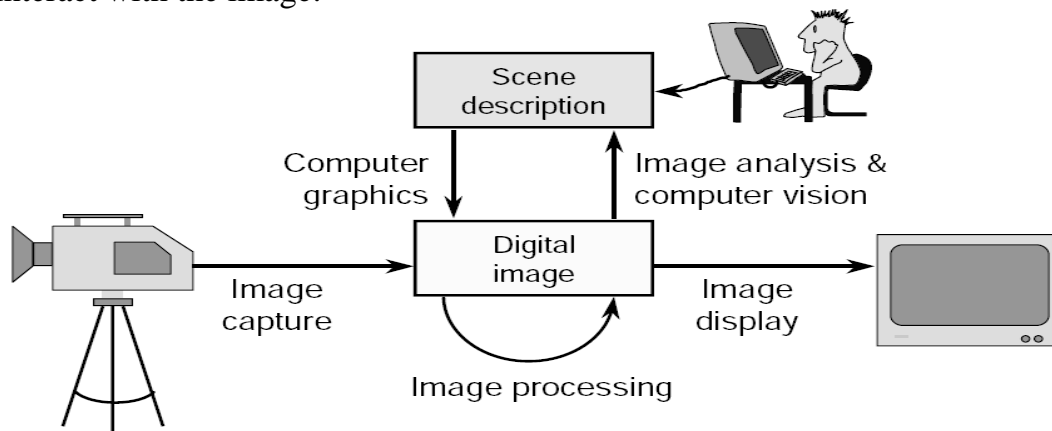


Part 1: Introduction to Computer Graphics

1. What do you mean by computer graphics?

The branch of science and technology concerned with methods and techniques for converting data to or from visual presentation using computers.

- Create an image.
- Store the image in the memory.
- Display the image on display device.
- Make a processing on the images.
- Interact with the image.



2. What are the applications of computer graphics?

1. Computer Aided Design
2. Graphical User Interface
3. Entertainment
4. Simulation and Training
5. Education and Presentation
6. Computer Generated Art
7. Scientific Visualization
8. Image Processing
9. Virtual reality

3. What can the programmer do in computer graphics?

- Develop the geometric model for objects of the images.
- Assemble these objects into an appropriate geometric space.
- Specify how the scene is to be displayed on the graphic device.
- Define some animation for the image.
- Design a ways for the user to interact with the scene as it is presented.

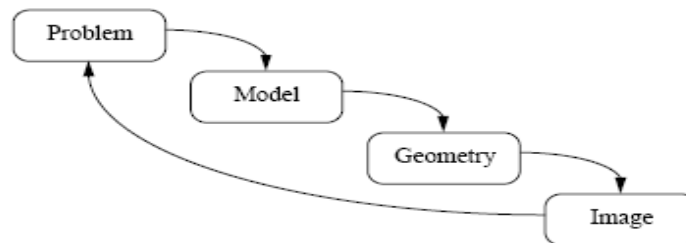
4. List of computer graphics software packages:

1. OpenGL	2. Alias	3. Director	4. Photoshop
5. CorelDraw	6. AutoCAD		

5. How can the computer graphics used in solving problems?

GC can solve a lot of problems:

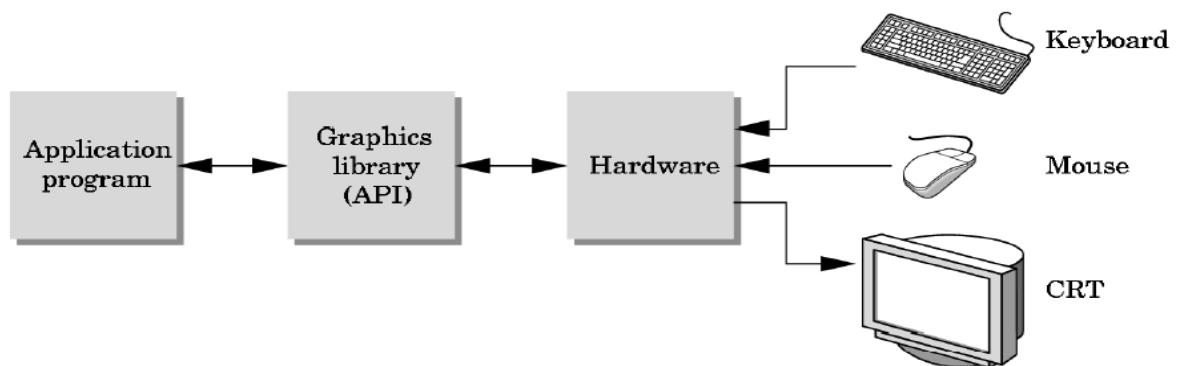
- Identifying a problem.
- Building the model.
- Represent the problem geometrically and create an image.
- Use the image to understand the problem and try find a possible solution.



6. Define Graphics API?

Is a set of tools and functions that:

- Allow a programmer to write computer graphics without dealing with system details.
- Perform a set of related operations such as drawing images and 3D surfaces into windows on the screen.

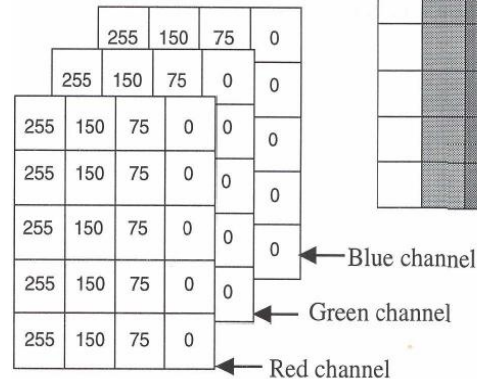
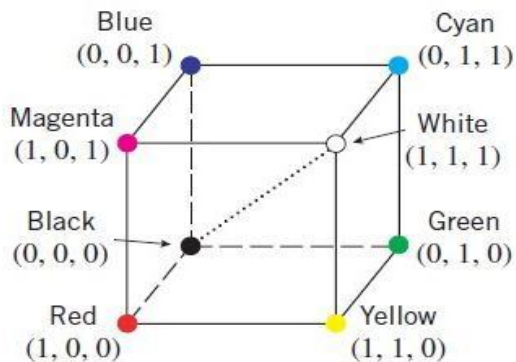


7. What do you mean by GUI?

- GUI stands for Graphical user interface.
- Consists of a window manager that allows a user to display multiple-window areas.
- Simply click in a window to make it active.
- Using of menus and icons for fast selection of processing options or parameter values.

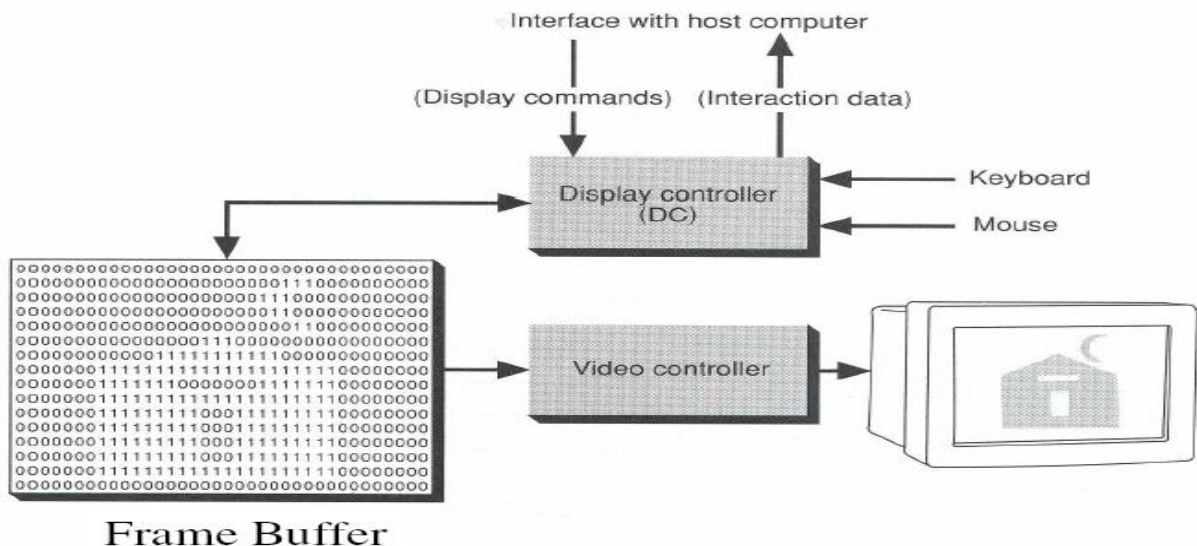
8. What does it mean by RGB?

- The RGB is a color model.
- Red, Green, and Blue light are added together to reproduce a different array of colors.



9. Define refresh buffer/Frame buffer?

- A memory area used to store Picture definition.
- It stores the set of intensity values for all the screen points.

