Hardware of a CAD/CAE/CAM System

25.353 Lecture Series

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History of Computer Systems

- **Mainframe Computer and Graphics Terminals**
  - “In these early years, it was common practice to wait in line to use a dedicated CAD terminal that sat in a cold, dark climate-controlled room.”

- **1980s and early 1990s** open hardware architecture and standard operating system; general-purpose hardware suppliers

- **Workstations & High-End Personal Computers**
  - Solve the memory, speed and storage problems
  - Supporting network
  - Graphics capability
  - Low costs
Basic Architecture of a CAD System

- Mainframe-based systems
  Minicomputer-based systems

- Workstation-based systems
  Microcomputer-based systems

(Nanua Singh, 1996)
Mainframe-/Minicomputer-based systems

- Powerful
- Inconvenient
- High cost
- Specialized devices and software
- Unpredictable response time

(Nanua Singh, 1996)
Workstation-/Microcomputer-based Systems

(CAD Workstation, Computer Terminals)

- Graphical Input
- Alpha-Numeric Input
- Graphical Output
- Alpha-Numeric Output
- Computer
  - CPU
  - HD
  - Display
  - RAM
  - Raster Display Processor

Local Net Work

- Low costs;
- Present and Trend
- Ease of use
- Easy maintenance
- No response delay
- Standardized hard/Software
## Output/Input Devices

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Basic Graphics Concepts

- **Dot Size**, spot size, the diameter of a single dot created on the device.
- **Addressability**, the number of individual dots per inch that can be created
  - differ in the horizontal and vertical directions.
  - The reciprocal of addressability is called **Interdot Distance**.
- **Resolution**, the number of distinguishable lines per inch that a device can create.
Vector vs. Raster Display

Vector Graphics/Display (before the early 1980s)
Image created by a sequence of straight line segments, which are defined by the coordinates $x$ and $y$ of their end points.

Raster Graphics/Display (dominant)
Screen is divided into a matrix of discrete cells called pixels, each of which can be made bright.
Lines can be approximated by a series of pixels close to the path of the line.
Vector vs. Raster Display (cont’d)

Vector or Stroke Device
(example – pen plotter)

Raster Scan Device
(example - dot matrix printer, laser printer)

Instructions:

Pen up $X^4, Y^4$
$X^1, Y^1$ $X^5, Y^5$
Pen down $X^1, Y^1$
$X^2, Y^2$ Pen up
$X^3, Y^3$

Use an array $A (I,J)$
where each element is "0" or "1"
0 – blank
1 – dot

(Kunwoo Lee, 1999)
Cathode Ray Tube (CRT)

The first commercially practical CRT perfected on January 29, 1901 by Allen B DuMont.
Monitors (1)

A Vector Device

\[ \begin{align*}
V_H & \quad \text{Horizontal Voltage} \\
V_V & \quad \text{Vertical Voltage} \\
V_c & \quad \text{Beam Control Voltage}
\end{align*} \]

- \( V_H = \) Beam on
- \( V_H = \) Beam off
- \( V_V = \) Beam on
- \( V_V = \) Beam off
- \( V_c = \) Beam on
- \( V_c = \) Beam off

From computer

Display Controller

-2 -3 0

-6 -5 1

-8 -3 1

D/A Converter

Electron Gun

VH

VV

Vc

Phosphor screen

Illuminated spot
Raster Display (cont’d)

- **Frame Buffer**
  - N = 3
  - $2^N$ Levels

- **Register**
  - N

- **2$^N$ DAC**

- **CRT Raster**
24-bit-plane color frame buffer

(Picture adopted from reference 4)

(David F. Rogers, 1998)
Size of Frame Buffer

Given: A 24-bit-plane color frame buffer has a 1280 x 1024 vertical dot matrix. Find the least RAM size of the bitmap (refresh buffer). If the resolution is 78 pixels per inch, what is the active display area of the screen?

Solve required frame buffer
1. size of frame buffer = 24 x 1280 x 1024 / 8 bits/byte = 3932160 byte or 3.9 MB
2. The active display area = 1280/78 * 1024/78 = 16.4” * 13.1”. 
Comparison of Vector and Raster Devices (pros)

Vector

• Good resolution
  - Straight lines
  - Smooth curves

• Require limited memory and few instructions

Raster

• Fixed frame buffer size and scanning independent of picture complexity

• Can do halftones shading
Comparison of Vector and Raster Devices (cons)

- **Vector**
  - Slow for complex images -- flicker on CRT
  - Two-level color intensity thus shading difficult and slow

- **Raster**
  - Limited resolution (Staircase (or called ‘zigzags’))
  - Requiring large memory for array storage
Other Types of Display

