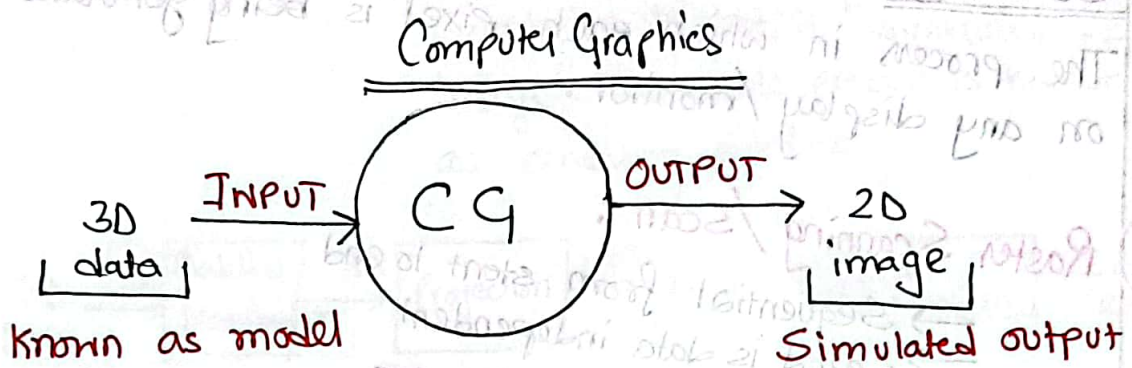


INTRODUCTION TO COMPUTER GRAPHICS

LECTURE 1

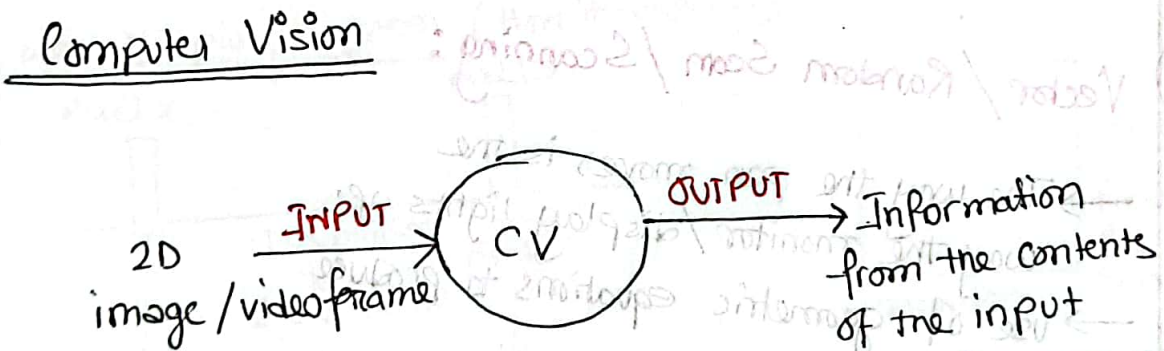
3D → 1



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

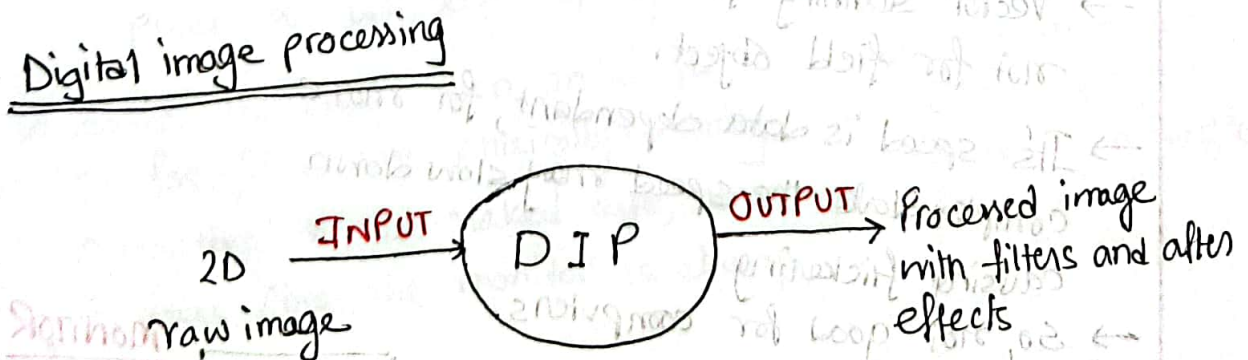
Example: Animated movies

if the input is 2D → 2



Example: Face ~~recognition~~ recognition

→ 3



Example: Adobe photoshop, Adobe after effects.

