

CHAPTER ONE



INTRODUCTION TO MULTIMEDIA

What is multimedia?

Multimedia can have many definitions these include:

- **A computer system perspective**

Multimedia means that computer information can be represented through audio, video, and animation in addition to traditional media.

- **Based on the word "Multimedia"**

The term multimedia has been coined from two terms : multiple and media.

Multi- multiple/many

Media- source

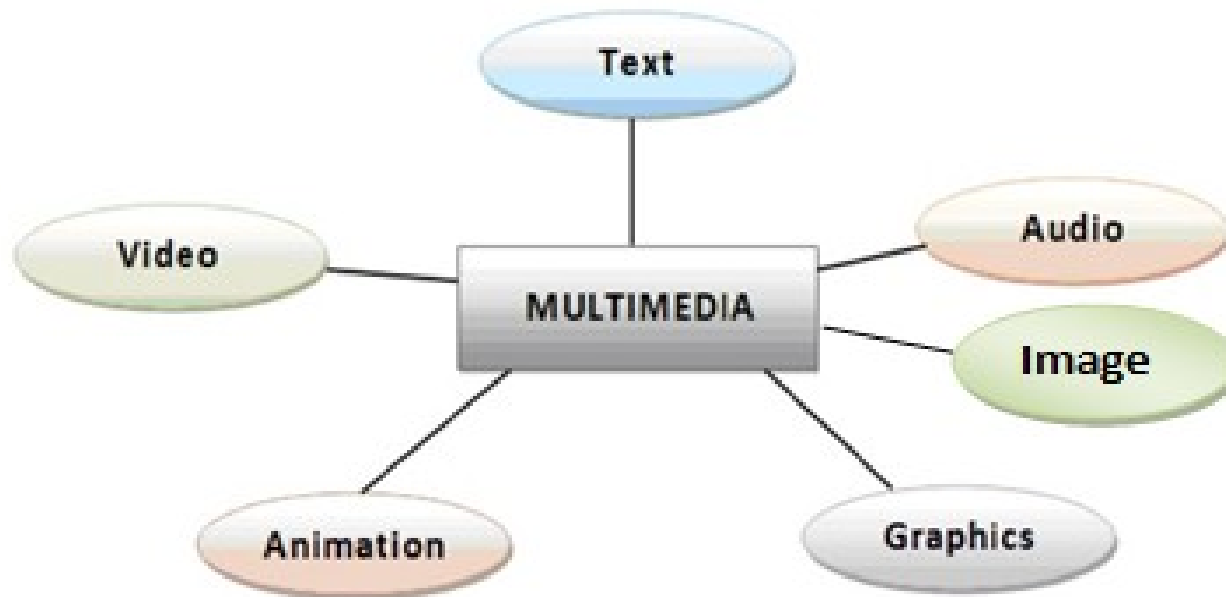
Source refers to different kind of information that we use in multimedia. This includes:

Text, graphics, audio, video and-images

Hence, multimedia means usage of multiple medias to communicate.

Cont...

- In other words, multimedia is a combination of different media elements like text, audio, image, graphics, video and animation.
- The combination of all the media elements makes the communication more structured and understandable to



dia

General definition



- Multimedia is the field concerned with the computer controlled integration of text, graphics, drawings, still and moving images (Video), animation, audio, and any other media where every type of information can be represented, stored, transmitted and processed digitally.

Hypermedia



- **Hypermedia** is not constrained to be text-based.
- It can include other media, e.g., graphics, images, and especially the continuous media – sound and video.
- Multimedia is **interactive** when the end-user is allowed to control what and when the elements are delivered.
- Interactive Multimedia is **Hypermedia**, when the end-user is provided with the structure of linked elements through which he/she can navigate.
- Example Hypermedia Applications.
 - The World Wide Web (WWW) is the best example of a hypermedia application.
 - Powerpoint

Cont...

Multimedia may be broadly divided into **linear** and **non-linear** categories.

- Multimedia is **linear**, when it is not interactive and the users just sit and watch as if it is a **movie**.
- Linear active content progresses without any navigation control for the viewer such as a **cinema** presentation.
- It is **nonlinear**, when the users are given the navigational control and can browse the contents .
- Non-linear content offers user interactivity to control progress as used with a computer game or used in self-paced computer based training.
- Non-linear content is also known as **hypermedia** content.



Multimedia presentations can be live or recorded.