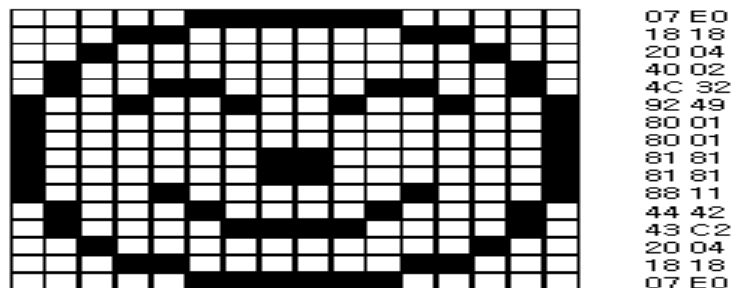


10. Define Pixel.

- Each screen point is referred to as a pixel or pel (Picture element).

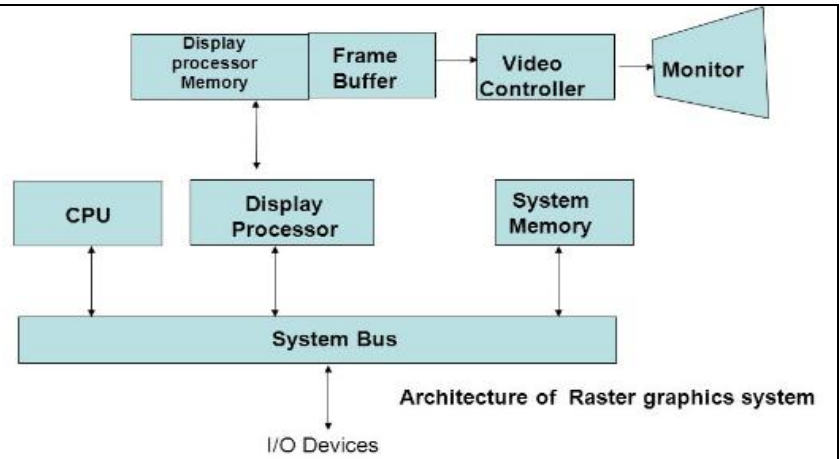
11. Define bitmap.

- On a black and white system with one bit per pixel, the frame buffer is commonly known as a bitmap.



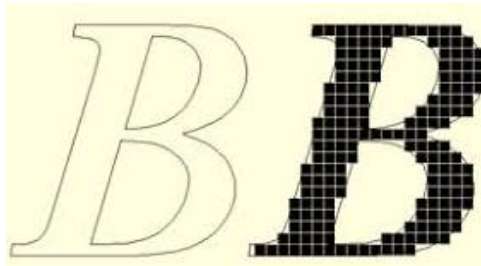
12. What is the role of a video controller?

- Used to control the operation of the display device.
- Copy the content of the frame buffer to refresh the screen.



13. What is the function of Graphics controller /Display controller/Display processor?

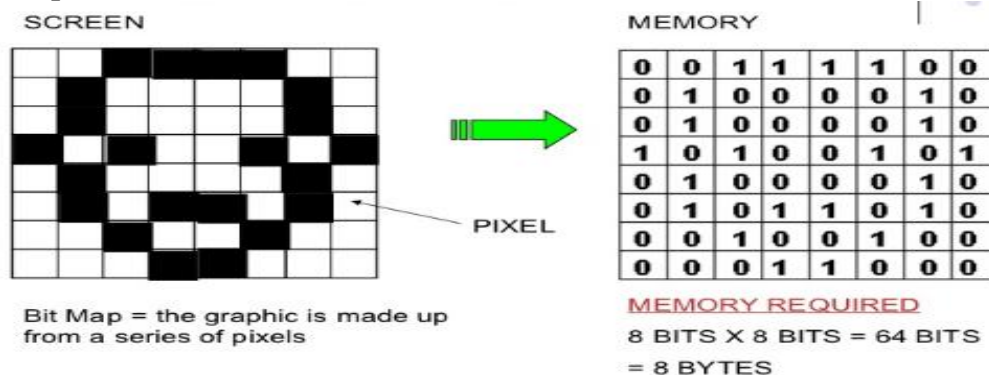
- Used to free the CPU from graphic chores.
- Digitizing a picture definition given in an application program into a set of pixel intensity values for storage in the frame buffer.
- This digitization is called scan conversion



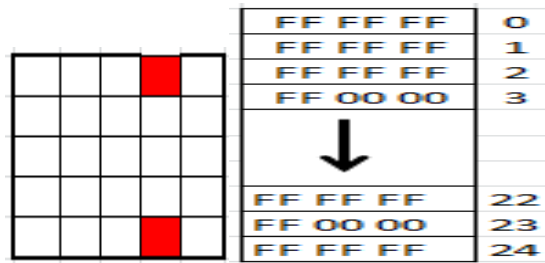
14. Memory mapping

The status of each pixel on the screen was stored in a memory location (memory mapped display).

- Each pixel is numbered sequentially.
- By writing values to the correct locations in memory the appearance of the screen can be controlled by a programmer.
- A program can pixel is turned on or off.

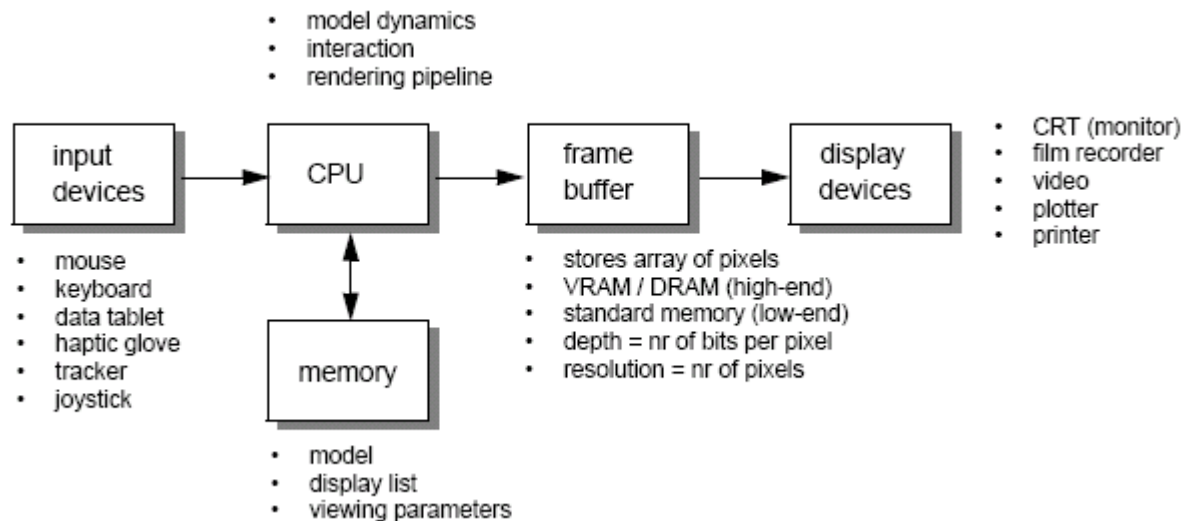


15. Give an example of memory mapping for 5 X 5 resolution color display device?



16. Describe the Basic Components of computer graphics system?

- A computer graphics system is a computer system; that have all the components of a general-purpose computer system.
- Input devices
- Central Processing Unit
- Graphics Processing Unit
- Memory
- Frame buffer
- Output devices



17. What is the difference between raster storage image and vector storage image?

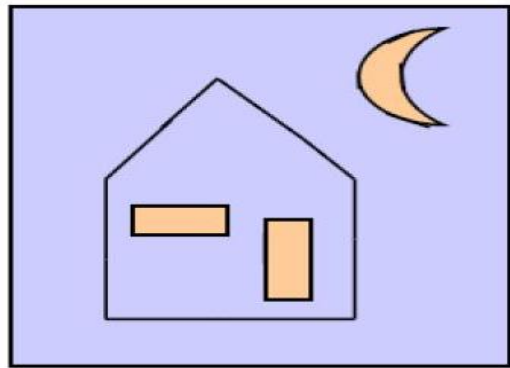
Raster Image:

- The images is considered as rectangular arrays of pixels.
- Each pixel have different colors stored as three numbers, for RGB.
- In a Monochrome system [black-and-white], each screen point is either on (a bit value of 1) or off (a bit value of 0).

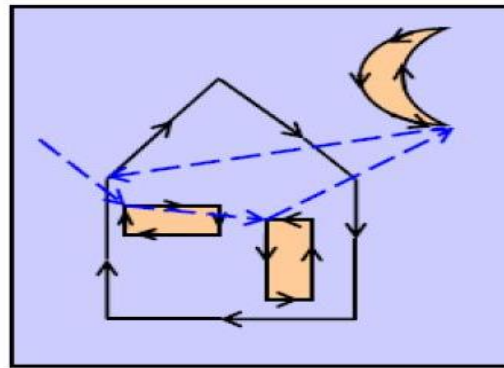
Random scan Image:

- The image is stored as a set of instructions for displaying the.

- Used for text, diagrams, mechanical drawings, and other applications where precision are important and photographic images and complex shading aren't needed.



