Multimedia System

Lecture 6: Media Representation and Media Formats (Part 2)

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Overview

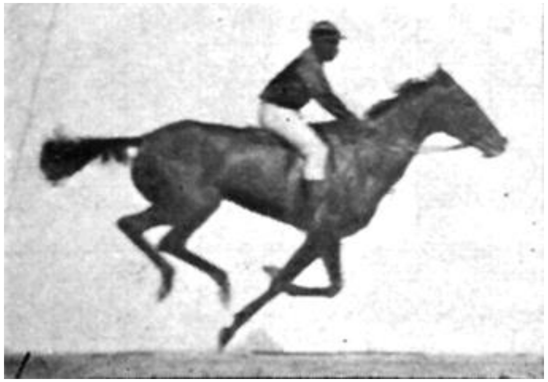
- Throughout the twentieth century, motion pictures stored on film have been the vehicle for much of our art, information, and entertainment.
- The medium changed to analog video stored on tapes, producing a revolution by giving the public direct access to the movies.
- Digital video is further altering the field by making available unprecedented levels of visual quality, distribution, and interaction.

Outlines

- Digital Videos
  - Representation of digital videos
  - Color Models of video
  - Analog Video and Television
  - Digital Video and Chroma Subsampling
    - Chroma subsampling Schemes
    - Bitrate and video size
  - Video Formats
    - Analog Video Formats
    - Digital Video Formats
  - Video display interface
- Digital Audio
- Graphics

Representation of digital videos

- Video is a medium of communication that delivers more information per second than any other element of multimedia we have considered.
- Video can be considered as an integrated Multimedia because it contains all the components of multimedia (images, sound, and text).
- Video, whether analog or digital, is represented by a sequence of discrete images shown in quick succession.
- Each image in the video is called a frame, which is represented as a matrix of pixels defined by a width, height, and pixel depth.
- These image attributes remain constant for all the images in the length of the video.



Representation of digital videos

- Thus, as with all images, video has the same properties such as width, height, and aspect ratio.
- In addition, two important properties govern video representation: frame rate and scanning format.
- frame rate is the rate at which the images are shown.
  - Video standards and applications do not necessarily adhere to the same frame rate.
    - Film is displayed at 24 frames per second.
    - Television standards use 30 frames per second (NTSC) or 25 frames per second (PAL).
  - If the frame rate is too slow, the human eye perceives an unevenness of motion called flicker.
  - Frame rate must be fast enough for motion to appear smooth in accordance to the persistence of human vision as well as a rate that can be synchronized for transmission.

Representation of digital videos (cont'd)

- Analog video is converted to a 1D signal of scan lines, as shown in Figure.
  - This scan line conversion was introduced to make analog television broadcast technology work, and is central to the manner in which televisions display images.
- Scanning formats, which is an outcome of the analog technology, can be represented as
  - Progressive scanning
  - Interlaced scanning

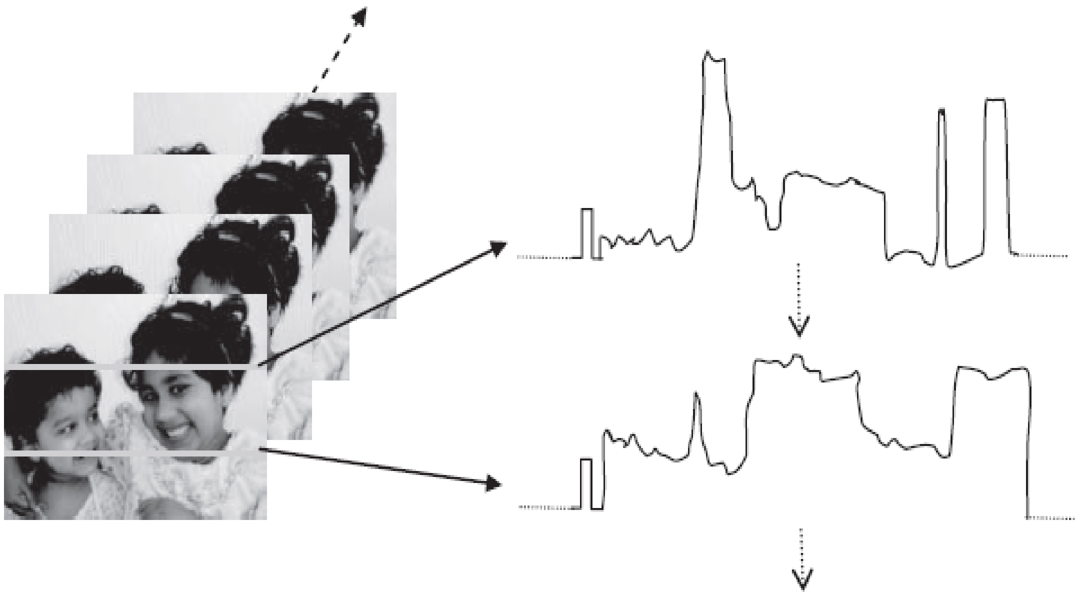


Figure 3-8 Left: Video is represented as a sequence of images. Right: Analog video of one frame scanned as a 1D signal.

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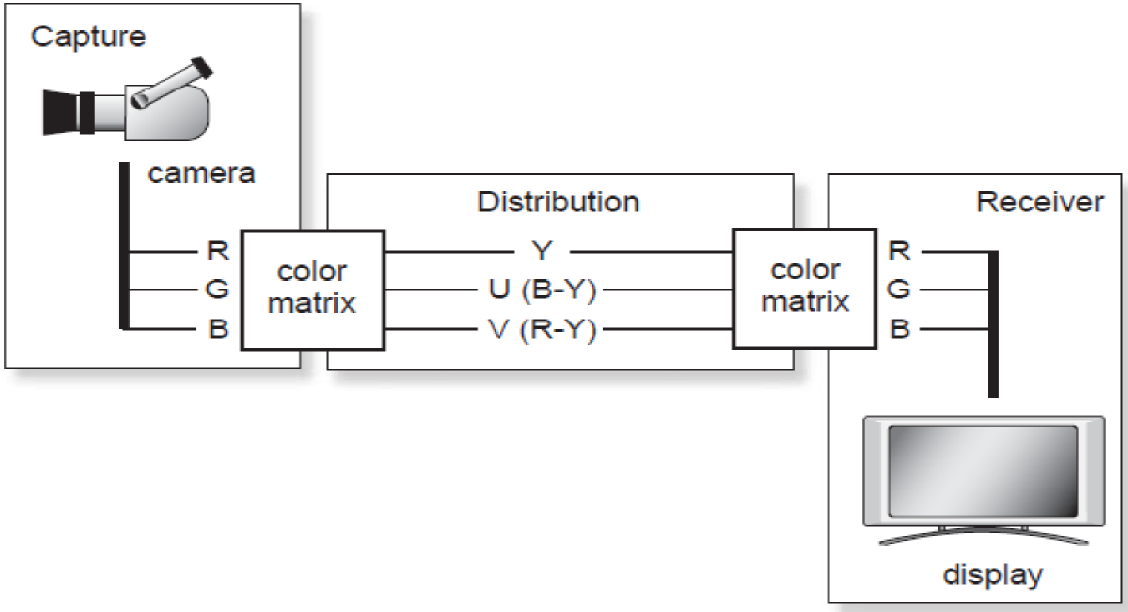
Videos color models

- There are different Color models used in Videos:
  - YUV
  - YIQ
  - YCbCr
- The YUV and YIQ are standard color spaces used for analog television transmission.
  - Y is linked to the component of luminance, which is brightness, or lightness, and **black and white TVs decode only the Y part of the signal**.
  - U and V or I and Q are linked to the components of chrominance, which provide color information
- YCbCr space is used in digital video, and in the JPEG and MPEG compression standards for images and video, respectively.

