Introduction

Today

- Welcome to OS
- Administrivia
- OS overview and history

Next time

- Architectural support

Course overview …

- Everything you need to know

  http://www.aqualab.cs.northwestern.edu/classes/eecs-343-f09/

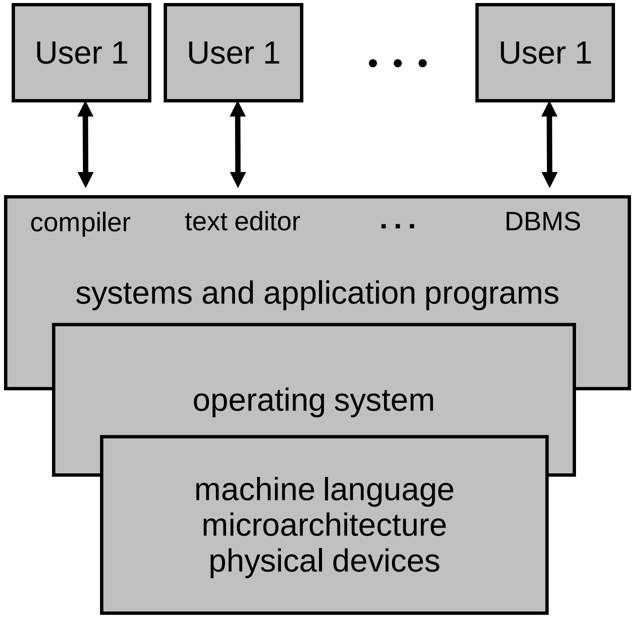
- Course staff
  - Fabián Bustamante
  - John Otto (TA)
- Overall structure
  - Lectures – read the text before class
  - TA Sessions - Once a week and focused on projects
  - Homework (4+1) - Look at them as reading enforcers
    - First one is posted on the web; due in ten days (Oct. 2)
  - …

Course overview

- Overall structure
  - …
  - Projects (4)
    - First one will be posted next Monday
    - Discuss on Wednesday
    - Due 11-12 days later (Oct. 9)
  - Exams (2)
    - Final on last day of classes (Dec. 3)
- *It's not that bad!*
  - They are really two classes in one: lectures + projects
  - Sometimes they are aligned, sometimes not
  - You will work a lot and you will also learn a lot

A computer system - Where's the OS?

- Hardware provides basic computing resources
- Applications define ways in which resources are used to solve users' problems
- *OS controls & coordinates use of hardware by users' applications*
- A few vantage points
  - End user
  - Programmer
  - OS Designer



What is an operating system?

- Extended machine – top-down/user-view
  - Hiding the messy details, presenting a virtual machine that's easier to program than the HW
- Resource manager – bottom-up/system-view
  - Everybody gets a fair-share of time/space from a resource (multiplexing in space/time)
  - A control program – to prevent errors & improper use (CP/M?)
- A bundle of helpful, commonly used things
- Goals
  - Convenience – make solving user problems easier
  - Efficiency – use hardware in an efficient manner ($$$ machines demand efficient use)
  - Easy to modify/evolve

What's part of the OS?

- Trickier than you think: file system, device drivers, shells, window systems, browser, ...
- Everything a vendor ships with your order?
- The one program running at all times, or running in kernel mode
  - Everything else is either a system program (ships with the OS) or an application program
  - *Can the user change it?*
- *Why does it matter? In 1998 the US Department of Justice filed suit against MS claiming its OS was too big*

Why having one?

- For applications
  - Programming simplicity
    - High-level abstractions instead of low-level hardware details
    - Abstractions are reusable across many programs
  - Portability (to != machines configurations/architectures)
- For user
  - Safety
    - Program works within its own virtual machine
    - OS protects programs from each other
    - OS fairly multiplexes resources across programs
  - Efficiency (cost and speed)
    - Share one computer across many users
    - Concurrent execution of multiple programs

Why study operating systems?

