

Chapter 4

Color in image and video

- **What is color?**

What is color?

- It is an attribute of objects (like *texture*, *shape*, *smoothness*, etc.)
- It depends on:
 - 1) spectral characteristics of the *light source(s)* (e.g., sunlight) illuminating the objects (relative spectral power distribution(s) SPD)
 - 2) spectral properties of *objects* (*reflectance*)
 - 3) spectral characteristics of the *sensors* of the *imaging device* (e.g., the human eye or a digital camera)

Primary and Secondary Colors

- Due to the different engagement curves of the cones, colors are seen as variable combinations of the so-called primary colors: *red*, *green*, and *blue*
- Their wavelengths were standardized by the CIE in 1931: *red*=700 nm, *green*=546.1 nm, and *blue*=435.8 nm
- The primary colors can be added to produce the secondary colors of light, *magenta* (R+B), *cyan* (G+B), and *yellow* (R+G)

Color Models

- The purpose of a *color model* (or *color space* or *color system*) is to facilitate the specification of colors in some standard way.
- A color model provides a *coordinate system* and a *subspace* in it where each color is represented by a single point.

Color spaces

- Color space specifies how color information is represented. It is also called color model.
- Any color could be described in a three dimensional graph, called ***a color space.***

Two types of color space

1. Device based color spaces:

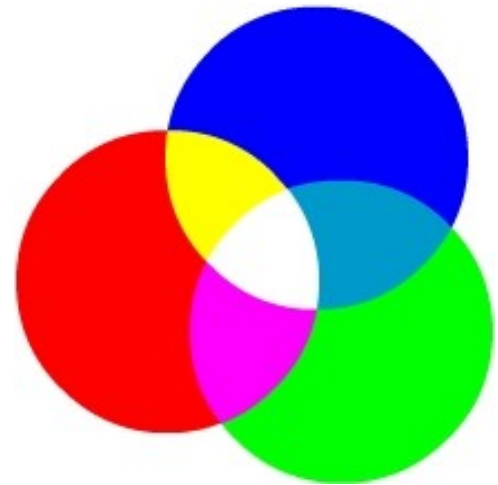
– color spaces based on the internal of the device: RGB, CMYK, YCbCr

2. Perception based color spaces:

– color spaces made for interaction: HSV

Red-Green-Blue

- Most commonly known color space
 - used (internally) in every monitor
 - additive(preservative)
- The three RGB primary colors, when mixed, produce **white**.



Cyan-Magenta-Yellow

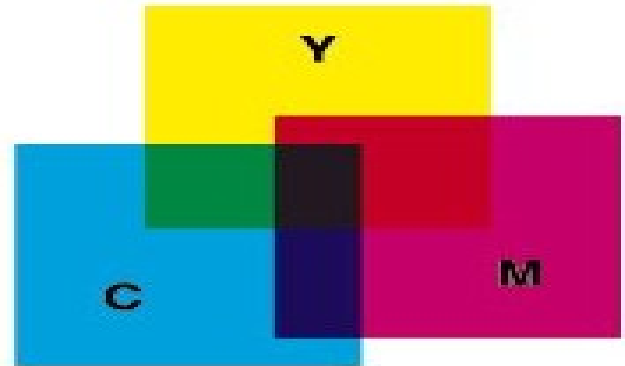
- Used internally in color printers
- they can be used as Subtractive Primaries
- Complementary to RGB:

$$C=1-R$$

$$M=1-G$$

$$Y=1-B$$

- Also CMYK (black)
 - mostly used for printer
 - the three CMY primary colors produce **black** when they are mixed together



CMYK

- K is for black
- Save on color inks, by using black ink preferably
- $K = \min(C, M, Y)$
- $C = C - K$
- $M = M - K$
- $Y = Y - K$

The HSI Color Model

- RGB, CMY, and the like are *hardware-oriented color spaces* (suited for image acquisition and display)
- The HSI (Hue, Saturation, Intensity) is a *perceptive color space* (suited for image description and interpretation)

Brightness, Hue, and Saturation

- Brightness is a synonym of intensity
 - Hue represents the impression related to the dominant wavelength of the color stimulus
 - Saturation expresses the relative color purity (amount of white light in the color)
- Hue and Saturation*** taken together are called the *chromaticity coordinates* (polar system)

