

CAP 4453

Robot Vision

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Administrative details

- Grader Email: yousafadeel1993@gmail.com
- Assignment Zero:
 - Due tomorrow
- Assignment 1:
 - Deadline: Next Friday

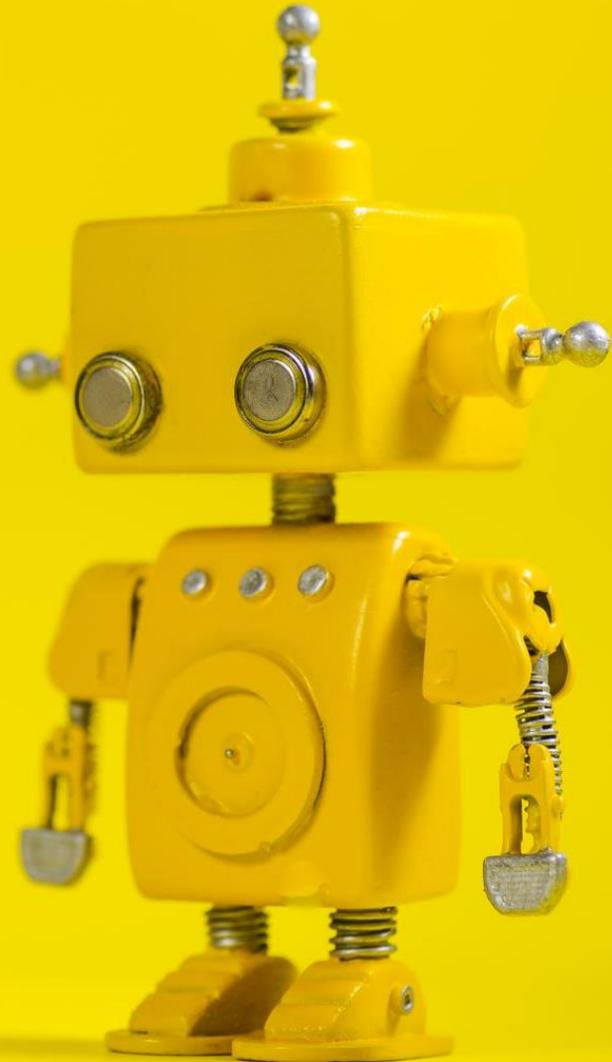


Questions?



Credits

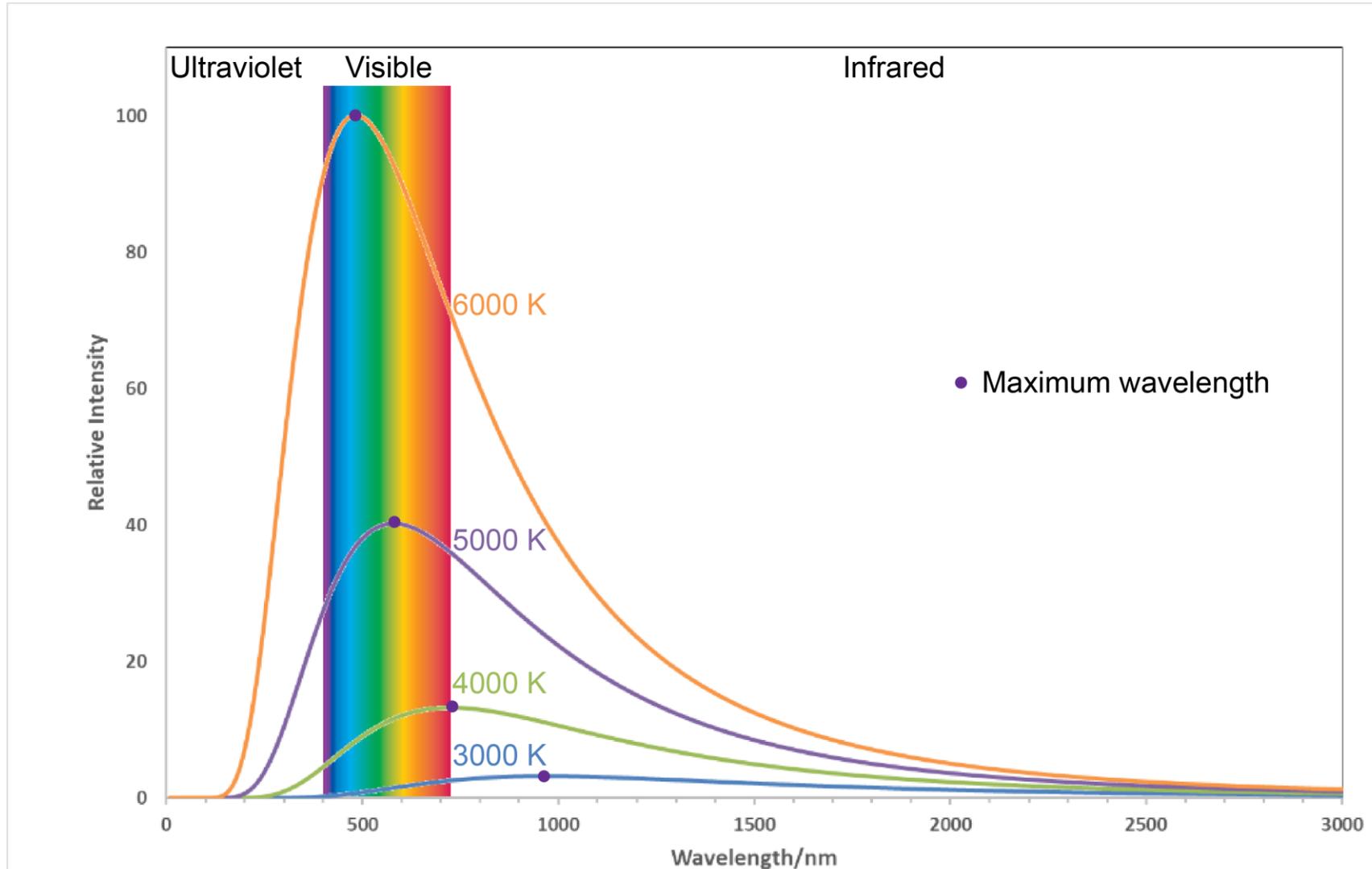
- Some of this slides comes from:
 - Yogesh S Rawat (UCF)
 - Noah Snavelly (Cornell)
 - Ioannis (Yannis) Gkioulekas (CMU)
 - Mubarak Shah (UCF)
 - S. Seitz
 - James Tompkin
 - Ulas Bagci
 - L. Lazebnik



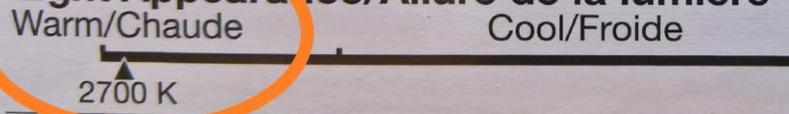
Robot Vision

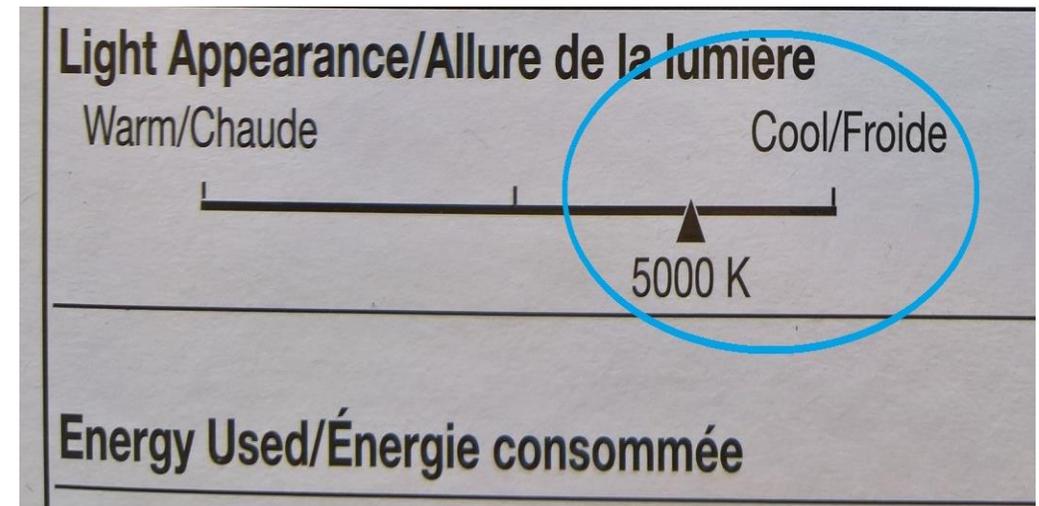
2. Basics of Images

Black Body radiation



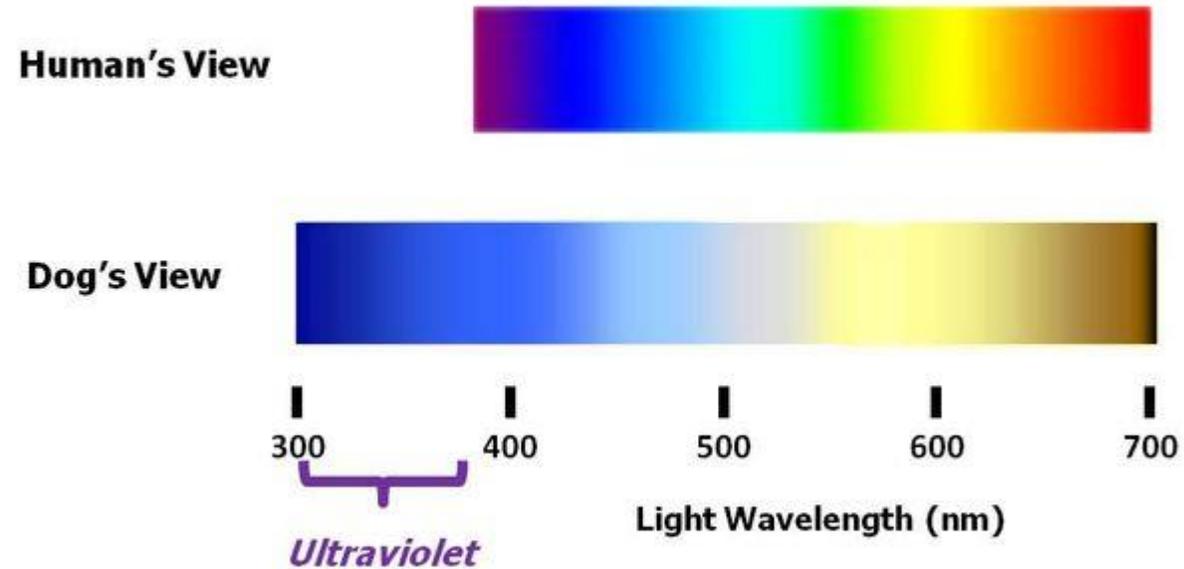
LED lights

Lighting Facts Données d'éclairage		Per Bulb Par lampe
Brightness/Luminosité	650 lumens	
Estimated Yearly Energy Cost Coûts énergétiques annuels estimés	\$0.90	
<small>Based on 3 hrs/day, 11¢/kWh. Cost depends on rates and use. / Basé sur une consommation de 3h/jour, 0,11\$/kWh. Les coûts varient selon les tarifs et l'usage.</small>		
Life/Durée de vie	10.0 years/ans	
Light Appearance/Allure de la lumière		
Warm/Chaude	Cool/Froide	
		
Energy Used/Énergie consommée	7.5 watts	



From last class

How the spectrum appears to people and dogs



From last class



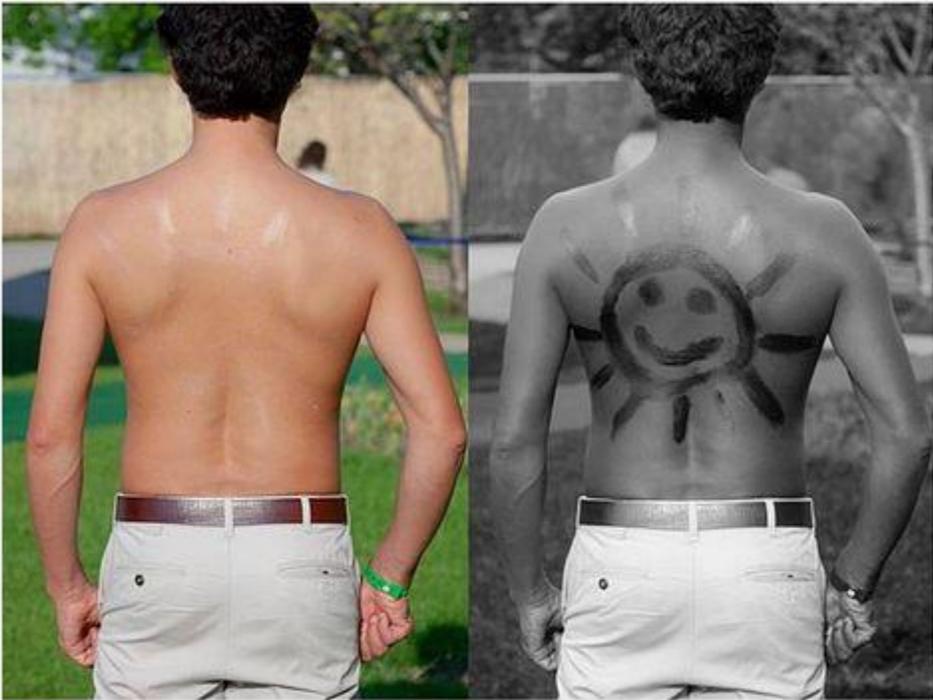
Human View
(No UV Sensitivity)