- Tangible reasons
  - Build/modify one - OSs are everywhere
  - Administer and use them well
  - Tune your favorite application performance
  - Great capstone course
- Intangible reasons
  - Curiosity
  - Use/gain knowledge from other areas
  - Challenge of designing large, complex systems

Major OS issues

- Structure: how is the OS organized?
- Sharing: how are resources shared?
- Naming: how are resources named?
- Security: how is integrity of the OS and its resources ensured?
- Protection: how is one user/program protected from another?
- Performance: how do we make it all go fast?
- Reliability: what happens if something goes wrong?
- Extensibility: can we add new features?
- Communication: how do programs exchange information, including across a network?

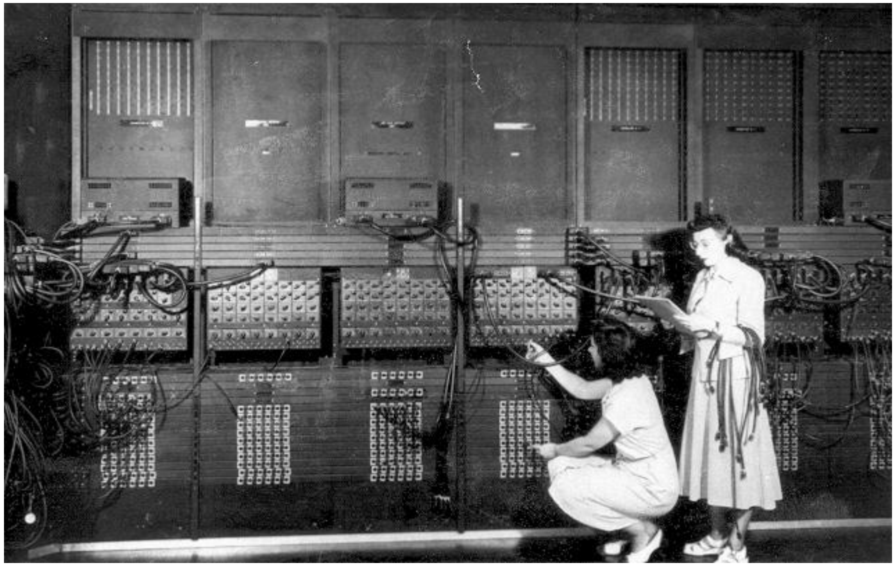
Other OS issues

- Concurrency: how are parallel activities created and controlled?
- Scale and growth: what happens as demands or resources increase?
- Persistence: how do you make data last longer than program executions?
- Distribution: how do multiple computers interact with each other? how do we make distribution invisible?
- Acounting: how do we keep track of resource usage, and perhaps charge for it?

There are a huge number of engineering tradeoffs in dealing with these issues!

The evolution of operating systems

- A brief history & a framework to introduce OS principles
- Early attempts – Babbage's (1702-1871)
  - Analytical Engine (Ada Lovelace – World's first programmer)
- 1945-55 – Vacuum tubes and plugboards
  - ABC, MARK 1, ENIAC
  - No programming languages, no OS
  - A big problem
    - Scheduling – signup sheet on the wall



Evolution ... Batch systems (1955)

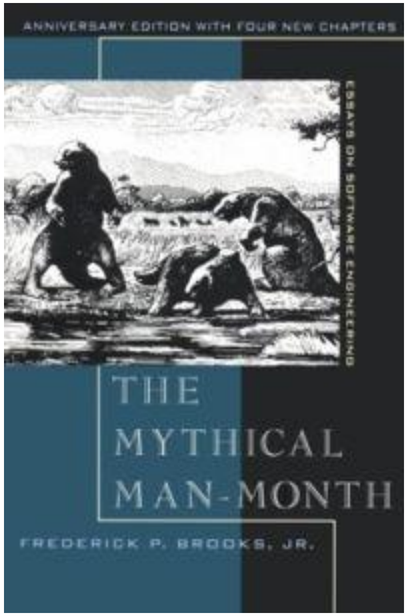
- Transistors → machs. reliable enough to sell
  - Separation of builders & programmers
- Getting your program to run
  - Write it in paper (maybe in FORTRAN)
  - Punch it on cards & drop cards in input room
  - Operator may have to mount/dismount tapes, setting up card decks, ... setup time!
- Batch systems
  - Collect a tray of full jobs, read them all into tape with a cheap computer
  - Bring them to the main computer where the “OS” will go over each jobs one at a time
  - Print output offline