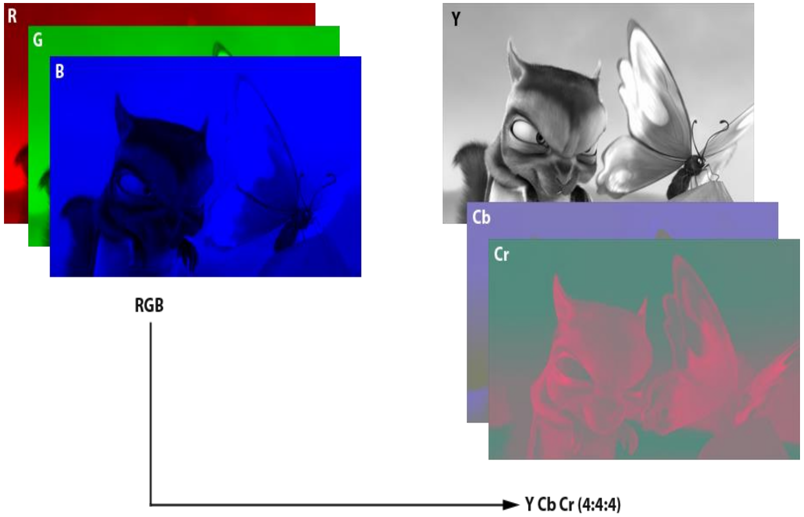
Representation of digital videos (cont'd)

- Through a process called "color space conversion," the video camera converts the RGB data captured by its sensors into either analog signals (YUV-YIQ) or digital signals (YCbCr).
- For rendering on screen, all these color spaces must be converted back again to RGB by the TV or display system.



Advantages of luma/chroma systems

- The primary advantage of luma/chroma systems such as YUV, and its relatives YIQ, is that they remain compatible with black and white analog television.
  - Y' channel saves data recorded by black and white cameras, so produces a signal suitable for old monochrome displays.
  - The U and V are simply discarded.
  - If **displaying color**, all three channels are used, and the original RGB information can be decoded.



Advantages of luma/chroma systems

- The YUV space has a very practical bandwidth-saving usage.
- It is known from visual experiments that humans are not as susceptible to changes in chrominance as they are to luminance.
  - In other words, luminance changes are captured by the human eye more precisely than chrominance changes. Because humans are less tolerant to chrominance, it might be worth transmitting less color information than luminance information.
  - The YUV color space allows the representation of a color in terms of its luminance and chrominance separately, thus allowing the chrominance information to be subsampled in video signals.

YUV color model

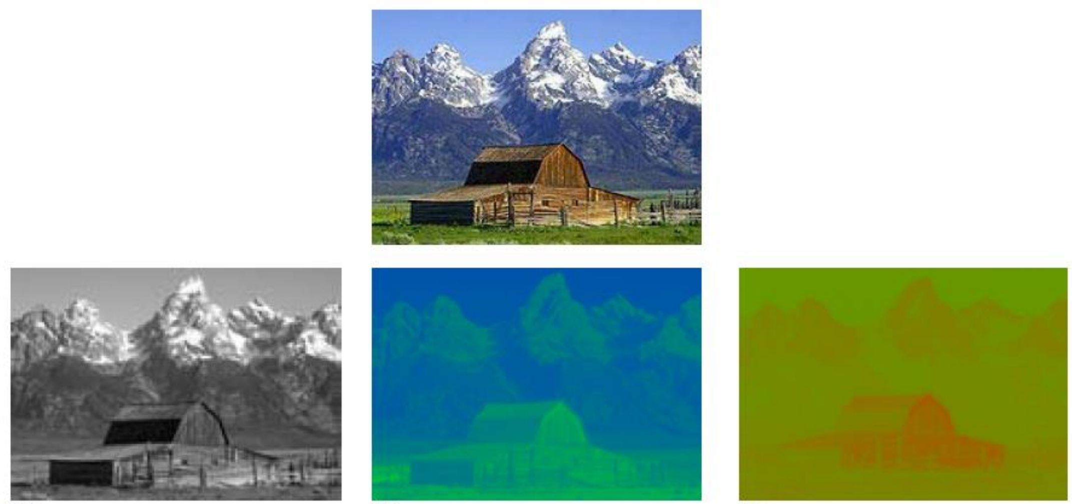
- It is an analog video model
- YUV: Black-and-White component (Y) and color information (U and V)
- To create the Y signal, the red, green and blue inputs to the Y signal must be balanced.

$$Y = 0.299R + 0.587G + 0.114B$$

- Chrominance is defined by U and V – the color differences

$$U = B - Y$$
$$V = R - Y$$

- **YUV** is not compressed **RGB** but are the mathematical equivalent of RGB.
- Eye is most sensitive to **Y**. Therefore any error in the luminance (Y) is more important than the chrominance (U,V) values.



Y U V

Figure(6): An image along with its Y, U, and V components.

YIQ color model

- **YIQ** used in color TV broadcasting (Analog video model)
- I and Q give the chromaticity information
  - I contains orange-cyan color information
  - Y contains green-magenta color information
- Y is stored with higher precision than I and Q because we can detect slight changes in brightness more easily than slight changes in hue
  - Human eyes are most sensitive to Y, next to I, next to Q.
  - therefore less bandwidth is required for Q than for I.
- Conversion between RGB and YIQ
  - Y value is the same as YUV color model
  - Chrominance

$$\boldsymbol{I = 0.6R - 0.28G - 0.32B}$$

$$\boldsymbol{Q = 0.21R - 0.52G + 0.31B}$$

YIQ color model (cont’d)

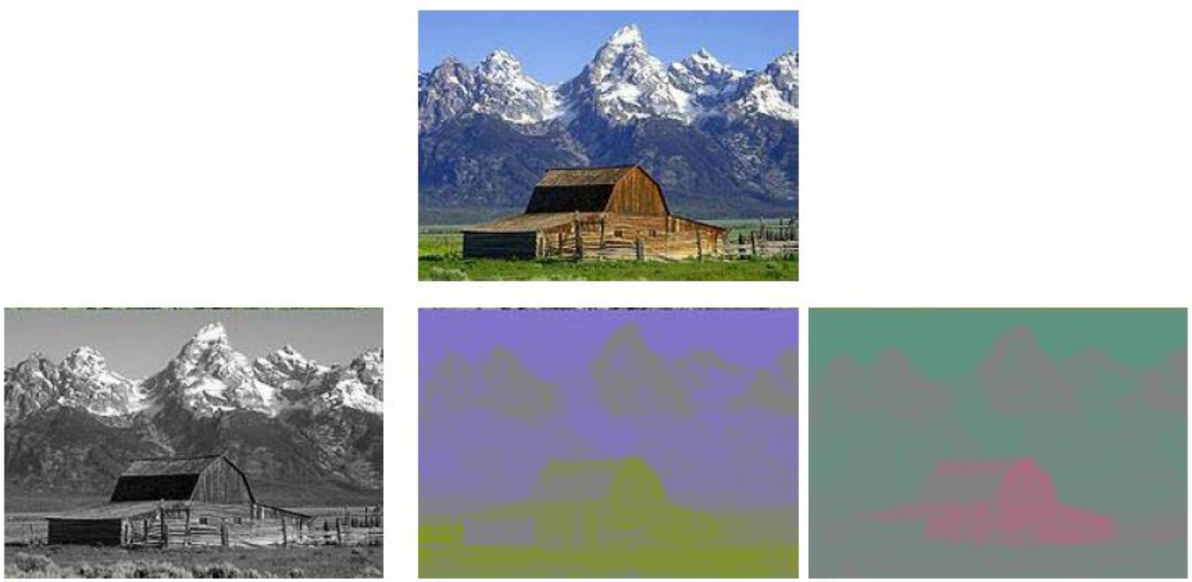
Y I Q

Figure(4): An image along with its Y, I, and Q components.

YCbCr color model

- **YCbCr color model**: uses in digital video model.
- Y′ is the Luma component and Cb and Cr are the Blue-difference and Red-difference Chroma components.
- Closely related to YUV: scaled and shifted YUV

$$\boldsymbol{Cb = ((B - Y)/2) + 0.5}$$
$$\boldsymbol{Cr = ((R - Y)/1.6) + 0.5}$$



Y C_B C_R

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Analog Video and Television

- Video signals have been traditionally transmitted as analog signals for television broadcast.
- The analog video signal used in broadcast is scanned as a one-dimensional signal in time
- This 1D signal captures the time-varying image intensity information only along scanned lines.
- Television requires this analog scanned information to be broadcast from a broadcast station to all users, as illustrated in Figure.

