

COMPUTER GRAPHICS 18BIT53C

UNIT I: Overview of Graphics System – Display Devices – CRT – Random Scan and Raster Scan Monitors – Techniques for Producing Colour Display – Beam – Penetration and Shadow – Mask Methods – DVST – Plasma – Panel Displays – Hardcopy Devices – Printers and Plotters – Display Processors – Output Primitives – DDA and Bresenham’s line drawing algorithms – Antialiasing lines – Bresenham’s Circle Algorithm – Character Generation.

UNIT II: Two-dimensional Transformations – Scaling, Translation and Rotation – Matrix Representations – Composite Transformations – Reflection – Shearing – Other Transformations. Windowing and Clipping – Concepts – Cohen and Sutherland Line Clipping Algorithm – Midpoint Subdivision.

UNIT III: Three dimensional Concept- Three-Dimensional object representations – polygon surfaces – polygon tables- plane equations - Three-Dimensional geometric transformations – translation – rotation – scaling – other transformations.

UNIT IV: Three-Dimensional viewing – viewing pipeline - Display Techniques – Parallel Projection – Perspective Projection – Hidden-Surface and Hidden-Line removal – Back face removal – Depth Buffer Method – Scan Line Method – BSP Tree Methods – Depth-Sorting Method – Area-subdivision Method – Octree Methods – Comparison of Hidden-Surface Methods.

UNIT V: Colour models and colour applications – properties of light – standard primaries and the chromaticity diagram – xyz colour model – CIE chromaticity diagram – RGB colour model – YIQ, CMY, HSV colour models, conversion between HSV and RGB models, HLS colour model, colour selection and applications.

TEXT BOOK

1. Donald Hearn and Pauline Baker, “Computer Graphics”, Prentice Hall of India, 2001.

Prepared by **Dr.P.Sumathi**

COMPUTER GRAPHICS

Computer graphics is an art of drawing pictures on computer screens with the help of programming. It involves computations, creation, and manipulation of data. In other words, we can say that computer graphics is a rendering tool for the generation and manipulation of images.

Chapter-1 : APPLICATION OF COMPUTER GRAPHICS

Computer Graphics has numerous applications, some of which are listed below –

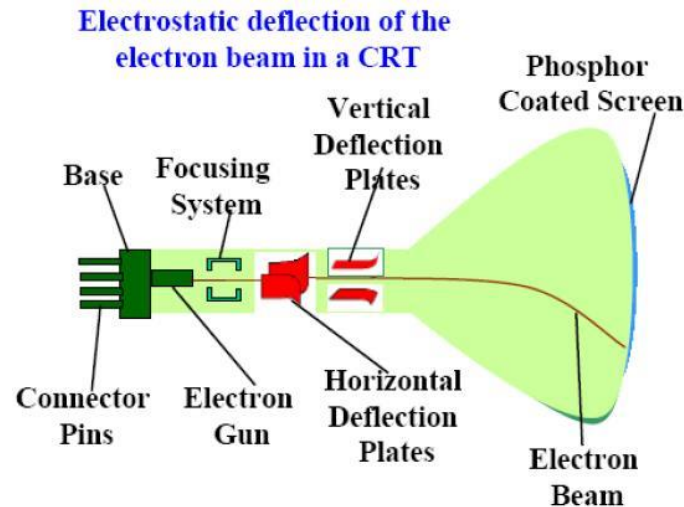
- **Computer graphics user interfaces (GUIs)** – A graphic, mouse-oriented paradigm which allows the user to interact with a computer.
- **Business presentation graphics** – "A picture is worth a thousand words".
- **Cartography** – Drawing maps.
- **Weather Maps** – Real-time mapping, symbolic representations.
- **Satellite Imaging** – Geodesic images.
- **Photo Enhancement** – Sharpening blurred photos.
- **Medical imaging** – MRIs, CAT scans, etc. - Non-invasive internal examination.
- **Engineering drawings** – mechanical, electrical, civil, etc. - Replacing the blueprints of the past.
- **Typography** – The use of character images in publishing - replacing the hard type of the past.
- **Architecture** – Construction plans, exterior sketches - replacing the blueprints and hand drawings of the past.
- **Art** – Computers provide a new medium for artists.
- **Training** – Flight simulators, computer aided instruction, etc.
- **Entertainment** – Movies and games.
- **Simulation and modeling** – Replacing physical modeling and enactments

Chapter-2 : REFRESH CATHODE RAY TUBES

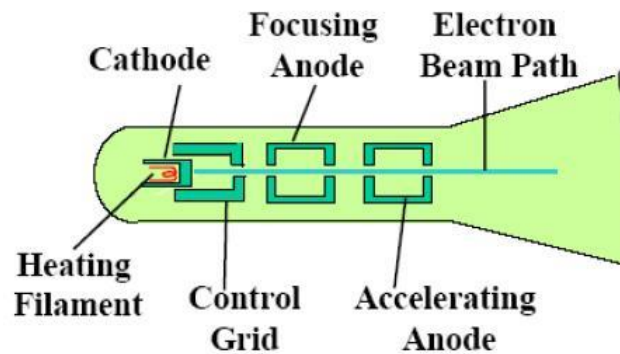
The primary output device in a graphical system is the video monitor. The main element of a video monitor is the **Cathode Ray Tube (CRT)**, shown in the following illustration.

- A CRT is an evacuated glass tube. The primary components of an **electron gun** in a CRT are the heated metal cathode and a control grid.
- Heat is supplied to the cathode by directing a current through a coil of wire, called the filament, inside the cylindrical cathode structure. This causes electrons to be boiled off" the hot cathode surface. In the vacuum inside the CRT envelope, the free, negatively charged electrons are then accelerated toward the phosphor coating by a high positive voltage. The accelerating voltage can be generated with a positively charged metal coating on the inside of the CRT envelope near the phosphor screen, or an accelerating anode can be used, as in the following figure.
- Intensity of the electron beam is controlled by setting voltage levels on the **control grid**, which is a metal cylinder that fits over the cathode. A **high negative voltage** applied to the control grid will shut OFF the beam by repelling electrons and stopping them from passing through the small hole at the end of the control grid structure. A **smaller negative voltage**

on the control grid simply decreases the number of electrons passing through. Since the amount of light emitted by the phosphor coating depends on the number of electrons striking the screen.



- **The focusing system** in a CRT is needed to force the electron beam to converge into a small spot as it strikes the phosphor. Otherwise, the electrons would repel each other, and the beam would spread out as it approaches the screen. Focusing is accomplished with either electric or magnetic fields.
- **Magnetic deflection** has two pairs of coils are used, with the coils in each pair mounted on opposite sides of the neck of the CRT envelope. One pair is mounted on the top and bottom of the neck and the other pair is mounted on opposite sides of the neck. The magnetic field produced by each pair of coils results in a transverse deflection force that is perpendicular both to the direction of the magnetic field and to the direction of travel of the electron beam. Horizontal deflection is accomplished with one pair of coils, and vertical deflection by the other pair. The proper deflection amounts are attained by adjusting the current through the coils.
- **Electrostatic deflection** has two pairs of parallel plates are mounted inside the CRT envelope. One pair coil plates is mounted horizontally to control the vertical deflection, and the other pair is mounted vertically to control horizontal deflection as shown in the following figure.



Operation of an electron gun with an accelerating anode

- Spots of light are produced on the screen by the transfer of the CRT beam energy to the phosphor. When the electrons in the beam collide with the phosphor coating, they are stopped and then kinetic energy is absorbed by the phosphor. The frequency of the light emitted by the phosphor is proportional to the energy difference between the excited quantum state and the ground state. Different kinds of phosphors are available for use in a CRT. Besides color, a major difference between phosphors is their persistence.
- **Persistence** is the time to which the phosphors in the cathode Ray Tubes emit light until the next electrons is fired. It is actually a measure of time taken by the emitted light from screen to decay one tenth of its original intensity. **Lower persistence phosphors** require higher refresh rates to maintain a picture on the screen without flicker. It is useful for animation. **Higher persistence phosphors** are used to display complex images.
- **Resolution** is actually the number of dots per centimeter that can be displayed horizontally and vertically in a Cathode Ray Tube. It depends on type of phosphors, focus and deflection method in Cathode Ray Tube, and the intensity.
- **Aspect Ratio:** This number gives the ratio of vertical points to horizontal points necessary to produce equal-length lines in both directions on the screen.

