SEMINAR REPORT
ON

IMAGE PROCESSING TECHNIQUES

CONTENTS

INTRODUCTION

- IMAGE:-

Image is a optical appearance of object produced through mirror or lenses .

- DIGITAL IMAGE:-

Digital image is composed of finite no. of elements each of which has a particular location and intensity values.

- DIGITAL IMAGE PROCESSING:-

The field of digital image processing refers to processing of digital images by means of digital computers .

VARIOUS TECHNIQUES OF IMAGE PROCESSING

- Geometric Transformation
- Image Smoothing
- Contrast Enhancement
- Edge Detection
- Negative Transformation
- Morphological Operation

GEOMETRIC TRANSFORMATION

GEOMETRIC TRANSFORMATION

- Geometric transformation are simply alignments done on images to collect the exact appearance of an objects.

    (i) Translation

    (ii)Rotation

    (iii)Scaling

Translation

In translation, axes of individual are displayed by their respective displacement factor.

XT=X+X0 YT=Y+Y0 ZT=Z+ZO

Input image

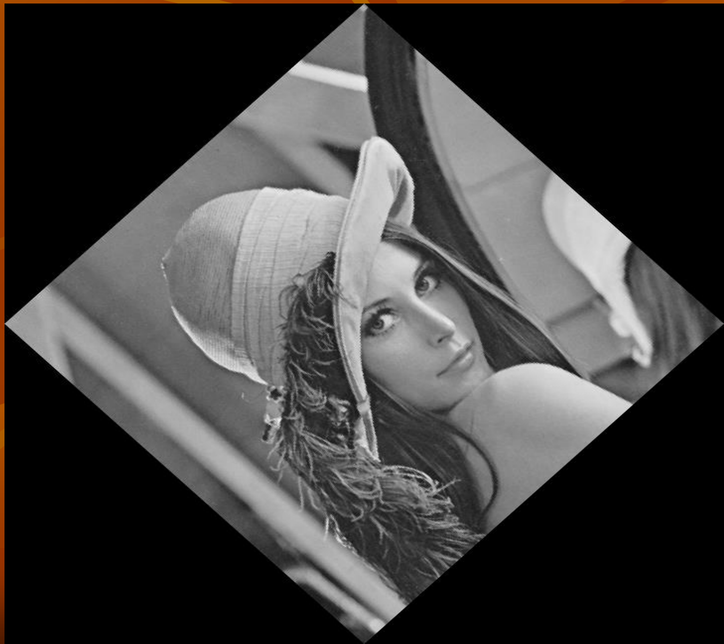
Translated image

Rotation

Rotation is one type of alignment where an image is rotated w.r.t different axes with different angles to align with the image plane

Input image

Output image



Scaling

In scalling operation axes of indivisuals are multiplied by respective scaling factor.

$X_S = S_X X$ $Y_S = S_Y Y$ $Z_S = S_Z Z$

Input image

Output image scaled
By 0.5

IMAGE SMOOTHING

IMAGE SMOOTHING

It is a technique to reduce noise in a digital image. It is usually applied to diminish the spurious noise.

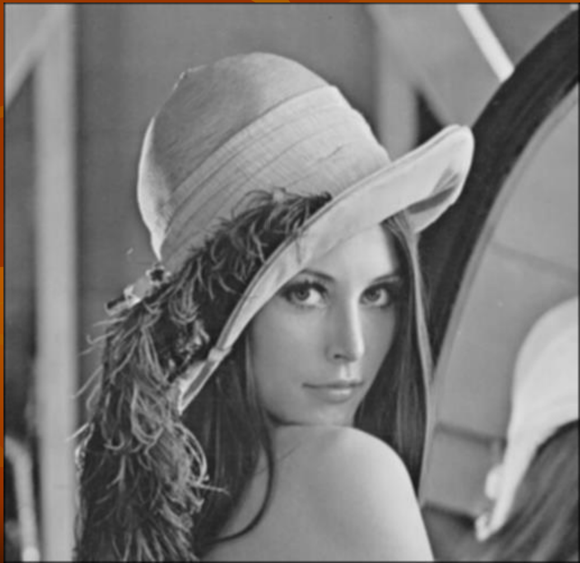
- Low pass filtering
- Gaussian filtering
- Median filtering

Low pass Filtering

Since noise contribute in high frequency component, so LPF is used to suppress such high frequency component to remove the noise.

General image

Output image



Cont…

Image with Gaussian noise

Output of LPF

Cont…

Image with salt and pepper noise

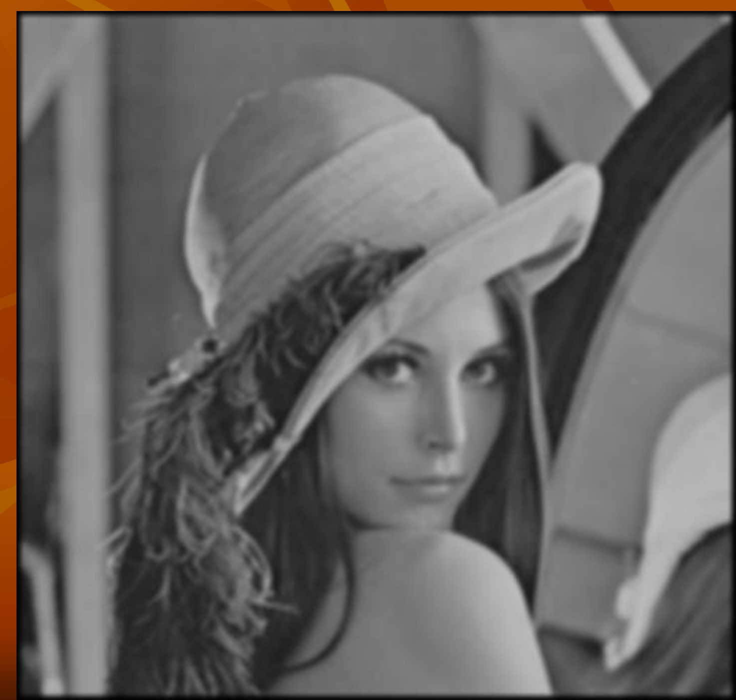
Output of LPF

Gaussian Filtering

It is sometimes useful to apply a Gaussian smoothing filter to an image before performing edge detection. The filter can be used to soften edges, and to filter out spurious points(noise) in an image.

General image

Output of Gaussian filter



Cont…

Image with Gaussian noise

Output of Gaussian filter

Cont…

Image with salt and pepper noise

Output of Gaussian filter

Median Filtering

This is a ordered statistic filter is defined by the equation:

wi =1 if i= (Ω-1)/2

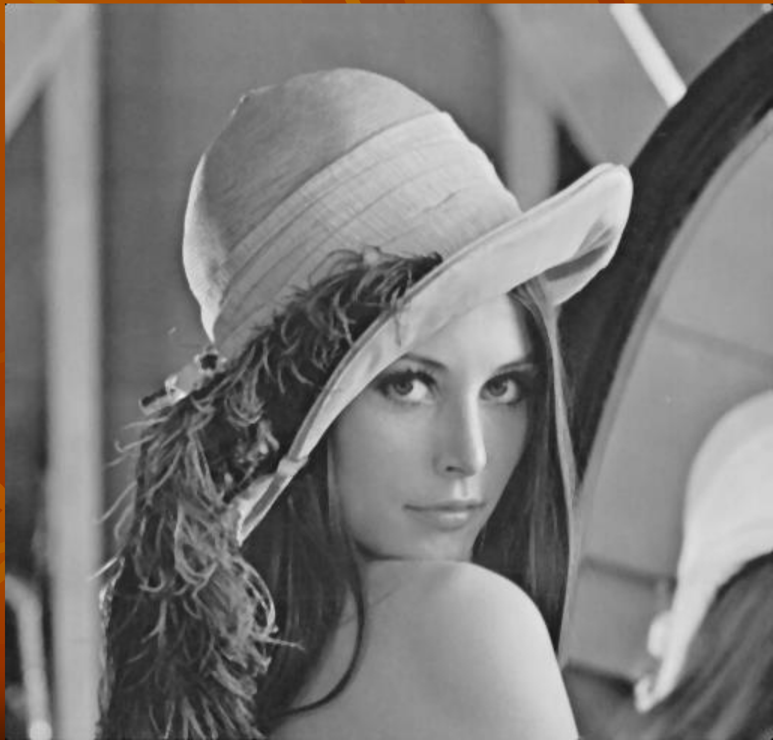
=0 otherwise

Where Ω is an odd number

Median filter is very effective to remove *impulsive noise.*

General image

Output of median filter



Cont…

Image with Gaussian noise

Output of median filter

Cont…

Image with salt and pepper noise

Output of median filter

CONTRAST ENHANCEMENT

CONTRAST ENHANCEMENT

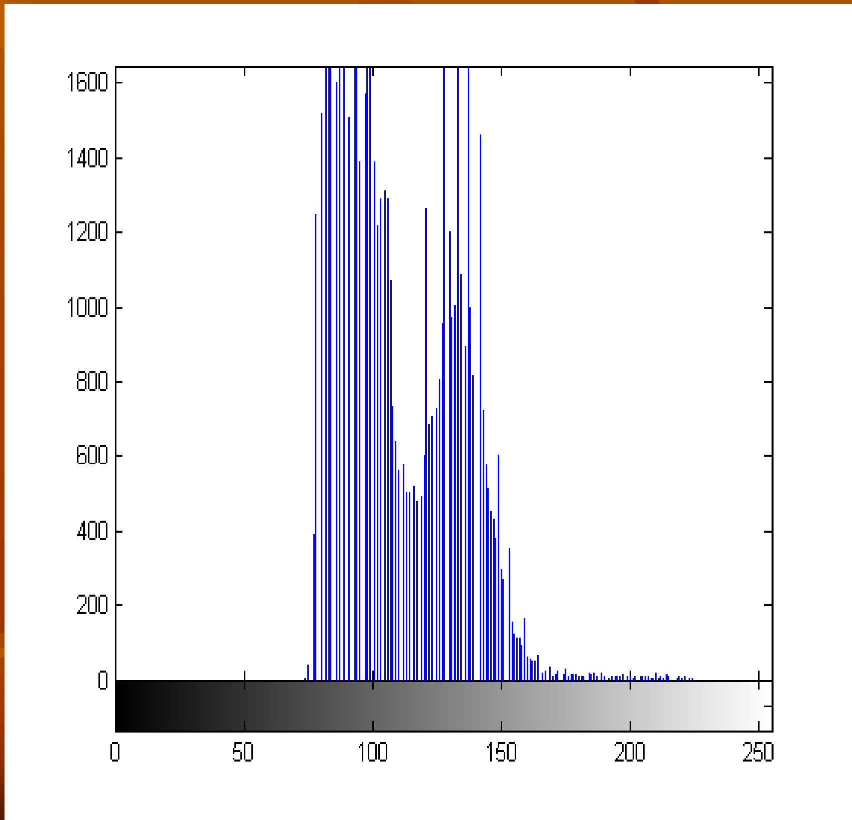
- Processing an image means to enhance certain features of the image.
- One of the defect found in images is its poor contrast due to inadequate lighting, aperture size, shutter speed etc.
- **Histogram:-**It gives global description of an image.
- **Histogram equalization:-**It means increasing dynamic range of the gray level.

Cont…

$p(r_k)=n_k/n$

Low contrast image

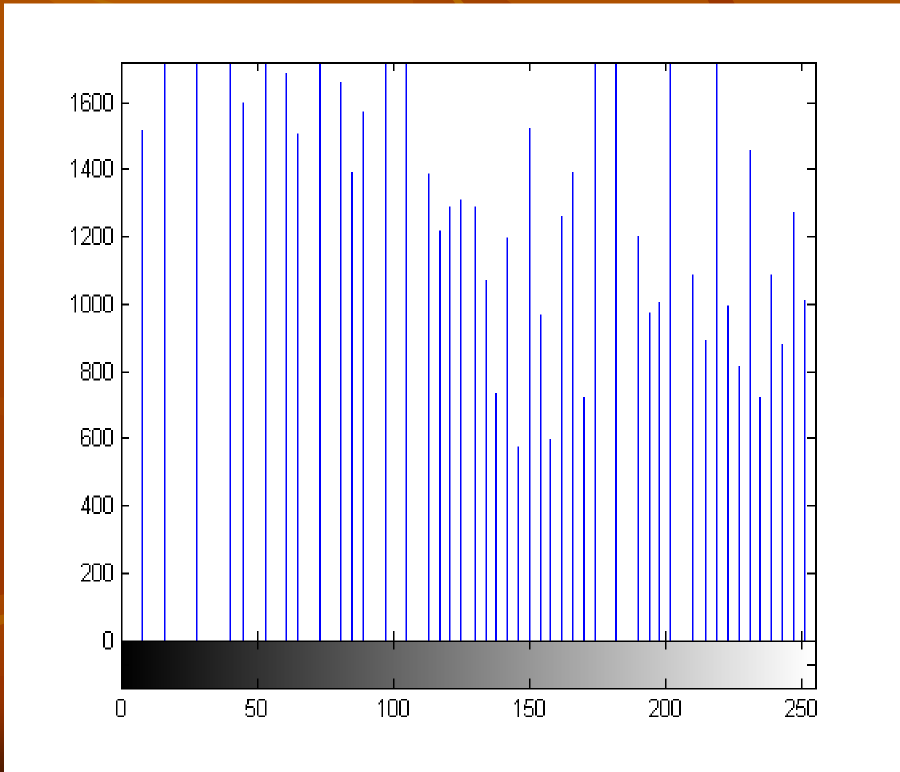
Histogram of low contrast image



Cont…

Output image

Histogram of output image



EDGE DETECTION

EDGE DETECTION

- It s the most common approach to detect the discontinuity.
- Edges are the boundary between two regions having distinct gray levels.
- Ariel images,road secton,river etc. need boundary information.

Cont…

There are four operators for edge detection:-

- Prewitt operators
- Robert operators
- Canny edge detection

Prewitt Operator

- **Prewitt** is a method of edge detection in image processing which calculates the maximum response of a set of convolution kernels to find the local edge orientation for each pixel.

Mask of prewitt edge detector

Gy=

-1	-1	-1
0	0	0
1	1	1

Gx=

-1	0	1
-1	0	1
-1	0	1

Cont…

Input image

Output image

Robert Operator

The equivalent masks of the robert operator are

d1=g0 – g1 and d2= g0 – g3

0	0
-1	1

0	-1
0	1

INPUT IMAGE

OUTPUT IMAGE

Canny Operator

- Canny operator is used for wide range of edge detection.
- It smooth the image by Gaussian filter to reduce noise, unwanted detail and texture.
- Canny then compute gradient using gradient operators

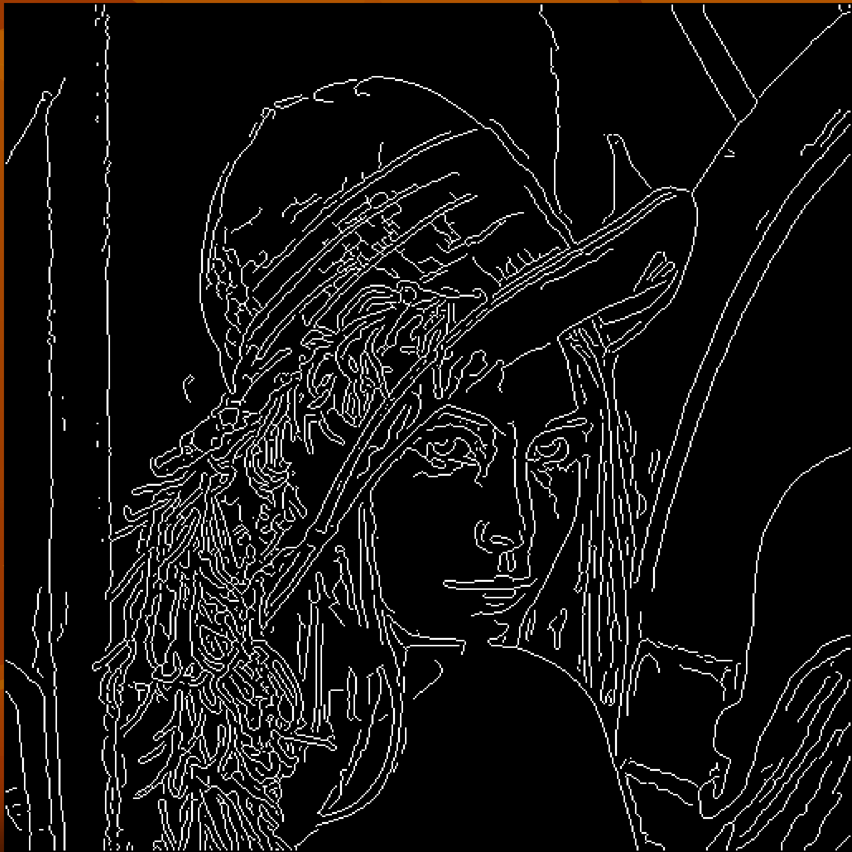
$$G = \sqrt{{G_x}^2 + {G_y}^2}$$

$$\Theta = \arctan\left(\frac{G_y}{G_x}\right)$$

Cont…

Input image

Output image



NEGATIVE TRANSFORMATION

NEGATIVE TRANFORMATION

- Negative transformation means reversing the intensity levels of an image.
- This type of processing is used for enhancing white or gray detail embedded in dark region of an image.
- Mostly used in medical application where minute informations are important.

Cont..

$$S=L-1-r$$

S:-Negative of an image
L:-total no.of pixels
R:-max intensity value

Input image

Negative of input image

Cont…

OUTPUT IMAGE

INPUT IMAGE

CONCLUSION

The seminar "Image processing technique" has been successfully finished.

we perform various operation:-

- Transformation of image
- Smoothing of image
- Contrast enhancement
- Negative transformation
- Edge detection

Now a days image processing have great application .These techniques are used in military purpose ,for identifying certain regions ,hills ,rivers. Image processing have many applications in medical purposes, specially the image negative for identifying small defects in the body.

THANKYOU

|| JAI SRI GURUDEV ||

Sri Adichunchanagiri Shikshana Trust (R)

BGS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

PPT PRESENTATION ON DIGITAL IMAGEPROCESSING-CHAPTER 1
DIGITAL IMAGE FUNDAMENTALS

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1. Introduction

- **In many image processing applications, the objective is to help a human observer perceive the visual information in an image. Therefore, it is important to understand the human visual system.**
- **The human visual system consists mainly of the eye (image sensor or camera), optic nerve (transmission path), and brain (image information processing unit or computer).**
- **It is one of the most sophisticated image processing and analysis systems.**

1.1. Structure of Human Eye

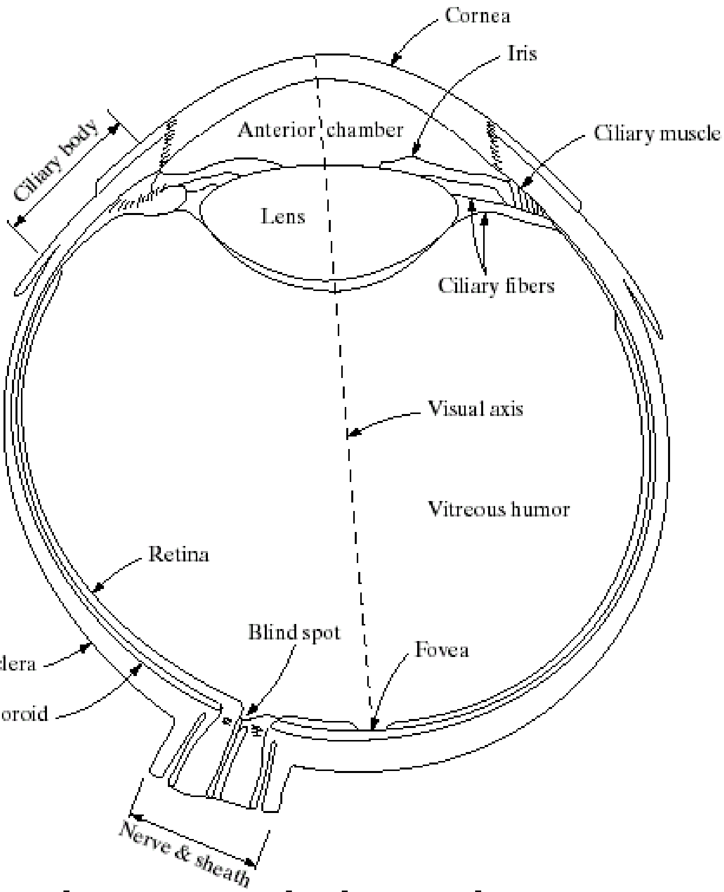
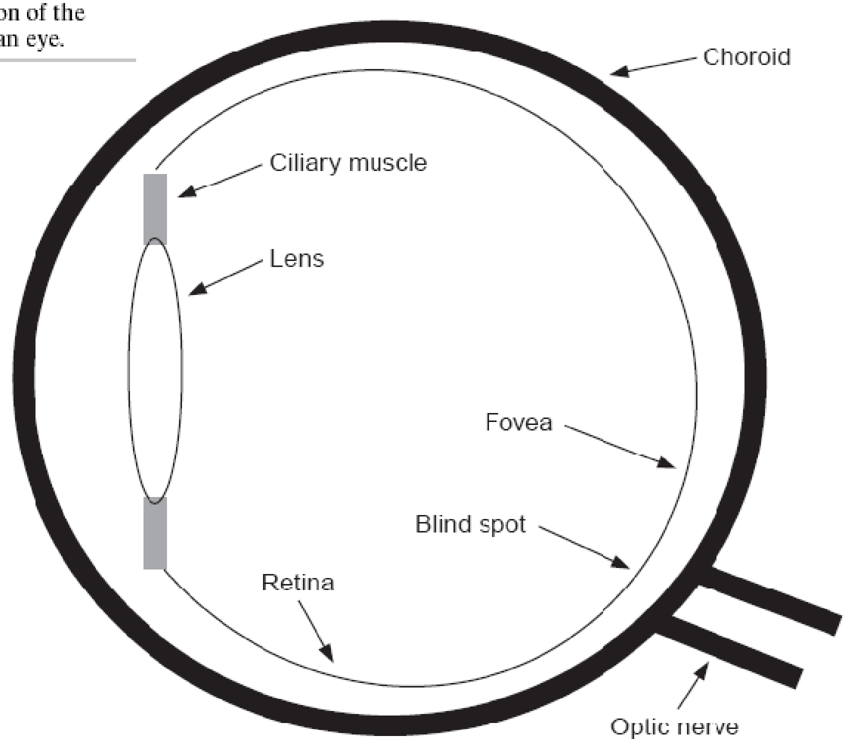


FIGURE 2.1 Simplified diagram of a cross section of the human eye.



The lens and the ciliary muscle focus the reflected lights from objects into the retina to form an image of the objects.

1.1. Retinal Photoreceptors

- Two types of photoreceptors: rods and cones (light sensors).
- **Cones:** 6-7 million, located in central portion of retina (fovea), responsible for photopic vision (bright-light vision) and color perception, can resolve fine details.
- **Rods:** 75-150 million, distributed over the entire retina, responsible for scotopic vision (dim-light vision), not color sensitive, gives general overall picture (not details).
- **Fovea :** Circular indentation in center of retina, about 1.5mm diameter, dense with cones.
- Photoreceptors around fovea responsible for spatial vision (still images).
- Photoreceptors around the periphery responsible for detecting motion.
- **Blind spot:** Point on retina where optic nerve emerges, devoid of photoreceptors.