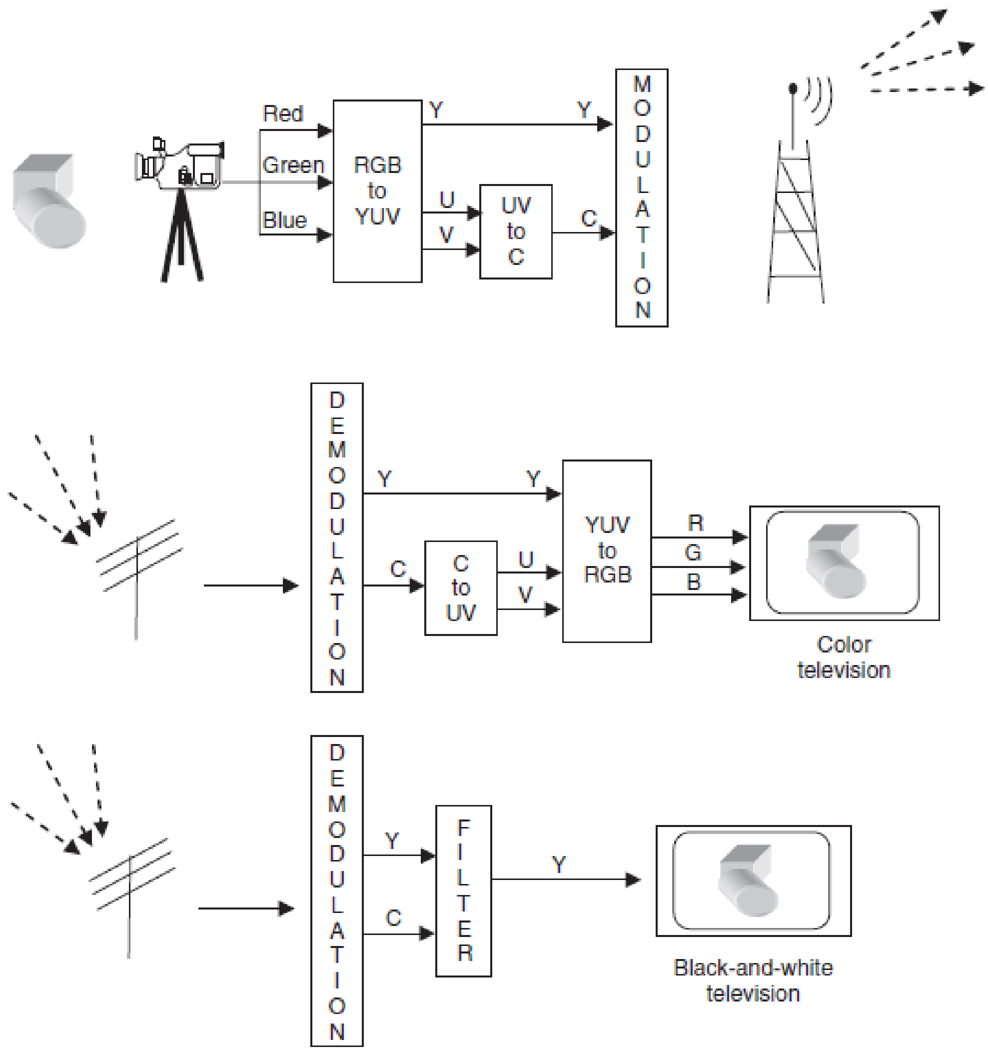


Figure 3-9 Television works by sending scan line information in interlaced YUV format.

Analog Video and Television (cont'd)

- The standardization process implemented in the broadcast of analog video for television mandated a few requirements, which were necessary for making television transmission viable:
  - YUV color space conversion
  - interlaced scanning
- These requirements, although not necessary for digital video representation, still need to be supported in the digital world because of the well-entrenched standards for analog television displays

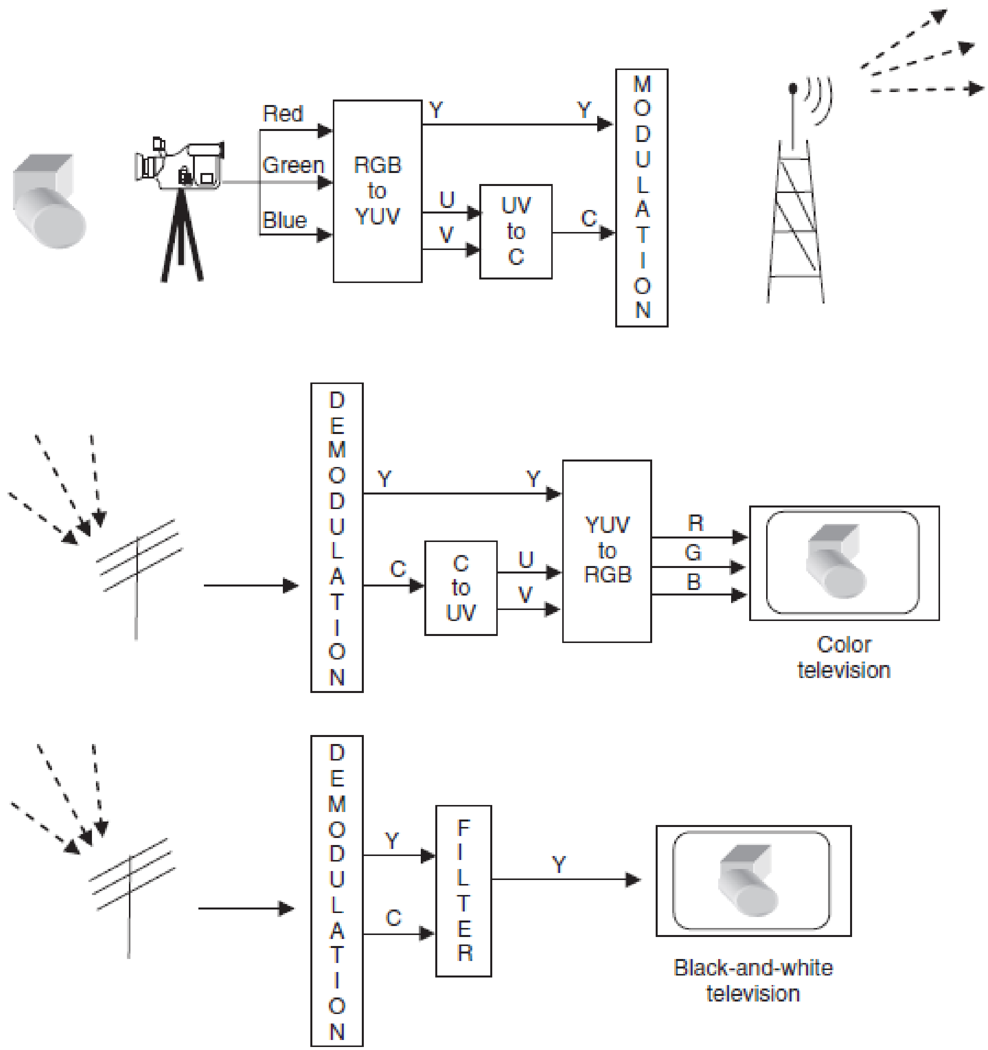


Figure 3-9 Television works by sending scan line information in interlaced YUV format.

