1) Routing

2) Logical Addressing (IP Address)

ARP & RARP → Reverse address resolution protocol

↓

Address resolution protocol

MAC address ~~Both~~ IP address are unique and are present for every host individually and uniquely.

→ Host ID different, network ID same like colony same, house address different.

→ IP address consists of 2 parts → Host ID & network ID.

11/1/18

Transport Layer (Process to process delivery)

→ responsible for process to process delivery.

1) → Port Addressing

2) → Segmentation and reassembly

Sender → divides msg into packets → sequence no is added to packets.

$\boxed{1}$ 0 1 0 1 1 1 0 1 $\boxed{2}$ 1 0 1 0 1 1 1 0

sequence no.

Receiver end → reassembly

removes seq no & retrieves the data and joins accordingly.

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3 — Connection control

It decides whether it should be connection less or connection oriented.
(UDP) (TCP)

4 — Flow Control

(End-to-end) flow control in transport layer is responsible for flow control in all the intermediary nodes as well.

5 — Error control

end-to-end

Flow control in data link layer is internal & in transport layer is end-to-end.

Application layer (User support layer)

→ user interacts directly to this layer.

SERVICES
→ provides services to the user.
→ Mail service
→ file transfer service
→ remote login
→ accessing World Wide Web.

→ session + presentation layer job is done by Application layer

II OSI - Model (7 layers) { + Session + Presentation layer }

→ It is a theoretical model. TCP/IP is the implemented model.

ISO - OSI Model (also called)
→ International standard organisation - open system inter connect Model.

Session layer

~~used to maintain~~
- Network dialog control
- It is used to establish, maintain and synchronize interaction b/w communicating systems.

Presentation layer

- syntax and semantics of information / data sent among systems.
- Encryption and Decryption → receiver end
used for security, original msg is converted to some form not readable by anyone else.
sender end
- Compression
(some folders for eg can't be sent as it is and we compress it)

→ OSI - Model ? → explain 7 layers
→ TCP / IP Model ? → explain 5 layers
+ protocol & networking device used at each layer.

* TCP / IP protocol suite

Protocols used	Layer	Devices used
HTTP, SMTP, FTP, TELNET	Application layer	Gateway
TCP, UDP (User Datagram Protocol)	Transport layer	Gateway
IP, ICMP (Internet Control msg Protocol)	Network layer	Router, switch (layer-3 switch)
	Data link layer	Hub, Bridge, Switch (layer-2 switch)
	Physical layer	Repeater

Session + presentation layer generally doesn't use any device, protocols.

Assignment questions

Q1 Write short note on SNA, AppleTalk and Netware.

Q2 Differentiate between connection less and connection oriented.

Q3 Explain wired transmission media and wireless transmission media in detail.

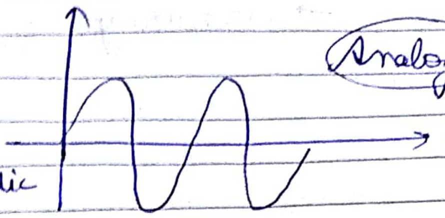
Q4 Explain network topologies.

Submit by :- Next ~~Thursday~~ Friday (19/1/18)

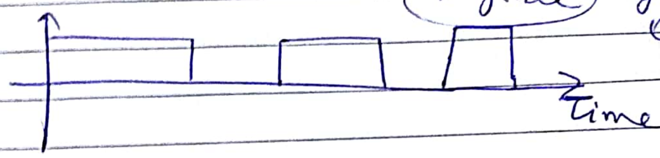
X —— (Unit - 1 completed) —— X

Unit-2 Physical Layer

SIGNALS
- Analog
  - Periodic
  - Aperiodic
- Digital
  - Periodic
  - Aperiodic



Analog → infinite no. of values in a range



Digital → generally 0 or 1

Periodic — have a particular pattern in a particular span of time / measurable time frame where 1 pattern completes → cycle (completion of 1 full pattern)

Aperiodic — no pattern, changes without executing / exhibiting a pattern or cycle that changes over time

In Data communication, we use →
Periodic Analog signals & Aperiodic Digital Signals.

Analog signals → simple
→ composite

Simple
→ consists of a single sine wave

Composite
→ multiple sine waves.

Characteristics → Amplitude
→ Phase
→ Frequency

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COMPUTER GRAPHICS

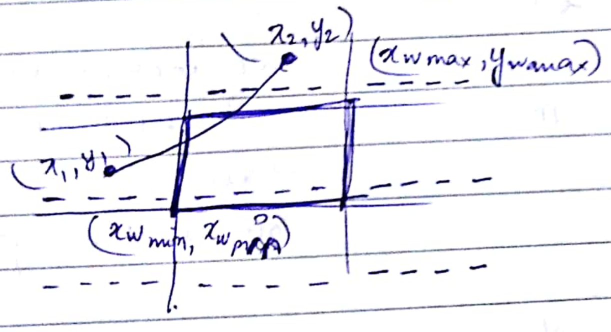
Screen (2D) — pixel → element, → picture

Resolution

1. drawing → primitive → mathematical equation knowledge
   - → line
   - circle
   - ellipse
   - parabola
   - hyperbola
2. manipulation
   - → clipping — line, polygon
3. colouring

9 areas so 4 bit address

Left	0001
Bottom	0010
Right	0100
top	1000

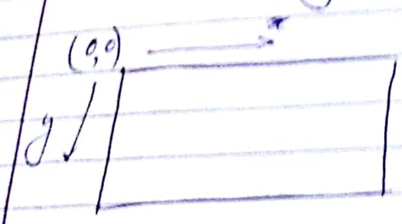


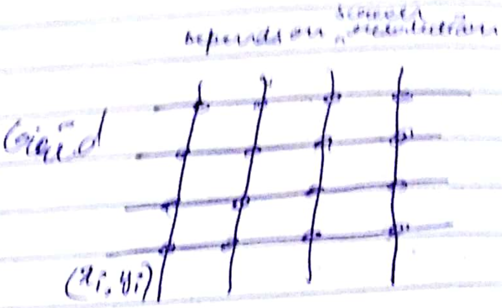

```
areaForCoor (x, y) { (x, y, xw_min, yw_min, xw_max, yw_max)
int temp = 0;
    if (x > xw_max)
        temp = temp | (1 << 2);
    else if (x < xw_min)
        temp = temp | (1);

    if (y > yw_max)
        temp = temp | (1 << 3);
    else if (y < yw_min)
        temp = temp | (1 << 1);
return temp
```

Line

$y = mx + C$





$y_i = mx_i + C$

x	10	. . .
y	10	

$y = mx + c$

lets say $m < 1$

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

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

we increment x & not y as $\tan\theta < 1 \Rightarrow \Delta x > \Delta y$ so more precise

```
x = x1   y = y1
dx = x2 - x1     dy = y2 - y1

if  abs(dy) < abs(dx) {
      putpixel(x, y, WHITE);
      while (x <= x2)
      {
         y + = m
         x++;
         putpixel(x, y, WHITE);
      }
}
```

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$y = mx + c$
$x = \frac{1}{m}y - \frac{c}{m}$

if $m > 1$

$y_{i+1} = y_i + 1$ $\quad x_{i+1} = x_i + \frac{1}{m}$

$x = x_1$ $\quad y = y_1$

```
if abs(dy) > abs(dx){
    putpixel(x, y, WHITE)
    while (y <= y2) {
        y += 1
        x += 1/m
        putpixel(x, y, WHITE)
    }
```

// here floating part ⟶

Floating part calculation takes a lot of time

⟹ instead ⟹

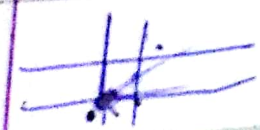
```
while (x <= x2){
    x++
    y += (float) dy/dx
    putpixel(x, round(y), WHITE);
}
```

round ⟶

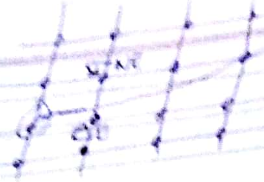
```
int round(float p){
    if (p - (int)p < 0.5)
        return p
    ~~else~~ return p+1
}
```

$$f(x, y) = ax + by + c \quad \begin{matrix} = 0 \\ < 0 \\ > 0 \end{matrix}$$

$$f(M) = f\left(x_i + 1, y_i + \tfrac{1}{2}\right) = a(x_i + 1) + b\left(y_i + \tfrac{1}{2}\right) +$$



d is the [illegible] of $ax + by + c$



if $d < 0$

selection E

$$d_{new} = f(M_E) = f(x_i + 2, y_i + \tfrac{1}{2})$$

$$= a(x_i + 2) + b(y_i + \tfrac{1}{2}) + c$$

(2) For a primitive drawing, note change

$$\Delta E = d_{new} - d$$

$$= a$$

$$= dy$$

$$y = mx + c$$

$$dx\,y = dy\,x + c\,dx$$

$$\cancel{dy\,x = dx\,y + c\,dx} \quad \Rightarrow a = dy$$

$$ax + by + c$$

$$dy\,x - dx\,y + c\,dx = 0$$

if $d \geq 0$

selection NE

$$f(M_E) = f(x_i + 2, y_i + \tfrac{3}{2})$$

$$= a(x_i + 2) + b(y_i + \tfrac{3}{2}) + c$$

$$\Delta NE = a + b$$

$$= dy - dx$$

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$$d = f(M) = f(x_i+1, y_i+\tfrac{1}{2})$$
$$= a(x_i+1) + b(y_i+\tfrac{1}{2}) + c$$
$$= ax_i + by_i + c + a + b/2$$
$$= a + \frac{b}{2}$$

as $ax_i + by_i + c = 0$ since x_i, y_i are ~~algo~~ already on line.

→ $b/2$ ~~dx~~ is floating line part

→ we can multiply the whole by 2
as $y = mx + c \equiv 2y = 2mx + 2c$

$$d = 2a + b$$

$$f(x, y) = 2(ax + by + c)$$

$$\Delta E = 2dy$$
$$\Delta NE = 2(dy - dx)$$

$x = x_1$ $y = y_1$ $dx = x_2 - x_1$ $dy = y_2 - y_1$

$$d = 2(dy) - dx$$

```
putpixel (x, y, white)
while ( x <= x2){
    if (d < 0 ){          //selection E
        d += 2*dy
    }
    else
    {
        d += 2(dy - dx)
        y++;
    }
    x++;
    putpixel (x,y, WHITE);
}
```

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dry run

	x_1	y_1	x_2	y_2
	10	10	20	18

$dx = 10$ $dy = 8$

$x_{initial} = 10$ $y_{initial} = 10$

$d_{initial} = 2dy - dx$

x_i	y_i	d
10	10	6
11	11	2
12	12	-2
13	12	14
14	13	10
15	14	6
16	15	2
17	16	-2
18	16	18
19	17	14
20	18	10

x_1	y_1	x_2	y_2
10	10	18	20

$dx = 8$ $dy = 10$

~~$d_{initial} = 20 - 8 = 12$~~

x_i	y_i	d
10	10	12
11	11	16
12	12	20
13	13	22
14	14	24
15	15	26
16	16	28
		29

$a(x_i+2) + b(y_i + 1/2) + c$

$ax_i + by_i + c + 2a + b/2$

$= 4a + b$

$40 - 8 = 32$

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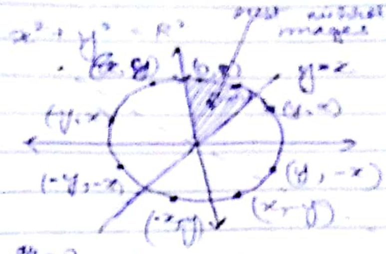
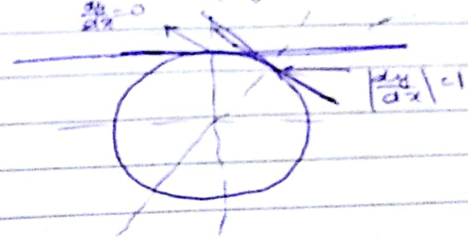
Scan conversion

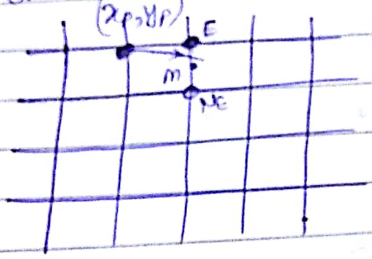
primitive — circle



void circleSymmetry(x,y)
putpixel(x, y, WHITE)
putpixel(y, x, WHITE)
:



major movement in x dirn



At (x_p, y_p) $\quad f(x_p, y_p) = x_p^2 + y_p^2 - R^2$ — ①

For decision consideration

$$d = f(M) = f(x_p+1, y_p - 1/2)$$

$$= (x_p+1)^2 + (y_p - 1/2)^2 - R^2 \quad \text{— ②}$$

If $d < 0$

selection → E

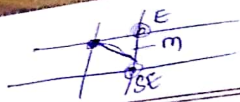
$$d_{new} = f(M_E) = f(x_p+2, y_p - 1/2)$$

$$= (x_p+2)^2 + (y_p - 1/2)^2 - R^2 \quad \text{— ③}$$

$$\Delta E = d_{new} - d \qquad ③ - ②$$

$$= (2x_p + 3)$$

$$\boxed{\Delta E = 2x_p + 3}$$



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else selection (SE)

$$d_{new} = f(m_{SE})$$

$$= f(x_p+2,\ y_p - 3/2).$$

$$= (x_p+2)^2 + \left(y_p - \frac{3}{2}\right)^2 - R^2 \quad \text{—— (4)}$$

$$\Delta SE = (4) - (2) = d_{new} - d$$

$$= (2x_p+3) + (2y_p - 2)(-1)$$

$$= 2x_p - 2y_p + 5$$

$$\boxed{\Delta SE = 2(x_p - y_p) + 5}$$

Initialisation

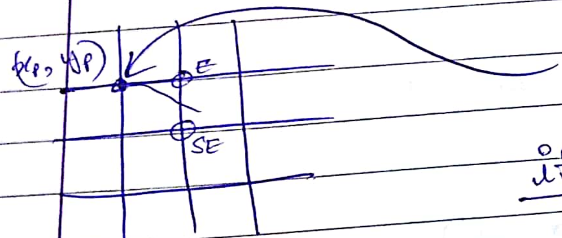
$$d_{initial} \longrightarrow d_{(0,R)} = \frac{5}{4} - R \approx 1 - R$$

```
x = 0; y = R
d = 1-R
circle symmetry (x,y)

  while (x <= y) {
      if d < 0                 // selection E
            d += 2*x + 3
      else {
            d += 2*(x - y) + 5
            y--;
      }
      x++;
      circle symmetry (x,y);
}
```

Eg $R = 8$

x	y	d
0	8	-7
1	8	-4
2	8	1
3	7	-6
4	7	3
5	6	2
6	5	5



$$\left.\begin{aligned}\Delta E &= 2x_p + 3 \\ \Delta SE &= 2(x_p - y_p) + 5\end{aligned}\right\} \rightarrow (1)$$

if $d < 0$ then

// selection (E)

$$\left.\begin{aligned}&\text{At } (E) \rightarrow [x_p + 1, y_p] \\ &\Delta E_{new} = 2x_p + 5 \\ &\Delta SE_{new} = 2(x_p - y_p) + 7\end{aligned}\right\} \rightarrow (2)$$

(2) − (1)

$\Delta^2 E = 2$

$\Delta^2 SE = 2$

else //selection (SE)

At (SE) $\rightarrow$ $[x_p + 1, y_p - 1]$

$\Delta E_{new} = 2x_p + 5$

$\Delta SE_{new} = 2(x_p - y_p) + 9$

(2) − (1)

$\Delta^2 E = 2$

$\Delta^2 SE = 4$

Initialisation $\{$At $(0, R)\}$

$d = 1 - R$

$\Delta E = 3$ $\qquad 2(0) + 3$

$\Delta SE = 5 - 2R$ $\qquad 2(0 - R) + 5$

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$x = 0 \quad y = R$
$d = 1 - R$
$\Delta E = 3$
$\Delta SE = 5 - 2R$

circle symmetry(x, y)
while (x <= y)
{
    if (d < 0) {   // selection E
        d += ΔE
        ΔE += 2,   ΔSE += 2 }

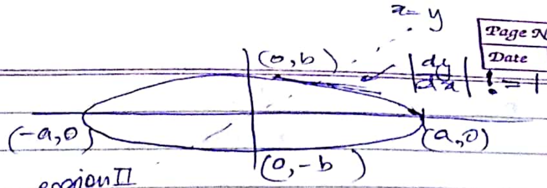
    else {
        d += ΔSE
        ΔE += 2 ,   ΔSE += 4
        y -- }.

