Chapter 8

ILLUMINATION AND SURFACE RENDERING METHOD

Chapter 9

INTRODUCTION TO OPENGL

Chapter – 1

Introduction and Application

1.1 Introduction

Graphics is an image or a visual representation of an object and the visual representation or image displayed on a computer screen is known as computer graphics. More precisely, computer graphics is the field or branch of science and technology related to generation (creation), storage and manipulation of graphics (images or pictures) of objects using computer i.e. using hardware and software. Objects may be the concrete real world objects or the abstract and synthetic objects such as mathematical surface, engineering structure, architectural design, survey results, etc. In other word, graphics means to plot some points on graph to make an image. Computer graphics means to plot some pixels (points) on a computer screen to make an image. Pixel or picture element is the elementary part of the computer screen. We see every day the images created by using computer in books, magazines, movies, TV, etc.

Computer graphics is the rendering (servicing or making) tools for the generation and manipulation of images. These tools include both hardware and software.

Hardware comprises monitor, printer, plotter (that display graphics) and input devices includes mouse, light pen, keyboard, scanner, etc. Software tools refer to the collection of graphics routine.

Computer graphics = Data structure + Graphics algorithm + Language

Data structure means those data structure that are suitable for computer graphics. Graphics algorithm refers to algorithm for picture generation and transformation. Language means high level language for generation of graphics or pictures of objects.

Computer graphics can be either two-dimensional or three-dimensional. Digital graphic files are divided into two categories:

i. Raster graphics

ii. Vector graphics

1.2 Raster Graphics

A raster graphic or image is made up of pixels (screen point). Raster graphics are composed of a simple grid of pixels. The pixel can be of different color. Raster graphics are rendered images on a pixel-by-pixel basis and they are well fit when handling shading and gradients. A raster graphic, such as a gif or jpeg, is an array of pixels of various colors, which together form an image. Raster graphics are the most common and are used for digital photos, web graphics, icons, and other types of images.

When a raster image is scaled up, it usually loses quality. A raster image can be enlarged by either adding more pixels or enlarging the size of the pixel. In either way original data is spread over a larger area at the risk to losing clarity.

Raster graphics based file format:

.jpg Joint Photographic Experts Group (JPEG)

.png Portable Network Graphics (PNG)

.gif Graphics Interchange Format (GIF)

.tiff Tagged Image File Format (TIFF)

.psd Adobe Photoshop File

.pat Corel Paint File

.pdf Portable Document Format (PDF)

(a) (b)

Figure 1.1: Raster and vector graphics

Advantages of raster graphics

Every pixel in a raster image can be of different color therefore we can create a complex image with any kind of color changes and variations. Raster graphics are useful for creating rich and detailed images.

Almost any program can work with a simple raster file. The most recognized application that handles raster graphics is Adobe Photoshop however there are also several other image editing software options out there to choose from.

Disadvantages of raster graphics

It looks grainy, distorted, and blurred when raster images are scaled up. This is because raster images are created with a finite number of pixels. When we increase the size of a raster image, the image will increase in size. However, because there are no longer enough pixels to fill in this larger space, gaps are created between the pixels in the image.

Raster images hold more data and may be slower to edit. Raster files are often quite large. Raster files contain all the information for every single pixel of the image. Each of these pixels has an X and Y coordinates as well as color information associated with it. Therefore, raster graphics files tend to be very large.

Raster graphics are not great for embroidery. Because raster images are based on square pixels, the embroidery may look like it has jagged edges. If we want to embroider an image with smoother edges, it is best to use vector graphics instead of raster graphics.

1.3 Vector Graphics

Vector graphics (also called geometric modeling or object oriented graphics) is made up of geometrical primitives such as points, lines, curves, and polygons which are all based upon mathematical equations to represent images in computer graphics. A vector graphic can be scaled to any size without losing quality.

Vector graphics are composed of paths which may be lines, shapes, letters, or other scalable objects. A vector graphic, such as an .eps file or Adobe Illustrator file, is composed of paths, or lines, that are either straight or curved. The data file for a vector image contains the points where the paths start and end, how much the paths curve, and the colors that either border or fill the paths. Vector graphics are not made of pixels, the images can be scaled to be very large without losing quality. They are often used for creating logos, signs, and other types of drawings. Unlike raster graphics, vector graphics can be scaled to a larger size without losing quality. Raster image's dimensions are measured in pixels (pixel per inch-ppi). Vector graphics are resolution independent.

The most recognized applications which handle vector based graphics are Adobe illustrator, Macro media freehand and Corel draw. Vector graphics are generally used for line art, illustrations, and embroidery.

All modern current computer video displays translate vector representation of an image to a raster format. The raster image, containing a value for every pixel on the screen, is stored in memory.

Probably the most common example of vector-based files that we use daily without even realizing is font files.

Vector graphics based file format:

- .eps Encapsulated PostScript File (EPS)
- .svg Scalable Vector Graphics (SVG)
- .ai Adobe Illustrator File
- .cdr Corel Draw File
- .pdf Portable Document Format (PDF)

Advantages of vector graphics:

Vector files are small because they contain a lot less data than raster files. Vector graphics are more flexible than raster graphics because they can be easily scaled up and down without any loss to the quality of the image. Vector graphics have smoother lines in comparison to raster graphics.

Disadvantages of vector graphics:

If there are small errors or faults in a vector graphic, these will be seen when the vector image is enlarged significantly. Vector graphics can't display the abundant color depth of a raster graphic.

1.4 Computer Graphics and Image Processing

The difference between computer graphics and image processing can be studied with the help of following table.

Computer graphics	Image processing
1. It is the field related to the generation of pictures using computers.	1. It applies technique to modify or interpret existing pictures.
2. It synthesizes pictures from mathematical or geometrical models.	2. It analyzes picture to derive description in mathematical or geometrical forms.
3. It includes the creation, storage, and manipulation of images of objects	3. It is the part of computer graphics that handles image manipulation or interpretation
4. E.g., drawing a picture	4. E.g., making blurred image visible.

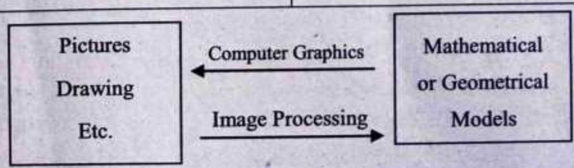

Figure 1.2: Computer graphics and image processing

1.5 History of Computer Graphics

- In 1950's outputs were via teletypes, line printer and Cathode Ray Tube (CRT). Using dark and light character, pictures were reproduced.
- In 1950, Been Laposky created the first graphic images on oscilloscope generated by an electronic (analog) machine. The image was produced by manipulating electronics beams and recording them onto high speed film.
- In 1951, UNIVAC-I, the first general purpose commercial computer; crude hardcopy devices, and line printer were invented. MIT-whirlwind computer, the first to display real time video and capable of displaying real time text and graphic on a large oscilloscope screen was developed.

