HA NOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

Biometric Authentication Systems

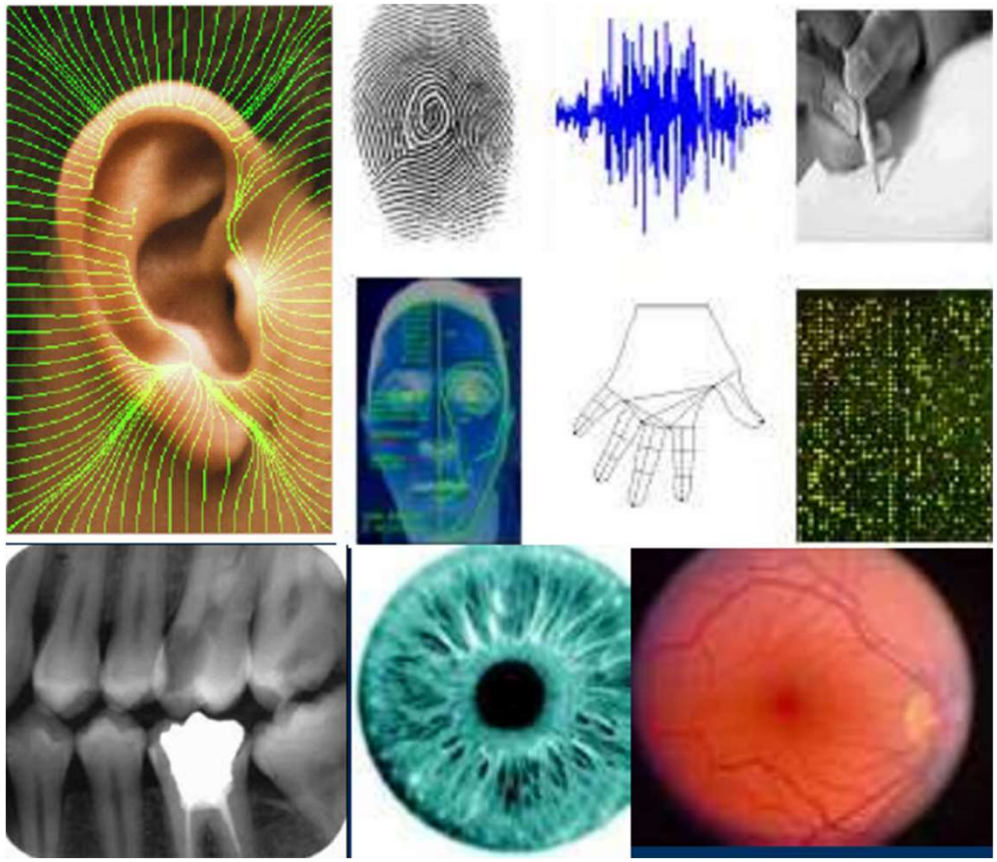
Chapter 1: Introduction

Content

- Biometric problem
- Related field – image processing/ computer vision
- Image formation and acquisition
- Color space and digital image representation

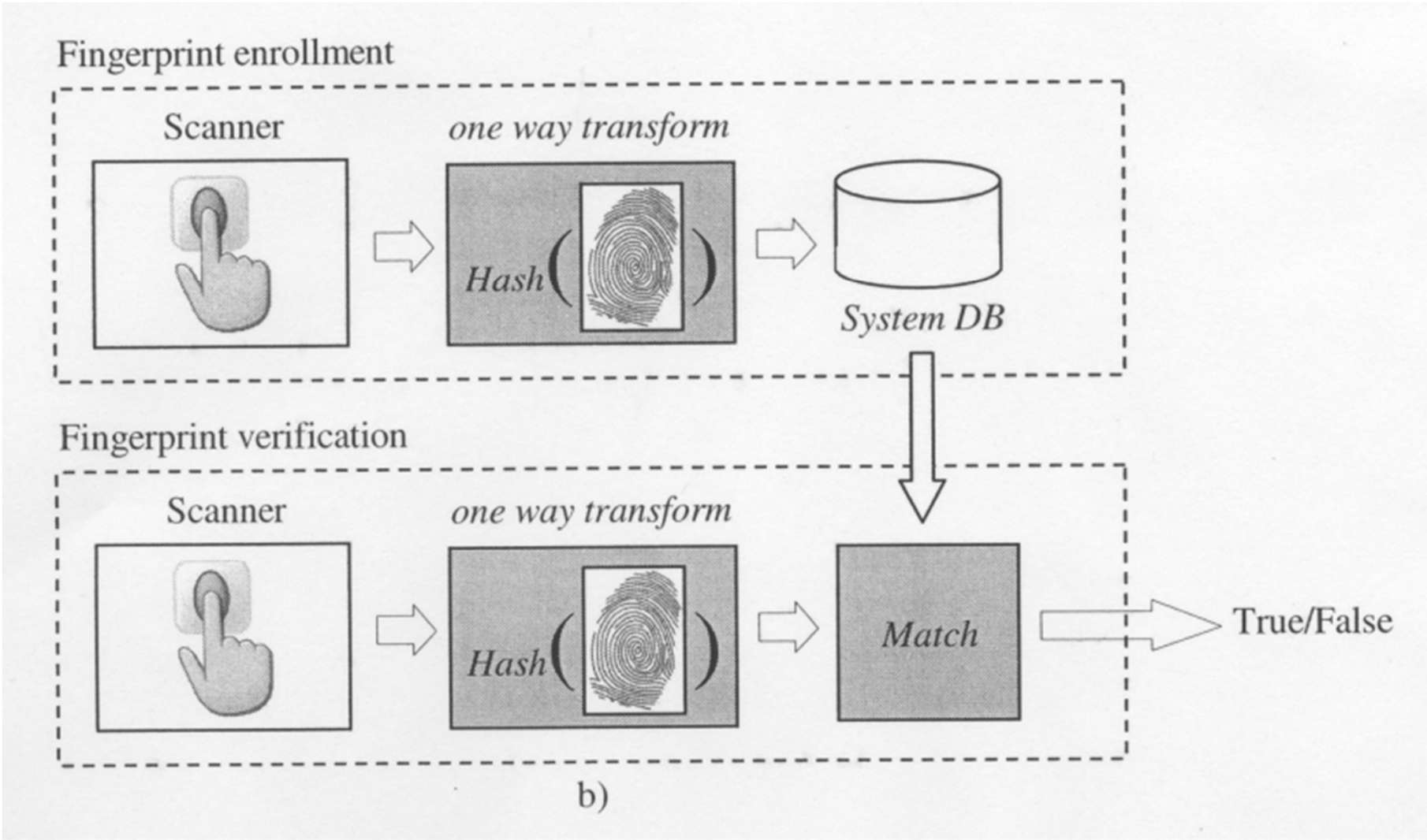
Biometrics?

- Biometric is the science and technology of measuring and analyzing the biological data
- It measures and analyze human body characteristics such as fingerprints, DNA, eye retinas and irises, voice patterns, facial patterns and hand measurements for authentication purposes



Examples of biometric types

Example of a biometric authentication system



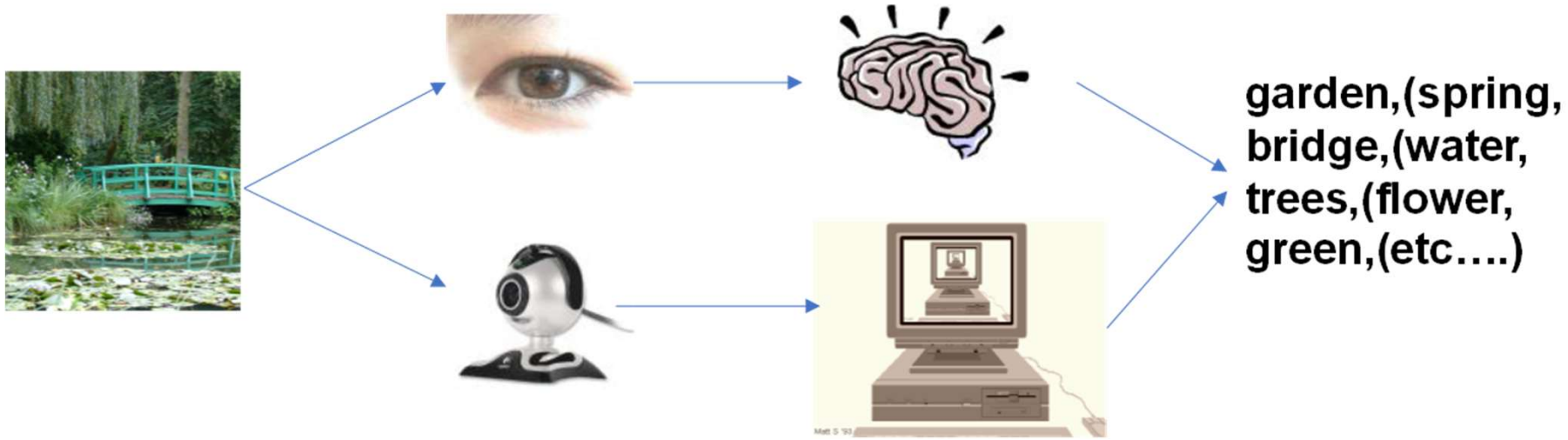
Biometric solutions

- Reliable authentication and authorization
  - Common measures authenticate the token/password
  - Repudiation problems can be resolved
  - Can provide negative identifications
  - Stop ID theft
- Biometrics cannot be lost, forgotten
- Streamline use of multiple tokens and passwords
- Drawbacks?
- Computer vision/Image processing knowledge is needed

What is computer vision?

Human vision

Image or video | Sensing (device) | Interpreting | Interpretations



Computer vision

From CS131 course “computer vision”,
Prof. Fei-Fei Li, Stanford 'Vision'Lab

The goal of computer vision

- To bridge the gap between pixels and “meaning”

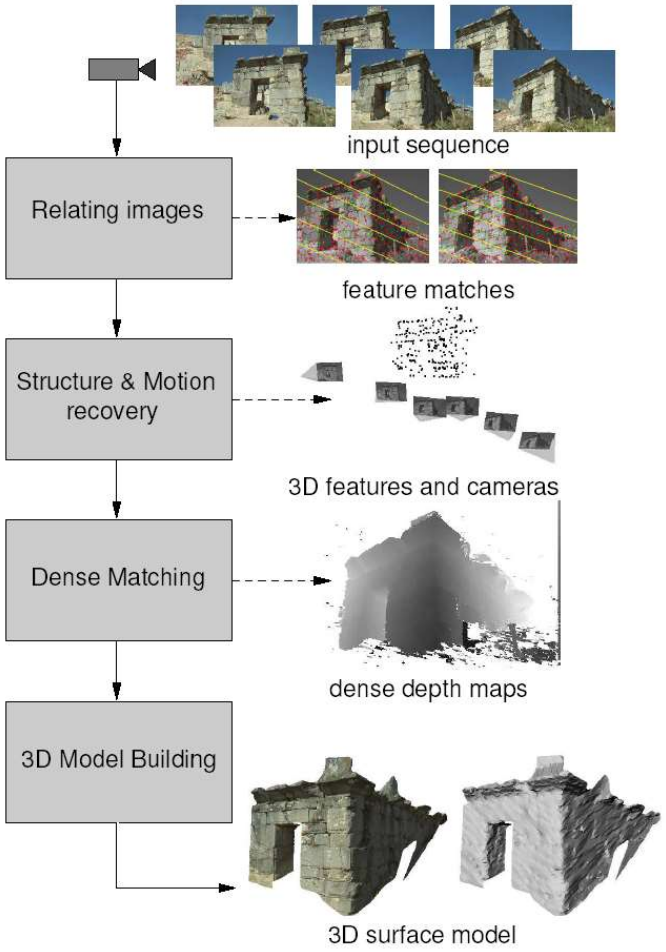
What we see

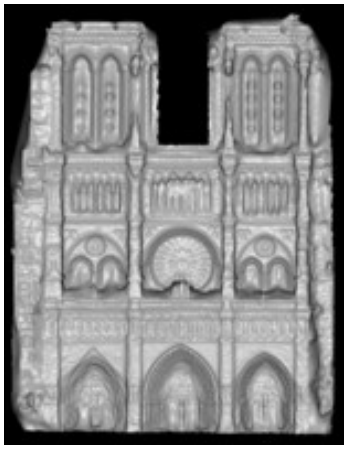
0	3	2	5	4	7	6	9	8
3	0	1	2	3	4	5	6	7
2	1	0	3	2	5	4	7	6
5	2	3	0	1	2	3	4	5
4	3	2	1	0	3	2	5	4
7	4	5	2	3	0	1	2	3
6	5	4	3	2	1	0	3	2
9	6	7	4	5	2	3	0	1
8	7	6	5	4	3	2	1	0

What a computer sees

Source: S. Narasimhan

Vision as measurement device





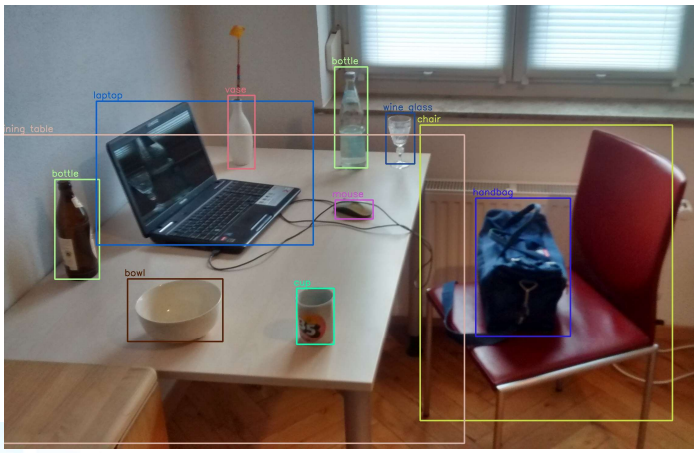
Pollefeys et al.

