Computer Vision

CSC-455

Muhammad Najam Dar

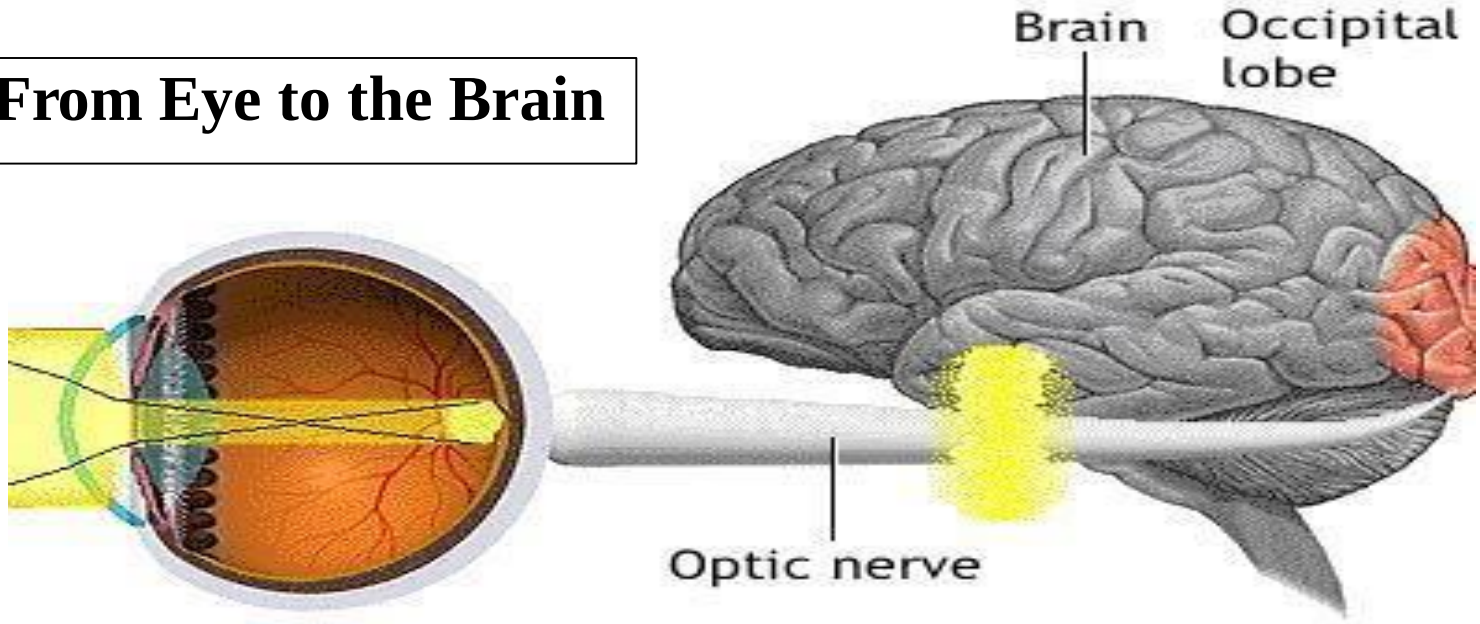
Today's Lecture

- Human Vision system
- Perception, Visual Context and Illusion.
- What is Digital Image
- Image Acquisition & Formation (Sampling & Quantization)

Human Vision

How does our brain receive this information?
Once the image is clearly focused on the sensitive part of the retina, energy in the light that makes up that image creates an electrical signal. Nerve impulses can then carry information about that image to the brain through the optic nerve.

