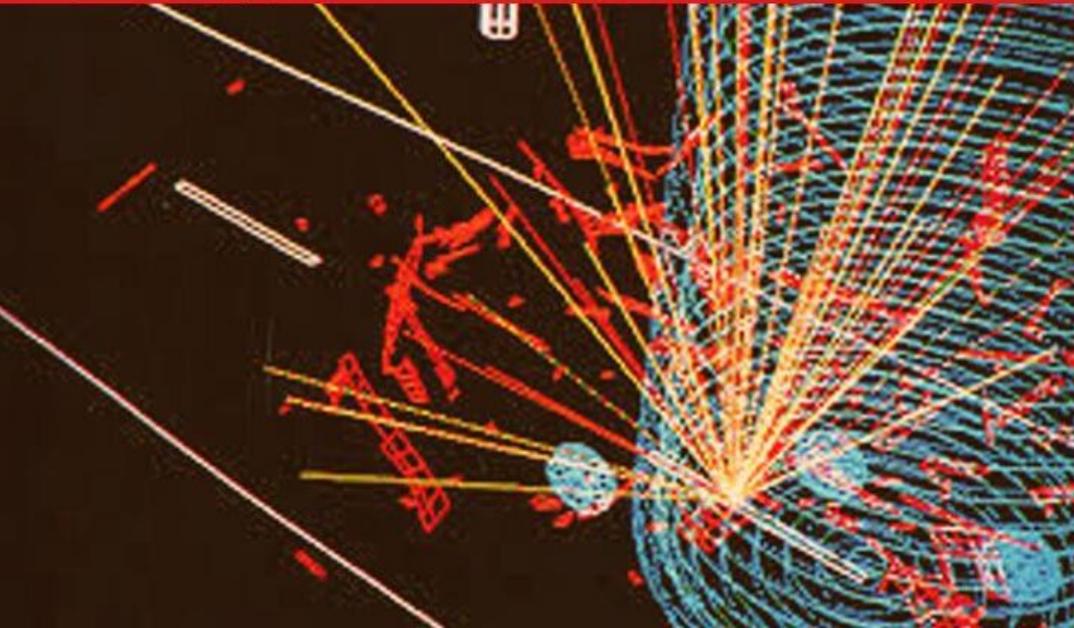


COMPUTER GRAPHICS



Course Outcomes

- ▶ Manipulate visual and Geometric information of images.
- ▶ Implement standard algorithms to draw various graphics objects using 'C' program.
- ▶ Develop programs for 2D and 3D Transformations.
- ▶ Use projections to visualize objects on view plane.
- ▶ Implement various clipping algorithms.
- ▶ Develop programs to create curves using algorithms.

Teaching and Examination Scheme

Teaching Scheme			Credit (L+T+P)	Examination Scheme													
L	T	P		Theory								Practical					
				Paper Hrs.	ESE		PA		Total		ESE		PA		Total		
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
3	-	2	5	3	70	28	30*	00	100	40	25@	10	25	10	50	20	

Teaching Hrs.& Marking Scheme

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basics of Computer Graphics	06	04	04	-	08
II	Raster Scan Graphics	12	02	06	10	18
III	Overview of Transformations	12	02	06	10	18
IV	Windowing and clipping	10	-	06	08	14
V	Introduction to Curves	08	-	04	08	12
Total		48	8	26	36	70

Suggested Learning Resources

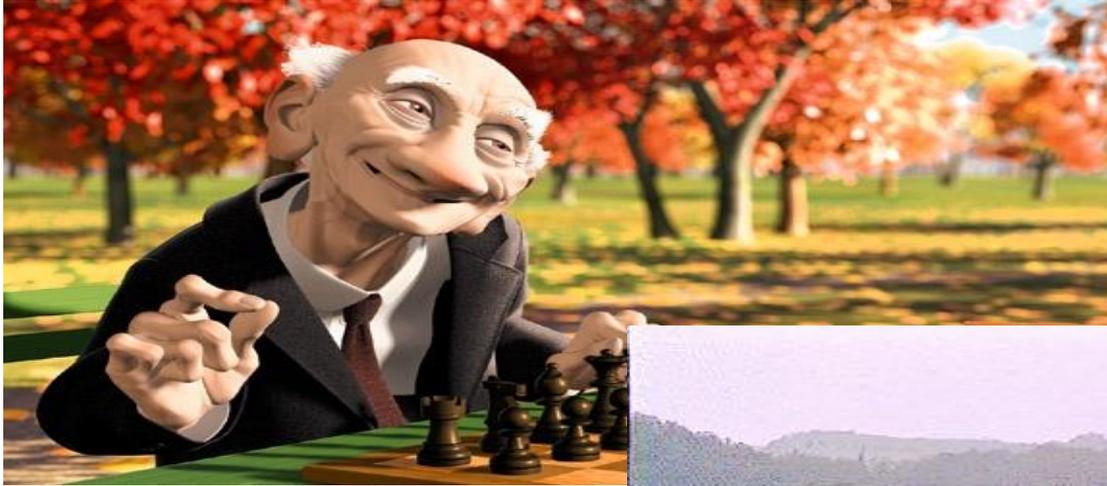
Sr. No.	Title of Book	Author	Publication
1.	Computer Graphics	Donald Hearn	Pearson Education
2.	Computer Graphics	Maurya Rajesh	Wiley India
3.	Computer Graphics	Dr. Chopra Rajiv	S.Chand
4.	Computer Graphics	A P Godse	Techical

Chapter-1

Basics of Computer Graphics

(08 Marks)

Computer Graphics is about animation (films)



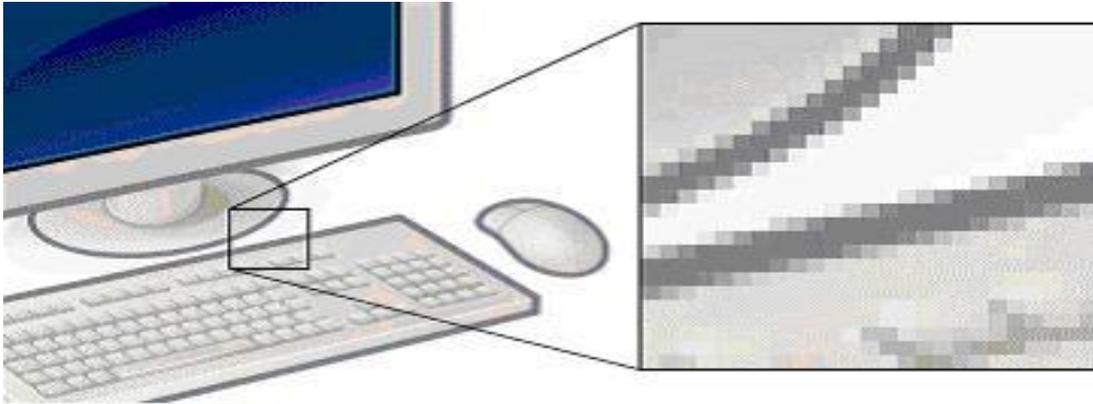
Definition: Computer Graphics

- ▶ It is the creation and manipulation of graphic images by means of a computer.
 - Computer graphics started as a technique to enhance the display of information generated by a computer.
 - This ability to interpret and represent numerical data in pictures has significantly increased the computer's ability to present information to the user in a clear and understandable form.
 - Large amount of data are rapidly converted into bar charts, pie charts, and graphs.

Pixel (picture element)

A **pixel** is the smallest piece of information in an image.

- Pixels are normally arranged in a regular **2D grid**, and are often represented using **dots** or **squares**.



Resolution

- ▶ Resolution is the number of rows that appear from top to bottom of a screen and in turn the number of pixels or pixel elements that appear from left to right on each scan line.
- ▶ Based on this resolution only the effect of picture appears on screen.
- ▶ In other words greater the resolution greater will be the clarity of picture. That is resolution value is directly proportional to clarity of picture.

Text mode

- ▶ Text mode is a personal computer display setting that divides the display screen into **25 rows and 80 columns** in order to display text without images.
- ▶ In text mode, each box can contain one character. Text mode contrasts with graphics mode, which features an array of pixels instead of text boxes.
- ▶ Text mode is also known as **character mode or alphanumeric mode**.

Graphics mode

- ▶ **Graphics mode** is a computer display mode that generates image using pixels.
- ▶ Today, most users operate their computer in a graphics mode opposed to a text mode or command line environment.
- ▶ Here, Screen is divided into small dots called pixels.
- ▶ e.g. VGA screen resolution is $640*480$ pixels.
SVGA screen resolution is $800*600$ pixels.