Dog View
(Some UV Sensitivity)



From last class



Sensitivity to UV makes targets that block or reflect these short wavelengths visible (like a drawing in sun screen lotion)

From last class

The ability to see ultraviolet (UV) helps guide bees to the pollen containing parts of flowers



**Human View
(No UV Sensitivity)**



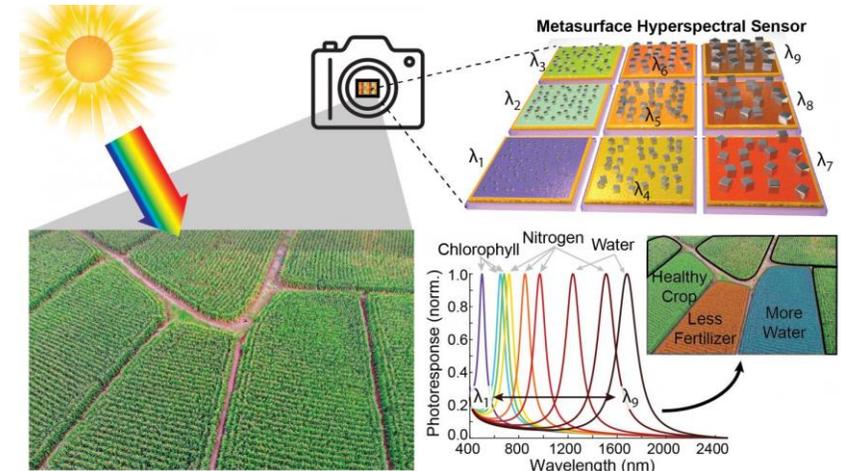
**Bee View
(UV Sensitivity)**

<https://www.psychologytoday.com/us/blog/canine-corner/201604/can-dogs-see-in-ultraviolet>

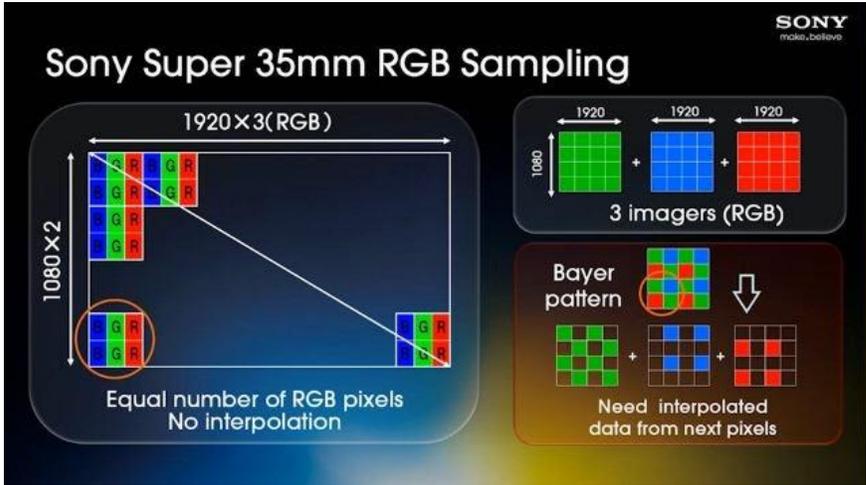
A large list of visual sensors



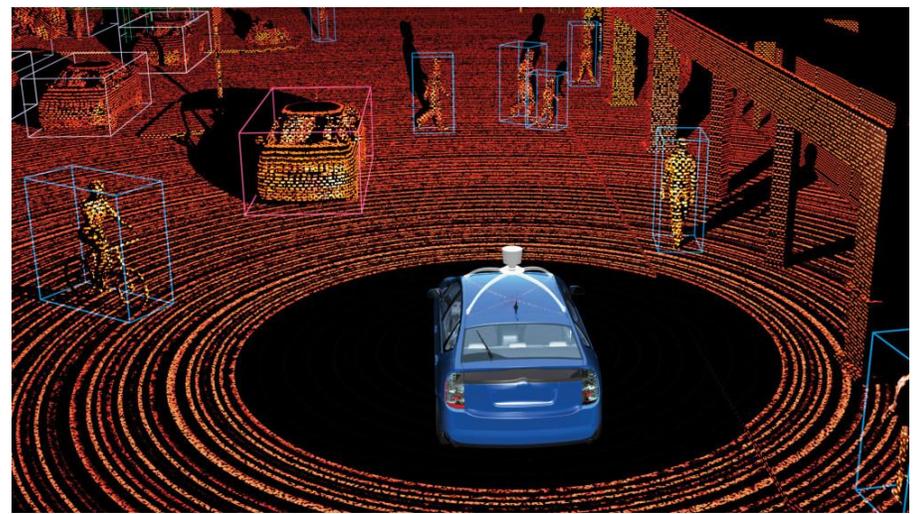
Monochrome cameras



MultiSpectral cameras

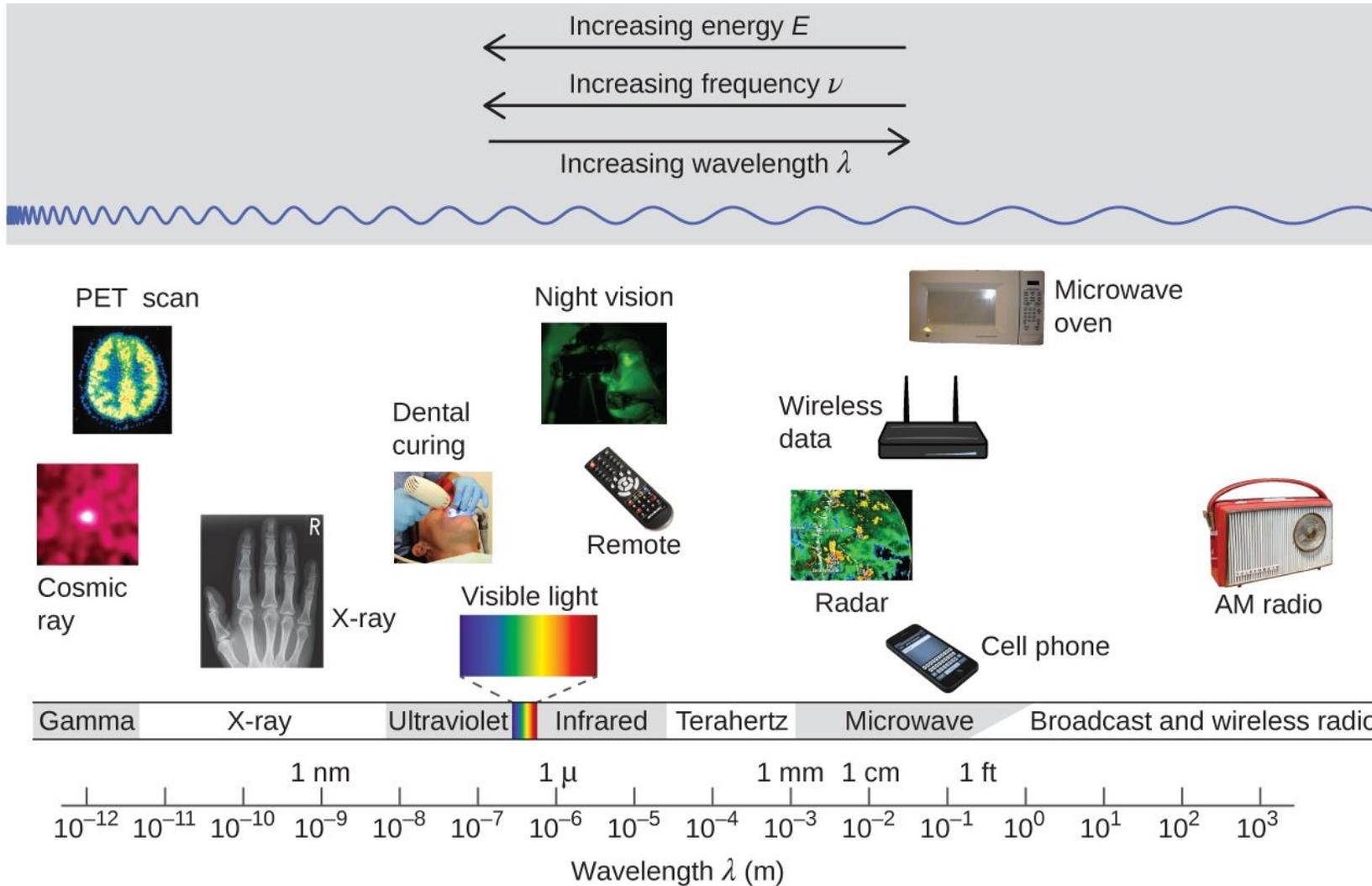


RGB cameras



Lidar / Time of flight cameras

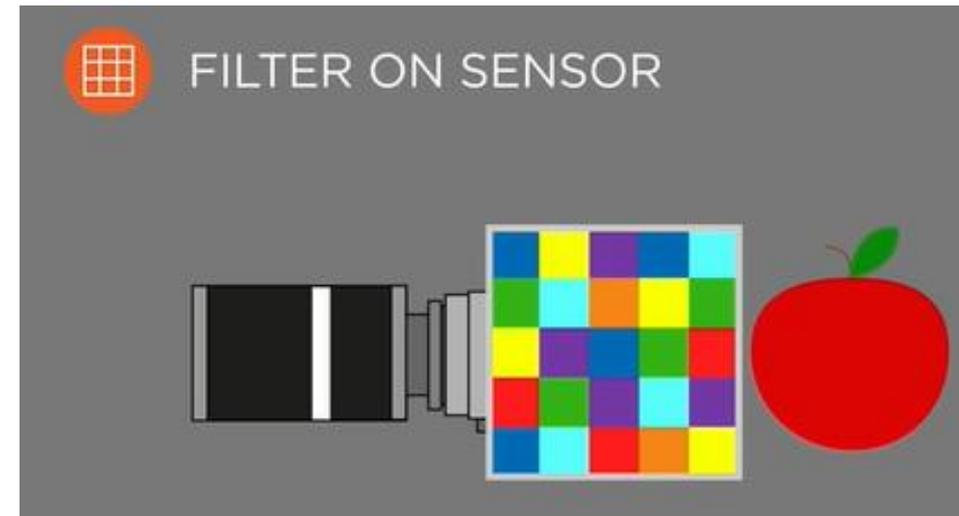
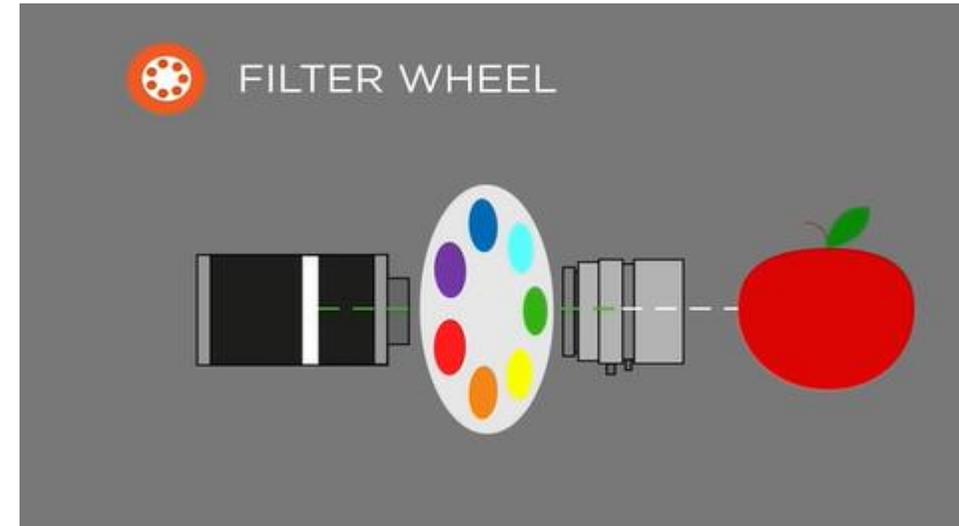
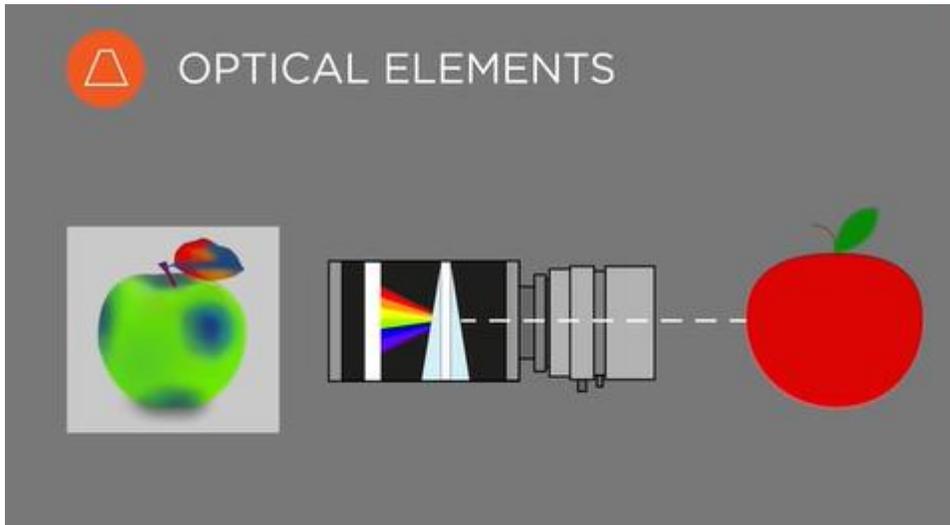
And beyond



