Learning Resources

Ebooks:

1)https://open.umn.edu/opentextbooks/textbooks/introduction-to-computer-graphics

2) http://www2.cs.uidaho.edu/~jeffery/courses/324/lecture.html#10

MOOC/Video lectures available at:

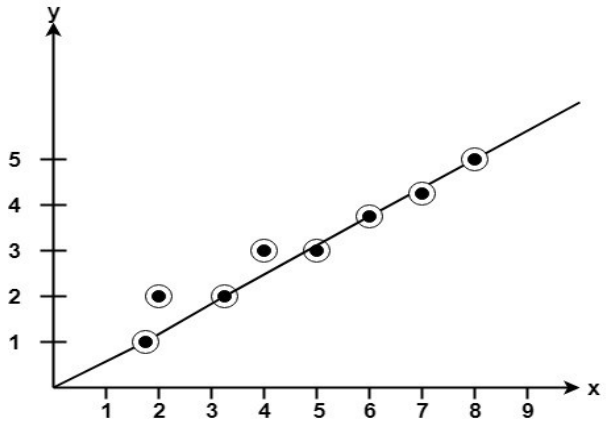
1)https://nptel.ac.in/courses/106/106/106106090/
2)https://nptel.ac.in/courses/106/102/106102065/

Line Drawing Algorithm

- What is Line
- Line Equation
- Slope of line
- Examples of Line Drawing
- DDA Algorithm

Line Drawing Algorithm

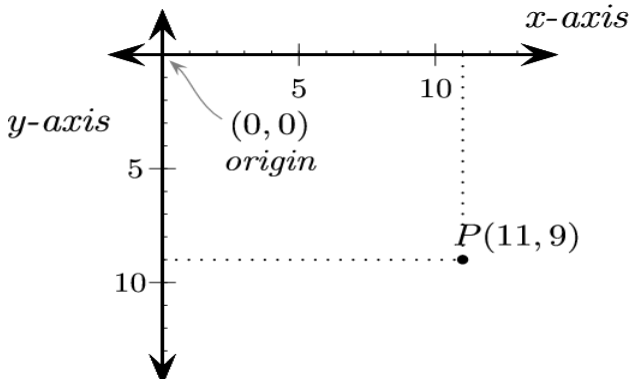
- Line in Computer graphics typically refers to line segment.
- It is defined by its two endpoints.
- In any 2-Dimensional plane if we connect two points (x0, y0) and (x1, y1), we get a line segment. But in the case of computer graphics we can not directly join any two coordinate points, for that we should calculate intermediate point's coordinate and put a pixel for each intermediate point,

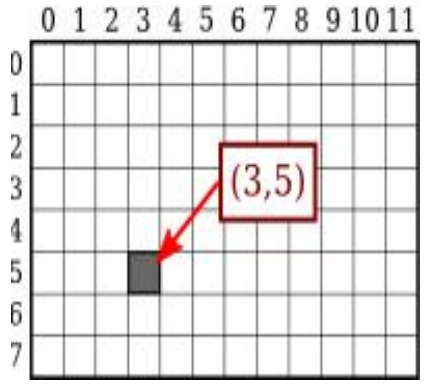


Line Drawing Algorithm

- Examples:
- **Input:** For line segment between (2, 2) and (6, 6) :
- we need (3, 3) (4, 4) and (5, 5) as our intermediate points.
- **Input:** For line segment between (0, 2) and (0, 6) :
- we need (0, 3) (0, 4) and (0, 5) as our Intermediate points.

- For using graphics functions, our system output screen is treated as a coordinate system where the coordinate of the top-left corner is (0, 0) and as we move down our y-ordinate increases and as we move right our x-ordinate increases for any point (x, y).





DDA Line Drawing Algorithm

- Now, for generating any line segment we need intermediate points and for calculating them we can use a basic algorithm called DDA(Digital differential analyzer) line generating algorithm.

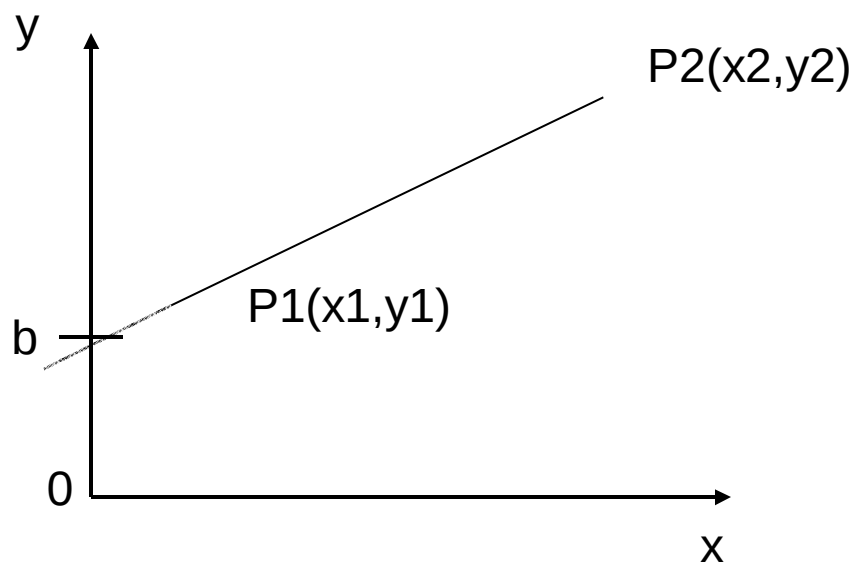
- DDA Line Drawing Algorithm is used for calculating pixels of plotting a line on computer screen.
- The slope intercept equation for a line:

$$y = mx + b$$

where, m = Slope of the line

b = the y intercept of a line

- The two endpoints of a line segment are specified at positions (x1,y1) and (x2,y2).


y
P2(x2,y2)
P1(x1,y1)
b
0
x

y = mx + b

m = slope

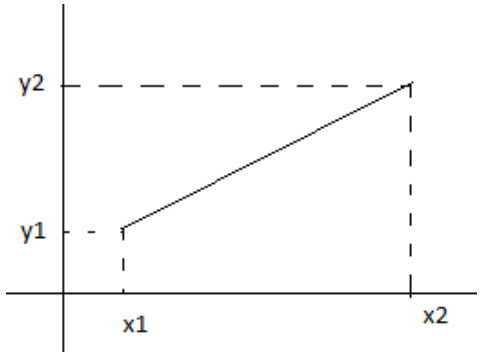
b = is the y intercept, is called as “slope intercept line Equation.”