Graphics Mode Graphics Function

- ▶ **GRAPHICS.H** ,this file contains definitions and explanation of all the graphic functions and constants. While **GRAPHICS.LIB** file contains standard graphic functions.

initgraph:

- ▶ Initializes the graphics system.

Declaration:

```
void initgraph(int *graphdriver, int *graphmode, char  
*pathtodriver);
```

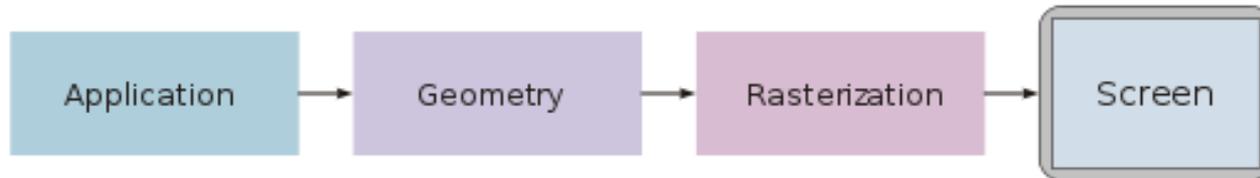
eg: `void initgraph(&gd,&gm,"C:\\turbo3\\bgi");`

Initgraph Arguments:

- ▶ `*graphdriver(&gd)`: Integer that specifies the graphics driver to be used.
- ▶ `*graphmode(&gm)` : Integer that specifies the initial graphics mode. If `*graphdriver = DETECT`, `initgraph` sets `*graphmode` to the highest resolution available for the detected driver.
- ▶ `pathtodriver` : Specifies the directory path where `initgraph` looks for graphics drivers (*.BGI) first.

A Graphics pipeline

- ▶ A graphics pipeline can be divided into three main parts: Application, Geometry and Rasterization.

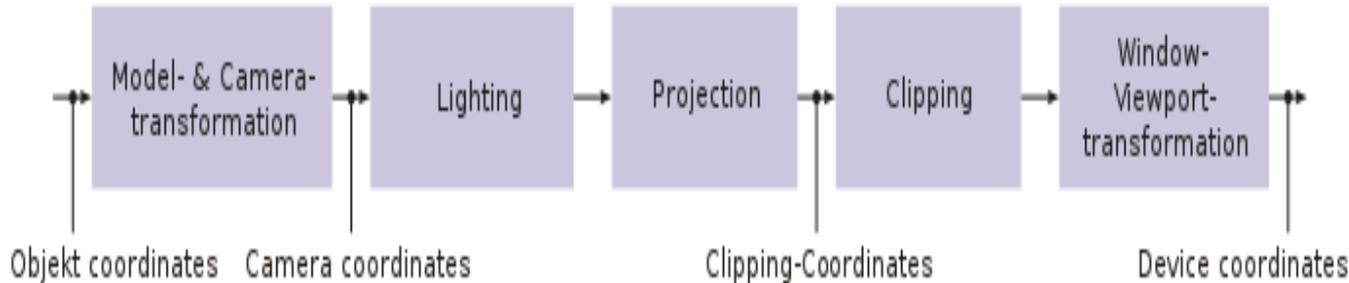


Application

- The application step is executed by the software on the main processor (CPU), it cannot be divided into individual steps, which are executed in a pipelined manner.
- In the application step, changes are made to the scene as required, for example, by user interaction by means of input devices or during an animation.
- The new scene with all its primitives, usually triangles, lines and points, is then passed on to the next step in the pipeline.

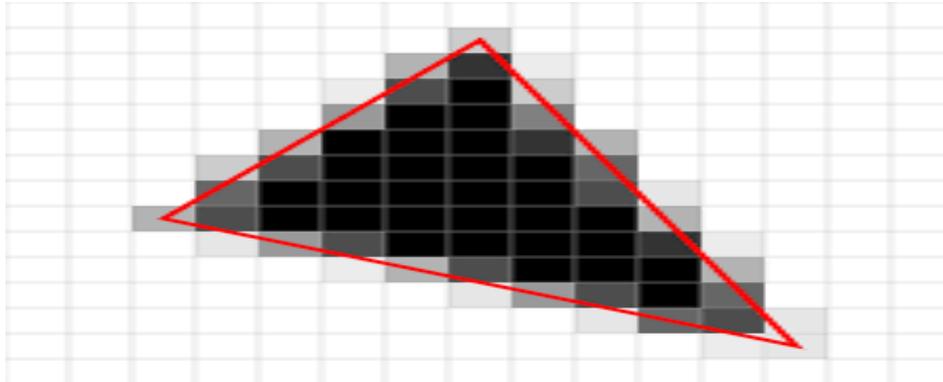
Geometry

- ▶ The geometry step is responsible for the majority of the operations with polygons and their vertices , can be divided into the following five tasks.
- ▶ It depends on the particular implementation of how these tasks are organized as actual parallel pipeline steps.



Rasterization

- ▶ **Rasterization** is the task of taking an image described in a vector graphics format (shapes) and converting it into a raster image (pixels or dots) for output on a video display or printer, or for storage in a bitmap file format. It refers to both rasterization of models and 2D rendering primitives such as polygons, line segments, etc.



Types of Graphics

- ▶ There are two basic types of graphics:
 - ▶ **Bitmapped**
 - ▶ **Vector**
- ▶ Bitmapped graphics are much more common
- ▶ Often they are called raster graphics
- ▶ When you create a bitmapped graphic you are basically creating a bunch of colored dots

Vector Graphics

The second major type of computer graphics

- ▶ Vector graphics are created and manipulated using *drawing programs* (as opposed to paint programs for bitmapped graphics)
- ▶ Instead of using pixels to describe the image, it describes the image using shapes
 - ▶ Circles
 - ▶ Lines
 - ▶ Curves
- ▶ Also has to store the color of these shapes

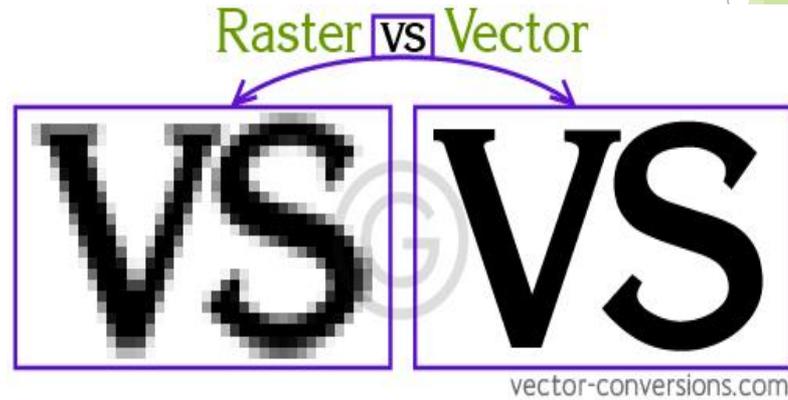
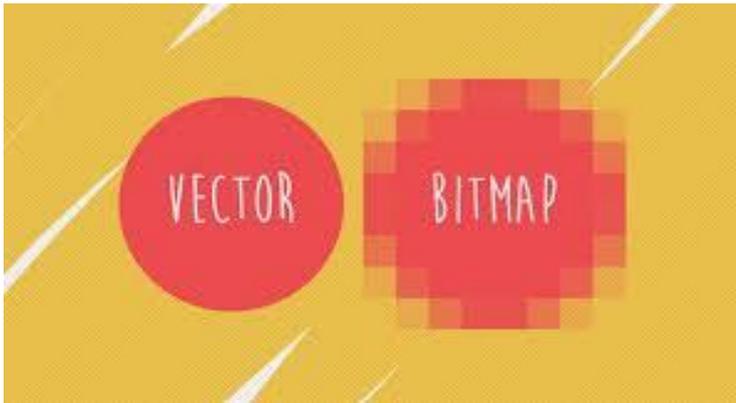


Vector Graphics, cont.

- ▶ The programs used with vector graphics are drawing programs
- ▶ Some of these programs include:
 - ▶ Corel Draw
 - ▶ Adobe Illustrator
 - ▶ Acrobat
- ▶ Most of these programs allow the use of bitmapped images as part of a vector image

Bitmap vs. Vector Images

- ▶ **Bitmap** (or raster) images are stored as a series of tiny dots called pixels. whereas **vector images** are not based on pixel patterns, but instead use mathematical formulas to draw lines and curves that can be combined to create an **image** from geometric objects such as circles and polygons.



Applications of Computer Graphics

- **Computer graphics user interfaces (GUIs)** – A graphic, mouse-oriented paradigm which allows the user to interact with a computer.
- **Business presentation graphics** – "A picture is worth a thousand words".
- **Cartography** – Drawing maps.
- **Weather Maps** – Real-time mapping, symbolic representations.
- **Satellite Imaging** – Geodesic images.
- **Photo Enhancement** – Sharpening blurred photos.
- **Medical imaging** – MRIs, CT scans, etc. - Non-invasive internal examination.

