CS 318 Principles of Operating Systems

Fall 2017

Lecture 1: Introduction

Ryan Huang

JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Slides courtesy of Geoff Voelker, Yuanyuan Zhou, David Mazières

Lecture 1 Overview

- **Course overview**
- **Administrative**
- **What is an Operating System?**
- **Walk-through of OS basics**

Quick Survey

- **How many graduate students?**
- **Any non-CS majors?**
- **Why are you taking this class?**

Course Overview

- **An introductory course to operating systems**
  - classic OS concepts and principles
  - prepare you for advanced OS and distributed system class
- **A practice course for hands-on experience with OS**
  - four large programming assignments on a small but real OS
  - reinforce your understandings about the theories
- **Course materials**
  - lectures are the primary references
  - textbooks, papers, and handout as supplementary readings

Topics Covered

- **Threads, Processes**
- **Concurrency, Synchronization**
- **Scheduling**
- **Virtual Memory**
- **I/O**
- **Disks, Filesystems**
- **Protection & Security**
- **Virtual Machines**

Who Am I?

- **Prof. Ryan Huang**
  - Web: https://cs.jhu.edu/~huang
  - Office Hours: Tue 4-5pm, Thu 11am-12pm, Malone 231
- **Research Areas**
  - Operating Systems
  - Cloud and Mobile Computing
  - Software Reliability
- **Bio**
  - PhD @UCSD, Postdoc @Microsoft Research
  - B.S. (Computer Science) and B.A. (Economics) @Peking University

Course Assistant Team

- **Head CA: (primarily project)**
  - Guoye Zhang
  - Office Hours: Mon, Wed 4:30-6pm, Malone 122 (ugrad lab)

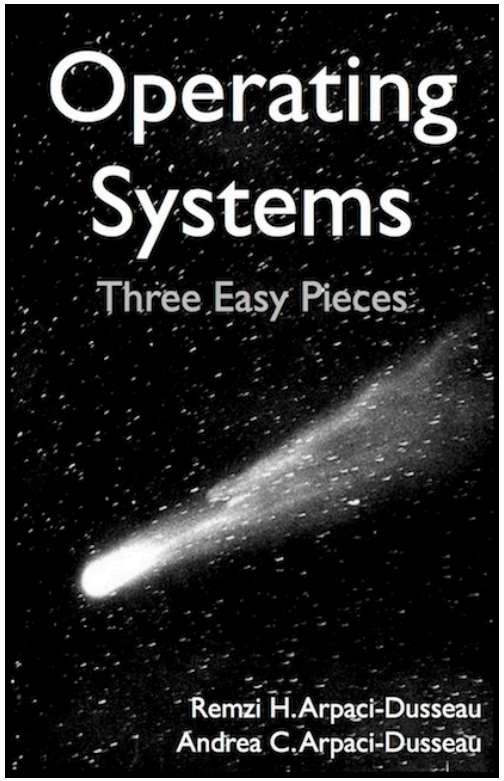
- **CA: (homework + lecture)**
  - Ying Liu
  - Office Hour: TBD

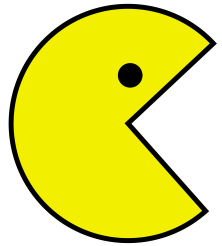
- **CA: (discussion + lecture)**
  - Dewank Pant
  - Office Hour: TBD

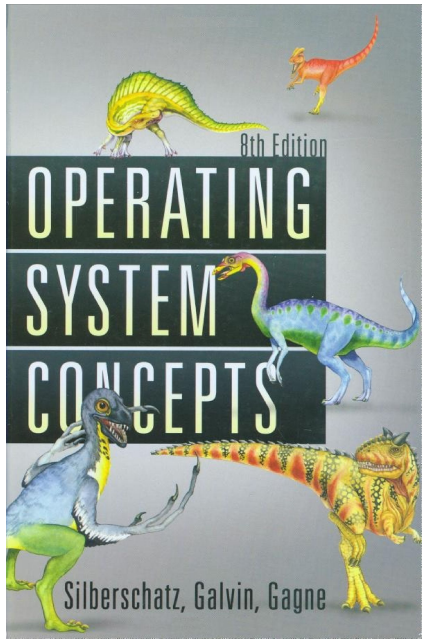
Couse Web

- **Portal:**
  - https://cs.jhu.edu/~huang/cs318/fall17/
  - Course syllabus and schedule
  - Lecture slides
  - Homework handouts
  - Project descriptions and references
- **Discussion forum:**
  - https://piazza.com/jhu/fall2017/cs318418618
- **Staff mail list:**
  - cs318-staff@cs.jhu.edu

