K. Sneka

III - BSc(CS)



# COMPUTER GRAPHICS

CG represents the creation and manipulation [Modification, Deleting, Adding, and Altering] of pictures with the help of a computer system. There are two forms of CG.

**I. Non-interactive or Passive form**

In this case the user has no control over the image.

Ex: Advertisement displays, Television display.

**II. Interactive**

User is given some control over the image.

Ex: Working with Page Maker, Paint, Flash

## CG SYSTEM COMPONENTS

**1. Digital memory or Frame buffer**

The memory area in which the displayed image stored as a matrix of intensity values. [zero for black, one for white]

**2. Display device**

To display the image on the screen. Ex: Monitor

**3. Display controller**

It is the interface between the display device and frame buffer. It converts the zero's and one's into corresponding video signal.

## APPLICATIONS OF CG

CG are used in science, medical, engineering, business, industries, government, art, entertainment, advertising, education and graph oriented presentations.

**1. Computer Aided Design(CAD)**

The major use of CG is in design process particularly for engineering and architectural system is called as CAD.

The methods are used for designing the building, automobiles, air craft, spacecraft, computers, textiles and many other products. Animation are often used with CAD applications.

The manufacturing process is also tied into the computer description of designed objects to automate the construction of the products. ie, called Computer Aided Manufacturing(CAM).

Architects use CG methods to layout floor plans and positioning of room, doors, windows and other building features.

Ex:.Auto desk's Auto CAD, 3D Home, Pro-Engineer.

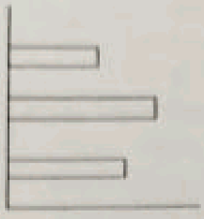
**2. Presentation Graphics**

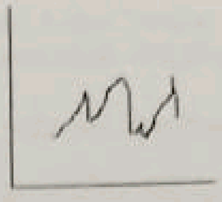
PG are used to produce illustrations for reports or to generate slides or transparencies used with the projectors.

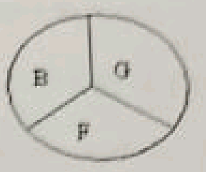
These are used for summarize financial, statistical, mathematical, scientific, economic, managerical reports and other types of reports.

Ex of PG are .bar chart, line chart, pie chart and other display showing the relationship between multiple parameters.

**Bar chart** **line graph** **pie chart**








Ex: MS-power point,. Macro Media -Flash

**3. Computer art**

The CG is used in both fine art and commercial art applications.

Ex: **Fine art:** Lumena

**Commercial art:**

Adobe photo shop, Corel draw, Corel paint, Photo finish, Adobe page maker

**4. Entertainment**

CG are used in making motion pictures, music, videos, television shows, advertisements and game designing.

Ex: Macro Media – Director, Dream weaver, Video, and Maya.

**5. Education and training**

CG models are used in physical system and economic as education tools. Models of physiological system, population trends or equipment such as color coded diagram can help trainees to understand the operations of the system.

Ex 1. Flight simulators 2. Space simulators 3. Car driving simulators.

**6. Visualization**

Producing graphical representation for scientific, engineering and medical data sets and process is generally referred to as scientific *visualization.*

Business visualization is used in connection with data sets related to commerce, industries, and other non scientific areas.

Mathematicians, scientists and others use visual techniques to analyze mathematical functions and processes or simply to produce interesting graphical representations.

Ex: Mathematical- Math CAD.

**7. Image processing**

Image processing is technique used for producing visual displays with various effects from a photograph or from a video clip.

Morphing: is a image processing technique used to produce a transformation of one person or object into another.

The applications of image processing are

1. Improving the picture quality. Ex : Photo Re-touching.
2. Machine perception of visual information are used in robotics.

3. Medical Applications.

a) Computed X-Ray tomography (CT scan)
b) Position emission tomography (PET)
c) Ultra sonic scanner
d) Nuclear medical scanners
e) Computer Aided Surgery
f) Model and study the physical functions.