Applications of Computer Graphics (cont. .)

- **Engineering drawings** – mechanical, electrical, civil, etc. - Replacing the blueprints of the past.
- **Architecture** – Construction plans, exterior sketches - replacing the blueprints and hand drawings of the past.
- **Art** – Computers provide a new medium for artists.
- **Entertainment** – Movies and games.
- **Simulation and modeling** – Replacing physical modeling and enactments

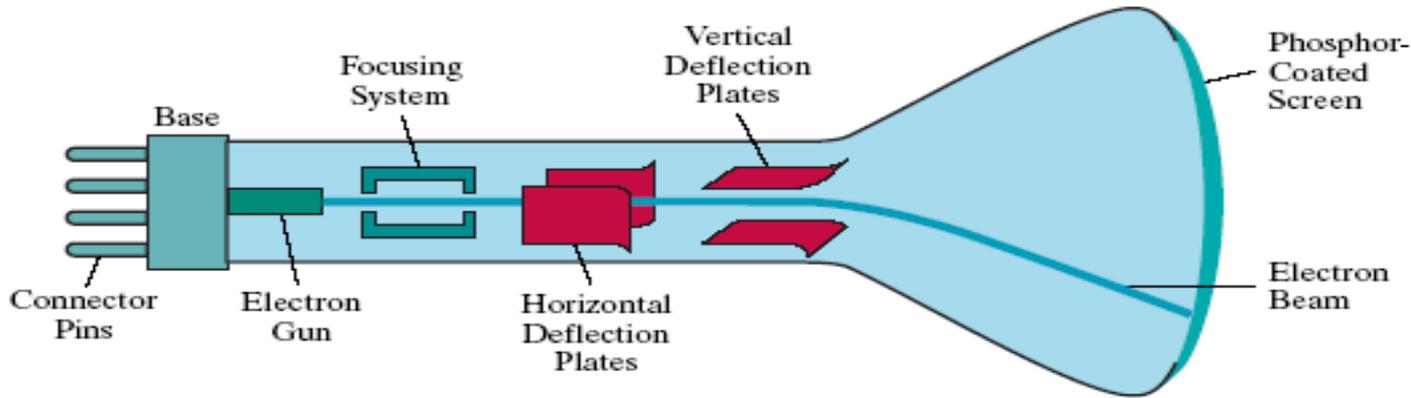
Types of Display Device

- ▶ Types of CRT(Cathode Ray Tube)
 - ▶ Random-Scan Displays
 - ▶ Raster-Scan-Displays

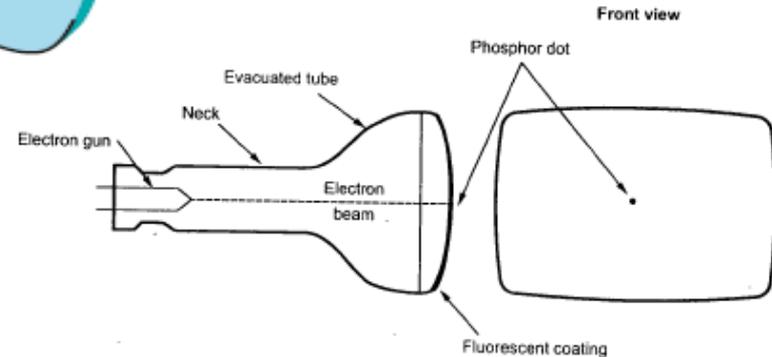
- ▶ Flat-Panel Displays
 - ▶ Emissive displays
 - ▶ Non emissive displays

Video Display Devices

► Cathode-Ray Tube(CRT)

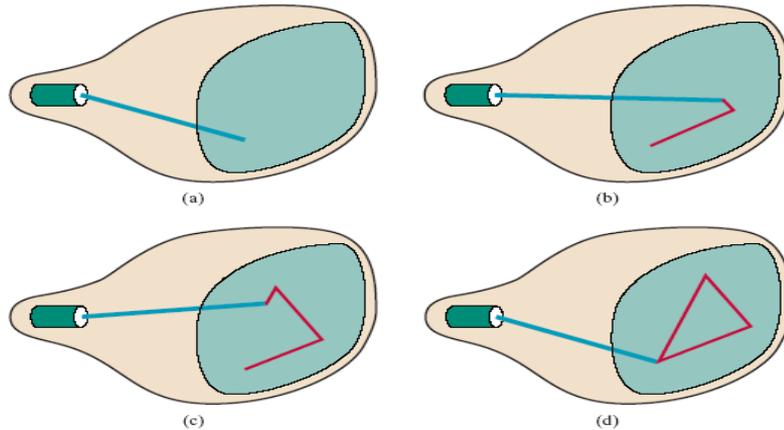


Cathode Ray Tube (CRT)

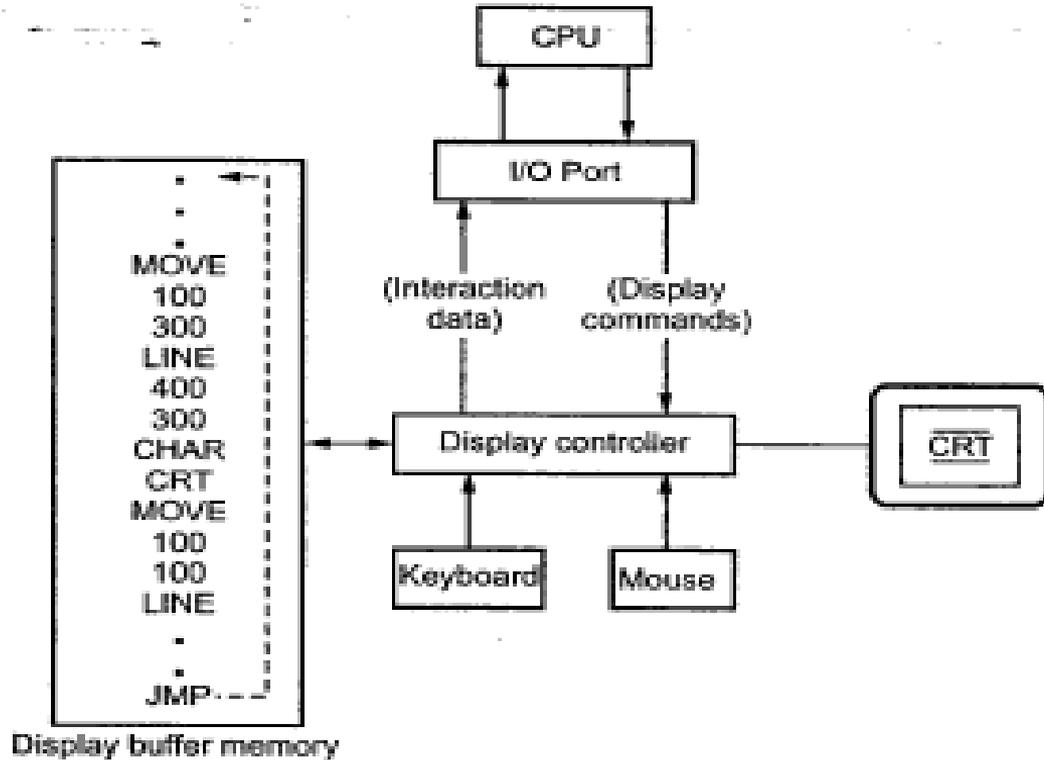


Random-Scan Displays

- ▶ Vector Display (calligraphic display) stored as a set of line-drawing commands in an area of memory (refresh display file, display list, display program) draw a picture one line at a time