- In 1960's, modern interactive graphics was begun. Outputs were vector graphics and interactive graphics, but the problems were the cost and inaccessibility of machine. In middle 1950's SAGE (Semi-Automatic Ground Environment) air defenses system was developed. It was the first to use command and control CRT display consoles on which operator identifies target, with light pen (hand –held pointing devices that senses light emitted by objects on screen)
- In 1960, William Fetter. coined the computer graphics to describe new design methods.
- In 1961, Stove Russel made space wars, first video/computer game
- In 1963, Douglas Englebart developed first mouse. Ivan Sutherland made sketch pad, interactive C.G. System, a man-machine graphical communication system, it features: pop-up menus, constrained –based drawing, hierarchal modeling, utilized light pen for interaction
- He developed the dragging, rubber banding and transforming algorithms, He introduced data structures for storing. He is considered data founded of computer graphics.
- In 1964, William Felter developed first computer model of a human figure.
- In 1965, Jack Bresenham developed line drawing algorithm.
- In 1968, Tekronix made a special CRT, the direct view storage tube, with keyboard and mouse, a simple computer interface for $15,000 which made graphics affordable.
- In 1969, John Warnock developed area subdivision algorithm, hidden –surface algorithms. Bell labs developed first frame buffer containing 3 bits per pixel. CAD (computer aided design), CAM (computer aided manufacturing) with enormous potentials for automating drafting and other drawing –intensive activities, were developed. The general motors' DAC system for automobile design and the Itek Digitek system for lens design were

pioneering efforts that showed the utility of graphical interaction in the interactive design cycles common in engineering.

A number of commercial products using these systems were appeared. But hardware was expensive.

- In the early 1970's, Output start using raster displays, graphics capability was still fairly chunky.
- In 1972, Nolan kay Bushnell Pong made video arcade game.
- In 1973, John whitiney Jr. and Gary Demos made "Westworld", first film with computer graphics.
- In 1974, Edwin catmuff developed texture mapping and z-buffer hidden surface algorithm. James Blim developed curved surfaces, refinement of texture mapping.
- In 1971, Rendering model Gouraud shading was developed.
- In 1974 – 77, Phong shading (rendering model) was developed.
- In 1977, Steve Wozmak made Apple II, color graphics personal computer.
- In the 1980's, outputs were built in raster graphic, bitmap image and pixel, personal computers cost decrease drastically, track ball and mouse became the standard interactive devices.

  1980's, Artists and graphic designers preferred to use Macintosh and PC's.
- In late 1980's, Artists and graphic designers preferred to use Macintosh and PC.
- In 1982, Ray tracing (Illumination based rendering method) was developed. In 1982, Steven Lisberger made 'Tron', first Disney movie which made extensive use of 3-D computer graphics. John Walkner and Dan Drake developed Auto CAD
- In 1983, Jaron Lanier made 'Data Glove", a virtual reality film features a glove installed with switches and sensors of detection hand motion.

- In 1984, Wave from tech developed Polhemus, first 3D graphics software
- In 1987, IBM introduced VGA(Video Graphics Array)
- In 1989, Video Electronics Standard Association (VESA) formed SVGA (Super VGA)
- In 1990's, since the introduction of VGA and SVGA personal computer could easily display photo realistic images and movies 3D image rendering were become the main advances and it stimulated cinematic graphics application.
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- In 1990, Render man system that provides fast accumulate and high quality digital computer effects was developed.
- In 1992, Silicon graphic developed open GL specification.
- In 1993, Mosaic, first graphic web browser and Jurassic park, a successful CG fiction film was made.
- In 1995, 'Toy story', first full length computer generated feature film was made.
- In 2003, ID software developed Doom graphics engine.

1.6 Uses of Computer Graphics

The main application areas of computer graphics are display of information (simple data to scientific visualization), design (graphic to industrial design), user interfaces (GUI to virtual reality), simulation (entertainment to academic purpose), etc. which can be synthesized as follows:

1. User interfaces
2. Plotting or visualization of measurement data
3. Office automation and electronic publishing

4. Computer aided design and drafting
5. Scientific and business visualization
6. Simulation and virtual reality
7. Entertainment
8. Art and commerce
9. Civil Engineering applications
10. Medical applications
11. Internet

1. User Interfaces

The interface between the human and the computer has been radically changed by the use of computer graphics. Most applications have a Graphical User Interface (GUI) for user friendly and interactive operation. Today's software has user interfaces that rely on the desktop window systems to manage multiple simultaneous activities and on point and click facilities to select items menu, icon, and objects on the screen.

2. Plotting or visualization of measurement data

Graphics is extensively used in plotting 2D and 3D graphs such as the histograms, bar and pie charts, the task scheduling charts of mathematical, physical, and economic functions. These plotting or visualization of measurement data are useful to analyze meaningfully and concisely the trend and pattern of complex data.

3. Office automation and electronic publishing

Nowadays, the necessary document that contains text, tables, graphs, drawings, pictures can be easily printed or saved as electronic (softcopy) document. The office automation and electronic publishing became possible by the development of computer graphics.

4. Computer aided design and drafting

A major use of computer graphics is in design process. Computer graphics is used to design components and systems (including building and other structural design) of architectural systems, mechanical, electrical, electrochemical and electronic devices, auto mobile bodies, aircrafts, watercrafts, spacecrafts, very large scale integrated (VLSI) chips, optical systems, and telephone and computer networks.

Figure 1.3: Computer aided design

5. Scientific and business visualization

Scientific visualization means generating computer graphics for scientific works and medical data sets. Business visualization is generating computer graphics for nonscientific data sets such as economic data set. Visualization makes easier to understand the trends and pattern inherent in huge amount of data sets. It would otherwise be almost impossible to analyze those data numerically.

6. Simulation and virtual reality

One of the most impressive and familiar uses of computer graphics is simulation and virtual reality. Simulation is the imitation of the conditions like those, which is encountered in real life. Virtual reality is an interactive computer-generated experience taking place within a simulated environment, that incorporates mainly auditory and visual, but also other types of sensory feedback like haptic. Simulation helps to learn or feel the condition one might have to face in near future without being in danger at the beginning of the course. Astronauts' simulator, flight simulator, military simulator, naval simulator, driving

simulator, air traffic control simulator, and heavy duty vehicle simulator are some of the mostly used simulators in practice.

