Data Compression
Fall 2022
JPEG-Part 1

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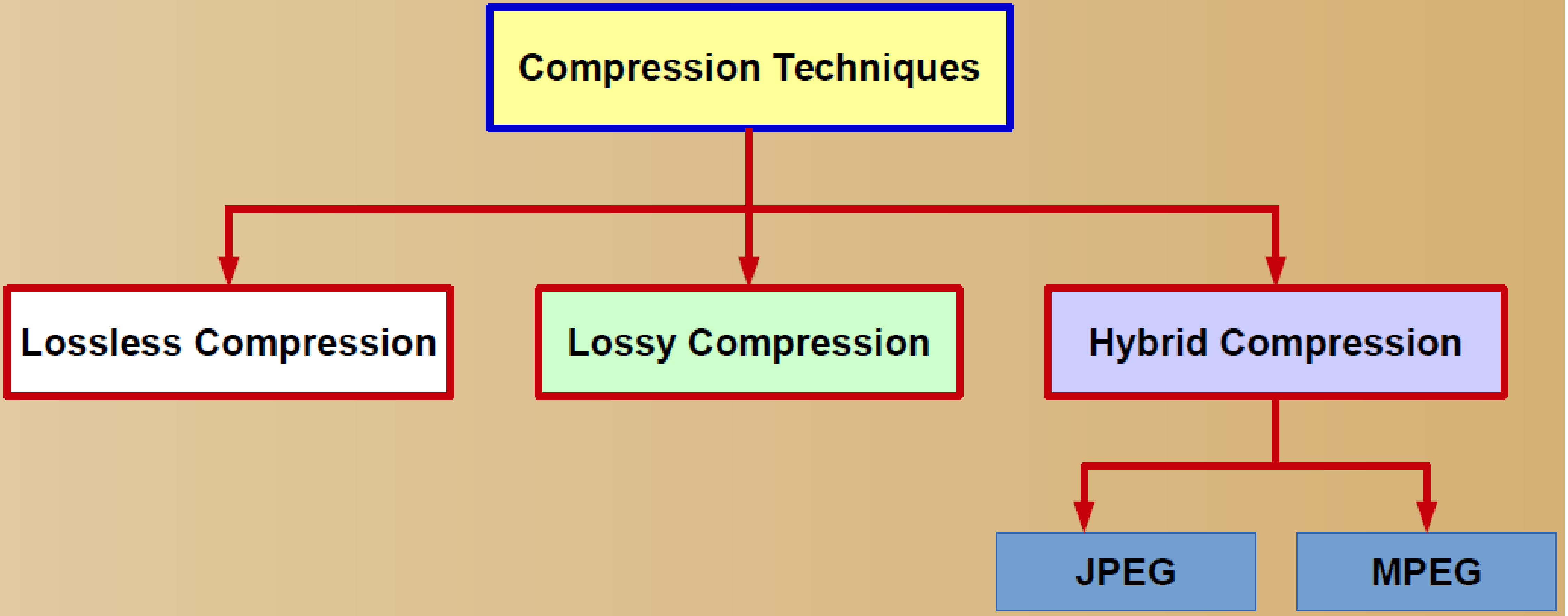
WHAT IS IMAGE COMPRESSION?

- Image Compression aims to reduce irrelevant and redundant image data in order to be able to store or transmit in an efficient form

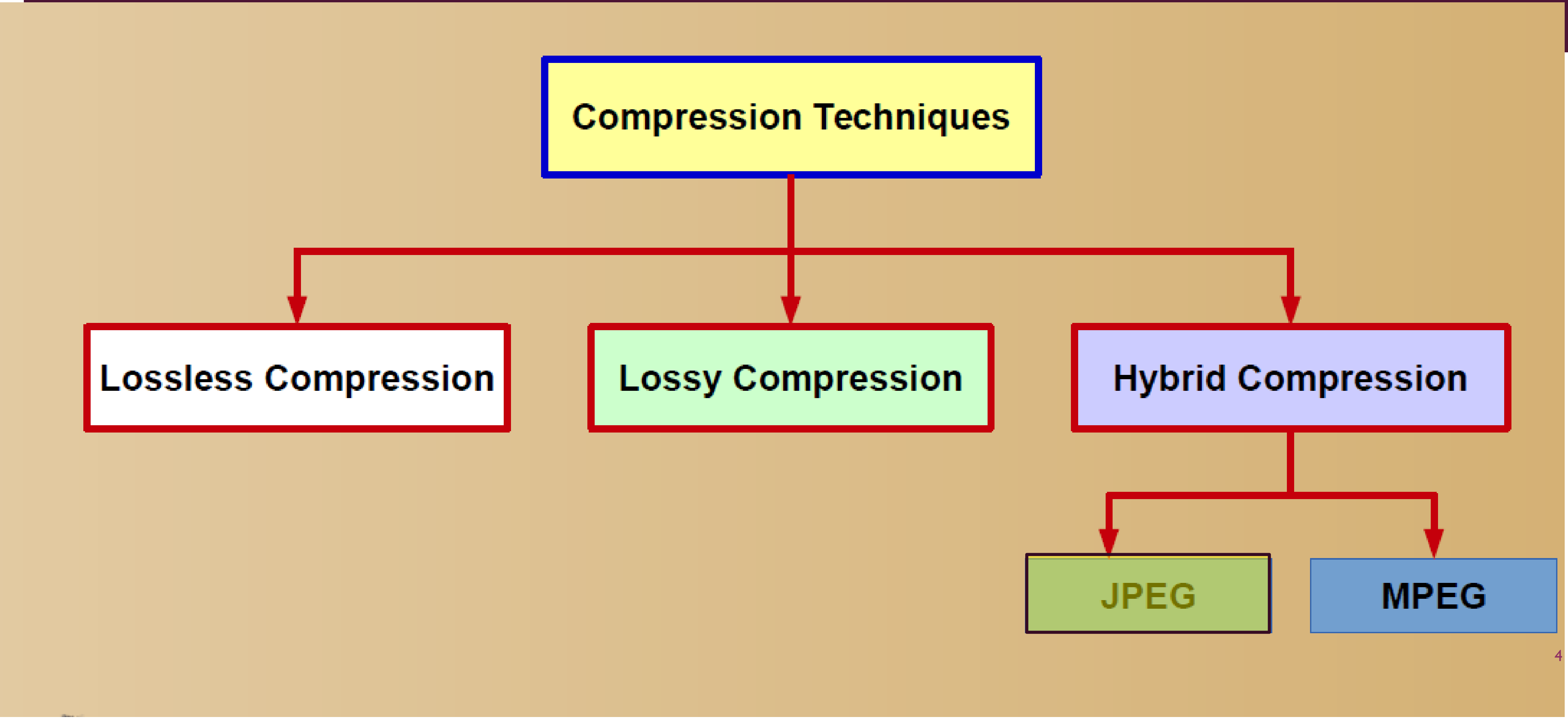
- Image compression is minimizing the size in bytes of a graphics file without degrading the quality of the image to an unacceptable level.