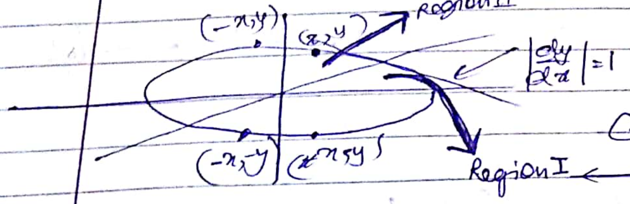
    x ++
    circlesymmetry (x, y)
}

R = 8	x	y	d	ΔE	ΔSE
	0	8	−7	3	−11
	1	8	−4	5	−9
	2	8	1	7	−7
	3	7	−6	9	−3
	4	7	3	11	−1
	5	6	2	13	3
	6	5	5	15	7

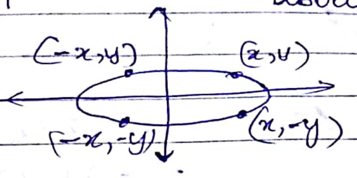
Result is still the same as before

Ellipse



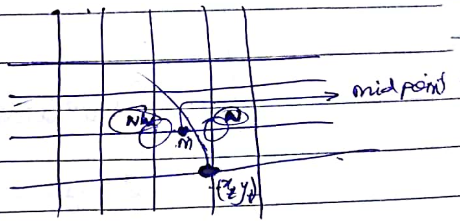


4 - way Symmetry about x & y axis



$$f(x,y) = b^2x^2 + a^2y^2 - a^2b^2$$

in Region I $\left|\frac{dy}{dx}\right| > 1$



major movement in y as $dy > dx$

At (x_t, y_t) $\quad d = f(M) = f\left(x_t - \frac{1}{2}, y_t + 1\right)$ — (1)

if $d < 0$

selection is (N)

$$b^2\left(x - \frac{1}{2}\right)^2 + a^2(y+1)^2 - a^2b^2$$

$$b^2\left(x^2 + \frac{1}{4} - x\right) + a^2(y^2 + 1 + 2y) - a^2b^2$$

$$\cancel{b^2x^2} + \frac{b^2}{4} - b^2x + \cancel{a^2y^2} + a^2 + 2a^2y - \cancel{a^2b^2} < 0$$

$$d_N^I = f(M_N) = f\left(x_t - \frac{1}{2}, y_t + 2\right) \text{ — (2)}$$

$$= b^2\left(x_t - \frac{1}{2}\right)^2 + a^2(y_t+2)^2 - a^2b^2$$

$$\Delta N = \cancel{b^2\left(2x_t - \frac{1}{2}\right)\left(-\frac{1}{2}\right)} + a^2(2y_t + 3)(1) = a^2(2y_t + 3)$$

$$= \cancel{-b^2x_t + \frac{b^2}{4} + 4a^2y_t + 4a^2}$$

else if $d > 0$
selection is NW

$$d_{NW} = f(x_t - 3/2,\ y_t + 2) \quad — (3)$$

$$d_{NW} = b^2\left(x_t - \frac{3}{2}\right)^2 + a^2(y_t+2)^2 - b^2a^2$$

$$\Delta NW = b^2(2x_t - 2)(-1) + a^2(2y_t + 3)$$
$$= -2b^2(x_t - 1) + a^2(2y_t + 3)$$

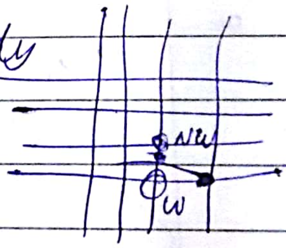
$d_{Initialisation} \rightarrow$ at $(a, 0)$

$$d_{init} = f(a - 1/2,\ 1) = b^2(a - 1/2)^2 + a^2 - a^2b^2$$
$$= \cancel{b^2a^2} + \frac{b^2}{4} - \cancel{2}ab^2 + a^2 - \cancel{a^2b^2}$$
$$= a^2 + \frac{b^2}{4} - ab^2$$

Region II

$$d^{II} = \cancel{f(x_t - 1/2,\ y_t + 1)}$$

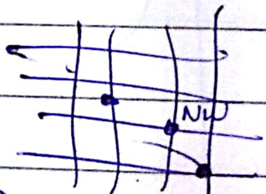
$dx > dy$



$$= f(x_t - 1,\ y_t + 1/2)$$

$$= b^2(x_t - 1)^2 + a^2\left(y_t + \frac{1}{2}\right)^2 - a^2b^2 \quad — (4)$$

if $d^{II} < 0$
selection is NW



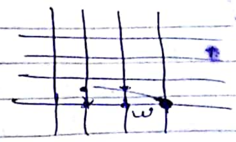
$$d^{II}_{NW} = f(x_t - 2,\ y_t + 3/2)$$

$$= b^2(x_t - 2)^2 + a^2(y_t + 3/2)^2 - b^2a^2 \quad — (5)$$

$$\Delta NW = b^2(2x_t - 3)(-1) + a^2(2y_t + 2)(1)$$

$\Delta NW = -b^2(2x_t-3) + 2a^2(y_t+1) = b^2(3-2x_t)+2a^2(y_t+1)$

else if $d^{II} > 0$
selection is W



$d_W^{II} = f(x_t-2,\ y_t+1/2)$

$= b^2(x_t-2)^2 + a^2(y_t+1/2)^2 - b^2a^2$

$\Delta W = b^2(2x_t-3)(-1) = b^2(3-2x_t)$

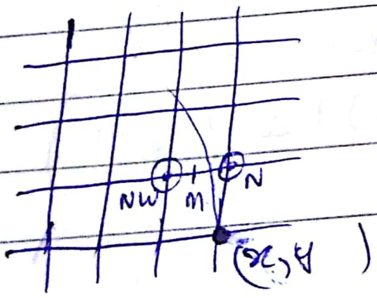
~~d initialisation~~

```
x = a
y = 0
d = a*a + (b*b)/4 - a*b*b
while (b²(x) >= a²(y))
{ /* REGION I */

}
d = b²(x-1)² + a²(y+1/2)² - a²b²
while ( x >= 0 )
{ /* REGION II */

}
```

Here x,y from previous will initialised

Ellipse → 2^{nd} differential eqn

REGION-I



$\Delta N_t = a^2(2y_t+3)$

$\Delta NW_t = a^2(2y_t+3) - 2b^2(x_t-1)$

$\Delta N_{t+1} = a^2(2(y_t+1)+3)$ $\Delta^2 N = 2a^2$

$\Delta NW_{t+1} = a^2(2(y_t+1)+3) - 2b^2((x_t-1)-1)$

$\Delta^2 NW = 2a^2 = 2a^2$

Initialisation at $(a,0)$

$\Delta N = 3a^2$ $\quad \Delta NW = 3a^2 - 2b^2a + 2b^2$

$= 3a + 2b^2(1-a)$

$d = f(x_t - 1/2, y_t + 1)$

$\Delta N = a^2(2y_t + 3)$ — (1) $\quad$ if $d^I < 0$

$\Delta NW = a^2(2y_t+3) + 2b^2(1-x_t)$ — (2)

selection N $\quad (x_t, y_t+1)$

$d_{new} = f(x_t - 1/2, y_t + 2)$

$\Delta N_{new} = a^2(2y_t + 5)$ — (3)

$\Delta N^{2I}_{N} = 2a^2$

$\Delta NW_{new} = a^2(2y_t + 5) + 2b^2(1-x)$ — (4)

$\Delta NW^{2I}_{N} = 2a^2$

else if $d^I > 0$

{ selection NW $\quad (x_t - 1, y_t + 1)$

$d_{new} = f(x_t - 3/2, y_t + 2)$

$\Delta N_{new} = a^2(2y_t + 5)$ — (5)

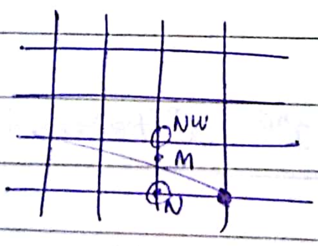
$\Delta NW_{new} = a^2(2y_t + 5) + 2b^2(2 - x_t)$ — (6)

(6) − (2) $\quad$ (5) − (1)

$\Delta N^{2I}_{NW} = 2a^2$

$\Delta NW^{2I}_{NW} = 2(a^2 + b^2)$

REGION – II



$\Delta W = b^2(3 - 2x_t)$ — (7)

$\Delta NW = b^2(3 - 2x_t) + 2a^2(y_t + 1)$ — (8)

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$d^{II} = f(x_t - 1, y_t + 1/2)$

if $d^{II} < 0$ selection is NW

$(x_t - 1, y_t + 1)$

$\cancel{\Delta W^{II}_{NW}}$ $\Delta W_{nw} = b^2(5 - 2x_t)$ —— (9)

$\Delta NW_{nw} = b^2(5 - 2x_t) + 2a^2(2 + y_t)$ — (10)

(9) − (7) (10) − (8)

$\Delta^2 W^{II}_{NW} = 2b^2$

$\Delta^2 NW^{II}_{NW} = 2b^2 + 2a^2 = 2(b^2 + a^2)$

else $d^{II} > 0$ selection is N

$(x_t - 1, y_t)$

$\Delta W_N = b^2(5 - 2x_t)$ —— (11)

$\Delta NW_N = b^2(5 - 2x_t) + 2a^2(y_t + 1)$ — (12)

(11) − (7) (12) − (8)

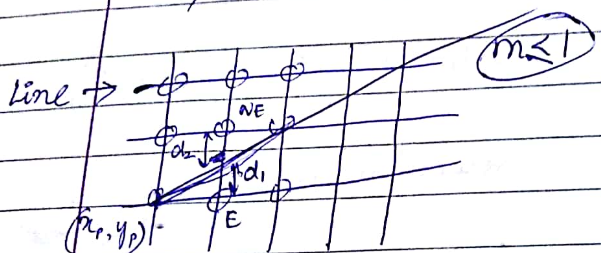
$\Delta^2 W^{II}_{N} = 2b^2$

$\Delta^2 NW^{II}_{N} = 2b^2$

Bresenham's Approach

difficulties / issues
1. floating point computation
2. mid point approach (overcame floating point computation)
but $f(m) < 0$, > 0 | deciding this is an issue

purpose: 1) measurable quantity
↳ difference in measurable quantity will decide
2) Use the measurable quantity in finding the difference



$$d_1 = y - y_E = y - y_p \quad \text{—①}$$

$$y = m(x_{p+1}) + C$$
$$= m(x_p + 1) + C$$

$$d_1 = m(x_p+1) + C - \cancel{mx_p} \; y_p$$

$$d_2 = (y_p + 1) - y \quad \text{—②}$$

$D = d_1 - d_2$ if $D < 0$ we choose E.
$D \geq 0$ we choose NE

$$d_1 - d_2 = y - y_p - y_p - 1 + y = 2(y - y_p) - 1$$

$$= 2(m(x_p+1) + c - y_p) - 1$$

$$= 2\left(\frac{\Delta y}{\Delta x}(x_p + 1) + c\right) - y_p - (y_p + 1)$$

$$p = \Delta x * D = 2(\Delta y(x_p+1) + \Delta x c) - \Delta x(2y_p + 1)$$

since $\Delta x > 0$ D will still determine the points

$$p = 2\Delta y \, x_p - 2\Delta x \, y_p + C$$

where $C = 2(\Delta y + \Delta x c) - \Delta x$

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if $D < 0$, selection is E

$p_{new} = 2\Delta y(x_p+1) - 2\Delta x(y_p) + C$

$\Delta E = p_{new} - p = 2\Delta y$

else, selection is NE

$p_{new} = 2\Delta y(x_p+1) - 2\Delta x(y_p+1) + C$

$\Delta NE = 2\Delta y - 2\Delta x = 2(\Delta y - \Delta x)$

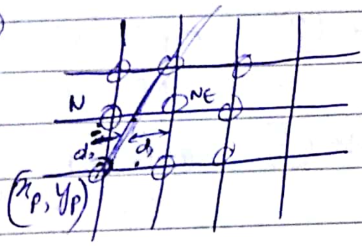
$p_{initial} = 2\left(\Delta y(x_p+1) + \Delta x C\right) - \Delta x\left(2\frac{\Delta y}{\Delta x}x_p + \frac{2c}{\Delta x} + 1\right)$

as $y_p = m x_p + c$

$= 2\Delta y \cancel{x_p} + 2\Delta y + \cancel{2\Delta x c} - \cancel{2\Delta y x_p} - \cancel{2\Delta x c} - \Delta x$

$= 2\Delta y - \Delta x$

$m > 1$



$d_1 = \cancel{x - (x_p+1)}$ $(x_p+1) - x$

$d_2 = \cancel{x_p - x}$ $x - x_p$

$x = \frac{1}{m}\left([y_p+1] - c\right)$

$p = d_1 - d_2 = (x_p+1) - x - x + x_p = 2x_p - 2x + 1$

$d_{initial} = 2\left[\frac{y_p - c}{m}\right] - \frac{2}{m}\left[[y_p+1] - c\right] + 1$

$p_{initial} = 2\Delta x(y_p - c) - 2\Delta x\left((y_p+1) - c\right) + \Delta y$

$= \Delta y - 2\Delta x$

$D = 2x_p - \frac{2\Delta x}{\Delta y}\left([y_p+1] - c\right)$

$\Delta y \cdot D = 2\Delta y x_p - 2\Delta x\left((y_p+1) - c\right)$

$p = 2\Delta y x_p - 2\Delta x y_p \underbrace{- 2\Delta x + 2\Delta x c}_{C}$

$= 2\Delta y x_p - 2\Delta x y_p + C$

if $p > 0$ we select N

$p_{new} = 2\Delta y x_p - 2\Delta x(y_p+1) + C$

$\Delta N = -2\Delta x$

else $p_{new} = 2\Delta y(x_p+1) - 2\Delta x(y_p+1) + C$ $\quad \Delta NE = 2(\Delta y - \Delta x)$

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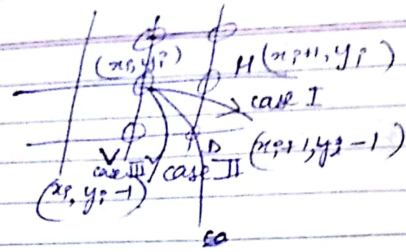
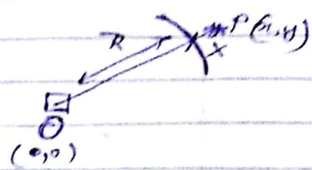
circle





$d_p = |OP^2 - OX^2|$

$d_p = |x^2+y^2 - R^2|$

$d_H = |(x_i+1)^2 + y_i^2 - R^2|$

$d_D = |(x_i+1)^2 + (y_i-1)^2 - R^2|$

$d_V = |x_i^2 + (y_i-1)^2 - R^2|$

case ① $OD^2 - R^2 < 0$

$OD^2 < R^2$

case ② $OD^2 - R^2 = 0$

$OD^2 = R^2$

case ③ $OD^2 - R^2 > 0$

$OD^2 > R^2$

if one wants to select between H and D

$\delta_{HD} = d_H - d_D$

$|(x_i+1)^2 + y_i^2 - R^2| - |(x_i+1)^2 + (y_i-1)^2 - R^2|$

use

$OH^2 - R^2 \geq 0$

$OD^2 - R^2 < 0$

to open | |

$|OH^2 - R^2| - |OD^2 - R^2|$

$= (OH^2 - R^2) - (R^2 - OD^2)$

$= (x_i+1)^2 + y_i^2 - R^2 - (R^2 - (x_i+1)^2 - (y_i-1)^2)$

$= 2(x_i+1)^2 + y_i^2 + (y_i-1)^2 - 2R^2$

$= 2\left((x_i+1)^2 + (y_i-1)^2 - R^2\right) + 2y_i - 1$

$\delta_{HD} = 2\Delta D_i + 2y_i - 1$

selection b/w V and D

$\delta_{VD} = d_V - d_D = |OV^2 - R^2| - |OD^2 - R^2|$

Here $OD^2 - R^2 > 0$
$OV^2 - R^2 < 0$

$= R^2 - OV^2 - OD^2 + R^2$

$= 2R^2 - (x_i^2 + (y_i - 1)^2) - ((x_i+1)^2 + (y_i - 1)^2)$

$= 2[R^2 - (x_i+1)^2 - (y_i-1)^2] + 2x_i + 1$

$\delta_{VD} = 2x_i + 1 - 2\Delta D_i$

$\Delta D_i \rightarrow [(x_i+1)^2 + (y_i-1)^2 - R^2]$ (x_i, y_i) are changing after ~~every~~ choosing a point

part I illuminating the pixel H

$pt \rightarrow (x_i+1, y_i)$

$\Delta D_{i_{new}} = ((x_i+2)^2 + (y_i-1)^2 - R^2)$

$\Delta H = \Delta D_{i_{new}} - \Delta D_i = (2x_i + 3)$

part II illuminating pixel V

$pt \rightarrow (x_i, y_i - 1)$

$\Delta D_{i_{new}} = (x_i+1)^2 + (y_i-2)^2 - R^2$

$\Delta V = \Delta D_{i_{new}} - \Delta D_i = (2y_i - 3)(-1)$
$= 3 - 2y_i$

part III illuminat pixel D

$pt \rightarrow (x_i+1, y_i-1)$

$\Delta D_{i_{new}} = ((x_i+2)^2 + (y_i-2)^2 - R^2)$

$\Delta D_D = \Delta D_{i_{new}} - \Delta D_i = (2x_i+3) + (2y_i - 3)(-1)$
$= 2(x_i - y_i) + 6$