RANDOM SCAN AND RASTER SCAN MONITORS

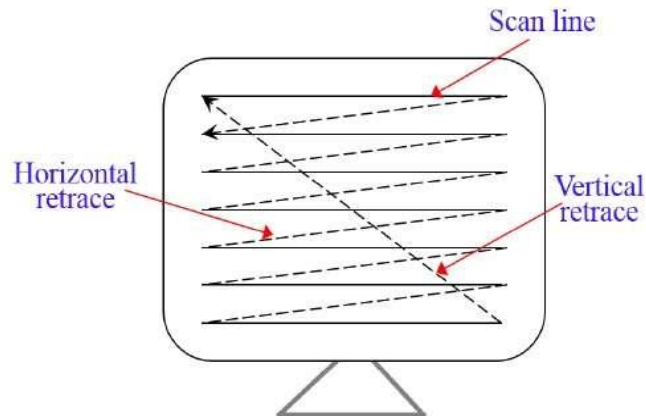
There are two ways by which we can display an object on the screen. ie., **Random scan and Raster scan.**

RASTER SCAN

In a raster scan system, the electron beam is swept across the screen, one row at a time from top to bottom. As the electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots.

Picture definition is stored in memory area called the **Refresh Buffer** or **Frame Buffer**. This memory area holds the set of intensity values for all the screen points. Stored intensity values are then retrieved from the refresh buffer and “painted” on the screen one row (scan line) at a time as shown in the following illustration.

Each screen point is referred to as a **pixel (picture element)** or **pel**. At the end of each scan line, the electron beam returns to the left side of the screen to begin displaying the next scan line.



ADVANTAGES OF RASTER SCAN DISPLAY

- It is capable of storing intensity information for each screen point. This makes it well suited for the realistic display of scenes containing suitable shading and color patterns.
- It offers full color display (Million Different colors to be generated) at relatively low cost.
- While application for this display has been increasing, the cost of raster scan display equipment has been decreasing.

DISADVANTAGES OF RASTER SCAN DISPLAY

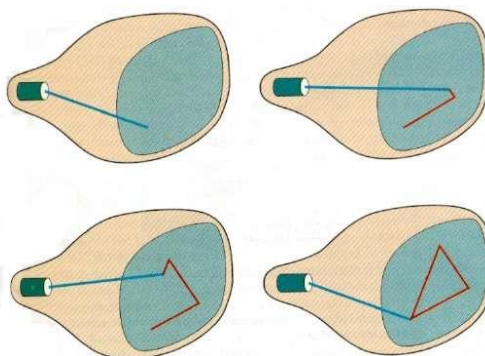
- Low resolution
- Expensive
- Electron beam directed to entire screen and only to that part of the screen where picture is to be drawn.

RANDOM SCAN (VECTOR SCAN)

In this technique, the electron beam is directed only to the part of the screen where the picture is to be drawn rather than scanning from left to right and top to bottom as in raster scan. It is also called **vector display**, **stroke-writing display**, or **calligraphic display**.

Picture definition is stored as a set of line-drawing commands in an area of memory referred to as the **refresh display file**. To display a specified picture, the system cycles through the set of commands in the display file, drawing each component line in turn. After all the line-drawing commands are processed, the system cycles back to the first line command in the list.

Random-scan displays are designed to draw all the component lines of a picture 30 to 60 times each second.



ADVANTAGE OF RANDOM SCAN DISPLAY

- It produce smooth line drawing .
- It is design for line drawing applications.
- An image produce by this method is modifiable, i.e any modification is easy.

DISADVANTAGE OF RANDOM SCAN DISPLAY

- Solid pattern is difficult to fill in this method.
- Random scan display method cannot produce realistic shaded picture.

DISTINGUISH BETWEEN RASTER & RANDOM SCAN

	RASTER SCAN DISPLAY	RANDOM SCAN DISPLAY
1	It draws the image by scanning one row at a time.	It draws the image by directing the electron beam directly to the part of the screen where the image is to be drawn.
2	They generally have resolution limited to pixel size.	They have higher resolution than Raster Scan System
3	Lines are jaggered and curves are less smoother.	Line plots are straight and curves are smooth.
4	They are more suited to geometric area drawing applications E.g. Monitors and Television.	They are more suited to line drawing application E.g. CRO.s, pen plotter.

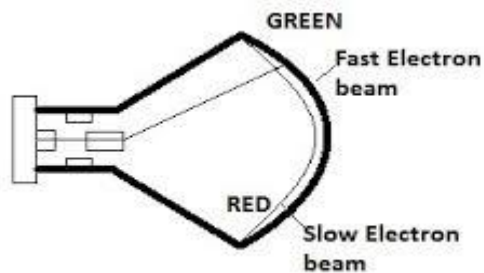
TECHNIQUES FOR PRODUCING COLOR DISPLAY

A CRT monitor displays color pictures by using a combination of phosphors that emit different-colored light. By combining the emitted light from the different phosphors, a range of colors can be generated. The two basic techniques for producing color displays with a CRT are

1. The Beam-Penetration method
2. The Shadow-Mask method

1. BEAM-PENETRATION METHOD:

The beam-penetration method for displaying color pictures has been used with random-scan monitors. **Two layers of phosphor**, usually **RED and GREEN**, are coated onto the inside of the CRT screen, and the displayed color depends on how far the electron beam penetrates into the phosphor layers.

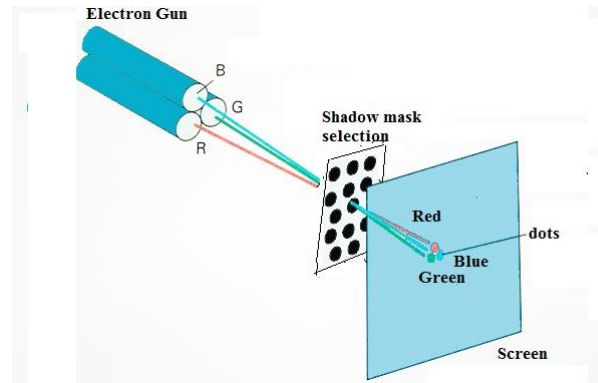


- A beam of slow electrons excites only the outer RED layer.
- A beam of very fast electrons penetrates through the RED layer and excites the inner GREEN layer.
- At intermediate beam speeds, combinations of red and green light are emitted to show two additional colors, ORANGE and YELLOW.
- The speed of the electrons, and hence the screen color at any point, is controlled by the beam- acceleration voltage.
- **Advantage:** Beam penetration has been an inexpensive way to produce color in random-scan monitors,
- **Disadvantage:** only four colors are possible, and the quality of pictures is not as good as with other methods.

2. SHADOW-MASK METHOD:

Shadow-mask methods are commonly used in raster scan systems because they produce a much wider range of colors than the beam penetration method.

- A shadow-mask CRT has three phosphor color dots at each pixel position.
- One phosphor dot emits a RED Light, another emits a GREEN light, and the third emits a BLUE light.
- This type of CRT has three electron guns, one for each color dot, and a shadow-mask grid just behind the phosphor-coated screen.
- **Delta-Delta Shadow-Mask method**, commonly used in color CRT systems. The three electron beams are deflected and focused as a group onto the shadow mask, which contains a series of holes aligned with the phosphor-dot patterns. When the three beams pass through a hole in the shadow mask, they activate a Dot Triangle, which appears as a small color spot on the screen. The phosphor dots in the triangles are arranged so that each electron beam can activate only its corresponding color dot when it passes through the shadow mask.
- **In-Line arrangement** in which the three electron guns, and the corresponding red-green-blue color dots on the screen, are aligned along one scan line instead of in a triangular pattern. This in-line arrangement of electron guns is easier to keep in alignment and is commonly used in high-resolution color CRTs.



- The color variations in a shadow-mask CRT by varying the intensity levels of the three electron beams.
- By turning OFF the RED and GREEN guns, gets the color coming from the BLUE phosphor. Other combinations of beam intensities produce a small light spot for each pixel position, since our eyes tend to merge the three colors into one composite.
- The color depends on the amount of excitation of the red, green, and blue phosphors.
- **White (or gray)** area is the result of activating all three dots with equal intensity.
- **Yellow** is produced with the green and red dots only.
- **Magenta** is produced with the blue and red dots.
- **Cyan** shows up when blue and green are activated equally.
- In some low-cost systems, the electron beam can only be set to on or off, limiting displays to **Eight Colors**.