- The reduction in file size allows more images to be stored in a given amount of disk or memory space. It also reduces the time required for images to be sent over the Internet or downloaded from Web pages.

TYPES OF COMPRESSION TECHNIQUES



TYPES OF COMPRESSION TECHNIQUES

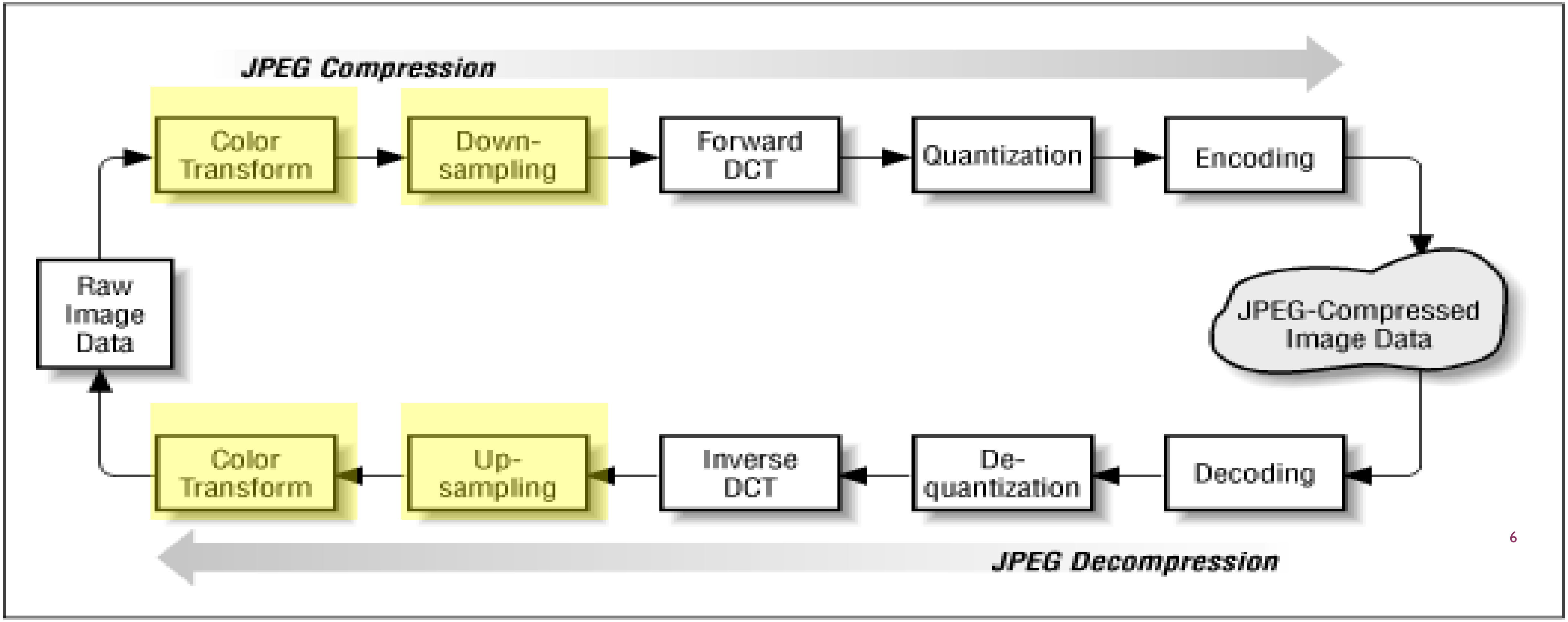


JPEG: JOINT PHOTOGRAPHIC EXPERTS GROUP

- JPEG is not a single algorithm. Instead, it may be thought of as a toolkit of image compression methods that may be altered to fit the needs of the user.
- JPEG is also different in that it is primarily a *lossy* method of compression.
- JPEG was designed specifically to discard information that the human eye cannot easily see. Slight changes in color are not perceived well by the human eye, while slight changes in intensity (light and dark) are.
- An end user can "tune" the quality of a JPEG encoder using a parameter sometimes called a *quality setting or a Q factor*. A range of 1 to 100 is typical. A factor of 1 produces the smallest, worst quality images; a factor of 100 produces the largest, best quality images. The optimal Q factor depends on the image content and is therefore different for every image.
- The art of JPEG compression is finding the lowest Q factor that produces an image that is visibly acceptable, and preferably as close to the original as possible.

