DIGITAL IMAGE PROCESSING-1

Lecture 6-7: Unit 1

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Unit 1: Introduction to DIP

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Last Session

- Fundamental Steps in DIP
- Components of an Image processing System
- Fundamentals of DIP
  - Visual perception

Today's Session

- Digital Image Fundamentals
  - **Elements of visual perception Cont…**
  - Image Sensing and acquisition
  - Image Formation Model

Elements of Visual Perception

- ✓ Structure of the Human eye
- Image formation in the eye
- Brightness adaptation
- Brightness discrimination

- When eye is properly focused, light from an object outside is imaged on the retina
- Pattern of light is formed by distribution of discrete light receptors over surface of retina
- Two classes of receptors:
  - Cones and Rods

Image Formation in the Eye

- Focal Length: Distance between center of lens and retina.
  - Vary between 14-17 mm
- When the eye focuses on a nearby object, lens strongly refracts.

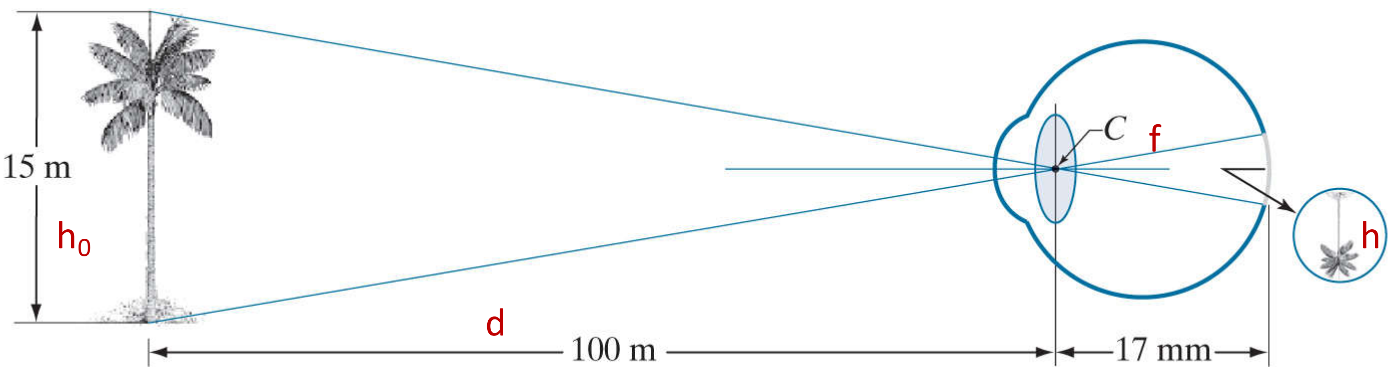


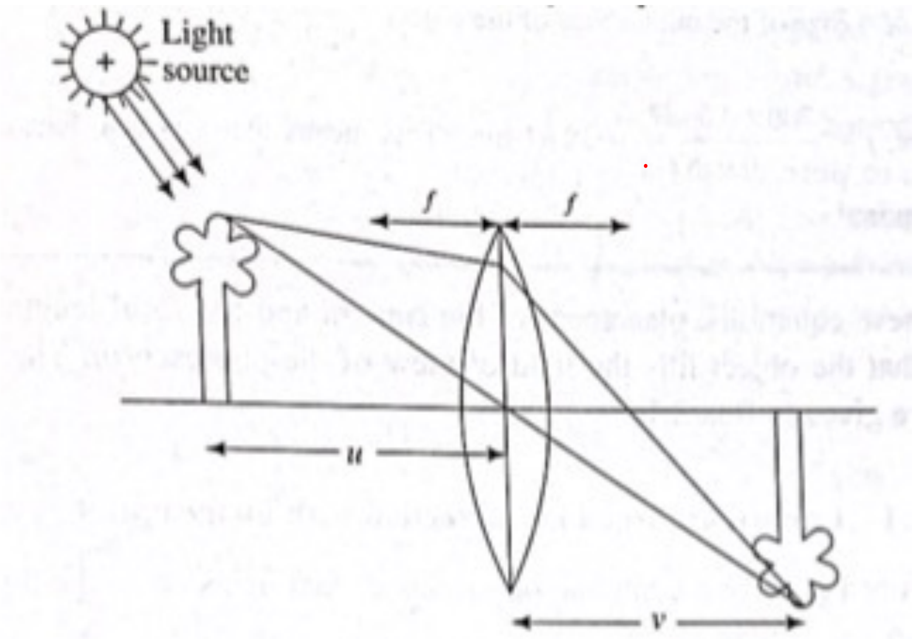
FIGURE 2.3
Graphical representation of the eye looking at a palm tree. Point *C* is the focal center of the lens.

$$\frac{h_0}{h} = \frac{d}{f}$$

$$\frac{15}{100} = \frac{h}{17}$$

Image Formation in camera

- The image formation using a camera lens is as shown in figure
- A lens is used to gather light and focus it onto the image plane



- Focal point is point where light rays converge
- Distance between focal point and centre of lens is called focal length
- Basic lens equation is given by

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

u is distance between object and lens

v is distance between image plane and lens

M = magnification factor = ratio of size of image by size of object and is given by

$$f=\frac{uM}{M+1}$$

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- These parameters quantify the gathering power and magnification of a lens
- Scotopic vision: vision in the presence of dim light (rods)
- Photopic vision: Vision in bright light (cones)

Examples

1. An object is 15 cm wide and is imaged with a sensor of size 8.8 x 6.6 mm^2 from a distance of 7 m. What should be the required focal length?
2. Assume that a 10 m high structure is observed from a distance of 50m. What is height of the retinal image?
3. Image transmission is done in packets. A packet consists of a start bit, a byte of data and a stop bit. Answer the following:

   (a) How many minutes would it take to transmit a 512 x 512 image with 256 gray levels at 300 baud rate?

   (b) What would be the time at 9600 baud?
4. Transmission is accomplished in packets. Find out the following;

   (a) How many minutes would it take to transmit 2048 x2048 image with 256 intensity levels using 33.6 k baud modem?