**8. Graphical User Interface (GUI)**

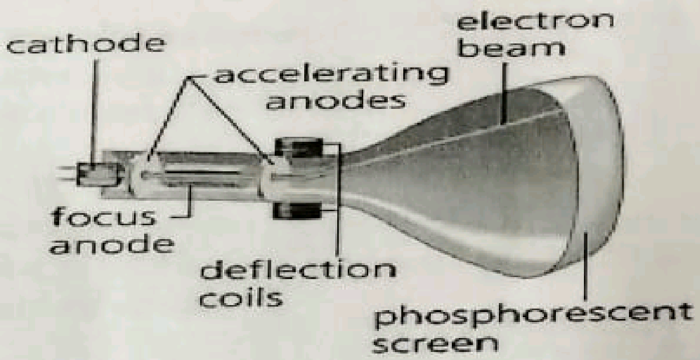
Now most of the software packages provides graphical user interface. Ex: MS-Office Package.

The major component of a GUI is a window manager that allows the user to display multiple window areas.

Icon is a graphical symbol. That is designed to look like the processing option it represents.

## CATHODE RAY TUBE (CRT)

The primary output device used in CG is a video monitor. The operation of the monitor is based on the CRT.




**Operation of CRT**

A beam of electrons [cathode Rays] emitted by an electron gun, passes through focusing and deflection system that direct the beam to the specified position on the phosphor screen that emits a small spot of light at each position contacted by the electron beam.

To keep the phosphor glowing, re-draw the picture repeatedly by quickly directing the beam back over the same points. This type of displays is called Refresh CRT.

The main component of the CRT is the electron gun. It has a heated metal cathode and a control grid. Heat is applied to the cathode by directing a current through the filament inside the cathode structure. The negatively charged electrons are then accelerated towards the phosphor screen by a high positive voltage.

### *Focusing system*

It is used to force the beam to converge into a small spot as it strikes the phosphor. Focusing is done with either electric or magnetic fields.

### *Deflection system*

The deflection system of the beam can be controlled by either with electric or magnetic fields. In some types of CRT, Magnetic deflection coils are mounted on the outside of the CRT. Two pairs of coils are used with the coils in each pair mounted on opposite sides of the neck of the CRT. In some type of CRT, the deflection system is built within the CRT. Horizontal deflection is done with one pair of plates and vertical with other pair of plates. Deflection amounts are obtained by adjusting the current through the coils or plates.

### *Phosphor*

Different kinds of phosphors are used in the CRT. The major difference between the phosphors is their persistence [how long they continue to emit the light]. A phosphor with low persistence is used for animation. A high persistence phosphor is useful for displaying highly complex and static picture.

### *Pixel*

* The smallest Picture element.
* Each screen point.
* Picture Element. [Pel]

### *Resolution*

The maximum number of points that can be displayed without over lap on a CRT is called as resolution. ie, resolution is the No. of points that can be plotted Horizontally and vertically.

Ex

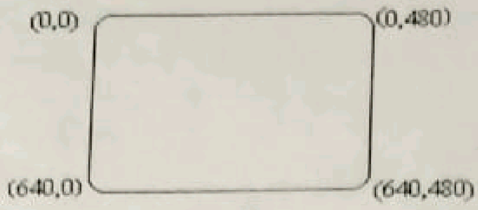
1024 * 1024 – high resolution monitor.
640 * 480 – medium resolution monitor.

### *Physical size*

Physical size of the monitor is varying from 12 inches to 27 inches.

### *Aspect ratio*

Is the number gives the ratio of vertical points and horizontal points necessary to produce equal length of lines in both directions on the screen. For ex ¾ means that a vertical line plotted with 3 points has the same length as a horizontally line plotted with 4 points.




***Frame buffer***

Picture definition stored in a memory area is called as frame buffer or Refresh buffer. This memory area holds the set of intensity values for all the screen points. The intensity values stored in a memory are retrieved and displayed on the screen one row at a time is called scan line.

On a black and white system with one bit per pixel, the frame buffer is called bit map. [0 for black, 1 for white]

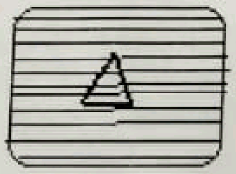
A system with 24 bits per pixel and a screen resolution of 1024 * 1024 requires 3 MB storage for the frame buffer.

For a system with multiple bits per pixel, the frame buffer is called pix map.

***Raster scan display***

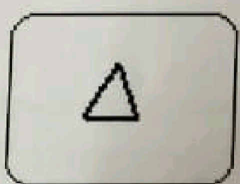
In a raster scan display system, the electron beam is directed across the screen one row at a time from top to bottom.

Ex: Television set.