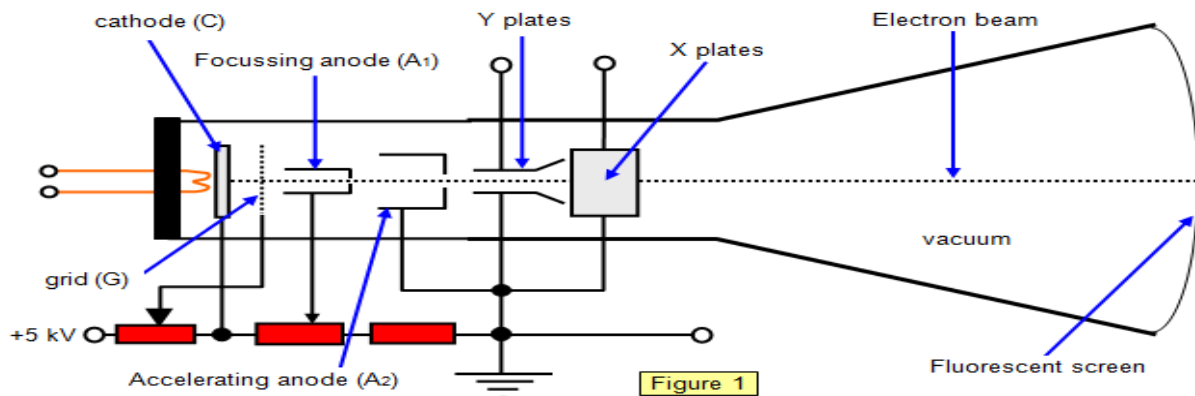
Ideal line drawing



Random Scan Display

18. List the operating characteristics for the video display systems based on the CRT technology?

- A beam of electrons emitted by an electron gun, passes through focusing System and deflection systems that direct the beam toward specified positions on the phosphor-coated screen.
- The phosphor-coated screen then emits a small spot of light at each position contacted by the electron beam.
- The light emitted by the phosphor fades very rapidly, the picture is redrawn by quickly directing the electron beam back over the same points. This type of display is called a refresh CRT.



19. Define persistence in terms of CRT Phosphorous.

Persistence means how long they continue to emit light after the electron beam is removed.

20. Define resolution.

The maximum number of points that can be displayed without overlap on a CRT monitor.

21. What do you mean by an aspect ratio?

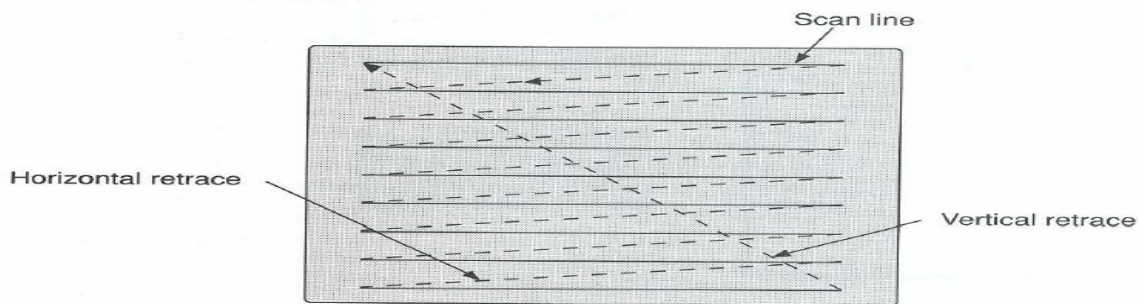
Aspect ratio is the ratio of vertical points to horizontal points necessary to produce equal length lines in both directions on the screen. An aspect ratio of $\frac{3}{4}$ means that a vertical line plotted with three points has same length as a horizontal line plotted with 4 points.

22. What are the different properties of phosphorus?

1. Color
2. Persistence

23. What do you mean by retracing? Define horizontal as well as vertical retracing.

- **Retracing:**
At the end of each scan line, the electron beam returns to the left side of the screen to begin displaying the next scan line.
- **Horizontal retrace**
The return to the left of the screen, after refreshing each scan line.
- **Vertical retrace**
At the end of each frame, the electron beam returns to the top left corner of the screen to begin the next frame.



Refresh rate is usually 60-75Hz

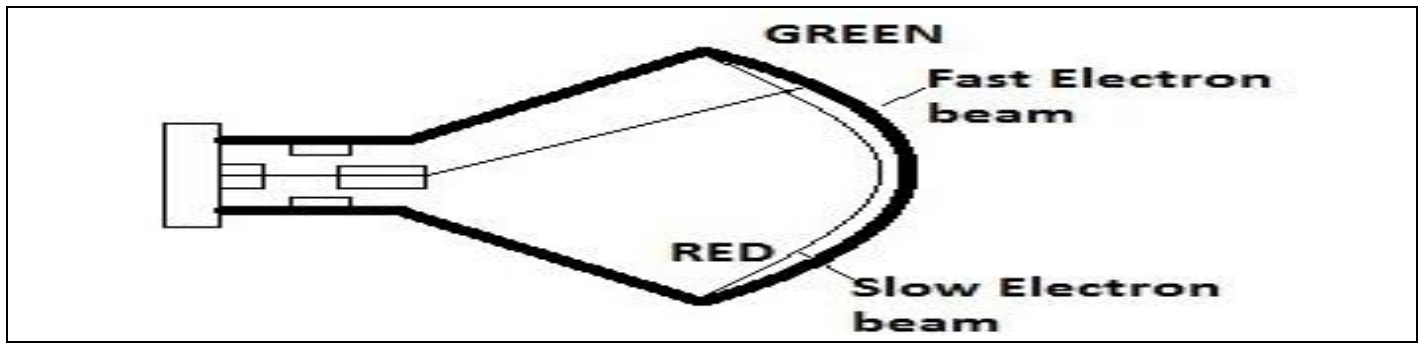
24. What do you mean by interlacing?

Used for displaying a visual on a CRT. On some raster scan systems, each frame is displayed in two passes using an interlaced refresh procedure. In the first pass, the beam sweeps across every other scan line from top to bottom. Then after the vertical retrace, the beam sweeps out the remaining scan lines.

25. What is a Beam penetration method?

A technique is used in **random scan display systems**.

- Two layers of phosphor (red and green) are coated onto the inside of the CRT screen.
- The displayed colors depends on how the electron beam penetrates into the phosphors layers. - A slow electron beam excites only the outer red layer.
- A very fast electron beam penetrates through the red layer and hence excites the green layer. - An average electron beam gives the combination of red and green color. (yellow and orange.)

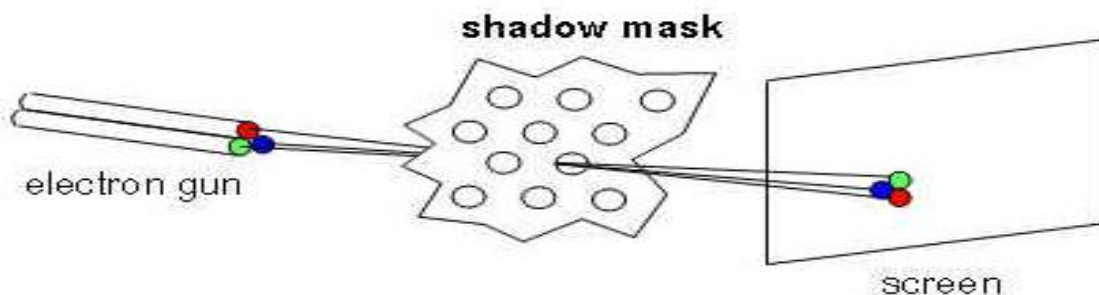


26. Define shadow masking (Three Electron Gun).

This technique is used in raster scan display devices.

- Gives more colors than a beam penetration method.
- A shadow Mask CRT has 3 guns to generate 3 phosphor color dots at each pixel location (red, green and blue).
- A shadow mask grid is installed just behind the phosphor coated screen.

When the three beams pass through a hole in the shadow mask, they activate a dot triangle, which appears as a small color spot on the screen.



27. What are the different types of Flat-Screens, and what is the difference between them?

- light-emitting diodes (LEDs) - light-emitting diodes that can be turned on and off
- liquid-crystal displays (LCDs) - polarization of the liquid crystals in the middle panel
- plasma panels - voltages on the grids to energize gases
- Similarities:
 - All use a two-dimensional grid to address individual light-emitting elements.
 - The two outside plates each contain perpendicular parallel grids of wires.
 - Sending electrical signals to a wire in each grid, generates electrical field at the Intersection of two wires, can control the corresponding element in the middle plate.

28. What are the popular image storage formats?

- **Jpeg format.** This Lossy format compresses image blocks based on thresholds in the human visual system. This format works well for natural images.
- **Tiff format.** This format is most commonly used to hold binary images or lossless compressed 8- or 16-bit RGB although many other options exist.
- **Ppm format.** A lossless, uncompressed format is most often used for 8-bit RGB images although many options exist.
- **Png format.** This is a set of lossless formats with a good set of open source management tools.

