Digital Image

Presented by: AIADI Oussama

MultiMedia data forms

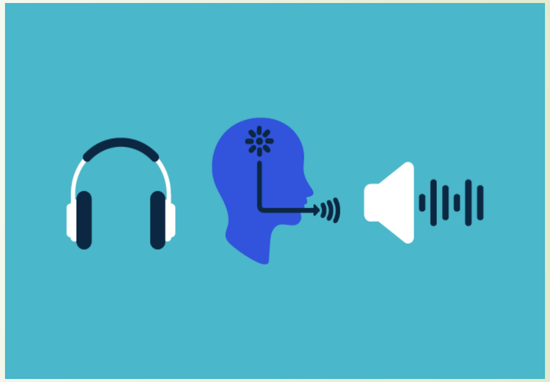
Other than image, there are several data formats, including the following

Image

Video

Image texture, defined as a function of the spatial variation in pixel intensities (gray values), is useful in a variety of applications and has been a subject of intense study by many researchers. One immediate application of image texture is the recognition of image regions using texture properties. For example, in Figure 1(a), we can identify the five different textures and their identities as cotton canvas, straw matting, raffia, herringbone weave, and pressed calf leather. Texture is the most important visual cue in identifying these types of homogeneous regions. This is called *texture classification*. The goal of texture classification then is to produce a classification map of the input image where each uniform textured region is identified with the texture class it belongs to as shown in Figure 1(b). We could also find the texture boundaries even if we could not classify these textured surfaces. This is then the second type of problem that texture analysis research attempts to solve — *texture segmentation*. The goal of texture segmentation is to obtain the boundary map shown in Figure 1(c). *Texture synthesis* is often used for image compression applications. It is also important in computer graphics where the goal is to render object surfaces which are as realistic looking as possible. Figure 2 shows a set of synthetically generated texture images using Markov random field and fractal models [9]. The *shape from texture* problem is one instance of a general class of vision problems known as "shape from X". This was first formally pointed out in the perception literature by Gibson

text



Audio

Why digital image

Digital image has a wide broad of interesting applications, ranging from medical and industrial apps to law enforcement, Hereafter, we shed the light into some of them

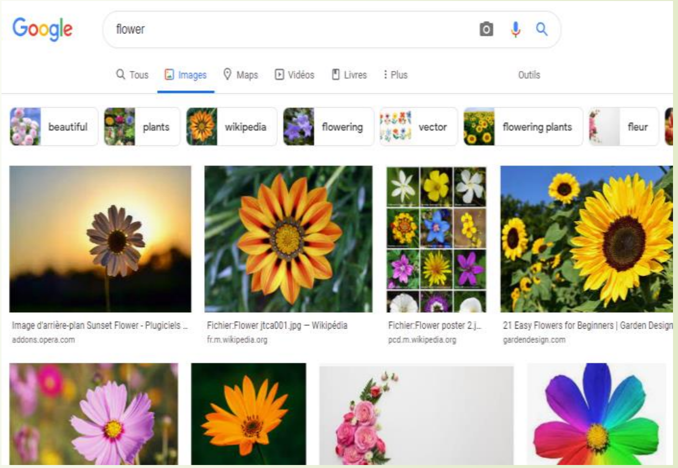
Medical diagnosis

Industrial inspection

Control Access

Why digital image

Other applications of digital image include also



Vehicle plate recognition

Historical document restoration

Image retrieval

Why digital image

Looking for more recent apps

Image inpainting

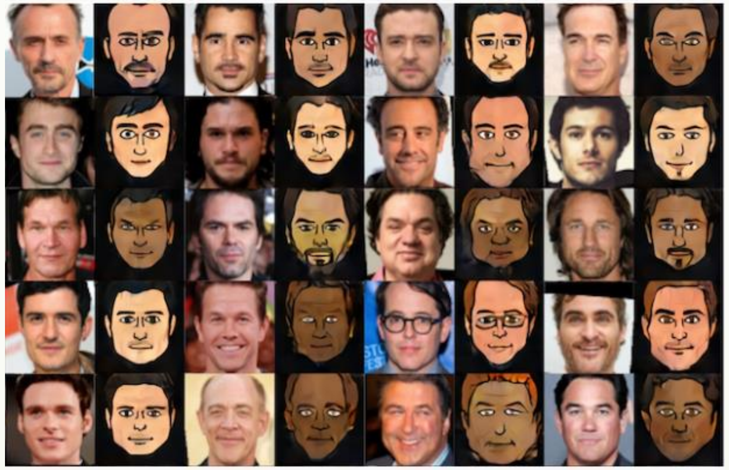
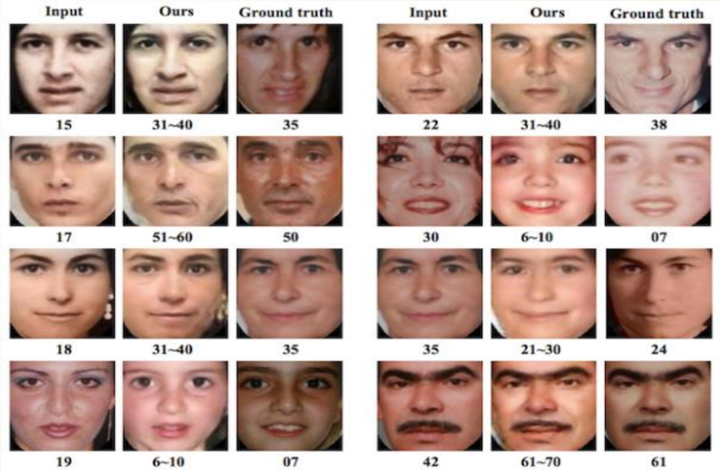


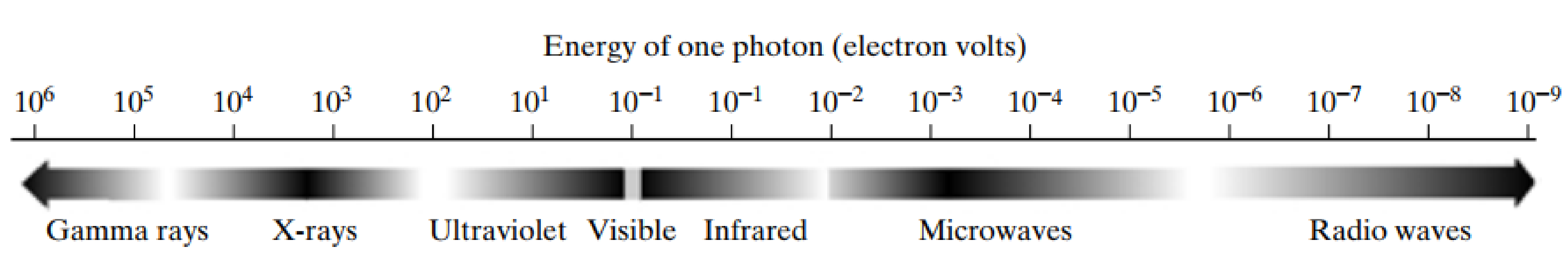
Photo to emojis



Face aging

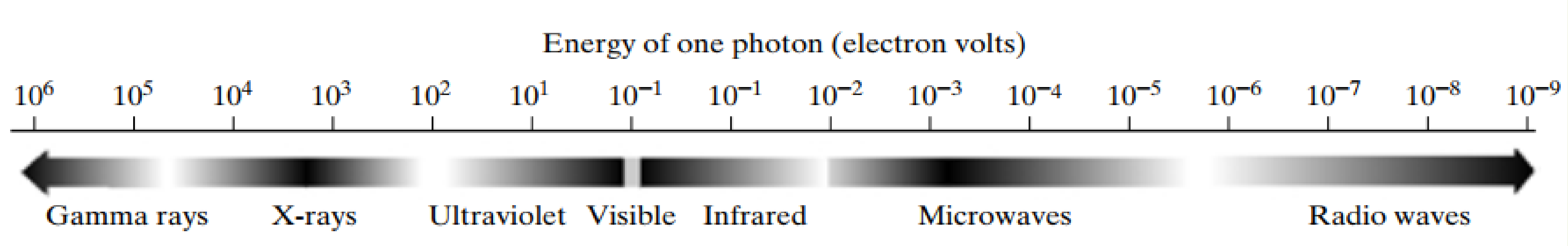
Imaging modalities

Images we see in our daily life can be produced based on different imaging techniques, which differ from each other in terms of energy source. The principal energy source for images in use today is the electromagnetic energy spectrum. Other important sources of energy include acoustic, ultrasonic, and electronic. In addition, synthetic images, used for modeling and visualization, are generated by computer.



Imaging modalities

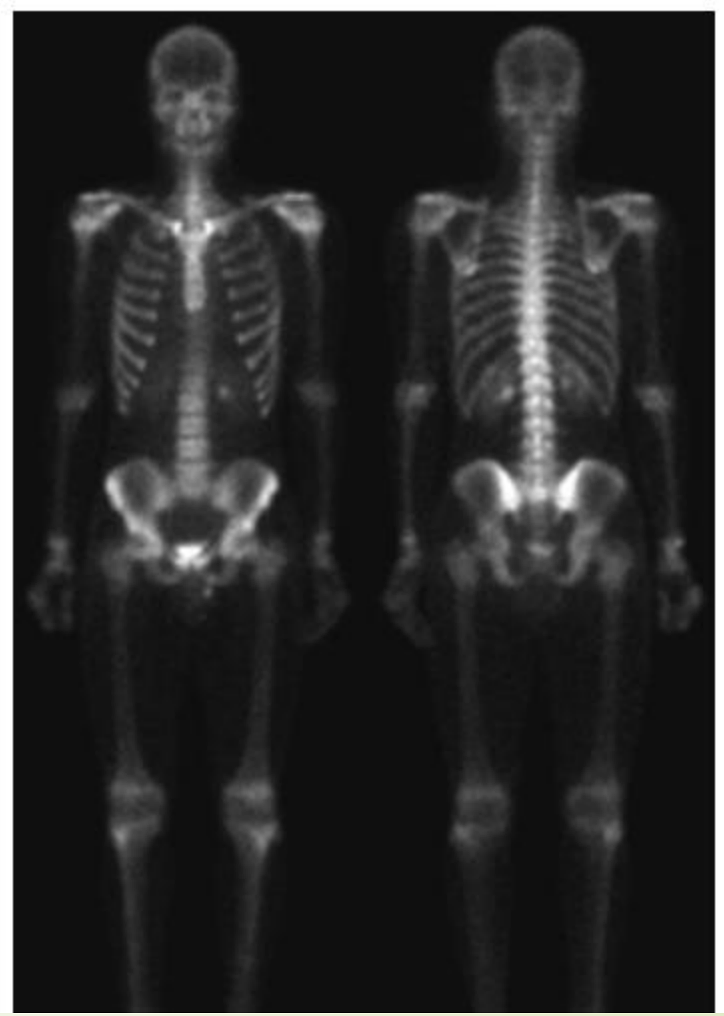
Images based on radiation from the EM spectrum are the most familiar. Electromagnetic waves can be conceptualized as propagating sinusoidal waves of varying ***wavelengths***, or they can be thought of as a stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light. Each massless particle contains a certain amount (or bundle) of energy. Each bundle of energy is called a ***photon***.



Imaging modalities

Gammas-Ray Imaging

Major uses of imaging based on gamma rays include nuclear medicine and astronomical observations. In nuclear medicine, the approach is to inject a patient with a radioactive isotope that emits gamma rays as it decays. Images are produced from the emissions collected by gamma ray detectors.



Imaging modalities

X-Ray Imaging

X-rays for medical and industrial imaging are generated using an X-ray tube, which is a vacuum tube with a cathode and anode. The cathode is heated, causing free electrons to be released. These electrons flow at high speed to the positively charged anode. When the electrons strike a nucleus, energy is released in the form of X-ray radiation.

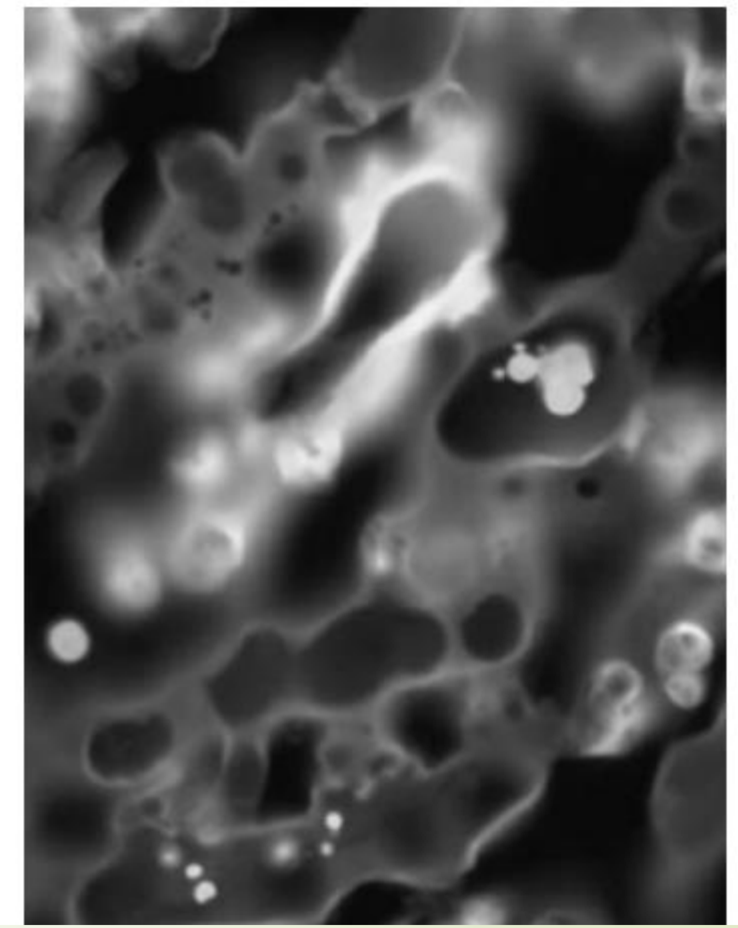
our ordinary medical radios are in X-Ray, which can surpass everything in human body except bones. The shows a familiar chest X-ray generated simply by placing the patient between an X-ray source and a film sensitive to X-ray energy.

Imaging modalities

Ultraviolet Imaging

Ultraviolet light is used in fluorescence microscopy, one of the fastest growing areas of microscopy. Fluorescence is a phenomenon discovered in the middle of the nineteenth century, when it was first observed that the mineral fluorspar fluoresces when ultraviolet light is directed upon it.

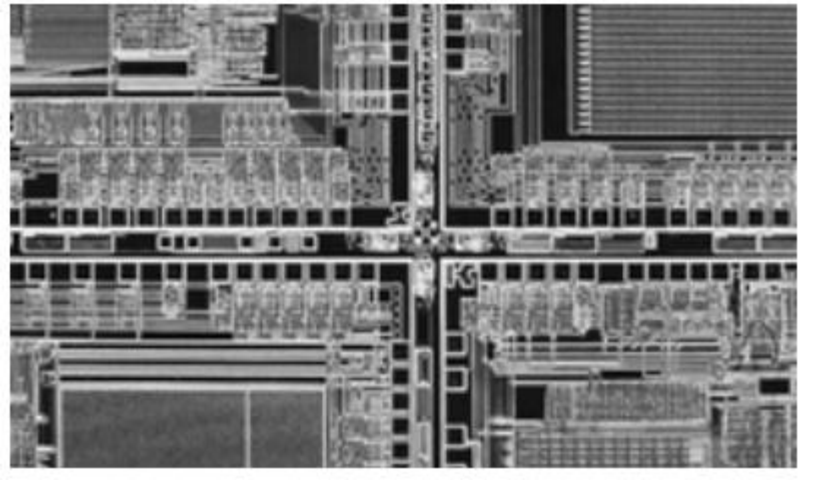
The basic task of the fluorescence microscope is to use an excitation light to irradiate a prepared specimen and then to separate the much weaker radiating fluorescent light from the brighter excitation light. Thus, only the emission light reaches the eye or other detector.