JPEG

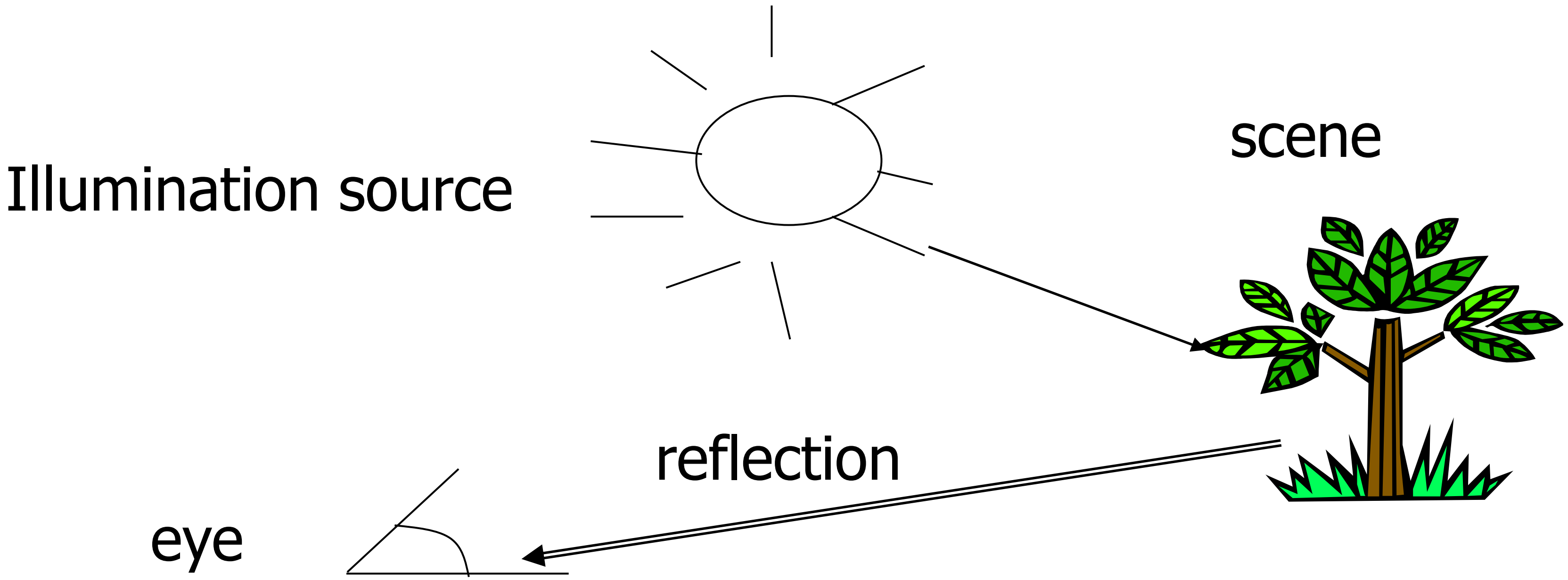
JPEG is an International standard (**J**oint **P**hotographic **E**xperts **G**roup)



I- JPEG: COLOR MODELS

COLOR FUNDAMENTALS

- The color that human perceive in an object = the light reflected from the object



I- COLOR MODELS
COLOR FUNDAMENTALS CONT.

- There are two types of photoreceptors involved in sight: *rods and cones*.

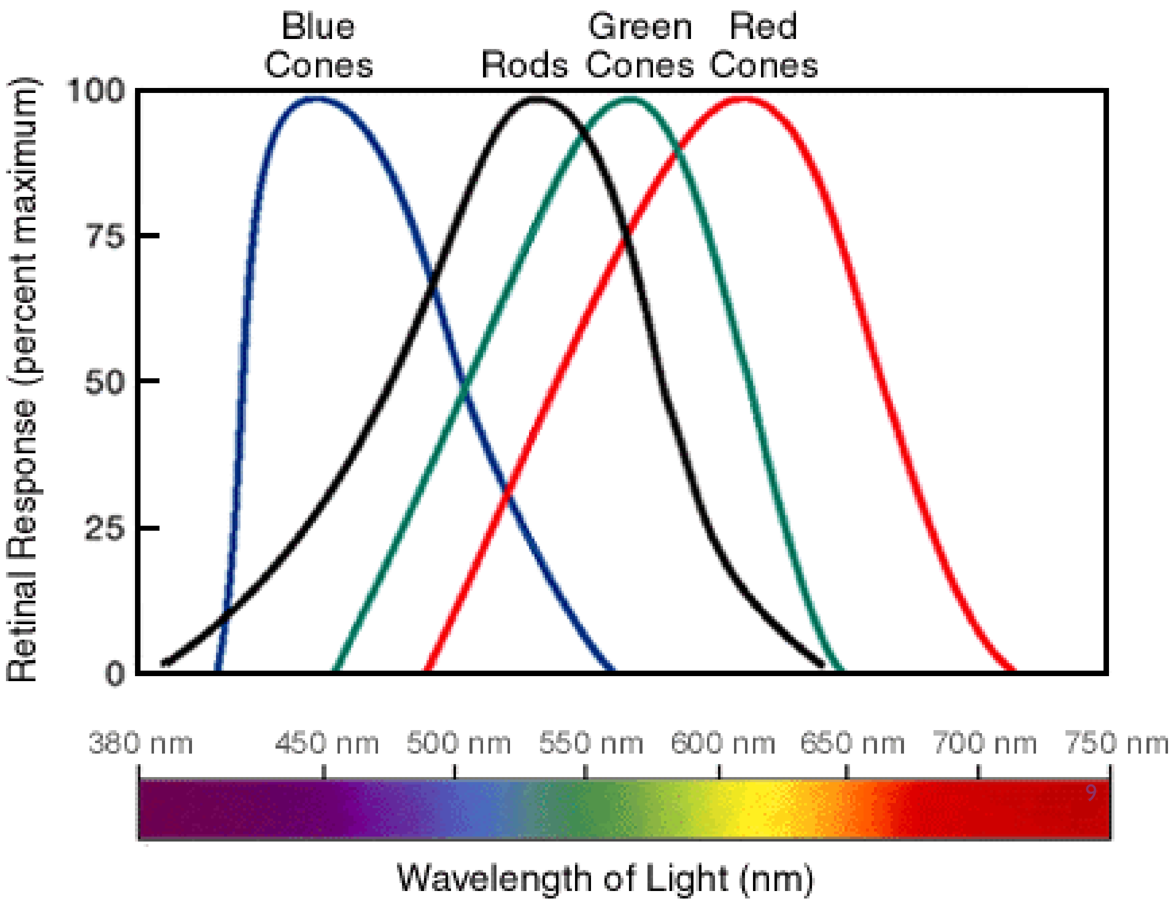
- Rods work at very low levels of light. We use these for night vision because only a few bits of light (photons) can activate a rod. Rods don't help with color vision, which is why at night, we see everything in a gray scale. The human eye has over 100 million rod cells.