Conversion to YUV

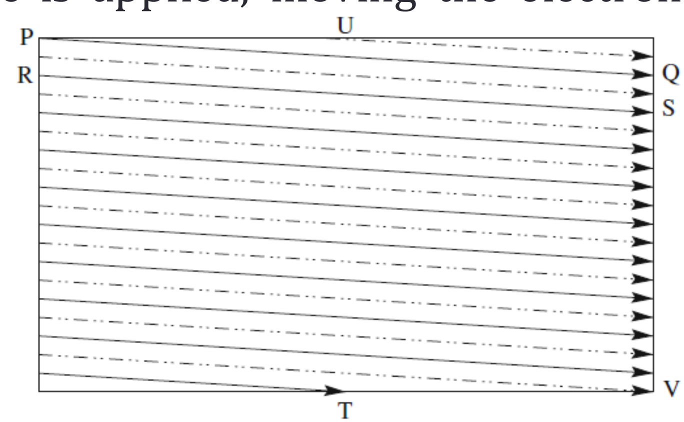
- Video frames, like images, are represented using a color format, which is normally RGB.
- This RGB color space is used by cathode-ray tube–based display devices, such as the television, to display and render the video signal.
- For transmission purposes the RGB signal is transformed into a YUV signal. The YUV color space aims to decouple the intensity information (Y or luminance) from the color information (UV or chrominance).
  - The separation was intended to reduce the transmission bandwidth and is based on experiments with the human visual system, which suggests that humans are more tolerant to color distortions than to intensity distortions.
  - In other words, reducing the color resolution does not affect our perception.

Analog Video Scanning

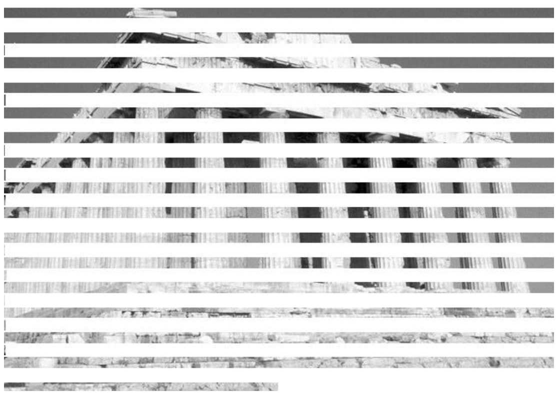
- The process of breaking down the scene into picture elements and reassembling them on the screen is known as scanning.
- **In scanning,** the scene is broken into a series of horizontal lines**.**
- There are two ways of scanning:
  - Interlaced scanning
  - Progressive scanning

Interlaced Scanning

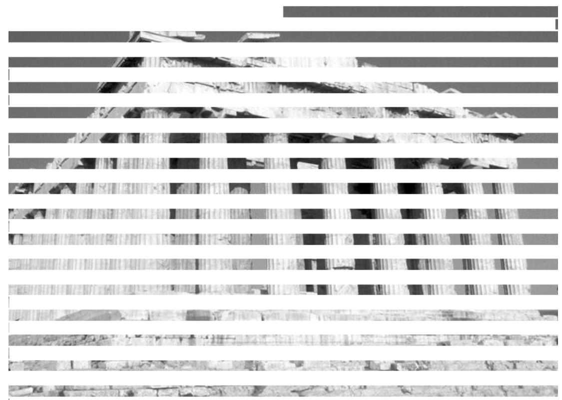
- In Interlaced scanning, the whole screen is filled by the two sets of interlaced scanning lines. These two sets of scanning lines are called **fields**.
- **There are two fields to each frame of television scanning.**
  - The odd-numbered lines are traced first, then the even-numbered lines. This results in "odd" and "even" *fields*—two fields make up one frame.
  - In fact, the odd lines (starting from 1) end up at the middle of a line at the end of the odd field, and the even scan starts at a half-way point.
  - Figure shows the scheme used. First the solid (odd) lines are traced—*P* to *Q*, then *R* to *S*, and so on, ending at *T* —then the even field starts at *U* and ends at *V*. The scan lines are not horizontal because a small voltage is applied, moving the electron beam down over time.
  - The jump from *Q* to *R* and so on in Figure is called the *horizontal retrace*, during which the electronic beam in the CRT is blanked. The jump from *T* to *U* or *V* to *P* is called the *vertical retrace*.



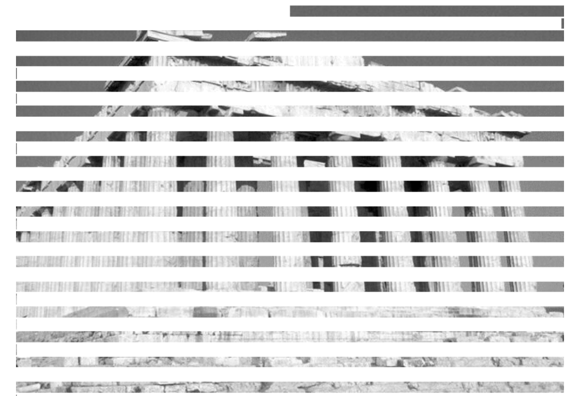
Interlaced Scanning (cont'd)



Field One



Field Two



Interlaced Together...

- But the resulting video drawn by interlaced scanning techniques might be unacceptable and has occasional flicker and artifacts.
- This is caused because the video is captured at different moments in time as two fields and, hence, interlaced video frames exhibit motion artifacts when both fields are combined and displayed at the same moment.

Progressive Scanning

- Video is of better quality when it is captured progressively and drawn progressively, which eliminates the occasional flicker.
- In Figure, all lines, whether even or odd, are drawn in succession, resulting in 30 frames per second.

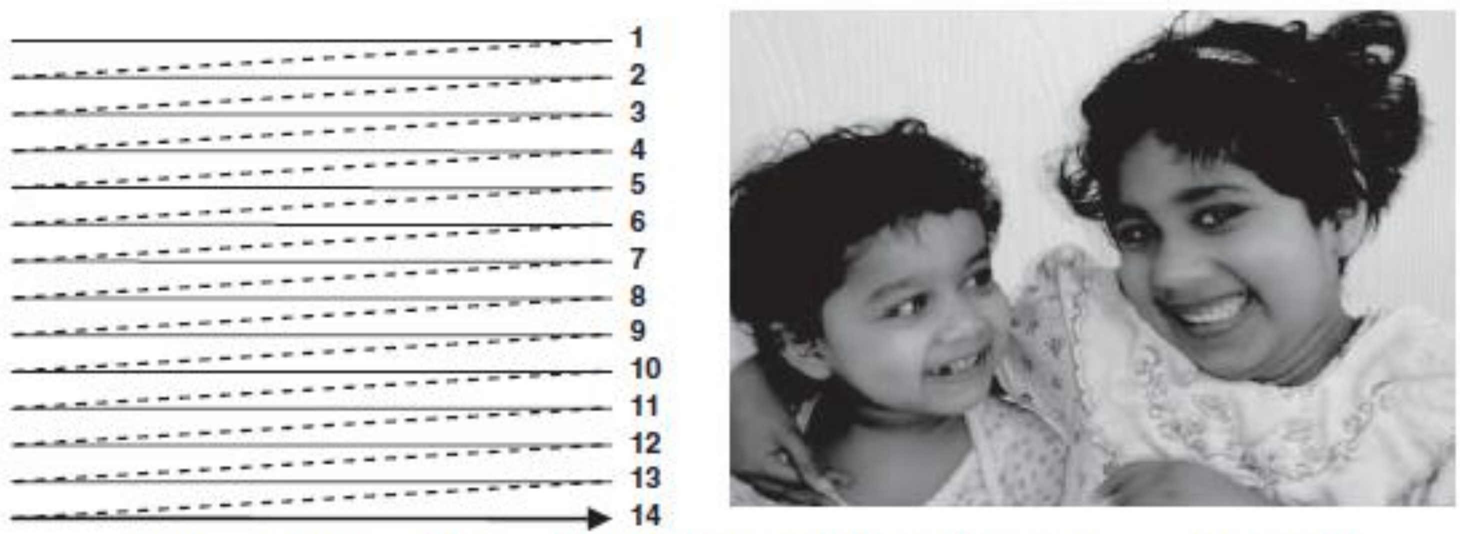


Figure 3-11 Progressive scanning. All the scan lines are drawn in succession, unlike in the interlaced case.

Progressive Scanning (cont'd)

- So-called *progressive* scanning traces through a complete picture (a frame) row-wise for each time interval.
- **Working**
  - Scans lines one at a time from left to right then from one row to the next (top to bottom) in chronological order, creating entire frame in one pass.
- **Properties**
  - All information is collected in one complete frame.
  - Complete frame is send to display.
  - Smoother, more detailed and clear image is obtained without any blurring.
  - Bandwidth requirement is twice as compared to interlaced video scanning.
  - Maximum frame rate is 30 frames/ second

Progressive vs. Interlaced scanning

Question: On a HD TV, what does the circled area mean?