Imaging modalities

Imaging in the Visible and Infrared Bands

The infrared band often is used in conjunction with visual imaging. Images taken using light microscopy are typical examples for images generated using the visual band. light microscopy simply enlarging species being imaged using lens and take photos in presence of light



Imaging modalities

Imaging in the Visible and Infrared Bands

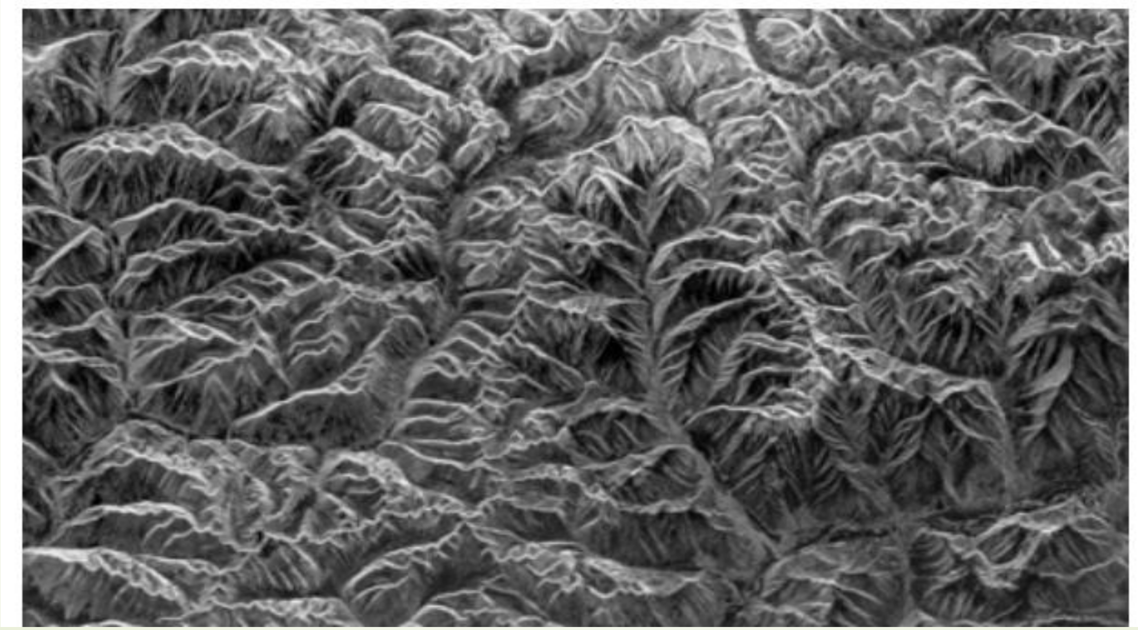
The infrared band often is used in conjunction with visual imaging. Here, an example of infrared image taken using NASA satellite. The Table represents different bands for imaging in this satellite.

Band No.	Name	Wavelength (m)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

Imaging modalities

Microwave Band Imaging

The dominant application of imaging in the microwave band is radar. The unique feature of imaging radar is its ability to collect data over virtually any region at any time, regardless of weather or ambient lighting conditions. The figure is for mountains in southeast Tibet.



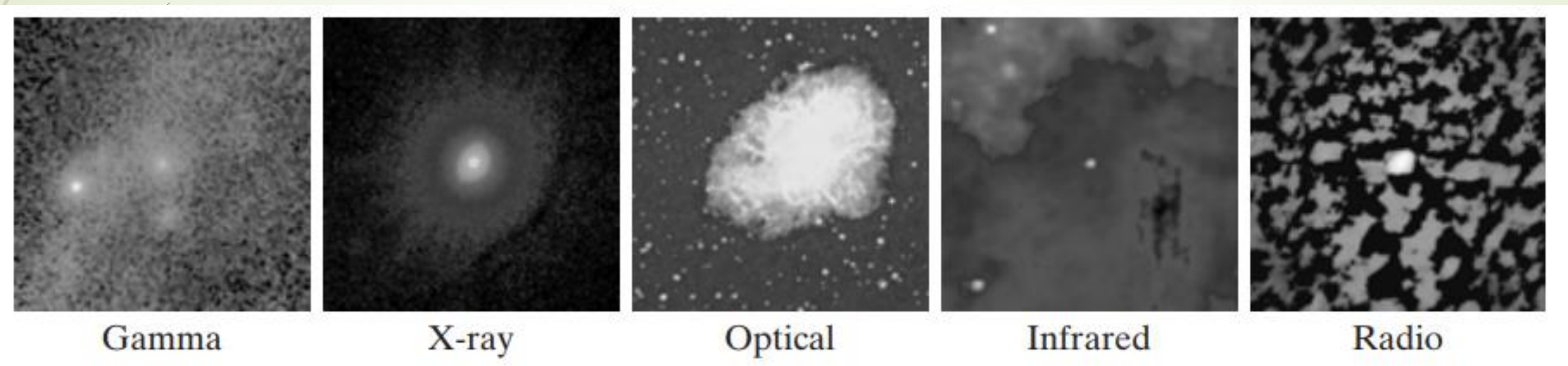
Imaging modalities

Radio Band Imaging

In medicine radio waves are used in magnetic resonance imaging (MRI). This technique places a patient in a powerful magnet and passes radio waves through his or her body in short pulses. Each pulse causes a responding pulse of radio waves to be emitted by the patient’s tissues. The location from which these signals originate and their strength are determined by a computer, which produces a two-dimensional picture of a section of the patient.

Imaging modalities

Multispectral image for Crab Pulsar



human visual perception

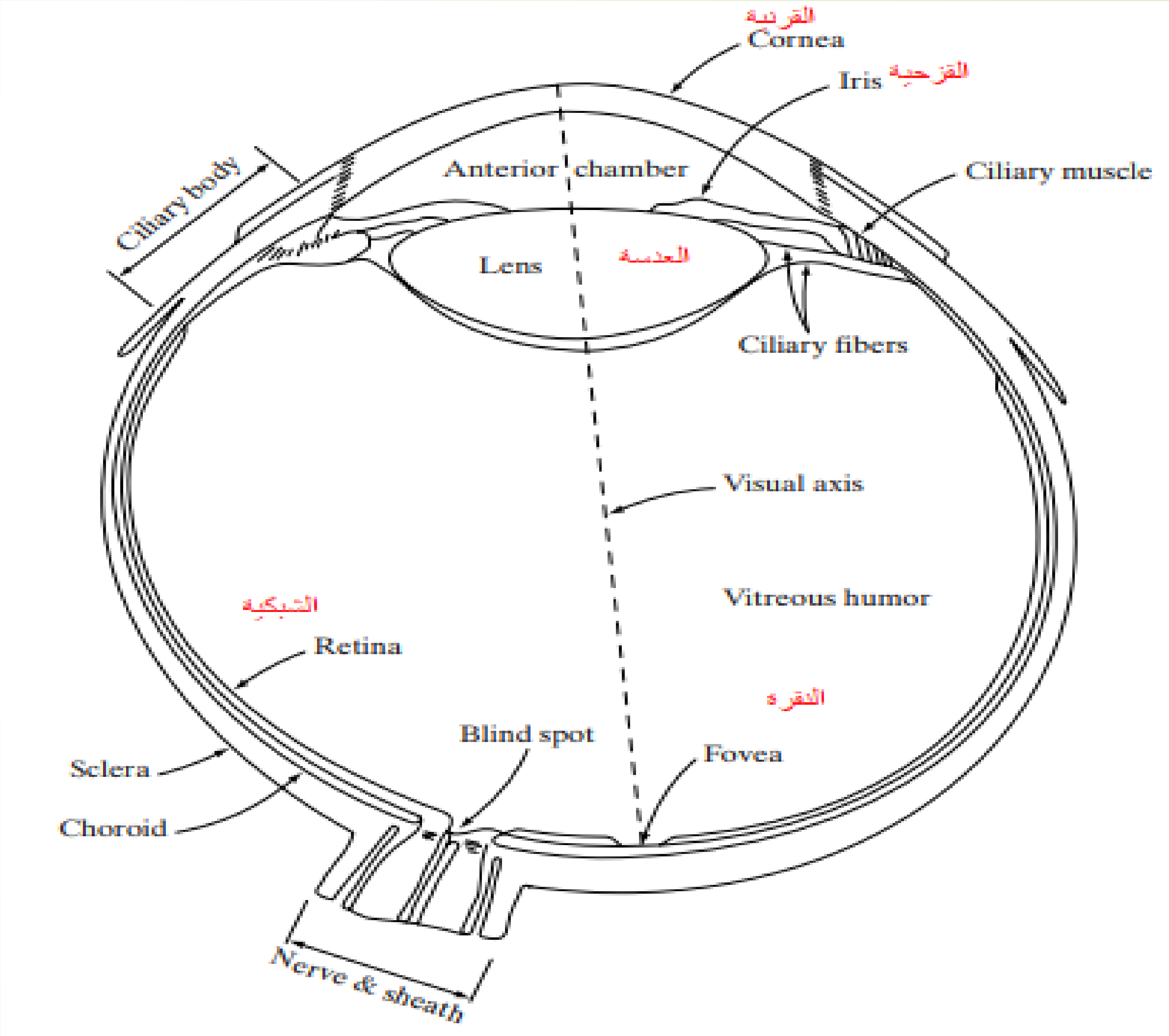
The organ responsible on human visual perception is the eye. Here is a cross diagram for the human eye .

- ***sclera***. contains a network of blood vessels that serve as the major source of nutrition to the eye

- ***Iris*** contracts or expands to control the amount of light that enters the eye.

- **The fovea** is responsible for sharp central vision, which is necessary in humans for activities for which visual detail is of primary importance e.g., reading

- When the eye is properly focused, light from an object outside the eye is imaged on the ***retina***. Pattern vision is afforded by the distribution of discrete light receptors over the surface of the retina.

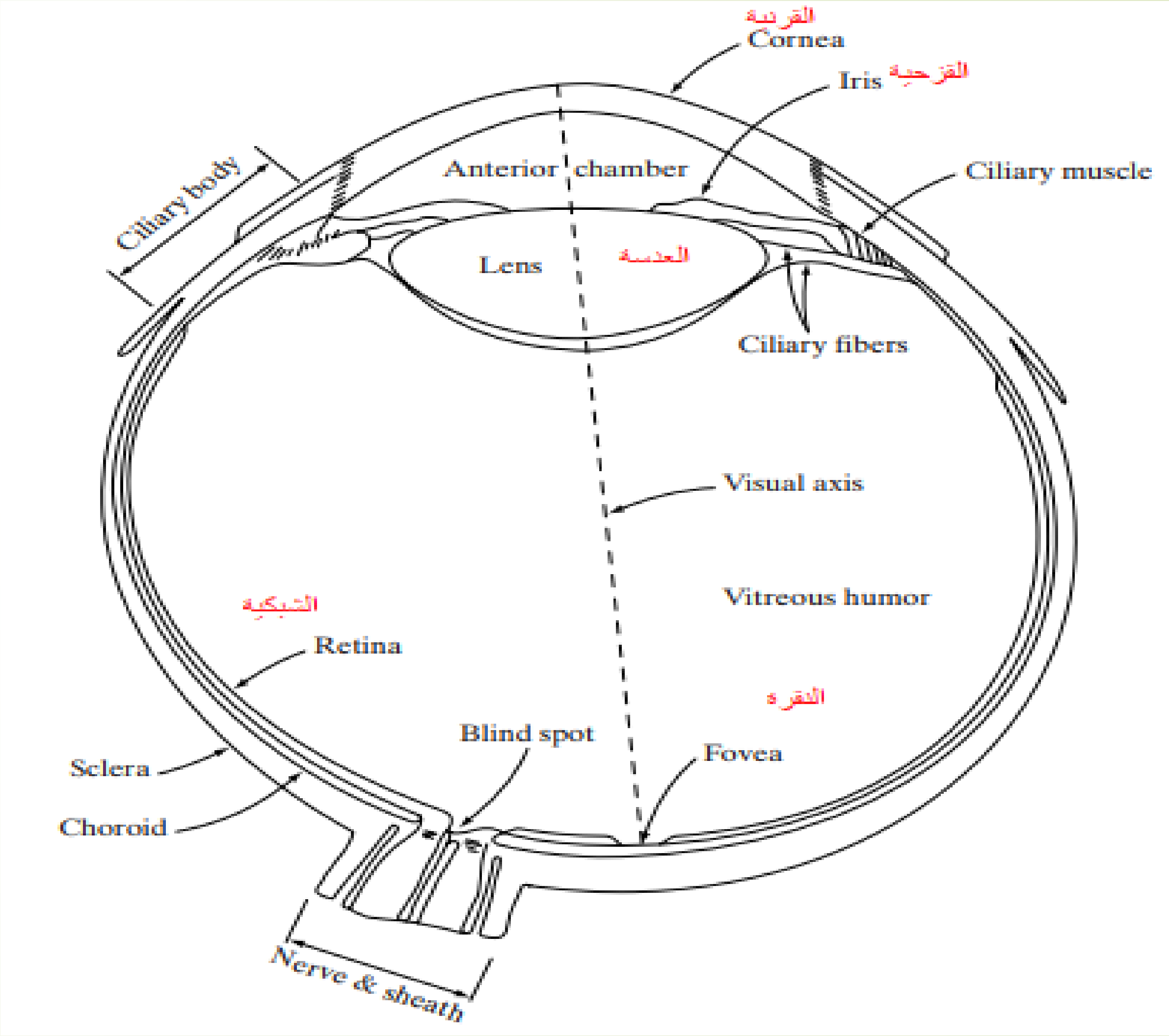


human visual perception

There are two classes of receptors: ***cones*** and ***rods***. The cones in each eye number between 6 and 7 million. They are located primarily in the central portion of the retina, called the ***fovea***.

Humans ***can resolve fine details with these cones*** largely because each one is connected to its own nerve end.

The number of rods is much larger: Some 75 to 150 million are distributed over the retinal surface. The larger area of distribution and the fact that several rods are connected to a single nerve end reduce the amount of detail discernible by these receptors. ***Rods serve to give a general, overall picture of the field of view.***



human visual perception

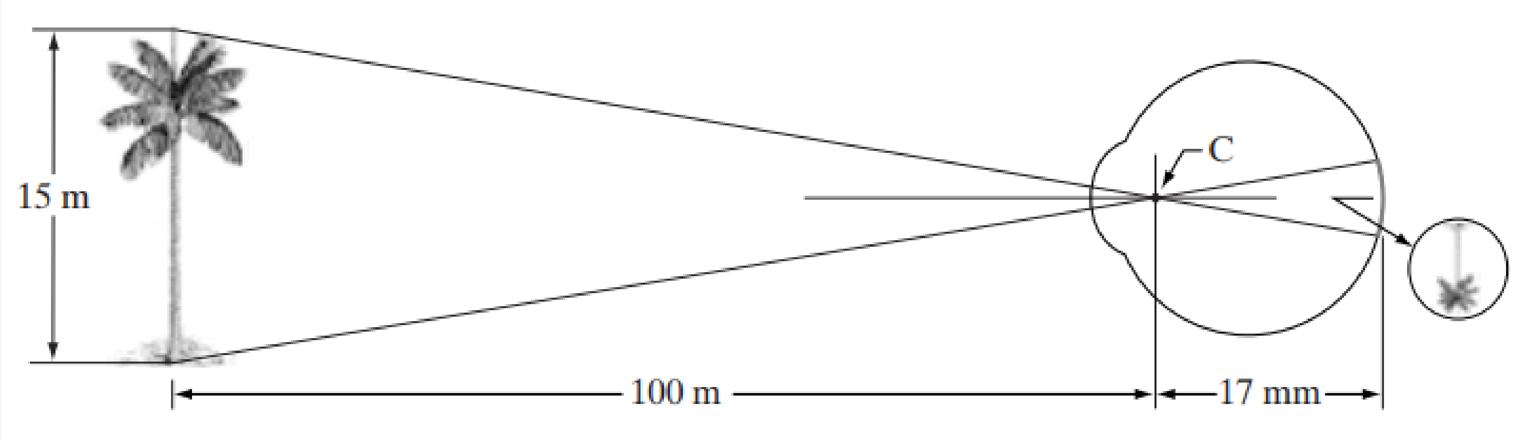
How does eye work?

Alhacen Iben Alhaithem was the first who revealed how human eyes work. This achievement is not the only provided by the Arabic and Islamic civilization in the middle centuries!

human visual perception

How does eye work?