7. Entertainment

Computer graphics is used in making games, special effects in movies, music videos, television shows, etc. Sometimes, the graphics scenes are displayed totally using computer graphics and sometimes, graphics objects are combined with the real actors and live scenes. Computer and video games such as FIFA, Formula-1, Doom and Pools are few to name where computer graphics is used extensively. Disney movies such as Lion King, The Beauty and the Beast, and other scientific movies like Star Trek are the best examples of application of computer graphics in the field of entertainment.

8. Art and commerce

Computer graphics are used in both fine art and commercial art. The ability to create any shape and play with any color with the help of computer graphics opened the new realm of art and commerce. Computer graphics is used to produce a picture that expresses a message and attract attentions such as a new model of a car moving along the ring of the Saturn.

These pictures are frequently seen at transportation terminal, super markets, hotel, etc. The slide production for commercial, scientific, or education presentation is another cost effective use of computer graphics. One of such graphics package is Power Point.

9. Civil engineering applications

Civil engineering applications include cartography, GIS (geographical information system), etc. Cartography is a subject which deals with the marketing of the maps and chart. Computer graphics is used to produce both accurate and schematically representation of geographical and other natural phenomenon from measurement data. It includes geographic map, oceanographic chart, weather map, color map, and population density map. Surfer is one of such graphic packages which in extensively used for cartography.

10. **Medical applications**

Computer graphics has become a powerful tool for diagnosis and treatment in medical fields. X-ray, video x-ray, complex operation, etc. are done using computer graphics method and techniques in medical field.

11. **Internet**

There is a large amount of multimedia content available on net. Internet became famous because of the development of computer graphics.

1.7 General Term and Terminologies

1. **Pixel (or pel)**

Pixel (picture element) is defined as the smallest screen element. It is the smallest piece of the display screen which can be controlled. The screen point is controlled by setting the intensity and color of the pixel.

2. **Aliasing**

Real objects or lines, polygon, edges are continuous but a raster device is discrete. The digitization of continuous signal produces jaggies i.e., a staircase problem. The sampling process digitizes the coordinate points and it produces staircase appearance. This process of distortion of information due to sampling is called aliasing.

3. **Antialiasing**

It is defined as the process which compensates the consequences of under sampling process.

4. **Pixel phasing**

It is a hardware based antialiasing technique in which the graphics system shifts individual pixels from their normal positions in the pixel grid by a fraction (typically 0.25 and 0.5) of the unit distance between the pixels. By moving pixels closer to the time line, this technique is very effective in smoothing out the stair steps without reducing the sharpness of the edges.

5. **Interlacing**

It is used when the perpetual threshold is greater than the frequency of standard line voltage. If refresh rate is greater than phosphor's persistence, then moving objects become blurred. If refresh rate is lesser than phosphor's persistence, then it creates flickering. Interlacing is used to break the raster line into two sweep patterns consisting of half the number of raster lines in original patterns.

6. **Bit depth (or color depth)**

It is defined as the number of bits needed (assigned) to a pixel in the image. It specifies the number of colors that a monitor can display. For example, if a pixel is denoted by a byte (8 bits), then the total number of color that can be displayed per pixel is $2^8 = 256$.

7. **Fluorescence and phosphorescence**

When the electron beam strikes the phosphor-coated screen of the CRT, some of this energy is dissipated as heat but the rest of energy is used to make the electron of the phosphor atoms to jump to higher quantum energy level. Fluorescence is the light emitted by very unstable electrons while the phosphor is being struck by electrons. Phosphorescence is the light given off by stable excited electron to their unexcited state once the electron beam excitation is removed. Fluorescence usually last for a fraction of microsecond. Most of the light emitted is phosphorescence.

8. **Persistence**

Persistence is how long phosphors continue to emit light (that is to have excited electron returning to ground state) after the CRT beam is removed. More precisely, persistence is the time to decay to $1/10^{th}$ of its original intensity of the emitted light. That is, how long phosphorescence persists is the persistence. Lower persistence phosphors require higher refresh rates to maintain a picture on the screen without flicker. The phosphor with low persistence is useful for animation. A high persistence phosphor is useful to highly complex static pictures. Graphics monitors are usually constructed with persistence in the range from 10 to 60 micro second.

9. Refresh rate

The light emitted by the phosphor fades very rapidly. So, some method is needed for maintaining the screen picture. One way to keep the phosphor glowing is to redraw the picture repeatedly by quickly directing the electron beam back over the same points. Refresh rate is the number of times the image is redrawn per second to give a feeling of picture without flick. It is the frequency at which the content of the frame buffer is sent to the display monitor. Refresh rate is usually 50 frames per second. Refresh rate above which flickering stops is called critical fusion frequency (CFF). The factors affecting CFF are persistence, image intensity, ambient room light, and wave length of emitted light.

10. Horizontal scan rate

The horizontal scan rate is the number of scan lines per second. The rate is approximately the product of the refresh rate and the number of scan lines.

11. Resolution

Resolution is the maximum number of pixels (points) that can be displayed horizontally and vertically without overlap on a display device. More precisely, it is the number of pixels per unit length that can be placed horizontally and vertically. It is the number of pixels in horizontal direction × number of pixels in vertical direction.

Factors affecting the resolution:

i) Spot profile: The spot intensity has a gaussian distribution as depicted in figure. So, two adjacent spots on the display device appear distinct as long as their separation D_2 is greater than the diameter of the spot D_1 at which each spot has an intensity of about 60 percent of that at the center of the spot.

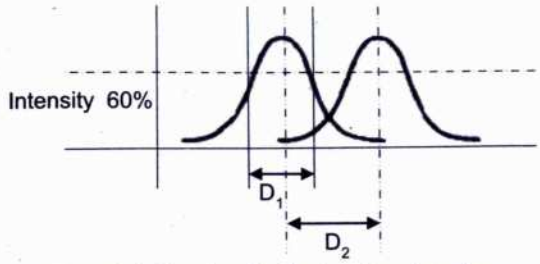

Figure 1.4: Gaussian distribution of spot intensity

ii) Intensity: As the intensity of electron beam increases, the spot size on the display tends to increase because of spreading of energy beyond the point of bombardment. This phenomenon is called blooming, and consequently, the resolution decreases.

12. Aspect ratio

It is defined as the ratio of vertical points to horizontal points necessary to produce equal length lines in both direction on the screen. Aspect ratio 3/4 means that a vertical line plotted with three points has the same length as a horizontal line plotted with four points. It is the ratio of image's height to its width.

