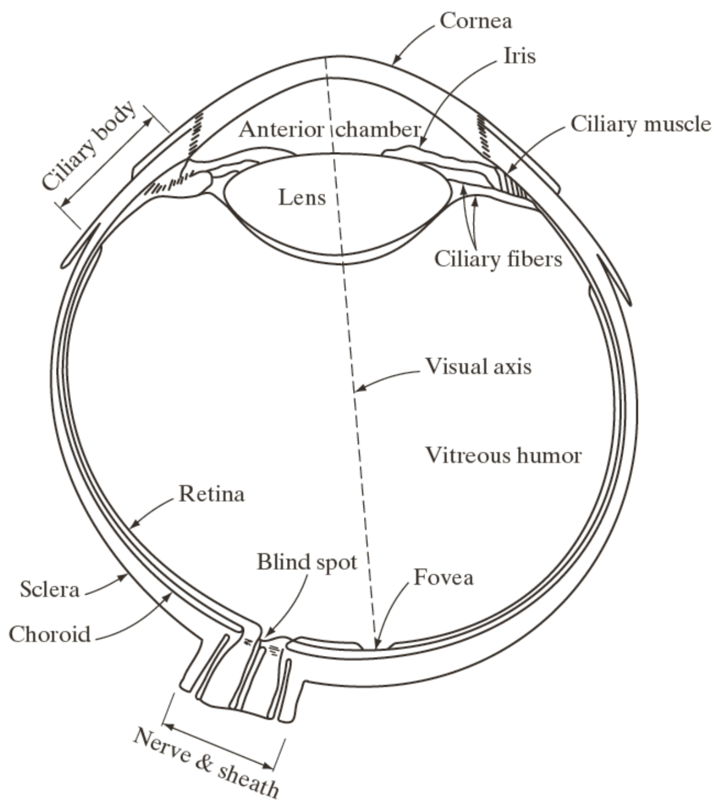
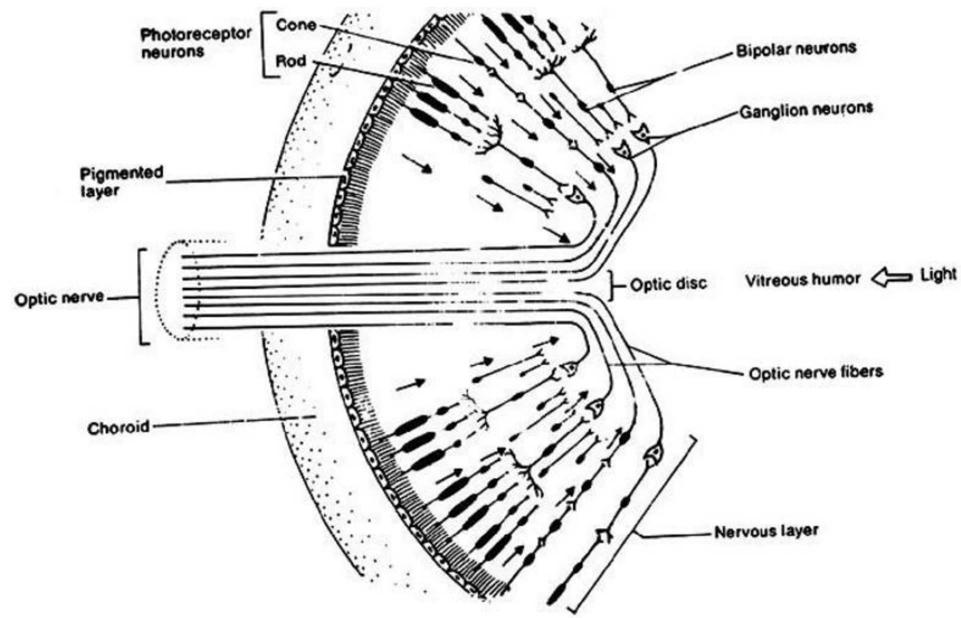
Chapter 2 - Fundamentals

Visual Computing

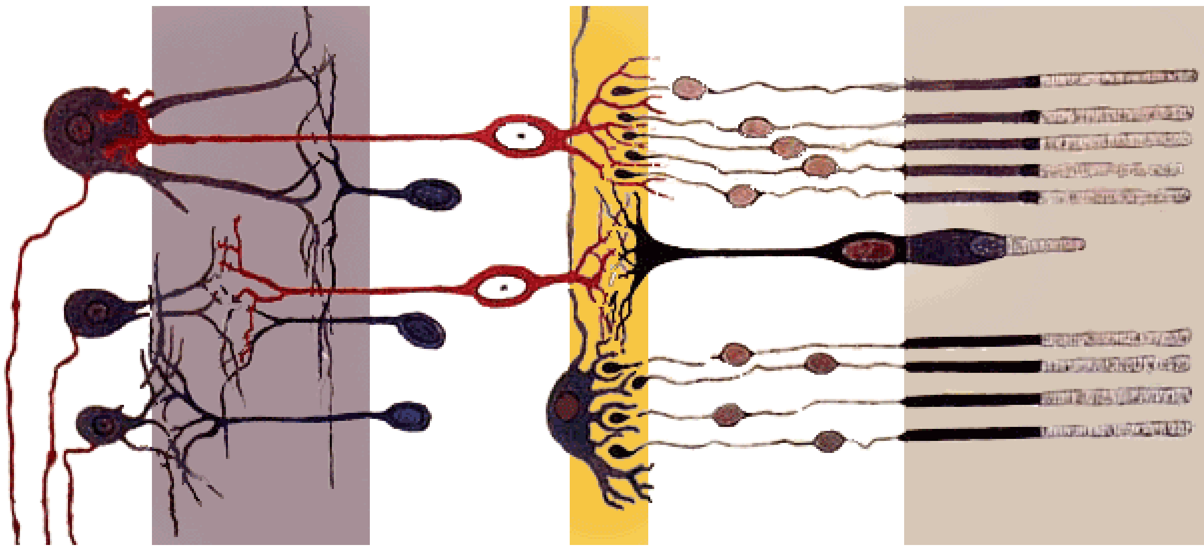
Structure of the human eye (1)

FIGURE 2.1 Simplified diagram of a cross section of the human eye.





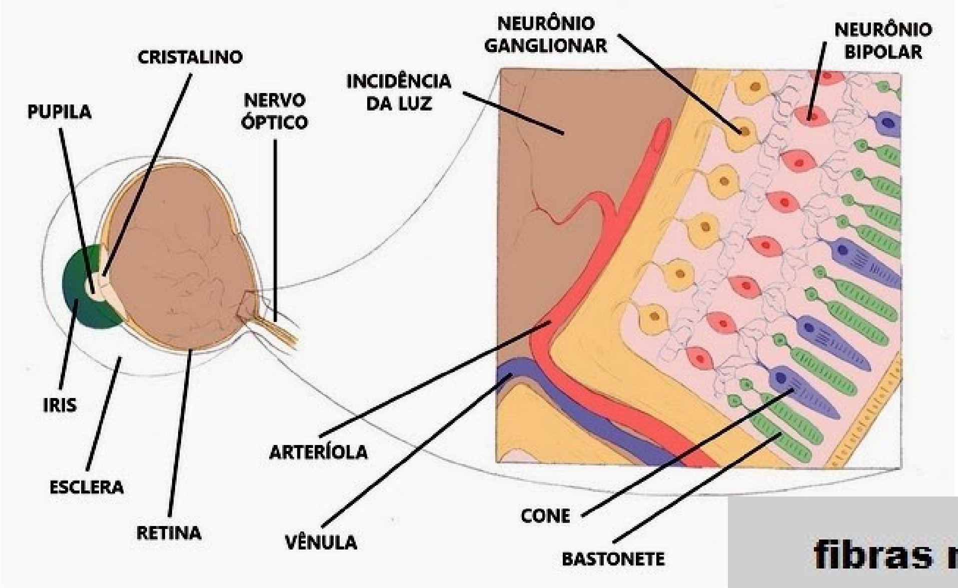
Structure of the human eye (2)

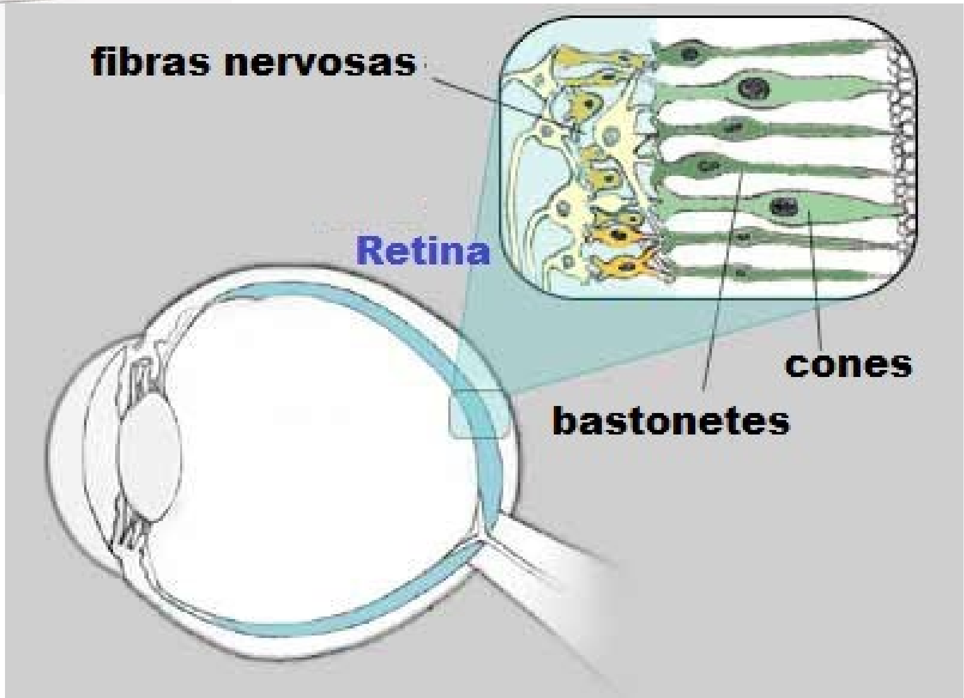


Celular structure of the retina. On the right we can see one cone between two groups of rods.

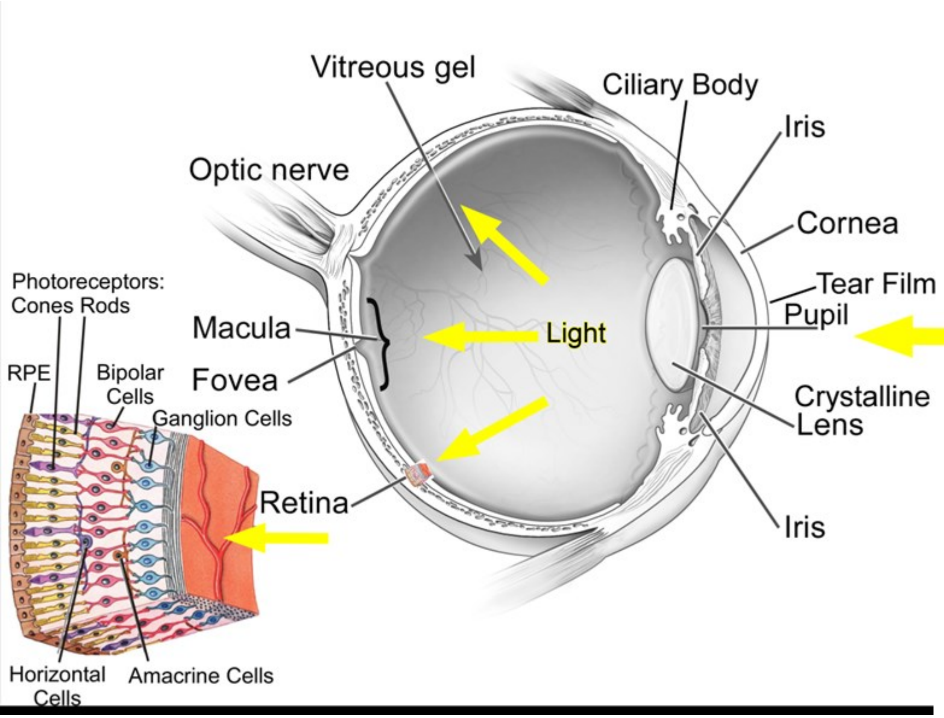
(The cone is conected in one nerve, and several rods are connected in one nerve.)

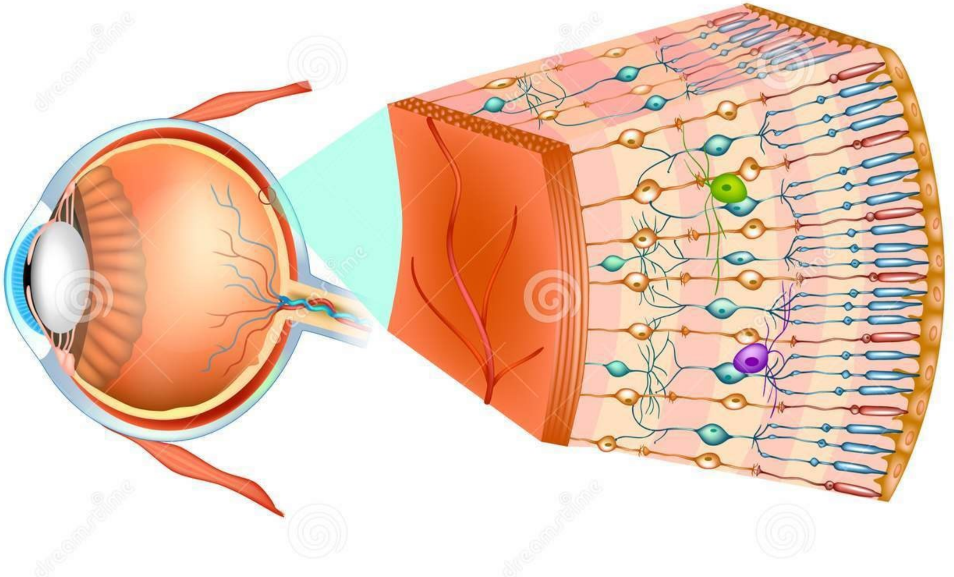
Structure of the human eye (3)





Structure of the human eye (4)





Structure of the human eye (5)

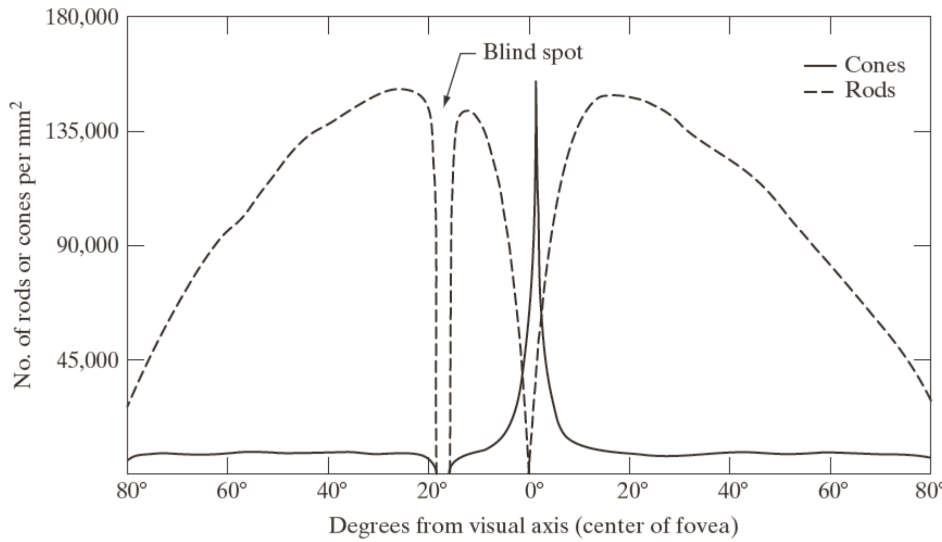


FIGURE 2.2 Distribution of rods and cones in the retina.