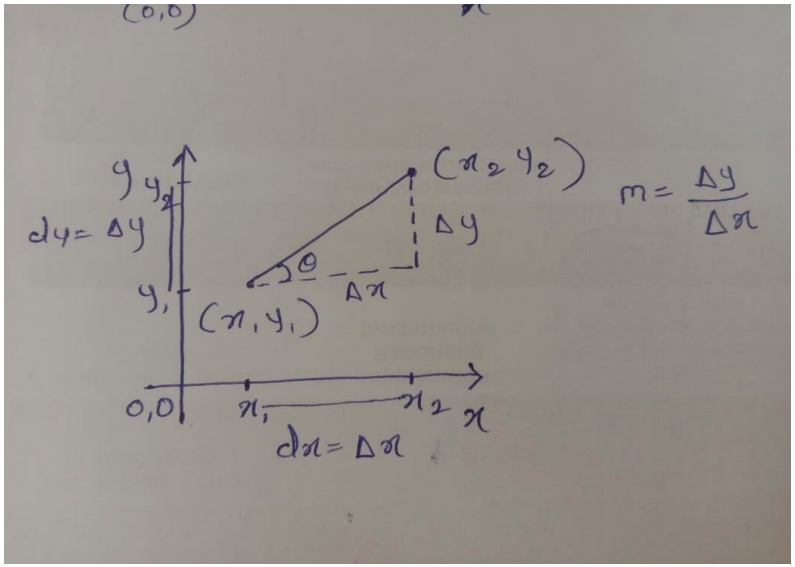
Therefore

Slope(m) = dy/dx

Slope(m) = y2 - y1 / x2 - x1 b=

y1 – m.x1 (y intercept)





DDA Algorithm

DDA is an incremental scan conversion method to determine points on a line.

It requires calculating the difference as Δx & Δy in x and y directions .

Thus , the values of x and y along the length of line, it is called rasterization.

The process of determining the appropriate pixel for representing, picture or graphics objects is known as rasterization.
Digital Differential Analyzer (DDA) routine for rasterizing a line.

Types of Slope

1)Gentle Slope:(m<1)

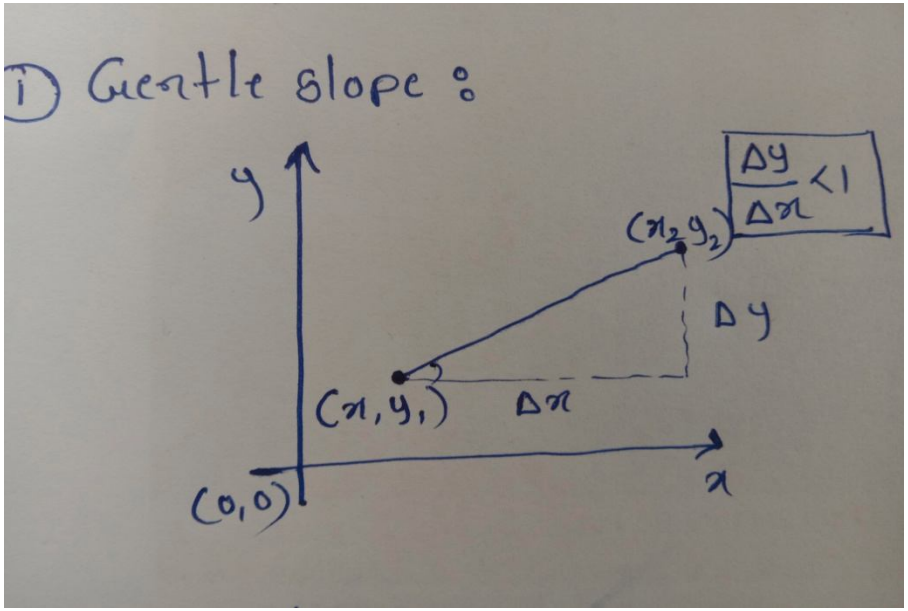
The lines which are closer to horizontal lines are the lines having Gentle slope

There are more columns than rows means Δx=(x2-x1) is longer than Δy=(y2-y1)

Δx>Δy

Δy/Δx<1

Means Θ<45˚



Slope of line

2)Sharp Slope:(m>1)

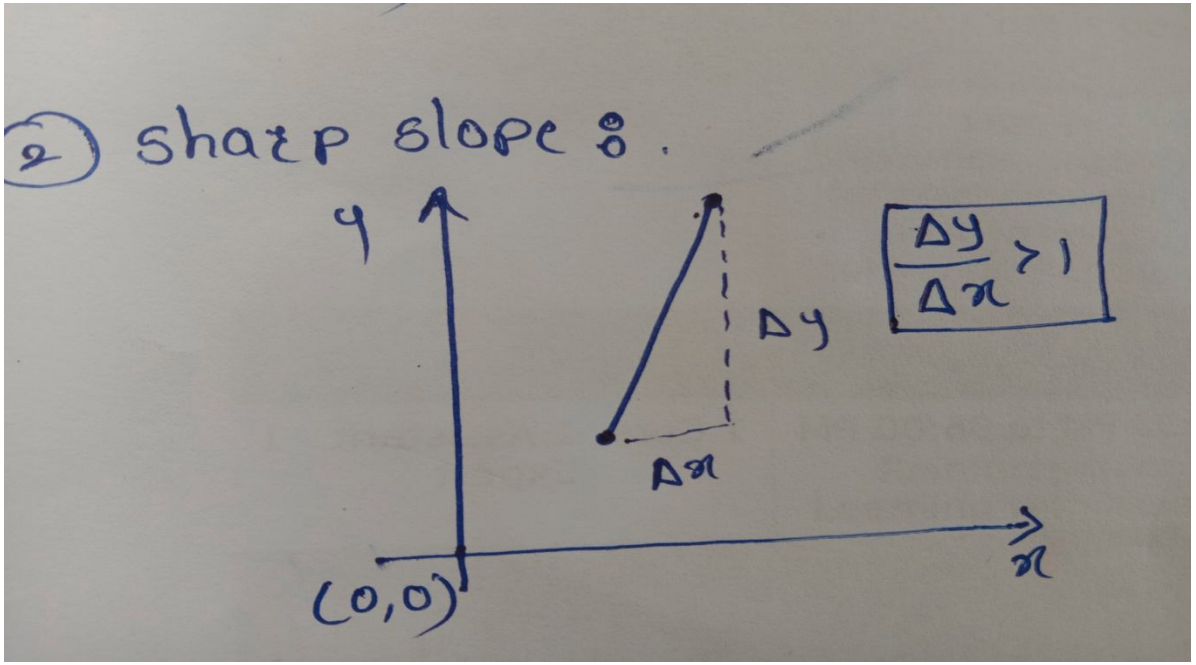
The lines which are closer to vertical lines are the lines having Sharp slope.