   (b) What would be the time taken at 3000 k Baud?

Monochromatic Light (Gray Scale)

- Devoid of color (if gray scale)
- Only attribute is intensity (vary from black to grays and finally to white)
- The term “gray level” is used to denote monochromatic intensity

Chromatic (Color) Light

- Spans the electromagnetic spectrum 0.43 to 0.79 μm

- Attributes: Radiance, luminance and brightness

  - Radiance: amount of energy from light source
  - Luminance: Amount of energy observer perceives from light source
    - Ex: light emitted in the infrared region have significant energy but observer will hardly perceive it, its luminance is almost zero
  - Brightness: is a subjective descriptor of light perception, it is impossible to measure

Elements of Visual Perception

- ✓ Structure of the Human eye
- ✓ Image formation in the eye
- **Brightness adaptation**
- **Brightness discrimination**

Brightness Adaptation and Discrimination

- The range of light intensity levels to which the human visual system can adapt is enormous—on the order of 10^{10}— from the scotopic threshold to the glare limit
- Subjective brightness (intensity as perceived by the human visual system) is a logarithmic function of the light intensity incident on the eye
- In photopic vision alone, the range is about 10^6.
- The transition from scotopic to photopic vision is gradual over the approximate range from 0.001 to 0.1 millilambert (−3 to −1 mL in the log scale)
- The visual system cannot operate over such a range simultaneously.
- Rather, it accomplishes this large variation by changing its overall sensitivity, a phenomenon known as **brightness adaptation.**

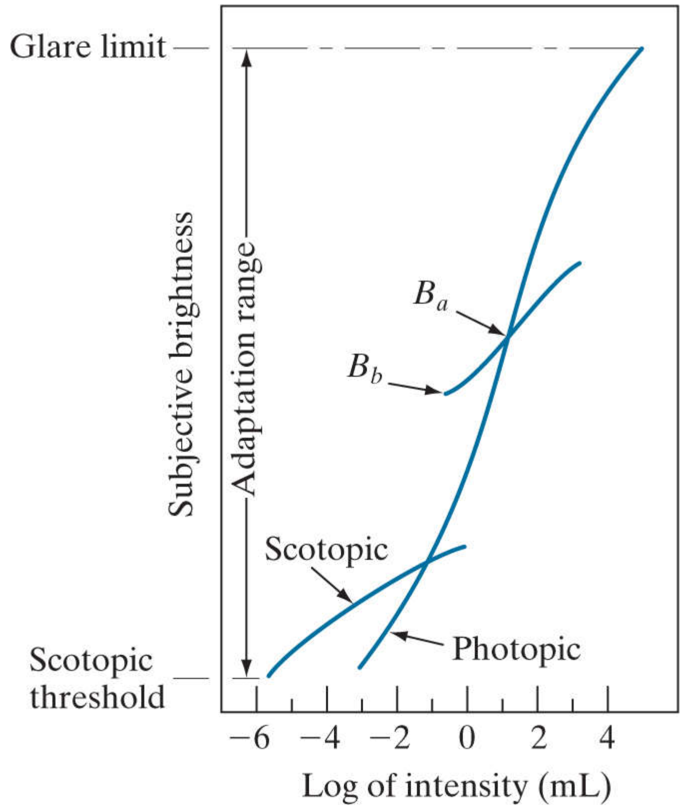


FIGURE 2.4
Range of subjective brightness sensations showing a particular adaptation level, B_a.

Brightness Adaptation and Discrimination

Brightness adaptation: The total range of distinct intensity levels the eye can discriminate simultaneously is rather small when compared with the total adaptation range.

- The current sensitivity level of the visual system is called the brightness adaptation level
- The short intersecting curve represents the range of subjective brightness that the eye can perceive when adapted to this level

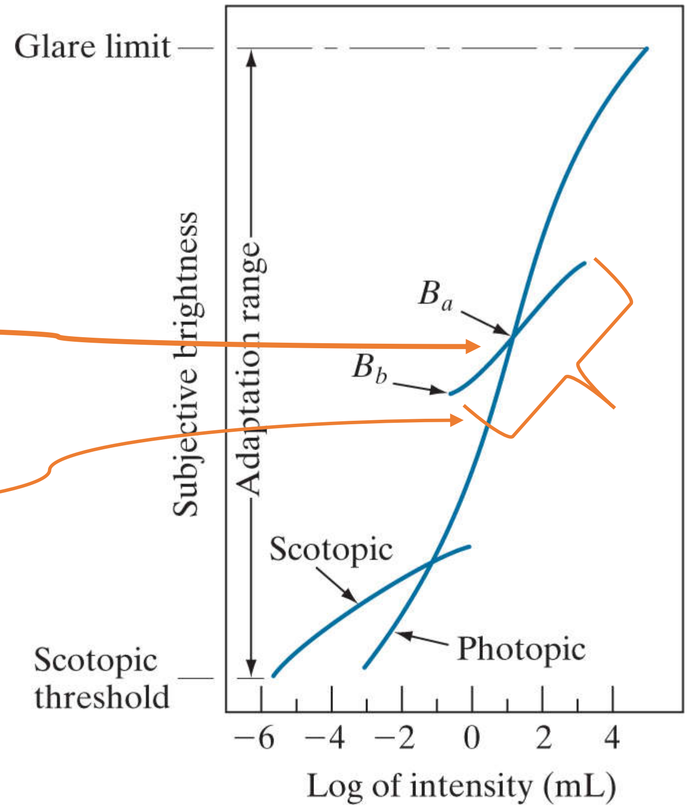
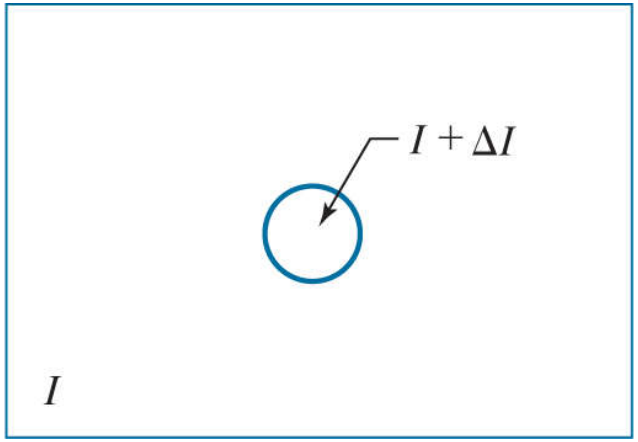


FIGURE 2.4
Range of subjective brightness sensations showing a particular adaptation level, B_a.

