

Computer Graphics

Lecture 02

A Brief History of Graphics Hardware

- **1950's:** Line printers and pen plotters
Both are limited to monochrome hard copy in batch mode. The line printer is a low-resolution raster scan device characterized by sequential access. Gray shades are produced by overstriking. The pen plotter is a high-resolution vector graphics or random-scan device in which the primitives (lines or vectors) are stored as a sequence of commands and endpoint coordinates.
- **Mid 1960's:** Vector system consisting of a CRT, display buffer, and display processor
- **Late 1960's:** Direct-view storage tube (DVST) (Tektronics terminal) | a monochrome CRT with long-persistence phosphor which eliminated the buffer and refresh process
- **Early 1970's:** CRT-based raster systems based on TV technology
- **Late 1970's:** PC, Dot matrix printer, and light pen
- **1980's:** Graphics workstations, coprocessors, laser printers, mouse, audio

CRT-based Raster System

- The advantages of CRT-based raster systems over CRT-based vector systems are the following:
 - Lower cost
 - Color-filled polygons (essential for realism)
 - A simple refresh process independent of image complexity
- The disadvantages are as follows:
 - Scan conversion of lines is expensive and must be done every time the image is transformed
 - Aliasing (jaggies, staircasing)

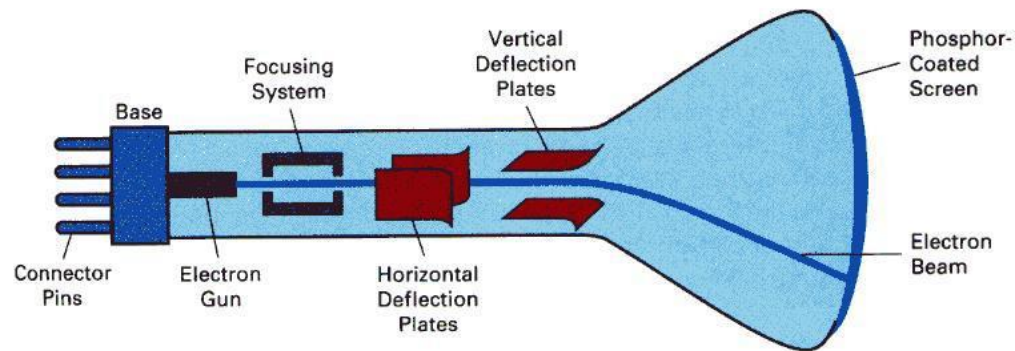
The aliasing problem is mitigated by antialiasing techniques, such as varying pixel intensity values by distance from a line segment or polygon edge. This requires a gray-scale or color system with several bits per pixel.

Raster Display Hardware

A bi-level monochrome **CRT** (Cathode Ray Tube) is a glass tube containing an electron gun, a phosphor-coated negatively-charged surface, and a yoke --

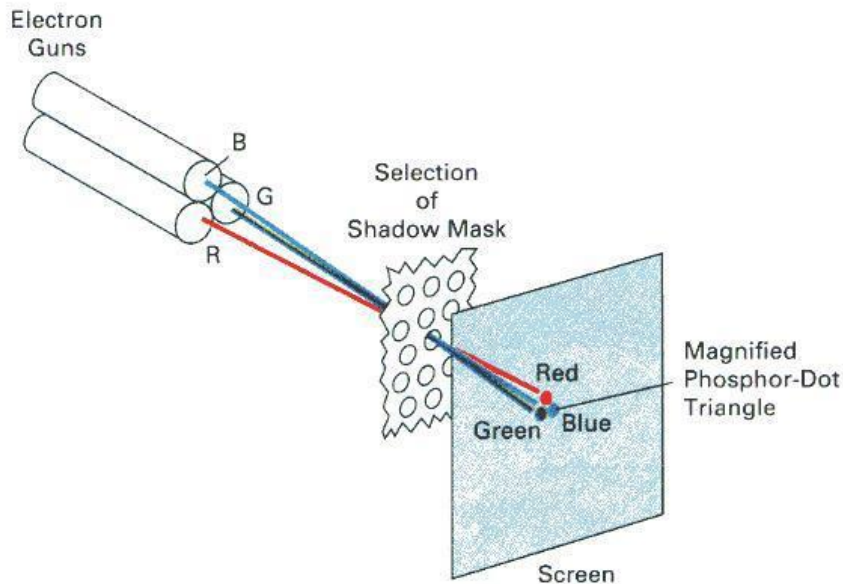
A system of electromagnetic coils which deflect the electron beam horizontally and vertically.