Textbook

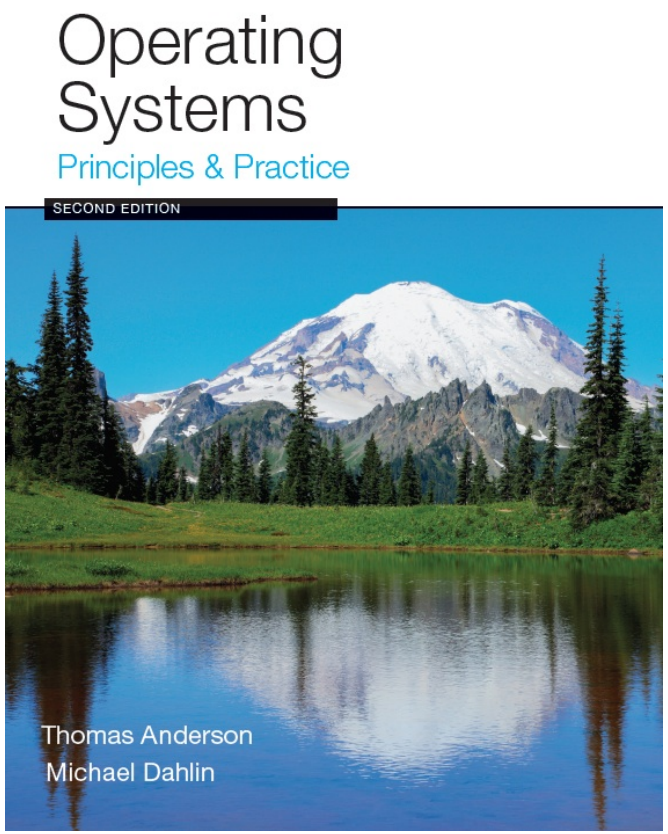


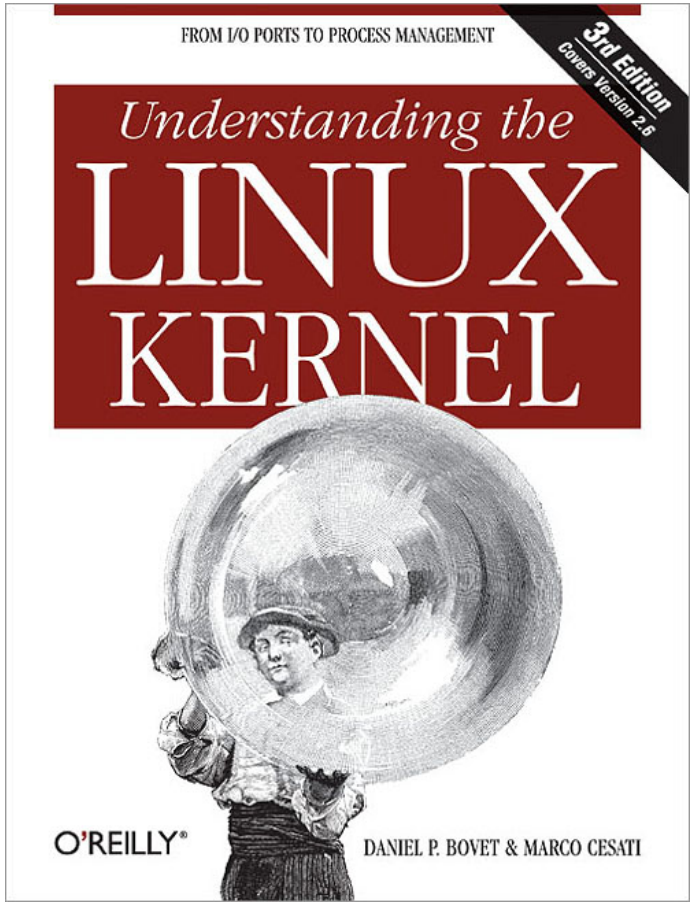




Remzi Arpaci-Dusseau and Andrea Arpaci-Dusseau,
Operating Systems: Three Easy Pieces, Version 0.91

Other Recommended Textbook





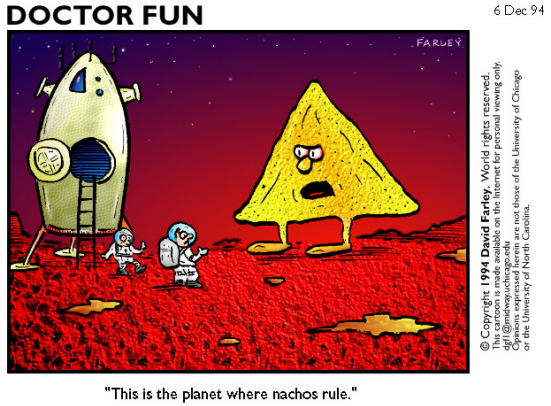
Homework

- **~5 homework assignments throughout the semester**
  - help you check understanding about the lectures
  - prepare you for the exams
- **The assignments will *not* be graded**
  - solutions released ~a week later
  - amount learned from doing homework is proportional to effort
  - your choice on how much effort