RED	GREEN	BLUE	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

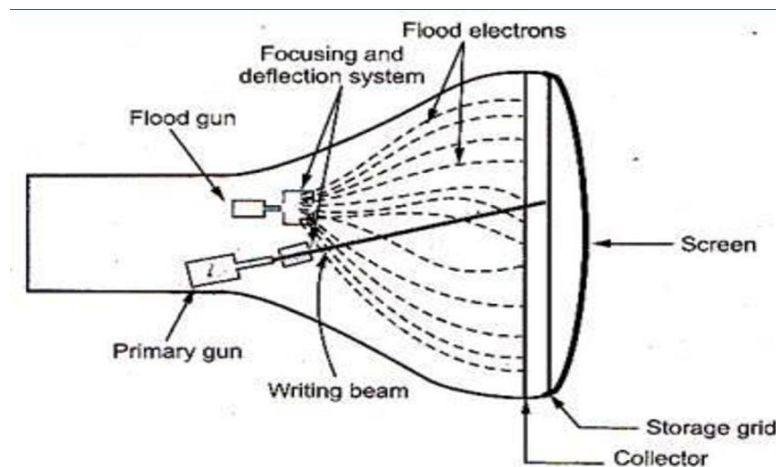
- More **sophisticated systems** can set intermediate intensity levels for the electron beams, allowing several million different colors to be generated.
- Color graphics systems can be designed to be used with several types of CRT display devices. Some inexpensive home-computer systems and video games are designed for use with a color TV set and an **RF (radio-frequency) modulator**.
- The purpose of the RF modulator is to simulate the signal from a broadcast TV station. This means that the color and intensity information of the picture must be combined and superimposed on the broadcast-frequency carrier signal that the TV needs to have as input. The RF modulator and TV circuitry decreases the quality of displayed images.
- These monitors use shadow-mask methods and take the intensity level for each electron gun (red, green, and blue) directly from the computer system without any intermediate processing.

- High-quality raster-graphics systems have 24 bits per pixel in the frame buffer, allowing 256 voltage settings for each electron gun and nearly 17 million color choices for each pixel.
- An RGB color system with 24 bits of storage per pixel is generally referred to as a **Full-Color System or a True-Color System**.

DIRECT-VIEW STORAGE TUBES

An alternative method for maintaining a screen image is to “store the picture information inside the CRT instead of refreshing the screen”. A **direct-view storage tube (DVST)** “stores the picture information as a charge distribution just behind the phosphor-coated screen”. Two electron guns are used in a DVST.

1. Primary gun: It is used to store the picture pattern
2. Flood gun: It maintains the picture display.



Conceptually the Direct View Storage Tube (DVST) behaves like a CRT with highly persistent phosphor. Pictures drawn on there will be seen for several minutes (40-50 minutes) before fading. It is similar to CRT as far as the electronic gun and phosphor-coated mechanisms are concerned. But instead of the electron beam directly writing the pictures on the phosphor coated CRT screen, the writing is done with the help of a fine-mesh wire grid.

The grid made of very thin, high quality wire, is located with a dielectric and is mounted just before the screen on the path of the electron beam from the gun. A pattern of positive charges is deposited on the grid and this pattern is transferred to the phosphor coated CRT by a continuous flood of electrons. This flood of electrons is produced by a "flood gun".

Just behind the storage mesh is a second grid called the collector. The function of the collector is to smooth out the flow of flood electrons. Since a large number of electrons are produced at high velocity by the flood gun, the collector grid, which is also negatively charged reduces, the acceleration on these electrons and the resulting low velocity flood pass through the collector and get attracted by the positively charged portions of the storage mesh, but are repelled by the other portions of the mesh which are negatively charged.

Thus, the electrons attracted by the positive charges pass through the mesh, travel on to the phosphor coated screen and display the picture. Since the collector has slowed the electrons down, they may not be able to produce sharp and bright images. To overcome this problem, the screen

itself is maintained at a high positive potential by means of a voltage applied to a thin aluminium coating between the tube face and the phosphor.

The dotted circle on the mesh is created by positive charges the flood of electrons hit the mesh at all points. But only those electrons that hit the dotted circle pass through and hit the CRT screen. The negatively charged mesh repels others.

Since the phosphor is of a very high persistence quality, the picture created on the CRT screen will be visible for several minutes without the need for being refreshed.

Now the problem arises as to how do we remove the picture, when the time for it's erasure or modification comes up. The simple method is to apply a positive charge to the negatively charged mesh so that it gets neutralized. This removes all charges and clears the screen. But this technique also produces a momentary flash, which may be unpleasant to the viewer.

A DVST monitor has both disadvantages and advantages compared to the refresh CRT.

Advantages

1. Because no refreshing is needed.
2. Very complex pictures can be displayed at very high resolutions without flicker.

Disadvantages

1. DVST systems are that they ordinarily do not display color and that selected parts of a picture cannot be erased.
2. To eliminate a picture section, the entire screen must be erased and the modified picture redrawn.
3. The erasing and redrawing process can take several seconds for a complex picture.
4. For these reasons, storage displays have been largely replaced by raster systems.

FLAT-PANEL DISPLAYS

Although most graphics monitors are still constructed with CRTs, other technologies are emerging that may soon replace CRT monitors.

The term flat-panel display refers to a class of video devices that have

- 1. Reduced volume**
- 2. Weight**
- 3. Power requirements compared to a CRT**

- A significant feature of it is that they are thinner than CRTs, and can hang them on walls or wear them on our wrists.
- Current uses for flat-panel displays include small TV monitors, calculators, pocket video games, laptop computers, armrest viewing of movies on airlines, as advertisement boards in elevators, and as graphics displays in applications requiring rugged, portable monitors and pocket notepads.
- Flat-panel displays into two categories:
 - 1. Emissive displays**
 - 2. Non-Emissive displays**

Emissive displays (or emitters): These devices that convert electrical energy into light.

Examples:

1. Plasma panels.
2. Thin-film electroluminescent.
3. Light-Emitting Diodes (LED).

Flat CRTs have also been devised, in which electron beams are accelerated parallel to the screen, then deflected 90° to the screen. But flat CRTs have not proved to be as successful as other emissive devices.

Non-emissive displays (or non-emitters): These devices use optical effects to convert sunlight or light from some other source into graphics patterns.

Example:

1. Liquid-Crystal Device (LCD)

PLASMA PANELS:

Plasma panels are also called gas-discharge displays.

- These are constructed by filling the region between two glass plates with a mixture of gases that usually includes neon.
- A series of vertical conducting ribbons is placed on one glass panel, and a set of horizontal ribbons is built into the other glass panel.
- Firing voltages applied to a pair of horizontal and vertical conductors cause the gas at the intersection of the two conductors to break down into glowing plasma of electrons and ions.
- Picture definition is stored in a refresh buffer, and the firing voltages are applied to refresh the pixel positions (at the intersections of the conductors) 60 times per second.
- Alternating methods are used to provide faster application of the firing voltages, and thus brighter displays.

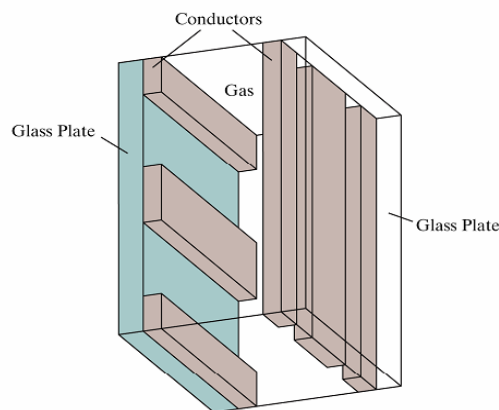


Figure 2-11

Basic design of a plasma-panel display device.

- Separation between pixels is provided by the electric field of the conductors.

Advantages of Plasma Panel

- Produce a very steady image.
- It has flat screen.
- Refreshing is not required.
- Allows selective writing and selective erasing.
- High resolution

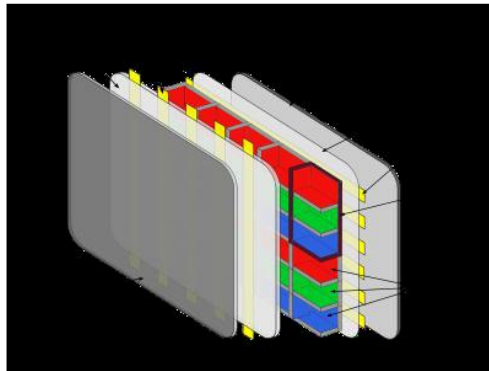
- Large screen size is possible.
- Images are much brighter than CRT.
- Less weight
- Low volume
- Less bulky than a CRT

Disadvantages of Plasma Panel

- It uses a lot of power.
- Relatively poor resolution of about 60 dots per inch.
- Does not show sharp contrast.
- Costlier than the CRT'S.
- It requires complex addressing and wiring.
- Technology is expensive

Thin-Film Electroluminescent:

- Thin-film electroluminescent displays are similar in construction to a plasma panel.
- The difference is that the region between the glass plates is filled with a phosphor, such as zinc sulfide doped with manganese, instead of a gas.
- When a sufficient high voltage is applied to a pair of crossing electrodes, the phosphor becomes a conductor in the area of the intersection of the two electrodes.
- Electrical energy is then absorbed by the manganese atoms, which then release the energy as a spot of light similar to the glowing plasma effect in a plasma panel.