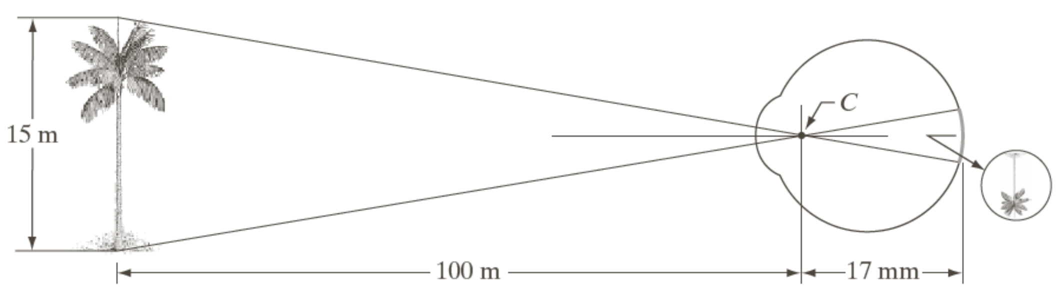
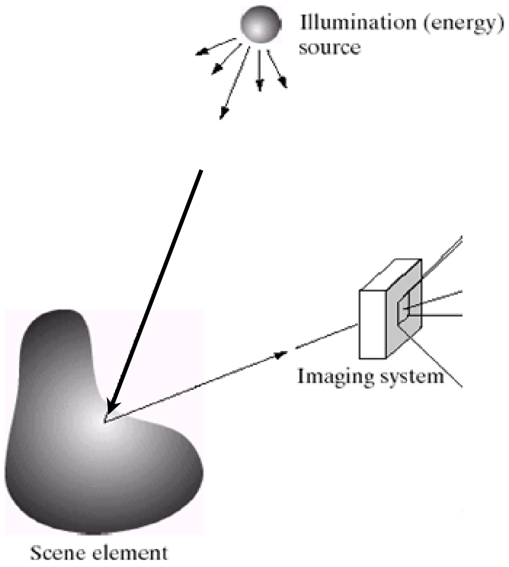


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

Photometric model



- source of light
- object on the surface
- sensor (camera)

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

$0 < i(x,y) < \infty$ Amount of illumination that strikes the object

$0 < r(x,y) < 1$ Amount of illumination reflected by the object

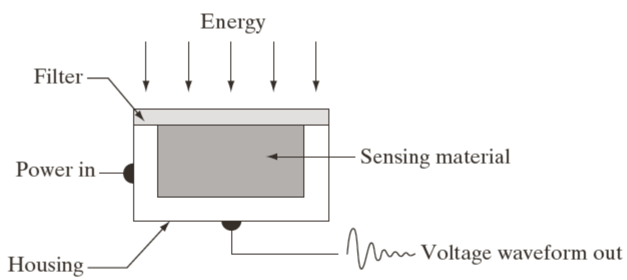
$l = f(x_0, y_0)$ where $L_{MIN} \le l \le L_{MAX}$

$[L_{MIN}, L_{MAX}]$ Interval variation of the light intensity

$[0, L-1]$ Normalization, where 0 corresponds to black and L-1 to white

Artificial Systems for Image acquisition (1)

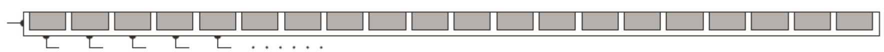
Main goal – Transform the energy source into a digital image

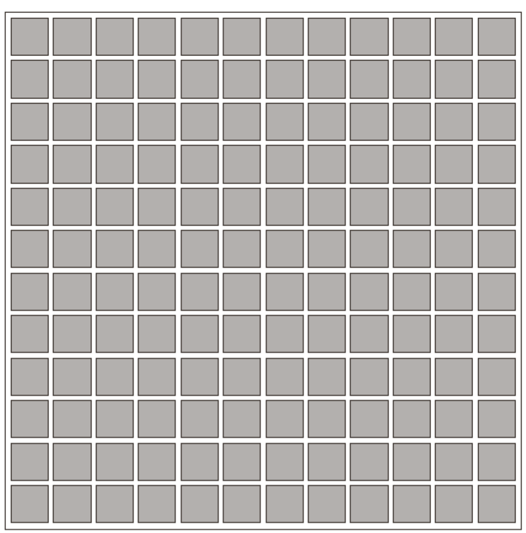


a
b
c

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.

Three main configurations of the sensors to transform illumination energy into digital images





Cameras CCD (*Charge-coupled devices*)

Typical dimensions: 6.4mm x 4.8mm – ½” (640x480 ou 512x512 pixels)

For each new image, the electric charges are cleaned and then the received light is integrated in a given time interval (controlled by the *shutter*)

In the final stage, the image plane (*array* 2D) is scaned. This process is accomplished line by line.

Artificial systems for image acquisition (2)

two different technologies for capturing images digitally

CCD vs CMOS

- Established technology;
- Specific technology;
- High production costs;
- High consumption;
- Higher sensibility;
- Sequential read;

- Recent technology;
- Standard IC technology;
- Cheaper;
- Less consumption;
- Lower sensibility;
- Pixel amplification;
- Random acess to pixels;
- Integration of other components in the same chip;

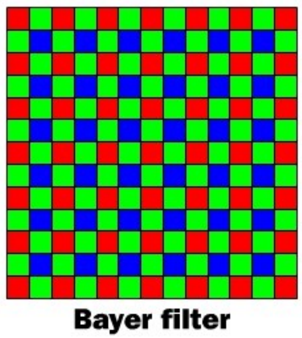
CCD vs CMOS

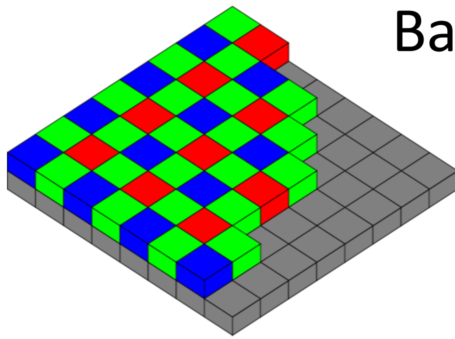
	CCD	CMOS
Resolution	Up to 100+ Megapixels	Up to 100+ Megapixels
Frame rate	Best for lower frame rates	Best for higher frame rates
Noise figure	Lower noise floor → Higher image quality	Higher noise floor → Lower image quality
Responsivity and linearity	Lower responsivity, broader linear range	Higher responsivity, lower linear range (saturates early)
Limit of detection	Low (more sensitive at low intensity)	High (less sensitive at low intensity)
Color depth	Higher (16+ bits is typical for expensive CCDs)	Lower, although becoming comparable to CCDs (12-16 bits is typical)

Artificial systems for image acquisition (2)

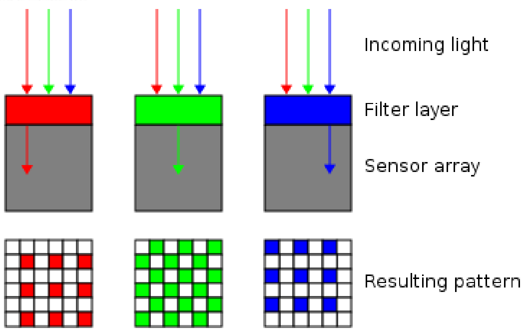
CCD vs CMOS

Artificial systems for image acquisition (3)
– RGB signal generators alternatives



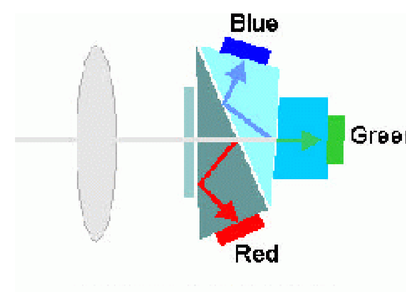


Bayer filter



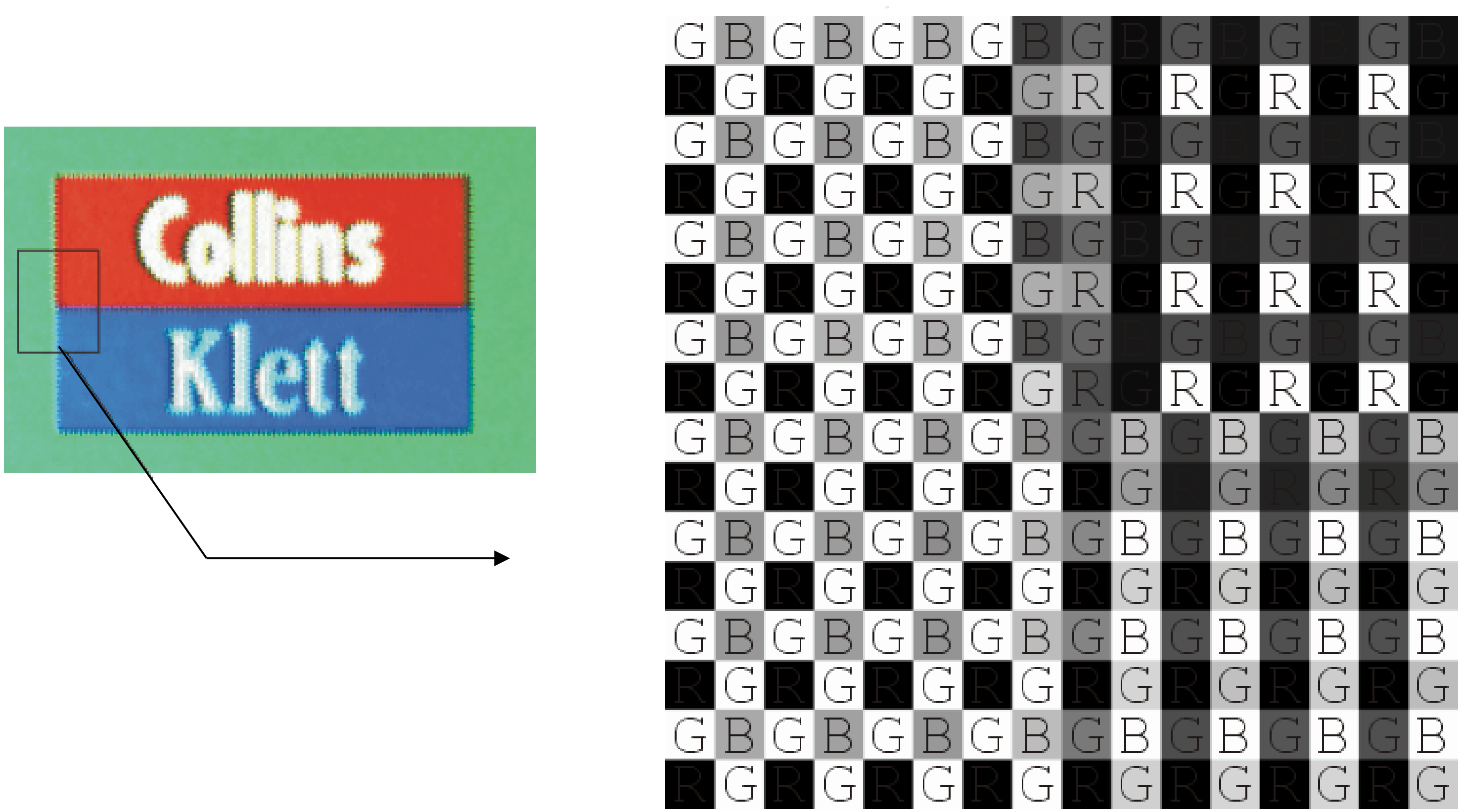
Sequential filters,
R(t1), G(t2), B(t3)

Beam splitter

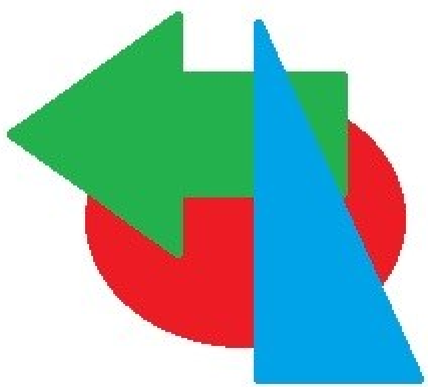


Notes: Bayer filter (in (i))

Monitor RGB



Notes: RGB Filter at different time instants (in (ii))



Original image

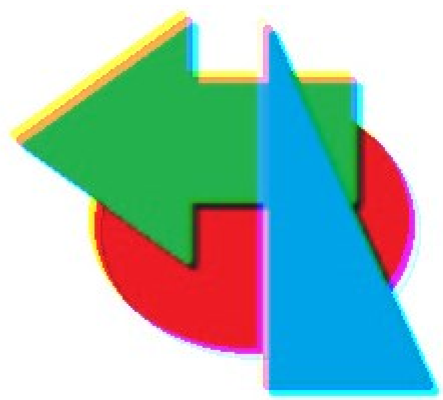


Imagem chromatic distortion

Artificial systems for image acquisition (4)

