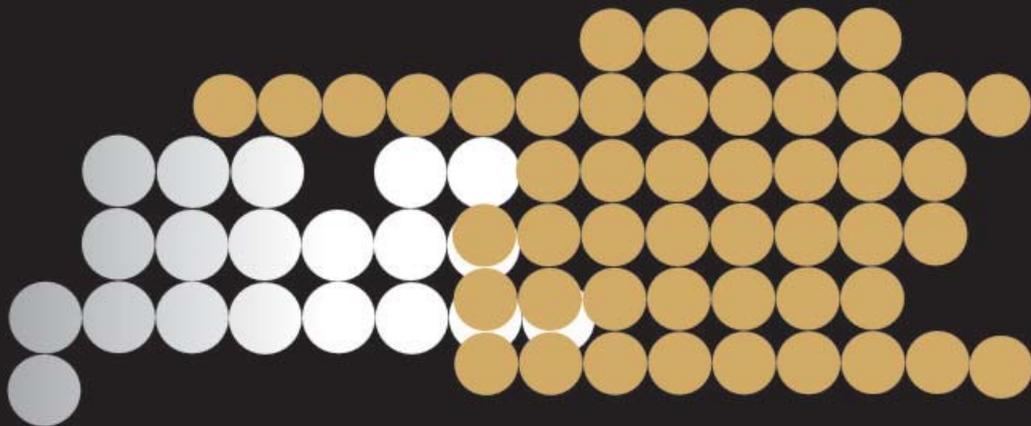


Introduction to  
**COMPUTER**  
**GRAPHICS**

First Edition



**Sumit Chauhan**

Himalaya Publishing House

# *INTRODUCTION To COMPUTER GRAPHICS*

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**FIRST EDITION : 2011**



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# Preface

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It is indeed a matter of great pleasure to write the preface of the first edition of this book entitled as "**Introduction to Computer Graphics**". Computer Graphics has always been one of the most visually spectacular branches of computer technology. It is also an extremely effective medium for communication between man and computer.

Over the years, those that I have met and worked with have continuously urged me to write a book, to put my knowledge down on paper, and to share my expertise of the subject. So at last, here it is.

Though many titles are available in the market today, still there was a need to capture some of the concepts under one cover from their scattered availability. This requirement infused with the idea of writing this text.

This book introduces the basic concepts of computer graphics, coupling the technical background and theory with practical examples and application programs throughout. Its user-friendly approach enables the reader to gain understanding through the practical examples and programs provided.

## **Features:**

- presents computer graphics theory and practice in integrated combination
- uses numerous easy-to-understand examples, C programs and end-of-chapter exercises
- provides an ideal, self-contained introduction to computer graphics
- also includes solved short question answers and previous question papers of different universities as appendix.

This book provides an introduction to Computer Graphics for students who wish to learn the basic principles and techniques of the field. Readers of every kind will, I hope, find material in this book of their interest. Also, who want technical substance, can read as a general introduction to computer graphics. It can be used by instructors and students as a resource/text book to know the subject in a better way.

The contents of the book covers the maximum syllabus of BCA, B. Tech and MCA of GGSIP University (GGSIPU), Delhi University (DU), U.P. Technical University (UPTU), Punjab Technical University (PTU), Guru Jambheshwar University (GJU), Kurukshetra University, Maharishi Dayanand University (MDU), Indira Gandhi National Open University (IGNOU), West Bengal Technical University (WBUT) and many other technical universities.

**Author**





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# CHAPTER

# 1

# Introduction to Graphics

## 1.1 INTRODUCTION

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Computer graphics is generally regarded as a branch of computer science that deals with creation, storage and manipulation of models and images. In 1960, William Fetter coined term “Computer Graphics” to describe his new design methods that he was pursuing at Boeing. Computer graphics is the study of techniques to enhance and include communication between human and machine. It allows communication through pictures, charts and diagrams to people.

By graphics, we will refer to any sketch, drawing, or any other method that pictorially represent an object or data, or process to convey information, as a supplement to written descriptions. The sketch may be a picture stating nature’s beauty, cartoon, building or human behaviour. It may be just few regular lines on the screen.

Computer graphics is all these — “a consciously managed and documented technology directed towards communicating information accurately and descriptively.” Anything that can be described in the object space, as well as, in the image space is Computer Graphics such as:

- Digital representation and display of **spatial** and **non spatial data**.
- Visual Inspection of spatial and non-spatial data.
- Analysis and manipulation of spatial data.
- Digital representation of analog world.

## 1.2 GRAPHICS AREAS

---

It is very difficult to categorize any field like computer graphics, but most of graphics expert would agree on the following major areas:

- **Modeling** deals with geometrical/mathematical specifications of an object and its visual properties in a way so they can be stored. For example that a glass of water might be specified with a set of 3-D pixels along with some interpolation method to connect all the pixels.
- **Rendering** is the process of producing realistic images. It is a term inherited from art and deals with the creation of images.
- **Animation** is a method of creating an illusion of motion by flashing sequence of images at a specific rate. The speed should be more than 20 images per second.

There are also many other areas involved in computer graphics, but whether they are included in core graphics areas is just a matter of opinion.

- **Image processing** are techniques to modify or interpret existing pictures such as photographs.
- **Interactive graphics** provides a very utilitarian function by serving as one of the most natural means of communicating with a computer.

## 1.3 APPLICATION AREAS

---

Today, computer graphics is used in various areas ranging from everyday routines activities to specialized areas in different fields like education, training, advertising, business, industry, research, art, real estate, entertainment and animation.

Some of the major application areas are:

- Building Design and Construction, e.g., making prototypes.
- Entertainment, e.g., video games, film special effects.
- Animation, and e.g., cartoons and advertisement.
- Medical Technology, e.g., CAT (Computerized Axial Tomography).
- Engineering Field, e.g., CAD (Computer Aided Design).
- Simulated Environment, e.g., HMDs (Head Mounted Displays) used in flight simulators.

