Computer Graphics

Computer Graphics

A field related to the generation of graphics using computers

- It includes the **creation, storage** and **manipulation** of images of objects.

Until early 1980's it was a small specialized field

- **Hardware** was expensive
- Graphics based **application programs** that were easy to use and cost effective were few

PCs with built in raster graphics displays such as the **Xerox Star, Apple Macintosh** and **the IBM PC** – popularized the use of **bitmap graphics** for user computer interaction.

A bitmap is a 1 and 0s representation of the rectangular array of points on the screen.

- Each point is called a pixel, short for **"picture elements".**

Computer Graphics

Once the bitmap graphics became **affordable** an explosion of easy to use, inexpensive graphics based user interfaces allowed millions of new users to control simple low cost application programs such as **word processors, spreadsheets** and **drawing programs**

The concept of a **“desktop”** now became popular metaphor for organizing screen space.

Even people who do not use computers encounter computer graphics in TV commercials and as cinematic special effects.

Computer Graphics

Thus computer graphics is an **integral part** of all computer user interfaces, and is indispensable for visualizing 2D, 3D objects in all most all areas such as **education , science , engineering, medicine, commerce the military advertizing** and **entertainment.**

The theme is that learning how to program and use computers now includes learning how to use simple **2D graphics**

Early History of Computer Graphics

Crude plotting of hardcopy devices such as **teletypes** and **line printers** dates from the early days of computing

The **whirlwind computer** developed in 1950 at the Massachusetts Institute of Technology (MIT) had **computer driven CRT displays** for output.

Early History of Computer Graphics

SAGE air-defense system developed in the middle 1950s was the first to **use command** and **control CRT display consoles** on which operators identified targets with light pens
(hand held pointing devices that sense light emitted by objects on the screen)

The **General Motors** DAC system for **automobile design** and the **Itek-Digitek system** for **lens design**

Early History of Computer Graphics

Later on **Sketchpad system** by Ivan Sutherland came in light.

- The beginning of **modern interactive graphics**.
- **Keyboard** and **light pen** used for pointing, making choices drawing.

Prospects of the use of **(CAD)** and **(CAM)** in computer, automobile, and aerospace manufacturing Drafting and Drawing activities.

By the mid 60s, a number of **commercial products** using these systems had appeared

Early History

At that time only the **most technology intensive organizatins** could use the interactive computer graphics where as others used **punch cards**, a non-interactive system .

Reasons:

The **high cost of graphics hardware** – at a time when automobiles cost a few thousand dollars, computers cost several millions of dollars, and the first commercial computer displays cost more than a hundred thousand dollars

The need for large scale **expensive computing resources** to support massive design database

The difficulty of writing large interactive programs using **batch oriented FORTRAN programming**

Early History of Computer Graphics

One of a kind , **non-portable software,** typically written for a particular manufacturer’s display devices.

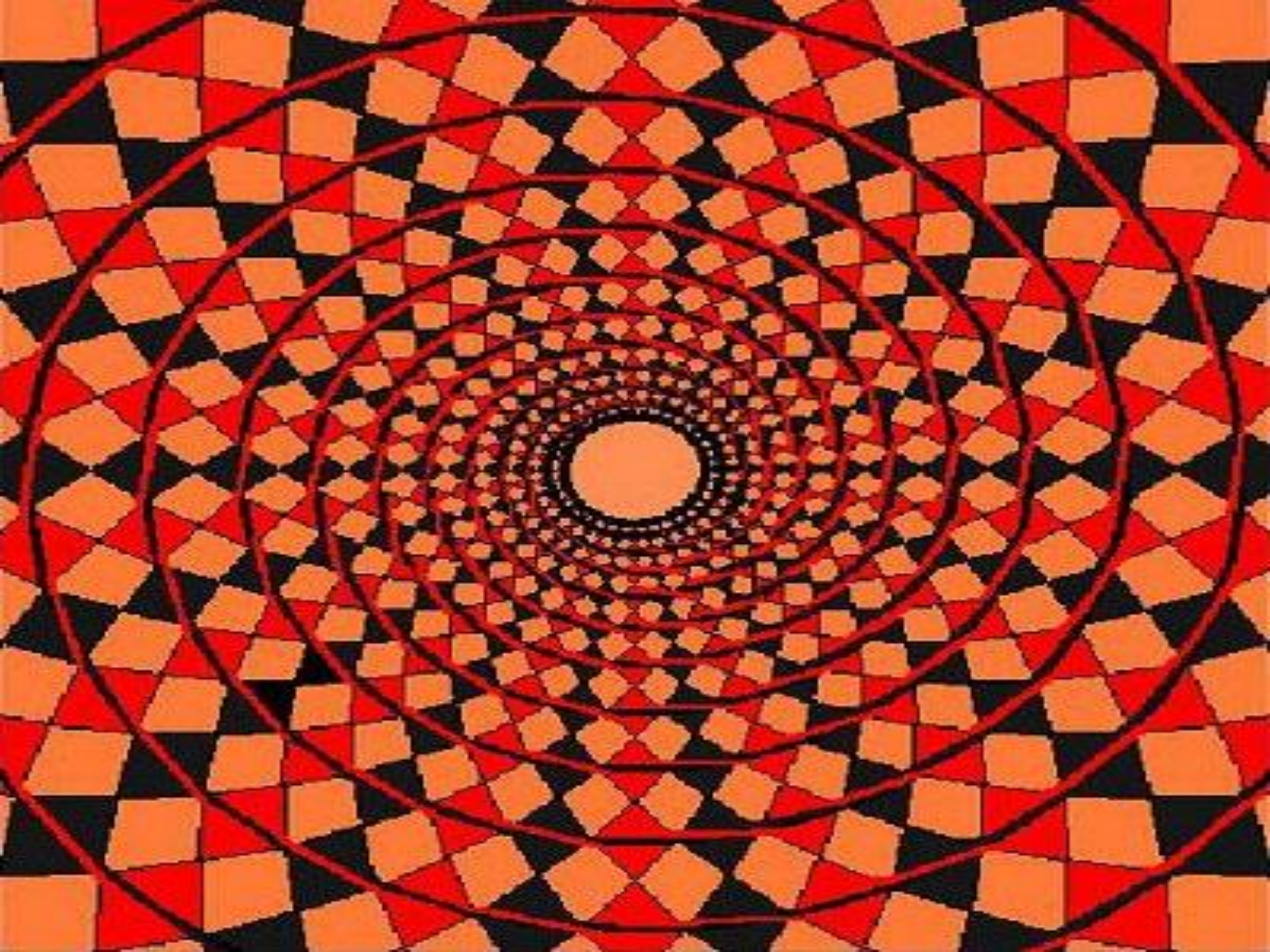
(When software is non-portable, moving to new display devices necessitates expensive and time consuming rewriting of working programs)

Thus **interactive computer graphics** had a limited use when it started in the early sixties but it became very common once the **Apple Macintosh** and **IBM PC** appeared in the market with affordable cost

Uses of Computer Graphics

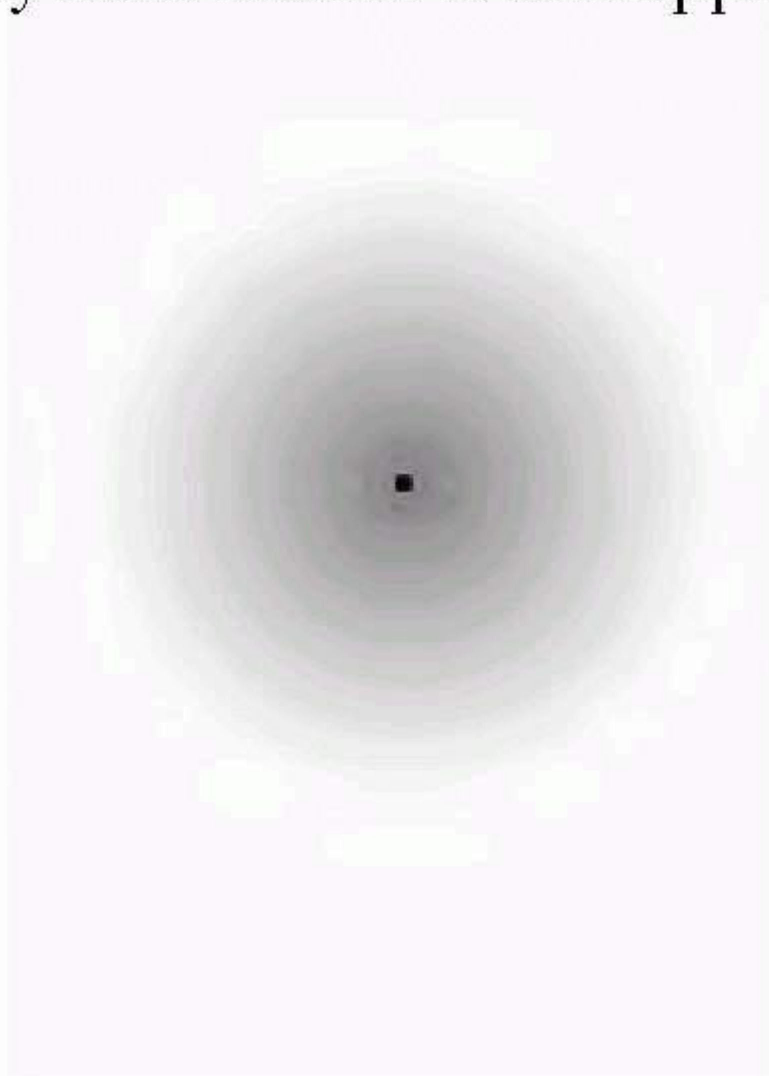
- User interfaces
- Plotting
- Office automation and electronic publishing
- Art and commerce
- Cartography
- Computer aided drafting and design
- Entertainment
- Simulation
- Scientific and business visualization

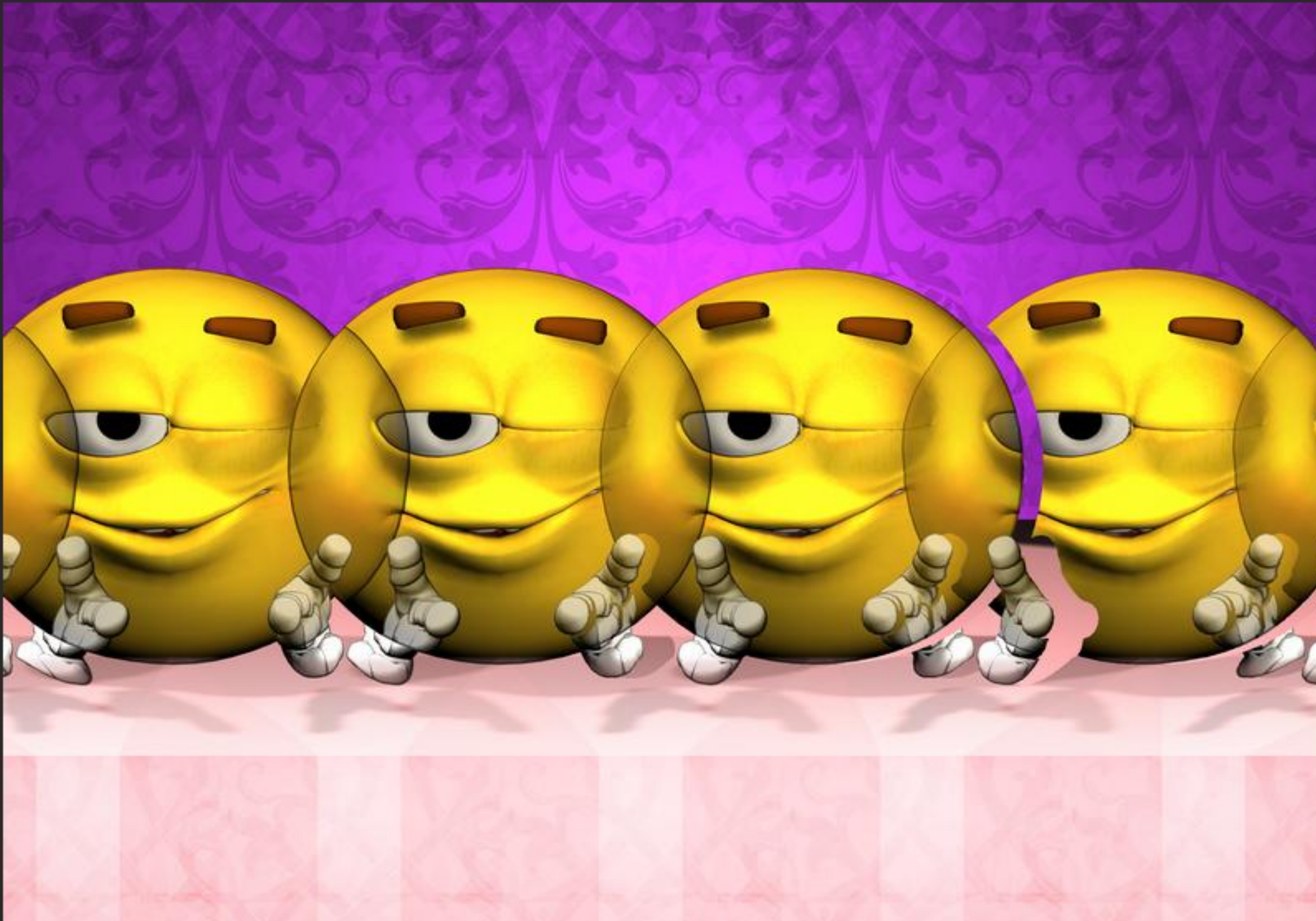

Second Life
File Edit View World Tools Help Advanced
Search

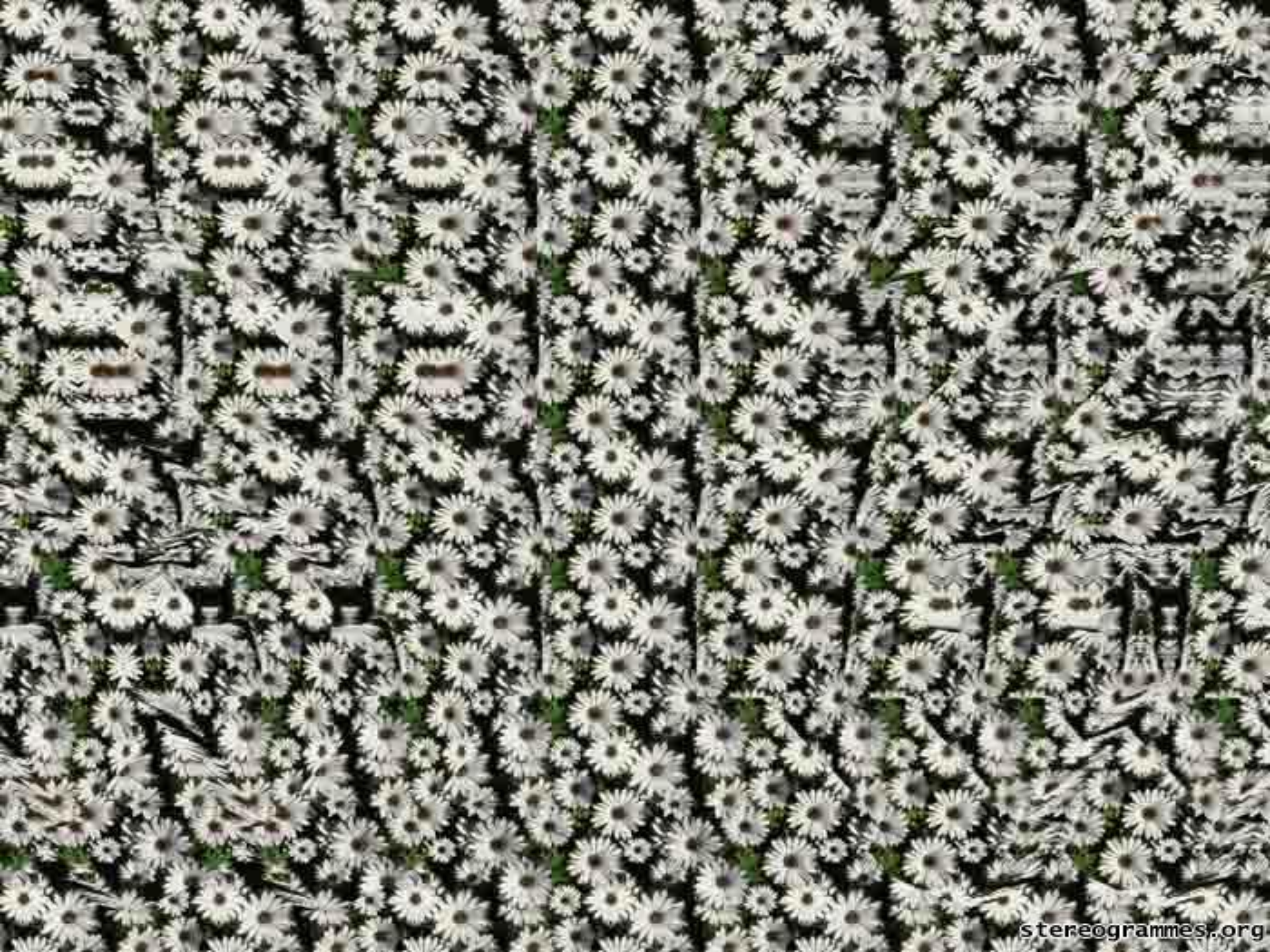



stereogrammes.org

Keep staring at the black dot. After a while the gray haze around it will appear to shrink.



