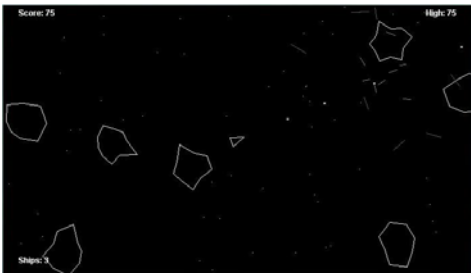


Department of Computer Science **Vector Graphics**

- Used for pen plotters and vector displays



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Department of Computer Science **Polylines**

- A **polyline** is a connected sequence of straight lines
 - Example: sequence (2,4), (2,11), (6,14), (12,11), (12,4), etc.
 - Each pair of points defines a line segment
 - This is a *line drawing*

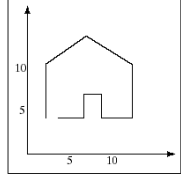


FIGURE 1.10 A sample polyline.

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Department of Computer Science **Polylines**

- Terms:
 - Edge** – line segment in multi-line polyline
 - Vertex** – endpoint of two edges
- Polylines can be *open* or *closed*
 - Open – first and last points are not connected by a line segment
 - Closed – forms a *polygon*

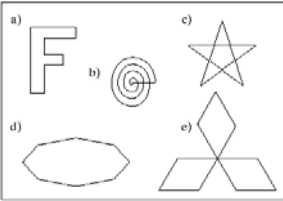
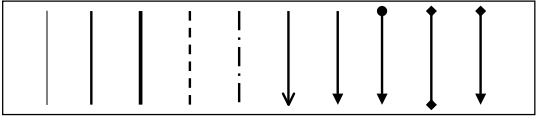


FIGURE 1.11 Examples of polygons.

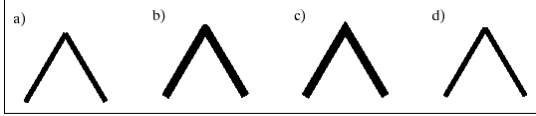
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Department of Computer Science **Polylines**

- Can vary line attributes to alter appearance
 - Thickness – in terms of point size
 - Composition – continuous, dashed, arrows



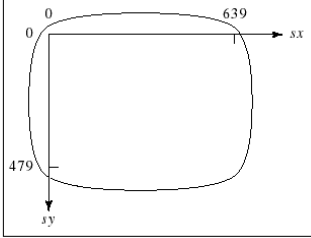
- At vertices, can alter method of joining



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Department of Computer Science **Raster Displays**

FIGURE 1.35 The built-in coordinate system for the surface of a raster display.



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Department of Computer Science **Raster Displays**

- Important component: frame buffer
 - Holds the image to be displayed
 - Each pixel is represented by data in the frame buffer
 - Display refreshed (redrawn) line by line, top to bottom
 - May alternate rows (0, 2, 4, ..., 1, 3, 5, ...) to avoid flicker

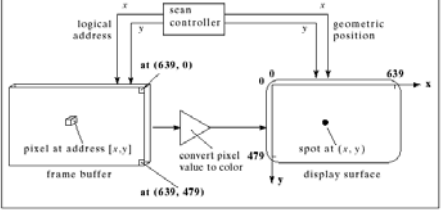


FIGURE 1.37 Scanning out an image from the frame buffer to the display surface.

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Video Monitor

- Based on cathode-ray tube (CRT) technology

FIGURE 1.38 Operation of a color video monitor display system.

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Video Monitor

- Number of "planes" in the frame buffer (FB) determines the color depth
 - Six planes → six bits per pixel
 - Bits are paired; pairs associated with colors (RGB)
 - Two bits per color → four voltage/brightness levels
 - Thus, $4 \times 4 \times 4 = 64$ different color combinations
 - Input/Output characteristics of a two bit DAC:
- Raster display pixels are identified by (x,y) coordinates
 - Note orientation – (0,0) at top left

Value	Voltage
00	$0.0 * \text{Max}$
01	$0.333 * \text{Max}$
10	$0.666 * \text{Max}$
11	$1.0 * \text{Max}$

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Video Monitor

- Alternate color scheme: use a lookup table (LUT)
 - Programmable association between FB and color
 - LUT entries can be N-bit per color → wider color palette

FIGURE 1.40 A color display system that incorporates an LUT.

