ECE595: Introduction to Operating Systems

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About Me (www.ece.purdue.edu/~ychu)

- Ph.D in CS, 1997, Harvard
- Joined Purdue 2002
- Research interests:
  - Operating systems
    - Virtual memory
    - File system
  - Networking (Internet, Datacenter, Wireless)
  - Distributed systems
    - Peer-to-Peer
    - Cloud computing
  - Mobile (Smartphone Energy Debugging)
- Teach ECE673 (Distributed Systems) in Springs

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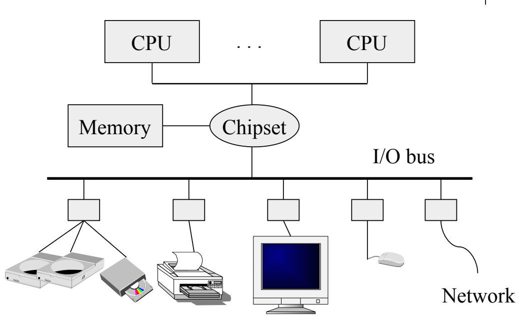
A Typical Computer from a Hardware Point of View



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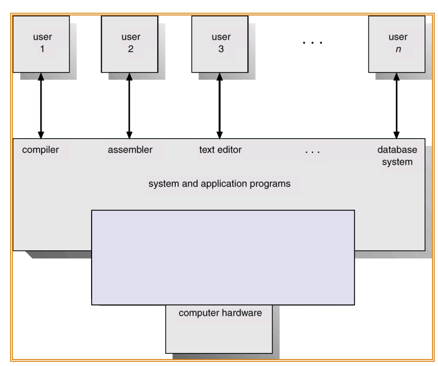
Computer System Components



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Missing piece of the "puzzle"

main.c
math.c

compiler

main.o
math.o

linker

a.out

OS

Load a.out to mem
Manage resources
to run a.out

arch

Instruction
execution

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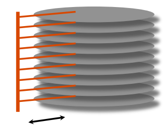
Example: programming hard drive

- Physical reality
  - Block oriented (e.g. 512 bytes)
  - Physical sector numbers
  - No protection among users of the system
  - Data might be corrupted if machine crashes
  - Programming:
    - Loading values into special device registers



"I will save my lab1 solution on platter 5, track 8739, sectors 3-4."

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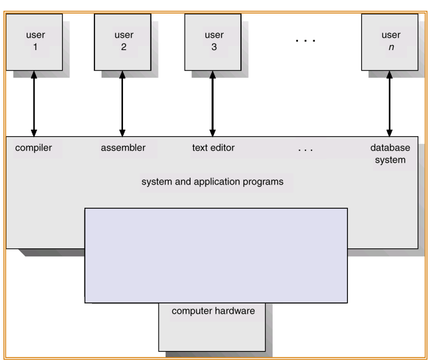
Computer System Components



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Example: programming hard drive

- Physical reality
  - Block oriented
  - Physical sector numbers
  - No protection among users of the system
  - Data might be corrupted if machine crashes
  - Programming:
    - Loading values into special device registers

- File system abstraction
  - Byte oriented
  - Named files
  - Users protected from each other
  - Robust to machine failures
  - Programming
    - open/read/write/close

"I will save my lab1 solution on platter 5, track 8739, sectors 3-4."

"My lab1 solution is in ~ychu/lab1/process.c."

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Brief History of Computer Systems (1)

- In the beginning, 1 user/program at a time
- Simple batch systems were 1st real OS
  - Spooling and buffering allowed jobs to be read ahead of time
- Multiprogramming systems provided increased utilization (throughput)
  - multiple runable jobs loaded in memory
  - overlap I/O with computation
  - benefit from asynchronous I/O devices (interrupt, DMA, …)
  - 1st instance where the OS must schedule resources
    - CPU scheduling
    - Memory management
    - Protection

Brief History of Cmputer Systems (2)

- Timesharing systems support interactive use
  - Logical extension of multiprogramming
  - Permits interactive work
    - Each user feels he/she has the entire machine
  - Optimize response time by frequent time-slicing multiple jobs
  - More complex than multiprogramming OS
    - In addition to CPU scheduling, memory management, protection
    - Virtual memory to allow part of the job be in memory
    - File system (needed by interactive use)
    - Job communication, synchronization
    - Handling deadlocks
  - Most systems today are timesharing (focus of this class)

What is an OS?