Project Assignments

- **Implement parts of Pintos operating system**
  - Developed in 2005 for Stanford's CS 140 OS class
  - Written in C, built for x86 hardware
    - can boot on your machine!
  - Use hardware emulator (QEMU/Bochs) during development

pinto beans



nachos

Project Assignments (2)

- **One setup project (lab 0)**
  - due next Thursday (done individually)
- **Four implementation projects:**
  - Threads, User processes, Virtual memory, File system
- **Implement projects in groups of up to 3 people**
  - Start picking your partners today
  - Git version control
- **Automated tests**
- **Design document and style**
- **Warning: the projects require serious time commitments**
  - Don’t wait until the last minute to start

Project Lab Environment

- **The CS department ugrad and grad lab machines**
  - running Linux on x86
  - the toolchain already setup
- **You may also use your own machine**
  - we provide instructions for setting up the environment
  - Unix and Mac OS preferred. Windows needs additional setup
  - testing will be done on lab machines
    - make sure to test your submission there

Exams

- **Midterm**
  - Covers first half of class + something related to projects
  - Tuesday, October 17th
- **Final**
  - Covers second half of class + selected materials from first part
    - I will be explicit about the material covered
  - Also include some project questions
- **No makeup exams**
  - Unless dire circumstances

Grading

- **Midterm: 15%**
- **Final: 35%**
- **Project: 50%**
  - Breakdown for five labs:
    - 601.418/618: 2%, 8%, 10%, 14%, 16%
    - 601.318: 2%, 12%, 15%, 21%, 6% (bonus points)
  - For each project, 70% of score based on passing test cases
  - Remaining 30% based on design and style

Project Design and Style

- **Must turn in a design document along with code**
  - Large software systems not just about producing working code
  - We supply you with templates for each project's design doc
- **CAs will manually inspect code**
  - e.g., must actually implement the design
  - must handle corner cases (e.g., handle `malloc` failure)
  - will deduct points for error-prone code
- **Code must be easy to read**
  - Indent code, keep lines and functions short
  - Use a consistent coding style
  - Comment important structure members, globals, functions

Late Policies

- **Late submissions receive penalties as follows**
  - 1 day late, 10% deduction
  - 2 days late, 30% deduction
  - 3 days late, 60% deduction
  - after 4 days, no credit
- **Each team will have 72-hour grace period**
  - can spread into 4 projects
  - for interview, attending conference, errands, etc., no questions asked
  - use it wisely

Collaboration and Cheating Policies

- **Collaboration**
  - Explaining a concept to someone in another group
  - Discussing algorithms/testing strategies with other groups
  - Helping debug someone else's code (in another group)
- **Do not look at other people's solutions**
  - including solutions online (e.g., GitHub)
  - we will run comprehensive tools to check for potential cheating.
- **Do not publish your own solutions**
  - online (e.g., on GitHub) or share with other teams
- **Cite any code that inspired your code**
  - as long as you cite what you used, it's not cheating
    - in worst case, we deduct points if it undermines the assignment

How *Not* to Pass CS 318?

- **Do not come to lecture**
  - Lecture is early, the slides are online, and the material is in the book anyway
  - Lecture material is the basis for exams and directly relates to the projects

- **Do not do the homework**
  - It's not part of the grade
  - Concepts seem straightforward...until you apply them
  - Excellent practice for the exams, and project

How *Not* to Pass CS 318?