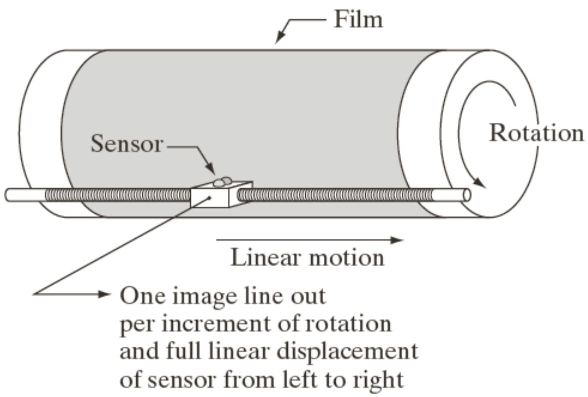
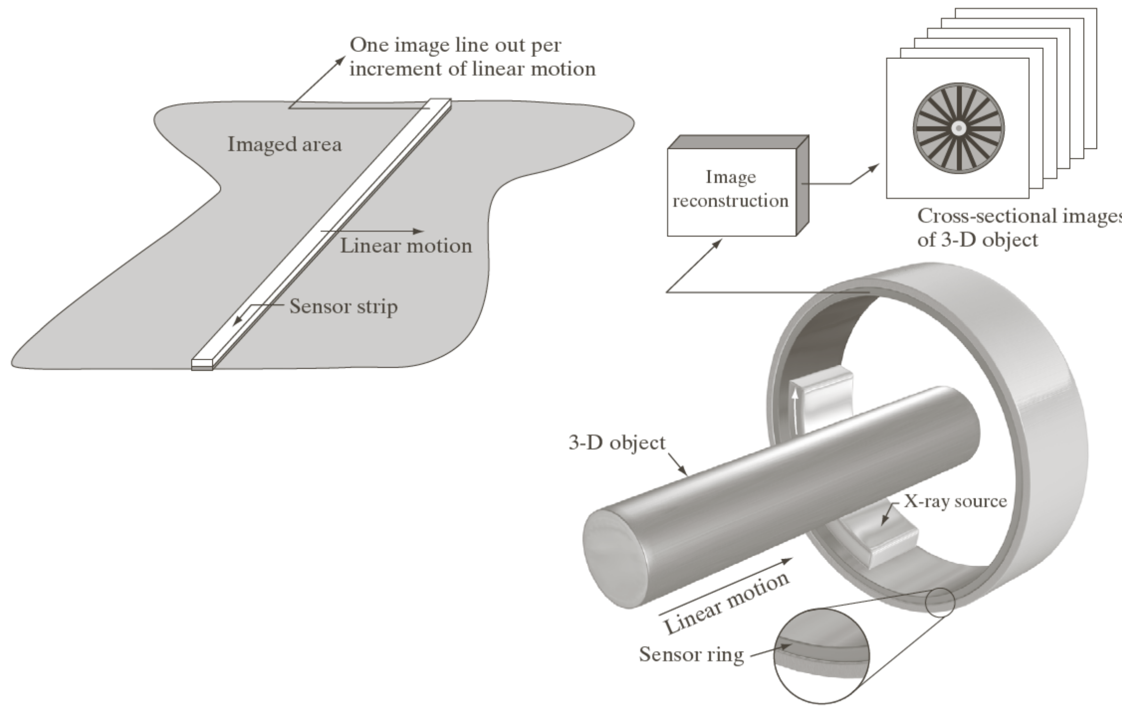


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.



a b

FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

Artificial systems for image acquisition (5)

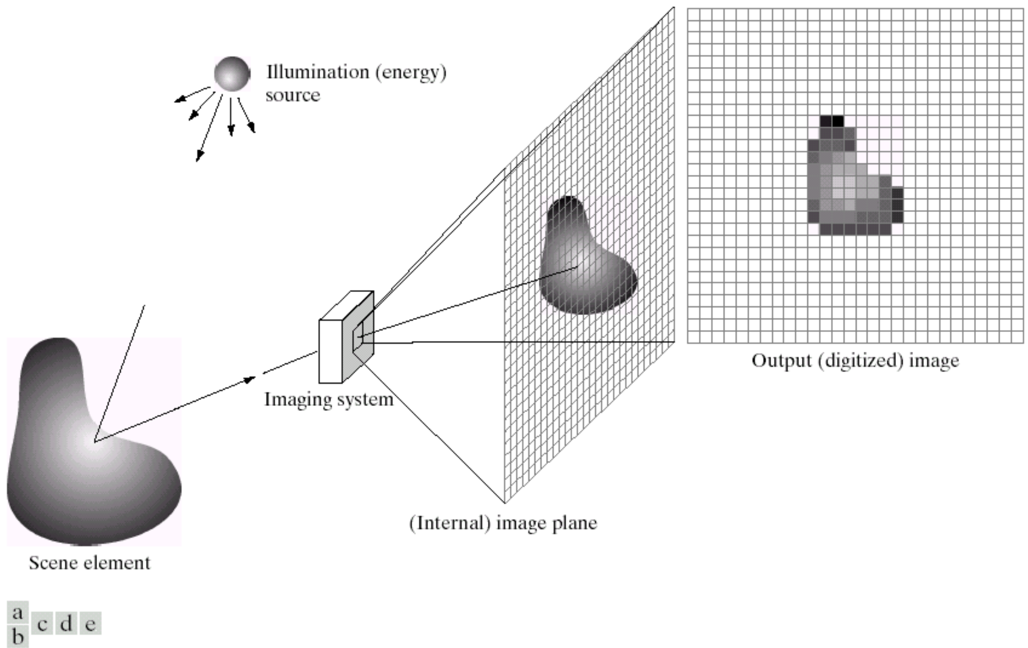
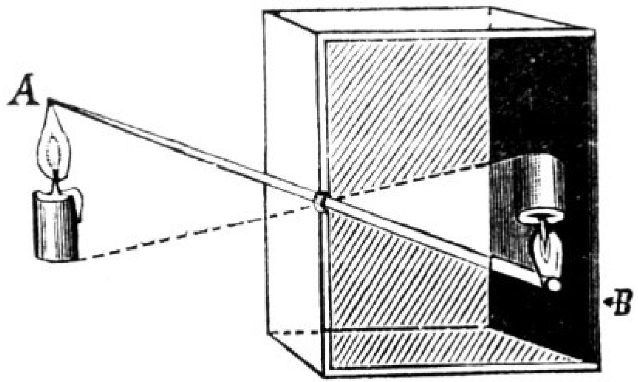


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

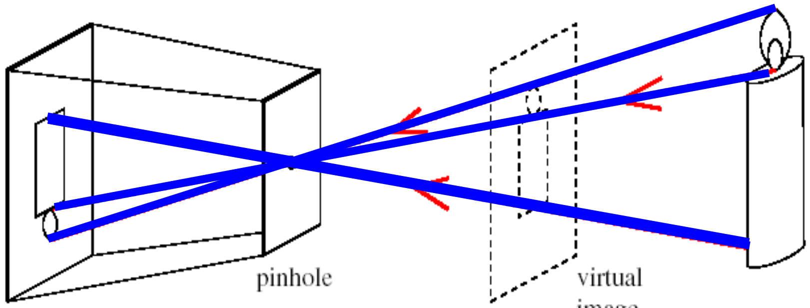
No motion mechanism needed !

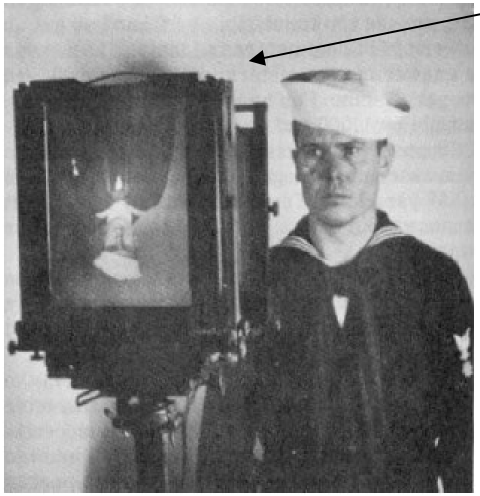
Image formation

pin-hole Model – perspective projection



Inspired by human vision system !



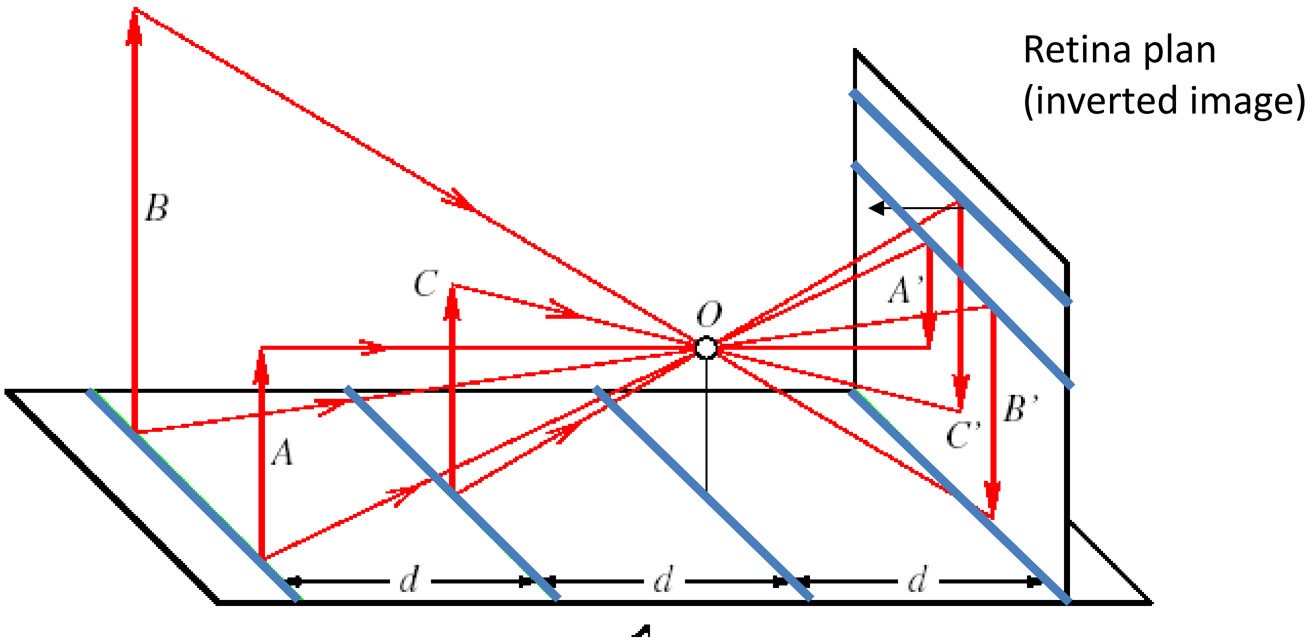


Translucent material

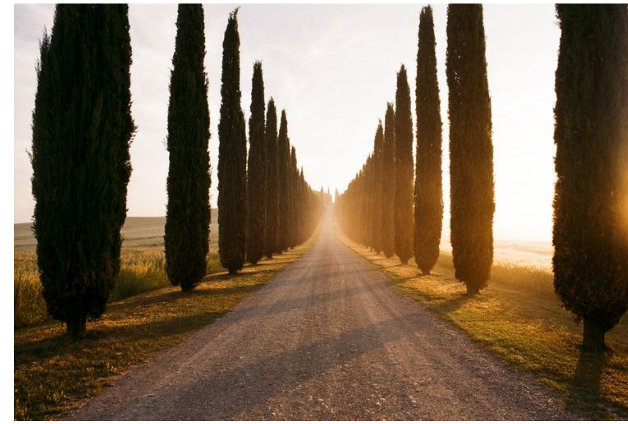
Dark camera Century XVI

Perspective effects (I)

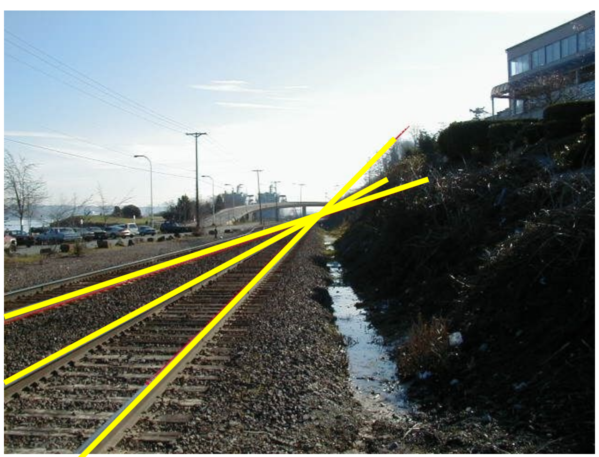
The apparent size of the object depends on its distance

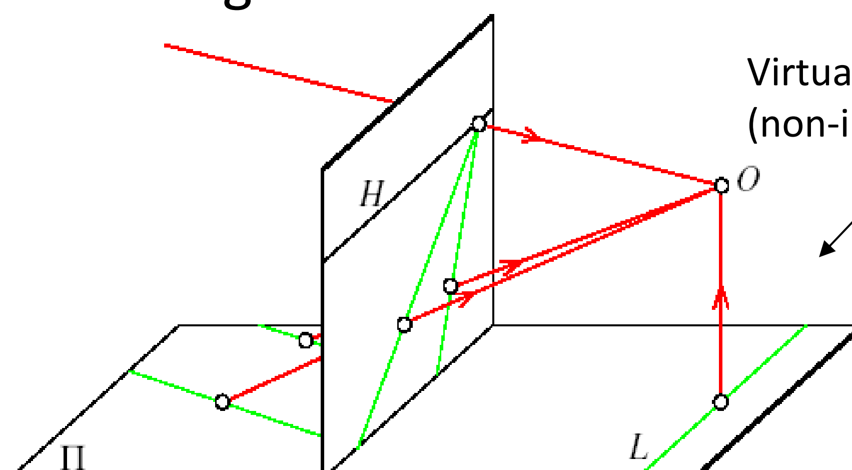


Perspective effects (II)



