INTRODUCTION TO COMPUTER GRAPHICS

LECTURE 1

3D → 1) **Computer Graphics**

3D data (known as model) —INPUT→ CG —OUTPUT→ 2D image (Simulated output)

The equation of the object to be simulated is called the model / 3D data.

Example : Animated movies

if the input is 2D → 2) **Computer Vision**

2D image / videoframe —INPUT→ CV —OUTPUT→ Information from the contents of the input

Example: Face ~~reg~~ recognition

3) **Digital image processing**

2D raw image —INPUT→ DIP —OUTPUT→ Processed image with filters and alter effects

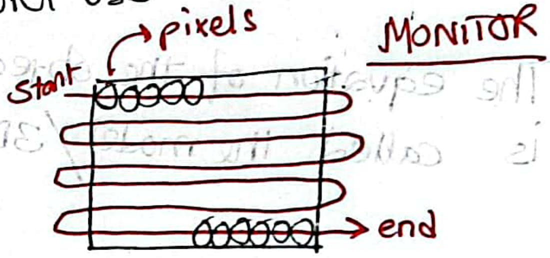
Example: Adobe photoshop, Adobe after effects.

Ø Scanning

The process in which each pixel is being generated on any display / monitor.

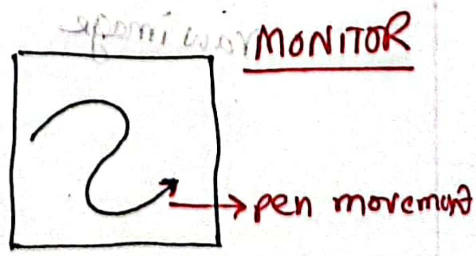
1) Raster Scanning / Scan :

→ Sequential from start to end
→ Speed is data independent
→ is better for computer use



2) Vector / Random Scan / Scanning :

→ The way the pen moves is the way the monitor / display lights up.
→ use of geometric equations to produce image.
→ Vector scanning for line drawing, but not for field object.
→ It's speed is data dependant, for more complex data the speed may slow down causing flickering
→ So, not good for computers.



Rendering Pipe-Line: From input 3D data (model) through simulation to output "simulated 2D image". The whole process is known as rendering pipeline.

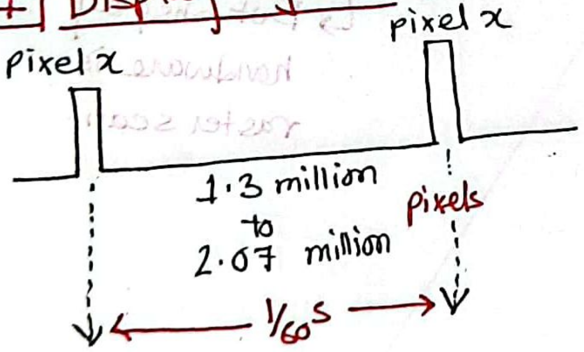
3D Data → Modeling transformation → 3D → Projection → 2D → .... → Scan Conversion → Display 2D-image

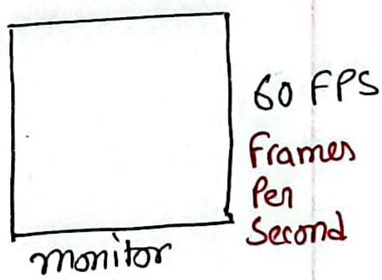
Hardware used: GPU → Graphical processing unit

Display Hardware

- It is part of computer graphics which takes in 2D input

1. Display System (How it displays)





pixel x will light up again after $1/60$ seconds.

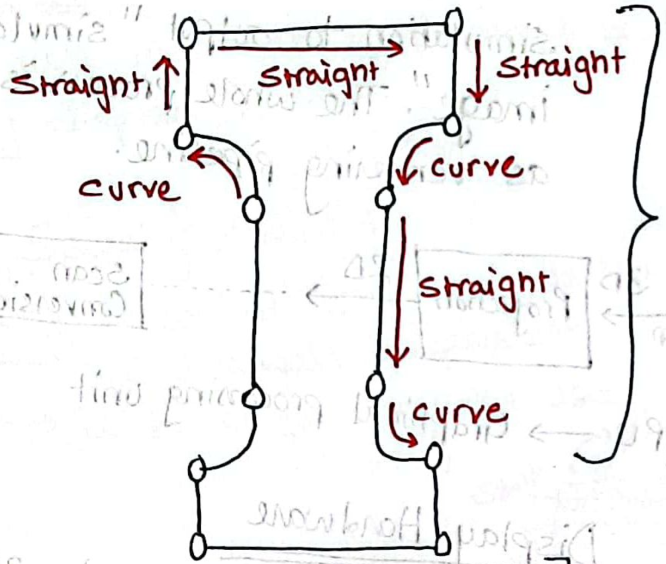
- Since the pixels turn on & off so fast, it is not phisically/visually perceptive to the naked eye, hence it feels like the monitor is always "on".
- When all pixels light up, it is known as a single frame.