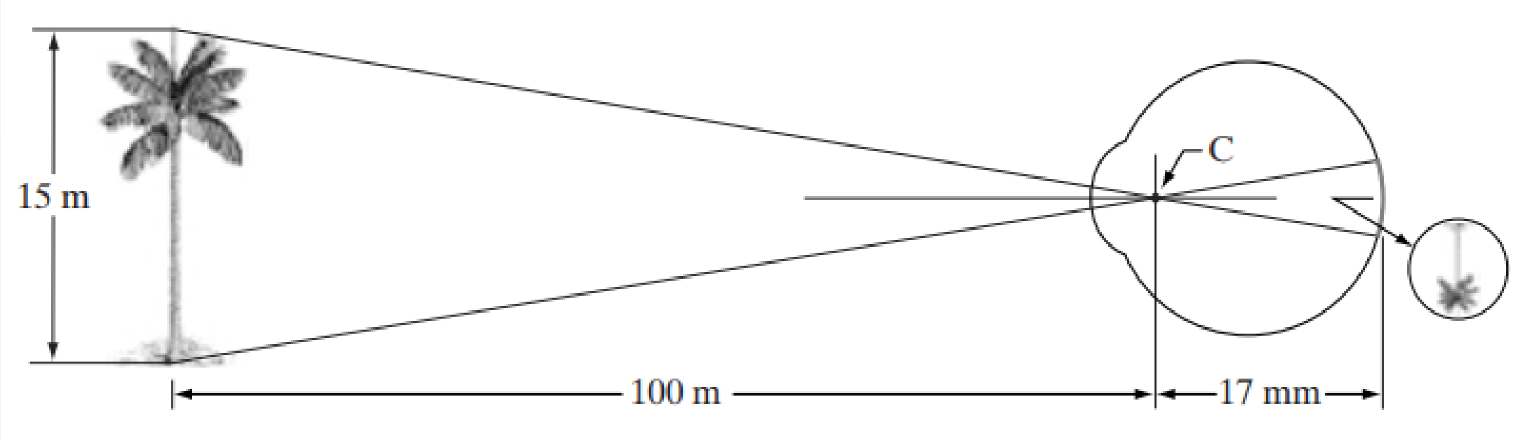
A light beam enter the eye through the cornea, this beam is refrected, as it falls on a convex surface. The image being observed is reflcted on the retina which contains millions of light sensors. After having receving this light, it is sent to the brain as electrical impulses that are ultimately decoded by the brain. We can calculate the size of the retinal image according to the geometry shown by following figure



human visual perception

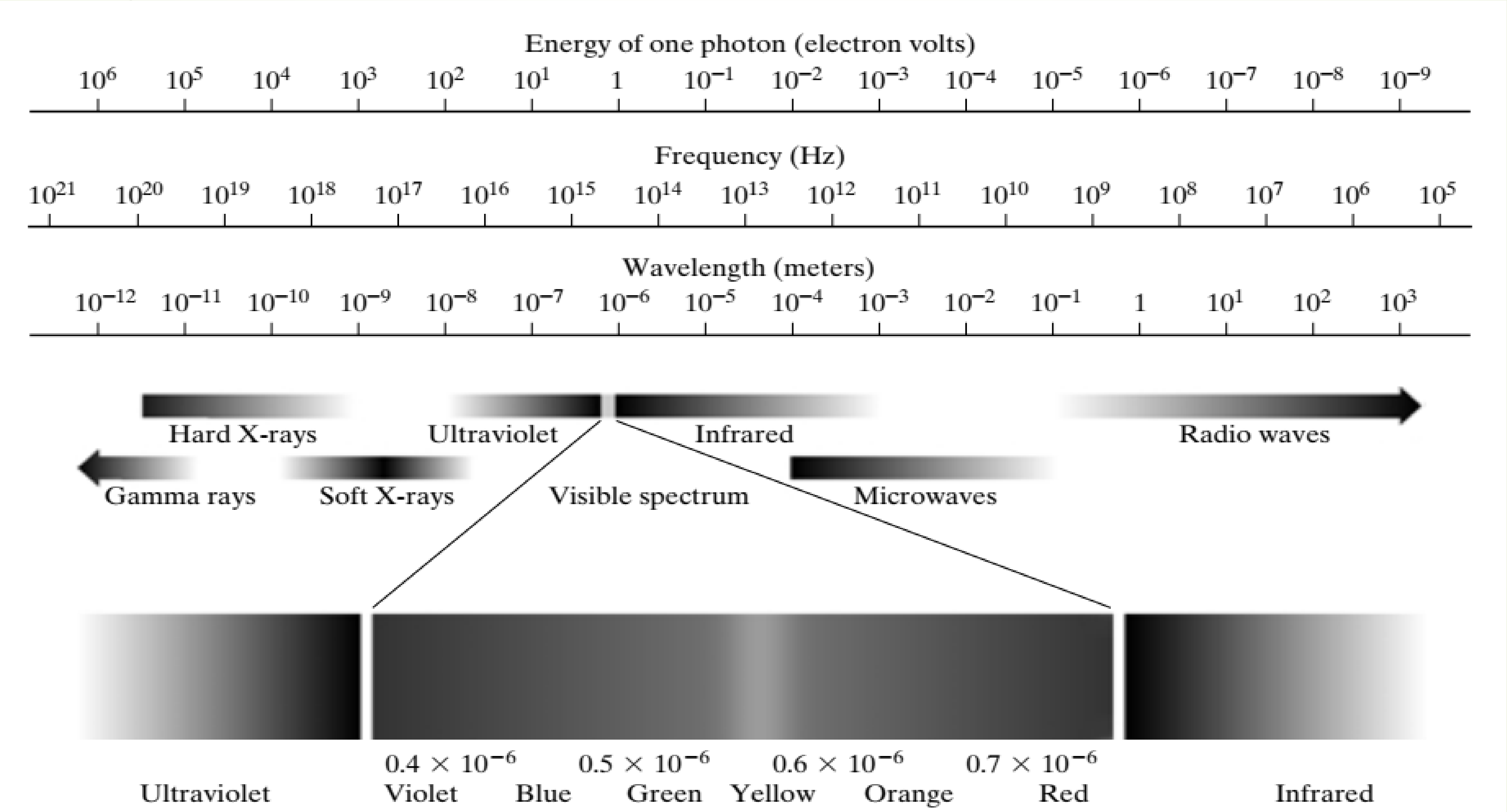
How does eye work?

For example, the observer is looking at a tree 15 m high at a distance of 100 m. If ***h*** is the height in mm of that object in the retinal image, the geometry yields 15/100=h/17 or ***h*=2.55 mm**.



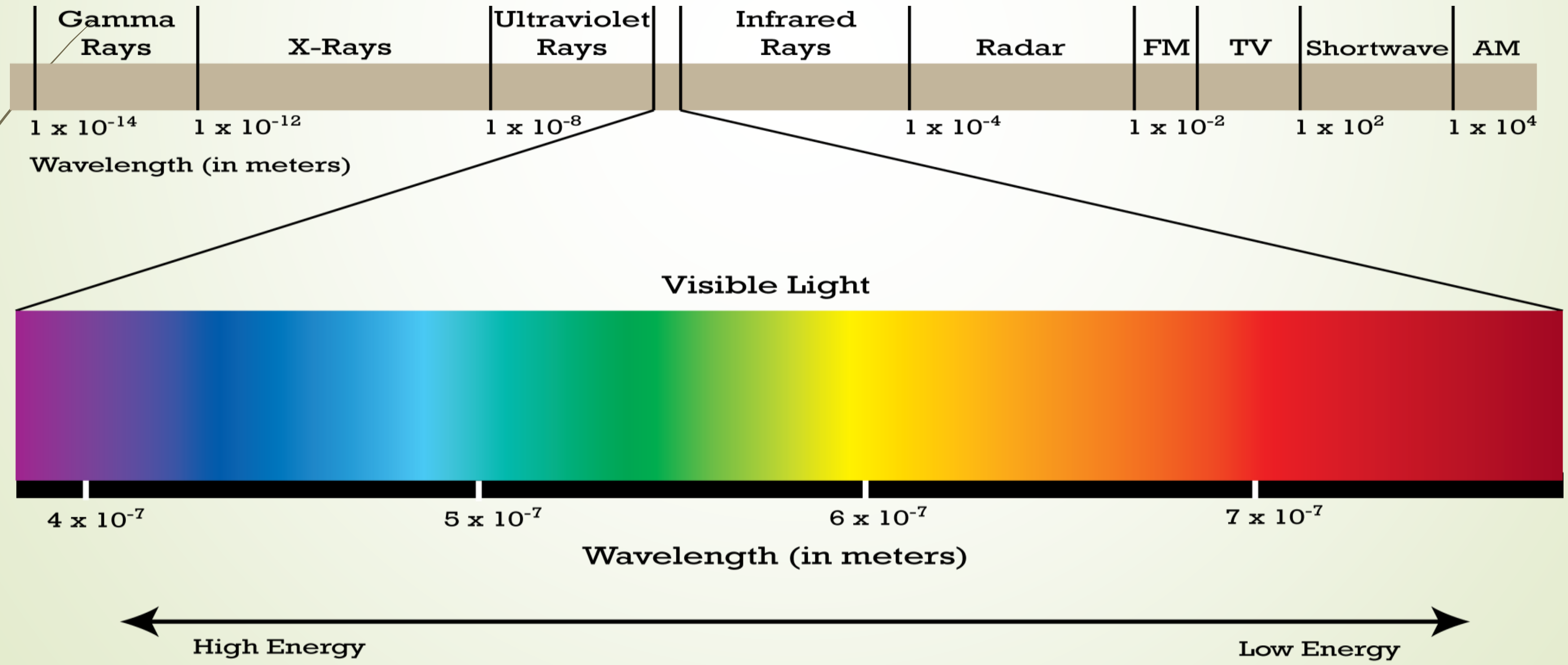
Electromagnetic Spectrum

As it has already mentioned, electromagnetic spectrum can be viewed as massless particles or waves.



Electromagnetic Spectrum

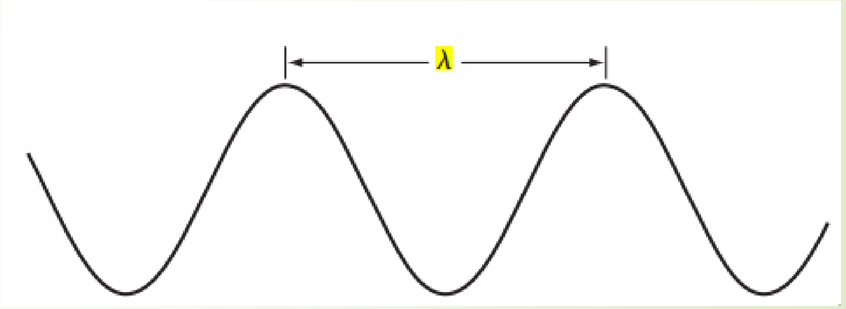
In 1666, Sir Isaac Newton discovered that when a beam of sunlight is passed through a glass prism, the emerging beam of light is not white but consists instead of a continuous spectrum of colors ranging from violet at one end to red at the other.



Electromagnetic Spectrum

The electromagnetic spectrum can be expressed in terms of wavelength, frequency, or energy. Wavelength λ and frequency v are related by the expression

$$\lambda = \frac{c}{v}$$



Such that c is the speed of light $(2{,}998 \times 10^{3}\ m/s)$

The energy of the various components of the electromagnetic spectrum is given by the expression

$$E = hv$$

Where h is Planck's constant, The units of wavelength are meters, with the terms *microns* (denoted μm and equal to 10^{-6} m) and *nanometers* $(10^{-9}$ m) being used just as frequently. Frequency is measured in Hertz (Hz), with one Hertz being equal to one cycle of a sinusoidal wave per second. A commonly used unit of energy is the electron-volt.

Electromagnetic Spectrum

Imaging requirement

It is important to note, however, that the wavelength of an electromagnetic wave required to “see” an object must be of the same size as or smaller than the object. For example, a water molecule has a diameter on the order of 10^{-10} m. Thus, to study molecules, we would need a source capable of emitting in the far hard X-ray region. This limitation, along with the physical properties of the sensor material, establishes the fundamental limits on the capability of imaging sensors, such as visible, infrared, and other sensors in use today.

Image Acquisition

Again, it should be noted that Alhacen Iben Alhaithem was the first to invent the camera 'القمرة'

اخترع ابن الهيثم الكاميرا و هي غرفة مظلمة ينفذ اليها الضوء عبر ثقب صغيرة
بتصغير الثقب الى حد كبير تحدث ظاهرة التشتت بحيث بتشتت الشعاع الداخل الى الغرفة ليظهر الصورة مقلوبة
كما أوضح أيضا أن جودة الصورة تزيد كلما صغر الثقب

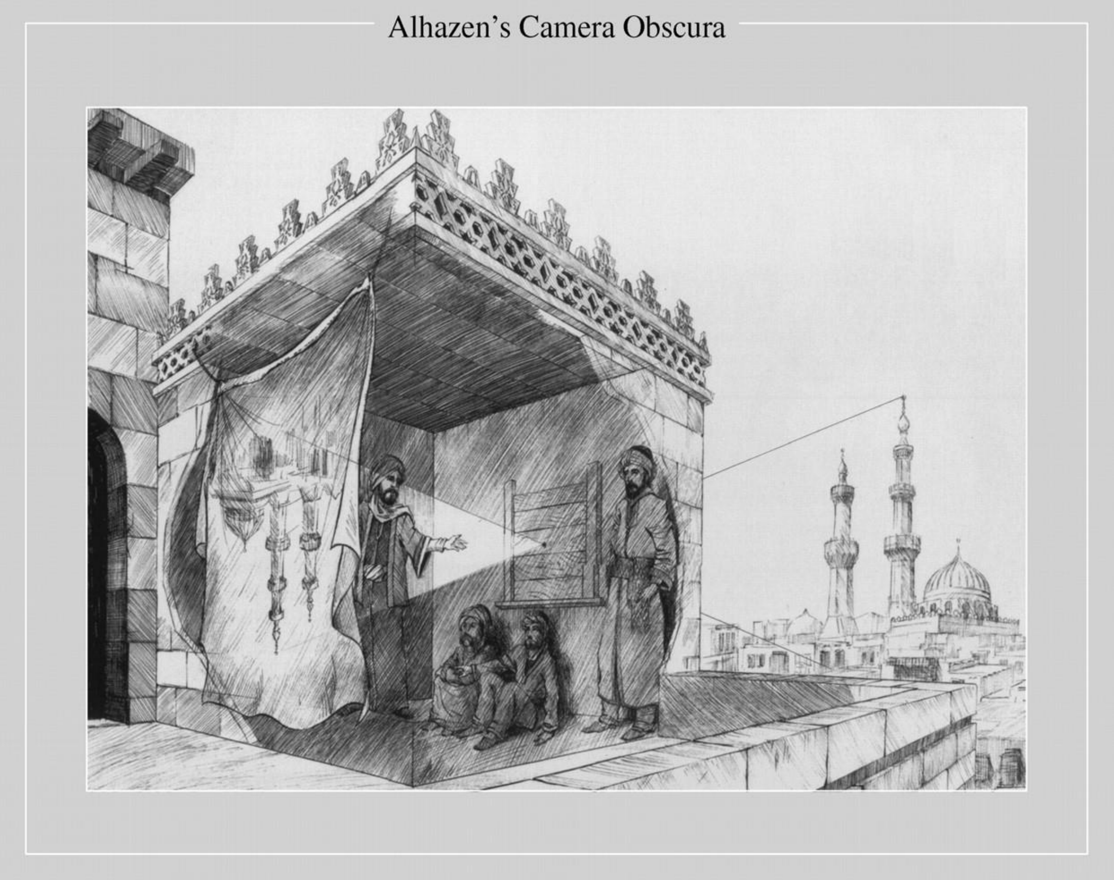


Image Acquisition

Acquisition techniques can be classified according to the industrial technology used for constructing the sensor. In this course, and since numerous electromagnetic and sensing devices frequently are arranged in an array format, we consider sensor arrays

A typical sensor for these cameras is a CCD array, which can be manufactured with a broad range of sensing properties and can be packaged in arrays of 4000 x 4000 elements or more.

