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Notes

Computer Graphics

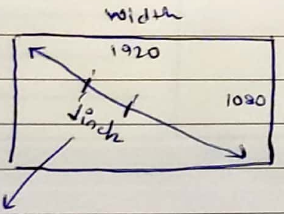
A pixel (Picture element) is the smallest unit of info in an image in 2D space.
Intensity of each pixel is variable.

Pixel → Red (8 bits)
→ Green (8 bits) 3 Byte
→ Blue (8 bits)

→ $2^8 \; 2^8 \; 2^8 = 2^{24}$ shades of color

let say image ~~size~~ res. is 1000×750
= 750 000 Pixels = $7.5 \times 10^5 \times 3$ bytes

Image Resolution: Width × Height
x pixel × y pixel
1920 × 1080



PPI Pixel Per Inch $1920^2 + 1080^2 = x^2$
(Pixel Density) $x = \frac{2205}{5x} = 440$ PPI
($x = 5$)

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Aspect Ratio: Ratio of width to height

Vector / Random scan display: [Dia]
→ Vector scan is a technique used for producing images on screen.
→ Beam is directed to the area where picture is to be drawn.
→ The display buffer memory stores the 'display list' which contains point & line plotting cmds with (x, y) or (x, y, z) char as well char plotting cmds.
→ Phosphorus light decays after few milli-second so ∴ we have to refresh phosphorus at least 30-60 times per second i.e 30-60 fps.

Adv:
→ High resolution than raster scan
→ Produces smooth line.
→ Needs less memory to store picture defin

Dis:
→ Can't draw realistic image.
→ limitation on clops to be displayed (Mx

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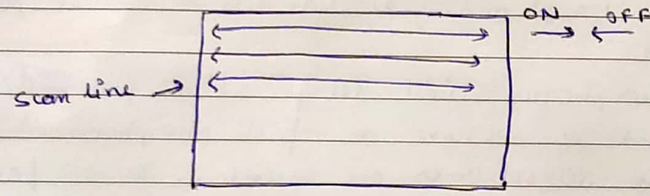
Raster Scan Display

→ Displayed image is stored in form of 0/1 in the refresh buffer.

→ Frame buffer holds Intensity value of Pixel.

→ The video controller reads the refresh buffer & produces the Actual image on the screen.

→ It does this by scanning one line at a time, from top to bottom & then back to top.



Vector scan V/S Raster scan.

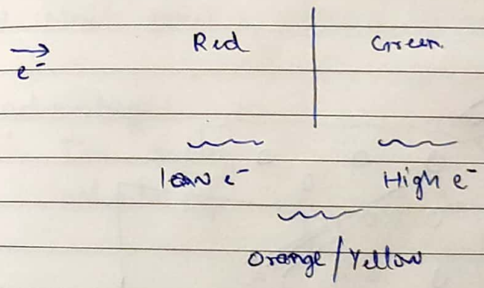
Beam Penetration Technique

→ Normal CRT can generate images of single color due to limitation of Phosphor coating.

→ It generates a range of colors by combining the emitted light from multilayered Phosphor coated color crt.

→ 2 Techniques for producing colour display.
- Beam Penetration Tech.
- Shadow Mask Tech.

Beam Penetration tech. is used with Vector Scan → 2 layers of phosphor



→ Inexpensive.

→ Only 4 colors and not good quality.

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Shadow Mask CRT

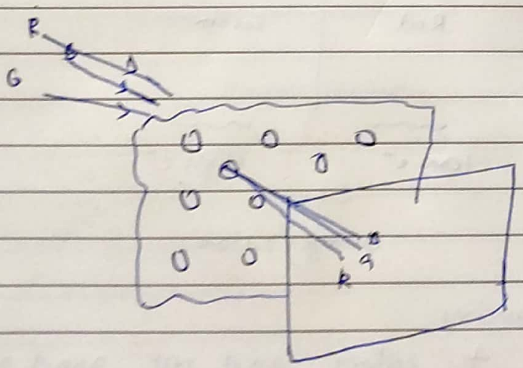
→ Used in Raster scan & produces wide range of color.

→ 3 phospor dot of RGB at each Pixel position, emits corresponding color.

→ 3 e^- beam one for each color & shadow mask grid just behind coated screen.

→ 3 e^- beam are deflected & focussed as a group on shadow mask & excite a dot Δ By passing hole.

- 1 beam activate only 1 corresponding clr.