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Input Hardware

Tablet

Tablet a tablet is a **digitizer.**

- scan over an object and input a set of discrete coordinate positions.

These positions can then be joined with straight line segments to approximate the shape of the original object.

A tablet digitizes an object detecting the position of a movable stylus (a pencil shaped device) or a puck(a mouse like device with cross hairs for sighting positions) held in the user's hand

Input Hardware

Input Hardware

i. Electrical Tablet

A grid of wires on ¼ to ½ inch centers is embedded in the tablet surface

Electromagnetic signals generated by electrical pulses applied in sequence to the wires in the grid induce an electrical signal in a wire coil in the stylus or puck

The strength of the signal induced by each pulse is used to determine the position of the stylus.

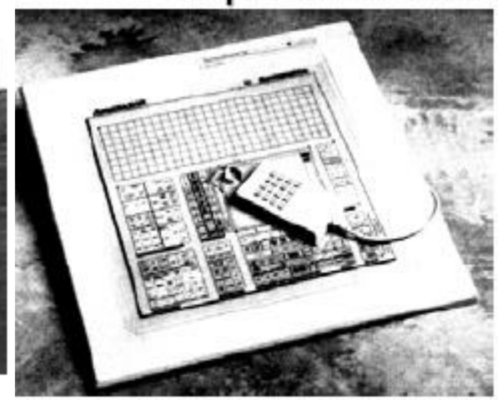
The signal strength is also used to determine roughly how far the stylus is from the tablet

Input Devices: Tablets

desktop tablet with stylus

artist's digitizer system with cordless stylus

Input Devices: Tablets



desktop tablet with a 16-button hand cursor

large tablet with hand cursor

Input Hardware

ii. Sonic Tablet

The sonic tablet uses sound waves to couple the stylus to microphones positioned on the periphery of the digitizing area

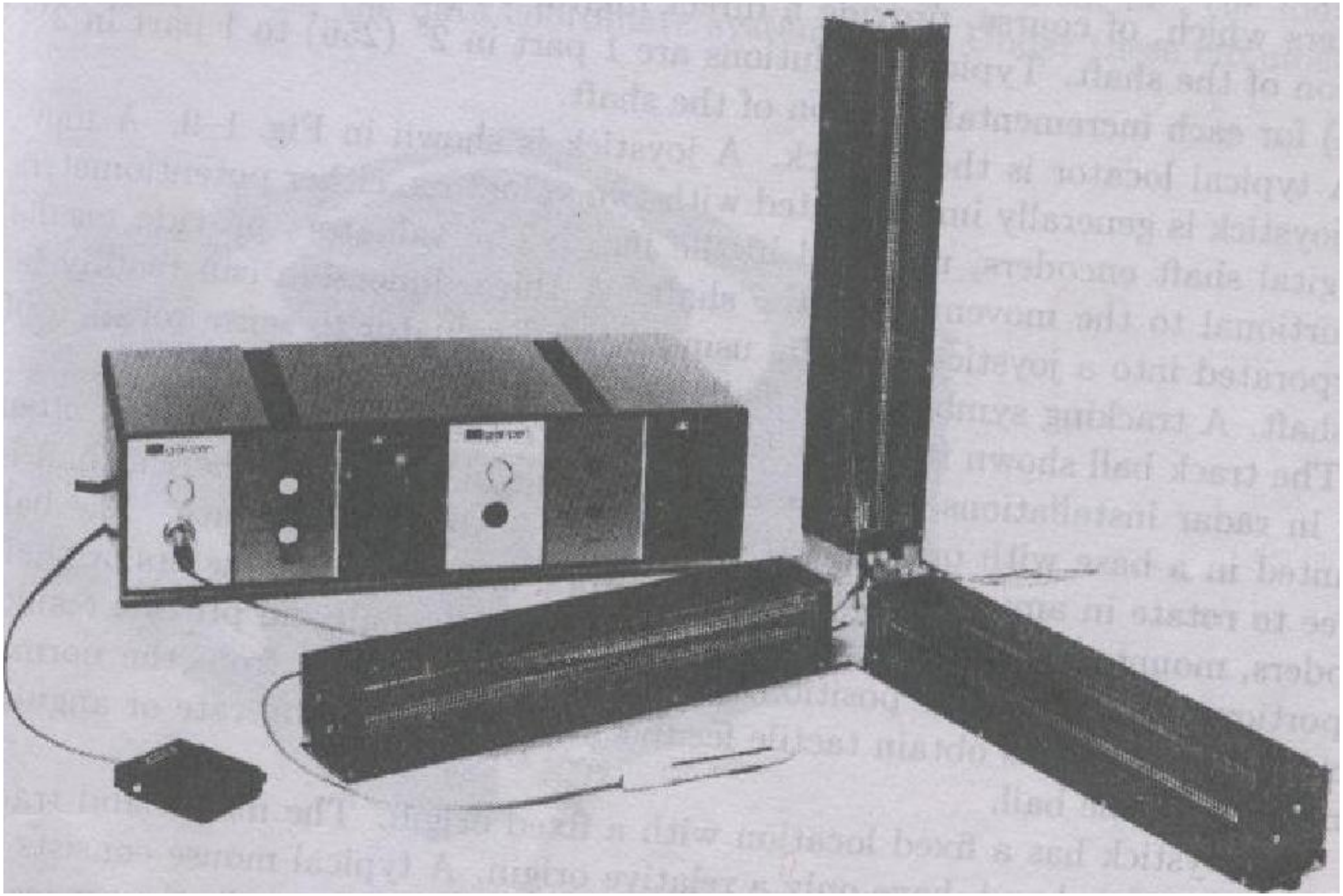
An electrical spark at the tip of the stylus creates **sound bursts**.

The position of the stylus or the coordinate values is calculated using the **delay between** when the spark occurs and when its sound arrives at each microphone

Input Hardware

The main advantage of sonic tablet is that it **doesn't require a dedicated working area** as the microphones can be placed on any surface to form the tablet work area

This facilitates digitizing drawing on thick books because in an electrical tablet this is not convenient for the stylus can not get closer to the tablet surface



3D Digitizers

manual digitizer
with stylus

Input Hardware

iii. Resistive Tablet

The tablet is just a piece of glass coated with a thin layer of conducting material

When a battery powered stylus is activated at certain position it emits high frequency radio signals which induces the radio signals on conducting layer.

The strength of the signal received at the edges of the tablet is used to calculate the position of the stylus

Input Hardware

Several types of tablets are transparent, and thus can be backlit for digitizing x-ray films and photographic negatives.

The Resistive tablet can be used to digitize the objects on CRT because it can be curved to the shape of the CRT.

The mechanism used in the electrical or sonic tablets can also be used to digitize the 3D objects

Input Hardware

Touch Panels

The touch panel allows the user to point at the screen directly with a finger to move the cursor around the screen or to select the icons.

i. Optical Touch Panel

It uses a series of infrared **light emitting diodes (LED)** along one vertical edge and along one horizontal edge of the panel

The opposite vertical and horizontal edges contain **photo detectors** to form a grid of invisible infrared light beams over the display area.

Input Hardware

Touching the screen breaks one or two vertical and horizontal light beams thereby indicating the fingers position

The cursor is then moved to this position or the icon at this position is selected

This is a low resolution panel which offers 10 to 50 positions in each direction

Input Devices: Touch Screens

plasma panels with touch screens

Input Hardware

ii. Sonic Touch Panel

Bursts of high frequency sound waves traveling alternately horizontally and vertically are generated at the edge of the panel .

Touching the screen causes part of each wave to be reflected back to its source

The screen position at the point of contact is then calculated using the time elapsed between when the wave is emitted and when it arrives back at the source

This is a high resolution touch panel having about 500 positions in each direction

Input Hardware

iii. Electrical Touch Panel

It consists of slightly separated two transparent panel one coated with a thin layer of conducting material and the other with resistive material

When the panel is touched with a finger the two plates are forced to touch at the point of contact thereby creating the voltage drop across the resistive plate which is then used to calculate the coordinate of the touched position

The resolution of the touch panel is similar to that of sonic touch panel

Input Hardware

Light pen

It is a pencil shaped device to determine the coordinates of a point on the screen where it is activated such as pressing the button .

In raster display ‘y’ is set at y_{max} and ‘x’ changes from 0 to x_{max} the first scan line .

For the second line ‘y’ decreases by one and ‘x’ again changes from 0 to x_{max} and so on

When activated light pen sees a burst of light at certain position as the electron beam hits the phosphor coating at that position it generates an electric pulse

Input Hardware

This is used to save the video controller's 'x' and 'y' registers and interrupt the computer

By reading the saved valued the graphics package can determine the coordinates of the position seen by the light pen

Drawbacks

i. Light pen **obscures screen images** as it is pointed to required spot

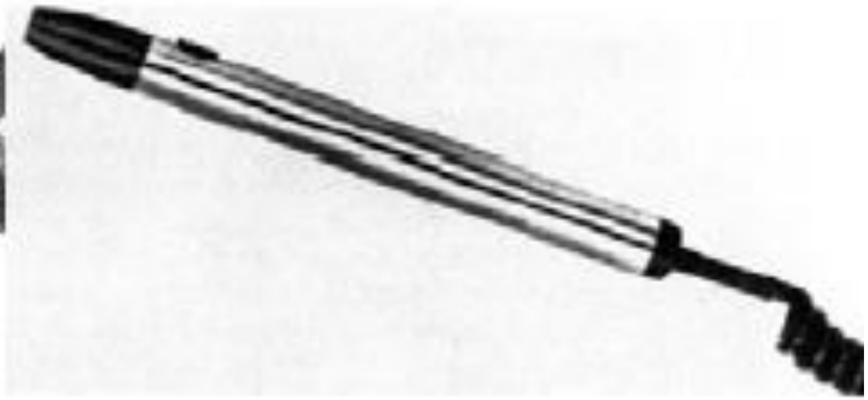
ii. Prolong use of it can cause **arm fatigue**

iii. It cannot report the coordinates of a point that is **completely black** as a remedy one can display a dark blue field in place of the regular image for a single frame time

iv. It gives sometimes **false reading** due to back ground lighting in a room

Input Devices: Light Pen

recognizes cathod ray
to calculate position



Display Devices

Fluorescence / Phosphorescence

A phosphors fluorescence is the light emitted as the very unstable electrons lose their excess energy whole the phosphor is being struck by electrons

Phosphorescence is the light given off by the return of the relatively more stable excited electrons to their unexcited state once the electron beam excitation is removed

Display Devices

Persistence

A phosphor’s persistence is defined as the time from the removal of excitation to the moment when phosphorescence has decay to 10 percent of the initial light output

The range of persistence of different phosphors can reach many seconds

The phosphors used for graphics display devices usually have persistence of 10 to 60 micro seconds

A phosphor with low persistence is useful for animation and a high persistence phosphor is useful to highly complex static pictures

Display Devices

The factors affecting the CFF are:

i. Persistence: longer the persistence the lower the CFF But the relation between the CFF and persistence is non linear

ii. Image intensity: Increasing the image intensity increases the CFF with non linear relationship

iii. Ambient room light Decreasing the ambient room light increases the CFF with nonlinear relationship

iv. Wave lengths of emitted light

v. Observer

Display Devices

Refresh rate

The refresh rate is the number of times per second the image is redrawn to give a feeling of un-flickering pictures and it is usually 50 per second

As the refresh rate decreases flicker develops because the eye can no longer integrate the individual light impulses coming from a pixel

The refresh rate above which a picture stops flickering and fuses into a steady image is called the critical fusion frequency (CFF)

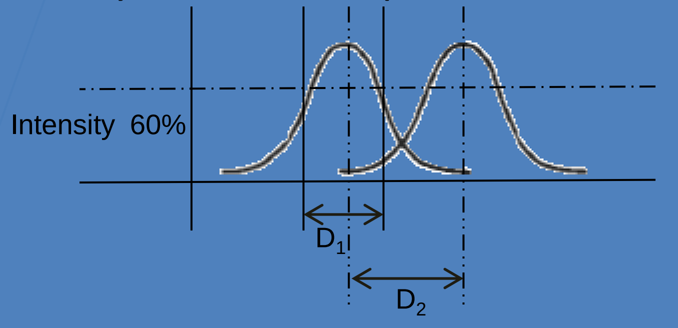
Display Devices

Resolution

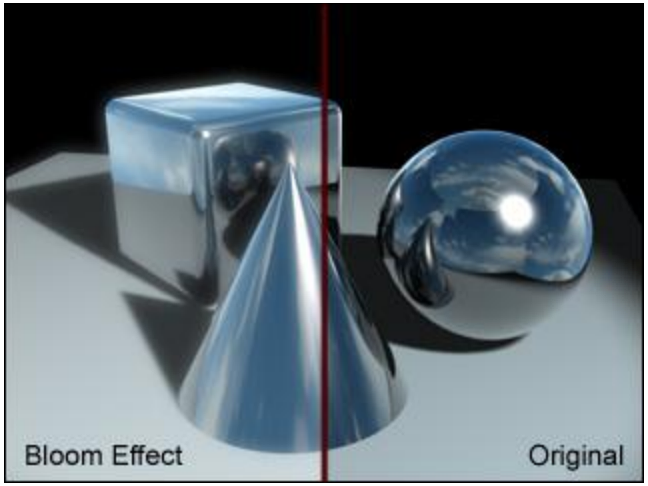
Resolution is defined as the maximum number of points that can be displayed horizontally and vertically with out overlap on a display device Factors affecting the resolution are as follows

i. Spot profile:

The spot intensity has a Gaussian distribution. So two adjacent spots on the display device appear distinct as long as their separation D_2 is greater than the diameter of the spot D_1 at which each spot has an intensity of about 60 percent of that at the center of the spot



Display Devices



ii. Intensity:

As the intensity of the electron beam increases the spot size on the display tends to increase because of spreading of energy beyond the point of bombardment

This phenomenon is called *blooming* Consequently , the resolution decreases.

