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CS 560

Computer Graphics

Professor Richard Eckert

Lecture # 4

January 31, 2001

Lecture 4

Wednesday, 1-31-01

- A. An Introduction to MFC Programming, continued
- B. Computer Graphics Hardware

SKETCH Application

- Example of Using AppWizard and ClassWizard
- Mouse used as a drawing pencil
- Left mouse button down
  - Line in window follows mouse motion (sketching)
- Left mouse button up
  - Sketching stops
- User clicks "Drawing Color" menu item
  - popup menu to choose drawing color
- User clicks "Clear" menu item
  - Window client area is erased

Last Class We:

- Used AppWizard to set up an SDI Skeleton
- Defined Variables in View Class:
  – m_butdn, m_ptold, m_pt, m_color, *pDC
- Used Menu Editor to add menu items:
  – IDM_RED, IDM_GREEN, IDM_BLUE, IDM_CLEAR
- Used ClassWizard to add handlers for:
  – WM_LBUTTONDOWN, WM_LBUTTONUP
  – WM_MOUSEMOVE

Code Requirements

- WM_LBUTTONDOWN:
  – Set m_butdn to TRUE & record point in m_ptold
- WM_LBUTTONUP:
  – Set m_butdn to FALSE

WM_MOUSEMOVE handler code:

- *if (m_butdn)*
  - *{pDC = GetDC();*
  - *m_pt = point;*
  - *CPen pen(PS_SOLID, 1, m_color);*
  - *CPen *pPenOld = pDC->SelectObject(&pen);*
  - *pDCMoveTo(m_ptold);*
  - *pDCLineTo(m_pt);*
  - *m_ptold = m_pt;*
  - *pDC->SelectObject(pPenOld);}*

Adding the WM_COMMAND menu item handlers

- Invoke ClassWizard and scroll "ObjectIDs" list (not "Messages") to "IDM_BLUE"
- Select it and choose "COMMAND" in "Messages" list box
- Click "Add Function" button
- Click "OK" in resulting "Add Member Function" dialog box

- Result:
  - ClassWizard generates *On_Blue()* handler to message map
  - Press "Edit Code" to go to skeleton handler and add following code after // TODO...

    m_Color = RGB(0,0,255);
- Do same to add *OnGreen()* and *OnRed()* handlers
- Add *OnClear()* handler in same way
- Code to be added:

  Invalidate(); //forces WM_PAINT msg

Member Variable Initialization

- All data members added to *CSketchView* class must be initialized
  - If not, they will contain garbage when application begins
- From Project Workspace window choose ClassView icon
  - Expand "sketch classes" icon and *CSketchView* Class icon

– Double click on *CSketchView()* constructor

– Add following initialization code under "// TODO..." comment:

```
m_pt = m_ptold = CPoint(0,0);
m_butdn = FALSE;
m_color = RGB(0,0,0);  // initial draw color black
```

Build project

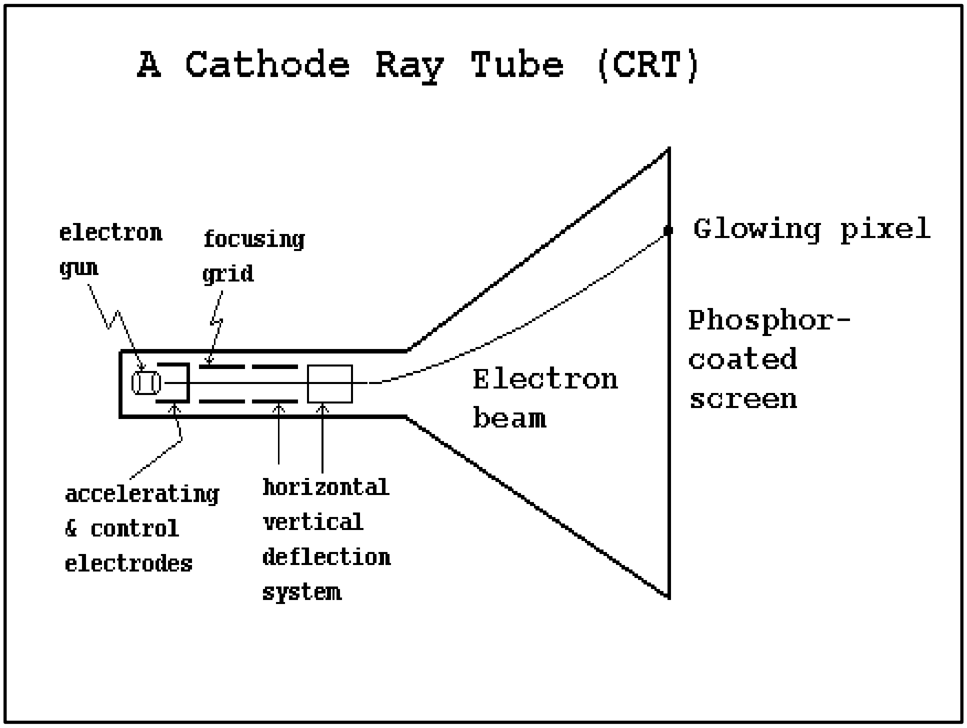
- “Build” from main menu
- If no errors, you get a functioning Document/View color sketching application