Evolution ... Spooling (1965)

- Disks much faster than card readers & printers
- Spool (Simultaneous Peripheral Operations On-Line)
  - While one job is executing, spool next one from card reader onto disk
    - Slow card reader I/O overlapped with CPU
  - Can even spool multiple programs onto disk
    - OS must choose which one to run next (job sched)
  - But CPU still idle when program interact with a peripheral during execution

Evolution ... Multiprogramming (1965)

- To increase system utilization
  - Keeps multiple runnable jobs loaded in memory at once
  - Overlap I/O of a job with computing of another
  - Needs asynchronous I/O devices
    - Some way to know when devices are done
      - Interrupt or polling
  - Goal- optimize system throughput
      - Maybe at the cost of response time
- IBM OS/360 & the tar pit



Evolution ... Timesharing (1961)

- To support interactive use
  - Multiple terminals into one machine
  - Each user has the illusion of owing the entire machine
  - Goal – optimize response time maybe at the cost of throughput
- Time-slicing
  - Dividing CPU equally among users
  - If jobs are truly interactive, CPU can jump between them without users noticing it
  - Recovers interactivity for the user (why do you care?)
- CTSS (Compatible Time Sharing System), MULTICS and UNIX

Evolution … Parallel systems (1962)

- Some applications can be written as multiple parallel threads or processes
  - Can speed up the execution by running on several CPUs
  - Need OS and language primitives for dividing program into multiple parallel activities
  - Need OS primitives for fast communication among activities
    - Degree of speedup dictated by communication/computation ratio
  - Many flavors of parallel computers today
    - SMPs (symmetric multi-processors, multi-core)
    - SMT (simultaneous multithreading [“hyperthreading”]
    - MPPs (massively parallel processors)
    - NOWs (networks of workstations) [clusters]
    - computational grid (SETI @home)

Evolution ... PCs (197x)

- Large-scale integration >> small & cheap machines
- 1974 – Intel's 8080 & Gary Kildall's CP/M
- Early 1980s – IBM PC, BASIC, CP/M & MS-DOS
- User interfaces, XEROX Altos, MACs and Windows