600×800 pixels in display has the aspect ratio

$$A.R. = \frac{600}{800} = \frac{3}{4} = 3:4$$

13. Horizontal and vertical retrace

Horizontal retrace means at the end of each scan line, the returning of the electron beam to the left side of the screen to begin displaying the next scan line. The return to the left of the screen, after refresh each scan line is called the horizontal retrace of the electron beam. At the end of each frame ($\frac{1}{50}$ thof a second), the electron beam returns to the top left corner of the screen to begin the next frame. It is called vertical retrace.

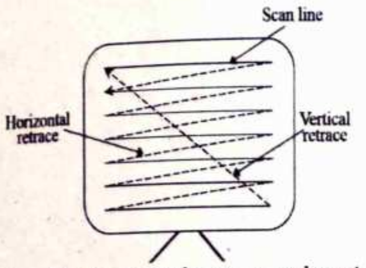

Figure 1.5: Scan line, horizontal retrace, and vertical retrace

14. Refresh buffer/ frame buffer/ bit map/ pix map:

In 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 the beam intensity turned on and off to create a pattern of illuminated spots. Picture definition is stored in a memory. The memory is 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. Each screen point is referred to as a pixel or pel (picture element). On black and white system with one bit per pixel, the frame buffer is commonly called a bit map. For system with multiple bits per pixel, the frame buffer is commonly called a pixmap.

Color depth	Number of color displayed	Byte of storage per pixel	Common name for color depth
4bit	16	0.5	Standard
8bit	256	1	256 color mode
16 bit	65,536	2	High color
24 bit	16,717,216	3	True color

1.8 Hardware Concepts

1. Tablet

Tablet, a digitizer, is a device used to scan an object. A tablet digitizes an object detecting the position of a movable

stylus (a pencil shaped device) or a puck (a mouse like device with cross hairs for sighting positions) held in the user's hand. These discrete co-ordinate positions can be then joined with straight line segments to approximate the shape of original object. A tablet is a flat surface and its size varies from 6 by 6 inches up to 48 by 72 inches or more. The accuracy of the tablet usually varies from about 0.2 mm on desktop models to about 0.05 mm or less on larger models.

Types of tablet:

i. Electrical tablet
ii. Sonic (acoustic) tablet
iii. Resistive tablet

i) Electrical tablet

In electrical tablet, a rectangular grid of wires is embedded in the tablet surface. Electromagnetic pulses are generated along the wires and electric signal is induced in a wire coil in the stylus or puck. The strength of the signal induced by each pulse is used to determine the position of the stylus. A signal is sent to the computer when the tip of the stylus is pressed against the tablet or when any button on the puck is pressed. The information provided by the tablet repeats 30 to 60 times per second.

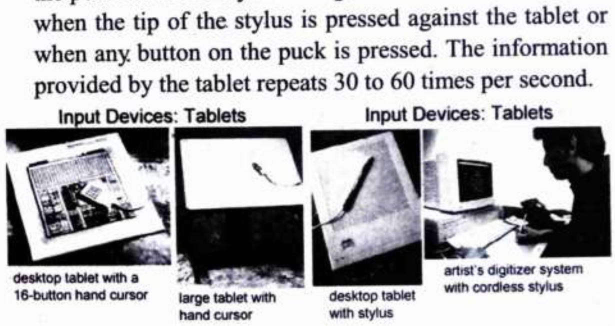

Figure 1.6: Tablets

ii) Sonic (acoustic) tablet

Sonic (acoustic) tablet uses sound waves to detect the stylus position. Microphone is used to detect the sound emitted by an electrical spark from a stylus tip. The position of the stylus or the co-ordinate values is calculated using the delay between when the spark occurs and when its sound arrives at each microphone. The main advantage of sonic tablet is that it doesn't require a dedicated working area as the microphones can be placed on any surface to form the tablet work area. This facilitates digitizing drawing on thick books.

iii) Resistive tablet

Resistive tablet is a piece of glass coated with a thin layer of conducting material. When a battery is powered, stylus is activated at certain position. The device emits high frequency radio signals which induces the radio signals on its conducting layer. The strength of the signal received at the edges of the tablet is used to calculate the position of the stylus. Several types of tablets are transparent, and thus can be backlit for digitizing x-ray films and photographic negatives. The resistive tablet can be used to digitize the objects on CRT because it can be curved to the shape of the CRT. The mechanism used in the electrical or sonic tablets can also be used to digitize the 3D objects.

2. Touch panels

The touch panel allows the user to select the screen positions directly with the touch of a finger to move the cursor around the screen or to interact with the icons. There are three types of touch panels:

i. Optical touch panel
ii. Electric touch panel
iii. Sonic (acoustic) touch panel

i. Optical touch panel

Optical touch panel employs a series of infrared light emitting diodes (LED) along one vertical edge and along one horizontal edge of the panel. The opposite vertical and horizontal edges contain light detectors which are used to record beams that are interrupted when the panel is touched. Touching the screen breaks one or two vertical and horizontal light beams. The interrupted beams identify the coordinate positions.

ii. Electrical touch panel

Electrical touch panel consists of slightly separated two transparent panels one coated with a thin layer of conducting material and the other with resistive material. When the outer plate is touched with a finger, it is forced into contact with the inner plates by creating the voltage drop across the resistive plate which is then used to calculate the co-ordinate of the touched position.

iii. Sonic (acoustic) touch panel

In sonic (acoustic) touch panel, high frequency sound waves traveling alternately horizontally and vertically are generated at the edge of the panel (glass plate).Touching the screen causes part of each wave to be reflected back to its source. The screen position at the point of contact is then calculated using the time interval between the transmission of each wave and its reflection to the emitter.

3. Light Pen

It is a pencil shaped device used to select the co-ordinates of a screen point by detecting the light coming from the points on the CRT screen. In raster display 'Y' is set at Y_{max} and 'X' changes from 0 to X_{max} in the first scan line. For the second line, 'Y' decreases by one and 'X' again changes from 0 to X_{max} and so on. When activated light pen sees a burst of light at certain position as the electron beam hits the phosphor coating at that position, it generates an electric pulse. This is used to save the video controller's 'X' and 'Y' registers and interrupt the computer. By reading the saved value, the graphics package can determine the co-ordinates of the position seen by the light pen.

4. Keyboard

Keyboard is used for entering text. It consists of alphanumeric key, function keys, cursor-control keys, and separate numeric pad. It is used to move the cursor, to select the menu, item, predefined functions. In computer graphics, keyboard is mainly used for entering screen co-ordinate and text to invoke certain functions. Nowadays, ergonomically designed keyboard (ergonomic keyboard) with removable palm rests is available. The slope of each half of the keyboard can be adjusted separately.