Lecture 4, Part B:

Introduction to Computer Graphics Hardware

GRAPHICS HARDWARE

- Display Devices
  - Vector Scan
  - Raster Scan
- Both based on CRT (TV)
  - Electron beam accelerated toward screen
    - focused
    - deflected
    - strikes phosphorescent material on screen
      -->pixel that glows



A Pixel

- Visible point where electron beam hits screen
- Screen phosphors glow & fade
- Have a finite size
- Not a mathematical point

Resolution

- Max number of pixels that can be plotted without overlap
- Expressed in # horizontal X # vertical pixels
- Depends on:
  - phosphor used
  - focusing system (how small a point)
  - speed of deflection system
  - video memory size (raster scan)--as we'll see

Aspect Ratio

- Ratio of # of pixel columns to # of pixel rows
- Examples:
  - SVGA VESA mode 100h: 640 X 400, A.R. = 1.6
  - Standard Windows: 640 X480. A.R. = 1.33
- **Pixel Ratio** (often called Aspect Ratio)
  - Ratio of pixel height to pixel width
  - Ratio of # of horizontal pixels to vertical pixels needed to produce equal length lines
  - For a square screen, A.R. = P.R.
  - If P.R. != 1, figures are distorted

Dot Pitch

- Minimum distance between centers of adjacent pixels of same color
- Should be less than 0.28 mm for sharp images
- For fixed sized screen
  - Decreasing distance between pixels ==> Increase Resolution
  - So dot pitch determines max resolution

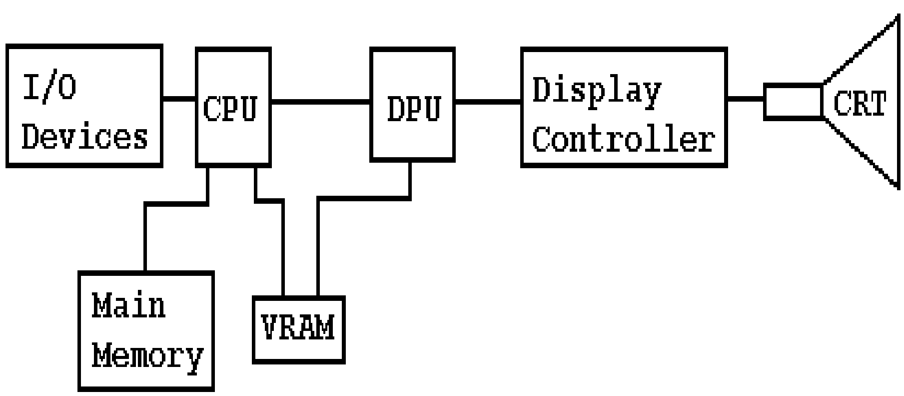
Persistence

- After beam leaves a phosphor, it fades
- Definition of persistence:
  - Time to reduce initial intensity by 10%
  - Value depends on type of phosphor (10 - 100 msec.)
- Finite persistence==>screen must be redrawn
  - Refresh rate determined by persistence
- Example: If persistence = 20 msec
  - 1st pixel on screen invisible after that time ==>
    - screen must be refreshed once every 20 msec
    - so refresh rate must be > 50 Hz.