Scanned by CamScanner

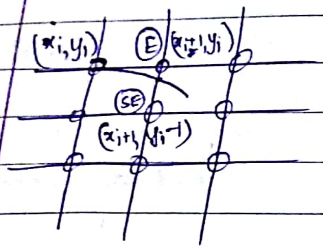
initialisation if starting from $(0,R)$

$\Delta D_i = (1^2 + (R-1)^2 - R^2)$

$= 1 + R^2 + 1 - 2R - R^2$

$= 2(1-R)$

Another Approach — measurable quantity is in highest degree of equation



$d_1 = y_i^2 - y^2$ — d_1 w.r.t E

$d_2 = y^2 - (y_i-1)^2$ — d_2 w.r.t SE

$x^2+y^2-R^2$

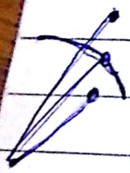
$D_i = d_1 - d_2 = y_i^2 - 2y^2 + (y_i-1)^2$

$= 2y_i^2 + 1 - 2y_i - 2y^2$

$y^2 = R^2 - (x_i+1)^2 \Rightarrow$

$2y_i^2 + 1 - 2y_i - 2[R^2 - (x_i+1)^2]$

$$\boxed{D_i = y_i^2 + (y_i-1)^2 - 2[R^2 - (x_i+1)^2]} \quad (1)$$



if $D_i < 0$ selection E

pt $\rightarrow (x_i+1, y_i)$

$D_{i+1} = y_i^2 + (y_i-1)^2 - 2[R^2 - (x_i+2)^2] \quad (2)$

(2) − (1)

$\Delta E = D_{i+1} - D_i = 2(2x_i + 3)$

Initialisation $D_i(0,R) \rightarrow (R^2 + (R-1)^2 - 2(R^2-1))$

$= \cancel{R^2} + \cancel{R^2} + 1 - 2R - \cancel{2R^2} + 2$

$= 3 - 2R$

else selection (SE) $\xrightarrow{rt} (x_i+1,\ y_i-1)$

$$D_{i+1} = (y_i-1)^2 + (y_i-2)^2 - 2\left[R^2 - (x_i+2)^2\right] \quad -(3)$$

(3) − (1)

$$\Delta SE = (2y_i-2)(-2) - 2\left[\cancel{R^2} - (x_i+2)^2 - \cancel{R^2} + (x_i+1)^2\right]$$

$$= 4(1-y_i) - 2(2x_i+3)(-1)$$

$$= 4(1-y_i) + 2(2x_i+3)$$

Algo →

```
x = 0,   y = R,   d = 3 - 2R
while ( x <= y ) {
    if d < 0
        d+ = 2 x (2x+3)
    else {
        d+ = 2*(2x+3) + 4*(1 - yi)
        y--
    }
    x++
}
```

(x_i, y_i) (x_i+1, y_i)

(x, y)

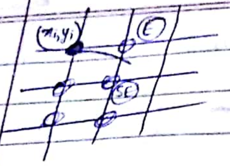
(x_i+1, y_i-1)

$$d_1 = (x_i+1)^2 + y_i^2 - R^2 - (x_i+1)^2 - y^2 + R^2$$

$$= y_i^2 - y^2$$

$$d_2 = (x_i+1)^2 + y^2 - R^2 - (x_i+1)^2 - (y_i-1)^2 + R^2$$

$$= y^2 - (y_i-1)^2$$



$d = 3 - 2R$

$\Delta E = 2 * (2x_i + 3)$

$\Delta SE = 4 * (1 - y_i) + 2 * (2x_i + 3)$

$(0, R)$ Initialisation

$\Delta E = 6$

$\Delta SE = 4(1 - R) + 6 = 10 - 4R$

$= 2(5 - 2R)$

if $d < 0$ selection E

pt @E $(x_i + 1, y_i)$

$\Delta E_{new} = 2(2(x_i + 1) + 3)$

$\boxed{\Delta^2 E^{E} = 4}$

$\Delta SE_{new} = 4(1 - y_i) + 2(2(x_i + 1) + 3)$

$\boxed{\Delta^2 SE^{E} = 4}$

else selection SE

pt $(x_i + 1, y_i - 1)$

$\Delta E_{new} = 2(2(x_i + 1) + 3)$

$\boxed{\Delta^2 E^{SE} = 4}$

$\Delta SE_{new} = 4(1 - (y_i - 1)) + 2(2(x_i + 1) + 3)$

$\boxed{\Delta^2 SE^{SE} = 8}$

Algo

$x = 0$, $y = R$, $d = 3 - 2R$, $\Delta E = 6$ $\Delta SE = 2(5 - 2R)$

```
while ( x <= y) {
    if ( d<0) {
            d+= ΔE
            ΔE+= 4
            ΔSE+= 4
    }else {
            d+= ΔSE
            ΔE += 4
            ΔSE += 8
            y-- }
}       x++;
```

$(y_i - y)(y_i + y) + (y_i - y - 1)(y_i + y - 1)$

$\varepsilon(y_i + y) + (\varepsilon - 1)(y_i + y - 1)$

$(2\varepsilon - 1)(y_i + y) + (1 - \varepsilon)$

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Bresenham $\rightarrow$ Ellipse

$b^2x^2 + a^2y^2 = a^2b^2$

y_i

$(2\varepsilon-1)(2y_i - \varepsilon) + (1-\varepsilon)$

$2y_i(2\varepsilon - 1)$

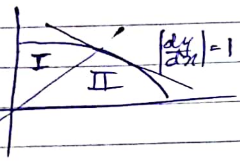
$-(2\varepsilon^2 - \varepsilon) + 1 - \varepsilon$

$2y_i(2\varepsilon - 1) - 2\varepsilon^2 + 1$

derivative

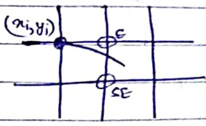
$= -4\varepsilon + 4y_i$

$= 4(y_i - \varepsilon)$



$\left|\frac{dy}{dx}\right| = 1$

Region I



(x_i, y_i) E SE

$d_{E} = a^2y_i^2 - a^2y^2$

$d_{SE} = a^2y^2 - a^2(y_i - 1)^2$

let $y_i - y = \varepsilon$

$D_i^{I} = d_E - d_{SE} = a^2y_i^2 - 2a^2y^2 + a^2(y_i - 1)^2$

$= a^2(y_i^2 + (y_i - 1)^2 - 2y^2)$

$= a^2\big((y_i - y)(y_i + y) + (y_i - y - 1)(y_i + y - 1)\big)$

$= a^2(\varepsilon(y_i + y) + (\varepsilon - 1)(y_i + y - 1))$

$= a^2[2\varepsilon(y_i + y) + \varepsilon - (y_i + y + 1)$

$= a^2((y_i + y)(2\varepsilon - 1) - (\varepsilon - 1))$

$= a^2((2y_i - (y_i - y))(2\varepsilon - 1) + (\varepsilon - 1))$

$= a^2((2y_i - \varepsilon)(2\varepsilon - 1) + (\varepsilon - 1))$

$= a^2(2y_i(2\varepsilon - 1) - 2\varepsilon^2 + 2\varepsilon - 1)$

$a^2(2y_i(2\varepsilon - 1) + 2(\varepsilon - \varepsilon^2) - 1)$

$a^2(2y_i(2\varepsilon - 1) + 2\varepsilon(1 - \varepsilon) - 1)$

if $D^{I} < 0$ we select E

pt $= (x_i + 1, y_i)$

$\cancel{d_E = a^2y_i^2}$

$D_i^{I} = a^2(y_i^2 + (y_i - 1)^2 - 2y^2)$

$a^2(y_i^2 + (y_i - 1)^2) - 2a^2y^2$

$a^2(y_i^2 + (y_i - 1)^2) + 2(b^2(x_i + 1)^2 - a^2b^2)$ $D_{i+1}^{I} = y$

if $D^{I} < 0$ select E

$\Delta E = 2b^2(2x_i + 3)$

$D_{i+1} = a^2(y_i^2 + (y_i - 1)^2) + 2(b^2(x_i + 2)^2 - a^2b^2)$

$\Delta SE = 2b^2(2x_i + 3) + 4a^2(1 - y_i)$

$\Delta E = D_{i+1} - D_i = 2b^2(2x_i + 3)$

else $D_{i+1} = a^2((y_i - 1)^2 + (y_i - 2)^2) + 2(b^2(x_i + 2)^2 - a^2b^2)$

$\Delta SE = 2b^2(2x_i + 3) + 4a^2(1 - y_i)$

$D_{init} = (0, b)$

$\cancel{a^2 + 2(b^2 - a^2b^2)}$

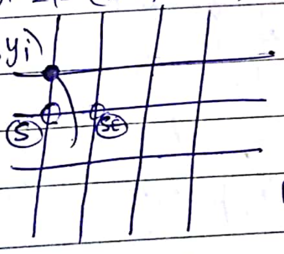
$\cancel{a^2 + 2b^2 - 2a^2b^2}$

$= a^2(b^2 + (b-1)^2) + 2b^2 - 2a^2b^2$

$= \cancel{a^2b^2} + \cancel{a^2b^2} + a^2 - 2a^2b + 2b^2 - \cancel{2a^2b^2}$

$D_{init} = a^2 + 2b^2 - 2a^2b$

Region II (x_i, y_i)



S SE

$d_S = \cancel{b^2x_i^2} \quad b^2x^2 - b^2x_i^2$

$d_{SE} = \cancel{b^2x^2 - b^2(x_i+1)^2} \quad b^2(x_i + 1)^2 - b^2x^2$

$D_i^{II} = d_S - d_{SE} = -(b^2x_i^2 + b^2(x_i + 1)^2 - 2b^2x^2)$

$= -b^2(x_i^2 + (x_i + 1)^2) + 2(b^2x^2 - a^2b^2)$

$= 2(a^2b^2 - a^2y^2) - b^2(x_i^2 + (x_i + 1)^2)$

$= 2(a^2b^2 - a^2(y_i - 1)^2) - b^2(x_i^2 + (x_i + 1)^2)$

if $D < 0$ select S

$(x_i, y_i - 1)$ $D_{i+1}^{II} = 2(a^2b^2 - a^2(y_i - 2)^2) - b^2(x_i^2 + (x_i + 1)^2)$

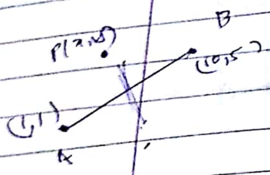
$\Delta S = 2a^2((y_i - 1)^2 - (y_i - 2)^2)$

$= 2a^2(2y_i - 3)$

else //SE $x_i + 1, y_i - 1$ D_{i+1} $2(a^2b^2 - a^2(y_i - 2)^2) - b^2((x_i + 1)^2 + (x_i + 2)^2)$

$\Delta SE = 2a^2(2y_i - 3) + b^2(2x_i + 2)(2) = 2a^2(2y_i - 3) + 4b^2(x_i + 1)$

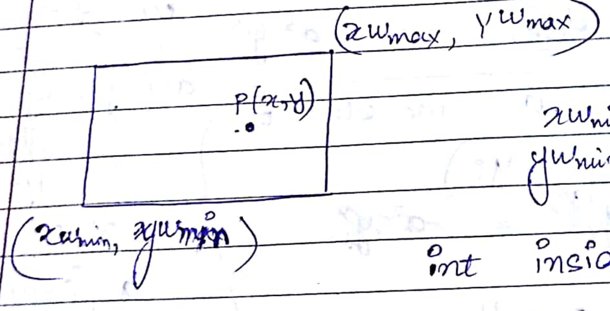
$a^2\left(y_i^2+(y_i-1)^2-2y^2\right)$



$\vec{AB} = 9i+4j$

$-4i+9j$

Clipping

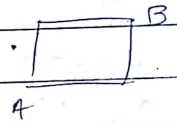


if P lies inside or on rectangle

$xw_{min} \le x \le xw_{max}$

$yw_{min} \le y \le yw_{max}$

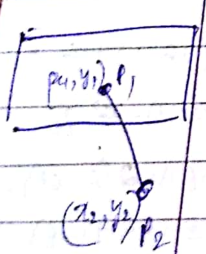
int inside (point P, A, B){



return 0 when outside

return 1 when inside

}



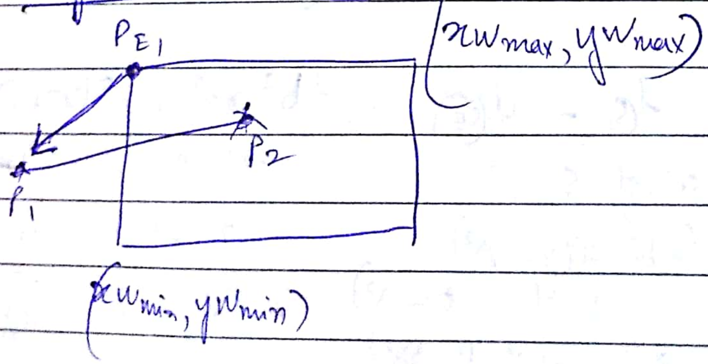
For a line with P_1 and P_2 end points we will get either

$\underbrace{\overset{P_1P_2}{00}}_{\text{line inside}}, \overset{P_1P_2}{01}, \overset{P_1P_2}{10}, \overset{P_1P_2}{11}$

line outside or may pass through window

clipping should be performed

Cyrus - Beck



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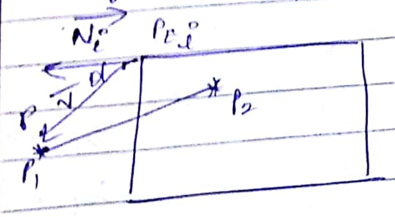
Parametric Eqn

$$P(t) = P_1 + (P_2 - P_1)t \qquad 0 \le t \le 1$$

vector $\vec{V}$ from P_{E_1} to line P_1P_2 such that it swing from P_1 to P_2 and reverse

$$\vec{V} = P(t) - P_{E_1}$$



N_i is normal to any edge i

$$\vec{V} \cdot \vec{N_i} \quad \begin{cases} < 0 \\ = 0 \\ > 0 \end{cases}$$

$\cos\theta > 0$ that means $\theta < 90°$ or point outside edge

At intersection $\vec{V} \cdot \vec{N_i} = 0$ $\quad (P(t) - P_{E_i}) \cdot \vec{N_i} = 0$

