Operating Systems Design
24. Windowing
Paul Krzyzanowski
psk@cs.rutgers.edu

User Interfaces: 1\textsuperscript{st} Generation

Historically, the \textit{command-line interface}

\begin{verbatim}
cat *.txt | tr -cs "[:alpha:]" "\n" |
tr A-Z a-z | sed '/^$/d' |
sort | uniq -c | sort -nr
\end{verbatim}

User Interfaces: 2\textsuperscript{nd} Generation

Most users prefer a graphical UI

- Dominant interface:
  - desktop metaphor
  - WIMP (Window, Icon, Menu, Pointer) design paradigm
  - 1964-1968: Douglas Engelbart
    - 1968 demo: mouse, windows, hypermedia links, video teleconferencing
  - 1973: Xerox Alto – PC with GUI, folders, mouse, keyboard

WIMP

User Interfaces: 3\textsuperscript{rd} Generation

- Touch (& multitouch) interactive
  - no windows, mouse, pointer
  - Jeff Han, NYU: Multitouch sensing, 2006
  - huge mindshare due to the popularity of the iPhone & iPad

Hardware for graphics

- Fundamental interface
  - Framebuffer
    - Memory buffer containing a video frame
    - Memory mapped into system’s memory space
  - Graphics accelerator (GPU)
    - Send drawing commands to the GPU, which rasterizes the results onto a framebuffer
    - Abstraction libraries: OpenGL, DirectX/Direct3D
      - Provide a uniform interface for hardware graphics
    - Translate commands into GPU-specific commands
      - GPUs are multithreaded, driver may control thread scheduling
    - GPU’s results are sent to the framebuffer

© 2012 Paul Krzyzanowski
Windowing System
- Interfaces with mice, keyboards, cursor, & graphics HW
- Provides virtual interfaces to processes
  - Virtual screen (framebuffer)
  - Virtual keyboard
  - Virtual mouse

Window System

Virtual desktop
- Large virtual desktop (64K x 64K)
- Portions are mapped to monitors through views

X Window System (X11)
- Window system
  - User-level interface to hardware
  - Manages graphics card, keyboard, and mouse
  - I/O multiplexing
  - Client-server API
    - Create/destroy windows
      - Basic drawing (text, lines, fills) commands into windows

Windows Display Driver Model
- Virtual video memory (memory protection)
- GPU thread scheduling
- Lots of rendering APIs
  - Legacy: DirectDraw, Direct3D (3..8)
  - Mainline: GDI, Direct3D 9/9Ex, OpenGL
  - New: Direct3D 10, Windows Presentation Foundation
- Separate rendering from device management
  - Direct3D 10 manages graphics
  - DXGI component manages
    - Adapters, display modes, output, gamma/color, monitor controls
- Desktop Window Manager
  - Composited desktop

Kernel Interface: Windows ≥ Vista
Windows Display Driver Model (WDDM)
- Direct3D 10 manages graphics
- DXGI component manages
  - Adapters, display modes, output, gamma/color, monitor controls

Window Manager
- Handles interactions between windows, applications, and the underlying windowing system
- Does not interact with the hardware
- Stacking (floating) window manager
  - Draws windows in a specific order (sorted by z-order)
  - Allows overlapping windows by drawing background windows first
  - Contents have to be redrawn when window new parts exposed
  - Limited ability to accelerate with a graphics card
- Compositing window manager
  - Windows drawn separately. Graphics HW places them in a 2D or 3D environment
  - OS X, Vista and Windows 7 use this
- Hybrid: treat foreground window differently: have graphics card render it
X Windows

- **X Server**
  - Provides mechanism, not policy
  - Provide windows, drawing primitives, cut buffers, text rendering

- **Window manager**
  - Application that runs on X
  - Controls the placement & appearance of windows, icons, …
  - fvwm, 3dwm, afterstep, Window Maker, Enlightenment, …

- **Widget Libraries (Toolkits, APIs)**
  - Common UI components: scrollbars, sliders, dialog boxes, …
  - GTK, Qt, LessTif

- **Desktop environments**
  - Window manager + applications to provide consistent UI (program launchers, …)
  - GNOME, KDE, Software Compilation, CDE, …