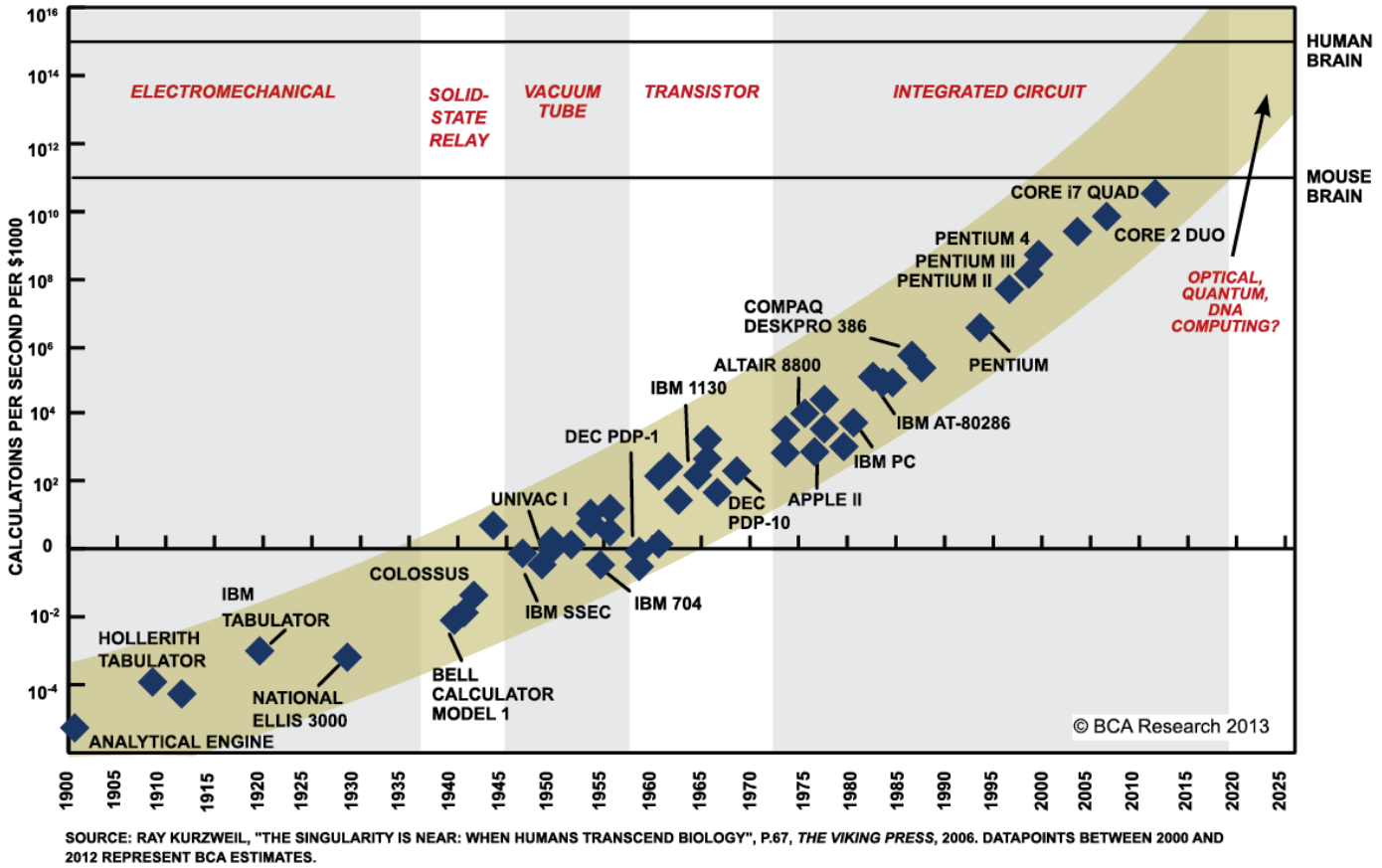
- **Do not ask questions in lecture, office hours or online**
  - It's scary, I don't want to embarrass myself
  - Asking questions is the best way to clarify lecture material
  - Office hours and email will help with homework, projects
- **Wait until the last couple of days to start a project**
  - We'll have to do the crunch anyways, why do it early?
  - The projects cannot be done in the last few days
  - Repeat: **The projects cannot be done in the last few days**
  - (p.s. The projects cannot be done in the last few days)

Questions

- **Before we start, any questions about the class structure, contents, etc.?**

Why Study Operating Systems?

- **Technology trends**



SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

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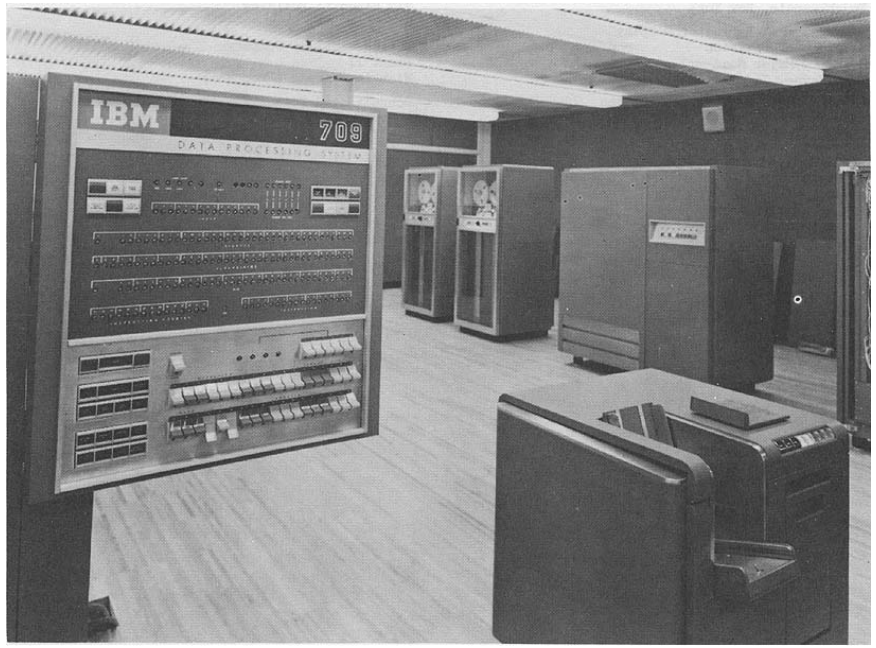


