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-f14/
- Course staff
  - Fabián Bustamante
  - John Rula and Dipendra Jha (TAs)
- Overall structure
  - Lectures – Read the text before class
  - Readings – Extra reading for extra points
  - Homework – Mainly a reading enforcer
  - Projects – Key to the course, learn-by-doing nature
  - TA Sessions – Try them, a great way to bootstrap projects
  - Exams

Course overview ...

- Homework (4+1)
  - In part, reading enforcers – textbook + papers
- Readings
  - Optional set of papers; outline in the webpage
  - Basis for extra-credit questions in exams
- Projects (4)
  - To do in groups of 2-3
  - New aspect of projects: *Walkthrough code review*
  - *Must run in the VM image we will make available*
- Exams (2)
  - Final (not cumulative) on second day of final weeks (Dec. 9)

- *Whatever you have heard, it's not that bad!*

On projects – Code walkthrough

- For every project, code walkthrough by randomly selected groups with the staff

To get full credit for your project you must be able to carry the walkthrough, showing you understand your own code

- A few points
  - Sampling with replacement – you can do it multiple times
  - To be done in first week after submission
  - Every team member must be there, each drives at one point
  - Other participants comment and ask questions

On reading

- Optional papers (others as well, but these few for exams)
  1. D.D. Redell et al., ***Pilot: An Operating System for a Personal Computer,*** CACM, Feb. 1980.
  2. C. Waldspurger et al., ***Lottery scheduling: Flexible proportional-share resource management***, OSDI, 1994.
  3. H. Levy et al., ***Virtual Memory Management in the VAX/VMS Operating System,*** IEEE Computer, Mar. 1982.
  4. T. Anderson et al., ***Scheduler activations: effective kernel support for the user-level management of parallelism***, ACM TOCS, 10(1):53-79, Feb. 1992.
  5. B. Lampson et al., ***Experiences with Processes and Monitors in Mesa,*** CACM, Feb. 1980.
  6. M, Rosenblum et al., ***Design and implementation of the log-structured file system,*** SOSP, 1991.
- Mandatory
  - K. Ousterout et al,. ***Sparrow: Distributed, Low Latency Scheduling,*** SOSP, 2013.

Your TODO list

- Project
  - First one will be posted ***TOMORROW***, due Oct. 9
- Homework
  - First one will be posted in two weeks (Oct. 6); due on Oct. 14
- Get and install the VMM and VM image
- Check you have access to T-Lab and/or Wilkinson Lab
  - Email help@eecs otherwise
- Start reading
- Start looking for partners for your project!

FEATURE PRESENTATION

Windows Vista

android

OS X
Mountain Lion

ubuntu

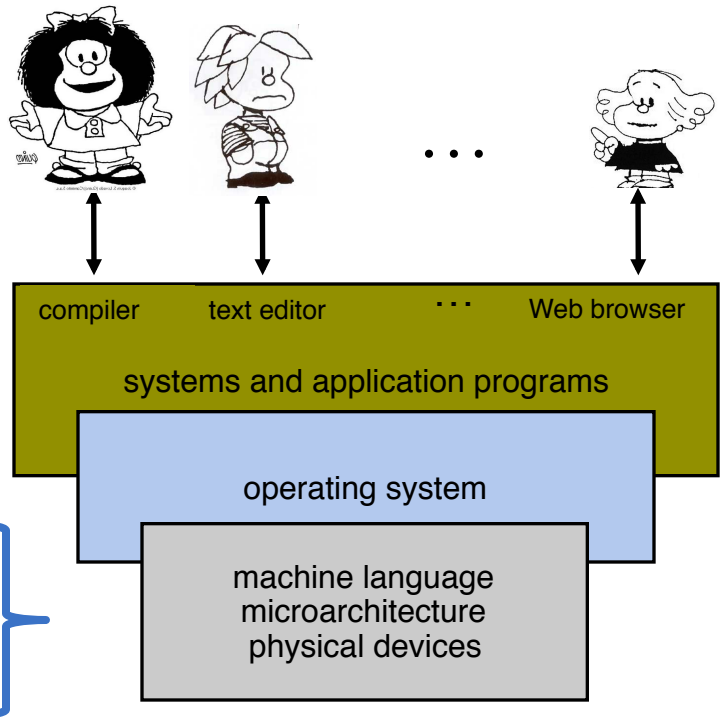
Windows 8

debian

iOS 6

A computer system - Where's the OS?