- **Disadvantage:** These displays require more power than plasma panels, and good color and gray scale displays are hard to achieve.

Light-Emitting Diode (LED):

- A matrix of diodes is arranged to form the pixel positions in the display, and picture definition is stored in a refresh buffer.
- As in scan-line refreshing of a CRT, information is read from the refresh buffer and converted to voltage levels that are applied to the diodes to produce the light patterns in the display.

Liquid-Crystal Device (LCD):

- These are commonly used in small systems, such as calculators and portable, laptop computers.
- These non-emissive devices produce a picture by passing polarized light from the surroundings or from an internal light source through a liquid-crystal material that can be aligned to either block or transmit the light.
- The term liquid crystal refers to the fact that these compounds have a crystalline arrangement of molecules, yet they flow like a liquid.
- Flat-panel displays commonly use nematic (threadlike) liquid-crystal compounds that tend to keep the long axes of the rod-shaped molecules aligned.
- A flat-panel display can then be constructed with a nematic liquid crystal.
- **Passive-Matrix LCD:** Two glass plates, each containing a light polarizer at right angles to the other plate, sandwich the liquid-crystal material. Rows of horizontal transparent conductors are built into one glass plate, and columns of vertical conductors are put into the other plate. The intersection of two conductors defines a pixel position. Normally, the molecules are aligned as shown in the "on state".
- Polarized light passing through the material is twisted so that it will pass through the opposite polarizer. The light is then reflected back to the viewer.
- To turn off the pixel, apply a voltage to the two intersecting conductors to align the molecules so that the light is not twisted.
- This type of flat-panel device is referred to as a passive-matrix LCD. Picture definitions are stored in a refresh buffer, and the screen is refreshed at the rate of 60 frames per second, as in the emissive devices.
- Back lighting is also commonly applied using solid-state electronic devices, so that the system is not completely dependent on outside light sources be displayed by using different materials or dyes and by placing a triad of color pixels at each screen location.
- **Active-Matrix Displays:** Another method for constructing LCD is to place a transistor at each pixel location, using thin-film transistor technology. The transistors are used to control the voltage at pixel locations and to prevent charge from gradually leaking out of the liquid-crystal cells. These devices are called active-matrix displays.

HARDCOPY DEVICES

PRINTERS

A printer is an electromechanical device which converts the text and graphical documents from electronic form to the physical form. Generally they are the external peripheral devices which are connected with the computers or laptops through a cable or wirelessly to receive input data and print them on the papers. A wide range of printers are available with a variety of features ranging from printing black and white text documents to high quality colored graphic images.

The quality of pictures obtained from a device depends on dot size and the number of dots per inch, or lines per inch, that can be displayed. To produce smooth characters in printed text strings, higher-quality printers shift dot positions so that adjacent dots overlap.

Printers are also classified by the following characteristics: **Quality of type and speed.**

Quality of type: The output produced by printers is said to be either letter quality or draft quality. **Speed** is measured in characters per second (cps) or pages per minute (ppm).

There are two types of printers: **Impact printers and Non impact printers.**

An impact printer makes contact with the paper. It usually forms the print image by pressing an inked ribbon against the paper using a hammer or pins. Following are some examples of impact printers.

- Dot-Matrix Printers
- Daisy-wheel printers
- Line printers
- Drum printer
- Chain printers
- Band printers

Dot-Matrix printer

It has a print head containing a rectangular array of protruding wire pins, with the number of pins depending in the quality of the printer. Individual characters or graphics patterns are obtained by retracting certain pins so that the remaining pins form the pattern to the printed.

Daisy-wheel printers

In order to get the quality of type found on typewriters, a daisy-wheel impact printer can be used. It is called daisy-wheel printer because the print mechanism looks like a daisy; at the end of each “Petal” is a fully formed character which produces solid-line print. A hammer strikes a “petal” containing a character against the ribbon, and the character prints on the paper. Its speed is slow typically 25-55 characters per second.

Line printers

In business where enormous amount of material are printed, the character-at-a-time printers are too slow; therefore, these users need line-at-a-time printers. Line printers, or line-at-a-time printers, use special mechanism that can print a whole line at once; they can typically print the range of 1,200 to 6,000 lines per minute. Drum, chain, and band printers are line-at-a-time printers.

Drum printer

A drum printer consists of a solid, cylindrical drum that has raised characters in bands on its surface. The number of print positions across the drum equals the number available on the page. This number typically ranges from 80-132 print positions. The drum rotates at a rapid speed. For each possible print position there is a print hammer located behind the paper. These hammers strike the paper, along the ink ribbon, against the proper character on the drum as it passes. One revolution of the drum is required to print each line. This means that all characters on the line are not printed at exactly the same time, but the time required to print the entire line is fast enough to call them line printers. Typical speeds of drum printers are in the range of 300 to 2000 lines per minute.

Chain printers

A chain printer uses a chain of print characters wrapped around two pulleys. Like the drum printer, there is one hammer for each print position. Circuitry inside the printer detects when the correct character appears at the desired print location on the page. The hammer then strikes the page, pressing the paper against a ribbon and the character located at the desired print position. An impression of the character is left on the page. The chain keeps rotating until all the required print positions on the line have filled. Then the page moves up to print the next line. Speeds of chain printers range from 400 to 2500 characters per minute.

Band printers

A band printer operates similar to chain printer except it uses a band instead of a chain and has fewer hammers. Band printer has a steel band divided into five sections of 48 characters each. The

hammers on a band printer are mounted on a cartridge that moves across the paper to the appropriate positions. Characters are rotated into place and struck by the hammers. Font styles can easily be changed by replacing a band or chain.

NON-IMPACT PRINTERS

Non-impact printers do not use a striking device to produce characters on the paper; and because these printers do not hammer against the paper they are much quieter. Following are some non-impacted printers.

- Laser printers
- Ink-jet printers
- Electrostatic Device
- Electro thermal Device

Laser printer

Alaser beam creates a charge distribution on a rotating drum coated with a photo electric material, such as selenium. Toner is applied to the drum an then transferred to paper.

Ink-jet printer

It produces output by squirting the ink in horizontal row across a roll of paper wrapper on a drum. The electrically charged ink stream is deflected by an electric field to produce dot matrix patterns.

Electrostatic Device

It places a negative charge on the paper, one complete row at a time along the length of the paper. Then the paper is exposed to a toner. The toner is positively charged and so is attracted to the negatively charged ares, Where it adheres to produce the specified output.

Electro thermal Device

This method uses heat in a dot matrix print head to output patterns on heat sensitive paper. The printer of the invention permits high rate printing at a relatively low cost of supplies. With the ink ribbon omitted, printing can be effected directly on thermo-sensitive paper. A thermoplastic ink is transferred from a ribbon to the base medium by localized heating. The heating occurs as current is passed from discrete electrical contacts on the print head through a resistive layer in the ribbon to a common return layer.

Benefits of Impact Printers

Impact printers have a couple of benefits.

- The first is that since they use pressure to generate an image, they work with multipart forms that either have leaves of carbon paper or use carbon-imprinted paper.
- The second is that since they print one line at a time instead of one page at a time, their paper feed mechanisms are designed to let them use continuous forms.

Benefits of Non-Impact Printers

- Non-impact printers have advanced to a point that they are better than impact printers at just about everything other than feeding continuous paper and working with multi-part forms.

- They have much higher resolutions since, instead of using metal pins, they can use drops of ink measured in toner particles measured in micrometers.
- Non-impact printers are also much quieter, making it possible for them to be used out in the open in office settings.

PLOTTERS

A graphic printer that images with ink pens. It actually draws point to point lines directly from vector graphics files. The plotter was the first computer output device that could print graphics as well as accommodate full size engineering and architectural drawings. Using different colored pens, it was able to print in color long before ink jet printers became an alternative.

Types of plotters: Drum plotter, Flatbed plotter and Inkjet Plotter.

Drum plotter

A drum plotter is a pen plotter that wraps the paper around a drum with a pin feed attachment. The drum then rotates the paper as pens move across it and draw the image. It was the first output device used to print graphics and large engineering drawings. There are two types of drum plotters, external and internal. With an external drum plotter, the paper is wrapped around its external surface, while the internal drum plotter uses a sheet of paper wrapped around its internal surface.

