Tribhuvan University
Institute of Science and Technology
Bachelor of Science in
Computer Science and Information Technology

3RD Semester

CSC209: Computer Graphics

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Introduction of Computer Graphics 3 Hrs.

1.1 A Brief Overview of Computer Graphics, Areas of Applications.

1.2 Graphics Hardware: Display Technology, Architecture of Raster-Scan Displays, Vector Displays, Display Processors, Hard copy device. Input Devices.

1.3 Graphics Software: Software standards, Need of machine independent graphics language.

Computer Graphics

- Computer graphics is a field related to the generation of graphics using computer.
- It includes the creation, storage and manipulation of images of object.
- These objects come from diverse field such as medicine, physical, mathematical, engineering, architecture, entertainment, advertisement.
- It is related to the generation and the representation of graphics by a computer using specialized graphic hardware and software.

Computer Graphics

- The graphics can be photographs, drawings, movies, or simulation etc.
- Computer graphics today is largely interactive; that is the user controls the contents structure and appearance of images of the objects by using input devices
- such as keyboard, mouse, or touch sensitive panel on the screen.

Applications of Computer Graphics

Different application area of computer graphics:

- Computer Aided Design (CAD)
- Presentation Graphics
- Computer Art
- Entertainment
- Education and Training
- Computer animation
- Image Processing
- Graphical User Interfaces
- Simulation
- Cartography

Terminologies in Graphics

Imaging: Formation of an image.
- representation of 2D images.

Modelling: Representing 3D images.

Rendering: Constructing 2D images from 3D models.

Animation: Stimulating changes over time.
- describing how objects change in time.

Terminologies in Graphics

Raster: A rectangular array of points and dots.

Pixel (picture element): One dot or picture element of the raster.

- basic unit of programmable color on a computer display or in a computer image

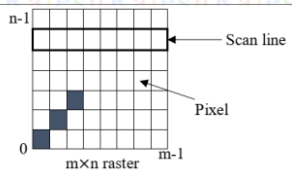
Scan line: A row of pixel.

Bit map: Ones and Zeros representation of rectangular array of point on the screen.

Black & white → bitmap

Color→ pixmap

Terminologies in Graphics

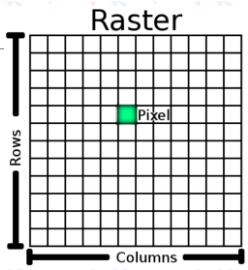


we don't have any pixel like 1.2, 5.8.

Raster device co-ordinate can have only integer values.

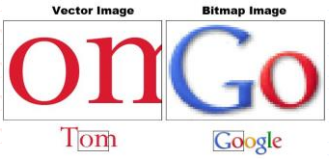
Raster

A rectangular array of points or dots.



Vector

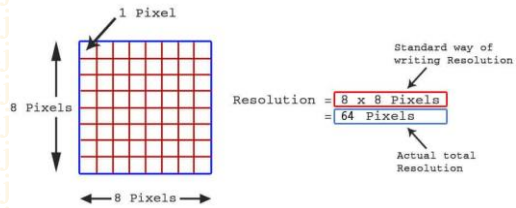
Vector graphics is the creation of digital images through a sequence of commands or mathematical statements that place lines and shapes in a given two-dimensional or three dimensional space



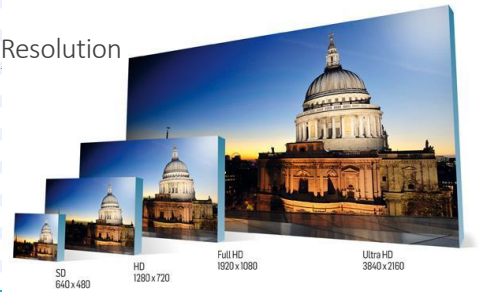
Resolution

- The maximum number of points (pixel) that can be displayed without overlap on a CRT is referred to as the resolution.
- It is also defined as the number of points per unit of measure (per centimeter or per inch) that can be plotted horizontally and vertically.

Resolution



Resolution

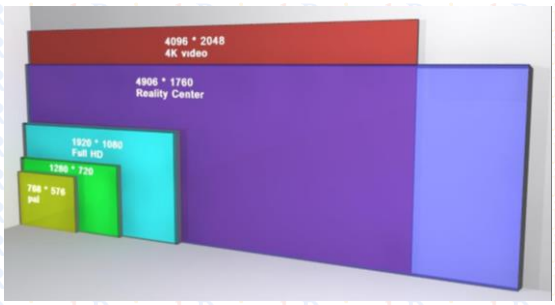


Resolution

- SD: 480p / 576p Here, p stands for pixels
- HD: 720p / 1080p
- 4K: 2160p
- 8K: 4320p

➢It gives idea of how many rows of pixels – from top to bottom – are contained in a video, TV set or screen.