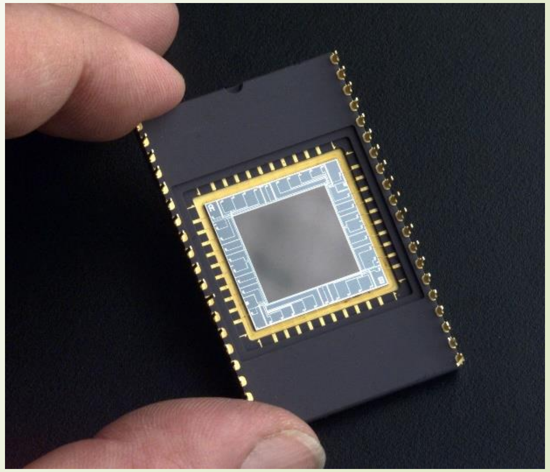


Image Acquisition

The first function performed by the imaging system is to collect the incoming energy and focus it onto an image plane. If the illumination is light, the front end of the imaging system is a lens, which projects the viewed scene onto the lens focal plane. The sensor array, which is coincident with the focal plane, produces outputs proportional to the integral of the light received at each sensor. Digital and analog circuitry sweep these outputs and convert them to a video signal, which is then digitized by another section of the imaging system.

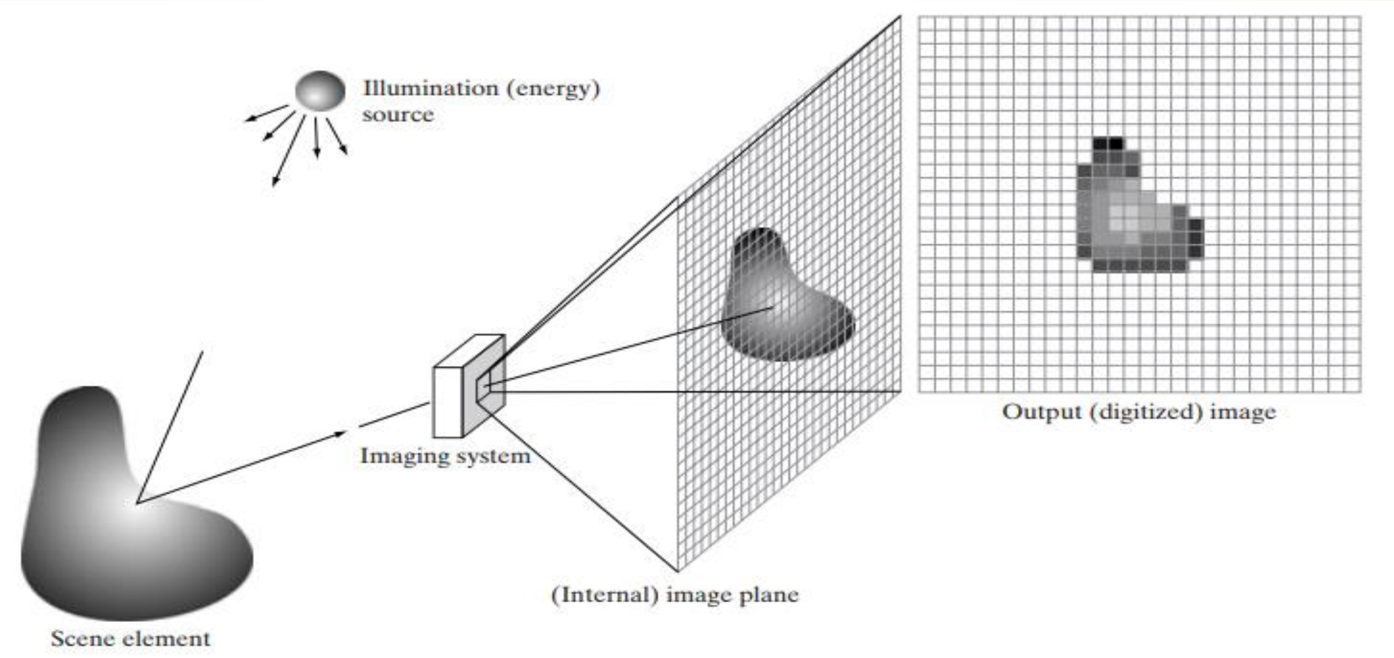


Image Formation

Image is a two-dimensional function of the form **f(x, y).** The value or amplitude of ***f*** at spatial coordinates ***(x, y)*** is a positive scalar quantity. The function ***f(x, y)*** may be characterized by two components: (1) the amount of source illumination incident on the scene being viewed, and (2) the amount of illumination reflected by the objects in the scene. Appropriately, these are called the ***illumination*** and ***reflectance*** components and are denoted by ***i(x, y)*** and ***r(x, y)***, respectively. The two functions combine as a product to form f(x, y):

$$f(x, y) = i(x, y) \,.\, r(x, y)$$

Where $0 < i(x, y) < \infty$ and $0 < r(x, y) < 1$

indicates that reflectance is bounded by 0 (total absorption) and 1 (total reflectance).The nature of ***i(x, y)*** is determined by the illumination source, and ***r(x, y)*** is determined by the characteristics of the imaged object.

Image Formation

we call the ***intensity*** of a ***monochrome*** image at any coordinates **(x,y)** the ***gray level (L)*** of the image at that point

$$L = f(x,y)$$

where ***L*** falls in the range ***Lmin < L < Lmax***

The interval is called the *gray scale*. Common practice is to shift this interval numerically to the interval ***[0, L-1],*** where ***L=0*** is considered black and ***L=L-1*** is considered white on the gray scale. All intermediate values are shades of gray varying from black to white.

Image Sampling and Quantization

An image may be continuous with respect to the x- and y-coordinates, and also in amplitude. To convert it to digital form, we have to sample the function in both coordinates and in amplitude. Digitizing the coordinate values is called ***sampling***. Digitizing the amplitude values is called ***quantization***. The one-dimensional function shown in Figure is a plot of amplitude (gray level) values of the continuous image along the line segment ***AB***. To sample this function, we take equally spaced samples along line ***AB***. In order to form a digital function, the gray-level values also must be converted (***quantized***) into discrete quantities.

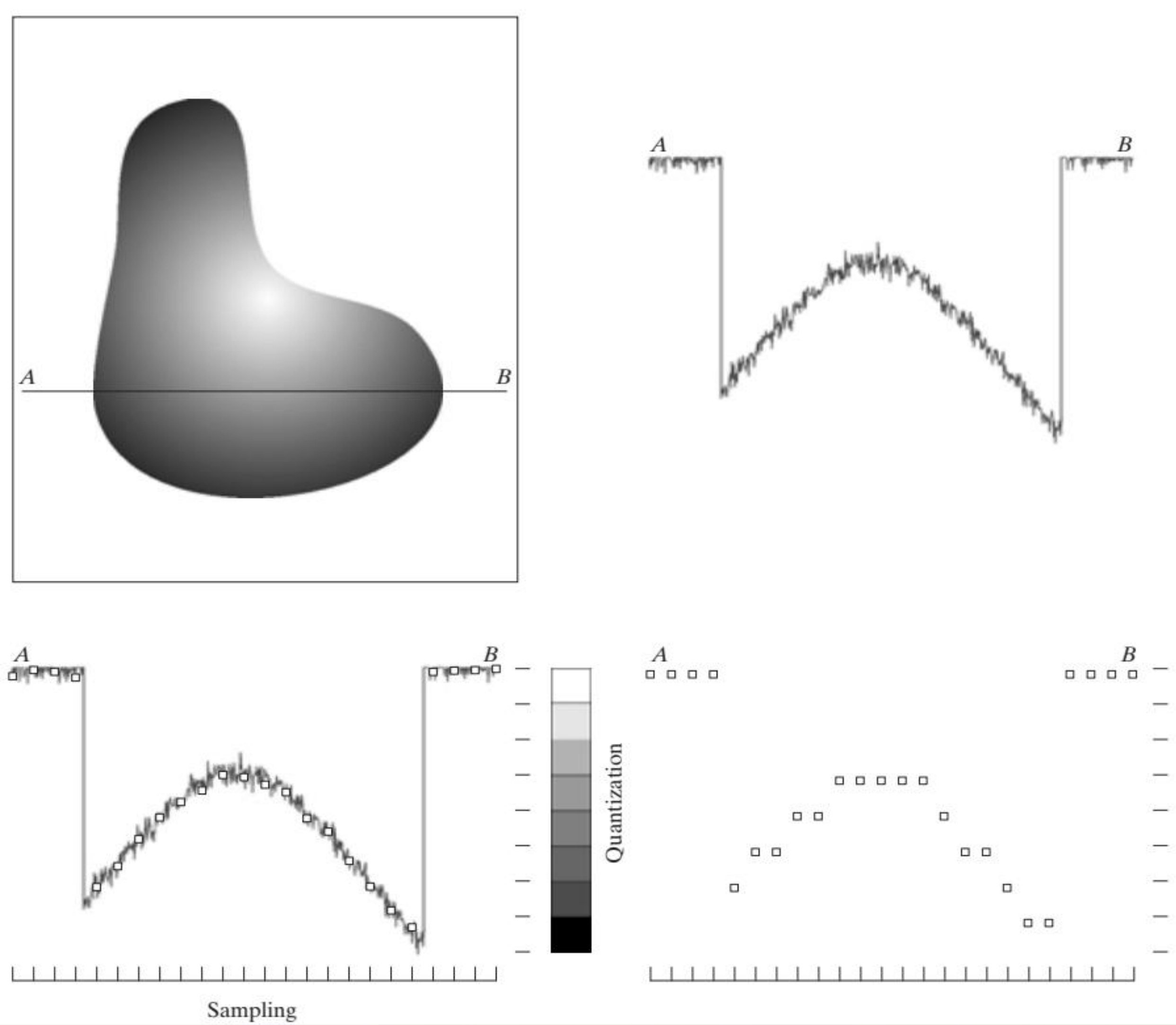
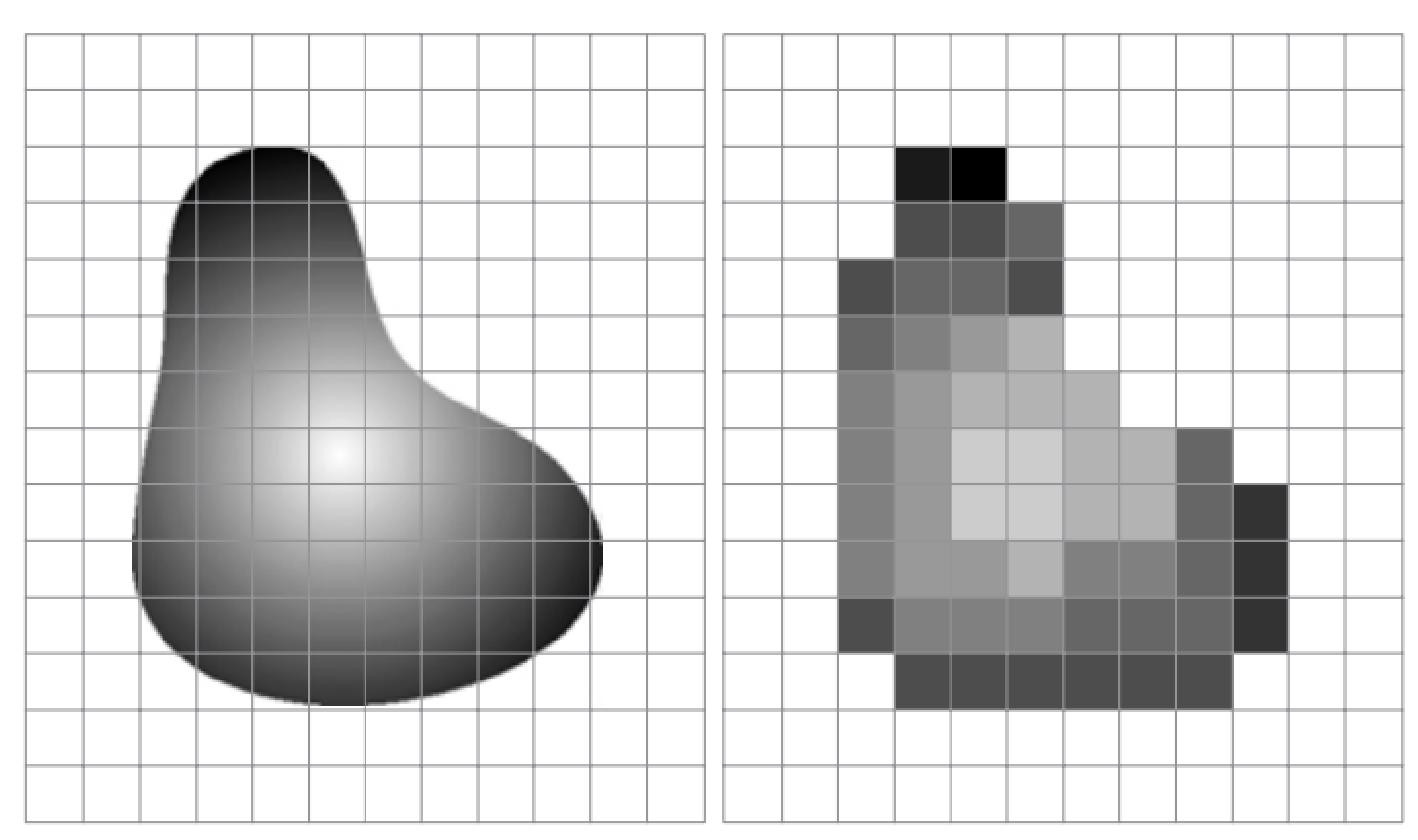


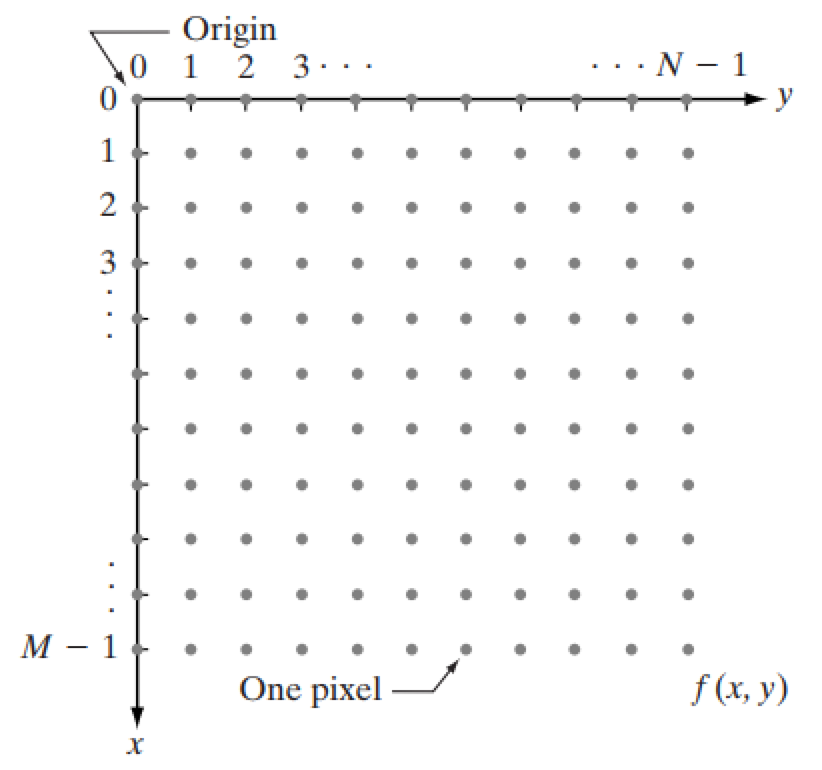
Image Sampling and Quantization

The final output looks like



Representation of Digital Image

Assume that an image ***f(x, y)*** is sampled so that the resulting digital image has ***M*** rows and ***N*** columns. The values of the coordinates ***(x, y)*** now become ***discrete*** quantities. Thus, the values of the coordinates at the origin are ***(x, y)=(0, 0).*** The next coordinate values along the first row of the image are represented as ***(x, y)=(0, 1).***



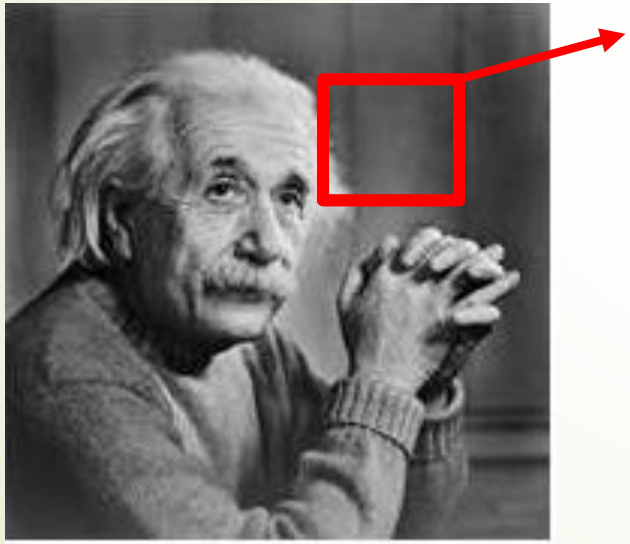
Representation of Digital Image

The notation introduced in the preceding paragraph allows us to write the complete ***MxN*** digital image in the following matrix form

$$f(x, y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0, N-1) \\ f(1,0) & f(1,1) & \cdots & f(1, N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1, N-1) \end{bmatrix}$$

Each element of this matrix array is called an ***image element***, ***picture element, pixel***

Representation of Digital Image



255	100	0	5	22	10
147	20	128	26	78	99
33	25	58	0	0	11
37	221	111	52	68	98
255	87	102	84	5	7
44	78	158	255	0	0

Brightness and contrast

Brightness is a relative term! For two different images we may judge which one is brighter (Resp. darker).

