Lecture 9: Software systems
operating systems, applications, ...

Software systems, buzzwords, issues

- operating systems
  - runs programs, controls the computer, stores information, communicates
- applications ("apps")
  - programs that do things
- cloud computing, virtual machines, ...
  - where boundaries become even less clear

- intellectual property
  - copyrights, patents, licenses
- interfaces, standards, antitrust, ...
  - agreements on how to communicate and inter-operate
- open source software
  - freely available, non-proprietary
- jurisdiction
  - where are the computers? where is the data? who has access to it?

Programs come in lots of sizes

- programs come in different sizes
  - cos109 psets and labs: tiny, like a response paragraph
  - 10-20 lines
- projects in COS courses like 333
  - like a term paper
  - 2000-5000 lines
- significant applications
  - like a book, maybe a very big book
  - 100,000 – 10,000,000 lines
- operating systems, major applications
  - like a multi-volume book ?
  - 10,000,000 and up

- a typical programmer produces at most a few thousand lines of production code per year

Operating system

- a <u>program</u> that controls the resources of a computer
  - interface between hardware and all other software
  - examples: DOS, Windows 3.0/95/98/NT/ME/2000/XP/Vista/7/8/10
    Unix/Linux, macOS, iOS, Android, ...

- runs other programs ("applications", your programs, ...)
- manages information on disk (file system)
- controls peripheral devices, communicates with outside world
- keeps things from interfering with each other

- provides a level of abstraction above the raw hardware
  - makes the hardware appear to provide higher-level services than it really does
  - makes programming much easier

What an operating system does

- **manages CPUs, schedules and coordinates running programs**
  - switches CPU among programs that are actually computing
  - suspends programs that are waiting for something (e.g., disk, network)
  - keeps individual programs from hogging resources
- **manages memory (RAM)**
  - loads programs in memory so they can run
  - swaps them to disk and back if there isn't enough RAM (virtual memory)
  - keeps separate programs from interfering with each other
  - and with the operating system itself (protection)
- **manages and coordinates input/output to devices**
  - disks, display, keyboard, mouse, network, ...
  - keeps separate uses of shared devices from interfering with each other
  - provides uniform interface to disparate devices
- **manages files on disk (file system)**
  - provides hierarchy of directories and files for storing information

History of general-purpose operating systems

- 1950's: signup sheets
- 1960's: batch operating systems
  - operators running batches of jobs
  - OS/360 (IBM)
- 1970's: time-sharing
  - simultaneous access for multiple users
  - Unix (Bell Labs; Ken Thompson & Dennis Ritchie)
- 1980's: personal computers, single user systems
  - DOS, Windows, MacOS, Unix
- 1990's: personal computers, PDA's, …
  - PalmOS, Windows CE, Unix / Linux
- 2000's: Windows, Unix/Linux, MacOSX (a Unix variant)
- 2010's: Apple vs. Google vs. Microsoft
  - iOS, Android, ChromeOS, … (all Unix/Linux-based)
  - cloud computing
- not all computers have general-purpose operating systems
  - "embedded systems": small, specialized, but increasingly general (often Unix/Linux)

Unix operating system

- **developed ~1971 at Bell Labs**
  - by Ken Thompson and Dennis Ritchie
- **clean, elegant design**
  - at least in the early days
- **efficient, robust, easy to adapt, fun**
  - widely adopted in universities, spread from there
- **written in C, so easily ported to new machines**
  - runs on everything (not just PC's)

- **influence**
  - languages, tools, de facto standard environment
  - enabled workstation hardware business (e.g., Sun Microsystems)
  - supports a lot of Internet services and infrastructure
    - often Linux

Ken Thompson and Dennis Ritchie (circa 1972)

Linux

- **a version of Unix written from scratch**
  - by Linus Torvalds, Finnish student (started 1991)
- **source code freely available (kernel.org)**
  - large group of volunteers making contributions
  - anyone can modify it, fix bugs, add features
  - Torvalds approves, sets standard
  - commercial versions make money by packaging and support,
    not by selling the code itself
- **used by many major sites, including**
  - Google, Amazon, Facebook, Twitter, YouTube, ABC, CBS, CNN, ...