➢720p of HD means that videos or TV sets in HD typically have 720 rows of pixels



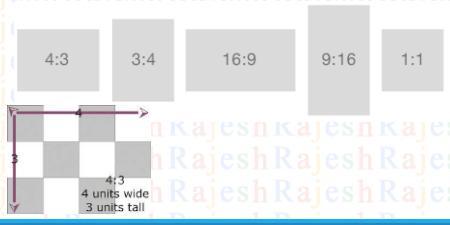
Aspect Ratio

The aspect ratio of an image describes the proportional relationship between its width and its height.

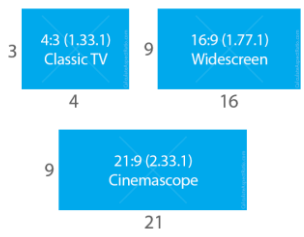
It is commonly expressed as two numbers separated by a colon, as in 16:9. For an x:y aspect ratio, no matter how big or small the image is, if the width is divided into x units of equal length and the height is measured using this same length unit, the height will be measured to be y units.

In, for example, a group of images that all have an aspect ratio of 16:9, one image might be 16 inches wide and 9 inches high, another 16 centimeters wide and 9 centimeters high, and a third might be 8 yards wide and 4.5 yards high.

Aspect Ratio



Aspect Ratio



Aspect Ratio

Aspect Ratio

Aspect Ratio

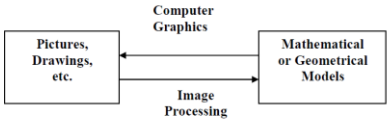
Persistence

- It means how long they continue to emit light after the electron beam is removed.
- The time it takes the emitted light from the screen to decay to one-tenth of its original intensity.
- Lower persistence phosphors require higher refresh rates to maintain a picture on the screen.
- A phosphor with lower persistence is useful for animation and a higher–persistence phosphor is useful for displaying highly complex static picture.
- Graphics monitor are usually constructed with the persistence 10 to 60 microseconds.

Refresh Rate

- The number of times the screen is redrawn each second.
- Higher refresh rates mean less flicker on the screen, which translates into less eyestrain.

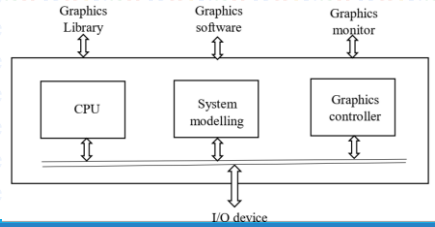
Computer Graphics Vs Image Processing



Computer Graphics Vs Image Processing

Computer graphics	Image processing
Computer graphics involves in generating images from mathematical or geometrical models.	Image processing involves in analyzing the images to generate mathematical or Geometrical models.
It includes the creation, storage and manipulation of images or objects.	It is the part of computer graphics that handles image manipulation or interpretation.
E.g. Drawing a picture	E.g. Making blur image visible.

Graphics Hardware System



Cathode Ray Tube (CRT)

A CRT is an evacuated glass tube, with a heating element on one end and phosphor-coated screen on the other end.

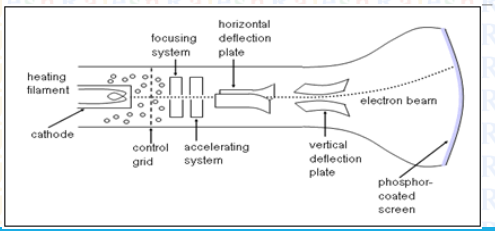
When current flows through heating filament, the electrons are piled upon the filament.

These electrons are attracted by accelerating systems on the phosphor coated screen.

When electron strikes on the screen, the phosphor emits a small spot of light at each position contacted by the electron beam.

The glowing positions are used to represent the picture in the screen.

Cathode Ray Tube (CRT)



Fluorescence / Phosphorescence

- When the beam of electron emitted by electron gun strikes phosphor coated screen on the CRT, the phosphor emits a small spot of light at each position contacted by the electron beam, such phenomenon is known as fluorescence / phosphorescence.

