Computer Graphics

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Introduction to Computer Graphics:

- Definition,
- Applications,
- Graphics Hardware,
- Display Devices:

  - Refresh Cathode Ray Tube,
  - Raster Scan Display,
  - Plasma display,
  - Liquid Crystal display,
  - Plotters,
  - Printers.

Definition

Computer graphics is the most effective and commonly used way to communicate the processed information to the user. It displays the information in the form of graphics objects such as pictures, charts, graphs & diagrams in place of simple text.

Definition

It is the use of computers to create and manipulate pictures on a display device. It comprises of software techniques to create, store, modify, represents pictures.

Branch of computer science concerned with methods & Technology to convert data to & from visual information using computers

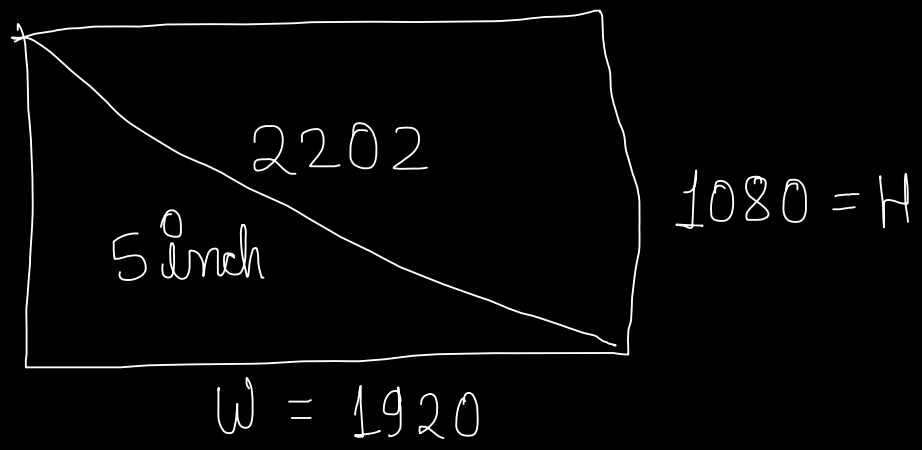
Applications

- User Interfaces
- Plotting Graphs and Charts
- Office Automation and Desktop Publishing
- Computer Aided Designing and Drafting
- Simulation and Animation
- Art and Commerce
- Process Control
- Cartography

Important Terms

- Pixel → any screen point is called pixel
- Resolution → # pixels on entire screen → width x height ⇒ 1920 x 1080
- PPI ⇒ 2202/5 ⇒ 440 PPI
- Aspect Ratio ⇒ 16:9 (width : height)
- Frame Buffer (yaha info store hoti h)

1920 : 1080
480 : 270
16 : 9



Important Formulae

Refresh Rate = $1/(\text{time per pixel} * \text{Resolution})$

$A^{-1} = \text{adj}(A)/|A|$

$$\text{Access Rate} = \frac{1}{\text{Access time per pixel}}$$

Access time per pixel = 1 / Access rate

Scalar Triple product = $\vec{a} \cdot (\vec{b} \times \vec{c})$

Scan Conversion and Rasterization

Scan conversion → process of determining appropriate pixels for representing a picture or graphics object.

Rasterization → process of representing continuous pictures or graphics object as a collection of discrete pixels.

Graphics Hardware

Input Devices

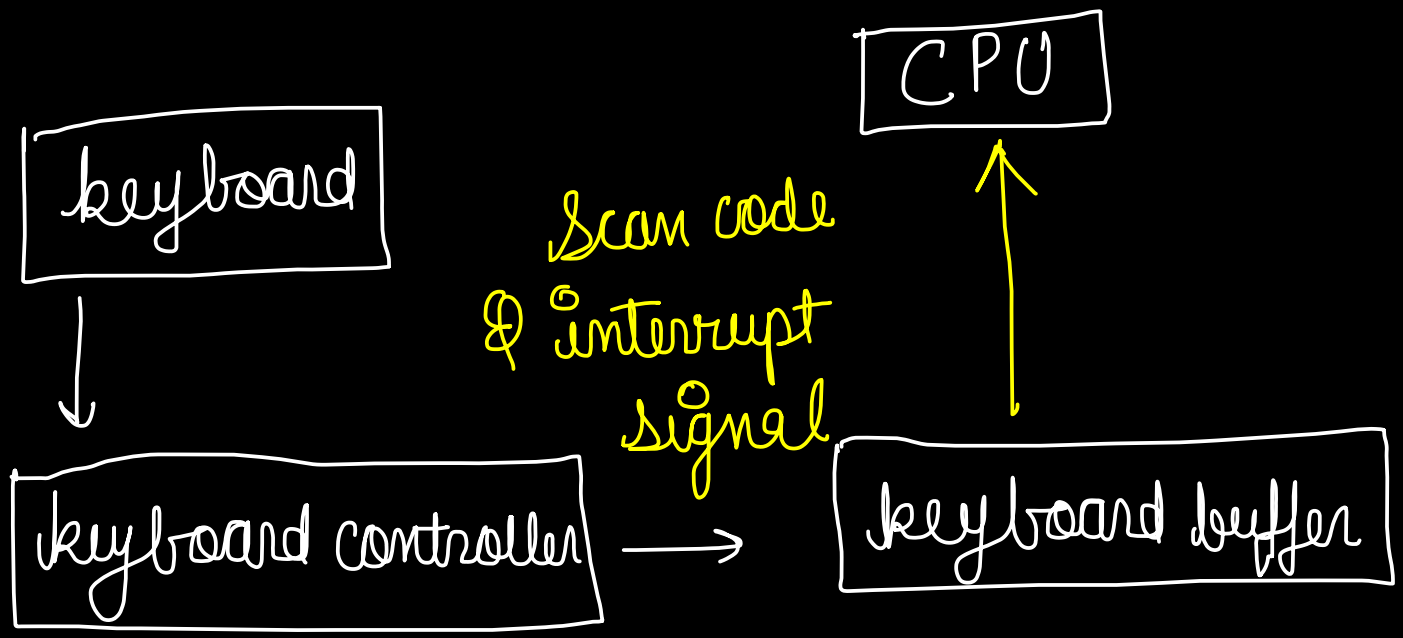
① Keyboard ② Mouse
③ Trackball/Spaceball ④ Joystick