Exercises

29. Consider three different raster systems with resolutions of 640 x 480, 1280 x 1024, and 2560 x 2048.

a. What size is frame buffer (in bytes) for each of these systems to store 12 bits per pixel?

Because eight bits constitute a byte, frame-buffer sizes of the systems are as follows:

$640 \times 480 \times 12 \text{ bits} / 8 = 450\text{KB};$

$1280 \times 1024 \times 12 \text{ bits} / 8 = 1920\text{KB};$

$2560 \times 2048 \times 12 \text{ bits} / 8 = 7680\text{KB};$

b. How much storage (in bytes) is required for each system if 24 bits per pixel are to be stored?

Similarly, each of the above results is just doubled for 24 (12×2) bits of storage per pixel.

30. Q33. Consider two raster systems with the resolutions of 640 x 480 and 1280 x 1024.

a. How many pixels could be accessed per second in each of these systems by a display controller that refreshes the screen at a rate of 60 frames per second?

Since 60 frames are refreshed per second.

Each frame consists of 640 x 480 pixels,

- The access rate of such a system = $(640 \times 480) \times 60 = 1.8432 \times 10^7$ pixels/second.

For the 1280 x 1024 system,

- The access rate is $(1280 \times 1024) \times 60 = 7.86432 \times 10^7$ pixels/second.

b. What is the access time per pixel in each system?

The access time per pixel = $1 / \text{access rate}$.

The access time is around 54 nanoseconds/pixel for the 640 x 480 system,

The access time is around 12.7 nanoseconds/pixel for the 1280×1024 system.

31. Consider a raster system with the resolution of 1024 x 768 pixels and the color palette calls for 65,536 colors. What is the minimum amount of video RAM that the computer must have to support the above-mentioned resolution and number of colors?

No of Colors = 65,536 colors

Number of bits per pixel = $\log_2 (65,536) = 16$ -bit color.

The display's resolution is 1024X768 pixels

Total Number of pixels = 786,432 (1024×768) pixels.

The total number of bits required

$= 786,432 \times 16 = 12,582,912 \text{ Bits} = 1,572,864 \text{ bytes} = 1,536 \text{ KB} = 1.5 \text{ MB}$

32. How Many k bytes does a frame buffer needs in a 600 x 400 pixel?

Given :- Resolution is 600 x 400

Suppose 1 pixel can store n bits

Then, the size of frame buffer	=	<i>Resolution X bits per pixel</i>	
	=	$(600 \times 400) \times n \text{ bits}$	
	=	$240000 \times n \text{ bits}$	
	=	$\frac{240000 \times n}{1024 \times 8} \text{ k bytes}$	(as 1kb = 1024 bytes)
	=	29.30 n k bytes	

- 33. Q38. How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution of 1280 X 1024 and a refresh rate of 60 frames per second?**

Resolution = 1280 X 1024

That means system contains 1024 scan lines and each scan line contains 128 pixels

Refresh rate = 60 frame/sec.

1 frame takes = $1/60$ sec = 0.01666 sec.

1 frame buffer consist of 1024 scan lines (It means then 1024 scan lines takes 0.01666 sec) 1 1

scan line takes = $0.01666 / 1024 = 10.6 \mu\text{sec}$

- 34. Suppose RGB raster system is to be designed using on 8 inch X 10 inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 6 bits per pixel in the frame buffer, how much storage (in bytes) do we need for frame buffer?**

Resolution = 8 inch X 10 inch (100 pixels per inch)

Resolution = 8 X 100 by 10 X 100 pixel = 800 X 1000 pixel

1 pixel can be stored in 6 bits

Frame buffer size = 800 X 100 X 6 bits = 100 X 100 X 6 Byte

- 35. Find out the aspect ratio of the raster system using 8 x 10 inches screen and 100 pixel/inch.**

We know that,

$$\begin{aligned} \text{Aspect ratio} &= \frac{\text{Width}}{\text{Height}} \\ &= \frac{8 \times 100}{10 \times 100} = 4 / 5 \\ \text{Aspect ratio} &= 4 : 5 \end{aligned}$$

- 36. Consider three different raster systems with resolutions of 640 by 480, 1280 by 1024, and 2560 by 2048. What size frame buffer (in bytes) is needed for each of these systems to store 12 bits per pixel? How much storage is required for each system if 24 bits per pixel are to be stored?**

Frame-buffer size for each of the systems is

$640 \times 480 \times 12 \text{ bits} \div 8 \text{ bits per byte} = 450 \text{ KB}$

$1280 \times 1024 \times 12 \text{ bits} \div 8 \text{ bits per byte} = 1920 \text{ KB}$

$2560 \times 2048 \times 12 \text{ bits} \div 8 \text{ bits per byte} = 7680 \text{ KB}$

For 24 bits of storage per pixel, each of the above values is doubled.

900 KB & 3840 KB & 15360 KB

- 37. How long does it take to load a 640-by-480 frame buffer with 12 bits per pixel, if 10^5 bits can be transferred per second?**

Let X the time that will be taken to load a 640-by-480 frame buffer with 12 bits per pixel.

Number of bits = $640 \times 480 \times 12 = 3686400$ bits

1 sec X 10^5 bits

X sec(s) X 3686400 bits

Then $X = 3686400 / 10^5 = 36.864$ second

38. How much time is spent in scanning across each row of pixels during screen refresh on a raster system with a resolution of 1280 by 1024 and refresh rate of 60 frames per second?

The time required for scanning one frame is $1/60 = 0.01666$
One frame has 1024
The time of scanning on row = $0.01666 / 1024 = 1.627 * 10^{-5}$ sec

39. Suppose we have a video monitor with a display area with 12 inches width and 9.6 inches high. If the resolution is 1280 X 1024 and the aspect ratio is 1, what are the width and the height of each point on the screen?

Answer:

1280 pixels wide = 12 inches

1024 pixels high = 9.6 inches

$1280 / 1024 = 12 / 9.6 =$ aspect ratio of 1 (so the width should equal height)

1 pixel width = $12 / 1280 = 0.009375$ inches

1 pixel height = $9.6 / 1024 = 0.009375$ inches

40. How long would it take to load a 640-by-480 frame buffer with 12 bits per pixel, if 105 bits can be transferred per second? How long would it take to load a 24-bit-per-pixel frame buffer with a resolution of 1280 by 1024 using this same transfer rate?

Total number of bits for the frame = $640 \times 480 \times 12$ bits = 3686400 bits
The time needed to load the frame buffer = $3686400 / 105$ sec = 36.864 sec
Total number of bits for the frame = $1280 \times 1024 \times 24$ bits = 31457280 bits
The time needed to load the frame buffer = $31457280 / 105$ sec = 314.5728 sec

41. Suppose an RGB raster system is to be designed using an 8-inch by 10-inch screen with a resolution of 100 pixels per inch in each direction. If we want to store 6 bits per pixel in the frame buffer, how much storage bytes do we need for the frame buffer?

The size of frame buffer is $(8 \times 10 \times 100 \times 100 \times 6) / 8 = 600000$ bytes

Part 2: Graphics Primitives (Line)

1. How can an application program actually draw something on screen?

In summary, the process of generating a graphics image on the display device can be represented by the following pipeline: Figure 25 - “Programmer’s model of a computer graphics system - version 2” .



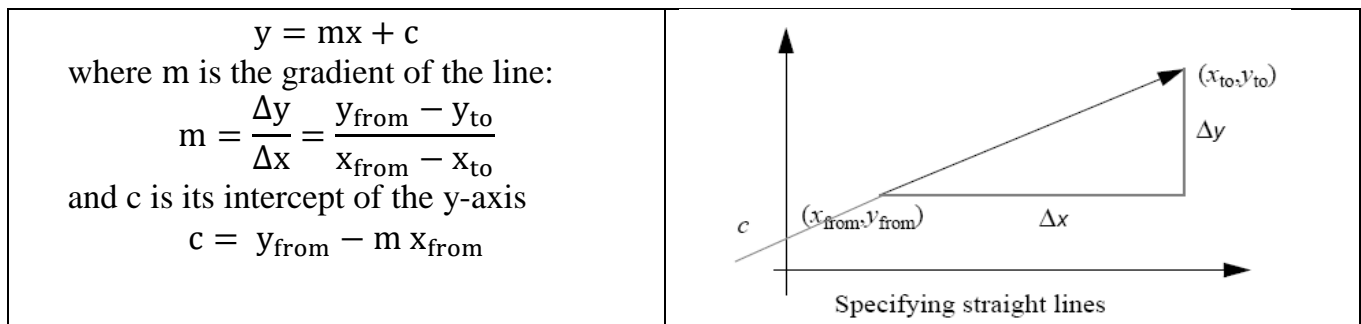
2. Describe what is performed by the following functions:

- **Setpixel**(x, y, color) - Sets the pixel at position (x, y) to the given color.
- **Getpixel**(x, y): Gets the color at the pixel at position (x, y).

Brute force Line Drawing Algorithm

3. For the brute force line drawing algorithm:

- Analyze the Basic concept of drawing a line using the brute force algorithm?