IBM 709

CPU: ~4000 mult/div per sec.

memory: 32K 36-bit words

price: $2,630,000+

size: half room

CPU: 1.85 GHz dual-core

memory: 2 GB

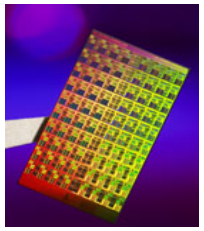
price: $329

size: 9.4 in × 6.6 in

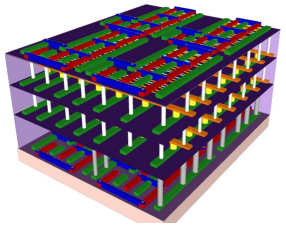
iPad

Why Study Operating Systems?

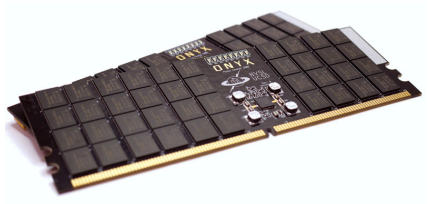
- **Technology trends**



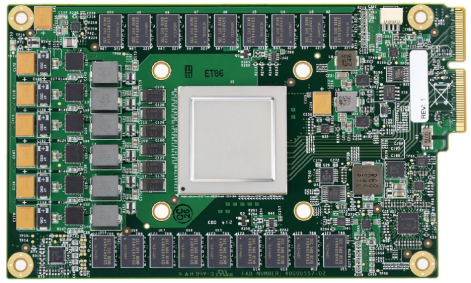
manycore



3D stacked chip



persistent memory



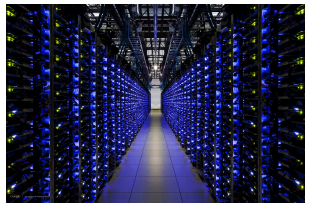
Tensor Processing Unit

smartphones

IoT device

self-driving cars

robots



data centers

...

Why Study Operating Systems?

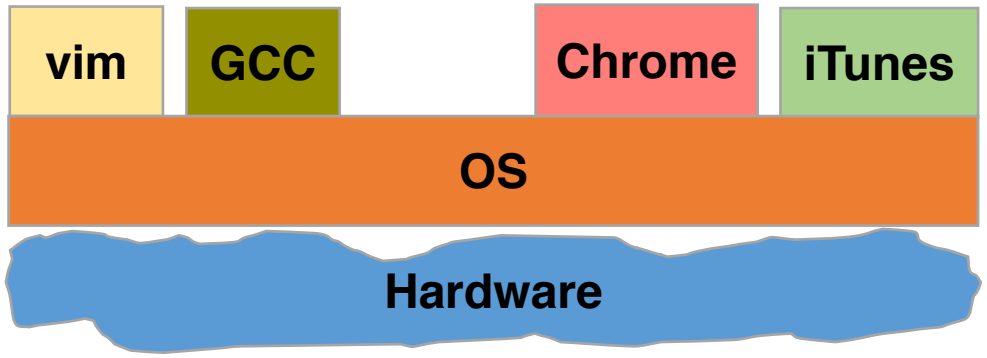
- **An exciting time for building operating systems** — some of you
  - New hardware, smart devices, self-driving cars, data centers, etc.
  - Facing OS issues in performance, battery life, security, isolation
- **Pervasive abstractions and principles for systems in general** — many of you
  - Caching, concurrency, memory management, I/O, protection
- **Understand what you use** — all of you
  - System software tends to be mysterious
  - Understanding OS makes you a more effective programmer (highly competitive in career)
- **Complex software systems** — all of you
  - Many of you will go on to work on large software projects
  - OSes serve as examples of an evolution of complex systems

What Is An Operating System?