Images using other bands



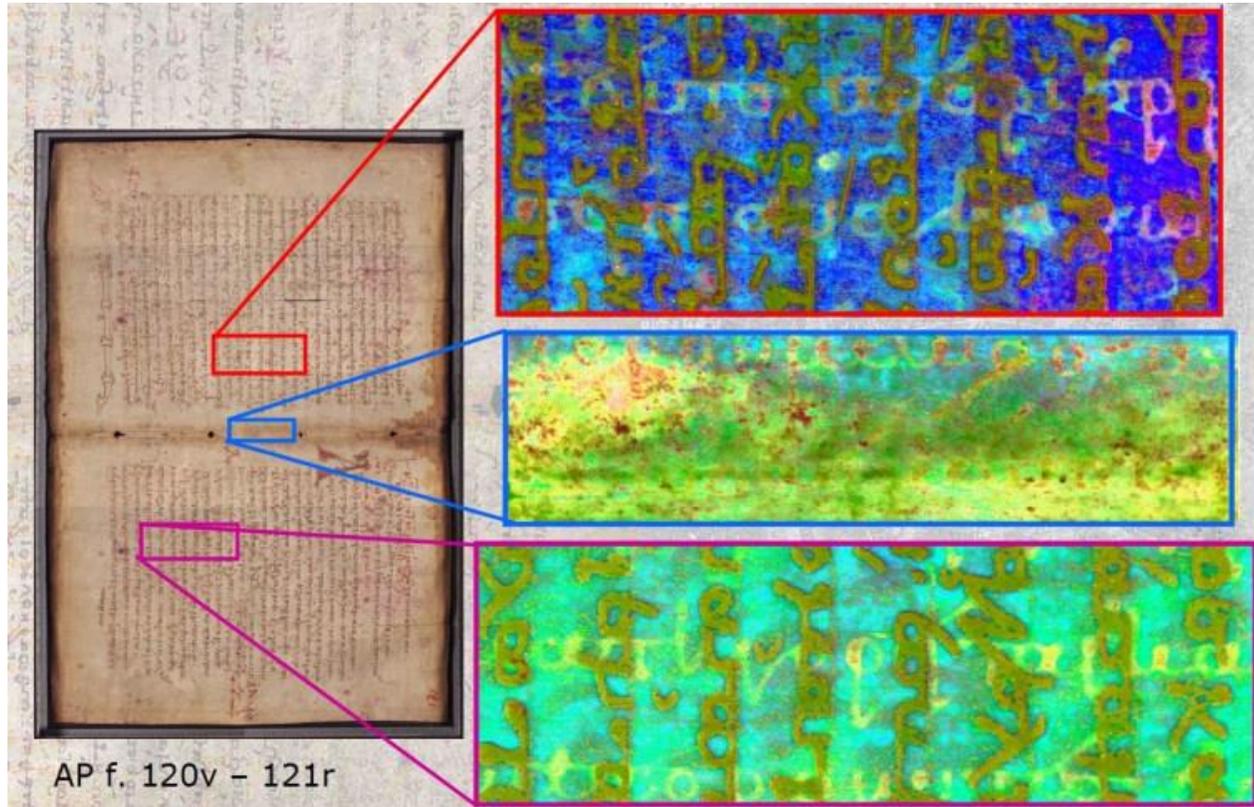
Multispectral cameras



[Multispectral Cameras and Where Are They Used](#)



MultiSpectral cameras



- PCB inspection
- Skin characterization
- Food inspection
- Agriculture
 - Analyzing crops
- Military

[Multispectral Imaging: New Technology Resurrects Centuries-Old Texts \(nbcnews.com\)](http://www.nbcnews.com)

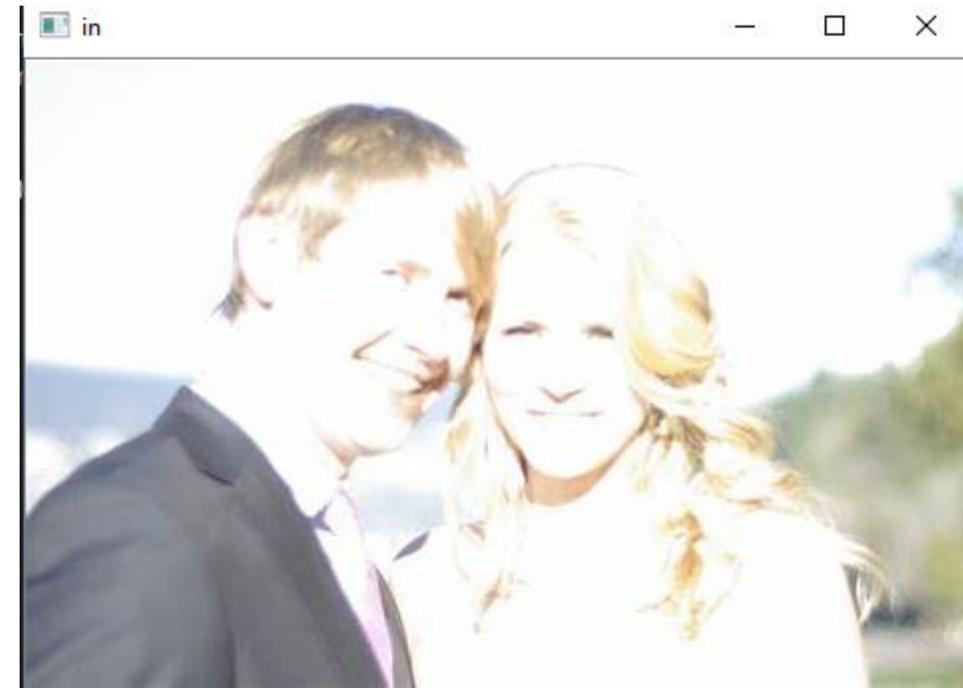


Outline

- Image as a function
 - Sampling
 - Quantization
- Extracting useful information from Images
 - **Histogram**
- Color spaces
 - RGB
 - HUE
 - CIE
- Homework 1

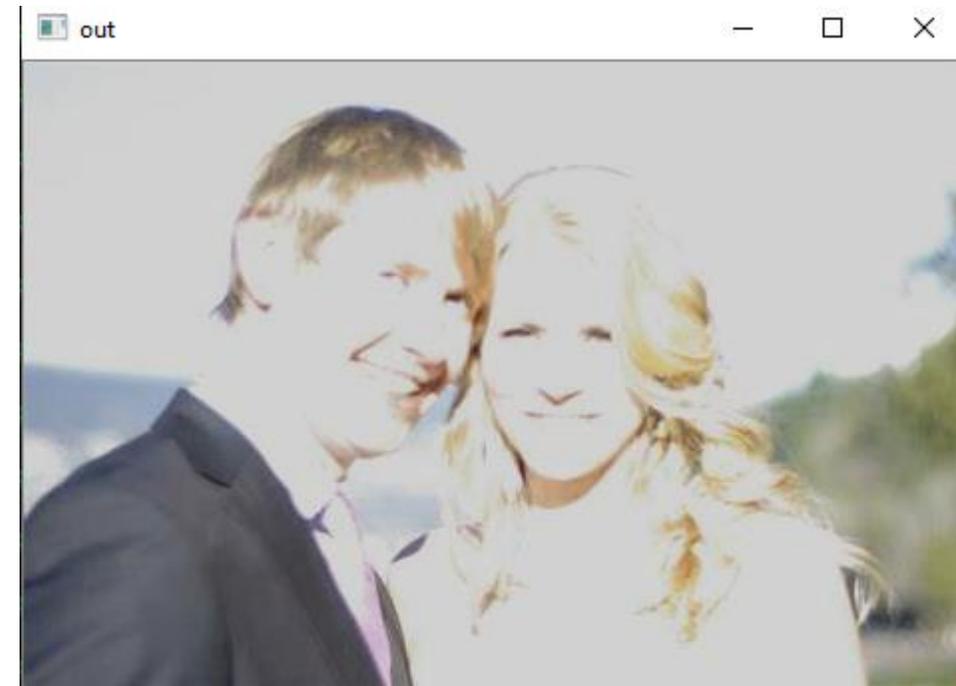
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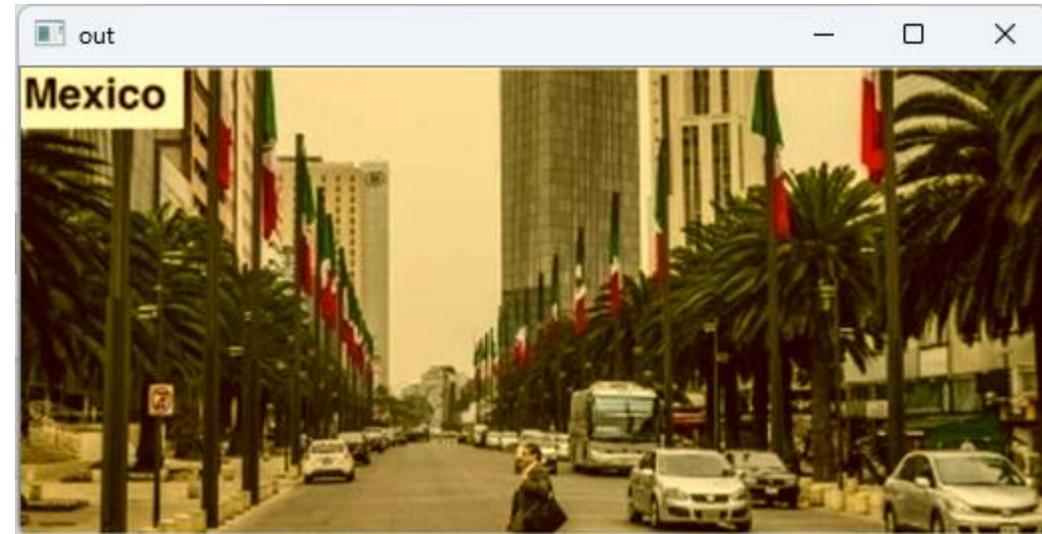
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- Color spaces
 - RGB
 - HUE
 - CIE
- Homework 1



Traffic movie (2000)



You learn today



Digitization

- Computers use discrete form of the images
- The process transforming continuous space into discrete space is called **digitization**