- Flat CRT
- Liquid Crystal Display (LCD)
- Plasma-Panel / Electro-Luminescent Display (ELD)
Liquid Crystal Display (LCD)
Gas-Plasma/Electro-Luminescent Display (ELD)

- Light emission from gas-discharge elements arranged in a matrix.
- Works much like a fluorescent or neon light in which light at certain wavelengths is emitted by ionizing gases entrapped between cathodes and anodes with the passage of a current at high voltage.
- AC-driven panels for color TV display and DC-driven panel for computer display
- Currently electro-luminescent display technology is more widely used.
## Comparison of CRT, LCD and ELD

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<th>Electro-luminescent</th>
<th>Liquid Crystal</th>
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<td>Power consumption</td>
<td>fair</td>
<td>fair–good</td>
<td>excellent</td>
</tr>
<tr>
<td>Screen size</td>
<td>excellent</td>
<td>good</td>
<td>fair</td>
</tr>
<tr>
<td>Depth</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Weight</td>
<td>poor</td>
<td>excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Ruggedness</td>
<td>fair–good</td>
<td>good–excellent</td>
<td>excellent</td>
</tr>
<tr>
<td>Brightness</td>
<td>excellent</td>
<td>excellent</td>
<td>fair–good</td>
</tr>
<tr>
<td>Addressability</td>
<td>good–excellent</td>
<td>good</td>
<td>fair–good</td>
</tr>
<tr>
<td>Contrast</td>
<td>good–excellent</td>
<td>good</td>
<td>fair</td>
</tr>
<tr>
<td>Intensity levels per dot</td>
<td>excellent</td>
<td>fair</td>
<td>fair</td>
</tr>
<tr>
<td>Viewing angle</td>
<td>excellent</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Color capability</td>
<td>excellent</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Relative cost range</td>
<td>low</td>
<td>medium–high</td>
<td>low</td>
</tr>
</tbody>
</table>
Printer

- Dot-matrix printer
- Laser printer
- Ink-jet printer
- Thermal transfer printer
Graphical Input Devices

- Keyboard
- Tablet and Puck
- Light Pen
- Valuator
- Mouse
- Touch Screen
- 3-D Scanning devices
Key Parameters for Input Devices

**Resolution**: the smallest distance the device requires to recognize two adjacent points as spatially separate or addressable.

**Accuracy**: the error in the measurement of actual data by the input data.

**Repeatability** measures the device ability to return to a given position.

**Linearity** measures the response of a device to the user hand movements.
Keyboard

Alphanumeric characters

ASCII (American Standard Code for Information Interchange)

A --- 1000001
a --- 1100001
Tablet and Puck

Tablet Coordinates

Screen

Command Buffer

x1 x2

y1 y2
Tablet

(Ibrahim Zied, 1991)
Valuators/Control Dials

Valuators provide scalar values that are based on potentiometers. Generally this value is a real number between zero and some real maximum.

Used for activating rotation, translation, scaling or zoom function.

(adapted from reference 10)
Light Pen

- The photomultiplier records the passage of the electron beam. Time lapse from the start of Raster determines the pen location.
Mouse

measures its relative movement from its last position

The rotation of the wheel is encoded into digital values via potentiometers
Trackball

A trackball allows a precise fingertip control. The ball rotates freely within its mount. It was used historically in radar and flight control systems to navigate the screen display cursor.
Mouse and Joystick
Touch Screen

- Arrays of infrared light sources and array of detectors are used to generate invisible light grids. A finger interrupts two light beams and provides x and y coordinates.
Scanning Devices (3-D)

- Digitizer
- Scanner
- Machine vision
3-D Digitizer

Contact
Non-contact

(adapted from reference 7)
Data Glove

The data glove records 3D hand and finger positions as well as motions. Many pressure sensors are embedded in the glove finger joints. The sensor converts the small pressure generated by blending the finger into an electrical signal.
Scanner
Triangulation-based Scanning
References

2. http://www.sceptre.com/Products/Monitors/definitions/definitions.htm#CRT
6. http://www.5dt.com/hardware.html#glove
Quick Questions

- Raster devices are good for shaded images
- Vector devices have poor resolution for smooth curves
- LCD involves the light emission from gas-discharge elements
- Touch sensors work by detecting blocked light beams by finger, pen, etc.
- An eight-plane raster display (8bits/pixel) has a 640*800 dot matrix, what is the minimum refresh buffer size?
- If one sees 10 black lines per inch on a white screen, the resolution of the device is then 10 lines/inch along the direction.
- Today’s hardware of a CAD system needs only common and inexpensive devices.
- 3D scanners are widely used in reverse engineering.
Summary

- Evolution of hardware configuration for CAD systems
- Output devices
  - Vector devices versus raster devices
  - Printers
  - CRT, LCD, ELD
- Input devices
- Scanning devices