***Random scan display***

In this type of system, the electron beam is directed only to the parts of the screen where a picture is to be drawn.



The Random scan monitor draw a picture one line at a time. Therefore it is called as vector displays or stroke writing displays.

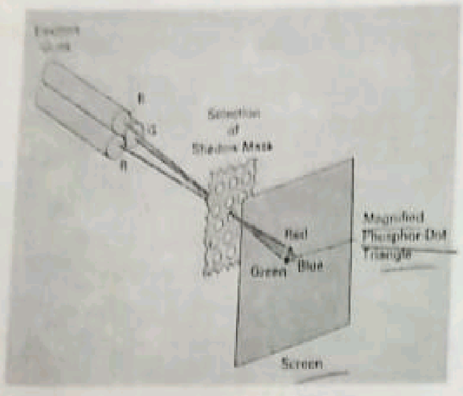
***Color CRT monitors***

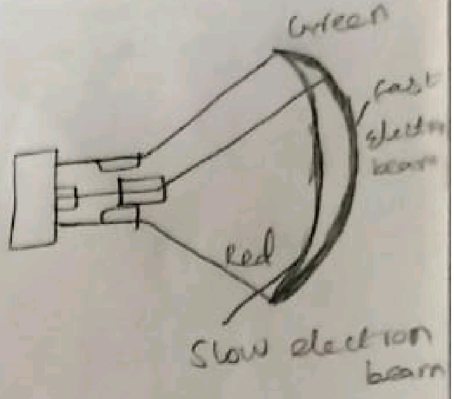
A CRT monitor displays color pictures by using a combination of phosphor that emit different colored light. There are two basic techniques are used in color CRT.

1. Beampenetration method.
2. Shadow mask method.

**1. Beam penetration method** → Multi layer phosporus

This method is used for displaying color picture in random scan monitors. Two layers of phosphor, usually red and green coated on the inside of the CRT screen.



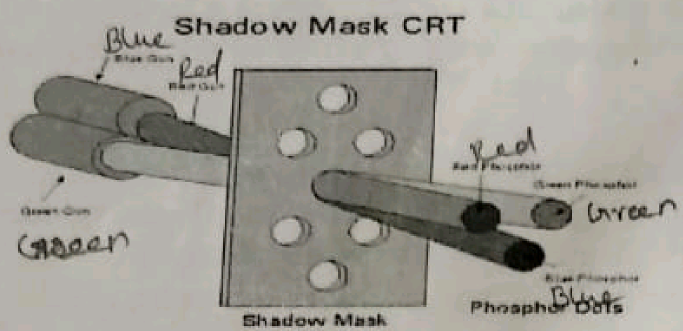




A beam of slow electrons strikes only the outer red layer. A beam of very fast electrons penetrates through the red layer and strikes the inner green layer. For an intermediate beam, combinations of red and green light are emitted to show two additional colors orange and yellow. The speed of electrons is controlled by the beam acceleration voltage.

Advantages: Less expensive

Disadvantages : Only four colors are possible. Quality of the picture is not so good.

**Shadow mask method**



This method is used in the raster scan systems. It consists of three phosphor color dots at each pixel position. One phosphor dot is used for red color another for green and the third one for blue color [RGB].

This type of CRT has three electron guns, one for each color dots and a shadow mask grid just behind the screen. The three electron beams are deflected and focused as a group on to the shadow mask which contains a series of holes aligned with the phosphor dots.

With the three beam pass through the hole, they activate dot triangle, which appears as a small spot on the screen. The phosphor dots in the triangle are arranged so that each electron beam can strikes only its corresponding color dots. It is called as delta arrangement. We obtain color variations in the CRT by varying the intensity levels of three [RGB] electron beams.

**Color table**

| R | G | B | COLOR |
|---|---|---|---|
| 0 | 0 | 0 | Black |
| 0 | 0 | 1 | Blue |
| 0 | 1 | 0 | Green |
| 0 | 1 | 1 | Cyan |
| 1 | 0 | 0 | Red |
| 1 | 0 | 1 | Magenta |
| 1 | 1 | 0 | Yellow |
| 1 | 1 | 1 | White |

Red
magenta
yellow

**Composite monitor**

These are adaptations of TV sets that allowed by pass of the broadcast circuitry. These display devices required that the picture information we combined, but no carrier signal is needed. Picture information is combined into a composite signal and then separated by the monitor, so the picture quality not so well.