2. Scanning:

→ takes place at the time of capturing and at the time of displaying

- A process that streams a 1 D (dimensional) dot, from a 2D image.
- Can use set of dots to create a 2D image.

Example of scanning :



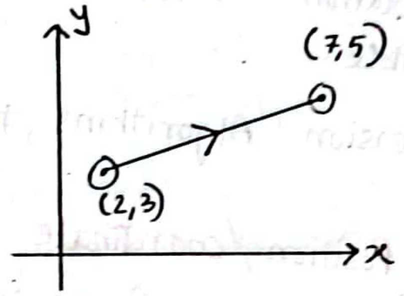
Creating the boundary is the work of vector graphics

while filling the letter boundary with pixels is work of raster scanning

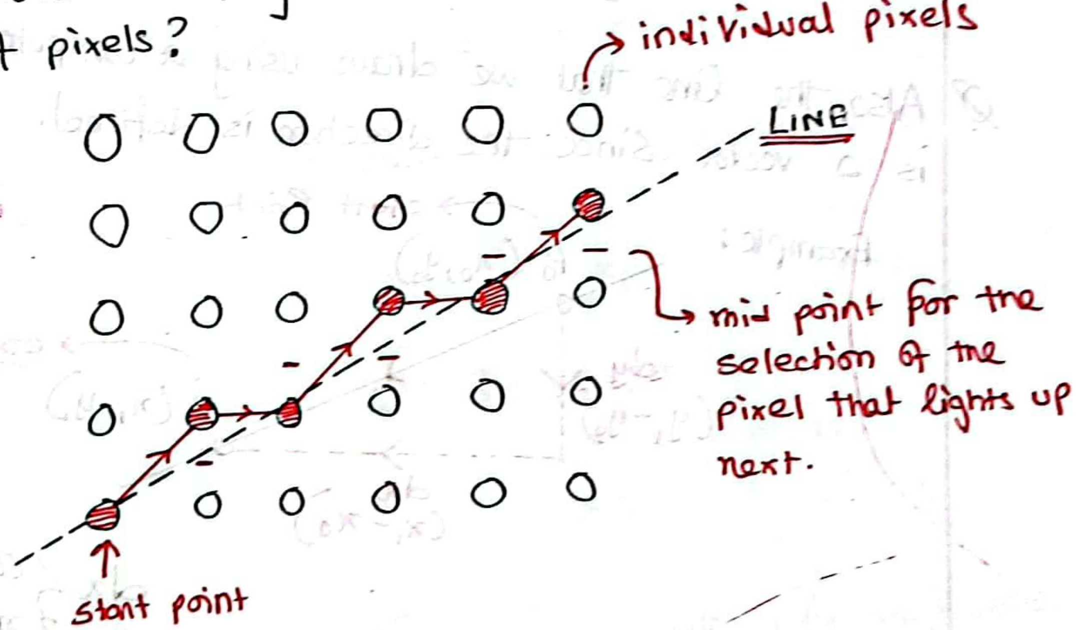
Recent hardware is a hybrid of both.

↳ But display hardware is raster scan.

- In the case of drawing a line, the line segment is defined by the starting point (the coordinate) an the ending point (the coordinate).



- But how does a display outputs this information through the use of pixels?



∅ But how do we select which pixel to turn on?

Few considerations:

1) The line has to be as smooth looking as possible.

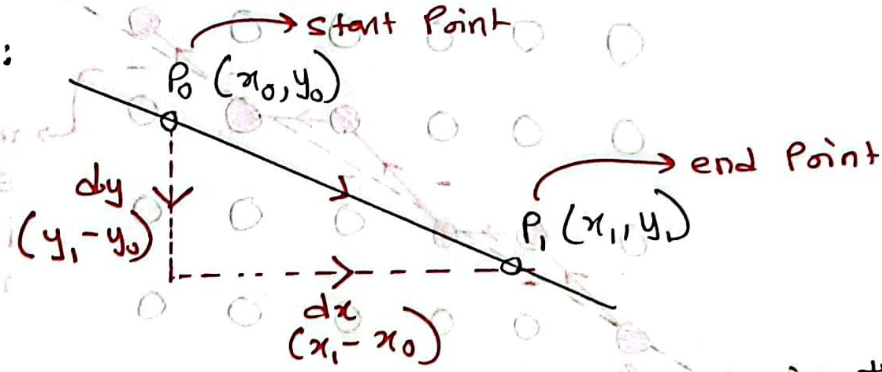
2) The calculations should be as fast as possible.