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Image 1

0,3	0,3	0,3	0,3
0,3	0,3	0,3	0,3
0,3	0,3	0,3	0,3
0,3	0,3	0,3	0,3

Image 2 = Image 1+0,3

0,6	0,6	0,6	0,6
0,6	0,6	0,6	0,6
0,6	0,6	0,6	0,6
0,6	0,6	0,6	0,6

Image 3 = Image 2+0,3

Brightness and contrast

We notice that image 2 is brighter than image 1. Contrary, we can see that image 2 is darker than image 3. It can be calculated according the following equation (average brightness)

$$B = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} I(i,j)$$

As for contrast, it can be defined as the difference between maximum and minimum pixel intensity in an image.

$\boldsymbol{Contrast} = Max\ intensity\ - Min\ intensity$

Example: contrast of image 1 = contrast of image 2 = 0

Brightness and contrast

Other definitions for the contrast

$$\sqrt{\frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left(I_{ij}-\bar{I}\right)^2}$$

$$\frac{I_{\max}-I_{\min}}{I_{\max}+I_{\min}}$$

Low contrast image

High contrast image

Representation of Digital Image

How many level there are?

This digitization process requires decisions about values for ***M***, ***N***, and for the number, ***L***, of discrete gray levels allowed for each pixel. There are no requirements on ***M*** and ***N***, other than that they have to be positive integers. However, due to processing, storage, and sampling hardware considerations, the number of gray levels typically is an integer power of **2**

$$L = 2^K$$

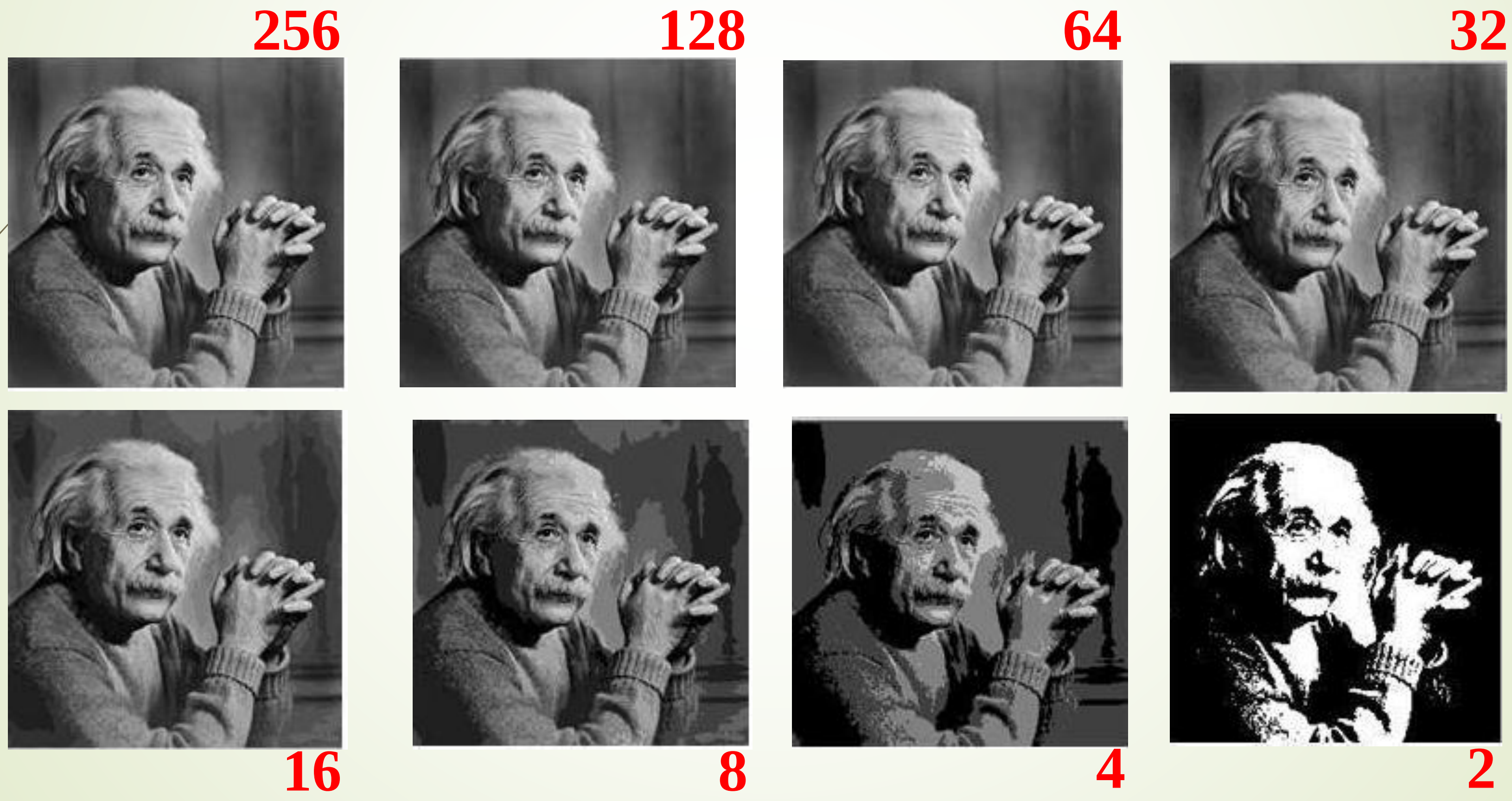
K in this case is called **B**its **P**er **P**ixel (**BPP**) or ***bit depth***, which refers to the number of bits dedicated to represent intensity of a given pixel.

Generally, in gray-level images ***BPP = 8***. Thus, the total number of levels is 2^8**=256**

00000000
00000001
00000010
00000011
....
....
....
11111111

Representation of Digital Image

The following image shows the effect of reducing number of gray level progressively



Storage Requirements

Theoretically, the number, ***b***, of bits required to store a digitized image is

$$b = M \times N \times K$$

N/k	1 (L = 2)	2 (L = 4)	3 (L = 8)	4 (L = 16)	5 (L = 32)	6 (L = 64)	7 (L = 128)	8 (L = 256)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

For an image of **300 x 500** pixels ***Size= Height* × *Width* × *BPP* = *300* × *500* × *8* = *12 00 000 bit***

Size (Ko) = (12 00 000 / 8) / 1024 = 146 Ko

Storage Requirements

Calculate the size of color image and its gray level version

If for each channel RGB and gray scale, we have a bit depth = 8, and if the image size is **300 x 500** pixels then,

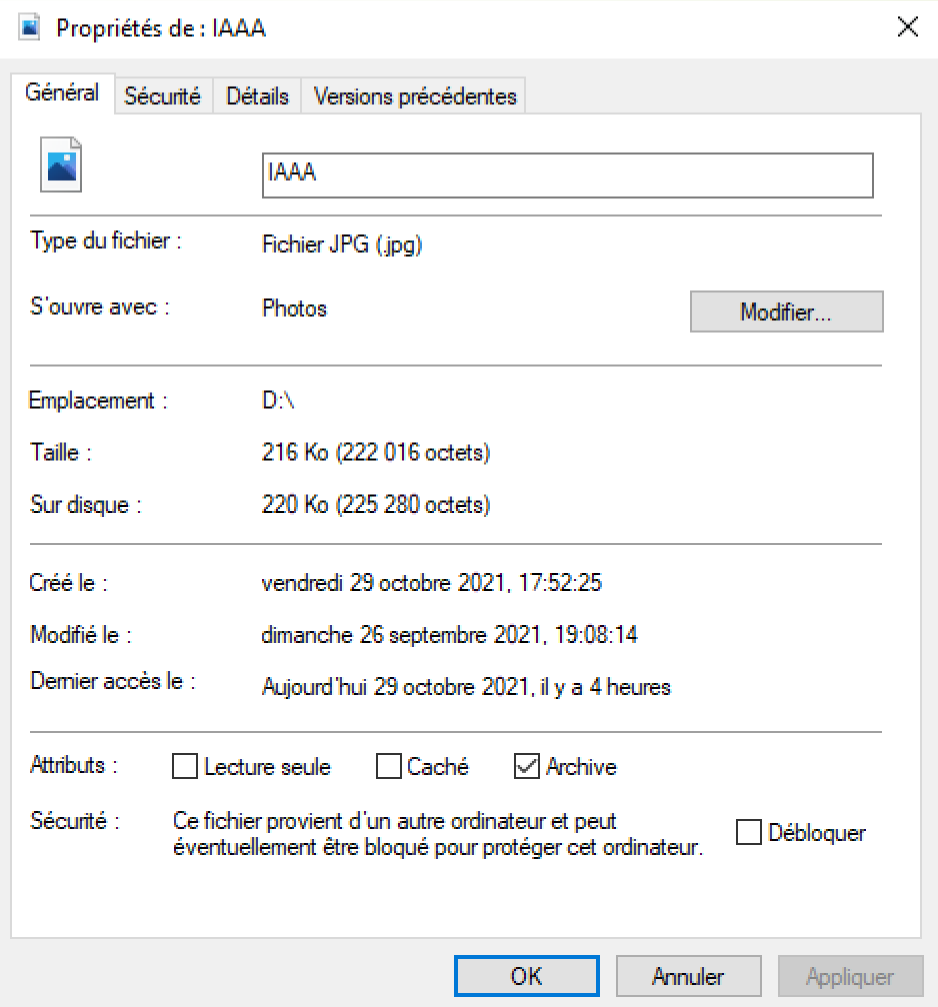
Size of Gray image= 300 × 500 × 8 = 12 00 000 bits = (12 00 000 / 8) / 1024 = 146 Ko

Size of Color image= 300 × 500 × 24 = 36 00 000 bits = (36 00 000 / 8) / 1024 = 439 Ko

Image formats

Actual VS calculated image size

*Calculated size = **439 Ko***
*Actual size = **216 Ko !!!!! why***



Pixel and Spatial Resolution

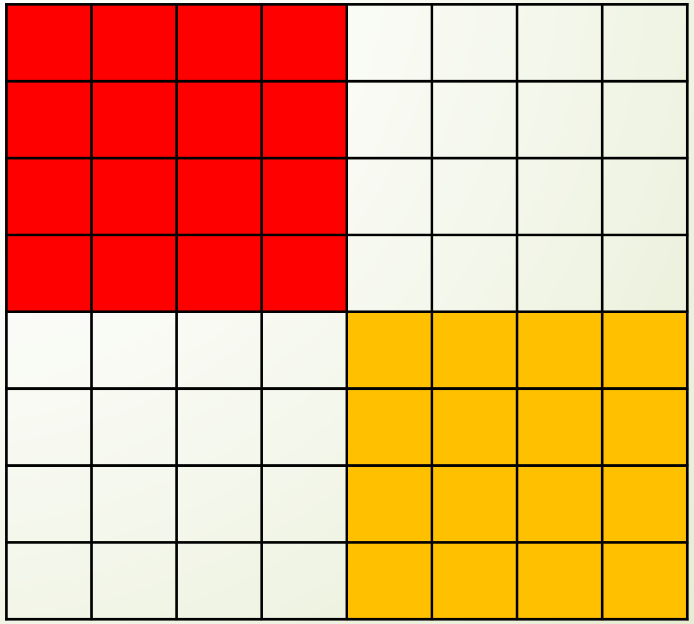
It refers to the total number of pixels in the image. Given an image I with a height = M and width = N

Pixel Resolution $(\boldsymbol{I})$ = $M \times N$

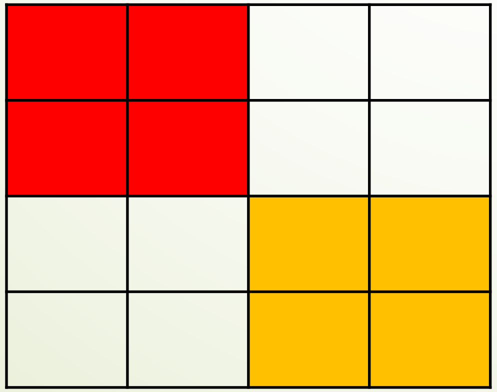
In ***Mega Pixels,*** pixel resolution is $\frac{M\times N}{1\,000\,000}$ E.g., for an image of 3000×2000 dimensions, pixel resolution is equal to

$$\frac{(3000\times 2000)}{1000\,000} = 6\ Mega\ Pixel$$

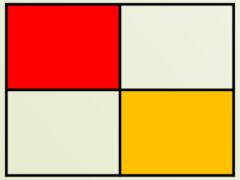
$\mathbf{8 \times 8}$



$\mathbf{4 \times 4}$



$\mathbf{2 \times 2}$

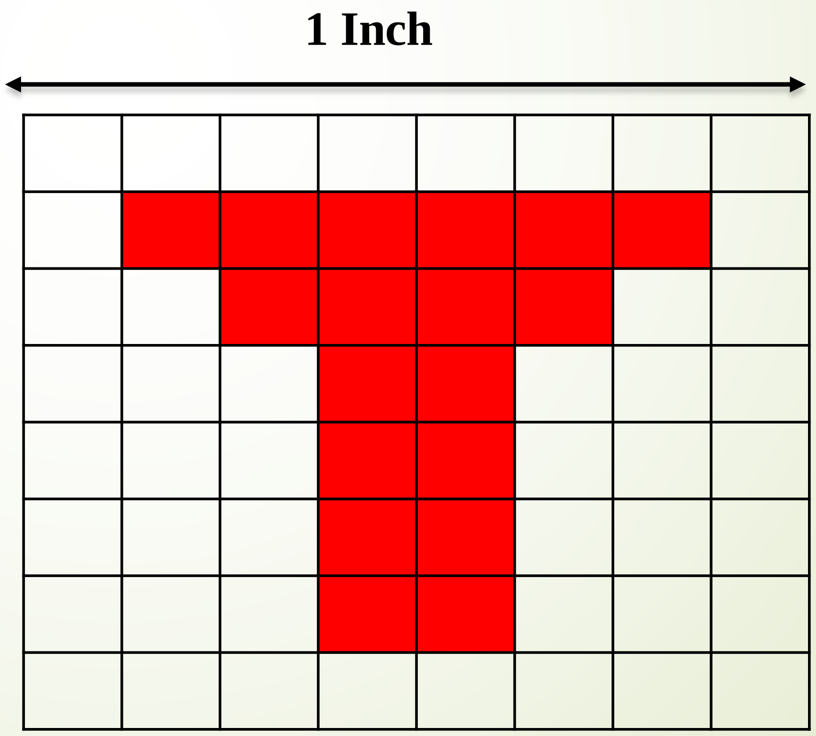


Pixel and Spatial Resolution

What is the difference between the two following images

Pixel and Spatial Resolution

Suppose that we construct a chart with vertical lines of width ***W***, with the space between the lines also having width ***W***. A ***line pair*** consists of one such line and its adjacent space. A widely used definition of resolution is simply the smallest number of discernible line pairs per unit distance; for example, 100 line pairs per millimeter.