4. Write pseudo code for applying the algorithm.

```
Method lineBrute (xfrom, yfrom, xto, yto) {  
    DeltaY = yto - yfrom;  
    DeltaX = xto - xfrom;  
    m = DeltaY/DeltaX;  
    c = yfrom - (m * xfrom);  
    for(int x = xfrom; x < xto; x++) {  
        y = (m * x) + c;  
        Plot(x, y)  
    } } //lineDraw
```

5. Using the Brute force algorithm to digitize a line with end points (20, 10) and (26, 14).

Start Point		End Point		C
20	10	26	14	-3.3333333
X1	Y1	X2	Y2	
				$y=m*x+c$
Delta X	6	Delta Y	4	
Slope (m)	0.666666667			
slope is less than 1 (Loop on X)				
Valus Of X	Values of Y	Int Y	15	
20	10	10	14	
21	10.666666667	10	13	
22	11.333333333	11	12	
23	12	12	11	
24	12.666666667	12	10	
25	13.333333333	13		
26	14	14		

6. Digitize a line with end points (20, 10) and (30, 18).

DDA Line Drawing Algorithm

1. Write the algorithm of the line drawing algorithm using Digital Differential Analyzer (DDA).

1. START
2. Get the values of the starting and ending co-ordinates i.e. , (x_1, y_1) and (x_2, y_2) .
3. Find the value of slope $m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$
4. If $|m| \leq 1$ then $\Delta x = 1, \Delta y = m \Delta x$
 $x_k + 1 = x_k + 1, y_k + 1 = y_k + m$
5. If $|m| \geq 1$ then $\Delta y = 1, \Delta x = \Delta y / m$
 $x_k + 1 = x_k + 1/m, y_k + 1 = y_k + 1$
6. STOP

2. Using the DDA line drawing algorithm, find out the successive points that will be plotted by drawing a line (7, 5) to (13, 9)?
3. Consider a line from (0,0) to (6,7), (0,0) to (6,6) and (0,0) to (6,7).Using simple DDA algorithm, rasterize this line.
4. Consider a line from (0,0) to (6,7), (0,0) to (6,6) and (0,0) to (6,7).Using simple DDA algorithm, rasterize this line.

5. Using the DDA algorithm digitize a line with end points (10, 15) and (15, 30).
6. Digitize a line with end points (20, 10) and (30, 18) using DDA line drawing Algorithm.

Example – Draw a line from (20,10) to (30,18)

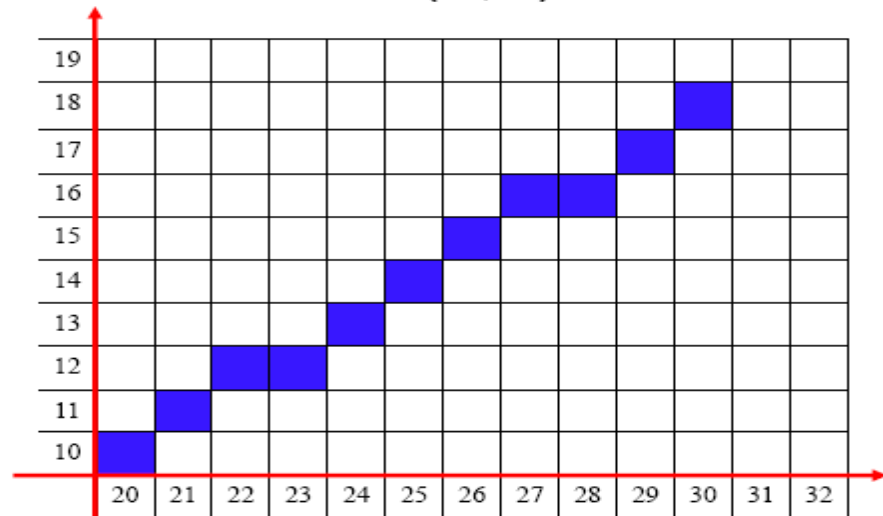
$$dx = 10$$

$$dy = 8$$

$$\text{initial decision } d_0 = 2dy - dx = 6$$

$$\text{Also } 2dy = 16, \quad 2(dy - dx) = -4$$

i	d_i	(x_{i+1}, y_{i+1})
0	6	(21,11)
1	2	(22,12)
2	-2	(23,12)
3	14	(24,13)
4	10	(25,14)
5	6	(26,15)
6	2	(27,16)
7	-2	(28,16)
8	14	(29,17)
9	10	(30,18)



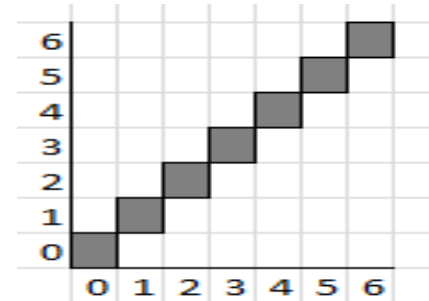
26

Start Point		End Point		#	slope	x	y	round(y)
X1	Y1	X2	Y2					
20	10	30	18	#	0.8	20	10	10
				#	0.8	21	10.8	11
				#	0.8	22	11.6	12
				#	0.8	23	12.4	12
				#	0.8	24	13.2	13
				#	0.8	25	14	14
				#	0.8	26	14.8	15
				#	0.8	27	15.6	16
				#	0.8	28	16.4	16
				#	0.8	29	17.2	17
				#	0.8	30	18	18
DDA Algorithm					DDA Data			

7. Implement the DDA algorithm to draw a line from (0,0) to (6,6).

$$M = (6-0)/(6-0) = 6/6 = 1 \quad X_{k+1} = X_k + 1 \quad Y_{k+1} = Y_k + m = Y_k + 1 \quad X_k = 0 \quad Y_k = 0$$

K	X	Y
0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6



Eg. Example: Digitize a line with end points (10,15) and (15,30).

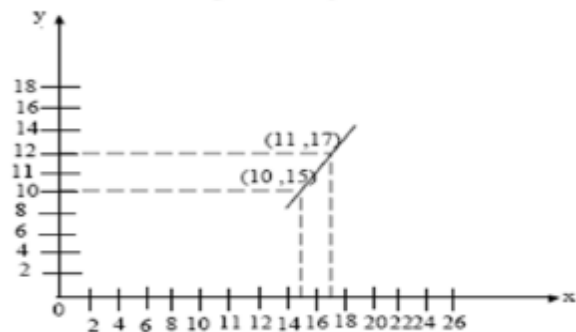
Solution:

The slope of line is $m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{30 - 15}{15 - 10} = \frac{15}{5} = 3$

$|m| > 1$

So we sample at y interval. The formula is given by $x_{k+1} = x_k + 1/m$.

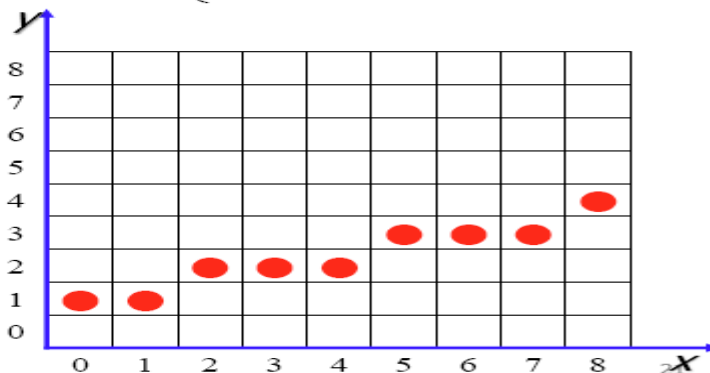
S.N	x	y
1	10	15
2	10	16
3	11	17
4	11	18



Example (DDA)

$$y = \frac{1}{3}x + 1 \quad \begin{cases} 0 \leq m \leq 1 \\ x_{i+1} = x_i + 1 \\ y_{i+1} = y_i + \frac{1}{3} \end{cases}$$

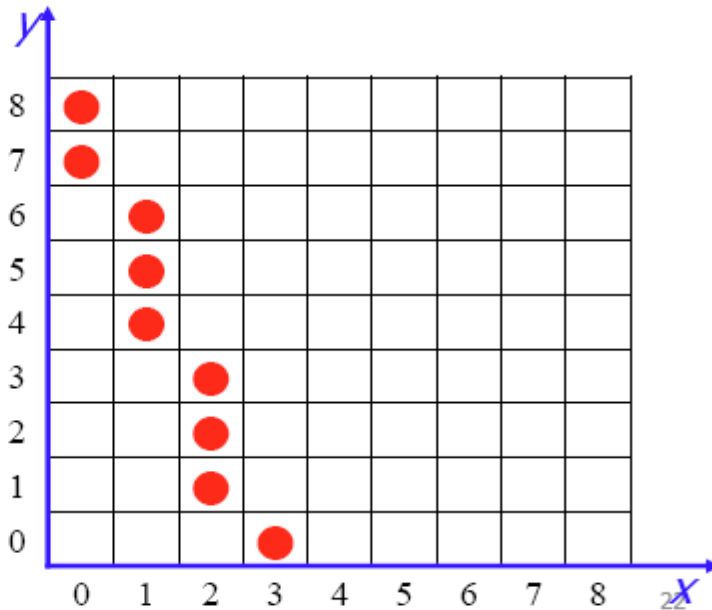
x	y	round(y)
0	1	1
1	4/3	1
2	5/3	2
3	2	2
4	7/3	2
5	8/3	3
6	3	3
7	10/3	3
8	11/3	4