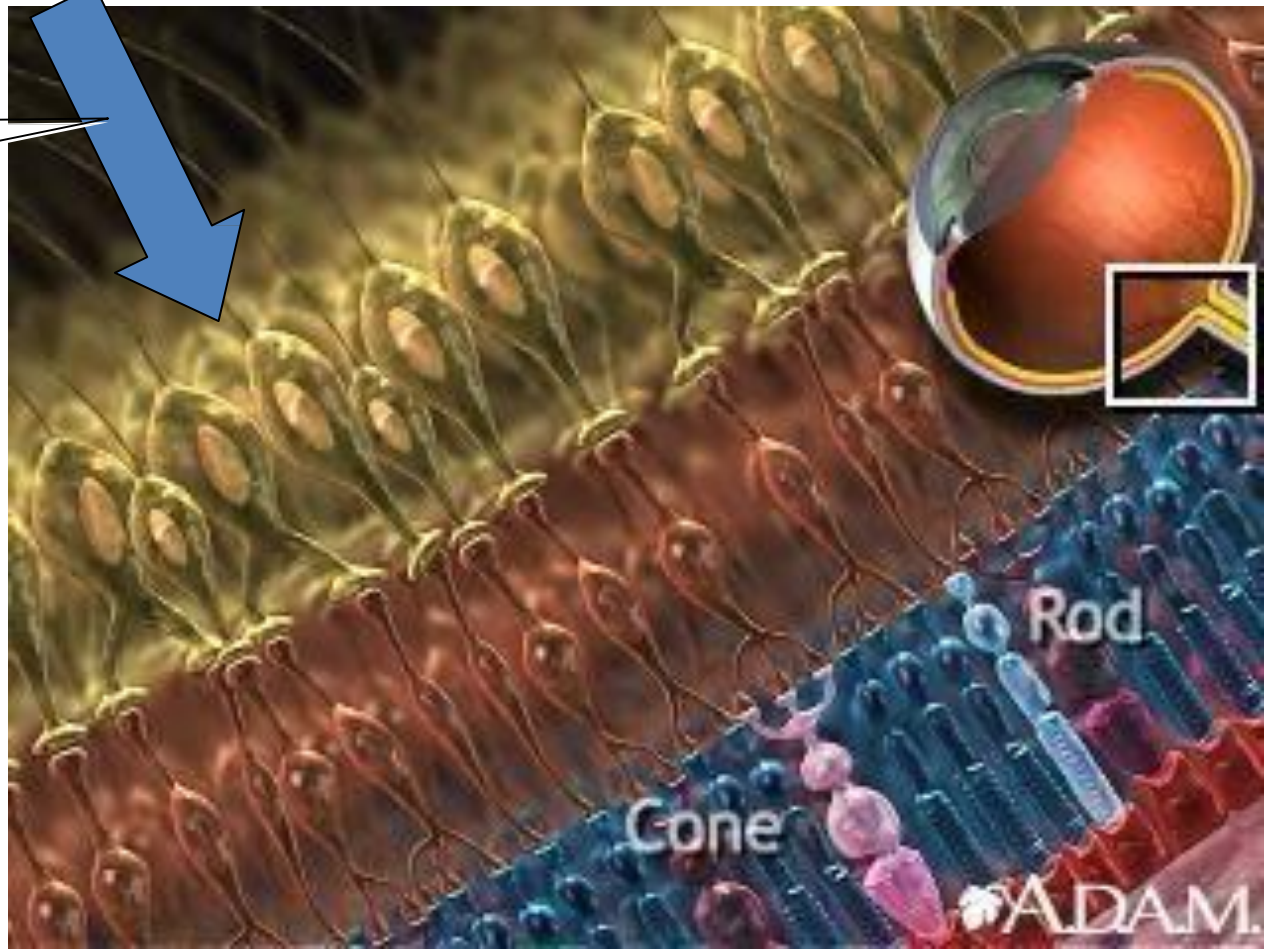
From Eye to the Brain



Human Vision

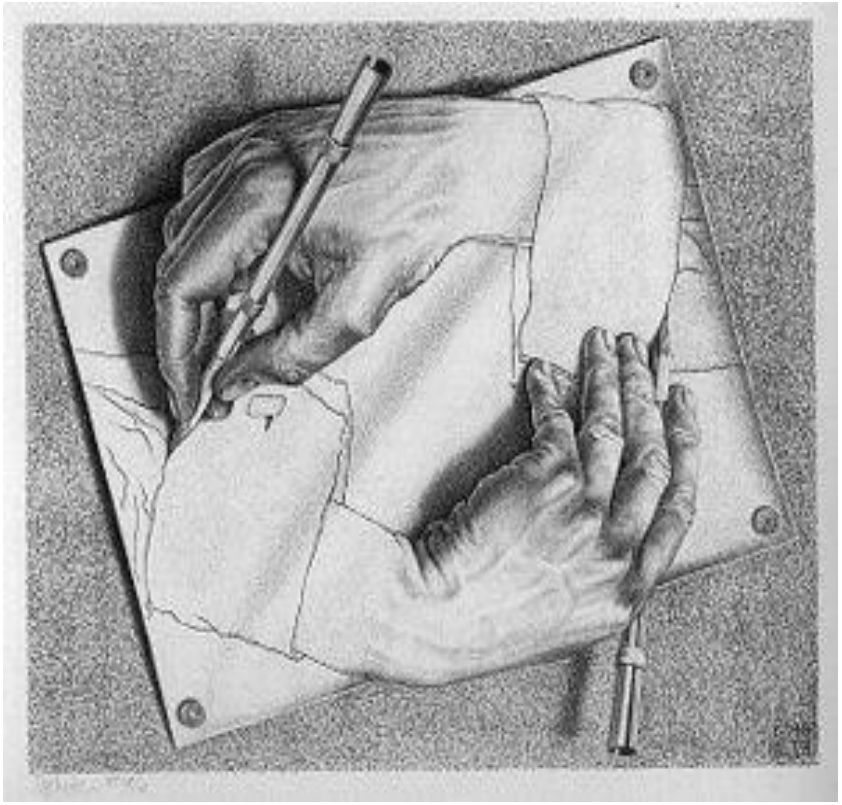
Direction of Light

Retina: Contains specialized cells: (photo) receptors *{converts light into electrical signals}*



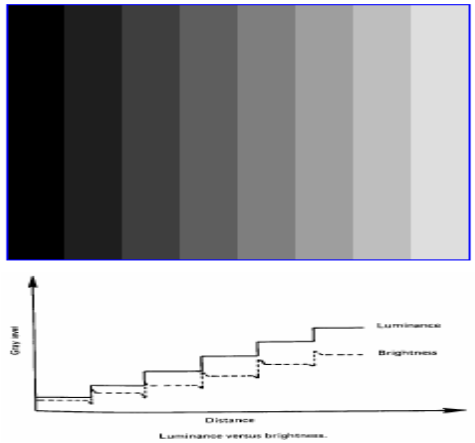
Rods – Black & White (Gray) images in low light (night) (Illumination sensitive)
Cones – Color Vision in bright light (day) (Color sensitive)

Human Perception