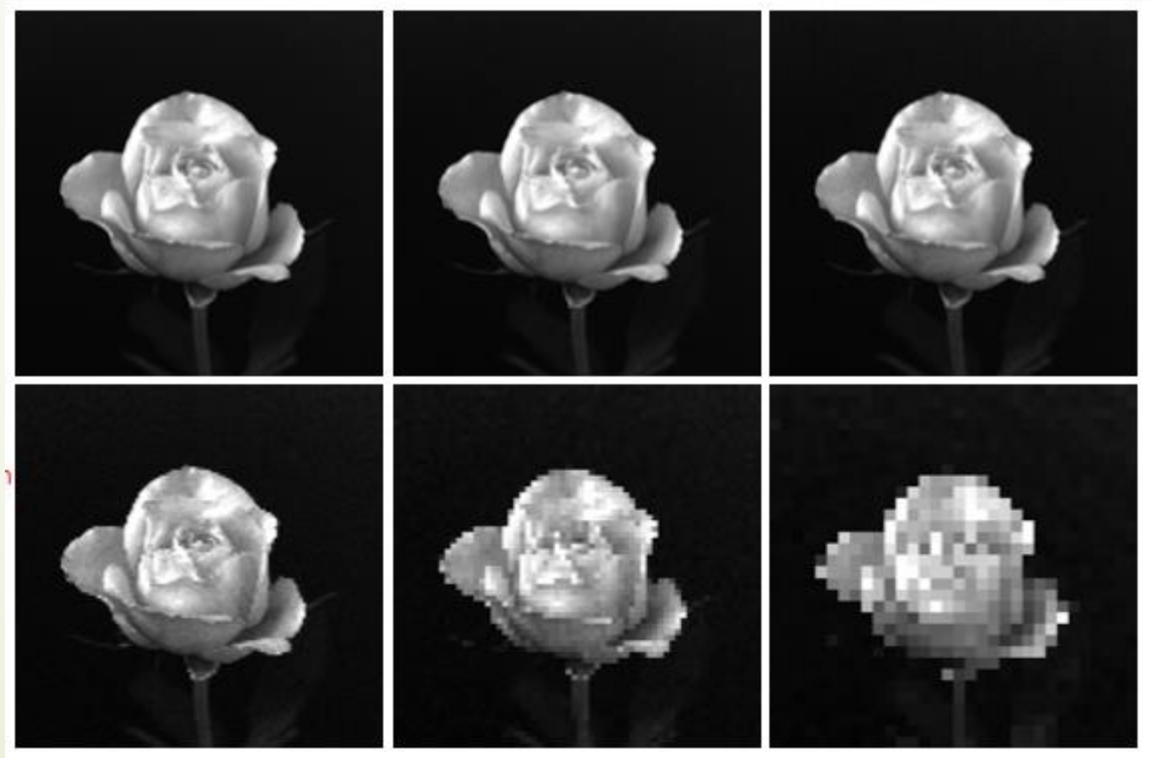


Pixel resolution = 8×8

Spatial resolution = 8 pixels/Inch

Pixel and Spatial Resolution

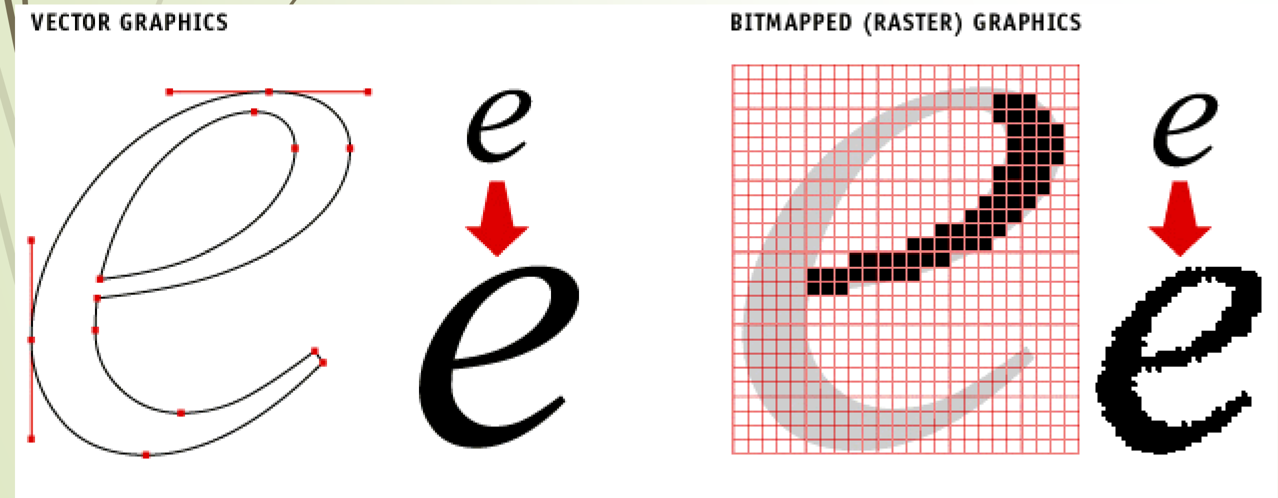
Increasing image size doesn’t increase its spatial resolution, noting that increasing size can be done by replicating every row and column

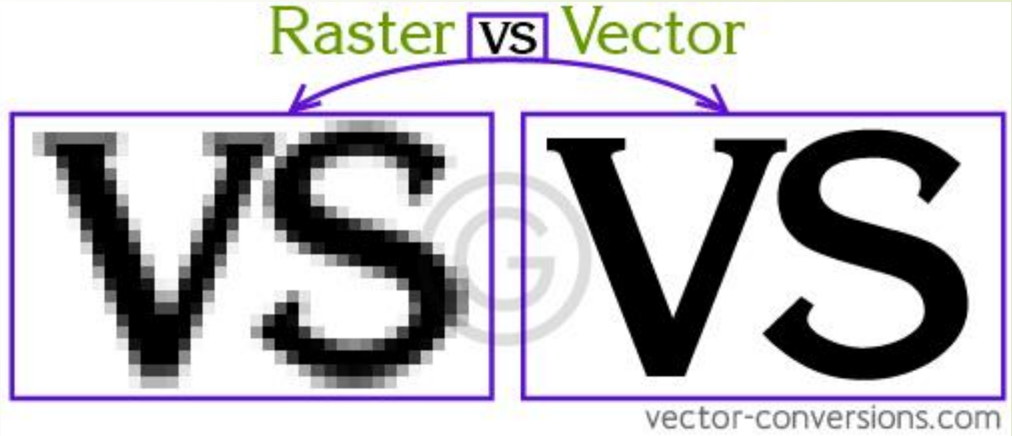


Raster versus vector image

Mainly, there are two type of images namely ***Raster*** and ***Vector***.

Raster images are pixel-based and they are created using pixel-based software or captured with a camera or scanner e.g., jpg, gif, png. Vector images are math-defined shapes created with vector software and are not common (e.g., they are used in graphic Design). Vector images created using geometric shapes defined on a Cartesian plane, such as points, lines, Curves and polygons.





Raster versus vector image

Raster	Vector
Created using pixels	Shapes based on mathematical calculations
Well-suited for editing photos and soft color blends	Well-suited for logos, drawings and illustrations
Scale up image degrade its quality. Image must be created/scanned for a better resolution	Can be scaled to any size without losing quality
Large dimensions = large file size	A large dimension vector graphic maintains a small file size. For example, a square can be unambiguously defined by the locations of three of its four corners only.
Depending on the complexity of the image, conversion to vector may be time consuming	Vector image can be easily rasterized to be used for all processes
The most common image format including: jpg, gif, png, tif, bmp, psd, eps	Common formats: ai, cdr, svg, and eps created by vector programs
Common programs for photo editing and painting such as Photoshop, Paint Shop, GIMP.	Common vector programs: drawing programs such as Illustrator, CorelDraw, Inkscape.

Image formats

There are several image formats which differ from each other in terms of several features, common formats include JPEG, PNG, BMP, GIF, TIF,…..etc.

	JPEG	PNG	TIF	PSD	BMP
Max Pixel Depth	8 bits	16 bits	32 bits	16 bits	8 bits
Compression	JPEG	Deflate	None / LZW / RLE / ZIP	NONE / RLE	NONE / RLE
Transparency	NON	YES	YES	YES	YES
Type of image	Raster	Raster	Raster / vector	Raster / vector	Raster

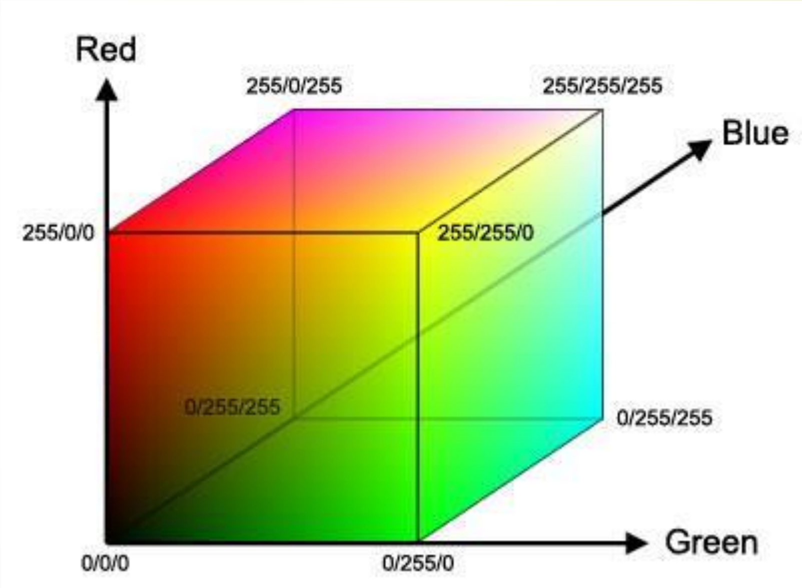
Color Spaces (RGB)

- The principle of this color space is to represent every visible color into a combination of three colors: **R**ed, **G**reen and **B**lue (primary colors).

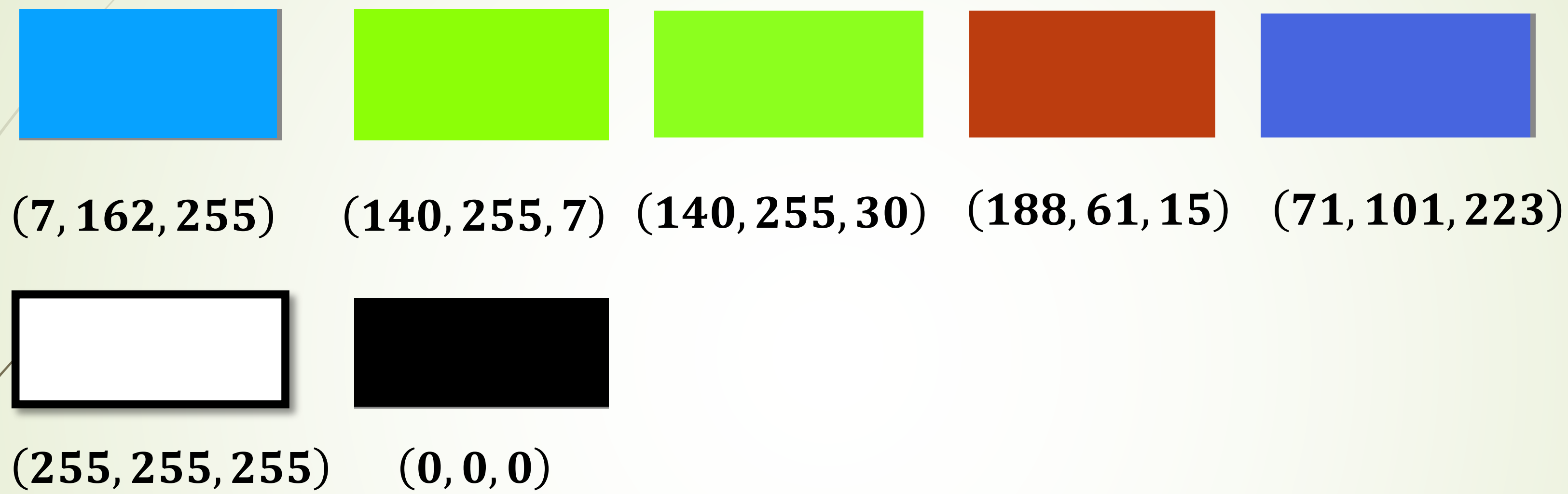
- Wavelength of these color are $\boldsymbol{\lambda_R = 700\,nm \quad \lambda_G = 546\,nm \quad \lambda_B = 435\,nm}$

- The intensity of each primary color ranges from 0 to 255.

- By mixing different intensities of the primary colors, about 17 000 000 (256^3) colors is counted.

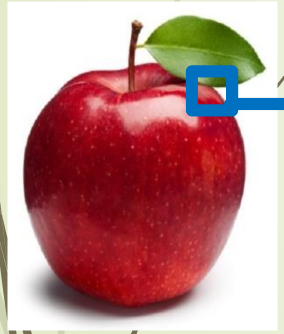


Color Spaces (RGB)



However, it is difficult for humans to distinguish colors having very close values.

Color Spaces (RGB)



255	220	223
58	222	10
78	111	12

25	0	1
25	255	10
100	20	54

125	17	47
0	124	255
0	13	95

R

G

B

Color Spaces (RGB)

Conversion of color image to gray-scale

As gray scale represents one channel, one way to generate intensity image is to average the values of the three RGB channels as follows:

$$I_{GL}(X,Y) = I_R(X,Y) + I_G(X,Y) + I_B(X,Y)$$

Of course, this is not the gray level image we always see. The resulting image seems much more darker.

Color Spaces (RGB)

Conversion of color image to gray-scale

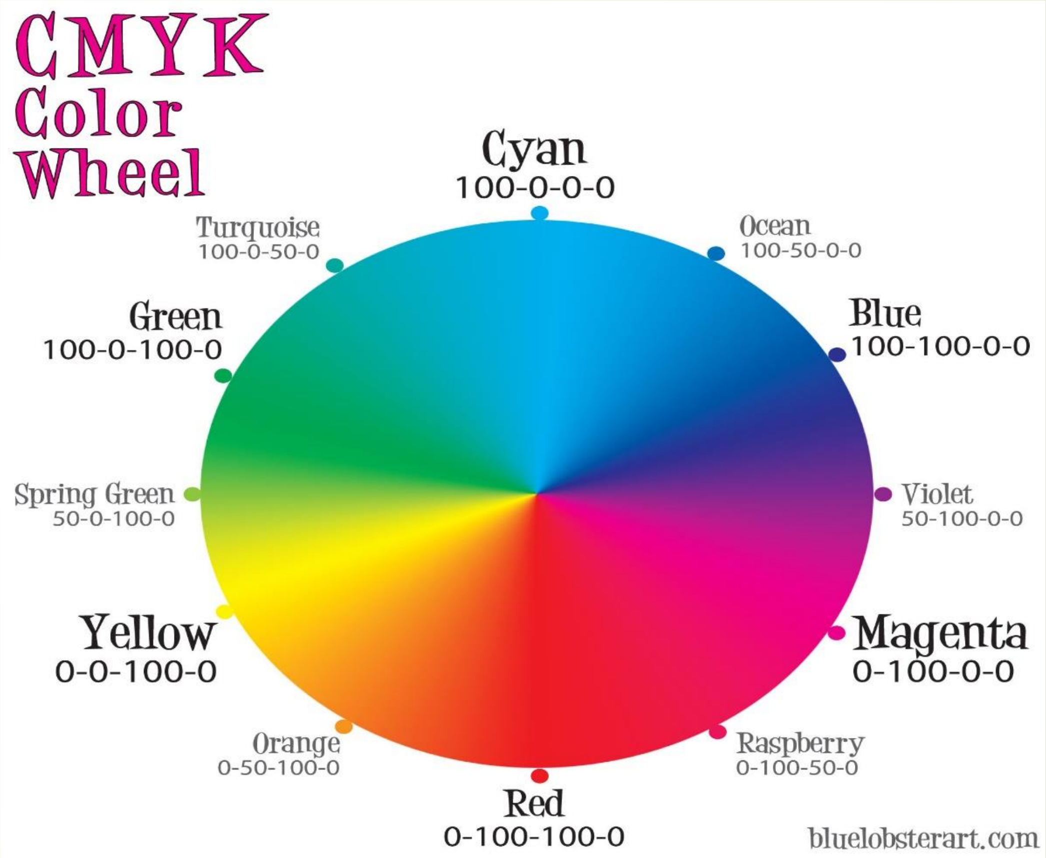
Through many experiments, psychologists figured out that humans perceive red, green and blue differently e.g., green is look brighter several times than blue. Therefore, a weighted averaging is considered to calculate the intensity image.

$$\boldsymbol{I_{GL}(X,Y) = 0.29 \times I_R(X,Y) + 0.58 \times I_G(X,Y) + 0.11 \times I_B(X,Y)}$$

Color Spaces (CMYK)

CMYK stands for **C**yan, **M**agenta, **Y**ellow and **K**ey (i.e., black), and it is used by printers. Compared to RGB, which uses light to show images in different screens (TV, PC, smartphone,…), CMYK uses colored ***ink*** to mask colors on a light background (white paper). This light background (usually white) reflects light, so each layer of ink applied subtracts from white light to make new colors.