There are more rows than columns means Δy=(y2-y1) is longer than Δx=(x2-x1)

Δy>Δx

Δy/Δx>1

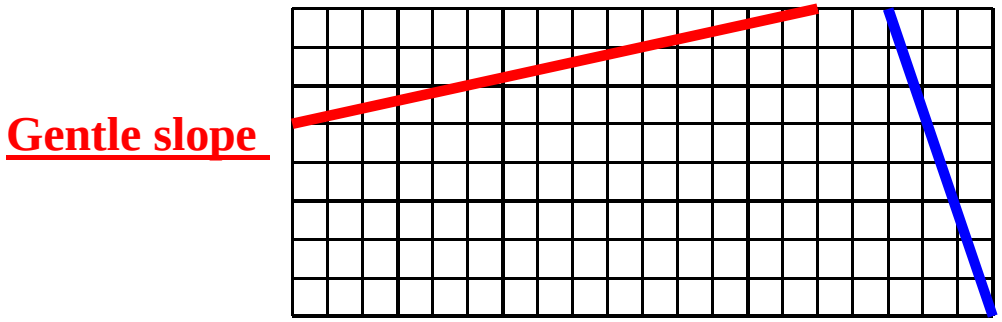
Means Θ>45°



Types of Slopes :

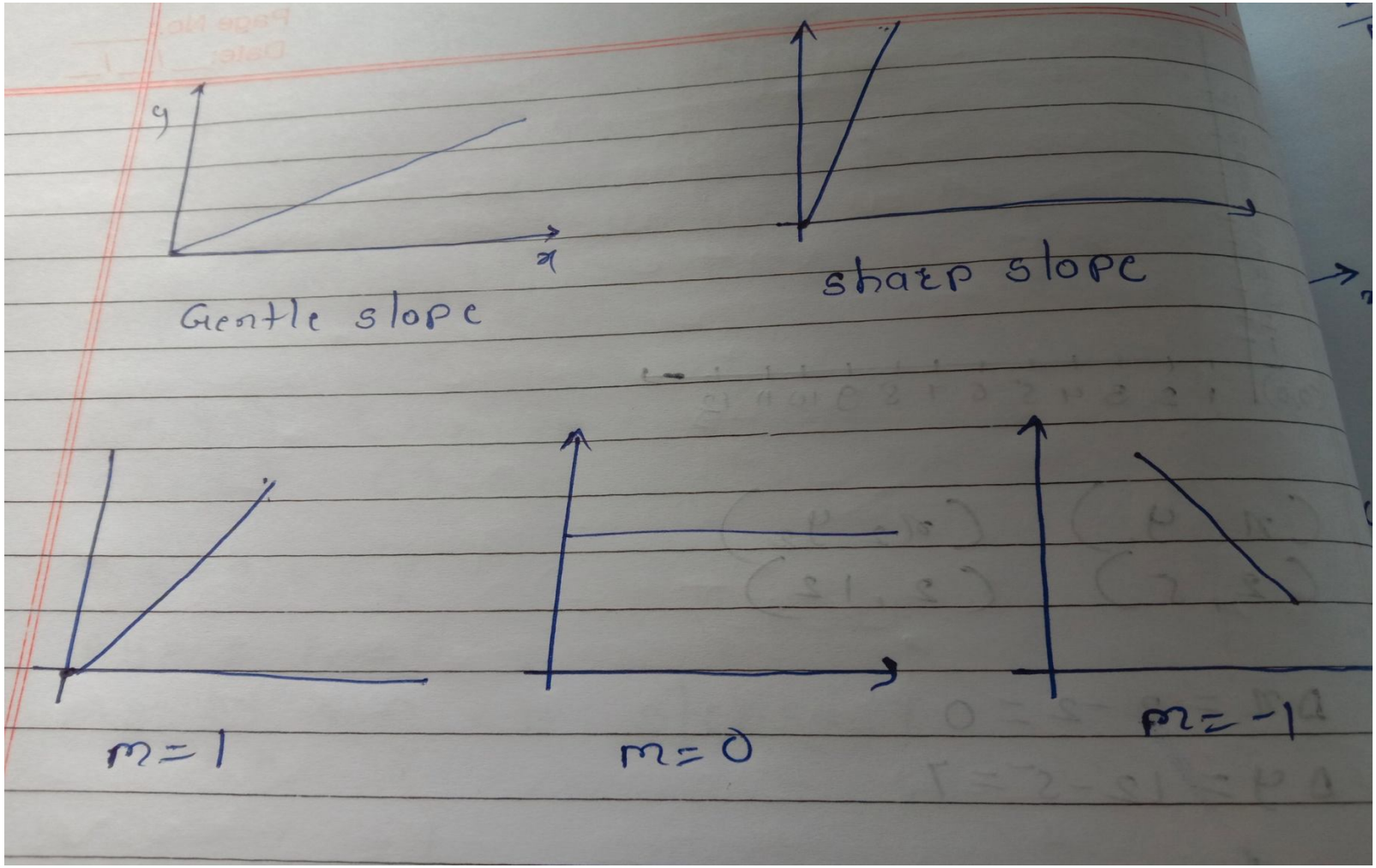
Gentle slope :- The lines which are closer to horizontal lines are the lines having Gentle slope. For gentle slope (-1<m<1) there are more columns than rows(abs(dx)>abs(dy)) .

Sharp slope: The lines which are closer to vertical lines are the lines having Sharp slope. For sharp slope there are more rows than column(abs(dy)>abs(dx)).