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Display Characteristics

- Number of colors **displayable** is dependent on width (w) of whatever drives the color guns
 - E.g., 24-bit LUT → 2^{24} colors → 16,777,216 colors
- Number of colors displayable **at one time** depends upon depth of the FB in bits (b)
 - E.g., 8-bit FB → 2^8 colors → 256 colors
- Normally, $w > b$

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Display Comparisons

- Relative cost of direct vs. LUT approaches.

FIGURE 1.41 Comparison of two raster display systems.

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Hard-Copy Raster Devices

- Various types of printed output
 - Film recorders
 - Laser printer
 - Inkjet plotter
- Printers accept print jobs in the format of a **page description language**
 - PostScript
 - PDF
 - TIFF, etc.
- PostScript is **device-independent**
 - Different printers produce same basic image (barring quality differences).

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Raster Images

- Array of small **cells**.
- Each cell represents a **pixel**.
 - Often called a pixel map, or bitmap

2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	7	7
2	2	2	2	2	7	7	1	1	1
2	2	2	7	1	1	1	1	1	1
2	2	2	7	1	1	1	1	1	7

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Raster Images

- Simplest form of a bitmap – two levels, one bit per pixel, or a **pixel depth of 1**.
- To generalize, a pixel depth of **n** has 2^n possible levels.

1	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	0	0	0	0	0
1	1	1	1	1	1	0	0	0	0
1	1	1	1	1	1	1	0	0	0
1	1	1	1	1	1	1	1	0	0
1	1	1	1	1	1	1	1	0	0
1	0	1	1	1	0	0	0	0	0
1	0	0	0	1	1	0	0	0	0
0	0	0	0	1	1	0	0	0	0
0	0	0	0	0	1	1	0	0	0
0	0	0	0	0	1	1	0	0	0
0	0	0	0	0	0	1	1	0	0
0	0	0	0	0	0	0	1	1	0
0	0	0	0	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0

FIGURE 1.26 (a) A bilevel image of a cursor. (b) A bit map of the image.

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Raster Images

- Lines that are not horizontal or vertical suffer the **jaggies** when zoomed in on.
- **Antialiasing** is a technique used to minimize jaggies.

FIGURE 1.21 (a) A collection of lines and text. (b) Blowup of part (a), having "jaggies".

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Flat Panel Display

- Alternate approach to raster display
 - Grid wires control polarization of LC molecules.
 - Either block light or allow it to pass through.

FIGURE 1.42 Flat-panel displays.

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Active Matrix and Plasma Panels

- Active matrix panels
 - LCD panels with tiny transistors at each pixel.
 - Brightness is controlled by adjusting the liquid crystals proportional to the electric field.
 - The transistors provide **memory** that holds the crystals in their adjusted state
 - No need to constantly refresh the display.
- Plasma panels
 - Tiny neon bulbs at each pixel, controlled by an electric field.
 - Also provides memory.

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Text

- Two distinct display modes
 - **Text mode** – built in characters with limited positioning.
 - **Graphics mode** – Richer set of character shapes and positioning.

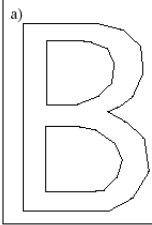
Text mode - Zork

Graphics mode

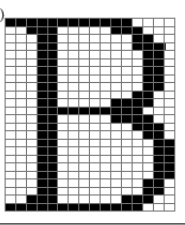
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Department of Computer Science **Text**

- Can alter fonts (typefaces)
- Can represent characters as polylines or bitmaps



a) polylines



b) bitmap

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Department of Computer Science **Lots of Polygons**

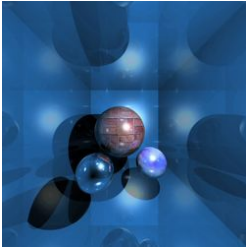
- Most objects are represented as a set of surface polygons



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Department of Computer Science **Ray Tracing**



- Ray Tracing in real time?
 - http://en.wikipedia.org/wiki/Ray_tracing#Ray_tracing_in_real_time



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Department of Computer Science **Graphics Input Devices**

- Different devices send different types of input:
 - **Valuator** - value within a range (e.g., 0.0-1.0).
 - **String** - sequence of characters.
 - **Choice** - selection from a set of options.
 - **Locator** - position
- Types of devices:
 - Keyboard
 - Mouse, joystick, trackball
 - Buttons
 - Tablet
 - Knobs
 - Many others

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