Output Devices

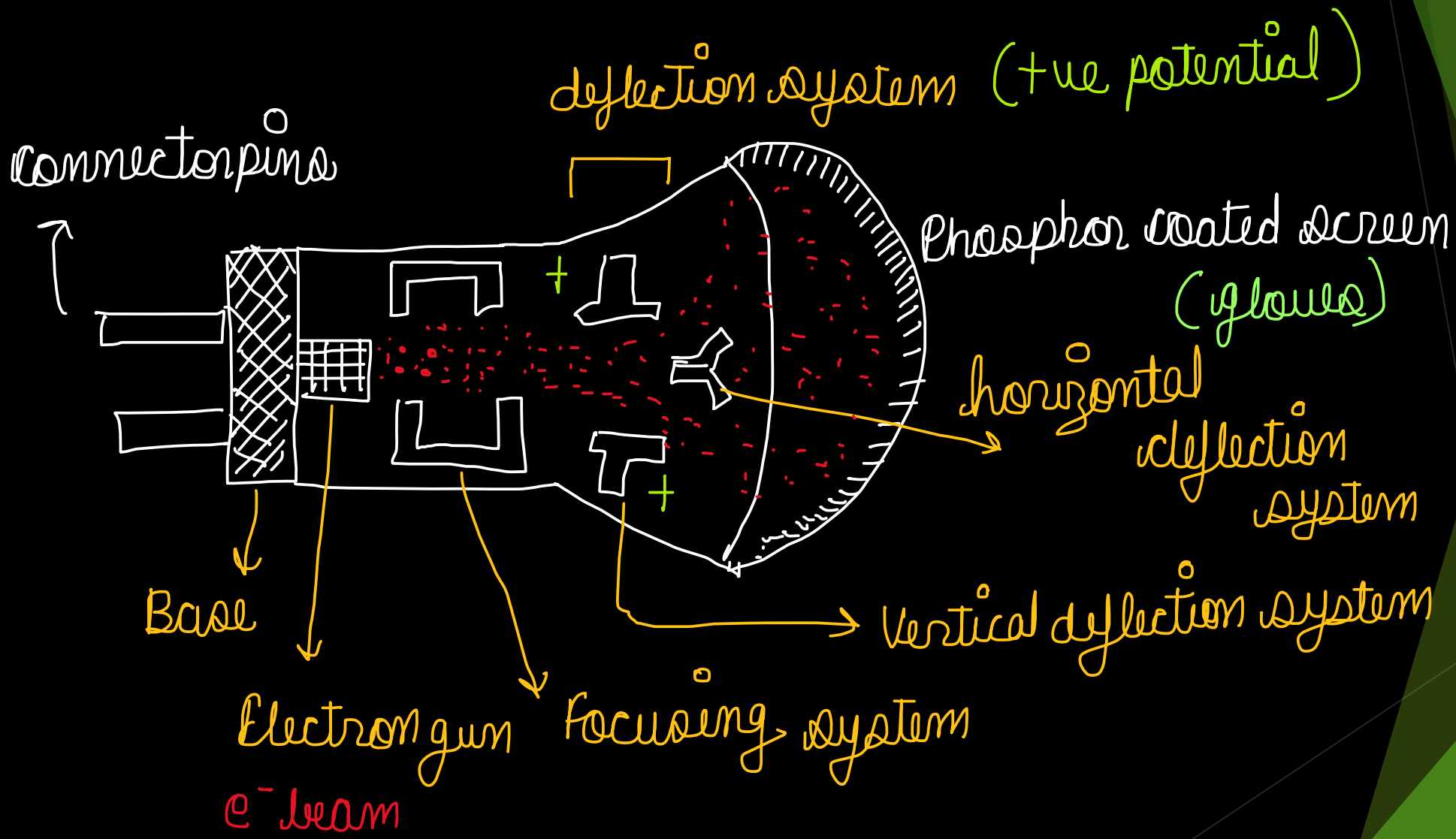
① CRT
② LED, LCD, TFT
③ Plasma
④ Colored Monitor

Graphics Software

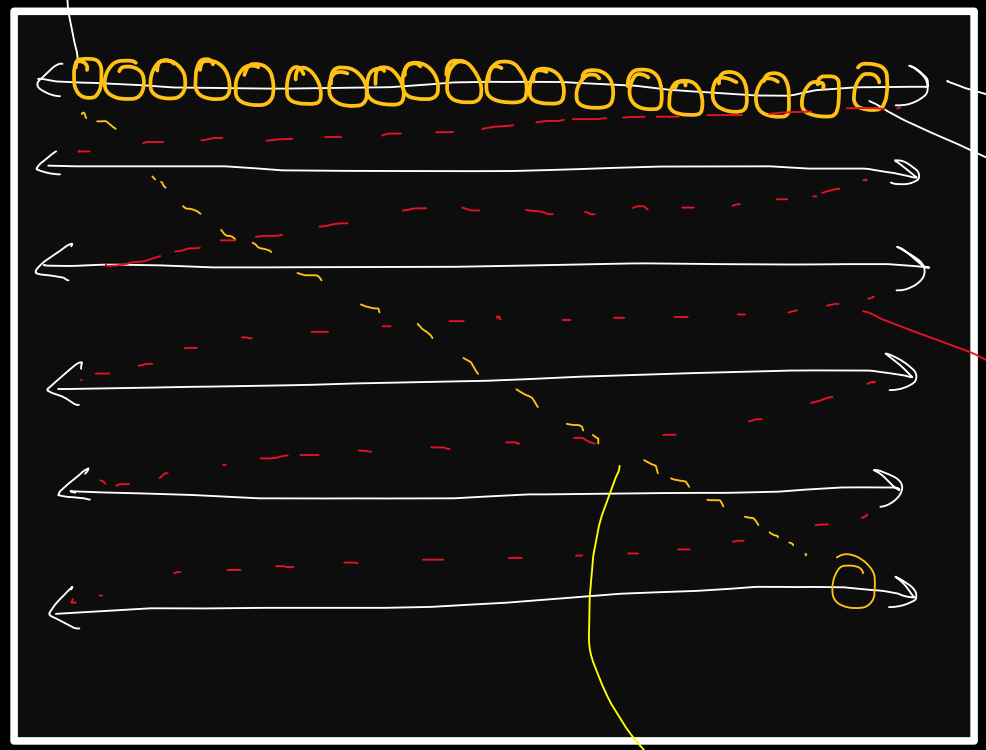
① Photoshop ③ Cad S/F
② Maya 3D ④ Corel Draw



Cathode Ray Tube(CRT)