- A recorded presentation may allow interactivity via a navigation system.
- A live multimedia presentation may allow interactivity via interaction with the presenter or performer.
- Recorded multimedia may be a ***linear multimedia(T\F)?***

World Wide Web (WWW) and Multimedia



- Multimedia is closely tied to the World Wide Web (WWW).
- Without networks, multimedia is limited to simply displaying images, videos, and sounds on your local machine.
- The true power of multimedia is the ability to deliver this rich content to a large audience.

Multimedia System

- A multimedia system is a system capable of processing multimedia data and applications.
- It is characterized by the processing, storage, generation, manipulation and rendition of Multimedia information.
- Following the dictionary definitions, ***Multimedia system is any system that supports more than a single kind of media.***
- Implies any system processing **text and image** will be a multimedia system!!
- Note, the definition is quantitative.
- A qualitative definition would be more appropriate.



- The kind of media supported should be considered, rather the number of media.
- Multiple forms of information content are often considered as multimedia if they contain **conventional media** and **new media**, say image and audio or video.

Cont...

- A multimedia system is characterized by computer controlled, integrated production, manipulation, storage and communication of independent information, which is encoded at least through a **continuous** (time-dependent) and a **discrete** (time-independent) medium.
- Which of the following is a multimedia system?
 - A word processor that handles embedded graphics/image along with text
 - Macromedia flash that helps to create animated objects

Challenges of Multimedia Systems

1) *Synchronization issue:*

- in MM application, varieties of media are used at the same instance.
- In addition, there should be some relationship between the media. E.g between Movie (video) and sound.
- There arises the issue of synchronization.

2) *Data conversion:*

- in MM application, data is represented digitally.
- The information they handle must be represented digitally.
- Because of this, we have to convert analog data into digital data.

3) *Compression and decompression:*

- Why? Because multimedia deals with large amount of data (e.g. Movie, sound, etc) which takes a lot of storage space.

4) Render different data at same time — continuous data.

Properties of Multimedia System



- Multimedia system handles discrete and continuous media
 - It is a system capable of handling at least one discrete and one continuous media in digital form E.g. Image and audio
- Multiple forms of information content are often not considered multimedia if they don't contain, say, audio or video.
- Integrate and use minimal number of different devices for presentation of multimedia
- Synchronize well the presentation of the result of the different media such that information flows in the correct order
- Multimedia system must be computer controlled.
- A digital device, like computer must be involved in the presentation of the multimedia information to users

Desirable Features for a Multimedia System

- 
- ***Very high processing speed processing power.*** Why? Because there are large data to be processed. Multimedia systems deals with large data and to process data in real time, the hardware should have high processing capacity.
 - ***It should support different file formats.*** Why? Because we deal with different data types (media types).
 - ***Efficient and High Input-output:*** input and output to the file subsystem needs to be efficient and fast.
 - ***Special Operating System:*** to allow access to file system and process data efficiently and quickly.
 - ***Storage and Memory:*** large storage units and large memory are required.
 - ***Network Support:*** Client-server systems common as distributed systems common.
 - ***Software Tools:*** User-friendly tools needed to handle media, design and develop applications, deliver media.

Components of a Multimedia System

Now let us consider the Components (Hardware and Software) required for a multimedia system:

- Capture devices — Video Camera, Video Recorder, Audio Microphone, Keyboards , graphics tablets
- Storage Devices — Hard disks, CD-ROMs, DVD-ROM, *etc*
- Computer Systems — Multimedia Desktop machines, Workstations
- Display Devices — CD-quality speakers, monitors , Colour printers *etc.*
- Communication Networks — Local Networks, Intranets, Internet or other special high speed networks.

Media Type

Media Types: *Based on* Human Perception

- How do human perceive information?
- Based human perception media can be categorized into two.

Auditory and Visual media

● **Auditory media:**

- A media that transmit what human's hear.
- It includes sound, music and voice.

● **Visual media:**

- A media that transmit what humans see, observe and visualize.
- It includes text, still and moving pictures

Media Types: Based on Time dimensions



Discrete (or Static) media:

- it refers to text, graphics, and images as they are composed of **time independent** information item.
- Information in these media consists exclusively of a sequence of individual elements without a time component.
- Indeed they may be displayed according to a wide variety of timing or even sequencing and still remain meaningful.

Continuous (or Dynamic) media:

- refers to **time-dependent** media like sound, and video, where the presentation requires a continuous play-out as time passes.
- Information is expressed as not only of its individual value, but also by the time of its occurrence.
- In other word, time dependency between information items is part of the information itself.
- Thus if the timing of the items change, or the sequence is modified, the meaning of the items is altered.