Flatbed plotter

A flat-bed plotter is a mechanical drafting device used with many CAD programs for designers. The paper remains stationary on a flat surface while a pen moves across it horizontally and vertically. This plotter may use several different pen colors to create the graphics. The size of the graphic is limited to the size of the flat-bed plotter's surface.

Inkjet Plotter

The inkjet plotter creates an image by spraying small droplets of ink on to paper. A popular choice for advertising agencies and graphic designers, inkjet plotters are used generally for large outputs, such as banners and billboards and large signs often seen along roadsides. Inkjet plotters typically produce better quality graphics than other plotter types.

Distinguish Between Printer And Plotter

	PLOTTER	PRINTER
1	All plotters can be considered printers.	But all printers are definitely not plotters.
2	Plotters are used to draw line images.	whereas printers are used to draw images through dots.
3	A plotter holds pen and draws lines	whereas printers make use of laser and Ink technology
4	A plotter can draw very large images that are of use in architecture	whereas printers cannot make use of large papers.
5	Plotter can print on large paper Sheets for example Posters, Banners etc.	Printer can print on small paper sheets. For example, A3, A4 sheets.

6	Plotters are used in Industrial area, it cannot be used for Domestic use.	Printers can be used for Domestic and Industrial use.
7	Plotter is much expensive as compared to printer	Printers are cheaper as compare to plotter
8	Types of Plotters are: <ul style="list-style-type: none"> • Drum plotter • Flatbed plotter • Electrostatic Plotter 	Types of Printers are: <ul style="list-style-type: none"> • Dot matrix printer • Inkjet printer • Laser printer



PLOTTER



PRINTER

ALIASING and ANTI-ALIASING

On dealing with integer pixel positions, jagged or stair step appearances happen very usually. This distortion of information due to low frequency sampling is called **Aliasing**. A number of anti-aliasing methods have been developed to compensate this problem.

Anti-aliasing is any of a number of techniques to combat the problems of aliasing in a sampled signal such as a digital image or digital audio recording. i.e., this is a technique used to reduce aliasing effect.

- In digital signal processing, anti-aliasing is the technique of minimizing aliasing (jagged or blocky patterns) when representing a high-resolution signal at a lower resolution.
- In most cases, anti-aliasing means removing this part data at too high a frequency to represent. When sampling is performed without removing this part of the signal, it causes undesirable artifacts such as the black-and-white noise near the top of figure.

OUTPUT PRIMITIVES

Introduction

The basic elements constituting a graphic are called output primitives. Each output primitive has an associated set of attributes, such as line width and line color for lines. The programming technique is to set values for the output primitives and then call a basic function that will draw the desired primitive using the current settings for the attributes. Various graphics systems have different graphics primitives.

LINE- DRAWING ALGORITHMS

The Cartesian slope-intercept equation for a straight line is

$$y = m \cdot x + b \quad \rightarrow (1)$$

with 'm' representing the slope of the line and 'b' as the y intercept.

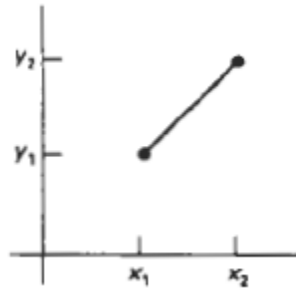


Figure 1: Line path between endpoint positions (x_1, y_1) and (x_2, y_2) .

Given that the two endpoints of a line segment are specified at positions (x_1, y_1) and (x_2, y_2) as shown in figure 1. We can determine the slope m and y intercept b with the following calculations:

$$m = \frac{(y_2 - y_1)}{(x_2 - x_1)} \quad \rightarrow (2)$$

$$b = y_1 - m \cdot x_1 \quad \rightarrow (3)$$

Algorithms for displaying straight lines are based on the line equations (1) and the calculations given in equations (2) and (3).

For any given x interval Δx along a line, we can compute the corresponding y interval Δy from equation (2) as,

$$y = m \Delta x \quad \rightarrow (4)$$

Similarly, we can obtain the x interval Δx corresponding to a specified Δy as

$$\Delta x = \frac{\Delta y}{m} \quad \rightarrow (5)$$

These equations form the basis for determining deflection voltages in analog devices.

- ❖ For lines whose slopes have magnitudes $|m| < 1$, Δx can be set proportional to a small horizontal deflection voltage and the corresponding vertical deflection is then set proportional to Δy as calculated from Equation 4.

- ❖ For lines whose slopes have magnitudes $|m| > 1$, Δy can be set proportional to a small vertical deflection voltage with the corresponding horizontal deflection voltage set proportional to Δx , as calculated from Equation 5.
- ❖ For lines with $m = 1$, $\Delta x = \Delta y$ and the horizontal and vertical deflections voltages are equal. In each case, a smooth line with slope m is generated between the specified endpoints.
- ❖ On raster systems, lines are plotted with pixels, and step sizes in the horizontal and vertical directions are constrained by pixel separations. The scan conversion process for straight lines is illustrated in Figure 2, for a near horizontal line with discrete sample positions along the x axis.

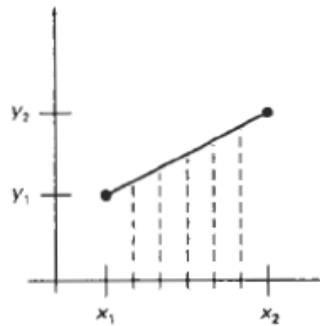


Figure 2: Straight line segment with five sampling positions along the x axis between x_1 , and x_2 .

DDA Algorithm:

The **Digital Differential Analyzer (DDA)** is a Scan- Conversion line algorithm based calculating either Δy or Δx using equations (4) and (5).

Consider first a line with positive slope as shown in figure 1, less than or equal to 1, we sample at unit intervals ($\Delta x = 1$) and compute each successive y value as

$$y_{k+1} = y_k + m \rightarrow (6)$$

Subscript k takes integer values starting from 1, for the first point, and increases by 1 until final endpoints is reached.

Since m can be any real number between 0 & 1, the calculated y values must be rounded to the nearest integer.

For lines with a positive slope greater than 1, we reserve the roles of x & y . That is, we sample at unit y intervals ($\Delta y = 1$) and calculate each succeeding x value as

$$x_{k+1} = x_k + \frac{1}{m} \rightarrow (7)$$

Equations (6) and (7) are based on the assumption that lines are to be processed from the left endpoint to the right endpoint.

If this processing is reversed, so that the starting endpoint is that, then either we have $\Delta x = -1$ and

$$y_{k+1} = y_k - m \rightarrow (8)$$

or (when the slope is greater than 1) we have $\Delta y = -1$ with

$$x_{k+1} = x_k - \frac{1}{m} \rightarrow (9)$$

Equations (6), (7), (8) and (9) can also be used to calculate pixel positions along a line with negative slope. If the absolute value of the slope is less than 1 and the start endpoint is at the left, we set $\Delta x = 1$ and calculate y values with equation (6).

When the start endpoint is at the right (for the same slope), we set $\Delta x = -1$ and obtain y positions from equation (8). Similarly, when the absolute value of a negative slope is greater than 1, we use $\Delta y = -1$ and equation (9) or we use $\Delta y = 1$ equation (7).

This algorithm is summarized in the following procedure, which accepts as input the two end point pixel positions. Horizontal and vertical differences between the endpoint positions are assigned to parameters **dx** and **dy**. The difference with the greater magnitude determines the value of parameter **steps**. Starting with pixel position (**x₀** , **y₀**), we determine the offset needed at each step to generate the next pixel position along the line path. We loop through this process **steps** times. If the magnitude of **dx** is greater than the magnitude of **dy** and **xa** is less than **xb**, the values of the increments in the x and y directions are 1 and m, respectively. If the greater change is in the x direction, but **xa** is greater than **xb**, then the decrements -1 and **-m** are used to generate each new point on the line. Otherwise, we use a unit increment (or decrement) in the direction and an x increment (or decrement) of **1 / m** .

```
procedure DDA ( xa, ya, xb, yb: integer);
var
    dx, dy, steps,k: integer;
    xIncrement, yIncrement, x, y: real;
begin
    dx := xb - xa; dy := yb - ya;
    if abs(dx) > abs(dy) then {m less than 1}
        steps := abs(dx); {steps is larger of dx, dy}
    else
        steps := abs(dy);
    xIncrement:= dx / steps;
    yIncrement:= dy / steps;
    setpixel(round(x), round(y), 1);
    x:=xa, y:=ya;
    for k := 1 to steps do
    begin
        x := x + xIncrement;
        y := y + yIncrement;
        setpixel(round(x), round(y), 1);
    end;
end; {DDA}
```

Advantages of DDA Algorithm

- 1) The DDA algorithm is a faster method for calculating pixel positions than the direct use of line equations.
- 2) Does not calculate coordinates based on the complete equation.