5. **Mouse**

Mouse is a small handheld device used to position the cursor on the screen. It can be picked up, moved in space, and then put down again without any change in the reported position. For this, the computer maintains the current mouse position, which is incremented or decremented by the mouse movements. Following are the mice, which are mostly used in computer graphics:

i. **Mechanical mouse**

When roller in the box of this mechanical mouse is moved, a pair of orthogonally arranged toothed wheels, each place in between LED and a photo detector, interrupts the light path. The numbers it interrupts, so generated, are used to report the mouse movements to the computer.

ii. **Optical mouse**

The optical mouse is used on a special pad having grid of an alternating light and dark lines. A LED in the bottom of the mouse directs a beam of light down onto the pad from which it is reflected and sensed by the detectors on the bottom of the mouse. As the mouse is moved the reflected light beam is broken each time a dark line crossed. The number of pulses so generated, which is equal to the number of lines crossed are used to report mouse movements to the computer.

6. **Barcode reader**

A barcode reader (or barcode scanner) is an electronic device for reading printed barcodes. Like a flatbed scanner, it consists of a light source, a lens, and a light sensor. Barcode reader translates optical impulses into electrical ones. Additionally, nearly all barcode readers contain decoder circuitry analyzing the barcode's image data provided by the sensor and sending the barcode's content to the scanner's output port.

7. **Data glove**

A data glove is an interactive device resembling a glove worn on the hand, which facilitates tactile sensing and fine-motion control in robotics and virtual reality. Data gloves are one of several types of electromechanical devices used in haptics applications. Tactile sensing involves simulation of the sense of human touch and includes the ability to perceive pressure, linear force, temperature, and surface texture. Fine-motion control involves the use of sensors to detect the movements of the user's hand and fingers and the translation of these motions into signals that can be used by a virtual hand (for example, in gaming) or a robotic hand (for example, in remote-control surgery).

1.9 Refresh Cathode Ray Tube

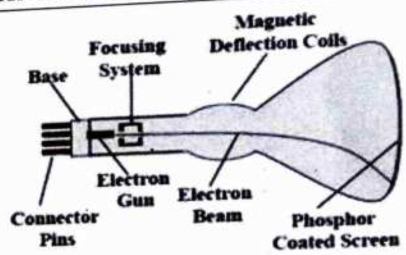

***Figure 1.7:** Basic design of a magnetic-deflection CRT*

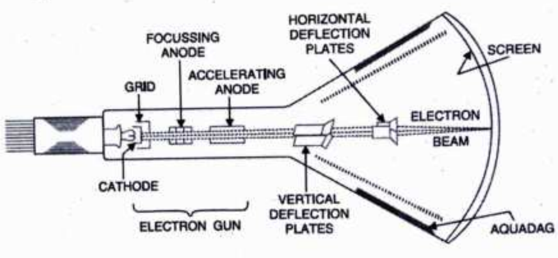

***Figure 1.8:** Operation of an electron gun with an accelerating anode.*

It consists of a CRT along with control circuits. CRT is a vacuum glass tube with the display screen at one end and connectors to the control circuits at the other. Inside of display screen is a special material called phosphor which emits light for a period of time when hit by a beam of electrons. The color of light and the time period vary from one type of phosphor to another.

The major parts of refresh CRT are:

1. **Electron gun**

   Electron gun is made up of heated metal cathode and a control grid.

   i. **Heated metal cathode**

   Heat is supplied to the cathode by directing a current through a coil by wire, called heating filament, inside the cylindrical cathode structure. This causes electron to be "boiled off" the cathode surface.

   ii. **Control grid**

   Control grid is responsible for controlling the brightness of a display. By setting voltage level on control grid, the brightness emitted by phosphor coating depends on the number of electrons that strike the phosphor coat.

2. **Accelerating anode**

   In the vacuum inside the CRT envelope, the freely negatively charged electrons are accelerated towards the phosphor coating by a high positive voltage (15000-20000).This high positive voltage can be generated by using accelerating anode.

3. **Focusing system/focusing anode**

   It is required to force the electron beam to converge into small spot when it strikes the phosphor coat. Otherwise, the electrons would repel each other and the beam would spread out as it approaches the screen. There are two types of focusing system: electrostatic focusing and magnetic field focusing. Additional focusing hardware is used in high precision systems to keep the beam in focus at all screen positions. Because of radius of curvature for CRT monitor as beam moves to the outer edges of the screen displayed image may be blurred. To adjust this, the focusing is necessary.

4. **Deflection system**

   Deflection system is needed to direct the electron beam towards a particular point on the screen. It is done in two ways: electrostatic deflection system and magnetic deflection system. When electron beam passes through the horizontal and vertical deflection plates, it is bent or deflected by the electric fields between the plates. The horizontal plates control the beam to scan from left to right and retrace from right to left (horizontal retrace).The vertical plates control the beam to go from the first scan line at the top to the last scan line at the bottom and retrace from the bottom back to the top (known as vertical retrace).

1.10 Raster and Random (Vector) Scan Display

1.10.1 Raster Scan Display

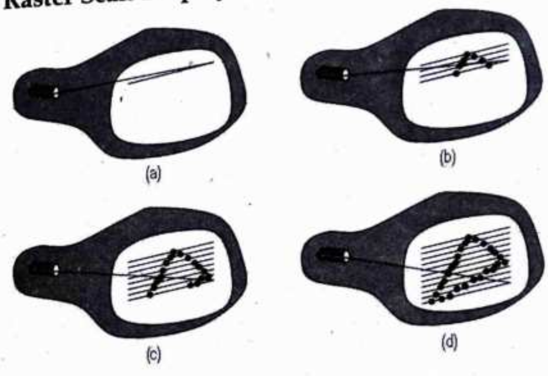

Figure 1.9: *Raster scan display*

Most common type of graphics monitor are employing a CRT (based on television technology). The electron beam is swept across the screen one row at a time from top to bottom. Picture definition is stored in memory area called "refresh buffer" or "frame buffer". The set of intensity values is retrieved from refresh buffer and "painted" on the screen one row at a time. Each screen point is referred as a "pixel" or "pel". For black and white system, each screen point (pixel) is represented by one bit either "on" or "off". For color system, additional bit is needed to represent single pixel (24 bit per pixel in high quality systems).For black and white system with one bit per pixel, the frame buffer is called "bitmap" whereas for system with multiple bits per pixel, the frame buffer is called "pixmap". Normal refresh rate is 50-60 frames per second.