Example (DDA)

$$y = -3x + 8 \quad \begin{cases} m < -1 \\ y_{i+1} = y_i - 1 \\ x_{i+1} = x_i - (-\frac{1}{3}) \end{cases}$$

y	x	round(x)
8	0	0
7	1/3	0
6	2/3	1
5	1	1
4	4/3	1
3	5/3	2
2	2	2
1	7/3	2
0	8/3	3



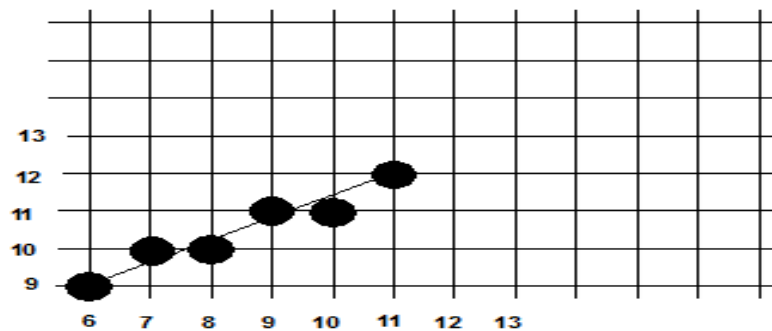
DDA Example

Compute which pixels should be turned on to represent the line from (6,9) to (11,12).

Slope = 0.6

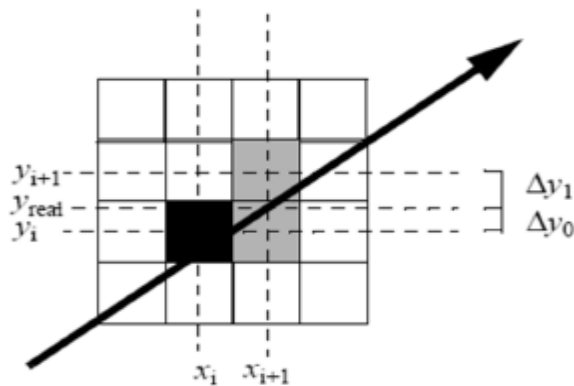
Values computed are:

- (6,9),
- (7,9.6),
- (8,10.2),
- (9,10.8),
- (10,11.4),
- (11,12)



Bresenham's Line Drawing Algorithm

1. State the idea of Bresenham's line drawing algorithm?



2. Explain Bresenham's Line Drawing Algorithms.

Bresenham's Line-Drawing Algorithm for $|m| < 1$

1. Input the two line endpoints and store the left endpoint in (x_0, y_0)
2. Load (x_0, y_0) into the frame buffer; that is, plot the first point.
3. Calculate constants $\Delta x, \Delta y, 2\Delta y$, and $2\Delta y - 2\Delta x$, and obtain the starting value for the decision parameter as $p_0 = 2\Delta y - \Delta x$
4. At each x_k along the line, starting at $k = 0$, perform the following test:
If $p_k < 0$, the next point to plot is (x_{k+1}, y_k) and
$$p_{k+1} = p_k + 2\Delta y$$

Otherwise, the next point to plot is (x_{k+1}, y_{k+1}) and
$$p_{k+1} = p_k + 2\Delta y - 2\Delta x$$
5. Repeat step 4 Δx times.

3. Digitize the line from (12, 16) to (1, 24) by using Bresenham's line drawing algorithm.
4. Derive the decision parameter to draw line using Bresenham's algorithm?
5. Digitize a line from point (-1,-1) to point (4, 5) using Bresenham's line generation algorithm?
6. Use the Bresenham's algorithm to find all points on a triangle in the first quadrant with vertices at (0, 2), (6, 2) and (3, 6).
7. Applying Bresenham's algorithm to draw a line from (4, 4) and end point is (-3, 0).
8. Use the Bresenham's algorithm to find all points on a triangle in the first quadrant with vertices at (0, 2), (6, 2) and (3, 6).
9. Applying Bresenham's algorithm to draw a line from (4, 4) and end point is (-3, 0). Plot a circle at origin having center as (0, 0) and radius=8 using Bresenham's circle algorithm.

Given the following line equation:

$$y=4x - 2$$

Trace the Bresenham line drawing algorithm to fill the following table, from a starting point (2, 6) to an ending point (3, 10):

Hints:

$$p_0 = 2\Delta y - \Delta x$$

If ($p_k < 0$)

$$p_{k+1} = p_k + 2\Delta y$$

Otherwise

$$p_{k+1} = p_k + 2\Delta y - 2\Delta x$$

k	x_k	y_k	p_k
0	2	6	-2
1	2	7	0
2	2	8	2
3	3	9	-4
4	3	10	-2

Ans:

Since its obvious that we need to fix y value and calculate when to increment x, we will swap x and y input coordinates, to be from (6, 2) to (10, 3)

Since we have the line equation we can calculate Δy and Δx , taking into consideration the swapping

Generally $m = \Delta y / \Delta x = 4$, making $\Delta y = 4$ and $\Delta x = 1$, after the swapping $\Delta y = 1$ and $\Delta x = 4$

$$P_0 = 2\Delta y - \Delta x = 2 - 4 = -2$$

$$P_1 = P_0 + 2\Delta y = -2 + 2 = 0$$

$$P_2 = P_1 + 2\Delta y = 0 + 2 = 2$$

$$P_3 = P_2 + 2\Delta y - 2\Delta x = 2 + 2 - 8 = -4$$

$$P_4 = P_3 + 2\Delta y = -4 + 2 = -2$$

decision is to keep y unchanged while incrementing x (7, 2)

decision is to keep y unchanged while incrementing x (8, 2)

decision is to increment y while incrementing x (9, 3)

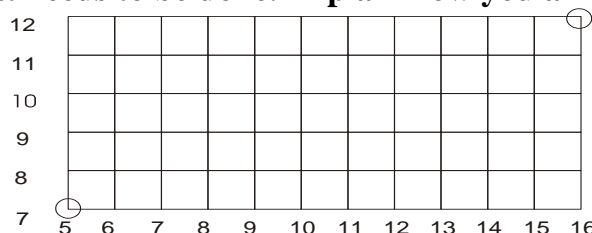
decision is to keep y unchanged while incrementing x (10, 3)

decision is to keep y unchanged while incrementing x (11, 3)

Plot the following *Lines* using Bresenham's line algorithm. Show all the step necessary to draw caluclate each vertex.

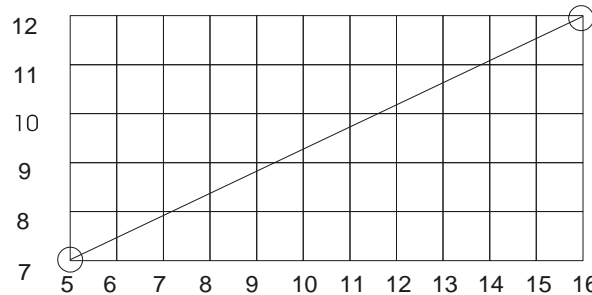
- Line A : (15, 10) \rightarrow (20, 13)
- Line B : (10, 11) \rightarrow (13, 15)
- Line C : (5, 12) \rightarrow (10, 8)
- Line D : (4, 4) \rightarrow (-1, 7)

10. Consider the Figure below where a line is to be placed on the grid from the circle in the lower left-hand corner to the circle in the upper right-hand corner by Bresenham's algorithm. Graphically show how Bresenham's algorithm will generate the line by making appropriate grid-points. For the critical points, carry out simple calculations for the decision what needs to be done. Explain how you arrived at your answer.



The basic idea of the Bresenham's algorithm is that for a point P at (x_p, y_p) for a line of slope between 0 and 1, the point at $x = x_p + 1$ can be either E ($y = y_p$) or NE ($y = y_{p+1}$) depending on which one the line is close to.

To determine which points to turn on, a line is first drawn between the two end-points.

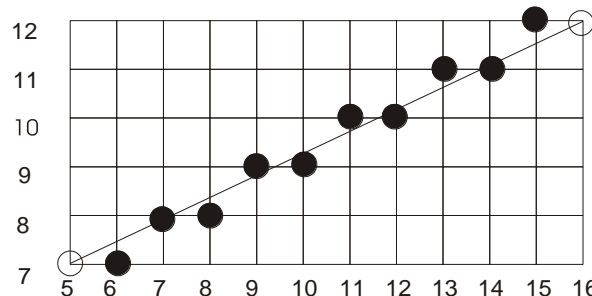


The line has slope $\frac{5}{11}$ and has equation $y = \frac{5}{11}x + b$ where $b = 7 - \frac{25}{11} = \frac{52}{11}$.