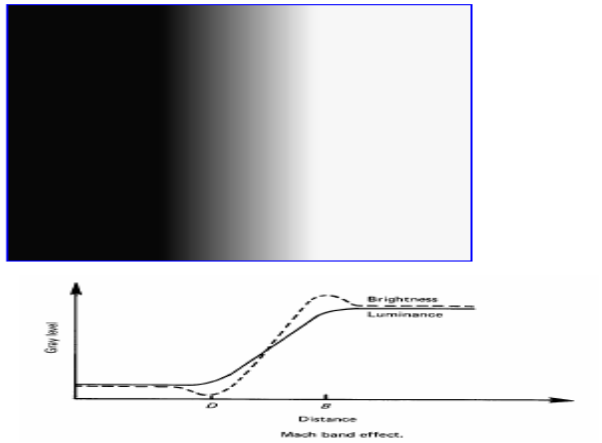


MACH Bands & Simultaneous Contrast

- Perceived brightness depends on **surroundings** as well as luminance



Luminance versus brightness.



Mach band effect.

The intensity of the stripes is constant but we actually perceive a brightness pattern which is strongly scalloped near the boundaries.

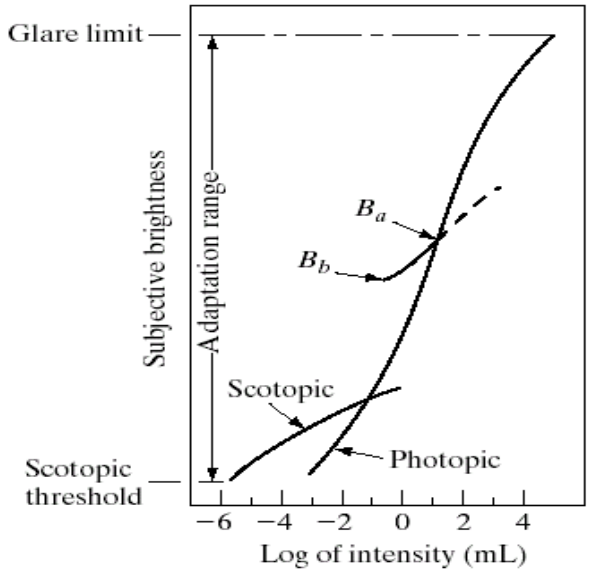
a b c

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.