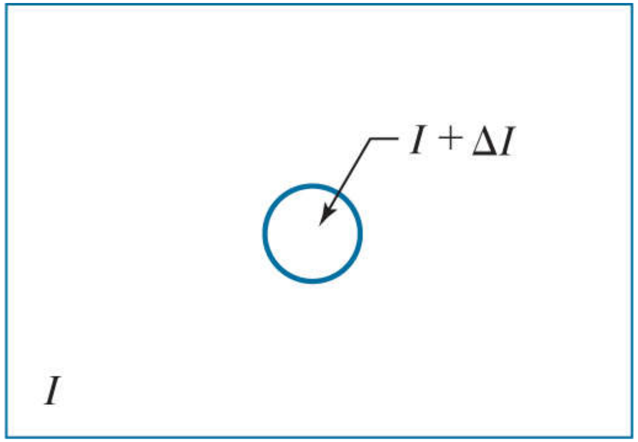
Brightness Adaptation and Discrimination

- **Brightness Discrimination**: The ability of the eye to discriminate between changes in light intensity at any specific adaptation level
- Consider a flat, uniformly illuminated area large enough to occupy the entire field of view.
- This area typically is a diffuser, such as opaque glass, illuminated from behind by a light source, I, with variable intensity.
- To this field is added an increment of illumination, ΔI, in the form of a short-duration flash that appears as a circle in the center of the uniformly illuminated field
- If ΔI is not bright enough, the subject does not perceive change.
- As ΔI gets stronger, the subject may perceive change.
- Finally, when ΔI is strong enough, the subject will perceive change all the time



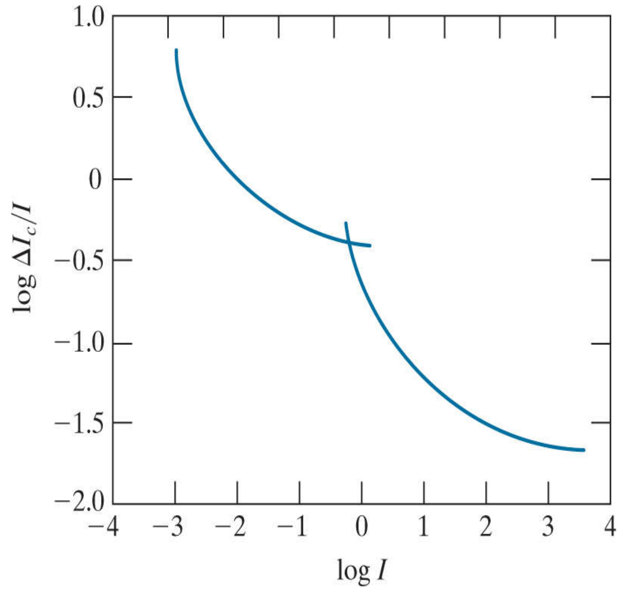
Brightness Adaptation and Discrimination

- **Brightness Discrimination**:
- **Weber ratio:** The quantity ΔI /I, where ΔI is the increment of illumination discriminable 50% of the time with background illumination
- A small value of ΔI/I means that a small percentage change in intensity is discriminable.
  - This represents "good" brightness discrimination.
- Conversely, a large value of ΔI/I means that a large percentage change in intensity is required for the eye to detect the change.
  - This represents "poor" brightness discrimination.



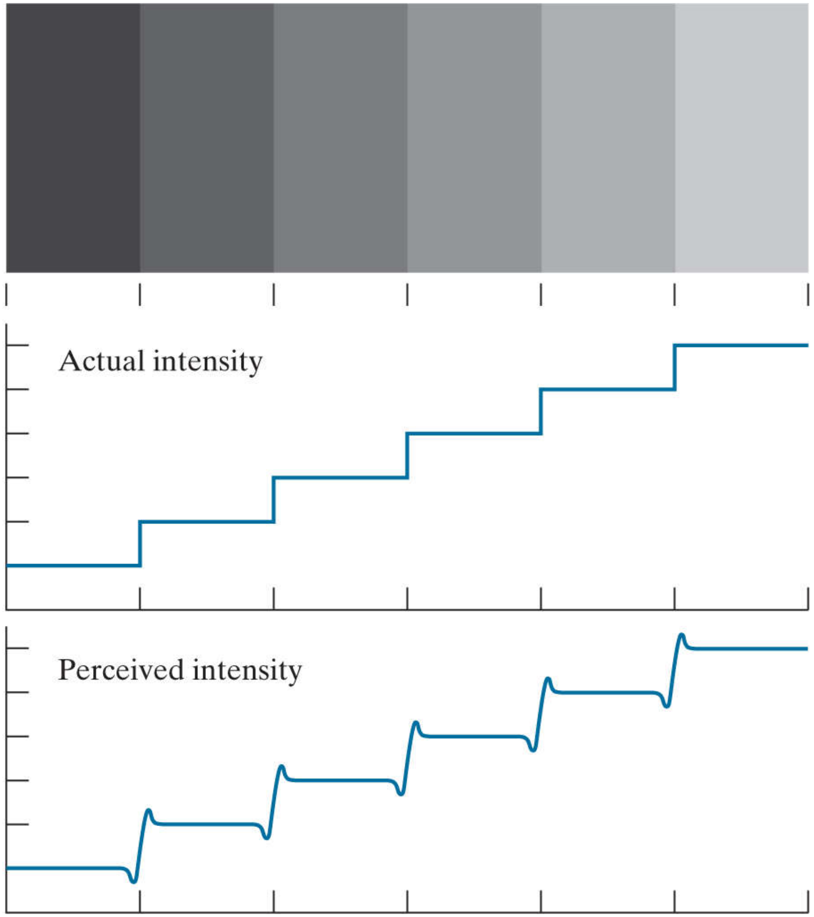
Brightness Adaptation and Discrimination

- **Brightness Discrimination**:
- A plot of ΔI/I shows that brightness discrimination is poor (the Weber ratio is large) at low levels of illumination, and it improves significantly (the Weber ratio decreases) as background illumination increases.
- The two branches in the curve reflect the fact that at low levels of illumination vision is carried out by the rods, whereas, at high levels, vision is a function of cones.