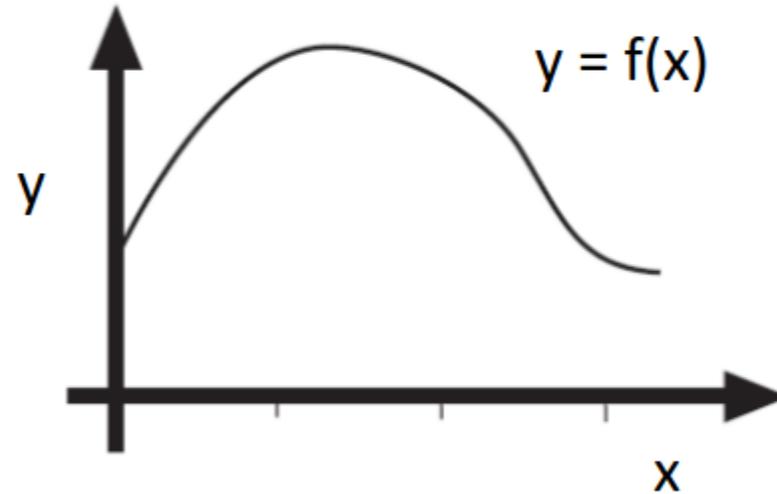


Digitization

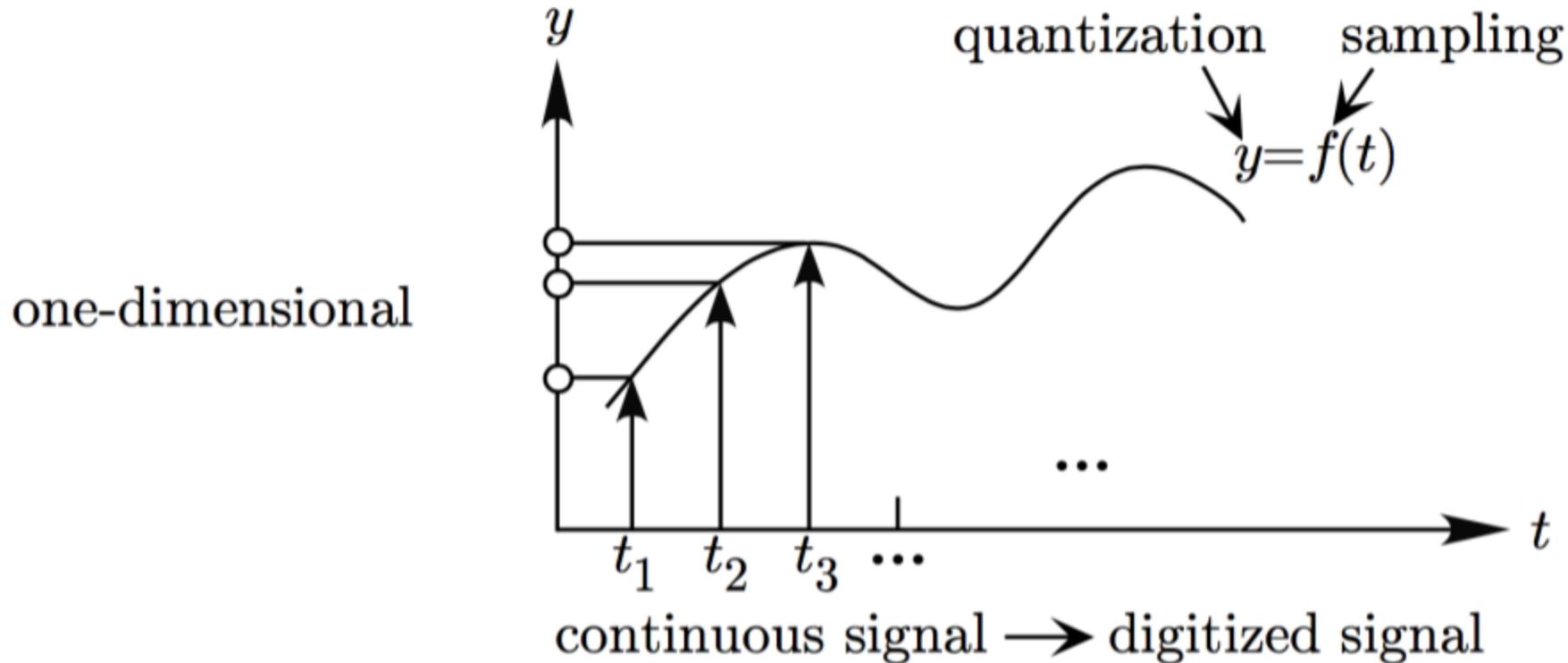
- Function

$$y = f(x)$$

- Domain of a function
- Range of a function
- Sampling
 - Discretization of domain
- Quantization
 - Discretization of range

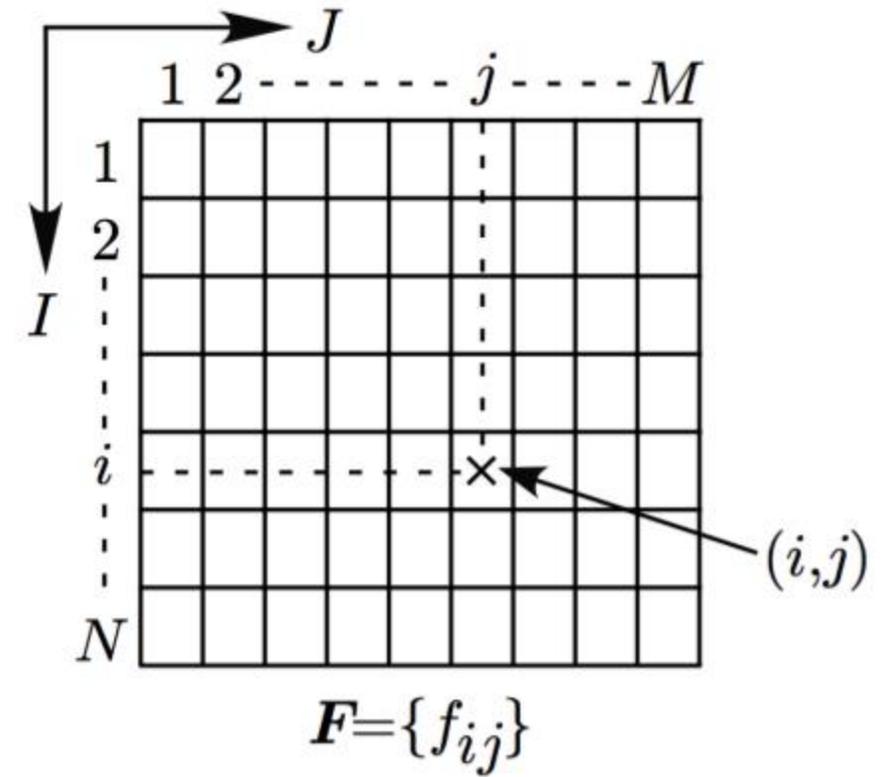
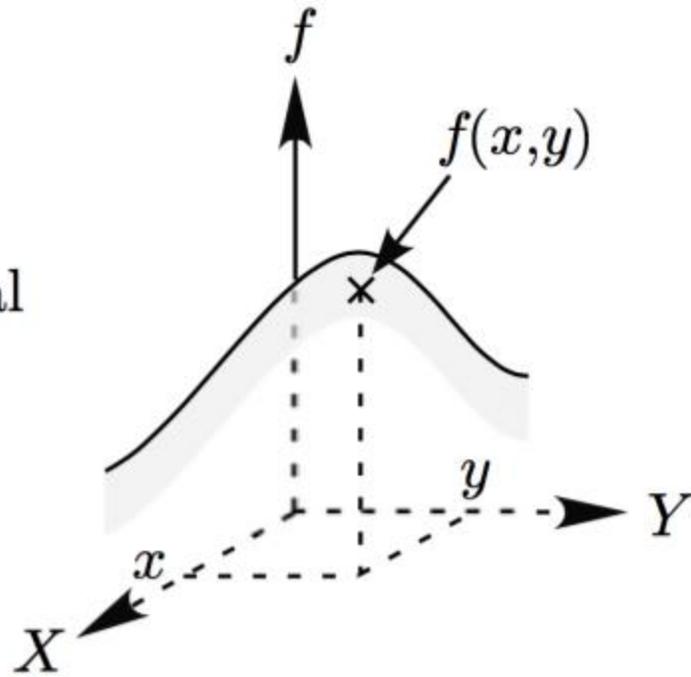