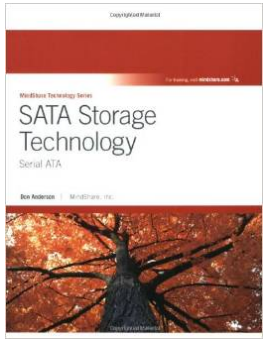
- Hardware provides basic computing resources
- Applications define ways in which resources are used to solve users' problems
- *OS controls & coordinates use of hardware by users' applications*
- A few vantage points
  - End user
  - Programmer
  - OS Designer



1+ processors, main memory, disks, keyboards, display, camera, network interfaces, mouse pad, …

What is an operating system?

- An *extended machine* and a resource manager

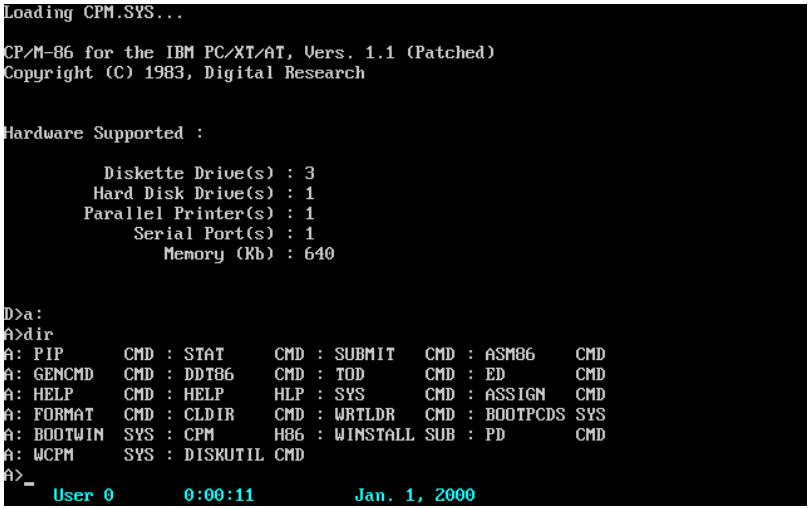


- Consider a disk
  - Manual for using a Serial ATA hard disk – 450pp … device driver
  - Devices drivers still too low-level – read/write blocks … file systems

- Extended machine – top-down/user-view
  - The *illusionist*
  - Hiding the messy details, presenting a virtual machine that's easier to program than the hardware
    - *How much memory do you have?*
    - *How is your disk formatted?*
    - *How many processors do you have?*

What is an operating system?

- Resource manager – bottom-up/system-view
  - The *referee*
  - 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?)



CP/M Control Program/Monitor

Created for Intel 8080/85 by Gary Kildall of Digital Research, Inc. IBM tried to license it for their “new” IBM PC. *Failing to get a non-disclosure agreement they used instead Microsoft to provide an OS*

What is an operating system?

- A bundle of helpful, commonly used things

- Goals and evaluation criteria
  - Reliability – the system does exactly what is designed to do
  - Security and privacy – the system operation cannot be compromised by a malicious attacker and the data stored in the computer is only accessible to authorized users
  - Convenience – make solving user problems easier
  - Efficiency – use hardware in an efficient manner ($$$ machines demand efficient use)
  - Easy to modify/evolve/port

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 Dept. 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 HW details
    - Abstractions are reusable across many programs
  - Portability
    - To different machines configurations/architectures






Why having one?

- …
- 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
  - Common source for job interview questions
- 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?*
- Accounting: *how do we keep track of resource usage, and perhaps charge for it?*

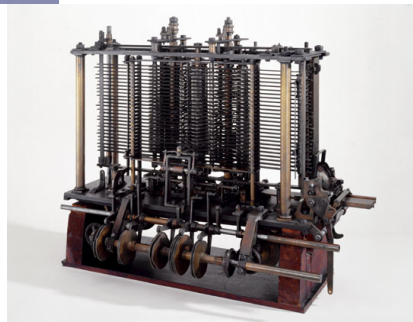
There are a huge number of engineering tradeoffs in dealing with these issues!