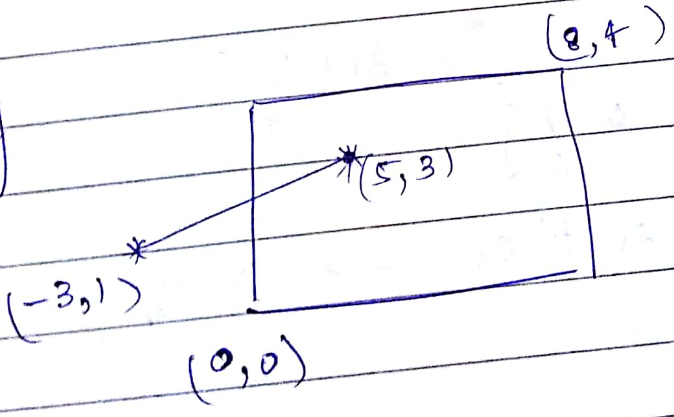
$$(P_1 + (P_2 - P_1)t - P_{E_i}) \cdot \vec{N_i} = 0$$

$$(P_1 - P_{E_i})\vec{N_i} + ((P_2 - P_1)t)\vec{N_i} = 0$$

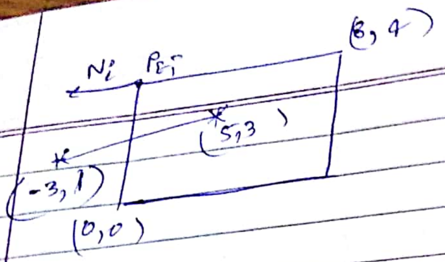
$$\boxed{t = \frac{\vec{N_i} \cdot (P_1 - P_{E_i})}{-((P_2 - P_1)t) \cdot \vec{N_i}}}$$

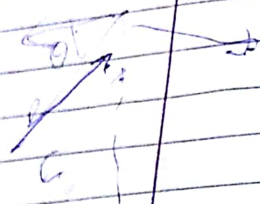
denominator $\vec{N_i}((P_2 - P_1)t)$

eg



We take this





Left Edge

$N_i = -\hat{i}$

$P_1 = -3\hat{i} + \hat{j}$

$P_2 = 5\hat{i} + 3\hat{j}$

$P_{E_i} = 4\hat{j}$

$$t = \frac{(-\hat{i})\cdot(-3\hat{i} + \hat{j} - 4\hat{j})}{(-1)(-\hat{i})\cdot(5\hat{i} + 3\hat{j} - (-3\hat{i} + \hat{j}))}$$

$$= \frac{(-\hat{i})\cdot(-3\hat{i} - 3\hat{j})}{\hat{i}\cdot(8\hat{i} + 2\hat{j})} = \frac{3\hat{i}(\hat{i} + \hat{j})}{2\hat{i}(4\hat{i} + \hat{j})}$$

$$t = \frac{3}{8}$$

Denominator $N_i \cdot (P_2 - P_1) \neq 0$

↳ > 0 → potentially ~~entering~~ exiting rectangle

< 0 → potentially ~~exiting~~ entering

$$P(t) = P_1 + (P_2 - P_1)t$$

$$= (-3\hat{i} + \hat{j}) + (5\hat{i} + 3\hat{j} + 3\hat{i} - \hat{j})\frac{3}{8}$$

$$= -3\hat{i} + \hat{j} + (8\hat{i} + 2\hat{j})\frac{3}{8}$$

$$= -3\hat{i} + \hat{j} + 3\hat{i} + \frac{3}{4}\hat{j}$$

$$= \frac{7}{4}\hat{j}$$

thus intersection → $(0, 7/4)$

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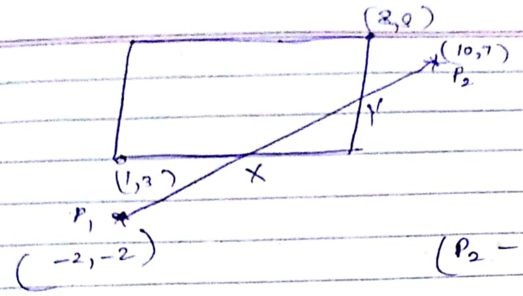
Eg 2



Normals

left $\rightarrow$ $N_i = -\hat{i}$
bottom $\rightarrow$ $N_i = -\hat{j}$
right $\rightarrow$ $N_i = \hat{i}$
top $\rightarrow$ $N_i = \hat{j}$

$(P_2 - P_1) = 12\hat{i} + 9\hat{j}$

Normal		$P_1 - P_{E_i}$	$N_i \cdot (P_1 - P_{E_i})$	$N_i \cdot (P_2 - P_1)$	t
left	$N_i = -\hat{i}$	$P_{E_i} = (1,8)$, $\hat{i} + 8\hat{j}$; $-3\hat{i} - 10\hat{j}$	3	-12 P_{Ent}	3/12
Bottom	$N_i = -\hat{j}$	$P_{E_i} = (1,3)$, $\hat{i} + 3\hat{j}$; $-3\hat{i} - 5\hat{j}$	5	-9 P_{Ent}	5/9
Right	$N_i = \hat{i}$	$P_{E_i} = (8,3)$, $8\hat{i} + 3\hat{j}$; $-10\hat{i} - 5\hat{j}$	-10	12 P_{Exit}	10/12
Top	$N_i = \hat{j}$	$P_{E_i} = (8,8)$, $8\hat{i} + 8\hat{j}$; $-10\hat{i} - 10\hat{j}$	-10	9 P_{Exit}	10/9

We will only take those t where $0 \leq t \leq 1$

we include 0

we make set of $P_{Entering}$ $S_1 \rightarrow (0, 3/12, 5/9)$ t we find max = 5/9

& of P_{Exit}

~~we include~~ 1

$S_2 \rightarrow (10/12, 1)$ we find min = 10/12 = 5/6

$$P(t) = P_1 + (P_2 - P_1)\, t$$

$$X = (-2,-2) + ((10,7) - (-2,-2))\, 5/9$$

$$Y = (-2,-2) + ((10,7) - (-2,-2))\, 5/6$$

n.shul

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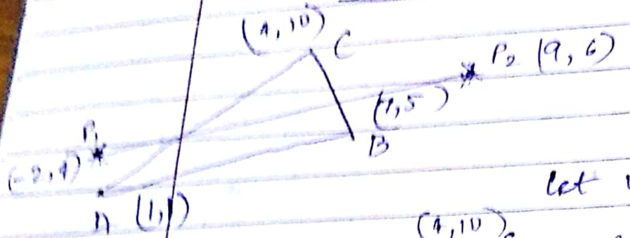
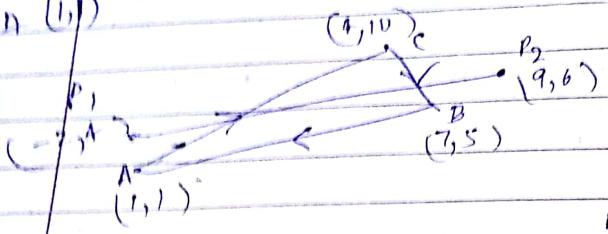
Non - Rectangular Window — Cyrus Beck



let us do it clockwise



Edge

$\vec{AC} = 3i + 9j$

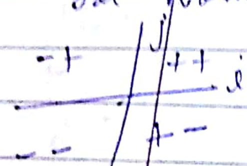
$\vec{CB} = 3i - 5j$

$\vec{BA} = -6i - 4j$

$P_2 - P_1 = 11i + 2j$

Edge	Normal	P_{E_i}	$P_1 - P_{E_i}$	$N_i \cdot (P_1 - P_{E_i})$	$N_i \cdot (P_2 - P_1)$	~~Exit~~ Exit
$\vec{AC}$ $3i + 9j$	$-9i + 3j$	$i + j$	$-3i + 3j$	$27 + 9 = 36$	$-99 + 6 = -93$	entre
$\vec{CB}$ $3i - 5j$	$5i + 3j$	$4i + 10j$	$-6i - 8j$	$-30 - 18 = -48$	$55 + 6 = 61$	
$\vec{BA}$ $-6i - 4j$	$4i - 6j$	$7i + 5j$	$-9i - j$	$-36 + 6 = -30$	$44 - 12 = 32$	~~Exit~~ Enter

for Normal



$t \rightarrow 12/31$ Enter

$48/61$ Exit

$15/16$ Exit

vector	normal
+ +	− +
+ −	+ +
− +	− −
− −	+ −
anticlockwise	normal

7420
0x742

CYRUS - BECK
FOR CONCAVE

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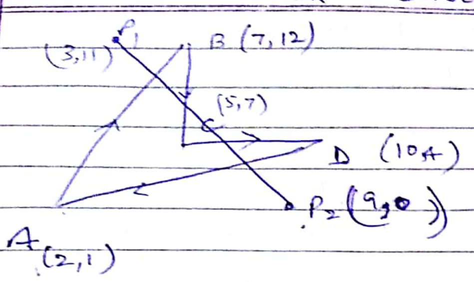

$P_2 - P_1 = \cancel{6i\ j}$
$6i - 11j$

$P_1 = 3i + 11j$

	Edge	Normal	P_{E_i}	$P_1 - P_{E_i}$	$N_i(P_1 - P_{E_i})$	$N_i(P_2 - P_1)$
$\overrightarrow{AB}$	$5i + 11j$	$-11i + 5j$	$2i + j$	$i + 10j$	$-11 + 50 = 39$	$-66 - 55 = -121$ P_{Ent}
$\overrightarrow{BC}$	$-2i - 5j$	$5i - 2j$	$7i + 12j$	$-4i + j$	$-20 + 2 = -18$	$30 + 22 = 52$ P_{Exit}
$\overrightarrow{CD}$	$5i - 3j$	$3i + 5j$	$5i + 7j$	$-2i + 4j$	$-6 + 20 = 14$	$18 - 55 = -37$ P_{Ent}
$\overrightarrow{DA}$	$-8i - 3j$	$3i - 8j$	$10i + 4j$	$-7i + 7j$	$-21 - 56 = -77$	$18 + 88 = 106$ P_{Exit}

$0 \le t \le 1$

$S: \left\{ \underset{P_{En}}{\frac{39}{121}}, \underset{P_{Ex}}{\frac{18}{52}}, \underset{P_{En}}{\frac{14}{37}}, \underset{P_{Ex}}{\frac{77}{106}} \right\}$

0 1

pair of entry & exit

pair of entry & exit

$t =$

$\overrightarrow{AB}$	$39/121$
$\overrightarrow{BC}$	$18/52$
$\overrightarrow{CD}$	$14/37$
$\overrightarrow{DA}$	$77/106$

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COHEN - SUTHERLAND

1001 (9)	1000 (8)	(xw_{max}, yw_{max}) 1100 (12)
0001 (1)	0000 (0)	0100 (4)
(xw_{min}, yw_{min})		
0011 (3)	0010 (2)	0110 (6)

9 addresses

For a line $P_1 P_2$
P_1 and P_2 would in these 9 areas only

Input : P_1, P_2

Method : Code1 = gencode (Point P_1), ~~Code~~ gencode (Point P_2)

```
gencode ( Point P ){
        int code = 0;
        if P.x < xwmin
            code |= LEFT
        P.x >= xwmax
            code |= RIGHT
        P.Y >= ywmax
            code |= TOP
        P.Y <= ywmin
            code |= BOTTOM
}
```

```
done = 0
{
I   if (code (P1) = 0000 & code (P2) = 0000 )   {(code1 & code2 == 0) && (code1 | code2) == 0}
        /* display line */
        done = 1                                  // get out of recursion
II  if (code1 & code2 != 0)
        /* dont display line */
        done = 1                                  // get out of recursion
III if ((code1 & code2 == 0) && (code1 | code2 != 0))
        /* line clip() */
} while ( done != 1 )
```

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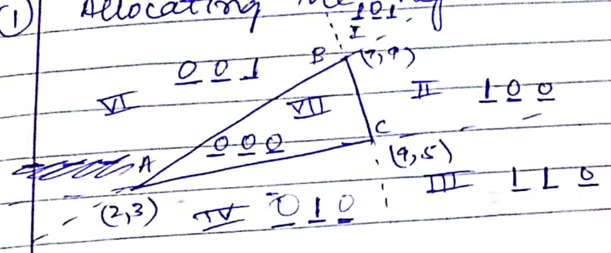
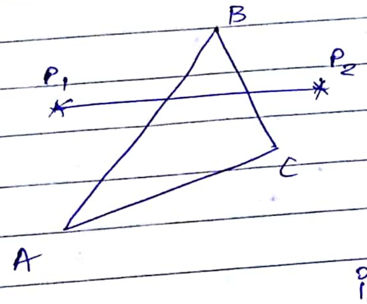
step(1) Allocating the Region code for Address



Non - Rectangular window



code1 = gencode (P_1)
code2 = gencode (P_2)

gencode (Point A, Point B, Point C, P_1)
code = 0

if

(2,3) (7,9)
Edge AB   f(x,y) => $\frac{6}{5} = \frac{y-3}{x-2}$ $6x - 12 - 5y + 15$

$5y - 6x - 3 = 0$ still took

$6x - 5y + 3 = 0$

C (9,5) < 0 $-6(9) + 5(5) + 3 = 25 - 57 = -32$

AC   f(x,y) $\frac{2}{7} = \frac{y-3}{x-2}$ $2x - 4 = 7y - 21$

$2x - 7y + 17 = 0$

B(7,9) < 0

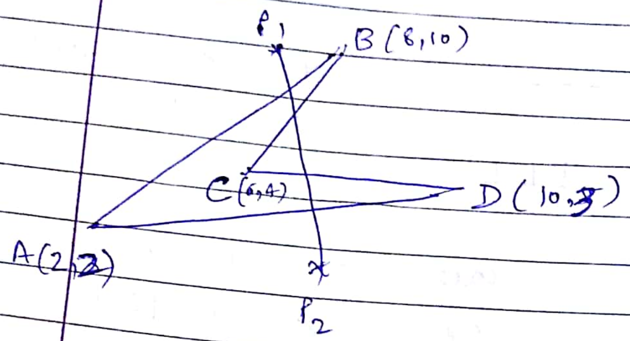
BC   f(x,y) = $\frac{4}{-2} = \frac{y-5}{x-9}$ $4x - 36 = -2y + 10$

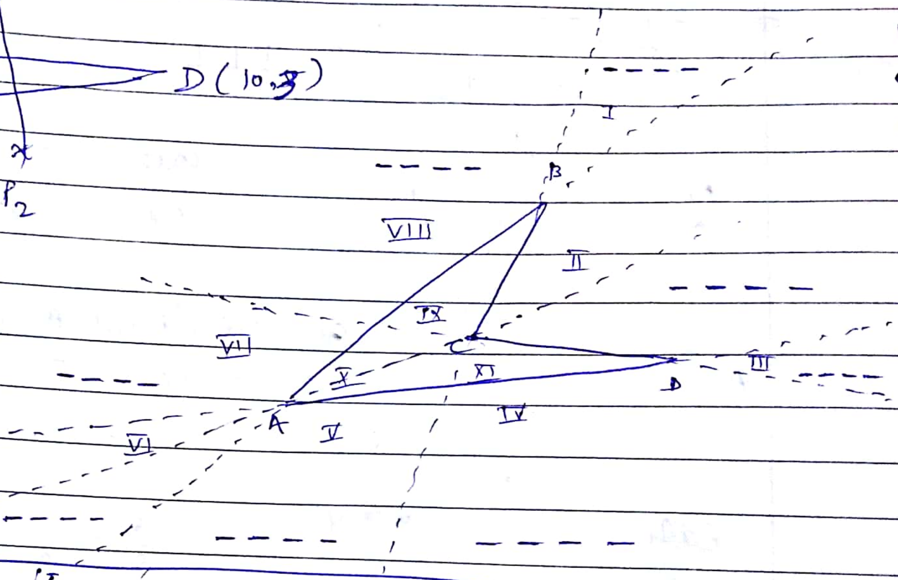
$4x + 2y - 46 = 0$

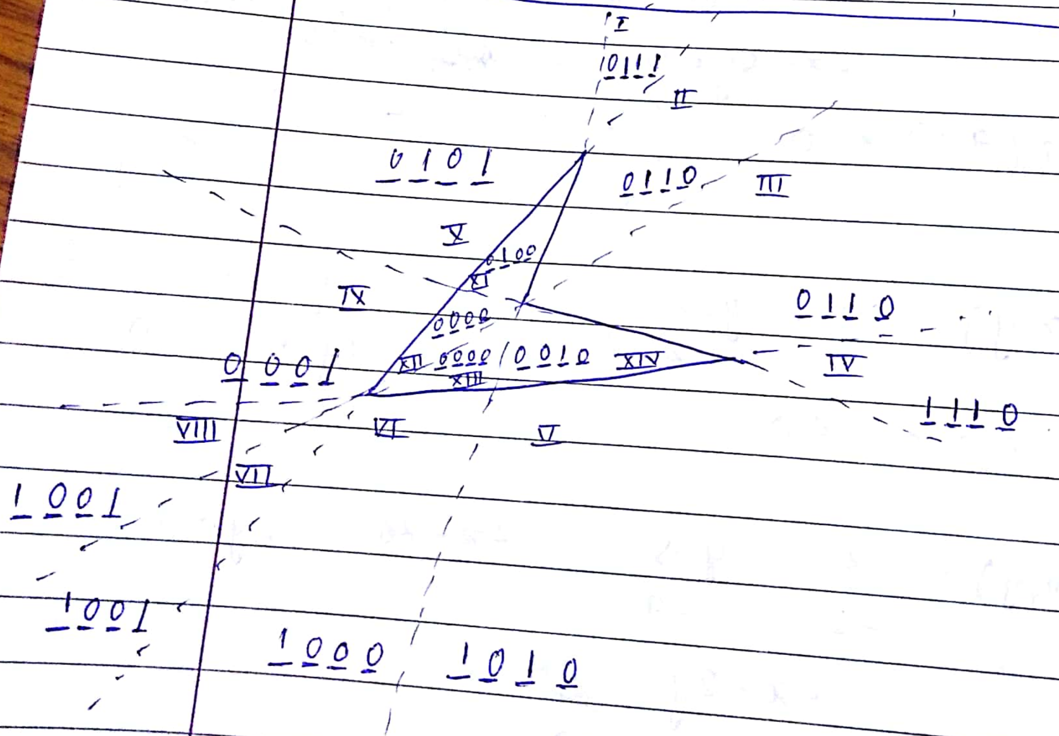
$2x + y - 23 = 0$

A (2,3) < 0

~~gencode (point p){ code = 0x0;~~







Line clipping

Nicholl – Lee – Nicholl   In rectangular window

9 regions ⟶ 3 cluster

cluster-I

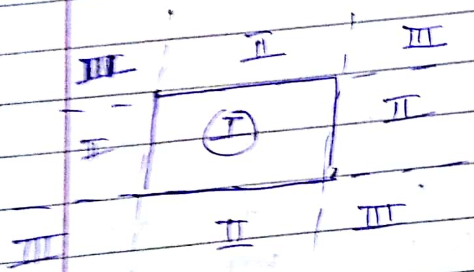
One of the end point of a line is at centre/ or within inside the rectangular window

