Operating Systems Design
24. Windowing

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User Interfaces: 1st Generation

Historically, the command-line interface

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

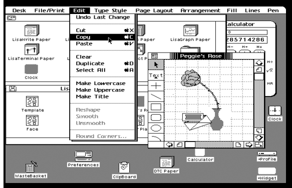
```
cat *.txt | tr -cs "[:alpha:]" "\n" |
    tr A-Z a-z | sed '/^$/d' |
    sort | uniq -c| sort -nr
```

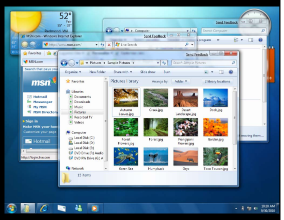
User Interfaces: 2nd Generation

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



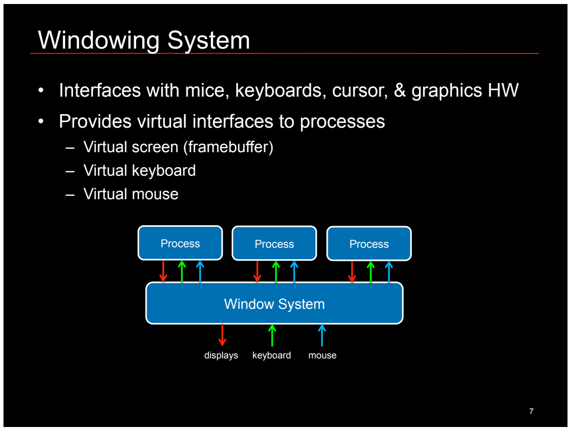


User Interfaces: 3rd Generation

- 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

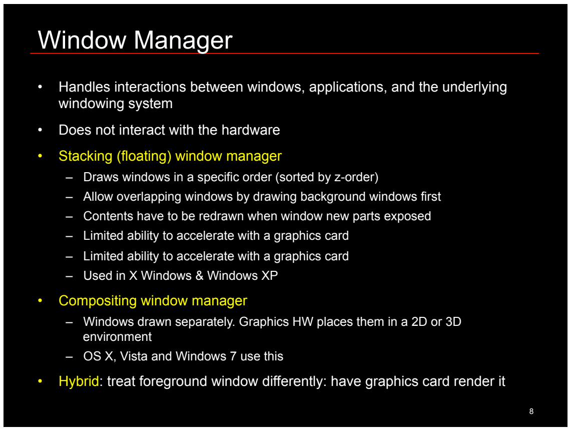
- Fundamental interface
  - Framebuffer
    - Memory buffer containing a video frame
    - Memory mapped into system's memory space
- Graphics accelerator (GPU)
  - Send drawing commands to the GPU, which rasterizes the results onto a framebuffer
  - Abstraction libraries: *OpenGL, DirectX/Direct3D*
    - 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 sent to the framebuffer



Windowing System

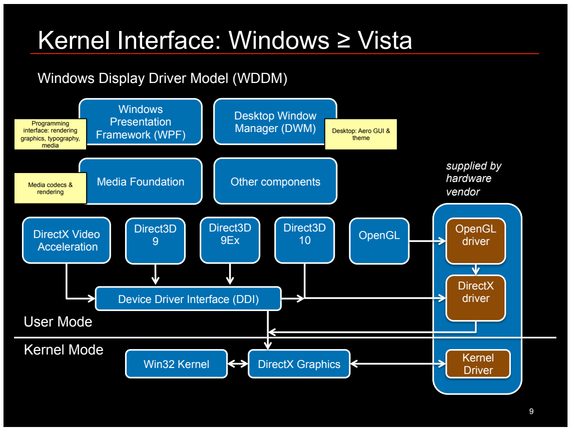
- Interfaces with mice, keyboards, cursor, & graphics HW
- Provides virtual interfaces to processes
  - Virtual screen (framebuffer)
  - Virtual keyboard
  - Virtual mouse

Process
Process
Process
Window System
displays
keyboard
mouse



Window Manager

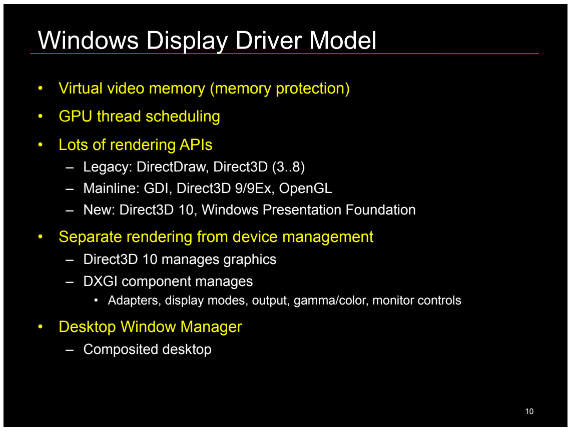
- Handles interactions between windows, applications, and the underlying windowing system
- Does not interact with the hardware
- Stacking (floating) window manager
  - Draws windows in a specific order (sorted by z-order)
  - Allow overlapping windows by drawing background windows first
  - Contents have to be redrawn when window new parts exposed
  - Limited ability to accelerate with a graphics card
  - Limited ability to accelerate with a graphics card
  - 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