Ø Scanning

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

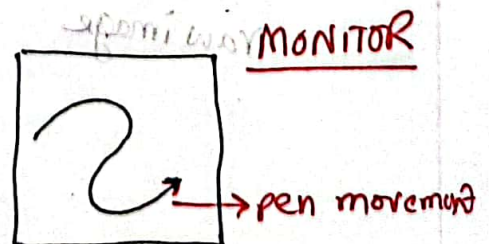
1) Raster Scanning / Scan :

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

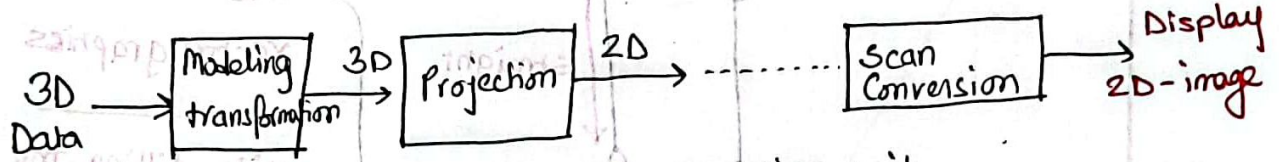


2) Vector / Random Scan / Scanning :

- 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.
- Its 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.

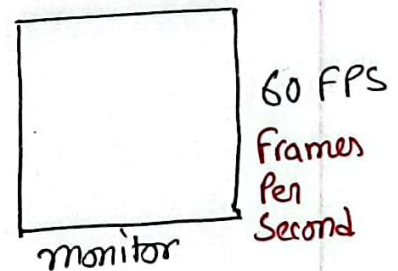
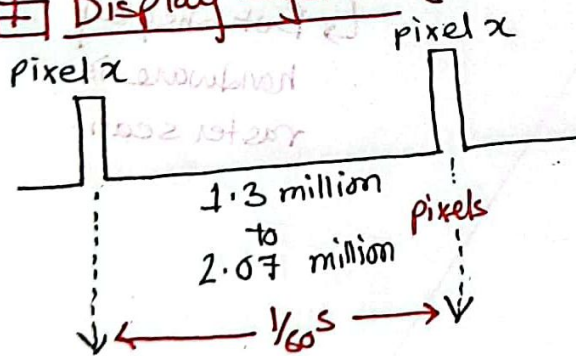


Hardware used : CPU → Graphical processing unit

Display Hardware

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

Display System (How it displays)



pixel x will light up again after $\frac{1}{60}$ seconds.

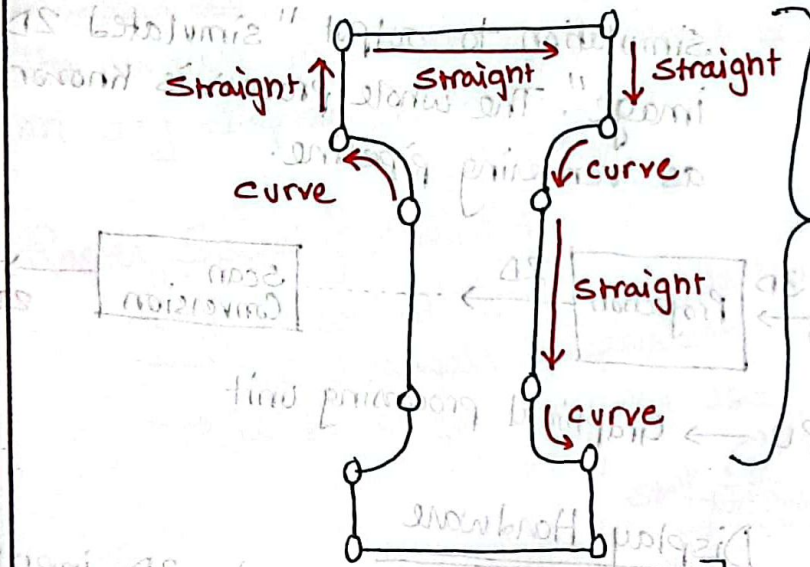
Since the pixels turn on & off so fast, it is not physically/visually perceptible to the naked eye, hence it feels like the monitor is always "on".