## 1.4 REPRESENTATIVE USES OF COMPUTER GRAPHICS

In today's world, usually in all the areas, computer graphics is helping in doing a number of things in an application area. For example:

(i) Computer Aided Design (CAD)	Design and drafting Mechanical parts Architecture Product design
(ii) Art	Paintings Interactive works
(iii) Education and Training	Process control (status displays in – refineries, power plant, computer network) Architecture Medicine Flight Simulation Virtual Reality training
(iv) Visualization	Geometrical representation Weather forecast (an accurate-schematic representation) Geography (Cartography, e.g., geographic maps.) Medicine (X-rays)
(v) Image Processing	MRI
(vi) Graphical User Interface	Interactive technique Icons Windowing
(vii) Entertainment	Virtual sets Animations Special effects in Films Video Games Commercials
(viii) Office Automation and Electronic Publishing	

## 1.5 COMPUTER GRAPHICS VERSUS IMAGE PROCESSING

---

Although methods used in computer graphics and image processing is moreover same, the two areas are concerned with fundamentally different operations. In *Computer Graphics*, a computer is used to create a picture. *Image processing*, on the other hand, applies techniques to modify or interpret existing pictures such as photographs.

Two principal applications of image processing are:

- (a) Improving the quality of the picture.
- (b) Machine perception of visual information as used in robotics.

Computer graphics concerns the pictorial synthesis of real or imaginary objects from their computer-based models; whereas the related field of image processing (also called picture processing) treats the converse process the analysis or the reconstruction of models of 2-D or 3-D objects from their pictures.

## 1.6 CLASSIFICATION OF COMPUTER GRAPHICS

---

There are different classifications in computer graphics given by various graphics practitioners. It is just a matter of opinion. Computer graphics can be categorized as follows:

- **Screen-based graphics:** By writing directly to screen, by manipulating screen elements, e.g., paint programs.
- **Model-based graphics:** By writing to internal data structure and the data structure is 'rendered' onto screen, e.g., drawing programs.

Computer graphics can also be classified as follows:

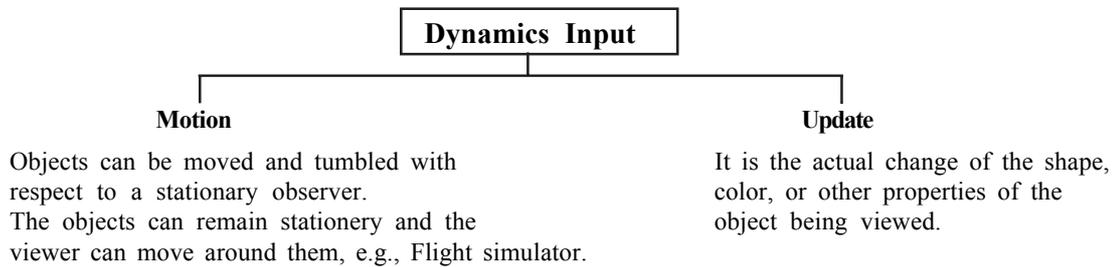
**Passive/Non-interactive graphics** – It involves the condition where the observer has no control over the image. Example: Titles shown on TV Logos and character generation etc.

**Interactive Graphics** – It provides a very utilitarian function by serving as one of the most natural means of communicating with a computer.

*Interactive computer graphics* involves 2-way communication between computer and user. The computer upon receiving signals from the input device can modify the displayed picture appropriately. To the user, it appears that the picture is changing instantaneously in response to his commands. He can give services of commands, each one generating a graphical response from the computer. In this way,; he maintains a conversation, or dialogue with the computer.

*Interactive graphics* is the most important means of producing pictures since the invention of photography and television, it has an added advantage that, we can make pictures not only of concrete, "real world" objects but also of abstract, synthetic objects (mathematical surfaces in 4-D), and of data that have no inherent geometry.

It is not confined to static images; even dynamically varying pictures can also be effectively shown.

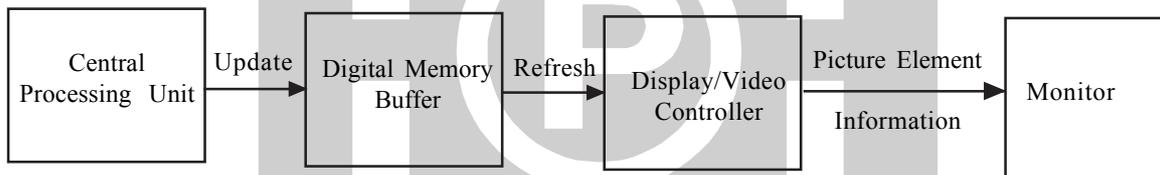


Interactive computer graphics thus permits extensive, high-bandwidth user-computer interaction. This significantly enhances our ability to understand data, to perceive trends and to privatize real or imaginary objects.

## 1.7 COMPONENTS OF COMPUTER GRAPHICS

Computer Graphics consists of three components:

- (1) Digital memory buffer (frame buffer)
- (2) Monitor
- (3) Video controller



*Fig. 1.1 Components Required to see the Output on Screen in the form of Pixels*

- (1) **Frame Buffer:** This is place where images or pictures are stored as an array in the form of 0's and 1's, 0 represents darkness and 1 represents image or picture.

Frame buffer is the video RAM (V-RAM) that is memory area that has the information about the image to be displayed on the screen. The amount of memory required to hold the image depends primarily on the resolution of the screen and also the color depth used per pixel. The formula to calculate how much video memory is required at a given resolution and bit depth is:-

$$\text{Memory in GB: } \frac{\text{X-resolution} \times \text{Y-resolution} \times \text{Bits per pixel}}{8 \times 1024 \times 1024 \times 1024}$$

- (2) **Monitor:** The purpose of display devices is to convert electrical signals into visible images.
- (3) **Video Controller:** It is an interface between digital memory buffer and TV monitor. The main function of this is to pass the contents of frame buffer to the monitor.

## 1.8 GRAPHICS PACKAGES

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**Graphics System:** A graphics system may be defined as any collection of hardware and software designed to make it easier to use graphic input and output in computer programs.