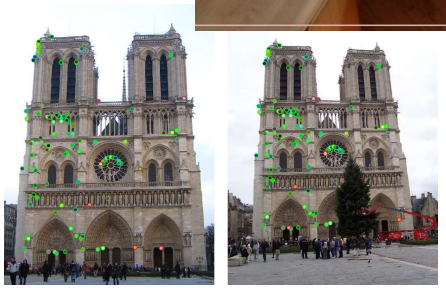
Goesele et al.

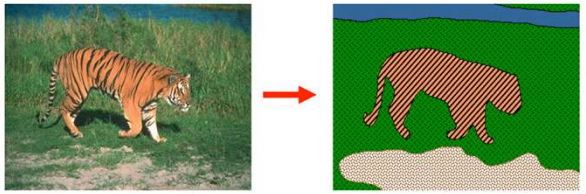
Vision as a source of semantic information

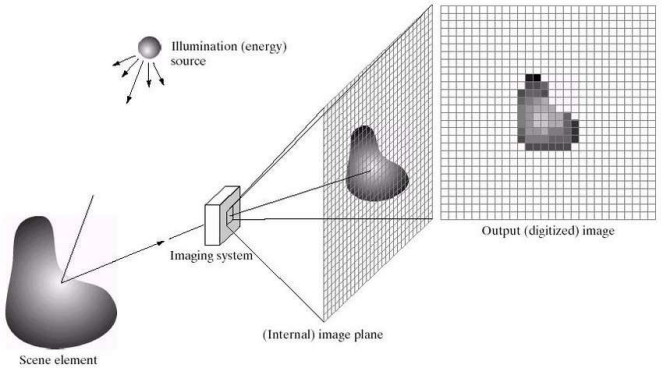
Slide credit: Kristen Grauman

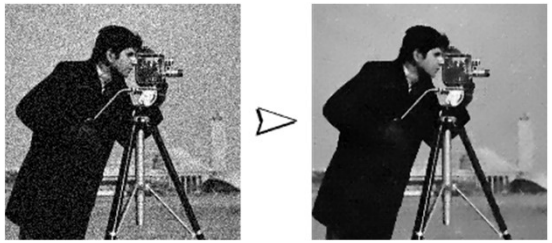
Image processing vs. Computer vision











High level (understanding)

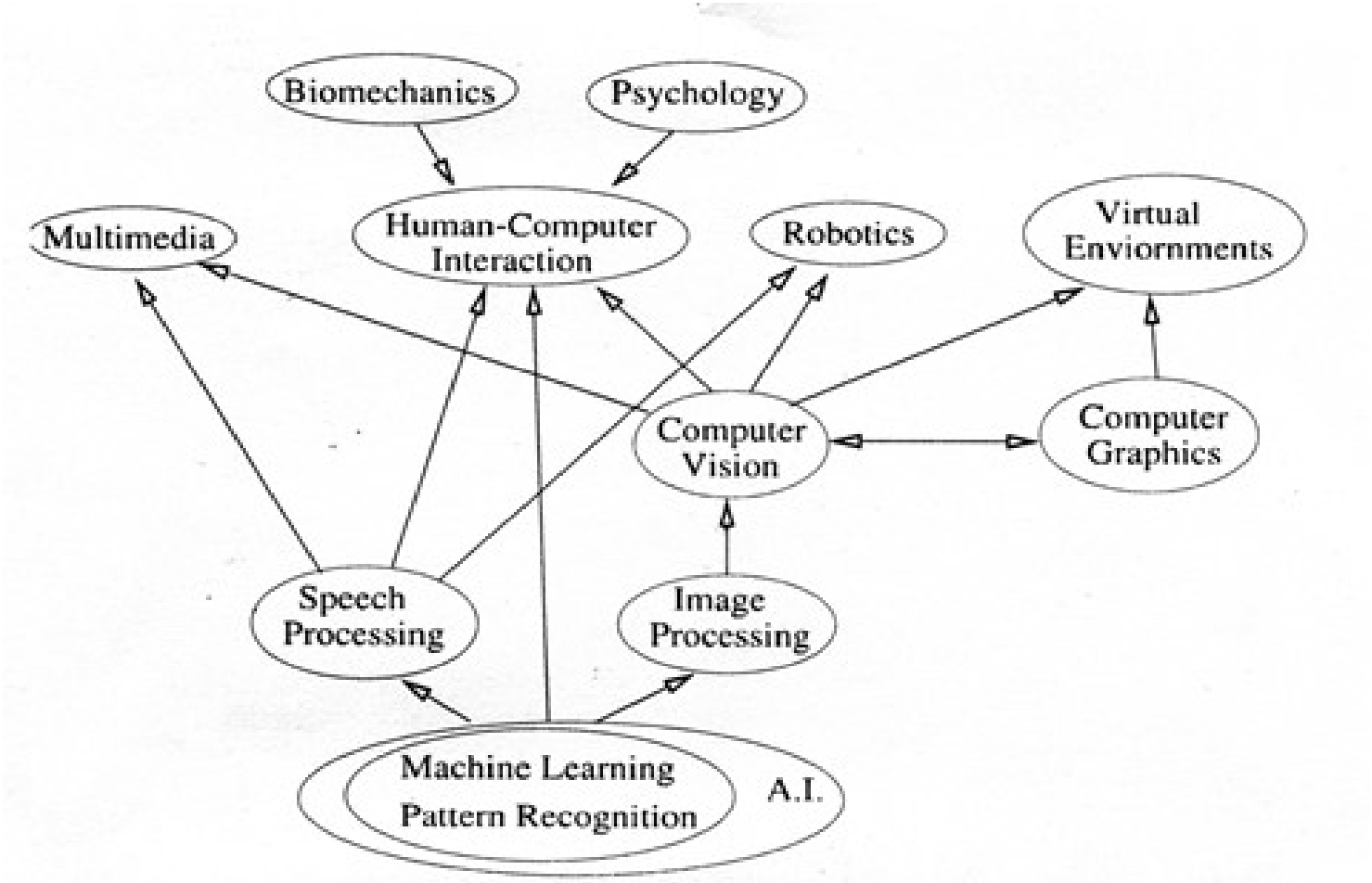
Middle level (feature extraction)

Low level (pre-processing)

Computer vision

Image processing

Related fields



Source: From EECS 432-Advanced Computer Vision, Northwestern University

Applications areas

Robotics Application

- Localization-determine robot location automatically
- Navigation
- Obstacles avoidance
- Assembly peg − in − hole, welding, painting
- Manipulation e. g. PUMA robot manipulator
- Human Robot Interaction HRI: Intelligent robotics to interact with and serve people

Applications areas

Security Application

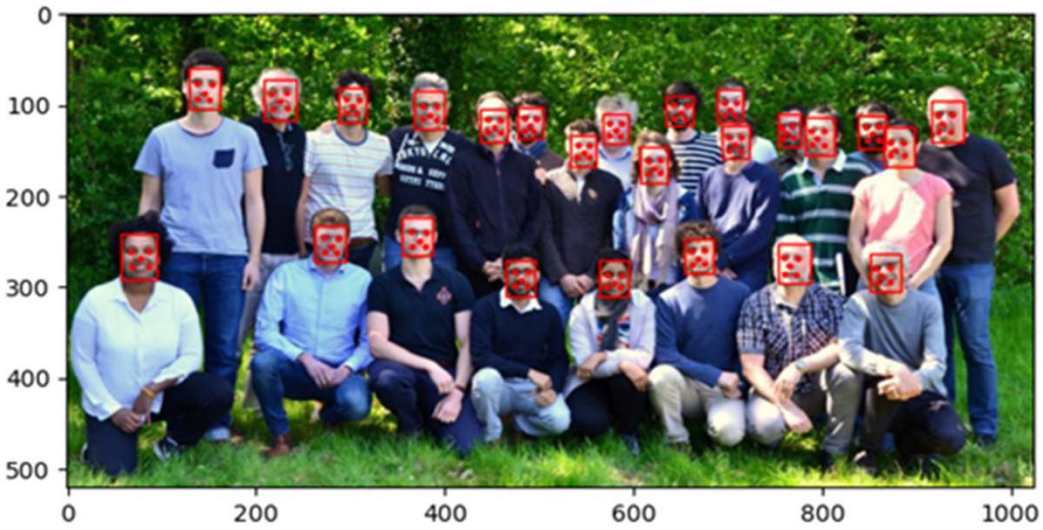
- Biometrics iris, fingerprint, face recognition
- Surveillance-detecting certain suspicious activities or behaviors
- …

Fingerprint scanners

Face recognition systems

Source: from S. Seitz

Examples
Face Detection



Source: from S. Seitz

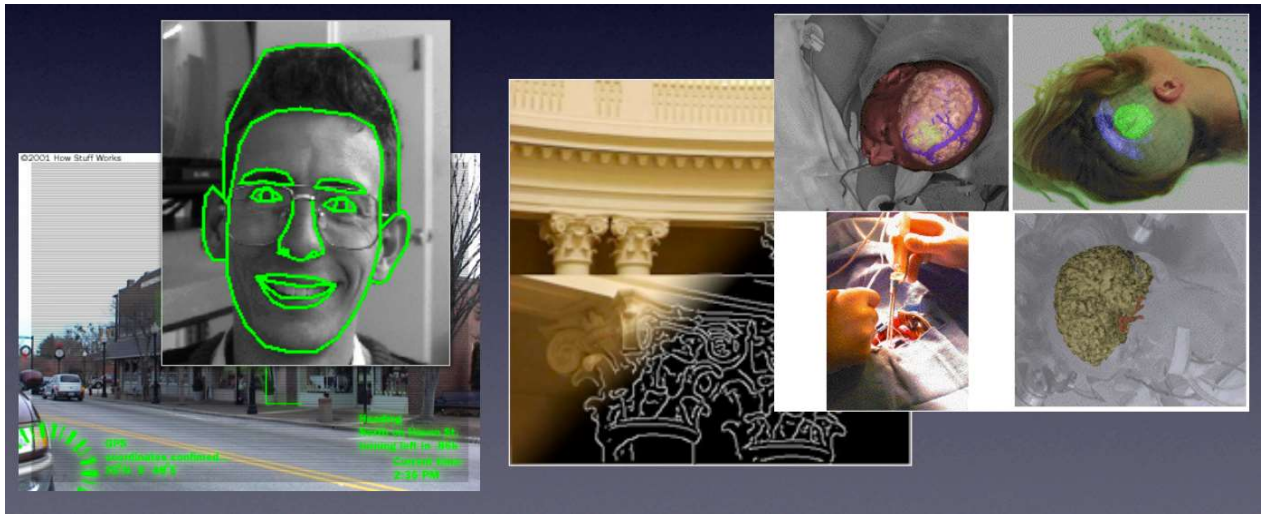
Examples of Computer Vision

Slide from Vicente Ordonez

Applications areas

Medicine Application

- Classification and detection e. g.
- 2D/3D segmentation
- 3D human organ reconstruction MRI or ultrasound
- Vision-guided robotics surgery
- …