A color TV or RGB monitor is a CRT with three electron guns, a shadow mask to improve focus, and discrete sets of red, green, and blue phosphor dots in place of a uniform phosphor coating.



Electrostatic Deflection (CRT)

An electron gun emits a beam of electrons, which passes through focusing and deflection systems and hits on the phosphor-coated screen. The number of points displayed on a CRT is referred to as resolutions (eg. 1024x768). Different phosphors emit small light spots of different colors, which can combine to form a range of colors. A common methodology for color CRT display is the Shadow-mask

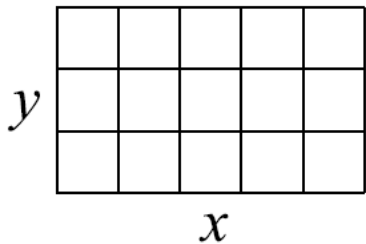


Raster Displays

The screen is represented by a 2D array of locations called pixels.



Zooming in on an image made up of pixels



Raster Scan

Raster scan is a scanning method in which the electron beam sweeps out a fixed path at fixed speed controlled by two oscillators -- horizontal and vertical.

- Vertical scan frequency, including a vertical retrace, is nominally 60 Hz (NTSC: National Television Standards Committee) or higher for monitors (70 or 72).
- Standard TV and some monitors use interlacing in which only half of each frame (refresh buffer contents) is displayed in each vertical cycle, resulting in a refresh rate of 30 frames/sec.
- This doubles the number of scan lines that can be displayed to less than $(15750 \text{ h-cycles/sec}) / (30 \text{ frames/sec}) = 525 \text{ h-cycles}$. In order to reduce flicker, the scan lines are interlaced [all even numbered lines none vertical cycle followed by all odd numbered lines in the next]. The alternative (non-interlaced mode) requires higher frequency which implies more expensive hardware.
- The vertical resolution (number of scan lines or rows of pixels) is less than 525 because some of the horizontal cycles occur during the vertical retrace. Also, there is a border or over scan area: pixels and scan lines not mapped to memory.

Illustration of a shadow-mask CRT

The light emitted by phosphor fades very rapidly, so it needs to redraw the picture repeatedly. There are 2 kinds of redrawing mechanisms: Raster-Scan and Random-Scan

Raster Scan

Phosphor persistence is the time from removal of excitation to the moment when phosphorescence (intensity) drops to 10% of its initial value (exponential decay): typically 10 to 60 ms or, roughly, short, medium, or long persistence.

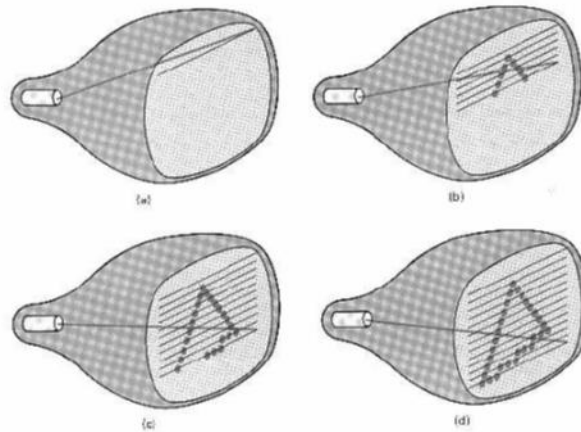
Critical fusion frequency (CFF) is the refresh rate (number of image redraws per second) at which the image stops flickering and fuses into a steady image.

It depends on

- phosphor persistence (nonlinearly): high persistence reduces CFF or flicker at a given refresh rate, but is problematic for animation
- image intensity and ambient room light: CFF increases with both
- wavelength
- the observer | by up to 20%

Video bandwidth (pixel rate) is the frequency with which the electron beam is switched on and off. It determines the resolution rather than speed. Standard TV frequency is 14.318 Mhz, limiting the horizontal resolution to less than $(14318000 \text{ pixels/sec}) / (15750 \text{ scanlines/sec}) = 909$ pixels per scan line.