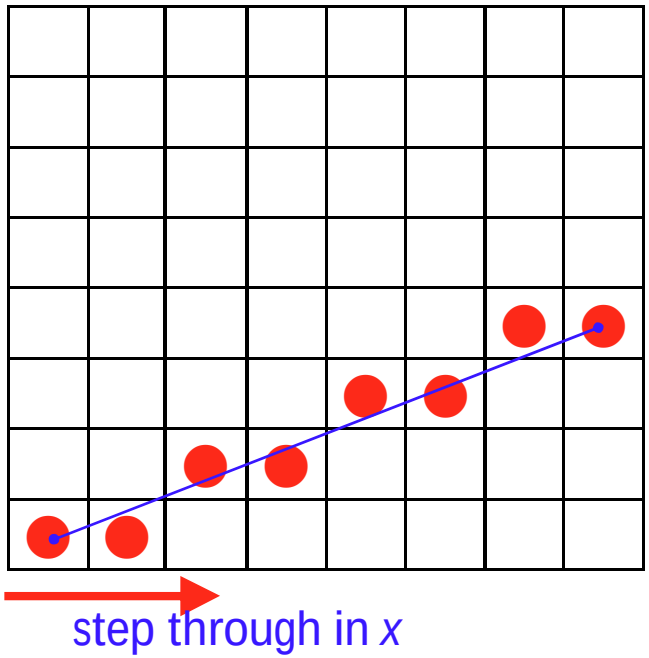
In DDA, we either step across X-Direction and solve for Y (In case of gentle slope)
or we step Y-Direction and solve for X (incase of sharp slope).

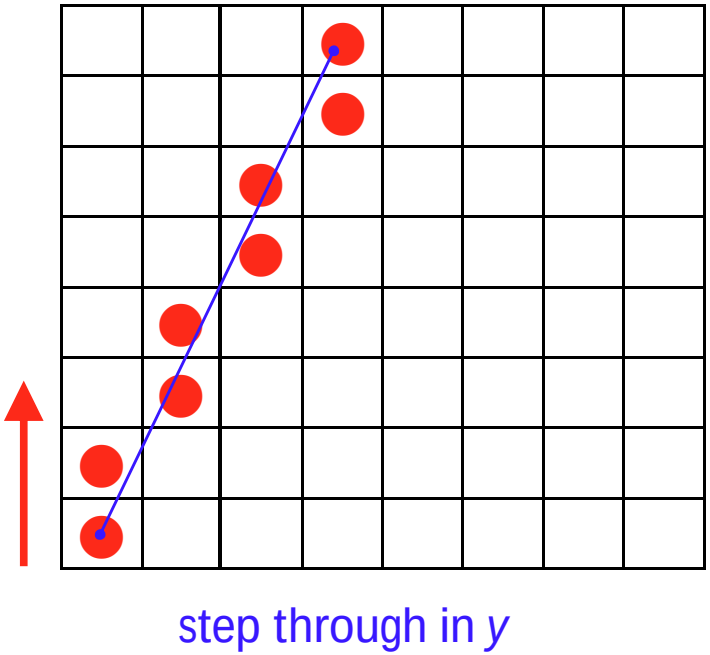
Slope Examples



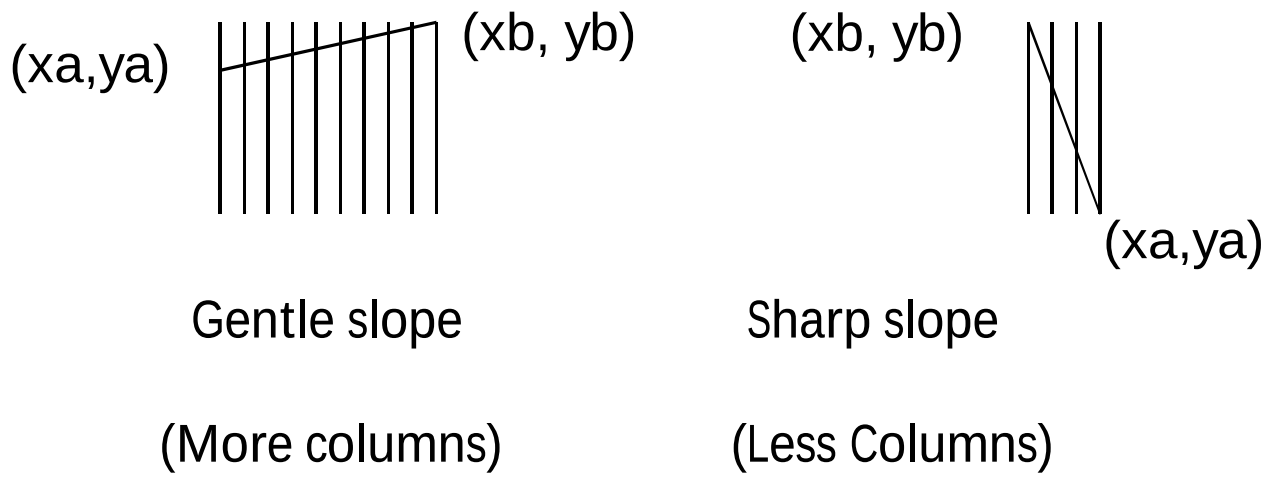
The DDA Method

- Uses differential equation of the line : *m*
- If slope $|m| \leq 1$ then increment *x* in steps of 1 pixel and find corresponding *y*-values.
- If slope $|m| > 1$ then increment *y* in steps of 1 pixel and find corresponding *x*-values.