Digitization of 1D function



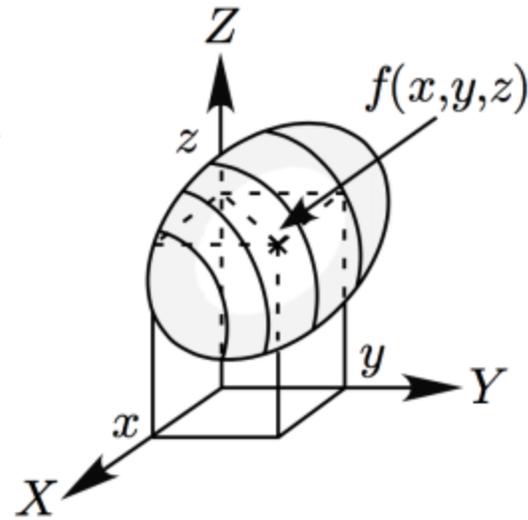
Digitization of 2D function

two-dimensional

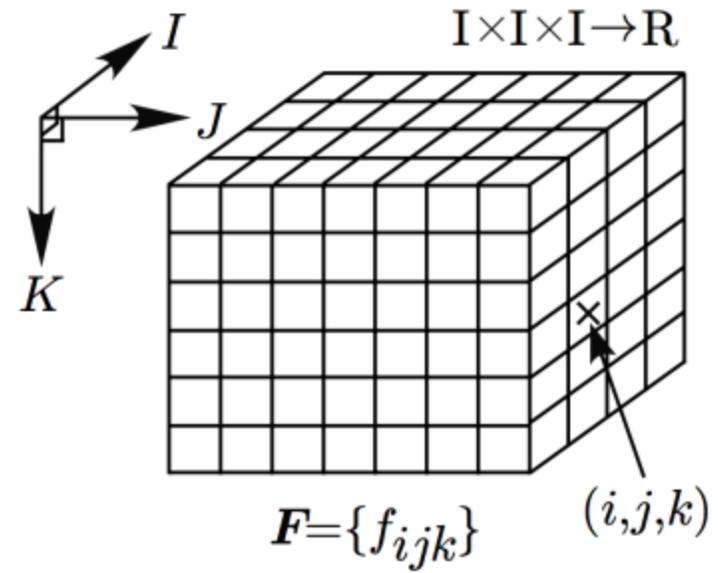


Digitization of 3D function

three-dimensional

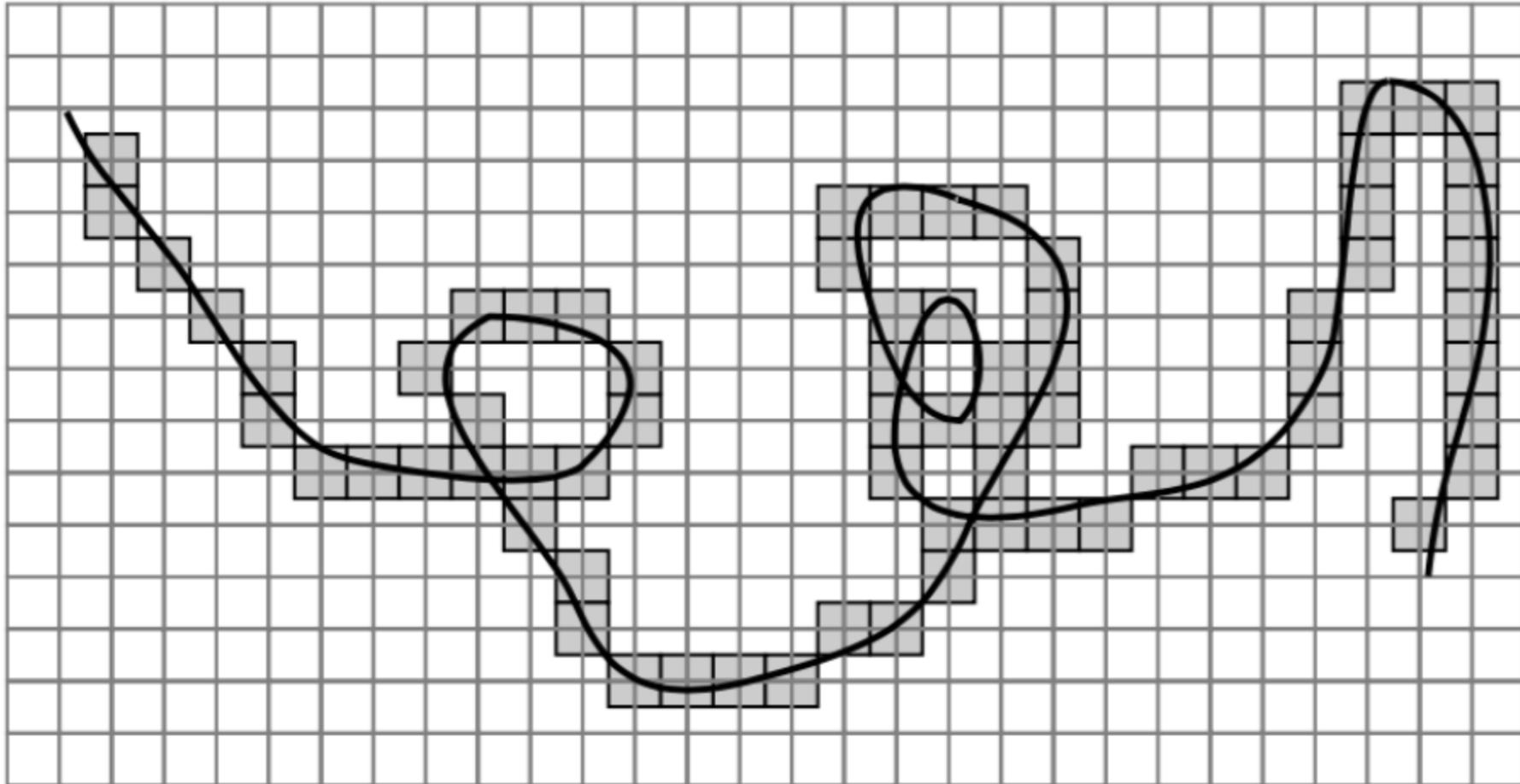


continuous image

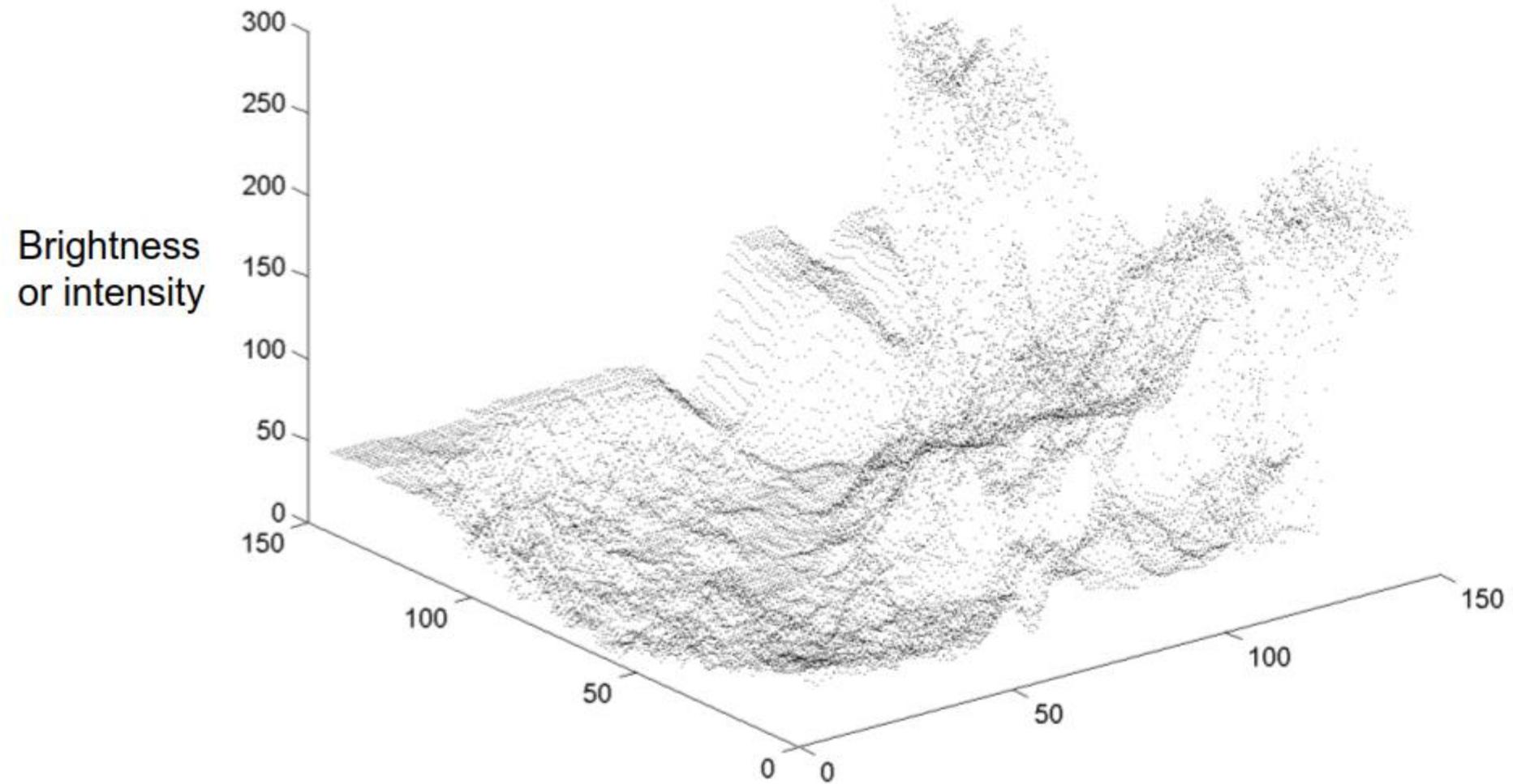


digitized image

Digitization of an arc

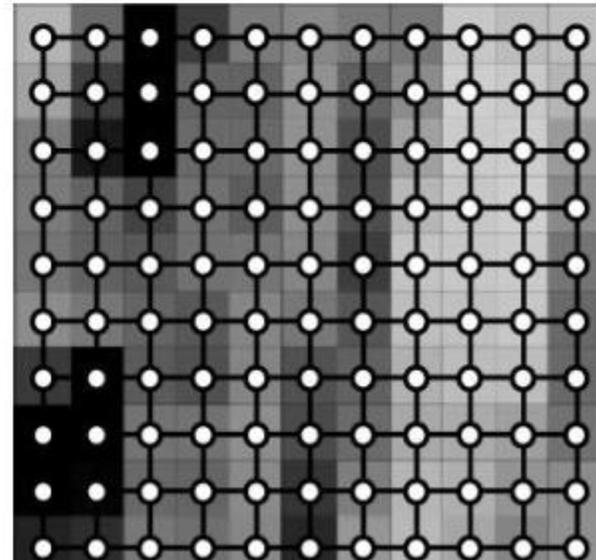
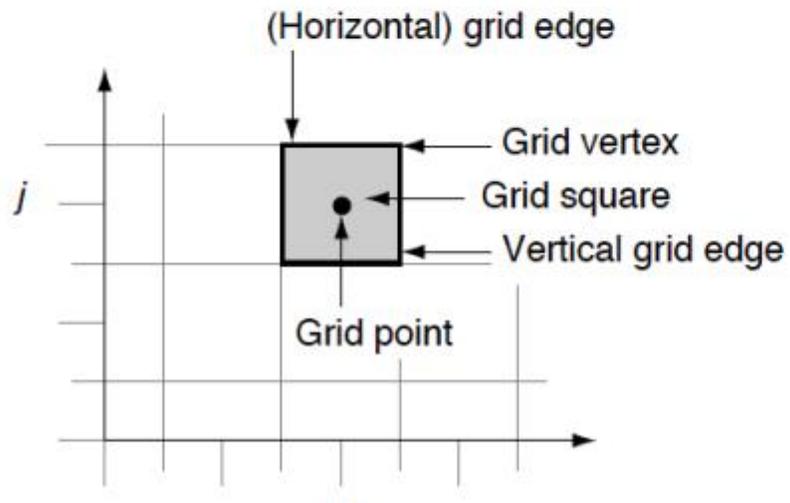


Gray scale digital image



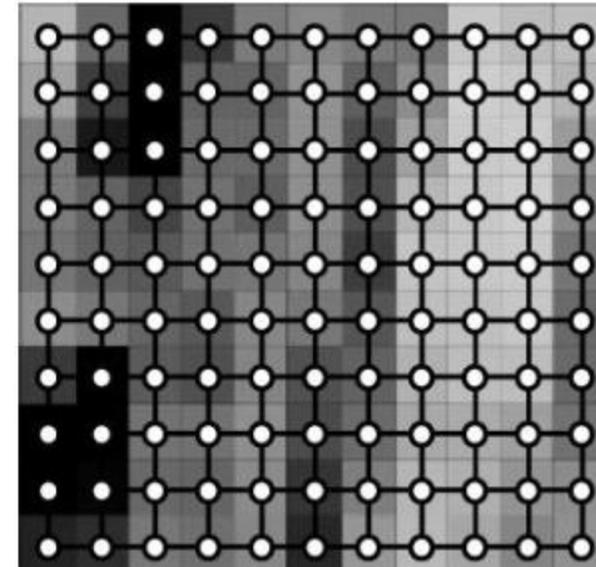
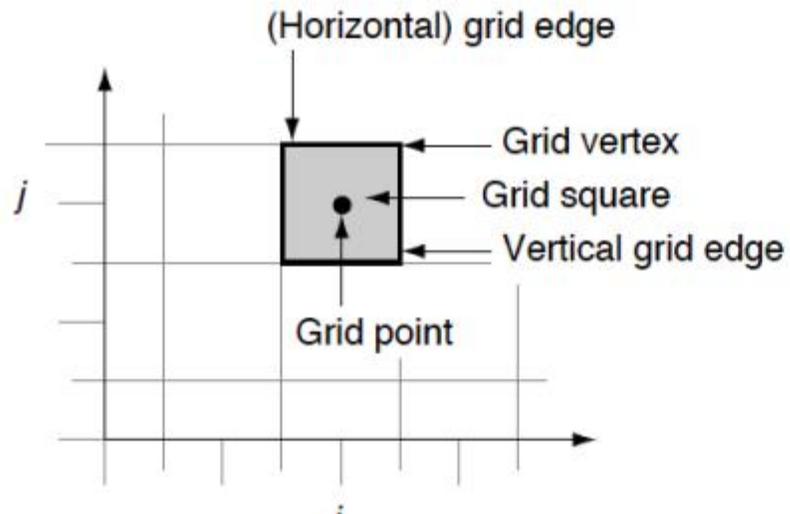
Definition

- An image P is a function defined on a (finite) rectangular subset G of a regular planar orthogonal array.
- G is called (2D) **grid**, and **an element of G is called a pixel**.
- P assigns a value of $P(p)$ to each $p \in G$

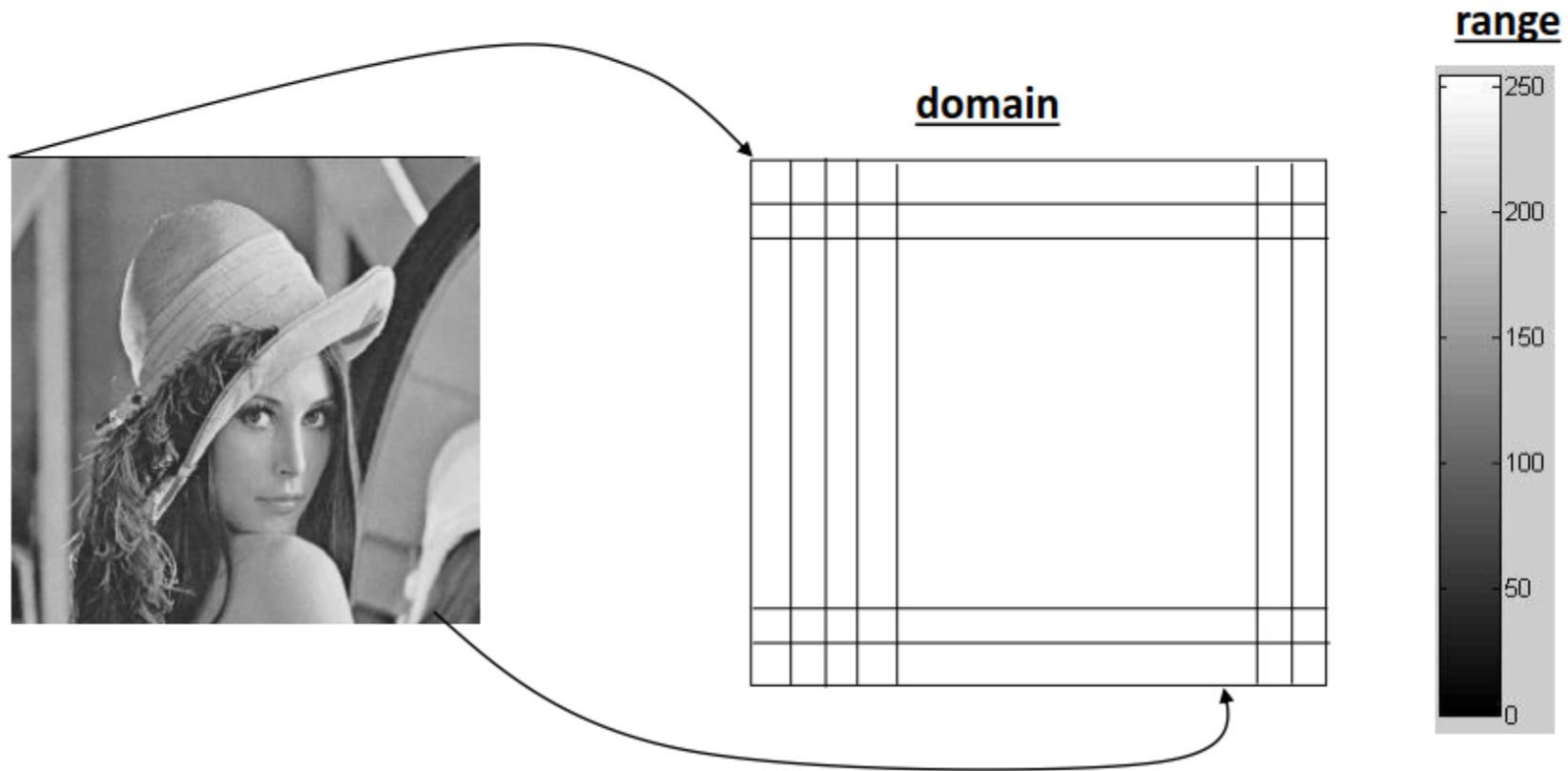


Definition

- Pictures are not only sampled
- They are also quantized
 - they may have only a finite number of possible values
 - i.e., 0 to 255, 0-1, ...



Digitization



Sampling



Quantization



Original
(256 colors)



8 colors



4 colors

About the picture



[Lena Forsen - playmate, who became the "mother" of JPEGs \(fotoblogia.pl\)](http://fotoblogia.pl)

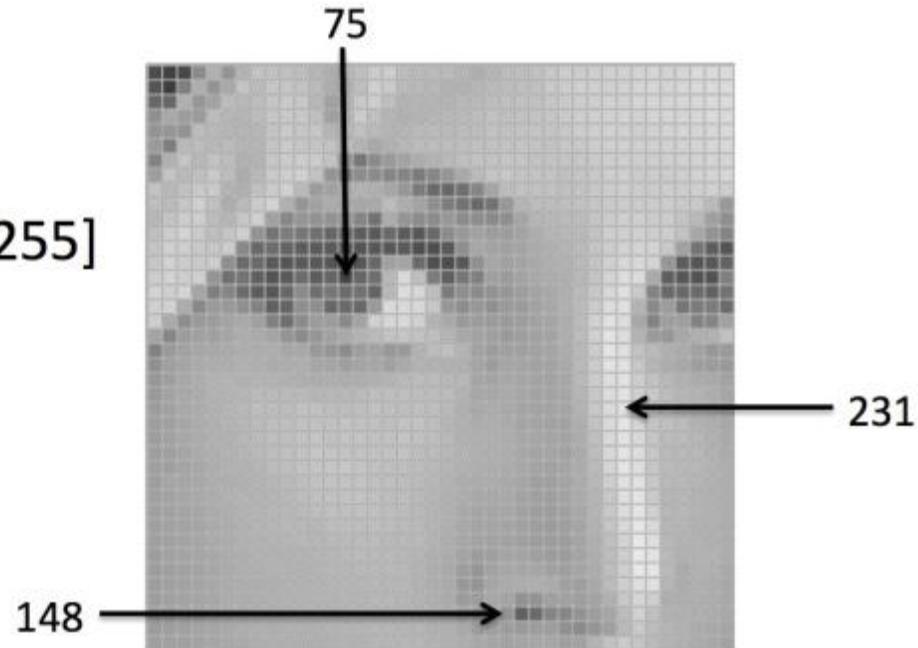
Resolution

- Also a display parameter
 - defined in **dots per inch (DPI)** or
 - measure of spatial pixel density
 - standard value for recent screen technologies is 72 dpi.
 - Recent printer resolutions are in 300 dpi and/or 600 dpi.