1.1. Retinal Photoreceptors

Cones

- There are 6 to 7 million cones in each eye.
- Concentrated in the central portion of the retina called the fovea.
- Highly sensitive to color.
- Each cone is connected to its own nerve end, so human can resolve fine details.
- Cone vision is called photopic or BRIGHT-LIGHT VISION

1.1. Retinal Photoreceptors

Rods

- There are 70 to 150 million cones in each eye.
- Distributed over the retina surface.
- Several rods are connected to a single nerve end.
- Rods don't discern fine details.
- Rods give a general picture of the field of view.
- Not involve in color vision and sensitive to low levels of illumination.
- Rod vision is called scotopic or DIM-LIGHT VISION.

1.1. Elements of Visual Perception.

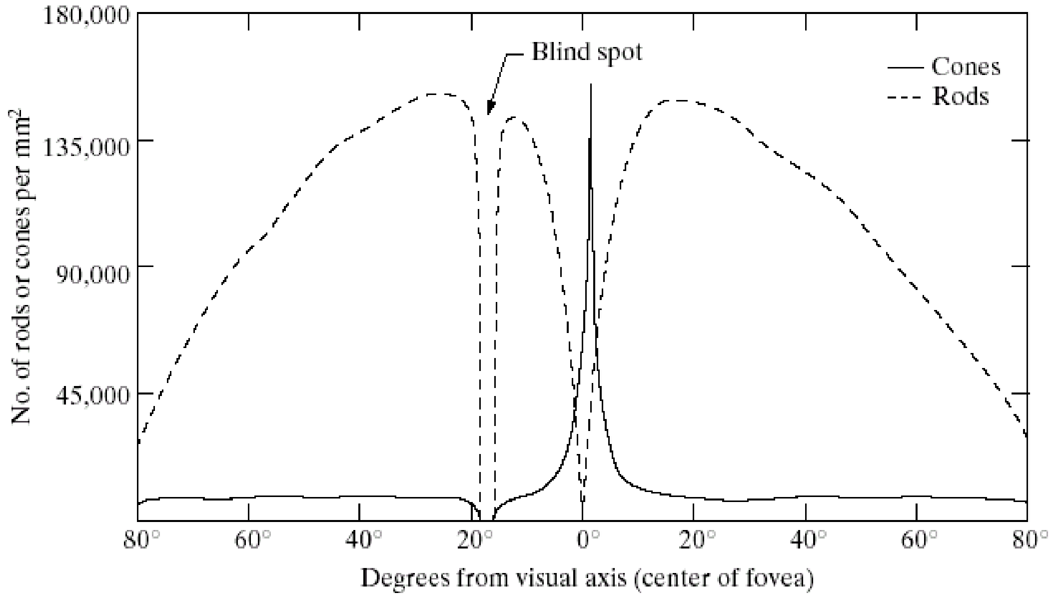
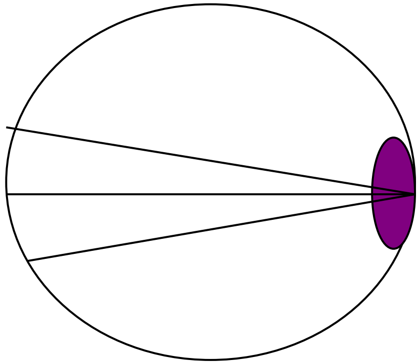


FIGURE 2.2 Distribution of rods and cones in the retina.

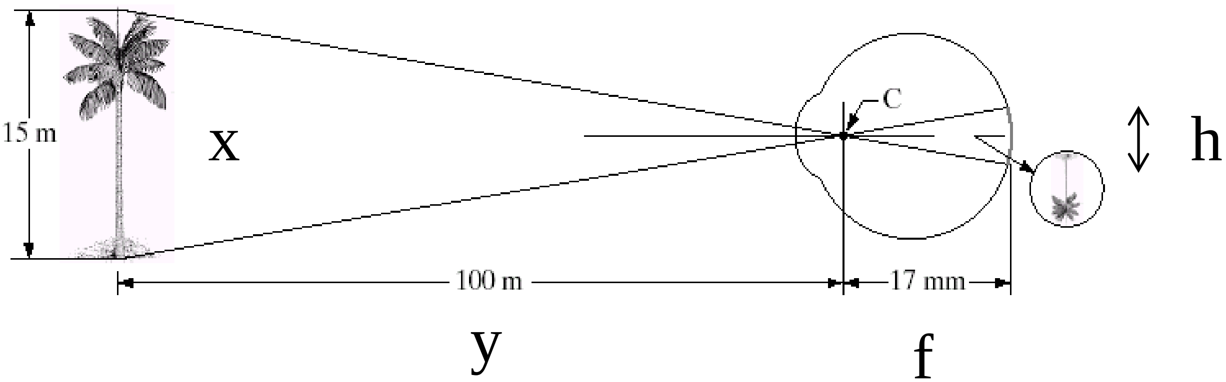


- Fovea size is 1.5 mm in diameter
- 1.5 mm × 1.5 mm square contain 337000 cones

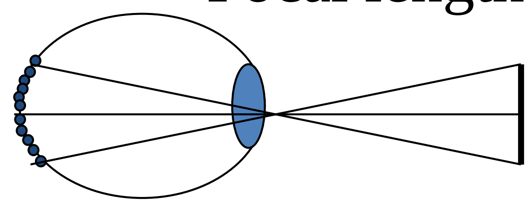
5mm × 5mm CCD imaging chip

1.2. Image Foundation in the Eye

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

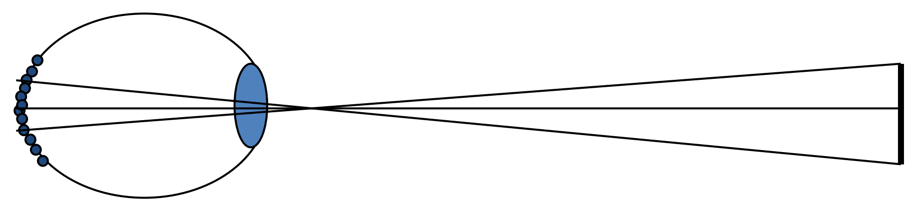


Focal length = f = 17 to 14 mm



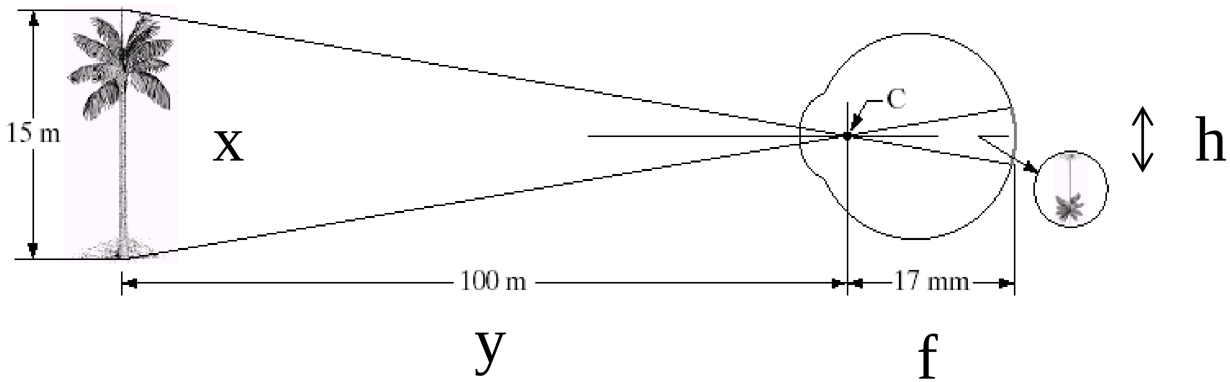
$$\frac{x}{y} = \frac{h}{f}$$

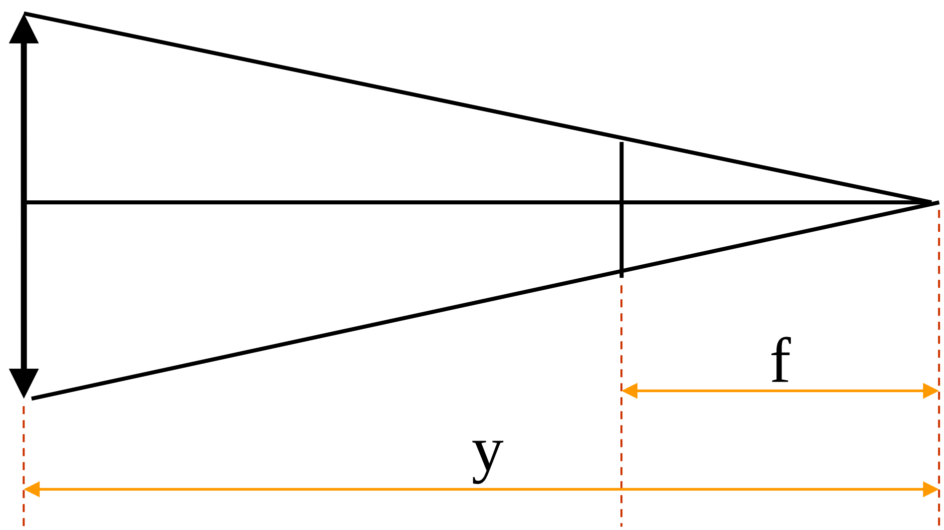
h = 2.55 mm



1.2. Image Foundation in the Eye

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



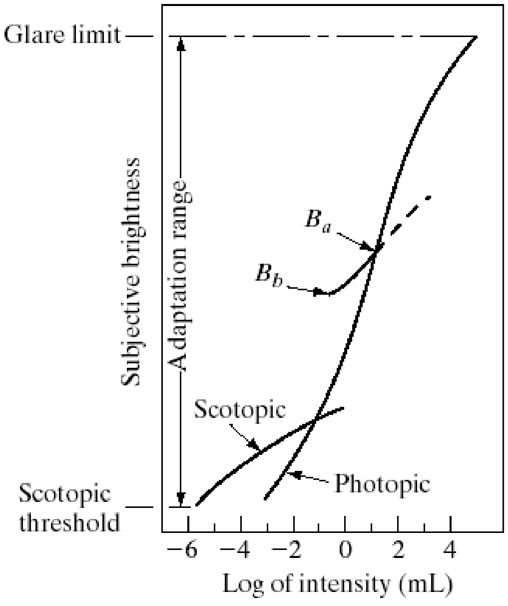


1.3. Brightness Adaptation and Discrimination

- The range of light intensity human can adapt to is in the range of 10^{10}
- Subjective brightness is a logarithmic function of the light intensity incident on the eye.
- The visual system does not operate simultaneously over the 10^{10} range. It accomplishes this large variation by changes in its overall sensitivity, a phenomenon known as brightness adaptation.

FIGURE 2.4 Range of subjective brightness sensations showing a particular adaptation level.

mL = millilambert



1.3. Brightness Adaptation and Discrimination

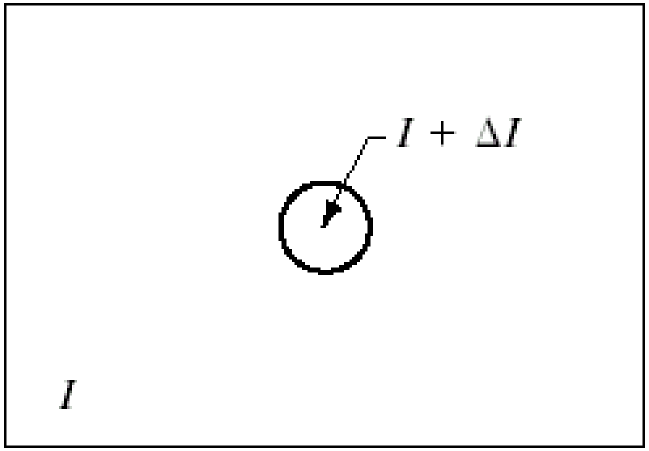


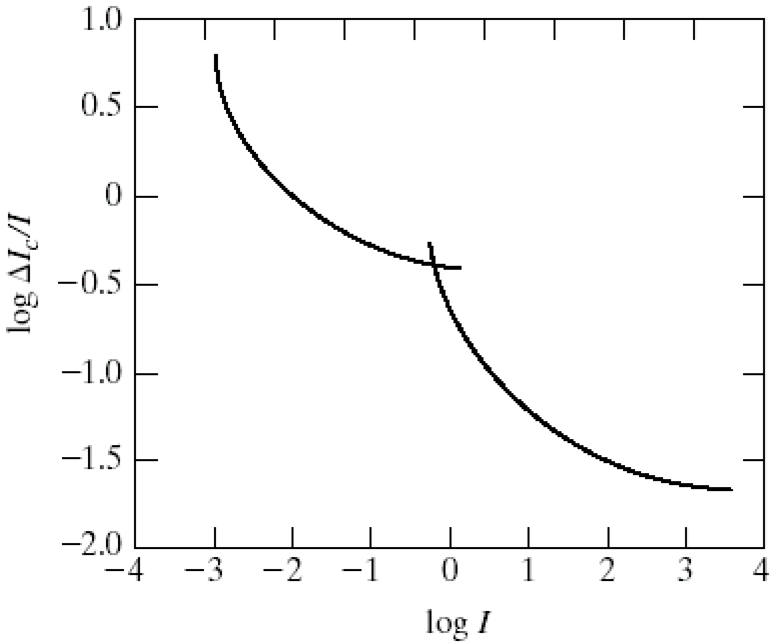
FIGURE 2.5 Basic experimental setup used to characterize brightness discrimination.

- Brightness discrimination is the ability of the eye to discriminate between changes in light intensity at any specific adaptation level.
- The quantity $\Delta I_d / I$, where ΔI_c is the increment of illumination discriminable 50% of the time with background illumination I, is called the Weber ratio. A small value of Weber ratio, means good brightness discrimination.

1.3. Brightness Adaptation and Discrimination

- Brightness discrimination is poor at low levels of illumination.The two branches in the curve indicate that at low levels of illumination vision is carried out by the rods, whereas at high level by the cones.

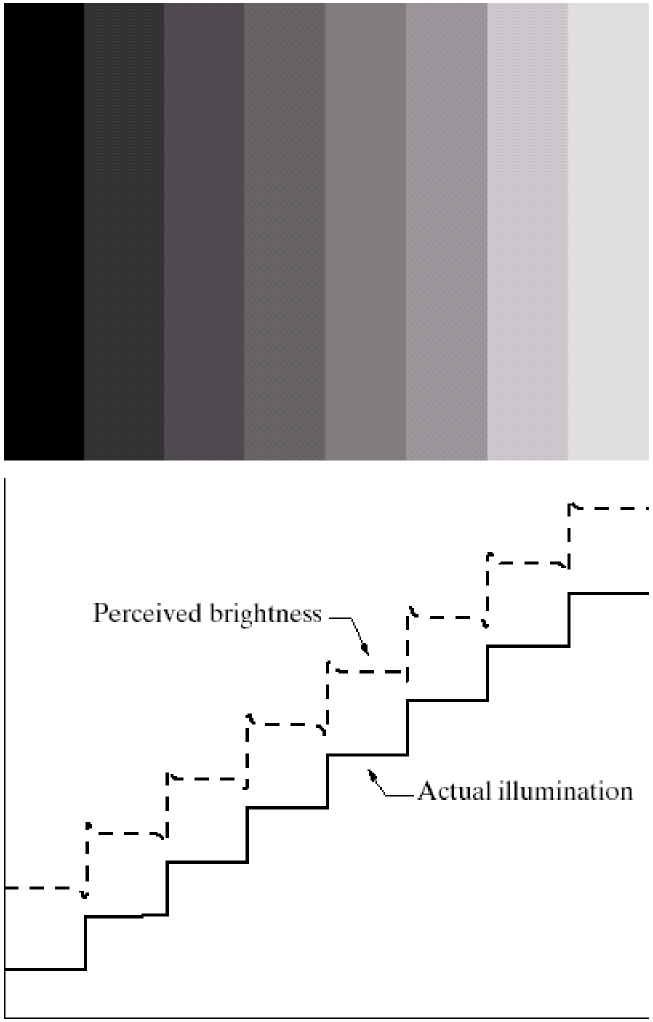
FIGURE 2.6
Typical Weber ratio as a function of intensity.



1.4. Perceived Brightness

Two phenomena clearly demonstrate that perceived brightness is not a simple function of intensity.

1.4. Perceived Brightness



a
b

FIGURE 2.7
(a) An example showing that perceived brightness is not a simple function of intensity. The relative vertical positions between the two profiles in (b) have no special significance; they were chosen for clarity.

First Phenomena
Visual system tends to undershoot or overshoot around boundary of regions of different intensities.

1.4. Perceived Brightness

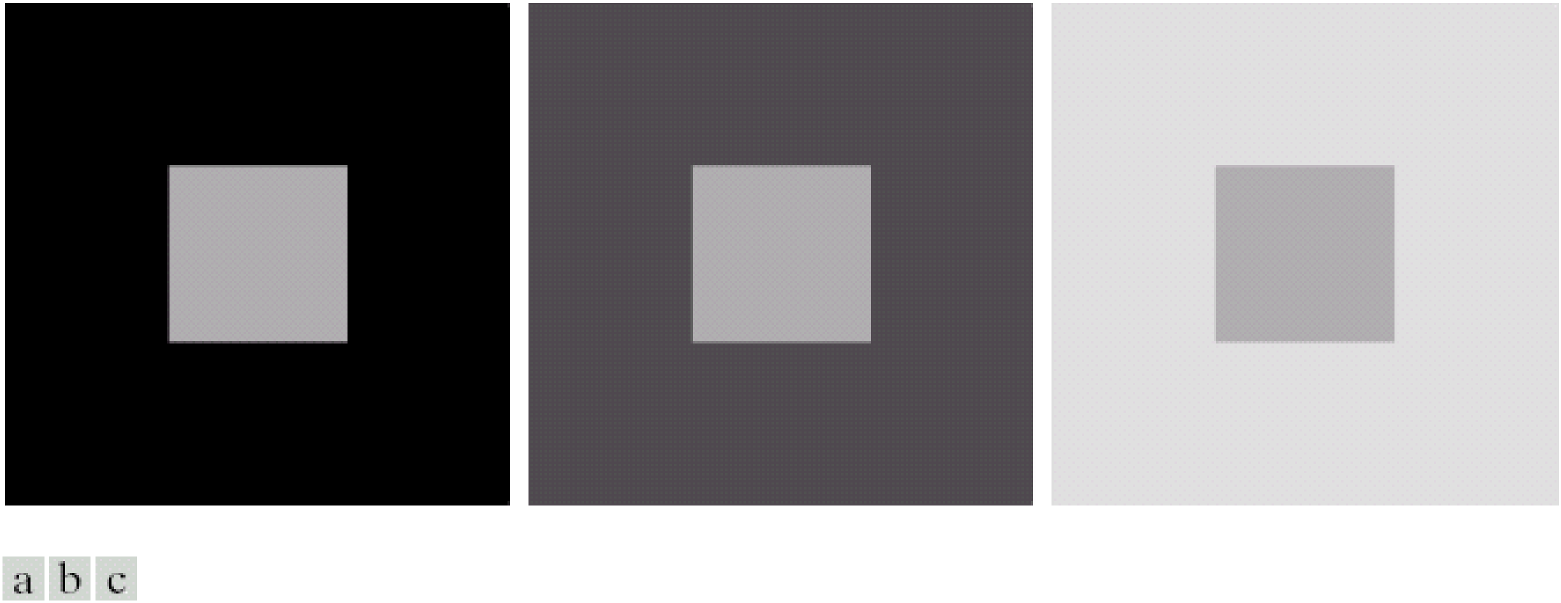
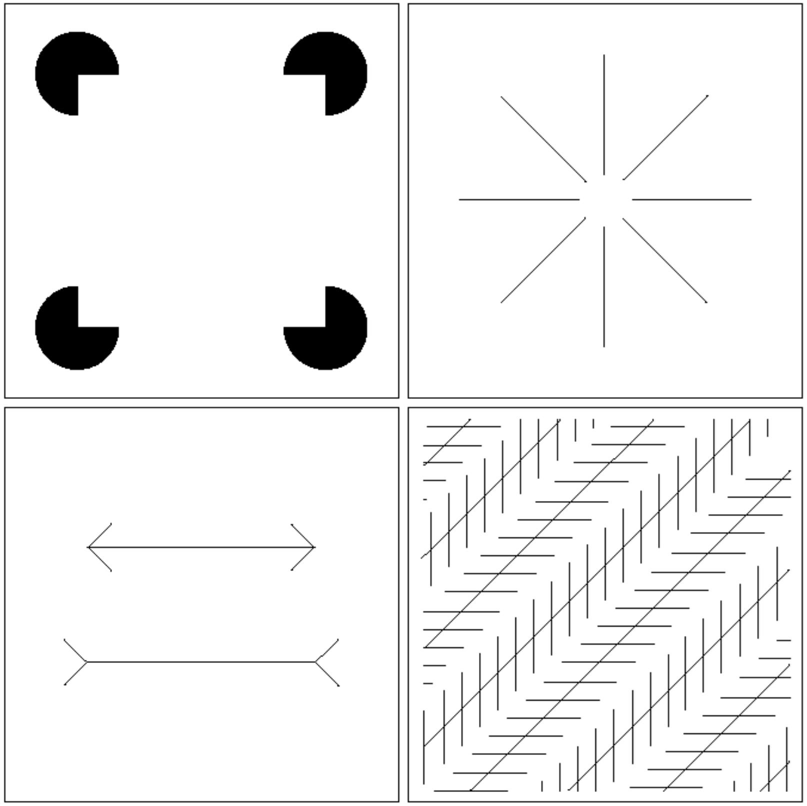


FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

The second phenomena, called simultaneous contrast, a spot may appears to the eye to become darker as the background gets lighter.

1.5. Optical Illusions

Optical illusions occurs when the eye fills in non-existing information or wrongly perceives geometrical properties of objects.

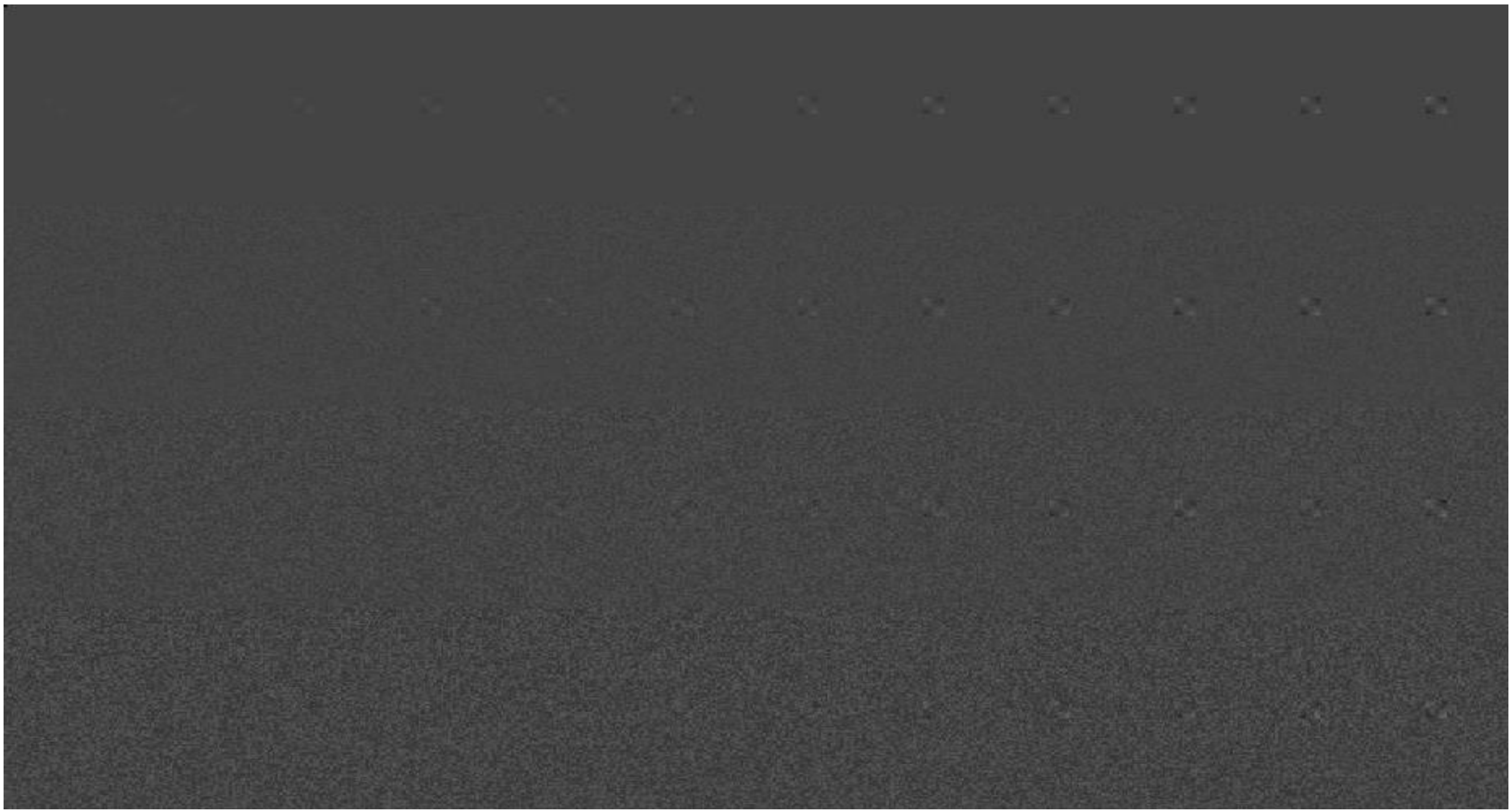


a b
c d

FIGURE 2.9 Some well-known optical illusions.