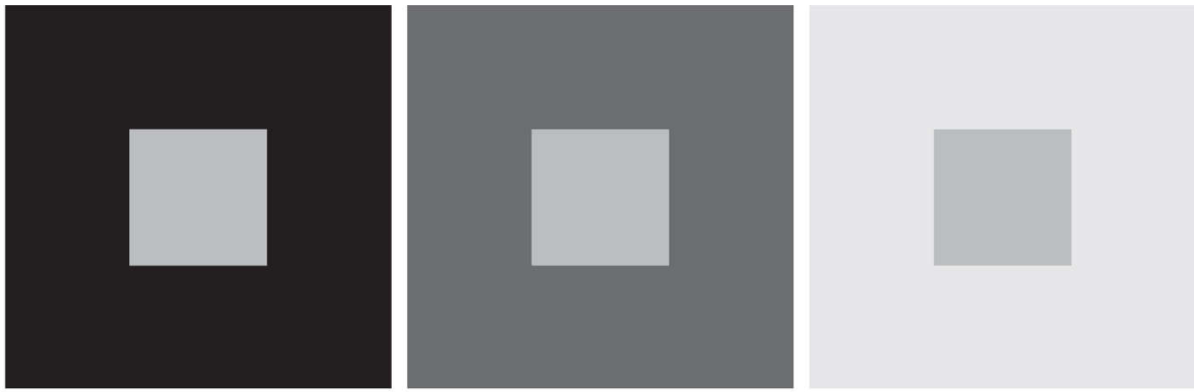
Brightness Adaptation and Discrimination

- **Human Perception:** Perceived brightness is not a simple function of intensity
  - The visual system tends to undershoot or overshoot around the boundary of regions of different intensities
    - These perceived scalloped bands are called Mach bands after Ernst Mach, who first described the phenomenon in 1865.



Brightness Adaptation and Discrimination

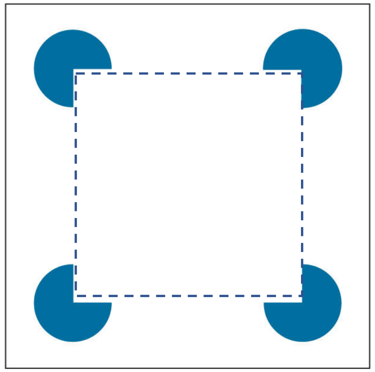
- **Human Perception:** Perceived brightness is not a simple function of intensity
  - Simultaneous contrast: a region's perceived brightness does not depend only on its intensity



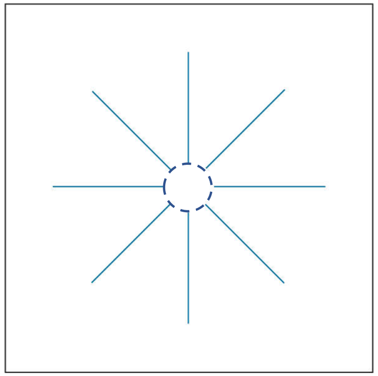
Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Brightness Adaptation and Discrimination

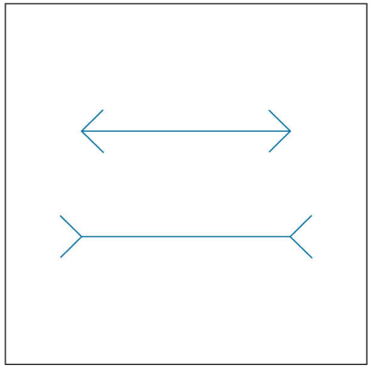
- **Human Perception:**
- Optical illusions: The eye fills in non existing details or wrongly perceives geometrical properties of objects.



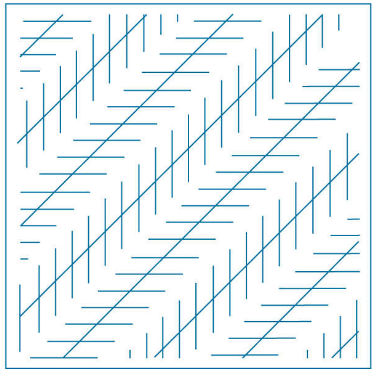
The outline of the square is seen clearly, despite the fact that no lines defining such a figure are part of the image



just a few lines are sufficient to give the illusion of a complete circle



The two horizontal line segments are of the same length

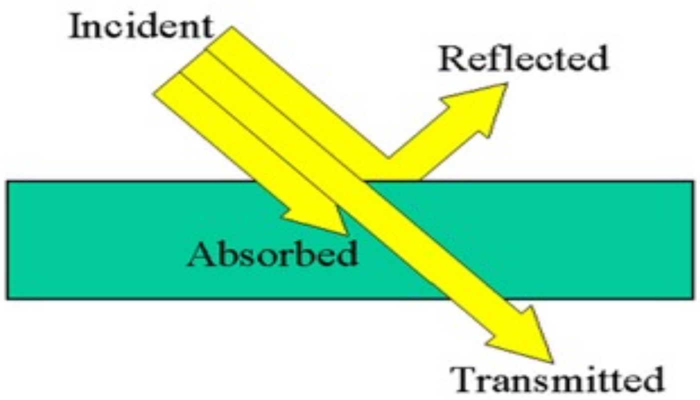


All long lines are equidistant and parallel

Some well-known optical illusions.