- It last just a fraction of millisecond.

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.

Raster Graphics

A raster image is made up of pixels, each a different color, arranged to display an image

The larger the image, the more disk space the image file will take up.

File extensions: .BMP, .TIF, .GIF, .JPG

Vector Graphics

A vector image is made up of paths, each with a mathematical formula (vector), that tells the path how it is shaped and what color it is bordered with or filled by.

Vector graphics are best for printing since it is composed of a series of mathematical curves resulting no loss of quality even enlarged.

In vector graphics, the file is created and saved as a sequence of vector statements, so small file size is obtained.

File extensions: SVG, EPS, PDF, AI, DXF

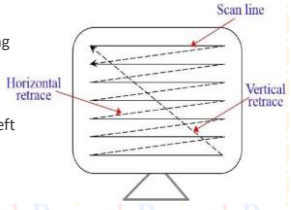
Raster Graphics	Vector Graphics
They are composed of pixels	They are composed of paths
Refresh process is independent of the complexity of the image	It displays flicker when the number of primitives in the image become too large.
It can draw mathematical curves, polygons and boundaries of curved primitives only by pixel approximation.	It can draw continuous and smooth lines.
They occupies more space which depends on image quality	They occupy less space
File ext: .BMP, .TIF, .GIF, .JPG	File ext: SVG, EPS, PDF, AI, DXF

Raster Scan display

- The electron beam is swept across the screen, one row at a time from top to bottom.
- As electron beam moves across each row, the beam intensity is turned on and off to create a pattern of illuminated spots.
- Picture definition is stored in memory called frame buffer or refresh buffer.
- This memory holds the set of intensity values for all the screen points.
- Stored intensity values are then retrieved from the frame buffer and painted on the screen one row at a time.

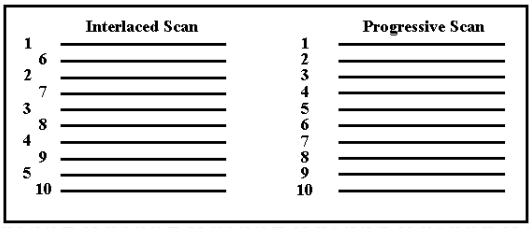
Raster Scan display

- Returning of electron beam from right end to left end after refreshing each scan line is called horizontal retrace.
- At the end of each frame, the electron beam returns to the top left corner to begin next frame called vertical retrace.

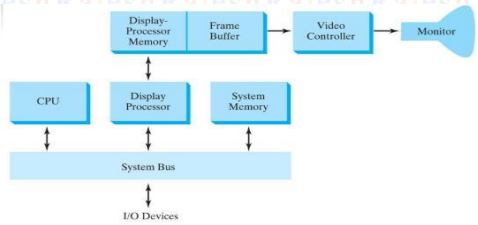


Interlaced vs. non-interlaced(progressive) scan

- Types of Raster-scan systems based on refresh procedure
- In interlaced scan, each frame is displayed in two passes. First pass for odd scan lines and another for even ones.
- In non-interlaced refresh procedure, electron beam sweeps over entire scan lines in a frame from top to bottom in one pass.
- Interlacing is primarily used with slower refreshing rates. This is an effective technique for avoiding screen flickering.

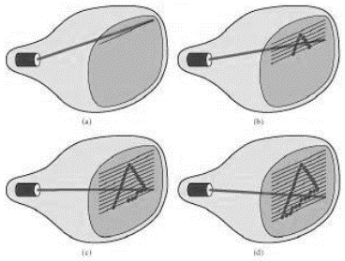


Architecture of Raster Scan display system:



Architecture of Raster Scan display system:

- Video controller or display controller is used to control the operation of the display device.
- When a particular command is called by the 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 a time.
- It will bring a value of each pixel contained in the frame buffer and uses it to control the intensity of the CRT electron beam.



Architecture of Raster Scan display system:

- The display processor memory holds data plus program that perform scan conversion and raster operation.
- The display processor is a separate processor that performs graphics function such as scan conversion and raster operation.
- System memory holds data and those program that execute on the CPU.
- The frame buffer stores displayable image created by scan conversion & raster operation.

Raster Scan display system

Advantages:

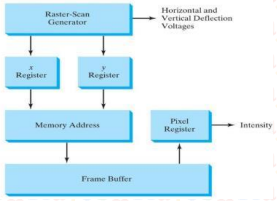
- It has an ability to fill the areas with solid colors or patterns
- The time required for refreshing is independent of the complexity of the image
- Low cost

Raster Scan display system

Disadvantages:

- Its resolution is poor.
- 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.