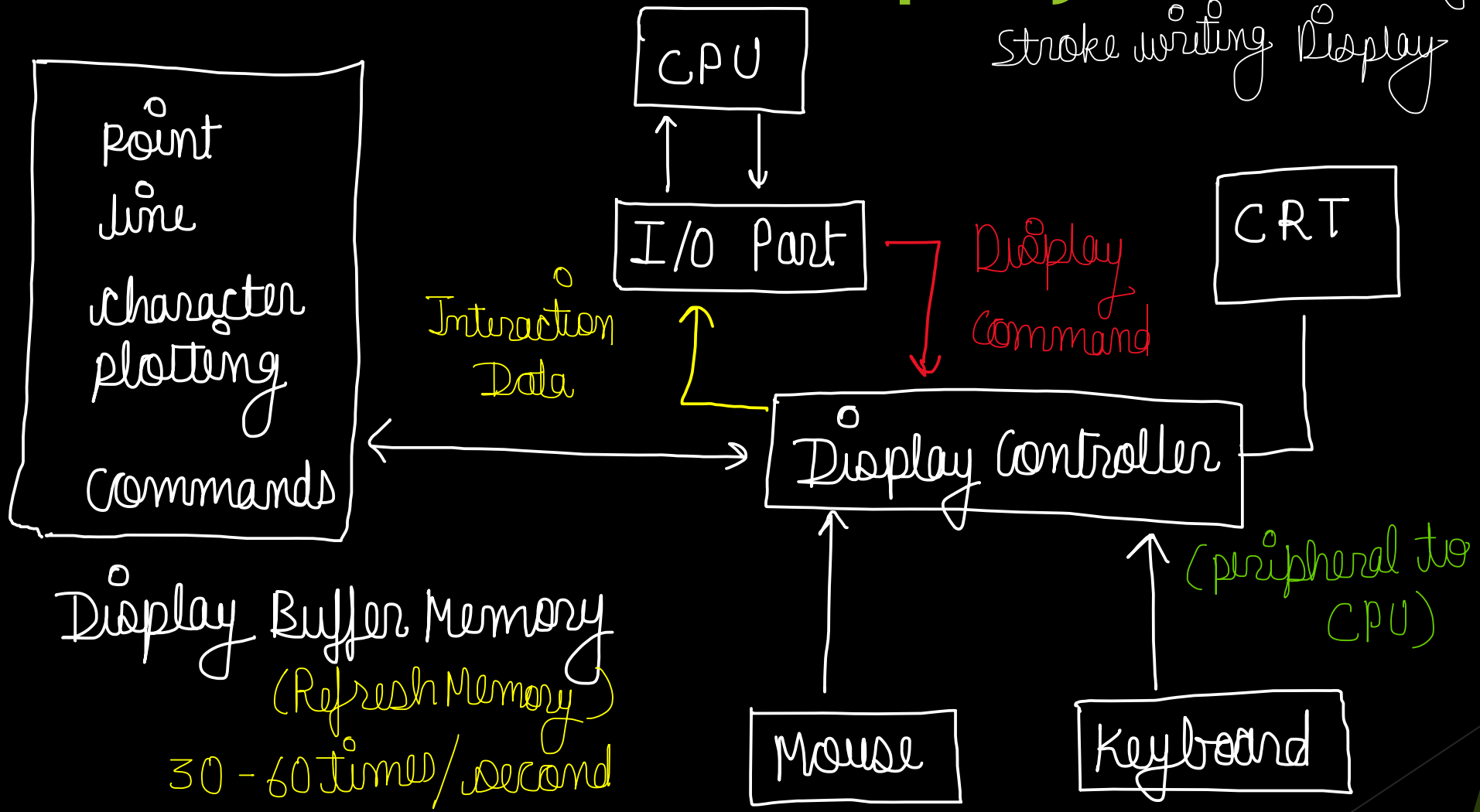
Rastor Scan Display



Intensity value ⇒ Refresh / Frame Buffer

Vector Scan Display

Random Scan Display
Calligraphic Display
Stroke writing Display



Display Controller ⇒ directs electron beam via deflection system

Vector Scan Display
Random Scan Display

1. High resolution
2. more expensive
3. Modification is easy
4. Solid pattern is tough to fill.
5. Refresh rate depends on resolution
6. only screen with view is displayed
7. # Beam Penetration Technology
8. doesn't use interlacing method
9. Restricted to line drawing applications

Raster Scan Display

1. low resolution
2. less expensive
3. Modification is tough
4. Solid pattern is easy to fill.
5. Refresh Rate depends on the picture
6. whole screen is Scanned
7. Shadow Mask technology
8. uses interlacing
9. suitable for realistic display

Interlacing

Properties of phosphor
→ color
→ persistence → kitni der?

≠ method of incrementally 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 steps across every scan line from top to bottom. Then after vertical retrace, the beam sweeps out the remaining scan lines.

→ provides only four colour {Red, Lyreen, Orange, yellow}

Beam Penetration (Random Scan Display)

#2 layers of phosphor (Red and green) are coated onto the inside of CRT screen. The displayed colors depend on how far the e⁻ beam penetrates the phosphor layers.

fast e⁻ beam → excites red

slow e⁻ beam → penetrates red and excites green

average e⁻ beam → excites combination of Red & green {Yellow & Orange}

Shadow Masking (Raster Scan Display)

→ gives more color than beam penetration

→ ∀ pixel → 3 color dots (RGB) → 17 billion different colors in full color system.

→ This type of CRT have 3 e⁻ guns for each colordot

→ A shadow mask grid is installed behind phosphor coated screen

Flat Panel Display

(volume, weight, power requirement) < CRT

→ TV, Monitor, Calculator, Laptop, etc.

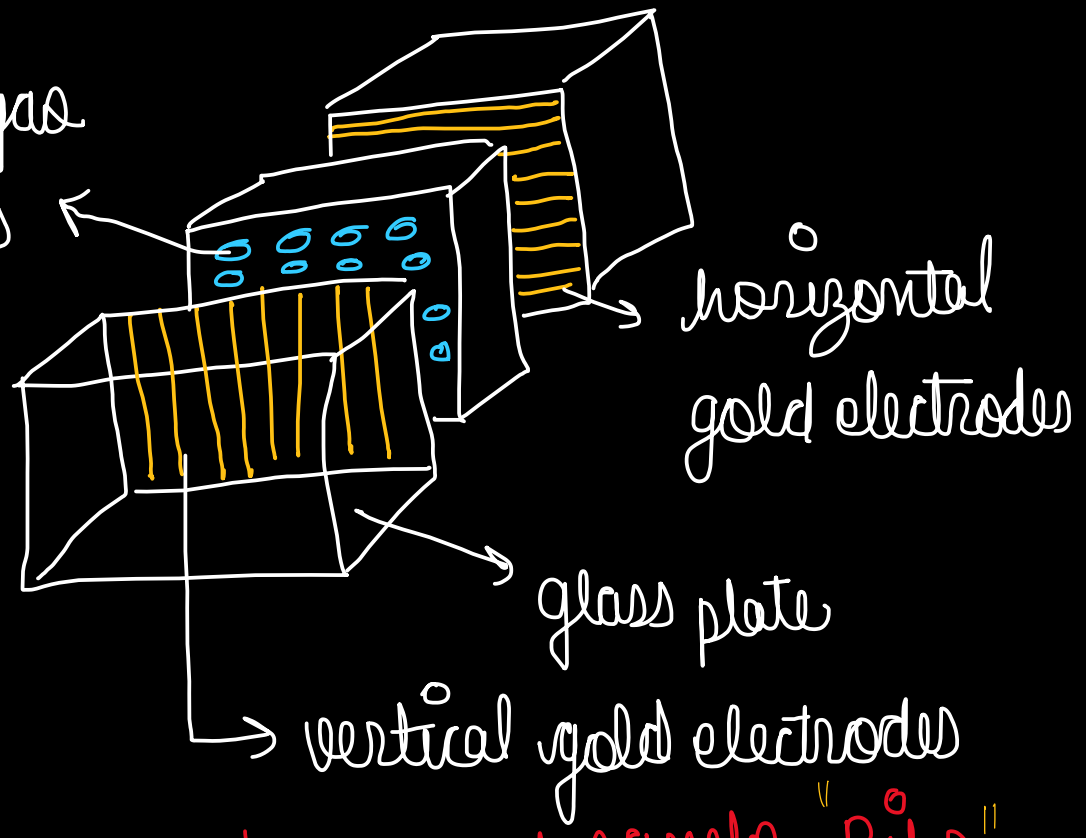
2 categories:

① Emissive Display → The devices which convert electrical energy into light. (Plasma, LED)

② Non Emissive Display → The devices which use optical effects to convert light into graphics pattern. (LCD)

Gas discharge display

Plasma Display



→ 2 parallel sheets of glass that enclose a mixture of discharged gases composed of (helium, xenon, Xenon)

→ comes in both B&W & color display

→ Thinner than CRT

→ Brighter than LCD, also cheaper

→ consumes more power

→ generates more heat

→ doesn't work well in high altitudes (high in pressure among gases)

to support panels, "Ribs" are present

LED (Light Emitting Diode)

→ a matrix of diodes is organized to form pixel positions in the display.

→ Picture definition is stored in a refresh buffer.

→ Data is read from refresh buffer & converted into voltage levels that are applied to the diodes to produce the light pattern in the display.

LCD (Liquid Crystal Display)

→ requires very little power

→ produce a picture by passing a polarized light from the surroundings or from an internal light source through a liquid crystal material that transmits the light.

→ 2 glass plates and liquid crystal is filled in between.

→ One glass plate → # rows of conductor in vertical direction

Other glass plate → # rows of conductors in horizontal direction

→ The pixel position is determined by intersection of horizontal & vertical conductor. Position → active part of the screen

→ Temperature dependent (0-70°C) operating temperature

LED vs LCD

Light Emitting Diode (LED)

1. better response time than LCD
2. consumes more power
3. more expensive
4. better picture quality than LCD
5. better color accuracy, contrast & black level.
6. uses gallium arsenide phosphide
7. no mercury used
8. range upto 90 inches
9. wider view angle

Liquid Crystal Display (LCD)

1. slower response time than LED
2. consumes less power
3. less expensive
4. good but not as great as LED
5. slight less color accuracy, contrast & black level
6. uses liquid crystals & glass electrodes
7. mercury is required
8. range 13 - 57 inches
9. wide angle less with 30^{0}

LED vs LCD

LED displays use an array of tiny light-emitting diodes to create images. Each diode produces a single color of light, typically red, green, or blue (RGB). By combining these three colors in various intensities, a wide range of colors can be produced. LED displays are known for their high brightness, vibrant colors, and energy efficiency.

LCD displays, on the other hand, use a backlight to illuminate a layer of liquid crystals. The crystals act as shutters, allowing or blocking the backlight to create an image. LCD displays typically use a color filter to produce colors. The filter is made up of tiny red, green, and blue sub-pixels that are arranged in a specific pattern to produce different colors. When light from the backlight passes through the filter, it creates the desired color. LCD displays are known for their good color accuracy, wide viewing angles, and low power consumption.

Mathematics of Computer Graphics:

- Point representation,
- Vector representation,
- Matrices and operations related to matrices,
- Vector addition and vector multiplication,
- Scalar product of two vectors,
- Vector product of two vectors.

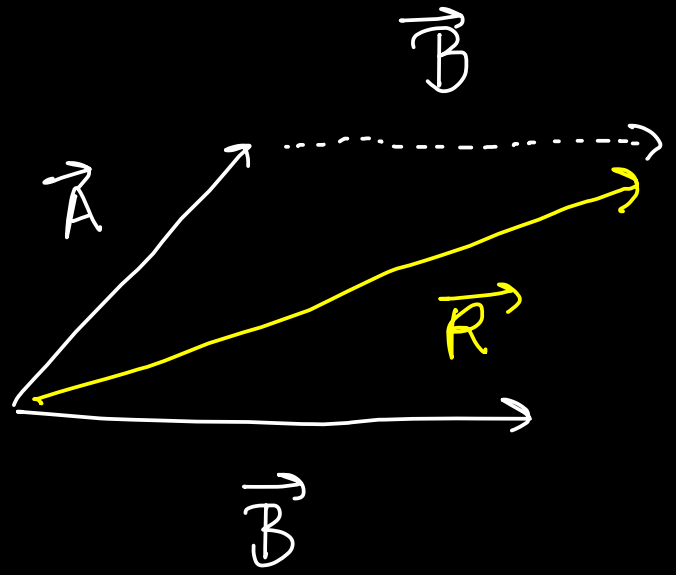
Parametric equations of lines and conics.

Vectors { Representation & Benefits }

Vector → magnitude + direction

$$\vec{A} = |\vec{A}| \cdot \hat{A}$$

Addition of vectors



Vectors

coplanar vectors → determinant = 0

$a = \hat{i} + \hat{j} + k$

$b = 2\hat{i} - 4k$

$c = \hat{i} + 8\hat{j} + 3k$

$$\begin{vmatrix} 1 & 1 & 1 \\ 2 & 0 & -4 \\ 1 & 8 & 3 \end{vmatrix} = 0$$

a, b, c are coplanar

Find 8

$1(0 - 48) - 1(6 + 4) + 1(28) = 0$

$-48 - 10 + 28 = 0$

$-10 = 28$

$8 = -5$

Line Drawing Algorithms:

- DDA algorithms,
- Bresenham's Line algorithm.
- Circle and ellipse generation algorithm.

Clipping:

- Point Clipping,
- Line Clipping.
- Polygon Clipping.

Filling:

- Inside Tests,
- Flood fill algorithm,
- Boundary-Fill Algorithm and
- scan-line polygon fill algorithm.