1.6. Masking

Masking in psychophysics is defined as the reduction in visibility of a stimulus due to the spatial non-uniformity in its surrounding.



1.6. Masking

1.6. Masking

2. Light and the Electromagnetic Spectrum

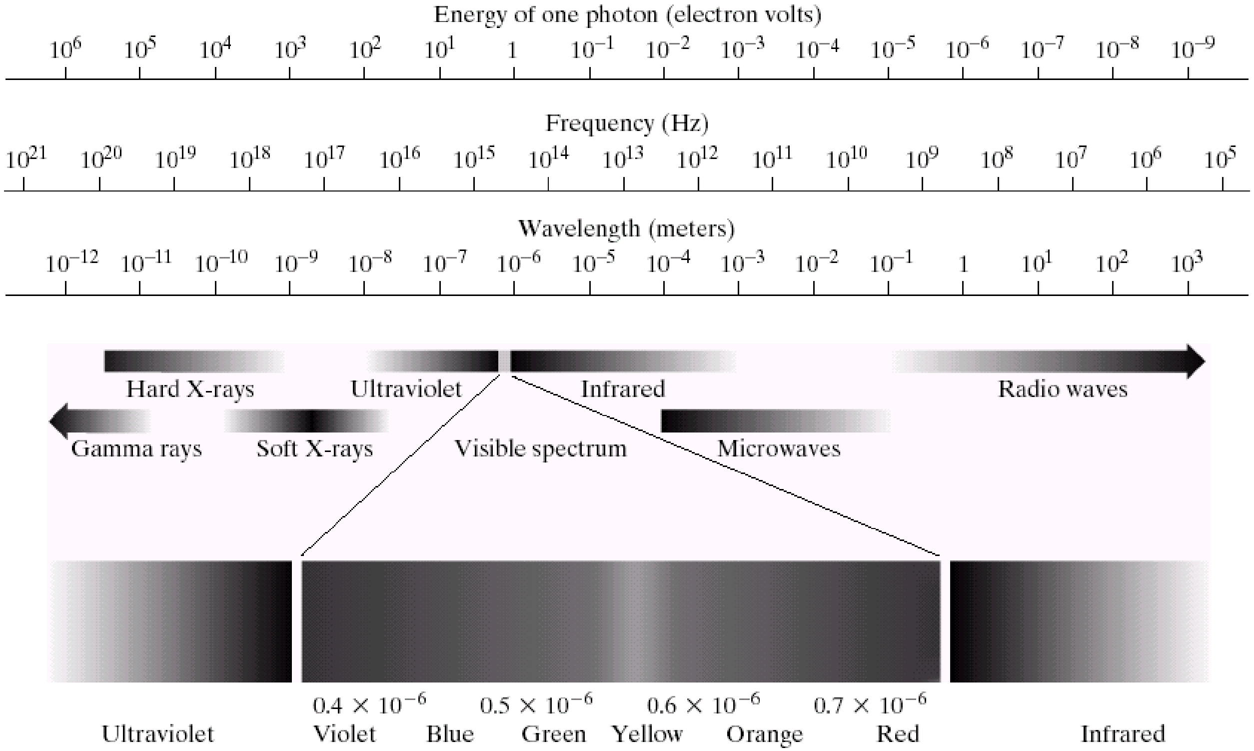


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

Wavelength (λ), frequency (ν), and energy (E) are related by the expressions

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

$$E = h\nu$$

The Wavelength of an Electromagnetic Wave Required to "SEE" an Object <u>Must</u> be of the Same Size as or Smaller Than the Object.

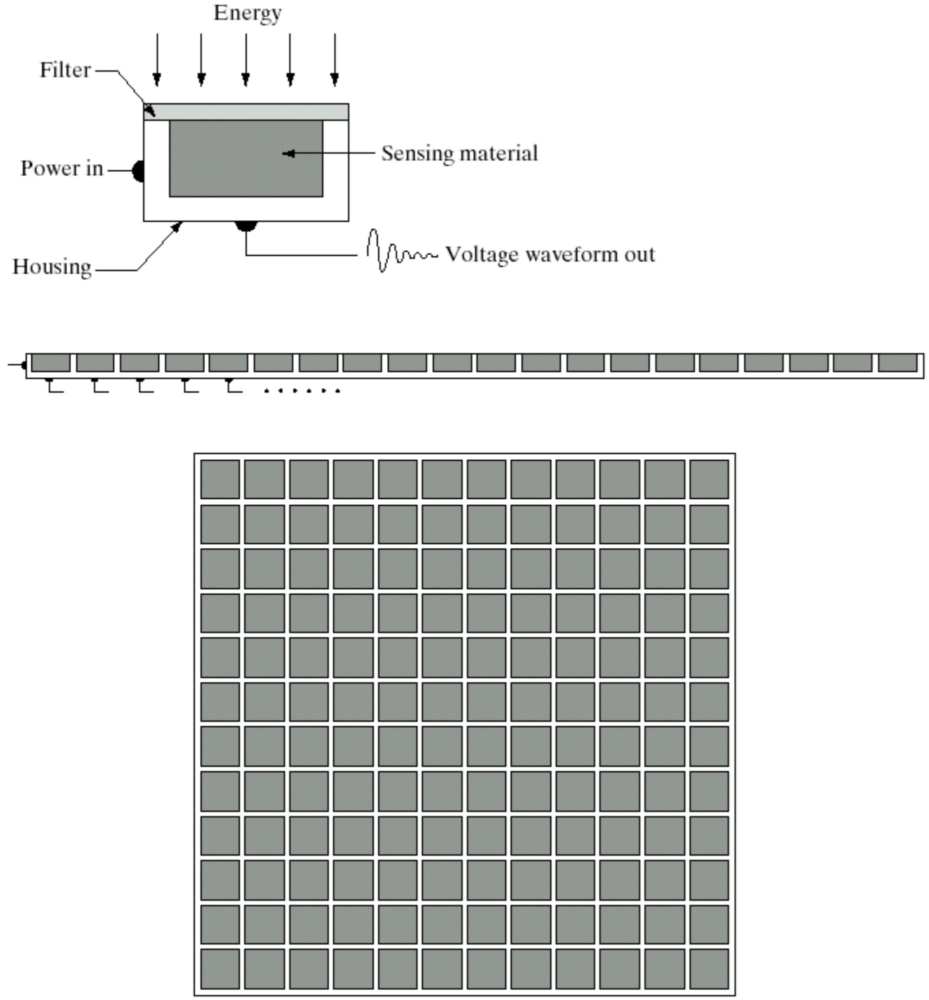
2. Light and the Electromagnetic Spectrum

- The colors that humans perceive in an object are determined by the nature of the light reflected from the object.
- Achromatic or monochromatic light is void of color, and is described by its intensity (gray level).
- Chromatic light spans the electromagnetic energy spectrum from 0.43 to 0.79 μm, and is described by
    - Radiance: Total amount of energy that flows from the light source, and measured in watts (W)
    - Luminance: Measured in lumens (lm), gives a measure of the amount of energy an observer perceives from a light source
    - Brightness: Subjective descriptor of light perception that is practically impossible to measure.

3. Image Sensing and Acquisition

- **Electromagnetic energy source and sensor that can detect the energy of the electromagnetic source are needed to generate an image. EM source will illuminate the objects that need to be imaged and then a sensor will detect the reflected energy from the objects.**
- **Different objects will have different degree of reflections and absorption of the electromagnetic energy. These differences in reflections and absorption are the reasons for objects to appear distinct in the images.**

3. Image Sensing and Acquisition



a
b
c

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

3.1. Image Acquisition Using a Single Sensor

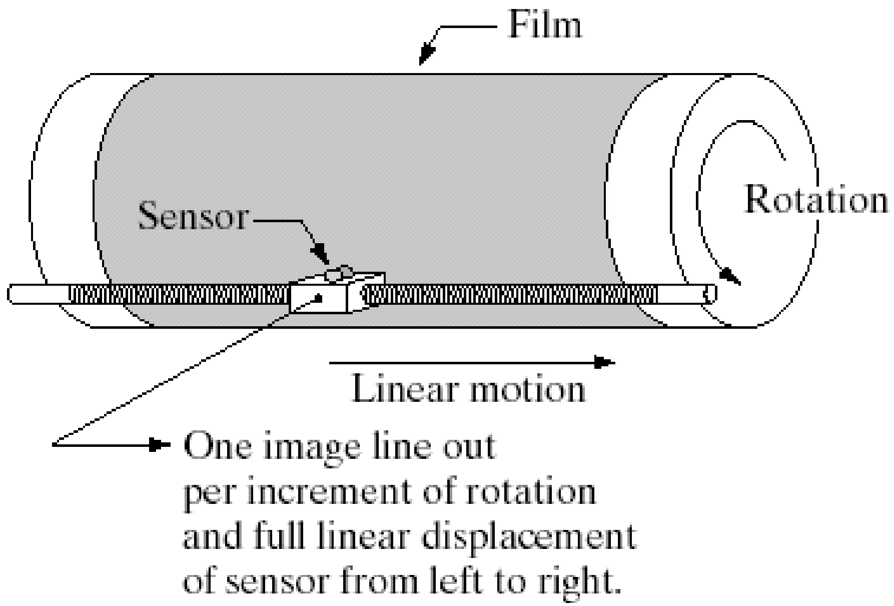
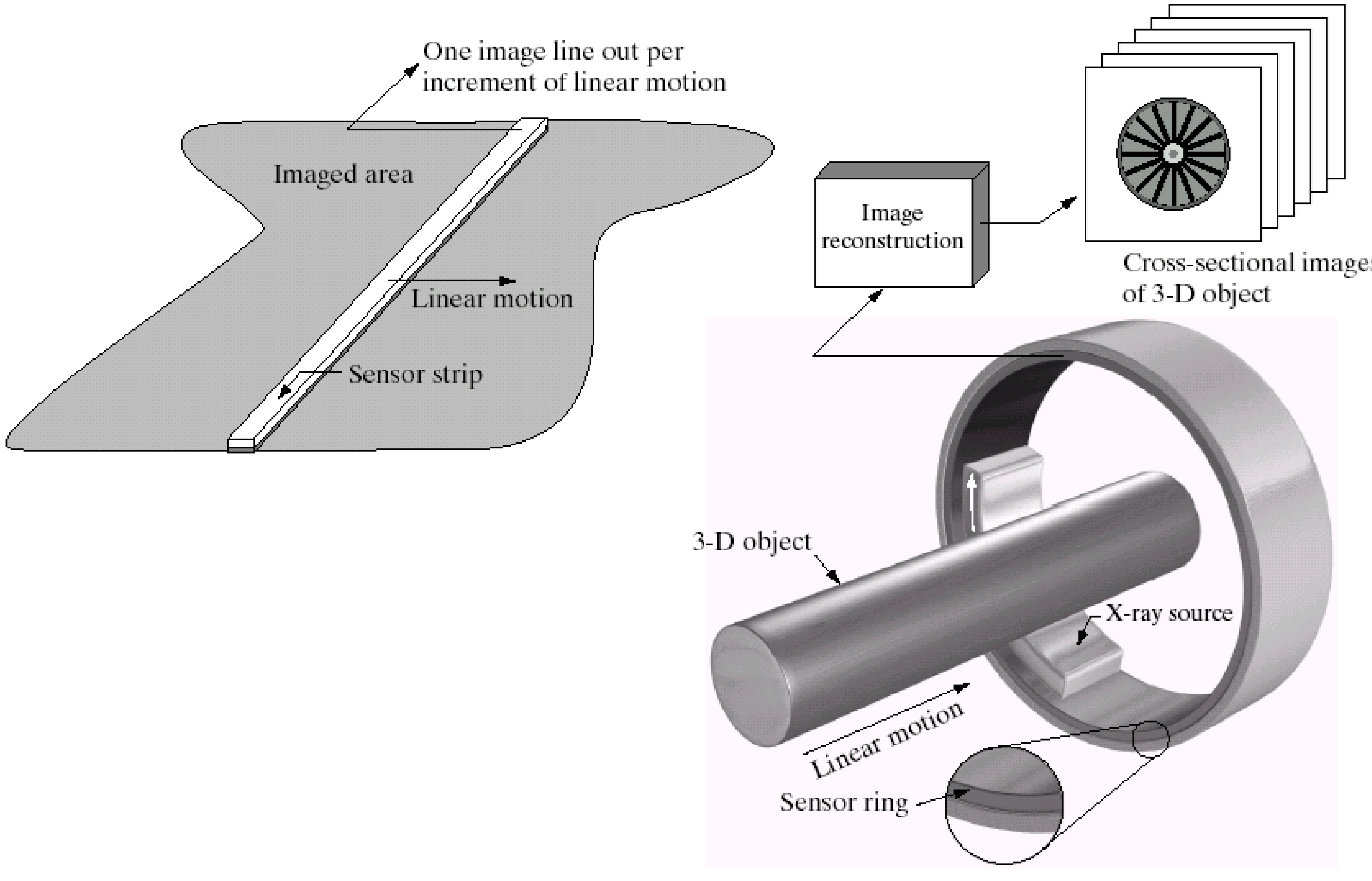


FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

3.2. Image Acquisition Using Sensor Strip



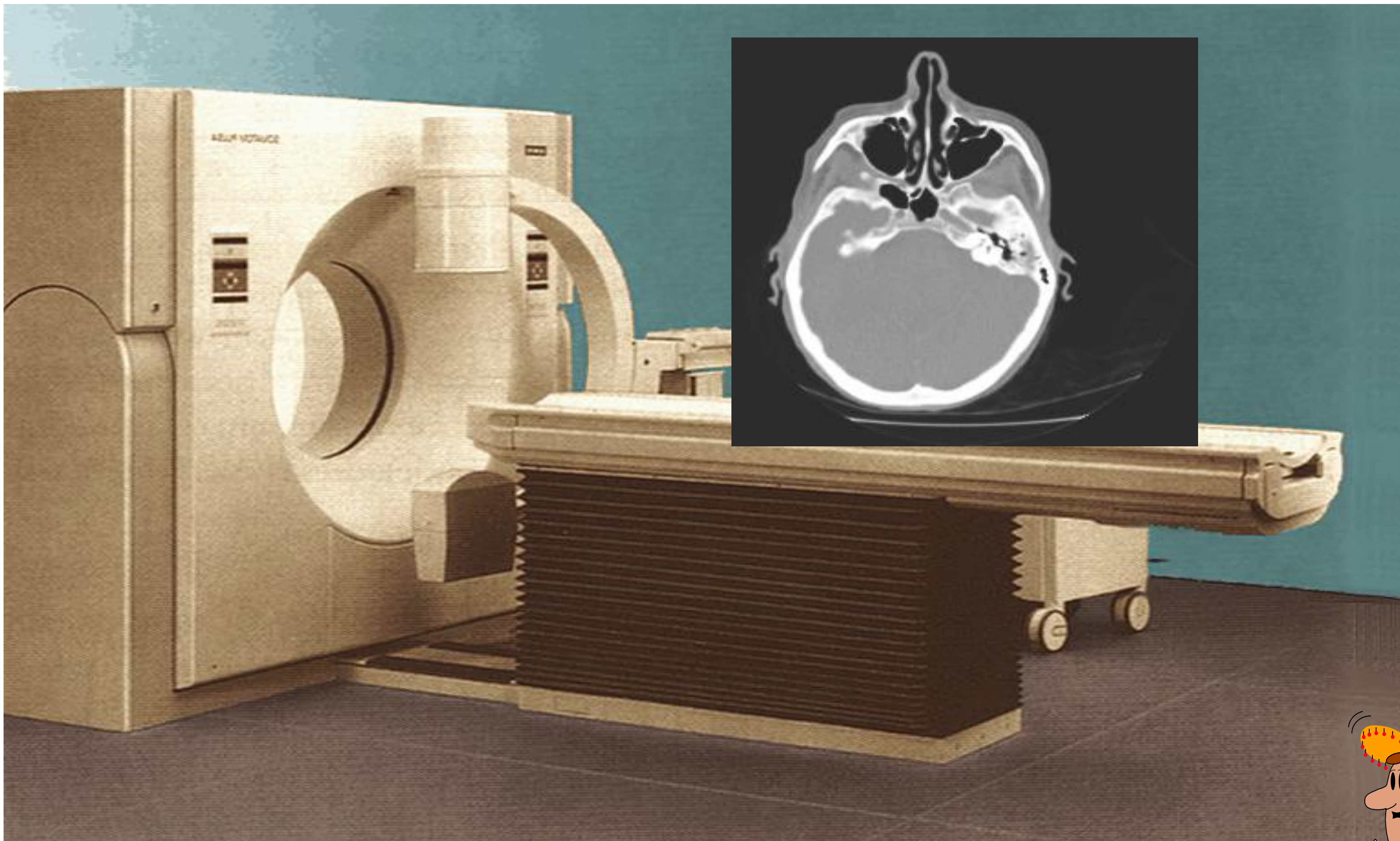
a b

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

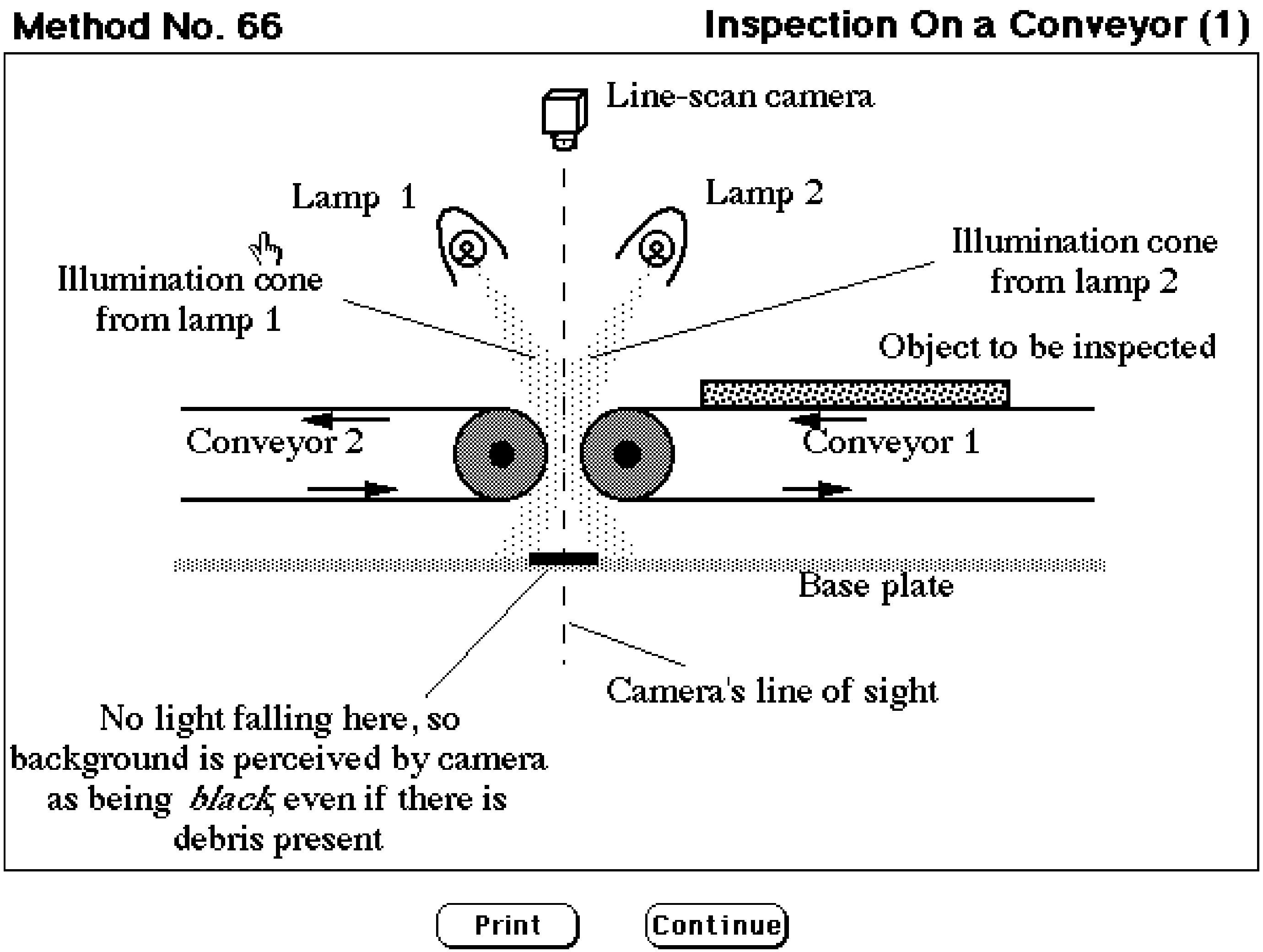
3.2. Image Acquisition Using Sensor Strip

- **Measure the width of objects**
- **Where we may be imaging and inspecting a continuous web of material flowing by the camera**

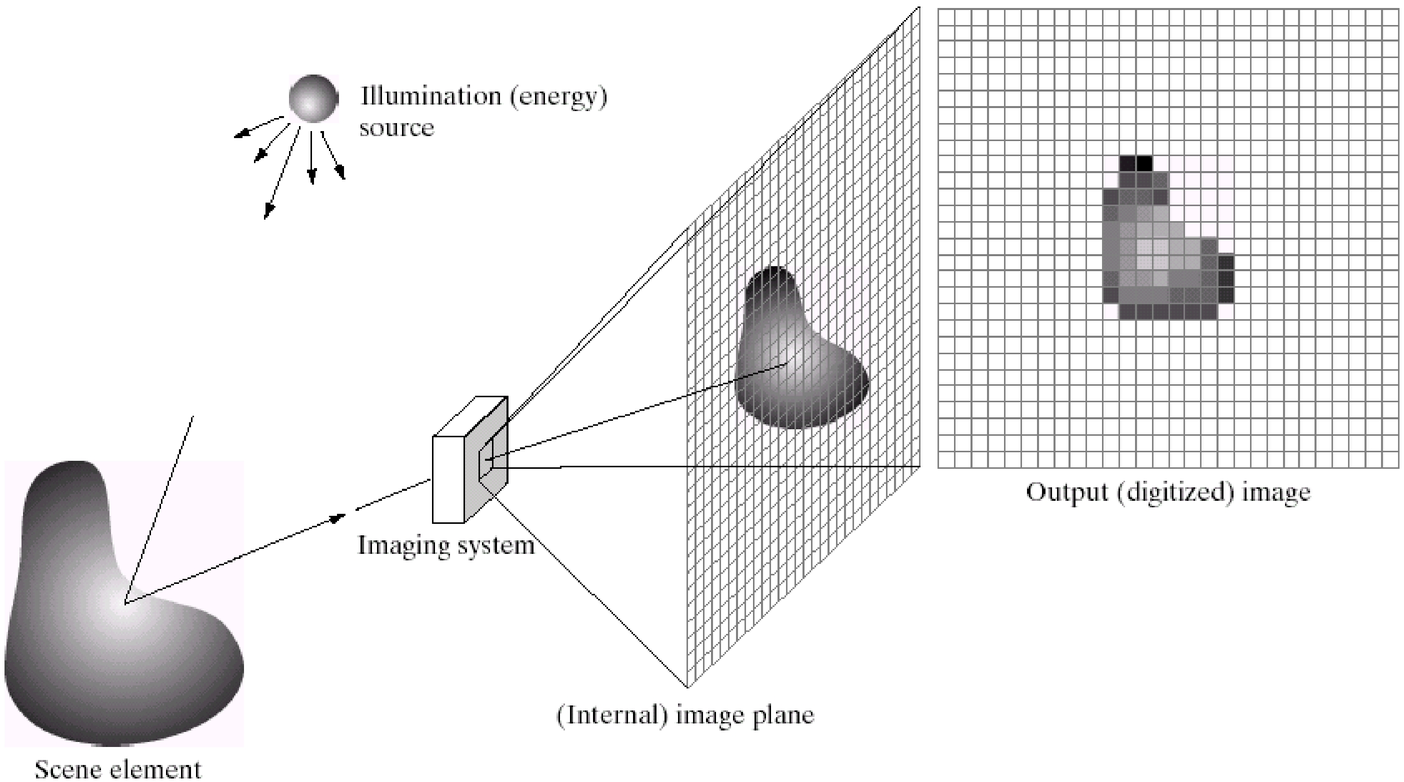
3.2. Image Acquisition Using Sensor Strip



3.2. Image Acquisition Using Sensor Strip



3.3. Image Acquisition Using Sensor Arrays



a
b
c d e

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.