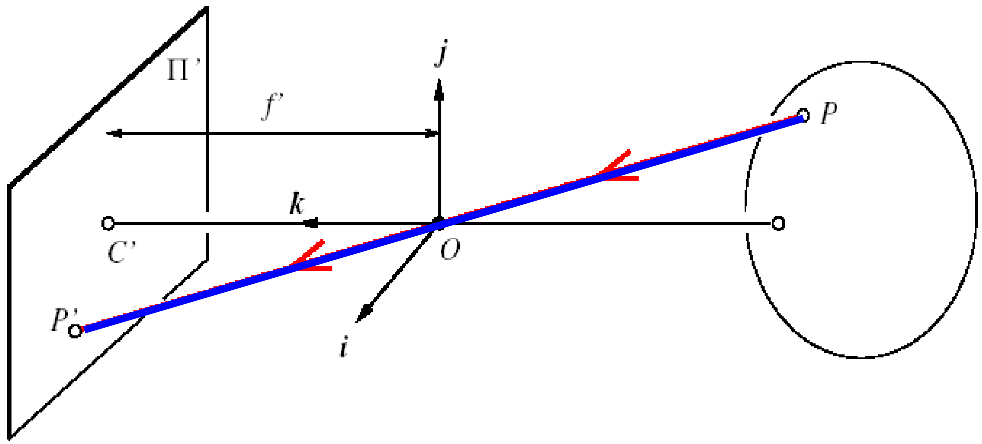
The projection of two parallel straight lines seems to converge to a point





Virtual plan
(non-inverted image)

Perspective projection – Mathematical model



$$\begin{cases} x' = -f' \dfrac{x}{z} \\ y' = -f' \dfrac{y}{z} \end{cases}$$

How to correlate the 3D coordinates of a point in the real world, *P*, with the corresponding 2D coordinates in the retina, *P'*?

$$P = (x, y, z) \qquad P' = (x', y', z')$$

Confirmations:

- The points *P*, *P'* and *O* (optical center) are collinear $\overrightarrow{OP'} = \lambda \overrightarrow{OP}$
- The point is projected on the sensor plan that is located at a distance *f'* (focal distance) of the optical center $z' = f'$

Perspective Projection– (II)

When the pin-hole model is used, the relation between the Cartezian coordinates (x, y, z) of a point in the reference of the camera *C* and the coordinates of the corresponding projection (x', y') to the plan of the image is given by

$$x' = -f'\frac{x}{z} \qquad y' = -f'\frac{y}{z}$$

With the assumption that the origin of the reference camera is coincident with the optical center of the camera, and the image origin is the main point.

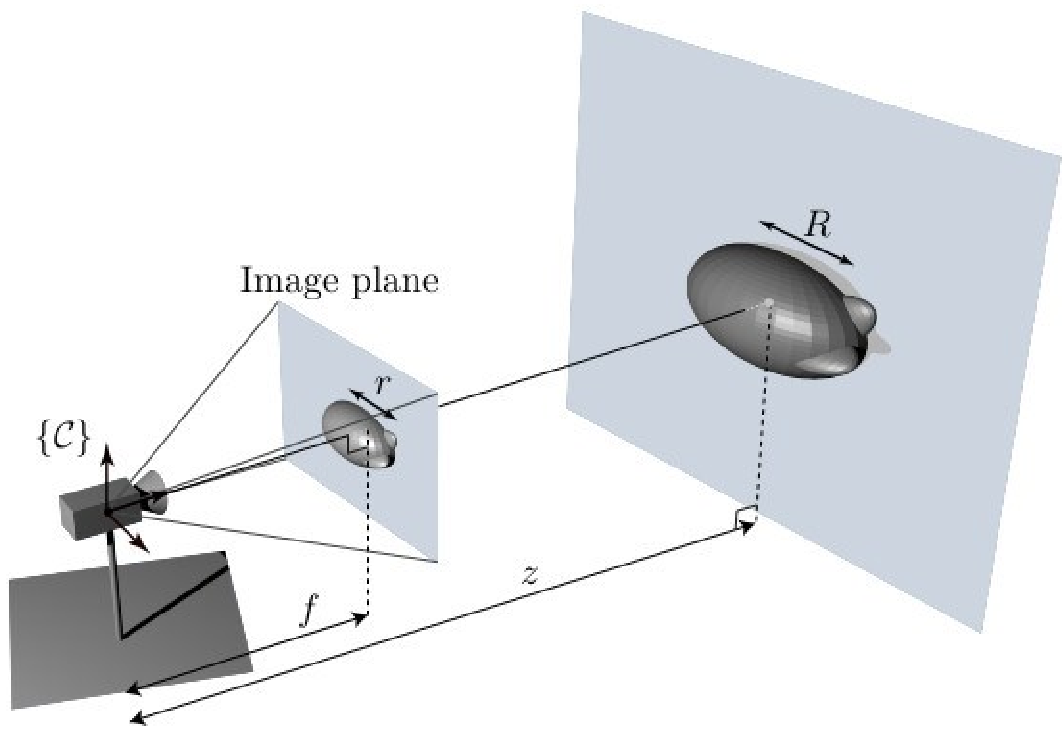
From the expressions of x' and y', it can be shown that the distance R between two points located in the plane at the distance z to the camera and the distance r, between the projection of these points in the image plan is given as

$$r = f\frac{R}{z}$$

Perspective Projection – (III)

From the expressions of x' and y', it can be shown that the distance R between two located points in the plane at the distance z to the camera and the distance r, between the projection of these points in the image plan is given as

$$r = f\,\frac{R}{z}$$

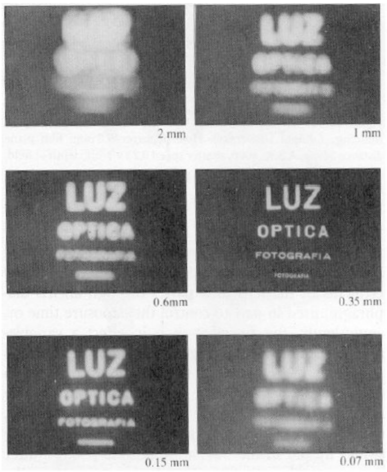


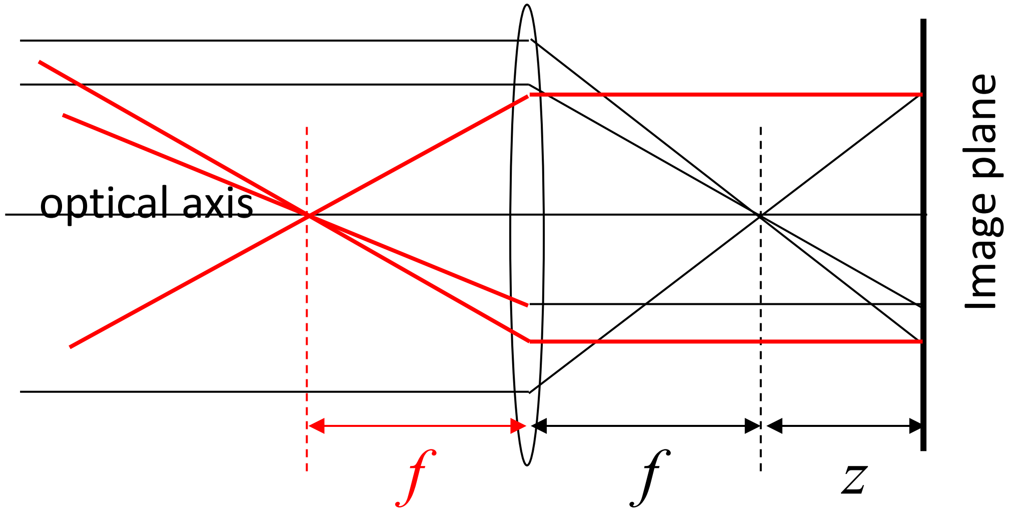
Cameras with lenses (1)

In practice we need to use lenses

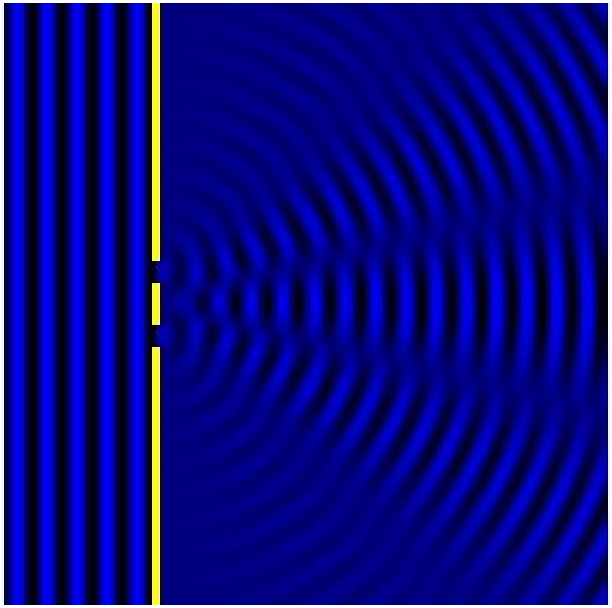
- It acts as light collector
- Allows to adjust the focus of objects (changing *f*)

Diffraction phenomena





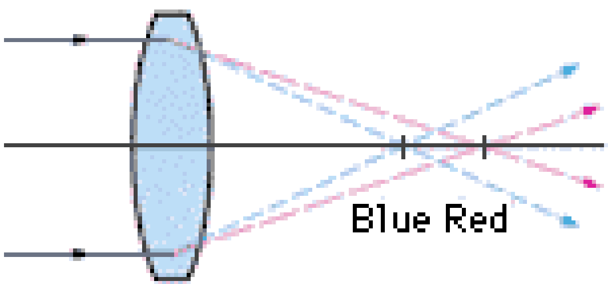
Difraction Example



Cameras with lenses (2)

Deviations from the model

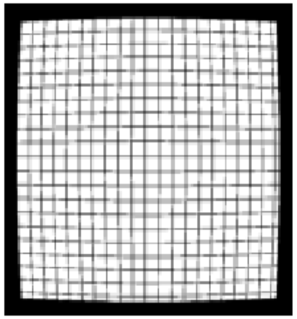
- Imperfections in the lens lead to a circle of confusion
- Sensor with discrete units; spatial integration leads to a *blurring effect;* limitation of the observed detail.



Chromatic distortion

Other problems

Clipping or wrap-around



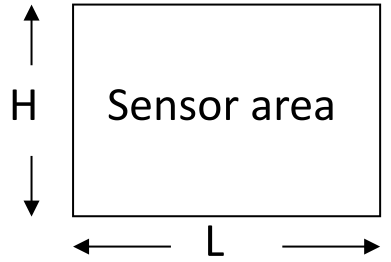
Geometric distortion

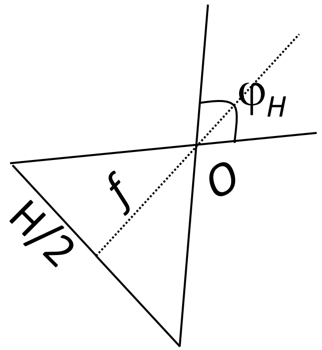
blooming

Focal distance of the lens (1)

F*ield of view* – space of the scene projected by the sensor

- It depends not only the focal distance, *f*, but also of the sensor dimensions (usually 1/4”, 1/3” ou 1/2”)
- When φ is large, the lens is said a ***wide angle lens***
- When φ small the lens is ***telescopic***



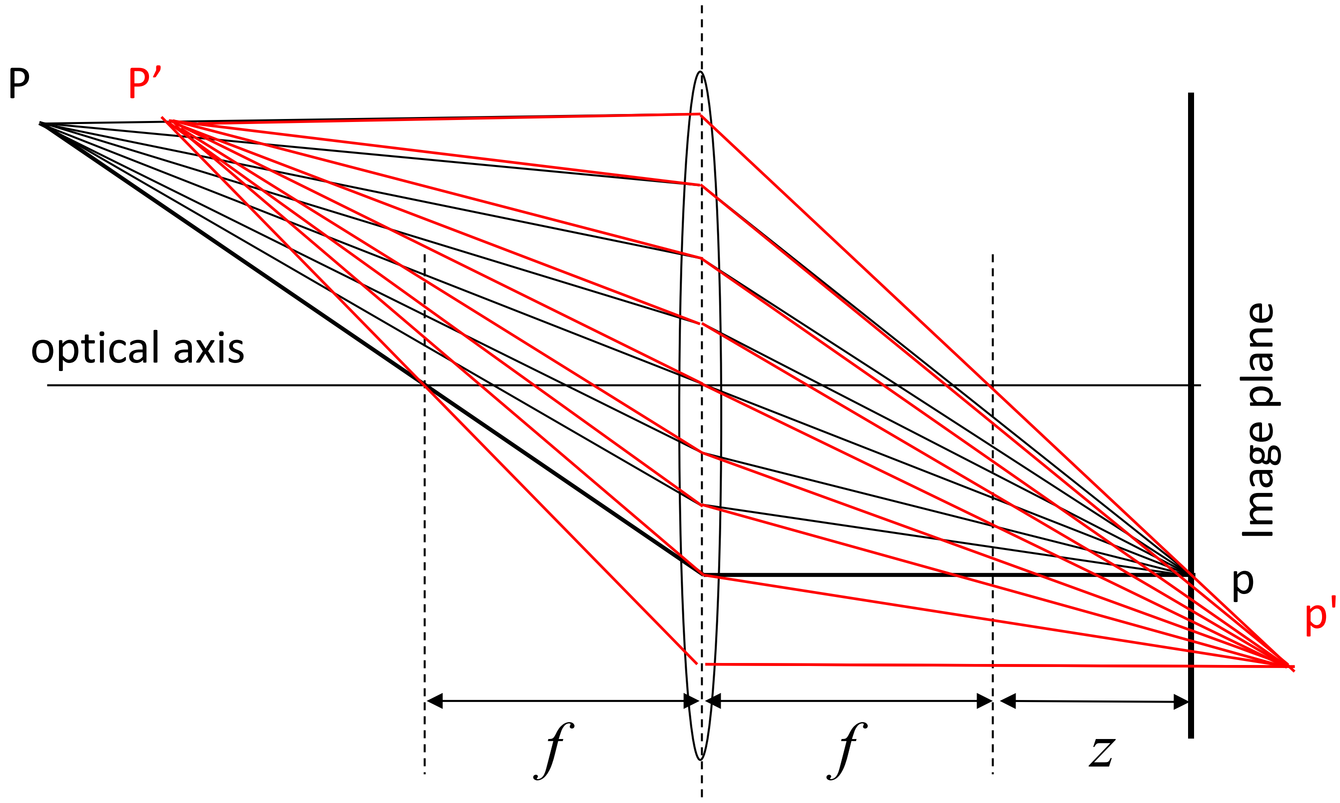


$$\varphi_H = 2\tan^{-1}\frac{H}{2f}$$

$$\varphi_L = 2\tan^{-1}\frac{L}{2f}$$

Focal distance of the lens (2)