Digital Differential Analyzer

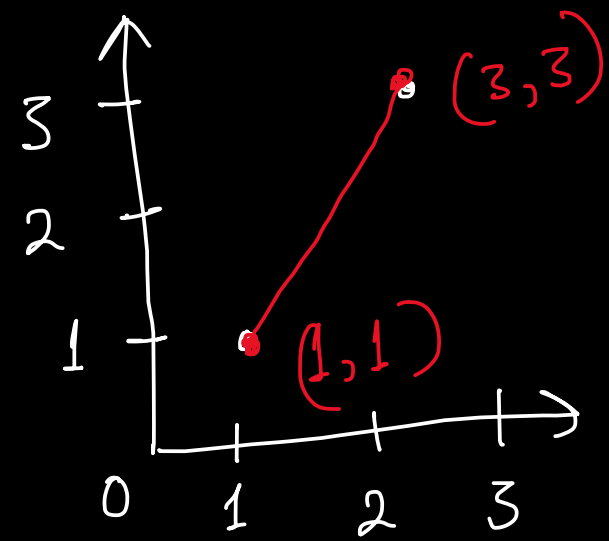
DDA Line Drawing Algorithm

Given two points (x_1, y_1) and (x_2, y_2)

$(1,1)$ $(3,3)$

① Slope, $m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$

$\Rightarrow \frac{3-1}{3-1} = \frac{2}{2} = 1$



② find Δx and Δy

$\Delta x = 2$

$\Delta y = 2$

DDA Line Drawing Algorithm

$m = \frac{\Delta y}{\Delta x}$

$\Delta y = m \Delta x$ — (1)

$\Delta x = \Delta y / m$ — (2)

if $|\Delta x| \geq |\Delta y|$

then assign $\Delta x = 1$

$$x_{i+1} = x_i + \Delta x$$
$$= x_i + 1$$

$$y_{i+1} = y_i + \Delta y = y_i + m \Delta x$$
$$= y_i + m(1)$$
$$= y_i + m$$

if $|\Delta x| < |\Delta y|$

then assign $\Delta y = 1$

$$y_{i+1} = y_i + \Delta y$$
$$= y_i + 1$$

$$x_{i+1} = x_i + \Delta x$$
$$= x_i + \Delta y / m$$
$$= x_i + 1/m$$

(1,1) and (3,3)

DDA

$\Delta x = 2$

$m = \frac{\Delta y}{\Delta x} = \frac{3-2}{3-2} = 1$

$\Delta y = 2$

$\because \Delta x \geq \Delta y$

$\Delta x = 1$, $\Delta y = m\Delta x = m$

$x_{i+1} = x + \Delta x = x + 1$

$y_{i+1} = y + m\Delta x = y + m$

x_i	y_i	$x+1$ x_{i+1}	$y+m$ y_{i+1}
1	1	2	2
2	2	3	3
3	3	4	4

Ans = { (1,1) , (2,2) , (3,3) }

DDA → gives coordinates in floating point values

Bresenham's Line Drawing Algorithm

① find slope, $m = \Delta y / \Delta x$ ② find Decision Parameter $(P) = 2\Delta y - \Delta x$

If $m < 1$

$P < 0$

$x_{i+1} = x_i + 1$

$y_{i+1} = y_i$

$P_{k+1} = P_k + 2\Delta y$

$P \geq 0$

$x_{i+1} = x_i + 1$

$y_{i+1} = y_i + 1$

$P_{k+1} = P_k + 2\Delta y - 2\Delta x$

If $m \geq 1$

$P < 0$

$x_{i+1} = x_i$

$y_{i+1} = y_i + 1$

$P_{k+1} = P_k + 2\Delta x$

$P \geq 0$

$x_{i+1} = x_i + 1$

$y_{i+1} = y_i + 1$

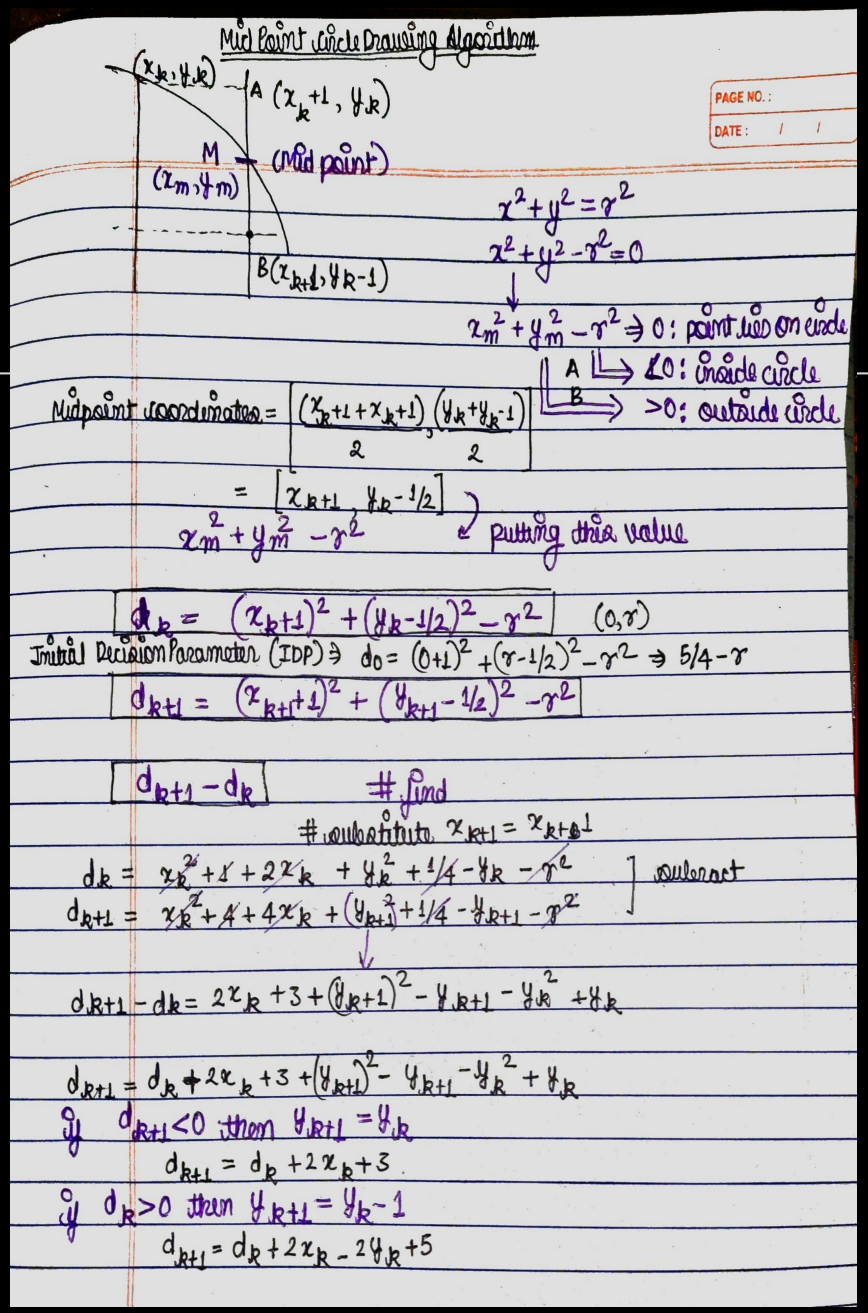
$P_{k+1} = P_k + 2\Delta x - \Delta y$

Mid Point Circle

Initial decision parameter (p) $= \frac{5}{4} - r$

If radius r is specified as an integer then the initial decision parameter is equal to

$$P = 1 - r$$



Brensenham Circle

start point (x_0, r)

Initial decision parameter = $3 - 2r$
(p)

while $(x_{i+1} < y_{i+1})$:

$x_{i+1} = x_i + 1$

if $p \leq 0$;

$y_{i+1} = y_i$; $p_{i+1} = p_i + 4x_{i+1} + 6$

else

$y_{i+1} = y_i - 1$; $p_{i+1} = p_i + 4(x_{i+1} - y_{i+1}) + 10$

Mid Sem-Practical

1. additive primary colors (RGB)
2. Refresh Buffer / Refresh Memory → Frame Buffer stores picture definition
3. Interlacing → incrementally displaying visual
   - ↳ vertical retrace krke Baar Baar dikhana
4. Beam penetration → 2 layers of phosphor in Random Scan Display
5. Shadow Masking → Raster Scan Display → 3 color data & shadow mask grid :)

Viva Prep

Graphics controller / Display controller / Display processor

↳ digitizing a picture definition into a set of pixel with appropriate intensity

Q28. What is the difference between impact and non-impact printers?