Xerox Alto 1973

IBM PC circa 1981

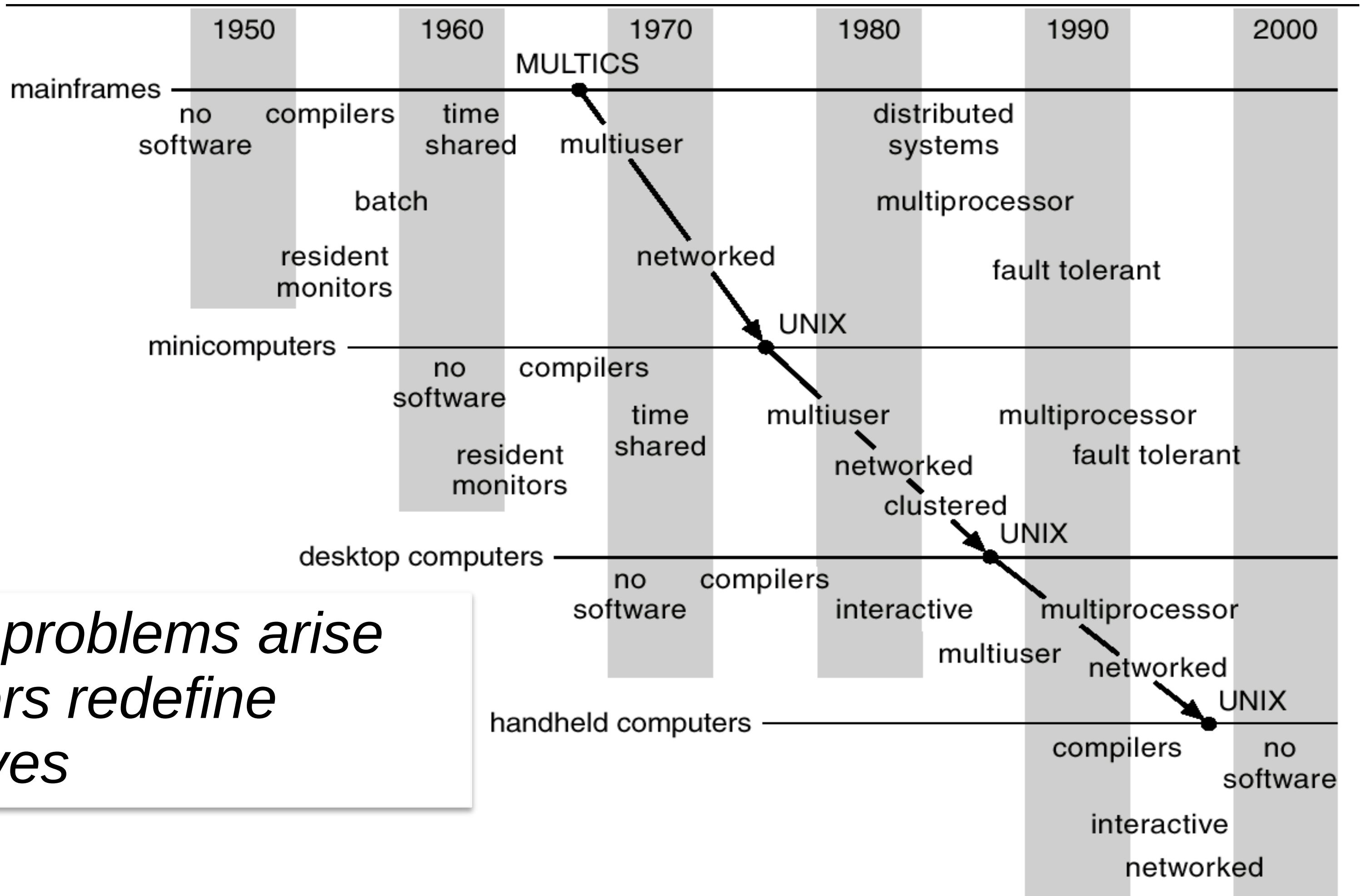
Evolution … Distributed & pervasive

- Facilitate use of geographically distributed resources
  – Workstations on a LAN or across the Internet
- Support communication between programs
- Speed up is not always the issue, but access to resources
- Architectures
  – Client/servers
    - Mail server, print server, web server
  – Peer-to-peer
    - (Most) everybody is both, server and client

Evolution … Embedded and pervasive

- Pervasive computing
  - cheap processors embedded everywhere
  - how many are on your body now? in your car?
  - cell phones, PDAs, games, iPod, network computers, …
- Typically very constrained hardware resources
  - slow processors
  - small amount of memory
  - no disk or tiny disk
  - typically only one dedicated application
  - limited power
- But technology changes fast

"Ontogeny recapitulates phylogeny"*



But new problems arise and others redefine themselves

The development of an embryo repeats the evolution of the species (* Ernst Haeckel)

Summary

- In this class you will learn
  - Major components of an OS
  - How are they structured
  - The most important interfaces
  - Policies typically used in an OS
  - Algorithms used to implement those policies
- Philosophy
  - You many not ever build an OS, but
  - As a CS/CE you need to understand the foundations
  - Most importantly, OSs exemplify the sorts of engineering tradeoffs you'll need to make throughout your careers