Cont...

Media types: Depend on signal representation

Analog signal

- Continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity.

Digital signal

- a signal which is represented as a sequence of numbers (usually in binary numbers)

Analog and Digital Signal Conversion

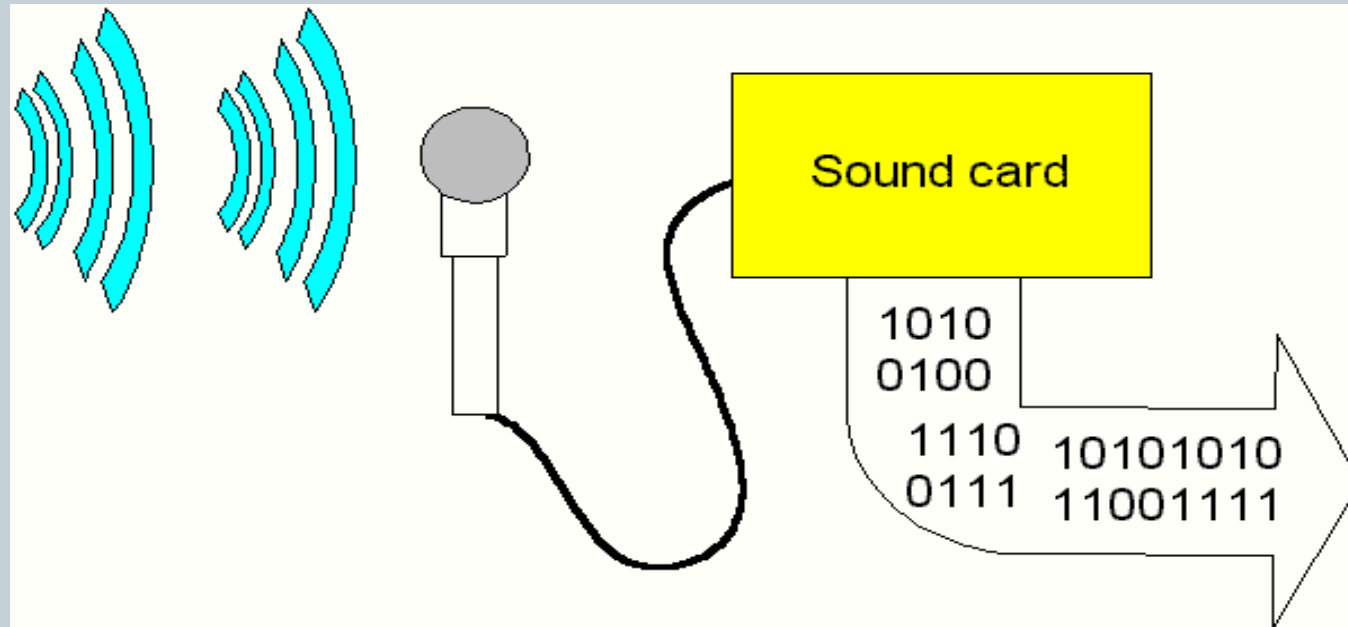


- The world we sense is full of analog signals.
- A transducer is a device (commonly implies the use of a sensor/detector) that converts one form of energy to another.
- Analog is continuous signals.
- It must be converted or digitized for computer processing.
- Digital: discrete digital signals that computer can readily deal with.

Cont...

Analog-to-Digital Converter (ADC)

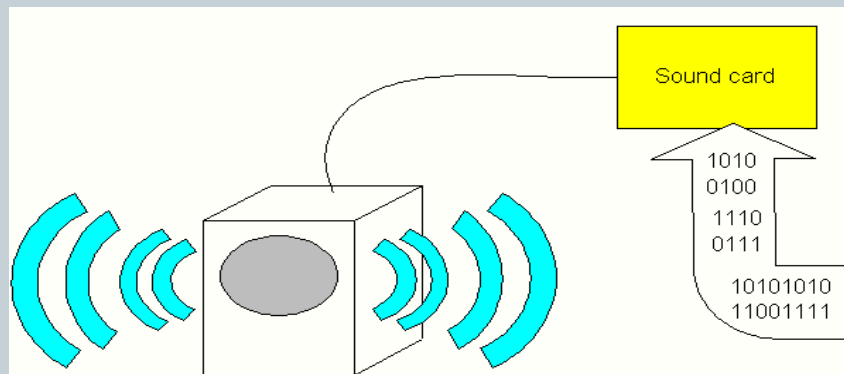
- Spatial hardware devices: Analog-to-Digital converters
- Take analog signal from analog sensor (e.g microphone) and digitally sample data.