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Digital Video

- Before a picture or motion video can be processed by a computer or transmitted over a computer network, it needs to be converted from analog to digital representation.
- **Digital video** is a representation of moving visual images in the form of encoded **digital data**. This is in contrast to analog video, which represents moving visual images with analog signals. Digital video comprises a series **digital images** displayed in rapid succession.
- Digital video can be copied with no degradation in quality. In contrast, when analog sources are copied, they experience **generation loss**.
- Digital video can also be stored on **hard disks** or **streamed** over the **Internet** to **end users** who watch content on a **desktop computer** screen or a digital **Smart TV**.
- In everyday practice, digital video content such as **TV shows** and **movies** also includes a **digital audio** soundtrack.

Digital Video (cont'd)

- In contrast, the advantages of digital representation for video are many. For example:
  - Video can be stored on digital devices or in memory, ready to be processed (noise removal, cut and paste, etc.), and integrated to various multimedia applications;
  - Direct access is possible, which makes nonlinear video editing achievable as a simple, rather than a complex task;
  - Repeated recording does not degrade image quality;
  - Ease of encryption and better tolerance to channel noise.

Chroma subsampling

- Because of storage and transmission limitations, there is always a desire to reduce (compress) the signal.
- Human visual system more sensitive to **brightness than color**, a video system can be optimized by **devoting more bandwidth to the luma component** (Y) than to the color difference components Cb and Cr. Each frame contains *three* pictures (YCrCb) as shown Figure.
  - *Luma* describes the lightness or darkness of a color. With just Luma, you would have a black and white image.
  - *Chroma* is only the color detail. Adding Luma to Chroma produces the color you expect.

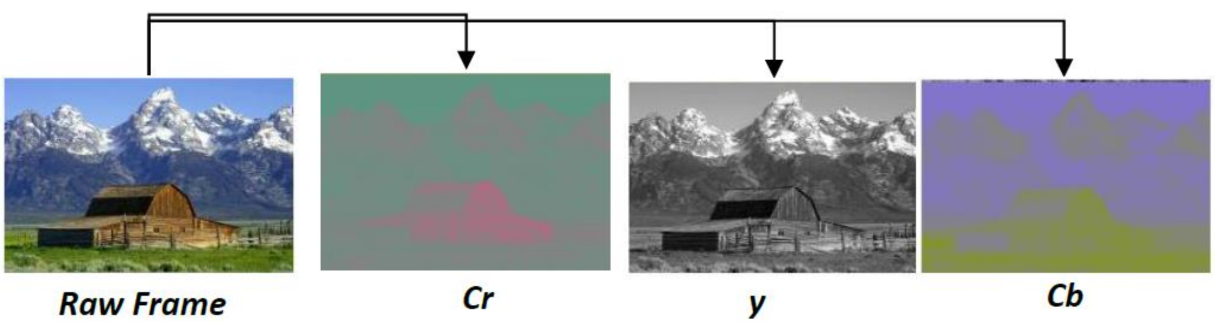


Figure 5.8: Single frame contains 3 pictures (YCrCb)

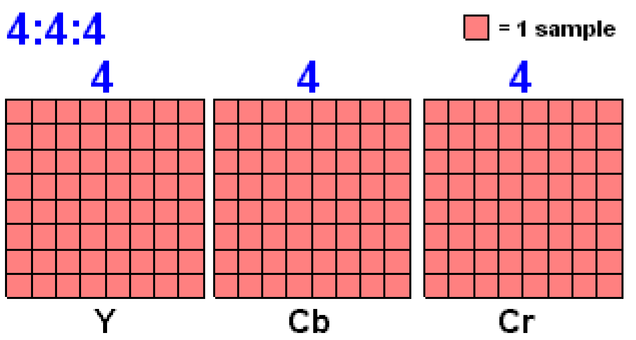
Chroma subsampling (cont'd)

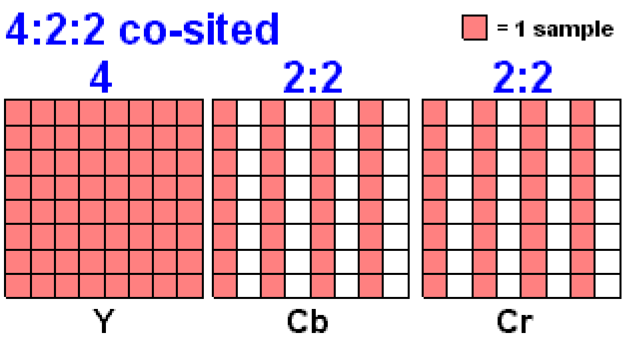
- As human visual system is more sensitive to **brightness than color, chroma subsampling (decimating) takes advantages of this.**
- **Chroma subsampling is** the **reduction of color resolution** in digital component video signals in order to save storage and bandwidth. The color components are **compressed by sampling them** at a lower rate than the brightness.

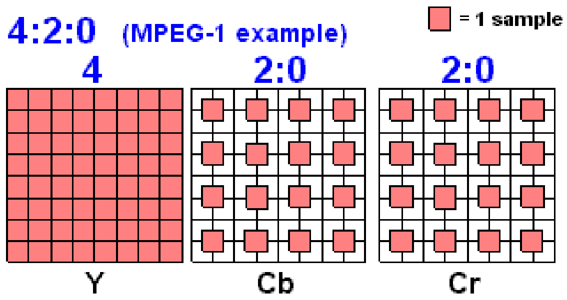
Types of subsampling

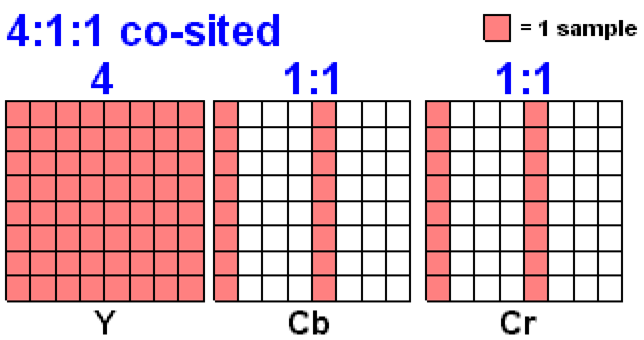
- To begin with, numbers are given stating how many pixel values, per four original pixels, are actually sent:
  1. The chroma subsampling scheme "4:4:4" indicates that no chroma subsampling is used: each pixel's Y, Cb and Cr values are transmitted, 4 for each of Y, Cb, Cr.
  2. The scheme "4:2:2" indicates *horizontal subsampling* of the Cb, Cr signals by a factor of 2. That is, of four pixels horizontally labelled as 0 to 3, all four Ys are sent, and every two Cb's and two Cr's are sent, as (Cb0, Y0)(Cr0,Y1)(Cb2, Y2)(Cr2, Y3)(Cb4, Y4), and so on (or averaging is used).
  3. The scheme "4:1:1" subsamples *horizontally* by a factor of 4.
  4. The scheme "4:2:0" subsamples in *both the horizontal and vertical* dimensions by a factor of 2. Theoretically, an average chroma pixel is positioned between the rows and columns as shown in following Figure .