Gray scale image

- An image contains discrete number of pixels
 - A simple example
 - Pixel value:
 - “grayscale”
 - (or “intensity”): $[0,255]$



Color image

- An image contains discrete number of pixels

- A simple example

- Pixel value:

- “grayscale”

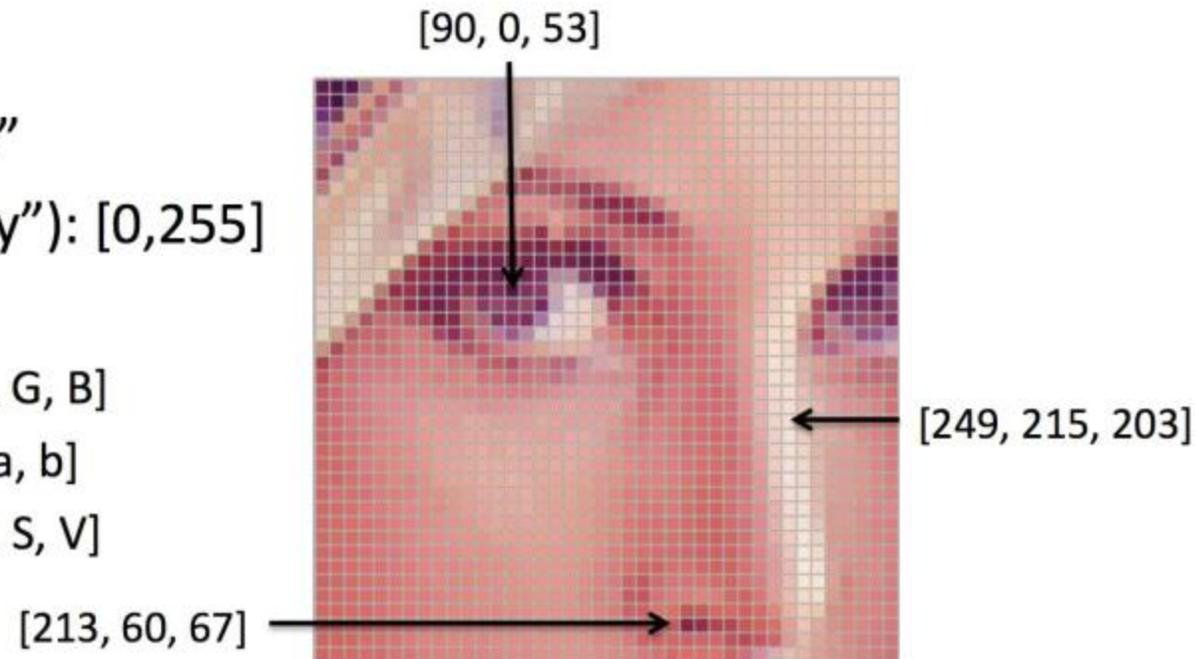
- (or “intensity”): [0,255]

- “color”

- RGB: [R, G, B]

- Lab: [L, a, b]

- HSV: [H, S, V]



Source: F.F. Li

RGB Channels



RGB Channels

640



480

How many pixels do you need to represent this image?



RGB Channels

640



480

How many bytes do you need to represent this image?



RGB Color Space

Compression technique

$$R = \int_{300}^{830} S(\lambda) R(\lambda) d\lambda$$

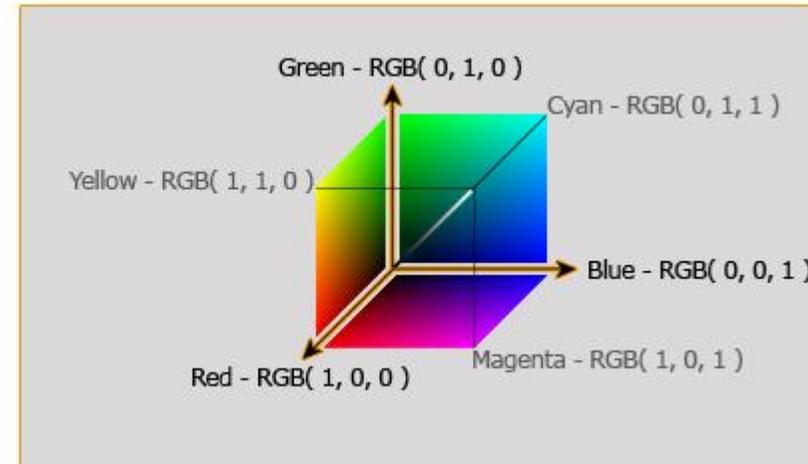
$$G = \int_{300}^{830} S(\lambda) G(\lambda) d\lambda$$

$$B = \int_{300}^{830} S(\lambda) B(\lambda) d\lambda$$

$S(\lambda)$ is the light spectrum,

$R(\lambda)$, $G(\lambda)$ and $B(\lambda)$ are the sensitivity functions

Color Cube
RGB Color Format



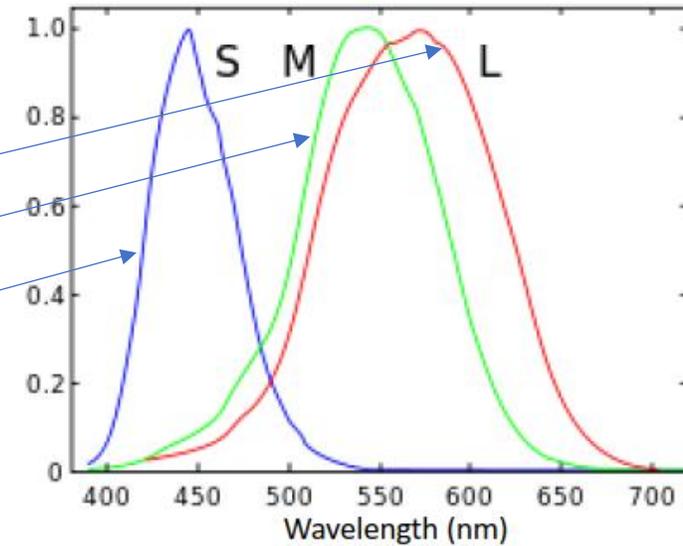
www.equasys.de

- These are colours with different spectra but with same perceptual values
- RGB colour space is the basic colour space
- Device-dependant colour space

RGB Color Space

Compression technique

Human Cone-cells (normalized) responsivity spectra



Color Cube
RGB Color Format

$$R = \int_{300}^{830} S(\lambda) R(\lambda) d\lambda$$

$$G = \int_{300}^{830} S(\lambda) G(\lambda) d\lambda$$

$$B = \int_{300}^{830} S(\lambda) B(\lambda) d\lambda$$

$S(\lambda)$ is the light spectrum,

$R(\lambda)$, $G(\lambda)$ and $B(\lambda)$ are the sensitivity functions

Red - RGB(1, 0, 0)

Magenta - RGB(1, 0, 1)

- These are colours with different spectra but with same perceptual values
- Device-dependant colour space
- RGB colour space is the basic colour space

RGB Color Space

Compression technique

$$R = \int_{300}^{830} S(\lambda) R(\lambda) d\lambda$$

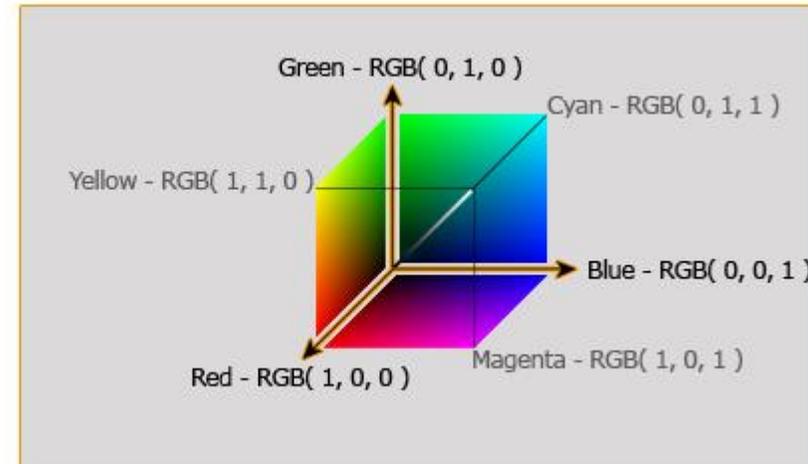
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Color Cube
RGB Color Format



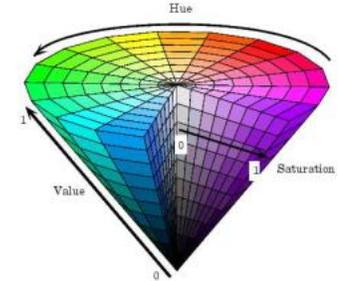
www.equasys.de

Disadvantages

- a high correlation between its components
 - about 0.78 for rBR (cross correlation between the Band R channel)
 - 0.98 for rRG
 - 0.94 for rGB
- It is psychologically non-intuitive
- Perceptual non-uniformity (add a value have different effect for every color)

Phenomenal color spaces

- Most natural way for humans of describing colors
- Described by 3 attributes
 - Hue: the colour is red, green, yellow, blue, purple ...
 - Saturation: the level of non-whiteness
 - Brightness is a measure of the intensity of light.
- HSL color space. Hue, Saturation, Luminance
 - transformations from the RGB space.
 - inherit all the short-comings of RGB space.
 - There is usually a hue discontinuity around 360 degrees.
 - This makes difficult to make arithmetic operations in such a color space.



$$I = \frac{R + G + B}{3}$$

$$S = 1 - \left(\frac{3}{R + G + B} \right) \min(R, G, B)$$

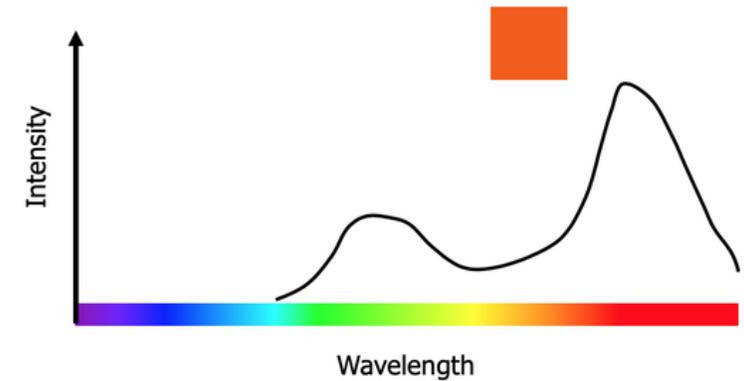
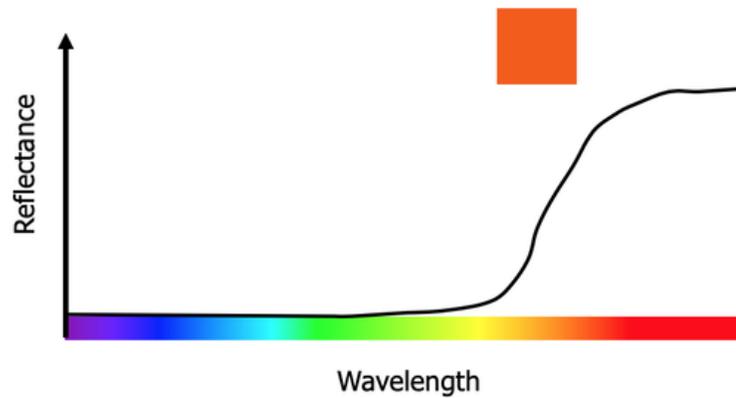
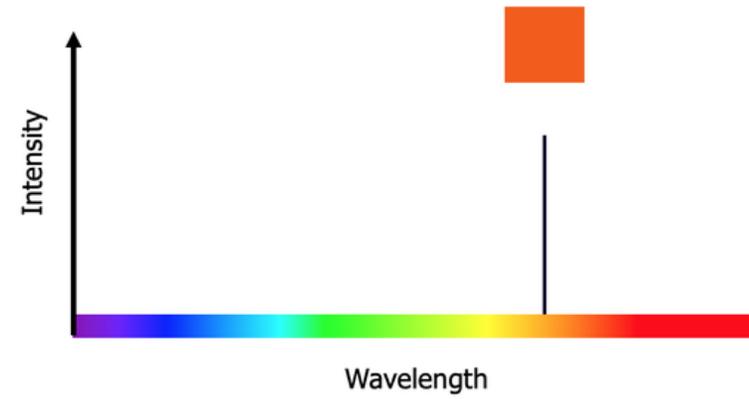
$$H = \cos^{-1} \left(\frac{0.5(R - G) + (R - B)}{\sqrt{(R - G)^2 + (R - B)(G - B)}} \right)$$

where I (intensity) is used instead of V (value).