DDA



If (Xa,Ya) and (Xb,Yb) are two end points then we define

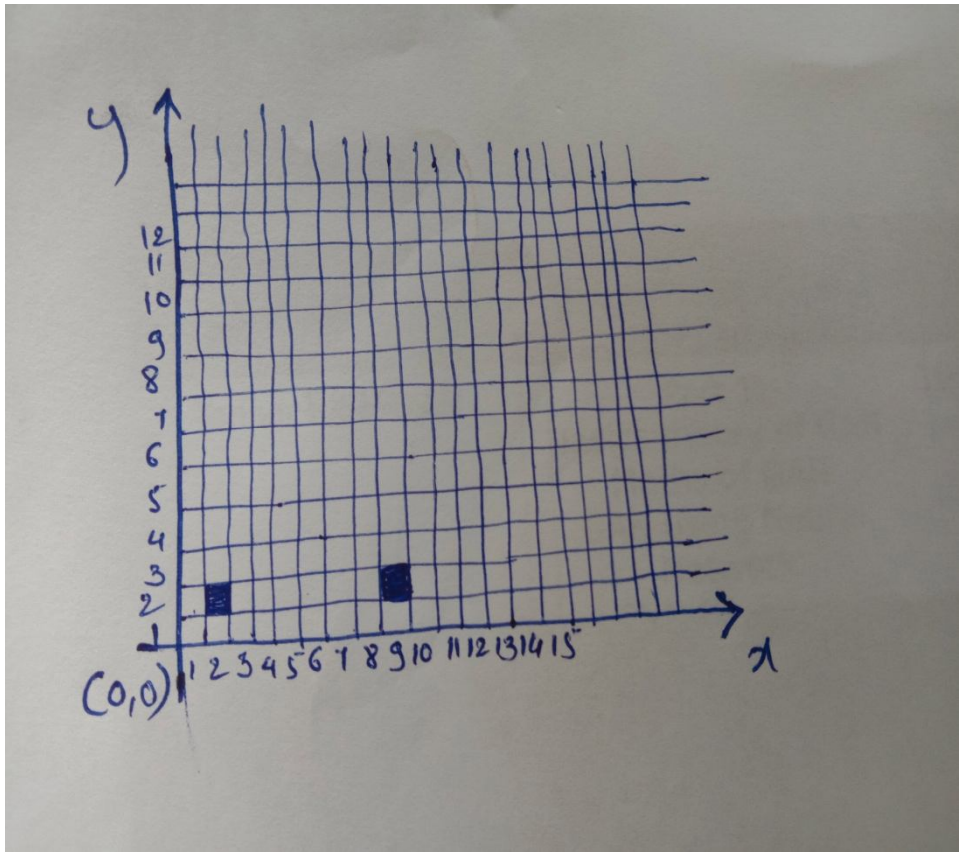
Dx = Xb –Xa and Dy = Yb – Ya

So if abs(Dx) > abs (Dy) then it is called as gentle slope else it is called as sharp slope.

Line Drawing Example

Example1:
(x1,y1) (x2,y2)
(2,2) (9,2)
Δx=9-2=7
Δy=2-2=0
m=Δy/Δx=0/7=0
steps=7
Xinc=7/7=1 Yinc=0/7=0

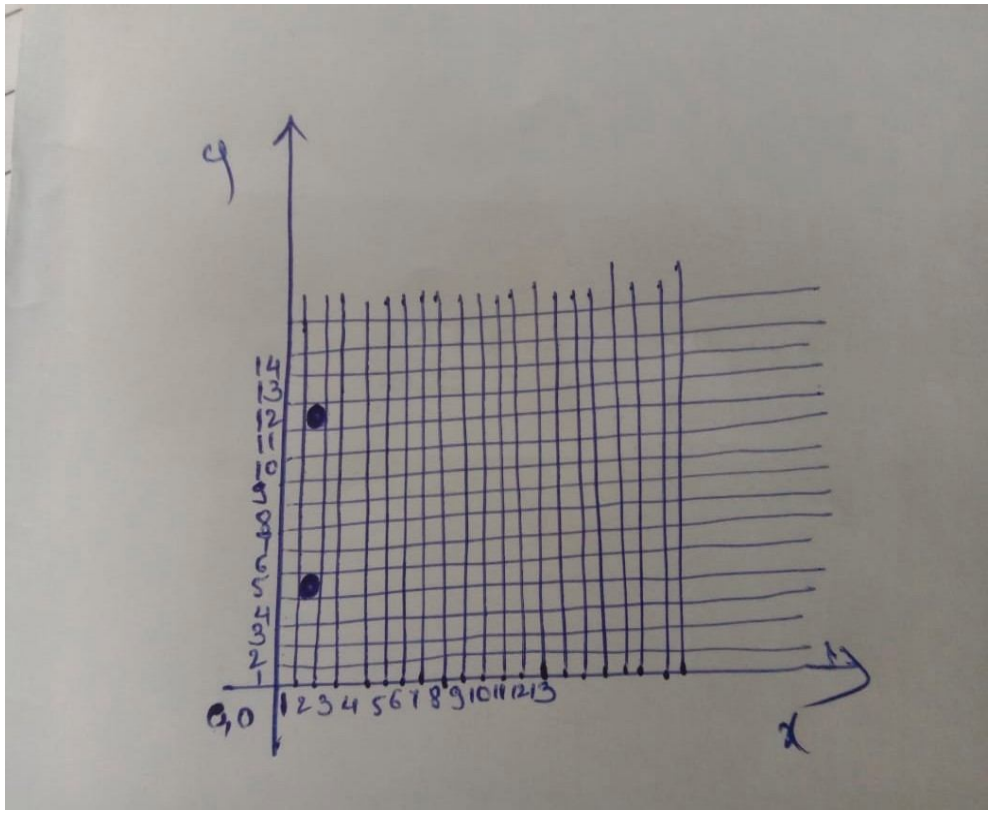
X	Y
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2



Line Drawing Example

Example2:
(x1,y1) (x2,y2)
(2,5) (2,12)
Δx=2-2=0
Δy=12-5=7
m=Δy/Δx=7/0=∞
steps=7
Xinc=0/7=0 Yinc=7/7=1