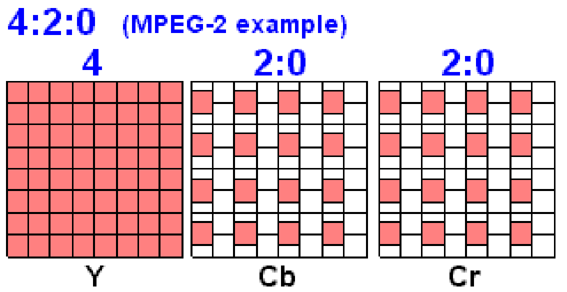
Types of subsampling (cont'd)









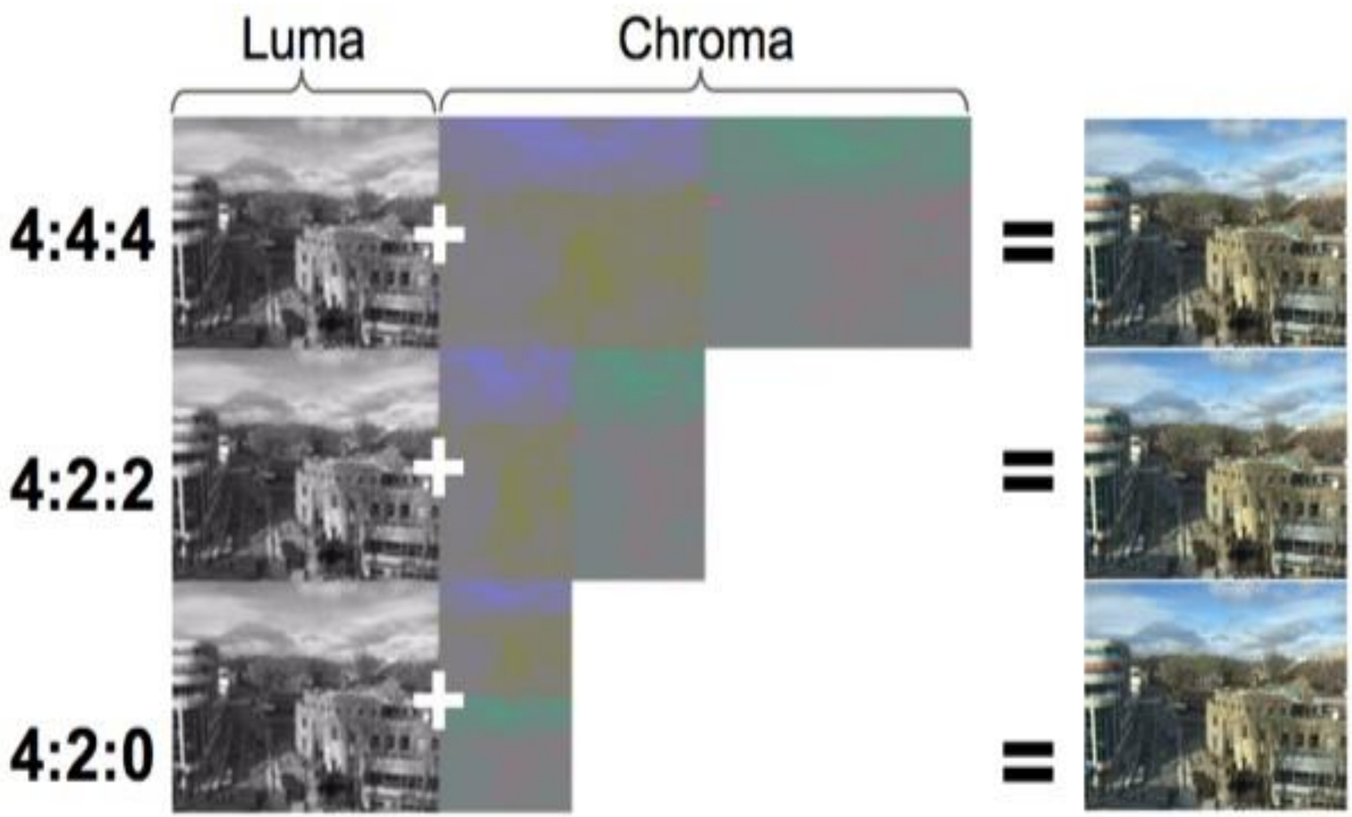


Types of subsampling (cont'd)

The picture can't be displayed.

Color Sampling Method	Amount of Y (luminance)	Amount of U (color or hue)	Amount of V (color or hue)	Amount of Compression	Used in
4:4:4	4 samples	4 samples	4 samples	None 12 samples for each group of 4 pixels	
4:2:2	4 samples	2 samples	2 samples	Reduced from 12 samples to 8, 33% reduction in storage	Digital Betacam format
4:2:0	4 samples	2 samples of either U or V, one scan line of U, then one scan line of V		12 to 6, 50% reduction in storage	HDV, MPEG-1, DVD, MPEG-2, PAL DV
4:1:1	4 samples	1 sample	1 sample	12 to 6, 50% reduction in storage	NTSC DV, miniDV digital camcorder

Types of subsampling (cont'd)



➢ Scheme 4:2:0 along with other schemes is commonly used in JPEG and MPEG

Bitrate and video size

- Bitrate (BR) describes the rate at which **bits are transferred from one location** to another. It measures **how much data is transmitted** in a given amount of time.
- Bitrate is commonly measured in bits per second (**bps)**, kilobits per second (**Kbps)** or megabits per second (**Mbps).**
- Every video file on your computer has a specific bitrate. Video clips, for example, have a data rate of 30 megabits per second (Mbps), whereas a broadband-quality web video clip can have a data rate of 500 to 1000 Kbps. **The total bitrate of video clip** is divided between the video track and audio track
  - The bit rate of video track is **video bitrate**
  - The bit rate of audio track is **audio bitrate**
- Bitrate determines the size and quality of video and audio files. In general, a **higher bit rate will accommodate higher image quality** in video output and **large file size.**
- **It's important to understand how bitrate control corresponds to video quality and the file size.**

Bitrate and video size (cont'd)

- As digital video comprises a series of bitmap digital images displayed in rapid succession at a constant rate. In the context of video these images are called frames. Bitrate (BR) measured the rate at which frames are displayed in frames per second (FPS).
- Since every frame is a bitmap image, it comprises a raster of pixels. If it has a width of W pixels and a height of H pixels we say that the frame size is $W \times H$.
- Pixels have only one property, their color. The color of a pixel is represented by a fixed number of bits. The more bits the more subtle variation of color can be reproduced. This is called the ***color depth*** of the video

$$Bitrate\ (BR) = width\ (W) \times Hight\ (H) \times Color\ depth \times fps$$

$$Video\ size = width\ (W) \times Hight\ (H) \times Color\ depth \times fps \times duration$$

Bitrate and video size (cont'd)

- For example, video of duration of 1 hour (3600sec) and frame size of 640 x 480 at color depth of 24 bits and frame rate 25 fps. This video has the following properties:

$$\text{Pixels per frame} = 640 \times 480 = 307{,}200$$

$$\text{Bits per frame} = 307{,}200 \times 24 = 7{,}372{,}800 = 7.37\ Mbits$$

$$\text{Bitrate (BR)} = 7.37 \times 25 = 184{,}25\ Mbits/sec$$

$$\text{Video size} = Bitrate \times duration = 184{,}25\frac{Mbits}{sec} \times 3600sec = 662{,}400\ Mbits$$

$$= 82{,}800\ Mbytes = 82.8\ Gbytes$$

- The above are accurate for uncompressed video. Because of the relatively high bit rate of uncompressed video as well storage and transmission limitations, there is frequently a desire to reduce (compress) the signal.
- One the most used method for video signal reduction is *chroma subsampling*.

How chroma subsampling affect file size and bit rate with examples?

- As mentioned before in chroma subsampling section, it performs as a compression factor for signal reduction.

<u>**Example 1**</u>: Resolution 720 × 485 frame rate 30 frames per sec (fps) using 4:4:4 and 4:2:2 sampling. **Calculate video bit rate**.

Solution:

Using 4:4:4 sampling:

Pixels per frame = 720 × 485 = 349,200 pixels/frame

4:4:4 sampling gives 720 × 485 × 3 =1,047,600 bytes/frame ≈ 1.05 M/frame

Video bit rate= $1.05 \times 30 = 31.5\ MBytes/sec \rightarrow 31.5M \times 8bits = 250\ Mbps$

Using 4:2:2 subsampling

Pixels per frame= $720 \times 485 \times 2 = 698{,}400\ bytes/frame \approx 0.698\ M/frame$

Video bit rate = $0.698 \times 30 = 21\ MB/sec = 21M \times 8 = 168Mbps$

How chroma subsampling affect file size and bit rate with examples?

- As mentioned before in chroma subsampling section, it performs as a compression factor for signal reduction.

Example 2: Resolution 1280×720 frame rate 30fps using 4:2:0 subsampling. **Find video bit rate**.