**Graphics Software:** The software component of graphic system. There are two general classifications for graphics software:

- (i) General programming packages
- (ii) Special-purpose applications packages
- (i) **General programming packages:** Provides an external set of graphics function that can be used in a high-level programming language such as C. Basic functions in a general package included those for generating picture components (straight lines, polygons, circles and other figures), setting color and intensity values, selecting views, and applying transformation.
- (ii) **Special-purpose applications packages:** These are designed for non-programmer so that users can generate displays without worrying about how graphic operations work. For example: various businesses, medical and CAD systems.

Thus, a graphic package is a set of function or subroutines used by an application program to generate pictures on a plotter or display and to handle graphical interaction.

## 1.9 GRAPHICS HARDWARE

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Graphics hardware consists of the following components:-

- 1.9.1 Input devices
- 1.9.2 Display Devices
- 1.9.3 Display controllers

### 1.9.1 Input Devices

Various devices are available for data input on graphics workstations. These may be classified as:

#### 1.9.1.1 Text Entry

- **Buttons:** Buttons are very simple to use and easy to map with the functionality of any process. There are different types of buttons:
  - fixed buttons with labels like ticket machines
  - e.g., gaming machines and programmable keypads.
- **Keyboard:** This device is meant for discrete entries. This is a primary device for entering text strings. It is very efficient device for inputting non-graphic data. It has various layouts.

### 1.9.1.2 Pointing Devices

#### 1.9.1.2.1 Direct Pointing Devices:

- **Light Pen:** Detects burst of light from screen phosphor. It addresses individual pixels. It contains a light-sensitive cell, which detects the light from the screen enabling the computer to identify the location of the pen on the screen.

##### **Disadvantages:**

- It is a fragile device.
- It obscures part of screen.
- Users have to remove their hands from keyboard while accessing light pen.
- **Pen-Pad:** It is a pressure-sensitive pen and pad. It is very good for drawing. You can directly use Pen on screen. Common in PDAs to draw or write.
- **Touch screen:** You can directly control the screen using your fingers. Touch screens use sensors to detect the touch of finger.

##### **Advantages:**

- Intuitive to use.
- Good for public access systems like ATMs.
- Good durability in high-use environment.
- Enables users to choose from available options by simply touching the desired icon or menu item.

##### **Disadvantages:**

- Inaccurate.
- Greasiness on screen from fingers, e.g., ATM Machine, Touch screen phones etc.
- Obscures part of the screen.
- Users come too close to screen for comfort.

#### 1.9.1.2.2 Indirect Pointing Devices:

- **Mouse:** A mouse functions as a pointing device used to position the screen cursor. You have to make selections with the help of the button placed on the top of the mouse.

Types of mouse based on mechanism:

- (1) **Mechanical Mouse:** It uses a ball that makes contact with inside wheels when it is rolled on a plain surface.
  - (2) **Optical Mouse:** As the name suggests, a mouse that uses light to detect movement. It emits a ray of light and senses its reflection when it is moved. Initial optical mouse required a special mouse pad, but a new device doesn't require the same.
- **Trackball:** A trackball is a pointing device that works like an upside-down mouse. It is used in portable computers.

**Advantages:**

- It requires no space.
- Ball can be rotated with the fingers or palm of the hand, to produce screen cursor movement.
- It is very popular with notebooks and portable computers.
- **Joystick:** It is a small, vertical lever mounted on a base that is used to steer the screen cursor around. Most joysticks select screen positions with actual stick movement; other respond to the pressure on the stick. It is very robust and inexpensive. Often found in computer games.
- **Graphics Tablets:** Positional information with pen. A special pen is used against the pressure sensitive surface of the tablet to move the cursor. It provides substantial control for editing finely detailed graphic elements.

**1.9.1.3 Scanners and Optical Character Recognition**

- **Scanners:** Drawings, graphs, color, text can be stored for computer processing with an image scanner by passing an optical scanning mechanism over the information to be stored.

There are two types of scanners:

1. **Handheld scanner:** In this, user had to move the scanner over the document that has to be scanned.
2. **Flat bed scanner:** The document is placed on the glass plate and cover is closed. The document is scanned using a lamp.

**Advantages:**

- Enable direct data entry into a computer system.
- It reduces human effort.
- It increases data accuracy and data processing speed.
- Converts hard copy to soft copy.
- **Optical character recognition:** We can convert paper documents into a word processing document without retyping or rekeying. It recognizes not only printed character but also handwriting, e.g.,: Bar code reader.

**1.9.1.4 Other Input Devices**

- **Data Glove:** A *data glove* is an interactive device, resembling a glove worn on the hand. A glove equipped with sensors that sense the movements of the hand and interfaces those movements with a computer. It facilitates tactile sensing and fine-motion control in robotics and virtual reality environments. Data glove is one of electromechanical device.

Tactile sensing involves simulation of the sense of human touch and also includes the ability to perceive pressure, linear force, torque, temperature, and surface texture. Sensors used to detect the movement of the user's hand and fingers, and the translation of these motions into signals that can be used by a virtual hand, like in gaming or a robotic hand, like in remote-control surgery.

- **Foot Mouse:** A *footmouse* is a type of computer mouse that gives the users the ability to move the cursor and click the mouse buttons with their feet. It consists of two separate pedals. One pedal operates the pointer, while the other is used for button clicking. By default, a heel-click engages the right mouse button, while a toe-click engages the left mouse button.

It is primarily used by users with disabilities or with high-back or neck problems. It is also promoted as a way to prevent such problems in the future and as a means to increase productivity by not having to move one's hand between the keyboard and mouse.

- **Speech Recognition:** Speech recognition is the ability of a machine or program to identify words and phrases in spoken language and convert them to a machine-readable format. Traditional speech recognition software has a limited vocabulary of words and phrases and may only identify these if they are spoken very clearly. More sophisticated software has the ability to accept natural speech. Speech recognition applications include call routing, speech-to-text, voice dialing and voice search.

## 1.9.2 Display Devices

The purpose of display devices is to convert electrical signals into visible images.