Raster Scan

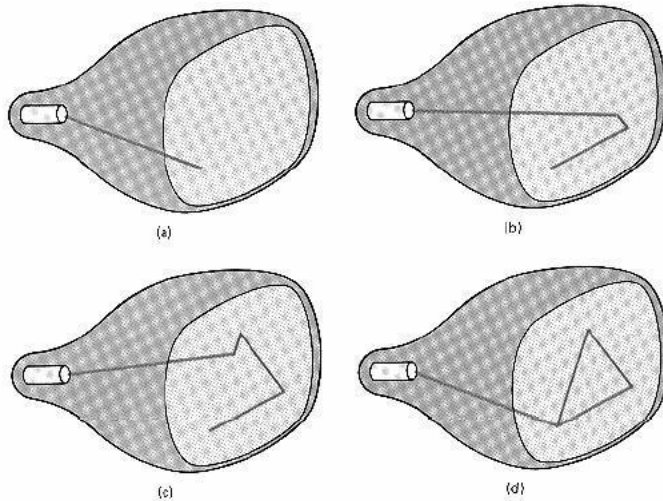


The electron beam is swept across the screen one row at a time from top to bottom. As it moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots. This scanning process is called refreshing. Each complete scanning of a screen is normally called a **frame**.

The refreshing rate, called the **frame rate**, is normally 60 to 80 frames per second, or described as 60 Hz to 80 Hz.

Picture definition is stored in a memory area called the **frame buffer**. This frame buffer stores the intensity values for all the screen points. Each screen point is called a **pixel** (picture element).

Random-Scan (Vector Display)



The CRT's electron beam is directed only to the parts of the screen where a picture is to be drawn. The picture definition is stored as a set of line-drawing commands in a refresh display file or a refresh buffer in memory. Random-scan generally have higher resolution than raster systems and can produce smooth line drawings, however it cannot display realistic shaded scenes.

Display Controller

For a raster display device reads the frame buffer and generates the control signals for the screen.

Ex:

The signals for horizontal scanning and vertical scanning. Most display controllers include a color map (or video look-up table).

The major function of a color map is to provide a mapping between the input pixel value to the output color.

On black and white systems, the frame buffer storing the values of the pixels is called a bitmap. Each entry in the bitmap is a 1-bit data which determine the on (1) and off (0) of the intensity of the pixel.

Color Bits

On color systems, the frame buffer storing the values of the pixels is called a **pixmap** (Though nowadays many graphics libraries name it as bitmap).

Each entry in the pixmap occupies a number of bits to represent the color of the pixel.

For a true color display, the number of bits for each entry is 24.

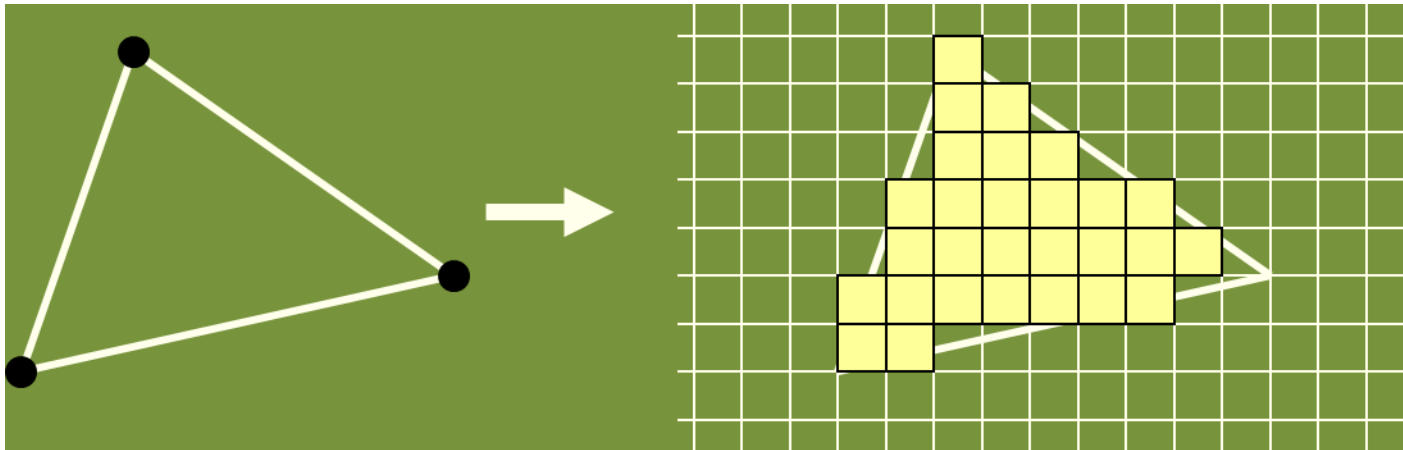
8 bits per red/green/blue channel, each channel $2^8=256$ levels of intensity value.

