clients

- **Atomic operations**
  - HW guarantees atomicity at word level
    - what happens during concurrent updates to complex data structures?
    - what if computer crashes during a block write?

- **Reliable communication channels**
  - At the hardware level, packets are lost…
OS as Glue

Simplify app design and facilitate sharing due to:

- send/receive of byte streams
- read/write files
- pass messages
- share memory
- UI

Decouples HW and app development
Issues in OS Design

- **Structure**: how is the OS organized?
- **Concurrency**: how are parallel activities created and controlled?
- **Sharing**: how are resources shared?
- **Naming**: how are resources named by users?
- **Protection**: how are distrusting parties protected from each other?
- **Security**: how to authenticate, authorize, and ensure privacy?
- **Performance**: how to make it fast?
Issues in OS Design

- **Reliability:** how do we deal with failures?
- **Portability:** how to write once, run anywhere?
- **Extensibility:** how do we add new features?
- **Communication:** how do we exchange information?
- **Scale:** what happens as demands increase?
- **Persistence:** how do we make information outlast the processes that created it?
- **Accounting:** who pays the bill and how do we control resource usage?