Thus it is noted that resolution is no necessarily a constant and it is not necessarily equal to the resolution of a pix-map, which is allocated in a buffer memory

Display Devices

Color CRTs

Color depends on the light emitted by phosphor.

Two type:

Beam Penetration Method

Shadow Mask Method

Display Devices

i. Beam Penetration Method:

Two different layers of phosphor coating used Red (outer) and Green (inner)

Display of color depends on the depth of penetration of the electron beam into the phosphor layers

- A beam of slow electrons excites only the outer red layer
- A beam of very fast electrons penetrates thru the red phosphor and excites the inner green layer
- When quantity of red is more than green then color appears as orange
- When quantity of green is more than red then color appears as yellow

Screen color is controlled by the beam acceleration voltage.

Only four colors possible, poor picture quality

Display Devices

ii. Shadow Mask Method

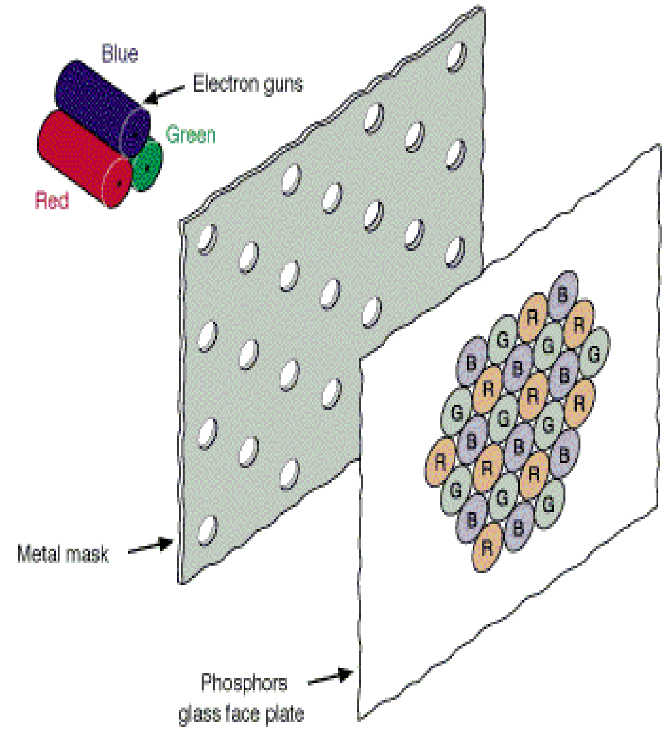
The inner side of the viewing surface of a color CRT consists of closely spaced groups of red, green and blue phosphor dots.

Each group is called a *triad*

A thin metal plate perforated with many small holes is mounted close to the inner side of the viewing surface. This plate is called *shadow mask*

The shadow mask is mounted in such a way that each hole is correctly aligned with a triad in color CRT

Display Devices



There are three electron guns one for each dot in a triad

The electron beam form each gun therefore hits only the corresponding dot of a triad as the three electron beams deflect

A triad is so small that light emanating from the individual dots is perceived by the viewer as a mixture of the three colors

Thus, a wide range of colors can be produced by each triad depending on how strongly each individual phosphor dot in a triad is excited.

Display Devices

a. A Delta –Delta CRT

A triad has a *triangular (delta) pattern* as are the three electron guns

Main drawback of this type of CRT is that a high precision display is very difficult to achieve because of technical difficulties involved in the alignment of shadow mask holes and the triad on one to one basis

b. Precision Inline CRT

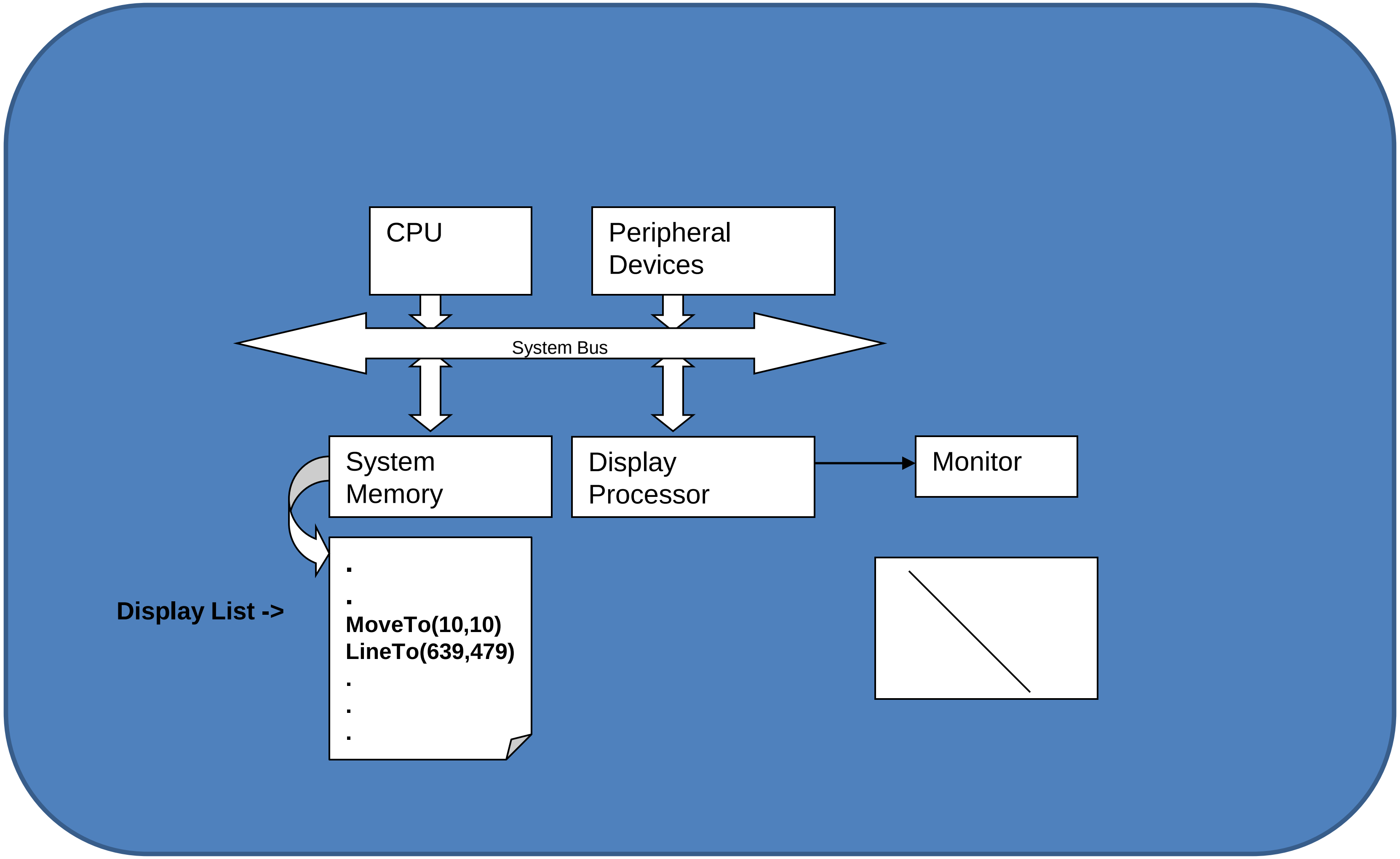
A triad has an *in-line pattern* as are the three electron guns

The introduction of this type of CRT has eliminated the main drawback of a Delta-Delta CRT

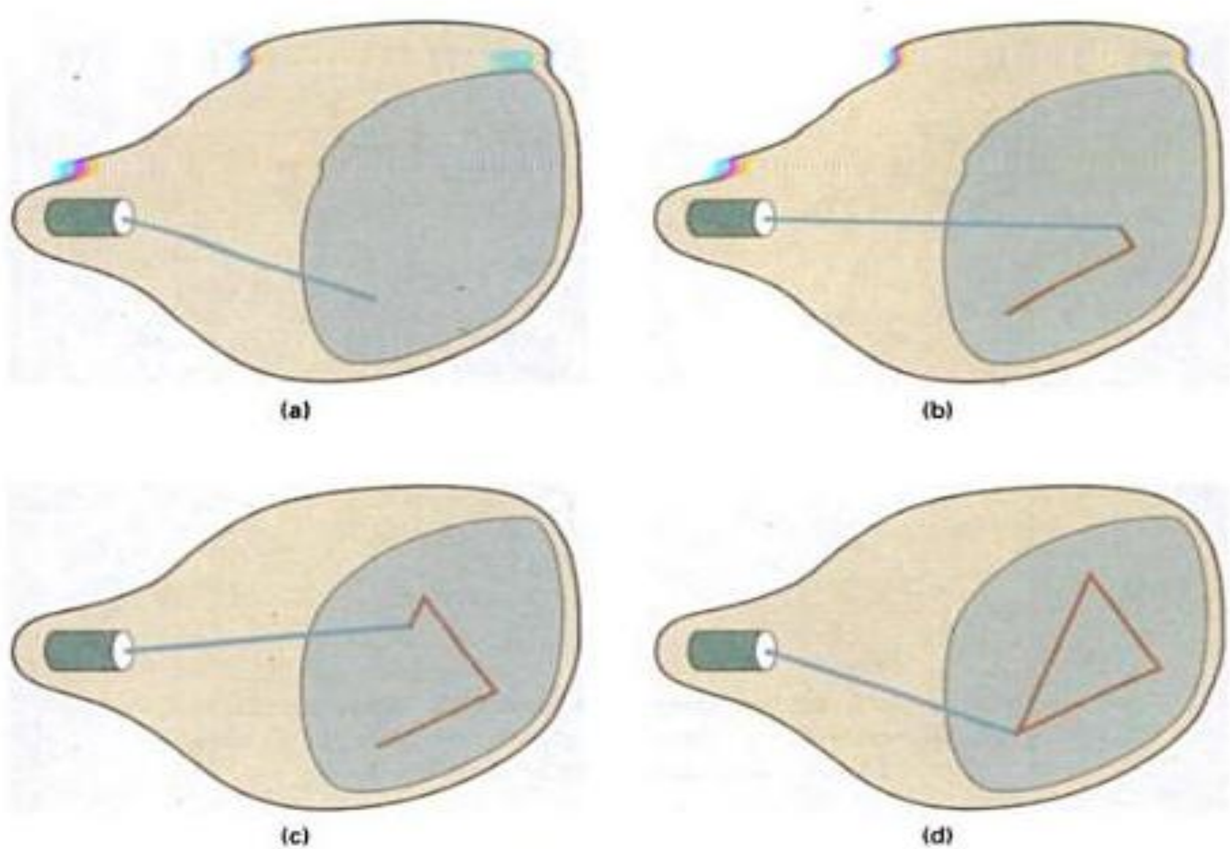
But a slight reduction of image sharpness at the edges of the tube has been noticed

Normally 1000 scan lines can be achieved

i. Vector Display Technology



i. Vector Display Technology



i. Vector Display Technology

It is also called **random scan, a stroke, a line drawing or calligraphic display**
Advantages:

i. It can produce a **smooth output primitives** with higher resolution unlike the raster display technology

ii. It is better than raster display for real time dynamics such as **animation**

iii. For transformation, only the end points has to be moved to the new position in vector display but in raster display it is necessary to move those end points and at the same time all the pixels between the end points must be scan converted using appropriate algorithm No prior information on pixels can be reused

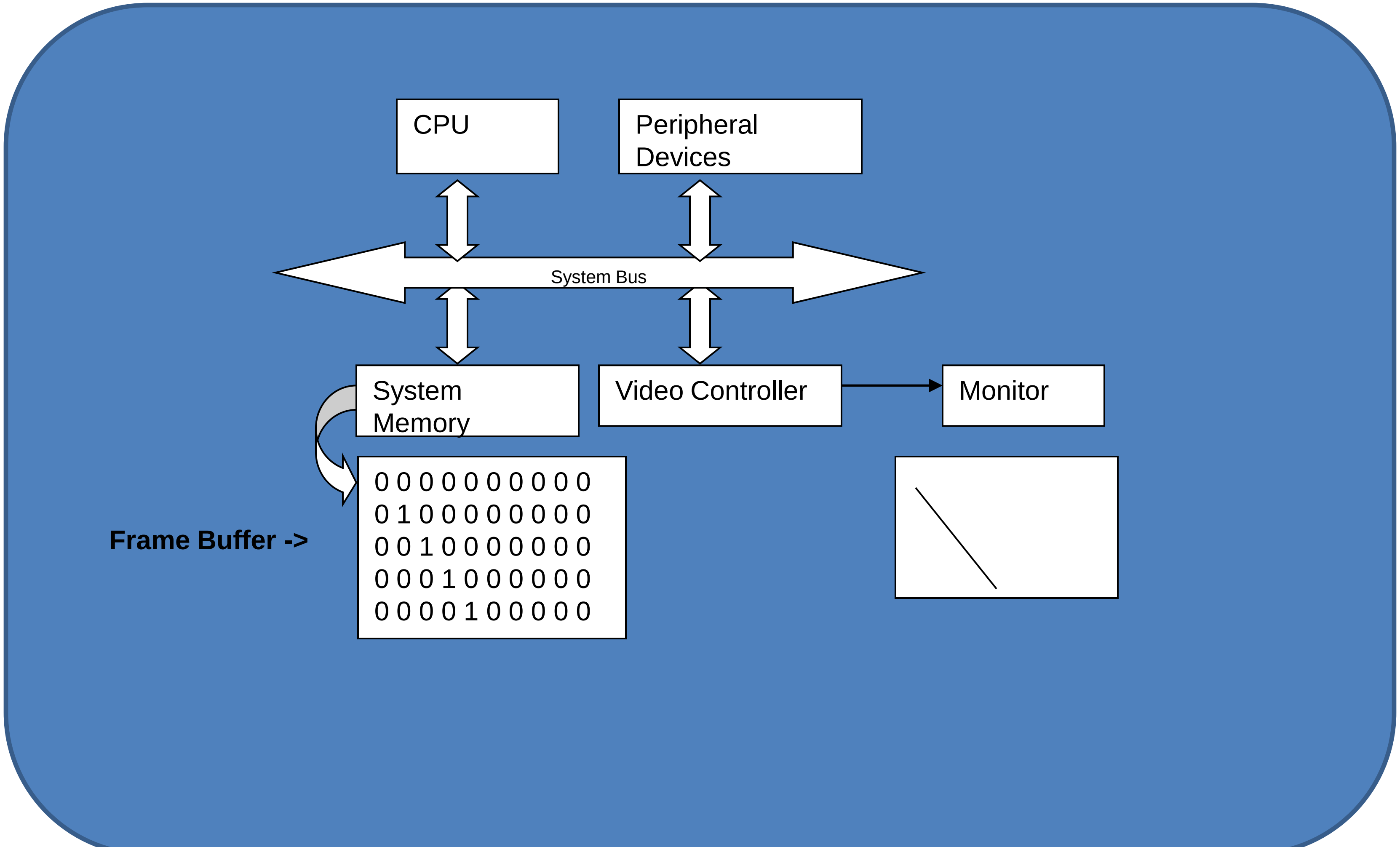
i. Vector Display Technology

Disadvantages:

i. A vector display **can not fill areas** with patterns and manipulate bits

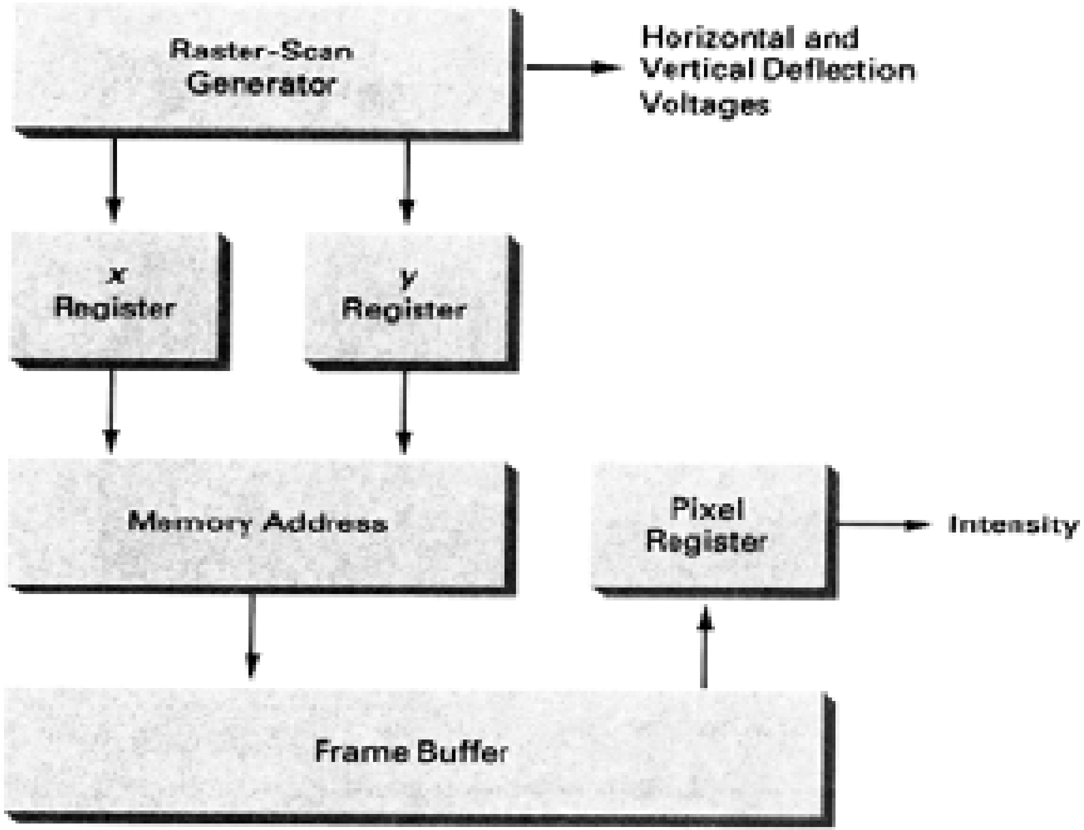
ii. Time required for refreshing an image depends upon its complexity **(more the lines, longer the time)** the flicker may therefore appear as the complexity of the image increases. The fastest vector display can draw about 100000 short vectors in a refresh cycle without flickering

ii. Raster Display Technology



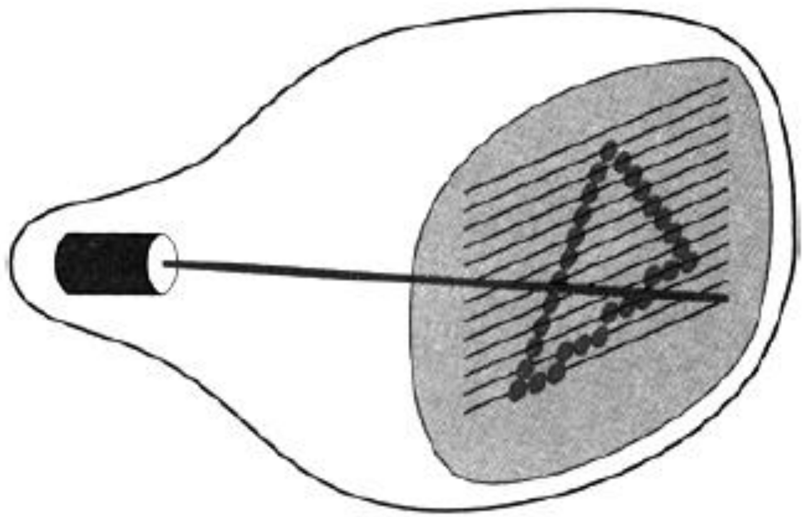
ii. Raster Display Technology

Raster-Scan: Video Controller



basic video-controller refresh operations

ii. Raster Display Technology



ii. Raster Display Technology

Advantages

i. It has an **ability to fill** the areas with solid colors or patterns

ii. The time required for refreshing is **independent of the complexity** of the image

iii. **Low cost**

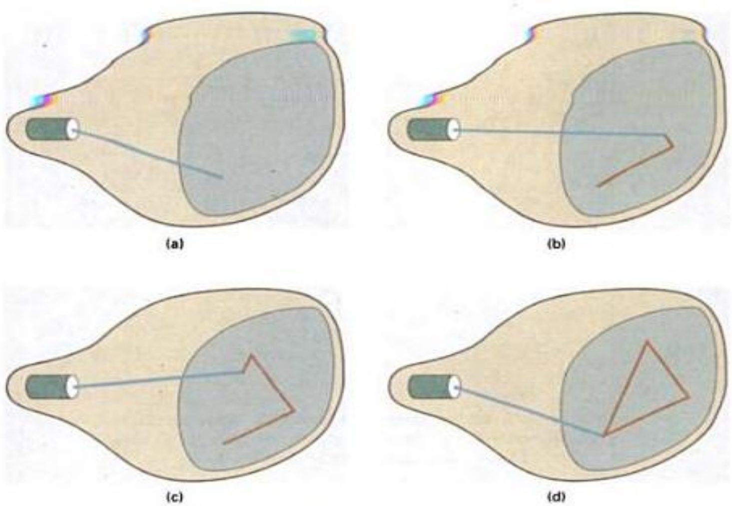
ii. Raster Display Technology

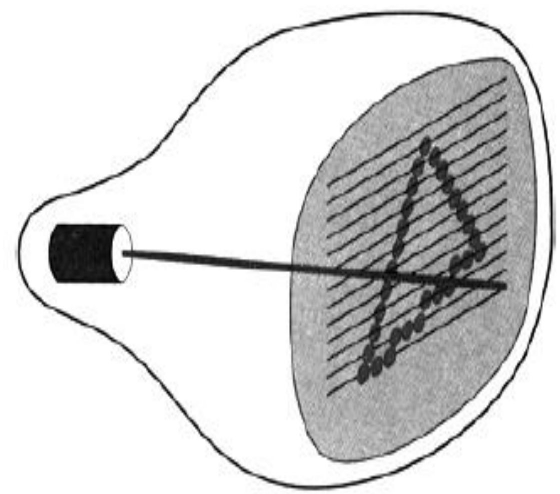
Disadvantages

i. For Real-Time dynamics not only the end points are required to move but all the pixels in between the moved end points have to be scan converted with appropriate algorithms which might slow down the dynamic process

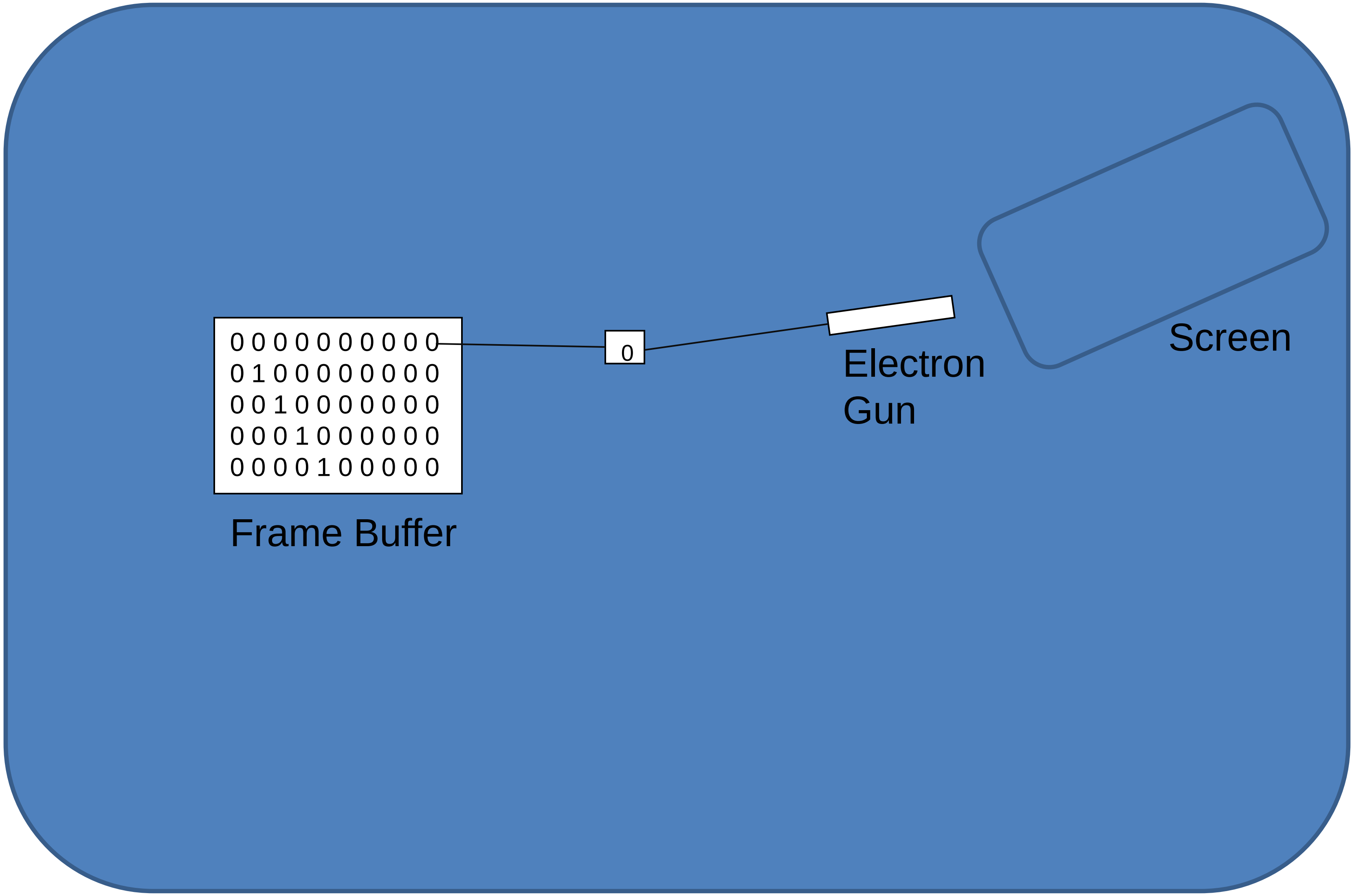
ii. Due to scan conversion **"jaggies"** or **"stair-casing"** are unavoidable