Video controller



Video controller

- It is a special-purpose processor used to control the operation of the display device.
- Two Registers (x and y) are used to store screen pixel coordinates.
- Initially, $x = 0$ and $y = 0$
- As first scan line is generated, the x register is incremented up to x_{max}.

Each pixel value is fetched and used to control the intensity of CRT beam.

After first scan line, x register address is reset to 0 and y register address is incremented by 1.

The process is continued until the last scan line ($y = y_{max}$) is generated.

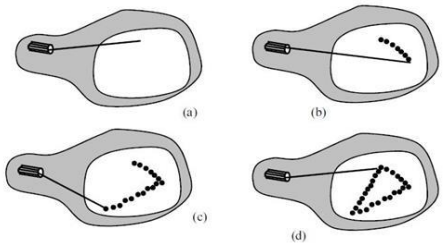
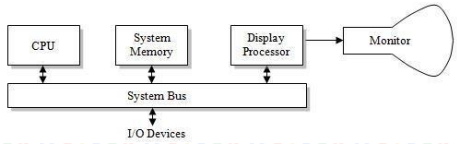


Figure: Random Scan Display

Random Scan (Vector) Display

- The electron beam is directed only to the part of screen where the picture is to be drawn.
- It draws a picture one line at a time, so it is also called vector display.
- Picture definition is stored as a set of line drawing commands in an area of memory called refresh display file.
- To display a picture, the system cycles through the set of commands in the display file.
- After all commands are processed, the system cycle backs to the first line command in the list.

Architecture of Random Scan system:



Architecture of Random Scan system:

- The graphics command in the application program are translated by the graphics package into a display list (display file) stored in system memory.
- The display list is accessed by the display processor to refresh the screen.
- The display processor cycles through each command in the display list once during each refresh cycle.
- Graphics are drawn on a vector display system by directing the electron beam along component lines of the picture.

Random Scan system

Advantages:

- Can produce output with high resolutions.
- Better for animation than raster system since only end point information is needed.

Disadvantages:

- Cannot fill area with pattern and manipulate bits.
- Refreshing image depends upon its complexity.

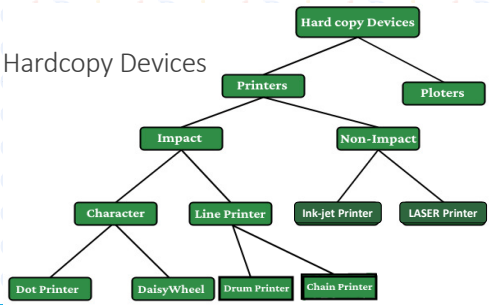
Display Processors

- The interpreter or a hardware that converts display processor code into picture.
- It converts the digital information from CPU to analog values.
- Its main purpose is to free the CPU from most of the graphic chores.
- It digitizes a picture definitions given in an application program into a set of pixel intensity values for storage in the frame buffer.
- This digitization process is called Scan Conversion.

Display Processors

- Display Processor was used before the GPU (Graphics Display Processor).
- Video Controller is the most widely used Display device that is based on CRT (Cathode Ray Tube).
- In addition with the system memory, Display Processor have a separate memory area.

Hardcopy Devices



Printers

Impact Printers:

A type of printer that works by direct contact with an ink ribbon with paper.

Mechanisms resemble to a typewriter.

Non-impact printers:

A type of printer that does not hit or impact a ribbon to the paper.

They used laser, xerographic, electrostatic, chemical and inkjet technologies.

Dot Matrix:

Each character is in the form pattern of dots and the head consists of a matrix of pins of size.

Oldest printing technology,

one character at a time by using a fixed no of pins.

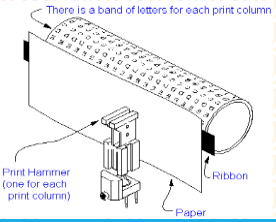
Daisy Wheel Printer:

It is called a daisy wheel because the print mechanism looks like a daisy,

at the end of each petal is a fully formed character that produces a solid line print.

Drum Printer

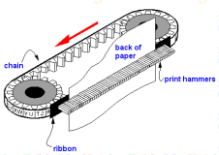
A line printer that uses a rotating drum with raised characters, against which the paper is pressed.



Chain Printer

An obsolete type of solid-font line printer in which the font was etched or engraved on small plates linked together to form a chain.