Class Y color spaces – similar to HSI

- YIQ, YUV, YCbCr...
- Used in television sets and videos
 - Y is luminance
 - I and Q is chromaticity
- Color TV sets convert to RGB
- YUV=PAL, YIQ=NTSC

Color Models for Video

YUV Model

- Human perception is more sensitive to luminance (brightness) than chrominance (color). Therefore, instead of separating colors, one can separate the brightness info. from the color info.
- **Y** is luminance
$$Y = 0.299R + 0.587G + 0.114B$$
- Chrominance is defined as the difference between a color and a reference white at the same luminance. It can be represented by **U** and **V** -- the color differences.
$$U = B - Y$$
$$V = R - Y$$
 - The YUV color space is commonly used in European television.

- Eye is most sensitive to Y. Therefore, any error in the resolution of the luminance (Y) is more important than the chrominance (U,V) values.
- In PAL, 5 (or 5.5) MHz is allocated to Y, 1.3 MHz to U and V.

YIQ Model

- Although U and V nicely define the color differences, they do not align with the desired human perceptual color sensitivities. Hence, **I** and **Q** are used instead.
- YIQ is used in NTSC color TV broadcasting, it is downward compatible with B/W TV where only Y is used.
- The YIQ color space is commonly used in North American television system.
- Eye is most sensitive to Y, next to I, next to Q. In NTSC broadcast TV, 4.2 MHz is allocated to Y, 1.5 MHz to I, 0.55 MHz to Q.

YCbCr Color

Model

- The YCbCr model is closely related to the YUV, it is a scaled and shifted YUV.
- Y is luminance
- Cb is **blue** chromaticity
- Cr is **red** chromaticity
 - $C_b = ((B - Y) / 2) + 0.5$
 - $C_r = ((R - Y) / 1.6) + 0.5$
- The chrominance values in YCbCr are always in the range of **0** to **1**.
- YCbCr is used in **JPEG** and **MPEG** video

Summary of Color

- Color images are encoded as triplets of values.
- RGB is an **additive** color model that is used for light-emitting devices, e.g., CRT displays.
- CMY is a **subtractive** model that is used often for printers
- Sometimes, an alternative CMYK model (K stands for Black) is used in color printing (e.g., to produce darker black than simply mixing CMY).

$$\begin{aligned} K &:= \min (C, M, Y); & C &:= C - K; & M &:= M - K; \\ Y &:= Y - K. \end{aligned}$$

- Two common color models in imaging are **RGB** and **CMY**, two common color models in video are **YUV** and **YIQ**.
- YUV uses properties of the human eye to prioritize information. Y is the black and white (luminance) image, U and V are the color difference (chrominance) images.

CHAPTER

FIVE

Fundamental Concepts

in

Video

- 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. These single images are called frames.
- The rate at which the frames are projected is generally between 24 and 30 frames per second (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.

- 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. TV has 720 vertical lines of pixels (from left to right) and 486 rows of pixels (top to bottom). A total of 349,920 pixels (720 x 486) for a single frame.
- There are two types of video:
 - Analog Video
 - Digital Video

Analog Video

- In an analogue video signal, each frame is represented by a fluctuating voltage signal known as an **analogue waveform**. One of the earliest formats for this was composite video.
- Analog formats are susceptible to loss due to transmission noise effects. Quality loss is also possible from one generation to another. This type of loss is like photocopying, in which a copy of a copy is never as good as the original.
- Distortion of images and noise are common problems for analog video. It is used throughout the television industry.

Digital Video

- Digital technology is based on images represented in the form of bits. A digital video signal is actually a pattern of 1's and 0's that represent the video image.
- With a digital video signal, there is no variation in the original signal once it is captured on to computer disc. Therefore, the image does not lose any of its original sharpness and clarity. The image is an exact copy of the original. A computer is the most common form of digital technology.

- The limitations of analog video led to the birth of digital video.
- Digital video is just a digital representation of the analogue video signal.
- There are two significant advantages for using computers for digital video :
 - ✓ the ability to randomly access the storage of video and
 - ✓ compress the video stored.