When all pixels light up, it is known as a single frame.

Scanning :

- takes place at the time of capturing and at the time of displaying
- A process that streams a 1D (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

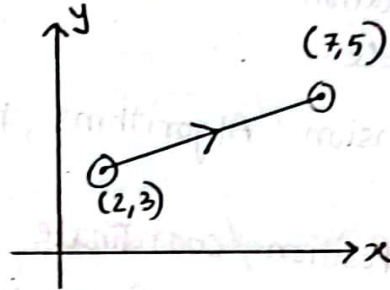
While filling the letter boundary with pixels is work of raster scanning

Recent hardware is a hybrid of both.

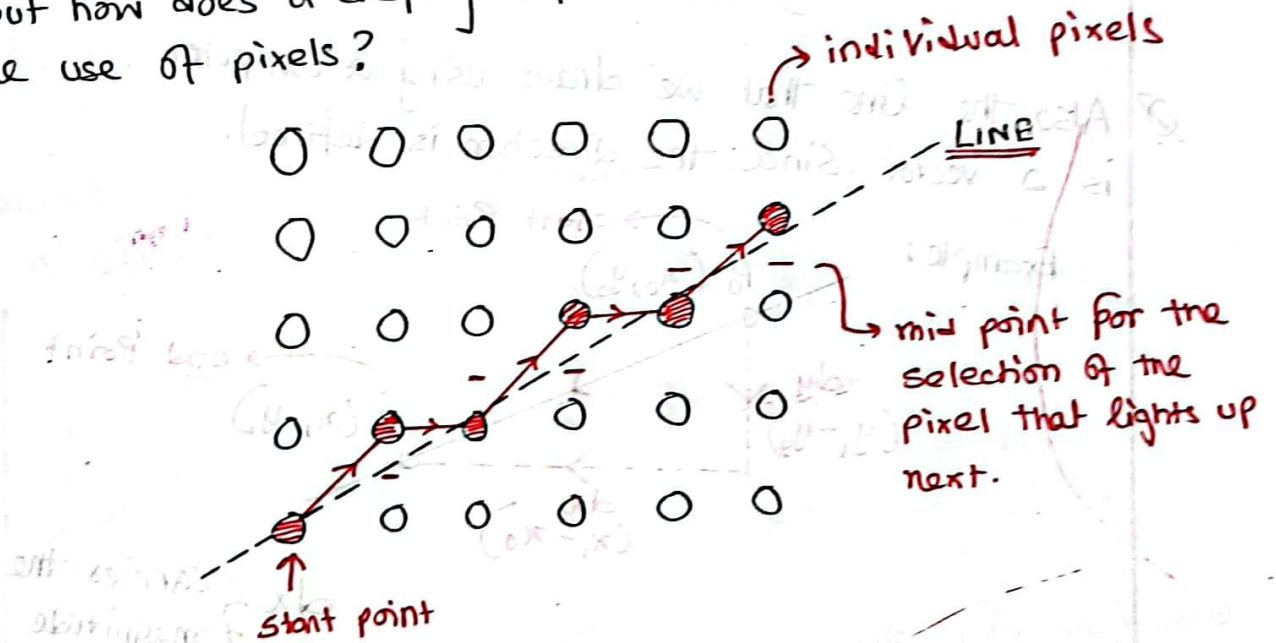


But display hardware is raster scan

- In the case of drawing a line, the line segment is defined by the starting point (the coordinate) and 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?