And now a short break …

Hardware/Software evolution/change

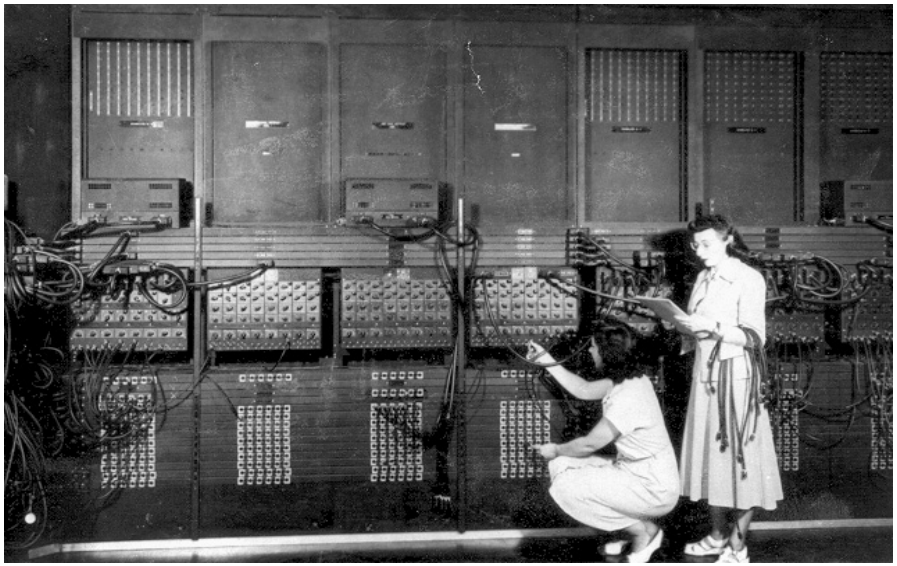
- 1960s Mainframes
- 1970s Minicomputers
- 1980s Microprocessors, workstations, LANs, Internet
- 1990s PC, Web
- 2000s Internet services, mobile computing
- 2010s Pervasive, sensor networks, cloud computing, data-intensive computing
- *It's up to you*

The evolution of operating systems



- Early attempts – Babbage's (1702-1871)
  - Analytical Engine (Ada Lovelace – World's first programmer)

- 1945-55 – Vacuum tubes & plugboards ~ Open shop
  - ABC, MARK 1, ENIAC, later IBM 701 (1952)
  - No programming languages, no OS
  - A big problem
    - Scheduling – signup sheet on the wall

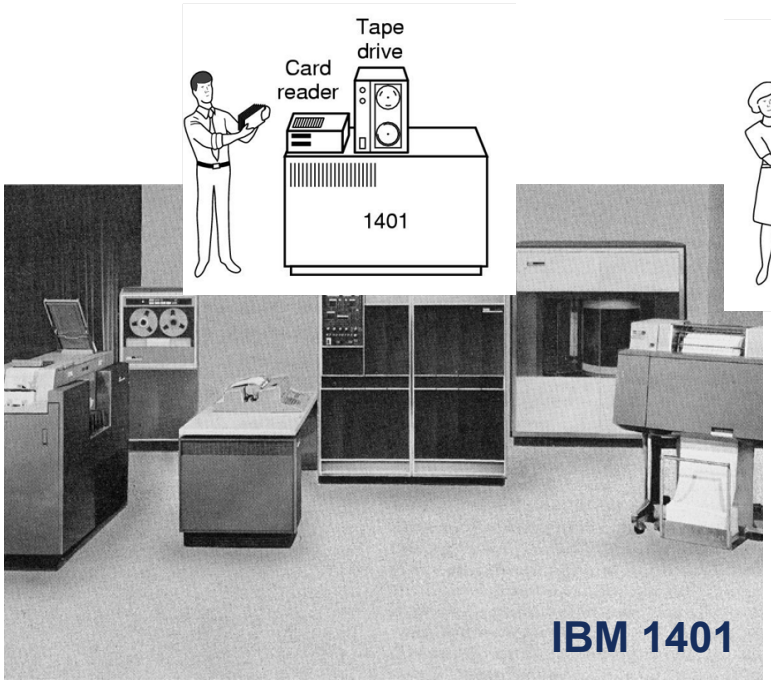


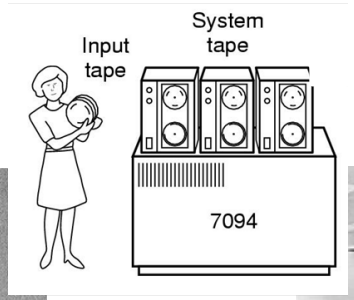
Evolution ... Batch systems (1955)