In scan conversion Algorithms, there's generally two outputs

1) Position / coordinate of a pixel (x, y)
2) RGB value of a pixel (The color)

Also, the line that we draw using a computer is a vector. Since the direction is defined.

Example:

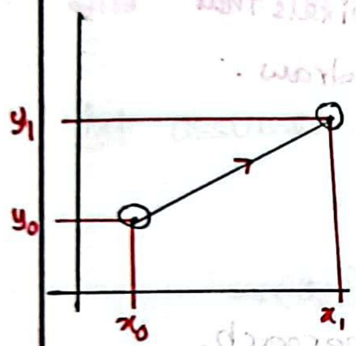


dx, dy — carries the magnitude & direction

+ve/-ve defines the direction.

Equations of a line :

$$y = mx + c, \quad \text{--- (i)}$$



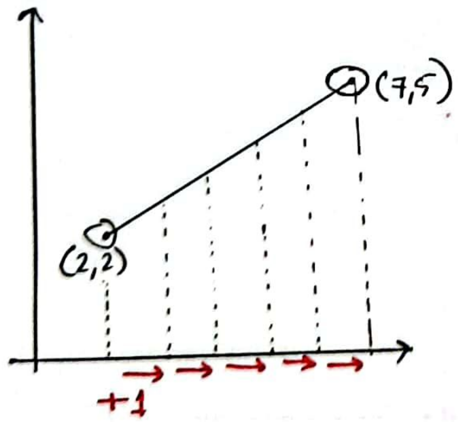
where,

$$m = \frac{y_1 - y_0}{x_1 - x_0} \quad \text{--- (ii)}$$

the constant c, can be figured out by plugging in the value of the start/end coordinates.

$$\Rightarrow c = y_0 - m \cdot x_0$$

Example of a simple approach to calculate each pixel in a line →



↳ we will increase the step size of x by one (+1) and calculate the value of y across it.

(1) $m = \dfrac{y_2 - y_1}{x_2 - x_1} = \dfrac{5-2}{7-2} = 3/5$

(2) The value of c:

$$c = y_1 - m \cdot x_1$$

$$\Rightarrow c = 2 - 3/5 \cdot 2 = 4/5$$

(3) Now calculate y for each value of x:

(i) $y(2) = \underline{2}$

(ii) $y(3) = (3/5 \cdot 3) + 4/5 = 13/5 = \underline{2.6}$

(iii) $y(4) = ((3/5 \cdot 4) + 4/5) = 16/5 = \underline{3.2}$

(iv) $y(5) = (3/5 \cdot 5) + 4/5 = 19/5 = \underline{3.8}$

(v) $y(6) = (3/5 \cdot 6) + 4/5 = 22/5 = \underline{4.4}$

(vi) $y(7) = (3/5 \cdot 7) + 4/5 = 5 = \underline{5}$

So,

	Pixel (x,y)
$\rightarrow y(2) = 2$	$(2,2)$
$\rightarrow y(3) = 2.6 \approx 3$	$(3,3)$
$\rightarrow y(4) = 3.2 \approx 3$	$(4,3)$
$\rightarrow y(5) = 3.8 \approx 4$	$(5,4)$
$\rightarrow y(6) = 4.4 \approx 4$	$(6,4)$
$\rightarrow y(7) = 5$	$(7,5)$

These are the pixels that we draw.

While this might be a very simple approach, the algorithm is way too slow since:

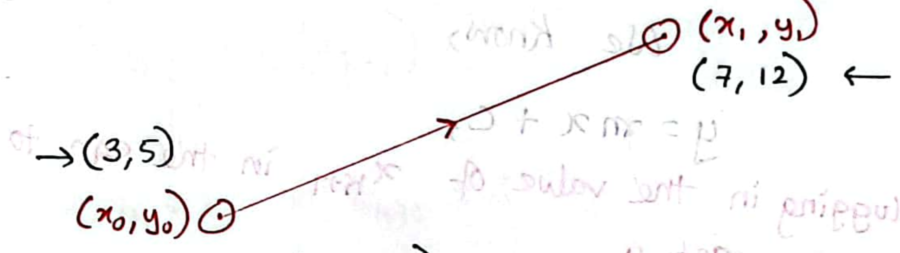
- → The equation $y = mx + b$ / $y = mx + c$, requires the multiplication of m and x in every step
- → we also need to Round off the resulting y coordinates.

