Fundamentals

Material de clase: **http://www.robotica-up.org/DIP2018.zip**

Biblio:
Gonzalez (Rafael) & Woods (Richard),
Digital Image Processing, Prentice Hall

Reasons for using cameras

Sensors:

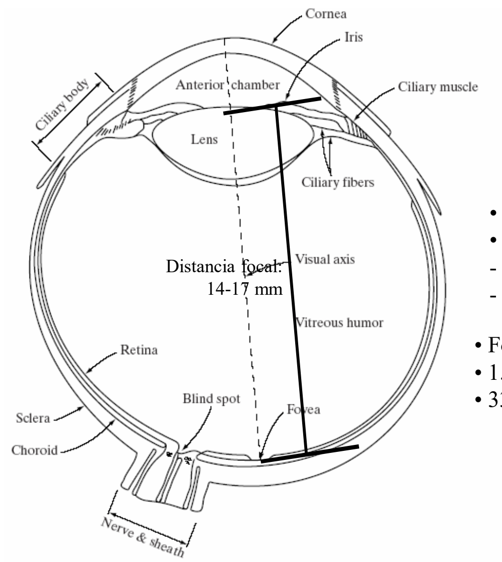
Active: sonar, radar, laser, infrared (IR), induction sensors

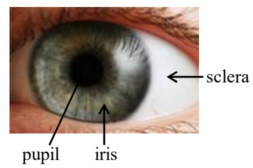
Passive: cameras, acoustic, electronic compass, odometers, gyroscopes

Cameras vs active sensors:

- All active sensors are invasive technology → detectable
- Sequential scanning → slow and limited range (laser)
- Sampling speed (cameras are 25 times faster)
- Cost
- 3D vs 2D
- Cameras imply more processing burden

Biologic inspiration: the human eye



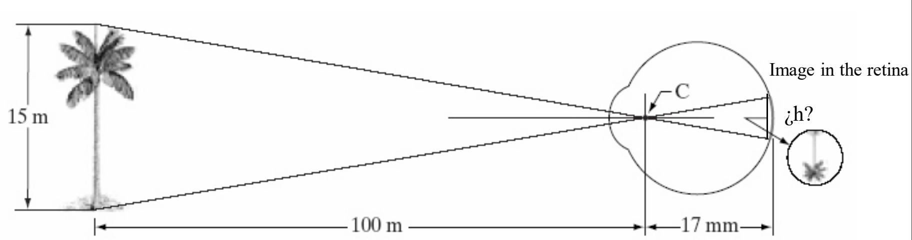


- The lens are flexible
- The ciliary fibers control the lenses:
  - Relaxed for far objects (> 3m)
  - Tense for near objects

- Fovea: the highest resolution area of the retina
- 1.5 x 1.5 mm matrix
- 337,000 elements (580 x 580)