### **Display Types:**

- 1.9.2.1 Cathode Ray Tubes (CRTs)
- 1.9.2.2 Raster Scan CRT
- 1.9.2.3 Random Scan CRT or Vector Display
- 1.9.2.4 Color CRT Monitors
- 1.9.2.5 Direct View Storage Tube (DVST)

### **Other Technologies:**

- 1.9.2.6 Plasma Panel
- 1.9.2.7 Liquid-Crystal Display (LCD)
- 1.9.2.8 Light-emitting Diodes (LEDs)

### **1.9.2.1 Cathode Ray Tube (CRT)**

Computer graphics may use many different output devices, such as monitors, printers, plotter etc. but most common display device is the CRT. Video monitor has always been the predominant display device for interactive computer graphics. The operations of most video monitors is based on the standard CRT design

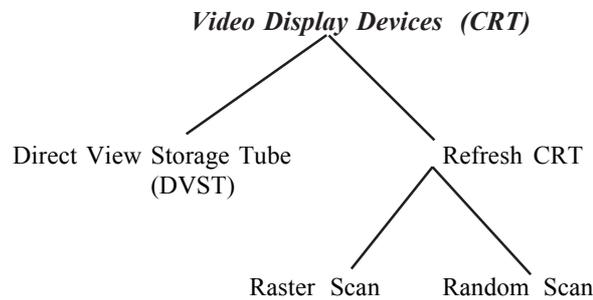


Fig. 1.2 Classification of Video Display Devices

The following figure illustrates the basic operation of CRT:

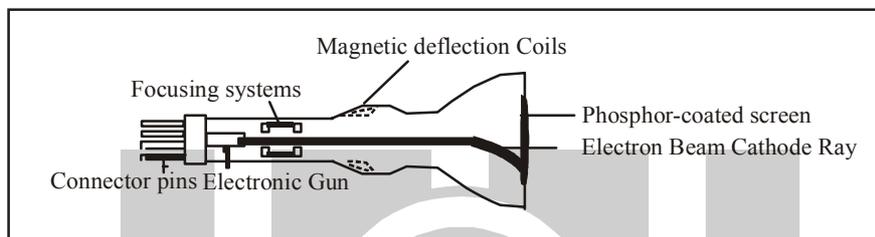


Fig. 1.3 Basic Design of Cathode Ray Tube (CRT)

A beam of  $e^-$  (cathode rays), emitted by an  $e^-$  gun passes through focusing and deflection systems that direct the beam toward specified positions on the phosphor-coated screen. The phosphor then emits a small spot of light at each position contacted by the  $e^-$  beam. This is known as *phosphorescence* that decays slower but still rapidly (in about 15-20 milliseconds) so there is a need to refresh the screen by redrawing the image. One way to keep the phosphor glowing is to redraw the picture repeatedly by quickly directing the  $e^-$  beam back over the same points. This type of display is called a refresh CRT.

#### Fundamentals of CRT:

- **Refresh Rate:** The rate at which the pixels get refreshed in a unit time is called *Refresh Rate*. It is sufficiently high to avoid flickering.
- **Pixel:** It is the smallest addressable screen element also called *picture element*. Values of all pixels are stored in an array in computer's memory called *frame buffer*.
- **Electron Gun:** It makes use of electrostatic fields to focus and accelerate  $e^-$  beam.

Its primary components are:

- Heated metal cathode
- Control grid
- **Deflection System:** It can be controlled either with electric fields or with magnetic fields. Cathode ray tubes are commonly constructed with magnetic deflection coils mounted on the outside of the CRT envelope. There are two pairs of coils used – horizontal deflection and vertical deflection. A primary requirement of the deflection system is that it deflects

rapidly, since speed of deflection determines how much information can be displayed without flicker.

- **Phosphors:** The phosphors used in a graphic display are normally shown for their color characteristics and persistence. Three colors of phosphor (red, blue, green) RGB are used. Besides color, a major difference between phosphor is their *persistence*, i.e., how long the phosphor continue to emit light even after the CRT beam is removed.
- **Persistence:** The persistence is defined as the time it takes the emitted light from the screen to decay to 1/10th of its original intensity.
- ☞ Lower persistence phosphors require higher refresh rates to maintain picture without flicker. It is useful in animation.
- ☞ Higher persistence phosphors allow for a lower refresh rate to avoid flicker. It is useful for displaying highly complex, static pictures. This is poor for animation since a “trail” is left with moving objects.

Thus, depending on the persistence of the phosphor-coated inside the screen, the monitors require different refresh rates.

- **Resolution:** The maximum number of points/pixels that can be displayed without overlap is called the *resolution* of a screen and is usually given as the number of horizontal points versus the number of vertical points per unit area.

More the resolution => more the number of pixels

i.e., Number of pixels  $\propto$  resolution of the screen.

The maximum resolution may be determined by:

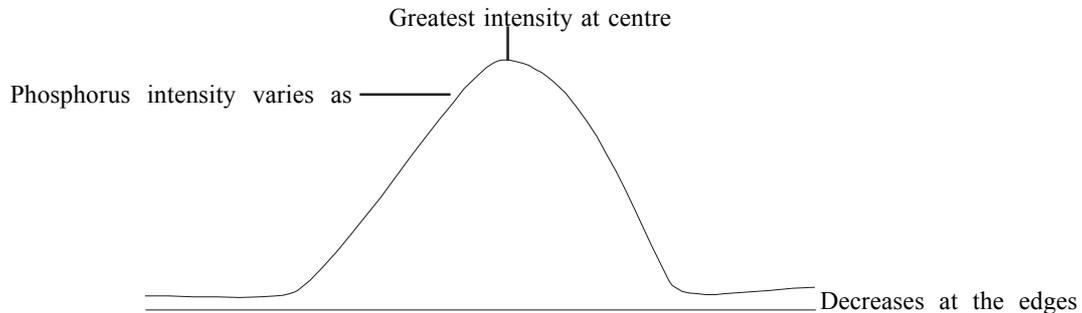
- Characteristics of the monitor for a random scan system.
- By combination of the monitor and graphics card memory for a raster scan system.

Resolution of CRT depends on:

- (i) type of phosphor
- (ii) intensity to be displayed
- (iii) focusing system
- (iv) deflecting system

High Resolution systems are often referred to as high-definition systems.