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→ Line Drawing Algorithm.
- Line basic concepts
- Incremental method. of line drawing
- Direct Method of Line Drawing
- DDA (Digital Differential Analyzer
- Bresenham's Line Drawing.
- All numerical

→ ~~Circle Drawing Algo.~~

Brute Force line Algo:

(1) Compute m.
(2) $x_i' = x+1$ $y_i = mx_i + c$.
(3) Next pixel = $(x_i, \text{round}(y_i))$

Disadvantage:

! Too many floating points calculation required in each iteration.

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→ [Digital Differential Analyser (DDA)]

$y_i = mx_i + b$

$y_i = m(x_{i-1} + 1) + b$

$y_i = y_{i-1} + m$ $\qquad$ $x_i = x_{i-1} + 1$

Algo:

$(x_1, y_1) \rightarrow (x_2, y_2)$
start $\qquad$ End

$dx = x_2 - x_1$
$dy = y_2 - y_1$ $\quad$ | change in x, y

if abs(dx) > abs(dy)
 step = |dx|
else $\qquad$ } # of iteration.
 step = |dy|

$x_{inc} = \frac{dx}{step}$, $y_{inc} = \frac{dy}{step}$

Plot (x_1, y_1)
for (i=1 → steps)
 $x = x + x_{inc}$ $\qquad$ $y = y + y_{inc}$
 Plot (x, y)

dv: No floating point ~~application~~ on multiplication

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Ex Draw line b/w (5,4) and (12,7)

$dx = 12 - 5 = 7$
$dy = 7 - 4 = 3$
$|dx| > |dy|$ $\qquad$ step = 7

$x_{inc} = \frac{7}{7} = 1$ $\qquad$ $y_{inc} = \frac{3}{7} = 0.4$

x_i	y_i	x_{i+1}	y_{i+1}
5	4	6	4.4 ~ 4
6	4.4	7	4.8 ~ 5
7	4.8	8	5.2 ~ 5
8	5.2	9	5.6 ~ 6
9	5.6	10	6 ~ 6
10	6	11	6.4 ~ 6
11	6.8	12	6.8 ~ 7

2. (2, 7) $\qquad$ (9, 1)

$dx = 9 - 2 = 7$
$dy = 1 - 7 = -6$
$|dx| > |dy|$ $\qquad$ step = 7

$x_{inc} = \frac{7}{7} = 1$ $\qquad$ $y_{inc} = \frac{-6}{7} = -0.8$

x_i	y_i	x_{i+1}	y_{i+1}
2	7	3	6.2
3	6.2	4	5.4
4	5.4	4	4.6

Ok whatever!

x_i	y_i	x_{i+1}	y_{i+1}
4	4.6	5	3.8
5	3.8	6	3.0
6	3.0	7	2.2
7	2.2	8	1.4
8	1.4	9	

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(3) # Bresenham's Line Drawing Algo :

Disadvantages of DDA
1) Floating point Addition
2) Round off function

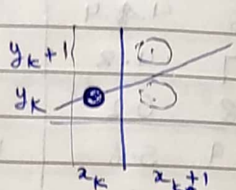
① $\boxed{0 < m < 1}$

$0 < \Delta y / \Delta x < 1$ $\quad \Delta y < \Delta x$

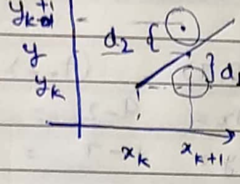
$(y_2 - y_1) < (x_2 - x_1)$

$x_k := x_k + 1$

$y_k := y_k + 1 \;/\; y_k$



choose the nearest pixel
min (d_2, d_1)



At $x_k \rightarrow y_k = m x_k + c$

$x_k + 1 \quad y_{k+1} = m\, x_{k+1} + c$

$= m(x_k + 1) + c$

y_{k+1} can be y_k or $y_k + 1$

$d_1 = y - y_k = (m\, x_{k+1} + c) - y_k$

$= (m(x_k + 1) + c) - y_k$

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$d_2 = (y_k + 1) - y$

$= y_k + 1 - m(x_k + 1) - c$

$d_1 = m(x_k + 1) + c - y_k$

$d_2 = y_k + 1 - m(x_k + 1) - c$

$d_1 - d_2 = 2m(x_k + 1) - 2y_k + 2c - 1$

Rearranging using slope equation to remove floating multiplication using $m = \Delta y / \Delta x$

$\underbrace{\Delta x (d_1 - d_2)}_{P_k} = \Delta x \left[2m(x_k + 1) - 2y_k + 2c - 1 \right]$