Slide from Jason Lawrence

Applications areas

Industrial Automation Application

- Industrial inspection defect detection
- Barcode and package label reading
- Object sorting
- Document understanding e. g. OCR
- …

Transportation Application

- Autonomous vehicle
- Safety, e.g., driver vigilance monitoring
- …

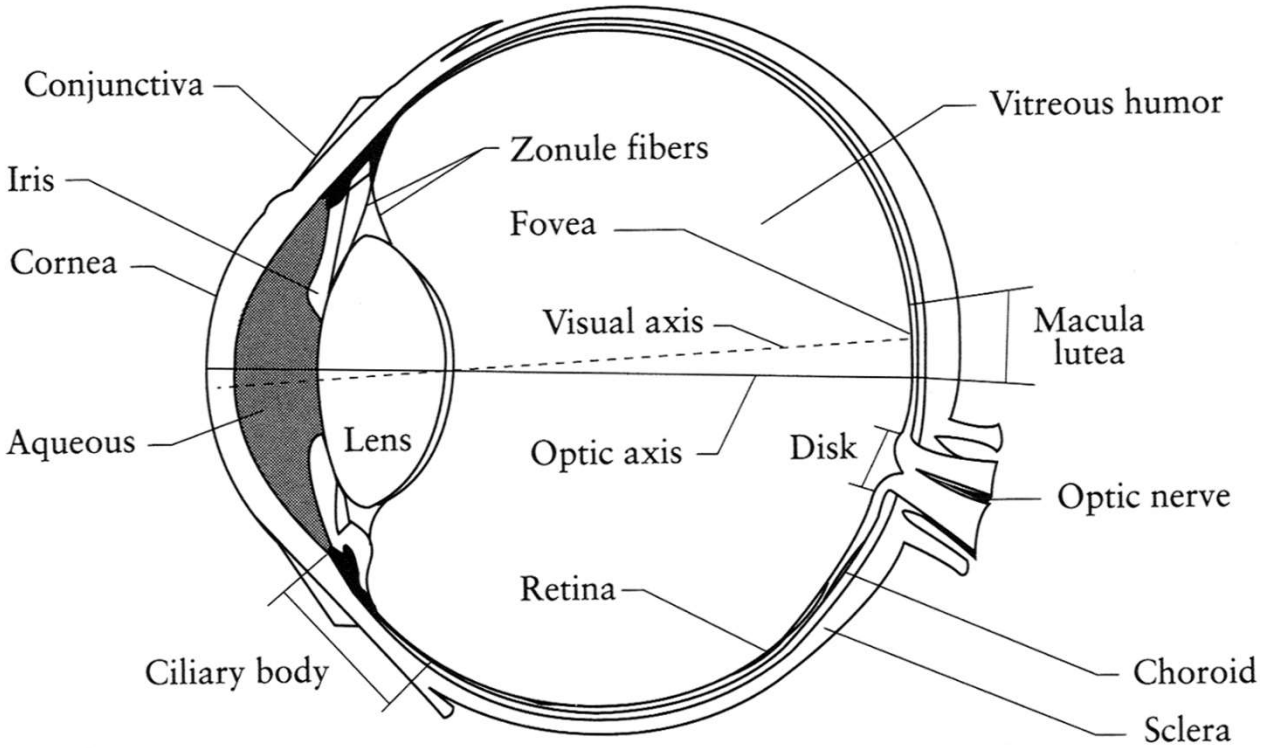
Facebook's suggestion

Image formation

Image formation studies the forward process of producing images and videos.

- Image formation encompasses the radiometric and geometric processes by which 2D images of 3D objects are formed. To produce a real image, the nature of the visual sensors (i.e. CCD and CMOS cameras), should be studied.
- Imaging process is a mapping of an object to an image plane.
- With digital images, the image formation process also includes analog to digital conversion, sampling
- **Human color vision (Perception) :** In the case of computer vision the light incident on the sensor comprises the image. In the case of visual perception, the human eye has a color dependent response to light which is the spectral sensitivity of human vision.

The Eye



- The human eye is a camera
  - **Iris -** colored annulus with radial muscles
  - **Pupil -** the hole (aperture) whose size is controlled by the iris
  - What's the sensor?
    - photoreceptor cells (rods and cones) in the **retina**