Solution:

Pixels per frame $= 1280 \times 720 = 921{,}600$ pixels/frame

$4{:}2{:}0 \rightarrow 921{,}600 \times 1.5 = 1{,}382{,}400$ bytes/frame ≈ 1.38 MB/frame

Video bit rate $= 1.38M \times 30 = 41MB/sec \rightarrow 41 \times 8 = 328Mbps$.

Example 3: Resolution 1080×1920 frame rate 60fps using 4:4:4 subsampling. **Find video bit rate**.

Solution:

Pixels per frame $= 1080 \times 1920 = 2{,}073{,}600$ pixels/frame

$4{:}4{:}4 \rightarrow 2{,}073{,}600 \times 3 = 6{,}220{,}800$ bytes/frame ≈ 6.22 MB/frame

Video bit rate $= 6.22\ M \times 60 = 373.25\ MB/sec \rightarrow 373.25 \times 82985.98Mbps \approx 3\ Gbps$.

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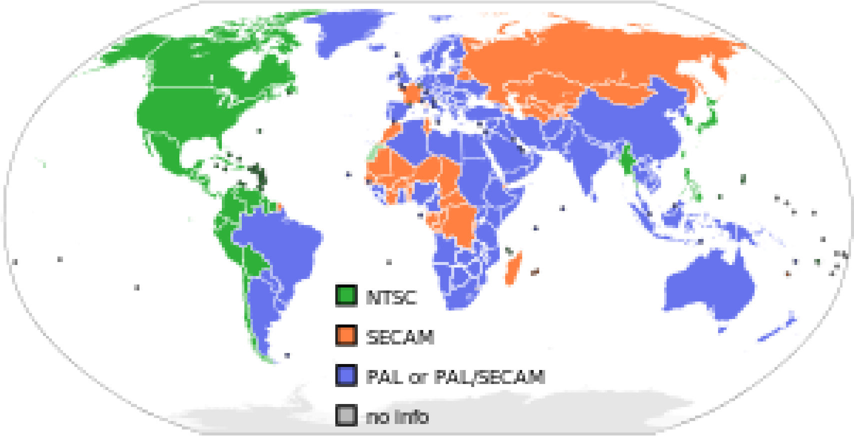
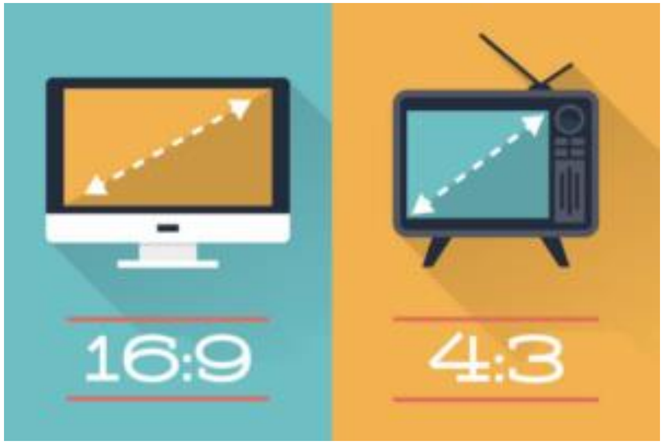
Analog Video Formats

- There are currently three sets of standards for analog broadcast video signals:
  1. NTSC (National Television Standards Committee)
  2. PAL Video (Phase altering line)
  3. SECAM Video (sequential color avec memoire)
- These are used for defining a method for encoding video information into electronic signal that creates a television picture.
- Each has its standard and are not compatible with each other.



NTSC video

- NTSC (National Television System Committee) TV standard is mostly used in North America and Japan. It uses the familiar 4:3 aspect ratio (i.e., the ratio of picture width to its height) and uses 525 scan lines per frame at 30 frames per second (fps).
  - NTSC follows the interlaced scanning system, and each frame is divided into two fields, with 262.5 lines/field.
  - Thus the horizontal sweep frequency is 525×29.97 ≈ 15, 734 lines/sec, so that each line is swept out in 1/15.734 × 103 sec ≈ 63.6μsec.
  - Since the horizontal retrace takes 10.9 μsec, this leaves 52.7 μsec for the active line signal during which image data is displayed
  - Used YIQ color model



PAL video

- **PAL (Phase Alternating Line)** is a TV standard widely used in Western Europe, China, India, and many other parts of the world.
- PAL uses 625 scan lines per frame, at 25 frames/second, with a 4:3 aspect ratio and interlaced fields.
  - PAL uses the YUV color model. It uses an 8 MHz channel and allocates a bandwidth of 5.5 MHz to Y, and 1.8 MHz each to U and V. The color subcarrier frequency is $fsc \approx 4.43\ MHz$.
  - In order to improve picture quality, chroma signals have alternate signs (e.g., +U and -U) in successive scan lines, hence the name "Phase Alternating Line".
  - This facilitates the use of a (line rate) comb filter at the receiver — the signals in consecutive lines are averaged so as to cancel the chroma signals (that always carry opposite signs) for separating Y and C and obtaining high quality Y signals.

SECAM video

- **SECAM** stands for Système Electronique Couleur Avec Mémoire, the third major broadcast TV standard. SECAM also uses 625 scan lines per frame, at 25 frames per second, with a 4:3 aspect ratio and interlaced fields.
- SECAM and PAL are very similar. They differ slightly in their color coding scheme:
  - In NTSC and PAL both U and V are **broadcast concurrently**
  - In SECAM, U and V are **sent alternately**.
    - They are sent in alternate lines, i.e., only one of the U or V signals will be sent on each scan line.

Analog video formats and their details

Property	NTSC	PAL	SECAM
Frame rate	30	25	25
Number of scan lines	525	625	625
Number of active lines	480	576	576
Aspect ratio	4:3	4:3	4:3
Color model	YIQ	YUV	YDbDr
Primary area of usage	North America (USA and Canada), Japan	Asia	France and Russia

Figure 3-13 Table illustrating analog video formats and their details

Digital Video Formats

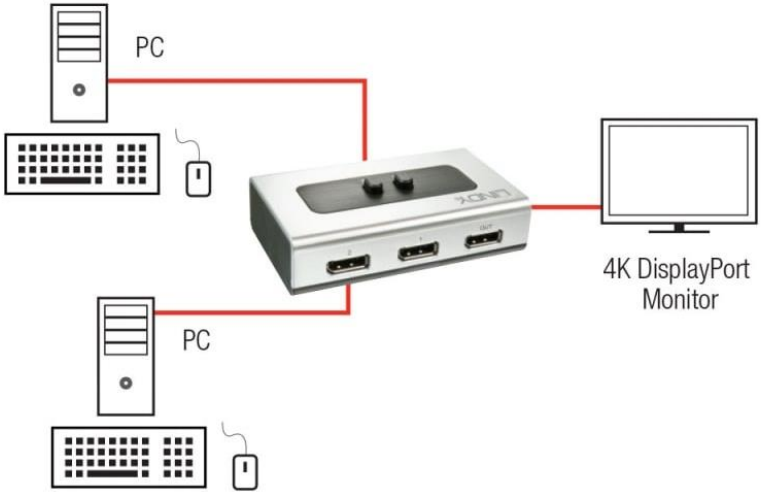
- The digital video formats have been established for digital video applications.
- The CCIR (Consultative Committee for International Radio) body has established the ITUR_601 standard that has been adopted by the popular DV video applications. For example,
  - CIF format (Common Interchange Format) was established for a progressive digital broadcast television.
  - The Quarter Common Interchange Format (QCIF) was established for digital videoconferencing over ISDN lines.
  - A class of digital television called HDTV supports a higher resolution display format along with surround sound. The visual formats used in HDTV are as follows:
    - 720*p*—1280 720 pixels progressive
    - 1080*i*—1920 1080 pixels interlaced
    - 1080*p*—1920 1080 pixels progressive

Outlines

- Digital Videos
  - Representation of digital videos
  - Color Models of video
  - Analog Video and Television
  - Digital Video and Chroma Subsampling
    - Chroma subsampling Schemes
    - Bitrate and video size
  - Video Formats
    - Analog Video Formats
    - Digital Video Formats
  - Video display interface
- Digital Audio
- Graphics

Video display interface

- Interfaces for video signal transmission from some output devices (e.g., set-top box, video player, video card, and etc.) to a video display (e.g., TV, monitor, projector, etc.).
- There have been a wide range of video display interfaces, supporting video signals of different formats (analog or digital, interlaced or progressive), different frame rates, and different resolutions.