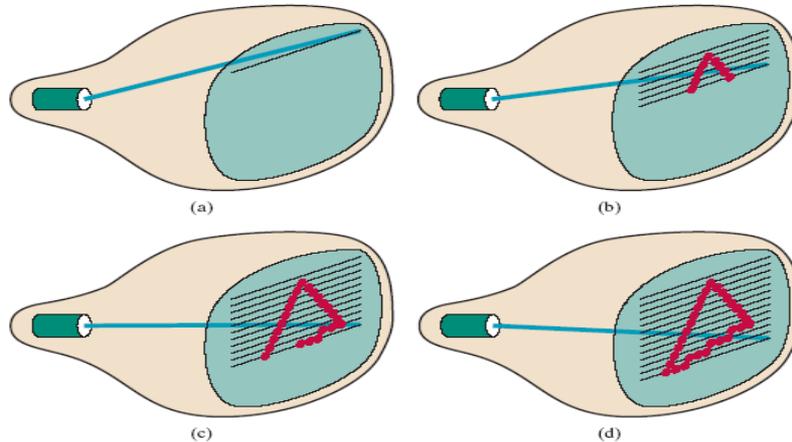


Random-Scan Displays

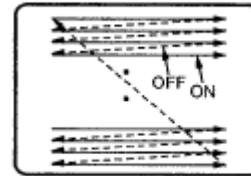
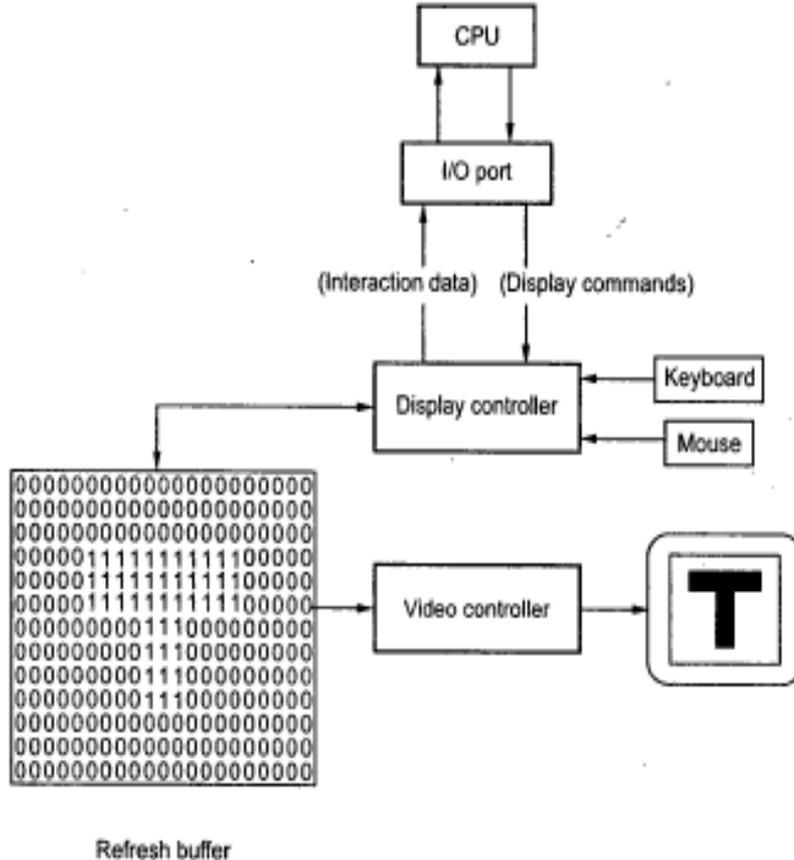


Raster-Scan Displays

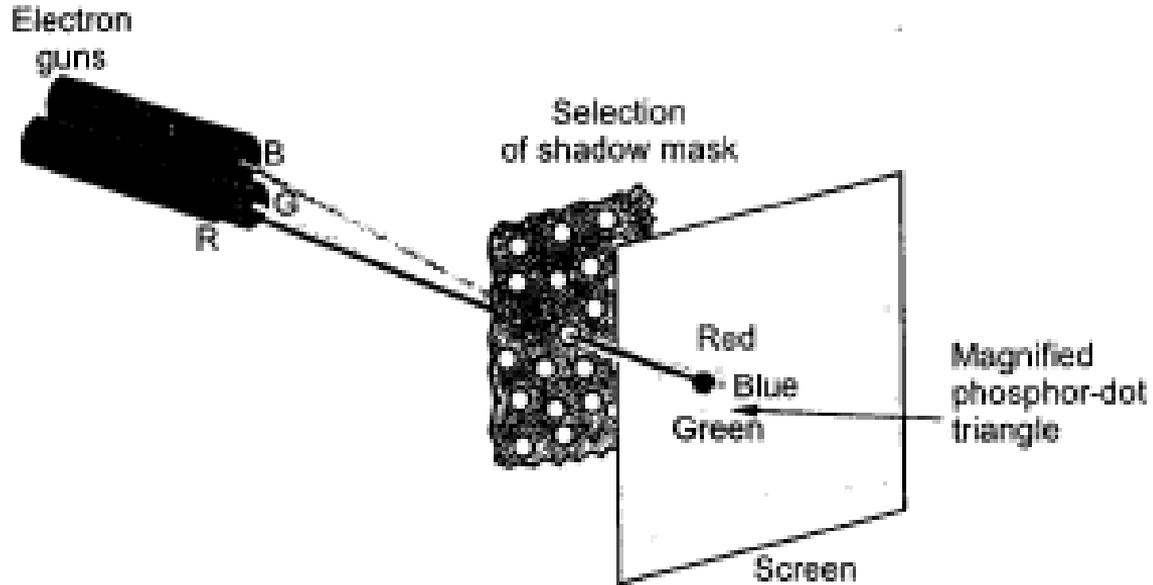
Point plotting device : *pixel* (Picture Element) picture info. for all the screen points is stored in separate Memory called *Frame buffer (Refresh Buffer)* one row at a time (*scan line*) from top to bottom



Raster-Scan Displays



Shadow Mask Technique



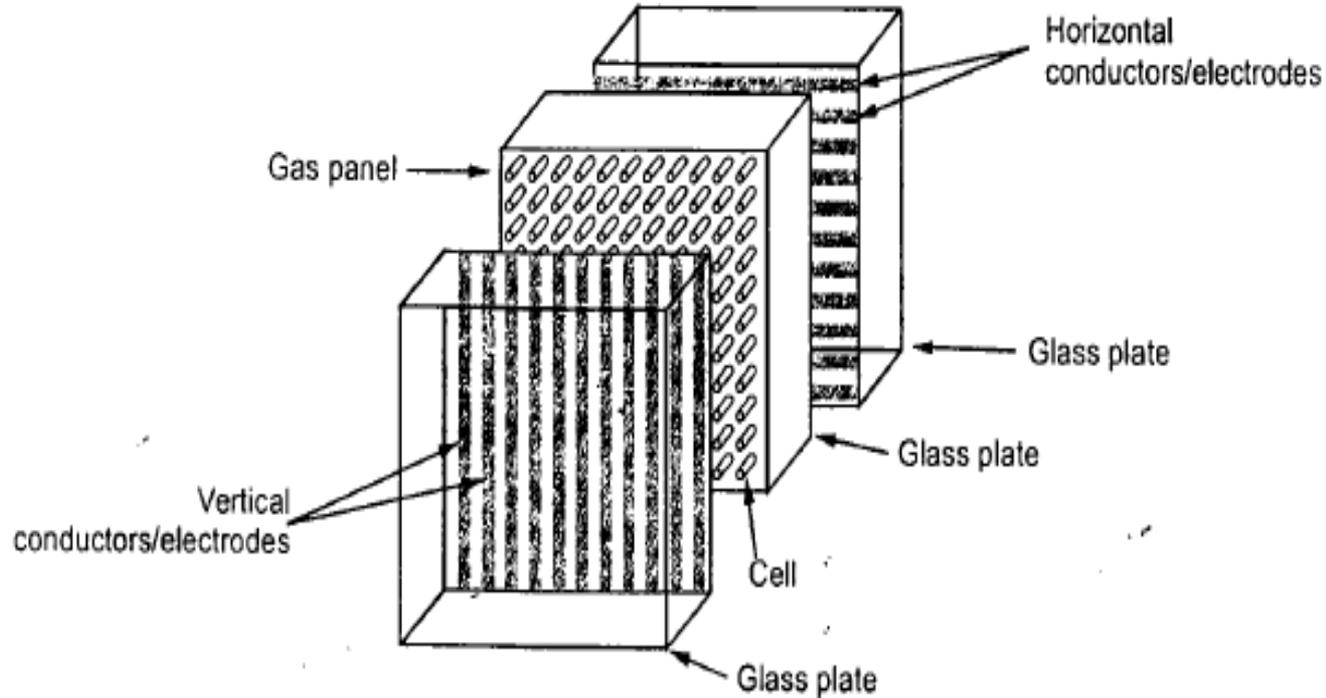
Shadow Mask Technique Video

Flat Panel Display

What does Flat Panel Display mean?

- ▶ A flat panel display is a television, monitor or other display appliance that uses a thin panel design instead of a traditional cathode ray tube (CRT) design.
- ▶ These screens are much lighter and thinner, and can be much more portable than traditional televisions and monitors. They also have higher resolution than older models.

Plasma Display Panel (PDP)





Advantages:

1. Light weight, less bulky the CRTs.
2. Produces flicker free image.
3. Refreshing is not required.
4. They have excellent color reproduction property.
5. They have large viewing angle.
6. They are promising for large format displays.