- **Anyone?**
  - (Yes, I know that's why you're taking the course)
  - (Note: There are many answers)

What Is An Operating System?

- **Layer between applications and hardware**



- **All the code that you didn't have to write to implement your app**

OS and Hardware

- **Manage hardware resources**
  - Computation (CPUs)
  - Volatile storage (memory) and persistent storage (disk, etc.)
  - Communication (network, modem, etc.)
  - Input/output devices (keyboard, display, printer, camera, etc.)
- **Provides abstractions to hide details from applications**
  - Processes, threads
  - Virtual memory
  - File systems
  - …

OS and Hardware (2)

- **Mediate accesses from different applications**
  - Who has access at what point for how much/long
- **Benefits to applications**
  - Simpler (no tweaking device registers)
  - Device independent (all network cards look the same)
  - Portable (across Win95/98/ME/NT/2000/XP/Vista/7/8/10)

OS and Applications

- **Virtual machine interface**
  - The OS defines a logical, well-defined environment
  - Each program thinks it owns the computer
- **Provides protection**
  - Prevents one process/user from clobbering another
- **Provides sharing**
  - Concurrent execution of multiple programs (time slicing)
  - Communication among multiple programs (pipes, cut & paste)
  - Shared implementations of common facilities, e.g., file system

Questions to Ponder

- **What is part of an OS? What is not?**
  - Is the windowing system part of an OS?
  - Is the Web browser part of an OS?
  - This very question leads to different OS designs
- **How different are popular OSes today?**



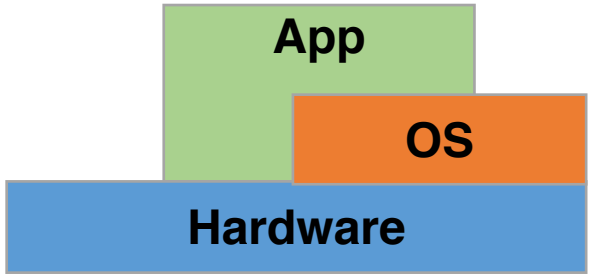

Questions to Ponder cont'd

- **OSes change all of the time**
  - Consider the series of releases of Windows, Linux, OS X
  - What drives the changes in OS?
  - What are the most compelling issues facing OSes today?
- **How many lines of code in an OS?**
  - Win7 (2009): 40M
  - OS X (2006): 86M
  - Linux (2011): 15M
  - What is largest kernel component?

Walk-through of OS basics

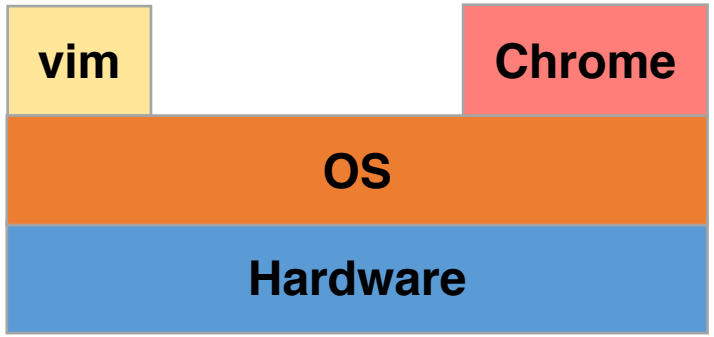
A Primitive Operating System

- **Just a library of standard services**



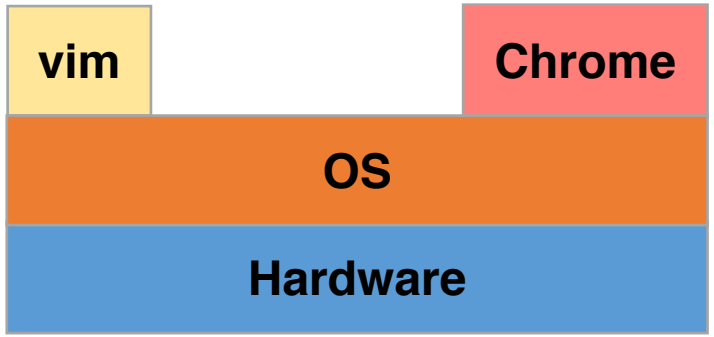
- **Simplifying assumptions**
  - System runs one program at a time
  - No bad users or programs
- **Problems: poor utilization**
  - ...of hardware (e.g., CPU idle while waiting for disk)
  - ...of human user (must wait for each program to finish)