Impact printers press formed character faces against an inked ribbon on to the paper.

A line printer and dot-matrix printer are examples.

Non-impact printer and plotters use Laser techniques, inkjet sprays, Xerographic process, electrostatic methods and electro thermal methods to get images onto the papers.

Examples are: Inkjet/Laser printers.

Viva Prep

DDA

$\Delta x = x_2 - x_1$ → dx

$\Delta y = y_2 - y_1$ → dy

if $\Delta x >= \Delta y$;

steps = abs (Δx)

else ;

steps = abs (Δy)

x_inc = Δx / steps

y_inc = Δy / steps

x += x_inc

y += y_inc

```
void DDA(int x1, int y1, int x2, int y2){
    int dx= x2-x1;
    int dy= y2-y1;
    int steps= dx>=dy? abs(dx):abs(dy);
    float xinc= dx/(float)steps;
    float yinc= dy/(float)steps;
    int i= 0;
    cout<<xinc<<'\t'<<yinc<<endl;
    cout<<"\nThe consequent coordinates are: "<<endl;
    int x= x1, y=y1;
    cout<< "x0: "<<x<<", y0:"<<y<<endl;
    while (i<=steps)
    // while (i<=10)
    {
        /* code */
        putpixel(x, y, RED);
        x+=xinc;
        y+=yinc;
        i++;
        cout<< "x_next: "<<x<<", y_next:"<<y<<endl;
    }
    putpixel(x, y, RED);
}
```

Brenshanham Line Drawing

$$\Delta x = x_1 - x_0$$
$$\Delta y = y_1 - y_0$$

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

if $p >= 0$:
- $y += 1$
- $p += 2\Delta y - 2\Delta x$

else :
- $y = y$
- $p += 2\Delta y$

$x += 1$

```
void brensanham(int x0, int y0, int x1, int y1){
    int x=x0; int y=y0;
    if (x0 > x1)
    {
        x = x1;         y = y1;
        x1 = x0;        y1 = y0;
        x0 = x;         y0 = y;
    }
    int dx= x1-x0;
    int dy= y1-y0;
    int p= 2*dy-dx;
    while(x<x1){
        if(p>=0){
            putpixel(x,y,WHITE);
            y=y+1;
            p=p+2*dy-2*dx;
        }
        else{
            putpixel(x,y,WHITE);
            p=p+2*dy;
        }
        x=x+1;
    }
}
```

Mid point circle

$P = 1 - r$

$x = 0, y = r$

while $x <= y$:

draw

$x += 1$

if $P <= 0$:

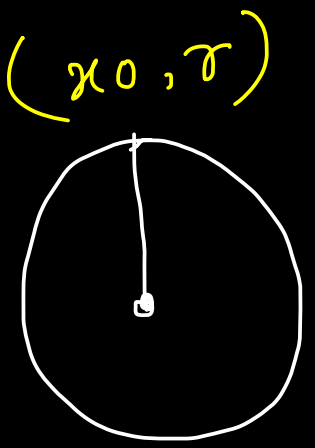
$P = P + 2x + 1$

else :

$y = y - 1$

$P = P + 2(x-y) + 1$

```
void drawMidPointCircle(int x0, int y0, int radius){
    int y = radius, x = 0;
    int decisionParam = 1 - radius;

    while (x <= y)
    {
        putpixel(x0 + x, y0 + y, 1);
        putpixel(x0 - x, y0 + y, 2);
        putpixel(x0 + x, y0 - y, 3);
        putpixel(x0 - x, y0 - y, 4);
        putpixel(x0 + y, y0 + x, 5);
        putpixel(x0 - y, y0 + x, 6);
        putpixel(x0 + y, y0 - x, 7);
        putpixel(x0 - y, y0 - x, 8);
        delay(400);

        x++;

        if (decisionParam <= 0)
            decisionParam += 2 *x  + 1;
        else{
            y--;
            decisionParam += 2 * (x-y) + 1;
        }
    }
}
```



Brensanham's Circle generation

$x = 0, y = r$

$p = 3 - 2r$

while $(x \leq y)$:

draw ⟶

$x+ = 1$

if $p <= 0$:

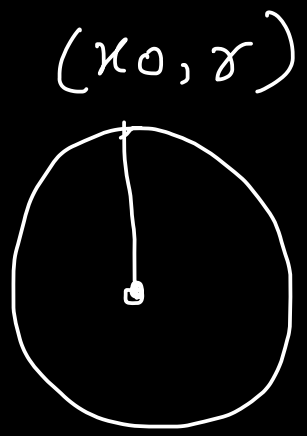
$p = p + 4x + 6$

else

$y = y - 1$

$p = p + 4(x - y) + 10$

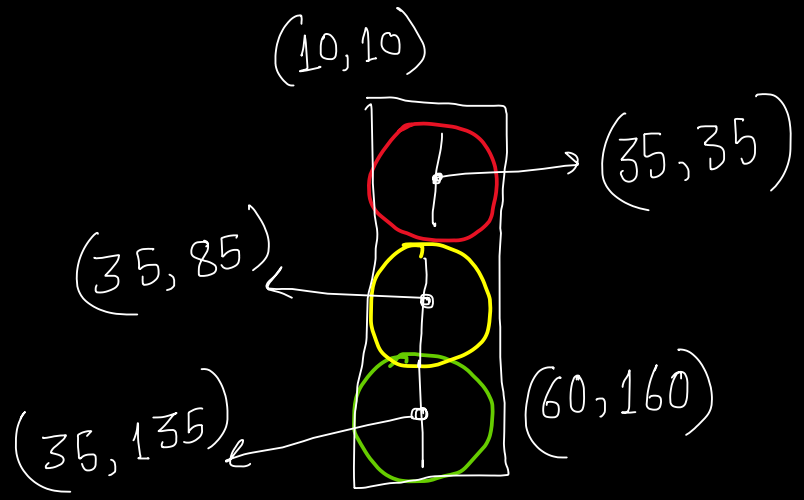
```
void drawBrensanhamCircle(int x0, int y0, int radius){

    int x = 0, y = radius;
    int decisionParam = 3 - 2 * radius;
    while (x <= y)
    {
        putpixel(x0 + x, y0 + y, RED);
        putpixel(x0 + y, y0 + x, RED);
        putpixel(x0 - y, y0 + x, RED);
        putpixel(x0 - x, y0 + y, RED);
        putpixel(x0 - x, y0 - y, RED);
        putpixel(x0 - y, y0 - x, RED);
        putpixel(x0 + y, y0 - x, RED);
        putpixel(x0 + x, y0 - y, RED);

        if (decisionParam <= 0){
            x++;
            decisionParam += 4 * x + 6;
        }
        else{
            x++;
            y--;
            decisionParam += 4 * (x - y) + 10;
        }
    }
}
```