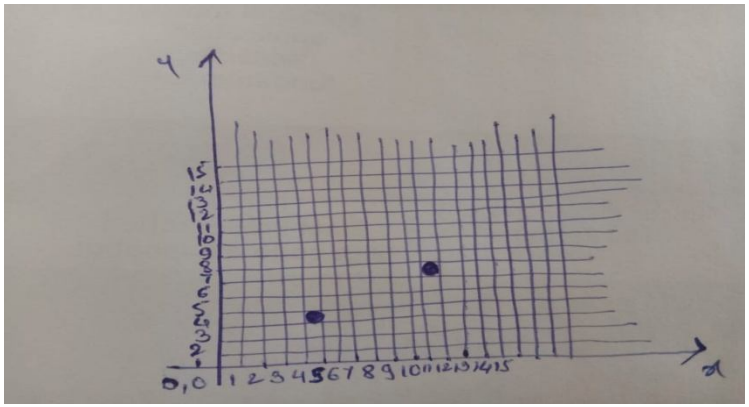
X	Y
2	5
2	6
2	7
2	8
2	9
2	10
2	11
2	12

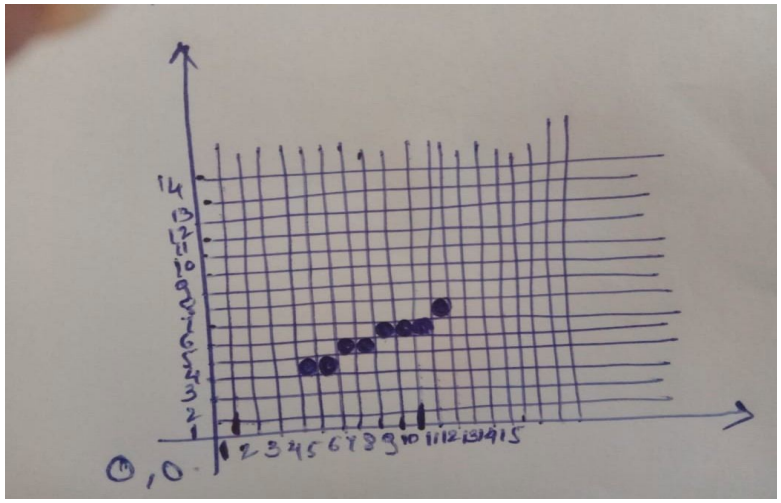


Line Drawing Example

Example3: (m<1)
(x1,y1) (x2,y2)
(5,4) (12,7)
Δx=12-5=7
Δy=7-4=3
m=Δy/Δx=3/7
steps=7
Xinc=7/7=1 Yinc=3/7=0.4

X	Y	
5	4	4
6	4.4	4
7	4.8	5
8	5.2	5
9	5.6	6
10	6	6
11	6.4	6
12	6.8	7





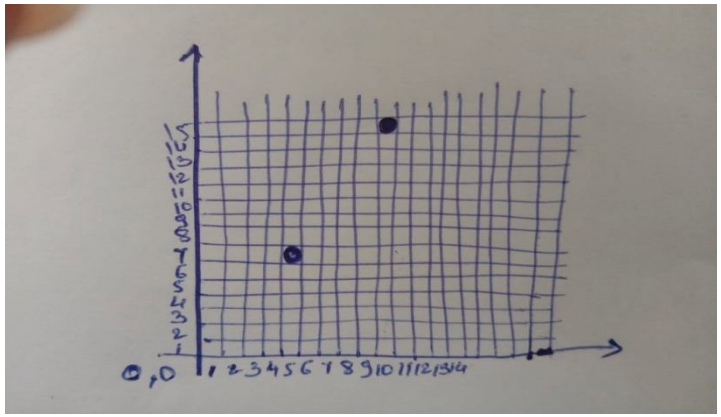
X_{p+1} will move in unit intervals i.e. $x_{p+1} = x_p + 1$

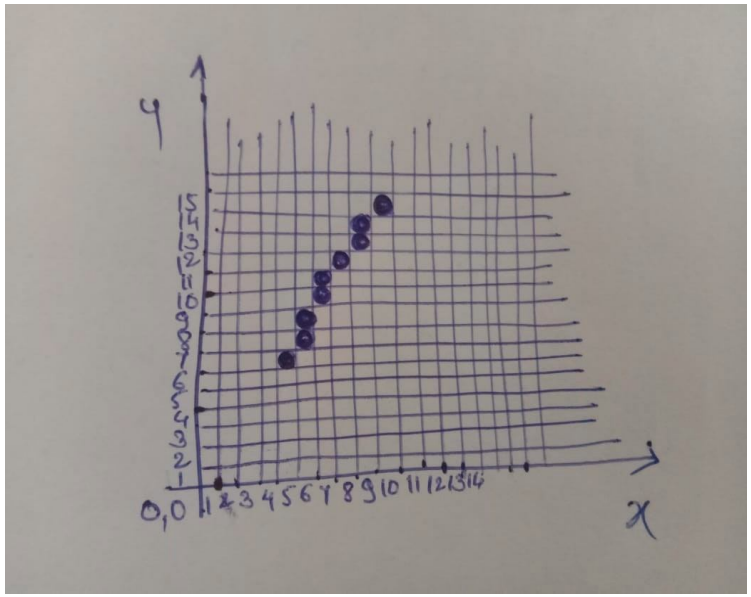
$m = (y_{p+1}-y_p)/(x_{p+1}-x_p)$ which gives $y_{p+1} = m + y_p$

Line Drawing Example

Example4: (m>1)
(x1,y1) (x2,y2)
(5,7) (10,15)
Δx=10-5=5
Δy=15-7=8
m=Δy/Δx=8/5
steps=8
Xinc=5/8=0.6 Yinc=8/8=1

	X	Y
5	5	7
6	5.6	8
6	6.2	9
7	6.8	10
7	7.4	11
8	8	12
9	8.6	13
9	9.2	14
10	9.8	15





Y_{p+1} will move in unit intervals i.e. $y_{p+1} = y_p + 1$

$m = (y_{p+1}-y_p)/(x_{p+1}-x_p)$ which gives $x_{p+1} = (1/m) + x_{kp}$

Line Drawing Example

Example4: (m=1)
(x1,y1) (x2,y2)
(12,9) (17,14)
Δx=17-12=5
Δy=14-9=5
m=Δy/Δx=5/5=1
steps=5
Xinc=5/5=1 Yinc=5/5=1

X	Y
12	9
13	10
14	11
15	12
16	13
17	14

X_{p+1} will move in unit intervals i.e. $x_{p+1} = x_p + 1$

Y_{p+1} will move in unit intervals i.e. $y_{p+1} = y_p + 1$

Procedure-

Given-
Starting coordinates = (X_0, Y_0)
Ending coordinates = (X_n, Y_n)
The points generation using DDA Algorithm involves the following steps-

Step-01:

Calculate ΔX, ΔY and M from the given input.
These parameters are calculated as-
$\Delta X = X_n - X_0$
$\Delta Y = Y_n - Y_0$
$M = \Delta Y / \Delta X$

Procedure-

Step-02:

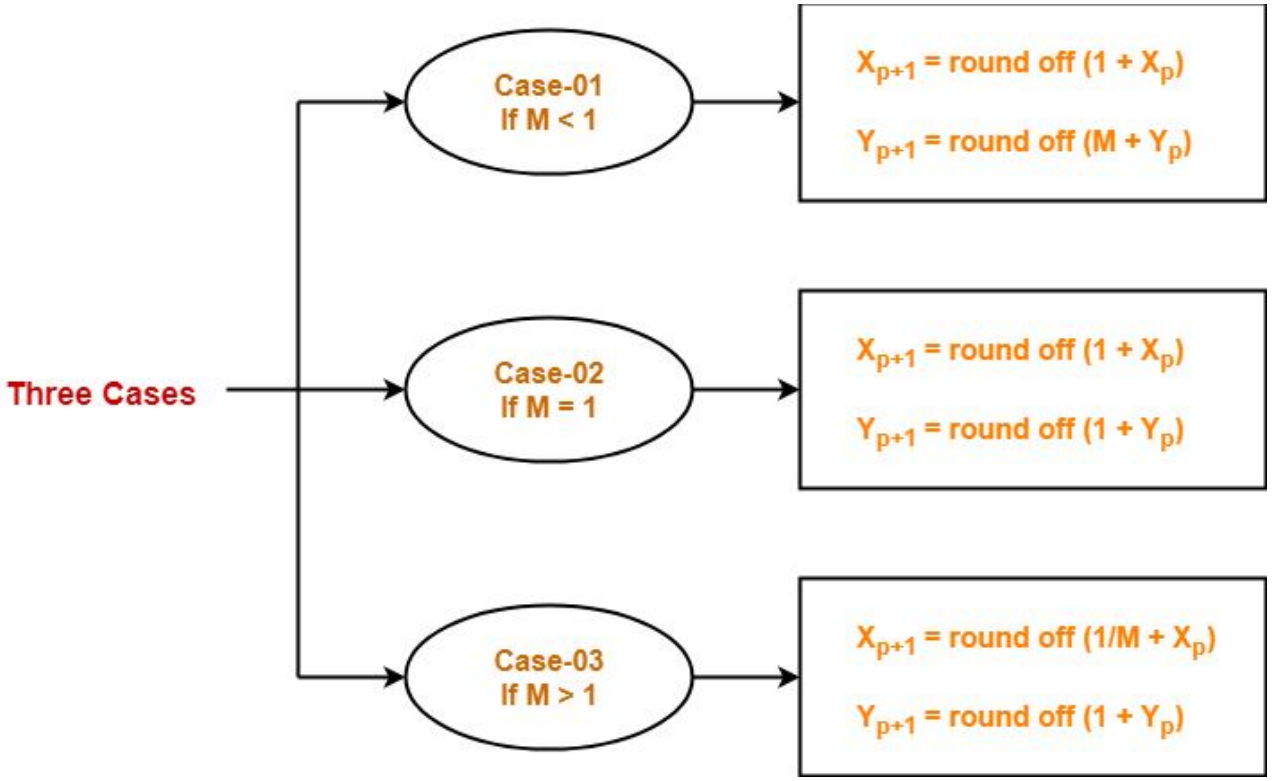
Find the number of steps or points in between the starting and ending coordinates.

if (absolute (ΔX) > absolute (ΔY))
Steps = absolute (ΔX);
else
Steps = absolute (ΔY);

Step-03:

Suppose the current point is (X_p, Y_p) and the next point is (X_{p+1}, Y_{p+1}).
Find the next point by following the below three cases-

Procedure-



Step-04:

Keep repeating Step-03 until the end point is reached or the number of generated new points (including the starting and ending points) equals to the steps count.

Problem-01:

Calculate the points between the starting point (5, 6) and ending point (8, 12).

Solution-

Given-
Starting coordinates = $(X_0, Y_0) = (5, 6)$
Ending coordinates = $(X_n, Y_n) = (8, 12)$

Step-01:

Calculate ΔX, ΔY and M from the given input.

$\Delta X = X_n - X_0 = 8 - 5 = 3$
$\Delta Y = Y_n - Y_0 = 12 - 6 = 6$
$M = \Delta Y / \Delta X = 6 / 3 = 2$

Step-02:

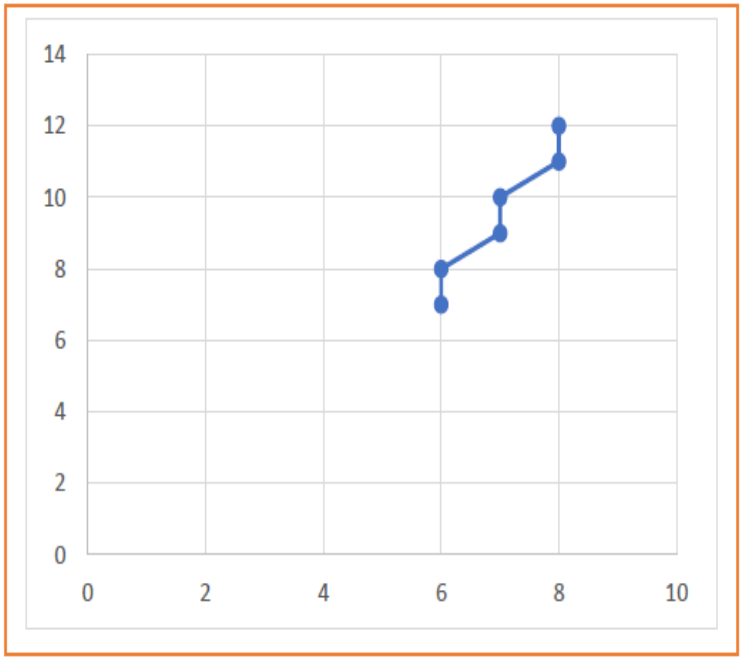
Calculate the number of steps.

As $|\Delta X| < |\Delta Y| = 3 < 6$, so number of steps = $\Delta Y = 6$

Step-03:

As M > 1, so case-03 is satisfied.
Now, Step-03 is executed until Step-04 is satisfied.

X_p	Y_p	X_{p+1}	Y_{p+1}	Round off (X_{p+1}, Y_{p+1})
5	6	5.5	7	(6, 7)
		6	8	(6, 8)
		6.5	9	(7, 9)
		7	10	(7, 10)
		7.5	11	(8, 11)
		8	12	(8, 12)



Problem-02:

Calculate the points between the starting point (5, 6) and ending point (13, 10).

