Operating Systems Design

24. Windowing

Paul Krzyzanowski
pxk@cs.rutgers.edu
User Interfaces: 1st Generation

Historically, the command-line interface

- Still great for scripting, systems management, remote access, and customized operations

```
cat *.txt | tr -cs "[:alpha:]" "\n" |
tr A-Z a-z | sed '/^$/d' |
sort | uniq -c | sort -nr
```
Most users prefer a graphical UI

- Dominant interface:
  - desktop metaphor
  - **WIMP** (Window, Icon, Menu, Pointer) design paradigm
  - 1964-1968: Douglas Englebart
    - 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
Windowing System

- Interfaces with mice, keyboards, cursor, & graphics HW
- Provides virtual interfaces to processes
  - Virtual screen (framebuffer)
  - Virtual keyboard
  - Virtual mouse
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)
  – Allow 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
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  – Used in X Windows & Windows XP
• **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
Kernel Interface: Windows ≥ Vista

Windows Display Driver Model (WDDM)

- Windows Presentation Framework (WPF)
- Desktop Window Manager (DWM)
- Media Foundation
- Other components

Programming interface: rendering graphics, typography, media

Media codecs & rendering

DirectX Video Acceleration
- Direct3D 9
- Direct3D 9Ex
- Direct3D 10
- OpenGL

Device Driver Interface (DDI)

User Mode
- Win32 Kernel
- DirectX Graphics

Kernel Mode
- DirectX Graphics
- Kernel Driver

supplied by hardware vendor

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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
Virtual desktop

• Large virtual desktop (64K × 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

Optional component: renders desktop. Responsible for window frames, icons, task bars, etc.

Some events are redirected to the window manager (e.g., create/move window)
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, At, LessTif

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