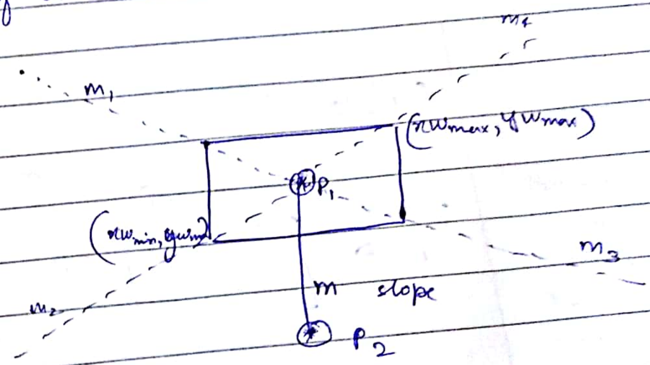
cluster-II

One of the end point of a line is before Edge (Left, Bottom, Right, Top)

cluster-III

One of the endpoint of a line lies at corner



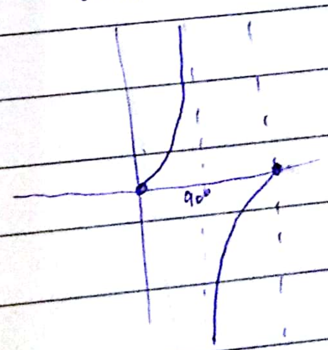


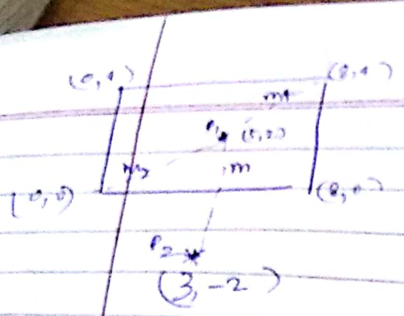
$m_1 \le m \le m_2$ $m_2 \le m \le m_3$ $m_3 \le m \le m_4$ $m_4 \le m \le m_1$

if: $P_2 \cdot y_2 < yw_{min}$ clip

else: no clipping

tan





$m_1 = \frac{-4}{-2} = 2$

$m_2 = \frac{-2}{-5} = 2/5$

$m_4 = \frac{2}{3}$

$m_3 = \frac{2}{-3}$

if $((m < m_1)$ && $(m > m_2)$ && $(P_1.y_1 > P_1.y_2))$

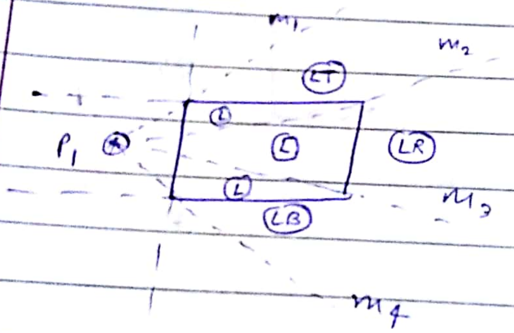
{

  if $P_2.y_2 < yw_{min}$

    /* clipping is done */

}

Cluster II



L means left line to clipping

LT means left & top both

- LEFT
  - $m_2 \le m \le m_1$
    - L
    - LT
    - X — when $P_2.x < xw_{min}$ we do not care
  - $m_3 \le m \le m_2$
  - $m_4 \le m \le m_3$
  - X — we do not care otherwise
- BOTTOM
- RIGHT
- TOP

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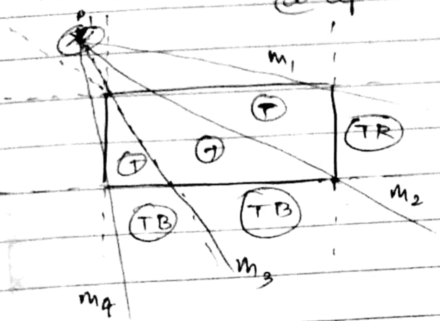
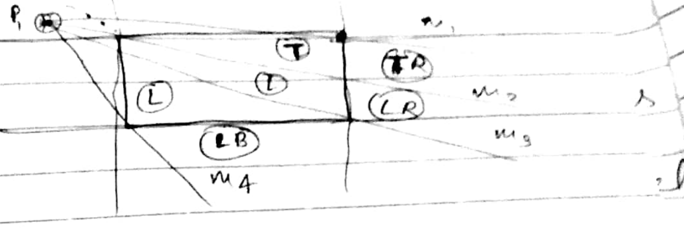
Cluster III

@up



@bottom



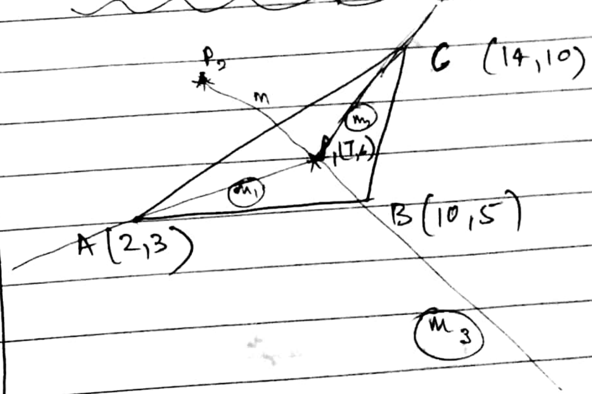
LTC RTC LBC RBC

@up @bottom

$m_1 \le m \le m_2$ $m_2 \le m \le m_3$ $m_3 \le m \le m_4$

T TR ?

Non - Rectangular Window



$m_1 \le m \le m_2$ $m_2 \le m \le m_3$ $m_3 \le m \le m_1$

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Recursive

a) code1 | code2 == 0
line visible

b) code1 & code2 != 0
line not visible

c) code1 & code2 == 0
recursive

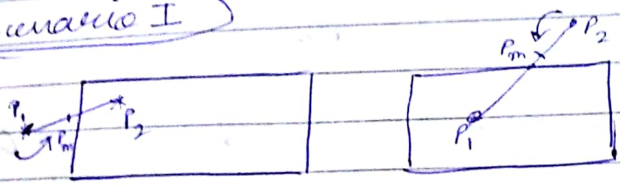
mid point line clipping

$P_m = (P_1 + P_2)/2$

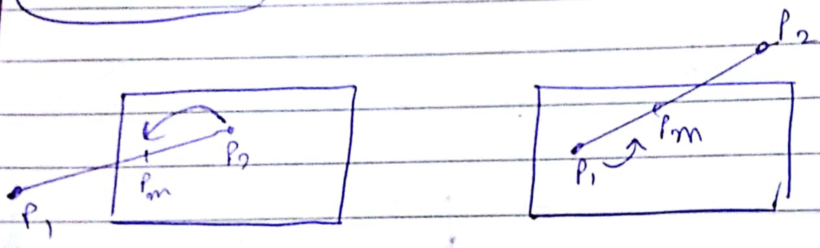
$\Rightarrow P_1 P_m$

$\Rightarrow P_m P_2$

Scenario I



Scenario II



Algorithm

input : P_1 , P_m , xw_{min} , xw_{max} , yw_{min} , yw_{max}

method: code1 = gencode (P_1) code2 = gencode(P_2)

step① if code1, code2 both = 0
draw $P_1 P_2$

step② if code1 & code2 != 0
/* ignore line */

step③ $P_m = (P_1 + P_2)/2$
code m = gencode (P_m)

line(P_1, P_2)

(P_1, P_m)

(P_m, P_2)

step

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Step (4) if codem != 0
then if code1 & code m != 0
then $P_1 \leftarrow P_m$; goto step(1)

else if code2 & code m != 0
then $P_2 \leftarrow P_m$; go to step(1)

Step (5) if code m == 0
if code1, codem both = 0
then consider $P_m P_2$
else if code2, code m both = 0
the consider $P_1 P_m$

Step (6) consider $P_1 P_m$
do {
P_{m_1} = $(P_1 + P_m)/2$;
codem1 = gencode (P_{m_1})
if (code m1 != 0) then $P_1 \leftarrow P_{m_1}$
else $P_m \leftarrow P_{m_1}$

} while ($P_1.x$!= xw_{min} && $P_1.x$ <= xw_{max} && $P_1.y$!= yw_{min}
&& $P_1.y$!= yw_{max})

$P_1 \leftarrow P_m$

Step (7) consider $P_m P_2$
do { P_{m_2} = $(P_2 + P_m)/2$; code m2 = gencode (P_{m_2})
if (code m2 != 0) then $P_2 \leftarrow P_{m_2}$
else $P_m \leftarrow P_{m_2}$

} while ($P_2.x$ . . . . .)

$P_2 \leftarrow P_m$

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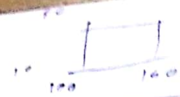

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Eg → $P_1 P_2$ $P_1 (120, 5)$ $P_2 (180, 30)$

$xw_{min} = 100$, $xw_{max} = 160$, $yw_{min} = 10$, $yw_{max} = 40$

P_1	code 1	P_2	code 2	P_m	code m	Remarks
(120, 5)	0010	(180, 30)	0100	(150, 18)	0000	consider $P_1 P_m$ consider $P_m P_2$

consider $P_1 P_m$

(120, 5)	0010	(150, 18)	0000	(135, 12)	0000	
(120, 5)	0010	(135, 12)	0000	(128, 9)	0010	
(128, 9)	0010	(135, 12)	0000	(132, 11)	0000	
(128, 9)	0010	(132, 11)	0000	(130, 10)	0000	$P_1 \leftarrow (130, 10)$
~~(128, 9)~~	~~0010~~	(130, 10)	0000			

boundary condition reached

consider $P_m P_2$

(150, 18)	0000	(180, 30)	0100	(165, 24)	0100	
(150, 18)	0000	(165, 24)	0100	(158, 21)	0000	
(158, 21)	0000	(165, 24)	0100	(162, 23)	0100	
(158, 21)	0000	(162, 23)	0100	(160, 22)	0000	$P_2 \leftarrow (160, 22)$

(160, 22)

boundary condition reached

Liang Baskey (DIY)

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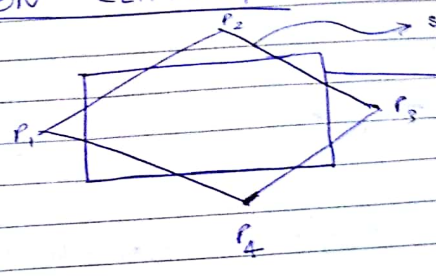
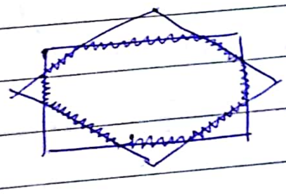
POLYGON CLIPPING



Input:
① subject Polygon (vertices list)
② clipping window (vertices list)

Methode:

Output: clipped Polygon (list of vertices)

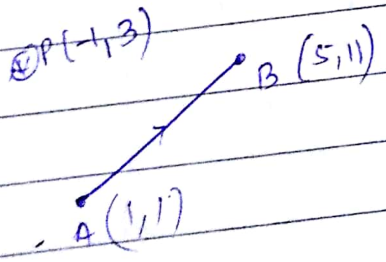


i/p → Left Edge clipping → Bottom Edge clipping → Right Edge clipping → Top Edge clipping → vertices list clipped polygon (8 vertices)

Subject Polygon vertices list (4 vertices)

||| (5 vertices) ||| (6 vertices) ||| (7 vertices)

inside function



$\vec{AB} = 4i + 10j$

$\vec{N_i}_{(A)} = -10i + 4j$

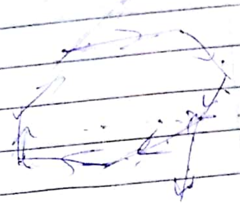
~~$\vec{N_i} \cdot \vec{AP}$~~

$(\vec{P} - P_{E_i}(A)) = -2i + 2j$

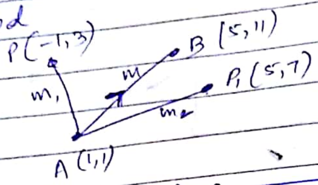
$N_i \cdot (P - P_{E_i}) = 20 + 8 = 28 > 0$

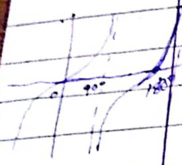
> 0 outside polygon

dot product > 0 then outside polygon else inside polygon



Another method





~~if (m1 && m2 > 0) {~~ ~~if (m2 < m ...)~~ ~~m1 > m~~

0 → outside
i → inside

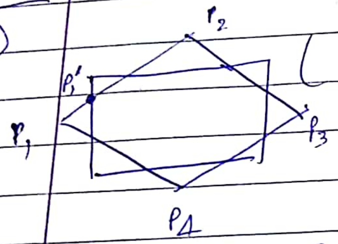
~~if (d.y - d.y > 0) {~~

subject Polygon list

i/p vertices list

P_1
P_2
P_3
P_4
P_1

we are seeing here only wrt left Edge (not as whole clipping window)



i/p vertices list	left Edge	o/p
P_1		
P_2	0 → i	P_1'
P_3	i → i	P_2
P_4	i → i	P_3
P_1	i → 0	P_4

repeat the first vertex

$x_I = xw_{min}$

$P_1' \to (x_I, y_I) \quad y_I = y_1 + \left(\frac{y_2 - y_1}{x_2 - x_1}\right)(x_I - x_1)$

SUTHERLAND HODGMAN RULES

P_1 → P_1'
P_2 → P_2
P_3 → P_3
P_4 → P_4
P_1 → P_4'

P_1'

Rule	$P_I \xrightarrow{Rules} P_j$
i → 0	Intersection (I)
0 → i	① Intersection point (I) ② second vertex (P_j)
i → i	second vertex (P_j)
0 → 0	- Nil -

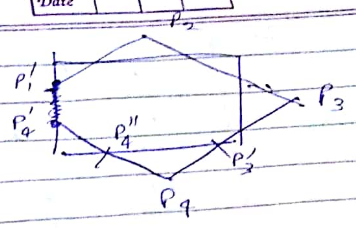
following it

case (I)