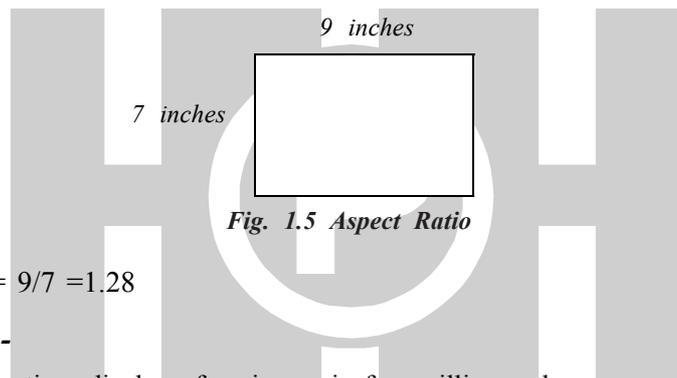
The figure 1.4 depicts the intensity distribution of a spot on the screen.



**Fig. 1.4 Intensity Distribution of a Spot on the Screen**

Spot size depends on intensity.

**Aspect Ratio:** The ratio of vertical pixels to horizontal pixels necessary to produce equal-length lines in both directions on the screen. It refers to the ratio of horizontal dimension/vertical dimension.



$$\text{Aspect ratio} = 9/7 = 1.28$$

**Features of CRT:-**

- (i) Rapid operation: display of an image in few milliseconds
- (ii) High power consumption
- (iii) Expensive
- (iv) Good for graphics video and animation
- (v) Reliable
- (vi) Low cost

**CRT is of two types:**

1. Raster CRT
2. Random CRT

Rasterization is referred to as converting geometric primitives (lines, polygons) to pixels. It is also known as *scan conversion*; it is converting a continuous object such as a line or circle into discrete pixel. Rasterization is also known as discretizing/sampling. Raster displays store the display primitives (such as lines, characters and solidly shaded or patterned areas) in the refresh buffer in terms of their component pixels.

### 1.9.2.2 Raster Scan CRT

The device scans the screen from top to bottom in a regular pattern from left to right. Raster scan implies that the image is scanned onto the screen surface in a raster sequence, i.e., as a succession of equidistant scan lines, each scan line made up of pixels.

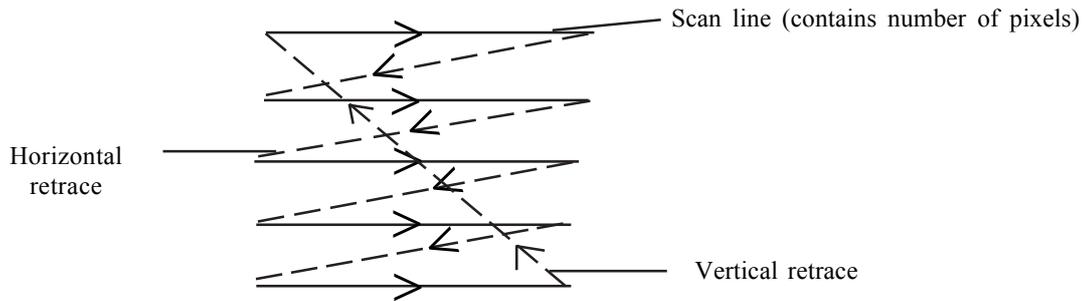


Fig. 1.6 Raster Scan

Picture definition is stored in a 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. Each screen point is referred to as a pixel.

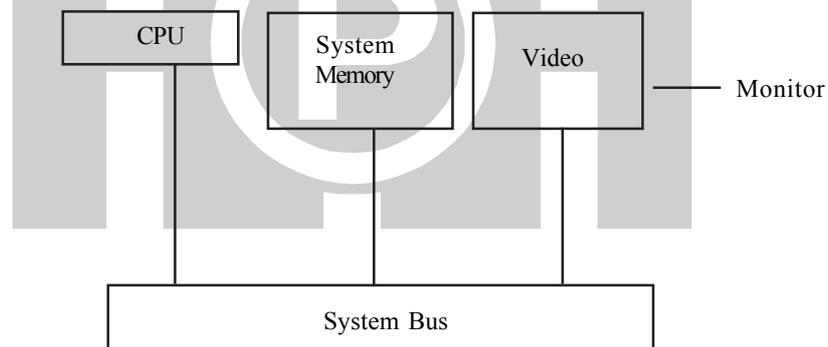


Fig. 1.7 Architecture of a Simple Raster Graphics System

In the raster scan display device, the screen is assumed to consist of a 2-D matrix. The term raster is used for 2-D matrix. Each point of the screen corresponding to a matrix element is called *pixel*.

Intensities of pixels are stored in an array in computer's memory called *frame buffer*. Refreshing on raster scan displays is carried out at the rate of 60 to 80 frames per second.

Raster scan displays owe their increase in popularity to two causes:-

- Need for greater realism in pictures.
- Cost of raster scan display equipments is decreasing.

***Applications of Raster Scan Graphics***

- Flight simulation
- Animation
- Design
- Technical Illustration
- Printing and plotting
- Image processing

***Drawbacks of Raster Displays***

- Low resolution, preventing display of fine detail.
- Slow speed of scan conversion.
- Discrete nature of pixel representation: primitives such as lines and polygons are specified in terms of their endpoints (vertices) and must be scan converted into their pixel components in their frame buffer. To provide effective anti-aliasing, it is necessary to understand the causes of aliasing itself. Fundamentally, the appearance of aliasing effects are due to the fact that lines, polygon edges, color boundaries, etc. is continuous, whereas, and raster device is discrete.

Fundamentally, there are two methods of *anti-aliasing*:

- (i) *Increase the sample rate*: It is accomplished by increasing the resolution (number of pixels) of the raster. Techniques include super sampling or post-filtering.
- (ii) Second method of anti-aliasing is to treat a pixel as a finite area rather than as a point.

***Half Toning***: Half toning is a technique for using a minimum number of intensity levels to obtain increase visual resolution, i.e., gray scaling, or multiple intensity levels.

***Patterning***: The visual resolution of computer-generated images can be increased using a technique called *patterning*.