P_k (decision parameter)

$P_k = 2\Delta y x_k - 2\Delta x y_k + \underbrace{(2\Delta y + \Delta x(2c - 1))}_{\text{constant } (d)}$

$\boxed{P_k = 2\Delta y\, x_k - 2\Delta x\, y_k + d}$

$P_k < 0$: $d_1 < d_2$: Plot lower pix

$P_k > 0$ $\quad d_1 > d_2$: plot upper pix.

as Δx is positive $(0 < m < 1)$

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For (k+1) iteration

$$P_{k+1} = 2\Delta y\, x_{k+1} - 2\Delta x\, y_{k+1} + d$$

$$P_{k+1} - P_k = 2\Delta y\,(\cancel{x_{k+1} - x_k}) - 2\Delta x\,(y_{k+1} - y_k)$$

$$P_{k+1} - P_k = 2\Delta y - 2\Delta x\,(y_{k+1} - y_k)$$

$$\boxed{P_{k+1} = P_k + 2\Delta y - 2\Delta x\,(y_{k+1} - y_k)}$$

↳ +ve $\quad y_{k+1} = y_k + 1$

↳ −ve $\quad y_{k+1} = y_k$

$$d_1 - d_2 = 2m(x_k + 1) - 2y_k + 2c - 1$$

$$P_0 = \Delta x\,[\cancel{2m x_0} + 2m - \cancel{2y_0} + \cancel{2c} - 1]$$

$$P_0 = \Delta x\,[2m - 1]$$

$$\boxed{P_0 = 2\Delta y - \Delta x}$$

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Algorithm

(1) Find Δx, Δy, $2\Delta y$, $2\Delta y - 2\Delta x$

$\Delta x = |x_2 - x_1| \qquad \Delta y = |y_2 - y_1|$

(2) Calculate $P_0 = 2\Delta y - \Delta x$

(3) Start at iteration $k = 0$,

at each x_k, do the following

if $P_k < 0$

plot $(x_k + 1, y_k)$

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

else

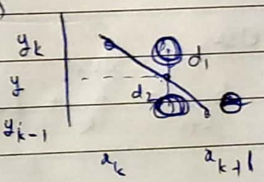
plot $(x_k + 1, y_k + 1)$

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

(4) Repeat steps Δx no. of times.

(symmetry about line)

$-1 < m < 0$



$d_1 = y_k - y$

$d_2 = y - y_{k-1}$

$y_{k-1} = y_k \mid y_k - 1$

$d_1 - d_2 < 0 \quad y_k$

$> 0 \quad y_k - 1$

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$\Delta x(d_1 - d_2) = \Delta x\,[2y_k + 2\Delta y + 2m - 2b - 1]$

$P_k = 2\Delta x\, y_k + 2\Delta y\, x_k + c$

$P_{k+1} = 2\Delta x\, y_{k+1} + 2\Delta y\, x_{k+1} + c$

$\boxed{p_0 = 2\Delta y - \Delta x}$

$P_{k+1} = P_k + 2\Delta y - 2\Delta x\,[y_k - y_{k+1}]$

$p_k < 0 \quad y_{k+1} = y_k$

$p_{k+1} = p_k + 2\Delta y$

else $\quad y_{k+1} = y_k - 1$

$p_{k+1} = p_k + 2\Delta y - 2\Delta x$

Result same hi h, consider it a mirror image about $y=0$. just d_1 and d_2 changes. u know.

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Midpoint Circle Algo

→ 8 way symmetry : OCTANTS.

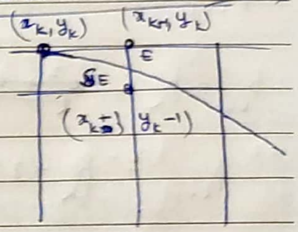
$(\pm\mp x, \mp\pm y)$ $(\pm\mp y, \mp\pm x)$

Brute force

$\forall x$, find y i.e. $y = \sqrt{r^2 - x^2}$

where $0 < x < r$

Disadv → sq rt calculations.



$E = x_k + 1,\ y_k$

$SE = x_k + 1,\ y_k - 1$

M → Mid Point.

