Slide 1

Administrivia

- Reminder: Homework 6 due today.
- Quiz 5 Friday. (We could do it Monday if most people will be here?)
- Homework 7 to be available early tomorrow. Due after the holiday.

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Minute Essay From Last Lecture

- (Naming conventions for devices — UNIX “special files” versus Windows drive letters.)
- Some votes for each, and several people thought the UNIX way seemed better for programmers and the Windows way for end users.

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I/O Continued — Device Specifics

- Next, a tour of major classes of devices. For each, we look first at what the hardware can typically do, and then at what kinds of device-driver functionality we might want to provide.

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Disks — Hardware

- Magnetic disks:
  - Cylinder/head/sector addressing may or may not reflect physical geometry — controller should handle this.
  - Controller may be able to manage multiple disks, perform overlapping seeks.
- RAID (Redundant Array of Inexpensive/Independent Disks):
  - Basic idea is to replace single disk and disk controller with “array” of disks plus RAID controller.
  - Two possible payoffs — redundancy and performance (parallelism).
  - Six “levels” (configurations) defined. Read all about it in textbook if interested.
- Optical disks — CD, CD-R, CD-RW, DVD. Okay to skim details!

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Disk Formatting

- Low-level formatting — each track filled with sectors (preamble, data, ECC bits).
- Higher-level formatting — master boot record, partitions (logical disks), partition table. Master boot record points to boot block in some partition. Partition table gives info about partitions (size, location, use).
- Partition formatting — boot block, blocks for file system.

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Disk Arm Scheduling Algorithms

- A little more about hardware: Time to read a block from disk depends on seek time, rotational delay, and data transfer time. First two usually dominate.
- Earlier we said that typical device driver for disk maintains a queue of pending requests (one per disk, if controller is managing more than one). What order to process them in? several “disk arm scheduling algorithms”:
  - FCFS (first come, first served).
  - SSF (shortest seek first).
  - Elevator.

  How do they compare with regard to ease of implementation, efficiency?

Disk Error Handling

- Almost all disks have sectors with defects. Some controllers can recognize them (repeated failures) and avoid them; if not, o/s (device driver) must do this.
- Other kinds of errors also possible, e.g., failure to correctly position read/write head; also must be handled either by controller (if possible) or o/s.

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Clocks — Hardware

- System clock — can be simple or programmable. Programmable clock can generate either one interrupt after specified interval or periodic interrupts (“clock ticks”).
- Backup clock — usually battery-powered, used at startup and perhaps periodically thereafter.

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Clocks — Software

- Clock(s) can be treated as I/O devices, with device driver(s). Functions to provide:
  - Maintain time of day.
  - Enforce time limits on processes.
  - Provide timer / alarm-clock function.
  - Do accounting, profiling, monitoring, etc.
  - Do anything required by page replacement algorithm (turn off R bits in page table entries, e.g.).
- Provide this functionality in code to be called on periodic clock-tick interrupts.

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Character-Oriented Terminals — Hardware Overview

- Hardware consists of character-oriented display (fixed number of rows and columns) and keyboard, connected to CPU by serial line.
- Actual hardware no longer common (except in mainframe world), but emulated in software (e.g., UNIX xterm) so old programs still work. (Why does anyone care? some of those old programs are still useful — e.g., text editors — and usually very stable.)

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Character-Oriented Terminals — Keyboard

- Hardware transmits individual ASCII characters.
- Device driver can pass them on one by one without processing, or can assemble them into lines and allow editing (erase, line kill, suspend, resume, etc.). Typically provide both modes.
- Device driver should also provide:
  - Buffering, so users can type ahead.
  - Optional echoing.

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Character-Oriented Terminals — Display

- Hardware accepts regular characters to display, plus escape sequences (move cursor, turn on/off reverse video, etc.).

  In the old days, escape sequences for different kinds of terminals were different — hence the need for a `termcap` database that allows calling programs to be less aware of device-specific details.
- Device driver should provide buffering.

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GUIs — Hardware Overview

- PC keyboard — sends very low-level detailed info (keys pressed/released); contrast with keyboard for character-oriented terminal.
- Mouse — sends (delta-x, delta-y, button status) events.
- Display can be vector graphics device (rare now, works in terms of lines, points, text) or raster graphics device (works in terms of pixels). Raster graphics device uses graphics adapter, which includes:
  - Video RAM, mapped to part of memory.
  - Video controller that translates contents of video RAM to display. Typically has two modes, text and bitmap.

  High-end controllers may incorporate processor(s) and local memory. (Indeed, they're becoming usable for general-purpose computing — "GPGPU".)

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GUI Software — Basic Concepts

- "WIMP" — windows, icons, menus, pointing device.
- Can be implemented as integral part of o/s (Windows) or as separate user-space software (UNIX).

GUIs — Keyboard

- Hardware delivers very low-level info (individual key press/release actions).
- Device driver translates these to character codes, typically using configurable keymap.

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GUIs — Display (Windows Approach)

- Each window represented by an object, with methods to redraw it.
- Output to display performed by calls to GDI (graphics device interface) — mostly device-independent, vector-graphics oriented. A `.wmf` file (Windows `metafile`) represents a collection of calls to GDI procedures. (Hm!)

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GUIs — Display (Traditional UNIX Approach)

- X Window System (its real name) designed to support both local input/output devices and network terminals, in terms of:
  - Programs that want to do GUI I/O.
  - Program that provides GUI services. Can run on the same system as applications, a different UNIX system, an X terminal (where it's the "o/s"), or under another o/s ("X emulators" for Windows).

  Which is the "client" and which the "server"?
- Core system is client/server communication protocol (input, display events akin to those in Windows) and windowing system. "Window manager" and/or "desktop environment" is separate, as are "widget" libraries. Modularity makes for flexibility and portability, at a cost in performance. Some Linux distributions moving toward alternatives (presumably to emphasize performance over flexibility).

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Minute Essay

- This wraps up what I have to say about I/O. Anything else you want to hear (more) about?