- Care must be taken in selecting the patterns; otherwise, unwanted small-scale structure or contouring is introduced.
- To avoid introducing unwanted artifacts into the image, patterns should not be symmetrical.
- Patterns should present a growth sequence.
- Patterns result in loss of spatial resolution.
- Stair-step appearances referred to as *jaggies* are produced. This drawback arises from the nature of raster itself. Also known as *aliasing*.

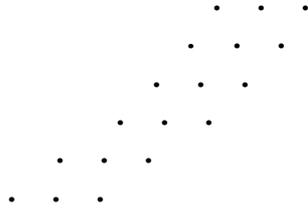


Fig. 1.8 Jaggies

Thus, *jaggies* are the discontinuities which are particularly noticeable on systems with low resolution. To improve this, use anti-aliasing.

- Use high resolution screen and driver setting.
- Modified using virtual pixels.

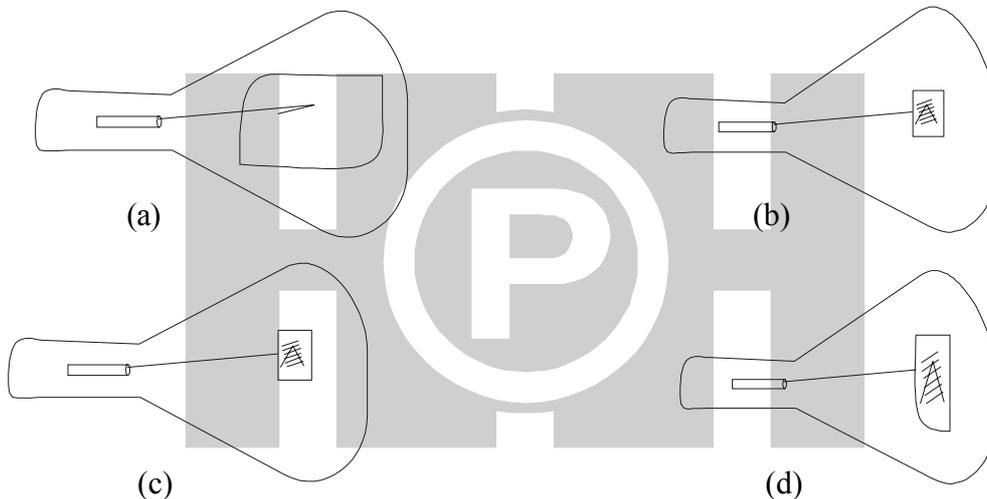


Fig. 1.9 A Raster Scan System from (a) to (d)

**To reduce flicker rate:**

- High scan rate ( $> 70$  Hz).
- High persistence phosphor.
- **Interlacing:** Displays odd and even rows alternatively. In some raster display devices, a frame buffer is displayed in two passes. This kind of refreshing is called *interlacing*. In the 1st pass, the odd rows are refreshed and the even rows are refreshed in the 2nd pass. Interlacing is primarily used with monitors of slower refreshing rates.

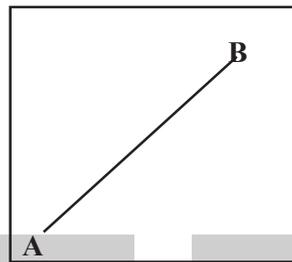
### 1.9.2.3 Random Scan CRT:

Here, a beam is deflected from end point to end point, as dictated by the arbitrary order of display commands. It is also known as vector stroke, line drawing or calligraphic displays. The commands for plotting points, lines and characters are interpreted by the display processor. It sends

digital and point coordinates to a vector generator that convert the digital coordinate values to analog voltages for beam-deflection circuits that displace the  $e^-$  beam writing on the CRT's phosphor coating.

*Here, the  $e^-$  beam directly draws the picture.*

- Turn  $e^-$  beam off. Move to A.
- Turn  $e^-$  beam on, and draw to B.
- Repeat move-drawn sequence.



**Random Scan**

*Fig. 1.10 Random Scan*

Refresh rate on a random scan system depends on the number of lines to be displayed. Refresh rate is greater than that of Raster scan.

Picture definition is stored as a set of line-drawing commands in area of memory called the refresh display file (display list, display program, refresh buffer).

***Advantages of Random Scan:***

1. Random scan displays line themselves to a wide variety of dynamic changes involving very little computation.
2. Vector displays produce smooth lines drawings because the CRT beam directly follows the line path.
3. No *jaggies* are formed.
4. Very high resolution, limited only by monitor.
5. Easy animation, just draw at different positions.
6. Requires little memory.

***Disadvantages of Random Scan:***

- Requires “intelligent  $e^-$  beam”, i.e., processor-controlled.
- Limited screen density before flickering, cannot draw a complex image.
- Limited color capability.
- Very expensive.

**Typical applications: CAD and air traffic control display.**

Raster Scan	Random Scan
(i) The device scans the screen from top to bottom in a regular pattern.	(i) The beam is deflected from end point to end point as dictated by an arbitrary order of display commands.
(ii) Picture definition is stored as intensity value of pixels in the memory area called frame buffer or refresh buffer.	(ii) Picture definition is stored as a set of line drawing commands in area of memory referred to as refresh display file.
(iii) Low resolution.	(iii) Very high resolution.
(iv) Jaggies are produced.	(iv) No jaggies.
(v) Refresh rate is low.	(v) Refresh rate is higher.
(vi) Cost is less.	(vi) Expensive.
(vii) It controls the intensity of each pixel (data) in the rectangular matrix (raster) of dots that covers the entire screen.	(vii) A display file for a line-drawing display contains only information about lines and characters to be drawn; the void areas of the screen are ignored.
(viii) Generate video images of extreme realism.	(viii) Flicker badly when displaying complex pictures.
(ix) Large capacity limited only by screen resolution.	(ix) Could not produce realistic image of solid objects.
(x) Changes generally involve large amounts of processing. It is therefore difficult to achieve the modification required for effective interaction.	(x) These displays end themselves to a wide variety of dynamic changes speed of involving very little computation.
(xi) Flexible as consists of number of intermediaries.	(xi) Inflexible.
(xii) Applications, Animation, Flight simulation etc.	(xii) High precision engineering drafting highly interactive solid-object design, and real line computer animation.