CIELAB



measure the spectral reflectance factors of an object





CIE Colour Spaces

- CIE (Commission Internationale de l'Éclairage (illumination))
 - In 1931 laid down the CIE 1931 standard colorimetric observer.
 - CIE XYZ: CIE standardized the XYZ values as tristimulus values that can describe any color that can be perceived by an average human observer
 - XYZ are positives
 - It is device dependent
 - CIELuv and CIELab: proposed in 1976
 - Goal: provide a perceptually equal space
 - CIElab
 - L^* closely matches human perception of lightness (black at 0 and white at 100)
 - a^* : green–red opponent colors, with negative values toward green and positive values toward red. Unbounded, usually bounded from -128 to 127
 - b^* : blue–yellow opponents, with negative numbers toward blue and positive toward yellow. Unbounded



CIELAb

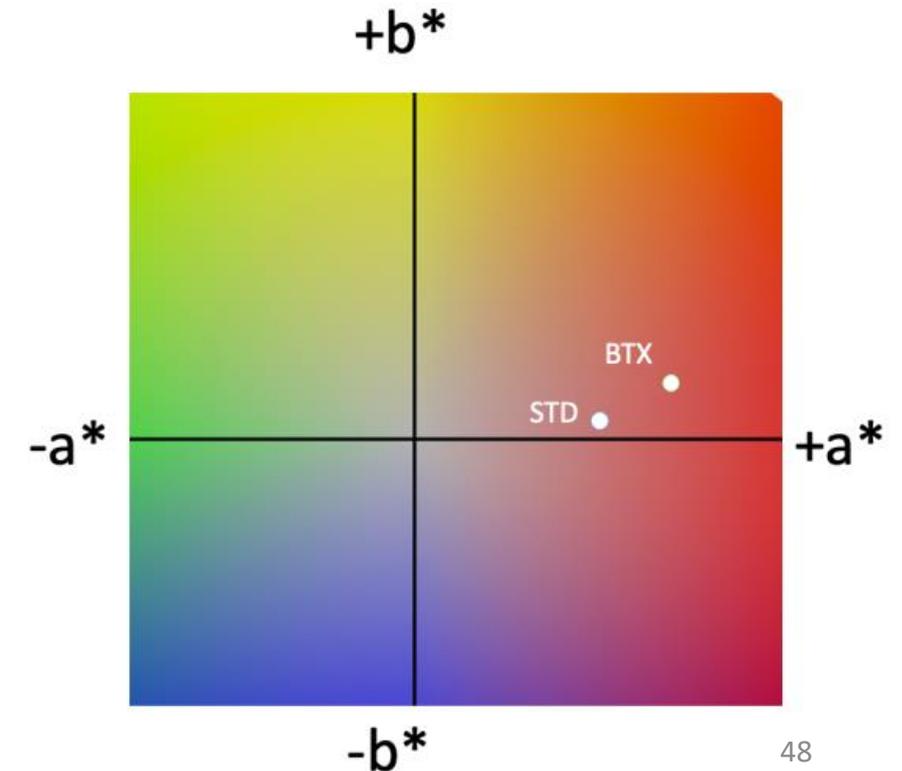
- L^* measures whether the sample is light (high L^*) or dark (low L^*).
- The a^* and b^* values together represent the hue and chroma of the sample.

	std	btx
L^*	56	58
a^*	26	36
b^*	3	9

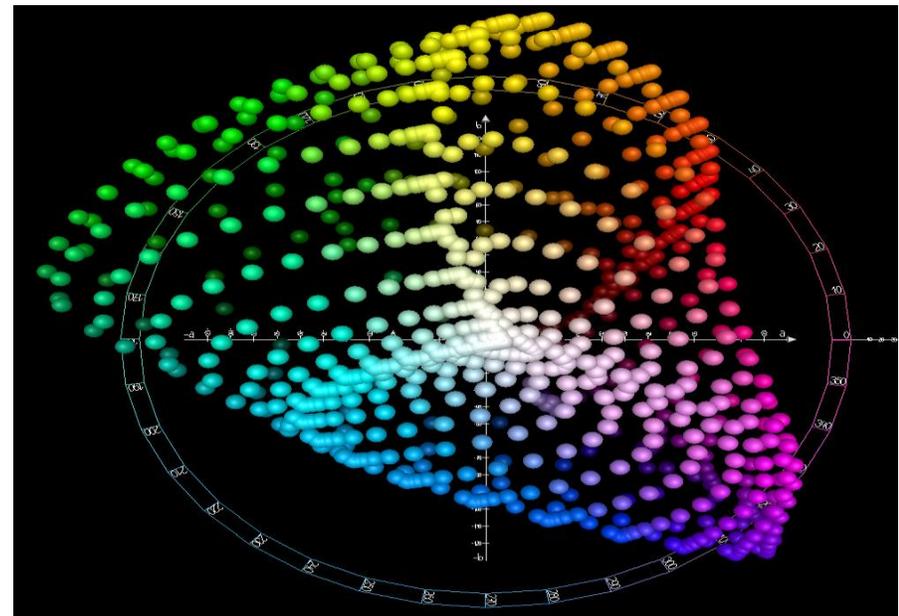
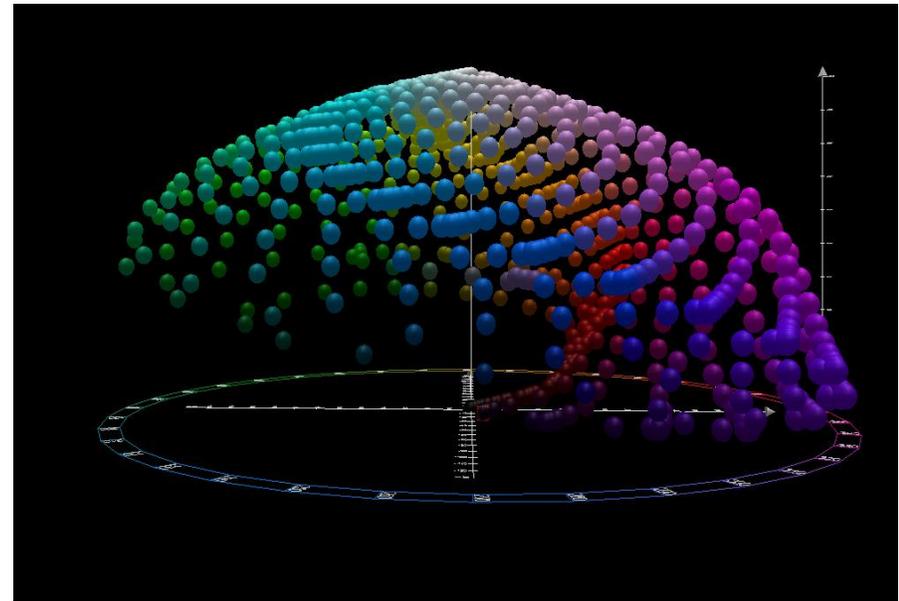
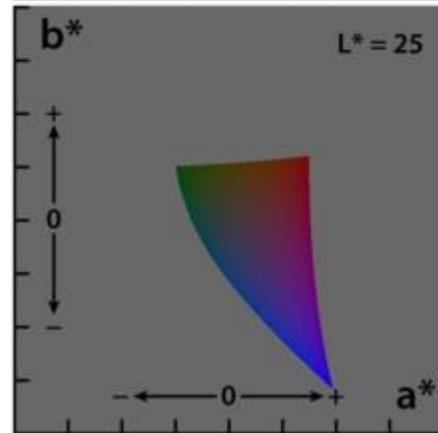
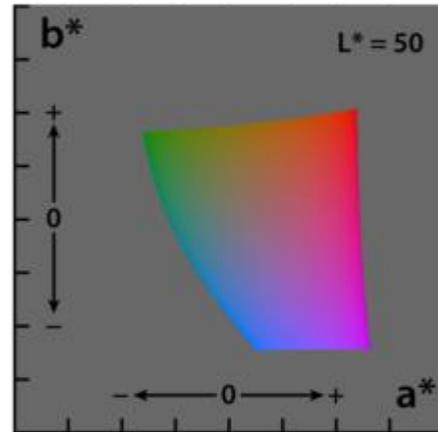
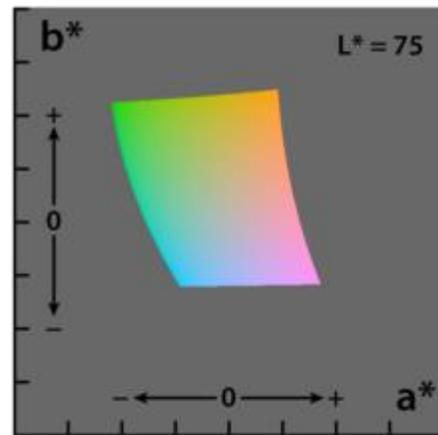
the btx is lighter, stronger and yellower than the std



std btx



CIE Lab



Cielab

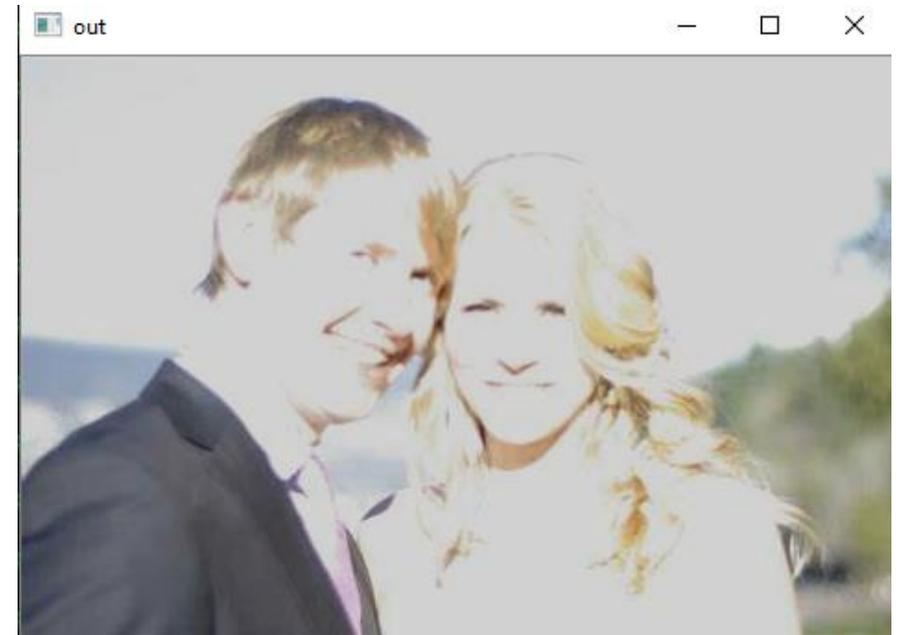
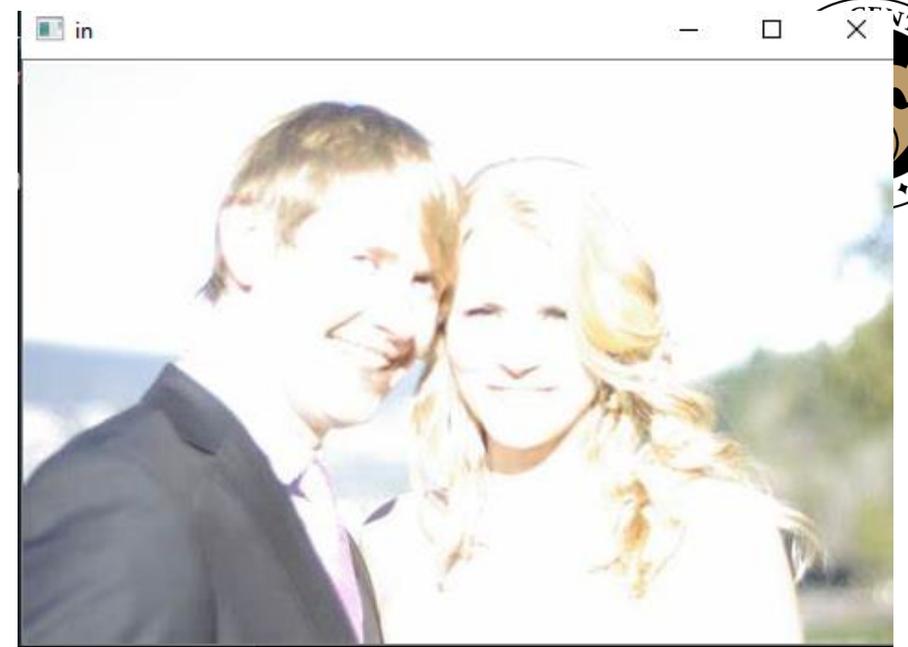


LAB color enhancement in Photoshop.