Depth-of-field – blurring example

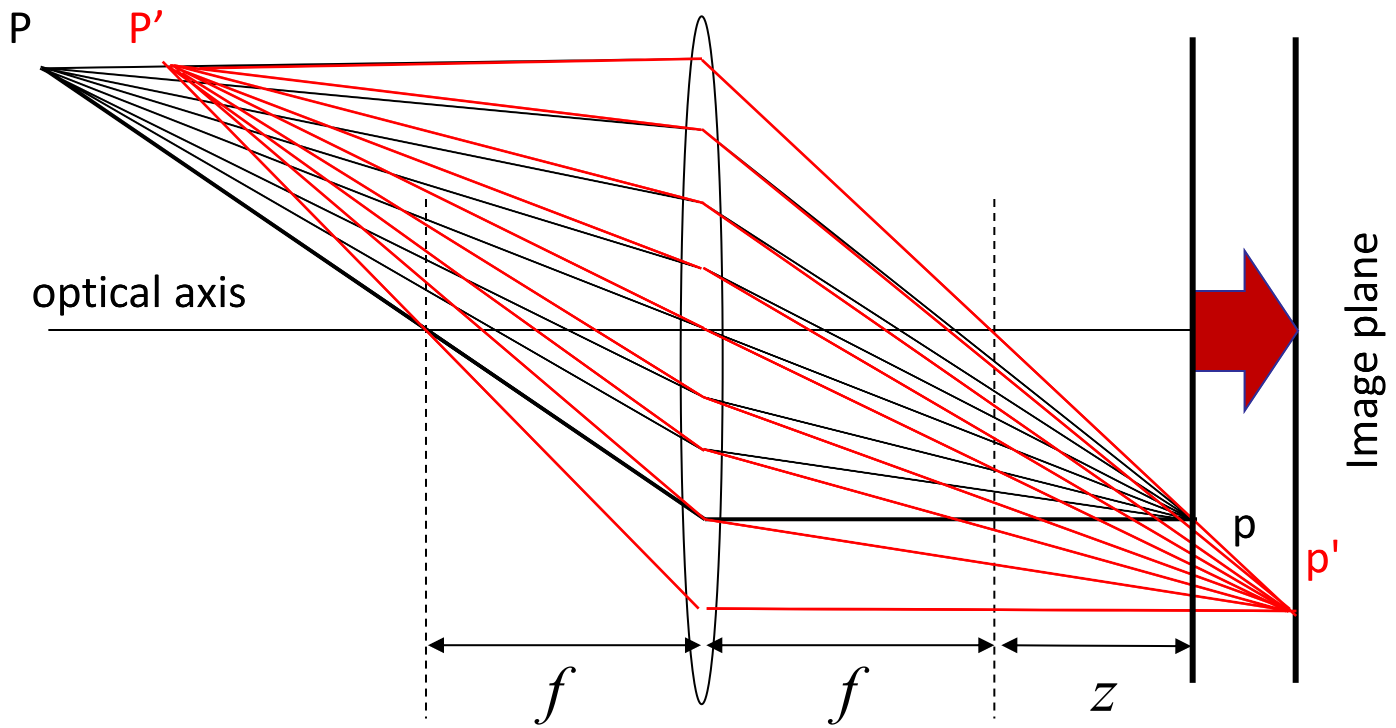


scales on a lens barre
erfocal distance oppos
are using. If you th
ne *d*epth of field w
e *to infinity.*◁ For
mera has a hyper
e focus at 18 feet

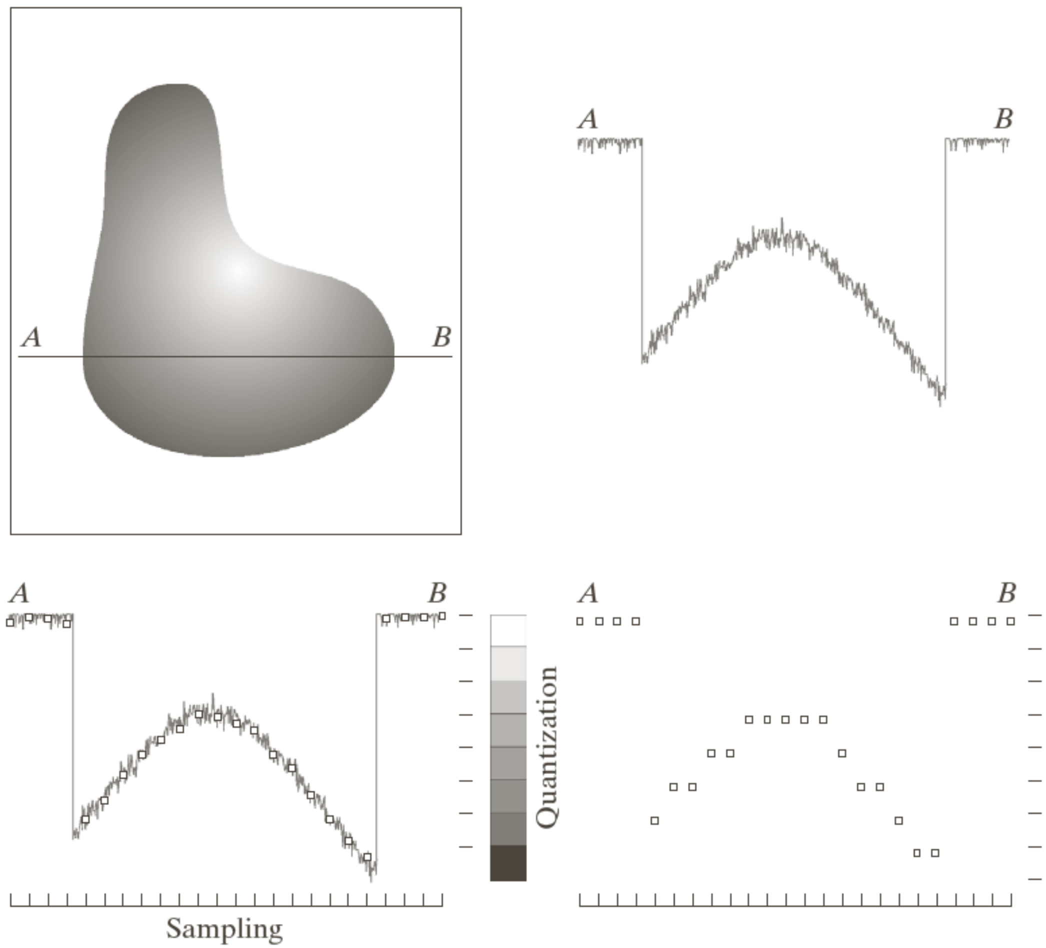
Focal distance of the lens (3)

Change of the depth-of-field

- Distance change between the lens and the image plan
- Deformation of the lens



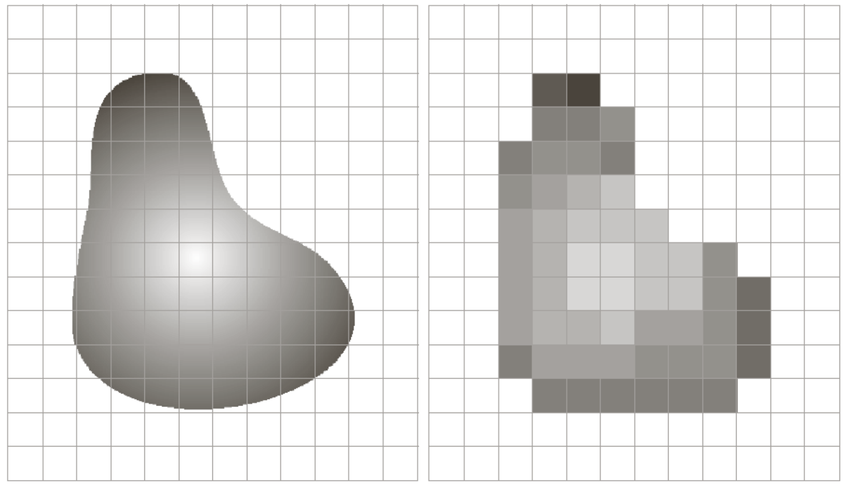
Sampling and quantization (1)



a b
c d

FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from *A* to *B* in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

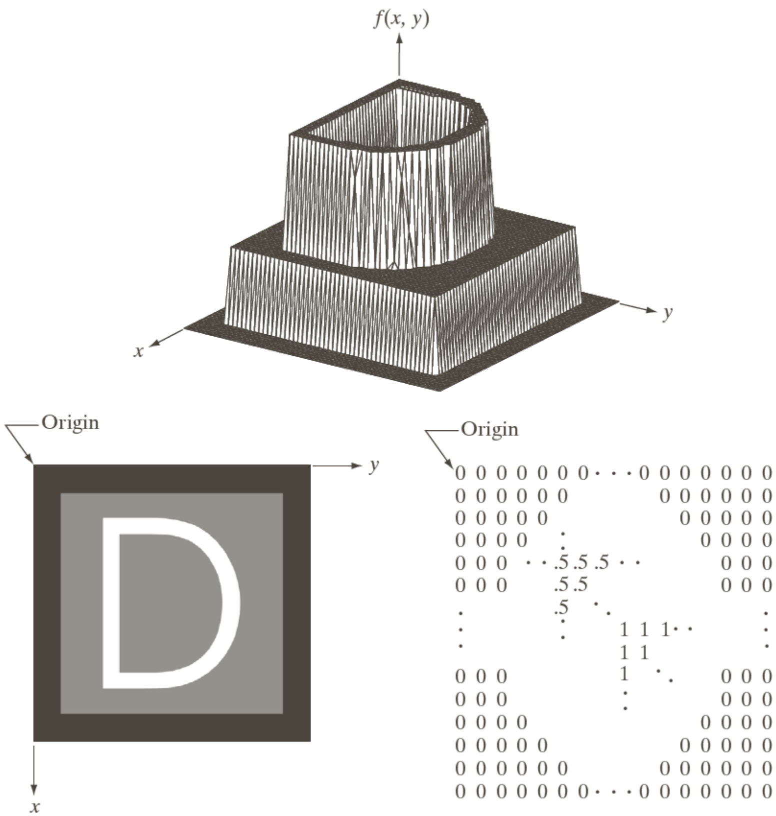
Sampling and quantization (2)



a b

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

Representation of the digital images (1)



a
b c

FIGURE 2.18
(a) Image plotted as a surface.
(b) Image displayed as a visual intensity array.
(c) Image shown as a 2-D numerical array (0, .5, and 1 represent black, gray, and white, respectively).

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

Representation of the digital images (2)

Gray level or number of colors

$$L = 2^k$$

Number of bits

$$b = M \times N \times k$$

TABLE 2.1

Number of storage bits for various values of N and 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

Spatial and gray level resolution
(sampling example)

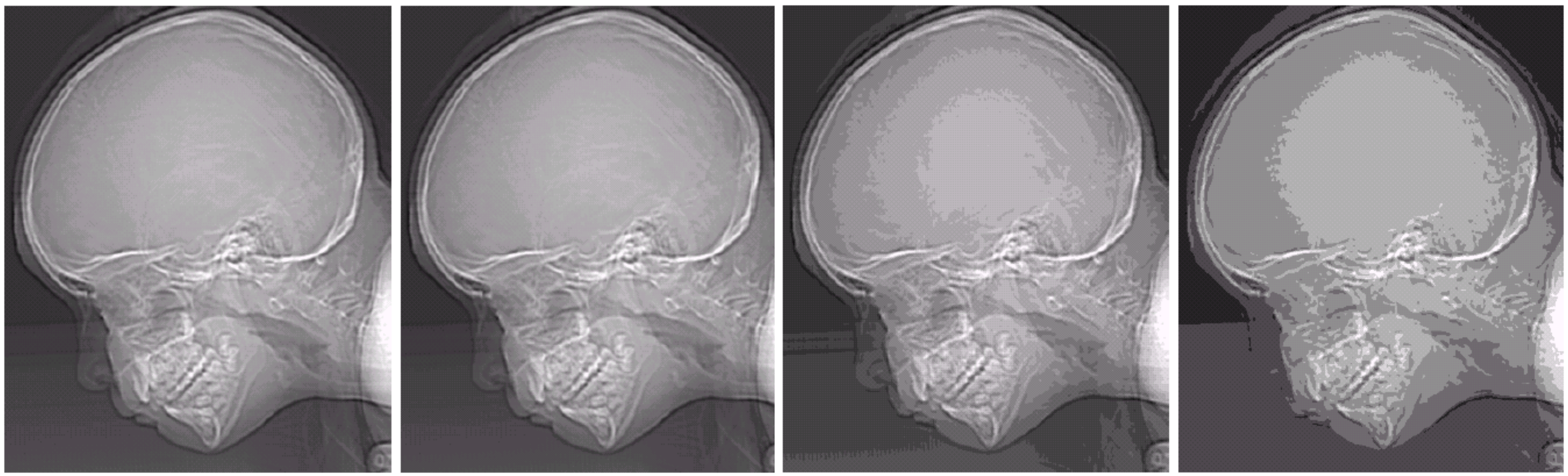
a b
c d

FIGURE 2.20 Typical effects of reducing spatial resolution. Images shown at: (a) 1250 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi. The thin black borders were added for clarity. They are not part of the data.

Number of quantification levels
(quantification example)

a b
c d

FIGURE 2.21 (a) 452 × 374, 256-level image. (b)–(d) Image displayed in 128, 64, and 32 gray levels, while keeping the spatial resolution constant.



e f
g h

FIGURE 2.21 *(Continued)* (e)–(h) Image displayed in 16, 8, 4, and 2 gray levels. (Original courtesy of Dr. David R. Pickens, Department of Radiology & Radiological Sciences, Vanderbilt University Medical Center.)