**RGB monitor**

These monitor used with shadow mask methods and take the intensity levels for each electron guns. Directly from the computer system without any internal processing. An RGB with 24 bits of storage per pixel ($2^8$ X $2^8$ X $2^8$). Can have a choice of 17 million colors. This is called as full color system or true color system.

**Direct View Storage Tubes (DVST)**

An alternate method for maintaining and image on the screen by storing the picture information inside the CRT, instead of refreshing the screen.

The DVST stores the picture information as a charge of distribution just behind the screen. Two electron guns are used in the DVST. One is used to store the picture pattern. The second one is used to maintain the picture display.

Advantage:

No need of refreshing. Complex picture can be displayed without flickering.

Disadvantage:

Displaying color pictures are not possible. Selected parts of the picture cannot be erased.

**Flat panel displays**

This class of video devices has reduced volumes, weight and power requirements compared to a CRT. These type of devices are thinner than CRT and also we can hang them on walks. Two types: Emissive category, Non-emissive category.

**Emissive**

These display devices convert the electrical energy into light.

Ex: Plasma panels, thin- film electro luminescent display devices, light emitting diodes. [LED].

**Non-emissive**

These display devices use optical effects to the convert sunlight or light from other sources into graphic pattern .Ex: Liquid crystal display [LCD]

**Plasma panel**

These are also called gas discard displays. It is constructed by filling the region between two glass plates with a mixer of gasses. [usually neon gas]

A series of vertical conducting ribbons is plated on one side and a set of horizontal ribbons is placed on the other side. Firing voltages applied to a pair of horizontal and vertical conductors causes the gas at the intersection of two conductors t o break down into glowing plasma of electrons. Picture definitions stored in the refresh buffer and the firing voltages are applied to refresh the pixel positions 60 times per second.

Disadvantage: Only monochromatic display.

**Thin-film electroluminescent display**

The construction of these devices is similar to plasma panel. The difference is the region between the glass plates is filled with a phosphor [manganese and zinc sulphide] instead of gas. When a high voltages is applied to a pair of conductors the electrical energy is then observed by the manganese which than release the energy as a spot of light.

**Light Emitting Diodes [LED]**

The matrix form of diodes is arranged to form the picture information is stored in the refresh buffer. Picture information read from the buffer and converted to a voltage levels that are applied to the diodes to produce the display.

**Liquid crystal display [LCD]**

LCD's are mainly used tin lap-top and calculators. These non-emissive devices produce a picture by passing polarized light from the internal light source. Through a liquid crystal material that can be aligned to transmit the light.

The term liquid crystal refers to the fact that these components have a crystal line arrangement of moleculesThere are two types of LCD's

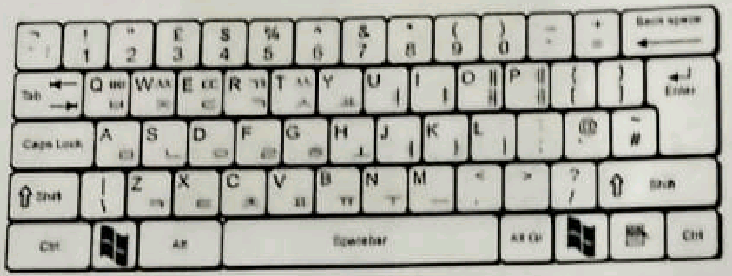
1. Active matrix LCD's
2. Passive matrix LCD's

**Input devices**

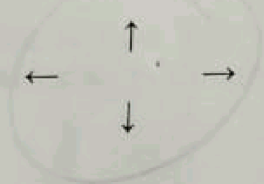
Various types of input devices are used in CG systems.

Ex: Key board, mouse, track ball, space ball, joystick, digitizers, H-panel, image scanner data glove, voice system.

**Key board**



It is primary input device for entering text. It is used for inputting non-graphical data as picture labels associated with graphics display. Function keys are used to enter frequently used operations (comments'). Cursor control keys



are used to select the displayed objects or positioning the screen cursor. Numeric pad is used for fast entry of numeric data. Additional keys are used for different types of special operations.

Ex: Windows key, internet explorer [IE]

**Mouse**

Mouse is a small hand held box used to position the cursor. Wheels or rollers on the bottom of the mouse are used to record the value and direction of movement. One, two or three buttons are usually included on the top of the mouse signaling the execution of some operation. The mouse is moved over a special mouse pad that has a grid of horizontal and vertical lines. Another method for detecting the mouse motion is with an optical sensor.