Interlacing

Some monitors use a technique called "interlacing" to double the refresh rate. In this case, only half of the scan lines in a frame are refreshed at a time, first the odd numbered lines, and then the even numbered lines. Thus, the screen is refreshed from top to bottom in half time it would have taken to sweep across all the scan line. This effect is quite effective in reducing flicker.

1.10.2 Random (Vector) Scan Display

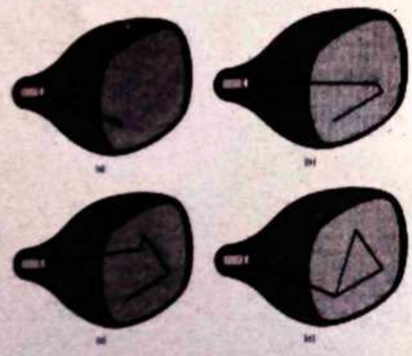

Figure 1.10: Vector scan display

In random or vector scan display, electron beam is directed only to the points of the screen where a picture is to be drawn e.g., pen plotter (hard copy device). In this system, refresh rate depends on the number of lines to be displayed. Picture definition is stored as a set of line drawing commands in system memory called display file (or display program or display list).To display a specified picture, the system cycles through the set of commands in display file, drawing each component line in turn. After all line drawing commands have been processed, the system cycles back to the first line command in the list. Random scan displays are designed to draw all the components of a picture 30 to 60 times each second.

1.10.3 Difference between Raster Scan Display and Random (Vector) Scan Display

Base of difference	Raster scan display	Random (vector) scan display
1. Electron beam	The electron beam is swept across the screen one row at a time from top to bottom.	The electron beam is swept to the parts of the screen where a picture is to be drawn.
2. Resolution	It has lower or poor resolution because picture definition is stored as an intensity value.	It has high resolution because it stores picture definition as a set of line commands.
3. Picture definition	Picture definition is stored as a set of intensity values for all screen points (pixels) in a refresh buffer.	Picture definition is stored as a set of line in a display list or file.
4. Realistic display	The capacity of the system to store intensity values for pixels make it well suited for realistic display with shadow and color pattern.	These systems are designed for line-drawing and can't display realistic shaded scenes.
5. Image drawing	Screen points or pixels are used to draw an image.	Mathematical functions are used to draw an image.
6. Cost	They are cheaper than random display.	It is more expensive than raster-scan display.

Base of difference	Raster scan display	Random (vector) scan display
7. Refresh rate	Refresh rate is 60-80 fps.	All components are drawn 30 to 60 times per second.
8. Interlacing	It uses interlacing.	It doesn't use interlacing.
9. Editing	Editing is difficult.	Editing is easy.
10. Refresh area	Refresh area is independent of picture complexity.	Refresh area depends on complexity of picture.
11. Smoothness	Produce jagged line.	Produce smooth line.
Example:	CRT, TV, Printer	Pen Plotter

1.11 Color CRT Monitors

Color CRT monitor displays color pictures using a combination of phosphors that emits different colored light.

Two basic techniques are available:

i) Beam penetration method

ii) Shadow mask method

i) Beam penetration method

In this method, two different layers of phosphor coating used red (outer) and green (inner).It displays color depending on the depth of penetration of electron beam into the phosphor layer.

i. A beam of slow electron excites only the outer red layer.

ii. A beam of very fast electrons penetrates through the red phosphor and excites the inner green layer.

iii. When quantity of red is more than green, then color appears as orange.

iv. When quantity of green is more than red, then color appears as yellow.

Screen colors as controlled by the beam acceleration voltage. Only four colors are possible and picture quality is poor.

ii) Shadow mask method

The inner side of the viewing surface of a color CRT consists of closely spaced groups of red, green, and blue phosphor dots. Each group is called a triad. A thin metal plate perforated with many small holes is mounted close to the inner side of the viewing surface. This plate is called shadow mask. The shadow mask is mounted in such a way that each hole is correctly aligned with a triad in color CRT. There are three electron guns one for each dot in triad. The electron beam from each gun therefore hits only the corresponding dot of a triad as the three electron beams deflect. A triad is so small that light emanatory from the individual dots is perceived by the viewer as a mixture of the three colors.

Two types of shadow mask method:

a) Delta-delta CRT

b) Precision inline CRT

a) Delta-delta CRT

A triad has a triangular or delta pattern as are three electron guns. Main drawback of this method is that a high precision display is very difficult to achieve because of technical difficulties involves in the alignment to shadow mask holes and the triad on one to one basis.

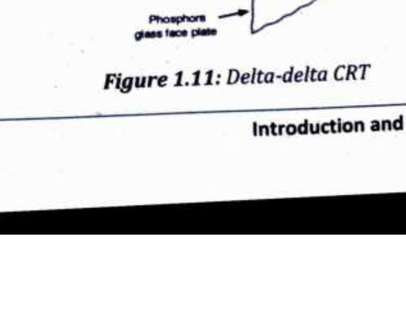

Figure 1.11: Delta-delta CRT

b) Precision inline CRT

A triad has an *in-line pattern* as are the three electron guns. The introduction of this type of CRT has eliminated the main drawback of a delta-delta CRT. Normally, 1000 scan lines can be achieved by this method.

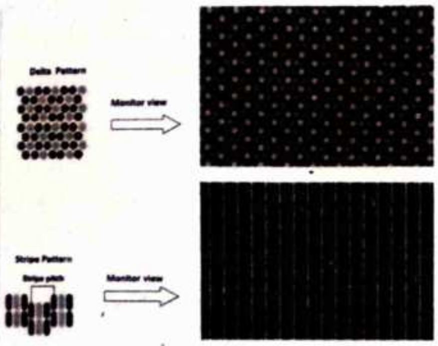

Figure 1.12: *Delta-delta and precision inline CRT*

But in this method, a slight reduction of image sharpness at the edges of the tube has been noticed. Normally, 1000 scan lines can be achieved. The necessity of triad has reduced the resolution of a color CRT. The distance between the centers of adjacent triads is called a *pitch.* In very high resolution tubes, pitch measures 0.21 mm (0.61 mm for home TV tubes). The diameter of each electron beam is set at 1.75 times the pitch. For example, if a color CRT is 15.5 inches wide and 11.6 inches high and has a pitch of 0.01 inches. The beam diameter is therefore $0.01 \times 1.75 = 0.018$ inches. Thus, the resolution per inch is about $\frac{1}{0.018} = 55$ lines. Hence, the resolution achievable for the given CRT is 850 (=15.5×55) by 638 (=11.6×55). The resolution of a CRT can therefore be increased by decreasing the pitch. But small pitch CRT is difficult to manufacture because it is difficult to set small triads and the shadow mask is more fragile owing to too many holes on it. Beside the shadow is more likely to warp from heating by the electrons.