- 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 …

Evolution ... Batch systems (1955)

- Batch systems
  - Collect a tray of full jobs, read them 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



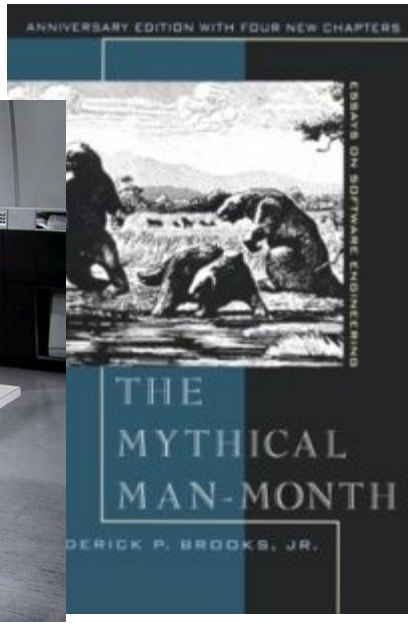


A. Tanenbaum, Modern Operating Systems, Pearson PH

Evolution ... Multiprogramming (1960s)

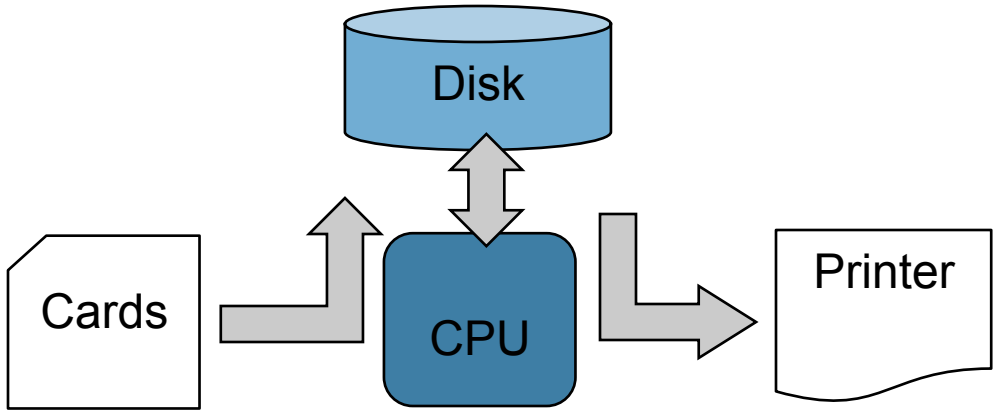
- To increase system utilization
  - Keeps multiple runnable jobs loaded in memory at once
  - Overlap I/O of a job with computing of another
  - Needs asynchronous I/O devices
    - Some way to know when devices are done
      - Interrupt or polling
  - Goal- optimize system throughput
      - Maybe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

IBM OS/360 & the tar pit



Evolution ... Spooling (1960s)

- Disks, random access, much faster than card readers & printers
- Spool (Simultaneous Peripheral Operations On-Line)
  - While one job runs, spool next one from card reader onto disk
    - Slow card reader I/O overlapped with CPU
    - No need for the 1401s now
  - With multiple programs onto disk, scheduling
  - But CPU still idle when program interact with a peripheral during execution



Evolution ... Timesharing (1960s)

- To support interactive use
  - Multiple terminals into one machine
  - Each user given the illusion of owing the entire machine
  - 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 (second-system effect) and UNIX

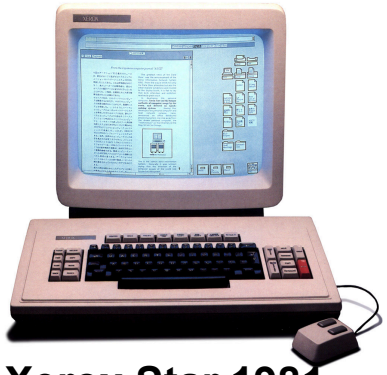
Evolution … Parallel systems (1970s)

- Some applications can be written as multiple tasks
  - Speed up when running on several CPUs
  - Need OS and language primitives for dividing/organizing the multiple tasks
  - Need OS primitives for fast communication between tasks
    - 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 (1980s)