Slide by Steve Seitz

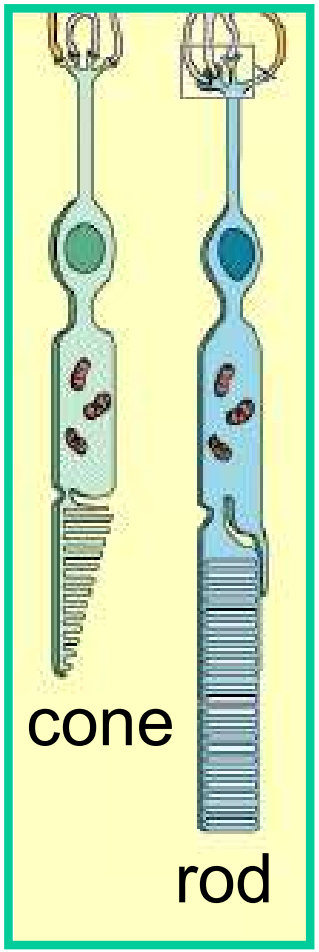
Two types of light-sensitive receptors

Cones

- cone-shaped
- less sensitive
- operate in high light
- color vision

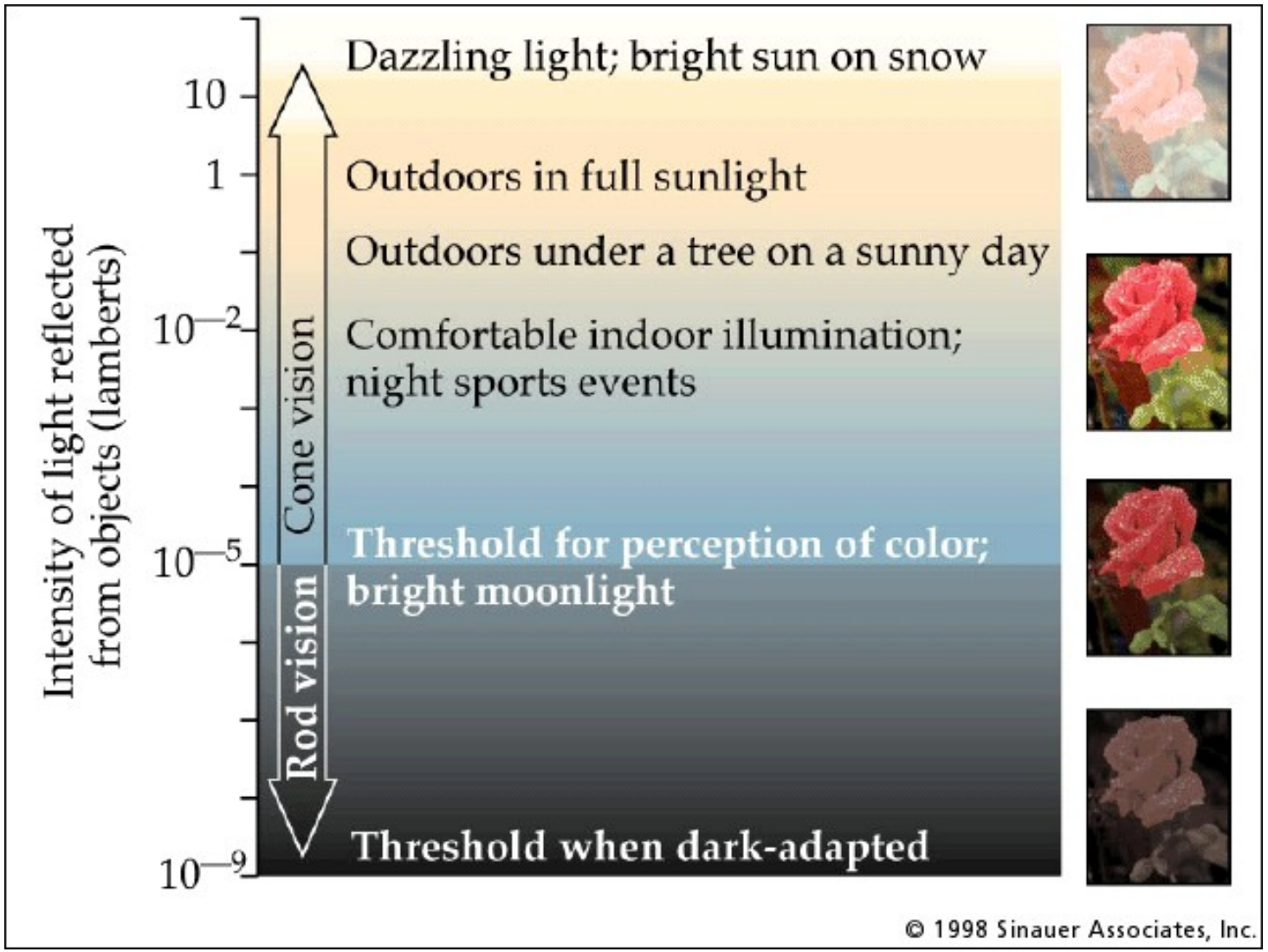
Rods

- rod-shaped
- highly sensitive
- operate at night
- gray-scale vision

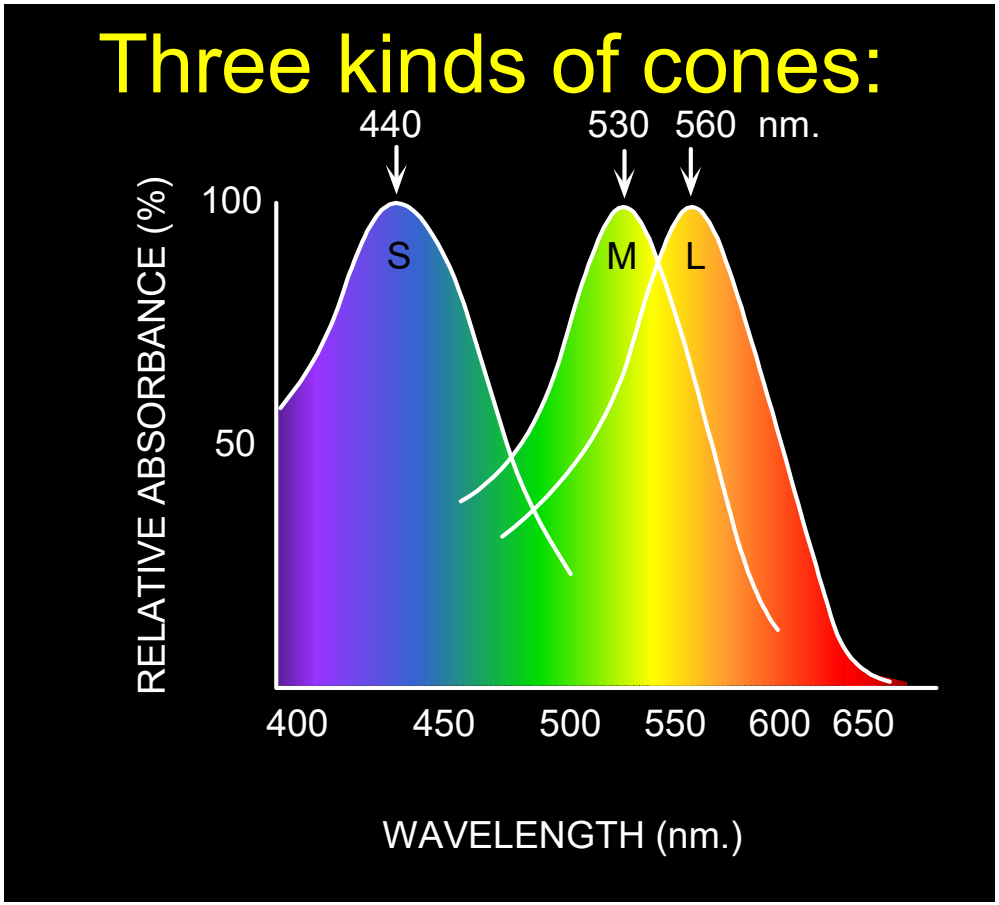


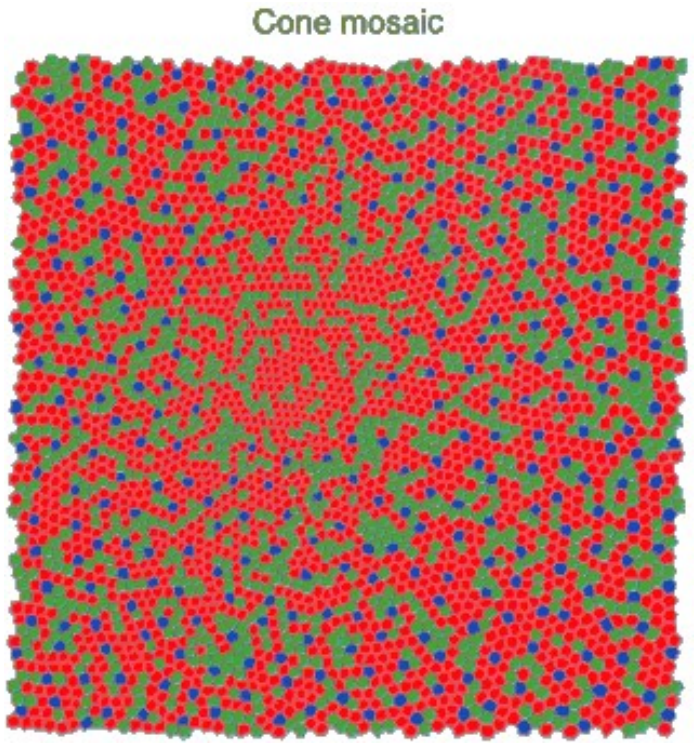
James Hays

Rod / Cone sensitivity



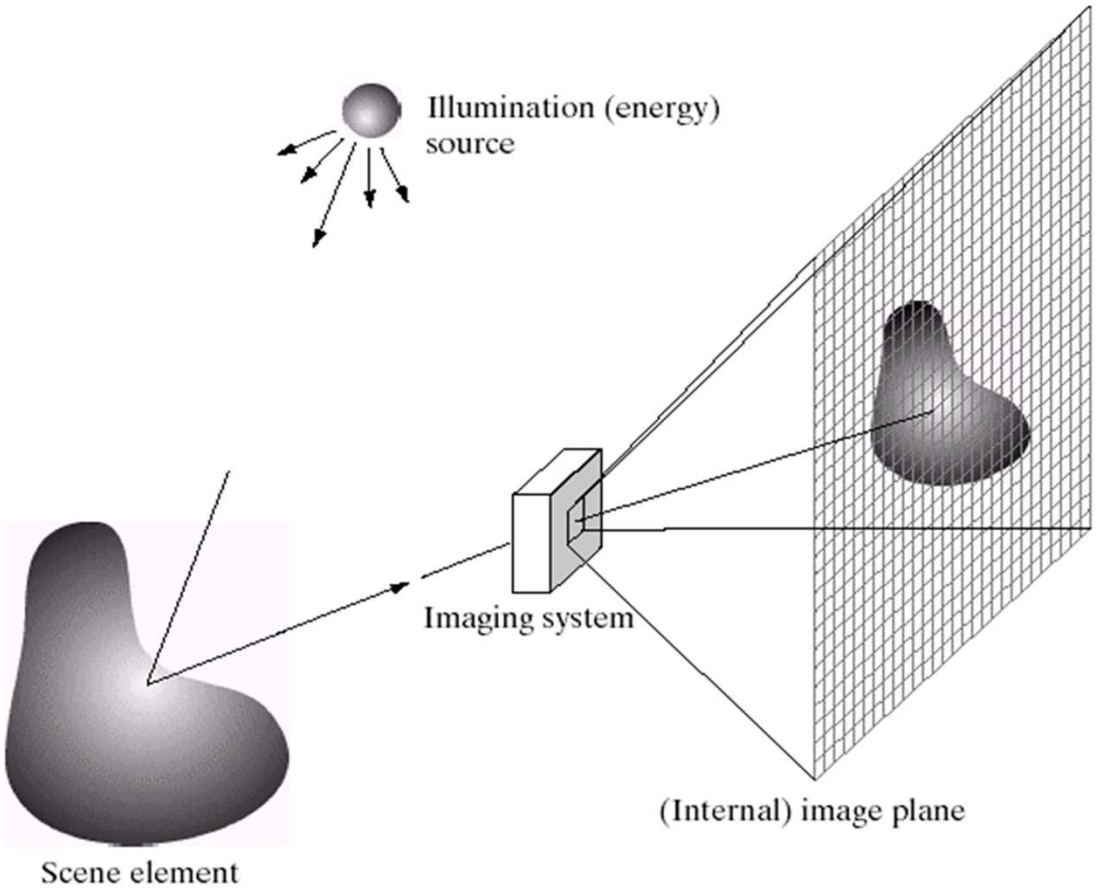
Physiology of Color Vision





© Stephen E. Palmer, 2002

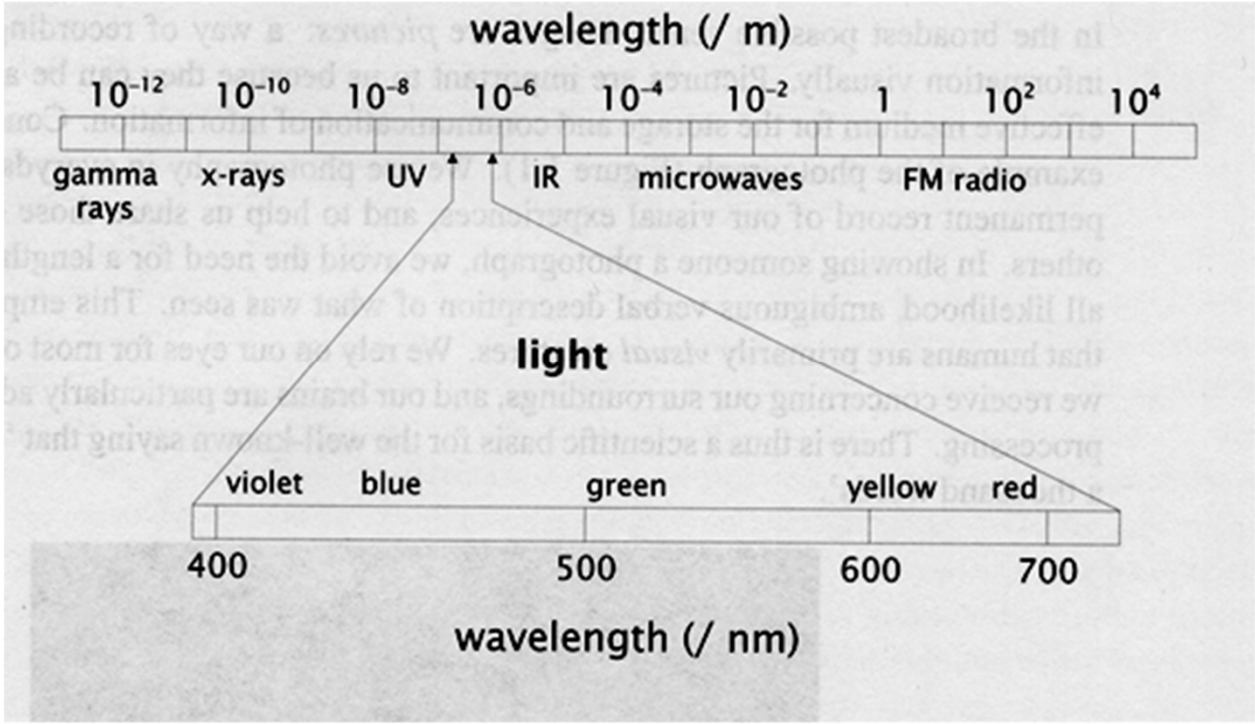
Image formation



Adapted from S. Seitz

What is light?

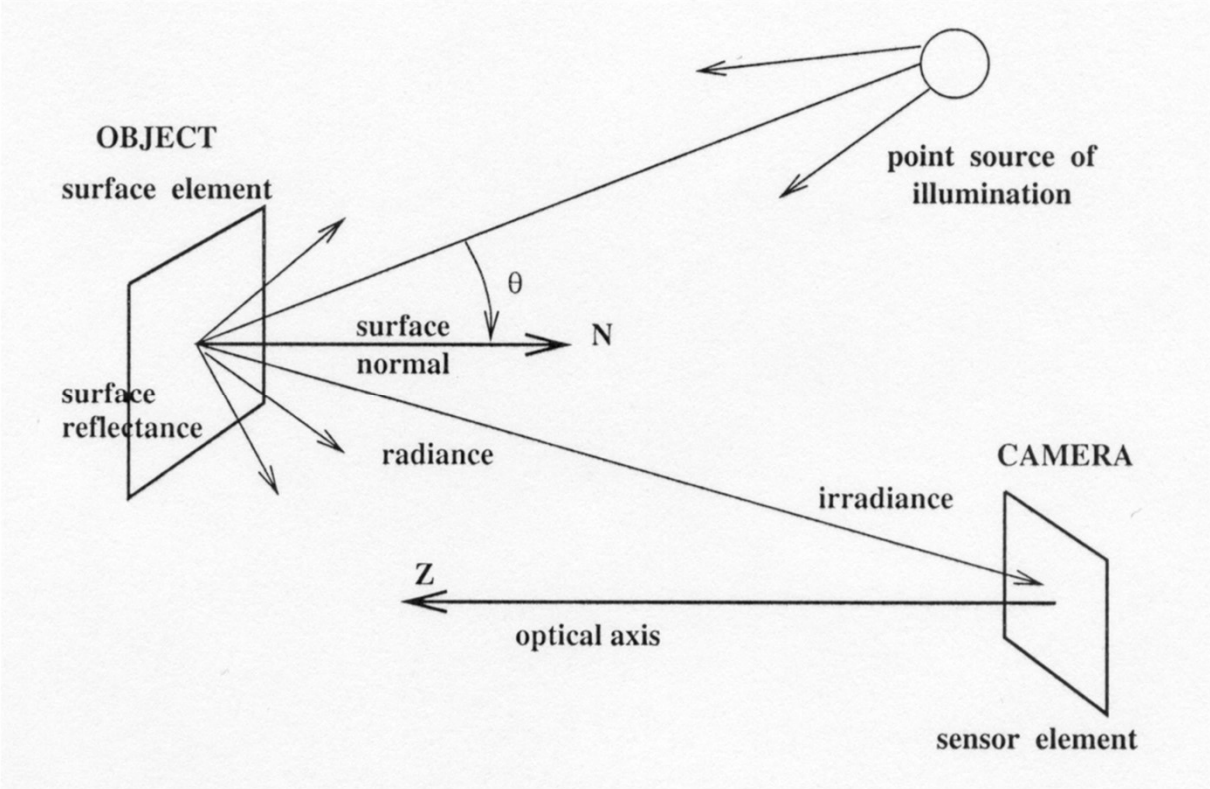
- Light: The visible portion of the electromagnetic (EM) spectrum.
- Light occurs between wavelengths of approximately 400 and 700 nanometers.