To run programs, the operating system must

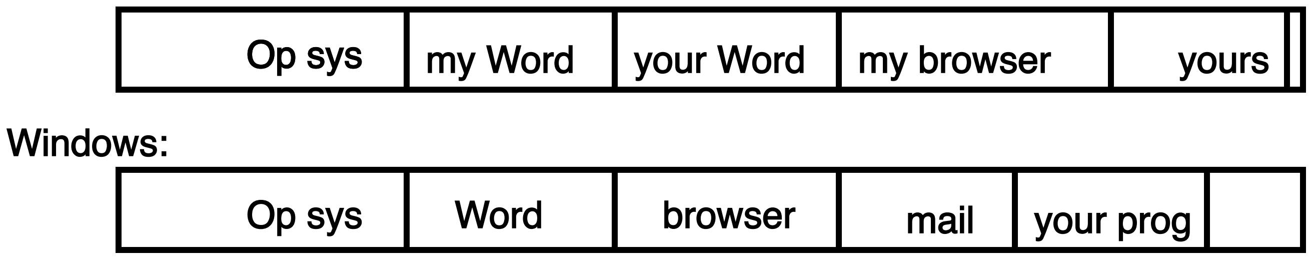
- fetch program to be run (usually from disk)
- load it into RAM
  - maybe only part, with more loaded as it runs (dynamic libraries)
- transfer control to it
- provide services to it while it runs
  - reading and writing info on disk
  - communications with other devices
- regain control and recover resources when program is finished
- protect itself from errant program behavior
- share memory and other resources among multiple programs running "at the same time"
  - manage memory, disks, network, ...
  - protect programs from each other
  - manage allocation of CPUs among multiple activities

Memory management

- what's in memory? over-simplified pictures:

Unix:

Windows:

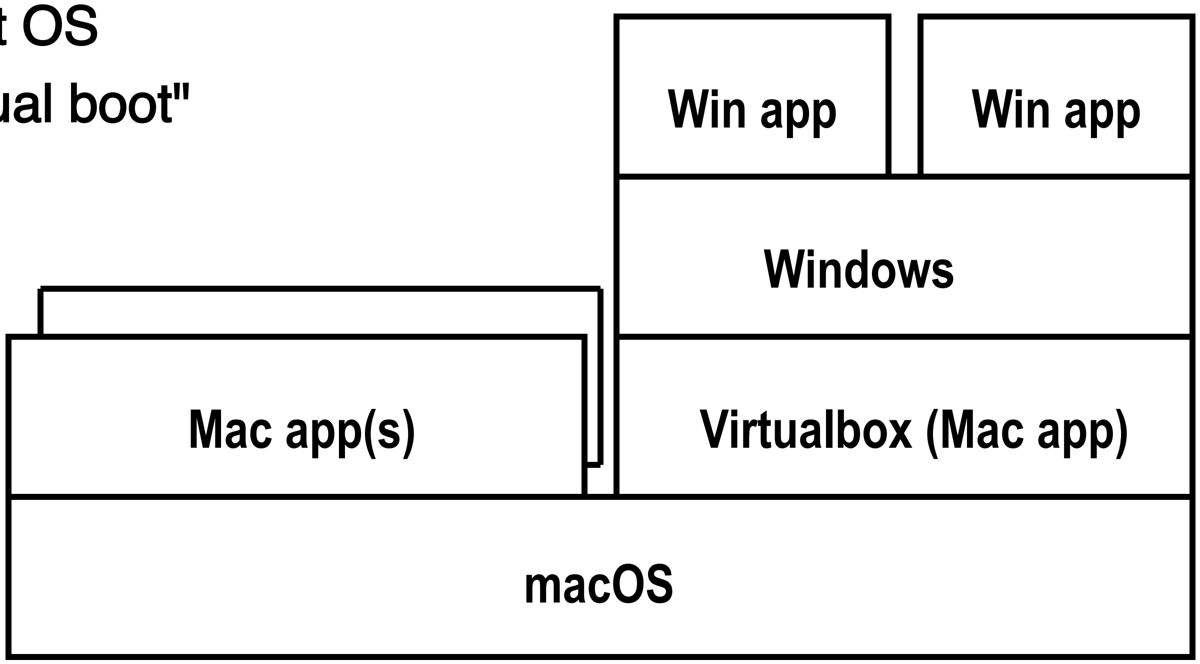


- reality is more complicated
  - pieces of programs are partly in RAM, partly on disk

    can only execute instructions that are in RAM
- memory protection:
  - making sure that one program can't damage another or the OS
- virtual memory:
  - making it look like there is more RAM than there really is