A Graphics Hardware System

- CPU--Runs pgm specifying what is to be drawn
- CRT--does the actual display
- Display Controller--Provides analog voltages needed to move beam and vary its intensity
- DPU--generates signals that drive display controller
  - (offloads task of video control to separate processor)
- VRAM--Stores info needed to draw the picture
  - Dual-ported (written to by CPU, read from by DPU)
  - Fast (e.g., 640X480, 50 Hz ==> 65 nsec access time!)
  - Also called Refresh Buffer or Frame Buffer
- I/O devices--interface CPU with user

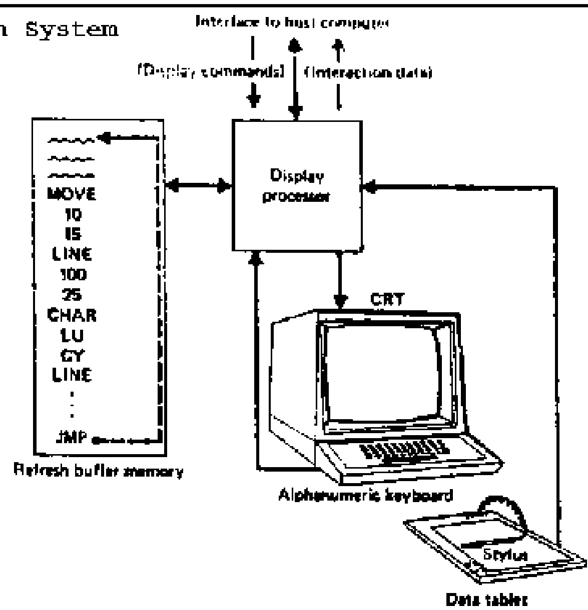
A Computer Graphics Hardware System (General)



Vector Scan systems

- Also called random, stroke, calligraphic displays
- Images drawn as line segments (vectors)
- Beam can be moved to any position on screen
- Refresh Buffer stores plotting commands
  - So Refresh Buffer often called "Display File”
  - provides DPU with needed endpoint coordinates
  - Pixel size independent of frame buffer
    - ==> very high resolution

Vector Scan System



Typical refresh display device. Display list in memory shows symbolic representation of plotting commands followed by values (e.g., *x*, *y* coordinates or characters).

Advantages of Vector Scan

- High resolution (good for detailed line drawings)
- Crisp lines (no "jaggies")
- High contrast (beam can dwell on a pixel==>very intense)
- Selective erase (remove commands from display file)
- Animation (change line endpoints slightly after each refresh)

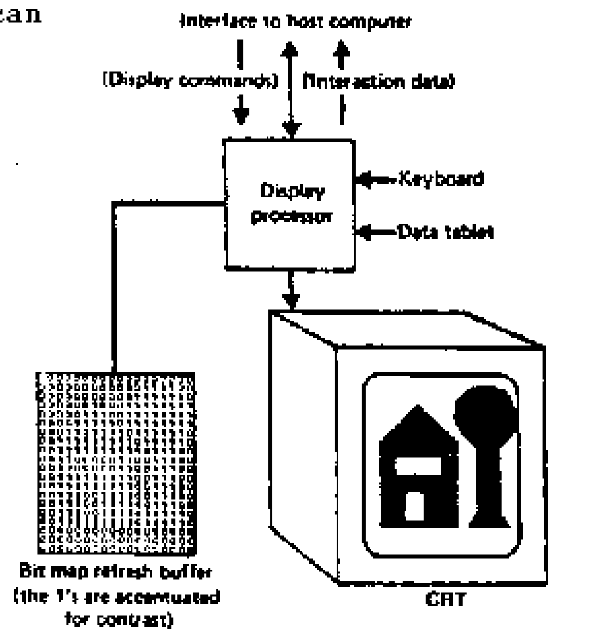
Disadvantages of Vector Scan

- Complex drawings can have flicker
  - Many lines
    - so if time to draw > refresh time ==> flicker
  - High cost--very fast deflection system needed
  - Hard to get colors
  - No area fill
    - so it’s difficult to use for realistic (shaded) images
  - 1960s Technology, only used for special purpose stuff today

Raster Scan Systems (TV Technology)

- Beam continually traces a raster pattern
- Intensity adjusted as raster scan takes place
  - Beam focuses on each pixel
  - Intensity value stored in refresh (frame) buffer
  - So resolution determined by size of frame buffer
- Each pixel on screen visited during each scan
  - Scan rate must be >= 30 Hz to avoid flicker

Raster Scan System



Typical raster graphics display showing house and tree.

Simplest system: one bit per pixel

- frame buffer called a bitmap

Gray Scale: N bits/pixel

- 2^N intensities possible
- memory intensive
  - Example:1000 X 1000 X 256 shades of gray ==> 8 Mbits

Scan Conversion

- Process of determining which pixels need to be turned on in the frame buffer to draw a given graphics primitive
- Need algorithms to efficiently scan convert primitives like lines, circles, etc.