We decided pixel by choosing nearest distance of r' to M

$x^2 + y^2 - r^2 = 0$ (on circle)

< 0 (inside)

> 0 (outside)

We can check for mid point

$x_m^2 + y_m^2 - r^2 = 0$ choose E / SE

< 0 choose E

> 0 choose SE

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Midpoint $= \left(x_k + 1 , y_k - \frac{1}{2} \right)$

decision boundary

$p_k = x_m^2 + y_m^2 - r^2$

$= (x_k + 1)^2 + \left(y_k - \frac{1}{2}\right)^2 - r^2$

$p_{k+1} = $ ——

Solve

$p_{k+1} - p_k = \cancel{x_k^2 + 4 + 4x_k}$

$p_{k+1} = p_k + 2x_k + 3 + y_{k+1}^2 - y_{k+1} - y_k^2 + y_k$

$p_k < 0 \quad y_{k+1} = y_k$

$p_{k+1} = p_k + 2x_k + 3$

$p_k > 0 \quad y_{k+1} = y_k - 1$

$p_{k+1} = p_k + 2x_k - 2y_k + 5$

first point $(0, r)$

$p_0 = (0+1)^2 + (r - 1/2)^2 - r^2$

$= 5/4 - r$

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r is radius , centre is origin

Steps:

(1) Plot $(0, r)$

(2) $p_0 = \frac{5}{4} - r$ (Initial decision Parameter)

(3) If $p_i < 0$, then

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

$y_{i+1} = y_i$

$p_{i+1} = p_i + 2x_i + 3$

(4) $p_i \geq 0$, then

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

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

$p_{i+1} = p_i + 2(x_i - y_i) + 5$

(5) Repeat (3,4) until $x \geq y$.

(6) Plot in remaing 7 octants

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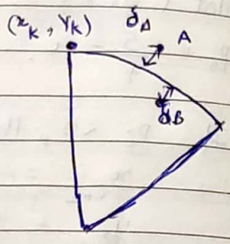
Bresenham's circle Drawing algorithm:

~~d_A~~ =



$A = (x_k + 1, y_k)$

$B = (x_k + 1, y_k - 1)$

$d_A = \sqrt{(x_{k+1})^2 + y_k^2}$

$d_B = \sqrt{(x_k + 1)^2 + (y_k - 1)^2}$

$\delta d_A = d_A - r$

$\delta d_B = d_B - r$ (-ve)

\# only Integral calculations in Bresenham's.

$\delta_A' = dA^2 - r^2$ $\delta_B^2 = dB^2 - r^2$

Decision Parameter: $\delta_A' + \delta_B'$

+ve if $\delta_A' > \delta_B'$ (choose B)

-ve $\delta_A' < \delta_B'$ (choose A)

$P_k = \delta A' + \delta B'$

$= (dA^2 - r^2) + (dB^2 - r^2)$

$= (x_k + 1)^2 + y_k^2 + (x_k + 1)^2 + (y_k - 1)^2 - 2r^2$

$P_k = 2(x_k + 1)^2 + y_k^2 + (y_k - 1)^2 - 2r^2$

$P_{k+1} = 2(x_{k+1} + 1)^2 + y_{k+1}^2 + (y_{k+1} - 1)^2 - 2r^2$

$P_{k+1} - P_k$ = simplify $x_{k+1} \to x_k + 1$

$P_{k+1} = P_k + 4x_k + 2(y_{k+1}^2 - y_k^2) - 2(y_{k+1} - y_k) + 6$

if $P_k < 0$ choose A

$P_{k+1} = P_k + 4x_k + 6$

else choose B

$P_{k+1} = P_k + 4x_k - 4y_k + 10$

$(0, r)$

$\boxed{p_0 = 3 - 2r}$

Steps :

→ Determine r, ensure circle at origin

→ First pixel at $(0, r)$

→ $P_0 = 3 - 2r$

→ Repeat $(x \le y)$

If $P_k < 0$

$$P_{k+1} = P_k + 4x_k + 6$$

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

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

Else

$$P_{k+1} = P_k + 4(x_k - y_k) + 10$$

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

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

Plot (x_{k+1}, y_{k+1})

→ Other octants.