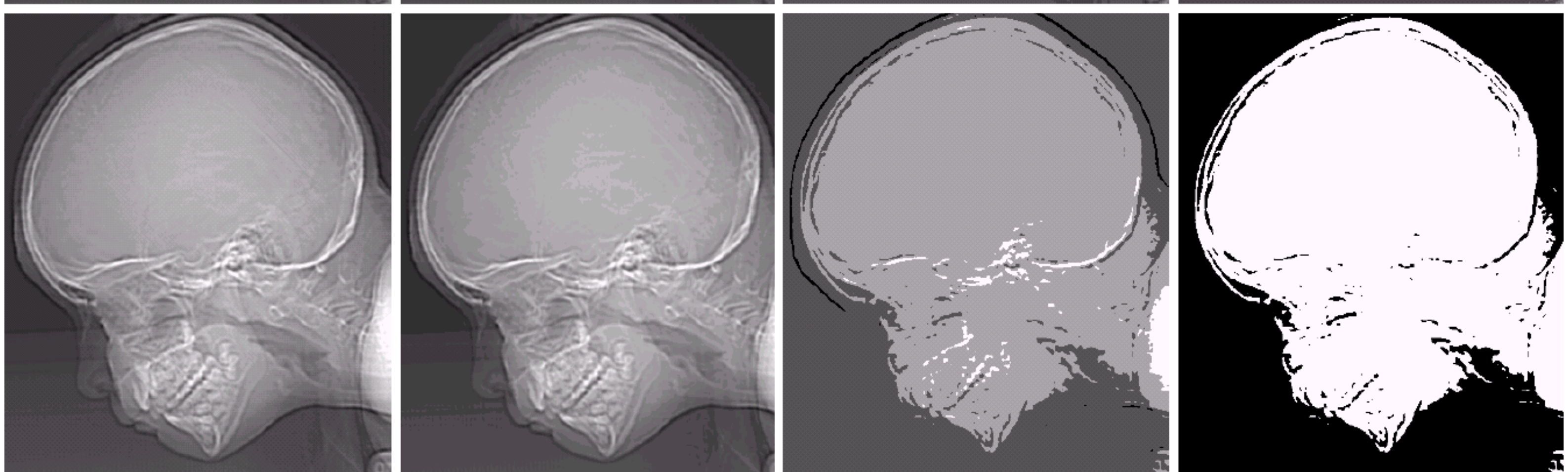
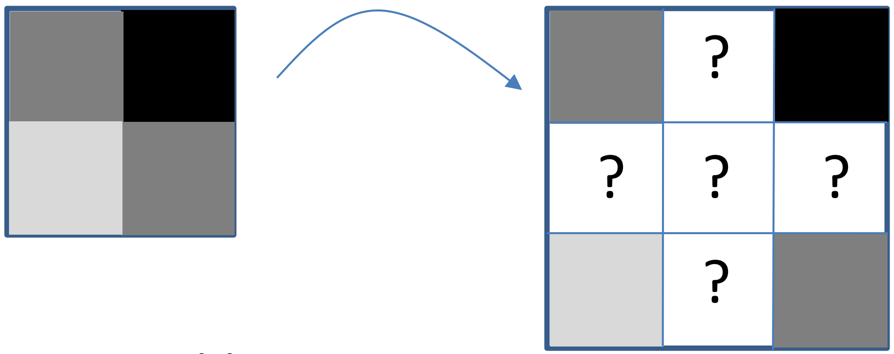
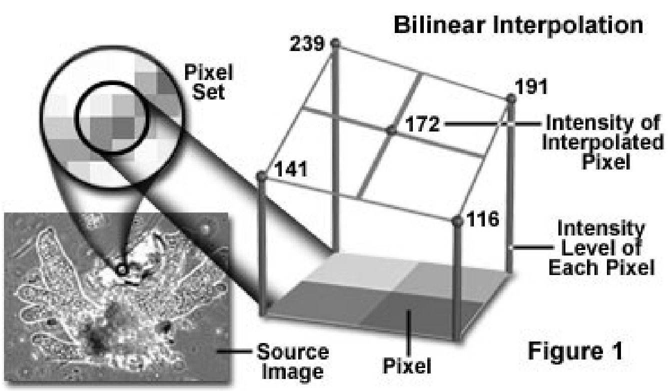


Image interpolation (1)

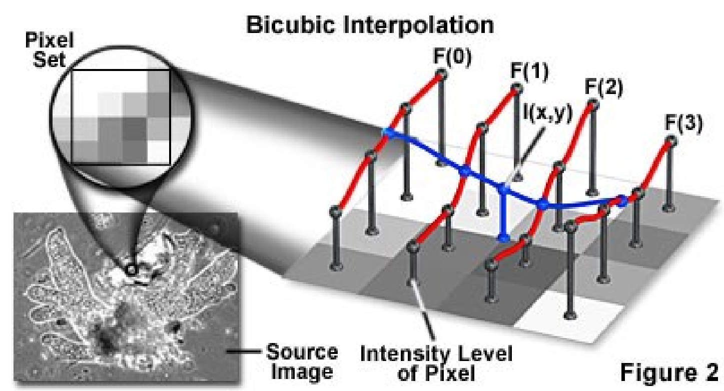


- Nearest neighbor
- Bilinear interpolation



$$v(x,y) = ax + by + cxy + d$$

- Bicubic interpolation



$$v(x,y) = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} x^i y^j$$

Image interpolation (2)

a b c
d e f

FIGURE 2.24 (a) Image reduced to 72 dpi and zoomed back to its original size (3692 × 2812 pixels) using nearest neighbor interpolation. This figure is the same as Fig. 2.20(d). (b) Image shrunk and zoomed using bilinear interpolation. (c) Same as (b) but using bicubic interpolation. (d)–(f) Same sequence, but shrinking down to 150 dpi instead of 72 dpi [Fig. 2.24(d) is the same as Fig. 2.20(c)]. Compare Figs. 2.24(e) and (f), especially the latter, with the original image in Fig. 2.20(a).

Relationships between pixels (1)

Neighborhood of a pixel

Neighborhood 4 N_4

		X	
y	X	?	X
		X	
		x	

$$(x+1, y), (x-1, y), (x, y+1), (x, y-1)$$

Neighborhood 8 N_8

X	X	X
X	?	X
X	X	X

$$(x+1, y+1), (x+1, y-1), (x-1, y+1), (x-1, y-1)$$

Relationships between pixels (2)

Path between $p \rightarrow (x, y)$ e $q \rightarrow (s, t)$

$(x_0, y_0), (x_1, y_1), \ldots, (x_n, y_n)$ where $(x_0, y_0) = (x, y)$, $(x_n, y_n) = (s, t)$

and $(x_i, y_i), (x_{i-1}, y_{i-1})$ are neighbors, for $i = 1, 2, \ldots, n$

Connectivity

Two pixels are connected if there exists a path that links them

Region

Set of connected pixels.

1	1	0	1	1	1	0	1
1	1	0	1	0	1	0	1
1	1	1	1	0	0	0	1
0	0	0	0	0	0	0	1
1	1	1	1	0	1	0	1
0	0	0	1	0	1	0	1
1	1	0	1	0	0	0	1
1	1	0	1	0	1	1	1

Relationships between pixels(3)

Distance metrics for pixels

$$p \rightarrow (x, y) \qquad q \rightarrow (s, t) \qquad z \rightarrow (v, w)$$

$$D(p, q) \geq 0$$

$$D(p, q) = D(q, p)$$

$$D(p, z) \leq D(p, q) + D(q, z)$$

Relationships between pixels(4)

Euclidian distance

$$D_e(p,q) = \sqrt{(x-s)^2 + (y-t)^2}$$

$$\begin{matrix} 2\sqrt{2} & \sqrt{5} & 2 & \sqrt{5} & 2\sqrt{2} \\ \sqrt{5} & \sqrt{2} & 1 & \sqrt{2} & \sqrt{5} \\ 2 & 1 & 0 & 1 & 2 \\ \sqrt{5} & \sqrt{2} & 1 & \sqrt{2} & \sqrt{5} \\ 2\sqrt{2} & \sqrt{5} & 2 & \sqrt{5} & 2\sqrt{2} \end{matrix}$$

Relationships between pixels(5)

City-block or D4 distance

$$D_4(p,q) = |x-s| + |y-t|$$

$$\begin{array}{ccccc} & & 2 & & \\ & 2 & 1 & 2 & \\ 2 & 1 & 0 & 1 & 2 \\ & 2 & 1 & 2 & \\ & & 2 & & \end{array}$$

Chessboard or D8 distance

$$D_8(p,q) = \max(|x-s|, |y-t|)$$

$$\begin{array}{ccccc} 2 & 2 & 2 & 2 & 2 \\ 2 & 1 & 1 & 1 & 2 \\ 2 & 1 & 0 & 1 & 2 \\ 2 & 1 & 1 & 1 & 2 \\ 2 & 2 & 2 & 2 & 2 \end{array}$$

Arithmetic operations (1)

Operations that are performed between corresponding pixels pairs (point-by-point operations)

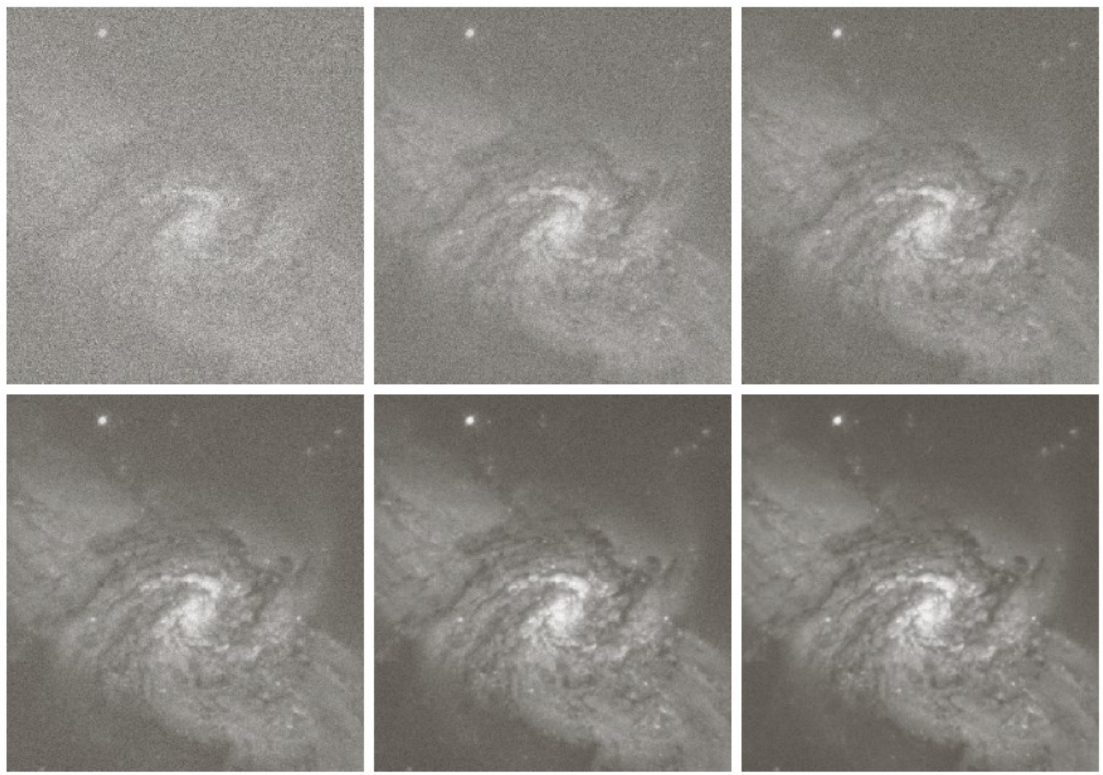
$$s(x, y) = f(x, y) + g(x, y)$$

$$d(x, y) = f(x, y) - g(x, y)$$

$$p(x, y) = f(x, y) \times g(x, y)$$

$$v(x, y) = f(x, y) \div g(x, y)$$

Arithmetic operations (2)



a b c
d e f

FIGURE 2.26 (a) Image of Galaxy Pair NGC 3314 corrupted by additive Gaussian noise. (b)–(f) Results of averaging 5, 10, 20, 50, and 100 noisy images, respectively. (Original image courtesy of NASA.)

Arithmetic operations (3)

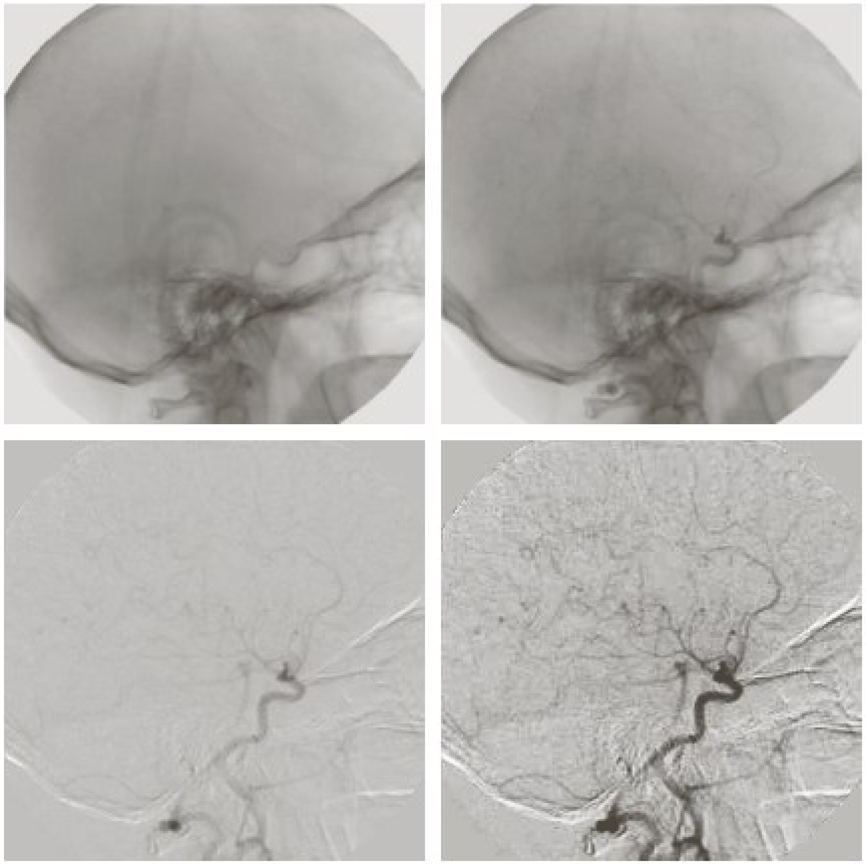


FIGURE 2.28 Digital subtraction angiography. (a) Mask image. (b) A live image. (c) Difference between (a) and (b). (d) Enhanced difference image. (Figures (a) and (b) courtesy of The Image Sciences Institute, University Medical Center, Utrecht, The Netherlands.)