"Code" that *sits between*:

- programs & hardware
- different programs
- different users

But what does it do/achieve?

What is an OS?

- Resource manager
- Extended (abstract) machine

Makes computers *efficient* and *easy* to use

- (will have a 3rd definition based on pragmatics)

What is an OS?

Resource manager (answer1)
- Allocation
- Reclamation
- Protection

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What is an OS?

Resource manager
- Allocation
- Reclamation
- Protection

Finite resources
Competing demands

Examples:
- CPU
- Memory
- Disk
- Network

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What is an OS?

Resource manager
- Allocation
- Reclamation
- Protection

"The OS giveth
The OS taketh away"

Implied at termination
Involuntary at run time
Cooperative (yield cpu)

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What is an OS?

Resource manager
- Allocation
- Reclamation
- Protection

"You can't hurt me
I can't hurt you"

Implies some degree of safety & security

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What is an OS?

Extended (abstract) machine (answer 2)

- Much more ideal environment than the hardware
  - Ease to use
  - Fair (well-behaved)
  - Supporting backward-compatibility
  - Reliable
  - Secure
- Illusion of infinite, private (reliable, secure) resources
  - Single processor → many separate processors
  - Single memory → many separate, larger memories

Separating Policies from Mechanisms

A fundamental design principle in Computer Science

Mechanism – tool/implementation to achieve some effect

Policy – decisions on what effect should be achieved

Example – CPU scheduling:

- All users treated equally
- All program instances treated equally
- Preferred users treated better

Separation leads to flexibility!

Is there a perfect OS?
(resource manager, abstract machine)

Efficiency
Fairness

Portability
Interfaces

Security
Robustness

- Conflicting goals
  - Fairness vs efficiency
  - Efficiency vs portablity
  - …
- Furthermore, …

Hardware is evolving…

- 60's-70's - Mainframes
  - Rise of IBM
- 70's - 80's – Minicomputers
  - Rise of Digital Equipment
- 80's - 90's – PCs
  - Rise of Intel, Microsoft
- 90's - 00's – handheld/portable systems (laptops)
- 2007 - today -- mobile systems (smartphones), Internet of Things
  - Rise of iPhone, Android

Implications on OS Design Goals: Historical Comparison

	Mainframe	Mini	Micro/ Mobile
System $/ worker	10:1 – 100:1	10:1 – 1:1	1:10-1:100
Performance goal	System utilization	Overall cost	Worker productivity
Functionality goal	Maximize utilization	Features	Ease of Use

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Hardware is evolving (cont) …

- New architectures
  - Multiprocessors
  - 32-bit vs. 64-bit
  - Multi-core

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May You Live in Interesting Times…

- Processor speed doubles in 18 months
  - Number of cores per chip doubles in 24 months
- Disk capacity doubles every 12 months
- Global bandwidth doubles every 6 months

→ Performance/cost "sweet spot" constantly decaying

** Does human productivity ever double?*

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Applications are also evolving…

- New applications
  - Scientific computing
  - Computer games
  - Java
  - WWW (web servers, browsers)
  - Networked games
  - Peer-to-peer
  - Web 2.0 (search, youtube, social network, …)
  - Mobile apps (> 2.8 million iPhone, Android apps)
  - …

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Implications to OS Design

- Constant evolution of hardware and applications continuously reshape
  - OS design goals (performance vs. functionality)
  - OS design performance/cost tradeoffs
- Any magic bullet to good OS design?