Multitasking



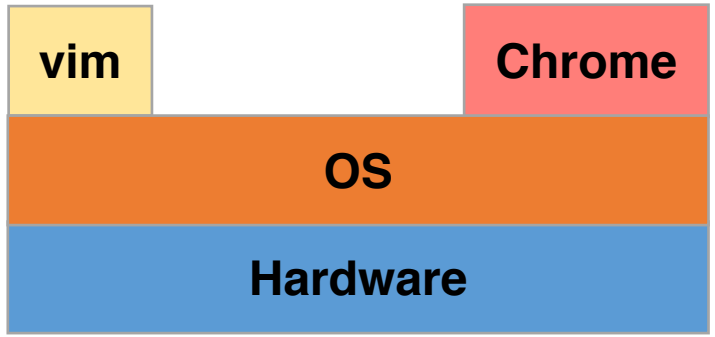
- **Idea: more than one process can be running at once**
  - When one process blocks (waiting for disk, network, user input, etc.) run another process
- **Mechanism: context-switch**
  - When one process resumes, it can continue from last execution point

Multitasking



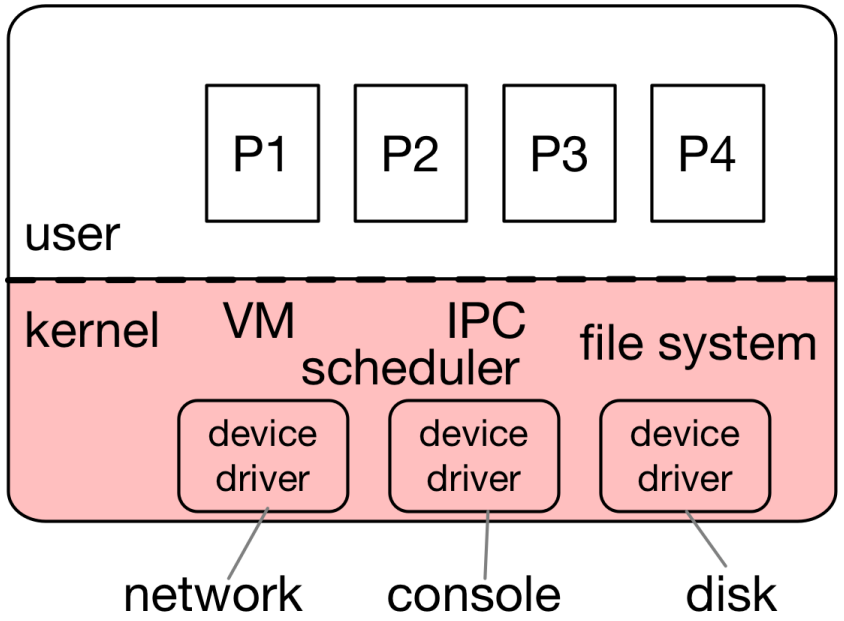
- **Idea: more than one process can be running at once**
- **Mechanism: context-switch**
- **Problems: ill-behaved process**
  - go into infinite loop and never relinquish CPU
  - scribble over other processes' memory to make them fail

Multitasking



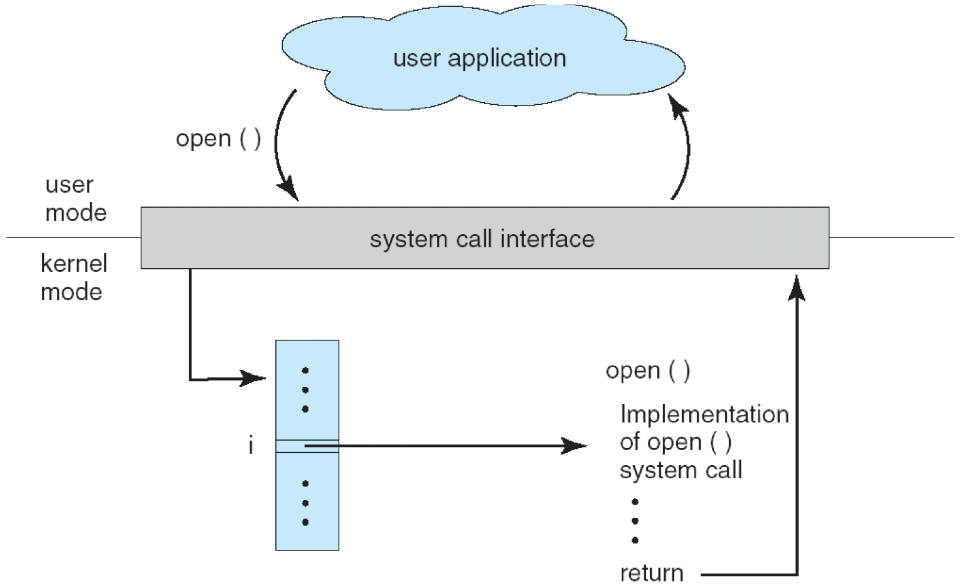
- **Problems: ill-behaved process**
  - go into infinite loop and never relinquish CPU
  - scribble over other processes' memory to make them fail
- **Solutions:**
  - **scheduling**: fair sharing, take CPU away from looping process
  - **virtual memory**: protect process's memory from one another