*Fig. 1.11 Basic Differences between Raster Scan and Random Scan***1.9.2.4 Color CRT Monitors**

A CRT monitor displays color pictures by using a combination of phosphors that emit different color 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:

- (a) Beam penetration method
- (b) Shadow mask method

**(a) Beam penetration method:** It has been used with random scan monitors for displaying color pictures 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  $e^-$  beam penetrates into the phosphor layers.

- A beam of slow  $e^-$  excites only the outer RED layer.
- A beam of very fast  $e^-$  penetrates through the red layer and excites the inner green layer.
- An intermediate beam speeds, combinations of red and green lights are emitted to show two additional colors, orange and yellow.

Speed of  $e^-$  and screen color at any point, is controlled by the beam acceleration voltage.

#### Advantages and Disadvantages:

- Inexpensive way to produce color.
- Only 4 colors possible.
- Quality of picture is not so good.
- In order to change or switch colors, we need to change the beam-accelerating potential by significant amounts. When accelerating potential changes, the deflection system must react to compensate.

(b) **Shadow mask CRT:** The shadow mask color CRT can display a much wider range of colors than the beam penetration CRT, and is used in raster scan systems.

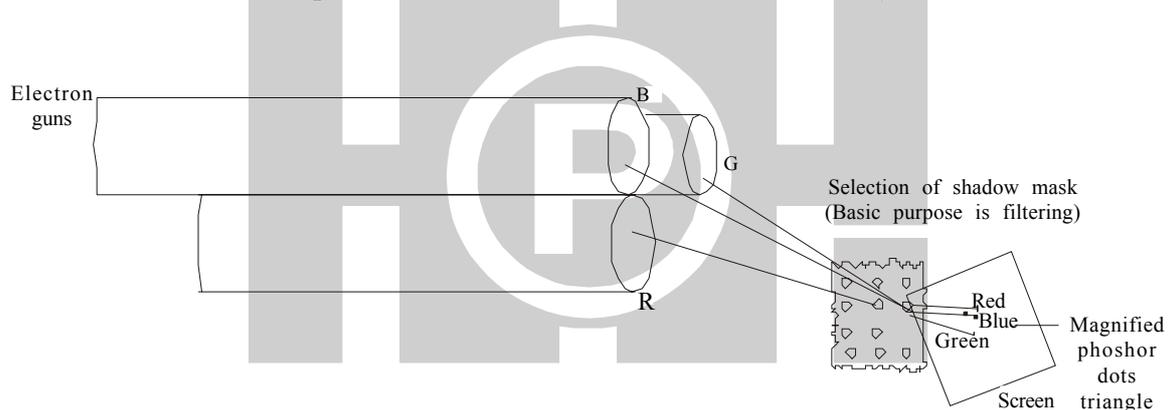


Fig. 1.12 Delta-delta Shadow Mask CRT

A shadow mask CRT has three phosphor colors at each pixel position:

- One phosphor dot emits: Red light
- Second phosphor dot emits: Green light
- Third phosphor dot emits: Blue light

This type of CRT has three  $e^-$  guns, one for each color dot and a shadow mask grid just behind the phosphor-coated screen. The three  $e^-$  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. So, by combining different intensities from different guns we can get different colors.

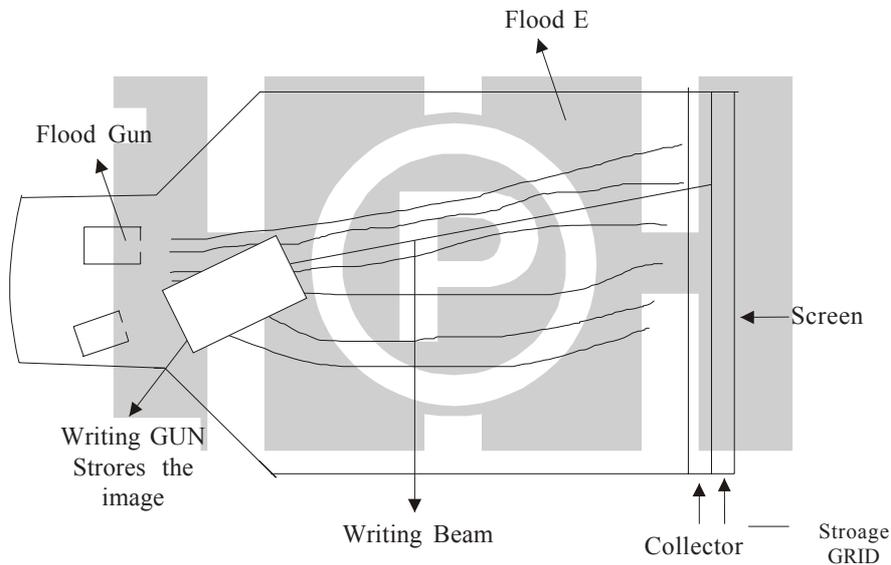
**Advantages**

- It can provide a “reasonable” number of simultaneous colors without requiring large frame buffers.
- Helps expanding intensity range.
- To create a pseudo color displays of a monochromatic.

**1.9.2.5 Direct View Storage Tubes (DVST)**

Refresh line drawing displays based on the CRT have the disadvantage of high cost and tendency to flicker when the displayed picture is complex. These two problems have led to the development of display devices with inherent image storage capability.

The most widely used of these devices is the direct view storage tubes. It is a modified random scan system.



*Fig. 1.13 The DVST*

The DVST stores the picture information as a charge distribution behind the phosphor coated screen. Two guns are used:

- **Writing beam gun:** Used to store picture pattern.
- **Flood gun:** Maintains picture display.

**Advantages:**

- No flickering.
- No refreshing is needed.
- Very complex pictures can be displayed at very high resolution without flicker.

**Disadvantages:**

- Ordinarily do not display color.
- Selected parts of the picture cannot be erased, to eliminate a picture section, the entire screen must be erased and the modified picture redrawn.
- Inferior in terms of performance to refresh CRT.