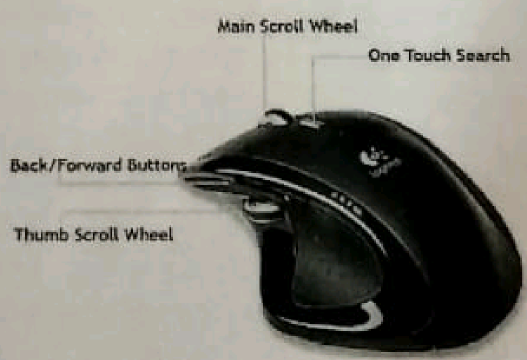
**Track ball**

The track ball is a ball that can be rotated with fingers t o produce cursor moments. Potential meters are attached with the ball to measure the amount and direction of rotation. These are usually placed on the key board or z-mouse.

**Space ball**

Space ball is similar to track ball which provides six degrees of freedom. It is used for 3-diemensional positioning modeling, CAD and other animation applications.

**Z – Mouse**

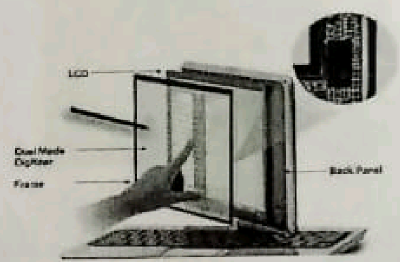


The Z-mouse has three buttons thump wheel on the side, a track ball on the top and a standards mouse ball. The design provides six degrees of freedom the select position, rotations and other parameters. Using Z– mouse, we can pick up an object, rotate it and move the object in any direction or we can navigate our viewing position and orientation through a 3-D scene. Z-mouse is usually used in virtual reality, CAD and animation applications.

**Joystick**

The joystick consist of a small vertical liver [stick] mounted on the base. It is used to steer the screen cursor. The distance that the stick is moved in any direction from its enter position. Correspondence to the cursor moment in the screen. Potantio meters are used to measure the amount of moment and springs are used to return the stick to the center position when it is released. These are mainly used in game playing.

**Digitizers**




These devisers are used for drawing painting or selecting an object. One type of digitizers is graphic tablet. [it is called as data tablet]. It is used to input 2-D co-ordinates by activating the hand cursor or stylus at selected positions on a flat surface stylus is a pen shaped device. ie, used to point the positions on the tablet. Hand cursor contains the cross hairs for select the sighting positions.

Artist digitizing system uses electro magnetic principles to detect the position of the stylus. The tablet size can be varies from 12 *12 inches to 44 *60 inches. The tablets are constructed with a rectangular rid of wires placed on the tablet surface. Electro magnetic plusses are generated in the wires and electro magnetic signals is included in the stylus to record the tablet position.

**Acoustic tablet [sound or sonic]**

Acoustic tablet uses sound waves to detect stylus positions. Either strip of micro phones or point microphones can be used to detect the sound generated by the stylus strip. The position of stylus is calculated by the timing of arrival of sounds at different microphones positions.

3-D digitizers use either sonic or electro magnetic transmission to record the positions.

**Image scanner**

Drawings, Graphs, color or black and white photos o text can be stored in a system using image scanner by the passing an optical scanning mechanism over the information to be stored. Once we have the internal representation of the picture, we can apply the transformations such as rotate, scale or cropping operations. There are two types of scanner:

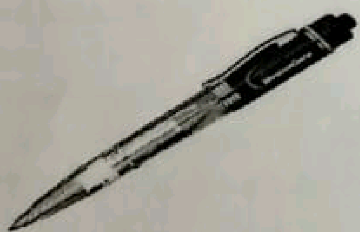
1. Hand held
2. Flat bed

**Touch screen (touch panels)**

The touch panels are used to select the displayed objects or screen position with the touch of a finger. It is mainly used in selecting of processing options that are represented with graphical icons. Touch panel input can be recorded using

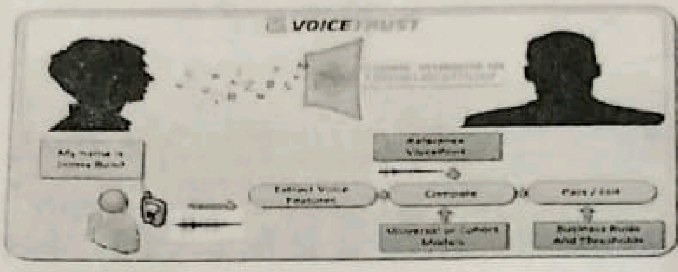
1) Optical
2) Electrical
3) Acoustic methods.