3.4. A Simple Image Formation Model

Mathematical representation of monochromatic images.

- **Two dimensional function $f(x,y)$, where f is the gray level of a pixel at location x and y.**
- **The values of the function f at different locations are proportional to the energy radiated from the imaged object.**

3.4. A Simple Image Formation Model

$0 < f(x,y) < \infty$ **Nonzero and Finite**

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

$f(x,y) = i(x,y) * t(x,y)$ ***Transmissivity***

$0 < i(x,y) < \infty$

$0 \leq r(x,y)$ and $t(x,y) \leq 1$

3.4. A Simple Image Formation Model

$i(x,y)$	: Sun on clear day	90,000 lm/m2
	: Sun on cloudy day	10,000 lm/m2
	: Full moon	0.1 lm/m2
	: Commercial office	1,000 lm/m2
$r(x,y)$	:Black Velvet	0.01
	:Stainless Steel	0.65
	:Flat-white Wall Paint	0.80
	:Silver-plated Metal	0.90
	:Snow	0.93

4.1. Image Sampling and Quantization

- **The output of most sensors is continuous in amplitude and spatial coordinates.**
- **Converting an analog image to a digital image require sampling and quantization**
- **Sampling: is digitizing the coordinate values**
- **Quantization: is digitizing the amplitude values**

4.1. Image Sampling and Quantization

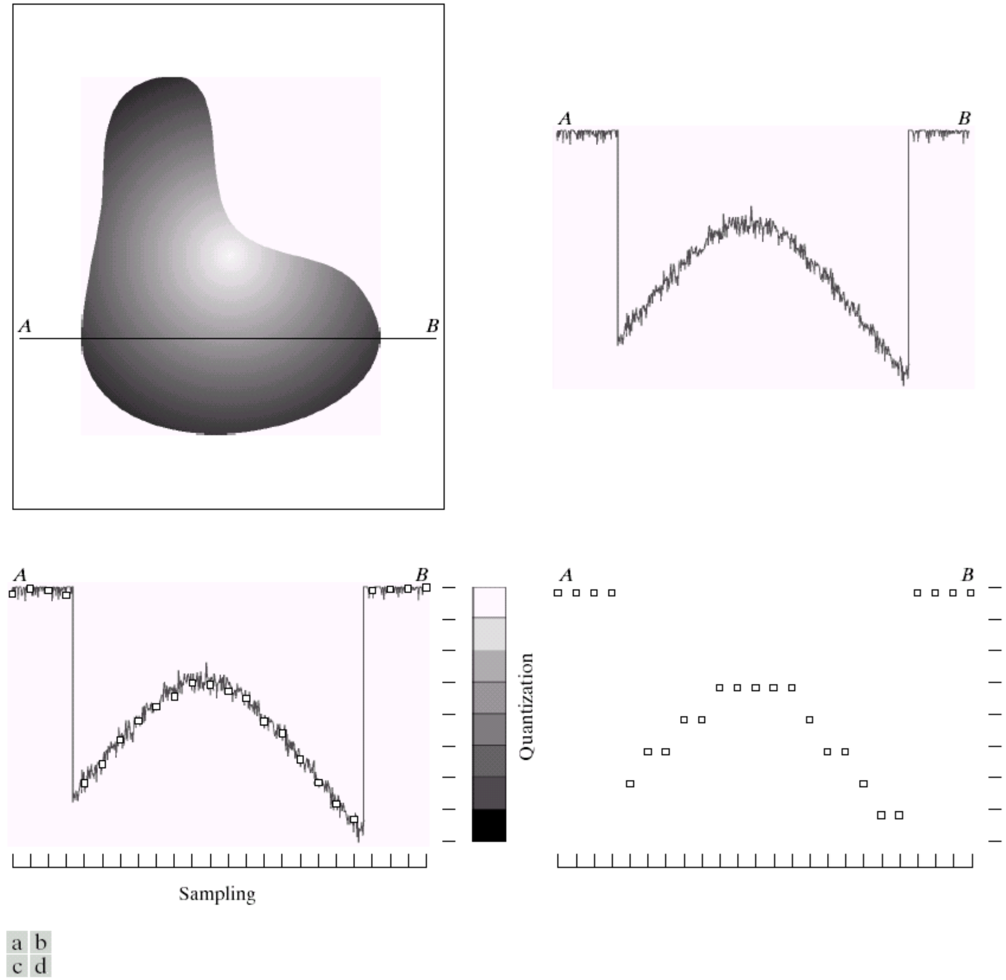
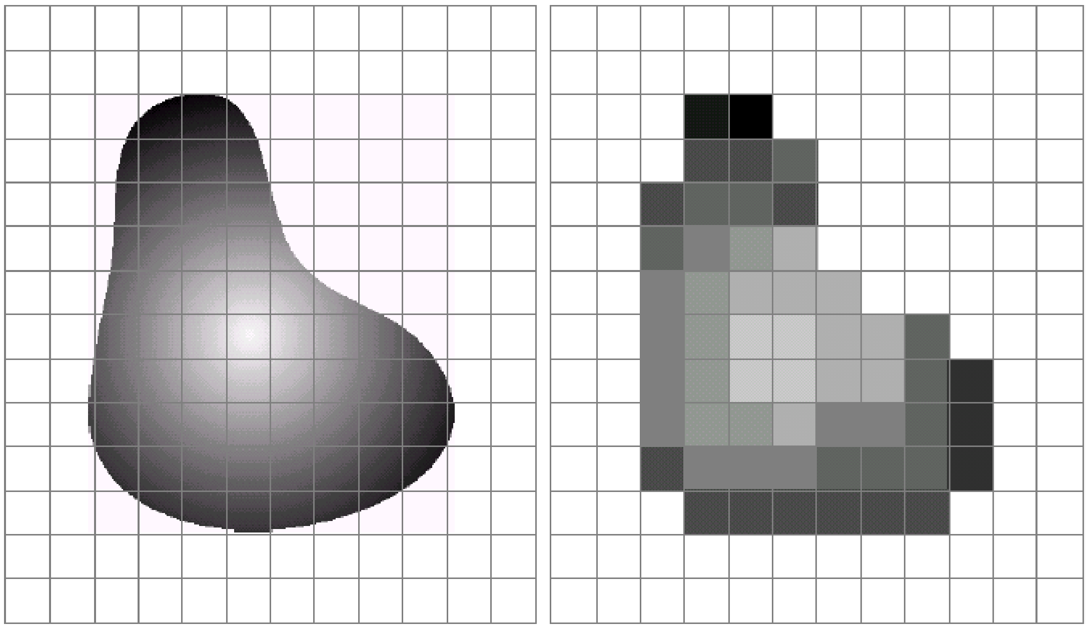


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Spatial sampling is accomplished by sensor arrangement and mechanical movement.

4.1. Image Sampling and Quantization



a b

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

Charge-coupled device (CCD)

4.2. Representing Digital Images

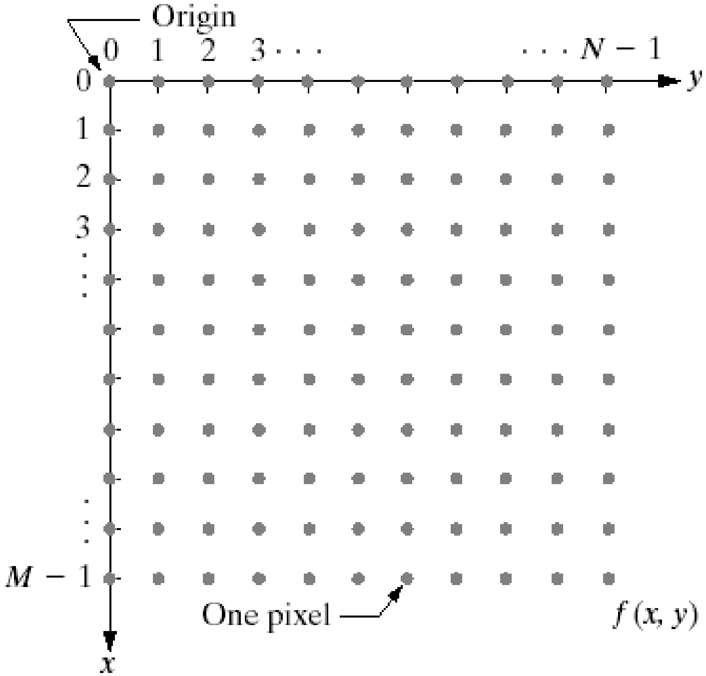


FIGURE 2.18 Coordinate convention used in this book to represent digital images.

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

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

$$L = 2^k$$

4.2. Representing Digital Images

The pixel intensity levels (gray scale levels) are in the interval of [0, *L*-1].

$$0 \leq a_{i,j} \leq L\text{-}1 \qquad \text{Where} \qquad L = 2^k$$

The dynamic range of an image is the range of values spanned by the gray scale.

The number, *b*, of bits required to store a digitized image of size *M* by *N* is

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

4.2. Representing Digital Images

Elaine image of size 512 by 512 pixels (5 by 5 inches), The dynamic range is [0, 255].

Find the following:

- The number of bits required to represent a pixel
- The size of the image in bits?

77	66	68	67	98	93	79	81
79	61	61	71	61	78	88	94
79	93	84	64	72	76	95	94
97	65	71	75	75	72	95	111
120	81	82	76	72	77	78	83
150	146	112	83	78	62	91	85
156	145	158	125	107	121	95	86
158	166	147	146	153	149	129	107

4.2. Representing Digital Images

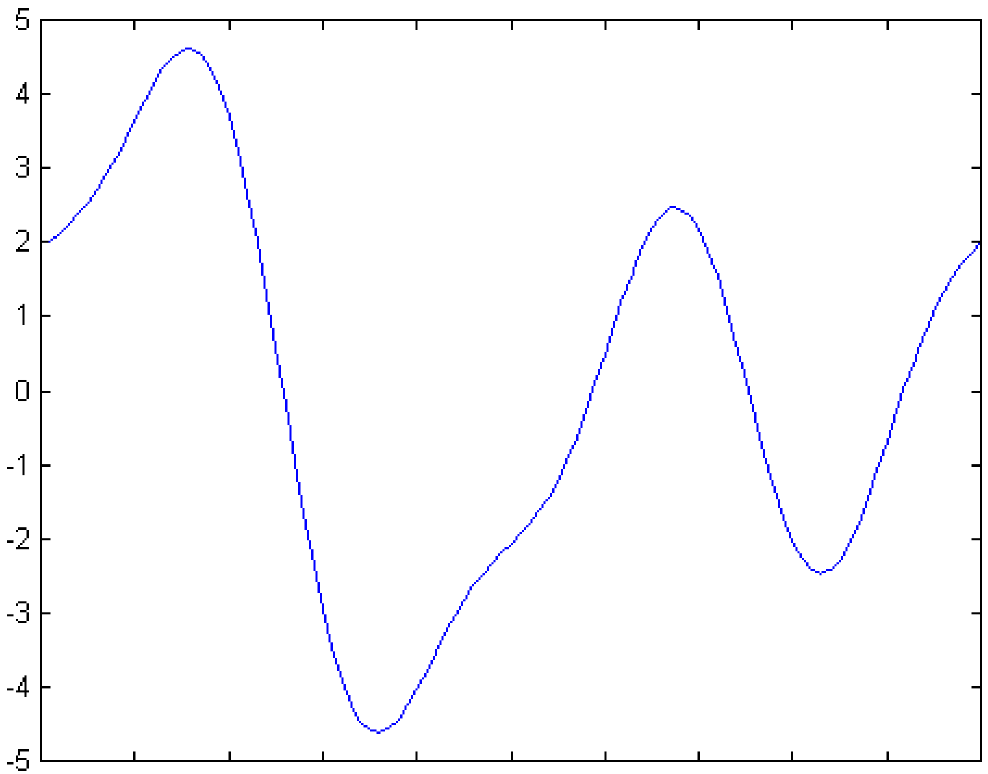
TABLE 2.1
Number of storage bits for various values of N and k.

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

(Sampling Theorem and Aliasing Effect)

Shannon sampling theorem states that if a function is sampled at a rate equal to or greater than twice its highest frequency, it is possible to recover completely the original function from its samples.

```
» x=linspace(0,0.01);
» x1=2*cos(2*pi*100*x);
» x2=2*sin(2*pi*200*x);
» x3=-sin(2*pi*400*x);
» xt=x1+x2+x3;
» plot(xt)
```



0 1 2 3 4 5 6 7 8 9 10

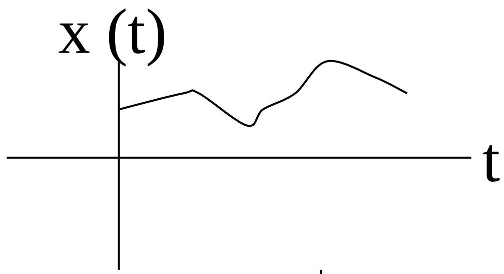
msec

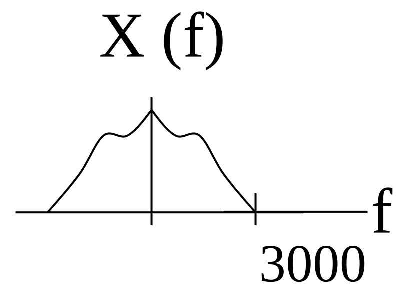
$x(t) = 2\cos(2\pi * 100t) + 3\sin(2\pi * 200t) - \sin(2\pi * 400t)$

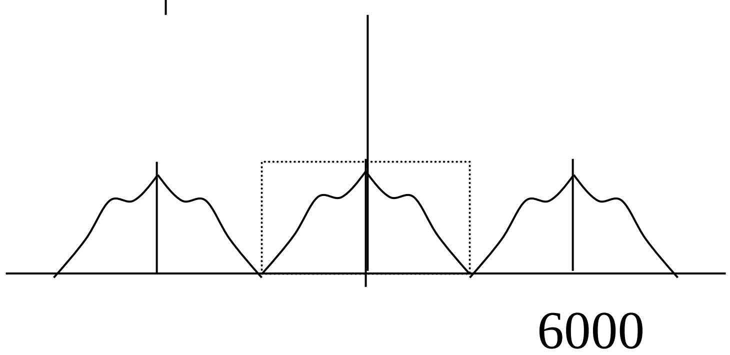
What is the sampling rate?

(Aliasing)

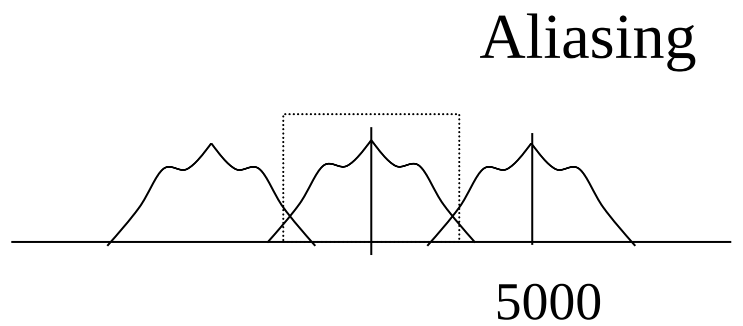
If the function is under-sampled, then *ALIASING* corrupts the sampled function.





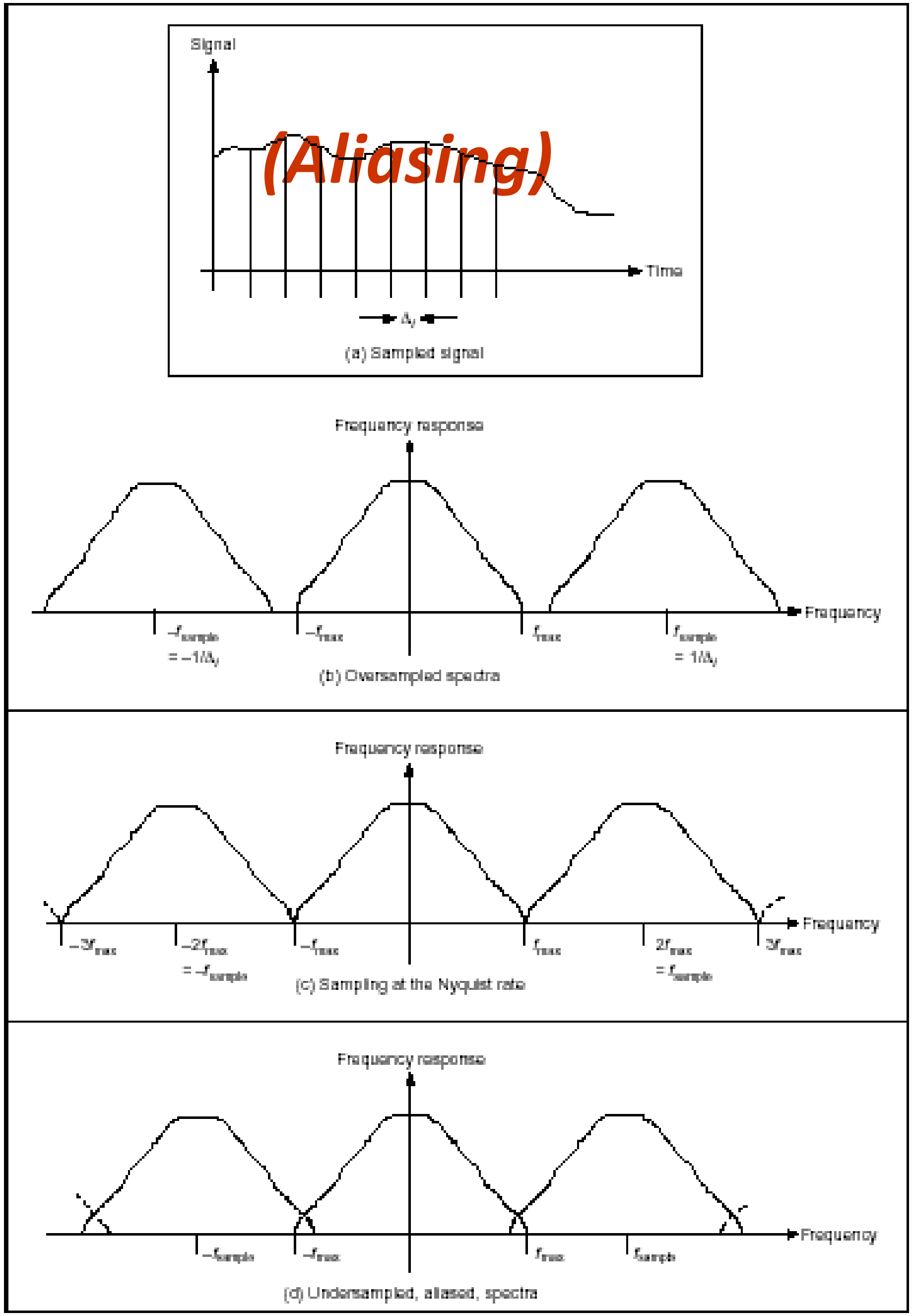


6000 samples/sec

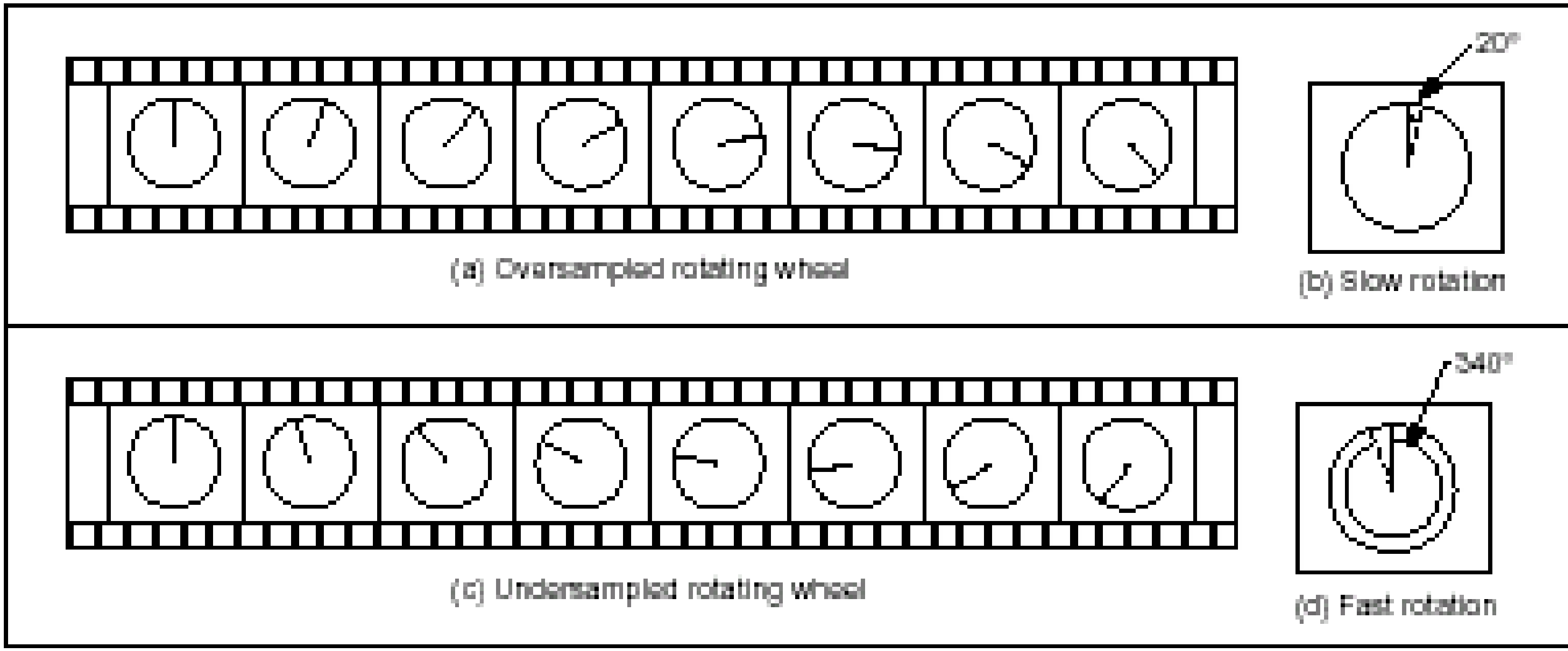


Under-"sampling (<6000)