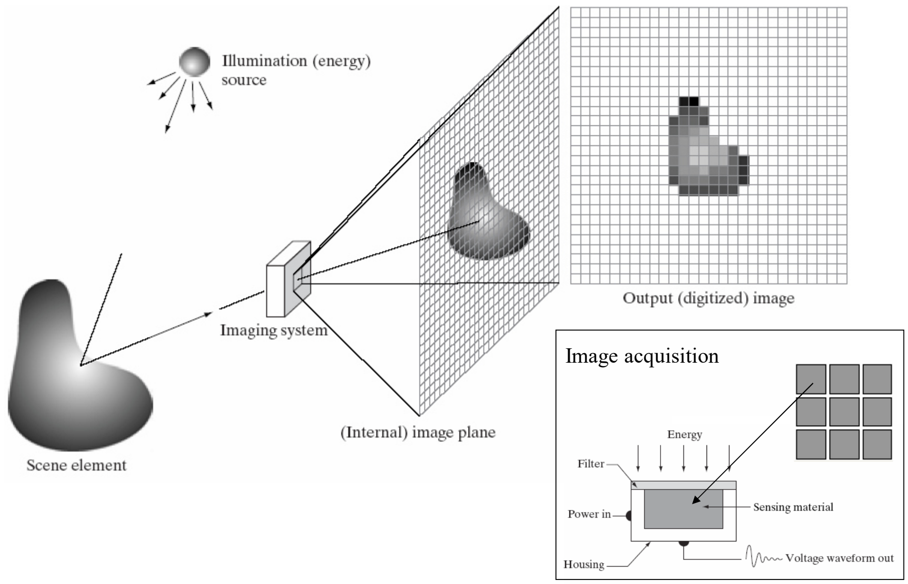
Camera: 580 x 580 requires 5 x 5 mm

How images are created in the eye

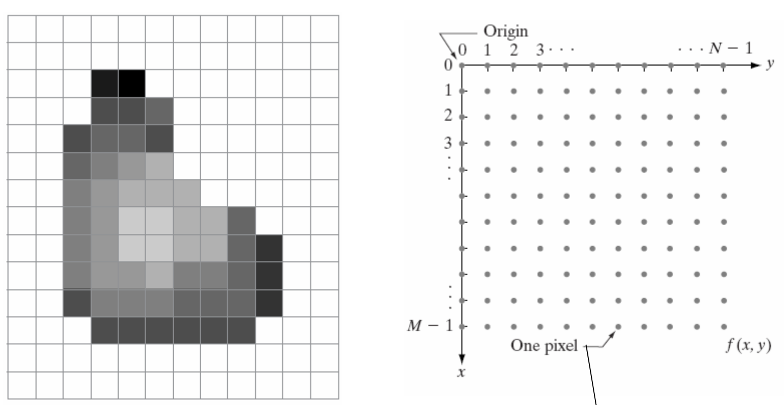


h=2.55mm

Camera: Operation principle



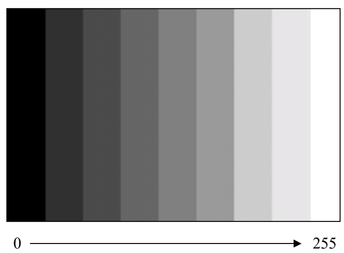
Digital Images



$$\mathbf{A} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}.$$

Digital Images

Gray level

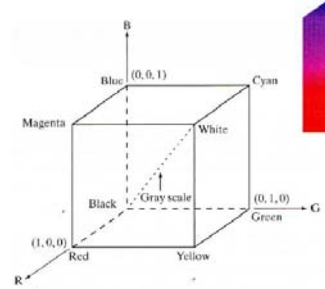


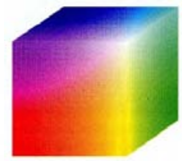
$$A_{MxN}$$

Gray levels $\rightarrow$ $$L = 2^k$$ $\leftarrow$ **bits**

Ex: An 8-bit image has 256 possible gray levels

Color: RGB Model





$$A_{MxNx3}$$

$$L = (2^k)^3$$

Ex: An 8-bit RGB image has 16,777,216 possible colors
→ Equivalent to a 24-bit gray level image

Digital Images

Image storage

Bits in hard disk $\rightarrow$ $$b = M\,N\,k$$

Ex: A 24-bit 100x100 image takes 240,000 bits or 30,000 bytes or 29.29 kB

Format	Extension	#bits / colors	Performance (photos)
JPEG (Joint Photographic Experts Group)	jpg, jpeg	24 bits	Best relation: Quality/size
TIFF (Tagged Image File Format)	tif, tiff	24, 48 bits	Best quality
GIF (Graphic Interchange Format)	gif	8 bits	Worst option
BMP (Windows bitmap)	Bmp, dib	1, 4, 8, 16, 24, 32 bits	Biggest file size, Windows…
PNG (Portable Network Graphics)	png	24, 48 bits	Best quality

Common Terms in Digital Images

1. Resolution: The image size. Expresses the total number of pixels in an image:

Example:
A 2048 x 1536 image has 3,145,728 pixels or 3.1 Megapixels

Note: 1 Megapixel= 1,000,000 pixels. The "1024" bit-byte conversion has nothing to do here.

2. Sharpness: The visual clarity of an image. Well-focused and defined details.

3. DPI (dots per inch): A measure for printing resolutions. It refers to the number of pixels that will be printed in an inch.

Example: A 2048 x 1536 image printed at:

-100 dpi measures: $\frac{2048}{100} \times \frac{1536}{100} = 20.48 \times 15.36$ in (52 x 39 cm)

- 250 dpi : 8.19 x 6.14 in (20.8 x 15.6 cm)

Conclusion: The better the dpi, the better the printing quality but the smaller the printing size.

Pixel Operations

Neighbors of pixel p

4-Neighbors: $N_4(p)$ $\begin{cases} (x+1, y) \\ (x-1, y) \\ (x, y+1) \\ (x, y-1) \end{cases}$

8-Neighbors: $N_8(p)$ $\begin{cases} N_4(p) \\ \left.\begin{array}{l} (x+1, y+1) \\ (x+1, y-1) \\ (x-1, y+1) \\ (x-1, y-1) \end{array}\right\} N_D(p) \end{cases}$

Adjacency and connectivity

2 pixels are connected if they are neighbors and satisfy certain criterion V (ex: same value)

<u>Adjacency-4:</u> 2 pixels p and q with values in V have adjacency 4 if : $q \in N_4(p)$

<u>Adjacency-8:</u> 2 pixels p and q with values in V have adjacency 8 if : $q \in N_8(p)$

<u>Adjacency-m:</u> 2 pixels p and q with values in V have adjacency m if :
a. q is in $N_4(p)$ or
b. q is in $N_D(p)$ and the set

$N_4(p) \cap N_4(q)$ is empty

(has no pixels whose values are from V)

Pixel Operations-Adjacency and Connectivity

$$\begin{matrix} 0 & 1 & 1 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{matrix} \qquad V=\{1,2\}$$

Adjacency-4	Adjacency-8	Adjacency-m
$\begin{matrix} 0 & 1 & 1 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{matrix}$	$\begin{matrix} 0 & 1 & 1 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{matrix}$	$\begin{matrix} 0 & 1 & 1 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{matrix}$

Pixel Operations

Paths

The path from pixel **p** to pixel **q** is a pixel sequence with 4-8-m adjacency

a) $V=\{0,1\}$
b) $V=\{1,2\}$

$$\begin{array}{ccccc} & & & & \mathbf{q} \\ & 3 & 1 & 2 & 1 \\ & 2 & 2 & 0 & 2 \\ & 1 & 2 & 1 & 1 \\ & 1 & 0 & 1 & 2 \\ \mathbf{p} & & & & \end{array}$$

Hands-on!

Warm up!

1. Open and visualize an image
2. Grayscale image
3. Color image
4. Color to gray transformation
5. 8, 16 Bits images
6. Useful commands: *impixelinfo*, *imdistline*, *size*
7. Writing images
8. Data classes
9. Data handling: vectors and matrixes

Data Classes

Data Class	Range	Suitable for images?
uint8	[0 255]	Yes
uint16	[0 65,535]	Yes
uint32	[0 2^{32-1}]	Yes
double	[-10^{308} 10^{308}]	Yes, but only in [0 1]

Conversions

You have	You perform	You obtain	To come back
f uint8 [0 255]	g=double (f) →	**g** double [0 255] →	f=uint8(g)
	g=im2double (f) →	**g** double [0 1] →	f=im2uint8(g)