Disadvantages of DDA Algorithm

- 1) Round-off errors are accumulated, thus line diverges more and more from straight line.
- 2) Round-off operations take time.
- 3) Perform integer arithmetic by storing float as integers in numerator and denominator and performing integer arithmetic.

Example for DDA:

Draw the line between (5,5) & (10,9) using DDA algorithm.

$$dx := xb - xa; \quad = 10 - 5 = 5$$

$$dy := yb - ya; \quad = 9 - 5 = 4$$

$$dx > dy, 5 > 4, \text{ so, } \mathbf{steps = 5}$$

$$xIncrement := dx / steps; \quad = 5 / 5 = 1$$

$$yIncrement := dy / steps; \quad = 4 / 5 = 0.8$$

Iteration	Plot(round(x),round(y))	X+ xIncrement	Y+ yIncrement
0	(5,5)	5+1= 6	5+0.8= 5.8
1	(6,6)	6+1= 7	5.8+0.8= 6.6
2	(7,7)	7+1= 8	6.6+0.8= 7.4
3	(8,7)	8+1= 9	7.4+0.8= 8.2
4	(9,8)	9+1= 10	8.2+0.8= 9
5	(10,9)	10+1= 11	9+0.8= 9.8

Bresenham's Line Drawing Algorithm

This algorithm is used for scan converting a line. It was developed by Bresenham. It is an efficient method because it involves only integer addition, subtractions, and multiplication operations. These operations can be performed very rapidly so lines can be generated quickly. In this method, next pixel selected is that one who has the least distance from true line.

Figures 1 and 2 illustrate sections of a display screen where straight line segments are to be drawn. The vertical axes show-scan-line positions, and the horizontal axes identify pixel columns.

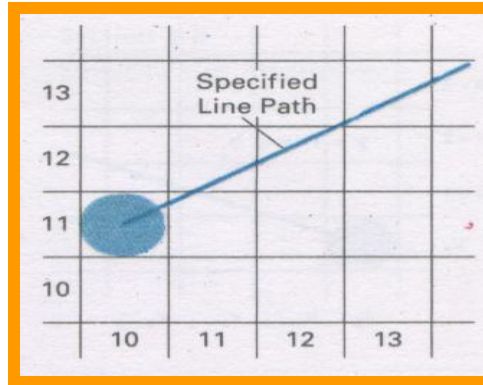


Figure 1: Section of a display screen where a straight-line segment is to be plotted, starting from the pixel at column 10 on scan Line 11

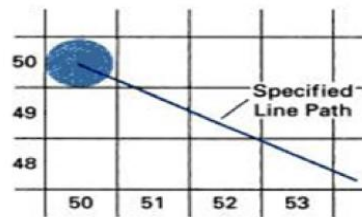


Figure 2: Section of a display screen where a negative slope line segment is to be plotted, starting from the pixel at column 50 on scan line 50.

We first consider the scan-conversion process for lines with positive slope less than 1. Pixel positions along a line path are then determined by sampling at unit x intervals. Starting from the left endpoint (x_0, y_0) of a line, we step to each successive column (x position) and plot the pixel whose scan-line y value is closest to the line path.

Figure 3 demonstrates the k^{th} step in this process. Assuming we have determined that the pixel at (x_k, y_k) is to be displayed, we next need to decide which is to be displayed, we next need to decide which pixel to plot in column $x_k + 1$. Our choices are the pixels at positions $(x_k + 1, y_k)$ and $(x_k + 1, y_k + 1)$.

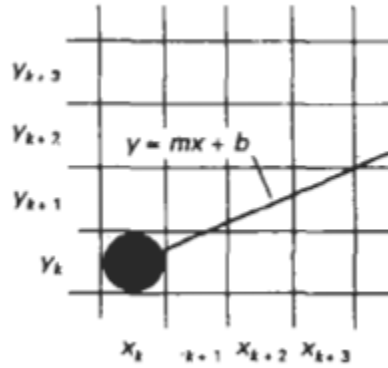


Figure 3: Section of the screen grid showing a pixel in Column x_k on scan line y_k that is to be plotted along the path of a line segment with slope $0 < m < 1$.

At sampling position $x_k + 1$, we label vertical pixel separations from the mathematical line path as d_1 and d_2 shown in the figure 4.

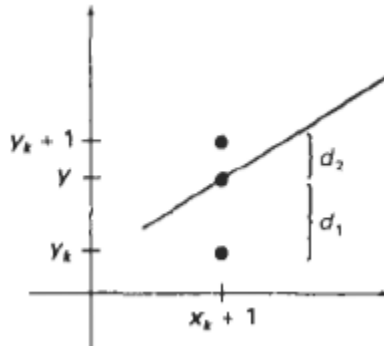


Figure 4: Distances between pixel positions and the line y coordinate at sampling position $x_k + 1$.

The y coordinate on the mathematical line at pixel column position $x_k + 1$ is calculated as

$$y = m(x_k + 1) + b \quad \rightarrow \quad (1)$$

Then

$$\begin{aligned} d_1 &= y - y_k \\ &= m(x_k + 1) + b - y_k \end{aligned}$$

and

$$\begin{aligned} d_2 &= (y_k + 1) - y \\ &= y_k + 1 - m(x_k + 1) - b \end{aligned}$$

The difference between these two separations is

$$d_1 - d_2 = 2m(x_k + 1) - 2y_k + 2b - 1 \quad \rightarrow \quad (2)$$

A decision parameter p_k for the k^{th} step in the line algorithm can be obtained by rearranging equation (2) so that it involves only integer calculations.

We accomplish this by substituting $m = \Delta y / \Delta x$, where Δy and Δx are vertical and horizontal separations of the endpoint positions, and defining:

$$\begin{aligned}
p_k &= \Delta x(d_1 - d_2) && \rightarrow (3) \\
&= 2\Delta y \cdot x_k - 2\Delta x \cdot y_k + c
\end{aligned}$$

The sign of p_k is the same as sign of $d_1 - d_2$, since $\Delta x > 0$ for our examples. Parameter c is constant and has the value $2\Delta y + \Delta x (2b - 1)$, which is independent of pixel position and will be eliminated in the recursive calculations for p_k .

If the pixel at y_k is closer to the line path than the pixel at $y_k + 1$ (i.e., $d_1 < d_2$), then decision parameter p_k is negative. In that case, we plot the lower pixel; otherwise, we plot the upper pixel.

Coordinate changes along the line occur in unit steps in either the x or y directions. Therefore, we can obtain the values of successive decision parameters using incremental integer calculations. At step $k+1$, the decision parameter is evaluated from equation (3) as

$$p_{k+1} = 2\Delta y \cdot x_{k+1} - 2\Delta x \cdot y_{k+1} + c$$

Subtracting equation (3) from the preceding equation, we have

$$p_{k+1} - p_k = 2\Delta y(x_{k+1} - x_k) - 2\Delta x(y_{k+1} - y_k)$$

But $x_{k+1} = x_k + 1$, so that

$$p_{k+1} = p_k + 2\Delta y - 2\Delta x(y_{k+1} - y_k) \quad \rightarrow (4)$$

Where the term $y_{k+1} - y_k$ is either 0 or 1, depending on the sign parameter p_k .

This recursive calculation of decision parameter is performed at each integer x position, starting at the left coordinate endpoint of the line. The first parameter, p_0 , is evaluated from equation (3) at the starting pixel position (x_0, y_0) and with 'm' evaluated as $\Delta y / \Delta x$:

$$p_0 = 2\Delta y - \Delta x \quad \rightarrow (5)$$

We can summarize Bresenham's line drawing for a line with a positive slope less than 1 in the following listed steps: The constants $2\Delta y$ and $2\Delta y - 2\Delta x$ are calculated once for each line to be scan converted, so the arithmetic involves only integer addition and subtraction of these two constants.