Then, scan from left to right along the x-axis to decide which points to turn on based on the idea shown above.

For point at $x = 6, y = 7.45$. Point (6, 7) will be turned on. The points at $x = 7$ to $x = 14$ are very obvious. For point at $x = 15, y = 11.55$. Point (15, 12) will be turned on.

Therefore, the result is:



11. Fill in the blanks

- (a) **Sampling** of the line at unit interval is carried out in one coordinate and corresponding integer value for the other coordinate is calculated.
- (b) Bresenham's line drawing algorithm is an accurate and efficient raster-line generating algorithm using only **incremental integer** calculations.

12. Compare DDA and Bresenham's line drawing algorithm.

13. Explain briefly the DDA line drawing algorithm.

14. Explain the Bresenham's line drawing algorithm with example.

Given the following line equation:

$$y=x+4$$

Trace the Bresenham line drawing algorithm to fill the following table, from a starting point (0, 4) to an ending point (4, 8):

Hints:

$$p_0 = 2\Delta y - \Delta x$$

If ($p_k < 0$)

$$p_{k+1} = p_k + 2\Delta y$$

Otherwise

$$p_{k+1} = p_k + 2\Delta y - 2\Delta x$$

k	x_k	y_k	p_k
0	0	4	

15. What are the advantages of Bresenham's line drawing algorithm over DDA and Brute force algorithm?

1. No rounding function
 2. Only integer arithmetic
 3. Calculation for the point (x_{i+1} , y_{i+1}) based on the point (x_i , y_i) only.
 4. Applicable to the integer computation of circles
 5. Line and integer circle algorithms provide the best-fit approximation
- Points 1 – 3 imply that the Bresenham's algorithm is faster than the DDA since rounding, floating arithmetic and non-incremental technique take more computing time.

Part 2: Graphics Primitives (Circle)

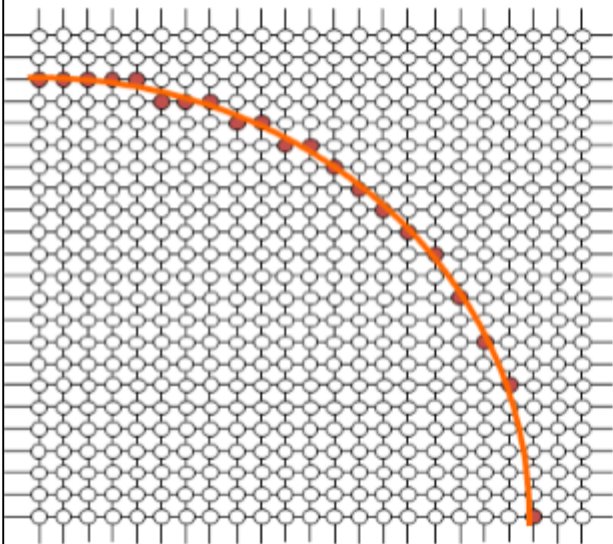
1. The process of drawing circle using Brute force method can be enhanced by taking greater advantage of the symmetry in a circle.

Write the complete algorithm used to apply this enhancement.

```
Public void bruteCircleWithCheating (int x0, int y0, int radius)
{
    for(int theta=0; theta<45; theta++)
    {
        int x = round(radius * cos(theta));
        int y = round(radius * sin(theta));
        circlepoints (x0, y0 , x,y)
    }
} //bruteCircle
```

```
/* Center at the origin */
Void circlepoints (int x, int y)
{
    putpixel ( x, y);
    putpixel ( y, x);
    putpixel ( y, -x);
    putpixel ( x, -y);
    putpixel ( -x, -y);
    putpixel ( -y, -x);
    putpixel ( -y, x);
    putpixel ( -x, y);
}
```

A Simple Circle Drawing Algorithm (cont...)



$$y_0 = \sqrt{20^2 - 0^2} \approx 20$$

$$y_1 = \sqrt{20^2 - 1^2} \approx 20$$

$$y_2 = \sqrt{20^2 - 2^2} \approx 20$$

⋮

$$y_{19} = \sqrt{20^2 - 19^2} \approx 6$$

$$y_{20} = \sqrt{20^2 - 20^2} \approx 0$$

Bresenham's Circle Drawing Algorithm

1. Explain the basic concept of Midpoint ellipse algorithm.

This algorithm uses the implicit function of the circle in the following way

$$f(x, y) = (x - x_c)^2 + (y - y_c)^2 - r^2$$

here $f(x, y) < 0$ means (x, y) is inside the circle

$f(x, y) = 0$ means (x, y) is on the circle

$f(x, y) > 0$ means (x, y) is outside the circle

The algorithm now follows as

2. Write the algorithm of drawing a circle using Midpoint Circle Algorithm

- Input radius r and circle center (x_c, y_c) , and obtain the first point on the circumference of a circle centered on the origin as
- $(x_0, y_0) = (0, r)$
- Calculate the initial value of the decision parameter as
 - $p_0 = \left(\frac{5}{4}\right) - r$
- At each x_k position, starting at $k = 0$, perform the following test: If $p_0 < 0$ the next point along the circle centered on $(0,0)$ is (x_{k+1}, y_k) and
- $p_{k+1} = p_k + 2(x_{k+1}) + 1$
 - Otherwise, the next point along the circle is (x_{k+1}, y_{k-1}) and
 - $p_{k+1} = p_k + 2(x_k + 1) + 1 - 2(y_k + 1)$
- Determine symmetry points in the other seven octants.
- Move each calculated pixel position (x, y) onto the circular path centered on (x_c, y_c) and plot the coordinate values: $x = x + x_c, y = y + y_c$
- Repeat steps 3 through 5 until $x \geq y$.

- ### **3. Derive the decision parameter to draw circle using Bresenham's algorithm (Mid-Point).**
- ### **4. Plot a circle at origin having center as $(0, 0)$ and radius=8 using Bresenham's circle algorithm.**
- ### **5. Plot a circle using mid-point algorithm whose radius=3 and center is at $(0, 0)$. Find the points lying on the circle centered at $(5, 10)$ and having radius 8 using Bresenham's circle algorithm (Mid-Point).**

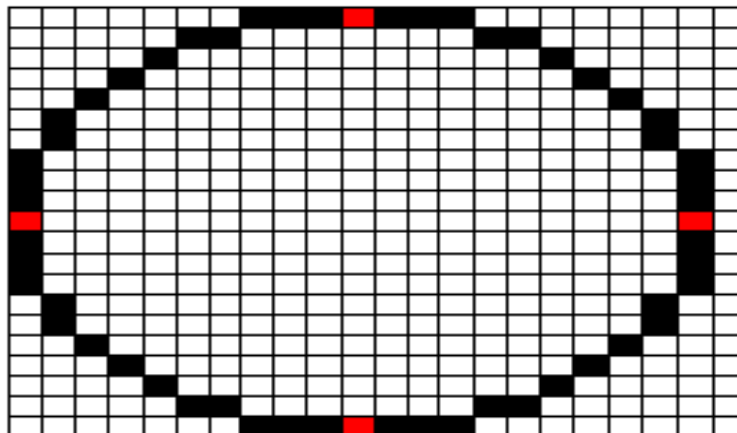
6. Draw the circle or radius $r=10$ and center is at $(3, 4)$ using midpoint algorithm

- Calculate the required points to plot the following circle using the midpoint circle algorithm.

Radius (r) = 10, Centre = $(3, 4)$

$P_0 = 1 - r = -9$, Initial Point $(x_0, y_0) = (0, 10)$

k	P_k	(X_{k+1}, Y_{k+1})	Other Quadrants	Other Octants	All Points after adding the centres
0	-9	(1,10)	$(-1, 10)(1, -10)(-1, -10)$	$(1,10)(10,1)(-1,10)(10,-1)$ $(1,-10)(-10,1)(-1,-10)(-10,-1)$	$(4,14)(13,5)(2,14)(13,3)(4,-6)(-7,5)(2,-6)(-7,3)$
1	-6	(2,10)	$(-2, 10)(2, -10)(-2, -10)$	$(2,10)(10,2)(-2,10)(10,-2)(2,-10)(-10,2)(-2,-10)(-10,-2)$...
2	-1	(3,10)	$(-3, 10)(3, -10)(-3, -10)$	$(3,10)(10,3)(-3,10)(10,-3)(3,-10)(-10,3)(-3,-10)(-10,-3)$...
3	6	(4,9)	$(-4, 9)(4, -9)(-4, -9)$	$(4,9)(9,4)(-4,9)(9,-4)(4,-9)(-9,4)(-4,-9)(-9,-4)$...
4	-3	(5,9)	$(-5, 9)(5, -9)(-5, -9)$	$(5,9)(9,5)(-5,9)(9,-5)(5,-9)(-9,5)(-5,-9)(-9,-5)$...
5	8	(6,8)	$(-6, 8)(6, -8)(-6, -8)$	$(6,8)(8,6)(-6,8)(8,-6)(6,-8)(-8,6)(-6,-8)(-8,-6)$...
6	5	(7,7)	$(-7, 7)(7, -7)(-7, -7)$	$(7,7)(-7,7)(7,-7)(-7,-7)$...