256 voltage settings for each of the red/green/blue electron guns.

Anti-Aliasing

On dealing with integer pixel positions, jagged or stair step appearances happen very usually. This distortion of information due to under sampling is called aliasing. A number of anti-aliasing methods have been developed to compensate this problem.

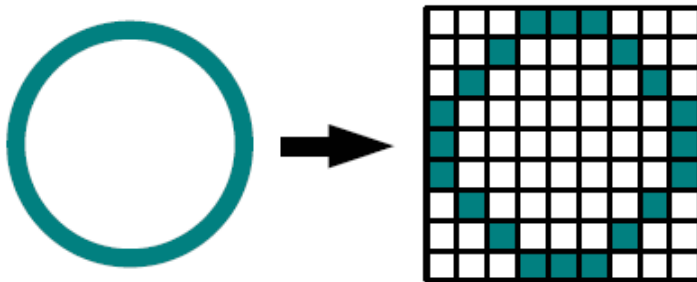
One way is to display objects at higher resolution. However there is a limit to how big we can make the frame buffer and still maintaining acceptable refresh rate.



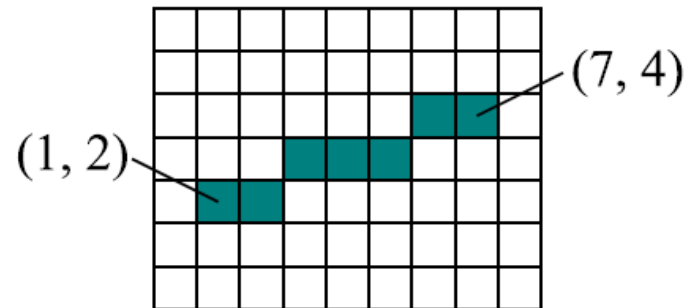
Take output from GEOMETRY and turn into visible pixels on screen

Scan conversion

The process of converting basic, low level objects into their corresponding pixel map representations. This is often an approximation to the object, since the frame buffer is a discrete grid.



Scan conversion of a circle



Basic Line Drawing

Set the color of pixels to approximate the appearance of a line from (x_0, y_0) to (x_1, y_1) .

It should be

- “straight” and pass through the end points.
- independent of point order.
- uniformly bright, independent of slope.
- The explicit equation for a line is $y = mx + b$.

Note:

Given two points (x_0, y_0) and (x_1, y_1) that lie on a line, we can solve for m and b for the line. Consider $y_0 = mx_0 + b$ and $y_1 = mx_1 + b$.

Subtract y_0 from y_1 to solve for $m = \frac{y_1 - y_0}{x_1 - x_0}$ and $b = y_0 - mx_0$.

Substituting in the value for b , this equation can be written as $y = m(x - x_0) + y_0$.

Basic Line Drawing Algorithm

setpixel(x, y, color)

Sets the pixel at position (x, y) to the given color.

Consider this simple line drawing algorithm:

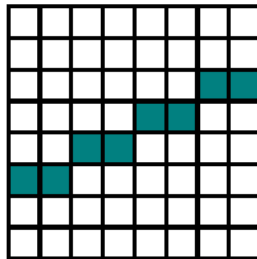
```
int x
float m, y
m = (y1 - y0) / (x1 - x0)
for (x = x0; x <= x1; ++x) {
    y = m * (x - x0) + y0
    setpixel(x, round(y), linecolor)
}
```


Problems with this algorithm:

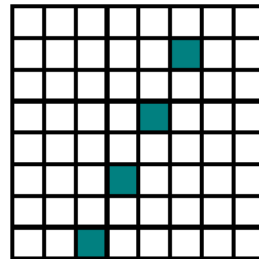
If $x_1 < x_0$ nothing is drawn.

- *Solution*: Switch the order of the points if $x_1 < x_0$.

Consider the cases when $m < 1$ and $m > 1$:



(a) $m < 1$



(b) $m > 1$

A different number of pixels are on, which implies different brightness between the two.

Solution: When $m > 1$, loop over $y = y_0 \dots y_1$ instead of x , then $x = \frac{1}{m}(y - y_0) + x_0$.

Inefficient because of the number of operations and the use of floating point numbers.

Solution: A more advanced algorithm, called Bresenham's Line Drawing Algorithm.