∅ We'll need a faster approach.

DDA (Digital Differential Algorithm)

The DDA Algorithm is an incremental approach in order to speed up scan conversion. Simply calculate y_{k+1} based y_k and the deciding factor here is the gradient (m).

let assume we want to draw the following line:

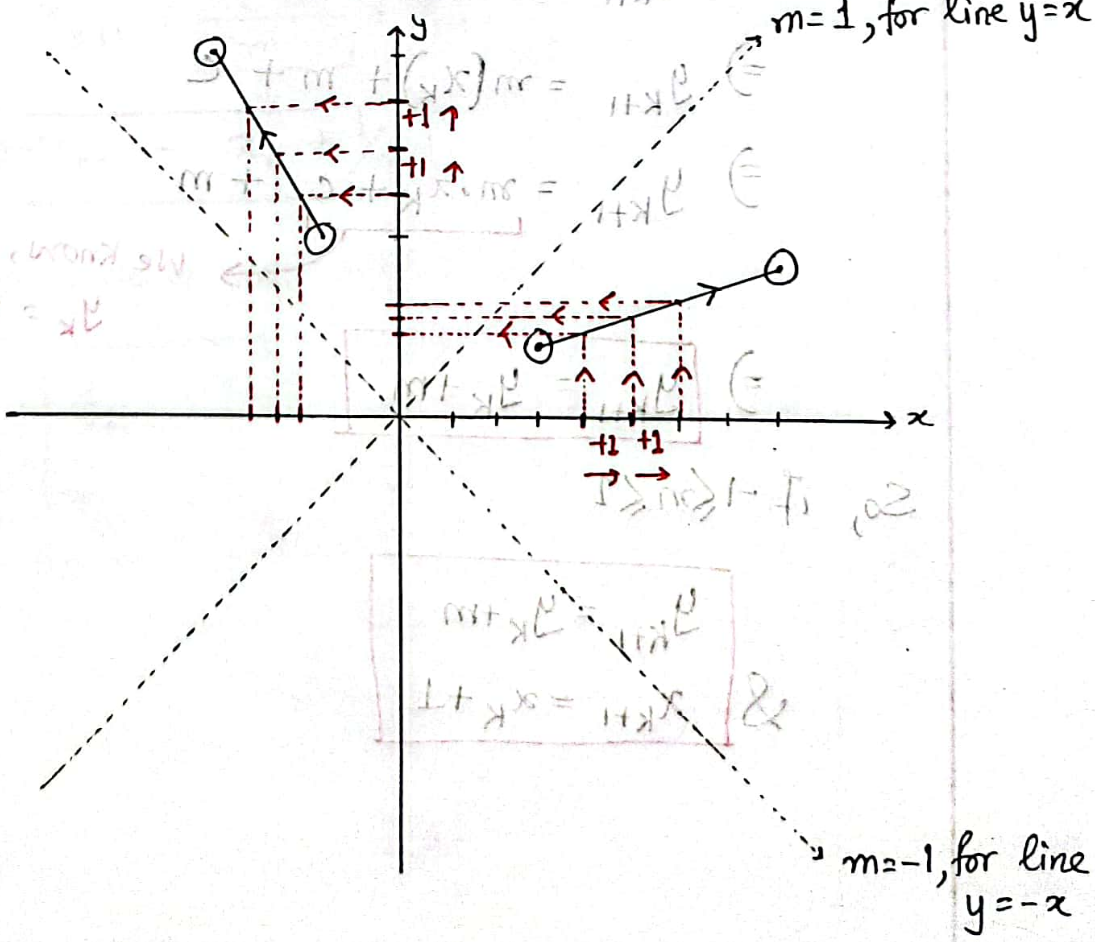


first,

$$m = \frac{(y_2 - y_1)}{(x_2 - x_1)} \quad \text{OR} \quad \frac{y_1 - y_0}{x_1 - x_0}$$

So,

$$m = \frac{12-5}{7-3} = 7/4$$



Ø There are two conditions to DDA

1) if gradient m is $(-1 \leq m \leq 1) \rightarrow$ increment of x will be by 1

$$\underbrace{x_{k+1}}_{\text{the next value of } x} = \underbrace{x_k}_{\text{the current value of } x} + 1$$

For this condition, why we increase x by 1?
if -1<m<1, then the angle of the less than 45 and we increase x by 1 to get accurate line