Arithmetic operations (4)

a b c

FIGURE 2.30 (a) Digital dental X-ray image. (b) ROI mask for isolating teeth with fillings (white corresponds to 1 and black corresponds to 0). (c) Product of (a) and (b).

Logical operations and sets (1)

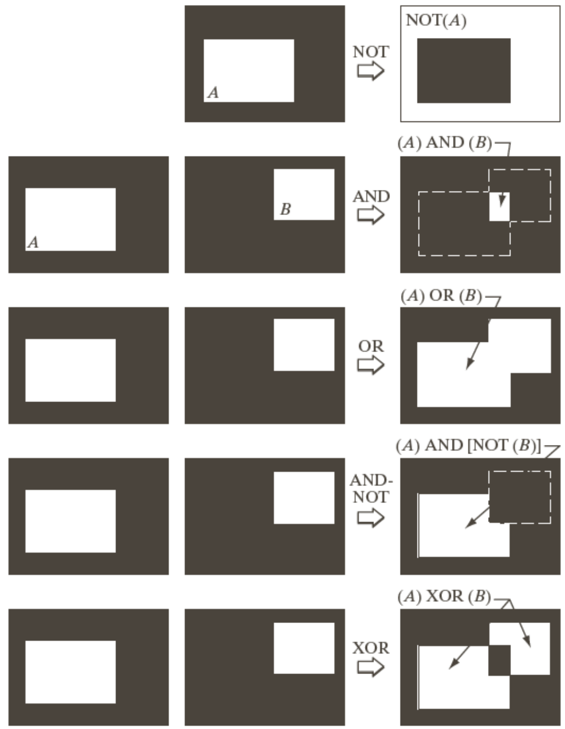
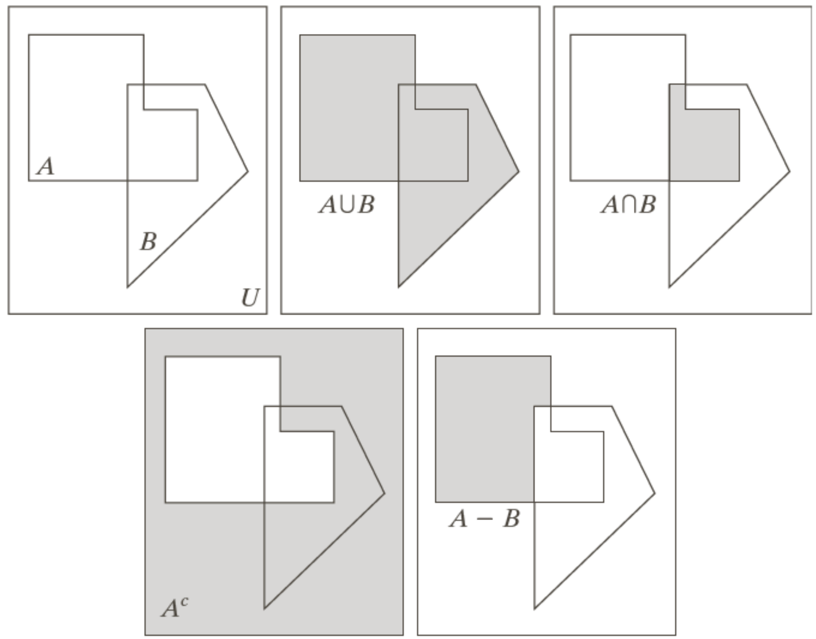


FIGURE 2.33 Illustration of logical operations involving foreground (white) pixels. Black represents binary 0s and white binary 1s. The dashed lines are shown for reference only. They are not part of the result.

Logical operations and sets (2)



a b c
d e

FIGURE 2.31
(a) Two sets of coordinates, A and B, in 2-D space. (b) The union of A and B. (c) The intersection of A and B. (d) The complement of A. (e) The difference between A and B. In (b)–(e) the shaded areas represent the member of the set operation indicated.

Spatial operations (1)

1. Operation based on one pxel

$$s = T(z)$$

2. Operation based on neighbors

S_{xy} Neighbors of the pixel $p \rightarrow (x, y)$

3. Geometric transformations

$$(x, y) = T\{(v, w)\}$$

Spatial operations – Examples (1)

Negative image

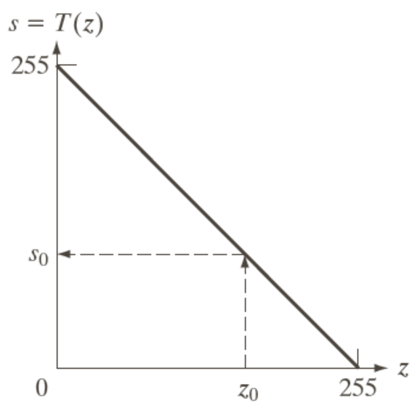


FIGURE 2.34 Intensity transformation function used to obtain the negative of an 8-bit image. The dashed arrows show transformation of an arbitrary input intensity value z_0 into its corresponding output value s_0.

Spatial operations – Examples (2)

Mean

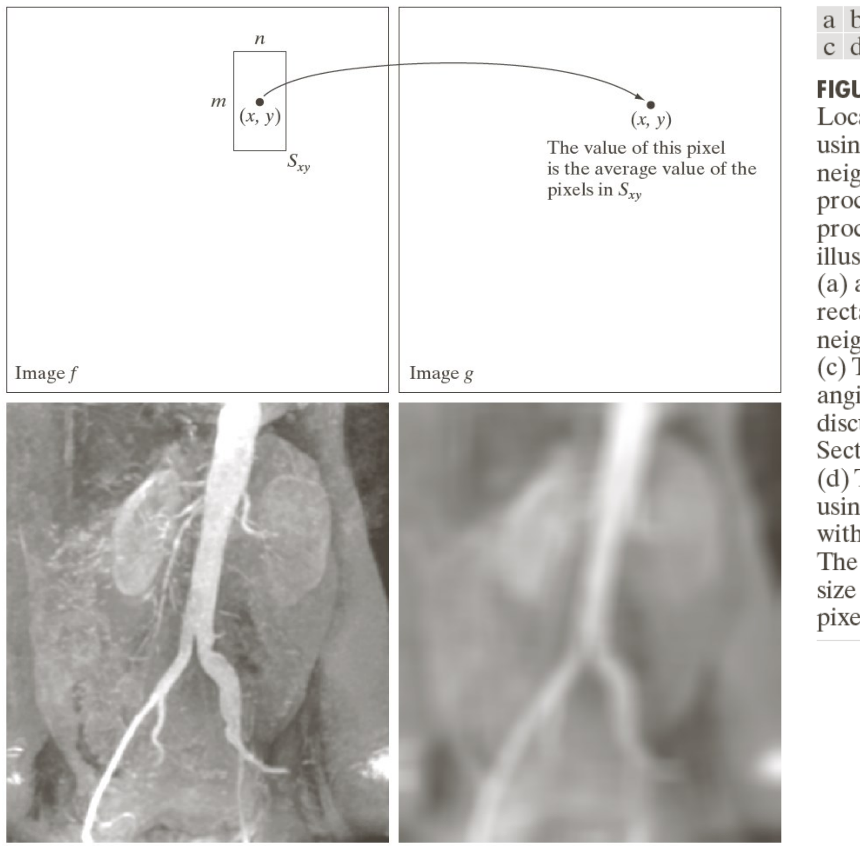


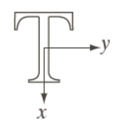
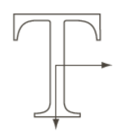
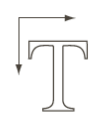
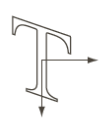
FIGURE 2.35 Local averaging using neighborhood processing. The procedure is illustrated in (a) and (b) for a rectangular neighborhood. (c) The aortic angiogram discussed in Section 1.3.2. (d) The result of using Eq. (2.6-21) with $m = n = 41$. The images are of size 790×686 pixels.

Spatial operations – Examples (3)

Afine transform

$$[x\ y\ 1] = [v\ w\ 1]T = [v\ w\ 1]\begin{bmatrix} t_{11} & t_{12} & 0 \\ t_{21} & t_{22} & 0 \\ t_{31} & t_{32} & 1 \end{bmatrix}$$

TABLE 2.2
Affine transformations based on Eq. (2.6.–23).

Transformation Name	Affine Matrix, T	Coordinate Equations	Example
Identity	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = w$	
Scaling	$\begin{bmatrix} c_x & 0 & 0 \\ 0 & c_y & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = c_x v$ $y = c_y w$	
Rotation	$\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v\cos\theta - w\sin\theta$ $y = v\cos\theta + w\sin\theta$	
Translation	$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ t_x & t_y & 1 \end{bmatrix}$	$x = v + t_x$ $y = w + t_y$	
Shear (vertical)	$\begin{bmatrix} 1 & 0 & 0 \\ s_v & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v + s_v w$ $y = w$	
Shear (horizontal)	$\begin{bmatrix} 1 & s_h & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$	$x = v$ $y = s_h v + w$	

Types of Images

- ***Definition:*** a monochromatic image (gray level), $I[r,c]$, assigns for each pixel one scalar value (intensity)

- ***Definition:*** a multiespectral imagem, $M[r,c]$, assigns for each pixel one N-dimensional vector. In the case of color images, we have N=3 (RGB)

- ***Definition:*** a binary image, $B[r,c]$, assigns each pixel the values of 0 or 1

- ***Definition*** a label image (classes), $L[r,c]$, assigns each pixel to a given label, that is chosen from a pre-defined alphabet of labels

Image Formats

- Header
- Data
  - Use (or not) data compression algorithms.
    - Compression without losses (*lossless*) or with losses (*lossy*)

Example of a format →

```
P2
# sample small picture 8 rows of 16 columns, max grey value of 192
# making an image of the word "Hi".
  16 8   192

 64 64  64  64  64  64  64  64  64 64 64  64  64 64 64 64
 64 64 128 128  64  64  64 128 128 64 64 192 192 64 64 64
 64 64 128 128  64  64  64 128 128 64 64 192 192 64 64 64
 64 64 128 128 128 128 128 128 128 64 64  64  64 64 64 64
 64 64 128 128 128 128 128 128 128 64 64 128 128 64 64 64
 64 64 128 128  64  64  64 128 128 64 64 128 128 64 64 64
 64 64 128 128  64  64  64 128 128 64 64 128 128 64 64 64
 64 64  64  64  64  64  64  64  64 64 64  64  64 64 64 64
```

Image File Format	No. Bytes "Hi"	No. Bytes "Cars"
PGM	595	509,123
GIF	192	138,267
TIF	918	171,430
PS	1591	345,387
HIPS	700	160,783
JPG (lossless)	684	49,160
JPG (lossy)	619	29,500

General concepts - Lossy vs Lossless

You **can not** recover the contents of the image

You **can** recover the contents of the image

General concepts - Magic Number

- Used for the identification of files format
  - It appeared for the 1st time in UNIX 7 version (1979)
    - To identify executable files
  - It is a set of bits at the beginning of the file

- Examples:
  - PDF: **`25 50 44 46`** (%PDF)
  - MS-OFFICE DOC: **`D0 CF 11 E0`** (“docfile0”)
  - Compiled JAVA Classes: **`CA FE BA BE`** (“cafe babe”)

General Concepts - Magic Number

For the image files we have

- PBM**: P4** [em ASCII]
- BPM: **42 4D** (BM)
- GIF: **47 49 46 38** (GIF8)
- PNG: **89 50 4E 47** (♦PNG)
- JPEG/JFIF: **FF D8 FF E0**
- TIFF
  - Big endian (motorola): **4D 4D 00 2A** (MM♦*)
  - Little endian (intel): **49 49 2A 00** (II*♦)