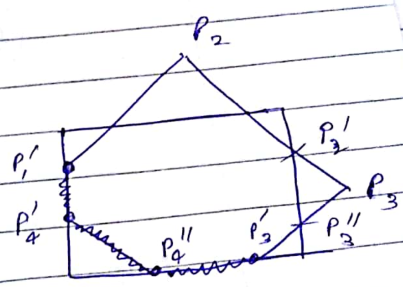
i/p		left Edge output
P_1		P_1'
P_2	0→i	P_2
P_3	i→i	P_3
P_4	i→i	P_4
P_1	i→0	P_4'
		P_1'

Now this output becomes input for next Edge

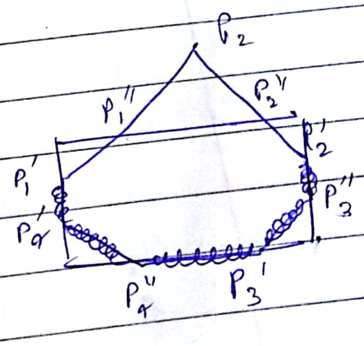
i/p		bottom edge
P_1'	$i \to i$	P_2
P_2	$i \to i$	P_3
P_3	$i \to o$	P_3'
P_4	$o \to i$	P_4''
P_4'	$i \to i$	P_4'
P_1'		P_1'
		P_2



i/p		right edge
P_2	$i \to o$	P_2'
P_3	$o \to i$	P_3''
P_3'	$i \to i$	P_3'
P_4''	$i \to i$	P_4''
P_4'	$i \to i$	P_4'
P_1'	$i \to i$	P_1'
P_2		P_2
		P_2'



i/p		top edge o/p
P_2'	$i \to i$	P_3''
P_3''	$i \to i$	P_3'
P_3'	$i \to i$	P_4''
P_4''	$i \to i$	P_4'
P_4'	$i \to i$	P_1'
P_1'	$i \to o$	P_1''
P_2	$o \to i$	P_2''
P_2'		P_2'
		P_3''



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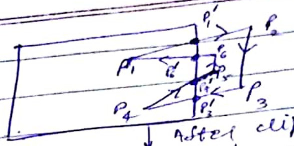
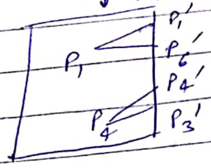


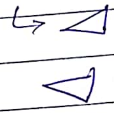
Case (2)

i/p	Right Edge
$P_1 \to P_2$ (i→o)	P_1'
$P_2 \to P_3$ (o→o)	
$P_3 \to P_4$ (o→i)	P_3', P_4
$P_4 \to P_5$ (i→o)	P_4'
$P_5 \to P_6$ (o→o)	
$P_6 \to P_1$ (o→i)	P_6', P_1
	P_1'

after clipping



Output expected



Received here

Thus, we need to modify

	Bit	Traversed
P_1'	1	0
P_3'	0	0
P_4	0	0
P_4'	1	0
P_6'	0	0
P_1	0	0
P_1'	0	0

we have set Bit=1 wherever there was i→o

intersection points occur only with i→o or o→i

step (2) (Filter intersection points)

P_1'
P_3'
P_4'
P_6'

sort acc to decreasing y coordinate

P_1'
P_6'
P_4'
P_3'

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	Bit	Traversal
P_1'	1	0
P_3'	0	0
P_4	0	0
P_4'	1	0
P_6'	0	0
P_1	0	0
P_1'	1	0

Traversal = 0 means not yet traversed

we start from here

~~we~~

P_1'
P_6'
P_4'
P_3'

Since bit = 1 here, we go to the filtered array

	Bit	Traversal
P_1'	1	~~0~~ 1
P_3'	0	~~0~~ 1
P_4	0	~~0~~ 1
P_4'	1	0
P_6'	0	~~0~~ 1
P_1	0	~~0~~ 1
P_1'	1	~~0~~ 1

P_1'
P_6'
P_4'
P_3'

~~we do~~
line (P_1', P_6')
& set traversal $P_1' = 1$
and check for P_6'
now

For P_6' traversal = 0 & Bit = 0, thus we make
P_6' and P_1
line (P_6', P_1)
line (P_1, P_1')

When we reach P_1', we have already traversed P_1' in line (P_1', P_6'), thus we traverse till we reach a Traversal = 0 i.e. P_3'

line (P_3', P_4)
line (P_4, P_4')

At P_4' Traversal = 0 but Bit = 1, Hence move to filtered array

line (P_4', P_3')

Now when we go to P_3', it has already Traversal = 1.
We again go in loop to check if Traversal = 0 anywhere
since its not we end here

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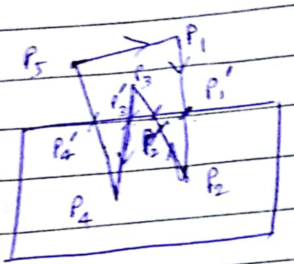
Finally → line (P_1', P_6') line (P_3', P_4)
line (P_6', P_1) line (P_4, P_4')
line (P_1, P_1') line (P_4', P_3')

CASE 3



$P_1 \xrightarrow{} $ 0→i
$P_2 \xrightarrow{} $ i→o
$P_3 \xrightarrow{} $ o→i
$P_4 \xrightarrow{} $ i→o
$P_5 \xrightarrow{} $ o→o
P_1

Top edge
P_1'
P_2
P_2',
P_3'
P_4
P_4'

P_1'

	Bit	Trav
P_1'	0	~~0~~ 1
P_2	0	~~0~~ 1
P_2'		~~0~~ 1
P_3'	0	~~0~~ 1
P_4	0	~~0~~ 1
P_4'		~~0~~ 1
P_1'	0	~~0~~ 1

filter
P_1'
P_2'
P_3'
P_4'

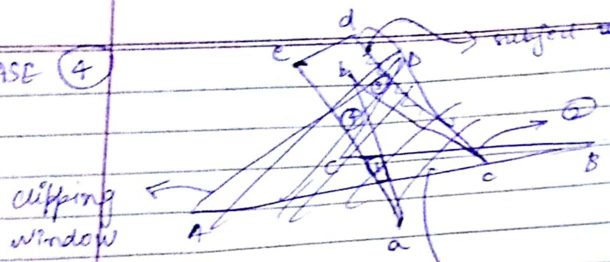
sort acc to ~~x axis~~ coordinate
decreasing

P_1'
P_2
P_3'
P_4'

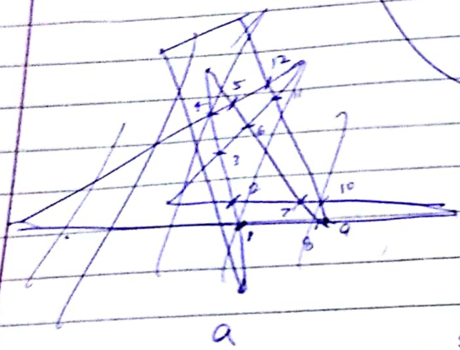
1) line (P_1', P_2)
2) line (P_2, P_2')
3) line (P_2', P_3')
4) line (P_3', P_4)
5) line (P_4, P_4')
6) line (P_4', P_1')

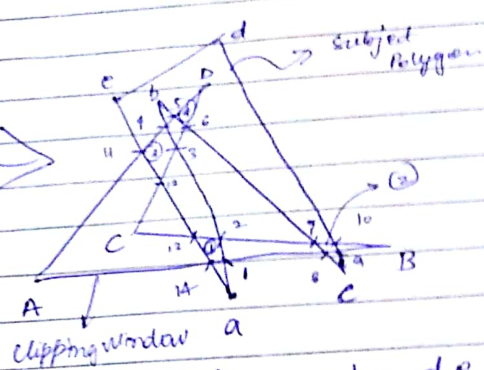
Weiler Atherton

CASE 4



4 areas that will be visible



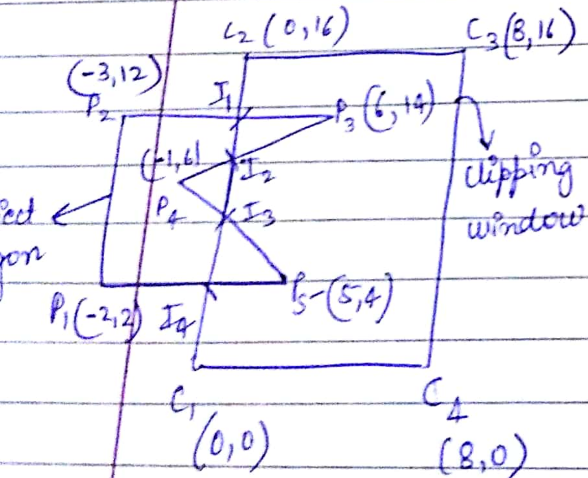


subject Polygon (SP) → a b c d e

CW → A B C D

SP → a 1 2 3 4 b 5 6 7 8 c 9 10 d e 11 12 13 14

CW → A 1



Weiler Atherton

$$t = \frac{N_i \cdot (P_1 - f_i)}{-(P_2 - P_1) \cdot N_i}$$

Edge	Normal	$P_i f_i$
$C_1 C_2$ $(16\hat{j})$		
$P_1 P_2$ $(-1\hat{i} + 10\hat{j})$	$-10\hat{i} - \hat{j}$	$-2\hat{i} + 2\hat{j}$
$P_2 P_3$ $(9\hat{i} + 2\hat{j})$	$-2\hat{i} + 9\hat{j}$	$-3\hat{i} + 12\hat{j}$
$P_3 P_4$ $(-7\hat{i} - 8\hat{j})$	$8\hat{i} - 7\hat{j}$	$6\hat{i} + 14\hat{j}$
$P_4 P_5$ $(6\hat{i} - 2\hat{j})$	$2\hat{i} + 6\hat{j}$	$-\hat{i} + 6\hat{j}$
$P_5 P_1$ $(-7\hat{i} - 2\hat{j})$	$2\hat{i} - 7\hat{j}$	$5\hat{i} + 4\hat{j}$

$C_2 - C_1 = 16\hat{j}$

$C_1 - P_{E_i}$	$N_i \cdot (C_1 - P_{E_i})$	$N_i(C_2 - C_1)$		t
$2\hat{i} - 2\hat{j}$	$-20 + 2 = -18$ ~~Enter~~	-16	Entering	$18/16 = 9/8$
$3\hat{i} - 12\hat{j}$	$-6 - 108 = -114$ ~~entering~~	144	Exit	$114/144 = 57/72 = \left(19/24\right)$
$-6\hat{i} - 14\hat{j}$	$-48 + 98 = 50$	-112	Enter	$50/112 = \frac{25}{56}$
$\hat{i} - 6\hat{j}$	$2 + 36 = 38$ ~~exit~~ ~~enter~~	96	exit	$\frac{\cancel{34}\,17}{\cancel{96}\,48}$
$-5\hat{i} - 4\hat{j}$	$-10 + 28 = 18$ ~~enter~~ ~~exit~~	-112	Entering	$18/112 = \frac{9}{56}$

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$t\left(\frac{19}{24}, \frac{30}{112}, \frac{1}{12}, \frac{9}{16}\right)$

$\frac{19}{24} \downarrow$ Entry, $\frac{1}{12} \downarrow$ Entry

step ① SP → P_1 P_2 P_3 P_4 P_5

CW → C_1 C_2 C_3 C_4

step ② a) Intersection points evolve
b) Entry / Exit note

Using t values we arrange the points and ~~mark the entry &~~ exit

Entry points are ~~tagged with~~ ① & exit with ⓪

step ③ SP → P_1 P_2 I_1 P_3 I_2 P_4 I_3 P_5 I_4

(① above I_1, ⓪ above I_2, ① above I_3, ⓪ above I_4)

CW → C_1 I_4 I_3 I_2 I_1 C_2 C_3 C_4

(① below I_4, ⓪ below I_3, ① below I_2, ⓪ below I_1)

Here we write opp of SP

We sorted using t values as C_1C_2 is the ~~clip~~ cline to be clipped for our subject polygon as clipping window

Entry list $\{I_1, I_3\}$
we start from a point

step ④ line (I_1, P_3) (traversing on subject polygon)
line (P_3, I_2) (I_2 is exit point so move to CW)
line (I_2, I_1) (traverse on CW) ←
line (I_3, P_5) (traversing on SP)

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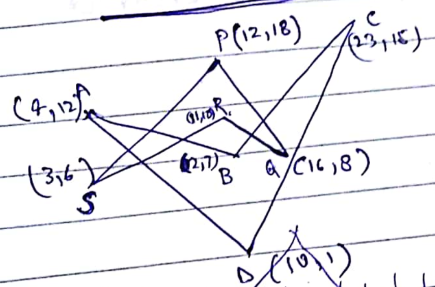
line (P_5, I_4) (~~then~~ I_4 is exit point so move to)

line (I_4, I_3) (traverse on CW)

Here we saw that I_1 is already visited thus we move to the next Intersection point in our Entry set.

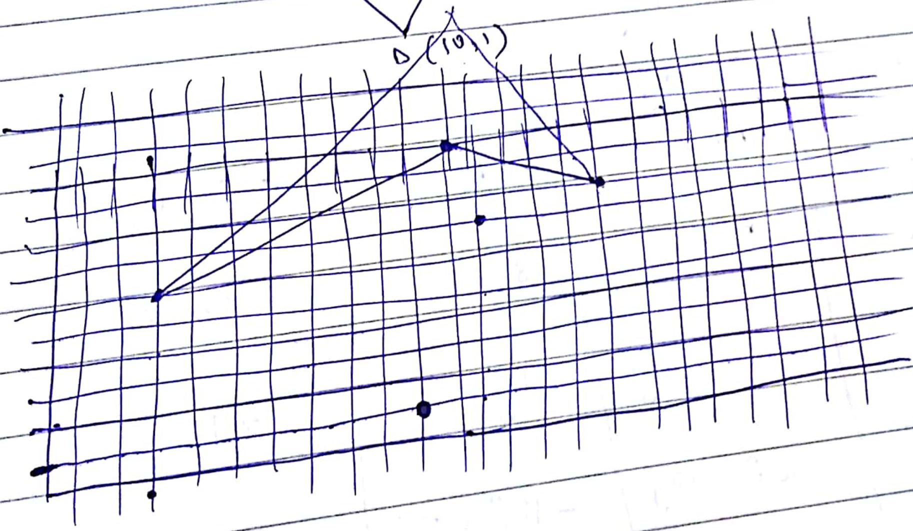
the same case is repeated here but since no more Intersection points in our Entry set, we conclude our process here.