**Light pen**



It is a pencil shaped device used to select the screen positions by the detecting the light coming from the points on the screen. An activated light pen, pointed at a spot an the screen as the electron beam lights up that spots generate an electrical pulse. That causes the co-ordinate position to be recorded. Light pen co-ordinates can be used to position and object or to select a processing options.
Disadvantage: Unfilled screen portions cannot be detected.

**Voice system**




Speech recognizer's are used in graphic system as input devices to accept voice commands. The voice system input can be used to initiate graphic operations or to enter the data. These systems operated by matching and input against a predefined dictionary of words.

A dictionary is setup for a particular operator by having the operators speak the command words to be used in the system. Each word is spoken several times and the system analyses the word and stored the frequency pattern for the word. Voice input is usually spoken into a micro phones mounted on a headset. Voice systems have some advantages over other input devices. Since the attention of the operator does not have to be switched from one device to another to enter a command.

**OUTPUT PRIMITIVES**

In a graphics programming, we have functions to describe the picture by means of basic geometric structure. These structures are called as output primitives.

Ex Points, Lines, Curves, Circles, Polygon etc.

**Point plotting [point drawing]**

Point plotting is done by converting a co-ordinate position given by a program into appropriate pixel of the output device.

For example, In the case of CRT, a electron beam is turned on to glow the phosphor at the selected location.

Point plotting procedure

1) Setpixel (x, y, intensity) or Putpixel (x, y, intensity) It is used to draw a pixel on the screen. ie, it loads the intensity value into the frame buffer at position x,y. ex: putpixel (10,10,1) ie, the pixel (10,10) turned on.

2) Getpixel (x, y ): It is used to retrieve the current frame buffer intensity settings for the location x, y.
Ex: getpixel (10,10); will return the value 1.
getpixel (20,20); will return the value 0.

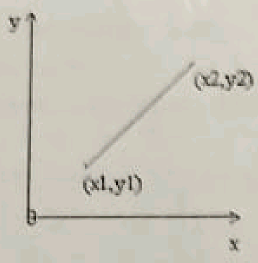
**Line plotting [line drawing]**

Line drawing is done by calculating the intermediate positions along the line path, between two specified end points. Then the output device is directed to fill these positions between the end points. The co-ordinates positions are calculated from the equation of the line.

Since the screen location are referenced with integer values. The line positions will be converted into integer pixel positions. For example (10.56, 12.3) is converted to (11, 12).

Rounding the values to integer causes the line displayed with a stair step appearance. This appearance can be smoothed by adjusting the pixel intensities along the line path.

A Line Equation is given by : $y = mx + c$




Where m is slope of the line and c is a constant.

For a line from (x1,y1) to (x2,y2) we have

$$M = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{\Delta Y}{\Delta X}$$

$y = mx + c$

$M = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta y}{\Delta x}$

**DDA line drawing algorithm** [DDA – Digital Differential Analyzers]

It is a scan conversion line algorithm based on calculating either Δy or Δx.

```
Procedure line DDA (x1,y1,x2,y2 : int)
Var
    dx,dy,steps,k : int;      x,y,xinc,yinc  : real;
Begin
    dx = x2-x1;     dy = y2-y1;
    if abs(dx) > abs(dy) then
        steps = abs(dx);
```

```
    else
       steps = abs(dy);
    xinc = dx/steps;  yinc = dy/steps;
    x = x1;           y = y1;
    putpixel (round (x),round (y), 1);
    for k = 1 to steps do
    begin
          x = x+xinc; y = y+yinc;
          putpixel (round (x), round (y), 1);
    end;
End.
```

Note

(x1,y1) is the starting point of a line.

(x2,y2) is the ending point of a line.

DDA is a fast method for calculating pixels then the direct use of the line equation.

Disadvantage :

1. Because of rounding operations some of the calculated pixel positions away from the true line path.
2. Floating point operations take much time.