Disadvantages:

1. Costly.
 2. They have poor resolutions (about 60 dpi).
 3. They have complex addressing and writing requirement.
 4. It is an expensive device.
- 

Liquid-Crystal Display(LCD)

- ▶ It is combination of two states of matter, the solid and the liquid.
- ▶ LCD uses a liquid crystal to produce a visible image.
- ▶ Liquid crystal displays are super-thin technology display screen that are generally used in laptop computer screen, TVs, cell phones and portable video games.
- ▶ LCD's technologies allow displays to be much thinner when compared to cathode ray tube (CRT) technology.

LCD Working

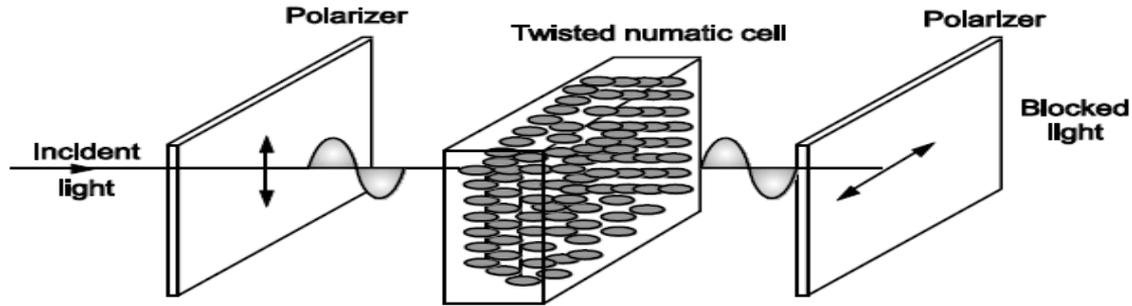
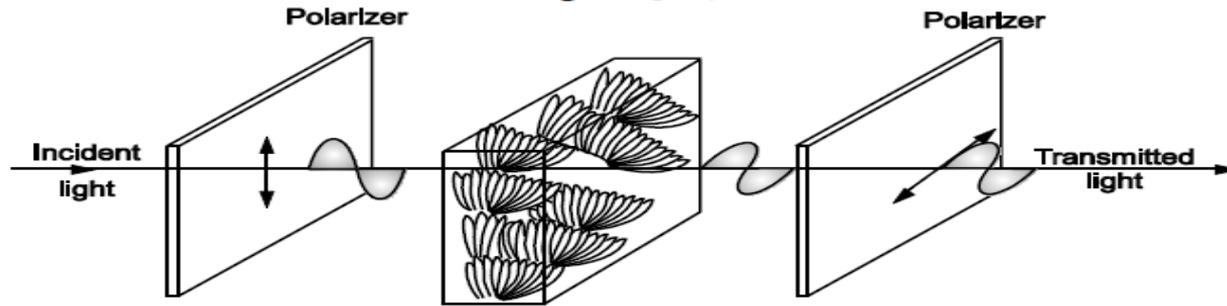


Fig. 1.24 (a)



Twisted nematic cell
Fig. 1.25 (b): Liquid Crystal Display

Advantages of an LCD's:

- ▶ LCD's consumes less amount of power compared to CRT and LED
- ▶ Provides excellent contrast
- ▶ LCD's are thinner and lighter when compared to cathode ray tube and LED

Disadvantages of an LCD's:

- ▶ Require additional light sources
- ▶ Range of temperature is limited for operation
- ▶ Low reliability
- ▶ Speed is very low

Applications of Liquid Crystal Display

- ▶ Liquid crystal thermometer, Optical imaging, Used in the medical applications

Light Emitting Diode (LED)

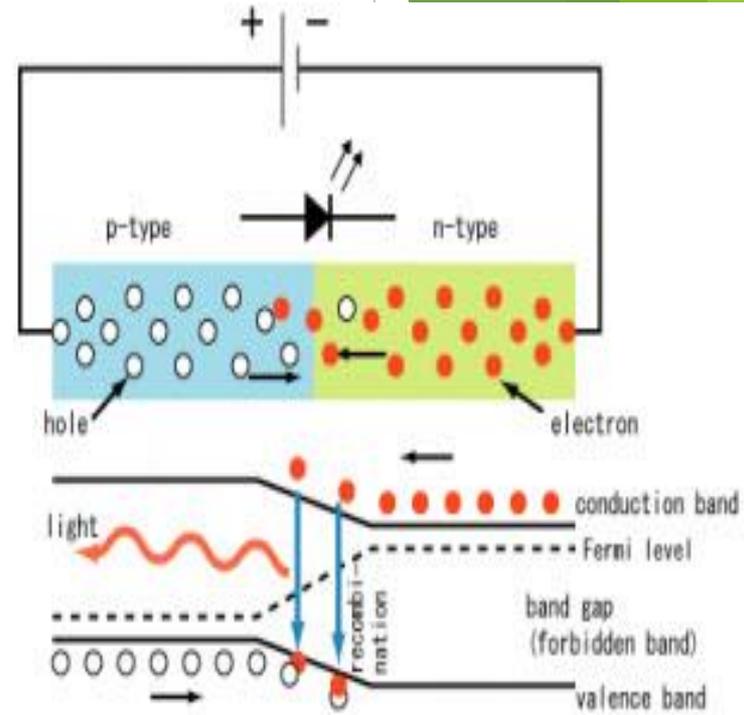
- An **LED display** is a flat panel display, which uses an array of light-emitting diodes as pixels for a video display.
- In recent years they have also become commonly used in destination signs on public transport vehicles, as well as variable-message signs on highways.
- LED displays are capable of providing general illumination in addition to visual display.



The 1,500-foot (460 m) long LED display on the Fremont Street Experience in Downtown Las Vegas, Nevada is currently the largest in the world.

Working of LED

- The LED is a PN-junction diode which emits light when an electric current passes through it in the forward direction. In the LED, the recombination of charge carrier takes place.
- The electron from the N-side and the hole from the P-side are combined and gives the energy in the form of heat and light. The LED is made of semiconductor material which is colorless, and the light is radiated through the junction of the diode.
- The LEDs are extensively used in segmental and dot matrix displays of numeric and alphanumeric character.



Video on LED Display



Applications of Light Emitting Diodes

- LED is used as a bulb in the homes and industries
- The light emitting diodes are used in the motorcycles and cars
- These are used in the mobile phones to display the message
- At the traffic light signals led's are used.

Advantages and Disadvantages of LED

Advantages of LED's

- The cost of LED's is less and they are tiny.
- By using the LED's the electricity is controlled.
- The intensity of the LED differs with the help of the microcontroller.
- The LED are available which emits light in the different colors like red, yellow, green and amber.

Disadvantages of LED

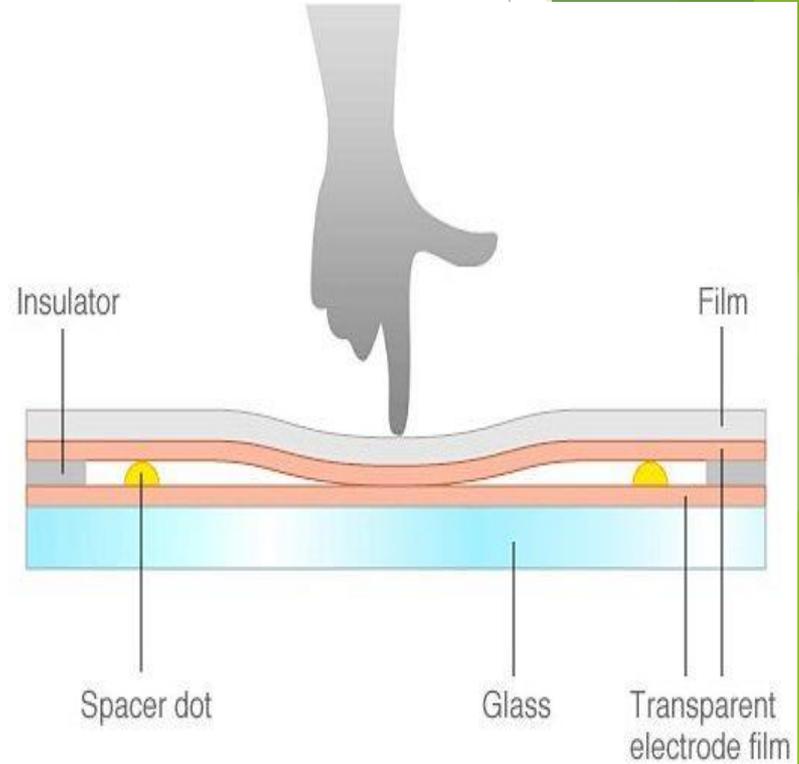
- The LED consume more power as compared to LCD, and their cost is high. Also, it is not used for making the large display.