Cont...

Digital-to-Analog Converter (DAC)

- Playback – a converse operation to Analog-to-Digital



- Takes digital signal, possible after modification by computer (e.g. volume change, equalization)
- Outputs an analog signal that may be played by analog output device (e.g. loudspeaker, CRT display)

Multimedia Applications (where it is applied)



- A Multimedia Application is an application which uses a collection of multiple media sources e.g. text, graphics, images, sound/audio, animation and/or video.
- Multimedia has become an integral part of our life.
- Multimedia finds its application in various areas including, but not limited to, advertisements, art, education, entertainment, engineering, medicine, mathematics, business
- A few application areas of multimedia are listed below:

Cont...

➤ Entertainment and Fine Arts

➤ Education and Training

➤ Engineering

➤ Mathematical and Scientific
Research

➤ Medicine

➤ Multimedia in Public Places

➤ Advertisements

➤ Home shopping

➤ Digital video editing and
production systems

➤ Interactive movies and TV

➤ Video conferencing

➤ Digital libraries

➤ World Wide Web

➤ On-line reference works e.g.
encyclopedias, games, etc.

➤ Electronic Newspapers/Magazines

➤ Games

➤ Groupware (enabling groups of
people to collaborate on projects and
share information)

Stages of Multimedia Application Development



- Multimedia is applicable to almost all the areas, should produced according to the field selected.
- For example, an application made for entertainment may not work with an educational application and vice versa.
- Irrespective of the field, the stages in multimedia production remain the same.
- Let us discuss the stages in multimedia production.

Cont...

1. Plan and Designing
2. Scripting (or Flowcharting)
3. Storyboarding
4. Collection of media elements and construction
5. Programming
6. Testing
7. Delivering

Advantage and disadvantage of multimedia

Advantage of multimedia



- **It is very user-friendly.**
- **It doesn't take much energy** from the user, in the sense that you can sit and watch the presentation; you can read the text and hear the audio.
- **It is multi sensorial.**

For example hearing and seeing .
- **It is integrated and interactive.**
 - All the different **mediums** are integrated through the digitization process.
- **It is flexible.**

Being digital, this media can easily be changed to fit different situations and audiences.
- **It can be used for a wide variety of audiences, ranging from one person to a whole group.**

Disadvantages of Multimedia

Information overload

- It contain too much information at once.

It takes time to compile

- Even though it is flexible, it takes time to put the original draft together.
- It can be expensive.
- As mentioned in one of my previous posts, multimedia makes use of a wide range of resources, which can cost you a large amount of money.

Too much makes it impractical

- Large files like video and audio has an effect of the time it takes for your presentation to load.
- Adding too much can mean that you have to use a larger computer to store the files.

CHAPTER TWO



MULTIMEDIA DATA REPRESENTATION

What is Text?

- Text is the graphic representation of speech.
- Unlike speech, however, text is silent, easily stored, and easily manipulated.
- Text in multimedia presentations makes it possible to convey large amounts of information using **very little storage space**.
- Text represent using the ASCII (American Standard Code for Information Interchange) system.
- The ASCII system assigns **a number** for each of the characters found on a typical typewriter.
- Each character is represent as a **binary number** which can be understood by the computer



A 10x10 grid with a black pattern forming the letter 'A'. The pattern is composed of black squares on a white background. The letter 'A' is formed by a central vertical column of 5 squares, with horizontal bars at the top and bottom. The top bar is 3 squares wide, and the bottom bar is 5 squares wide. The vertical column is 5 squares high. The letter 'A' is centered in the grid.

Cont...

Example of text representation/Encoding

Example: Hello, world!