We know,

$$y = mx + c,$$

□ plugging in the value of x_{k+1} in the eqn get y_{k+1}

$$y_{k+1} = m(x_{k+1}) + c$$

$$\Rightarrow y_{k+1} = m(x_k + 1) + c$$

$$\Rightarrow y_{k+1} = m(x_k) + m + c$$

$$\Rightarrow y_{k+1} = \underbrace{m \cdot x_k + c}_{\text{We know, } y_k = mx_k + c} + m$$

$$\Rightarrow \boxed{y_{k+1} = y_k + m}$$

So, if $-1 \leq m \leq 1$

$$\boxed{\begin{aligned} y_{k+1} &= y_k + m \\ \& \quad x_{k+1} &= x_k + 1 \end{aligned}}$$

CamScanner

For this condition, why we increase y by 1?
if m>1, then the angle of the greater than 45 and we increase y by 1 to get accurate line

2) If m lies outside the range : → increment of y will be by 1.

So, $y_{K+1} = y_K + 1$

& $y = mx + c$ ⟶ also, $x = \frac{y-c}{m}$

$\Rightarrow y_{K+1} = m(x_{K+1}) + c$

$\Rightarrow y_K + 1 = m \cdot x_{K+1} + c$

$\Rightarrow y_K - c + 1 = m \cdot x_{K+1}$

$\Rightarrow x_{K+1} = \frac{y_K - c + 1}{m}$

$\Rightarrow x_{K+1} = \underbrace{\frac{y_K - c}{m}}_{x_K} + 1/m$

$\Rightarrow \boxed{x_{K+1} = x_K + 1/m}$

So, for m outside the range :

$$\boxed{\begin{aligned} y_{K+1} &= y_K + 1 \\ \& \quad x_{K+1} &= x_K + 1/m \end{aligned}}$$

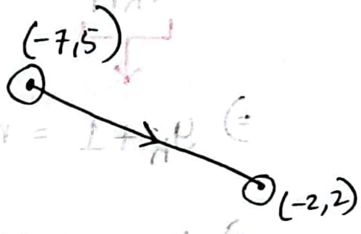
So,

$-1 \leq m \leq 1$	otherwise
$x_{k+1} = x_k + 1$	$x_{k+1} = x_k + 1/m$
$y_{k+1} = y_k + m$	$y_{k+1} = y_k + 1$

———X———

Q1 Draw a line using DDA for :

$P_1(-7,5)$ $P_2(-2,2)$



$$m = \frac{2-5}{-2+7} = \frac{-3}{5} = \boxed{-0.6}$$

Since m is in the range: $(-1 \leq m \leq 1)$

the value of
x increases
y decreases

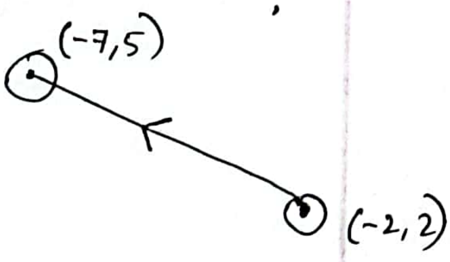
$$x_{k+1} = x_k + 1$$

$$y_{k+1} = \underbrace{y_k + m}$$

since m is inherently negative we don't need to use $(y_k - m)$

x (+1)	y (+m)	y (round off)	PIXEL
−7	5	—	(−7, 5)
−6	4.4	≈ 4	(−6, 4)
−5	3.8	4	(−5, 4)
−4	3.2	3	(−4, 3)
−3	2.6	3	(−3, 3)
−2	2	2	(−2, 2)

Q2 What if the line was in the opposite direction?



$$m = \frac{5-2}{-7+2} = \frac{3}{-5} = \boxed{-0.6}$$

in range $(-1 \leq m \leq 1)$

$x_k(-1)$	$y_k(-m)$	y_k (round off)	PIXEL
-2	2	—	(-2, 2)
-3	2.6	3	(-3, 3)
-4	3.2	3	(-4, 3)
-5	3.8	4	(-5, 4)
-6	4.4	4	(-6, 4)
-7	5	5	(-7, 5)

x decreases
y increases

since x decreases we will use $x_{K+1} = x_K - 1$ instead

since y increase and the value of m is negative we will use $y_{K+1} = y_K - m$ instead.

Pseudo Code for DDA

```
DDA (x0, y0 , x1 , y1) {
    m = (y1 - y0) / (x1 - x0) ;
    if ( m ≤ 1  && m ≥ -1) {
        while ( x0 ≤ x1 ) {
            x0 = x0 + 1
            y0 = y0 + m
            draw (x0, y0)
        }
    }
    (*)
```

```
(*) else {
        while ( y0 ≤ y1 ) {
            x0 = x0 + (1/m)
            y0 = y0 + 1
            draw (x0, y0)
        }
    }
```