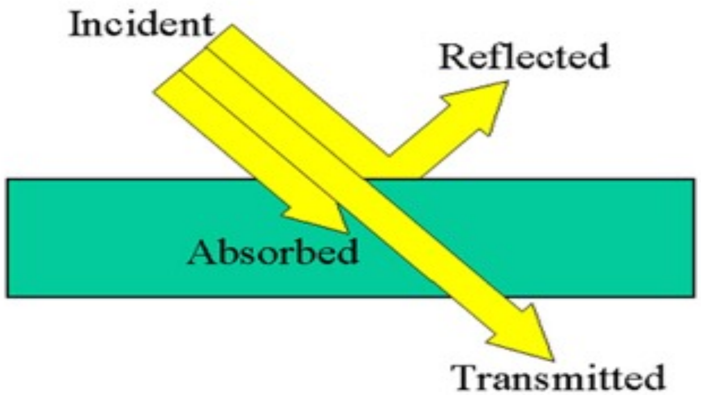
- Digital Image Fundamentals
  - Elements of visual perception
  - **Image Sensing and acquisition**
  - Image Formation Model
  - Image Sampling and Quantization
  - Representation of Digital Image

- Image generation:
  - Combination of 'illumination source' (could be from EM energy) and reflection or absorption of energy from that source by elements of 'scene' being imaged

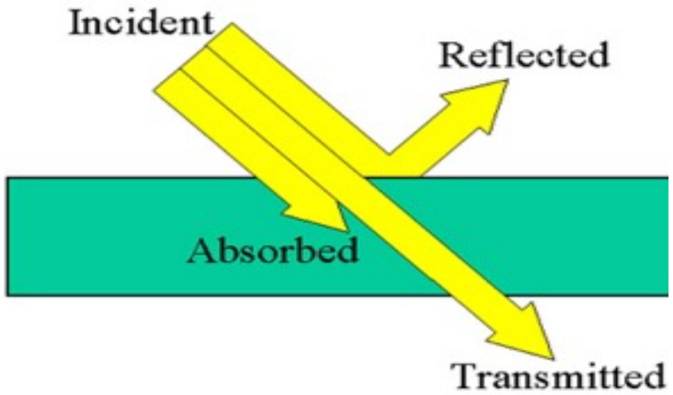


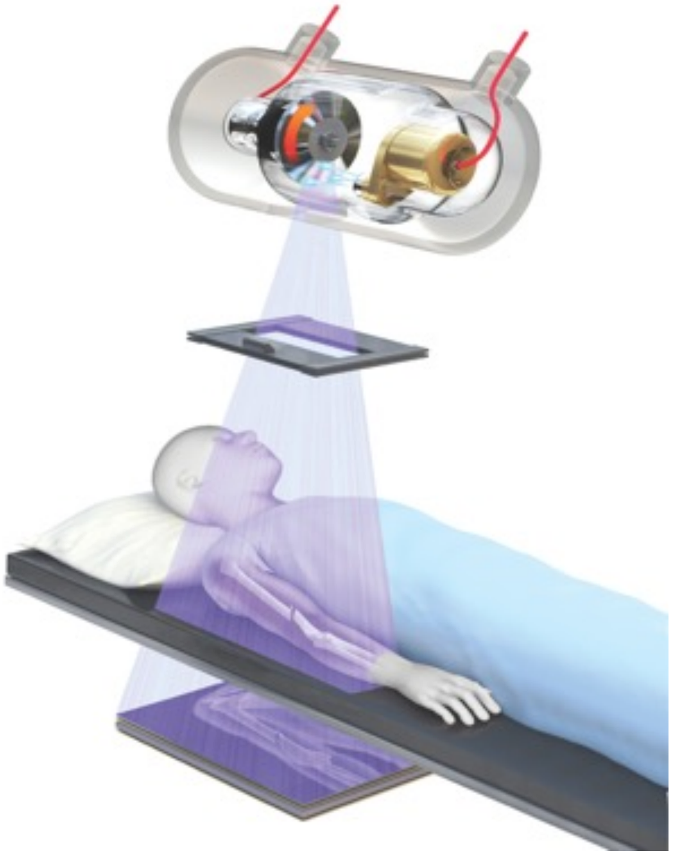
DIGITAL IMAGE PROCESSING-1

Reflected Energy Captured on Screen



Transmitted Energy Captured on Screen

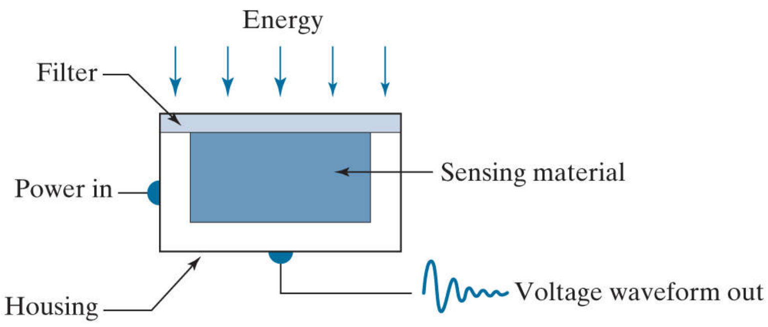




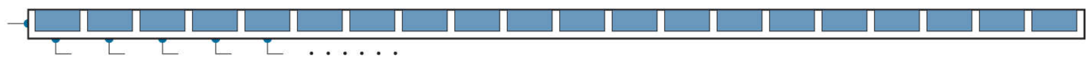
- In some applications, the Reflected or transmitted energy is focused on to a photo converter (eg. Phosphor screen)
- Photo converter converts the energy to visible light