Advantages of Raster Scan Systems

- Low cost (TV technology)
- Area fill (entire screen painted on each scan)
- Colors
- Selective erase (just change parts of bitmap)
- Bright display, good contrast
  - but not as good as vector scan:
  - can't make beam dwell on a pixel

Disadvantages

- Large memory requirement for high resolution
  - (but cost of VRAM has decreased!)
- Aliasing (due to finite size of pixels)
  - Jagged lines (staircase effect)
  - Moire patterns, scintillation, "creep" in animations
- Raster scan is the principal "now" technology for graphics displays!

Tektronix Direct View Storage Tube

- 1st "inexpensive" graphics display device
- Extension of vector scan technique
- Two electron guns
  - writing gun
  - flood gun

- Writing gun beam knocks electrons out
  leaves + charges behind (constitute image)
- Flood gun supplies continuous source of unfocused electrons
  - migrate toward the + charges on grid
  - pass through grid and strike screen phosphors
    --> lighted dots
  - electrons continue to hit + charges
  - continuous light (Up to an hour)

Erasure of DVST image

1. Plus charge applied to entire grid
   – Attracts electrons to entire grid
   – Entire screen flashes (Image gone)
2. Minus charge applied to entire grid
   – Provides electrons that can be knocked out by writing gun
   – Ready to draw next image with writing gun

Advantages to DVST

- No refresh needed
  – unlimited image complexity possible
- High resolution
- Crisp lines
- Low cost
  – no fast refresh circuitry needed

Disadvantages to DVST

- No selective erase
  - whole image or nothing
- No animation
- Low light output
  - poor contrast
  - must use in subdued light
- No color
- No area fill

Interlaced Displays

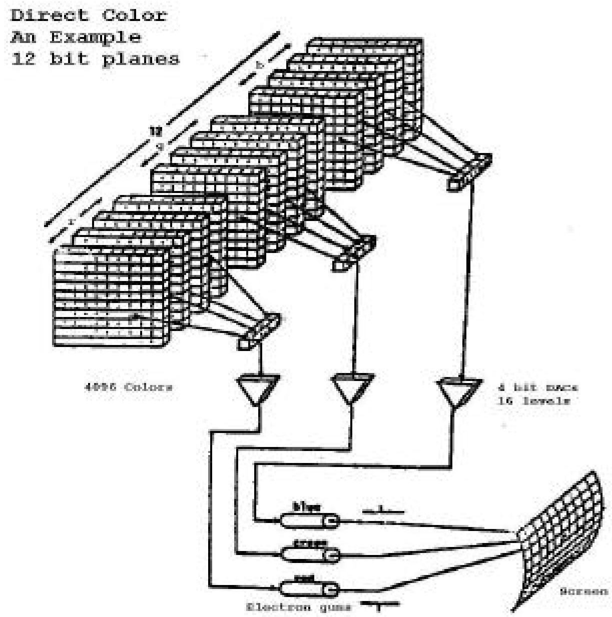
- All even then all odd screen lines scanned
- Typically 1/60 second each
  - Same image presented twice in 1/30 second
  - Image changed at 1/2 non-interlaced frequency
    - less demands on image generation system
    - can be less expensive
    - 30 Hz is borderline for flicker
    - lower quality image (seeing half the image at a time)

Color Display Hardware (raster)

- Each screen pixel composed of 3 phosphors
  - glow red, green, and blue
- 3 electron guns shoot their beams through a shadow mask
  - so beams hit the sensitive phosphors
- Intensity of 3 beams determines how bright each phosphor glows
- Human eye detects an additive color mix
  - e.g., max red, green, & blue perceived as white

Direct color systems

- Frame buffer divided into bit planes
- A bit plane contributes one bit to color of pixels
- If resolution of the screen is W x H pixels:
  - a bit plane is a W x H x 1 bit memory
- Bit planes can be organized into 3 sets
  - Each called a color channel: (R, G, B)
  - Bit planes of a color channel provide the intensity values fed to that channel's electron gun
- A system with N bit planes per color channel:
  - 2^N red, 2^N green, & 2^N blue shades
  - 2^3N different colors displayable simultaneously



True Color & High Color Systems

- True color: direct color system with:

  N=8

  so 2^24 = 16,777,216 different colors possible for each pixel on screen

  More colors than discernable by human eye

- High color: direct color system with:

  Nr=5, Ng=6, Nb=5

  2^16 = 65, 536 different colors possible