- Cones require a lot more light and they are used to see color. We have three types of cones: blue, green, and red. The human eye only has about 6 million cones.

I- COLOR MODELS

COLOR FUNDAMENTALS CONT.

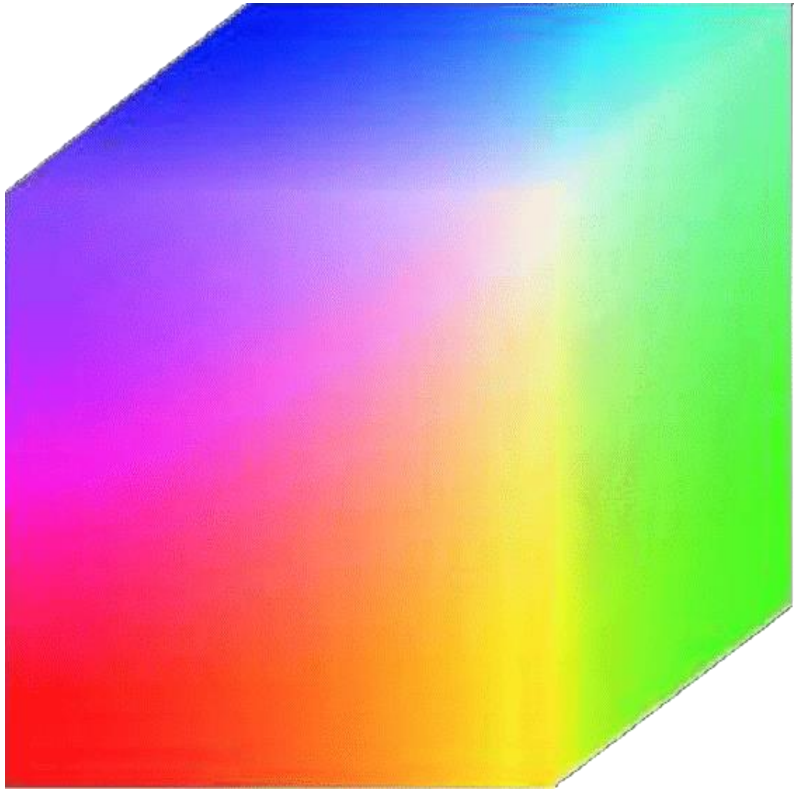
- We have three types of cones, each cone is able to detect a range of colors. Even though each cone is most sensitive to a specific color of light (where the line peaks),
- They also can detect other colors (shown by the stretch of each curve).
- It is the overlap of the cones and how the brain integrates the signals sent from them that allows us to see millions of colors.