Sensor

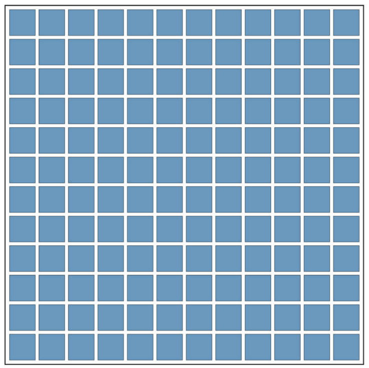
- Transforms illumination energy into digital images



Single sensing element

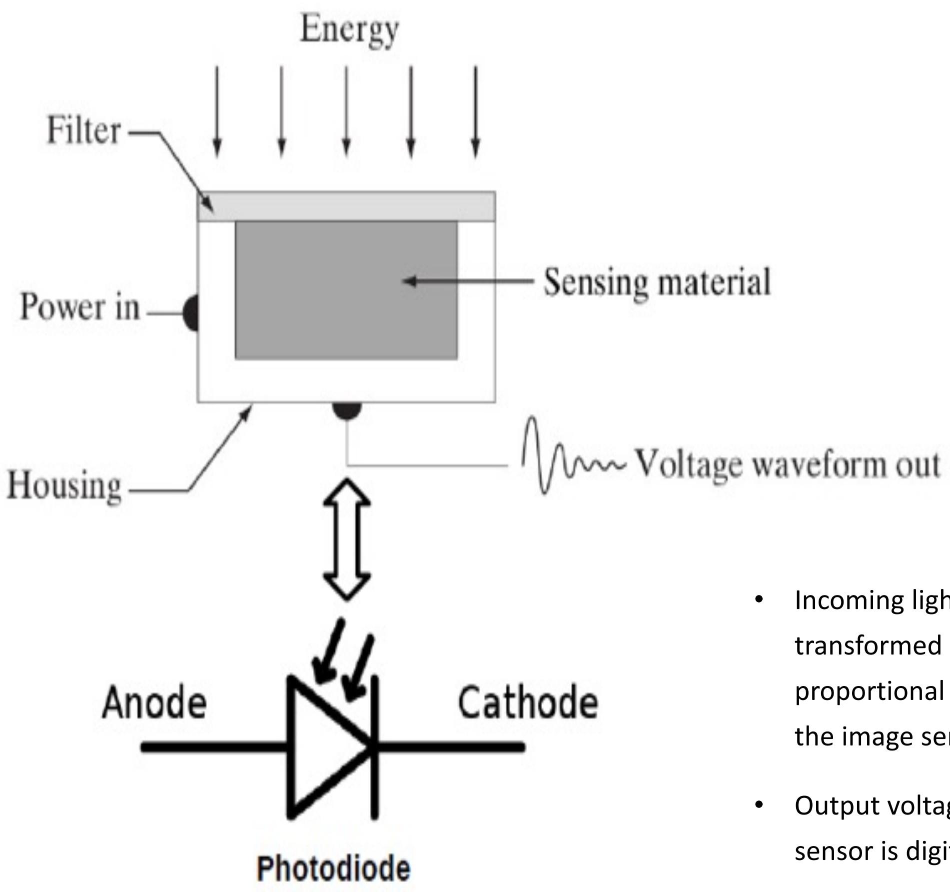


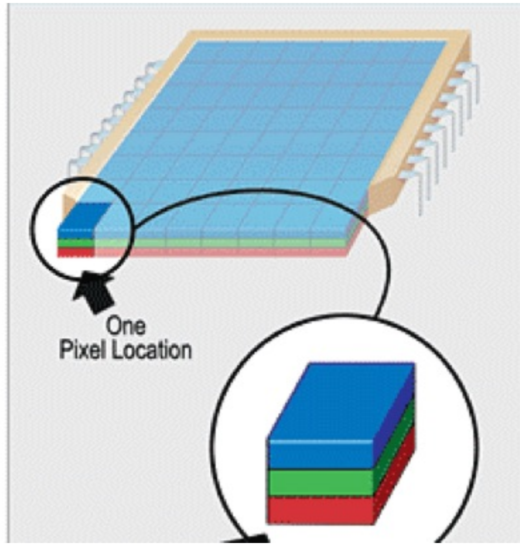
Line sensor



Array sensor

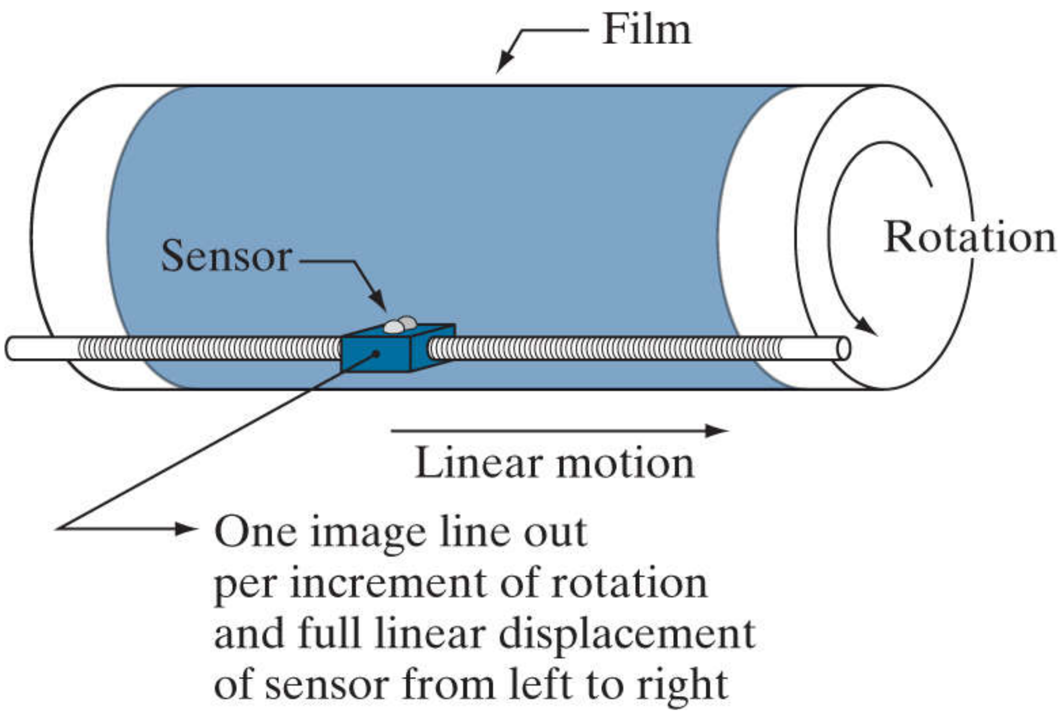
Image Acquisition using Single Sensor





- Incoming light energy is transformed into a voltage proportional to light energy by the image sensor.
- Output voltage from image sensor is digitized