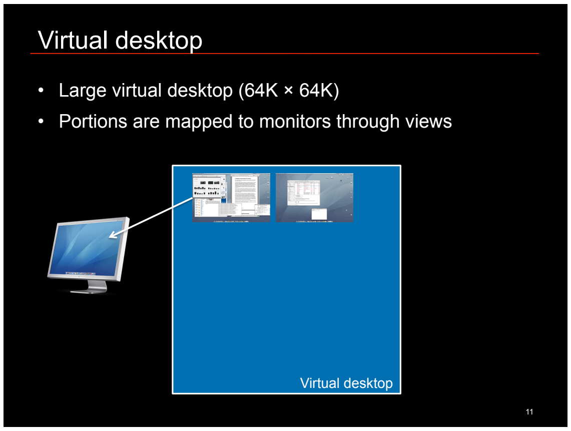
Windows Display Driver Model (WDDM)

Programming interface: rendering graphics, typography, media
Windows Presentation Framework (WPF)
Desktop Window Manager (DWM)
Desktop: Aero GUI & theme
Media codecs & rendering
Media Foundation
Other components
supplied by hardware vendor
DirectX Video Acceleration
Direct3D 9
Direct3D 9Ex
Direct3D 10
OpenGL
OpenGL driver
DirectX driver
Device Driver Interface (DDI)
User Mode
Kernel Mode
Win32 Kernel
DirectX Graphics
Kernel Driver



Windows Display Driver Model

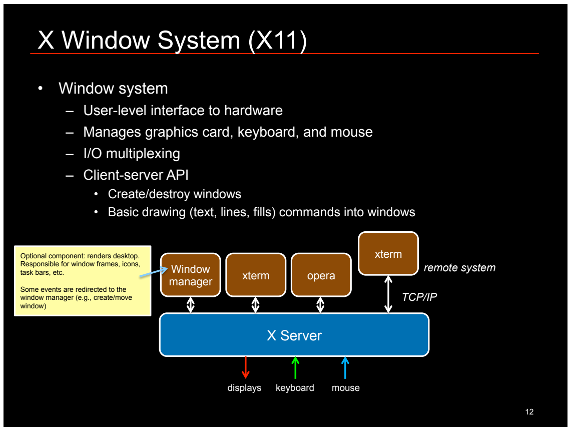
- Virtual video memory (memory protection)
- GPU thread scheduling
- Lots of rendering APIs
  - Legacy: DirectDraw, Direct3D (3..8)
  - Mainline: GDI, Direct3D 9/9Ex, OpenGL
  - New: Direct3D 10, Windows Presentation Foundation
- Separate rendering from device management
  - Direct3D 10 manages graphics
  - 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

Virtual desktop



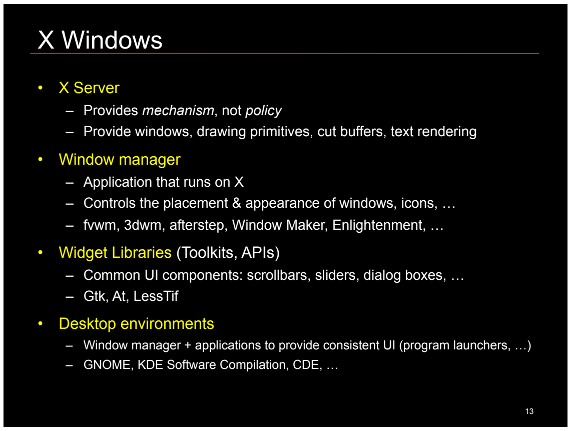
X Window System (X11)

- 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)

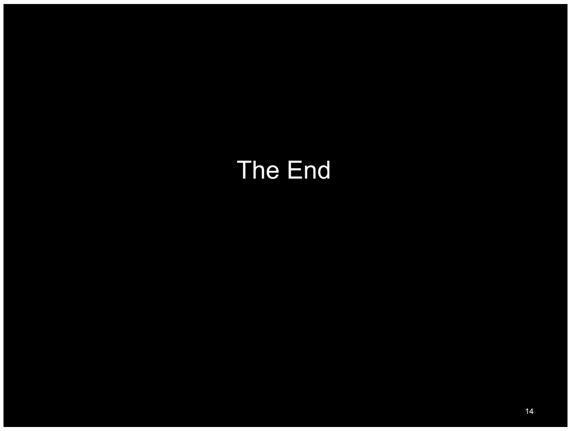
Window manager
xterm
opera
xterm
remote system
TCP/IP
X Server
displays
keyboard
mouse



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, …

13



The End

14