**Different Raster Output Devices:** CRT monitors, LCDs, laser and dot matrix printers.

**Different Non-Raster Output Devices:** Vector display and plotters.

**1.9.2.6 Plasma Panel**

A form of display used in association with computer systems in which light output is produced from the interaction between an electric current and an ionized inert gas such as neon. Plasma panels also called gas-discharge displays are constructed by filling the region between two glass plates with a mixture of gases. The top glass with embedded electrodes seals and forms a pixel where the junctions of the channels and the plate come together. 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 60 times per second.

**Advantages:**

- Large viewing angle.
- Good for large-format displays.
- Fairly bright.

**Disadvantages:**

- Expensive.
- Large pixels (~1 mm versus ~0.2 mm).
- Phosphors gradually deplete.
- Less bright as compared to CRTs, using more power.

**1.9.2.7 Liquid-crystal Display (LCD)**

A screen display technology developed in 1963 at the David Sarnoff Research Center in Princeton, NJ. LCD displays utilize two sheets of polarizing material with a liquid crystal solution between them. An electric current passed through the liquid causes the crystals to align so that light cannot pass through them. Each crystal, therefore, is like a shutter, either allowing light to pass through or blocking the light. The contrast between the opaque and transparent areas forms visible characters.

**Advantages:**

- Very compact and light.
- Low power consumption.
- No geometric distortion.
- Little or no flicker depending on backlight technology.
- Not affected by screen burn-in.
- No high voltage or other hazards present during repair/service.
- Can be made in almost any size or shape.

**Disadvantages:**

- Limited viewing angle.
- Dead pixels may occur either during manufacturing or through use.
- Cannot be used with light guns/pens.

**1.9.2.8 Light-emitting Diode (LED)**

The light emitting diode, or LED monitor is a recent introduction in the field of display technology. As an upgraded version of LCD monitors, these monitors employ LED technology to deliver superior quality graphics. They are typically used outdoors in store signs and billboards. LED panels are sometimes used as form of lighting, for the purpose of general illumination, task lighting, or even stage lighting rather than display.

The LED was first invented in Russia in the 1920s, and introduced in America as a practical electronic component in 1962. Oleg Vladimirovich Losev was a radio technician who noticed that diodes used in radio receivers emitted light when current was passed through them. In 1927, he published details in a Russian journal of the first ever LED.

LEDs are based on the semiconductor diode. When the diode is forward biased (switched on), electrons are able to recombine with holes and energy is released in the form of light. This effect is called electroluminescence and the color of the light is determined by the energy gap of the semiconductor. The LED is usually small in area with integrated optical components to shape its radiation pattern and assist in reflection.

**Advantages:**

- Lower energy consumption.
- Longer lifetime.
- Improved robustness.
- Smaller size and faster switching.

**Disadvantages:**

- Relatively expensive.
- Require more precise current and heat management than traditional light sources.

### 1.9.3 Display Controllers

A **Video Display Controller** or **VDC** is an integrated circuit which is the main component in a video signal generator, a device responsible to pass the contents of the frame buffer to the monitor. It is an interface between digital memory buffer and TV monitor. Some Video Display Controllers also generate an Audio signal, but in that case it's not their main function.

Video Display Controllers were most often used in the old home-computers of the 80s, but also in some early video game systems.

## 1.10 SUMMARY

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Graphical interfaces have replaced the character or textual interfaces. Nowadays, there are number of graphics areas like modeling, animation, rendering, image processing, etc. Computer graphics is classified as interactive and non-interactive graphics. There are three components of computer graphics: digital memory buffer, monitor, and video controller. Graphics hardware consists of input devices, display devices and display controllers. The display devices are also known as output devices. The most commonly used output devices in a graphics system is a video monitor. In this chapter, we have discussed all of the above topics.

## 1.11 GLOSSARY

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- **Computer graphics:** Generally regarded as a branch of computer science that deals with creation, storage and manipulation of models and images.
- **Refresh Rate:** The rate at which the pixels get refreshed in a unit time is called Refresh Rate. It is sufficiently high redisplay to avoid flickering.
- **Pixel:** It is the smallest addressable screen element also called picture element. Values of all pixels are stored in an array in computer's memory called frame buffer.
- **Computer Graphics:** Consists of three components such as Digital memory buffer (frame buffer), Monitor, and Video controller.
- **Frame Buffer:** This is place where images or pictures are stored as an array in the form of 0's and 1's, 0 represents darkness and 1 represents image or picture.
- **Mouse:** A mouse functions as a pointing device used to position the screen cursor. You have to make selections with the help of the button placed on the top of the mouse. Mouse can be classified on the basis of Mechanism: mechanical mouse, and Optical mouse.
- **Persistence:** The persistence is defined as the time it takes the emitted light from the screen to decay to 1/10th of its original intensity.
- **Resolution:** The maximum number of points/pixels that can be displayed without overlap is called the resolution and is usually given as the number of horizontal points versus the number of vertical points per unit area.
- **Aspect Ratio:** The ratio of vertical pixels to horizontal pixels necessary to produce equal-length lines in both directions on the screen. It refers to the ratio of horizontal dimension/vertical dimension.

- **Patterning:** The visual resolution of computer generated images can be increased using a technique called patterning.
- **Jaggies:** Jaggies are the discontinuities which are particularly noticeable on systems with low resolution.
- **In Raster Scan:** The device scans the screen from top to bottom in a regular pattern.
- **In Random Scan:** The beam is deflected from endpoint to endpoint as dictated by an arbitrary order of display commands.

## 1.12 EXERCISE

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- Q1. What do you understand by computer graphics?
- Q2. What is the difference between computer graphics and image processing?
- Q3. What are the major application areas of computer graphics?
- Q4. How many mega bytes does a frame buffer need in  $600 \times 400$  pixel?
- Q5. What do you understand by input and output devices?
- Q6. What is the difference between Raster scan and Random scan?
- Q7. Write short notes on:
  - (i) Resolution
  - (ii) Pixel
  - (iii) Aspect ratio
  - (iv) Persistence
  - (v) Trackball
  - (vi) Graphics system