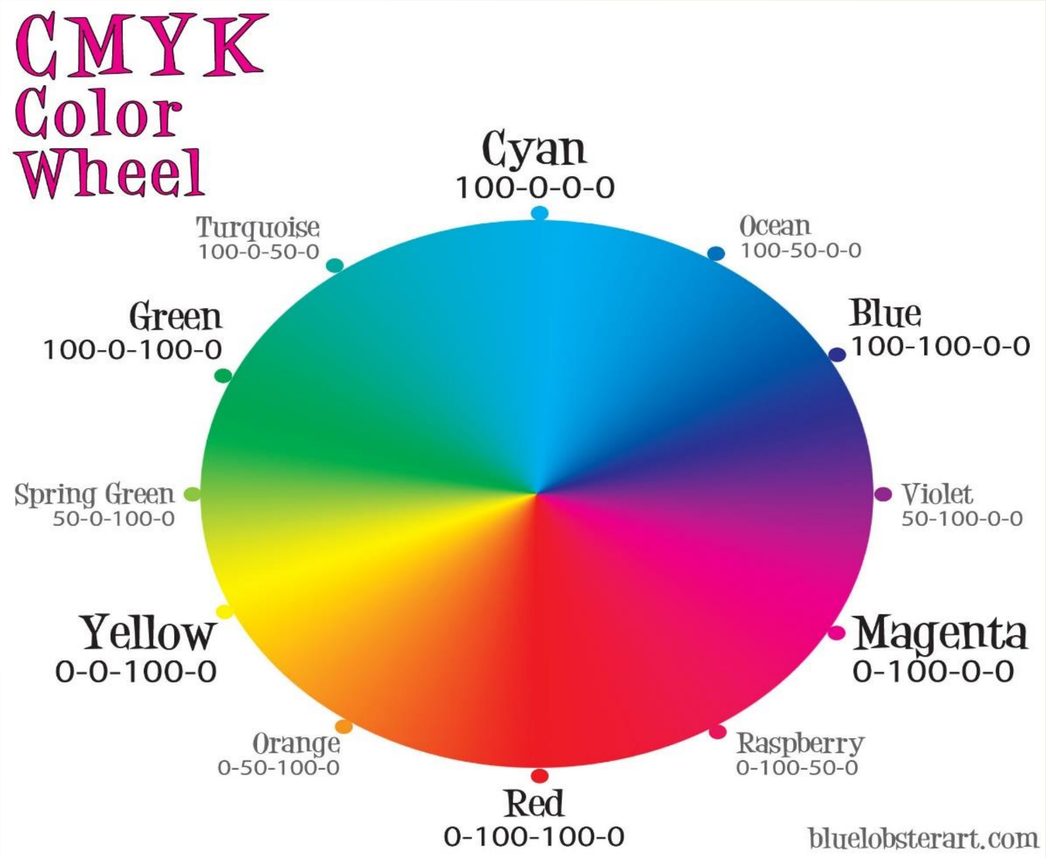
The CMYK color model is a ***subtractive*** color model. ***Subtractive*** means that the more ink added, the closer you get to black. In the contrary, RGB is ***additive*** model because we add colors to each other to go from black to white.



Color Spaces (CMYK)

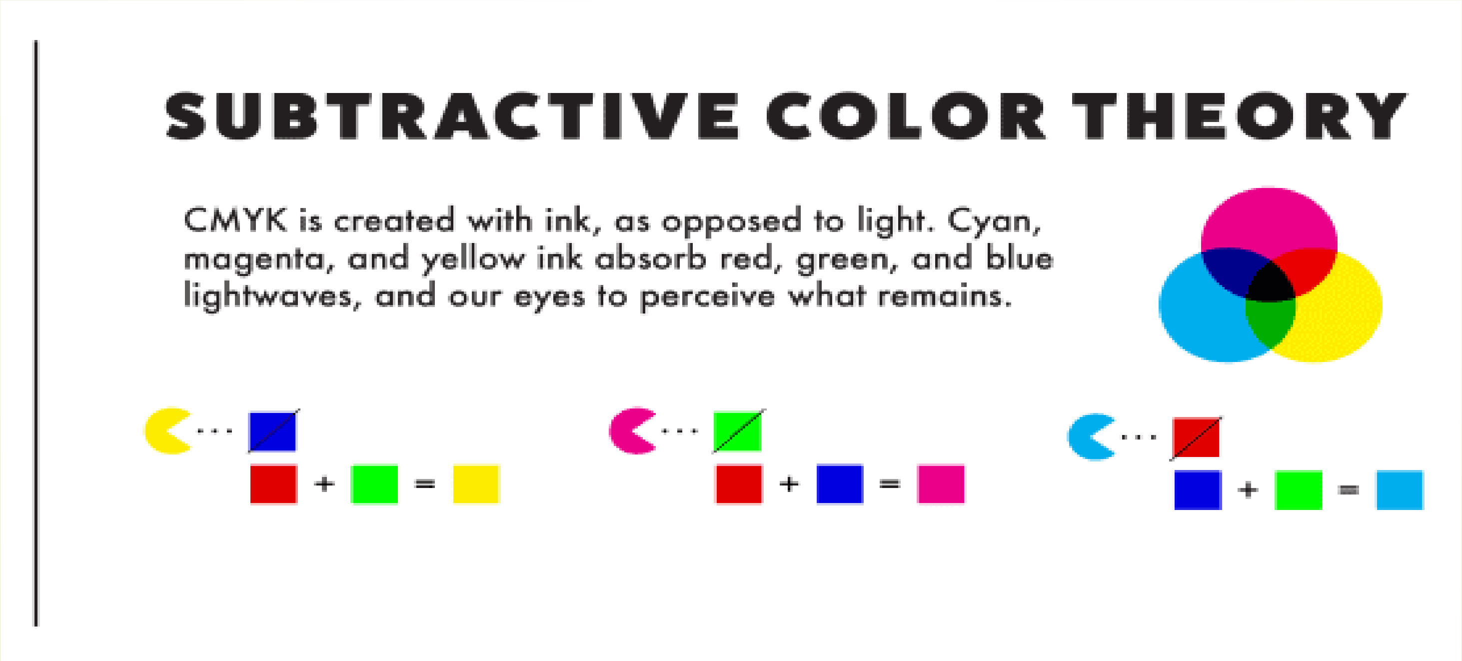
Why CMYK is used for printing

Compared to RGB which starts from black color and end up with white, in CMYK, all colors start as white (e.g., white paper), and each layer of ink reduces the initial brightness to create the preferred color. Thus, since the paper on which we print is white, CMYK is used for printing.



Color Spaces (CMYK)

Printers use ***cyan***, ***magenta*** and ***yellow*** inks in various percentages to control the amount of ***red***, ***green*** and ***blue*** light reflected from ***white*** paper. ***Cyan*** is the complement of ***red*** i.e., the ***cyan*** serves as a filter that absorbs ***red***. The amount of ***cyan*** applied to a ***white*** sheet of paper controls how much of the ***red*** in white light will be reflected back from the paper. It is worth mentioning that the ***cyan*** is completely transparent to ***green*** and ***blue*** light and has no effect on those parts of the spectrum. ***Magenta*** is the complement of ***green***, and ***yellow*** the complement of ***blue***.



Color Spaces (CMYK)

Here, we can notice that to produce ***red*** color, the value of cyan should be 0, as ***cyan*** controls the amount of ***red***. To produce the ***Green*** color the value of ***Magenta*** should be 0. In addition, to produce ***Blue*** the value of ***Yellow*** should be 0.

Note that pure black cannot be produced by mixing up the three components (Magenta, Cyan, Blue), for this reason a fourth component is added (key or black).

Color	Color name	(R,G,B)	Hex	(C,M,Y,K)
	Black	(0,0,0)	#000000	(0,0,0,1)
	White	(255,255,255)	#FFFFFF	(0,0,0,0)
	Red	(255,0,0)	#FF0000	(0,1,1,0)
	Green	(0,255,0)	#00FF00	(1,0,1,0)
	Blue	(0,0,255)	#0000FF	(1,1,0,0)
	Yellow	(255,255,0)	#FFFF00	(0,0,1,0)
	Cyan	(0,255,255)	#00FFFF	(1,0,0,0)
	Magenta	(255,0,255)	#FF00FF	(0,1,0,0)

Color Spaces (CMYK)

The values of CMYK are ranging from 0 to 100. **0 0 0 0** gives white (No ink is supplied), whereas, **0 0 0 100** gives black color.

C:	100	70	50	30	10	100	70	50	35	10
M:	0	0	0	0	0	50	35	25	15	5
Y:	30	20	15	10	3	0	0	0	0	0
K:	0	0	0	0	0	0	0	0	0	0

C:	20	15	10	5	2	0	0	0	0	0
M:	10	5	5	3	0	10	5	5	3	0
Y:	100	70	50	30	15	100	70	50	30	10
K:	0	0	0	0	0	0	0	0	0	0

C:	10	10	5	3	0	10	7	5	3	0
M:	100	70	50	30	10	100	100	50	30	10
Y:	0	0	0	0	0	50	35	25	15	5
K:	0	0	0	0	0	0	0	0	0	0

C:	0	0	0	0	5	100	100	100	60	0
M:	100	60	30	5	100	0	15	70	100	30
Y:	100	100	100	100	0	100	0	0	0	0
K:	0	0	0	0	0	0	0	0	0	0

C:	0	0	0	0	0	30	25	20	15	5
M:	0	0	0	0	0	30	25	20	15	5
Y:	0	0	0	0	0	30	25	20	15	5
K:	100	70	50	30	10	100	70	50	30	10

C:	0	0	0	0	0	20	15	10	5	2
M:	100	70	50	30	10	100	70	50	30	10
Y:	100	70	50	30	10	100	70	50	30	10
K:	0	0	0	0	0	0	0	0	0	0

Color Spaces (CMYK)

Conversion from RGB to CMYK

The R,G,B values are divided by 255 to change the range from 0/255 to 0/1

$$R' = R/255$$

$$G' = G/255$$

$$B' = B/255$$

$$K = 1 - \max(R', G', B')$$

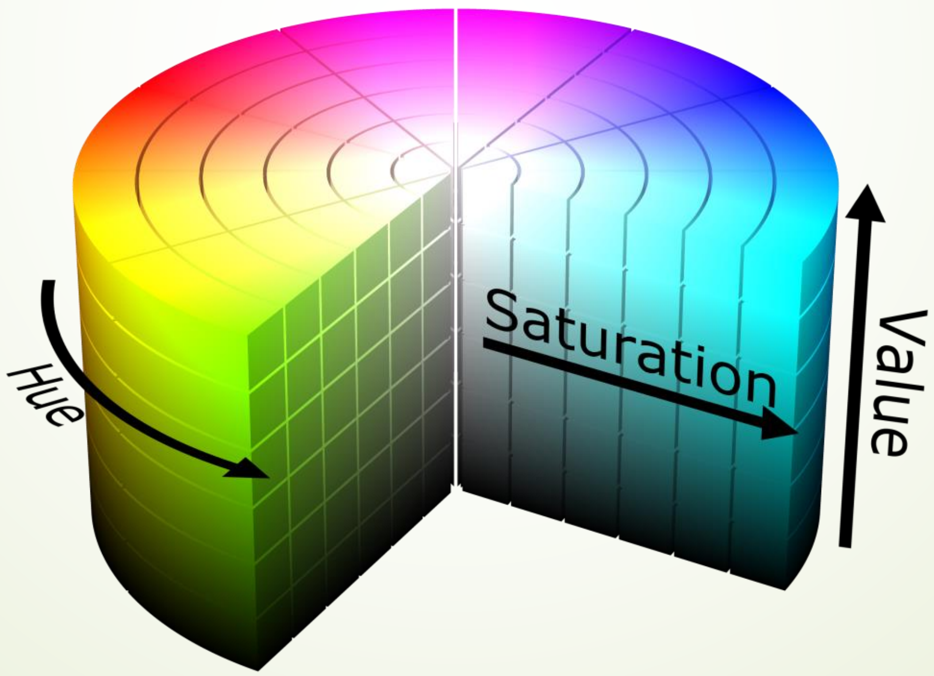
$$C = (1 - R' - K) / (1 - K)$$

$$M = (1 - G' - K) / (1 - K)$$

$$Y = (1 - B' - K) / (1 - K)$$

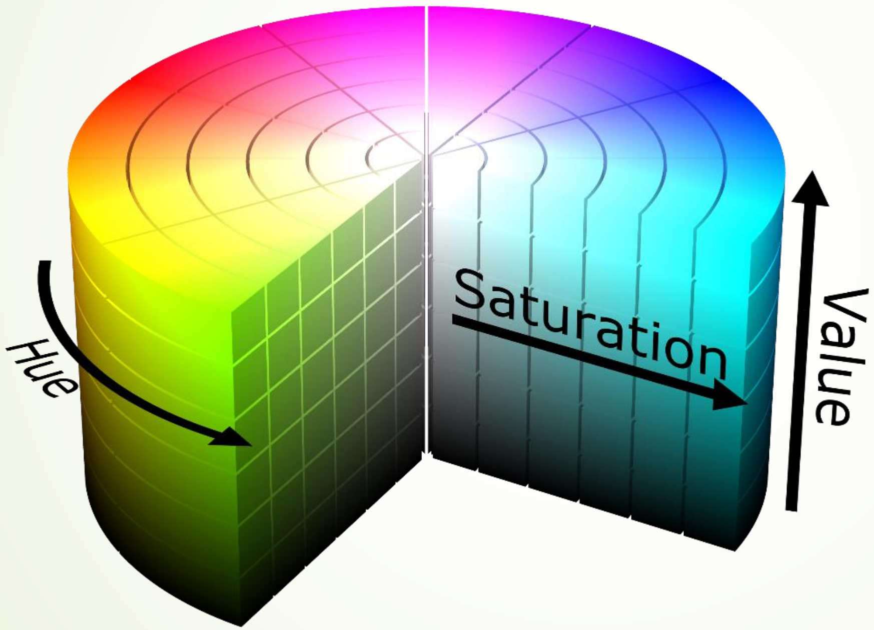
Color Spaces (HSV)

HSV color space is the most close space to the human perception i.e., how humans perceive colors. Indeed, human perception is not like RGB or CMYK colors. They are just primary colors fused to create the spectrum. The ***H*** stands for ***Hue***, ***S*** stands for ***Saturation***, and the ***V*** stand for ***value***.



Color Spaces (HSV)

Hue	
0-60	**Red**
60-120	**Yellow**
120-180	**Green**
180-240	**Cyan**
240-300	**Blue**
300-360	**Magenta**



Saturation: represents the amount of white light that is mixed with the color. A 100% saturation means stands for the complete pure color, whereas, a 0% saturation means no color (pure white). We can note that for saturation = 0, it's the *gray-scale*.

Value: represents the brightness concerning the saturation of the color. It represents the chromatic notion of intensity. The lower the value is the similar to black is (all colors (Hue) will be similar to black). The value 0 represents total black, while the value 100 will mean a full brightness and depend on the saturation.