(Aliasing)


Signal
Time
Δ_t
(a) Sampled signal
Frequency response
Frequency
$-f_{sample}$
$= -1/\Delta_t$
$-f_{max}$
f_{max}
f_{sample}
$= 1/\Delta_t$
(b) Oversampled spectra
Frequency response
Frequency
$-3f_{max}$
$-2f_{max}$
$= -f_{sample}$
$-f_{max}$
f_{max}
$2f_{max}$
$= f_{sample}$
$3f_{max}$
(c) Sampling at the Nyquist rate
Frequency response
Frequency
$-f_{sample}$
$-f_{max}$
f_{max}
f_{sample}
(d) Undersampled, aliased, spectra

(Aliasing)



(a) Oversampled rotating wheel

(b) Slow rotation

(c) Undersampled rotating wheel

(d) Fast rotation

(Aliasing)

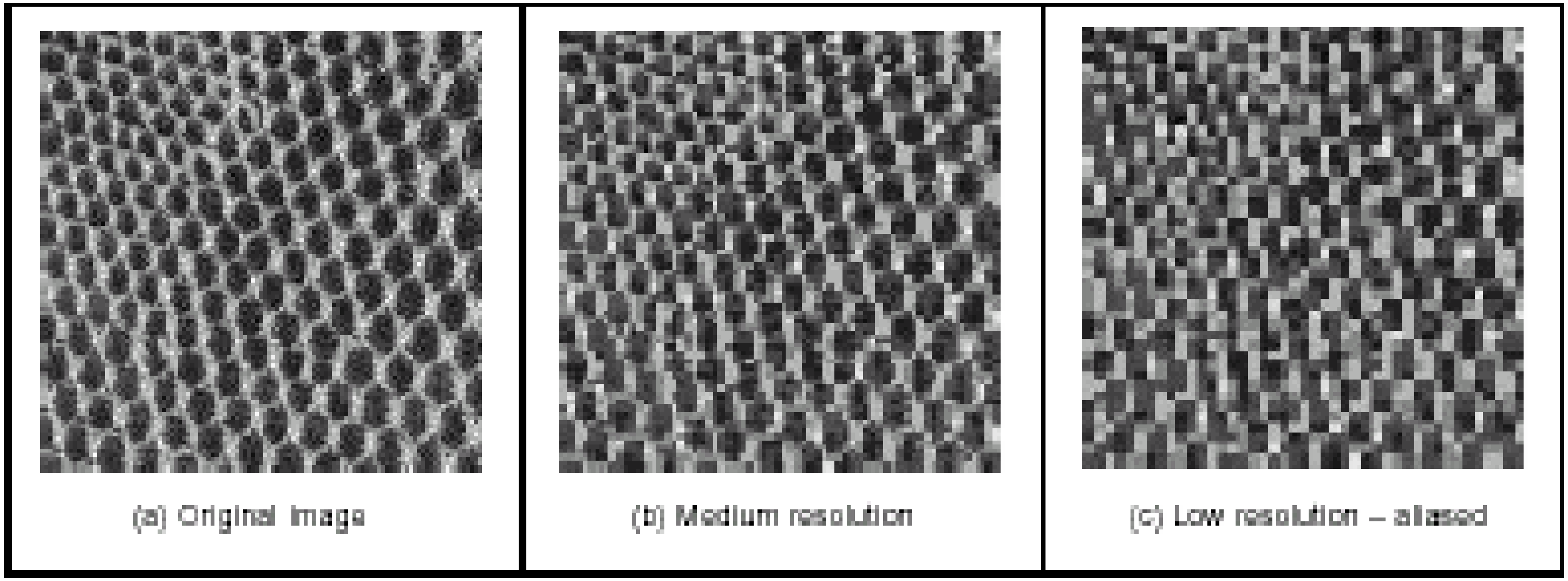


Figure 2.8 Aliasing in sampled imagery

(Aliasing and Moire Pattern)

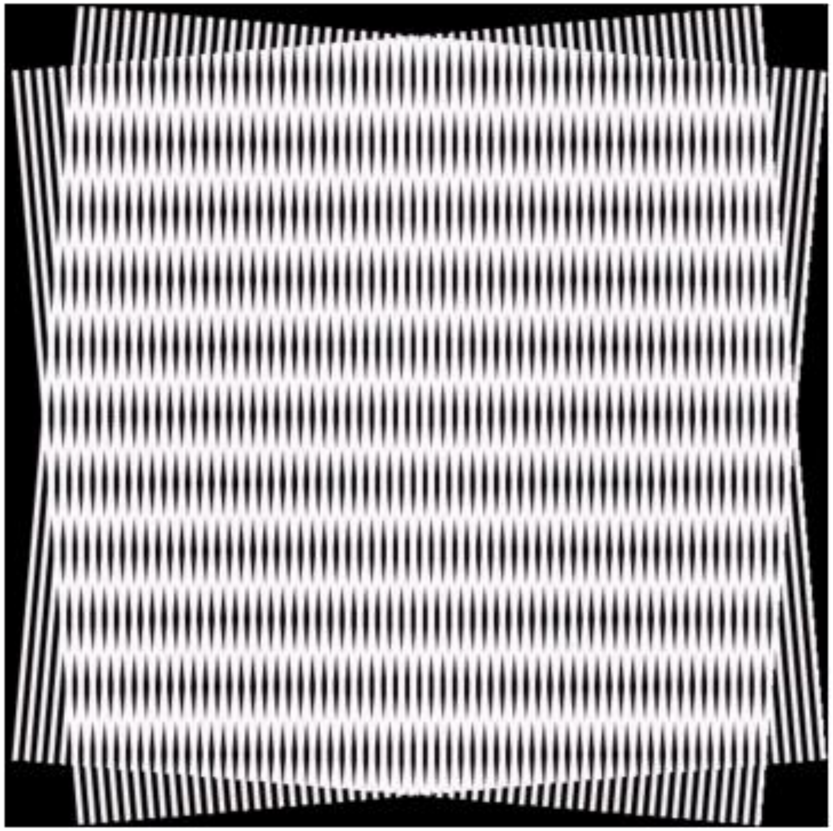
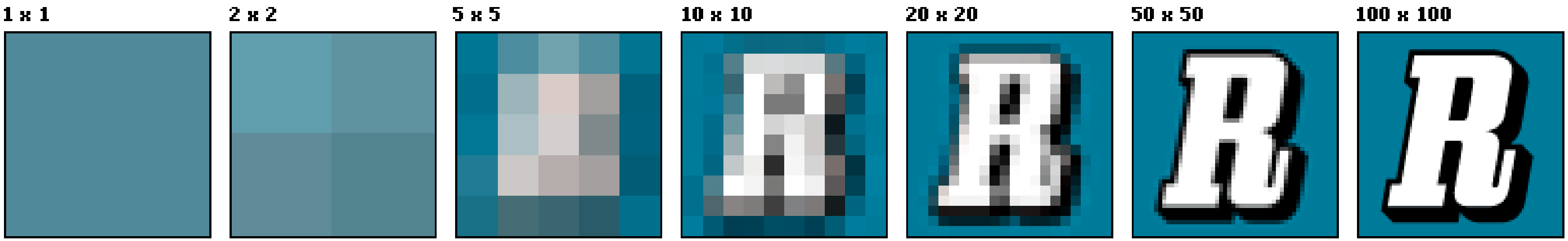


FIGURE 2.24 Illustration of the Moiré pattern effect.

4.3. Spatial Resolution



4.3. Spatial Resolution

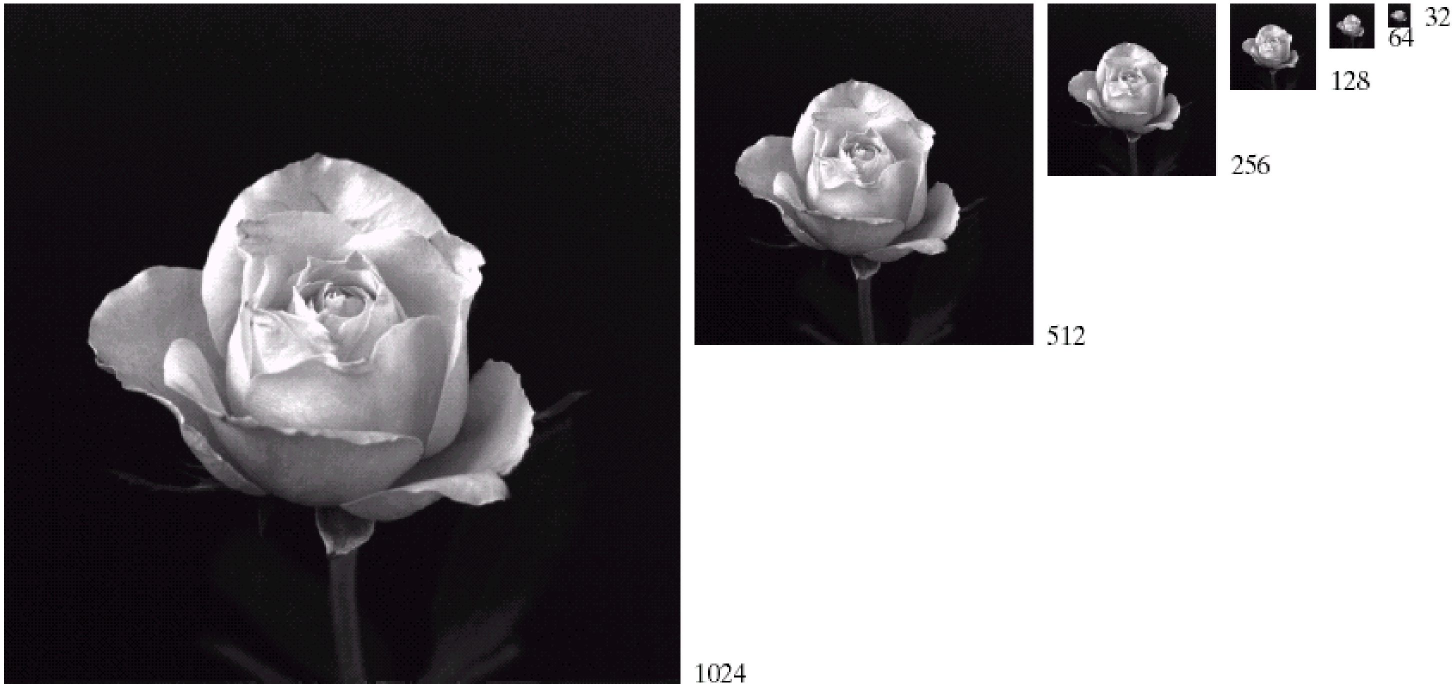


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

An image of size 1024×1024 is printed on paper of size 2.75 × 2.75 inch.
Resolution = 1021/2.75 = 372 pixels/inch (dots per inch, dpi)

4.3. Spatial Resolution

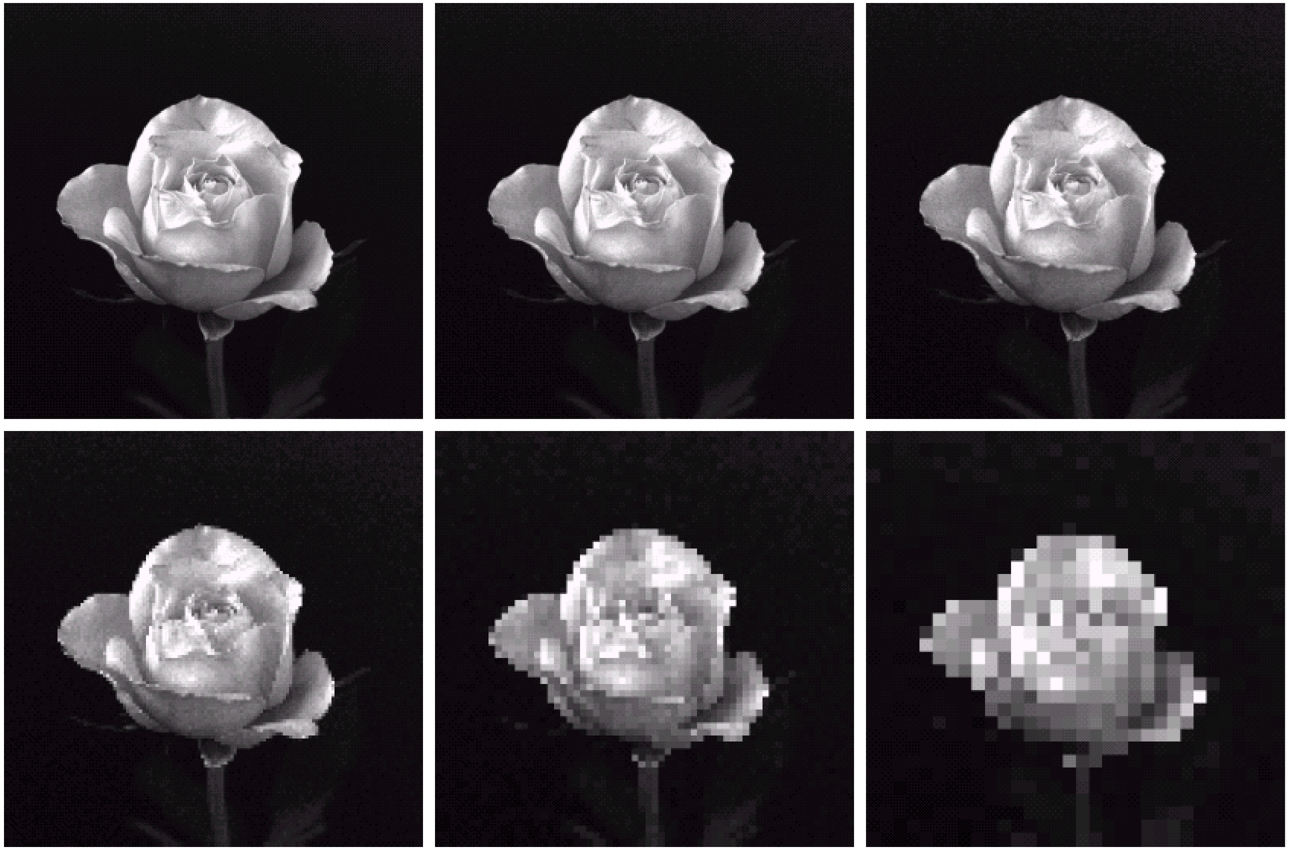
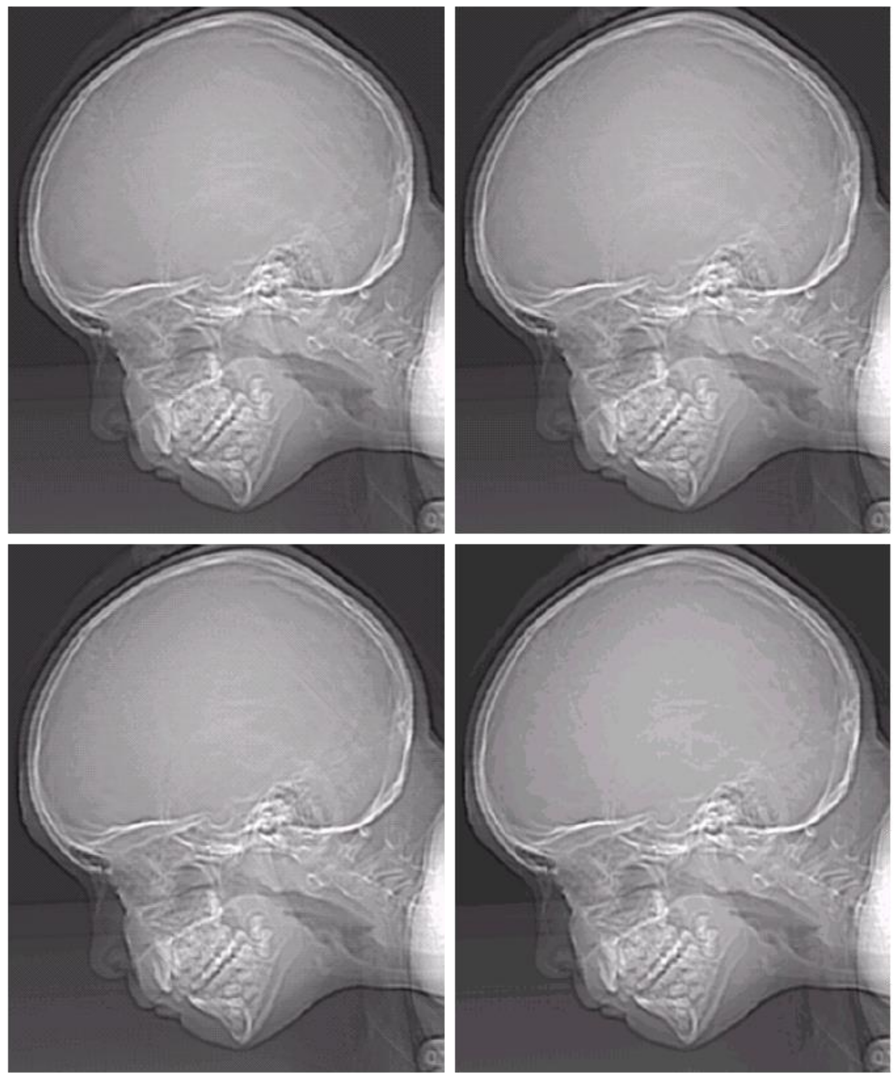


FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

4.3. Gray-Level Resolution

$k = 8$
$L = 256$



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.

$k = 7$
$L = 128$

$k = 6$
$L = 64$

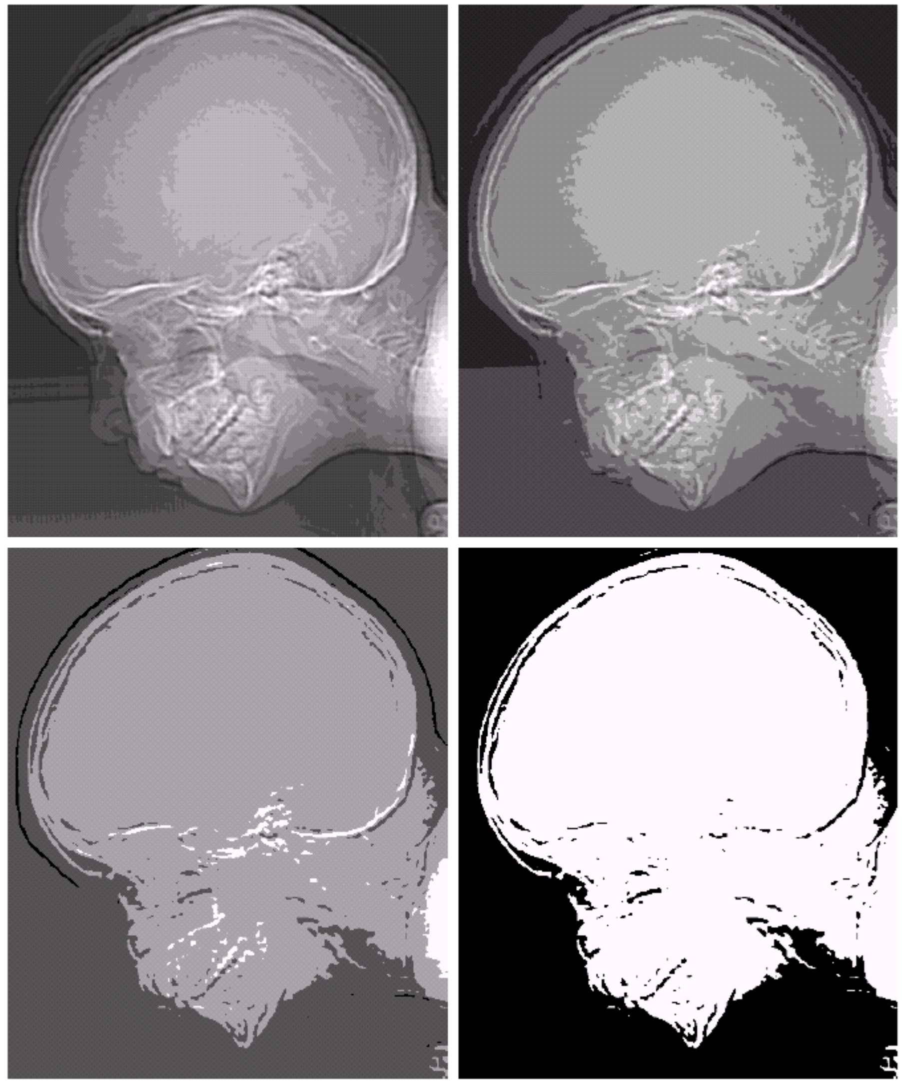
$k = 5$
$L = 32$

4.3. Gray-Level Resolution

$k = 4$
$L = 16$

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.)



$k = 3$
$L = 8$

$k = 2$
$L = 4$

$k = 1$
$L = 2$

4.3. Spatial and Gray-Level Resolution

a b c

FIGURE 2.22 (a) Image with a low level of detail. (b) Image with a medium level of detail. (c) Image with a relatively large amount of detail. (Image (b) courtesy of the Massachusetts Institute of Technology.)

Huang Experiment [1965] attempt to quantify experimentally the effects on image quality produced by varying N and k simultaneously.

4.3. Spatial and Gray-Level Resolution

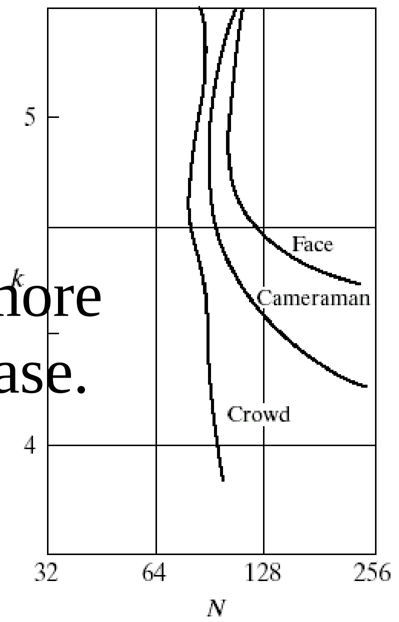


FIGURE 2.23 Representative isopreference curves for the three types of images in Fig. 2.22.

Isopreference curves tend to become more vertical as the detail in the image increase.

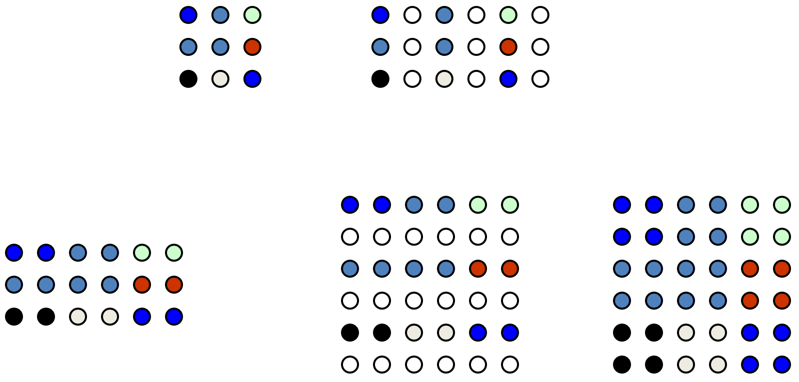
As the detail in the image decrease the perceived quality remained the same in some intervals in which the spatial resolution was increased, but the number of gray levels actually decreased. A possible explanation is that a decrease in *k* tends to increase the apparent *contrast* of an image, a visual effect that human often perceive as improved quality in an image.