Given a Circle with center at (2, 3) and radius 2, trace the mid point circle drawing algorithm for 4 points:

Hints:

$$p_0 = 1 - r$$

If ($p_k < 0$)

$$p_{k+1} = p_k + 2x_{k+1} + 1$$

Otherwise

$$p_{k+1} = p_k + 2x_{k+1} + 1 - 2y_{k+1}$$

k	x_k	y_k	p_k
0	0	2	-1
1	1	2	2
2	2	1	5
3	2	0	-
4	2	-1	-

Ans:

$$p_0 = 1 - r = -1$$

$$p_1 = p_0 + 2x_1 + 1 = -1 + 2 + 1 = 2$$

$$p_2 = p_1 + 2x_2 + 1 - 2y_2 = 2 + 4 + 1 - 2 = 5$$

decision is to keep y unchanged while incrementing x (1, 2)

decision is to decrement y while incrementing x (2, 1)

decision is to decrement y while incrementing x (3, 0)

With geometrical drawing, you will notice that at this point (3, 0) is outside the circle, because the radius is 2, then we finished this quadrant for this small circle and can just use symmetry (x, -y) to calculate next points without applying the conditions

(2, 0)

(2, -1)

(1, -2)

(0, -2)

4) Given a Circle with center at (4, 5) and radius 6, trace the mid point circle drawing algorithm for 4 points:

Hints:

$$p_0 = 1 - r$$

If ($p_k < 0$)

$$p_{k+1} = p_k + 2x_{k+1} + 1$$

Otherwise

$$p_{k+1} = p_k + 2x_{k+1} + 1 - 2y_{k+1}$$

k	x_k	y_k	p_k
0			
1			
2			
3			
4			

5) Given an ellipse with $r_x = 2$ and $r_y = 4$ and center (4, 5), trace the mid-point ellipse drawing algorithm for 4 points.

Hints:

$$p1_0 = r_y^2 - r_x^2 r_y + \frac{1}{4} r_x^2$$

$$increment = \begin{cases} 2r_y^2 x_{k+1} + r_y^2 & \text{if } p1_k < 0 \\ 2r_y^2 x_{k+1} + r_y^2 - 2r_x^2 y_{k+1} & \text{if } p1_k \geq 0 \end{cases}$$

k	x_k	y_k	p_k
0	0	4	
1			
2			
3			
4			

- Give three representations of circle, also give their equations.

- Fill in the blanks

In midpoint circle drawing algorithm if

$f(x, y) < 0$ means (x, y) is inside the circle

$f(x, y) = 0$ means (x, y) is on the circle

$f(x, y) > 0$ means (x, y) is outside the circle

- Discuss scan conversion of circle with Bresenham's and midpoint circle algorithms.

Multiple choice questions

1. Smallest size object that can be displayed on a monitor is called.....
a) **Picture element** b) Point c) Dot Pitch d) aspect ratio
2. Each screen point is referred to as.....
a) Resolution **b) Pixel** c) Persistence d) Dot Pitch
3. On a monochromatic monitor, the frame buffer is known as.....
a) Display file b) Pixmap **c) Bitmap** d) Refresh buffer
4. On a color monitor, the refresh buffer is also called.....
a) Frame buffer **b) Pixmap** c) Bitmap d) Display file
5. refers to pixel spacing.
A) Pixmap **b) Resolution** c) Pixel depth d) Persistence
6. The distance from one pixel to the next pixel is called.....
a) Resolution b) Dot Pitch c) Pixmap d) ppi
7. The maximum number of points that can be displayed without overlap on a CRT
a) Aspect Ratio **b) Resolution** c) Brightness d) Pixel
8. is the number of points per centimeter that can be plotted horizontally and vertically.
a) Aspect Ratio b) Pixel Depth **c) Resolution** d) Dot Pitch
9. is the ratio of horizontal points to vertical points necessary to produce equal length lines in both direction.
a) Dot Pitch b) Resolution **c) Aspect Ratio** d) Height-Width Ratio
10. The shortest distance between any two dots of the same color is called.....
a) Resolution **b) Dot Pitch** c) Pixel Depth d) ppi
11. The standard aspect ratio for PC is.....
a) 6:5 **b) 4:3** c) 3:2 d) 5:3

12. In CRT, the electron intensity is adjusted using.....
a) Accelerating anode **b) Control grid** c) Electron gun d) Focusing anode
13. Brightness of a display is controlled by varying the voltage on the.....
a) Focusing anode b) Connection pins **c) Control grid** d) Power supply
14. Lower persistence phosphorus is used in
a) **Animation** b) Simple object c) Complex object d) All of these
15. Lower persistence phosphorus needs _____ refresh rate
a) Lower **b) Higher** c) Medium d) None of these
16. Higher persistence phosphorus needs _____ refresh rate
a) Lower b) Higher c) Medium d) None of these
17. Higher persistence phosphorus is used in
a) Animation b) Simple object **c) High Complex object** d) All of these
18. Memory area holding the intensity information of an image is called.....
a) Refresh buffer b) Font cache c) Picture definition d) Video controller
19. Intensity representation of an image is called.....
a) Frame buffer **b) Picture definition** c) Display list d) Brightness
20. The purpose of refreshing a CRT is.....
a) Avoid flickering b) maintain steady picture c) avoid fading of pixels **d) All of the above**
21. The fly-back of electron beams from one scan line to next is known as.....
a) Vertical Retrace **b) Horizontal Retrace** c) Raster scanning d) Refreshing
22. The return of electron beam to top left corner of the screen after one frame is called.....
a) Horizontal fly-back **b) Vertical Fly-back** c) Scanning d) None of the above
23. In raster scan display, the frame buffer holds.....

- a) Line drawing commands b) Scanning instructions c) Image Resolution
d) Intensity information

24. In random scan display, the frame buffer holds.....

- a) Line drawing commands** b) Scanning instructions c) Image Resolution
d) Intensity information

25. Interlaced refresh procedure is allowed in.....

- a) LCD b) DVST **c) Raster scan display** d) Random scan display

26. Vector display is well suited for.....

- a) Animation **b) Line drawing applications** c) Cartoons d) All of the above

27. Beam penetration method is usually used in.....

- a) LCD b) Raster Scan display **c) Random scan display** d) DVST

28. Shadow mask method is usually used in

- a) LCD **b) Raster Scan display** c) Random scan display d) DVST

29. An RGB color system with 24 bits OS storage per pixel is known as.....

- a) Color CRT **b) True-color system** c) RGB monitor d) Color- Depth

30. Video devices with reduced volume, weight and power consumption are collectively known as.....

- a) Light weight monitors **b) Flat-panel displays** c) CRT d) Portable display
31. is responsible for accessing the frame buffer to refresh the screen.
a) Graphics package **b) Video controller** c) CPU d) Monitor
32. Digitizing a picture definition into a set of intensity values is known as.....
a) Digitization **b) Scan conversion** c) Refreshing d) Scanning
33. will free the CPU from graphics chores.
a) Display processor b) Monitor c) ALU d) Video controller
34. The simply reads each successive byte of data from the frame buffer.
a) Digital Controller b) Data Controller **c) Display Controller** d) All of above
35. used to regulate the flow of electrons in CRT ?
a) Electron gun b) Focusing anode **c) Control grid** d) All of the above
36. The technique used to summarize the financial, statistical, mathematical, scientific and economic data is?
a) Computer Art b) Image processing **c) Presentation Graphics** d) none of the above
37. Graphics and image processing technique used to produce a transformation of one object into another is called
a) Animation b) Morphing c) Half toning d) None of the above
38. The amount of light emitted by the phosphor coating depends on the?
a) Number of electrons striking the screen
b) Speed of electrons striking the screen
c) Distance from the cathode to the screen
d) None of above
39. Gray scale is used in.....
a) A Monitor that have color capability
b) A Monitor that have no color capability
c) Random scan display
d) Raster scan display
40. Vector graphics is composed of

a. Pixels **b. Paths** c. Palette` d. None of these

41. Raster graphics are composed of

a. Pixels b. Paths c. Palette d. None of these

42. RGB model are used for

a. Computer display b. Printing c. Painting d. None of these

43. The intersection of three primary RGB color produces

a. White color b. Black color c. Magenta color d. Blue color

44. Random scan systems are designed for

a. Line drawing application b. Pixel drawing application
c. Color drawing application d. None of these

45. Which of the following allow for 8 mirror images?

a) Parabola b) Ellipse c) Hyperbola **d) Circle**

46. The simplest output primitive is

a) Straight line b) Straight line segment **c) Point** d) Circle

47. The quality of an image depend on

a. **No. of pixel used by image** b. No. of line used by image
c. No. of resolution used by image d. None

48. The basic geometric structures that describes a scene on display is called.....

a) Attributes **b) Output primitive** c) Lines d) Curves

49. controls the basic display properties of output primitives.

a) Attribute parameter b) Setpixel c) Getpixel d) None of the above