H -> 72 -> 01001000
e -> 101 -> 01100101
l -> 108 -> 01101100
l -> 108 -> 01101100
o -> 111 -> 01101111
, -> 44 -> 00101100
-> 32 -> 00100000
w -> 119 -> 01110111
o -> 111 -> 01101111
r -> 114 -> 01110010
l -> 108 -> 01101100
d -> 100 -> 01100100
! -> 33 -> 00100001

ASCII (American Standard Code for Information Interchange) system



Graphic/Image Representation

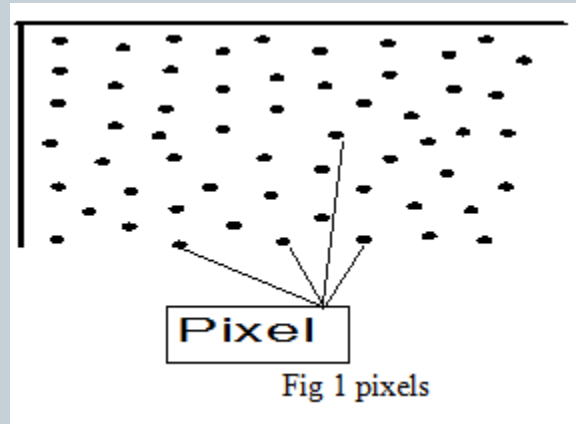


- An image could be described as two-dimensional array of points where every point is allocated its own color.
- Every such single point is called **pixel**.
- Image is a collection of these **points** that are colored in such a way that they produce meaningful information/data.
- Pixel contains the color and relative brightness of that point in the image.

Cont...

- A **digital image** consists of many picture elements, called *pixels*.
- The number of pixels determines the **quality** of the image □ *image resolution*.
- Higher resolution always yields better quality of image.
- **Bitmap** resolution most graphics applications let you create bitmaps up to 300 dots per inch (dpi).
- Such high resolution is useful for print media, but on the screen most of the information is lost, since monitors usually display around **72 to 96 dpi**.
- Most graphic/image formats incorporate compression because of the large size of the data.

Cont...



Types of Digital Images

Binary Image/Monochrome



- A binary image has only two values (0 or 1).
- A numerical value may represent either a black (0) or a white (1) dot/pixel.
- Binary image is quite important in image analysis and object detection applications.
- A 640 x 480 monochrome image requires 38.4 KB of storage.



Cont...

Grayscale image



- Usually we use 256 levels for each pixel.
- That means, the numerical value for gray levels range from 0 (for black pixels) to FF (256) for white.
- Gray scale ranges from black to **grays** and finally to white.
- Thus we need 8 bits to represent each pixel ($2^8 = 256$)
- This value indicates the degree of brightness of that point.
- This brightness goes from black to white
- A 640 x 480 grayscale image requires over 307 KB of storage.



A 8 bits grayscale image.

Color Image

- There are different color models: RGB, YUV, YIQ, HSV, CMYK, etc.



24 bit image

R

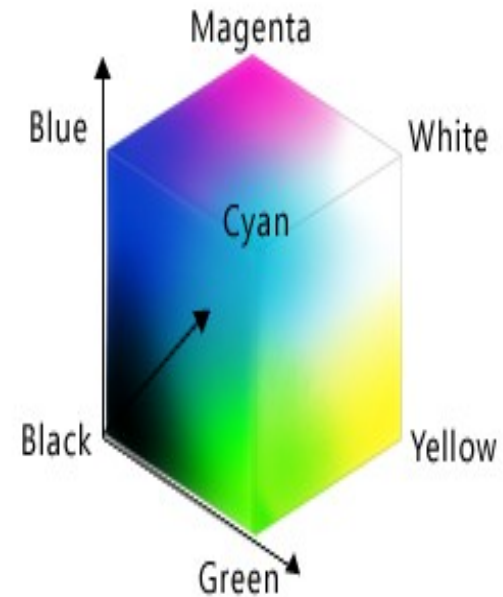
G

B



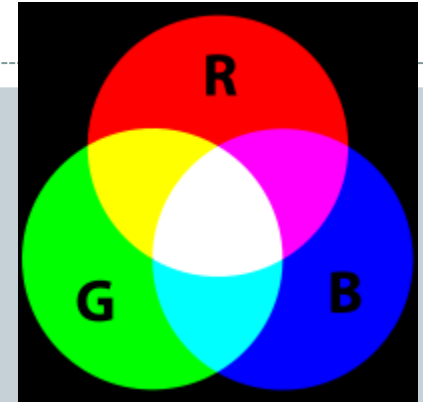
RGB Color Model

- To form a color with RGB, three separate color signals of one **red**, one **green**, & one **blue** must be mixed.
- Each of the three signals can have an arbitrary intensity, from **fully off to fully on**, in the mixture.
- The **RGB color model** is an additive color mixing model using which every color can be encoded as a combination of red, green, & blue light.
- **Projection** of primary color lights on a screen shows secondary colors where they overlap; for instance, the combination of all three of red, green, & blue in appropriate intensities makes white.



Cont...