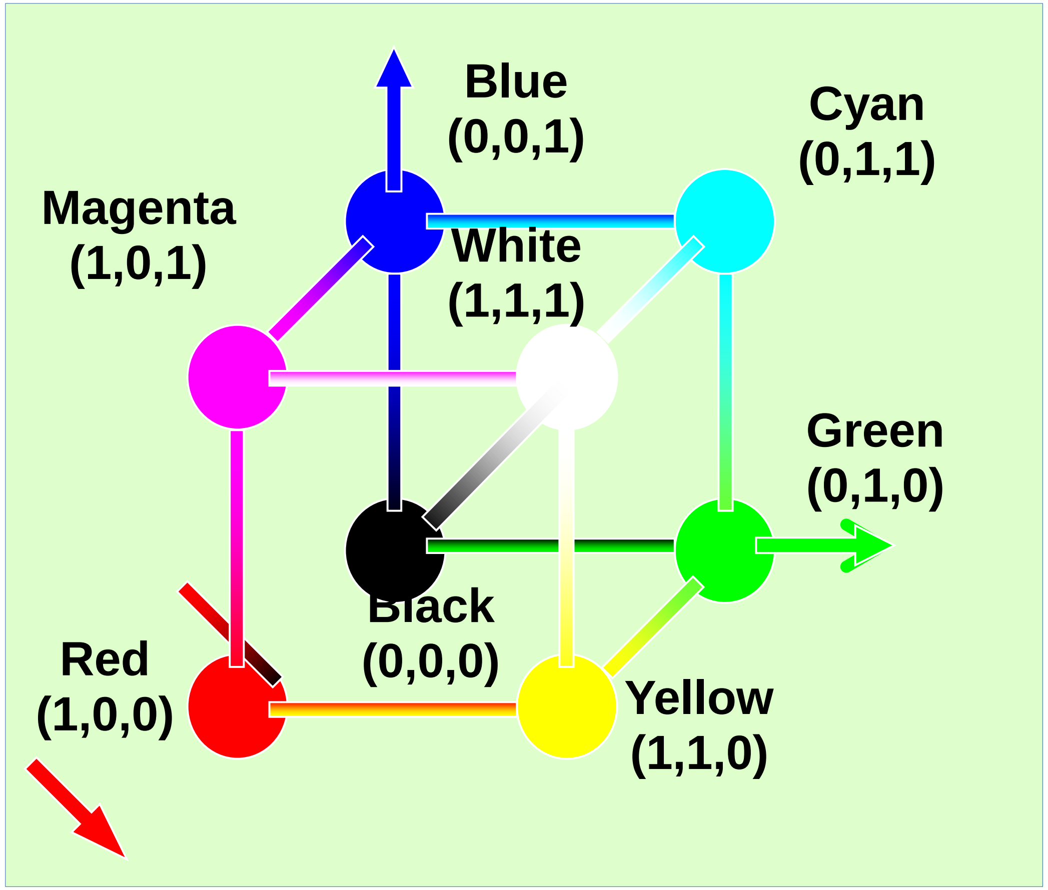
I- COLOR MODELS
DEFINITION AND TYPES

- Color models or color spaces refer to a color coordinate system in which each point represents one color.
- Different models are defined (standardized) for different purposes:
  - RGB for color monitors (CRT and LCD) and video cameras,
  - CMYK (cyan, magenta, yellow and black) for color printers Color manipulation models:
  - HSI (hue, saturation and brightness) is closest to the human visual system
  - YCbCr (or YUV) is often used in video where chroma is down-sampled (recall that the human visual system is much more sensitive to luminance than to color)
  - XYZ is known as the raw format
- others Two important aspects to retain about color models:
  - conversion between color models can be either linear or nonlinear,
  - some models can be more useful as they can decouple color and gray-scale components of a color image, e.g. HSI, YUV.

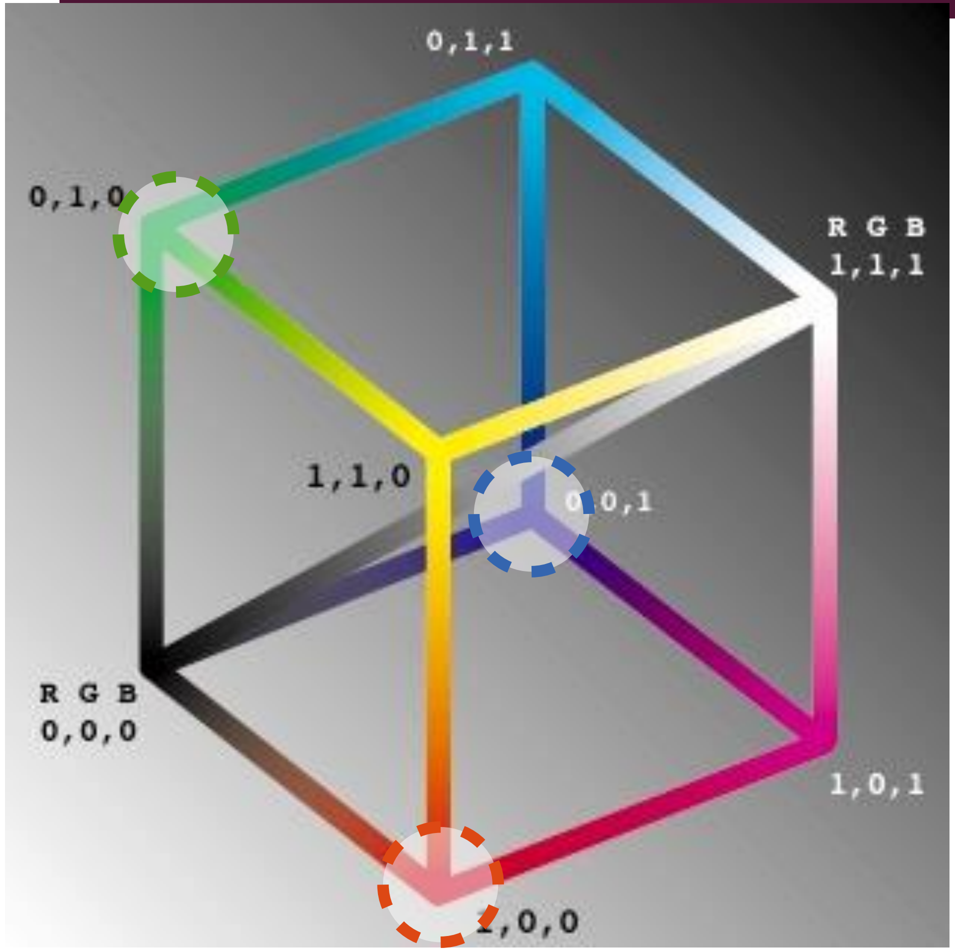
Red Green Blue (RGB) Color Space



RGB Color Space



RED GREEN BLUE (RGB) COLOR SPACE



- One of the simplest color models. Cartesian coordinates for each color; an axis is each assigned to the three primary colors red (R), green (G), and blue (B).
- Corresponds to the principles of additive colors.
- Other colors are represented as an additive mix of R, G, and B.
- Ideal for use in computers.