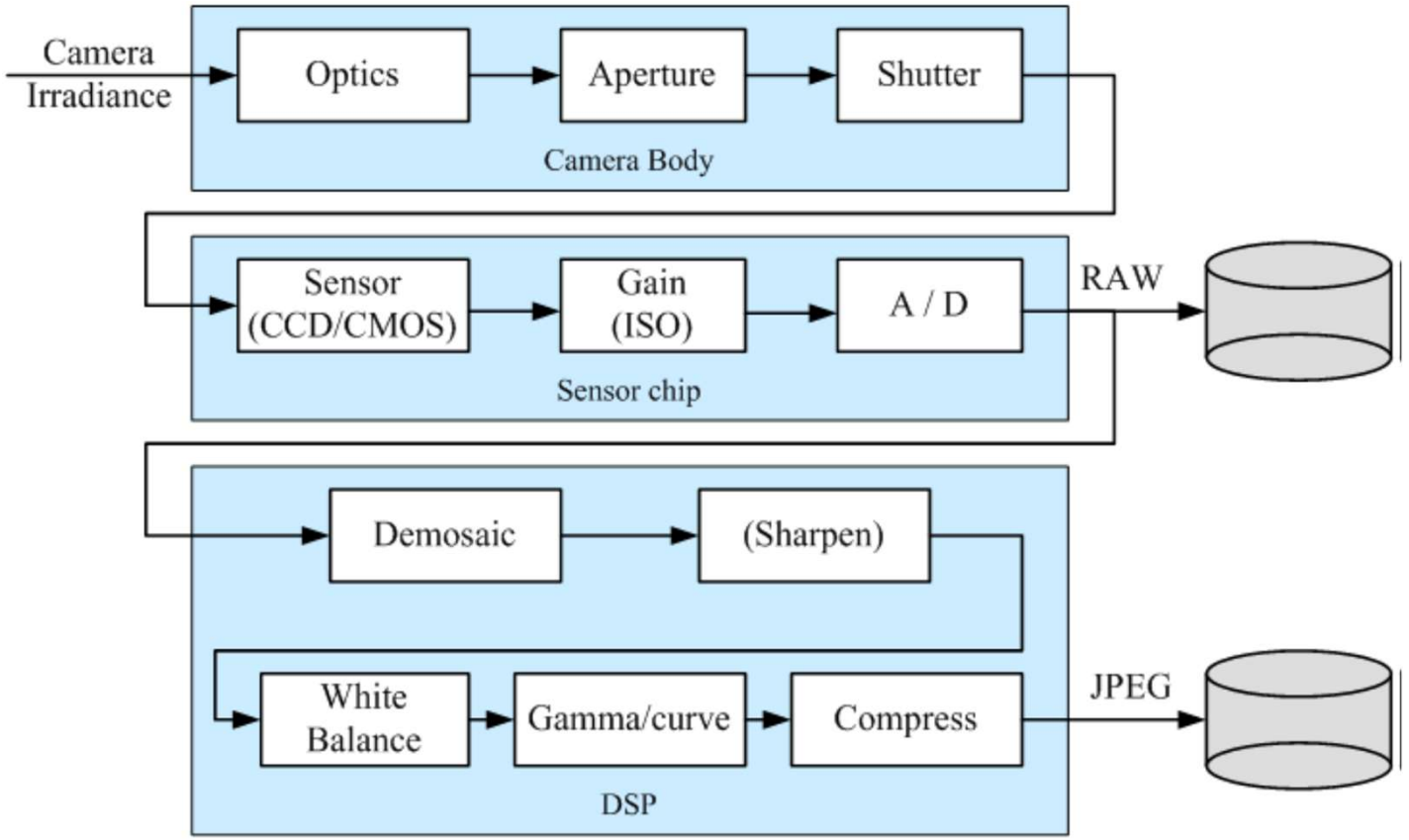
Photometric image formation

- Modeling the image formation process: 3D geometric features in the world are projected into 2D features in an image.
- A simplified model of photometric image formation is illustrated.

  - The scene is illuminated by a single source.
  - The scene reflects radiation towards the camera.
  - The camera senses it via CCD/ CMOS



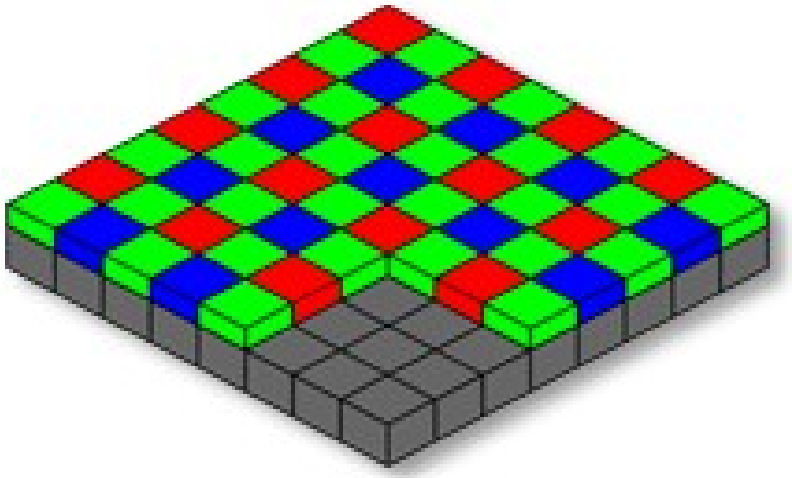
Acquisition and digitization: Digital camera



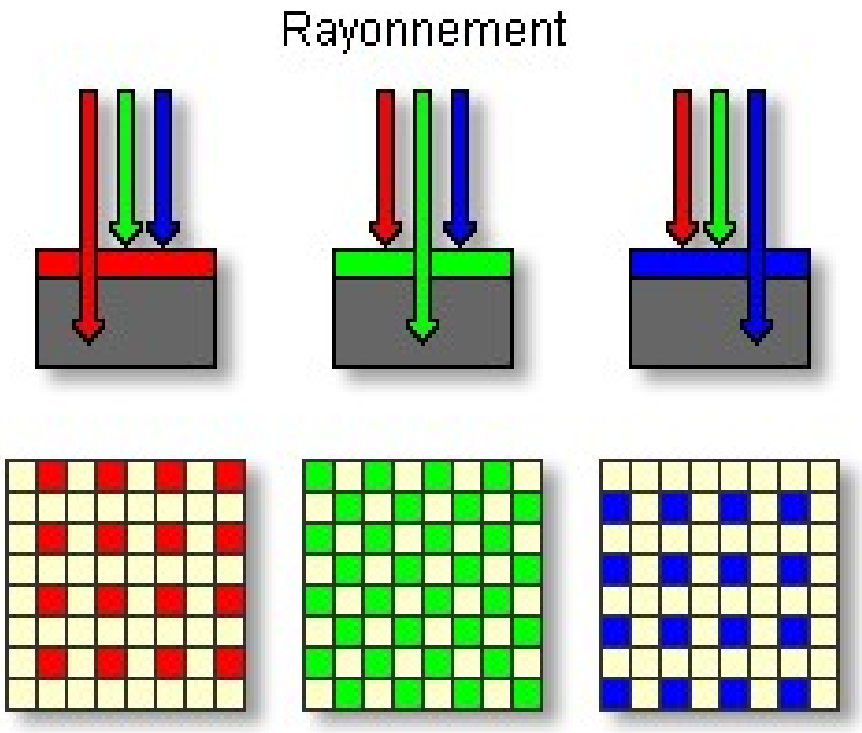
Digital camera: Image sensing and processing pipeline

Adapted from S. Seitz

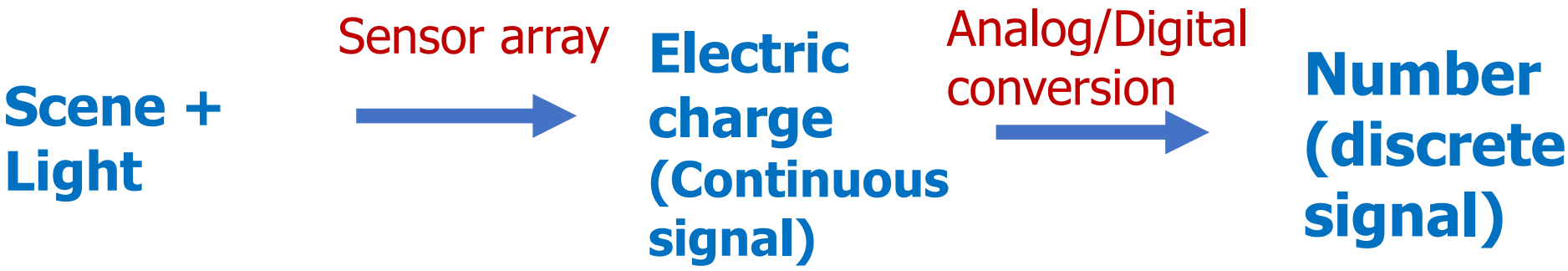
Sensor array : an example



Capteur photosensible
recouvert d'une grille de Bayer



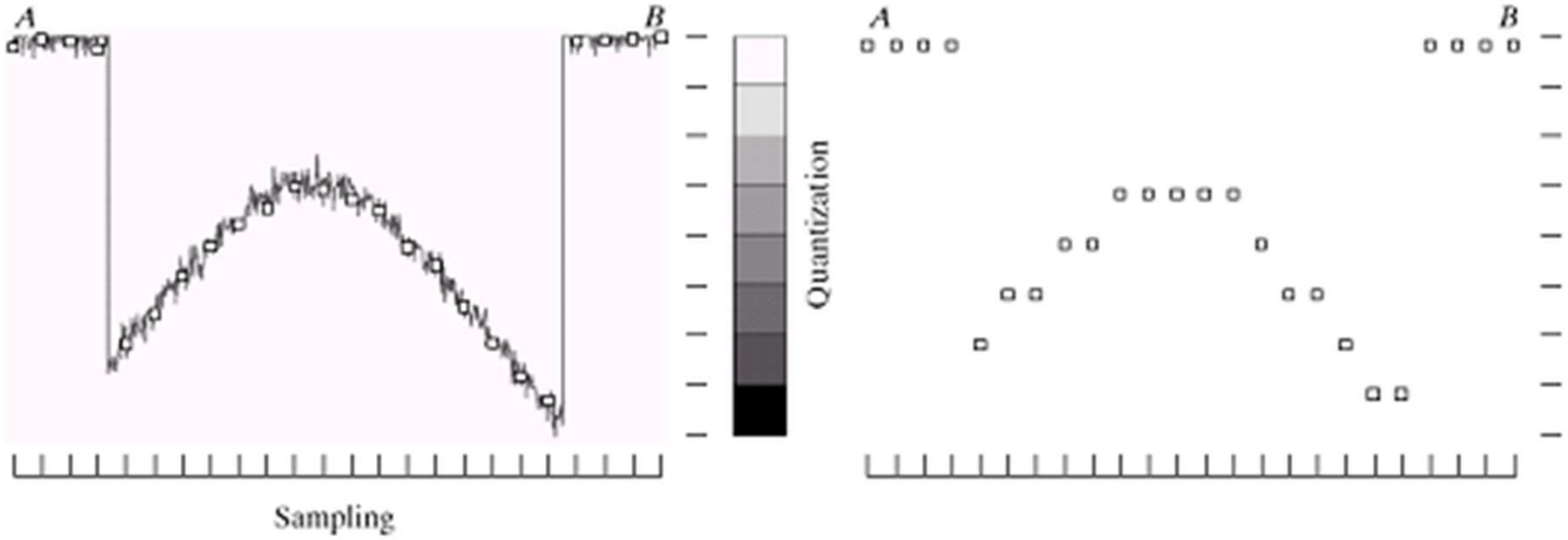
Real scene -> digital Image



Digitization = **Sampling (lấy mẫu)**
+ **Quantization (Lượng tử hóa)**

Sampling and quantization

- **Sample** the 2D space on a regular grid
- **Quantize** each sample (round to nearest integer)



Sampling and quantization

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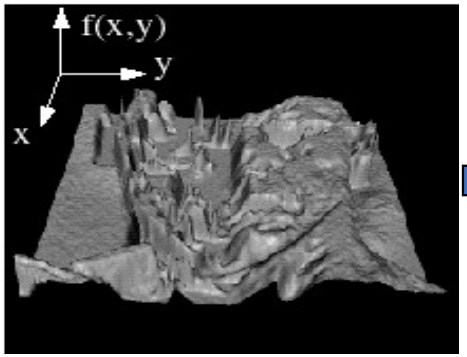