General concepts – direct representation

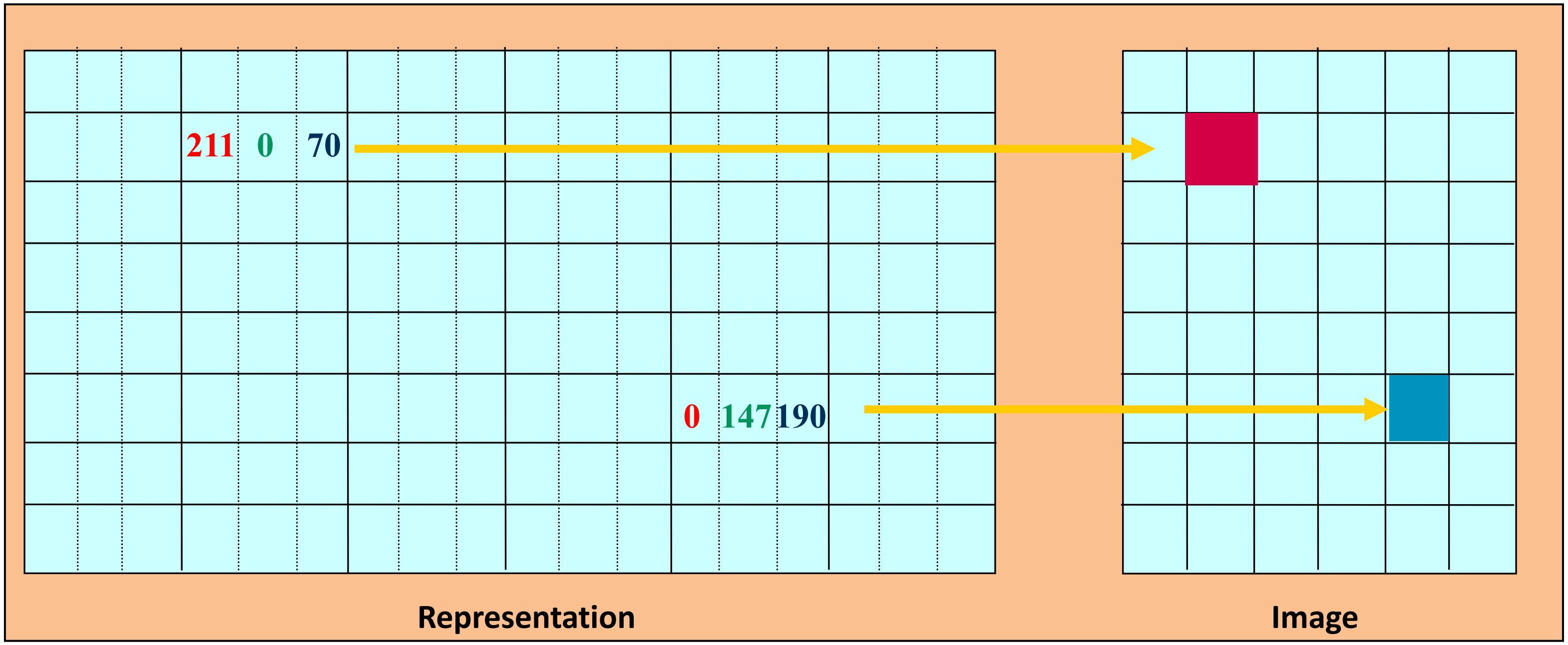
For each pixel

Represents the corresponding channel using the Triplet <R,G,B>

Maximum Reliability

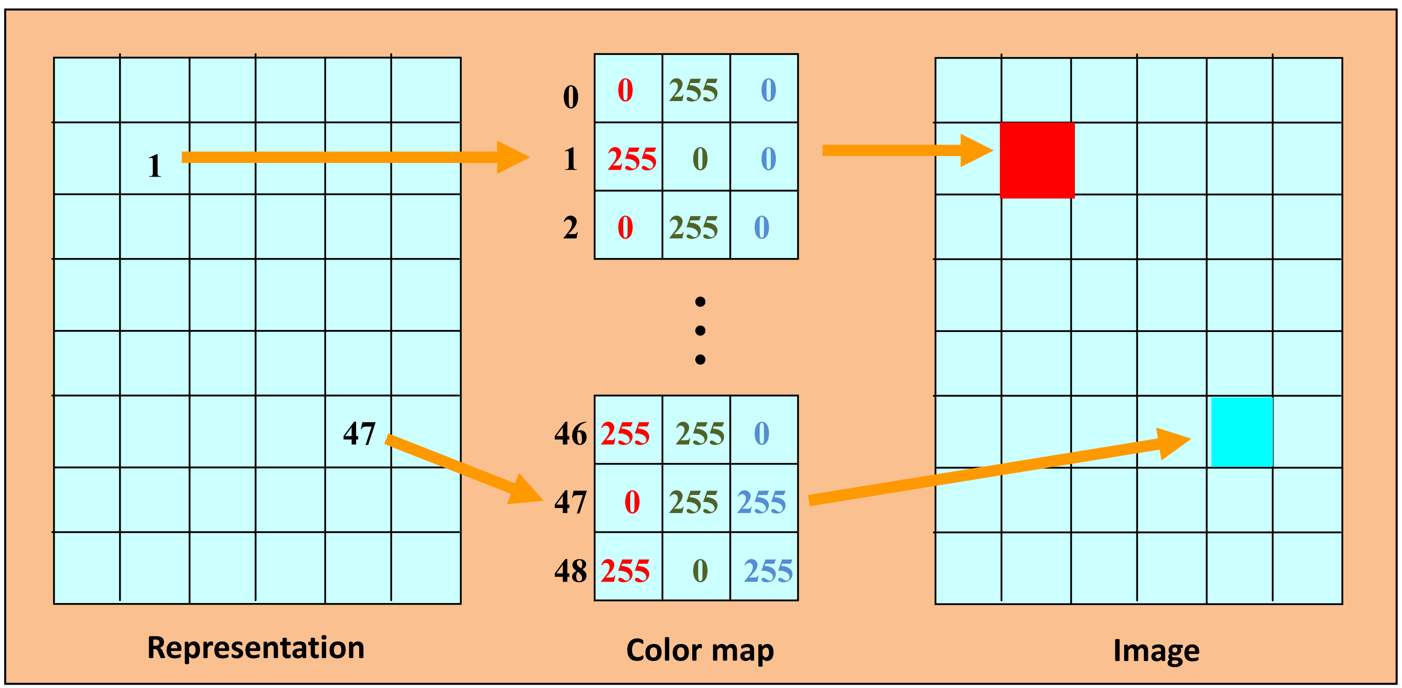
It depends only of the color depth

High memory requirements



General concepts - Map color representation

- The pixels are represented by color index
  - Instead of 3 color components
- Files with smaller dimension
  - Up to 256 colors
  - Not suitable for more than 256 colors



Initials

DIB: Device Independent Bitmap

"windows" BMP: Windows Bitmap

GIF: Graphics Interchange Format

PNG: Portable Network Graphics

JFIF: JPEG File Interchange Format

DIB Format (BMP) (1/2)

Colors:
2, 16, 256 e 16.777.216

Color model:
RGB

Compression:
RLE 4 e RLE 8

Color maps:
with 2, 16 e 256 colors

Interlacing:
Does not support

Transparency:
Does not support

800×600, 81232 colos, 1,37 Mb

RLE - 800×600, 251 colors, 530 kb

DIB Format (BMP) (2/2)

Advantages

- Real colors
- Multiple sub-types
  - For different types of image

Disadvantages

- Files with large sizes
- Compression is limited
- Compression not suited for images with photographic quality

GIF Format (1/3)

Colors:

2, 4, 8, 16, 32, 64, 128 e 256

Color model:

RGB

Compression:

LZW without losses

Color map:

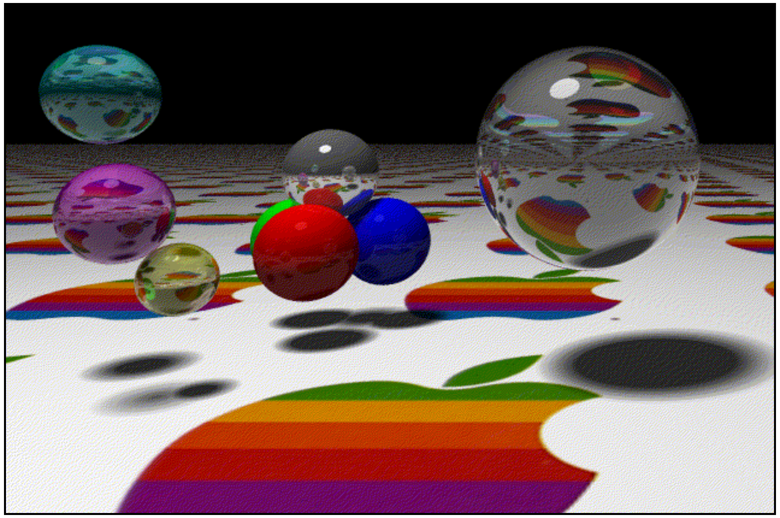
Mandatory

Interlacing:

Optional, by lines

Transparency:

One color



638×422, 144 cores, 94 kb

320×200, 255 cores, 57 kb

GIF Format (2/3)

Advantages

GIFs are suitable for sharp-edged line art (such as logos) with a limited number of colors. This takes advantage of the format's lossless compression, which favors flat areas of uniform color with well defined edges

Aanimated GIFs

Files with small sizes

Disadvantages

Up to 256 colors

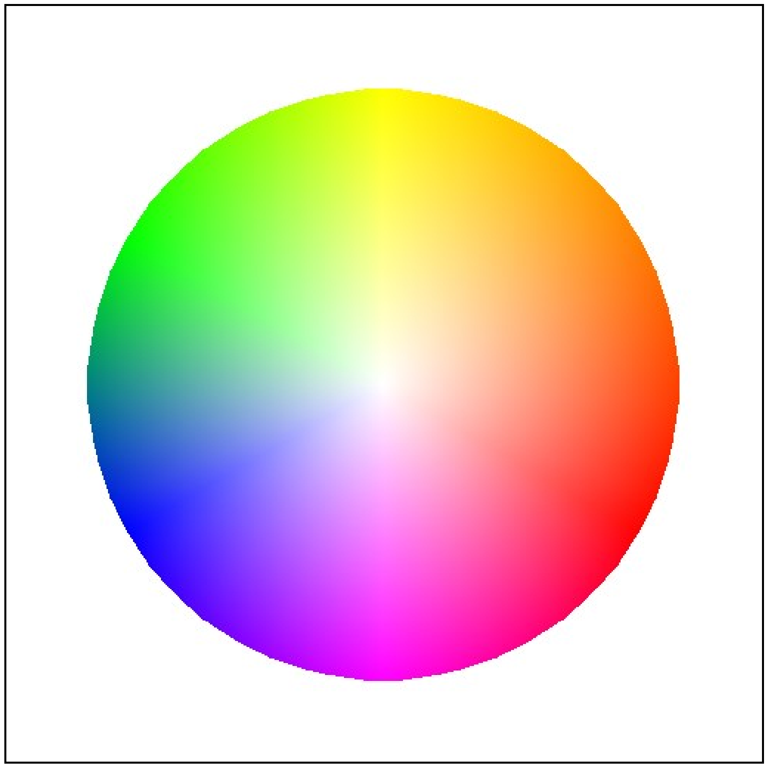
Owners of format and compression algorithm

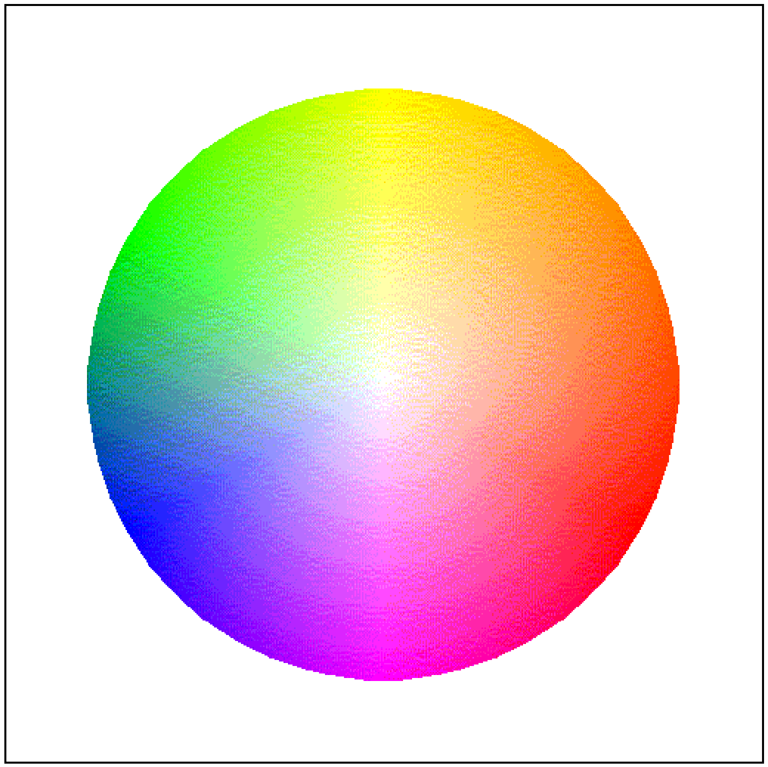
Not suited for images with photogtraphic quality

Transparency with one color

GIF Format (3/3)

Up to 256 colors





PNG Format (1/2)

Colors:

2, 4, 16, 256, 16.777.216 e 2^{48}

Color model:

RGB

Compression:

LZ77 swithout loss

Color maps:

with 2, 4, 16 e 256 colors

Interlacing:

Optional (by pixels)

Transparency:

By alfa channel (In computer graphics **alpha compositing** is the process of combining an image with a background to create the appearance of partial or full transparency.)

PNG Format (2/2)

Advantages

- It supports all image types
- The compression algorithm is publicly available
- Transparency by alfa channel
- Allows image sequences (***APNG** extension of the W3C norm)

Disadvantages

- It has a less suitable compression algorithm for photographic images quality

JFIF Format (JPEG) (1/2)

Colors:

16.777.216

Color model

YCbCr

Compression:

JPEG (with loss)

Color map:

Does not support

Enterlacing:

Does not support

Transparency:

Does not support

800×600, 59847 cores, 68,9 kb

800×600, 81232 cores, 60,9 kb

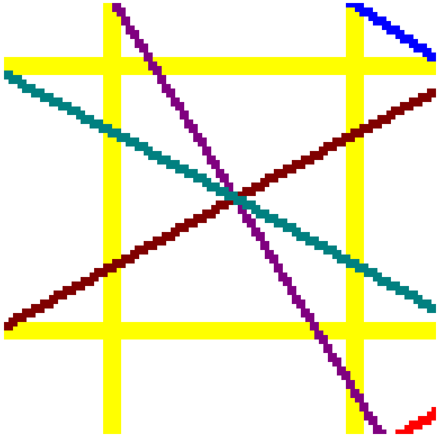
JFIF Format (JPEG) (2/2)

Advantages

- Recommended for photographic images quality
- Standard compression algorithms

Disadvantages

- There is always loss (although not perceptible to the human vision)
- Not proper for images with sudden color changes



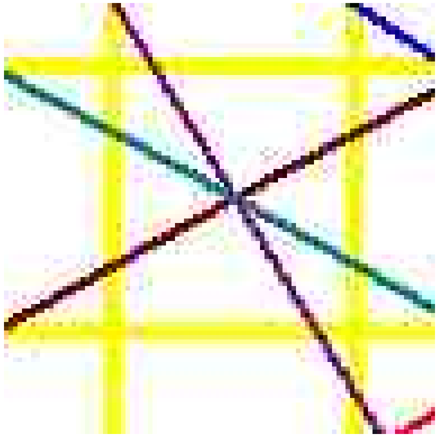


Image formats - Recommendations

Use ***GIF*** if

- Number of colors is small (<256)

Consider the ***PNG*** format if

- The image does not have photographic quality

Use ***JPEG/JFIF*** whenever the image

- Has photographic quality
- It has continuous tones

Use ***JPEG/JFIF***

- To store original images without (or small) loss
- Reduce the image size before to perform the compression with loss

Do not forget about the Readings!

- Chapter 1 e 2 de R. Gonzalez, R. Woods, "Digital Image Processing", 3ª edição, 2008.

- Chapter 2 de L. Shapiro, G. Stockman, "Computer Vision", 2001.