RGB COMPONENTS OF COLOR IMAGES

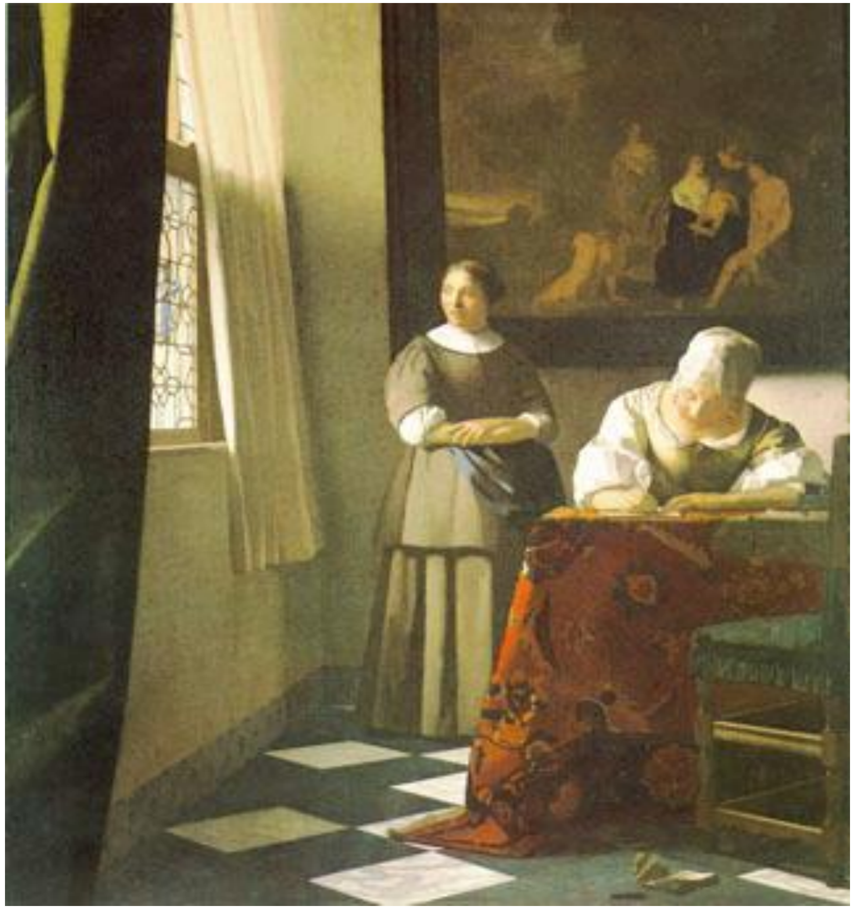
Full Color Image

Red Channel

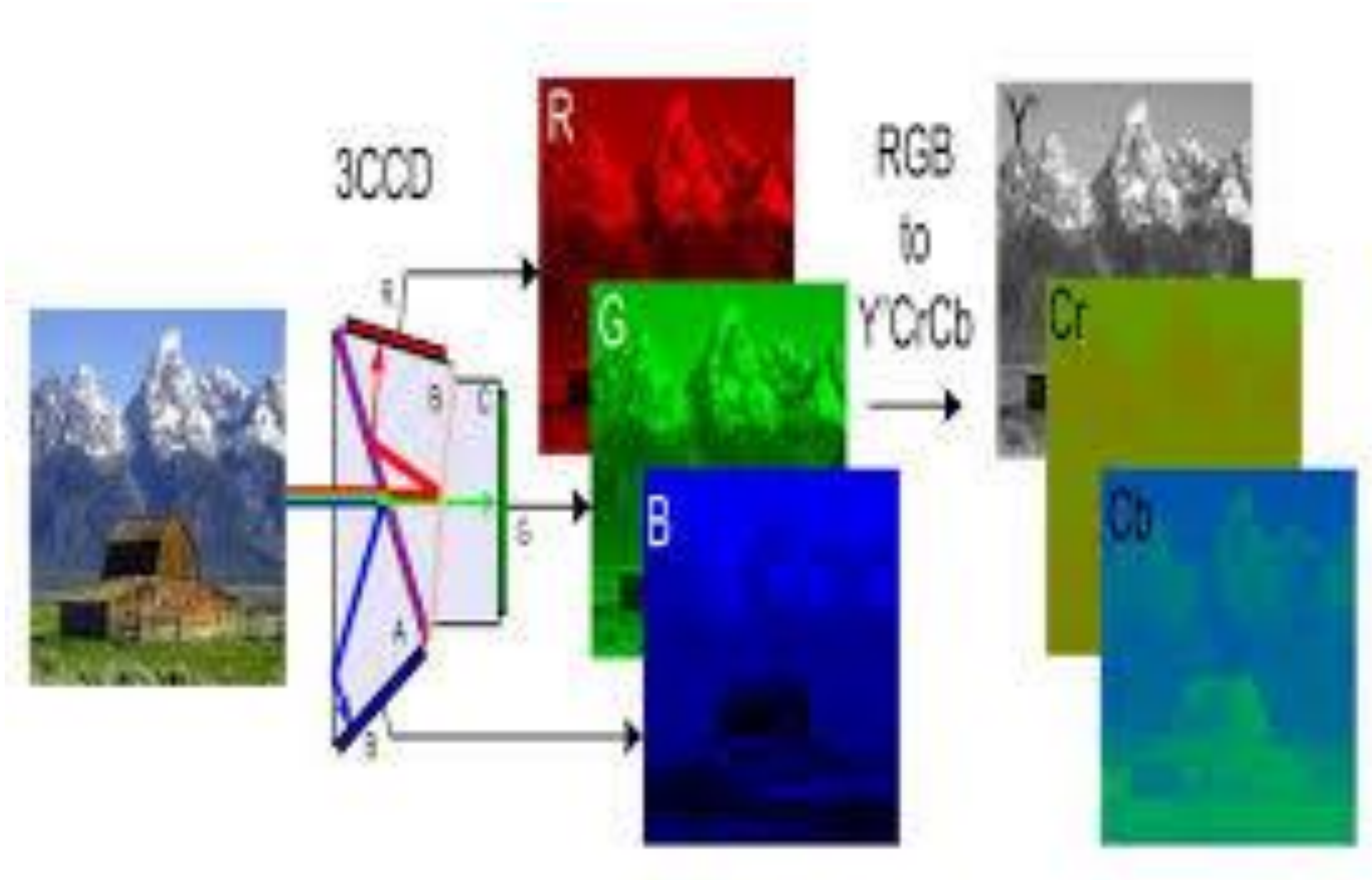
Green Channel

Blue Channel

CONVERSION FROM RGB TO GRAY



WHY YUV COLOR MODEL



RGB ⟺ YUV CONVERSION

Define the luminance coordinate to be:

- **Y = 0.299R + 0.587G + 0.114B**

$$\begin{pmatrix} \mathbf{Y} \\ \mathbf{U} \\ \mathbf{V} \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.288 & 0.436 \\ 0.615 & -0.149 & -0.1001 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.334 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} + \begin{pmatrix} 0 \\ 128 \\ 128 \end{pmatrix}$$

Cb and Cr are the components of chrominance

YUV ⟺ RGB CONVERSION

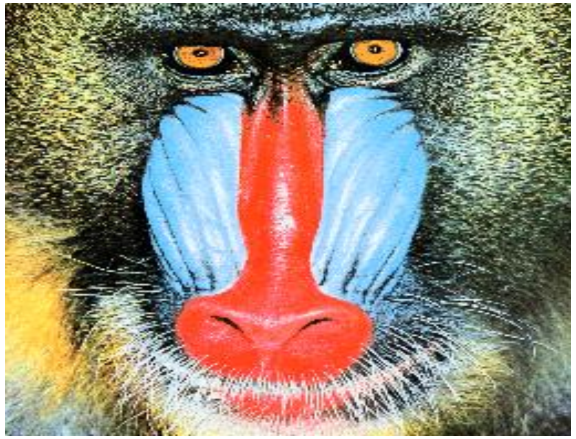
- **Invert the transformation matrix**

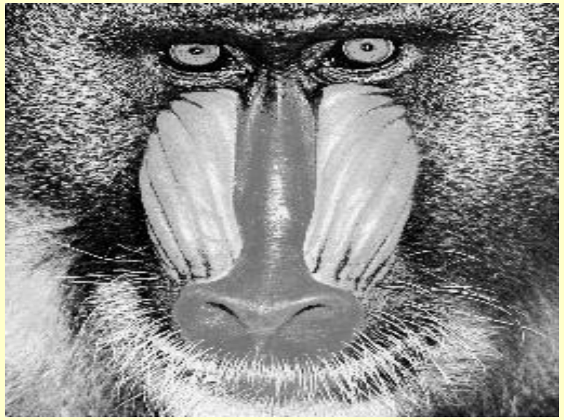
$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1 & 0 & 1.139 \\ 1 & -0.394 & -0.580 \\ 1 & 2.032 & 0 \end{pmatrix} \begin{pmatrix} Y \\ U \\ V \end{pmatrix}$$

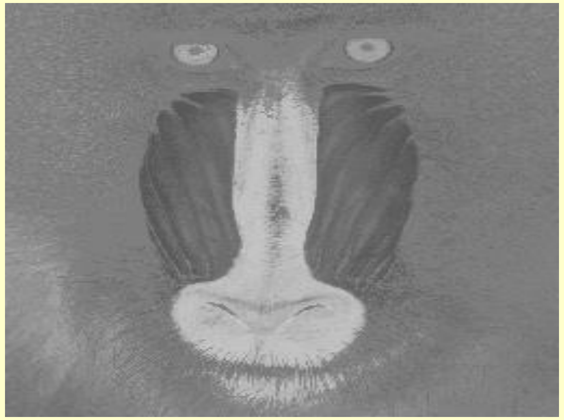
$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1 & 0 & 1.403 \\ 1 & -0.344 & -0.714 \\ 1 & 1.77 & 0 \end{pmatrix} \begin{pmatrix} Y \\ C_b - 128 \\ C_r - 128 \end{pmatrix} \quad \mathrm{R,G,B} \in [0,255]$$

RGB ⟷ YUV CONVERSION

Full Color Image







Y U V

LUMINANCE AND CHROMINANCE

- **Human eye is more sensible to luminance**

  (Y coordinate).

- **It is less sensible to color changes**

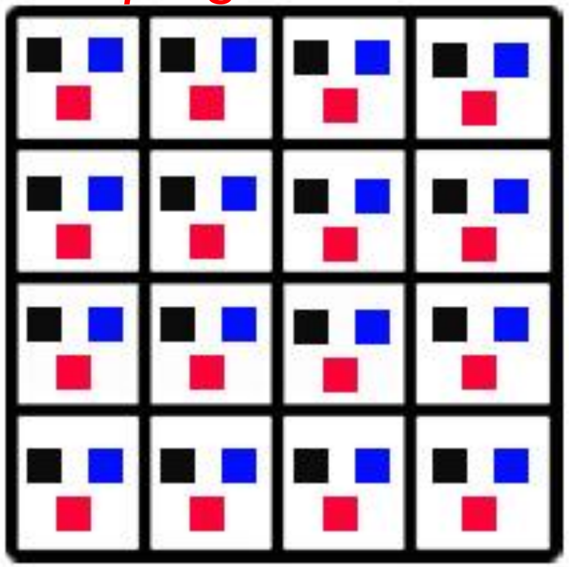
  (UV coordinates).