4.5. Zooming & Shrinking Digital Images

- *Zooming* and *shrinking* is applied to digital images, while sampling and quantization is applied to analog images.

- Zooming requires the creation of new pixel locations, and the assignment of gray levels.

Nearest neighbor interpolation

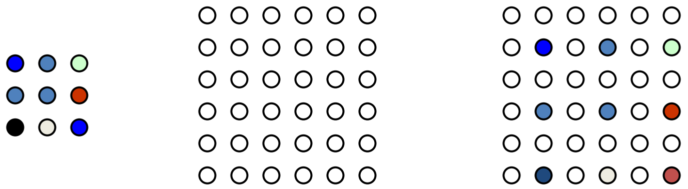


4.5. Zooming & Shrinking Digital Images

Bilinear interpolation (Forward Warping)

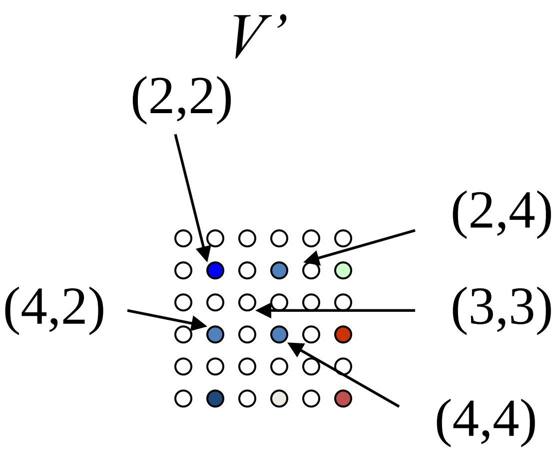
$$x' = r(x, y) = 2x$$

$$y' = s(x, y) = 2y$$



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

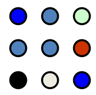
$$V(3,3) = a(3) + b(3) + c(9) \quad + d$$



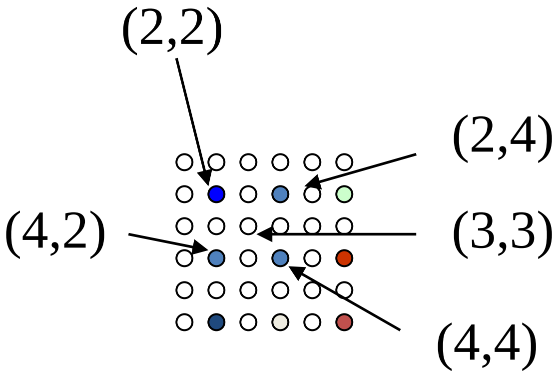
4.5. Zooming & Shrinking Digital Images

Bilinear interpolation (Forward Warping)

125	170	129
172	170	175
125	128	128



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



$$125 = a(2) + b(2) + c(4) \quad + d$$

$$170 = a(2) + b(4) + c(8) \quad + d$$

$$172 = a(4) + b(2) + c(8) \quad + d$$

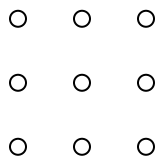
$$170 = a(4) + b(4) + c(16) + d$$

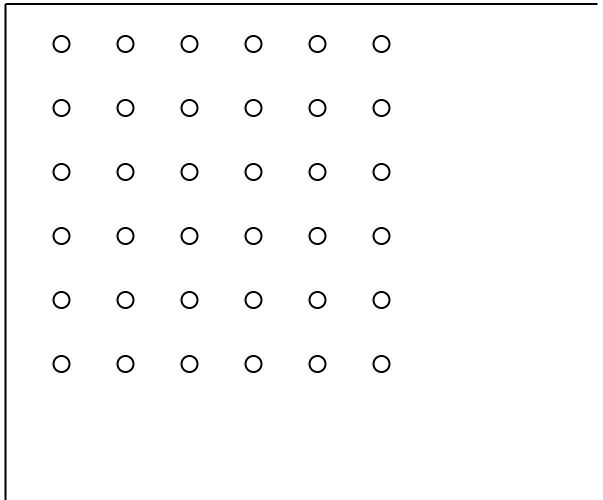
4.5. Zooming & Shrinking Digital Images

Image shrinking is done in a similar manner as just described for zooming. For example, to shrink an image by half, we delete every other row and column.

Bilinear interpolation can be used to estimate the pixels of the reduced image from the neighboring pixels of the original image.

To reduce possible aliasing effect it is suggested to blur an image slightly before shrinking it.





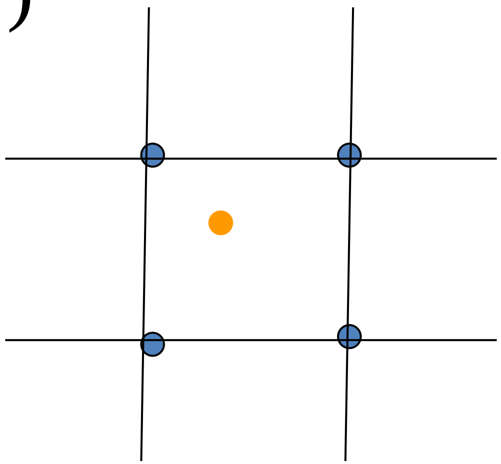
4.5. Zooming & Shrinking Digital Images

Forward Warping Versus Backward Warping

$$x' = r(x, y) \qquad x = r^{-1}(x', y')$$

$$y' = s(x, y) \qquad y = s^{-1}(x', y')$$

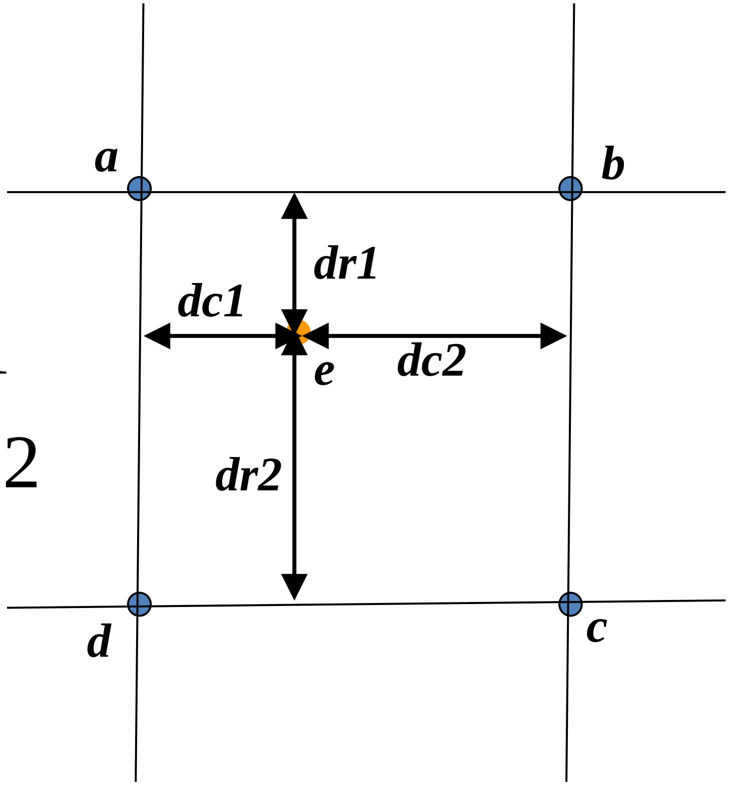
$$\begin{cases} x' = 2x \\ y' = 2y \end{cases} \Rightarrow \begin{cases} x = \dfrac{x'}{2} \\ y = \dfrac{y'}{2} \end{cases}$$



4.5. Zooming & Shrinking Digital Images

Forward Warping Versus Backward Warping

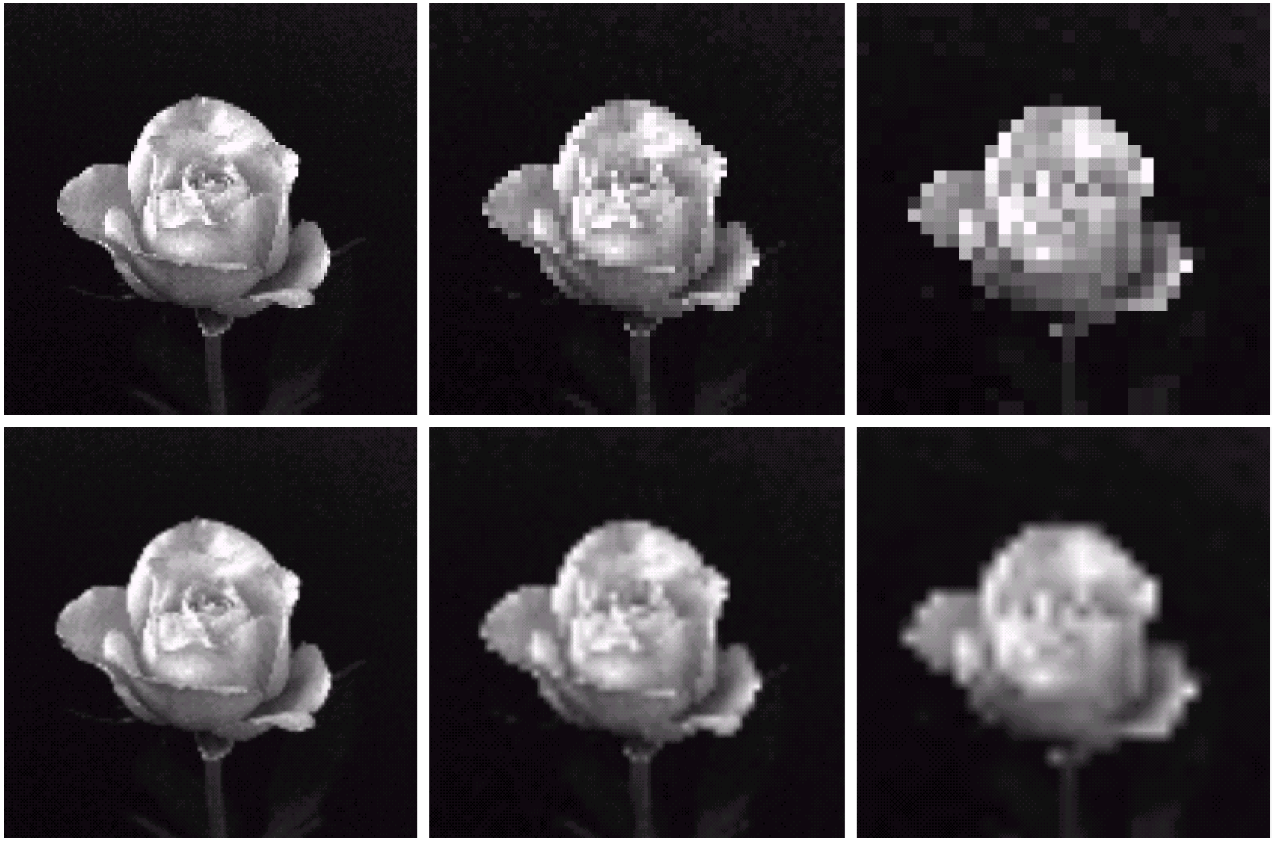
$$e = a * dr2 * dc2 + b * dr2 * dc1 + c * dr1 * dc1 + d * dr1 * dc2$$



$$dc2 = 1 - dc1$$

$$dr2 = 1 - dr1$$

4.5. Zooming & Shrinking Digital Images



a b c
d e f

FIGURE 2.25 Top row: images zoomed from 128 × 128, 64 × 64, and 32 × 32 pixels to 1024 × 1024 pixels, using nearest neighbor gray-level interpolation. Bottom row: same sequence, but using bilinear interpolation.

Top row using Nearest neighbor interpolation

Project1

تبديل هندسي با جايگزيني پيكسل و تبديل دوخطيالف) تصویری به اندازه 1024*1024 پیکسل را متشکل از 20 نوار افقی و 20 نوار عمودی با فواصل مساوی و هر یک به عرض 15 پیکسل تولید کنید.

ب) توسط تبدیل هندسی مناسب، تصویر را بر روی 120 درجه از یک سطح استوانه‌ای به شعاع 489 قرار دهید

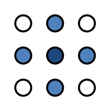
ج) تصویر (3-35-a) که دارای ابعاد 500*500 پیکسل است را به سایز 1024*1024 پیکسل تبدیل کرده, قسمت (ب) را بر این تصویر انجام دهید.

تبدیلات هندسی فوق به دو روش جایگزینی پیکسل و درونیابی دوخطی انجام شود.

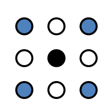
5. Some Basic Relationship Between Pixels

If pixel *p* at location (*x,y*) then its *neighbors* are:

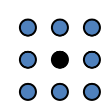
- 4-*neighbors* $N_4(p)$
  (x-1 , y), (x+1 , y), (x , y-1), (x , y+1)



- *4-diagonal neighbors* $N_D(p)$
  (x-1 , y-1), (x-1 , y+1), (x+1 , y+1), (x+1 , y-1)



- *8-neighbors* $N_8(p)$
  All pixels in $N_4(p)$ and in $N_D(p)$



5. Adjacency, Connectivity, Region and Boundary

- Two pixels are *connected* if they are neighbors and if their gray levels satisfy a specified criterion of similarity.

$145 < V \leq 170$

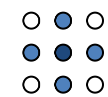
165	104	101
110	150	165
102	155	170

- Two pixels *p* and *q* are *adjacent* if they are connected.

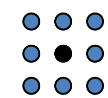
5.1. Adjacency

Three type of adjacency:

(a) *4-adjacency*. Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$.



(b) *8-adjacency*. Two pixels p and q with values from V are 8-adjacent if q is in the set N_8(p).

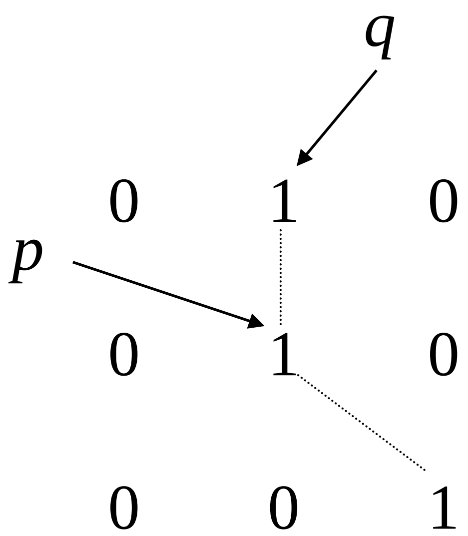


(c) *m-adjacency* (mixed adjacency). Two pixels p and q with values from V are m-adjacent if

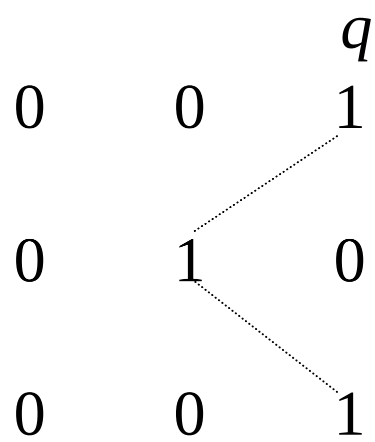
(i) q is in $N_4(p)$, or

(ii) q is in $N_D(p)$ and the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V

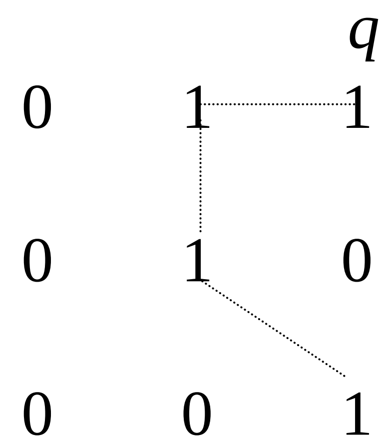
5.1. Adjacency



4-adjacency

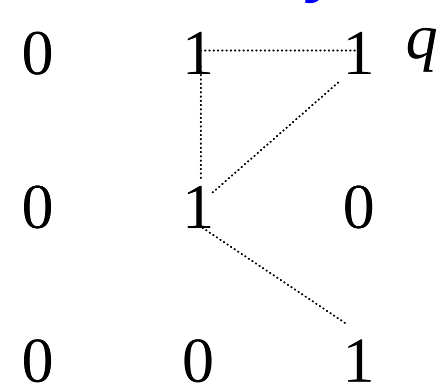


8-adjacency



m-adjacency

8-adjacency
!?



5.1.1. Region Adjacency

- Two image subsets S_1 and S_2 are *adjacent* if some pixel in S_1 is adjacent to some pixel in S_2.

$$V = \{1\}$$

$$\begin{array}{ccccccccccc}
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\
0 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0
\end{array}$$

S_1 S_2

$$\begin{array}{ccccccccccc}
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\
0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0
\end{array}$$

S_1 S_2

5.1.2. Digital Path (or Curve)

A path from pixel *p* with coordinates (x,y) to pixel *q* with coordinates (s,t) is a sequence of distinct pixels with coordinates

$$(x_0, y_0), (x_1, y_1), \ldots\ldots, (x_n, y_n)$$

where $(x_0,y_0) = (x,y)$ and $(x_n,y_n) = (s,t)$, and pixel (x_i, y_n) and (x_{i-1}, y_{n-1}) are *adjacent*

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

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

Closed Path $(x,y) = (s,t)$

5.1.2. Digital Path (or Curve)

p q

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

(2,4) , (2,3), (3,3), (4,3), (5,4), (5,5), (5,6), (4,7), (3,7), (2,6)

5.1.3. Connected Set

Let *S* be a subset of pixels in an image.
Pixels *p* and *q* are *connected* in *S* if there exists a path between them consisting entirely of pixels in *S*.
For any pixel *p* in *S*, the set of pixels that are connected to it in *S* is called a *connected component* of *S*. If set *S* has one connected component, then set S is called a *connected set*.

0	0	0	0	0	0	1	1	1	0	0
0	1	1	**1**	0	1	0	0	0	1	0
1	1	0	0	0	0	1	1	1	0	0
1	1	**1**	0	**1**	1	0	0	0	0	0
0	0	0	1	1	1	0	0	0	0	0

Not connected

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

Connected set

5.1.4. Region and Boundary

Let *R* be a subset of pixels in an image.
R is a *region* of the image if *R* is a *connected set*.
The *boundary* (border or contour) of a region *R* is the set of pixels in the region that have one or more neighbors that are not in *R*.

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

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

Edges are intensity discontinuities and *boundaries* are closed baths.

5.2. Distance Measure (Euclidean)

For pixels p, q, and z, with coordinates (x,y), (s,t), and (v,w), respectively, D is a distance function or metric if

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

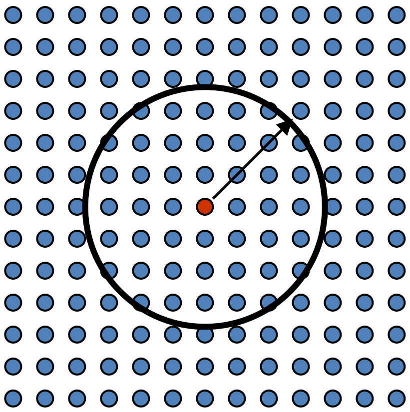
(b) $D(p,q) = D(q,p)$, (symmetry)

(c) $D(p,z) \leq D(p,q) + D(q,z)$ (triangular inequality)

Euclidean distance between p and q is

$$D_e(p,q) = [\ (x - s)^2 + (y - t)^2\ ]^{1/2}$$

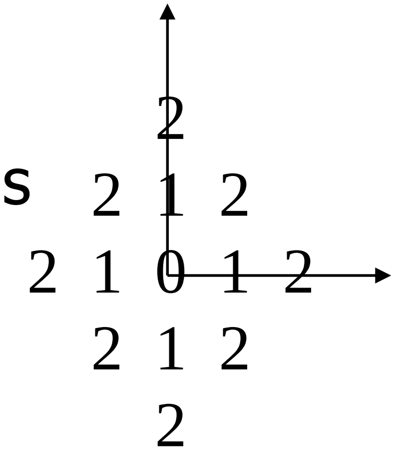
For this distance measure, the pixels having a distance less than or equal to some value r from (x,y) are the points contained in a disk of radius r centered at (x,y).



5.2. Distance Measure (City block, Chessboard)

The D_4 *distance* (*city-block*) between *p* and *q* is

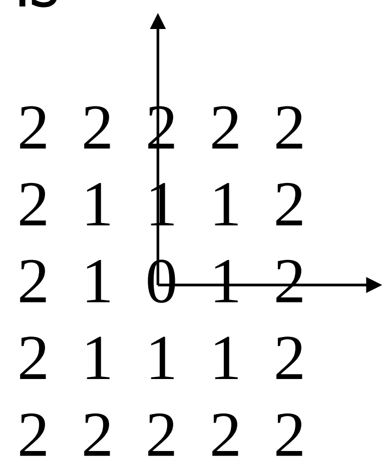
$$D_4(p,q) = |x - s| + |y - t|$$



Diamond shape

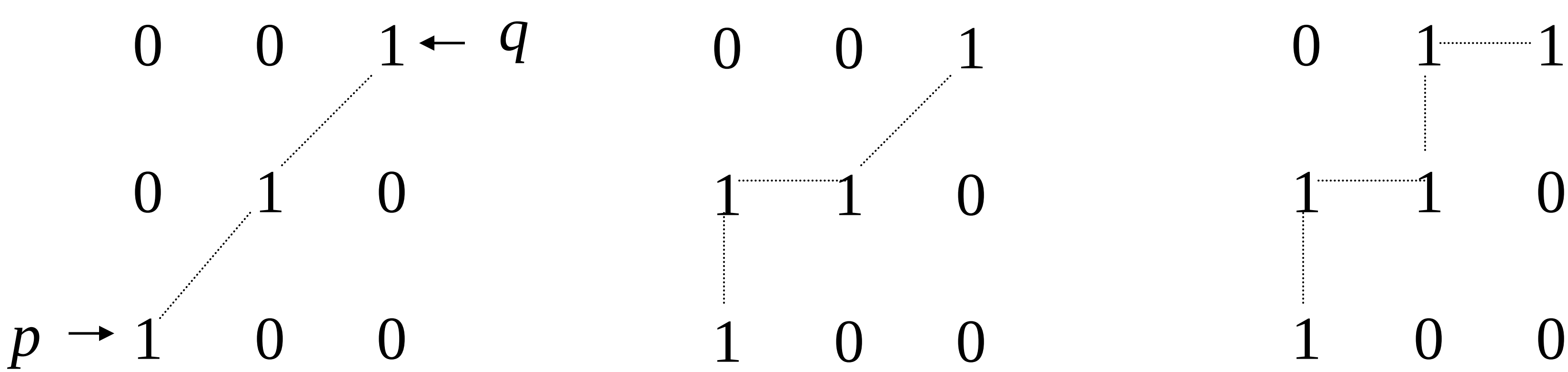
The D_8 *distance* (*chessboard*) between *p* and *q* is

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



5.2. Distance Measure of Path

If distance depend on the path between two pixels such as *m-adjacency* then the D_m distance between two pixels is defined as the shortest *m-path* between the pixels.