Combining Single Sensor with a Motion to Generate 2D Image



Combining Single Sensor with a Motion to Generate 2D Image

- There has to be relative displacements in both the x and y-directions between the sensor and the area to be Imaged.
- A film negative is mounted onto a drum whose mechanical rotation provides displacement in one Dimension
- The single sensor is mounted on a lead screw that provides motion in the perpendicular direction.

- **Advantage:** Mechanical motion can be controlled with high precision, this method is inexpensive
- **Disadvantage:** It is a slow method to obtain high-resolution images

Image Acquisition using Sensor Strips

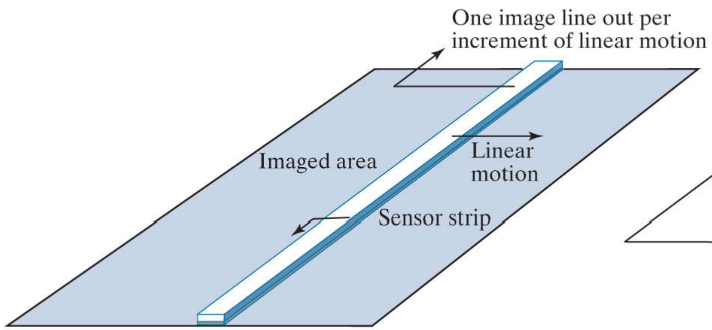


Image acquisition using a linear sensor strip.

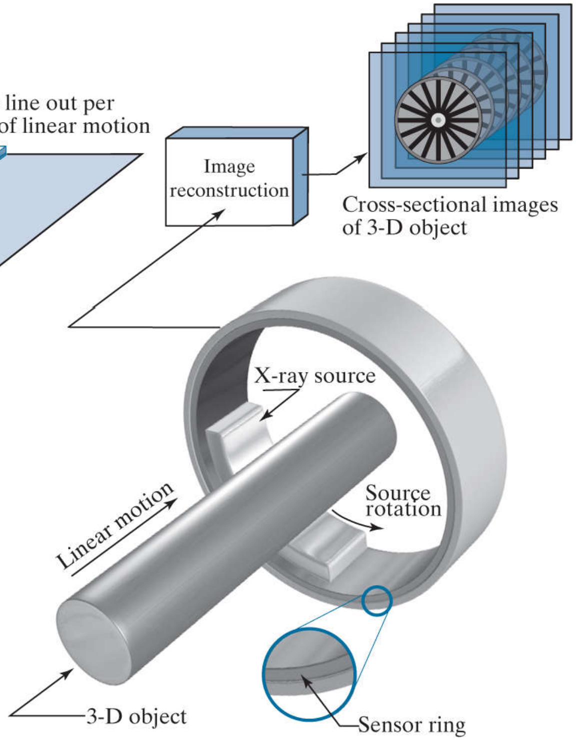
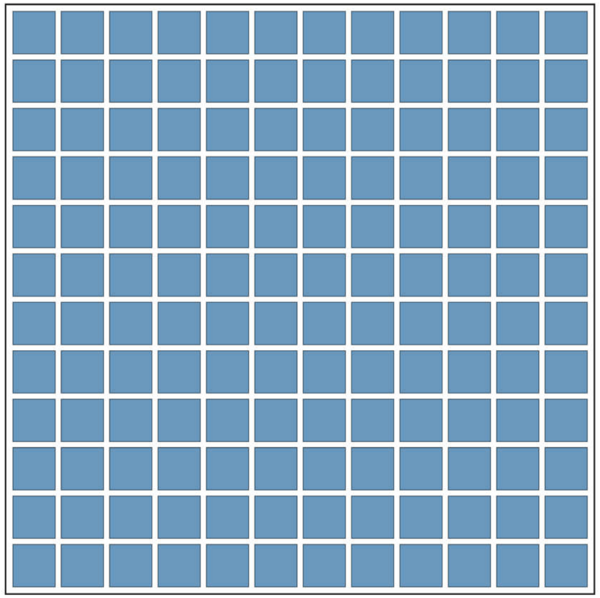


Image acquisition using a circular sensor strip.

Image Acquisition using Sensor Strips

- Used more frequently than single sensors. Consists of an inline arrangement of sensors in the form of a *sensor strip*
- The strip provides imaging elements in one direction.
- Motion perpendicular to the strip provides imaging in the other direction
- Sensing devices with 4000 or more in-line sensors are possible.
- Used in most flat bed scanners, airborne applications

Image Acquisition using Sensor Arrays



- Individual sensors arranged in the form of a 2-D array.
- Packaged in rugged arrays of 4000 * 4000 elements or more
- CCD sensors are used widely in digital cameras and other light sensing instruments
- The response of each sensor is proportional to the integral of the light energy projected onto the surface of the sensor
- Since array is 2D, complete image can be obtained and hence motion of elements is not necessary