- The figure shows an RGB image, along with its separate R, G and B components. Note that,
 - strong red, green, and blue produces **white** color;
 - strong red and green with little blue gives **brown**;
 - strong green with little red or blue gives **dark green**;
- The number of bits used to represent each pixel in RGB space is called the pixel depth.
 - strong blue and moderately strong red and green provides **light blue sky**
 - Consider an RGB image in which each of the red, green, and blue color is an 8-bit representation.
 - Under these conditions each RGB color pixel have a depth of 24 bits.



24-bit Color Images



- Each pixel is represented by three bytes (e.g., RGB)
- Supports $256 \times 256 \times 256$ possible combined colors (16,777,216)
- A 640×480 24-bits color image would require **921.6** KB of storage
- Most 24-bit images are 32-bit images,
 - the extra byte of data for each pixel is used to store an alpha value representing special effect information

Image Resolution



- Image resolution refers to the spacing of pixels in an image and is measured in pixels per inch, ***ppi***, sometimes called dots per inch, ***dpi***.
- The higher the resolution, the more pixels in the image.
- Image size refers to the physical dimensions of an image.
- Because the number of pixels in an image is fixed, increasing the size of an image decreases its resolution and decreasing its size increases its resolution **(How?)**

Discuss!

Popular File Formats

Why we need different file format?



- If you are, for example, creating image for web pages, then it should load fast.
- So such images should be **small size**.
- The other criteria to choose file type is taking into consideration the **quality** of the image that is possible using the chosen file type.
- You should also be concerned about the **portability** of the image.

To choose file type:

- resulting size of the image □ large file size or small
- quality of image possible by the file type portability of file across different platforms
- The most common formats used on internet are the GIF, JPG, and PNG.

Cont...

Graphics Interchange Format (GIF)

- **Graphics Interchange Format (GIF)** devised CompuServe, initially for transmitting graphical images over phone lines via modems.
- They display at a low blurry resolution first and then transition to full resolution by the time the download is complete.
- Supports animation—multiple pictures per file (animated GIF)
- GIF format has long been the most popular on the Internet, mainly because of its small size

Cont...

Portable Network Graphics (PNG)

- It is intended as a replacement for GIF in the WWW and image editing tools.
- One version of PNG, PNG-8, is similar to the GIF format.
- PNG-24 is another version of PNG, with 24-bit colour support, allowing ranges of colour to a high colour JPG.
- PNG-24 is a **loss-less compression** format which results in large filesize.

Cont...

Joint Photographic Experts Group (JPEG/JPG)

- A standard for photographic image compression
- Intended for encoding and compression of photographs and similar images
- Uses complex **lossy compression** which allows user to set the desired level of quality (compression).
- A compression setting of about 60% will result in the optimum balance of quality and filesize.
- Though JPGs can be interlaced, they do not support animation and transparency unlike GIF

Cont...

Tagged Image File Format (TIFF)

- Tagged Image File Format (TIFF), stores many different types of images (e.g., monochrome, grayscale, 8-bit & 24-bit RGB, etc.)
- Developed by the Aldus Corp. in the 1980's and later supported by the Microsoft
- TIFF is a lossless format.
- It does not provide any major advantages over JPEG and is not as user-controllable.
- Do not use TIFF for web images. They produce big files, and more importantly, most web browsers will not display TIFFs.

Video /Animation



- Video is a series of images.
 - When this series of images are displayed on screen at fast speed (e.g 30 images per second), we see a perceived motion.
 - It projects single images at a fast rate producing the illusion of continuous motion.
 - These single image are called frame.
 - The rate at which the frames are projected is generally between 24 and 30 fps.
 - The rate at which these images are presented is referred to as the **Frame Rate**
- A single image is called frame and video is a series of frames.

Cont...

- To model smooth motion psychophysical studies have shown that a rate of **30** frames a second is good enough to simulate smooth motion.
- Each screen-full of video is made up of thousands of pixels.
- A pixel is the smallest unit of an image.
- A pixel can display only one color at a time.
- Television has 720 vertical lines of pixels and 486 rows of pixels.

Cont...