RDT/VDT





Frame Buffer



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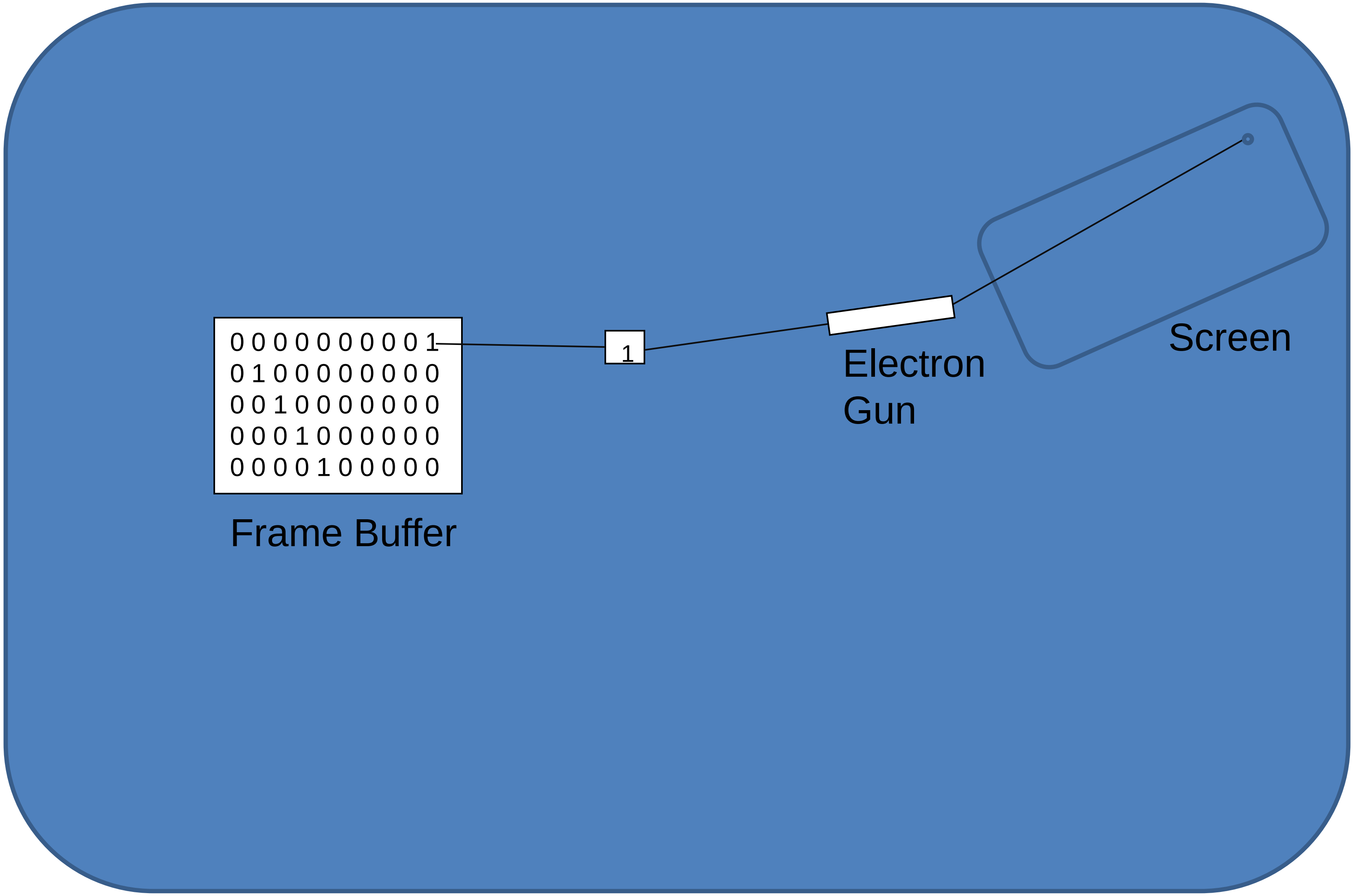
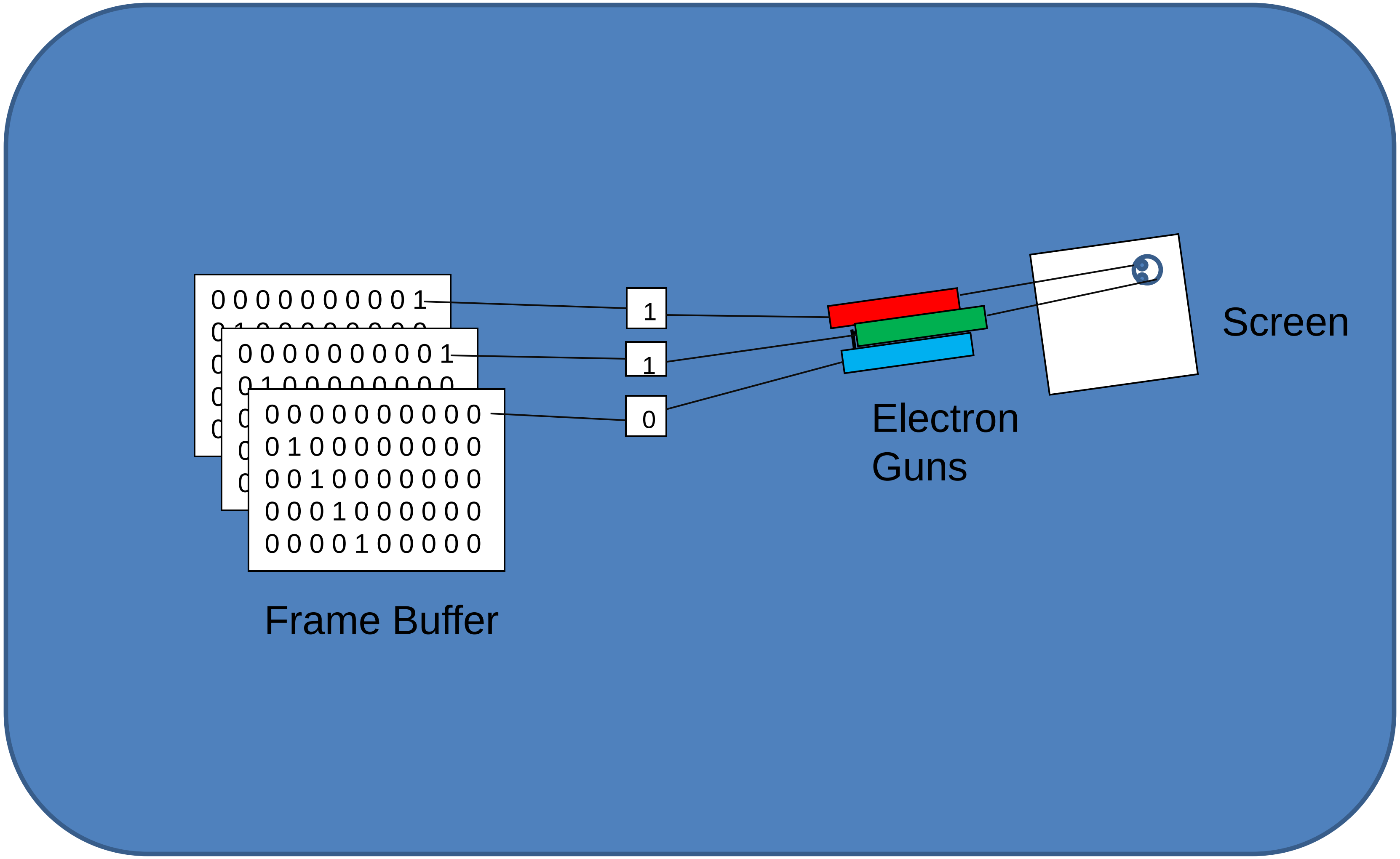
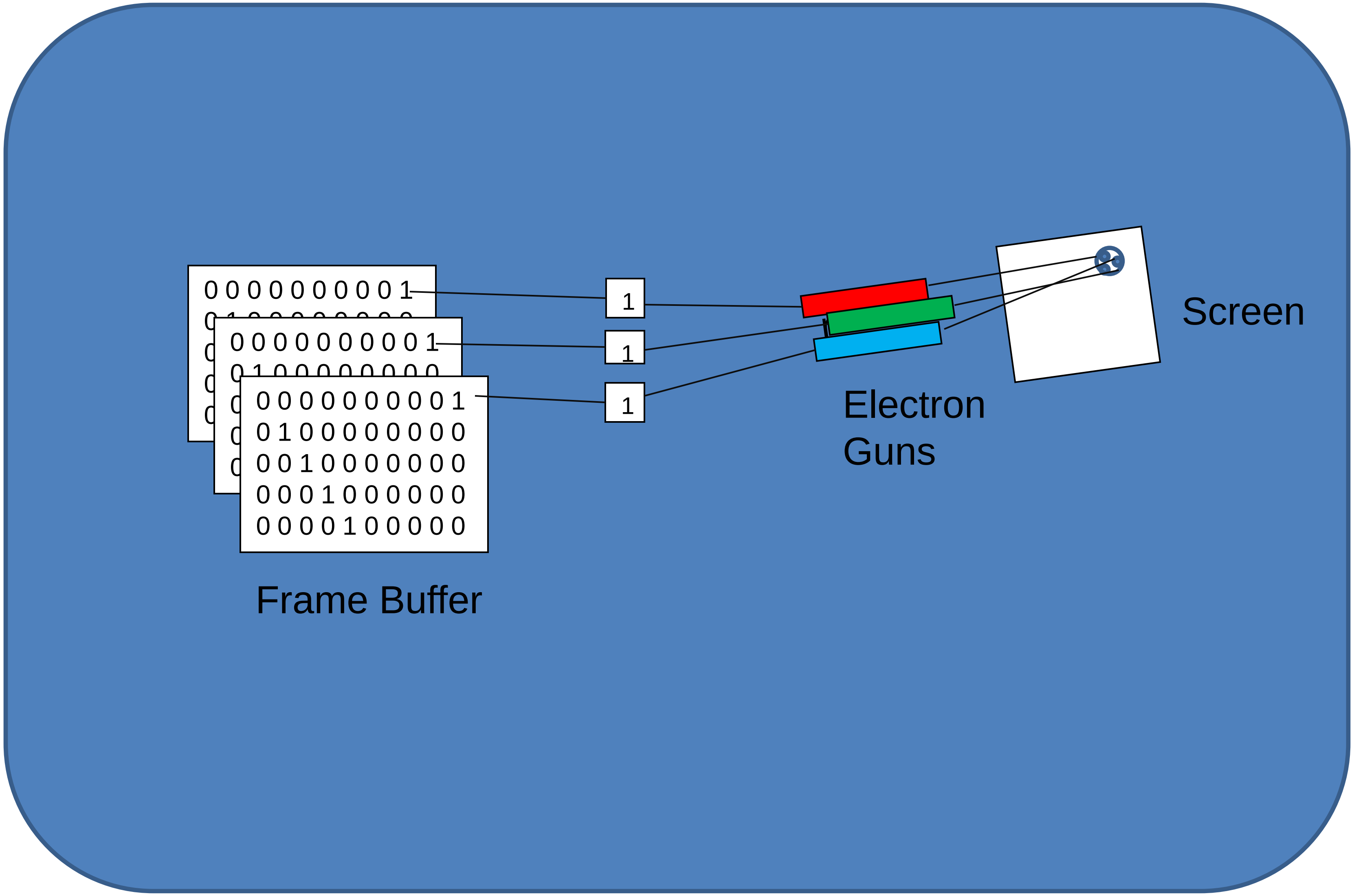


Frame Buffer



Frame Buffer



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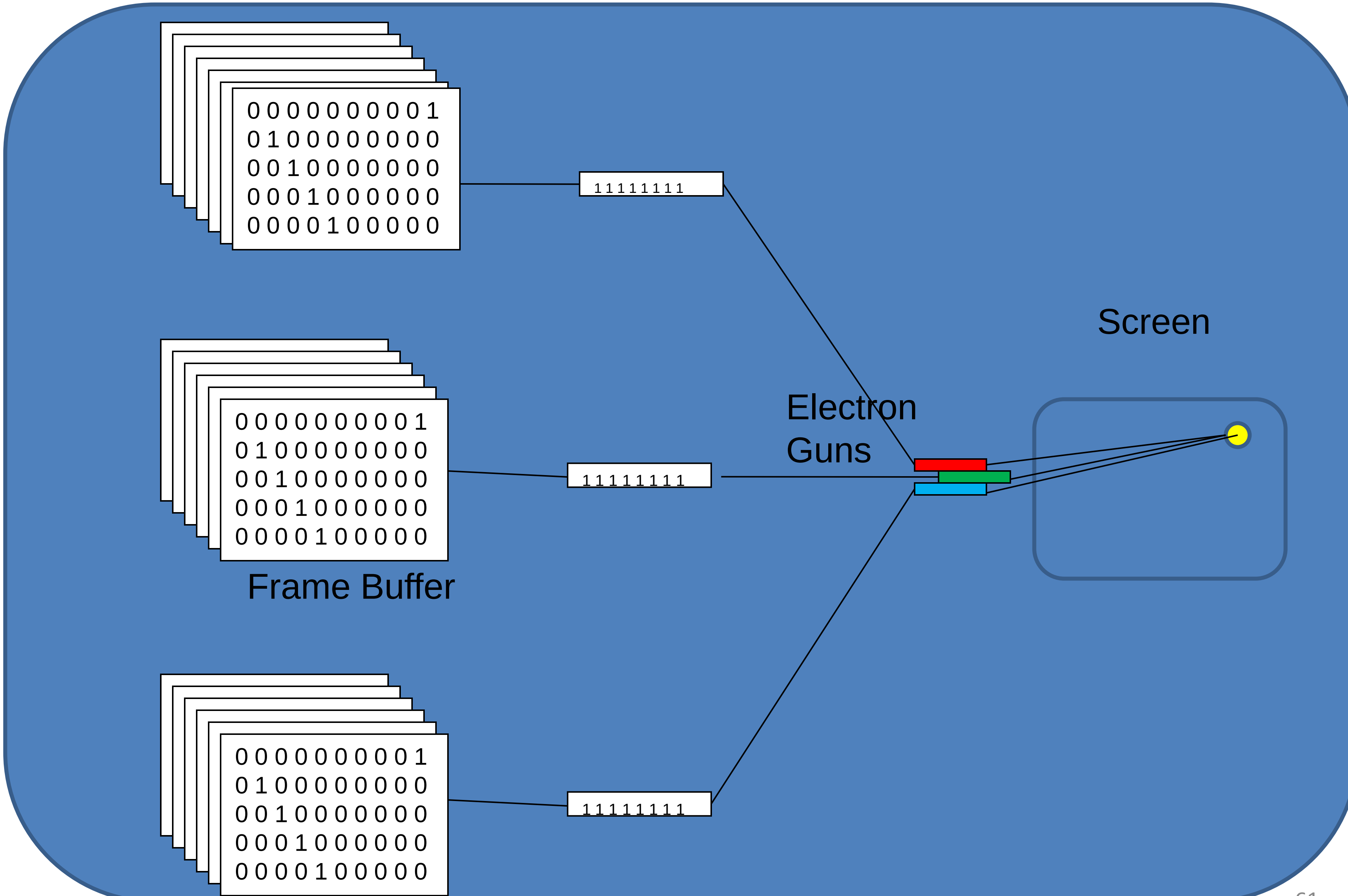