DIGITAL IMAGE PROCESSING-1

Image Acquisition using Sensor Arrays

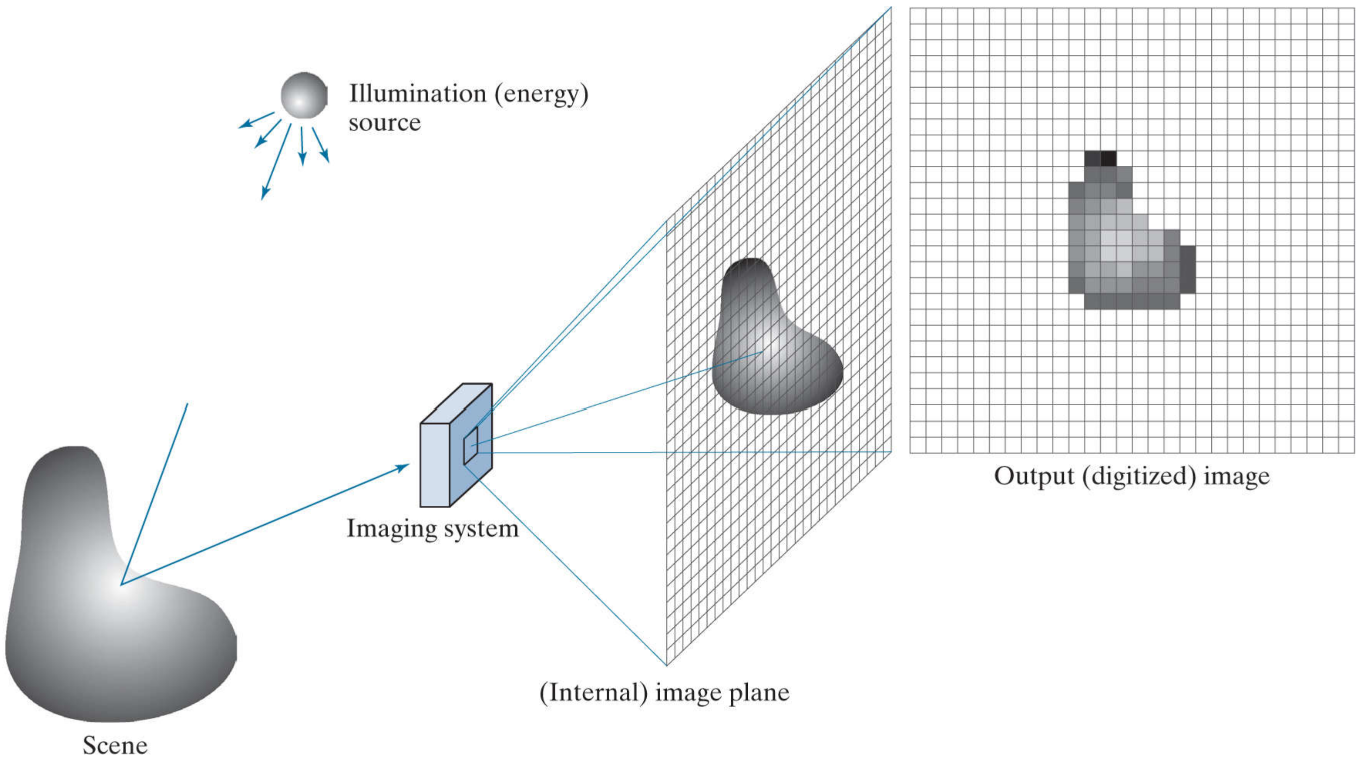


Image Acquisition using Sensor Arrays

- Energy from illumination source is being reflected from a scene element. Imaging system Collects the incoming energy and focus it onto an image plane
- Projects the viewed scene onto the lens focal plane, if the illumination is light
- The sensor array, which is coincident with the focal plane, produces outputs proportional to the integral of the light received at each sensor
- Digital and analog circuitry sweep these outputs and converts them to an analog signal, which is then digitized by another section of the imaging system.
- Yielding the output, that is a digital image

- Digital Image Fundamentals
  - ✓ Elements of visual perception
  - ✓ Image Sensing and acquisition
  - **Image Formation Model**
  - Image Sampling and Quantization
  - Representation of Digital Image

Simple Image Formation Model

- We represent digital images by two-dimensional functions of the form ***f(x,y)***
- The value or amplitude of ***f*** at spatial coordinates ***(x, y)*** is a positive scalar quantity whose value is decided by source of the image
- When an image is generated from a physical process, its values are proportional to energy radiated by a physical source
- ***f(x, y)*** must be nonzero and finite i.e,

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

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Simple Image Formation Model

- f(x,y) may be characterized by two components
  - Illumination Component: The amount of source illumination incident on the scene being viewed (*Illumination component)*

  i(x, y)
  - Reflectance Component: The amount of illumination reflected by the objects in the scene (*Reflectance component) r(x,y) or transmissivity*

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

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

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

- **1= total reflectance**
- **0 = total absorption**
- **r(x,y) is determined by characteristics of imaged objects**

Simple Image Formation Model

- **Illumination, i**
  - Clear sunny day (90,000 lm/m^2)
  - Cloudy day (10,000 lm/m^2)
  - Evening full moon day (0.1 lm/m^2)
  - Commercial office (1000 lm/m^2)

- **Reflectivity, r**
  - black velvet (0.01)
  - stainless steel (0.65)
  - white paint (0.80)
  - silver plate (0.90)
  - snow (0.93)

Simple Image Formation Model

- *Gray Level (l)*
- $l = f(x_0, y_0)$
- L_{min} *(ie.* $i_{min} * r_{min}$*)* $\leq l \leq L_{max}$*(ie.* $i_{max} * r_{max}$*)*
- *The interval [*L_{min} *-* L_{max}*] is called gray scale*
- *For office illumination* $L_{min}=10$ *and* $L_{max}=1000$
- *Common practice is to shift this [*L_{min} L_{max}*] to the interval [0 L-1], where l=0 is considered to be black and l=L-1 is considered white on the gray scale.*

Simple Image Formation Model

200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
200	200	200	200	200	200	200	200	200	200	200	200	200	80	80	80	80	200	200	200	200	200	200	200	200	200	200	200	200
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200	200	200	200	200	200	200	200	200	200	200	200	80	80	80	80	80	80	200	200	200	200	200	200	200	200	200	200	0

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Next Session

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THANK YOU

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