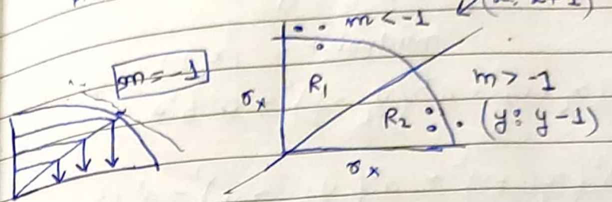
For center X_c, Y_c

$$x'_{k+1} = x_{k+1} + X_c$$

$$y'_{k+1} = y_{k+1} + Y_c$$

Mid point Ellipse

→ 4 way symmetry. (Quadrants)



→ on boundary slope of curve = -1

~~$r_y^2 x^2 + r_x^2 y^2 -$~~

$$b^2x^2 + a^2y^2 - a^2b^2 = 0.$$

$$\frac{dy}{dx}\left(b^2x^2 + a^2y^2 - a^2b^2\right) = 0.$$

$$\Rightarrow \frac{dy}{dx}(y^2) = \frac{dy}{dx}\left(\frac{a^2b^2 - b^2x^2}{a^2}\right)$$

$$\Rightarrow 2y\frac{dy}{dx} = -\frac{2b^2x}{a^2}$$

$$y' = -\frac{b^2}{a^2}\frac{x}{y} \quad \text{] slope}$$

$m = 1$ $\quad b^2x = a^2y$

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

Notes

Region 1 $\quad y_{k+1} = y_k , \; y_k - 1$

$Eq = b^2x^2 + a^2y^2 - a^2b^2 = 0$

midpoint = $(x_k + 1 , \; y_k - 1/2)$

$p_k = b^2(x_k+1)^2 + a^2\left(y_k - \frac{1}{2}\right)^2 - a^2b^2$

$p_{k+1} = b^2(x_{k+1}+1)^2 + a^2\left(y_{k+1} - \frac{1}{2}\right)^2 - a^2b^2$

$p_{k+1} - p_k = b^2\{2(x_k+1)+1\} + a^2\{y_{k+1}^2 - y_k^2 - y_{k+1} + y_k\}$

y_{k+1}

$p_k < 0 : y_k$

$p_k \geq 0 : y_k - 1$

$p_k < 0 : \quad p_{k+1} = p_k + b^2\, 2x_{k+1} + b^2$

$p_k \geq 0 : \quad p_{k+1} = p_k + 2x_{k+1} b^2 + b^2 - 2y_{k+1} a^2$

Initial point for R_1 = $(0, b)$

$p_0 = b^2 + a^2/4 - ba^2$

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Region 2 $\quad x_{k+1} = x_k \; / \; x_k + 1$

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

mid point = $\left(x_k + \frac{1}{2} , \; y_k - 1\right)$

$p_k = b^2\left(x_k + \frac{1}{2}\right)^2 + a^2(y_k - 1)^2 - b^2a^2$

$p_{k+1} - p_k = b^2\{x_{k+1}^2 + x_{k+1} - x_k^2 - x_k\} + a^2(1 - 2y_{k+1})$

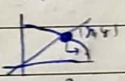
if $p_k > 0$: $x_{k+1} = x_k$

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

$p_{k+1} = p_k - 2y_{k+1} a^2 + b^2$

$p_k \leq 0$: $x_{k+1} = x_k + 1$

$p_{k+1} = p_k + b^2(2x_{k+1}) - 2y_{k+1} a^2 + a^2$



last point of Region 1

$p_0 = b^2\left(x + \frac{1}{2}\right)^2 + a^2(y-1)^2 - a^2b^2$

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Algo

~~Region~~ $a, b,$

$dx = 2b^2 x \qquad dy = 2a^2 y$

Region 1

$p_0 = b^2 + a^2/4 - ba^2$

while ($dx < dy$)

plot (x_k, y_k)

($p_k < 0$) {

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

$y_{k+1} = y_k$

$p_{k+1} = p_k + b^2 2x_{k+1} + b^2$

}

($p_k \geq 0$) {

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

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

$p_{k+1} = p_k + 2x_{k+1} b^2 + b^2 - 2y_{k+1} a^2$

}

$p_k = p_{k+1}$

$x_k = x_{k+1}$

$y_k = y_{k+1}$

$dx = 2b^2 x_{k+1}$

$dy = 2a^2 y_{k+1}$

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$p_0 = b^2(x+1/2)^2 + a^2(y-1) - a^2 b^2$

Region 2

while ($y > 0$) {

Plot (x_k, y_k)

($p_k > 0$)

$x_{k+1} = x_k$

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

$p_{k+1} = p_k - 2y_{k+1} a^2 + b^2$

else

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

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

$p_{k+1} = p_k + b^2(2x_{k+1}) - a^2 2y_{k+1} + a^2$

$p_k, x_k, y_k, dx, yy.$

$dx = 2x_k b^2 \qquad dy = 2a^2 y_k$