1.12 Raster Scan Display System/ Architecture/ Technology

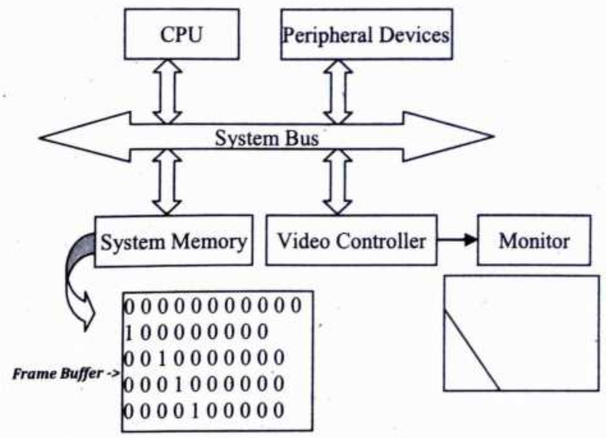

Figure 1.13: *Raster Scan System*

Raster scan system consists of CPU, a video controller (special-purpose processor), a monitor, system memory, and peripheral devices.

Advantages:

It has an ability to fill the areas with solid colors or patterns. The time required for refreshing is independent of the complexity of the image. It has low cost.

Disadvantages:

For real-time dynamics, not only the end points are required to move but all the pixels in between the moved end points have to be scan converted with appropriate algorithms which might slow down the dynamic process. Due to scan conversion, "*jaggies*" or "*stair-casing*" are unavoidable.

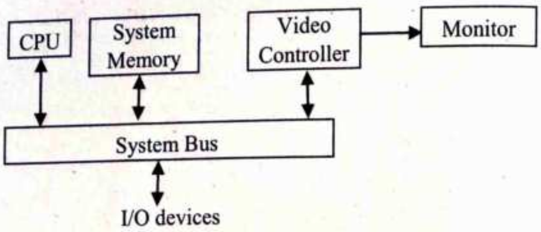

***Figure 1.15:** Architecture of a simple raster graphics system.*

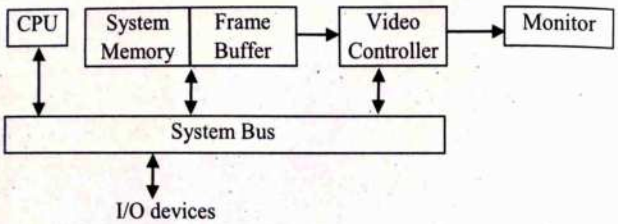

***Figure 1.14:** Architecture of RS with a fixed portion of the system memory reserved for the FB.*

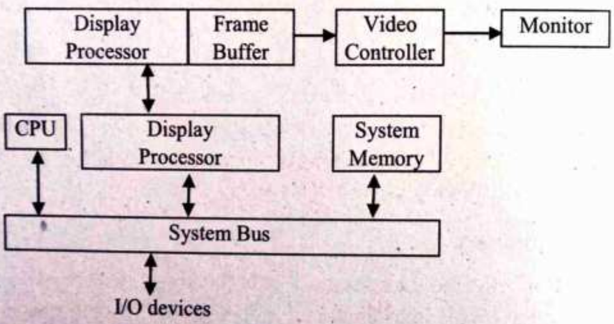

***Figure1.15:** Architecture of a raster-graphics system with a display processor.*

Application program and graphics subroutine package both reside in system memory and execute in CPU. When particular command (e.g., line (x_1, y_1, x_2, y_2)) is called by application program, the graphics subroutine package sets the appropriate pixels in the frame buffer. The video controller then cycles through the frame buffer, one scan line at the time (50 fps).It brings a value of each pixel contained in the buffer.

Video controller

A fixed area of the system memory is reserved for frame buffer and video controller is given direct access to the frame-buffer memory to refresh the screen.

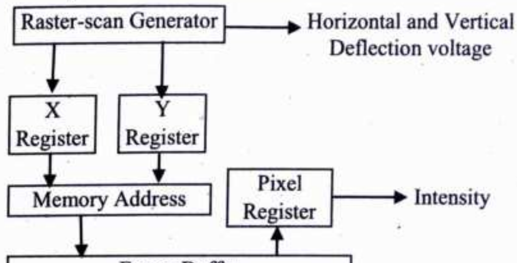

***Figure 1.16:** Basic video-controller refresh operation.*

The screen positions are referenced in Cartesian co-ordinate. Origin is defined as the lower left screen corner. The screen surface is then represented as the first quadrant of 2D system. Two registers are used to store co-ordinates of screen pixel.

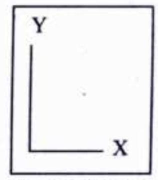

***Fig. 1.17:** Screen position*

Initially, Y-register is set to Y_{max} and X to 0.

The value stored in frame buffer for this pixel is retrieved and used to set intensity of CRT beam. Then X-register is incremented by 1 and same process is repeated for each pixel along scan line as before. After cycling through all pixels along bottom scan-line (y = 0), video controller resets register to first position on top scan line and refresh process starts again. Since the refreshing per pixel is slow process, the video controller retrieves the intensity values for a group of adjacent pixels from the frame buffer. This block of pixel intensity is stored in separate registers and used to control the CRT beam intensity for a group of adjacent pixels on the screen. Video controller can retrieve pixel intensities from different memory areas on different refresh cycles.

Display processing unit (DPU)

Display processing unit (DPU) is also called graphics controller or display co-processor. The purpose of display processor is to free the CPU from graphic chores (manipulation).It has its own memory. The major task is digitizing a picture definition given in an application program into a set of pixel intensity values for storage in frame buffer. The digitization process is called scan conversion.

DPU also performs generating various line style (dashed, dotted, solid lines), displaying color areas, and performing various transformation.