**Example**

Generate a line between (10,10) to (20,18) to using DDA.

Given x1 = 10;  y1 = 10;  x2 = 20;  y2 = 18;

dx = 20 – 10;  = 10;  dy = 18 – 10;  = 8;

If abs(dx) > abs(dy)  Abs(10) > abs(8)

Steps = abs (10);

xinc = 10/10;  =1;  yinc = 8/10  = 0.8;

x = 10;  y = 10;  putpixel (10, 10, 1)

x1, y1, x2, y2 } dx = x2 - x1

If abs(dx) >

&+

| k | X | Y | Putpixel |
|---|---|---|---|
| 0 | 10 | 10 | (10,10) |
| Loop 1 | 10+1 =11 | 10+0.8 = 10.8 | (11,11) |
| 2 | 11+1 = 12 | 10.8+0.8 = 11.6 | (12,12) |
| 3 | 12+1 =13 | 11.6+0.8 = 12.4 | (13,12) |
| 4 | 13+1 = 14 | 12.4+0.8 =13.2 | (14,13) |
| 5 | 14+1 =15 | 13.2+0.8 = 14 | (15,14) |
| 6 | 15+1 = 16 | 14+0.8 = 14.8 | (16,15) |
| 7 | 16+1 =17 | 14.8+0.8 = 15.6 | (17,16) |
| 8 | 17+1 =18 | 15.6+0.8 = 16.4 | (18,16) |
| 9 | 18+1 =19 | 16.4+0.8 = 17.2 | (19,17) |
| 10 | 19+1 =20 | 17+0.8 = 17.8 | (20,18) |

Digital Differential Analysis

**Example**

calculate the line points between (3,3) to (10,12) to using DDA.

Given x1, y1 = (3, 3) x2, y2 = ( 10,12)

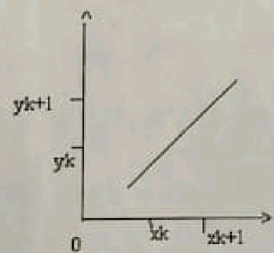
dx = 10-3 = 7 dy = 12 - 3 =9

Steps = abs (9); xinc = 7/9 =0.8; yinc = 9/9 = 1 x = 3; y = 3;

| k | x | y | Putpixel |
|---|---|---|---|
| 0 | 3 | 3 | (3,3) |
| 1 | 3+0.8 =3.8 | 3+1 = 4 | (4,4) |
| 2 | 3.8+0.8 = 4.6 | 4+1 =5 | (5,5) |
| 3 | 4.6+0.8 = 5.4 | 5+1 = 6 | (5,6) |
| 4 | 5.4+0.8 = 6.2 | 6+1 = 7 | (6,7) |
| 5 | 6.2+0.8 = 7 | 7+1 =8 | (7,8) |
| 6 | 7+0.8 = 7.8 | 8+1 = 9 | (8,9) |
| 7 | 7.8+0.8 = 8.6 | 9+1 = 10 | (9,10) |
| 8 | 8.6+0.8 = 9.4 | 10+1 =11 | (9,11) |
| 9 | 9.4+0.8= 10.2 | 11+1 =12 | (10,12) |

**Bresenham's Line Algorithm**

It was developed by Bresenham based on scan converts lines using only integer calculations. Consider the scan conversion process for lines with positive slope (m) less than 1. Assuming we have determine that the pixel at $(x_k, y_k)$ is displayed. Next we need to decide which pixel to be displayed in the column $x_k+1$. Our choices are at positions $(x_k+1, y_k)$ or $(x_k+1, y_k+1)$. i.e., decided by the decision factor p.




x, y calculation.

while, do-while condition method

26/8/22 **Procedure Bresenham (x1,y1,x2,y2: int)**

```
Var
    dx, dy, x, y, xend, p: int;
Begin
    dx = abs (x2-x1);    dy = abs(y2 – y1);
    p = 2 * dy – dx;
    If (x1 > x2)
      {
        x = x2; y = y2;  xend = x1;
```

```
  }
  else
  {
    x= x1; y = y1;  xend = x2;
  }
  setpixel (x,y,1);
  While (x < xend) do
  Begin
     x = x+1;
     If (p < 0)
         p = p+2*dy;
     else { y = y+1;  p = p + 2 (dy - dx); }
     setpixel (x,y,1);
  End;
End;
```

**Note :** For lines with slow |m|>|, we interchange the role of x and y direction. Ie, we step along the y direction in unit (1) steps and calculate the successive x value by the decision parameter p.