Touch Screen Displays

- A touch screen is a computer display screen that is also an input device. The screens are sensitive to pressure; a user interacts with the computer by touching pictures or words on the screen.
- There are three types of touch screen technology:
 - Resistive
 - Capacitive
 - Surface Acoustic wave(SAW)
 - Infrared(IR)

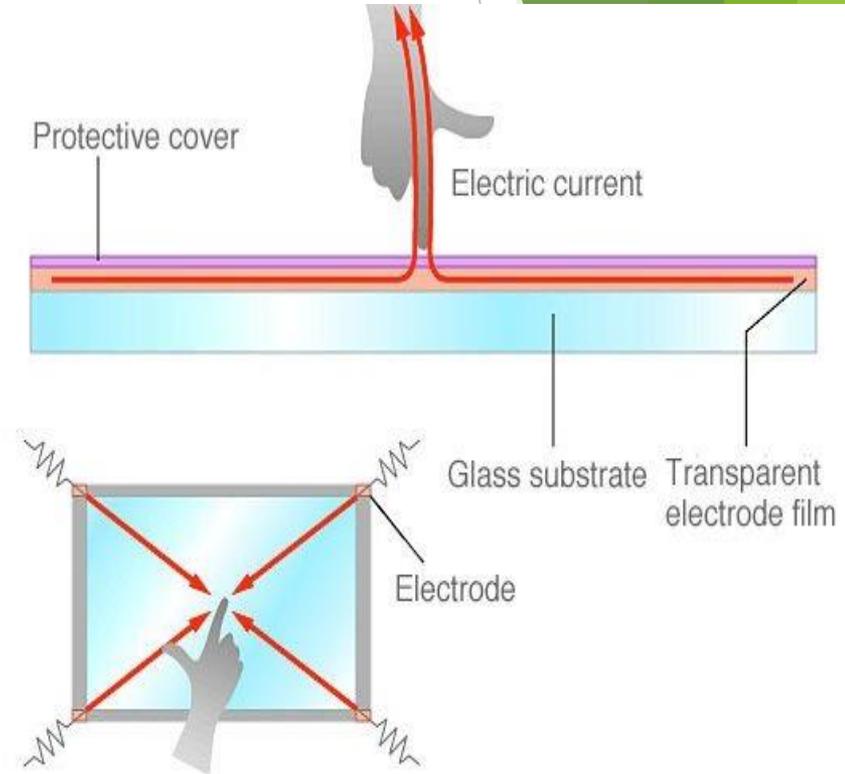
Resistive Touch Screen

- 5-Wire Resistive Touch is the most widely touch technology in use today.
- A resistive touch screen monitor is composed of a glass panel and a film screen, each covered with a thin metallic layer, separated by a narrow gap.
- When a user touches the screen, the two metallic layers make contact, resulting in electrical flow. The point of contact is detected by this change in voltage.



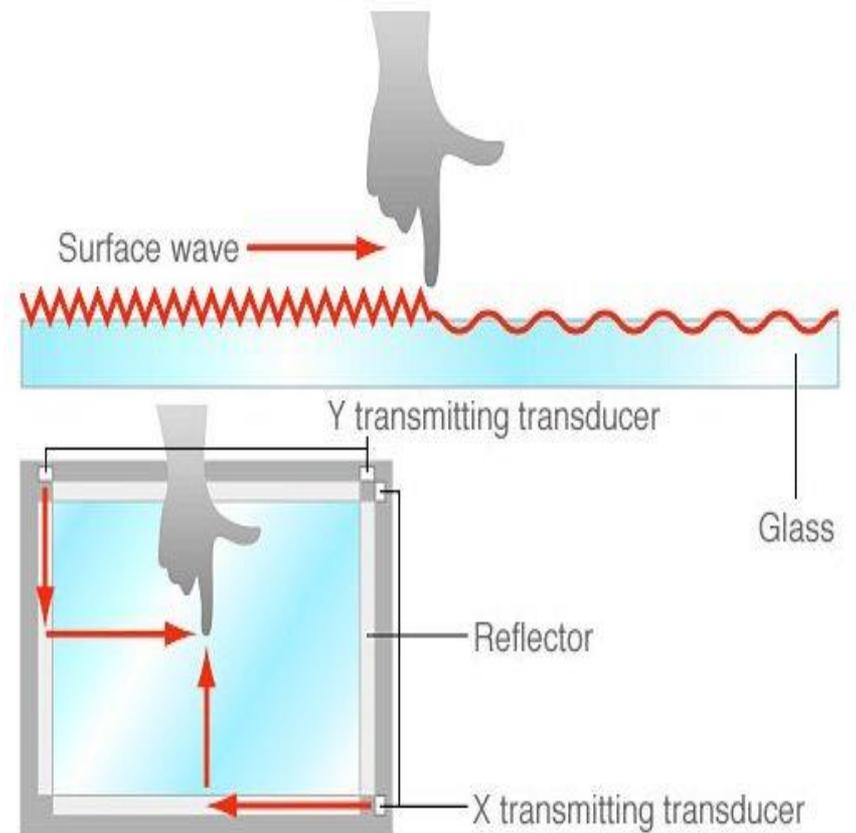
Capacitive Touch Screen

- In a capacitive touch screen monitor, a transparent electrode layer is placed on top of a glass panel.
- This is then covered by a protective cover. When an exposed finger touches the monitor screen, it reacts to the static electrical capacity of the human body.
- Some of the electrical charge transfers from the screen to the user. This decrease in capacitance is detected by sensors located at the four corners of the screen, allowing the controller to determine the touch point.
- Capacitive touch screens can only be activated by the touch of human skin or a stylus holding an electrical charge.



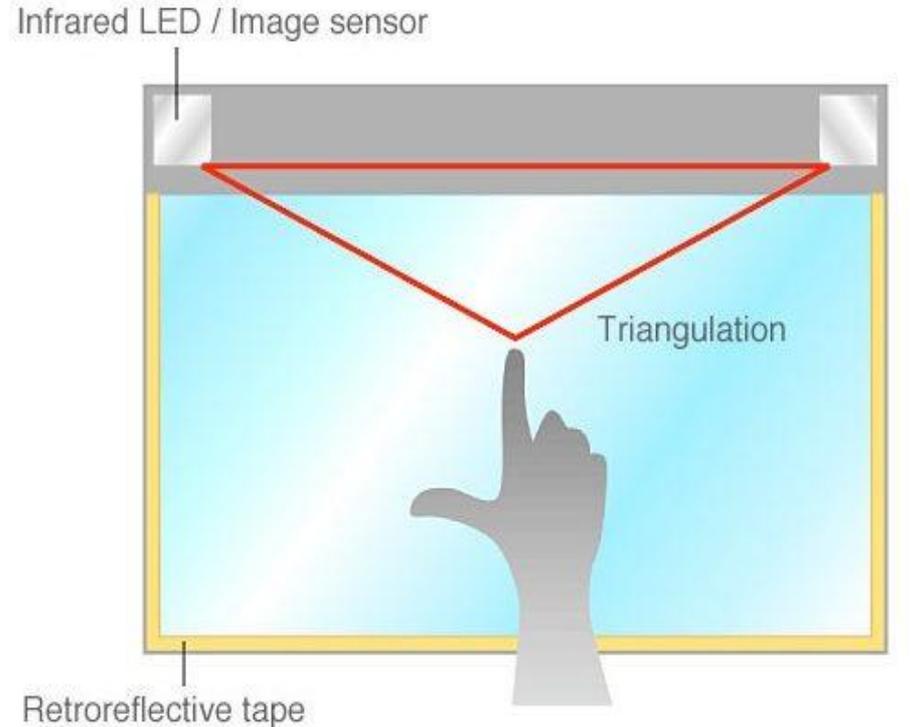
SAW Touch Screen

- SAW (Surface Acoustic Wave) touch screen monitors utilize a series of piezoelectric transducers and receivers.
- These are positioned along the sides of the monitor's glass plate to create an invisible grid of ultrasonic waves on the surface.
- When the panel is touched, a portion of the wave is absorbed. This allows the receiving transducer to locate the touch point and send this data to the computer.
- SAW monitors can be activated by a finger, gloved hand, or soft-tip stylus. SAW monitors offer easy use and high visibility.



Infrared(IR) Touch Screen

- IR (Infrared) type touch screen monitors do not overlay the display with an additional screen or screen sandwich.
- Infrared monitors use IR emitters and receivers to create an invisible grid of light beams across the screen.
- This ensures the best possible image quality. When an object interrupts the invisible infrared light beam, the sensors are able to locate the touch point.
- The X and Y coordinates are then sent to the controller.