Weiler - Atherton



ABCD → (Non rectangular window)

PQRS → Subject Polygon



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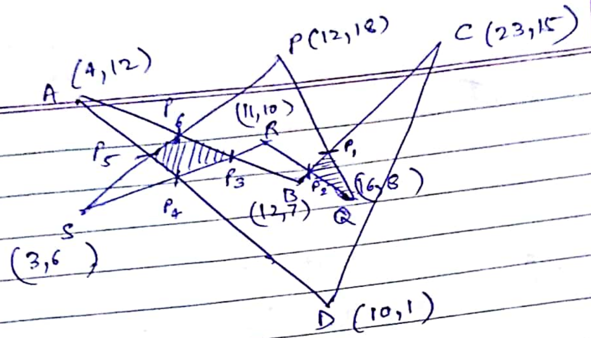

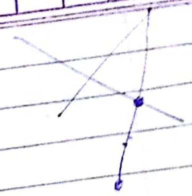

Step ① **input :** { CW A B C D ; SP P Q R S }

Method :

Step ② intersection point is evolved

PQ	$4\hat{i} - 10\hat{j}$
AB	$8\hat{i} - 5\hat{j}$
BC	$11\hat{i} + 8\hat{j}$
CD	$-13\hat{i} - 14\hat{j}$
DA	$-6\hat{i} + 11\hat{j}$

PQ $4\hat{i} - 10\hat{j}$

Edges	Normal	$C_1 - P_{t_i}$	$N_i \cdot (C_1 - P_{t_i})$	$N_i \cdot (C_2 - C_1)$
AB $8\hat{i} - 5\hat{j}$	$5\hat{i} + 8\hat{j}$	$8\hat{i} + 6\hat{j}$	$40 + 48 = 88$	$20 - 80 = -60$
BC $11\hat{i} + 8\hat{j}$	$-8\hat{i} + 11\hat{j}$	$11\hat{j}$	121	$-32 - 110 = -142$
CD $-13\hat{i} - 14\hat{j}$	$14\hat{i} - 13\hat{j}$	$-11\hat{i} + 3\hat{j}$	$-154 - 39 = -193$	$56 + 130 = 186$
DA $-6\hat{i} + 11\hat{j}$	$-11\hat{i} - 6\hat{j}$	$2\hat{i} + 17\hat{j}$	$-22 - 102 = -124$	$= -44 + 60 = 16$

SP : P P_1 Q

as entering

RS = $-8i - 4j$

Edges	Normal	$C_1 - P_{t_i}$	$N_i(C_1 - P_{t_1})$	$N_i(C_2 - C_1)$	t	Bites
AB $8i - 5j$	$5i + 8j$	$7i - 2j$	$35 - 16 = 19$	$-40 - 32 = -72$	Entering $19/72$	0
BC $11i + 8j$	$-8i + 11j$	$-i + 3j$	$8 + 33 = 41$	$64 - 44 = 20$	Exit $-41/20$	✗
CD $-13i - 14j$	$14i - 13j$	$-12i - 5j$	$-168 + 65 = -103$	$-112 + 52 = -60$	Entering $103/-60$	✗
AA $-6i + 11j$	$-11i - 6j$	$i + 9j$	$-11 - 54 = -65$	$88 + 24 = 112$	Exit $65/112$	1

as exit

$19/72$ $65/112$

P	P_1	Q		R	P_3	P_4	S
-1	0	-1		-1	0	1	-1

	Bit	t
~~Exit~~ Entering		✗ >1
~~Exit~~ Entering	0	$121/142$ → as entering
~~Entry~~ Exit		✗ >1
~~Entry~~ Exit		✗ >1

From here I am changing notation of entering/exiting by multiplying denominator by −1

SP = $9\hat{i} + 12\hat{j}$

Edge	Normal	$C_1 - P_t$		t	Bit
AB $8\hat{i} - 5\hat{j}$	$-5\hat{i} + 8\hat{j}$	$-\hat{i} - 6\hat{j}$		53/41	1
BC $11\hat{i} + 8\hat{j}$	$-8\hat{i} + 11\hat{j}$	$-9\hat{i} - \hat{j}$		−61/60	
CD $-13\hat{i} - 19\hat{j}$	$14\hat{i} - 13\hat{j}$			163/30	
DA $-6\hat{i} + 11\hat{j}$	$-11\hat{i} - 6\hat{j}$			47/171	0

SP:

					19/72	65/112		47/171	53/141
P	P_1	Q	P_2	R	P_3	P_4	S	P_5	P_6
−1	0	−1	1	−1	0	1	−1	0	1
0	0	0	0	0	0	0	0	0	0

Traversal bit

for P → Q → R → S

for A → B → C → D → A

SP → updated list

for A → B → C → D

~~for~~ for P → Q → R → S → P

CW → updated list

CW:

A	P_6	P_3	B	P_2	P_1	C	D	P_4	P_5
−1	0	1	−1	0	1	−1	−1	0	1
0	0	0	0	0	0	0	0	0	0

Traversal bit

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Step ③ →

P	P_1	Q	P_2	R	P_3	P_4	S	P_5	P_6
-1	0	-1	1	-1	0	1	-1	0	1
0	$\cancel{0}$ 1	$\cancel{0}$ 1	0	0	$\cancel{0}$ 1	$\cancel{0}$ 1	0	$\cancel{0}$ 1	$\cancel{0}$ 1

Jump 5

we now go here next as tag bit = 0 here

Jump 2

Jump 1

Jump 3

Jump 4

Jump 6

line (P_1, Q)

line (Q, P_2)

line (P_2, P_1)

line (P_3, P_4)

line (P_4, P_5)

line (P_5, P_6)

line (P_6, P_3)

A	P_6	P_3	B	P_2	P_1	C	D	P_4	P_5
-1	0	1	-1	0	1	-1	-1	0	1
0	$\cancel{0}$ 1	$\cancel{0}$ 1	0	$\cancel{0}$ 1	$\cancel{0}$ 1	0	0	$\cancel{0}$ 1	$\cancel{0}$ 1

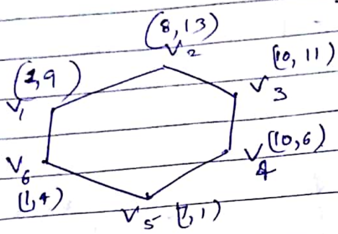
since tag bit = 0 has no longer any point where traversal = 0, thus we end

{ No more untraversed point in the entery set of Subject Polygon }

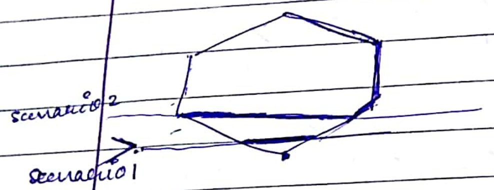
POLYGON FILLING

Approach - I

scanline — horizontal
— vertical
— or in any angle



cases: non-Horizontal Edges



Vertex can be

(I) Here y_{max} of both edges is same

(II) Here y_{min} of both edges is same

(III) $y_{min}E_1 = y_{max}E_2$ or $y_{max}E_1 = y_{min}E_2$

Here y_{max} of one edge is same y_{min} of other edge

In (I) and (II), we just put the vertex

In (III), we start illumination

GLOBAL EDGE TABLE

Structure → Edge

y_{max}	$x_{y_{min}}$	$1/m$	→

Example for V_5-V_6 here

4	7	-2	→

BOTTOM TO TOP

$y_{i+1} \rightarrow y_i + 1$

$x_{i+1} \rightarrow x_i \pm 1/m$

all others are set to λ

(we only store unique edges & do not repeat any edge)

for polygon given

$y_{max} = 13$ → λ

11 → [13 | 10 | -1 | →] → λ (V_2V_3)

9 → [13 | 1 | 3/4 | →] → λ (V_1V_2)

6 → [11 | 10 | 0 | →] → λ (V_3V_4)

4 → [9 | 1 | 0 | →] → λ (V_6V_1)

3 → λ

2 → λ

$y_{min} = 1$ → [4 | 7 | -2 | →] → [6 | 7 | 3/5 | →] → λ

V_5V_6 V_5V_4 NULL

We kept V_5V_6 before V_5V_4 as we are going from left to right

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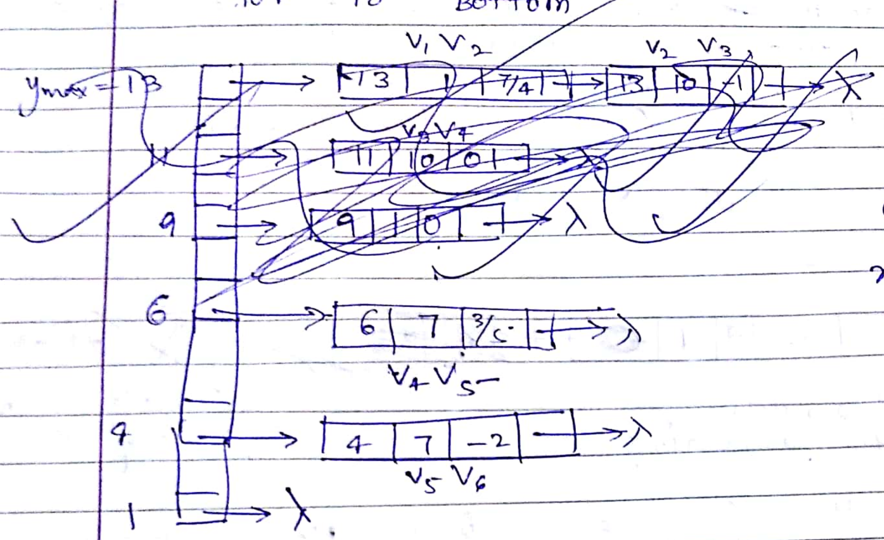
TOP TO BOTTOM



This is correct

$y_{i+1} \to y_i - 1$

$x_{i+1} = x_i \pm 1/m$

Active Edge Table (AET) [For filling the polygon]

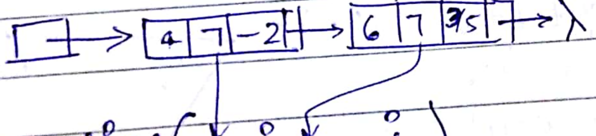
Using Bottom to Top

It starts with an empty node & ends with an empty node

□ → NULL

for $i \to y_{min}$ to y_{max}

$\vec{i} = 1$

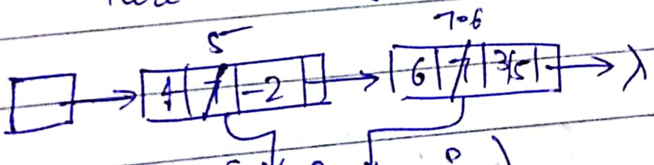


line(, i, , i)

Rules

1. merge
2. If nodes are old, update them
   $x_{i+1} \to x_i \pm 1/m$
   draw line

$\vec{i} = 2$ Here no merge req as no edge



line(, i, , i)

we delete ~~the~~ any node when $i = y_{max}$ of any of ~~the~~ the two nodes taken

$i=3$ → [ ] → [4 | ~~2~~ 3 | -2 |] → [6 | ~~7.6~~ 8.2 | 3/5 |] → λ

line(, i, , i)

$i=4$ → [ ] → [9 | 1 | 0 |] → ~~[4 | 8.2 | 3/5]~~ → [4 | ~~2~~ | -2 |] → [6 | 8.2 | 3/5] → λ

we delete the node where $y_{max} = i$

when we add a node we maintain the ascending order of x_{ymin}

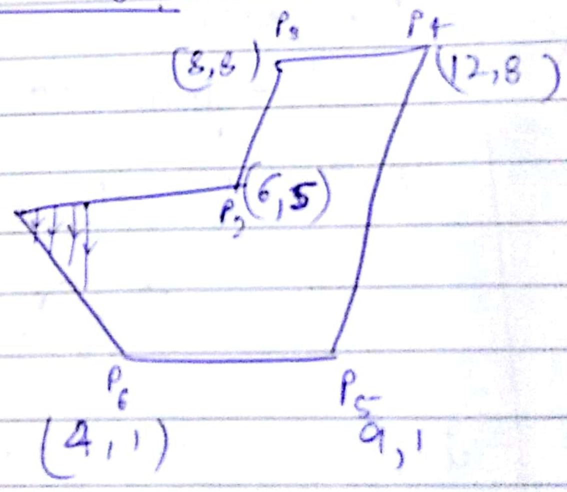
only [6 | 8.2 | 3/5] is old Hence, we only update this node.

[ ] → [9 | 1 | 0 |] → [6 | 8.8 | 3/5 |] → λ

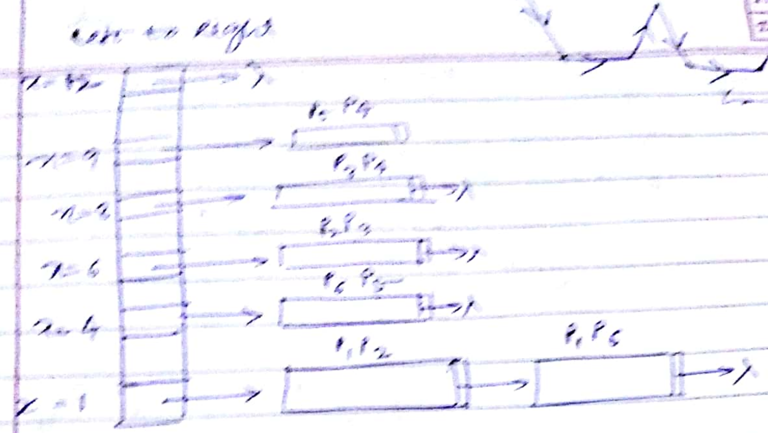
Scanline Polygon Filling

Vertical Scanning

Scanning top to bottom vertical scanning (starting from the left side to right) of polygon



Edge → [x_{max} | y_{xmin} | m] →



Active Edge Table   Rules/steps

1. Merge
2. Update (if node are the previous one)
3. Delete (if node (first member element) = i)
4. Draw line

We start with an empty node and must end with an empty node. Start with empty node bcs if no polygon there no edge.
In the end, we have traversed all edges & hence no edge left to traverse.

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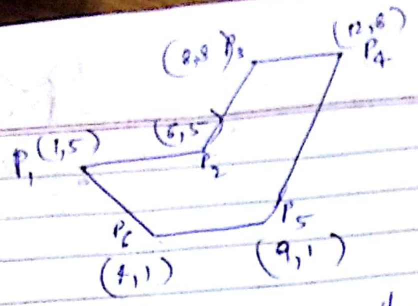
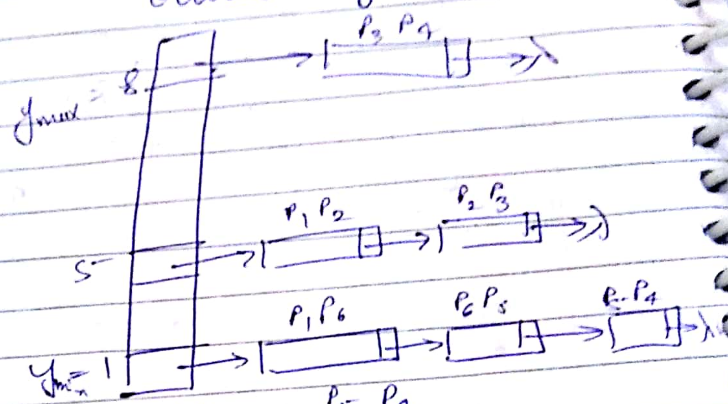
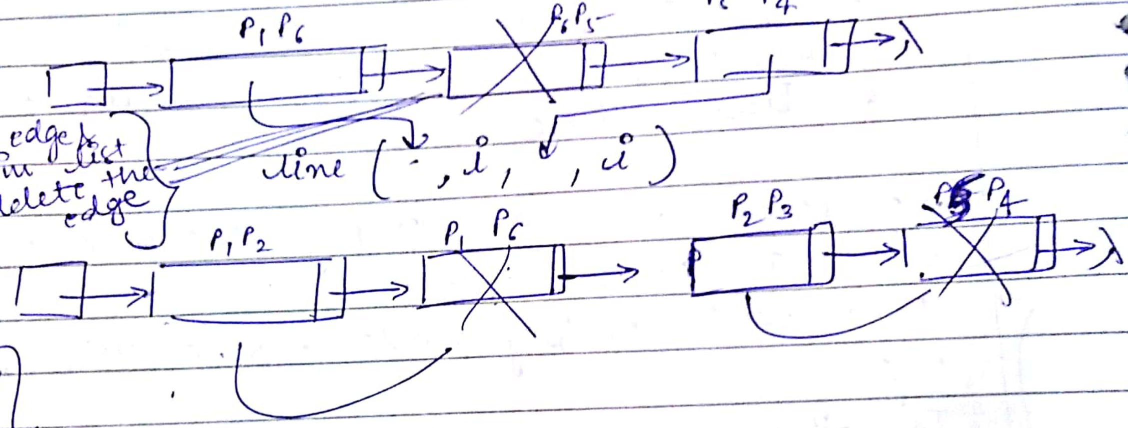
Horizontal Scanning



Global Edge Table

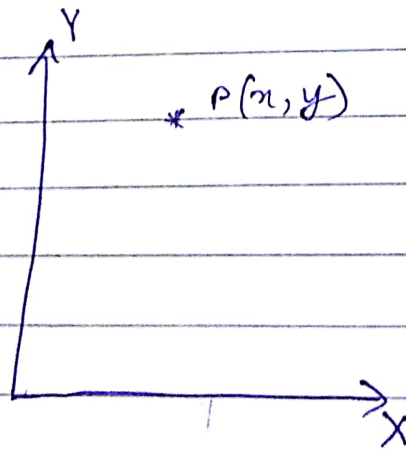




{Check horizontal edge & its position in list if even, delete the edge}

{Here position is odd for horizontal edge}

2D Transformation



- Translation
- Scaling
- Rotation

Translation, Scaling } Animation

Scaling, Rotation } → wrt a point

$$\begin{pmatrix}x'\\y'\\1\end{pmatrix} = \begin{pmatrix}1&0&\Delta x\\0&1&\Delta y\\0&0&1\end{pmatrix}\begin{pmatrix}x\\y\\1\end{pmatrix}$$