Bresenham's Line-Drawing Algorithm for $m < 1$

1. **Input two endpoints (x_0, y_0) , (x_n, y_n) where (x_0, y_0) is the left endpoint.**
2. **Load (x_0, y_0) into frame buffer, that is, plot the first point.**
3. **Calculate constants Δx , Δy and $2\Delta y$, $2\Delta y - 2\Delta x$, and initial value of decision parameter:**
$$p_0 = 2\Delta y - \Delta x$$
4. **At each x_k along the line, start at $k=0$, perform the following test:**
if $p_k < 0$, plot (x_{k+1}, y_k) and
$$p_{k+1} = p_k + 2\Delta y$$

else plot $(x_k + 1, y_k + 1)$ and
$$p_{k+1} = p_k + 2\Delta y - 2\Delta x$$
5. **Repeat step (4) Δx times.**

Advantages

- Algorithm is fast
- It uses only integer calculations, so very simple
- It can be implemented using h/w also

Disadvantages

- This algorithm is meant for basic line drawing only Initializing is not a part of Bresenham's line algorithm. So to draw smooth lines, you should want to look into a different algorithm.

Example: Bresenham Line Drawing

To illustrate the algorithm, we digitize the line with endpoints $(20, 10)$ and $(30, 18)$. This line has a slope of 0.8, with

$$\Delta x = 10, \quad \Delta y = 8$$
$$m = \Delta y / \Delta x$$
$$= 8/10 = 0.8$$

The initial decision parameter has the value,

$$p_0 = 2\Delta y - \Delta x = 16 - 10 = 6$$

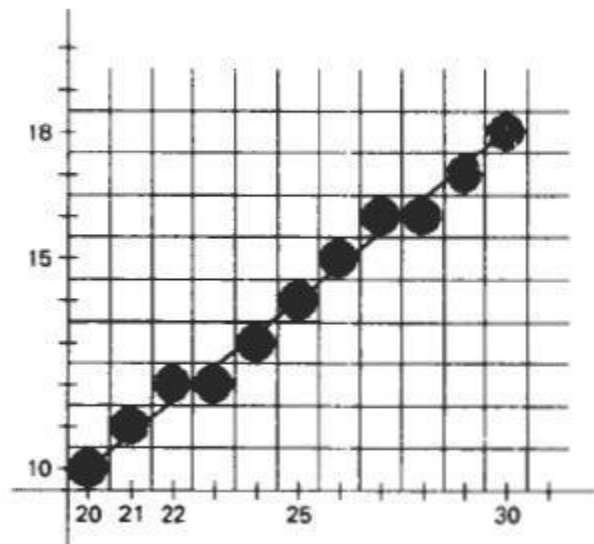
and the increments for calculating successive decision parameters are

$$2\Delta y = 16, \quad 2\Delta y - 2\Delta x = -4$$

We plot the initial point $(x_0, y_0) = (20, 10)$, and determine successive pixel positions along the line path from the decision parameter as

k	pk	(x_{k+1}, y_{k+1})
0	6	(21,11)
1	2	(22,12)
2	-2	(23,12)
3	14	(24,13)
4	10	(25,14)
5	6	(26,15)
6	2	(27,16)
7	-2	(28,16)
8	14	(29,17)
9	10	(30,18)

RESULT



CIRCLE – GENERATING ALGORITHMS

In general, a single procedure can be provided to display either circular or elliptical curves.

Properties of Circles:

A Circle is defined as the set of points that are all at a given distance r from a center position (x_c, y_c) as in the below figure.

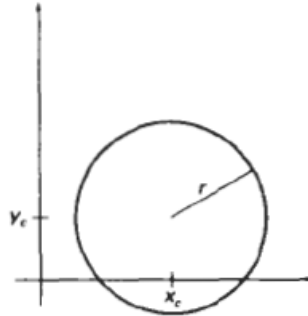


Figure: Circle with center coordinates (x_c, y_c) and radius r .

This distance relationship is expressed by the Pythagorean theorem in Cartesian coordinates as,

$$(x - x_c)^2 + (y - y_c)^2 = r^2 \rightarrow (1)$$

We could use this equation to calculate the position of points on a circle circumference by stepping along the x axis in unit steps from $x_c - r$ to $x_c + r$ and calculating the corresponding y value at each position as,

$$y = y_c \pm \sqrt{r^2 - (x_c - x)^2} \rightarrow (2)$$

But this is not the best method for generating a circle. One problem with this approach is that it involves considerable computation at each step. Moreover, the spacing between plotted pixel positions is not uniform, as shown in the following figure.

Another way to eliminate the unequal spacing is to calculate points along the circular boundary using polar coordinates r and θ . Expressing the circle equation in parametric polar form yields the pair of equations,

$$\begin{aligned} x &= x_c + r \cos \theta \\ y &= y_c + r \sin \theta \end{aligned} \rightarrow (3)$$

When a display is generated with these equations using a fixed angular step size, a circle is plotted with equally spaced points along the circumference.

Computation can be reduced by considering the symmetry of circles. The shape of the circle is similar in each quadrant.

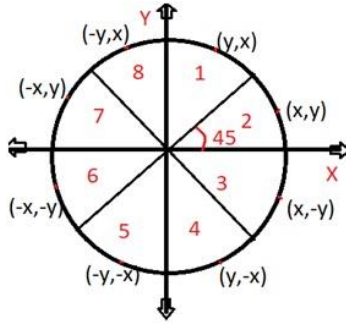


Fig: Symmetry of a circle.

These symmetry conditions are illustrated in the above diagram, where a point at position (x,y) on a one-eighth circle sector is mapped into the seven circle points in the other octants of the xy plane. Taking advantage of the circle symmetry in this way we can generate all pixel positions around a circle by calculating only the points within the sector from $x=0$ to $x=y$.

Determining pixel positions along a circle circumference using either equation (1) or equation (3) still requires a good deal of computation time.

Midpoint Circle Algorithm:

For a given radius r and screen center position (x_c, y_c) we can first set up our algorithm to calculate pixel positions around a circle path centered at the coordinate origin $(0,0)$. Then each calculated position (x,y) is moved to its proper screen position by adding x_c to x and y_c to y .

Along the circle section from $x = 0$ to $x = y$ in the first quadrant, the slope of the curve varies from 0 to -1. Positions in the other seven octants are then obtained by symmetry.

To apply the midpoint method, we define a circle function:

$$f_{circle}(x, y) = x^2 + y^2 - r^2 \quad \rightarrow (4)$$

Any point (x, y) on the boundary of the circle with radius r satisfies the equation $f_{circle}(x, y) = 0$. If the point is in the interior of the circle, the circle function is negative, and if the point is outside the circle, the circle function is positive.

To summarize, the relative position of any point (x, y) can be determined by checking the sign of the circle function.

$$f_{circle}(x, y) \begin{cases} < 0, & \text{if } (x, y) \text{ is inside the circle boundary} \\ = 0, & \text{if } (x, y) \text{ is on the circle boundary} \\ > 0, & \text{if } (x, y) \text{ is outside the circle boundary} \end{cases} \quad \rightarrow (5)$$

The following figure shows the midpoint between the two candidate pixels at sampling position $x_k + 1$.

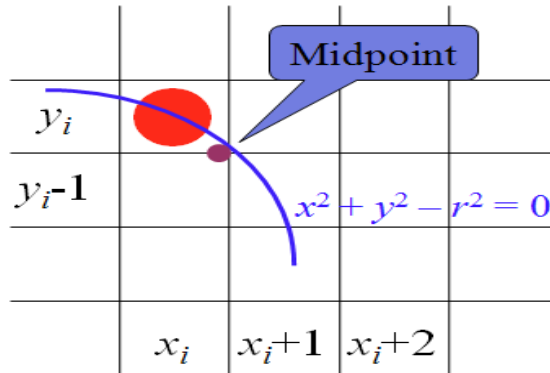


Fig: Midpoint between candidate pixels at sampling position $x_k + 1$ along a circular path

Assuming we have just plotted the pixel at (x_k, y_k) we next need to determine whether the pixel at position $(x_k + 1, y_k)$ or the one at position $(x_k + 1, y_k - 1)$ is closer to the circle.

Decision parameter is the circle function (4) evaluated at the midpoint between these two pixels:

$$\begin{aligned}
 p_k &= f_{\text{circle}}\left(x_k + 1, y_k - \frac{1}{2}\right) \\
 &= (x_k + 1)^2 + \left(y_k - \frac{1}{2}\right)^2 - r^2 \quad \rightarrow \quad (6)
 \end{aligned}$$

If $p_k < 0$, this midpoint is inside the circle and the pixel on scan line y_k is closer to the circle boundary. Otherwise, the mid position is outside or on the circle boundary, and we select the pixel on scanline $y_k - 1$.