$-4 < 0 = 4 > 0$

**Example**

Calculate the line points between (20,10) and (30,18)

x1 = 20;  y1 = 10;  x2 = 30;  y2 = 18;

dx = abs (30-20)=10;  dy = abs (18-10) = 8;

m = dy/dx = 8/10 = 0.8 < 1;

p = 2 *(8-10) = 16- 10; = ~~6>0~~ -4>0

If (20>30) { x = 20; y =10; xend = 30;}

putpixel (20,10)

dx = abs(x2 - x1)

dy = abs(y2 - y1)

| Index | X | y | p | Putpixel |
|---|---|---|---|---|
| 0 | 20 | 10 | P=2*dy-dx = ~~6>0~~ -4<0 | (20,10) |
| 1 | 20+1 =21 | 10+1 =11 | P= p+2(dy-dx) = 6+2(8-10) = 2>0 | (21,11) |
| 2 | 21+1 =22 | 11+1 = 12 | P= p+2(dy-dx) = 2+2(8-10) = -2 <0 | (22,12) |
| 3 | 22+1=23 | 12 | P= p+2*dy = -2+2*8 = 14>0 | (23,12) |
| 4 | 23+1 = 24 | 12+1 =13 | P= p+2(dy-dx) = 14+2(8-10)=10 >0 | (24,13) |
| 5 | 24+1 =25 | 13+1 =14 | P= p+2(dy-dx) =10+2(8-10) = 6>0 | (25,14) |
| 6 | 25+1 =26 | 14+1 =15 | P= p+2(dy-dx) =6+2(8-10) =2>0 | (26,15) |
| 7 | 26+1 =27 | 15+1 =16 | P= p+2(dy-dx) =2+2(8-10) =-2<0 | (27,16) |
| 8 | 27+1 =28 | 16 | P=p+2*dy =-2+2*8 =14>0 | (28,16) |
| 9 | 28+1 =29 | 16+1 = 17 | P= p+2(dy-dx) =14+2(8-10) =10>0 | (29,17) |
| 10 | 29+1 =30 | 17+1 =18 | P= p+2(dy-dx) =10+2(8-10) =6>0 | (30,18) |
| 11 | 28+1=29 P++ | 16+1 = 17 i++ | | |
| 12 | 29+1=30 | 17+1 = 18 | | |

12+(-4) = 8>0

13) 8+(-4) = 4>0

20+2(-2) = 20+(-4) = 16 >0

16 + 2(-2) = 16+(-4)

**Parallel line algorithm**

Both DDA and Bresenham's line algorithms determine the pixel. Sequentially. With a parallel computer, we can calculate the pixels simultaneously by partitioning computations among the various processors available.

**Method 1 :** The sequential algorithm used in multiple processors.

**Method2 :** Set of the processing so that pixel position can be calculated efficient in parallel.

Given $n_p$ processors, we can set up a parallel algorithm by subdividing the line path into $n_p$ partitions and simultaneously generating the line segment in each of the sub intervals.

For lines with slope $0<m<1$ and for the starting point $(x_0, y_0)$; a partition is in the x direction.

The distance between the partition is given by

$$\boxed{\Delta x_p = (\Delta x + n_p - 1) / n_p}$$

Where $\Delta x$ is the width of the line. We can calculate the starting coordinate for kth partition as

$$\boxed{x_0 + k.\ \Delta x_p}$$

For example,

for the line point x1=20, x2=35. the $\Delta x$ is given by x2-x1.

$$\Delta x = 15.$$

Suppose we have $n_p = 4$. the length of the partition is given by

$$\Delta x_p = \Delta x + n_p - 1 / np$$
$$= 15 + 4 - 1 / 4$$
$$= 18 / 4 = 4.5$$

Then the starting x values for the line segment are $x_0$, $x_0+1*4$, $x_0+2*4$. That is 20, 20+4 (24), 20+8 (28).

Another way to set up a parallel algorithm is to assign each processor to a particular group of screen pixels with Sufficient number of processors. We can assign each processor to pixels within same screen region. This approach can be adopted to the line display by assigning one processor to each of the pixels within the limits of the line quadrant extent [bounding rectangle] and calculating pixels distances from the line path.