$D_m(p, q) = 2$ $\quad$ $D_m(p, q) = 3$ $\quad$ $D_m(p, q) = 4$

Path Length

Find the shortest 4-, 8-, *m-path* between *p* and *q* for
V= {0, 1} and *V*={1, 2}

			(q)
3	1	2	1
2	2	0	2
1	2	1	1
1	0	1	2
(p)			

5.3. Image Operation on a Pixel Basis

Images are represented by Matrices, and matrix division is not defined. The following image division

$$\boldsymbol{C} = \boldsymbol{A}/\boldsymbol{B}$$

means that the division is carried out between corresponding pixels in the two images ***A*** and ***B*** to form image ***C***.

5.3. Linear and Nonlinear Operation

$$H(af + bg) = a\,H(f) + b\,H(g)$$

Is the operator that compute the absolute value of the difference of two images linear?

Digital Image Processing

TOPIC – Elements of Visual Perception and Image Formation

By:
Dr. NAVEEN B
ASSOC PROF
DEPT OF ECE
BGSIT

Roadmap

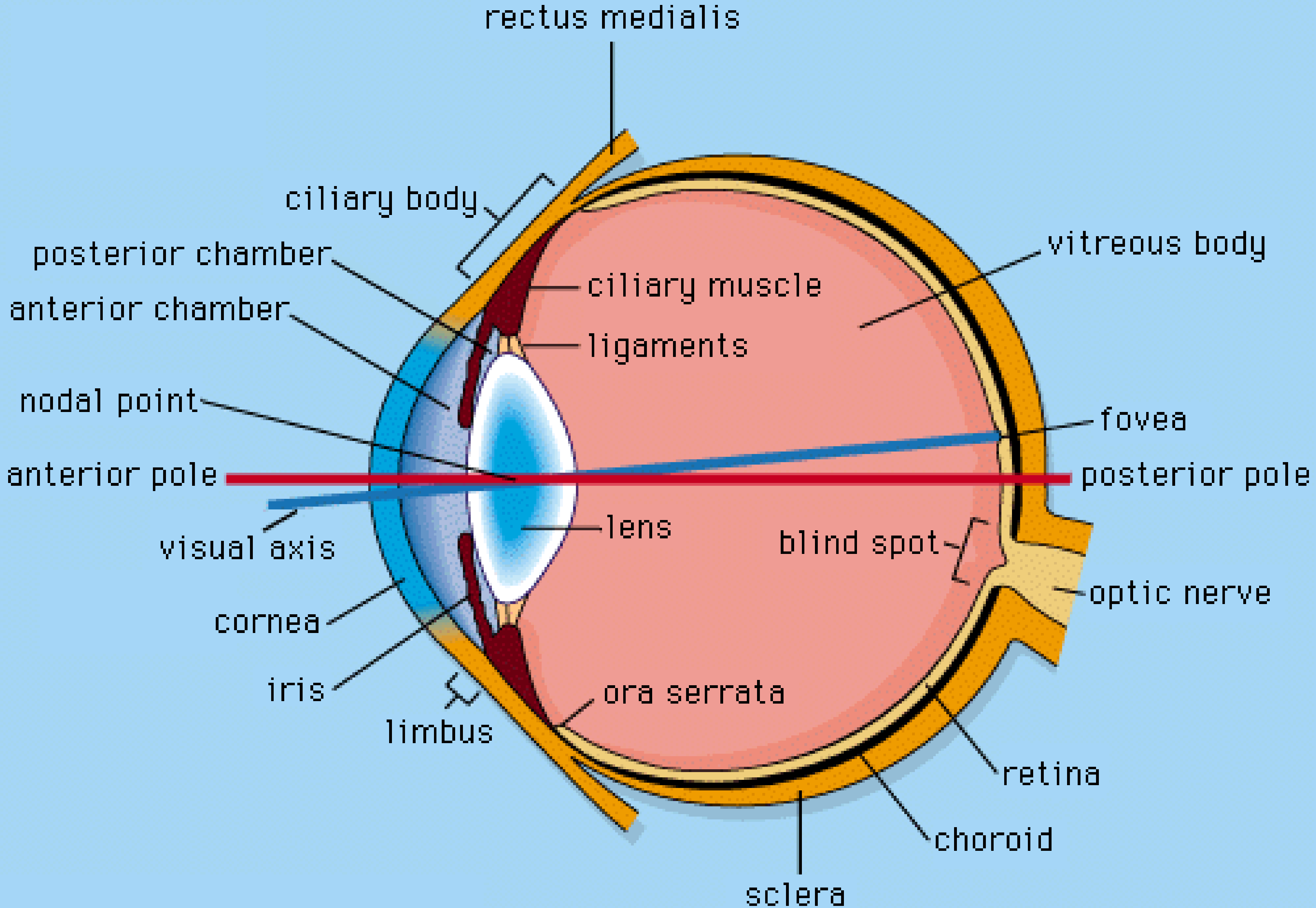
- Introduction
- Structure of human eye
- Brightness adaptation and Discrimination
- Image formation in human eye and Image formation model
- Basics of exposure
- Resolution
  - Sampling and quantization
- Research issues

Questions

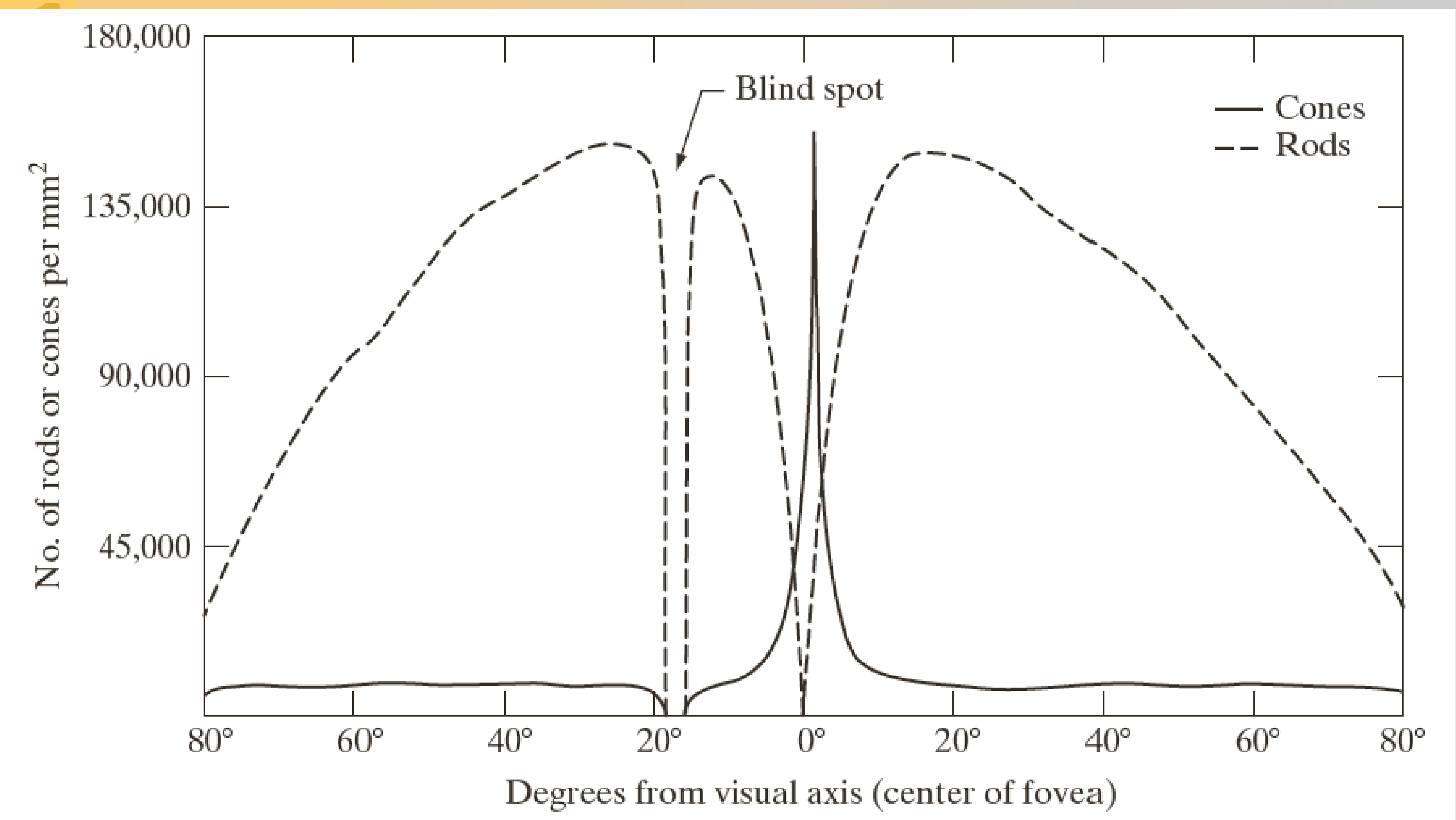
- Brightness adaptation
  - Dynamic range
- Weber ratio
- Cones vs. rods
  - Hexagonal sampling
  - Fovea or blind spot
- Flexible lens and ciliary body
  - Near sighted vs. far sighted
- Image resolution
  - Sampling vs. quantization

Structure of the human eye

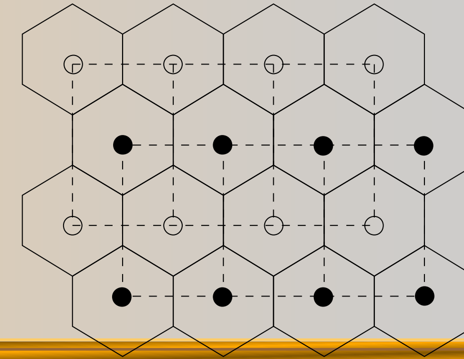
- The cornea and sclera outer cover
- The choroid
  - Ciliary body
  - Iris diaphragm
  - Lens
- The retina
  - Cones vision (photopic/bright-light vision): centered at fovea, highly sensitive to color
  - Rods (scotopic/dim-light vision): general view
  - Blind spot

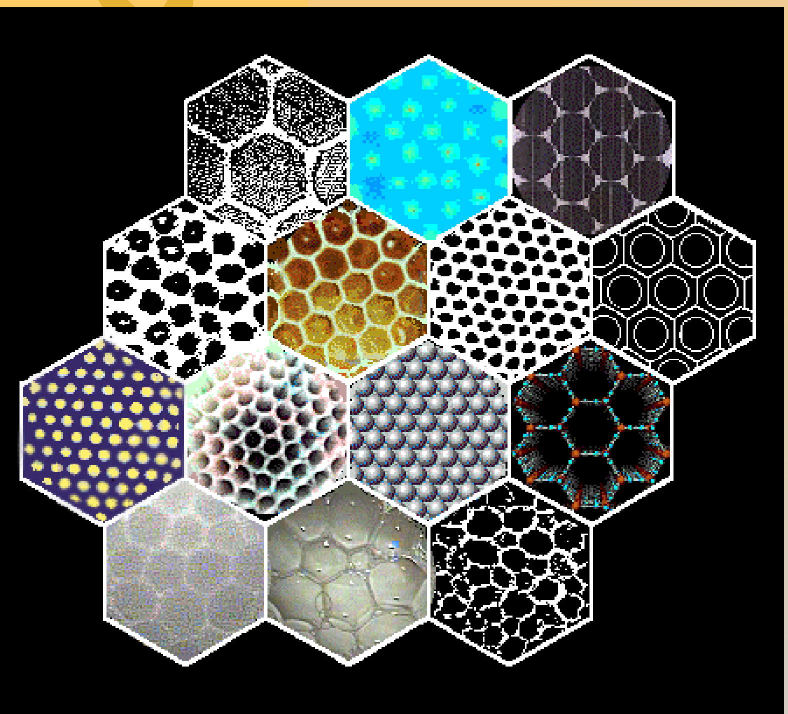

rectus medialis
ciliary body
posterior chamber
anterior chamber
nodal point
anterior pole
visual axis
cornea
iris
limbus
ciliary muscle
ligaments
lens
ora serrata
vitreous body
fovea
posterior pole
blind spot
optic nerve
retina
choroid
sclera

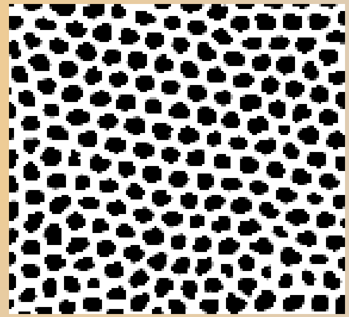
Cones vs. Rods



Hexagonal pixel



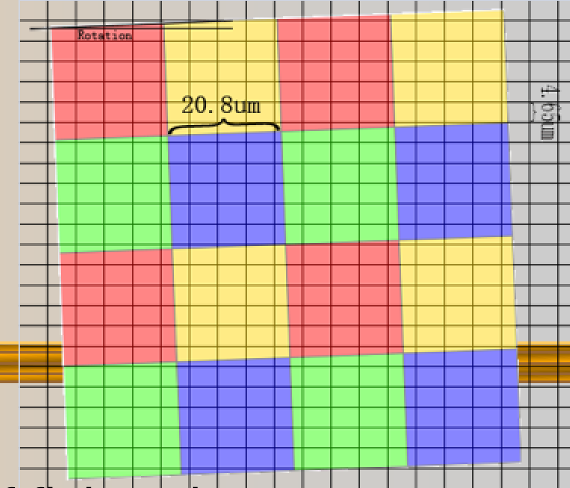


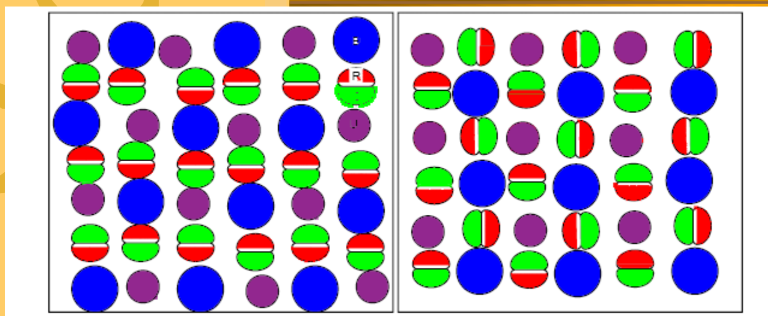


Cone distribution on the fovea (200,000 cones/mm^2)

- Models human visual system more precisely
- The distance between a given pixel and its immediate neighbors is the same
- Hexagonal sampling requires 13% fewer samples than rectangular sampling
- ANN can be trained with less errors

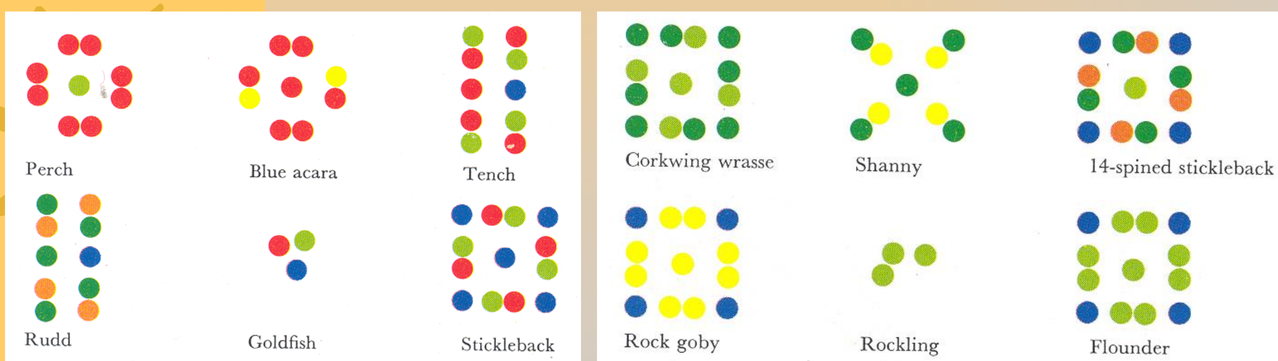
More on the cone mosaic



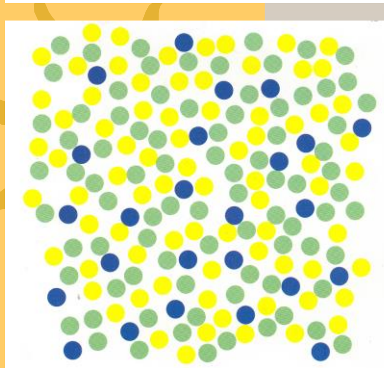


The cone mosaic of fish retina

http://www.nibb.ac.jp/annual_report/2003/03ann502.html

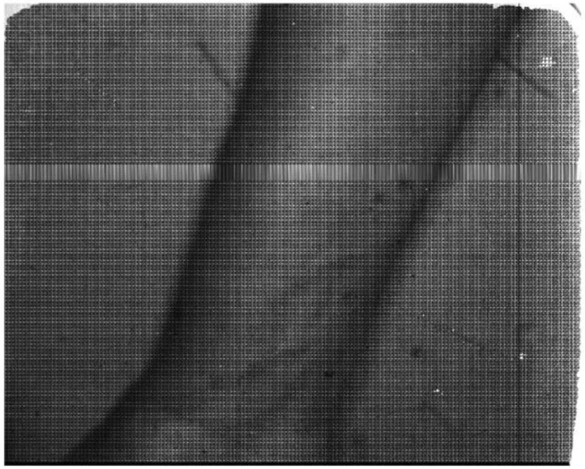


Lythgoe, *Ecology of Vision* (1979)

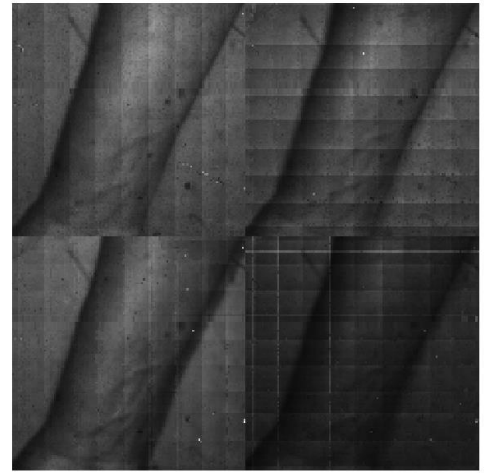


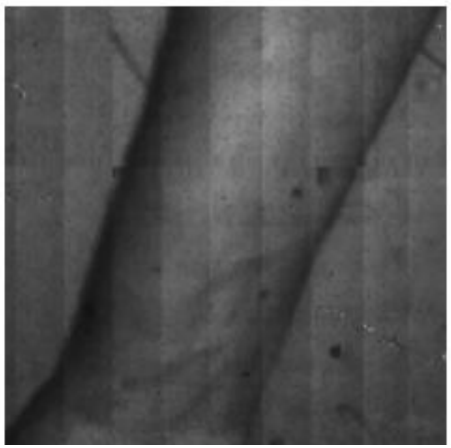
Human retina mosaic
-Irregularity reduces visual acuity for high-frequency signals
-Introduce random noise

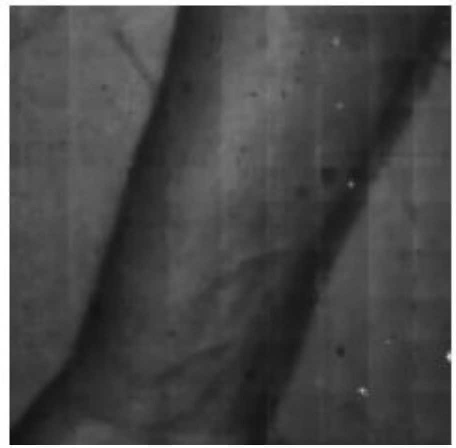
The mosaic array of most vertebrates is regular

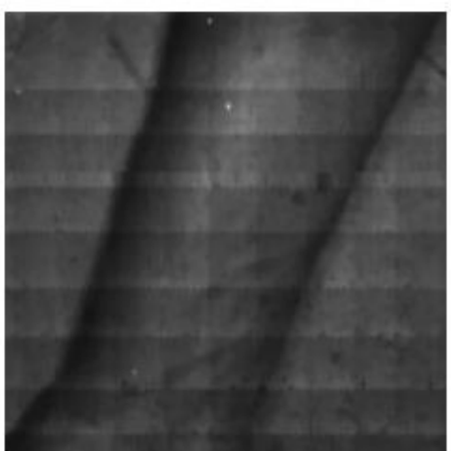


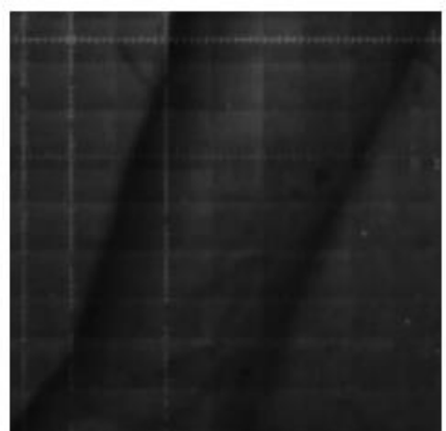
ed





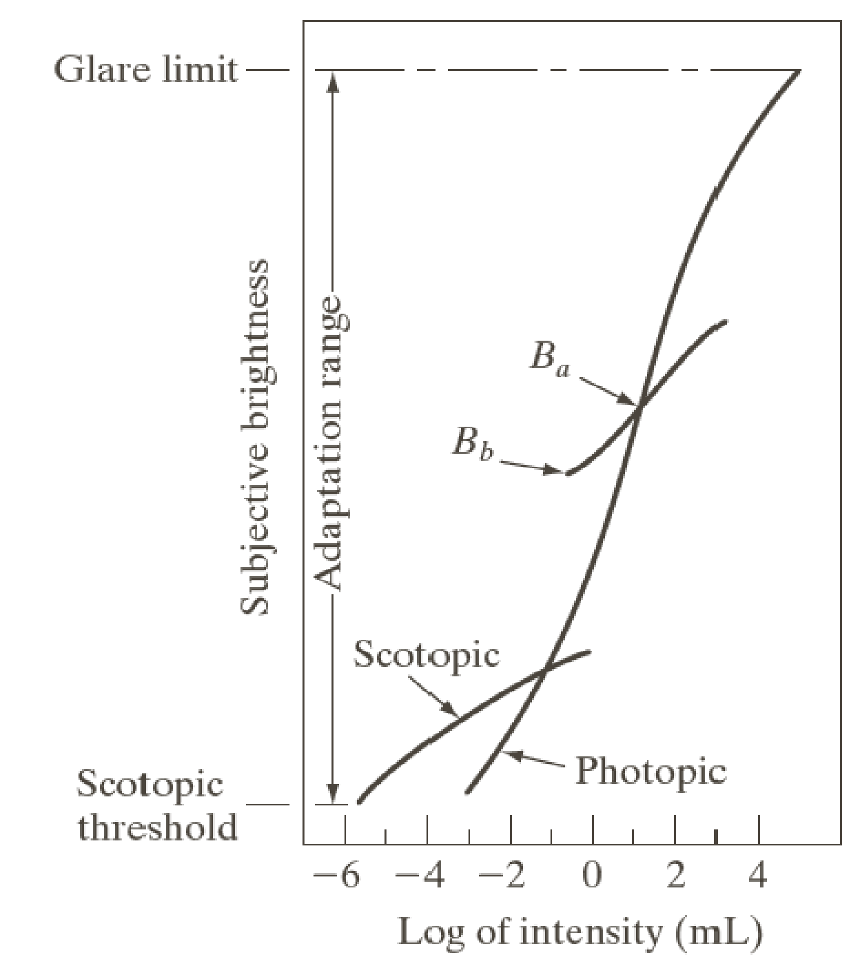






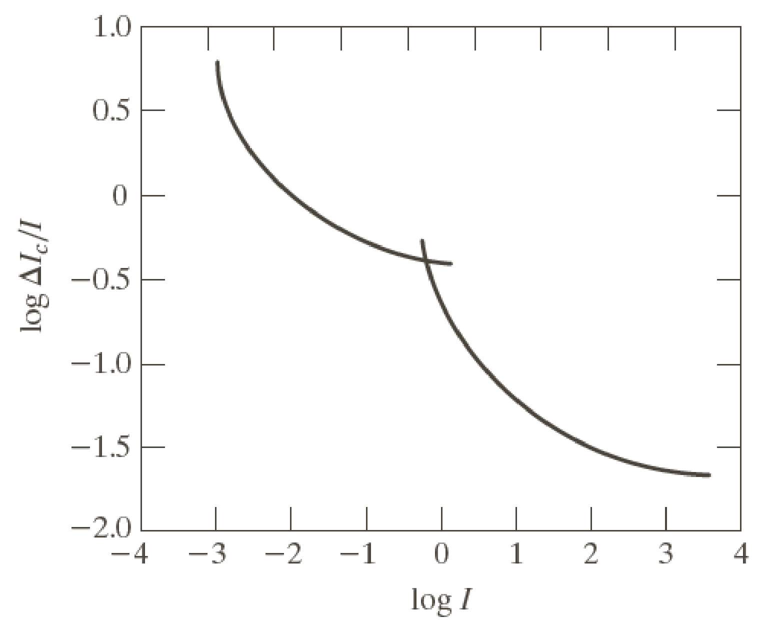
Brightness adaptation

- Dynamic range of human visual system
  - $10^{-6} \sim 10^{4}$
- Cannot accomplish this range **simultaneously**
- The current sensitivity level of the visual system is called the **brightness adaptation** level