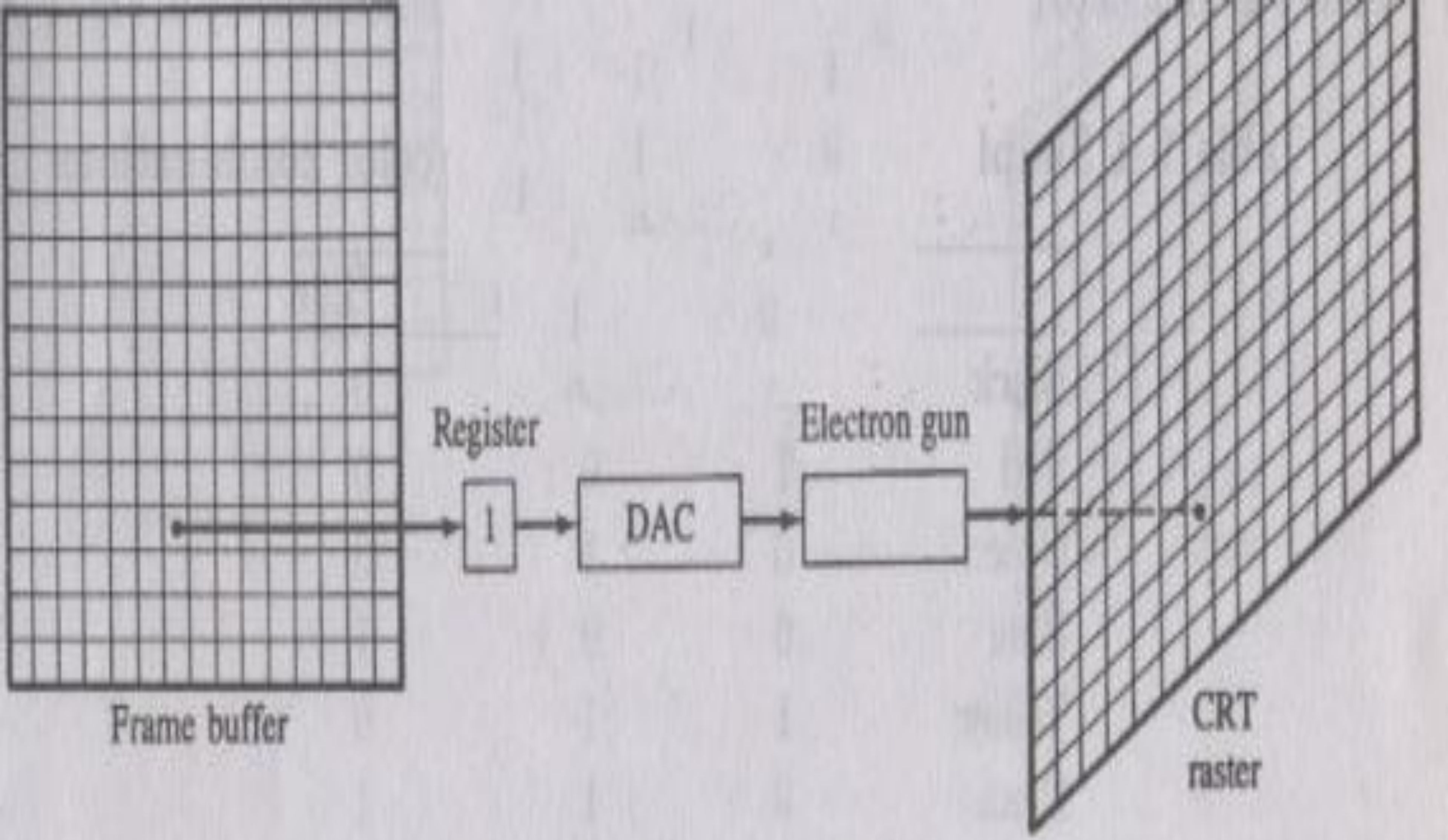
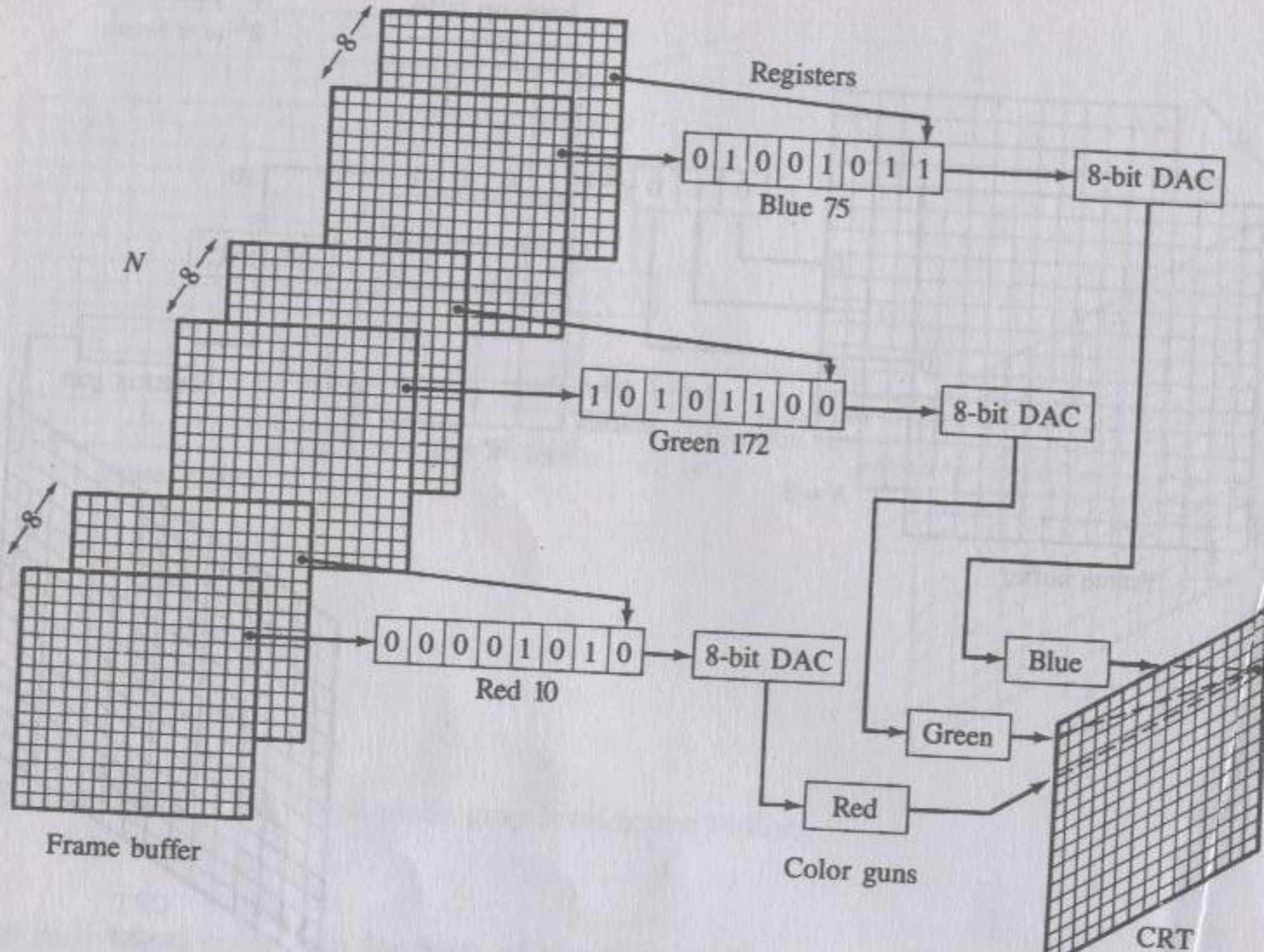


Figure 1–24 A single-bit-plane black-and-white frame buffer raster CRT graphics device.



8
N
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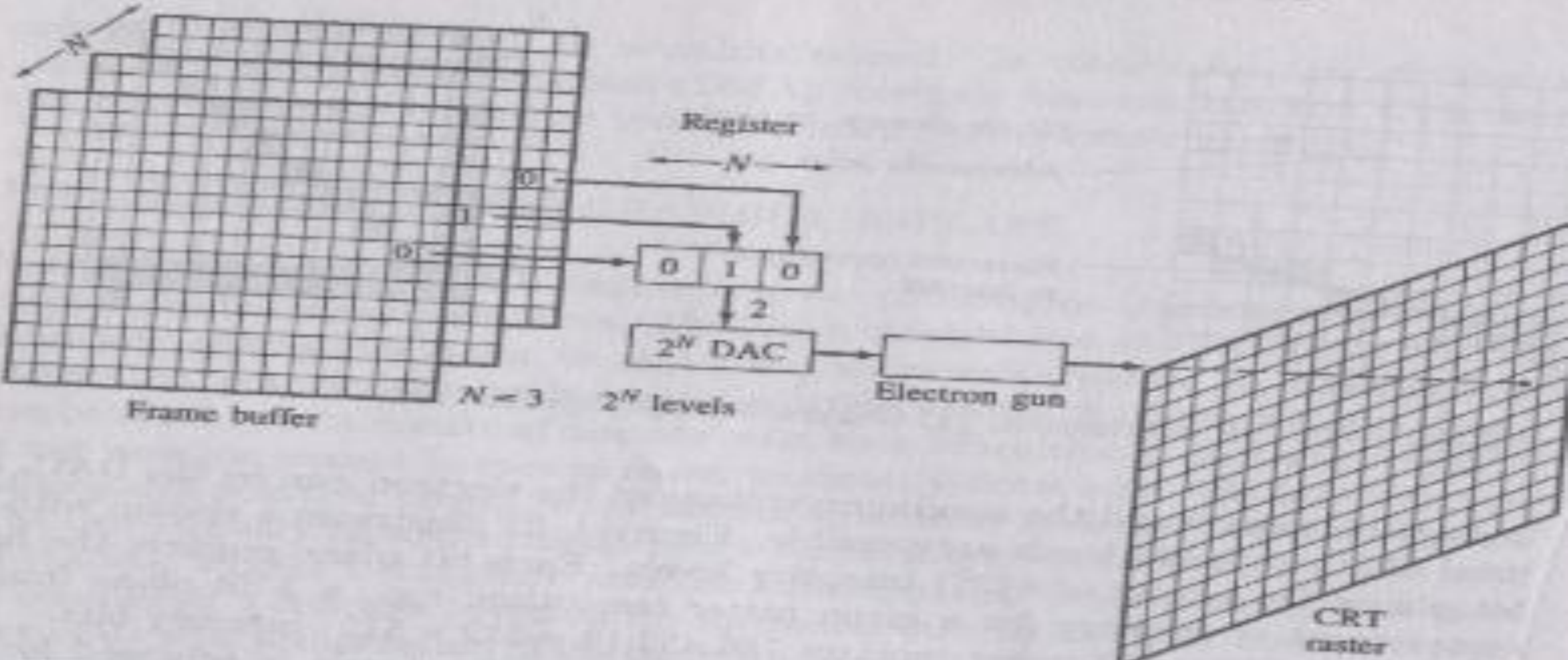
8
Registers
0 1 0 0 1 0 1 1
Blue 75
8-bit DAC
1 0 1 0 1 1 0 0
Green 172
8-bit DAC
0 0 0 0 1 0 1 0
Red 10
8-bit DAC
Blue
Green
Red
Frame buffer
Color guns
CRT


N
Register
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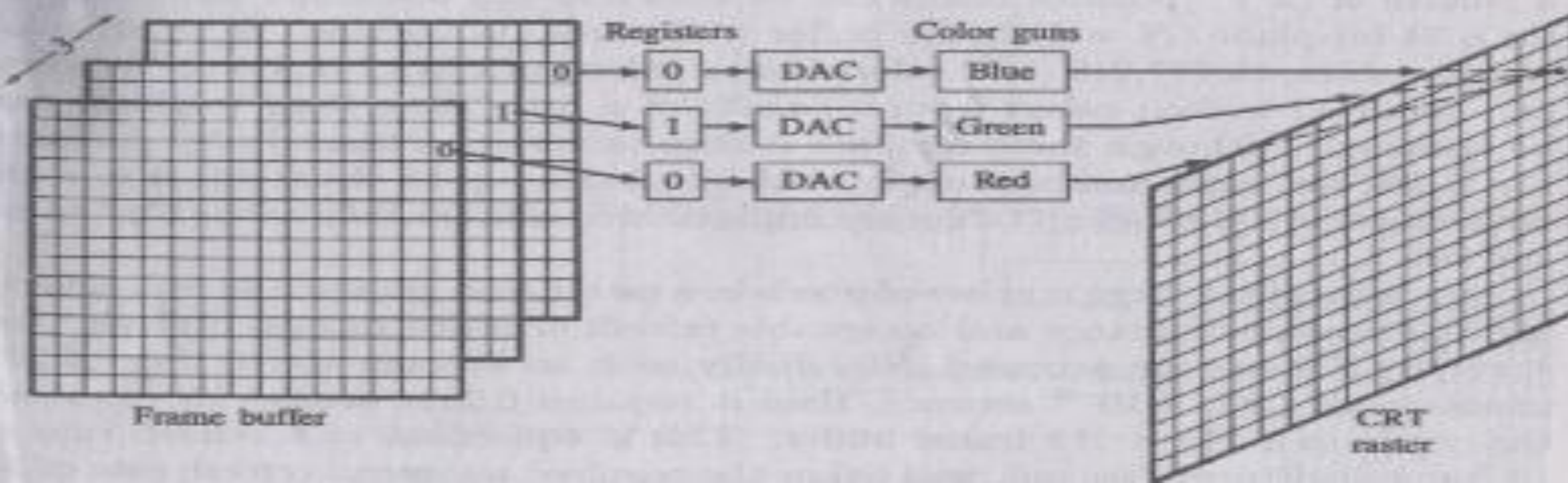
2^N DAC
Electron gun
Frame buffer
N = 3
2^N levels
CRT
raster


3
Registers
Color guns
0
1
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1
0
DAC
DAC
DAC
Blue
Green
Red
Frame buffer
CRT
raster

Refresh rate

When electron beam strikes a dot in CRT, the surface of the CRT **only glows for a fraction of a second** and then fades.

Monitor **must redraw** the picture many times per second to avoid having the screen flicker

Refresh rate

The refresh rate is the number of times per second that monitor redraws the images on the screen.

Very few people notice flicker at refresh rates above 72 Hz.

Higher refresh rates are preferred for better comfort in viewing the monitor

Quality of a CRT Monitor

Depends largely on its **resolution, dot pitch**, and **refresh rate**

Resolution describes the **sharpness** and **clearness** of an image

Manufacturers state the resolution of a monitor in pixel

Example: 800 X 600

A pixel (*pi*cture *el*ement) is a single point in an electronic image

A pixel is the smallest element in an electronic image

Video Cards and CRT Monitors

Many CRT monitors use an analog signal to produce an image

Video card converts **digital output from the computer into an analog video signal** and sends the signal through a cable to the monitor

Also called a **graphics card**

Video Cards and CRT Monitors

The number of colors a video card displays is determined by its **bit depth**

The video card's bit depth, also called the color depth, is the **number of bits it uses to store information** about each pixel
i.e. 8-bit video card uses 8 bits to store information about each pixel; this video card can display 256 colors (2x2x2x2x2x2x2x2)
i.e. 24-bit video card uses 24 bits to store information about each pixel and can display 16.7 million colors

The greater the number of bits, the better the resulting image

Color Depth	Number of Displayed Colors	Bytes of Storage Per Pixel	Common Name for Color Depth
4-Bit	16	0.5	Standard VGA
8-Bit	256	1.0	256-Color Mode
16-Bit	65,536	2.0	High Color
24-Bit	16,777,216	3.0	True Color

Video Display StandardsVideo Electronics Standards Association (VESA), which consists of video card and monitor manufacturers, develops video stands to define the resolution, number of colors, and other display properties.

- Monochrome Display Adapter (MDA)
- Hercules Graphics Card
- Color Graphics Adapter (CGA)
- Enhanced Graphics Adapter (EGA)
- Video Graphics Adapter (VGA)
- Super VGA (SVGA) and Other Standards Beyond VGA

Line Drawing

Point plotting is accomplished by converting a single coordinate position by an application program into approximate operation for the output device in use.

CRT electron beam is **turned on** to illuminate the screen phosphor at selected location.

Line Drawing

In **random scan system***,* point plotting commands are stored in display list and **coordinate values in these instructions are converted to deflection voltages** that position the electron beam at that screen location to be plotted during each refresh cycle.

In case of black and white **raster scan system** a point is plotted by **setting the bit value** corresponding to specified screen position **within *frame buffer* to 1**.