The chain was connected around two sprocket wheels so that the straight part of the chain between the wheels ran parallel to the paper and spanned the line to be printed.



Ink-jet printers:

Non impact character printers based on a new technology that prints characters by spraying small drops of ink onto to the paper.

The ink in the cartridge of the printers is in liquid form.

They have nozzles from which ink is sprayed onto paper and it gets printed.

Laser Printers:

Laser printers read the electronic data from your computer and

beam this information onto a drum inside the printer, which builds up a pattern of static electricity.

This attracts a dry powder called toner onto the paper which is then fused using heated rollers.

Plotters:

A special output device used to produce hard copies of large graphics and designs on paper,

such as contributed maps, and engineering drawings.

Drum plotter,

flatbed plotter,

inkjet plotter

are the different types of plotters

Input Devices

Mouse,

Touch Screen,

Light Pen,

Data Glove,

Tablet (Digitizer),

Bar Code Reader

Mouse

A small hand-held device used to position the cursor on the screen.

It is of two types as

1) Mechanical Mouse

2) Optical Mouse

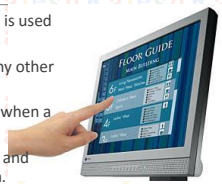
Touch Screen

Touch panels are a sensitive surface that is used to point directly.

The panel can be touched by finger or any other object like stylus.

A basic touch panel senses voltage drop when a user touches the panel.

It knows where the voltage has dropped and accordingly calculates the touch position.



Light Pen

A computer input device in the form of a light sensitive wand used in conjunction with a computer's CRT TV set or monitor

Works by sensing the sudden small change in brightness of a point on the screen when the electron gun refreshes that spot

Data Glove

Constructed with a series of sensors that can detect hand and finger motions.

The transmitting and receiving antennas can be structured as a set of three mutually perpendicular cols, forming a three dimensional Cartesian coordinates system.

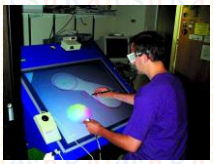
Electromagnetic coupling between the three pairs of coil is used to provide information about the position and orientation of hand.

Tablet (Digitizer)

In general a digitizer is a device which is used to scan over an object, and to input a set of discrete coordinate positions.

No keyboard, no mouse. Instead, you have an LCD screen and a stylus

Tablets are gaining popularity as a replacement for the computer mouse as a pointing device



Graphics Software

There are two general categories of graphics software

- General programming packages:
- Special-purpose application packages:

General programming packages

- Provides extensive set of graphics functions for high level languages (FORTRAN, C etc).
- Basic functions include those for generating picture components (straight lines, polygons, circles, and other figures), setting color and intensity values, selecting views, and applying transformations.
- Example: GL(Graphics Library)

Special-purpose application packages

- Designed for nonprogrammers, so that users can generate displays without worrying about how graphics operations work.
- The interface to the graphics routines in such packages allows users to communicate with the programs in their own terms.
- Example: artist's painting programs and various business, medical, and CAD systems.

Software standards

- Primary goal of standardized graphics software is portability.
- When packages are designed with standard graphics functions, software can he moved easily from one hardware system to another and used in different implementations and applications.
- International and national standards planning organizations in many countries have cooperated in an effort to develop a generally accepted standard for computer graphics.
- After considerable effort, this work led to following standards:

GKS (Graphical Kernel System):

- This system was adopted as the first graphics software standard by the International Standards Organization (ISO) and American National Standards Institute (ANSI).
- Although GKS was originally designed as a two-dimensional graphics package, a three dimensional GKS extension was subsequently developed.

PHIGS (Programmer's Hierarchical Interactive Graphics Standard)

- Extension to GKS, Increased Capabilities for object modeling, color specifications, surface rendering and picture manipulations are provided.
- Subsequently, an extension of PHIGS, called PHIGS+, was developed to provide three-dimensional surface-shading capabilities not available in PHIGS.

PHIGS (Programmer's Hierarchical Interactive Graphics Standard)

Although PHIGS presents a specification for basic graphics functions, it does not provide a standard methodology for a graphics interface to output devices (i.e. still machine dependent).

Nor does it specify methods for storing and transmitting pictures. Separate standards have been developed for these areas:

- **CGI** (Computer Graphics interface): Standardization for device interface
- **CGM** (Computer Graphics Metafile): Standards for archiving and transporting pictures

Coordinate Representations

Each object for a scene can be defined in a separate modeling Cartesian coordinate system, which is then mapped to world coordinates to construct the scene being independent of particular device.