Traffic Light

```
void drawTrafficLight(int x, int y, int lightSize, bool isRedOn, bool isYellowOn, bool isGreenOn){
    // Draw black background
    setfillstyle(SOLID_FILL, BLACK);
    bar(x, y, x + lightSize, y + 3 * lightSize);

    // Draw red light
    setfillstyle(SOLID_FILL, isRedOn ? RED : DARKGRAY);
    circle(x + lightSize / 2, y + lightSize / 2, lightSize / 2);
    floodfill(x + lightSize / 2, y + lightSize / 2, WHITE);

    // Draw yellow light
    setfillstyle(SOLID_FILL, isYellowOn ? YELLOW : DARKGRAY);
    circle(x + lightSize / 2, y + lightSize + lightSize / 2, lightSize / 2);
    floodfill(x + lightSize / 2, y + lightSize + lightSize / 2, WHITE);

    // Draw green light
    setfillstyle(SOLID_FILL, isGreenOn ? GREEN : DARKGRAY);
    circle(x + lightSize / 2, y + 2 * lightSize + lightSize / 2, lightSize / 2);
    floodfill(x + lightSize / 2, y + 2 * lightSize + lightSize / 2, WHITE);
}
```

Traffic Light




```
void red_circle()
{
    setfillstyle(SOLID_FILL, RED);
    circle(35, 35, 25);
    floodfill(35, 35, WHITE);
}

void yellow_circle()
{
    setfillstyle(SOLID_FILL, YELLOW);
    circle(35, 85, 25);
    floodfill(35, 85, WHITE);
}

void green_circle()
{
    setfillstyle(SOLID_FILL, GREEN);
    circle(35, 135, 25);
    floodfill(35, 135, WHITE);
}
```

```
while (1)
    {
        rectangle(10, 10, 60, 160);
        red_circle();
        delay(400);
        cleardevice();
        rectangle(10, 10, 60, 160);
        yellow_circle();
        delay(400);
        cleardevice();
        rectangle(10, 10, 60, 160);
        green_circle();
        delay(400);
        cleardevice();
    }
```

Smiley

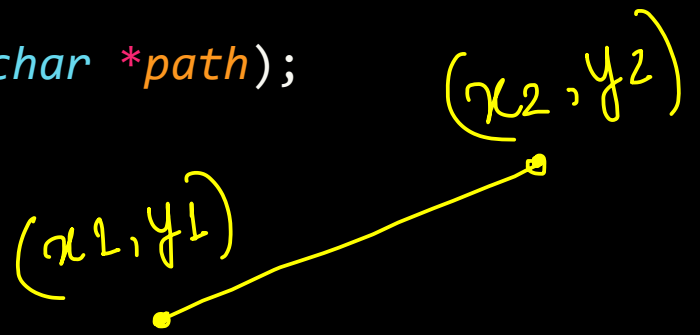
```c
#include <graphics.h>
int main(){
    // draw graphics using graphics.h
    int gDriver = DETECT, gMode;
    initgraph(&gDriver, &gMode, NULL);
    // draw a circle
    circle(200, 200, 100);
    // draw a smile
    arc(200, 200, 210, 330, 50);
    // draw eyes
    circle(170, 180, 5);
    circle(230, 180, 5);
    // draw a nose
    line(200, 200, 200, 230);
    getch();
    closegraph();
    return 0;
}
```

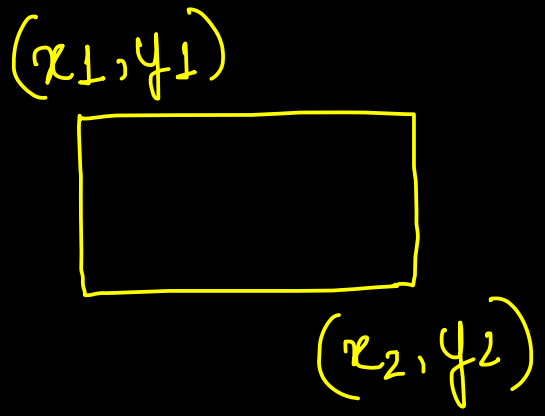
Hut

```
#include<graphics.h>
int main(){
    // draw a hut
    int gDriver = DETECT, gMode;
    initgraph(&gDriver, &gMode, NULL);
    // draw a rectangle
    rectangle(100, 100, 300, 300);
    // draw a triangle
    line(100, 100, 200, 50);
    line(200, 50, 300, 100);
    line(100, 100, 300, 100);
    // draw a door
    rectangle(150, 230, 200, 300);
    circle(150, 150, 30);
    circle(250, 150, 30);
    getch();
    closegraph();
    return 0;
}
```

Important Functions of <graphics.h>

```
// Initializes the graphics system
void initgraph(int *graphdriver, int *graphmode, const char *path);

// Closes the graphics system
void closegraph();

// Waits for a key press event and returns the key code
int getch();

// Draws a pixel of specified color at the given (x, y) coordinate
void putpixel(int x, int y, int color);

// Draws a line between two given points
void line(int x1, int y1, int x2, int y2);

// Draws a rectangle with given top-left and bottom-right coordinates
void rectangle(int left, int top, int right, int bottom);
```

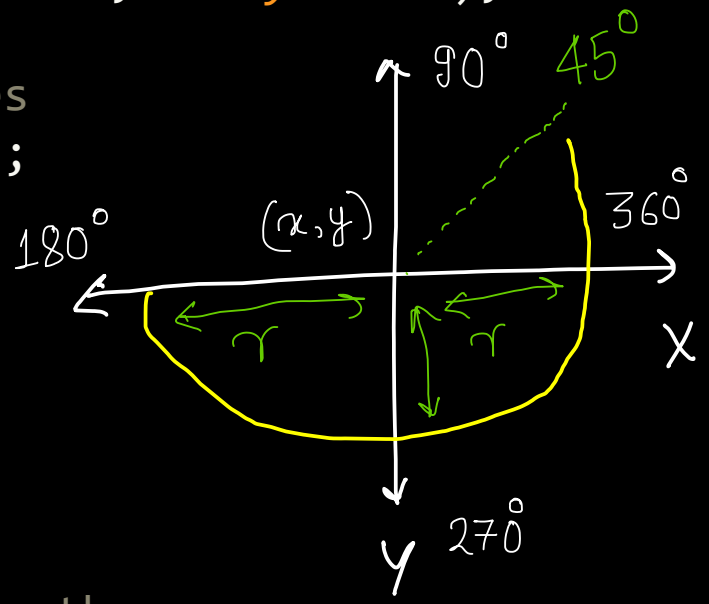




x1 y1 x2 y2

Important Functions of <graphics.h>

```
// Draws a circle with given center and radius
void circle(int x, int y, int radius);

// Draws an ellipse with given center, horizontal and vertical radius
void ellipse(int x, int y, int start_angle, int end_angle, int xradius, int yradius);

// Draws an arc with given center, radius, and start and end angles
void arc(int x, int y, int start_angle, int end_angle, int radius);
                                  180°          45°
// Sets the current drawing color to the specified color
void setcolor(int color);

// Sets the fill pattern and color for the next fill operation
void setfillstyle(int pattern, int color);

// Writes the specified text string at the given (x, y) position on the screen
void outtextxy(int x, int y, const char *text);
```