There are two types of video:

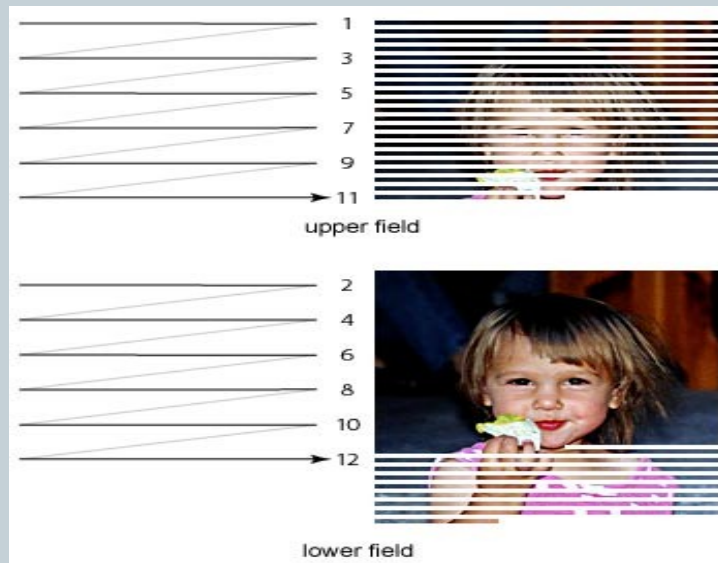
- ▮ Analog Video
- ▮ Digital Video

There are two ways of displaying video on screen

- 1. Interlaced scan**
- 2. Progressive scan**

Cont...

- Interlaced scanning writes line of the picture during a scan, and writes the other half during the next sweep.



Progressive scan

- Monitor writes a whole picture per scan.
- Progressive scan updates all the lines on the screen at the same time, 60 times every second.
- This is known as progressive scanning

Video Broadcasting Standards/ TV standards



There are mainly three conventional broadcast television systems:

PAL, *NTSC*, and *SECAM* and all current television broadcasting system are analog in nature.

PAL (Phase Alternate Line)

- PAL uses 625 horizontal lines at a field rate of 50 fields per second (or 25 frames per second).
- Only 576 of these lines are used for picture information with the remaining 49 lines used for sync or holding additional information such as closed captioning.
- It is used in Australia, New Zealand, United Kingdom, and Europe.
- Scans 625 lines per frame, 25 frames per second
- Interlaced, each frame is divided into 2 fields, 312.5 lines/field
- For color representation, PAL uses YUV (YCbCr) color model

Cont...

SECAM (Sequential Color with Memory)

- SECAM uses the same bandwidth as PAL but transmits the color information sequentially.
- SECAM (Système Electronique Pour Couleur Avec Memoire) is very similar to PAL.
- It specifies the same number of scan lines and frames per second.
- It is the broadcast standard for France, Russia, and parts of Africa and Eastern Europe.

Cont...

NTSC (National Television Standards Committee)



- NTSC is a black-and-white and color compatible 525-line system that scans a nominal 30 interlaced television picture frames per second.
- Used in USA, Canada, and Japan.
- 525 scan lines per frame, 30 frames per second
- Interlaced, each frame is divided into 2 fields, 262.5 lines/field
- 20 lines reserved for control information at the beginning of each field
- So a maximum of 485 lines of visible data

HDTV (High Definition Television)

- High-Definition television (HDTV) means broadcast of television signals with a higher resolution than traditional formats (NTSC, SECAM, PAL) allow.
- Except for early analog formats in Europe and Japan, HDTV is broadcasted digitally, and therefore its introduction sometimes coincides with the introduction of digital television (DTV).
- Modern plasma television uses this
- It consists of 720-1080 lines and higher number of pixels (as many as 1920 pixels).
- Having a choice in between **progressive and interlaced** is one advantage of HDTV.
- Many people have their preferences

Video File Formats



File formats in the PC platform are indicated by the 3 letter filename extension.

AVI (Audio Video Interleaved)

- AVI format was defined by Microsoft for its Video for Windows systems
- It supports video playback at up to 30 frames per second on a small window (typical size 300 x 200 with 8 or 16 bit colour)
- It supports a number of compression algorithms

QuickTime Movie Format(.mov)

- QuickTime was originally developed by Apple for storing audio and video in Macintosh systems
- It supports video playback at up to 30 frames per second on a small window (typical size 300 x 200 with 8 or 16 bit colour)
- It supports a number of compression algorithms

MPEG (Moving Picture Expert Group)

- MPEG was set standard for Audio and Video compression and transmission.
- MPEG-1 is a standard for lossy compression of video and audio.
- It is designed to compress VHS-quality raw digital video and CD audio down (26:1 and 6:1 compression ratios respectively) without excessive quality loss, making Video CDs, digital cable/satellite TV and digital audio broadcasting (DAB) possible.
- MPEG-1 has become the most widely compatible lossy audio/video format in the world, and is used in a large number of **products and technologies**.
- The best-known part of the MPEG-1 standard is the MP3 audio format.