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There is no magic in OS design

This is Engineering

- Imperfection
- Tradeoffs (perf/func)
- Constraints
  - hardware, cost, time, power
- Optimizations

Nothing's Permanent

- High rate of change
  - Hardware
  - Applications
- Cost / benefit analyses

One good news:

- Inertia of a few design principles

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Break / Assessment Quiz (7 min)

- Purposes
  - To assess your background knowledge, so
    - you know what you need to brush up
    - I know how to better structure lecture material
  - A glimpse of the midterm/final exam format

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About this course…

Principles of OS design

- Some theory
- Some rational
- Lots of practice

Goals

- Understand OS design decisions
- (Last) piece of the "puzzle"
- Basis for future learning

To achieve the goals:

- Learn concepts in class
- Get hands "dirty" in labs

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Expect (some) pain

Somewhat fast pace

Lots of programming projects

Some difficult (abstract) concepts

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Mechanics – Course Staff

Y. Charlie Hu, ychu@ecn, MSEE 232
Office hours: Wedn 1:30-3:30pm and by appt.

No TA. ☹

Volunteering Helper with programming projects:
Jiayi Meng, Ph.D student, ece595@purdue.edu

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Mechanics – General Info

- Course home page: engineering.purdue.edu/~ece595
  - login/password
- Mailing list: fall-2018-ece-59500-005@lists.purdue.edu
  - Class announcements
  - Q&A of general interests
- “TA” email: ece595@ecn.purdue.edu

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Mechanics – Q & A

- Questions of general interests → mailing list
- Other questions → ece595@ecn
- Announcements → mailing list

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Mechanics – Textbook

Operating System Concepts
Silberschatz, Galvin, and Gagne, 9^{th} (8^{th}, 7^{th}, 6^{th}) edition

Explains concepts very well

Some papers – will be available from class web page

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Mechanics – Lecture Notes

If available, will be provided on the web

Not necessary self-contained, complete, or coherent

Not a substitute for attending classes

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Mechanics - Projects

- 4 Programming projects
  - **Use DLXOS, simulated on Linux machines**
  - Build key components of a mini-OS (DLXOS)
- 1^{st} not graded (DLXOS tutorial)
- 3~4 weeks each
  - Explained in designated Friday lectures
  - due: *Sunday midnights, no extensions*
- Work in pairs (optional to work on your own)
  - Be decent to each other!

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Pairing Programming

From the McDowell et al. article (CACM 2006):

- Sitting shoulder to shoulder at 1 computer
  - one member of the pair is the "designated driver", actively creating code and controlling the keyboard and mouse.
  - The "non-driver" constantly reviews the keyed data in order to identify tactical and strategic deficiencies, including erroneous syntax and logic, misspellings, and implementations that don't map to the design

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The McDowell et al. Study (CACM 2006) (UC Santa Cruz)

	Female		Male		All	
	Pair	Solo	Pair	Solo	Pair	Solo
% that persisted in the course and took the final	88.1	79.5	91.7	81.5	90.8	80.4
% of students taking the final that passed the class with C or better	74.2	74.2	81.3	79.5	79.6	78.2
% of passers that took the 2nd programming course within 1 year	61.1	50.0	81.2	66.1	76.7	62.2
% of passers that took the 2nd course within 1 year—restricted to those indicating a planned CS related major at start of intro course	73.8	55.6	88.0	69.4	84.9	66.7
% of those taking the 2nd course that passed it on the first attempt	68.3	44.4	64.6	37.5	65.5	40.0
% of passers still at UCSC 1 year later that declared a CS major	46.3	11.1	59.5	41.1	56.9	33.8
% of passers still at UCSC 1 year later that declared a CS major—restricted to those indicating a planned CS related major at start of intro course	59.5	22.2	74.0	47.2	70.8	42.2

Shaded numbers indicate statistically significant differences.

Mechanics - Exams

- Midterm: close-book
  - Oct 4, Thursday 7-9pm (before October break)
- Final: close-book
- Short answers, some proof, some design (derivation), at most 1 programming problem

Mechanics – Grading

- Programming projects (50%: 15%-15%-20%)
- Midterm exam (25%)
- Final exam (25%)
- Bonus pop quizzes (up to 10%)

Academic Integrity

- Programming assignments
  - Ask instructor/helper for clarification
  - Each team must write their own solution
  - No discussion of or sharing of specific code or written answers is allowed
  - Any sources used outside of textbook/handouts/ lectures must be explicitly acknowledged

ABET outcomes

- By Oct 4: document on mapping of questions in labs/exams to ABET outcomes
- By Oct 4: Remediation homework

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Homework

- Reading assignment:
  - OSC, Chapters 1-2, by Thursday
- Find a lab partner and email ece595@ecn
  - No later than Sep 3

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