Ø Few considerations:

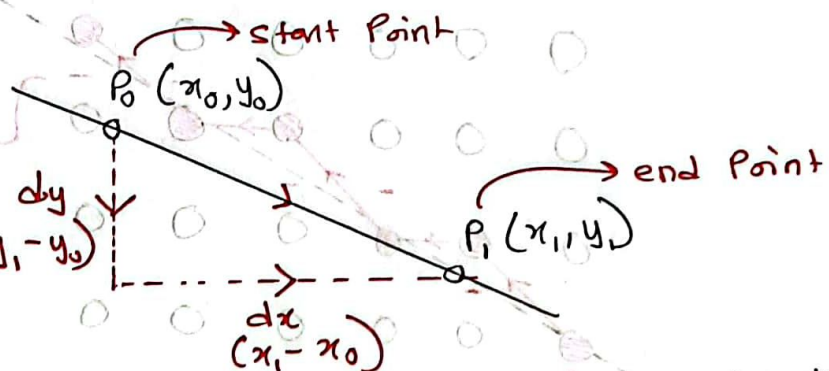
- 1) The line has to be as smooth looking as possible.
- 2) The calculations should be as fast as possible.

Ø 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)

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

Example:



dx
 dy } carries the magnitude & direction

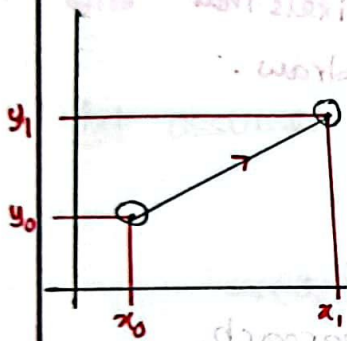
+ve/-ve defines the direction.

Equations of a line:

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

where,

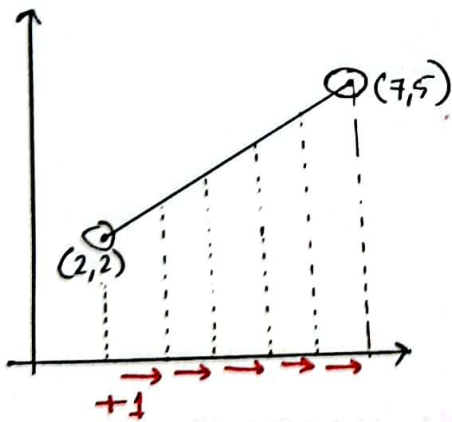
$$m = \frac{y_1 - y_0}{x_1 - x_0} \quad \text{--- (ii)}$$



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~~ Example of a simple approach to calculate each pixel in a line \rightarrow



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

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

(2) The value of c :

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

$$\Rightarrow c = 2 - \frac{3}{5} \cdot 2 = \frac{4}{5}$$

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

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

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

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

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

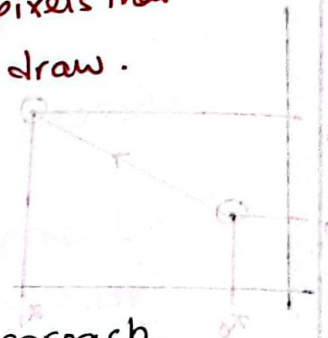
(v) $y(6) = \left(\frac{3}{5} \cdot 6\right) + \frac{4}{5} = \frac{22}{5} = \underline{4.4}$

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

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.

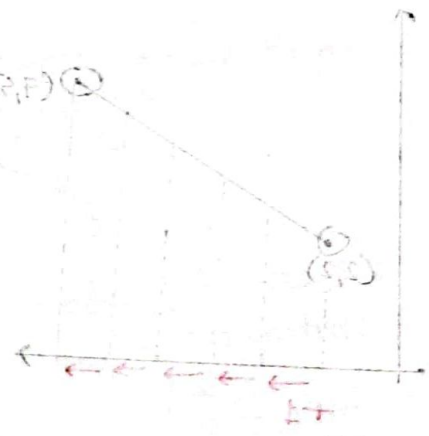


While this might be a very simple approach, the algorithm is way too slow since:

\rightarrow The equation $y = mx + b$ / $y = mx + c$, requires the multiplication of m and x in every step

\rightarrow We also need to Round off the resulting y coordinates.