Analog display interface

- Analog video signals are often transmitted in one of three different interfaces:
  - Component video,
  - Composite video
  - S-video.

Connectors for typical analog display interfaces. From left to right: Component video, Composite video, S-video, and VGA

Analog display interface

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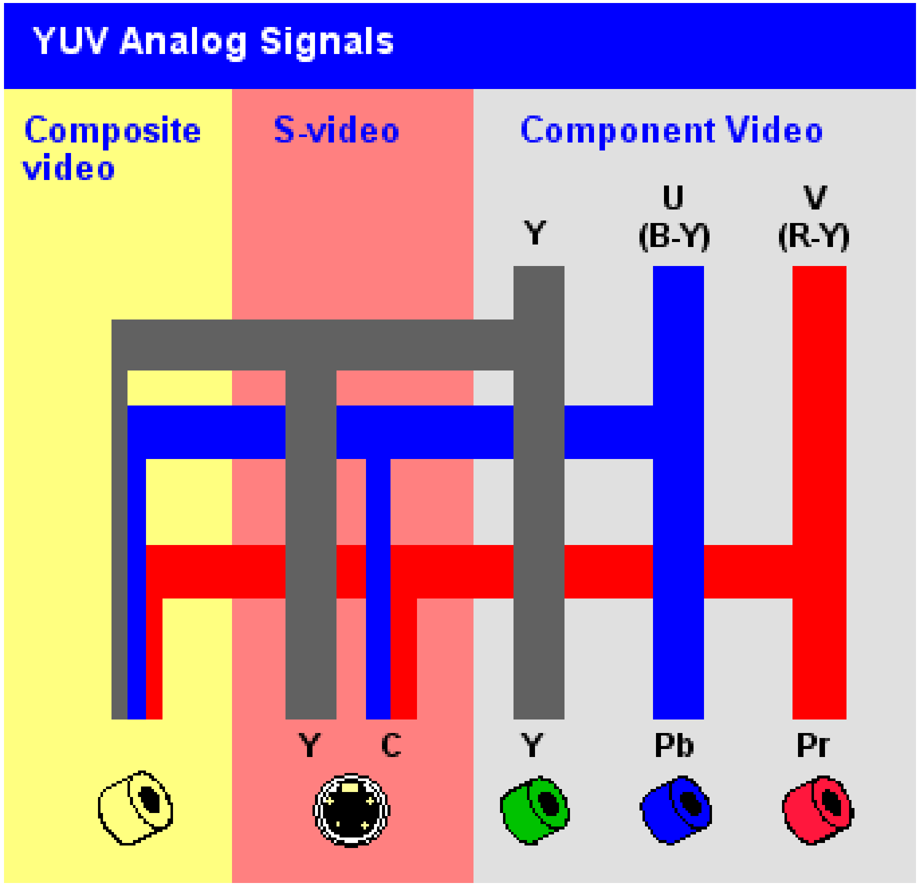
  - S-video



Component video

- Higher-end video systems make use of three separate video signals for the red, green, and blue image planes. Each color channel is sent as a separate video signal.
  a) Most computer systems use Component Video, with separate signals for R, G, and B signals.
  b) For any color separation scheme, Component Video gives the best color reproduction since there is no "crosstalk" between the three channels.
  c) This is not the case for S-Video or Composite Video, discussed next. Component video, however, requires more bandwidth and good synchronization of the three components.
- Color signals are not restricted to always being RGB separations. We can form three signals via a luminance chrominance transformation of the RGB signals (for example YIQ).

Composite video – 1 Signals

- **Composite video**: color ("chrominance") and intensity ("luminance") signals are mixed into a *single* carrier wave.
  a) **Chrominance** is a composition of two color components (I and Q, or U and V).
  b) In NTSC TV, e.g., I and Q are combined into a chroma signal, and a color subcarrier is then employed to put the chroma signal at the high-frequency end of the signal shared with the luminance signal.
  c) The chrominance and luminance components can be separated at the receiver end and then the two color components can be further recovered.
  d) When connecting to TVs or VCRs, Composite Video uses only one wire and video color signals are mixed, not sent separately. The audio and *sync* signals are additions to this one signal.
- Since color and intensity are wrapped into the same signal, some interference between the luminance and chrominance signals is inevitable.

S-Video – 2 Signals

- As a compromise, (Separated video, or Super-video, e.g., in S-VHS) uses two **wires**, one for luminance and another for a composite chrominance signal.
- As a result, there is **less** crosstalk between the color information and the crucial gray-scale information.
- The reason for placing luminance into its own part of the signal is that black-and-white information is most crucial for visual perception.
  - In fact, humans are able to differentiate spatial resolution in gray-scale images with a much higher acuity than for the color part of color images.
  - As a result, we can send less accurate color information than must be sent for intensity information | we can only see fairly large blobs of color, so it makes sense to send less color detail.

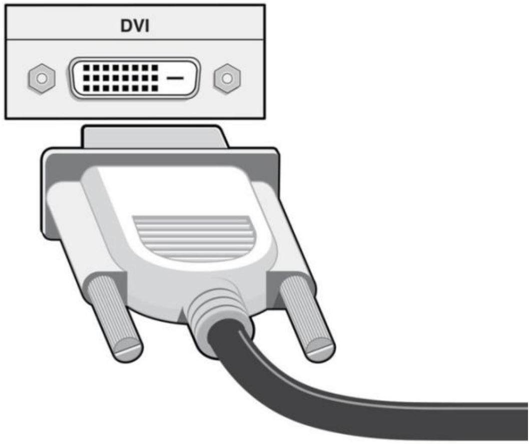
Digital display interface

- Given the rise of digital video processing and the monitors that directly accept digital video signals, there is a great demand toward video display interfaces that transmit digital video signals.
- Today, the most widely used digital video interfaces include
  - Digital Visual Interface (DVI),
  - High-Definition Multimedia Interface (HDMI), and
  - DisplayPort

Connectors of different digital display interfaces. From left to right: DVI, HDMI, and DisplayPort

Digital video interface (DVI)

- Digital Visual Interface (DVI) was developed by the *Digital Display Working Group* (DDWG) for transferring digital video signals, particularly from a computer's video card to a monitor.
- It carries uncompressed digital video and can be configured to support multiple modes, including DVI-D (digital only), DVI-A (analog only), or DVI-I (digital and analog).
- The support for analog connections makes DVI backward compatible with VGA (though an adapter is needed between the two interfaces).



High-Definition Multimedia Interface (HDMI)

- **High-Definition Multimedia Interface (**HDMI**)** is a newer digital audio/video interface developed to be backward-compatible with DVI. It was promoted by the consumer electronics industry, and has been widely used in the consumer market since 2002.
- The HDMI specification defines the protocols, signals, electrical interfaces, and mechanical requirements. Its electrical specifications, in terms of TMDS and VESA/DDC links, are identical to those of DVI.
- As such, for the basic video, an adapter can convert their video signals losslessly. HDMI, however, differs from DVI in the following aspects:
  a) HDMI does not carry analog signal and hence is not compatible with VGA.
  b) DVI is limited to the RGB color range (0–255). HDMI supports both RGB and YCbCr 4:4:4 or 4:2:2. The latter are more common in application fields other than computer graphics.
  c) HDMI supports digital audio, in addition to digital video.

DisplayPort

- DisplayPort is a digital display interface developed by VESA, starting from 2006. It is the first display interface that uses packetized data transmission, like the Internet or Ethernet.
- Specifically, it is based on small data packets known as *micro packets*, which can embed the clock signal within the data stream.
- As such, DisplayPort can achieve a higher resolution yet with fewer pins than the previous technologies.
- The use of data packets also allows DisplayPort to be extensible, i.e., new features can be added over time without significant changes to the physical interface itself.

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Digital Audio

- Next week !!!

Thank You