Successive decision parameters are obtained using incremental calculations. We can summarize the steps in the midpoint algorithm as follows:

The initial decision parameter is obtained by evaluating the circle function at the start position $(x_0, y_0) = (0, r)$:

$$p_0 = \frac{5}{4} - r \quad \rightarrow \quad (7)$$

If the radius r is specified as an integer, we can simply round p_0 to

$$p_0 = 1 - r \quad (\text{for } r \text{ an integer})$$

Since all increments are integers.

The midpoint method calculates pixel positions along the circumference of a circle using integer additions and subtractions, assuming that the circle parameters are specified in integer screen coordinates.

We can summarize the steps in the midpoint circle algorithm as follows.

Midpoint Circle Algorithm

1. Input radius r and circle center (x_c, y_c) , and obtain the first point on the circumference of a circle centered on the origin as

$$(x_0, y_0) = (0, r)$$

2. Calculate the initial value of the decision parameter as

$$p_0 = \frac{5}{4} - r$$

3. At each x_k position, starting at $k = 0$, perform the following test: If $p_k < 0$, the next point along the circle centered on $(0, 0)$ is (x_{k+1}, y_k) and

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

Otherwise, the next point along the circle is $(x_k + 1, y_k - 1)$ and

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

where $2x_{k+1} = 2x_k + 2$ and $2y_{k+1} = 2y_k - 2$.

4. Determine symmetry points in the other seven octants.
5. Move each calculated pixel position (x, y) onto the circular path centered on (x_c, y_c) and plot the coordinate values:

$$x = x + x_c \quad y = y + y_c$$

6. Repeat steps 3 through 5 until $x \geq y$.

Example: Midpoint Circle-Drawing

Given a circle radius $r = 10$, we demonstrate the midpoint circle algorithm by determining positions along the circle octant in the first quadrant from $x = 0$ to $x = y$. The initial value of the decision parameter is

$$P_0 = 1 - r = -9$$

For the circle centered on the coordinate origin, the initial point is

$$(x_0, y_0) = (0, 10)$$

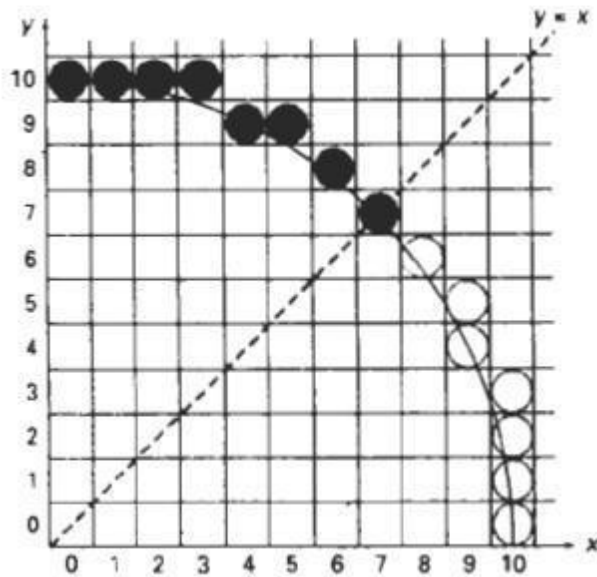
and initial increment terms for calculating the decision parameters are

$$2x_0 = 0, 2y_0 = 20$$

Successive decision parameter values and positions along the circle path are calculated using the midpoint method as

Tabulation

<u>k</u>	<u>pk</u>	<u>(x_{k+1}, y_{k-1})</u>	<u>2x_{k+1}</u>	<u>2y_{k+1}</u>
0	-9	(1,10)	2	20
1	-6	(2,10)	4	20
2	-1	(3,10)	6	20
3	6	(4,9)	8	18
4	-3	(5,9)	10	18
5	8	(6,8)	12	16
6	5	(7,7)	14	14



(2 marks)

CHARACTER GENERATION

Computer graphics involves display of picture, lines and other graphics like designs. These picture and graph will belong to some data. Some information and instruction should be given to the user about this data. This is possible with the help of text display. Since text consists of string of characters. so a character is a basic unit of text.

Any drawing and design needs to be labelled and dimensioned which requires letters, numbers and other special characters. The overall design and style of these characters are referred to as typeface or fonts. There are hundreds of fonts available. Based on styles some common ones are, for example, Times New Roman, Arial, Comic Sans, Courier New, Sans Serif etc., and based on language, it can be of any regional language type such as Korean, Japanese, English , Hindi etc. There are some font tables which offer some special character sets like Wingdings, Symbols etc., for generating special characters. Each one of these can be formatted as **bold faced**, *italic* or underlined.

A typeface is a design for a set of printer or display fonts, each for a set of characters, in a number of specific sizes. Since outline fonts such as TrueType and Type 1 are scalable, a computer typeface designer must anticipate the possibility of the design being scaled through a range of sizes. Typefaces often come as a family of typefaces, with individual typefaces for italic, bold, and other variations in the main design. Typefaces can be divided into two broad groups: serif and sans serif. Serifs comprise the small features at the end of strokes within letters.

There are two types of representations for storing any font: Bitmap font representation and Outline font representation.

Bitmap font: It uses rectangular grid patterns.

Outline font: It uses straight lines and curve sections to describe character shapes. When the pattern of Figure (a) is copied to an area of the frame buffer, the 1 bits designate which pixel positions are to be displayed on the monitor. To display the character shape in Figure (b) the interior of the character outline must be filled using the scan line fill procedure.

Bitmap fonts free the simplest to define and display. The character grid only needs to be mapped to a frame buffer position. However, bitmap fonts require more space because each variation must be stored in a font cache. Outline fonts require less storage since each variation does not require a distinct font cache. Different shapes and sizes can be generated using outline font and are easier to generate. But it takes more time to process the outline fonts because they must be scan converted into the frame buffer.

text (wcPoint, string)

Parameter string is assigned a character sequence which is then displayed at coordinate position wcPoint=(x,y).

polymarker (n, wcPoints)

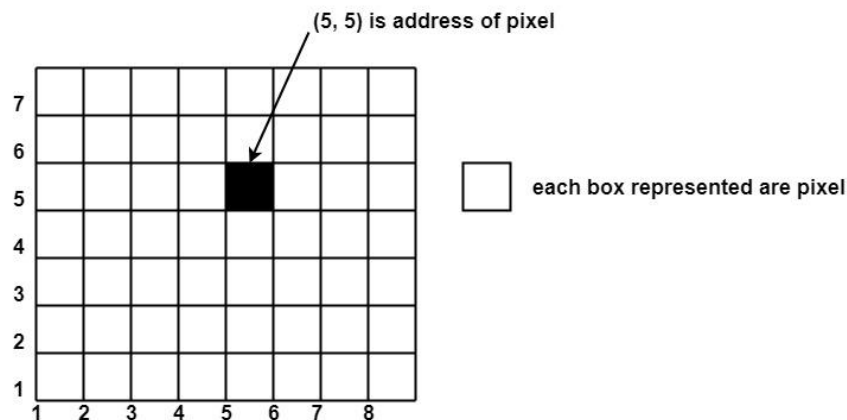
A marker symbol is placed at one of more selected positions. A predefined character is then centered at each of the 'n' coordinate positions in the list wcPoints.

What is a Pixel or Pel:

The term pixel is a short form of the **picture element**. It is also called a point or dot. It is the smallest picture unit accepted by display devices. A picture is constructed from hundreds of such pixels. Pixels are generated using commands. Lines, circle, arcs, characters; curves are drawn with closely spaced pixels. To display the digit or letter matrix of pixels is used.

The closer the dots or pixels are, the better will be the quality of picture. Closer the dots are, crisper will be the picture. Picture will not appear jagged and unclear if pixels are closely spaced. So the quality of the picture is directly proportional to the density of pixels on the screen.

Pixels are also defined as the smallest addressable unit or element of the screen. Each pixel can be assigned an address as shown in figure.



Different graphics objects can be generated by setting the different intensity of pixels and different colors of pixels. Each pixel has some co-ordinate value. The coordinate is represented using row and column.

P (5, 5) used to represent a pixel in the 5th row and the 5th column. Each pixel has some intensity value which is represented in memory of computer called a **frame buffer**. Frame Buffer is also called a **refresh buffer**. This memory is a storage area for storing pixel values using which pictures are displayed. It is also called as **digital memory**.

Inside the buffer, image is stored as a pattern of binary digits either 0 or 1. So there is an array of 0 or 1 used to represent the picture. In black and white monitors, black pixels are represented using 1's and white pixels are represented using 0's. In case of systems having one bit per pixel frame buffer is called a **bitmap**. In systems with multiple bits per pixel it is called a **pixmap**.