~~⊗~~ We'll need a faster approach.



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

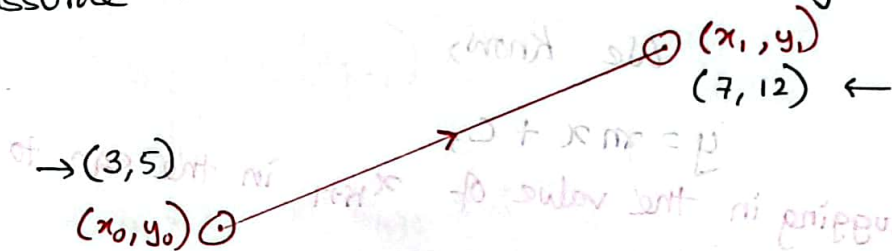
Now calculate y for each value of x .

- (i) $y(2) = \frac{5}{2} = 2.5$
- (ii) $y(3) = \left(\frac{5}{2} \cdot 3\right) = \left(\frac{15}{2}\right) = 7.5$
- (iii) $y(4) = \left(\frac{5}{2} \cdot 4\right) = \left(\frac{20}{2}\right) = 10$
- (iv) $y(5) = \left(\frac{5}{2} \cdot 5\right) = \left(\frac{25}{2}\right) = 12.5$
- (v) $y(6) = \left(\frac{5}{2} \cdot 6\right) = \left(\frac{30}{2}\right) = 15$
- (vi) $y(7) = \left(\frac{5}{2} \cdot 7\right) = \left(\frac{35}{2}\right) = 17.5$

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:

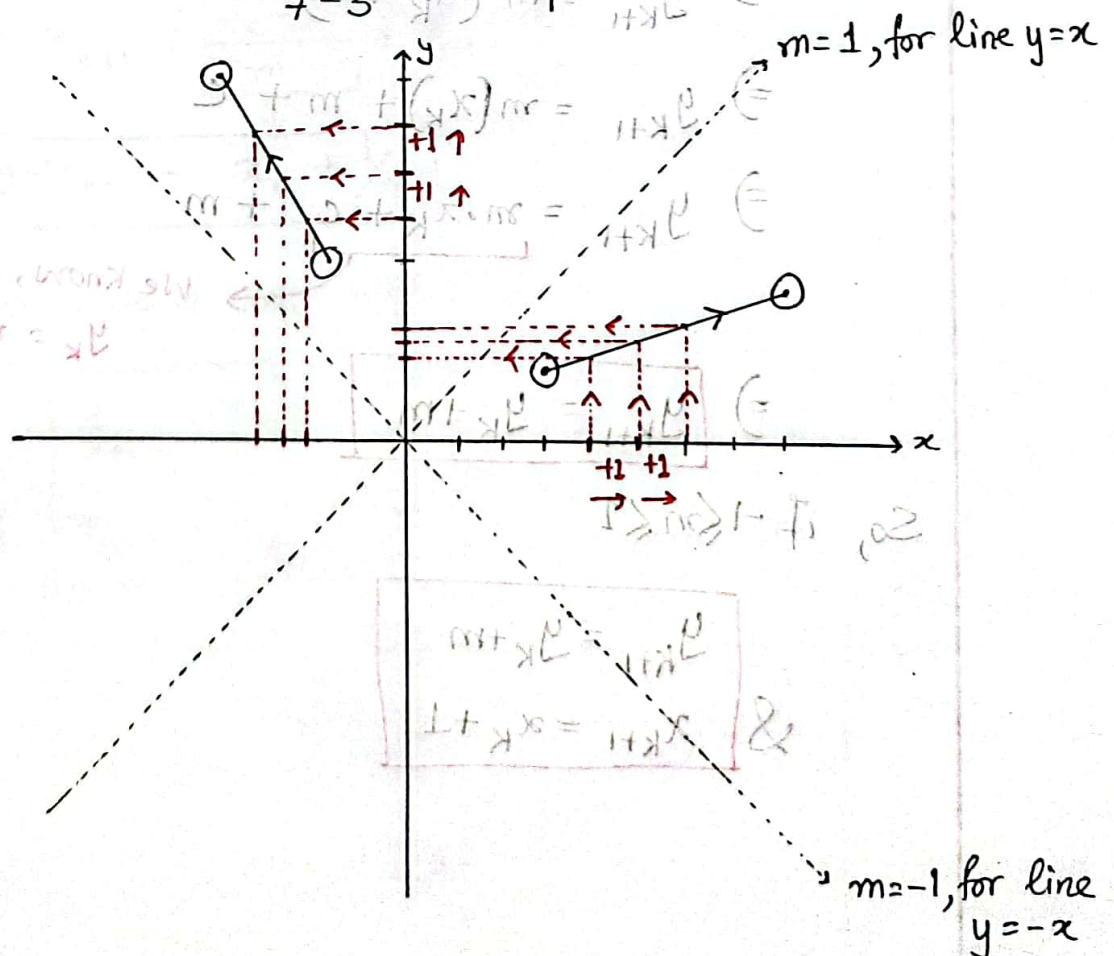


first,

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

So,

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



There are two conditions to DDA

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

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

the next value of x

the current value of x

We know,

$$y = mx + c,$$

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

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

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

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

$$\Rightarrow y_{k+1} = \underbrace{m \cdot x_k + c}_{y_k} + m$$

We know,

$$y_k = mx_k + c$$

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

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

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

$$\& \boxed{x_{k+1} = x_k + 1}$$

2) if m lies outside the range \Rightarrow increment of y will be by 1.

$$\text{So, } y_{k+1} = y_k + 1$$

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

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

$$\Rightarrow y_k + 1 = m \cdot x_{k+1} + c$$

$$\Rightarrow y_k - c + 1 = m \cdot x_{k+1}$$

$$\Rightarrow x_{k+1} = \frac{y_k - c + 1}{m}$$

$$\Rightarrow x_{k+1} = \frac{y_k - c}{m} + \frac{1}{m}$$

$$\Rightarrow x_{k+1} = x_k + \frac{1}{m}$$

So, for m outside the range:

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

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

otherwise

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

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

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

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

Q1

Draw a line using DDA for:

$$P_1(-7, 5)$$

$$P_2(-2, 2)$$

$$m = \frac{2 - 5}{-2 - (-7)} = \frac{-3}{5} = -0.6$$

Since m is in the range:

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

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

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

the value of

x increases
 y decreases

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

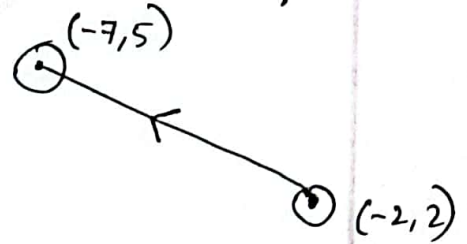
$x(k)$	$y(km)$	$y(\text{round off})$	PIXEL
-7	5	—	$(-7, 5)$
-6	4.4	≈ 4	$(-6, 4)$
-5	3.8	4	$(-5, 4)$
-4	3.2	3	$(-4, 3)$
-3	2.6	3	$(-3, 3)$
-2	2	2	$(-2, 2)$

Q2

What if the line was in the opposite direction?

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

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



$x_k(-1)$	$y_k(-m)$	$y_k(\text{round off})$	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 $(x_0, y_0, x_1, y_1) \{$

$$m = \frac{(y_1 - y_0)}{(x_1 - x_0)} ;$$

if $(m \leq 1 \text{ \& \& } m \geq -1) \{$

while $(x_0 \leq x_1) \{$

$$x_0 = x_0 + 1$$

$$y_0 = y_0 + m$$

draw (x_0, y_0)

}

}

*

* else {

while $(y_0 \leq y_1) \{$

$$x_0 = x_0 + (1/m)$$

$$y_0 = y_0 + 1$$

draw (x_0, y_0)

}