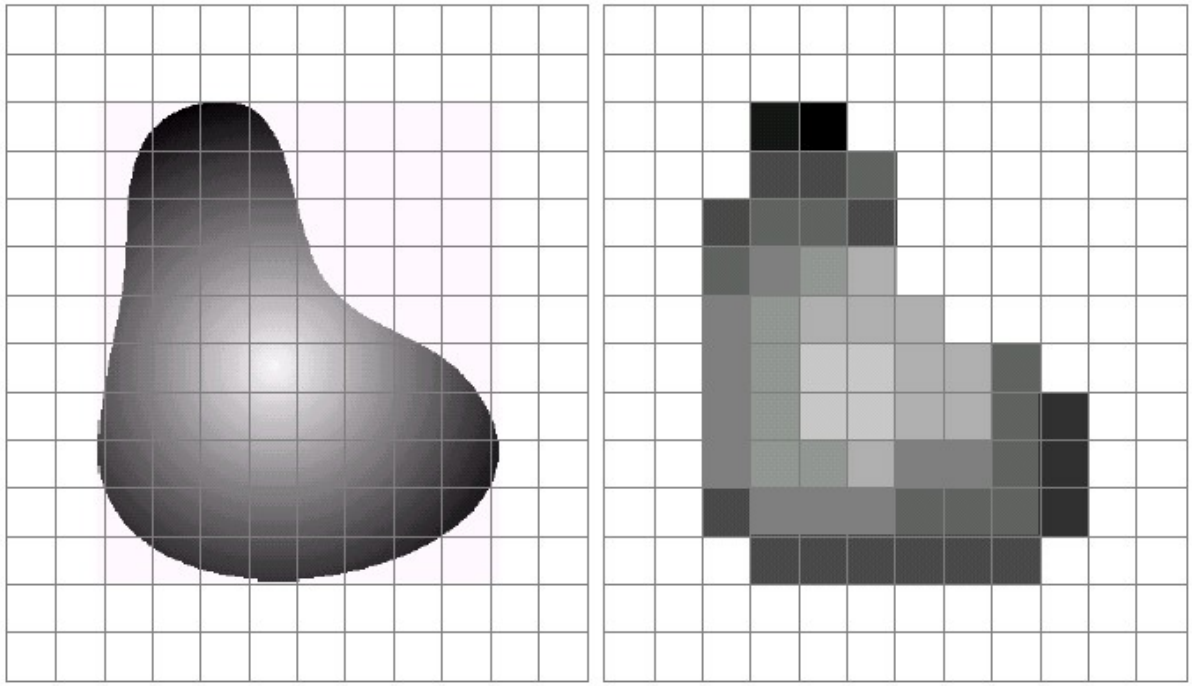
j

i

62	79	23	119	120	105	4	0
10	10	9	62	12	78	34	0
10	58	197	46	46	0	0	48
176	135	5	188	191	68	0	49
2	1	1	29	26	37	0	77
0	89	144	147	187	102	62	208
255	252	0	166	123	62	0	31
166	63	127	17	1	0	99	30

2D

Digital image



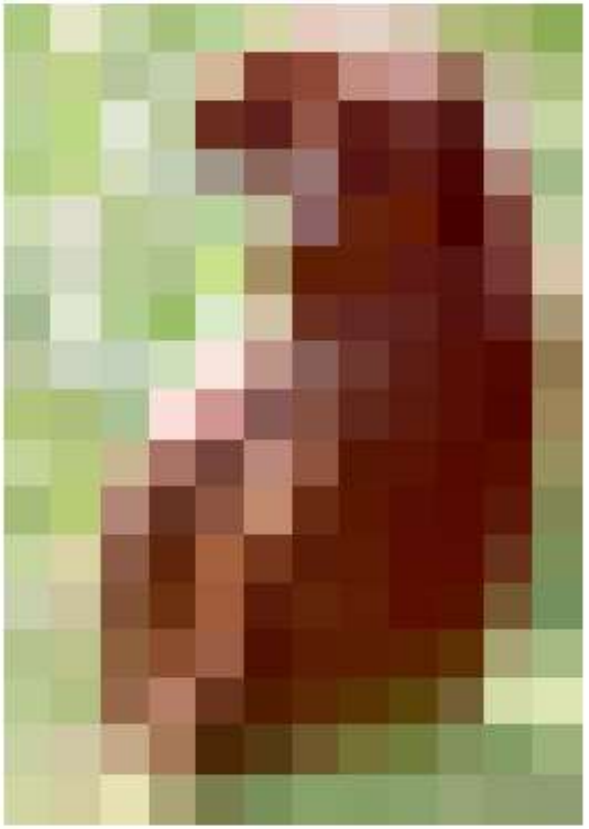
a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Spatial resolution (sampling)

200 X 278

50 X 70



12 X 18

Gray-level resolution (Quantization)

8 bits

4 bits

2 bits

Color spaces

- Color spaces; different types of color modes
- Color represented by vector of components
  - Red, Green, Blue (**RGB**)
  - Hue, Saturation, Value (**HSV**)
  - Luminance, chrominance (**YUV,** LUV)
  - **XYZ**
- Color convert: RGB – YUV

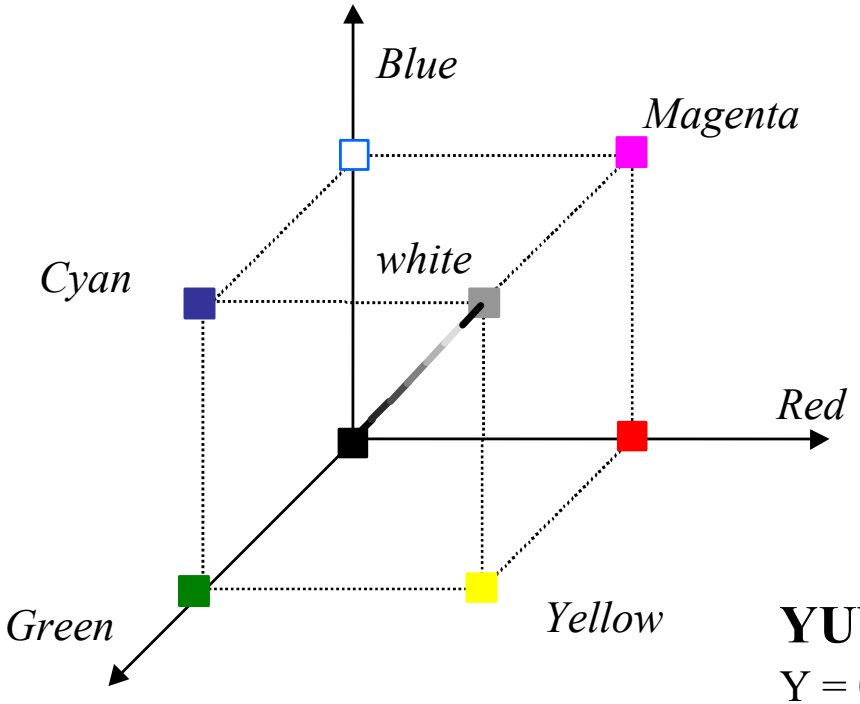
$$Y = 0.299R + 0.587G + 0.114B$$

$$U = 0.493\,(B - Y)\ ;\ \ V = 0.877\,(R - Y)$$

$$\begin{bmatrix} Y \\ C_R \\ C_B \end{bmatrix} = \begin{bmatrix} 0.257 & 0.504 & 0.098 \\ 0.439 & -0.368 & -0.071 \\ -0.148 & -0.291 & 0.439 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}$$

Color coordinate system

Màu sắc



RGB

Black	(0, 0, 0)
Red	(255, 0, 0)
Green	(0, 255, 0)
Yellow	(255, 255, 0)
Blue	(0, 0, 255)
Magenta	(255, 0, 255)
Cyan	(0, 255, 255)
White	(255, 255, 255)

YUV (Luminance)

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

$U = R - Y$

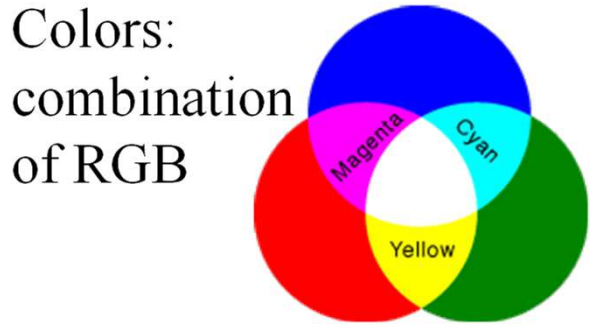
$V = B - Y$

Y Cb Cr (JPEG)

$Cb = U/2 + 0.5$

$Cr = V/1.6 + 0.5$

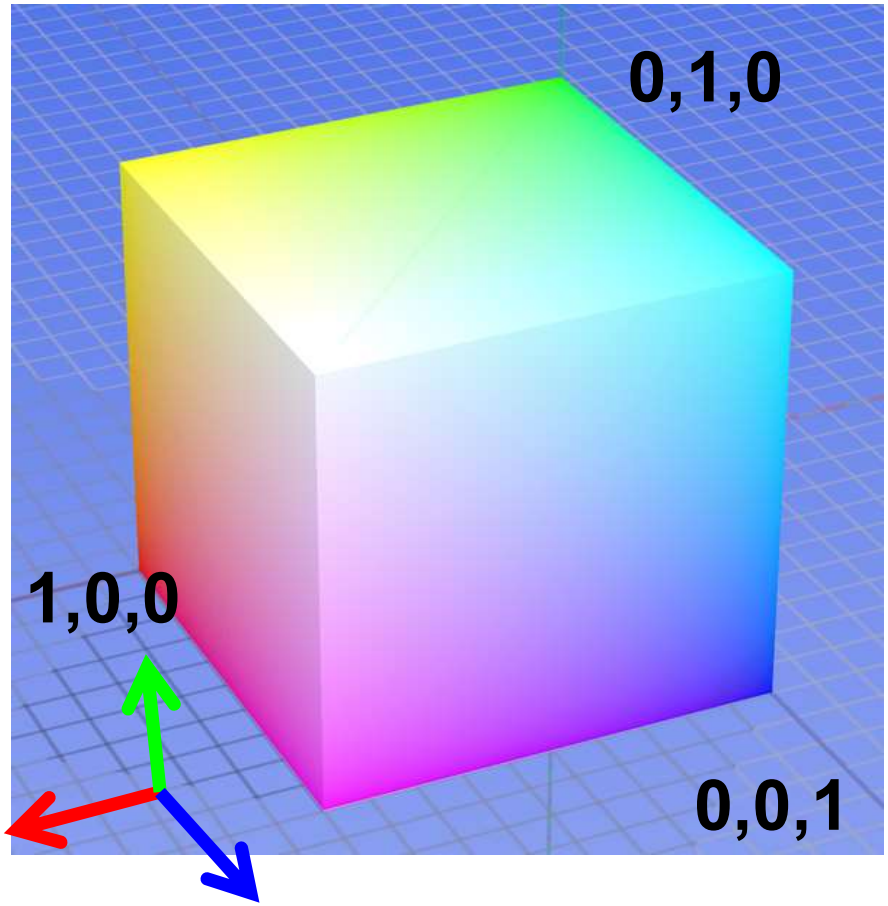
Color: Additive/Subtractive primary color



- **Primary color**: Red, Green, Blue (RGB)
- **Additive colors**:
  - Combination of RGB can be mixed to produce Cyan, Magenta, Yellow (CMY) &White.
  - ***Additive color reproduction system***:
    - Combination of RGB to reproduce a colored light.
- **Subtractive colors** CMY can be mixed to produce RBG & black
  - ***Subtractive color reproduction system***: A white light sequentially passes through cyan, magenta, yellow filters to reproduce a colored light.