Normal Image

CieLAB transformation

```
1 # -*- coding: utf-8 -*-
2 """
3 Created on Wed Aug 24 19:10:31 2022
4
5 @author: gonza
6 """
7
8 import cv2
9 import numpy as np
10
11 img=cv2.imread('overExposed.jfif')
12
13 imgcie = cv2.cvtColor(img, cv2.COLOR_BGR2LAB)
14 imgcie = imgcie.astype(np.float)
15 imgcie[:, :, 0] = imgcie[:, :, 0] - 80
16 #imgcie[:, :, 1] = imgcie[:, :, 1] - 30
17 imgcie[imgcie < 0] = 0
18 imgcie = imgcie.astype(np.uint8)
19 imgOut = cv2.cvtColor(imgcie, cv2.COLOR_LAB2BGR)
20
21 cv2.imshow('in', img)
22 cv2.imshow('out', imgOut)
23 cv2.waitKey(0)
24
```

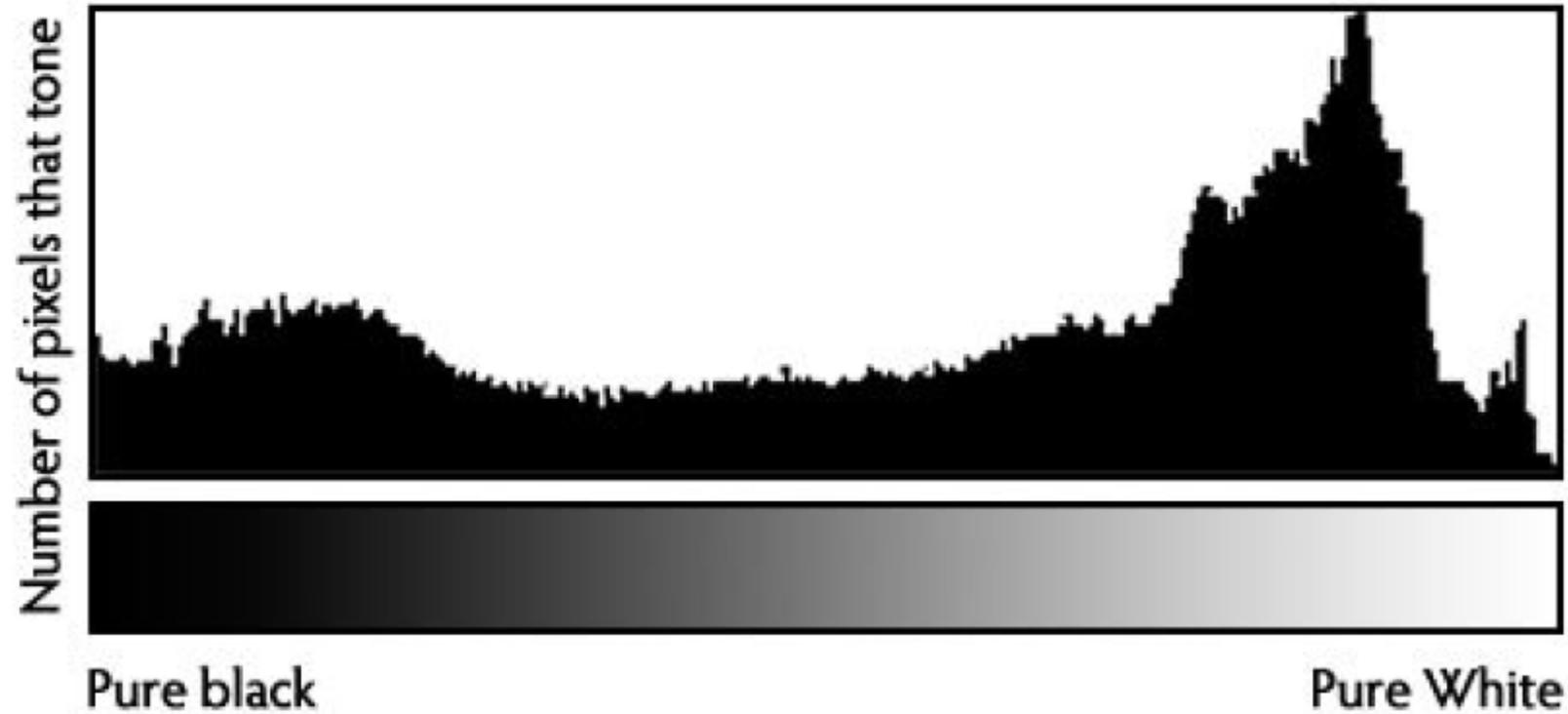




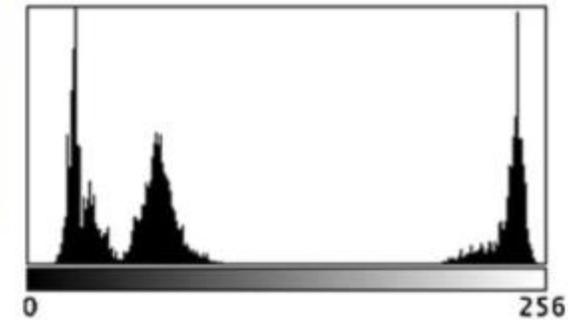
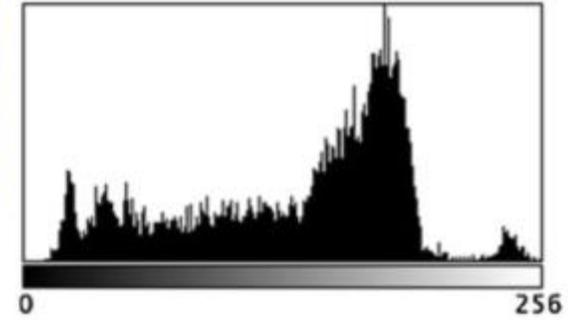
Histogram

- A histogram is a graphic representation of numerical data that shows the data distribution. When the number of observations is large, and the bin's size is small, the histogram will be similar to the distribution density chart.
- How to create a histogram?
 1. Find the range of the numerical data $\text{Range} = \text{Max} - \text{Min}$.
 2. Choose the number of bins you prefer to present.
 3. Calculate the bin size: $\text{Bin size} = \text{Range} / \text{number of bins}$.
 4. For every bin count, the total number of observations falls in the bin.
 5. Present the data as a column chart, where each column represents the number of observations in a bin.

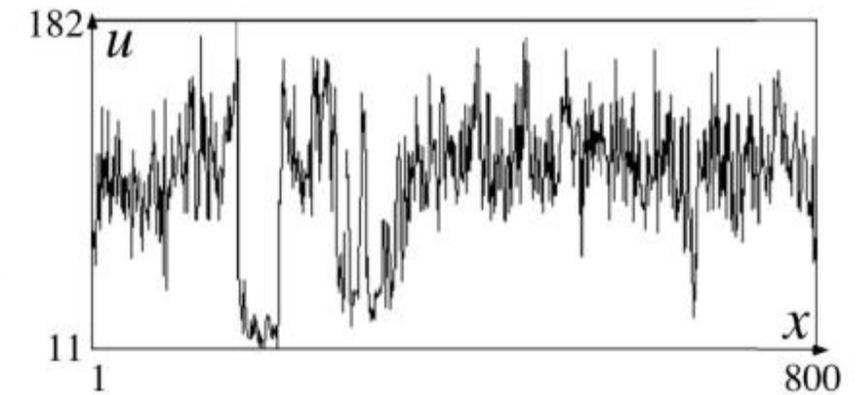
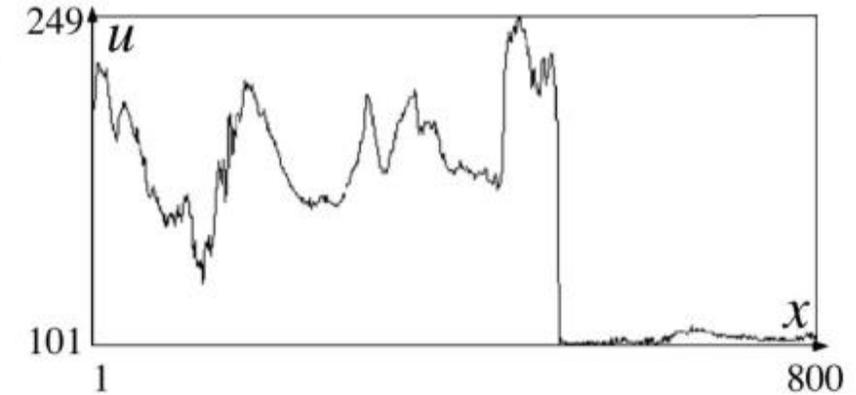
Image Histogram



Histogram Example



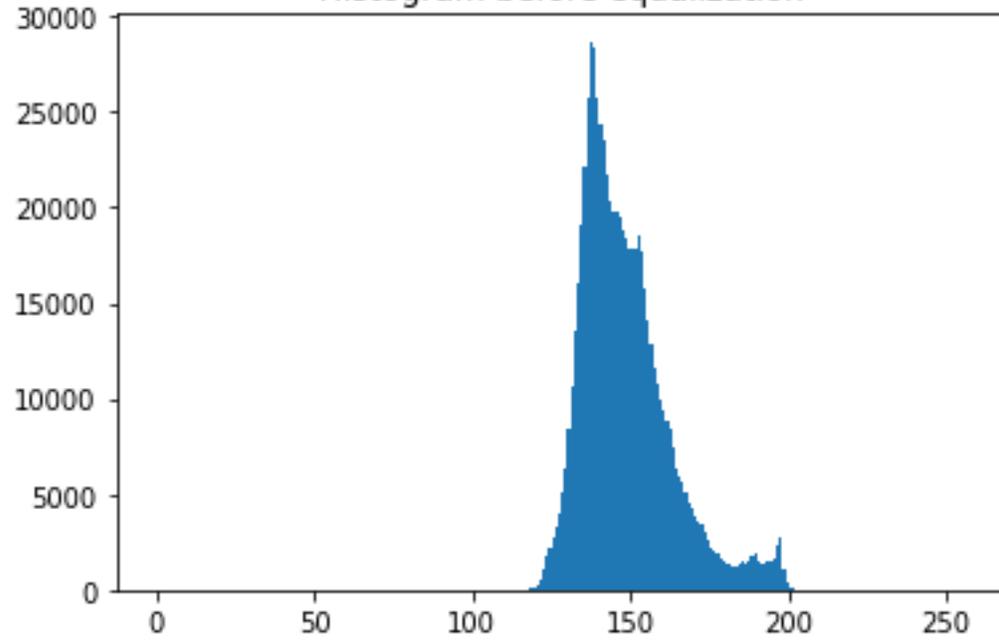
Intensity profiles for selected (two) rows



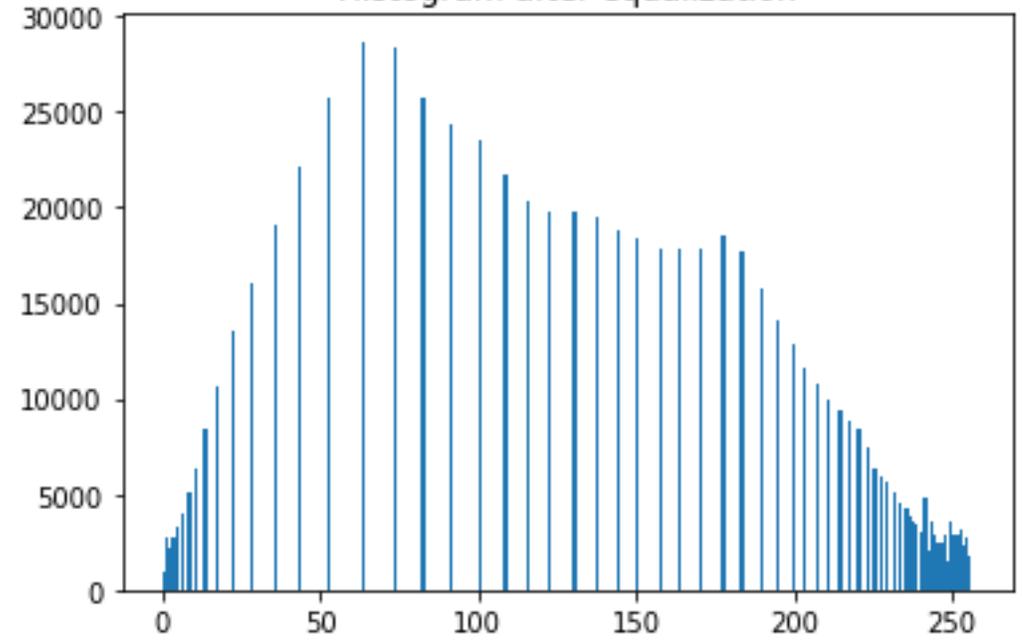
```
3 Created on Tue Jan 17 08:31:55 2023
4
5 @author: gonza
6 """
7
8 import cv2
9 import numpy as np
10 import matplotlib.pyplot as plt
11
12 # reading an image using imreadmethod
13 my_img = cv2.imread('madanmohan_temple.jpg', 0)
14 my_img = cv2.imread('Unequalized_Hawkes_Bay_NZ.jpg',0)
15 equ = cv2.equalizeHist(my_img)
16
17 # stacking both the images side-by-side orientation
18 res = np.hstack((my_img, equ))
19
20 # getting histograms
21 plt.hist(my_img.ravel(),bins = 256, range = [0,256])
22 plt.title('Histogram before equalization')
23 plt.show()
24
25 plt.hist(equ.ravel(),bins = 256, range = [0,256])
26 plt.title('Histogram after equalization')
27 plt.show()
28
29 # showing image input vs output
30 cv2.imshow('image', res)
31 cv2.waitKey(0)
32 cv2.destroyAllWindows()
33
34
35
36
```



Histogram before equalization



Histogram after equalization





Questions?



Coding homeworks

- Presented as a notebook using colab
 - <https://colab.research.google.com/>
- Homeworks are posted at webcouses as a link to:
 - [gonzo1978/CAP4453: Colab notes for CAP 4453 \(github.com\)](#)