Typical OS Structure



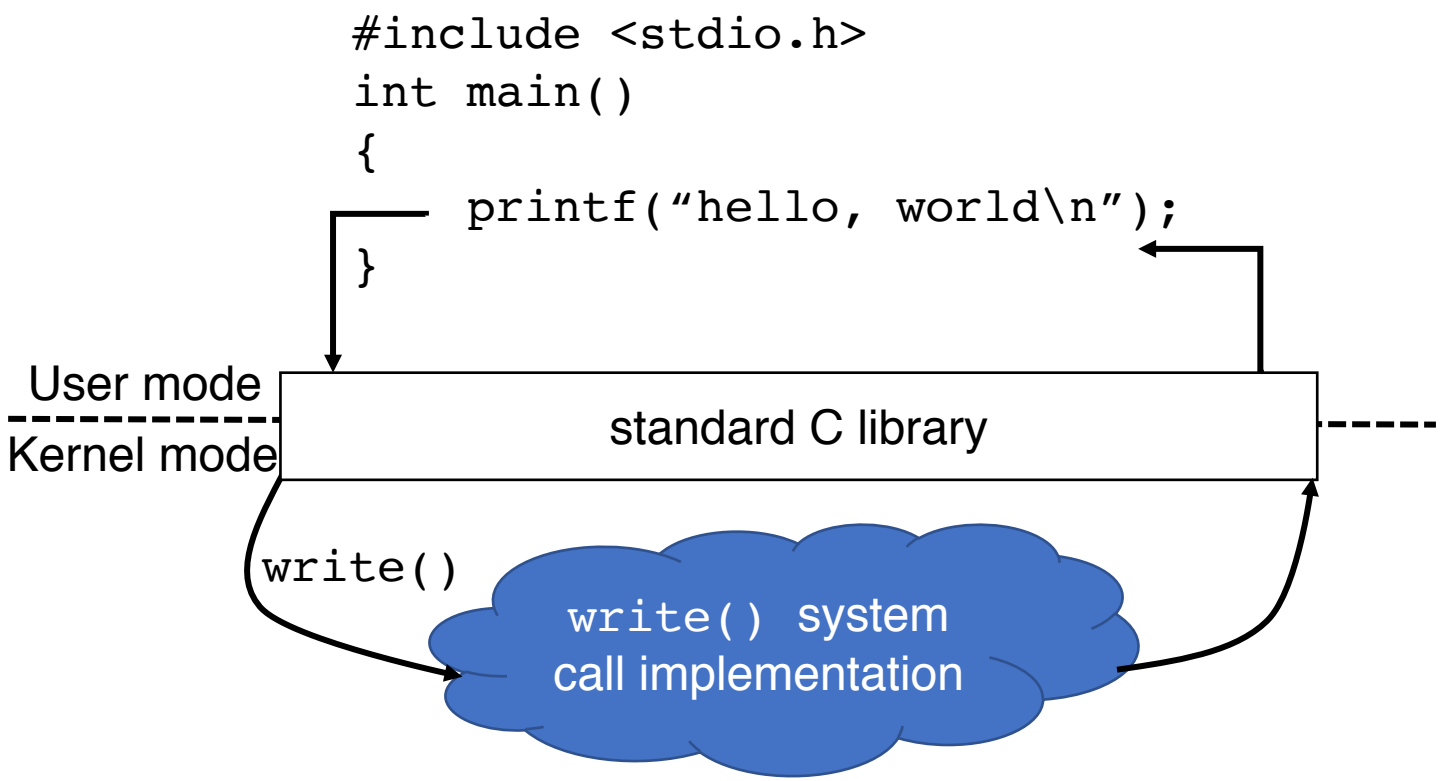
- **Most software runs as user-level processes (P[1-4])**
- **OS kernel runs in privileged mode (shaded)**

System Calls



- **Applications can invoke kernel through system calls**
  - Special instruction transfers control to kernel
  - ...which dispatches to one of few hundred syscall handlers

System Calls



- **Standard library implemented in terms of syscalls**

For Next Class...

- **Browse the course web**
  - https://cs.jhu.edu/~huang/cs318/fall17/
- **Read Chapters 1 and 2**
- **Start exploring Pintos and its documentation**
  - Work on Lab 0
- **Thinking about partners for project groups**

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