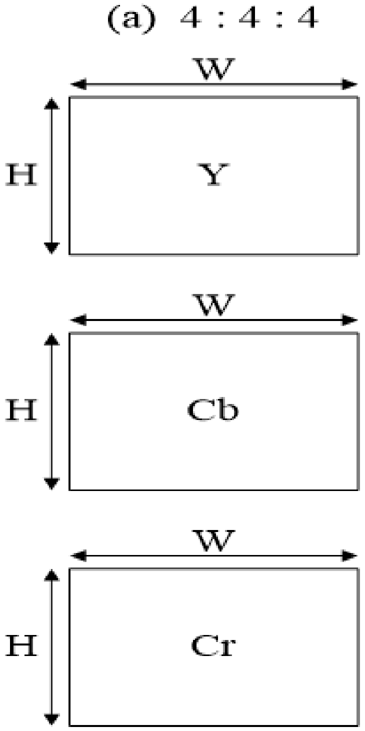
- ***Then: compress more on UV***

Consequence: color images are more compressible than grayscale ones

DOWN SAMPLING/UP-SAMPLING

Down-Sampling





In this example, every pixel has a Y value, a Cb value, and a Cr value.

Up-Sampling

No need to up-sampling. All values exist

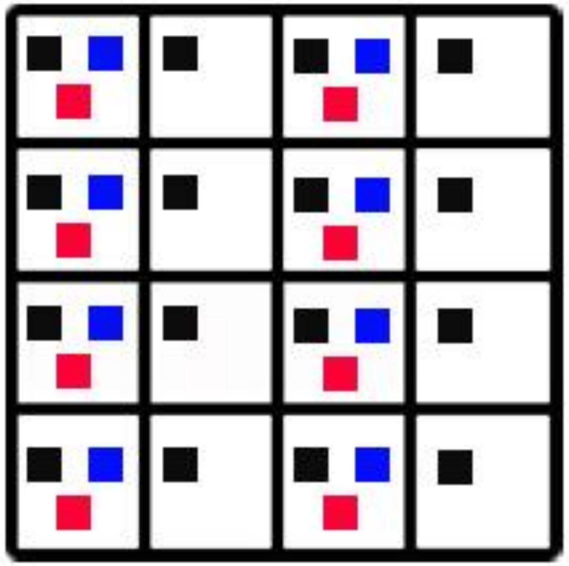
Compression Ratio

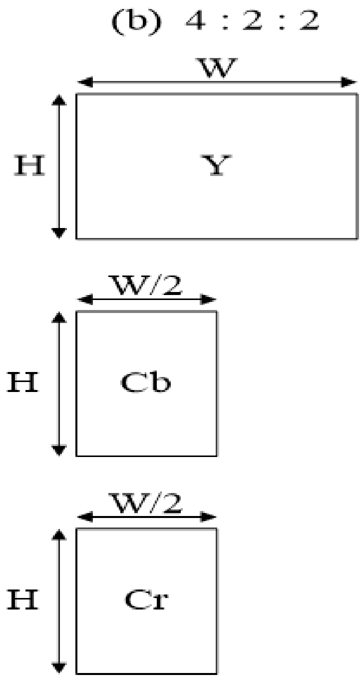
$$\frac{Original}{Compressed} = \frac{WxHx\,3}{WxHx\,3}$$

$$\frac{Original}{Compressed} = \frac{1}{1}$$

DOWN SAMPLING/UP-SAMPLING

Down-Sampling





half of the pixels are missing the color data

Up-Sampling

Use the neighboring color values and average in the values of the missing color values.

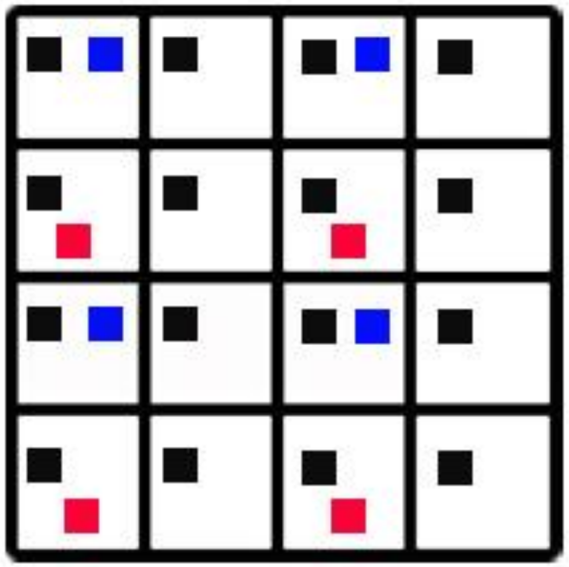
Compression Ratio

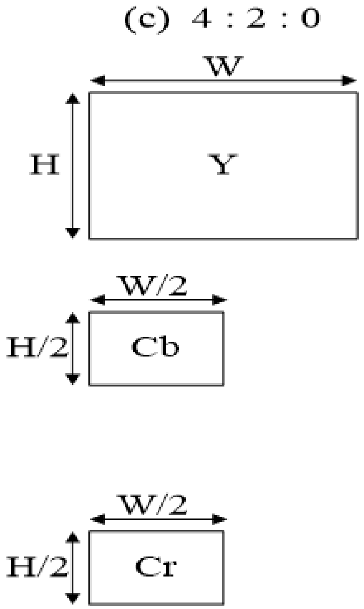
$$\frac{Original}{Compressed} = \frac{WxHx\,3}{WxH\; + WxH}$$

$$\frac{Original}{Compressed} = \frac{3}{2}$$

DOWN SAMPLING/UP-SAMPLING

Down-Sampling





Luma samples for each pixel, one line has Cb samples for every other pixel, and the next line has Cr samples for every other pixel.

Up-Sampling

using the surrounding intact color values, and providing smoothing between the averaged values.

Compression Ratio

$$\frac{Original}{Compressed} = \frac{WxHx\,3}{WxH \ + 2x\,(H \ / \, 2xW \ / \, 2)}$$

$$\frac{Original}{Compressed} = \frac{2}{1}$$

DOWN SAMPLING/UP-SAMPLING

- Subsampling is allowed in all the components (Y,Cr,Cb)
- Only the chroma subsampling is usually used!!!

Original | Luma Subsampled 8x | Chroma Subsampled 8x

COLOR IMAGE CONVERSION