Output primitives

- ▶ The Primitives are the simple geometric functions that are used to generate various Computer Graphics required by the User. Some most basic Output primitives are point-position(pixel), and a straight line.
- ▶ Point, Line , polyline, polygon , marker , text and image

LINE ATTRIBUTES

- ▶ A straight-line segment can be displayed with three basic attributes: **color, width, and style.**
- ▶ Line color is typically set with the same function for all graphics primitives, while line width and line style are selected with separate line functions.
- ▶ Additionally, lines may be generated with other effects, such as pen and brush strokes.

Output Primitives

Output Primitive	Attributes
Point	Size Color
Line	Thickness (1pt, 2pt ...) Type (Dashed, Dotted, Solid) Color
Text	Font (Arial, Courier, Times Roman...) Size (12pt, 16pt ..) Spacing Orientation (Slant angle) Style (Bold, Underlined, Double lined) Color
Filled Region	Fill Pattern Fill Type (Solid Fill, Gradient Fill) Fill Color
Images	Color Depth (Number of bits/pixel)

Output Primitives Summary

SUMMARY OF ATTRIBUTES			
<i>Output Primitive Type</i>	<i>Associated Attributes</i>	<i>Attribute-Setting Functions</i>	<i>Bundled-Attribute Functions</i>
Line	Type Width Color	setLinetype setLineWidthScaleFactor setPolylineColourIndex	setPolylineIndex setPolylineRepresentation
Fill Area	Fill Style Fill Color Pattern	setInteriorStyle setInteriorColorIndex setInteriorStyleIndex setPatternRepresentation setPatternSize setPatternReferencePoint	setInteriorIndex setInteriorRepresentation
Text	Font Color Size Orientation	setTextFont setTextColourIndex setCharacterHeight setCharacterExpansionFactor setCharacterUpVector setTextPath setTextAlignment	setTextIndex setTextRepresentation
Marker	Type Size Color	setMarkerType setMarkerSizeScaleFactor setPolymarkerColourIndex	setPolymarkerIndex setPolymarkerRepresentation

Graphics Functions (contd..)

- ▶ C graphics using graphics.h functions can be used to draw different shapes, display text in different fonts, change colors and many more.
- ▶ Using functions of graphics.h in Turbo C compiler you can make graphics programs, animations, projects, and games.
- ▶ You can draw circles, lines, rectangles, bars and many other geometrical figures. You can change their colors using the available functions and fill them.

Graphics Functions (contd..)

- ▶ Window ()
 - ▶ This function specifies a window on screen

Syntax

Window(left, top, right, bottom)

- ▶ putch()
 - ▶ It displays a single character at cursor position

Syntax

putch(char)

Example

putch('A')

Graphics Functions (contd..)

- ▶ `clrscr()`
 - ▶ It clears the entire screen
 - ▶ Locates the cursor in top left i.e. (1,1)

Syntax

```
clrscr()
```

- ▶ `gotoxy()`
 - ▶ It positions the cursor to the specified location on screen

Syntax

```
goto(x,y)
```

Example

```
goto(3,4)
```

Graphics Functions (contd..)

- ▶ puts()
 - ▶ It display string at cursor position.

Syntax

puts(S1)

Example

puts("Hello")

- ▶ **Example**

```
gotoxy(3,4)
```

```
puts("Hello")
```

```
gotoxy(10,10)
```

```
putch('A')
```

Graphics Functions (contd..)

► `textcolor()`

► It sets the color for the text

Color Constants	Color Name
0	BLACK
1	BLUE
2	GREEN
3	CYAN
4	RED
5	MAGENTA
6	BROWN
7	LIGHT GRAY
8	DARK GRAY
9	LIGHT BLUE

Syntax

`textcolor(color)`

Example

`textcolor('GREEN')`

Graphics Functions (contd..)

▶ delline()

- ▶ It deletes a line specified by cursor position.

Syntax

```
delline()
```

▶ inline()

- ▶ It insert a blank line at current cursor position

Syntax

```
insert()
```

Graphics Functions (contd..)

► textbackground()

- It changes background of text.

Color Constants	Color Name
0	BLACK
1	BLUE
2	GREEN
3	CYAN
4	RED
5	MAGENTA
6	BROWN

Syntax

```
textbackground(color)
```

Graphics Functions (contd..)

▶ moveto()

- ▶ It moves cursor to the location specified by int (x,y)

Syntax

```
moveto(x,y)
```

- ▶ outtextxy(“sentence”) OR outtextxy(x,y,sentence)
- ▶ It displays text within quotation mark

Graphics Mode

- ▶ Display different effective text as well as we can draw different graphical figures.
- ▶ `initgraph()`
 - ▶ It is used to initialise graphic mode

Syntax

```
initgraph(int driver, int mode, char path)
```

Graphics Mode (contd..)

TABLE 1.3

Driver selected	Mode constant	Display mode
CGA	CGAC0	320 × 200, 4 colour, palette 0
	CGAC1	320 × 200, 4 colour, palette 1
	CGAC2	320 × 200, 4 colour, palette 2
	CGAC3	320 × 200, 4 colour, palette 3
	CGSHI	640 × 200, 2 colour
EGA	EGALO	640 × 200, 16 colour
	EGAHI	640 × 350, 16 colour
VGA	VGALO	640 × 200, 16 colour
	VGAMED	640 × 350, 16 colour
	VGAHI	640 × 480, 16 colour

Graphics Mode (contd..)

▶ Path

- ▶ It specifies path of graphics driver

- ▶ Example:

```
initgraph(&gd, &gm, "C:\\tc\\bgi")
```

```
int gm, gd = DETECT
```

▶ closegraph()

- ▶ It is used to close graphics mode.

Shapes

- ▶ `lineto(x,y)`
 - ▶ This command draws a line on screen from current cursor position.
 - ▶ Syntax :
 - ▶ `lineto(x,y)`
- ▶ `line()`
 - ▶ `line(x1,y1,x2,y2)`

Shapes (contd..)

▶ circle(x, y, radius)

- ▶ **circle()** function which draws a circle with center at (x, y) and given radius
- ▶ where, (x, y) is center of the circle. 'radius' is the Radius of the circle.
- ▶ **Examples :**

```
circle(250, 200, 50);
```

▶ rectangle(int left, int top, int right, int bottom)

- ▶ **rectangle()** is used to draw a rectangle.
- ▶ Coordinates of left top and right bottom corner are required to draw the rectangle. left specifies the X-coordinate of top left corner, top specifies the Y-coordinate of top left corner, right specifies the X-coordinate of right bottom corner, bottom specifies the Y-coordinate of right bottom corner.
- ▶ **Examples :**

```
rectangle(150, 150, 450, 450);
```

Shapes (contd..)

▶ **ellipse(int x, int y, int start_angle, int end_angle, int x_radius, int y_radius)**

- ▶ In this function x, y is the location of the ellipse. x_radius and y_radius decide the radius of form x and y.
- ▶ start_angle is the starting point of angle and end_angle is the ending point of angle. The value of angle can vary from 0 to 360 degree.

▶ **Examples :**

```
ellipse(250, 200, 0, 360, 100, 50);
```

▶ **drawpoly(n,array)**

- ▶ **drawpoly()** function which is used to draw polygons i.e. triangle, rectangle, pentagon, hexagon etc.

▶ **Examples :**

```
int arr[] = {320, 150, 400, 250, 250, 350, 320, 150};  
drawpoly(4, arr);
```

Colors

- ▶ `setcolor(int color)`
 - ▶ `setcolor()` function which is used to set the current drawing color to the new color.
 - ▶ In Graphics, each color is assigned a number. Total number of colors available are 16. Number of available colors depends on current graphics mode and driver.
 - ▶ For example, `setcolor(RED)` or `setcolor(4)` changes the current drawing color to RED. Remember that default drawing color is WHITE.

▶ Example

```
setcolor(GREEN);
```

OR

```
setcolor(2);
```

Color Constants	Color Name
0	BLACK
1	BLUE
2	GREEN
3	CYAN
4	RED
5	MAGENTA
6	BROWN
7	LIGHT GRAY
8	DARK GRAY
9	LIGHT BLUE

Virtual Reality

- ▶ Virtual reality (VR) means experiencing things through our computers that don't really exist.
- ▶ A believable, interactive 3D computer-created world that you can explore so you feel you really are there, both mentally and physically.

Putting it another way, virtual reality is essentially:

- ▶ **Believable:** You really need to feel like you're in your virtual world and to keep believing that, or the illusion of virtual reality will disappear.

Virtual Reality (contd..)