Solution-

Given-
Starting coordinates = $(X_0, Y_0) = (5, 6)$
Ending coordinates = $(X_n, Y_n) = (13, 10)$

Step-01:

Calculate ΔX, ΔY and M from the given input.
$\Delta X = X_n - X_0 = 13 - 5 = 8$
$\Delta Y = Y_n - Y_0 = 10 - 6 = 4$
$M = \Delta Y / \Delta X = 4 / 8 = 0.50$

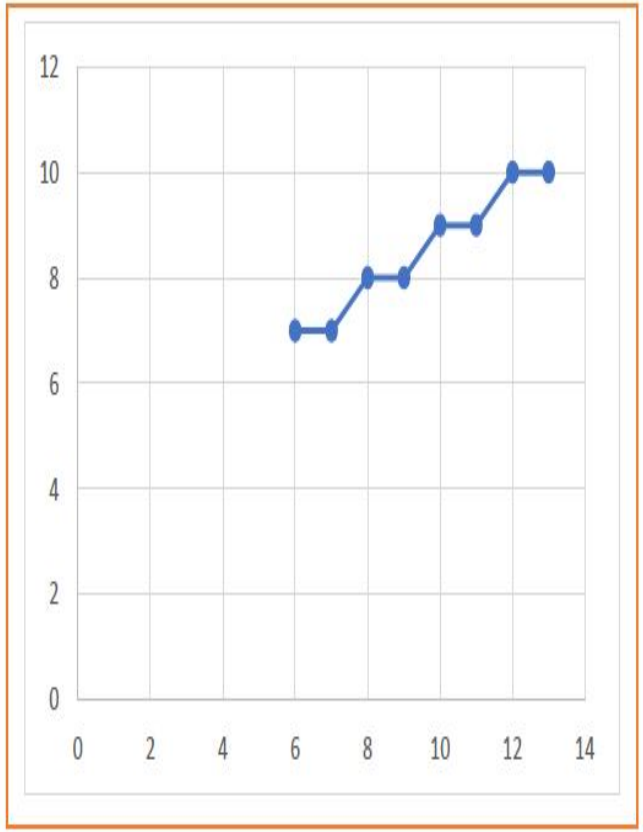
Step-02:

Calculate the number of steps.
As $|\Delta X| > |\Delta Y| = 8 > 4$, so number of steps = $\Delta X = 8$

Step-03:

As $M < 1$, so case-01 is satisfied.
Now, Step-03 is executed until Step-04 is satisfied.

X_p	Y_p	X_{p+1}	Y_{p+1}	Round off (X_{p+1}, Y_{p+1})
5	6	6	6.5	(6, 7)
		7	7	(7, 7)
		8	7.5	(8, 8)
		9	8	(9, 8)
		10	8.5	(10, 9)
		11	9	(11, 9)
		12	9.5	(12, 10)
		13	10	(13, 10)



Problem-03:

Calculate the points between the starting point (1, 7) and ending point (11, 17).

Solution-

Given-

Starting coordinates = $(X_0, Y_0) = (1, 7)$

Ending coordinates = $(X_n, Y_n) = (11, 17)$

Step-01:

Calculate ΔX, ΔY and M from the given input.

$\Delta X = X_n - X_0 = 11 - 1 = 10$

$\Delta Y = Y_n - Y_0 = 17 - 7 = 10$

$M = \Delta Y / \Delta X = 10 / 10 = 1$

Step-02:

Calculate the number of steps.

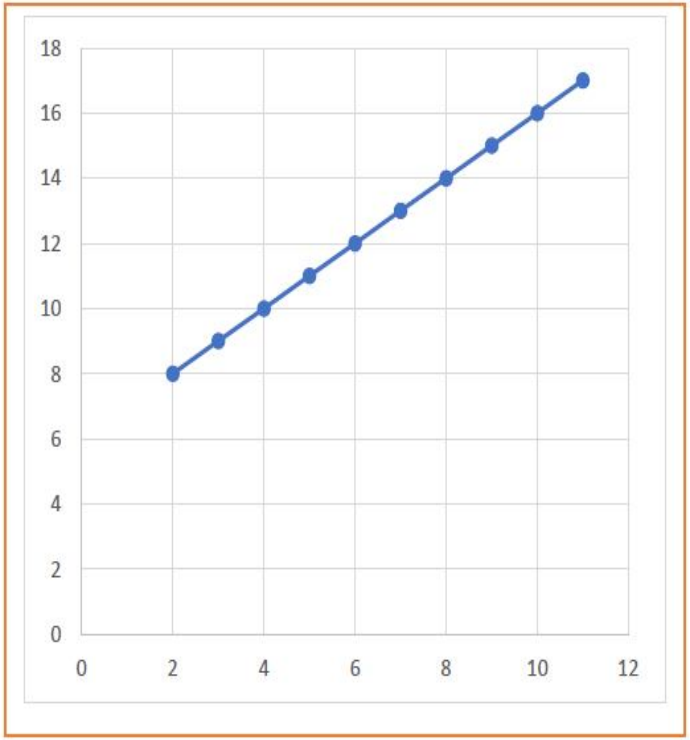
As |ΔX| = |ΔY| = 10 = 10, so number of steps = ΔX = ΔY = 10

Step-03:

As M = 1, so case-02 is satisfied.

Now, Step-03 is executed until Step-04 is satisfied.

X_p	Y_p	X_{p+1}	Y_{p+1}	Round off (X_{p+1}, Y_{p+1})
1	7	2	8	(2, 8)
		3	9	(3, 9)
		4	10	(4, 10)
		5	11	(5, 11)
		6	12	(6, 12)
		7	13	(7, 13)
		8	14	(8, 14)
		9	15	(9, 15)
		10	16	(10, 16)
		11	17	(11, 17)



DDA Algorithm
Digital Differential Analyzer

Step 1 − Get the input of two end points (X0,Y0) and (X1,Y1).

Step 2 − Calculate the difference between two end points.

```
dx = X1 - X0
 dy = Y1 - Y0
```

Step 3 − Based on the calculated difference in step-2, you need to identify the number of steps to put pixel. If dx > dy, then you need more steps in x coordinate; otherwise in y coordinate.

```
if (absolute(dx) > absolute(dy))
        Steps = absolute(dx);
else
        Steps = absolute(dy);
```

Step 4 − Calculate the increment in x coordinate and y coordinate.

```
Xincrement = dx / steps;
Yincrement = dy / steps;
```

Step 5 − Put the pixel by successfully incrementing x and y coordinates accordingly and complete the drawing of the line.

```
for(int v=0; v < Steps; v++)
 {
        x = x + Xincrement;
        y = y + Yincrement;
        putpixel(Round(x), Round(y));
}
```

Advantages of DDA Algorithm-

The advantages of DDA Algorithm are-

•It is a simple algorithm.

•It is an easy method because each step involves just two additions.

•It avoids using the multiplication operation which is costly in terms of time complexity.

Disadvantages of DDA Algorithm-

The disadvantages of DDA Algorithm are-

•There is an extra overhead of using round off( ) function.

•Using round off( ) function increases time complexity of the algorithm.

•Resulted lines are not smooth because of round off( ) function.

•The points generated by this algorithm are not accurate.

DDA Quiz

https://forms.gle/uebLcexqQJRP38mK7