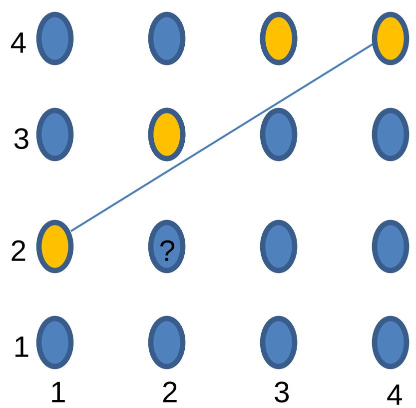
Line Drawing

For drawing lines, we need to calculate **intermediate positions** along the line path between two end points

e.g. 10.45 is rounded off to 10 (this causes **stair cases** or **jaggies** to be formed)

To *load* intensity value into frame buffer at position x, y we use function **setpixel (x, y, intensity)**

To *retrieve* current frame buffer intensity value for specified location we use **getpixel(x,y)**



DDA (Digital Differential Analyzer)

Slope intercept equation of a straight line is $y = m x + c$

For points (x1, y1) and (x2,y2) slope $m = y2 – y1/x2 - x1$ or $\Delta y/\Delta x$

Algorithms for displaying lines depend on these equations for given interval x we can compute y interval

$\Delta y = m \cdot \Delta x$

'x' interval Δx is obtained by $\Delta x = \Delta y/m$

These equations **form the basis for determining deflection voltages** in analog devices

DDA (Digital Differential Analyzer)

For lines with slope m = 1, Δy and Δx are equal

DDA scan conversion algorithm is **based on calculating Δx, Δy**

We **sample line at unit interval** in one coordinate and **determine corresponding integer values** nearest the line path for other coordinate

DDA (Digital Differential Analyzer)

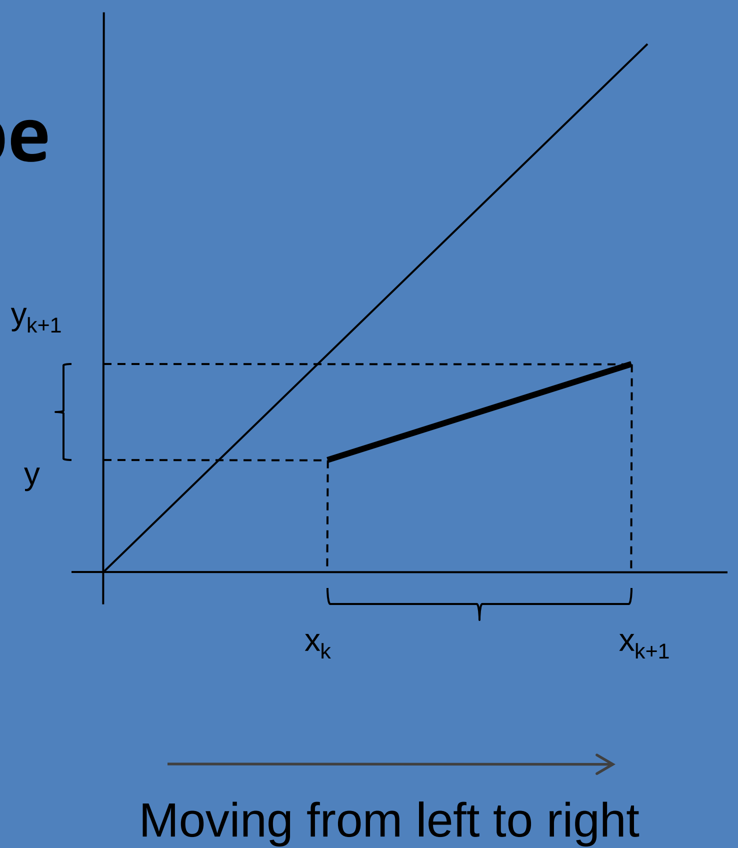
Positive Slope

For slope < 1

$\Delta x > \Delta y$

$y_{k+1} - y_k = m$

or $y_{k+1} = y_k + m$



DDA (Digital Differential Analyzer)

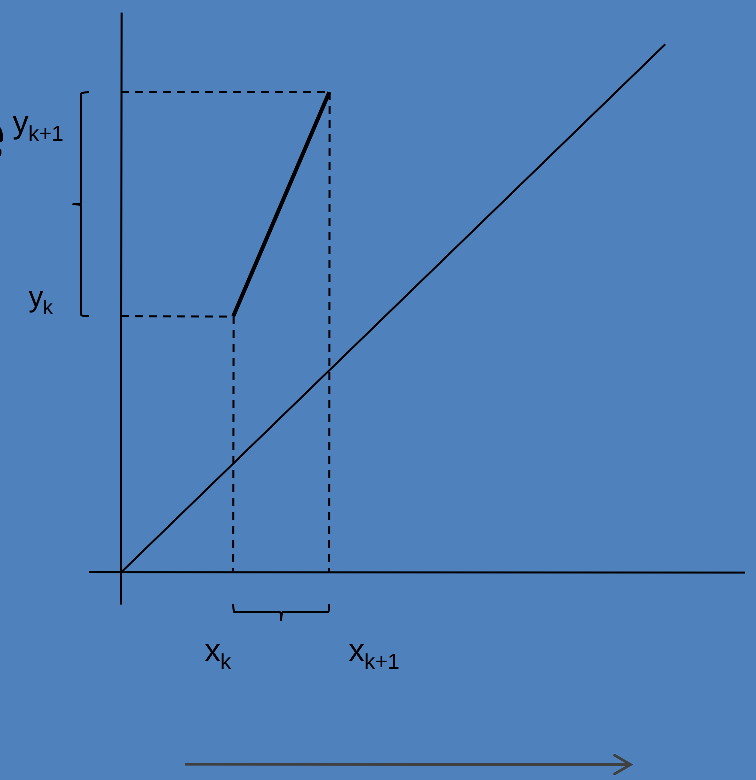
Positive Slope

For slope > 1

$\Delta y > \Delta x$

$x_{k+1} - x_k = 1/m$

or $x_{k+1} = x_k + 1/m$



Moving from left to right

DDA (Digital Differential Analyzer)

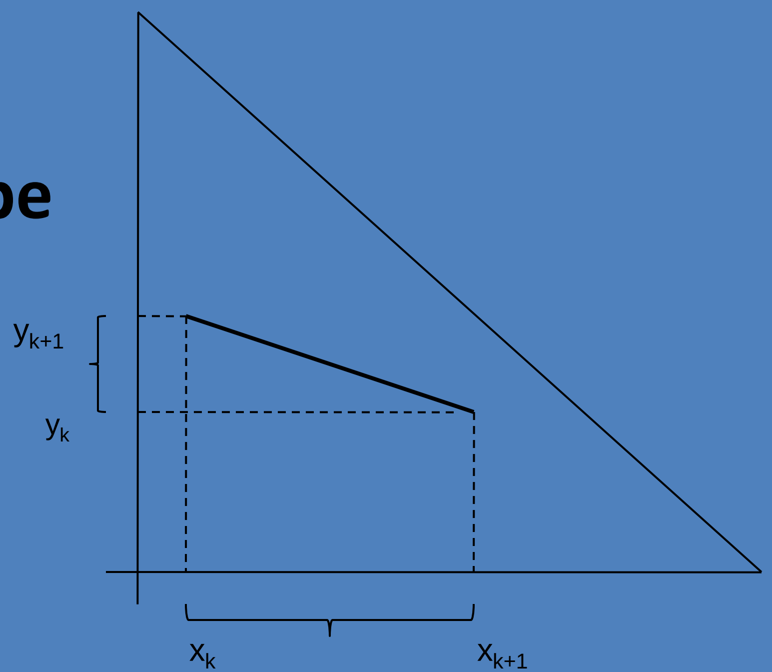
Negative Slope

For slope < 1

$\triangle y > \triangle x$

$y_{k+1} - y_k = m$

or $y_{k+1} = y_k + m$



Moving from left to right

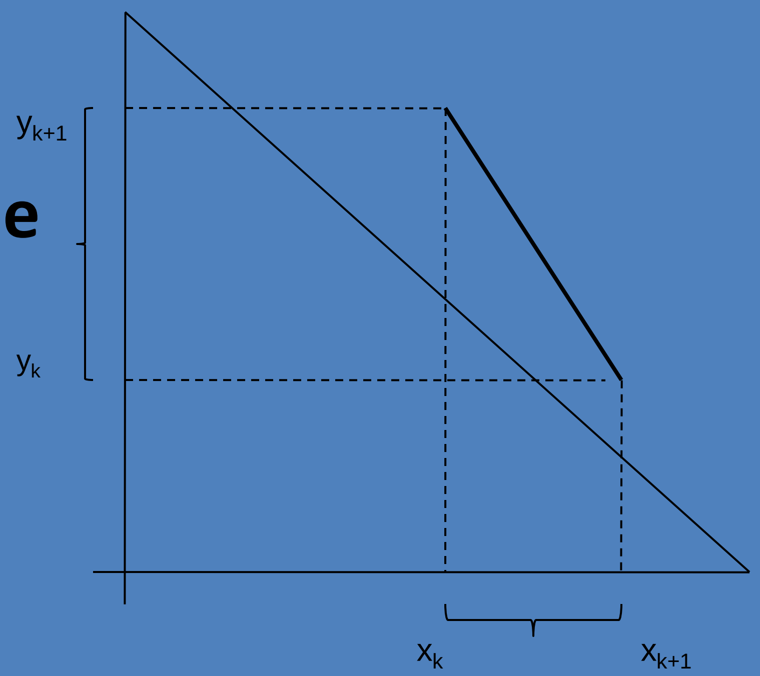
DDA (Digital Differential Analyzer)

Negative Slope

For slope > 1

$\Delta y > \Delta x$

or $x_{k+1} = x_k - m$?



Moving from left to right

DDA (Digital Differential Analyzer)

Advantages:

i. Accurate

Disadvantages :

i. Slower as it uses floating point arithmetic

Bresenham's Line Drawing Algorithm

Accurate and easier line drawing algorithm by Bresenham

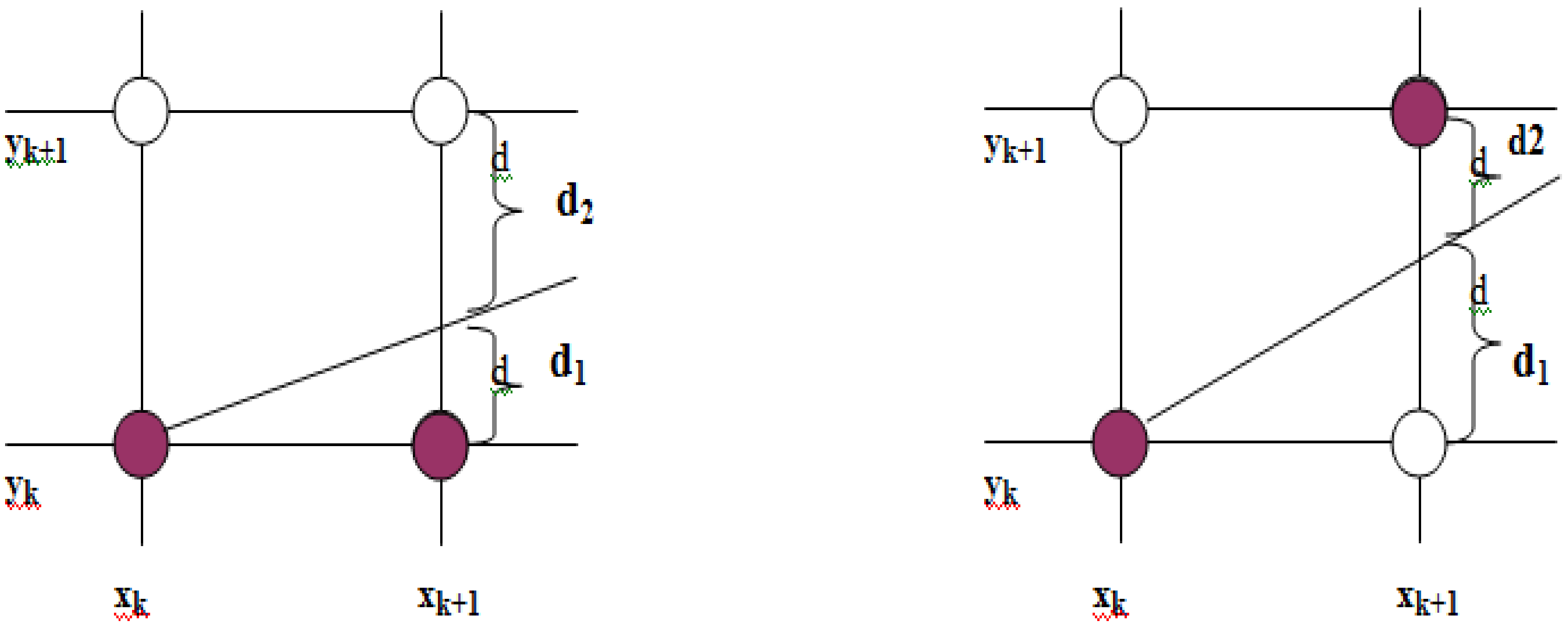
Vertical axis: *scan line*

Horizontal axis: *pixel column*

For slope < 1 sample at unit *'x'* interval in *'x'* direction, determine which of the two possible pixel positions is closer to the line path at each sample step.

Bresenham's algorithm gives the solution to this problem by testing the sign of the integer parameter whose value is proportional to difference between the separation of two pixel positions from actual line path.

Line Drawing



(x_k, y_k) plotted next to plot (x_{k+1}, y_k) or (x_{k+1}, y_{k+1})

Line Drawing

Algorithm for 0<m<1

Input the two line endpoints and store the left end point in (x_0, y_0)
Load (x_0, y_0) into the frame buffer; that is, plot the first point

Calculate constants Δx, Δy, $2\Delta y$, and $2\Delta y - 2\Delta x$, and obtain the starting value for the decision parameter as

At each x_k along the line, start at $k = 0$, perform the following test:

If $p_k < 0$, the next point to plot is (x_k+1, y_k) and

Otherwise, the next point to plot is (x_k+1, y_k+1) and

Repeat step 4 Δx times

Dot Pitch

The distance between adjacent sets of red, green and blue dots.

The dot pitch of the monitor indicates how fine the dots are that make up the picture.

The smaller the dot pitch, the more sharp and detailed the image.

Filled Area Primitives

Standard output primitive in graphics packages is solid color ,patterned polygon area

Polygons are easier to process due to linear boundaries

Two basic approaches to area filling on a raster system

1. Determine the overlap intervals **for scan lines that cross the area. Typically useful for filling polygons, circles, ellipses**

2.Start from a given interior position **and paint outwards from this point until we encounter the specified boundary conditions useful for filling more complex boundaries, interactive painting system.**

Filling rectangles

Two things to consider

i. which pixels **to fill**

ii. with what value **to fill**

Move along scan line (from left to right) that intersect the primitive and fill in pixels that lay inside

To fill rectangle with solid color

Set each pixel lying on scan line running from left edge to right with same pixel value, each span from x_{max} to x_{min}

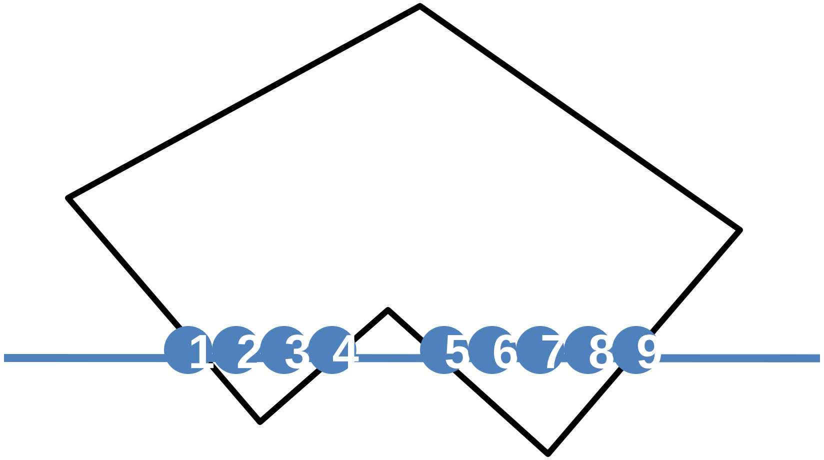
```
for( y  from y_min    to y_max   of rectangle)              /*scan line*/
   for( x  from x_min    to x_max  of rectangle)          /*by pixel*/
        writePixel(x, y, value);
```