Color spaces: RGB

Default color space



R = 1
(G=0,B=0)

G = 1
(R=0,B=0)

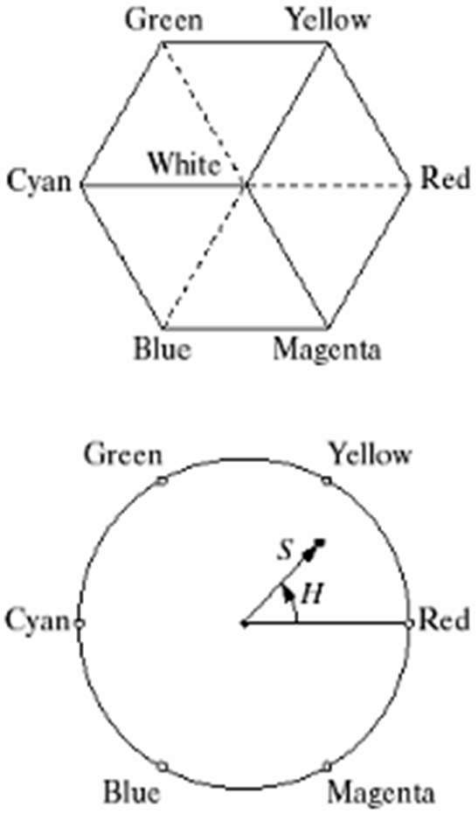
B = 1
(R=0,G=0)

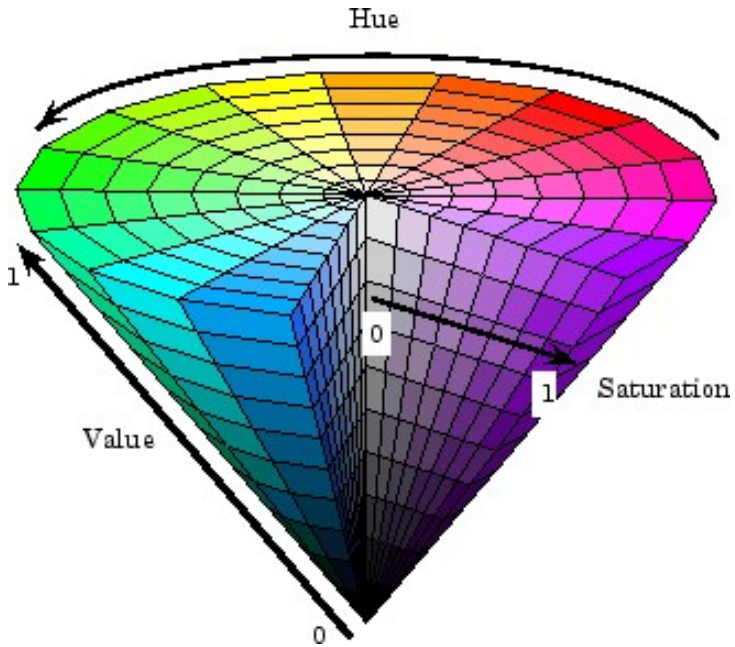
Any color = r*R + g*G + b*B

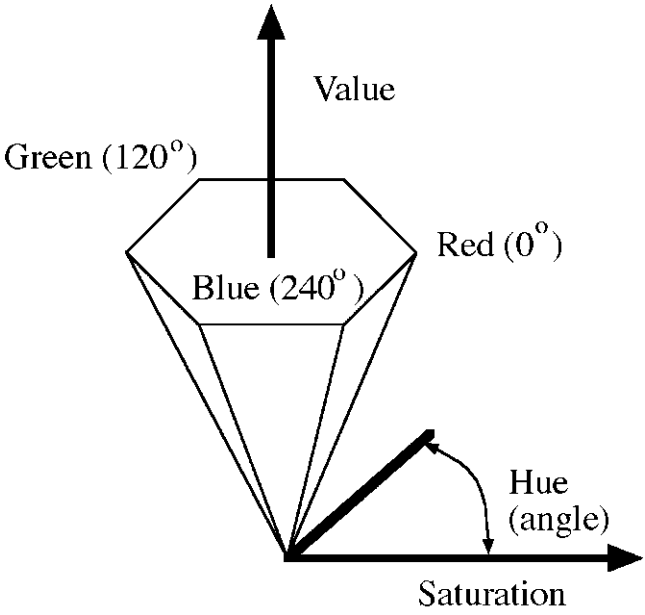
- Strongly correlated channels
- Non-perceptual

Image from: http://en.wikipedia.org/wiki/File:RGB_color_solid_cube.png

Nonlinear color spaces: HSV



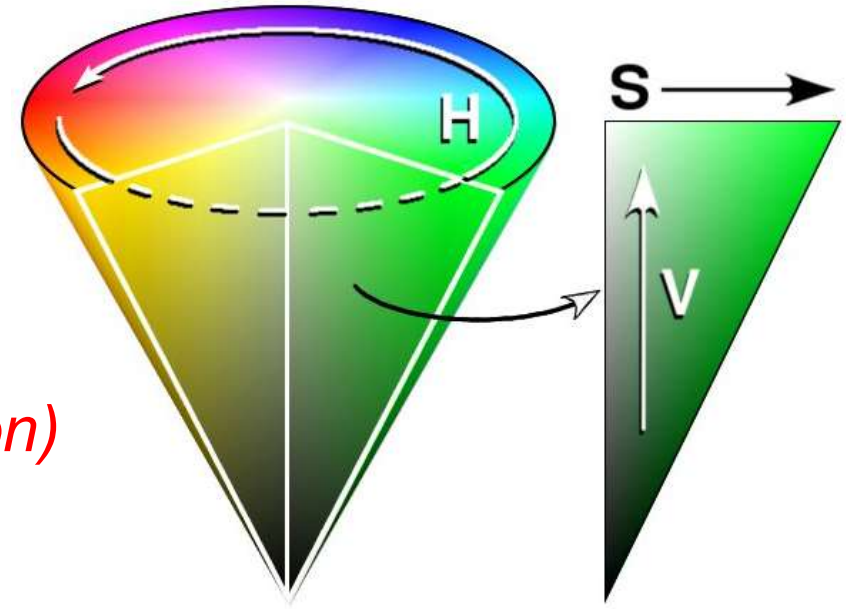




- Perceptually meaningful dimensions:
  - Hue, Saturation (chroma)
  - Value (Intensity)

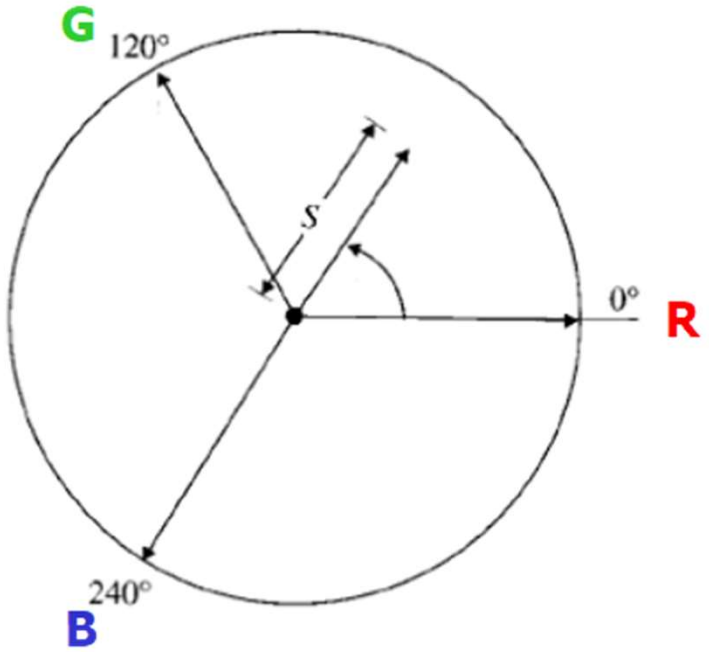
HSV (Hue – Saturation- Value)

- The Hue-Saturation-Value (HSV) color space is use for segmentation and recognition
  - Non-linear conversion
  - Visual representation of colors
- We identify for a pixel:
  - The pixel *intensity (value)*
  - The pixel *color (hue + saturation)*
- RGB does not have this seperation



HSV (Hue – Saturation- Value)

- **Hue (H)** is coded as an angle between 0 and 360
- **Saturation (S)** is coded as a radius between 0 and 1
  - S = 0 : gray
  - S = 1 : pure color
- **Value (V)** = MAX (Red, Green, Blue)



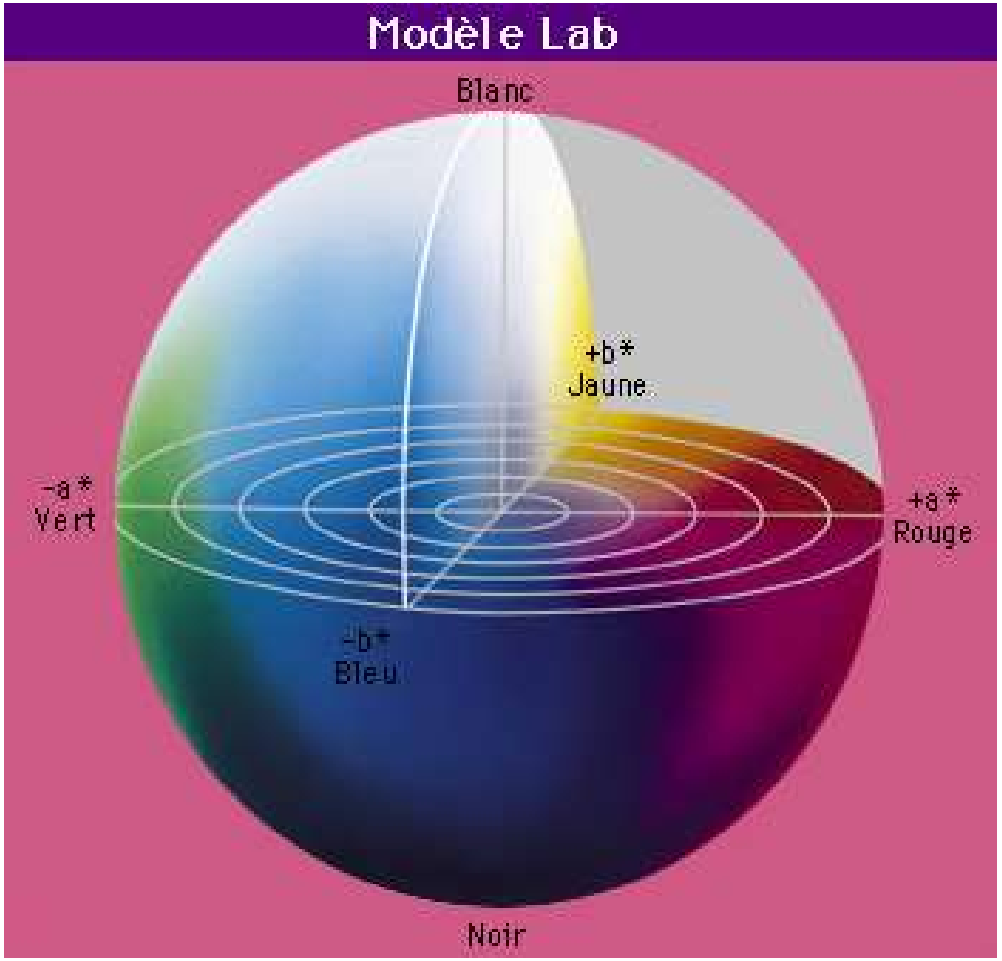
HSV (Hue – Saturation- Value)