- ▶ **Interactive:** As you move around, the VR world needs to move with you. You can watch a 3D movie and be transported up to the Moon or down to the seabed—but it's not interactive in any sense.
- ▶ **Computer-generated:** Only powerful machines, with realistic 3D computer graphics, are fast enough to make believable, interactive, alternative worlds that change in real-time as we move around them.
- ▶ **Explorable:** A VR world needs to be big and detailed enough for you to explore.
- ▶ **Immersive:** To be both believable and interactive, VR needs to engage both your body and your mind. Paintings by war artists can give us glimpses of conflict, but they can never fully convey the sight, sound, smell, taste, and feel of battle.

Types of VR System

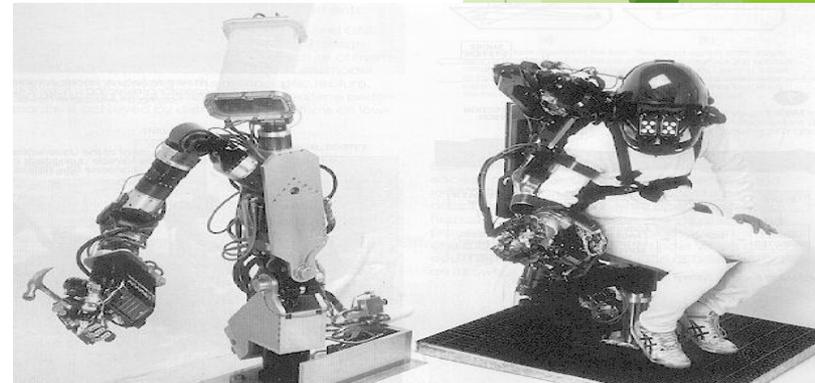
- Windows on World (WoW)
 - ▶ Also called Desktop VR.
 - ▶ Using a conventional computer monitor to display the 3D virtual world.

- Immersive VR
 - ▶ Completely immerse the user's personal viewpoint inside the virtual 3D world.
 - ▶ The user has no visual contact with the physical world.
 - ▶ Often equipped with a Head Mounted Display (HMD).



Types of VR System (contd..)

- Telepresence
 - ▶ A variation of visualizing complete computer generated worlds.
 - ▶ Links remote sensors in the real world with the senses of a human operator. The remote sensors might be located on a robot. Useful for performing operations in dangerous environments.



Types of VR System (contd..)

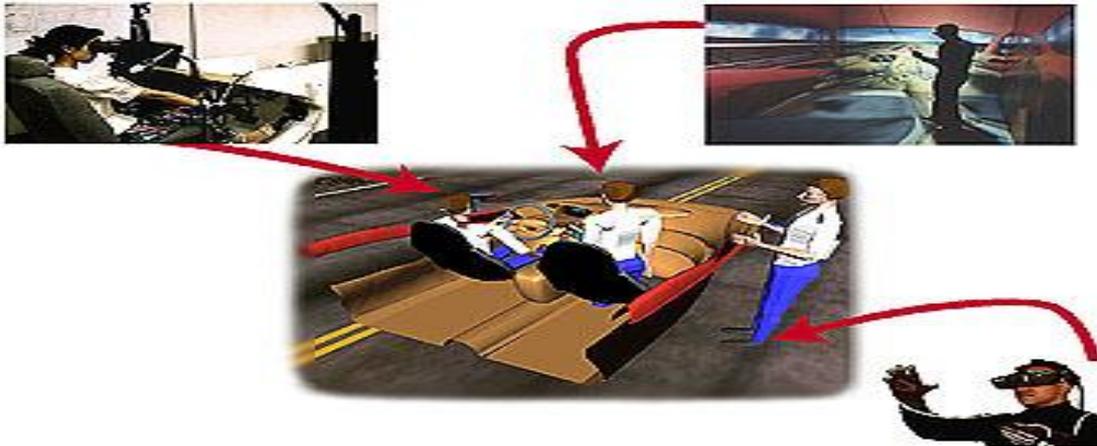
- Mixed Reality(Augmented Reality)
 - ▶ The seamless merging of real space and virtual space.
 - ▶ Integrate the computer-generated virtual objects into the physical world which become in a sense an equal part of our natural environment.



VR Examples (contd..)

Distributed VR

- ▶ A simulated world runs on several computers which are connected over network and the people are able to interact in real time, sharing the same virtual world.



Applications

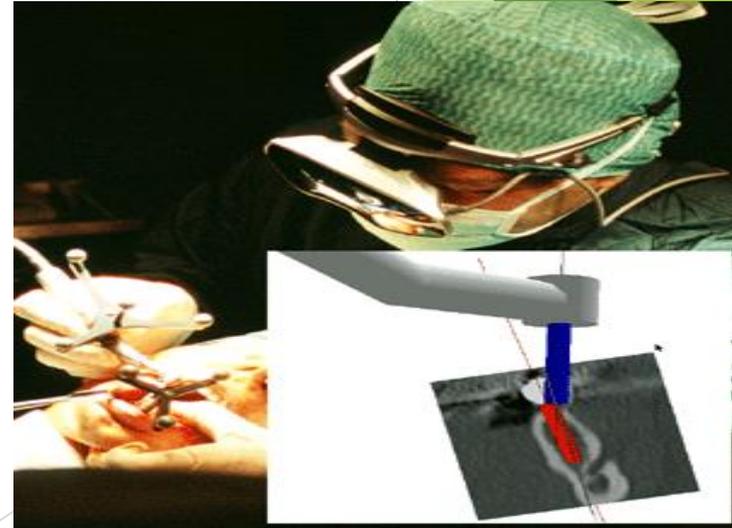
- **Entertainment**
 - ▶ More vivid
 - ▶ More exciting
 - ▶ More attractive



Applications (contd..)

▪ Medicine

- Practice performing surgery.
- Perform surgery on a remote patient.
- Teach new skills in a safe, controlled environment.



Applications (contd..)

- Manufacturing
 - ▶ Easy to modify
 - ▶ Low cost
 - ▶ High efficient



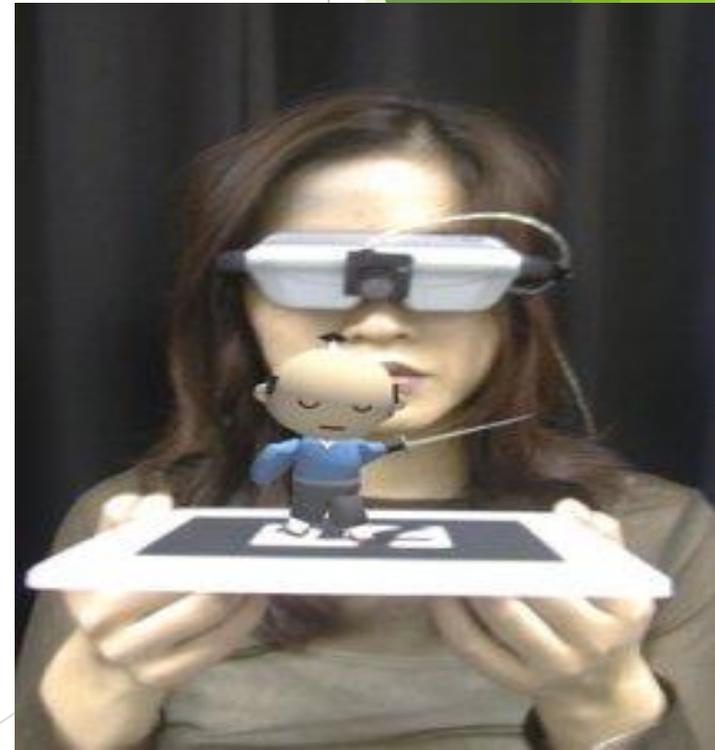
Applications (contd..)

- Education & Training
 - ▶ Driving simulators.
 - ▶ Flight simulators.
 - ▶ Ship simulators.
 - ▶ Tank simulators.



What Is Augmented Reality (AR)?

- ▶ A combination of a real scene viewed by a user and a virtual scene generated by a computer that augments the scene with additional information.
 - ▶ ARToolkit demo movie
 - ▶ T-immersion 2004 video



What is AR? (cont.)

- ▶ Ronald Azuma defines an augmented reality system as one that:
 - ▶ Combines real and virtual world aspects
 - ▶ Is interactive in real-time
 - ▶ Is registered in three dimensions

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Virtual Reality vs. Augmented Reality

► Virtual Reality (VR)

a computer generated, interactive, 3D environment in which a person is immersed :
virtual, interactive and immersive

► Augmented Reality (AR)

Supplements the real world with the virtual(computer generated) objects that appear to coexist in the same space as the real world.