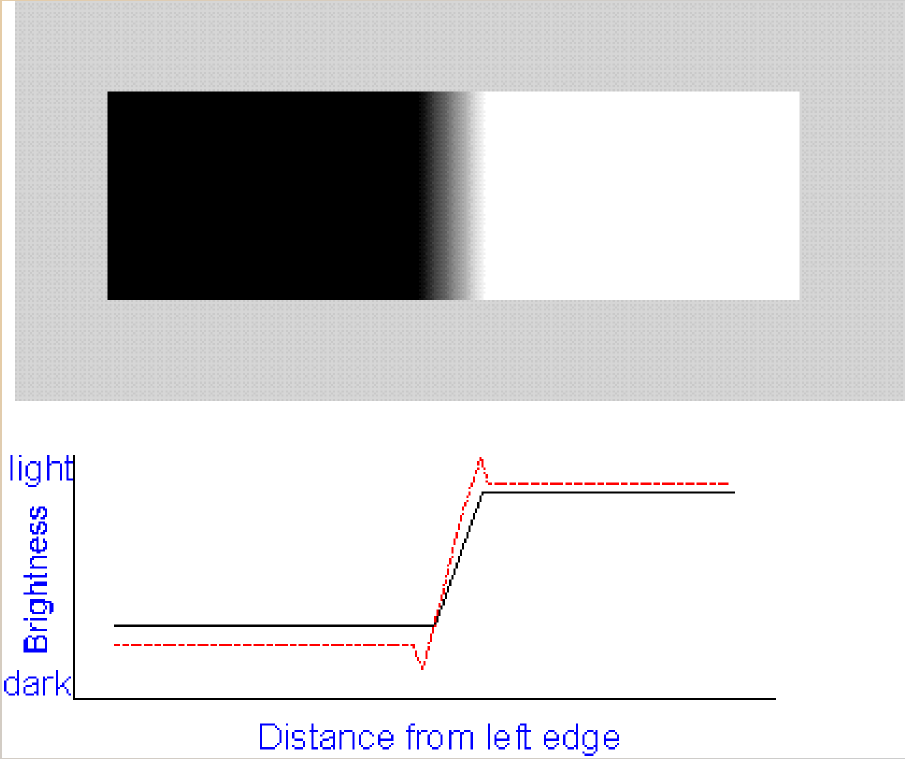
Brightness discrimination

- Weber ratio (the experiment) $\Delta I_c/I$
  - I: the background illumination
  - ΔI_c : the increment of illumination
  - Small Weber ratio indicates good discrimination
  - Larger Weber ratio indicates poor discrimination



Psychovisual effects

- The perceived brightness is not a simple function of intensity
  - Mach band pattern
  - Simultaneous contrast
  - And more… (see *link*)



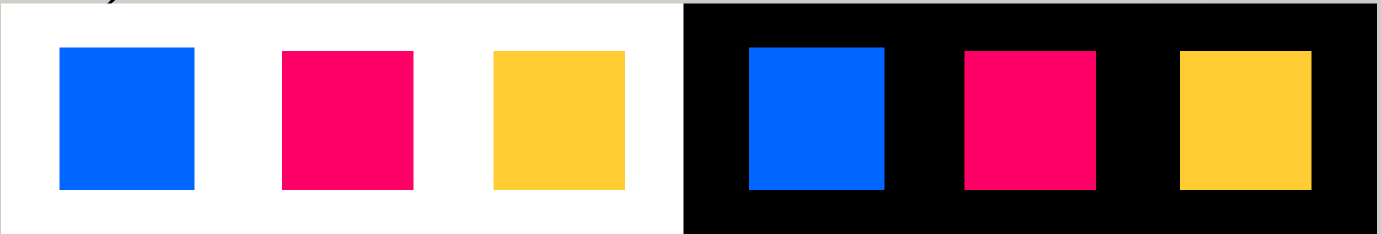
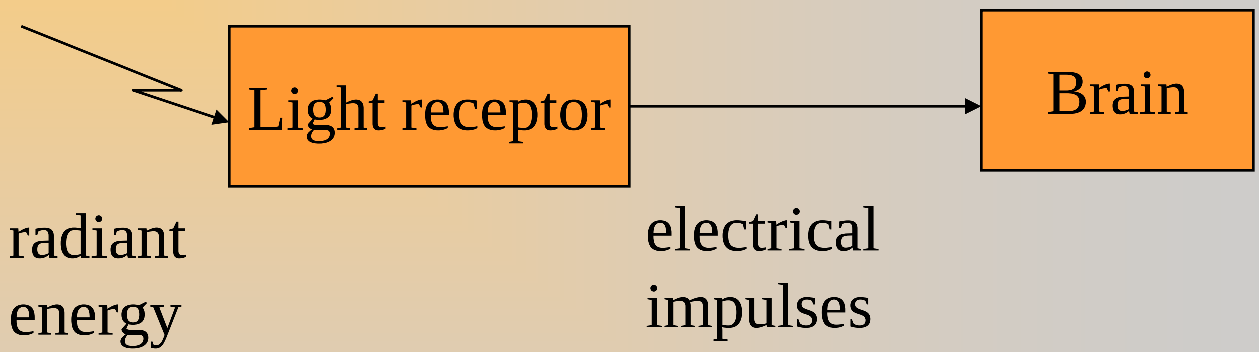


Image formation in the eye

- Flexible lens
- Controlled by the tension in the fibers of the ciliary body
  - To focus on distant objects?
  - To focus on objects near eye?
  - Near-sighted and far-sighted

Image formation in the eye



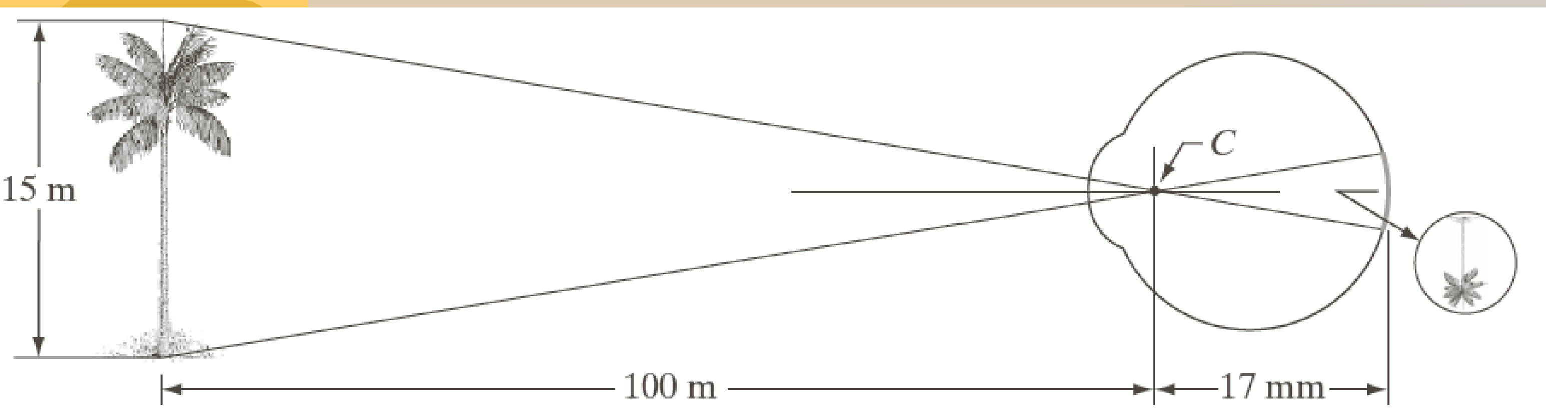


FIGURE 2.3 Graphical representation of the eye looking at a palm tree. Point *C* is the optical center of the lens.

A simple image formation model

- $f(x,y)$: the intensity is called the **gray level** for monochrome image
- $f(x, y) = i(x, y).r(x, y)$
  - $0 < i(x, y) <$ inf, the illumination (lm/m^2)
  - $0 < r(x, y) < 1$, the reflectance
- Some illumination figures (lm/m^2)
  - 90,000: full sun
  - 10,000: cloudy day
  - 0.1: full moon
  - 1,000: commercial office

- 0.01: black velvet
- 0.93: snow

Camera exposure

- ISO number
  - Sensitivity of the film or the sensor
  - Can go as high as 1,600 and 3,200
- Shutter speed
  - How fast the shutter is opened and closed
- f/stop
  - The size of aperture
  - 1.0 ~ 32

Sampling and Quantization

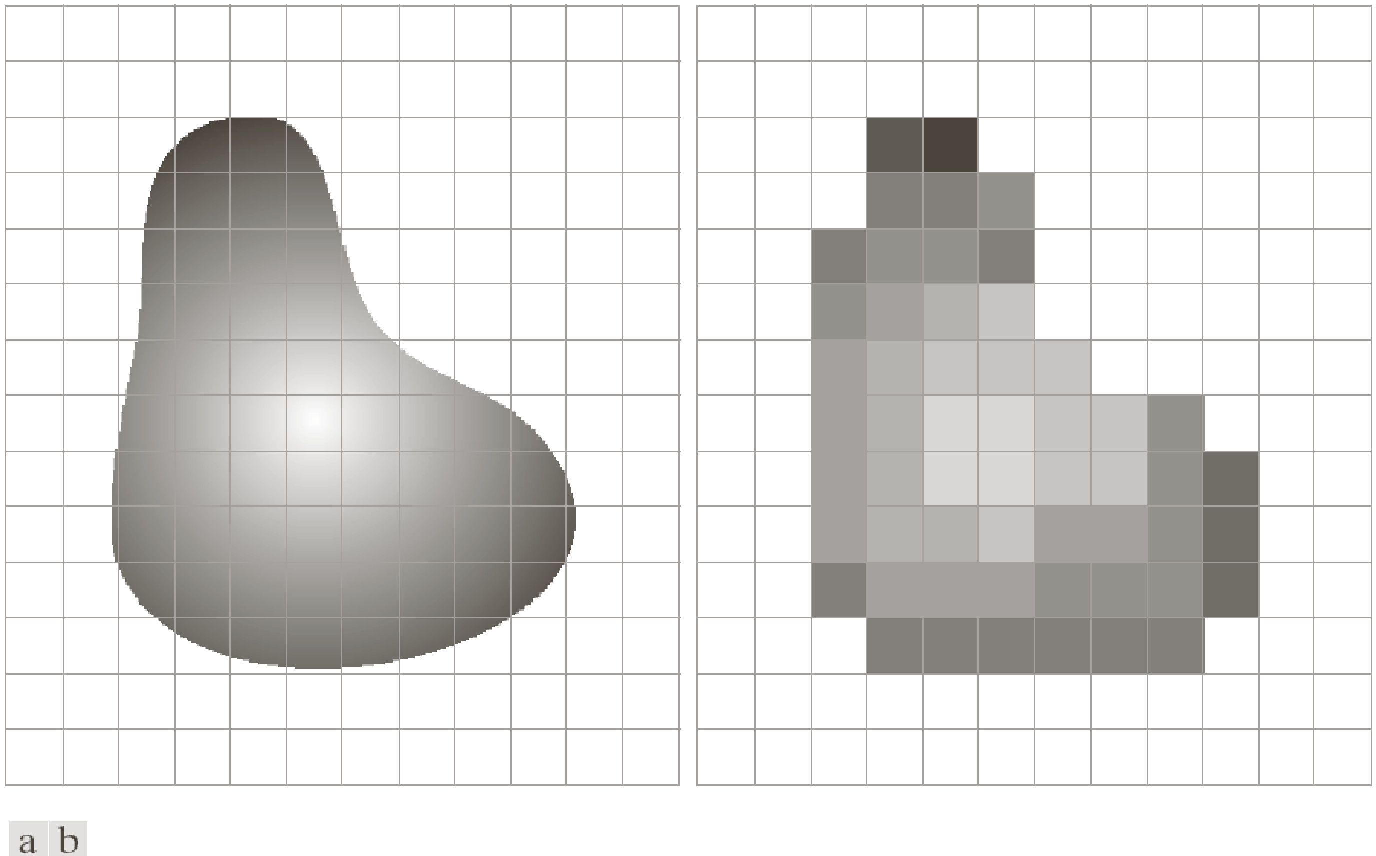


FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

Uniform sampling

- Digitized in spatial domain ($I_{M \times N}$)
- M and N are usually integer powers of two
- Nyquist theorem and Aliasing

(0,0)	(0,1)	(0,2)	(0,3)
(1,0)	(1,1)	(1,2)	(1,3)
(2,0)	(2,1)	(2,2)	(2,3)
(3,0)	(3,1)	(3,2)	(3,3)

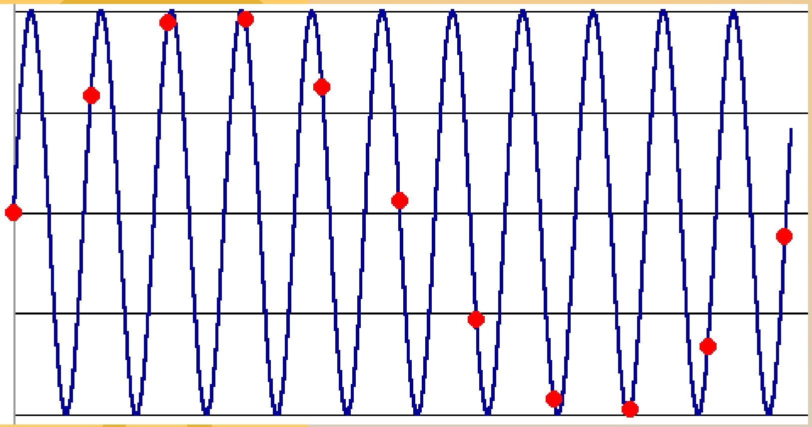
Sampled by 2 →

(0,0)	(0,0)	(0,2)	(0,2)
(0,0)	(0,0)	(0,2)	(0,2)
(2,0)	(2,0)	(2,2)	(2,2)
(2,0)	(2,0)	(2,2)	(2,2)

- Non-uniform sampling
  - communication

More on aliasing

- Aliasing (the Moire effect)



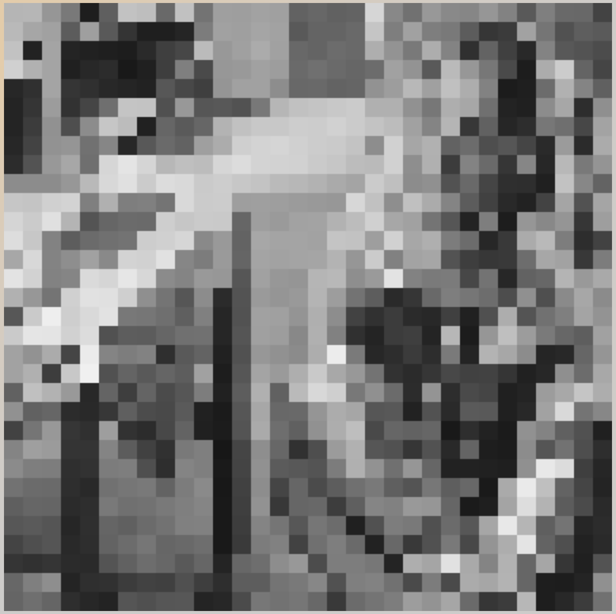
http://www.wfu.edu/~matthews/misc/DigPhotog/alias/

original

Sampled by 2

Sampled by 4

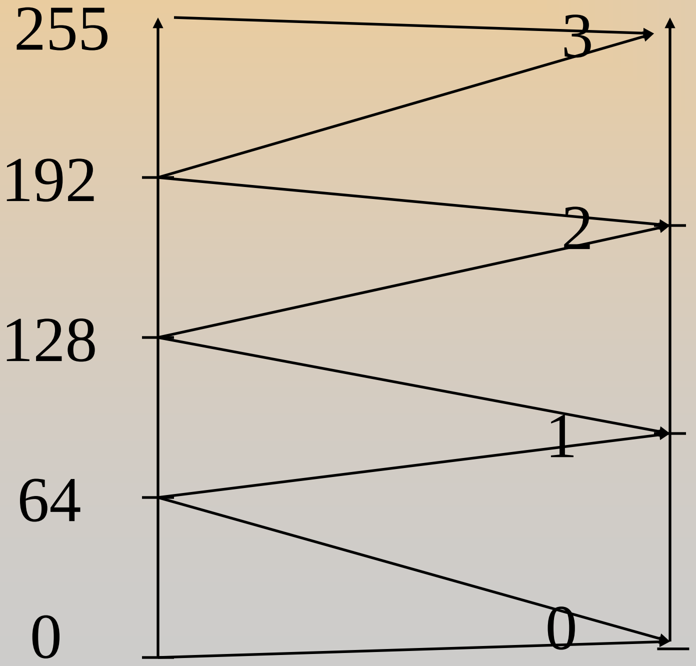
Sampled by 8



Sampled by 16

Uniform quantization

- Digitized in amplitude (or pixel value)
- PGM – 256 levels ➔ 4 levels



original

128 levels (7 bits)

16 levels (4 bits)

4 levels (2 bits)

2 levels (1 bit)

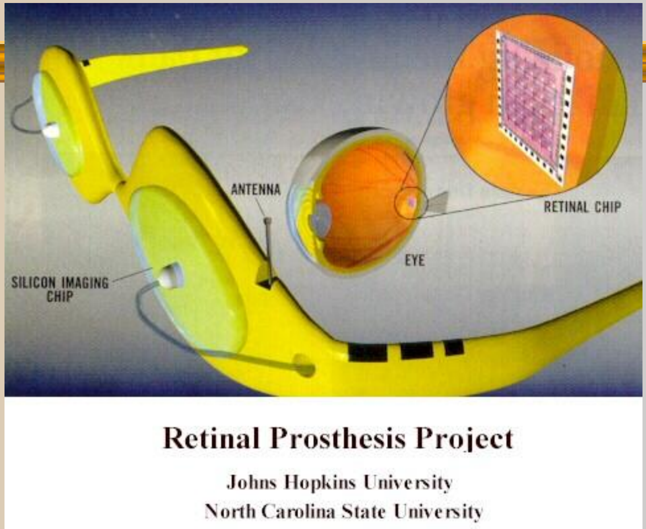
Image resolution

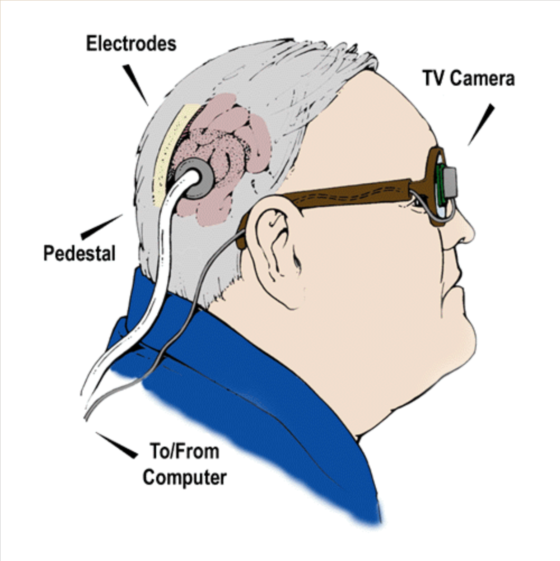
- Spatial resolution
  - Line pairs per unit distance
  - Dots/pixels per unit distance
    - dots per inch - dpi
- Intensity resolution
  - Smallest discernible change in intensity level

- The more samples in a fixed range, the higher the resolution
- The more bits, the higher the resolution

The research

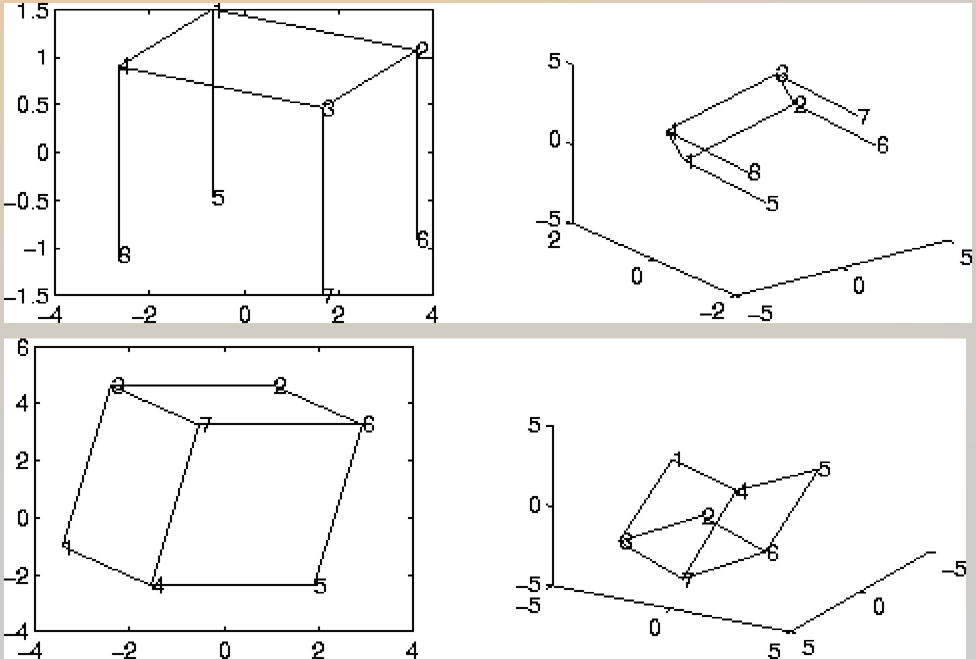
- Artificial retina (refer to the *link*)
- Artificial vision (refer to the *link*)
- 3-D interpretation of line drawing
- Compress sensing





3D interpretation of line drawing

- Emulation approach
  - A given 3-D interpretation is considered less likely to be correct if some angles between the wires are much larger than others



Research publications

- Conferences (IEEE)
  - International Conference on Image Processing (ICIP)
  - International Conference on Computer Vision (ICCV)
  - International Conference on Computer Vision and Pattern Recognition (CVPR)
- Journals (IEEE)
  - Transactions on Image Processing (TIP)
  - Transactions on Medical Imaging (TMI)
  - Transactions on Pattern Analysis and Machine Intelligence (PAMI)
- IEEE Explore

Summary

- Structure of human eye
  - Photo-receptors on retina (cones vs. rods)
- Brightness adaptation
- Brightness discrimination (Weber ratio)
- Be aware of psychovisual effects
- Image formation models
- Digital imaging
  - Sampling vs. quantization
  - Image resolution