1.13 Random Scan System/Architecture/Technology

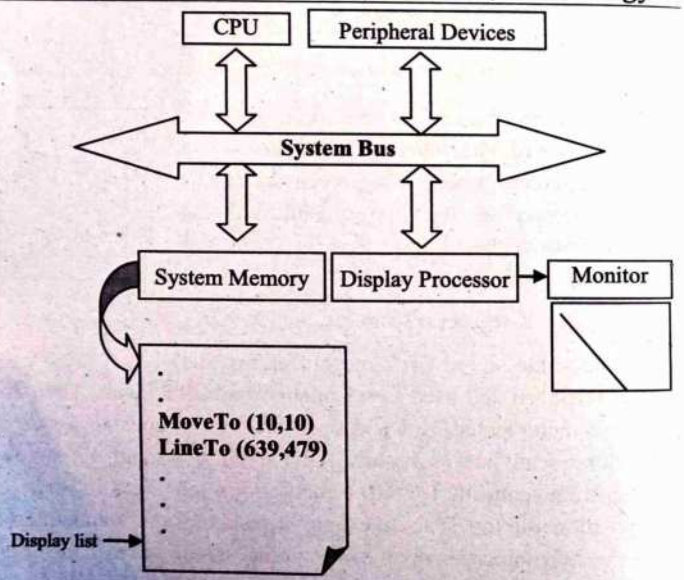

Figure 1.18: Architecture of a simple random scan system

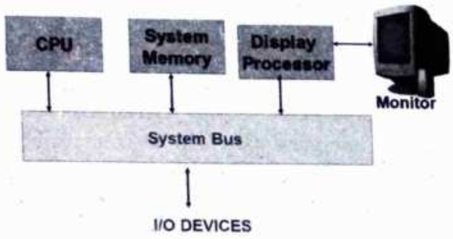

Figure 1.19: *Architecture of a simple random scan system.*

Random scan system was developed in 60's and used as common display device until 80's. The system consists of CPU, a display processor (DPU or graphics controller), a CRT monitor, system memory, peripheral devices. An application program is input and stored in the system memory along with a graphics package. Graphics commands in the application program are translated by graphics package into a display file stored in the system memory. The display list or file is then accessed by the display processor to refresh the screen. The display processor cycle through each command in the display file program once during every refresh cycle.

1.14 Flat Panel Displays

Flat panel displays have reduced volume, weight and power requirements compared to CRT. Current uses of flat panel displays are like, in TV monitor, calculator, pocket video games, laptop, and armrest viewing of movies on airlines.

Two types:

i. Emissive displays

ii. Non-emissive displays

1.14.1 Emissive Displays (Emitter)

Emissive displays are devices that convert electrical energy into light energy.

E.g., plasma panel, LED, thin-film electroluminescent displays.

Plasma Panel

Plasma panel is also known as gas-discharge display. Region between two glasses plates is filled with mixture of gases usually neon. A series of vertical conducting ribbons is placed on one glass plate and horizontal ribbons in another. Firing voltage is applied the pair of conductor to break down into glowing plasma of electrons and ions. Picture definition is stored to refresh buffer and firing voltage is applied to refresh the pixel position 60 times per second. Separation between pixels is provided by electric field of conductors.

Thin-Film Electroluminescent Displays

Thin film electroluminescent displays are similar in construction to a plasma panel filled with phosphor such as zinc sulfide doped with manganese instead of gas. When sufficiently 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 manganese atoms which release the energy as spot of light to glowing plasma affect in plasma panel.

LED

In LED, a matrix of diodes is arranged to form the pixel positions in the display and picture definition is stored in a refresh buffer. 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.

1.14.2 Non-Emissive Displays (Non-Emitter)

It uses optical effects to convert sun light or light from some other source into graphic pattern.

E.g., LCD (Liquid crystal device)

LCD (Liquid Crystal Display)

LCD is 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.

SOLVED NUMERICAL

1. ***Calculate the frame buffer size (in KB) for a raster system recording a video for 1 min with resolution of 1280 × 1024, and storing 24 bits per pixel with a refresh rate of 25 fps.***
[2076 Ashwin Back]

Solution:

Screen resolution = 1280 × 1024

Refresh rate = 25 fps

Bit required to represent a pixel = 24 bits

Memory required just for a frame = 1280 × 1024 × 24 bits

Memory required for 1 second = 1280 × 1024 × 24 × 25 bits

Memory required for recording a video for 1 min is

= 1280 × 1024 × 25 × 24 × 60 bits = 5760,0000 KB

2. ***If pixels are accessed from the frame buffer with an average access the 300ns. Then will this rate produce the flickering effects? (screen resolution = 640×480)***

Solution:

Access time for 1 pixel = 300ns

Access time for 640×480 pixels = 640 × 480 × 300ns

$$\text{Frequency} = \frac{1}{t} = \frac{1}{640 \times 480 \times 300 \times 10^{-9}}$$

= 10.85 frame per second (fps)

This value is lesser than 50fps, so flicker occurs.

2. ***If the total intensity available for a pixel is 256 and the screen resolution is 640×480. What will be the size of the frame buffer?***

Solution:

Size in frame buffer for 1 pixel = 8 bit

For 640×480 pixels, size in frame buffer = 640 × 480 ×8 bits

= 300 KBytes

4. ***Consider 256 pixel × 256 scan lines image with 24-bit true color. If 10 minutes video is required to capture, calculate the total memory required?***

Solution:

Memory required for 1 sec = 256×256×3×50 Bytes

For 10 minutes, total memory required

$$= \frac{(256\times256\times3\times50\times10\times60)}{(1024\times1024\times1024)} = 5.49 \text{ GB}$$

5. ***If we want to resize at 1024×768 image to one that is 640 pixels wide with the same aspect ratio, what would be the height of the resized image?*** *[2070 Ashadh]*

Solution:

$$\text{Aspect ratio} = \frac{H}{W} = \frac{768}{1024}$$

Even after the image is resized, the aspect ratio remains same. So,

$$\frac{H}{640} = \frac{768}{1024}$$

$$\therefore H = 480$$

6. ***How much time is spent scanning across each row of pixels during screen refresh on a raster system with resolution 1024×768 and refresh rate 60 frames per second?*** *[2070 Chaitra]*

Solution:

Resolution = 1024×768

Refresh rate = 60fps

For 60 frames, it takes 1 second to scan

For 1 frame, it takes $\frac{1}{60}$ second

1 frame means total 1024×768 pixels

For 1024×768 pixels, it takes $\frac{1}{60} = 0.016667$ second

For scanning 1 pixel, it takes $\frac{0.016667}{1024\times768}$ second

For scanning 1 row of pixels i.e., 1024 pixels, it takes $\frac{0.016667}{1024\times768}\times1024 = 0.0000217013$ second.

7. ***Consider a raster scan system having 12 inch by 10 inch screen with a resolution of 100 pixels per inch in each direction. If the display controller of this system refreshes the screen at the rate of 50 frames per second, how many pixels could be accessed per second and what is the access time per pixel of the system?*** *[2071 Shrawan]*

Solution:

Total pixels = 12×100×10×100

Refresh rate= 50 frames per second.

Pixels accessed per second(f) = 12×100×10×100×50

= 60000000

Access time per pixel $= \frac{1}{f} = 1.667\times10^{-8}$ second