Translation

$x' = x + \Delta x$ $\qquad y' = y + \Delta y$ $\qquad \begin{bmatrix}x'\\y'\end{bmatrix} = \begin{bmatrix}1 & \Delta x\\ \Delta y & 1\end{bmatrix}\begin{bmatrix}x\\y\end{bmatrix}$

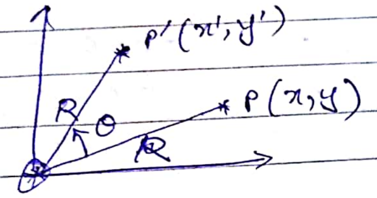
Scaling $\qquad S_x \qquad S_y$

multiplication operator

$$\begin{bmatrix}x'\\y'\end{bmatrix} = \begin{bmatrix}S_x & 0\\0 & S_y\end{bmatrix}\begin{bmatrix}x\\y\end{bmatrix} \qquad \boxed{x' = S_x \cdot x \qquad y' = S_y \cdot y}$$

Rotation

anticlockwise rotation as +ve



$R\sin\alpha = y$

$R\cos\alpha = x$

$R\sin(\theta+\alpha) = y'$

$R(\sin\theta\cos\alpha + \sin\alpha\cos\theta) = y'$

$x\sin\theta + y\cos\theta = y'$

$R\cos(\theta+\alpha) = x'$

$R(\cos\theta\cos\alpha - \sin\theta\sin\alpha) = x'$

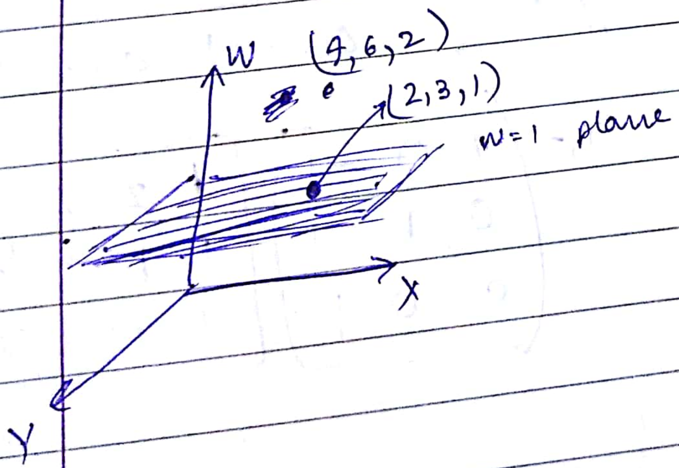
$x\cos\theta - y\sin\theta = x'$

$\cancel{2\times 2}$ 2×1

$$\begin{bmatrix}\cos\theta & -\sin\theta\\ \sin\theta & \cos\theta\end{bmatrix}\begin{bmatrix}x\\y\end{bmatrix} = \begin{bmatrix}x'\\y'\end{bmatrix} \qquad \{P' = R_\theta * P\}$$

2D plane → 3 vector

To homogenise



Homogenous Coordinate System

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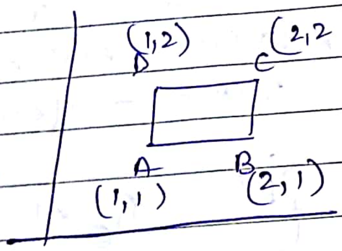
Translation $\rightarrow$ $\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & \Delta x \\ 0 & 1 & \Delta y \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$

Scaling $\rightarrow$ $\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$

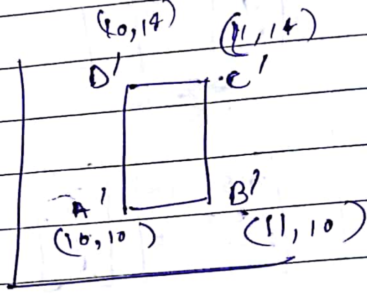
Rotation $\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$

Example

I/P

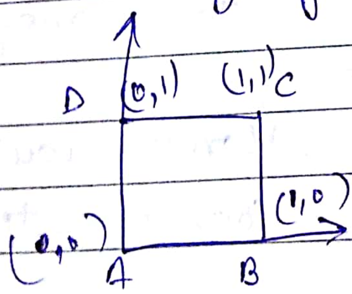


$\longrightarrow$ O/P



Everything is done wrt origin

Step 1 Bringing to Origin $\Delta x = -1$ $\Delta y = -1$

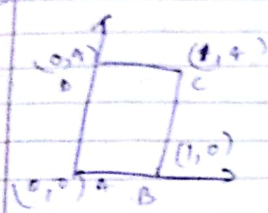


$T_1 = \begin{pmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{pmatrix} \begin{bmatrix} 1 & 2 & 2 & 1 \\ 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 1 \end{bmatrix}$

{ Check result should give }

ax + by + cz = d

Step (2) Scale $\quad S_x = 1, \; S_y = 4$

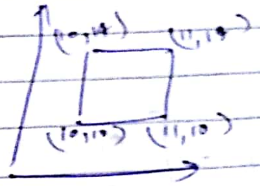


$$S_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Step (3) Bring A ~~to~~ all w.r.t. (10,10)

$\Delta x = \Delta y = 10$

$$T_2 = \begin{bmatrix} 1 & 0 & 10 \\ 0 & 1 & 10 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 4 & 4 \\ 1 & 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 10 & 11 & 11 & 10 \\ 10 & 10 & 14 & 14 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$



~~$T_1 \rightarrow S \rightarrow T_2$~~

$C = T_2 \, S \, T_1$

$\longleftarrow$

as $(T_2(S(T_1 \text{ Origin})))$

$$C = \begin{bmatrix} 1 & 0 & 10 \\ 0 & 1 & 10 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 10 \\ 0 & 1 & 10 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 \\ 0 & 4 & -4 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 9 \\ 0 & 4 & 6 \\ 0 & 0 & 1 \end{bmatrix}$$

Final result $= \begin{bmatrix} 1 & 0 & 9 \\ 0 & 4 & 6 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 2 & 1 \\ 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 1 \end{bmatrix}$

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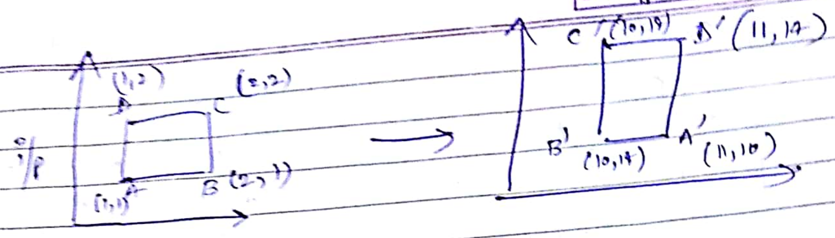
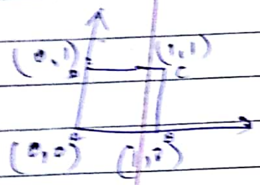
Example ②



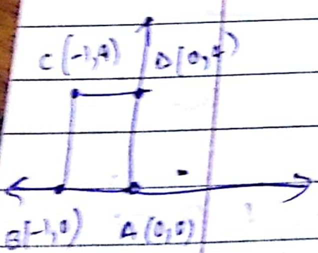
Step ① Translate to origin $\Delta x = -1 \quad \Delta y = -1$

$$T_1 \rightarrow \begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 2 & 1 \\ 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$



② scale by $\Delta x = -1 \quad \Delta y = 4$

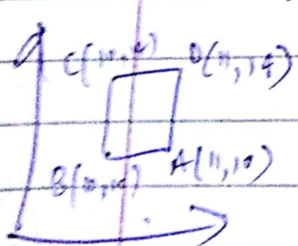
$$S = \begin{bmatrix} -1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 0 & -1 & -1 & 0 \\ 0 & 0 & 4 & 4 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$



③ Translate B & all to (10,10)

$\Delta x = 11 \quad \Delta y = 10$

$$T_2 \rightarrow \begin{bmatrix} 1 & 0 & 11 \\ 0 & 1 & 10 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & -1 & -1 & 0 \\ 0 & 0 & 4 & 4 \\ 1 & 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} 11 & 10 & 10 & 11 \\ 10 & 10 & 14 & 14 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$



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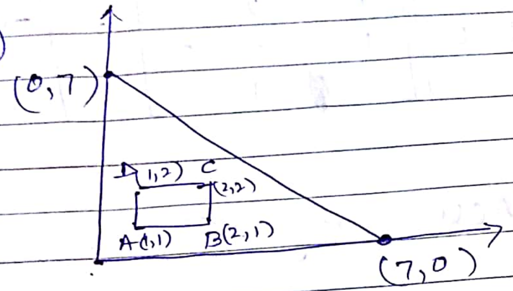
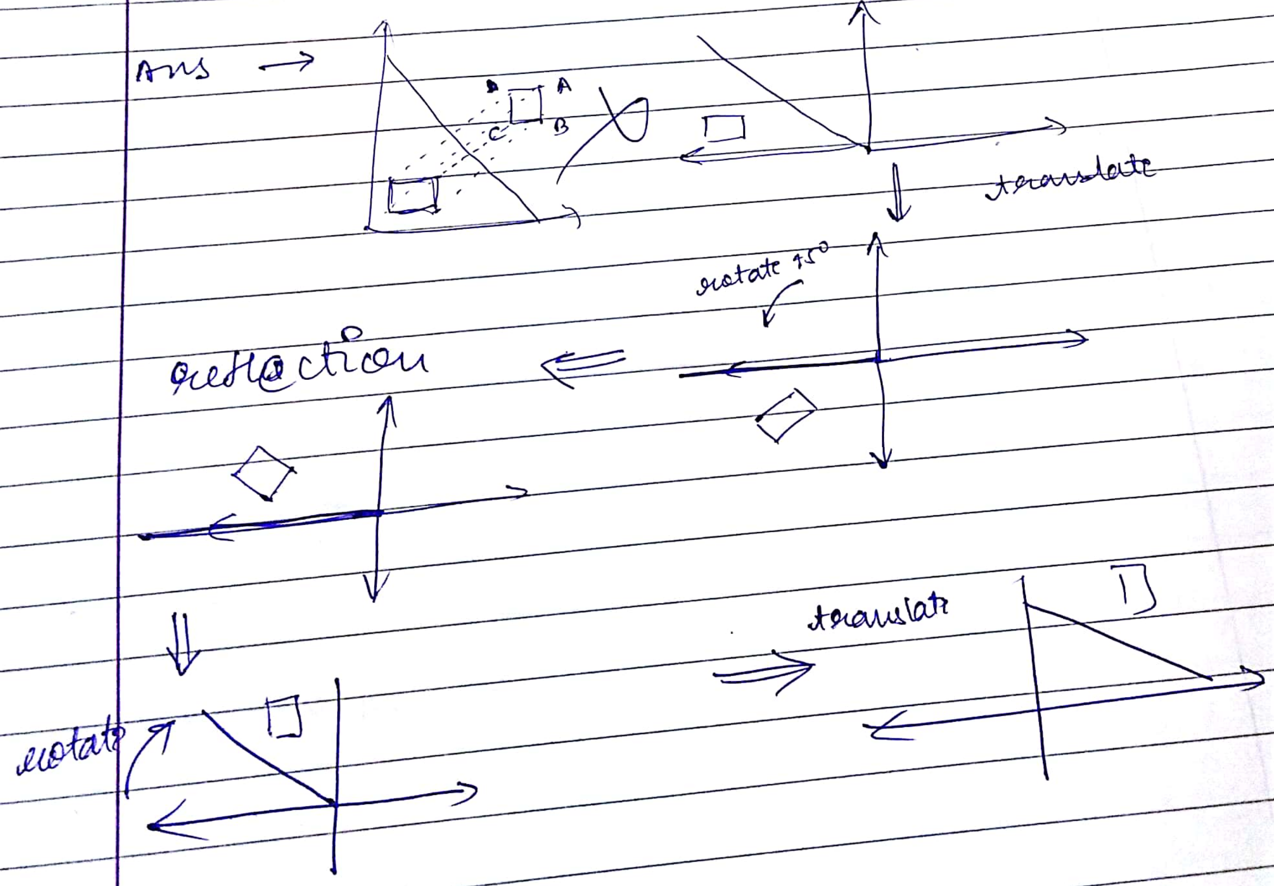
$$C = T_2 \, S \, T_1 = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}\begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}\begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}$$

Example 3



Find mirror image of ABCD about the given line

Ans →



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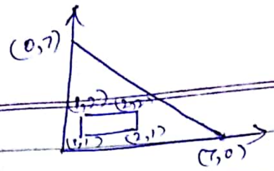
$x + \Delta x$
$y + \Delta y$

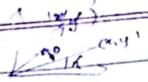
$R\cos\alpha = x \quad R\sin\alpha = y$

$R(\cos\theta\cos\alpha - \sin\theta\sin\alpha) = x'$

$x\cos\theta - y\sin\theta = x'$

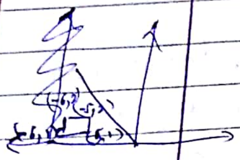
$x\sin\theta + y\cos\theta = y'$





step ① Translate all by $\Delta x = -7 \quad \Delta y = 0$

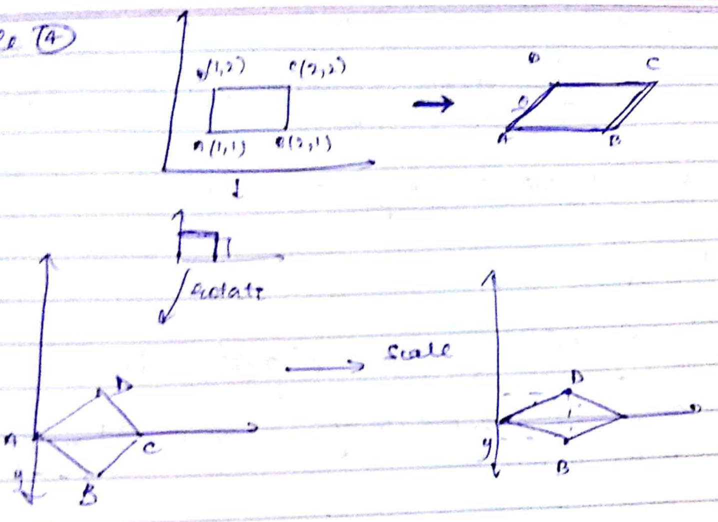
$$T_1 = \begin{bmatrix} 1 & 0 & -7 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 2 & 2 & 1 \\ 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 1 \end{bmatrix} = \begin{bmatrix} -6 & -5 & -5 & -6 \\ 1 & 1 & 2 & 2 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$



step ② Rotate ACW by 45°

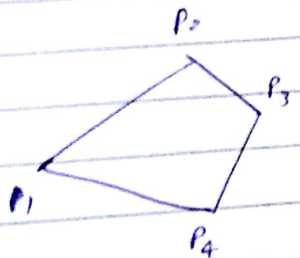
R_1

Example (4)



Given object
Sqr ABCD

SEED FILL (POLYGON FILLING)



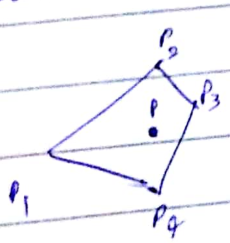
seed point has to be inside

point inside_poly_point ( ){

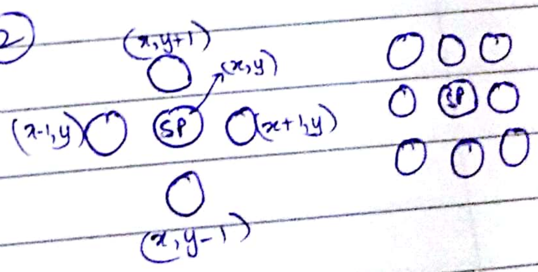
}

step ① Finding a seed point

If concave polygon, break it into convex polygon.



step ②



void seedfill (color, background color, boundary color, S.P. (x,y))

{ (color, bg color, boundary color, S.P)

we can remove bg color as it is constant

~~seedfill (~~

void seedfill (color, bkg clr, boundary clr, x,y)

condition for exiting { if (seed(x,y) == color || seed(x,y) == boundary color)

exit

recursive function { seedfill (c, bkg, boundary color, x+1, y)
seedfill ( )
.
.
.

}