- 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



Xerox Star 1981

IBM PC circa 1981

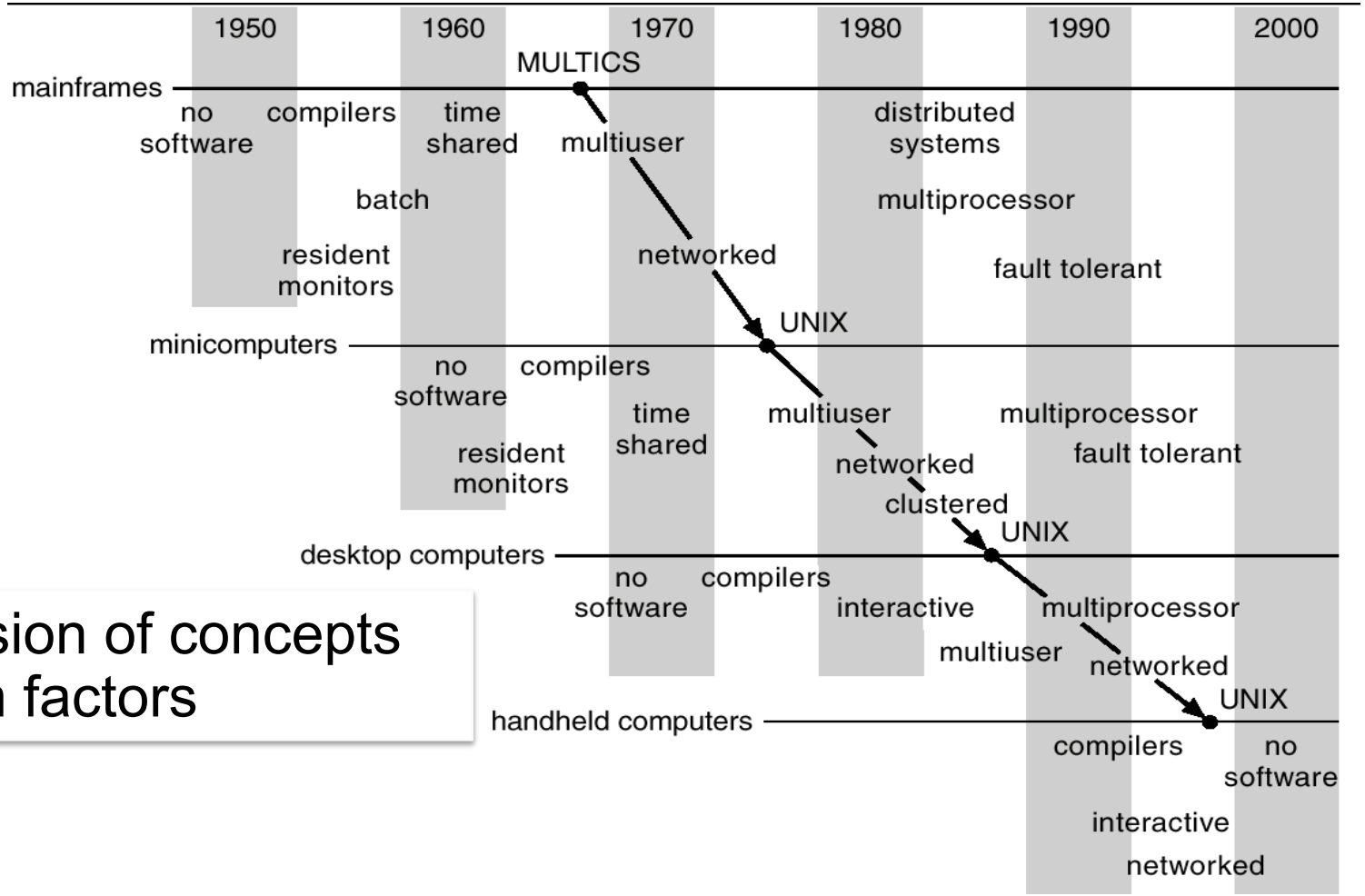
Evolution ... Distributed and pervasive

- 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 (including information)
- 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"*



Progression of concepts and form factors

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

Has it all been done then?

- New challenges constantly arise
  - Embedded computing
  - Sensor networks
  - Multiple cores
  - Cloud services
  - Peer-to-peer computing
  - Software defined networking
- Old problems redefine themselves
  - Evolution of smart phones recapitulated that of PC, which recapitulated that of minicomputers which …
  - But the ubiquity of PC's redefined the issues of protections, phones are doing this again …

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 may never build an OS, but
  - If you are 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