Virtual machines

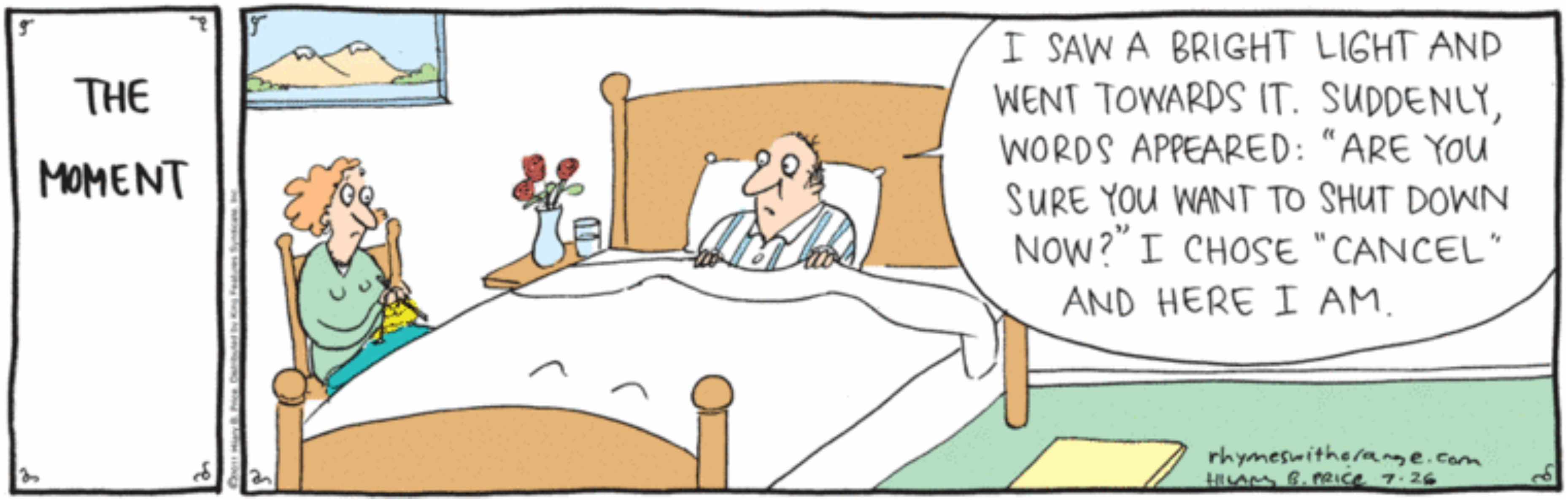
- running other operating systems on top of an OS
  - e.g., VMWare, VirtualBox, Xen, HyperV, ...
- system calls from applications to "guest" OS are intercepted by "host" OS
  - e.g., guest == Windows 10 or Linux, host == macOS
- passed to guest OS, which handles them by converting into system calls to host OS
- not the same as "dual boot"



Bootstrapping: how does it all get started?

- when turned on, user sees screen turn on, desktop appear, mouse/keyboard come alive
- underneath, CPU begins executing at a specific memory location when turned on
  - location is defined by the hardware: part of machine's design
  - often in flash memory so not volatile but still changeable

- "bootstrap" instructions place there read more instructions
  - CPU tries to read first block from disk, which has instructions to read more of the operating system
  - if that fails, tries to read bootstrap instructions from somewhere else
    - e.g., USB drive, network, ...


THE MOMENT
I SAW A BRIGHT LIGHT AND WENT TOWARDS IT. SUDDENLY, WORDS APPEARED: "ARE YOU SURE YOU WANT TO SHUT DOWN NOW?" I CHOSE "CANCEL" AND HERE I AM.
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