- *Advantages of digital video:*
 - Direct random access -> good for nonlinear video editing
 - No problem for repeated recording
- Almost all digital video uses component video

Displaying Video

- There are two ways of displaying video on screen:
 - ✓ Progressive scan
 - ✓ Interlaced scan

Interlaced Scanning

- This is idea of splitting up the image into two parts became known as **interlacing** and the splitted up pictures as **fields**. Graphically seen a field is basically a picture with every 2nd line black/white. Here is an image that shows [interlacing](#).

Progressive Scanning

- PC CRT displays are fundamentally different from TV screens. 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**.

Here is a comparison of computer and television display

Computer

- Scans 480 horizontal lines from top to bottom
- Scan each line progressively
- Scan full frame at a rate of typically 66.67 HZ or higher
- Use RGB color model

Television

Scans 625, 525 horizontal lines.

Scan line using interlacing

Scan 25-30 HZ for full time

Uses limited color palette and

restricted

luminance (lightness or darkness)

Types of Color Video Signals

Component video – each primary is sent as a separate video signal. The primaries can either be RGB or a luminance-chrominance transformation of them (e.g., YIQ, YUV).

- Best color reproduction
- Requires more bandwidth and good synchronization of the three components
- Component video takes the different components of the video and breaks them into separate signals. Improvements to component video have led to many video formats, including S-Video, RGB etc.

- **Composite video** – color (chrominance) and luminance signals are mixed into a single carrier wave.
- Composite analog video has all its components (brightness, color, synchronization information, etc.) combined into one signal.
- Due to the *compositing* (or combining) of the video components, the quality of composite video is marginal at best. The results are color bleeding, low clarity and high generational loss.

- **S-Video** (Separated video) – a compromise between component video and the composite video. It uses two lines, one for luminance and another for composite chrominance signal.

Video Broadcasting Standards/ TV standards

- There are three different video broadcasting standards: *PAL*, *NTSC*, and *SECAM*

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.
- For color representation, PAL uses YUV (YCbCr) color model.
- In PAL,
 - 5.5 MHz is allocated to Y,
 - 1.8 MHz each to U and V

SECAM (Sequential Color with Memory)

- SECAM uses the same bandwidth as PAL but transmits the color information sequentially. It is used in France, East Europe, etc
- SECAM (Système Electronique Pour Couleur Avec Memory) 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.

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.

NTSC Video Color Representation

- For color representation, NTSC uses YIQ color model.
- Basic Compression Idea
This is still Analog Compression:
- In NTSC,
 - 4.2 MHz is allocated to Y,
 - 1.5 MHz to I,
 - 0.55 MHz to Q.

HDTV (High Definition Television)

- High-Definition television (HDTV) means broadcast of television signals with a higher resolution than traditional formats (NTSC, SECAM, PAL) allow.
- ✓ Modern plasma television uses HDTV.
- ✓ 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.

Four Factors of Digital Video

- With digital video, four factors have to be kept in mind. These are :
 1. Frame rate
 2. Spatial Resolution
 3. Color 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

- This second factor is a bit more complex. 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 colors).

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.
- A standard analogue video signal displays a full, over scanned image without the borders common to computer screens. 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.

Image Quality

- The last, and most important factor is video quality. The final objective is video that looks acceptable for your application. For some this may be 1/4 screen, 15 frames per second (fps), at 8 bits per pixel. Other require a full screen (768 by 484), full frame rate video, at 24 bits per pixel (16.7 million colours).

Advantages and disadvantages of digital video

The advantages of digital video are:

- Single-pass, analog-type impairments are non-cumulative if the signal stays digital.
- There is a reduced sensitivity to noise and interference.
- Digital equipment efficiently and economically performs tasks that are difficult or impossible to perform using analog technology.
- It is amenable to the application of techniques for efficient retention of essential information such as compression.

The disadvantages of digital video are:

- Analog-type of distortions, as well unique digital distortions related to sampling and quantizing, result in a variety of visible impairments.
- Wide bandwidth requirements for recording, distribution and transmission necessitate sophisticated bit-rate reduction and compression schemes to achieve manageable bandwidths.
- Unlike analog signals, the digital signals do not degrade gracefully and are subjected to a cliff effect.