Important Functions of <graphics.h>

```
// Sets the font and size of the text to be drawn
void settextstyle(int font, int direction, int charsize);

// Returns the maximum x coordinate of the current graphics screen
int getmaxx();

// Returns the maximum y coordinate of the current graphics screen
int getmaxy();

void floodfill(int x, int y, int boundary_color);
```

Brensenham v/s DDA line generation

Accuracy: DDA line algorithm provides high accuracy for line generation, as it generates points based on the exact slope of the line. Bresenham algorithm, on the other hand, generates points based on integer arithmetic operations, which can result in some inaccuracies in the line.

Speed: Bresenham algorithm is faster than DDA algorithm, as it uses only integer arithmetic operations, which are faster than floating-point arithmetic operations used in DDA algorithm.

Efficiency: Bresenham algorithm is more efficient than DDA algorithm in terms of memory usage, as it requires only two variables to generate the line, whereas DDA algorithm requires variables for both x and y coordinates.

Implementation: Bresenham algorithm is more complex to implement than DDA algorithm, as it involves checking for multiple decision parameters and adjusting the values of these parameters based on the value of the error term. DDA algorithm, on the other hand, is relatively simple to implement, as it involves only basic arithmetic operations.

Applications: DDA algorithm is suitable for applications that require high accuracy in line generation, such as CAD systems and architectural design. Bresenham algorithm, on the other hand, is suitable for applications that require fast and efficient line generation, such as real-time graphics and video games.

more accurate

more efficient

Brensenham Circle v/s Mid Point Circle

Accuracy: Bresenham's algorithm is more accurate than the Midpoint algorithm. Bresenham's algorithm uses integer arithmetic and only calculates the points that lie closest to the actual circle, resulting in fewer rounding errors. Midpoint algorithm uses floating-point arithmetic, which can lead to some inaccuracies.

Efficiency: Midpoint algorithm is more efficient than the Bresenham's algorithm. The Midpoint algorithm uses only addition and subtraction, whereas Bresenham's algorithm ~~involves division and multiplication operations~~, which can be more time-consuming.

Implementation: Bresenham's algorithm is harder to implement than Midpoint algorithm. Bresenham's algorithm is more complex, and it requires additional calculations for each octant of the circle. In contrast, the Midpoint algorithm is simpler and only requires one set of calculations.

Circle size: Bresenham's algorithm works better for small circles, while Midpoint algorithm works better for large circles. Bresenham's algorithm is limited by the accuracy of integer arithmetic, which can make it difficult to draw large circles. Midpoint algorithm, on the other hand, can handle larger circles without loss of accuracy.

Symmetry: Bresenham's algorithm has better symmetry than Midpoint algorithm. Bresenham's algorithm calculates points that are symmetric to each other along the circle, while the Midpoint algorithm doesn't.

Parametric Equations

Parametric equations are a way of representing geometric shapes such as lines and conics using parameters instead of the traditional x and y coordinates. These parameters can be either angles or distances, depending on the shape being represented.
The parametric equation of a line in two dimensions is usually written in the form:

```
x = x1 + t(x2 - x1)
y = y1 + t(y2 - y1)
```

where (x1, y1) and (x2, y2) are two points on the line, and t is a parameter that varies between 0 and 1. As t varies, the point (x, y) traces out the line segment connecting the two points.

For a conic section such as an ellipse, the parametric equation is written in terms of two parameters, usually denoted by u and v. For example, the parametric equation for an ellipse centered at the origin is:

```
x = a cos u
y = b sin u
```

where a and b are the lengths of the major and minor axes of the ellipse, respectively. As u varies from 0 to 2π, the point (x, y) traces out the entire ellipse.

Parametric Equations

Similarly, the parametric equation for a hyperbola can be written in terms of two parameters, usually denoted by u and v, as:

```
x = a cosh u
y = b sinh u
```

where a and b are again the lengths of the major and minor axes of the hyperbola. As u varies, the point (x, y) traces out the two branches of the hyperbola.

In general, the advantage of using parametric equations to represent geometric shapes is that they provide a more flexible and compact way of expressing complex shapes. They are also useful for animations and computer graphics, where the motion of a point along a path can be easily described using a parametric equation.

Plotters

A plotter is an output device that produces graphical output on paper or similar material. Plotters work by using one or more pens to draw continuous lines on the paper based on digital instructions sent to the device. Plotters are commonly used in engineering, architecture, and other fields where detailed graphical output is required.

There are two main types of plotters:

Drum Plotters: Drum plotters use a drum to rotate the paper, and the pens are moved along the drum's length to draw the lines.

Flatbed Plotters: Flatbed plotters use a flat surface to hold the paper and the pens are moved across the paper's width and length to draw the lines.

Printers

Printers, on the other hand, are devices that produce printed output on paper or other media. Printers work by transferring ink or toner onto paper to create text or images. There are several types of printers available, including:

Inkjet printers: Inkjet printers spray ink onto the paper to create text and images.
Laser printers: Laser printers use a toner cartridge and a laser to fuse the toner onto the paper.
Dot matrix printers: Dot matrix printers use a print head that strikes an inked ribbon to create the characters.
Thermal printers: Thermal printers use heat to transfer ink onto paper.
3D printers: 3D printers use various materials, such as plastic, to create three-dimensional objects layer by layer.

Impact vs Non Impact Printers

Impact printers work by physically striking an inked ribbon against the paper to create an image. The print head typically contains a series of pins or hammers that strike the ribbon, leaving ink on the paper. Examples of impact printers include dot matrix printers and daisy wheel printers. Impact printers are generally slower and noisier than non-impact printers, but they can produce carbon copies or multipart forms, and are often used for printing invoices, receipts, and other forms.

Non-impact printers, on the other hand, do not physically strike the paper. Instead, they use various technologies such as inkjet, laser, or thermal to create an image on the paper. Examples of non-impact printers include inkjet printers, laser printers, and thermal printers. Non-impact printers are generally faster and quieter than impact printers and produce higher quality output, but they cannot produce carbon copies or multipart forms.