From world coordinates, objects are transferred to normalized device coordinates, then to the final display device coordinates with the help of device drivers.

An initial modeling-coordinate position (x_{mc}, y_{mc}) in this illustration is transferred to a device coordinate position (x_{dc}, y_{dc}) with the sequence:

$(x_{mc}, y_{mc}) \rightarrow (x_{wc}, y_{wc}) \rightarrow (x_{nc}, y_{nc}) \rightarrow (x_{dc}, y_{dc})$

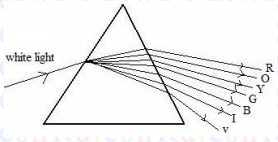
Color Models

A method for explaining the properties or behavior of color within some particular context.

No single color model can explain all aspects of color, so we make use of different models to help describe the different perceived characteristics of color.

Physical properties of light

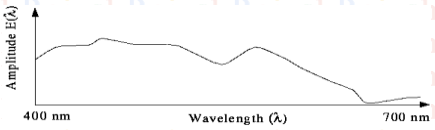
- White light consists of a spectrum of all visible colors.
- All kinds of light can be described by the energy of each wavelength.



Physical properties of light

Most light we see is not just a single wavelength, but a combination of many wavelengths like below.

This profile is often referred to as a spectrum, or spectral power distribution.



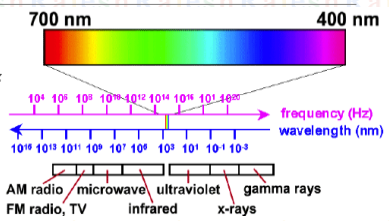
Physical properties of light

Frequency:

- Red: 3.8 × 10^{14} hz
- Violet: 7.9 × 10^{14} hz

Wavelength:

- Red: 700 nm
- Violet 400 nm



Color Models

There are two types of color models:

1) Additive and 2) Subtractive

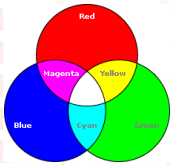
Additive color models use light to display color while subtractive models use printing inks.

Colors perceived in additive models are the result of transmitted light.

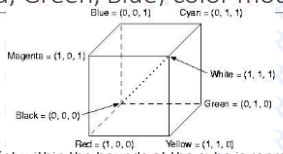
Colors perceived in subtractive models are the result of reflected light.

RGB (Red, Green, Blue) color model

- Used in color CRT monitors where Red, Green and Blue are added together to get the resultant color white.



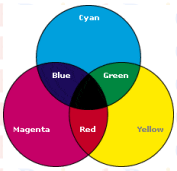
RGB (Red, Green, Blue) color model



- Each color point within the bounds of the cube is represented as the triple (R, G, B), where value for R, G, B are assigned in the range from 0 to 1.
- All other colors are generated from these three primary colors.

CMY (Cyan, Magenta, Yellow) color model

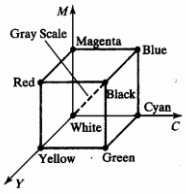
- Used in color printing devices where Cyan, Magenta, and Yellow are added together to get the resultant color BLACK.



CMY (Cyan, Magenta, Yellow) color model

Relation between RGB and CMY:

$$\begin{pmatrix} c \\ m \\ y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} r \\ g \\ b \end{pmatrix}$$



CMYK (Cyan, Magenta, Yellow, Black) color model

- For printing and art industry the CMY model is not enough. So, fourth primary color K (Black) is added to CMY model.

- CMYK (subtractive color model) is the standard color model used in offset printing for full-color document.

- Because such printing uses inks of these four basic colors, it is often called four-color printing.

HSV (Hue, Saturation, Value) color model

- HSV is a cylindrical coordinate representation of points in an RGB color model.

Hue: the dominant color as perceived by an observer

Saturation: the amount of white light mixed with Hue

Value: the chromatic notion of intensity

HSV (Hue, Saturation, Value) color model

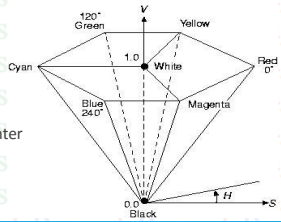
- HSV is described by a hexacone derived from the RGB cube.

- (h, s, v), where h ϵ [0, 360) and s, v ϵ [0, 1]

hue: angle round the hexagon

saturation: distance from the center

value: axis through the center



END OF UNIT 1