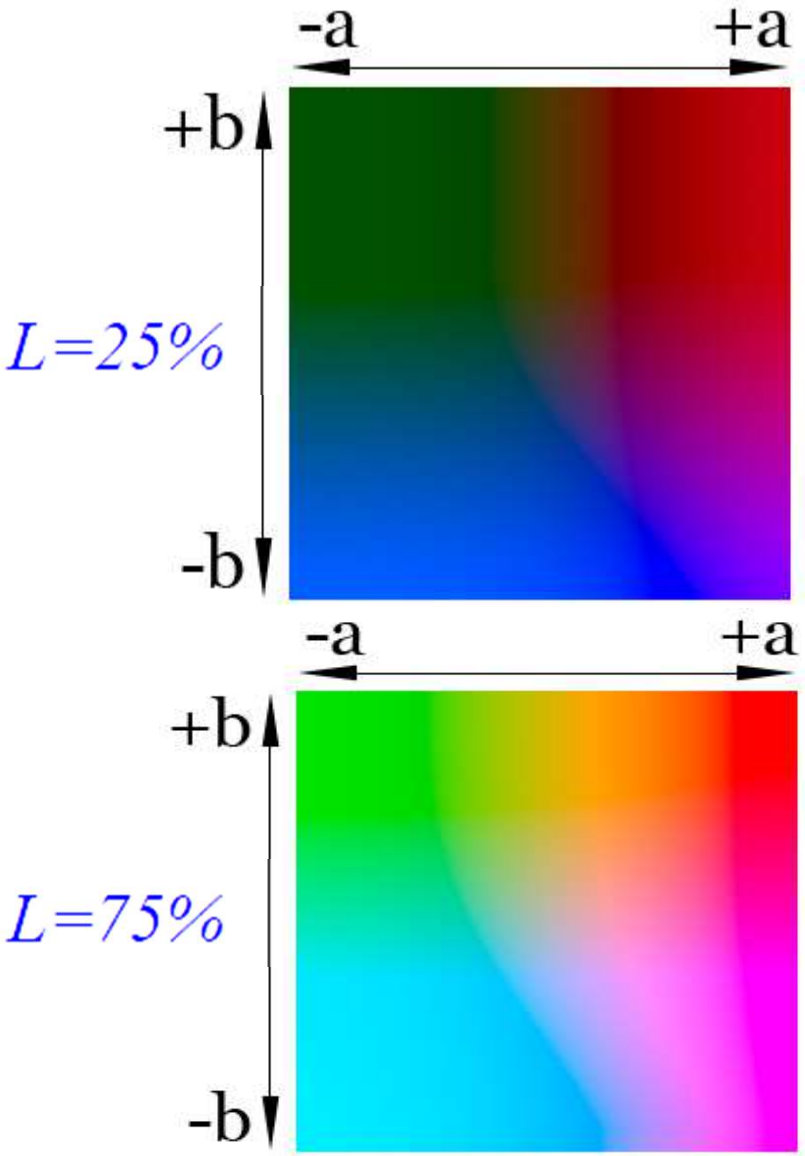
- If we know the color of the object we are looking for, can model it using a **hue interval**
- Take care, because it is an angle (periodic value)
  - Hue < 60° means nothing
    - *Is 350° smaller or bigger than 60°?*
  - Define an interval: 350° < Hue < 60° (for example)
- This interval is valid if **S**aturation > *threshold* (otherwise gray level)
- This is independant of **V**alue , which is more sensible to light conditions

Lab color space

- The **Lab** system (sometimes **L*a*b***) is based on a study from human vision
  - independant from all technologies
  - presenting colors as seen by the human eyes
- Colors are defined using 3 values
  - **L** is the luminance, going from 0% (black) to 100% (white)
  - a* represents an axis going from green (negative value, -127) to red (positive value, +127)
  - b* represents an axis going from blue (negative value, -127) to yellow (positive value,+127)

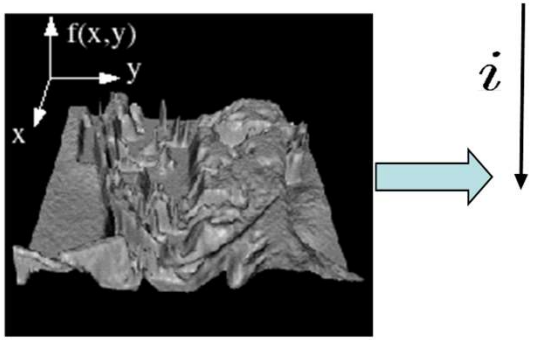
Lab color space





Digital images representation

- Sample the 2D space on a regular grid is pixel
- Quantize each sample (round to nearest integer)
- Image data is represented as a matrix of integer values.

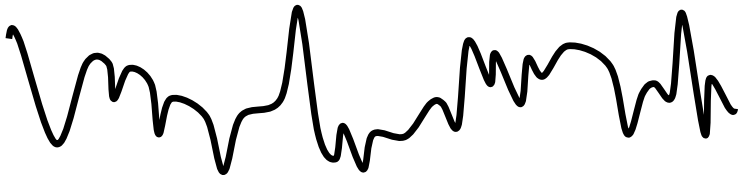


j

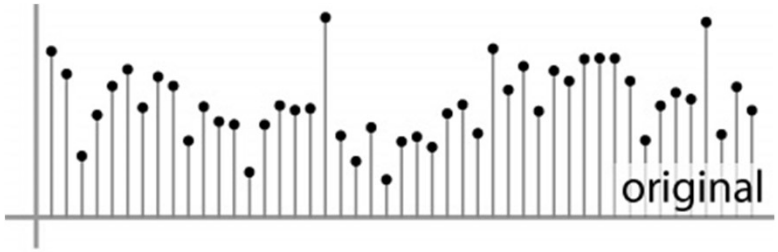
i

62	79	23	119	120	105	4	0
10	10	9	62	12	78	34	0
10	58	197	46	46	0	0	48
176	135	5	188	191	68	0	49
2	1	1	29	26	37	0	77
0	89	144	147	187	102	62	208
255	252	0	166	123	62	0	31
166	63	127	17	1	0	99	30

2D



Analog signal



Digital signal: Data

Adapted from S. Seitz

Definition: Digital images

- Digital image functions *f* represented as matrices X(i,j).
- **Image data** is represented by a rectangular array of integers
- An integer represents the brightness or darkness of the monochromatic image at that point (pixel). Limited brightness integer values (8 bit) = gray levels = values 0 to 255
- **Definition**: **Digital image is a matrix X(i,j)** of pixels, N:number of rows, M: number of columns, Q: integer brightness values (levels) of pixels

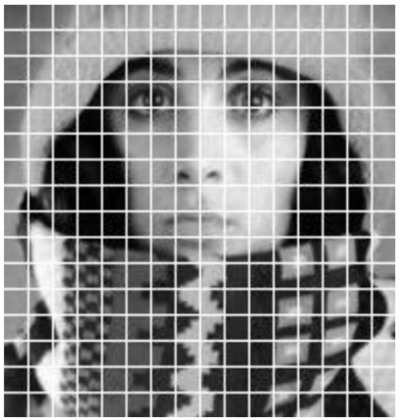
$$X(i,j) = \begin{matrix} f(0,0) & f(0,1) & \dots & f(0,M-1) \\ f(1,0) & f(1,1) & \dots & f(1,M-1) \\ \dots & \dots & \dots & \dots \\ f(N-1,0) & f(N-1,1) & \dots & f(N-1,M-1) \end{matrix}$$

Digital gray image

- Example: Matrix X(i,j) of pixels of a gray level image
- Image data: 2D array X(i,j) of integer brightness value uint8 of pixels at coordinates (i,j).

Columns

Rows

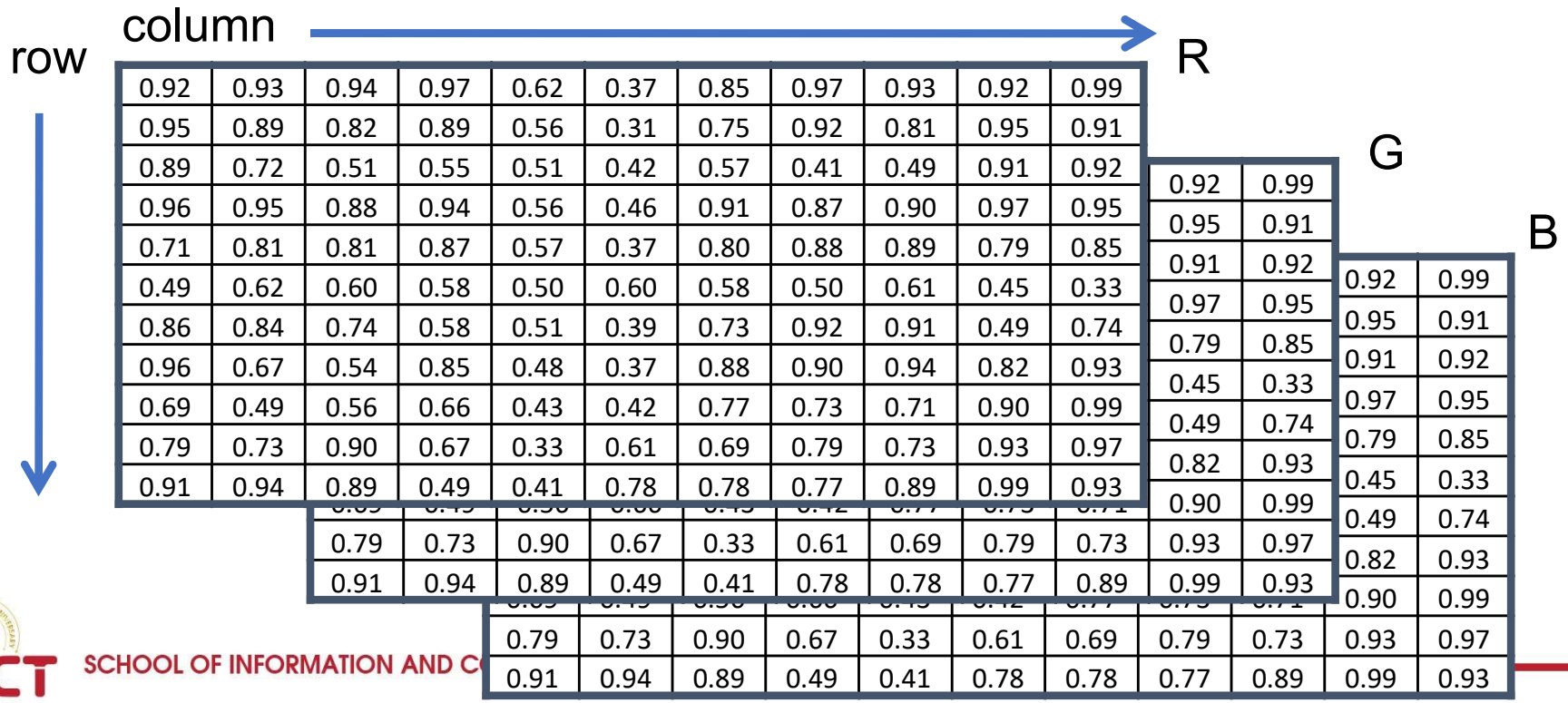


	i-1, j	
i, j-1	i, j	i, j+1
	i+1, j	

i-1, j-1	i-1, j	i-1, j+1
i, j-1	i, j	i, j+1
i+1,j-1	i+1, j	i+1,j+1

RGB color images in Matlab

- Images represented as a matrix X(i,j)
- Suppose we have a NxM RGB image called “Im”
  - Im(1,1,1) = top-left pixel value in R-channel
  - Im(y, x, b) = y pixels down, x pixels to right in the bth channel
  - Im(N, M, 3) = bottom-right pixel in B-channel
- imread(filename) returns a uint8 image (values 0 to 255)
  - Convert to double format (values 0 to 1) with im2double



Slide credit: Derek Hoiem

Digital image format

- **Parameters for digital image formats**:
  - **Digital image resolution:** (height x width) in pixels
  - **Quantization** (bits per pixel):

    Gray level image: 8 bits/ pixel

    RGB color image: 24 bits/ pixel

    Binary image: 1 bit/ pixel
- **Digital Image Storage**: file stored in two parts: Header; Data
- **Common image file formats:**
  - GIF (Graphic Interchange Format) -
  - PNG (Portable Network Graphics)
  - JPEG (Joint Photographic Experts Group)
  - TIFF (Tagged Image File Format)
  - PGM (Portable Gray Map)
  - FITS (Flexible Image Transport System)

Digital video format

- Parameters for digital video formats
  - Digital image resolution (height x width) in pixels
  - Quantization (bits per pixel)
  - Frame rate (frames per second)
- Standard video file formats
  - AVI, M-JPEG,
  - H26X (ITU_T:H.261, H.263, H.263, H264)
  - MPEG-1, MPEG-2, MPEG-4 Part 10 / H264 AVC,mp4…

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