Four Factors of Digital Video

With digital video, four factors have to be kept in mind. These are :

1. Frame rate
2. Color Resolution
3. Spatial Resolution
4. Image Quality

Frame Rate



- The standard for displaying any type of non-film video is 30 frames per second (film is 24 frames per second).
- This means that the video is made up of 30 (or 24) pictures or *frames* for every second of video.
- Additionally these frames are split in half (odd lines and even lines), to form what are called *fields*.

Color Resolution



- Color resolution refers to the number of colors displayed on the screen at one time.
- Computers deal with color in an *RGB* (red-green-blue) format, while video uses a variety of formats.
- One of the most common video formats is called *YUV*.
- Although there is no direct correlation between RGB and YUV, they are similar in that they both have varying levels of color depth (maximum number of colours).
- This is more complex.

Spatial Resolution



- The third factor is spatial resolution - or in other words, "*How big is the picture?*".
- Since PC and Macintosh computers generally have resolutions in excess of 640 by 480, most people assume that this resolution is the video standard.
- The National Television Standards Committee (NTSC) standard used in North America and Japanese Television uses a 768 by 484 display.
- The Phase Alternative system (PAL) standard for European television is slightly larger at 768 by 576.
- Most countries endorse one or the other, but never both.
- Since, the resolution between analogue video and computers is different, conversion of analogue video to digital video at times must take this into account.
- This can often the result in the *down-sizing* of the video and the loss of some resolution.

Cont...

Image Quality



- The last, and most important factor is video quality.
- The final objective is video that looks acceptable for your application.

Digital Audio



- Sound is produced by a rapid variation in the average density or pressure of air molecules above and below the current atmospheric pressure.
- We perceive sound as these pressure fluctuations cause our eardrums to vibrate.
- These usually minute changes in atmospheric pressure are referred to as ***sound pressure*** and the fluctuations in pressure as ***sound waves***.

How to Record and Play Digital Audio

- In order to play digital audio (i.e WAVE file), you need a card with a Analog to Digital Converter circuitry on it.
- Most sound cards have both an ADC (Analog to Digital Converter) and a DAC
- So that the card can both record and play digital audio.
- This DAC is attached to the **Line Out jack** of your audio card, and converts the digital audio values back into the original analog audio.
- This analog audio can then be routed to a mixer, or speakers, or headphones so that you can hear the recreation of what was originally recorded.
- Playback process is almost an exact reverse of the recording process.

cont...



What is digitizing of Sound?

Common Audio Formats

There are two basic types of audio files:

- the traditional *discrete* audio file that you can save to a hard drive or other digital storage medium
- *streaming* audio file that you listen to as it downloads in real time from a network/internet server to your computer.

Discrete Audio File Formats

- Common discrete audio file formats include WAV, AIF, AU and MP3.
- A fifth format, called MIDI is actually not a file format for storing digital audio, but a system of instructions for creating electronic music.

WAV



- The WAV format is the standard audio file format for Microsoft Windows applications, and is the default file type produced when conducting digital recording within Windows.
- It supports a variety of bit resolutions, sample rates, and channels of audio.
- This format is very popular upon IBM PC (clone) platforms, and is widely used as a basic format for saving and modifying digital audio data.

Cont...

AIF/AIFF



- The Audio Interchange File Format (AIFF) is the standard audio format employed by computers using the Apple Macintosh operating system.
- Like the WAV format, it supports a variety of bit resolutions, sample rates, and channels of audio and is widely used in software programs used to create and modify digital audio.

AU



- The AU file format is a compressed audio file format developed by Sun Microsystems and popular in the Unix world.
- It is also the standard audio file format for the Java programming language.
- Only supports 8-bit depth thus cannot provide CD-quality sound

MP3



- MP3 stands for Motion Picture Experts Group, Audio Layer 3 Compression.
- MP3 files provide near-CD-quality sound but are only about $1/10^{\text{th}}$ as large as a standard audio CD file.
- Because MP3 files are small, they can easily be transferred across the Internet and played on any multimedia computer with MP3 player software.

Cont...

MIDI/MID(read!)



- MIDI (Musical Instrument Digital Interface), is not a file format for storing or transmitting recorded sounds, but rather a set of instructions used to play electronic music on devices such as synthesizers.



THE END
THANK YOU!!