Saturation and value are well-suited to represent the notion of color brightness and darkness, for this reason HSV is considered to be close to the human perception

Color Spaces (HSV)

Conversion from RGB to HSV

$$R' = R/255$$

$$G' = G/255$$

$$B' = B/255$$

$$Cmax = \max(R', G', B')$$

$$Cmin = \min(R', G', B')$$

$$\Delta = Cmax - Cmin$$

Hue calculation:

$$H = \begin{cases} 0^\circ & \Delta = 0 \\ 60^\circ \times \left(\frac{G'-B'}{\Delta} mod 6\right) & , C_{max} = R' \\ 60^\circ \times \left(\frac{B'-R'}{\Delta} + 2\right) & , C_{max} = G' \\ 60^\circ \times \left(\frac{R'-G'}{\Delta} + 4\right) & , C_{max} = B' \end{cases}$$

Saturation calculation:

$$S = \begin{cases} 0 & , C_{max} = 0 \\ \frac{\Delta}{C_{max}} & , C_{max} \neq 0 \end{cases}$$

Value calculation:

$$V = Cmax$$

Color Spaces (HSV)

Conversion from HSV to RGB

When $0 \le H < 360$, $0 \le S \le 1$ and $0 \le V \le 1$:

$$C = V \times S$$

$$X = C \times (1 - |(H / 60°) \bmod 2 - 1|)$$

$$m = V - C$$

$$(R', G', B') = \begin{cases} (C, X, 0) & , 0° \le H < 60° \\ (X, C, 0) & , 60° \le H < 120° \\ (0, C, X) & , 120° \le H < 180° \\ (0, X, C) & , 180° \le H < 240° \\ (X, 0, C) & , 240° \le H < 300° \\ (C, 0, X) & , 300° \le H < 360° \end{cases}$$

$$(R,G,B) = ((R'+m)\times 255, (G'+m)\times 255, (B'+m)\times 255)$$

Color Spaces (YCbCr)

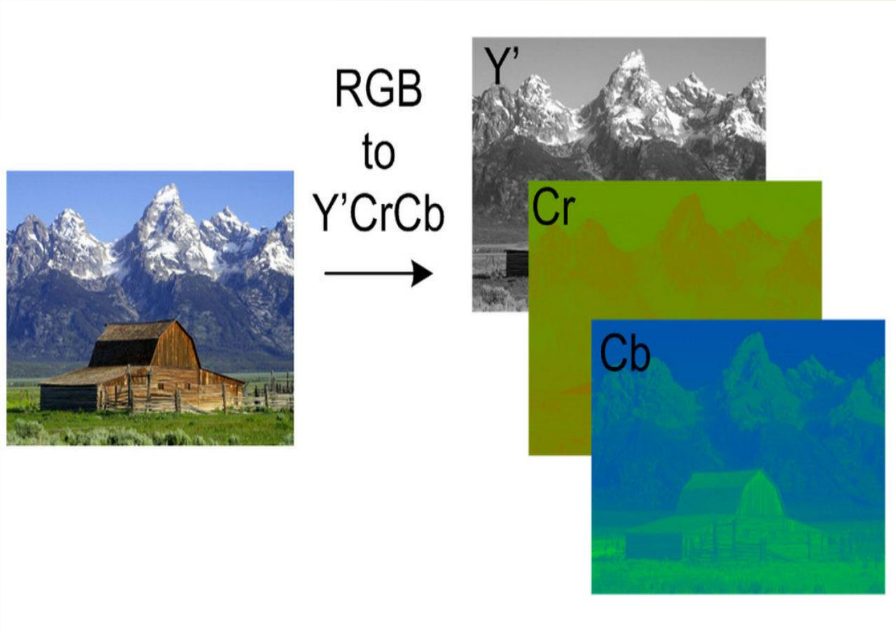
The YCbCr color space separate the image into three components:

- ***The luminance*** component which represents the brightness (like gray-scale).

- ***Cb*** is the chrominance blue value

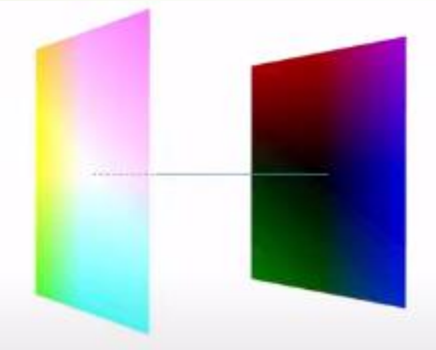
- ***Cr*** is the chrominance red value

We can notice that luminance (achromatic) and color (chromatic) components are separated.

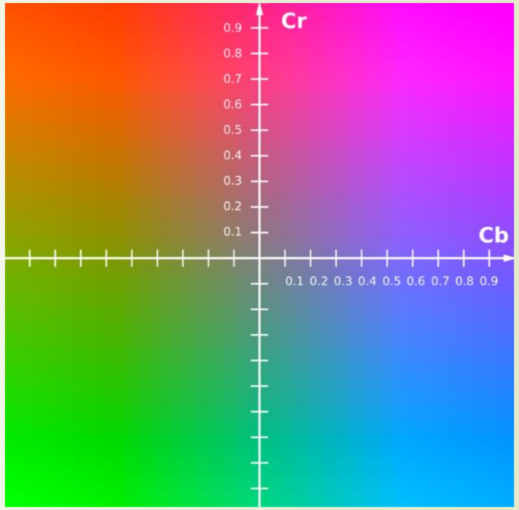


Color Spaces (YCbCr)

YCbCr can be visualized in 3 dimensions



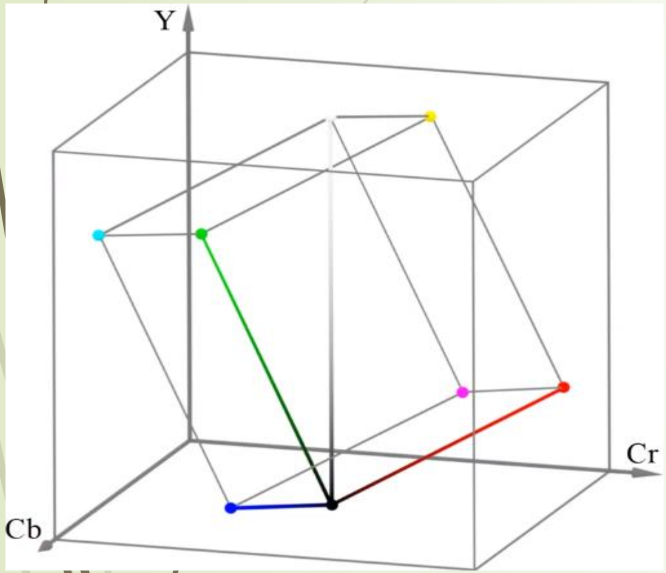
Y = 0.5

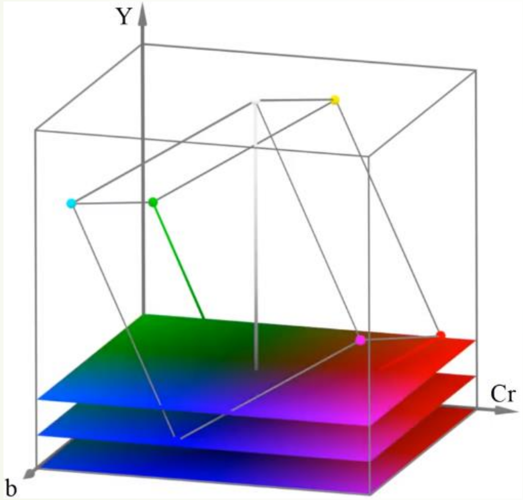


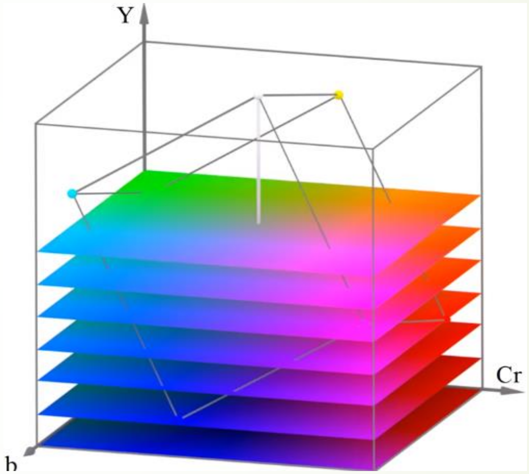
The center of the cube face is ***white***, and the center of the opposite side is ***black***. The line linking the both sides is the luminance component (from black to white). Therefore, each color can be represented by the center of one thin slice from the cube (luminance) + coordinates in the plane of ***Cb / Cr.***

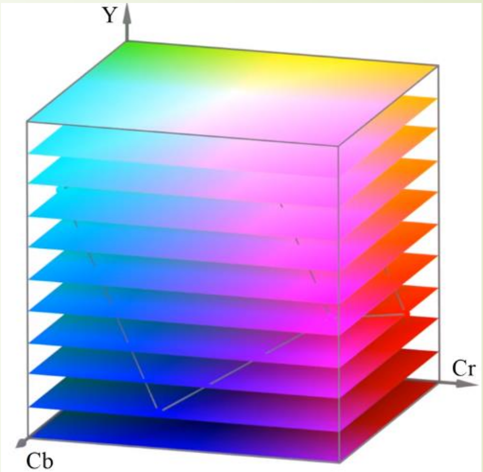
Color Spaces (YCbCr)

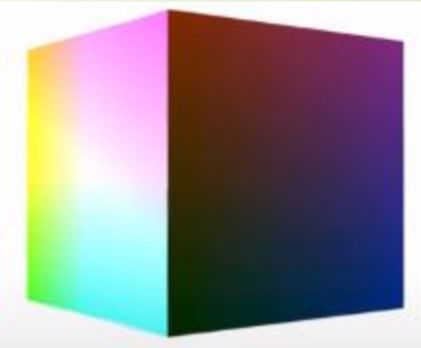
The RGB color space inside the YCbCr, here is shown how cube slices are constructed







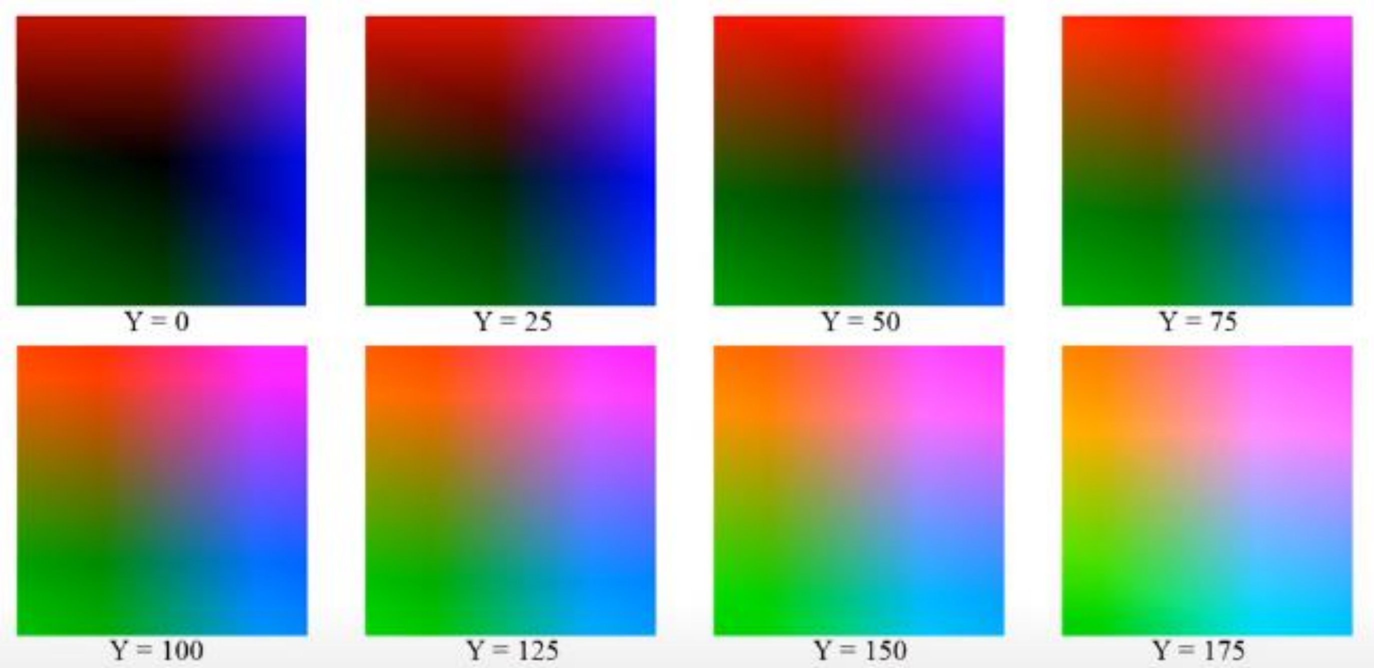




We can notice the change in CbCr planes
with the intersection with the RGB cube

Color Spaces (YCbCr)

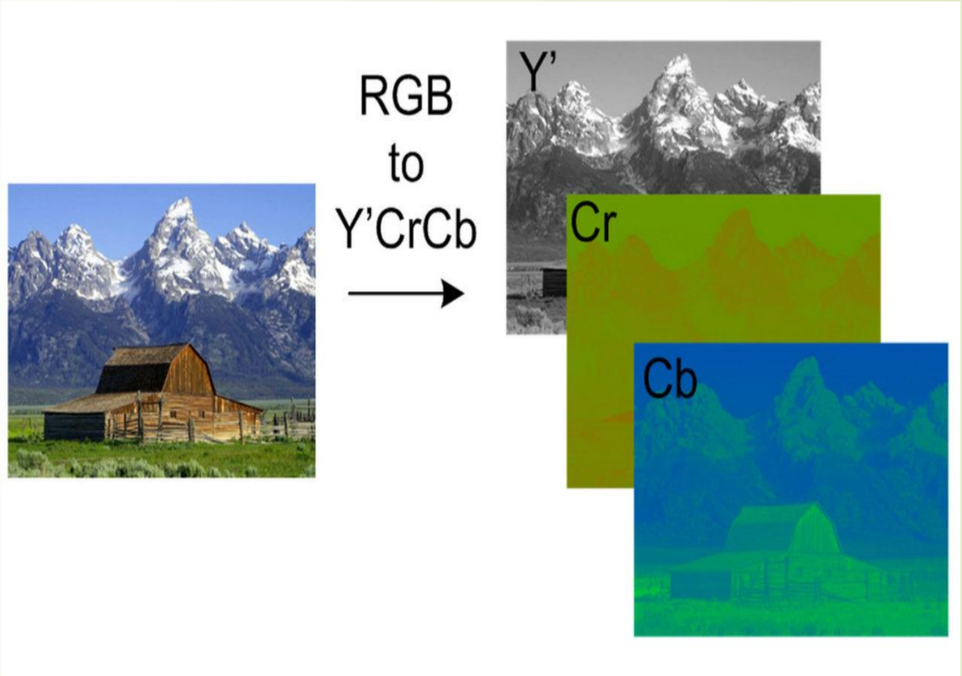
CbCr planes for different values of Y



Color Spaces (YCbCr)

A highly desirable property of YCbCr

Researchers have shown that humans are more sensitive to different levels of brightness than it is to differences in color. Since the brightness component (Y) is separated from the color (chromatic) components, these components are subsampled. This is called chroma. subsampling and it allows reducing the amount of bit allocated to the image.



Color Spaces (YCbCr)

Conversion between RGB and YCbCr

$$
\begin{aligned}
Y &= 0.299 \cdot R + 0.587 \cdot G + 0.114 \cdot B \\
Cb &= 0.564 \cdot (B - Y) + 128 \\
Cr &= 0.713 \cdot (R - Y) + 128
\end{aligned}
$$

$$
\begin{aligned}
R &= Y + 1.403 \cdot (Cr - 128) \\
G &= Y - 0.344 \cdot (Cb - 128) - 0.714 \cdot (Cr - 128) \\
B &= Y + 1.773 \cdot (Cb - 128)
\end{aligned}
$$

Image Basics

- ## Quantization Algorithm

Algorithm: Quantization;

Input: image **I (N,M)**;   int **GL_Values** [1..K]; int **Nbre_Levels**; Boolean **B**;
Output: image **QI**;

```
Begin
For i=1 to N
  For j=1 to M
     B = Faux;
     For t=1 to K
        if (GL_Value[t] >= I(i,j) )
           QI(i,j) = GL_Value[t];
            B = Vrai;
            break;
        end
     end
If (B == Faux)
QI(i,j) = GL_Value[end];  % or 255
End end end
End.
```