Filling Polygons

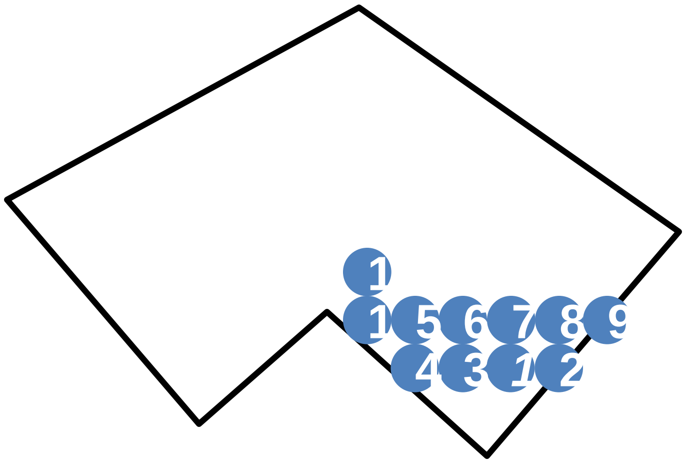
Filling Polygons

Scan-line fill algorithm

Inside-Outside tests



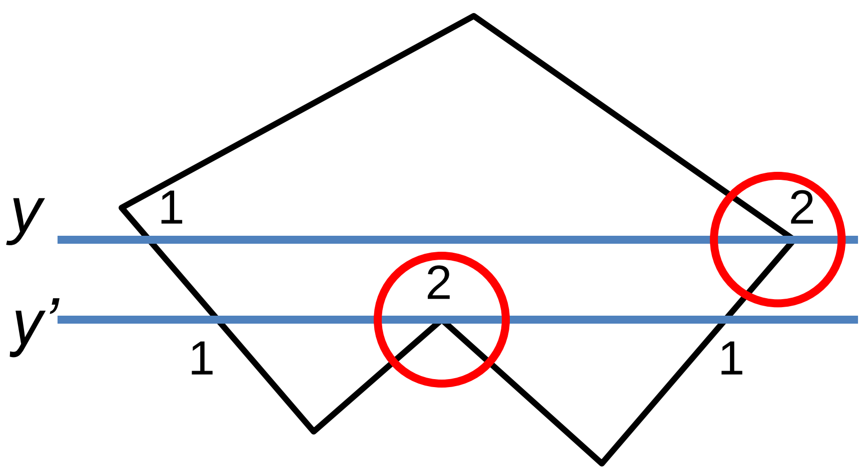
Boundary fill algorithm

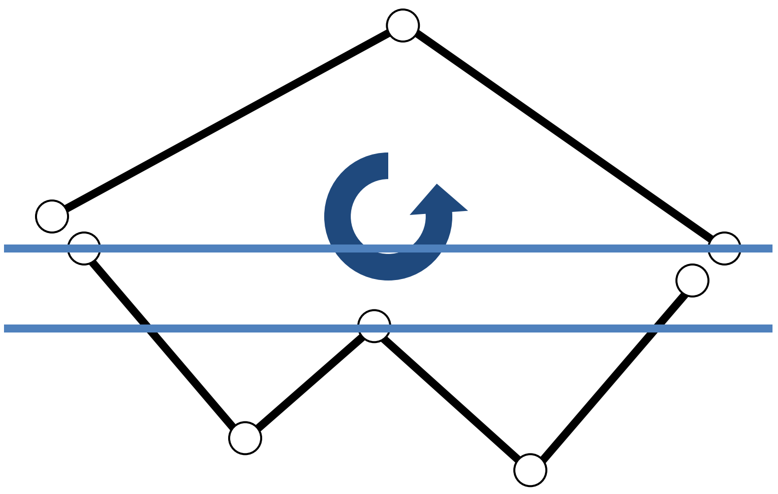


Topological Difference between 2 Scan lines

y : intersection edges are opposite sides

y' : intersection edges are same side

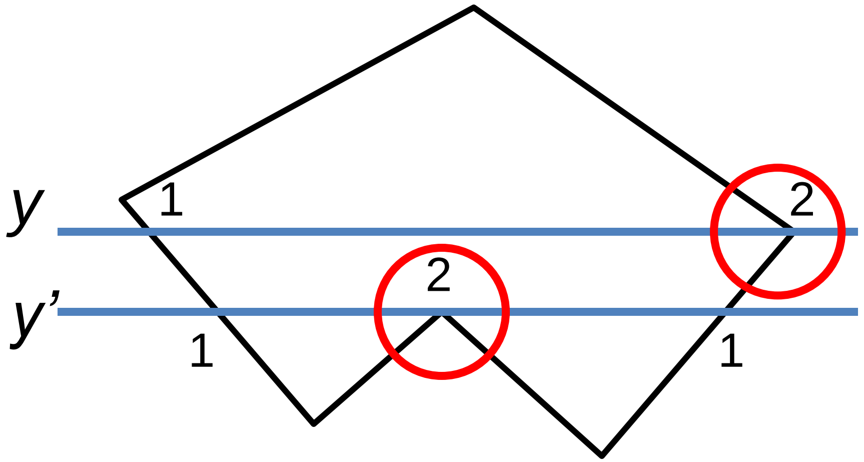


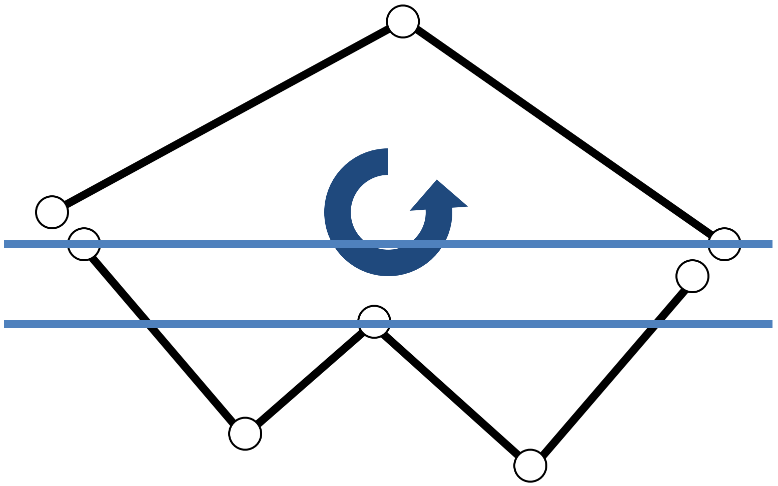


Topological Difference between 2 Scan lines

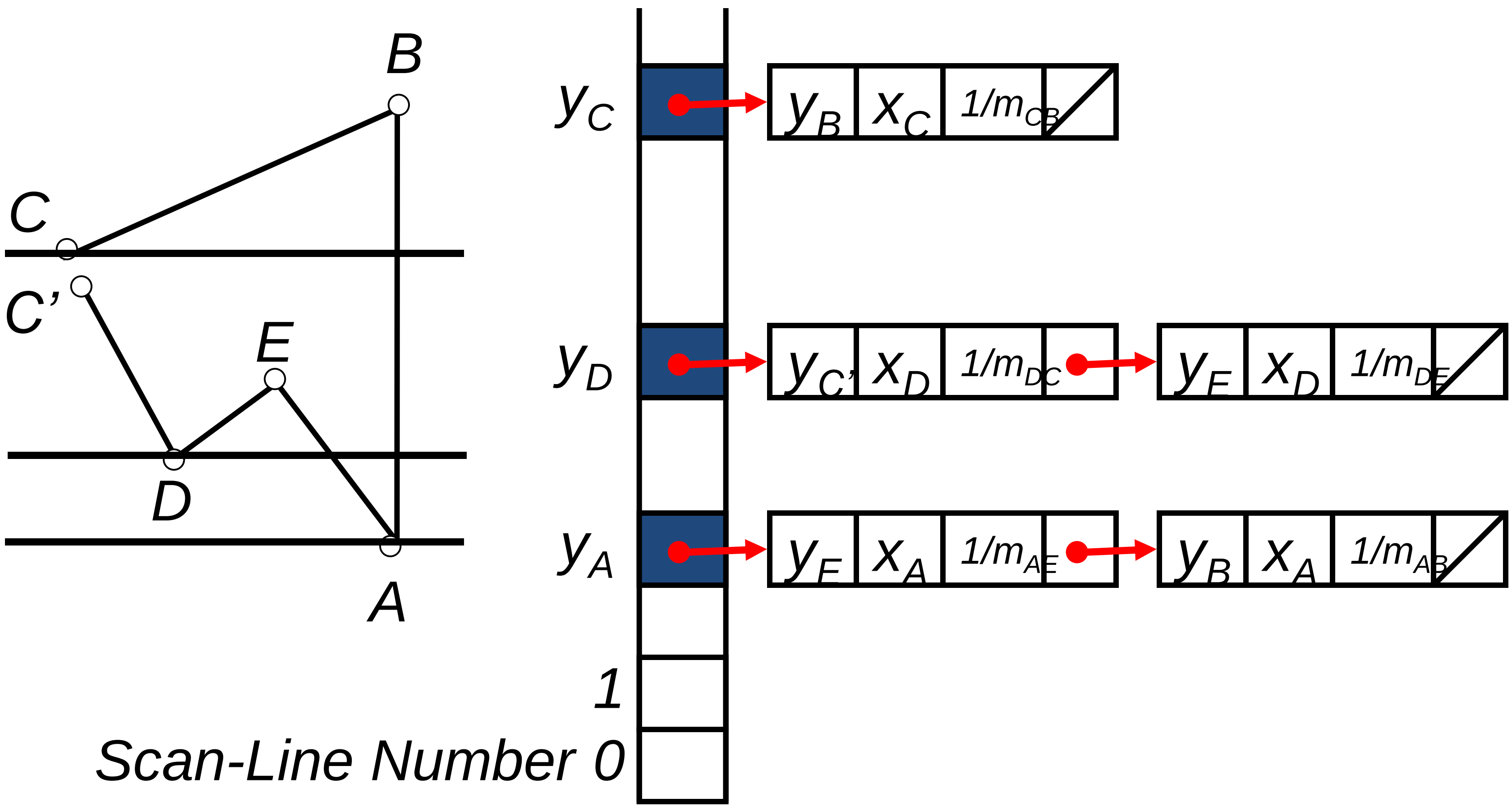
y : intersection edges are opposite sides

y’ : intersection edges are same side





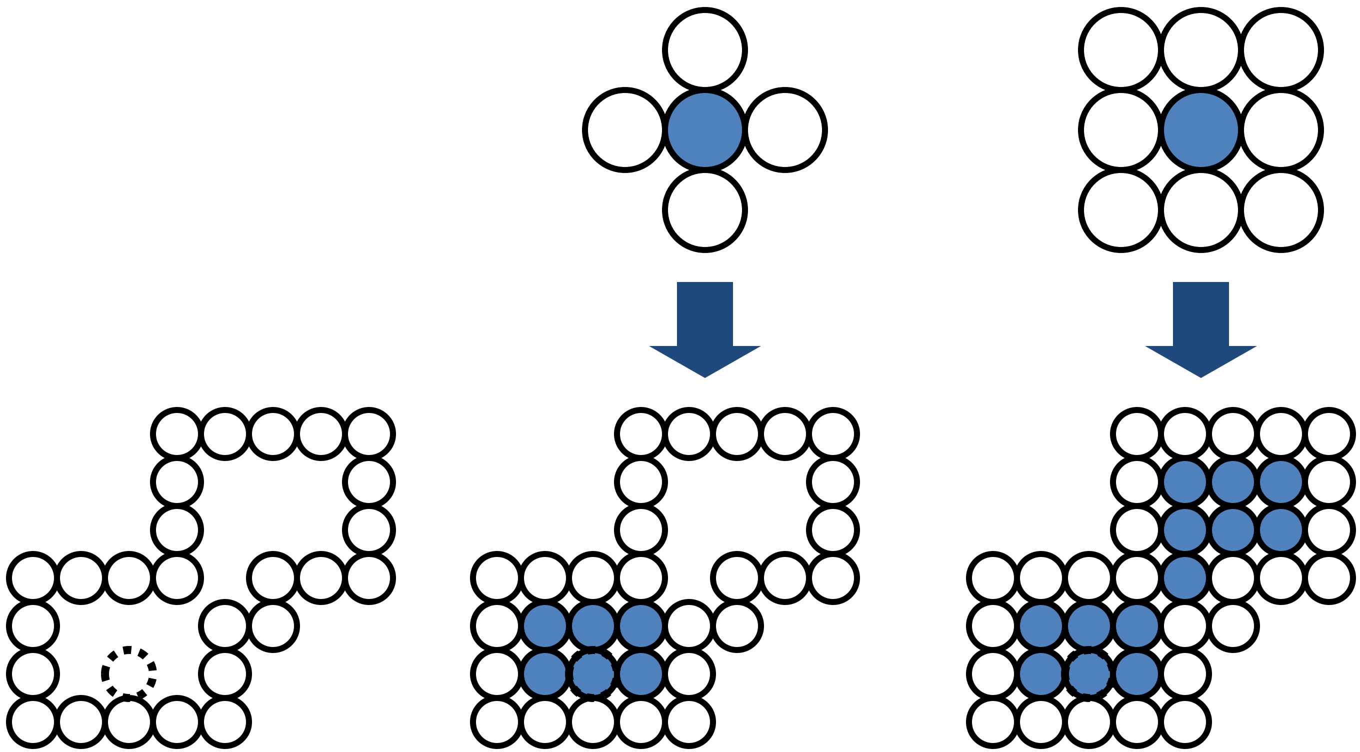
Edge Sorted Table



Proceed to Neighboring Pixels

4-Connected

8-Connected



Boundary Fill

Start at a point inside a region **and paint the interior outward toward the boundary.**

If boundary is specified in a single color the fill algorithm proceeds outward pixel by pixel until the boundary color is encountered

Accepts as input coordinates of an interior point (x, y) a fill color and boundary color.

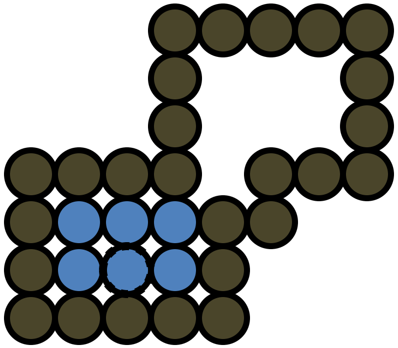
Starting from (x, y) the procedure tests neighboring position to determine whether they are of the boundary color.

If not they are painted with fill color and their neighbors are tested

Process continues until all pixels up to boundary color for the area have been tested

```
boundaryFill(int x,y,fill_color, boundary_color){
 int color;
  getpixel(x,y,color)
  if(color !=  boundary_color AND color != fill_color ){
     setpixel( x,y,fill_color)
     boundaryFill( x+1,y,fill_color, boundary_color)
     boundaryFill( x,y+1,fill_color, boundary_color)
     boundaryFill( x-1,y,fill_color, boundary_color)
     boundaryFill( x,y-1,fill_color, boundary_color)
  }

}
```



Flood Fill

Filling an area that is not defined within a single color boundary.

In this case replace a specified interior color instead of searching for boundary color value.

Start from specified interior point (x , y) and reassign all pixel values that are currently set to a given interior color with the desired color.

If the area we want to paint has more than 1 interior color , first assign pixel values so that all interior points have same color.

We can then use 8 or 4 connected approach to move on until all interior points have been repainted.

```
floodFill(int x,y,fill_color, original_color){
  int color;
    getpixel(x,y,color)
    if(color == original_color ){
        setpixel(x,y,fill_color)
        floodFill(x+1,y,fill_color, original_color)
        floodFill(x,y+1,fill_color, original_color)
        floodFill(x-1,y,fill_color, original_color)
        floodFill(x,y-1,fill_color, original_color)
    }

}
```