Brightness Adaptation and Discrimination

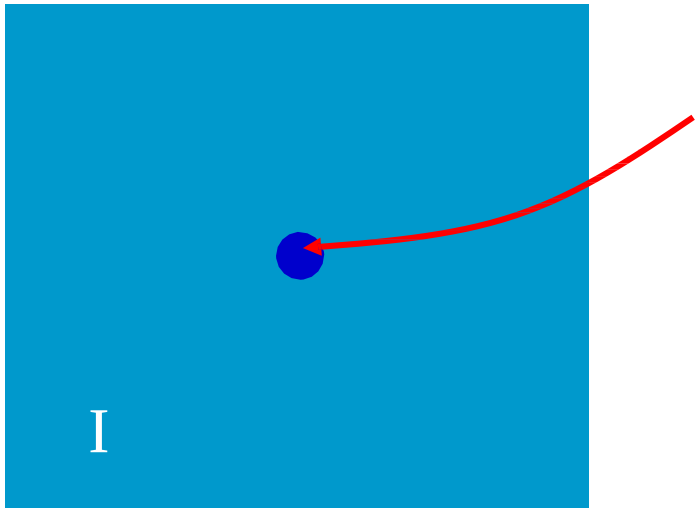
- The human visual system can perceive approximately 10^{10} different light intensity levels
- However at any one time we can only discriminate between a much smaller number – *brightness adaptation*

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



Human visual system cannot operate over such a high dynamic range simultaneously, But accomplish such large variation by changes in its overall sensitivity, a phenomenon called "brightness adaptation"

Contrast Sensitivity



Δ Ic= Increment of Illumination.
I= Backgroud Illumination.

Weber's ratio: $\Delta I_c/I$

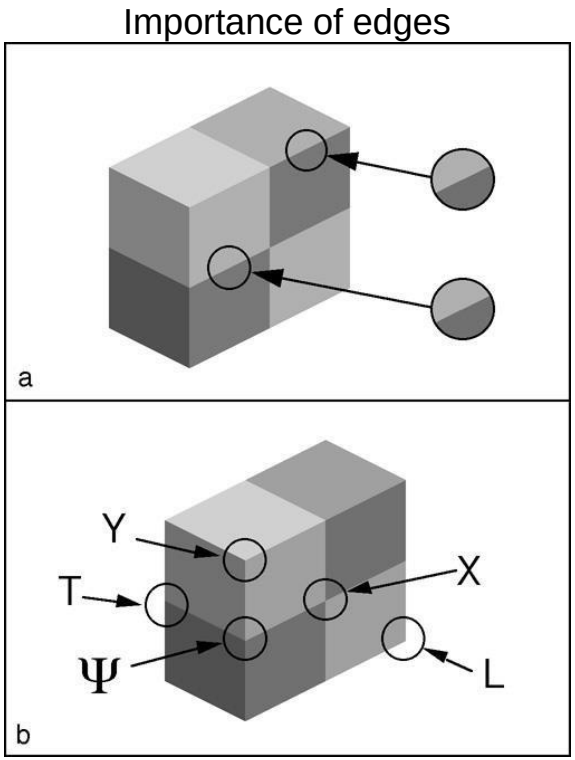
Good brightness discrimination

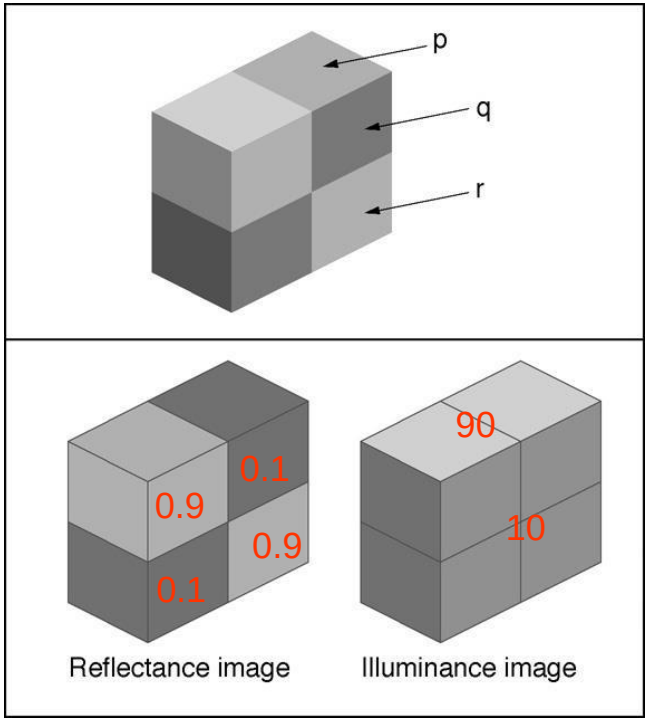
⇨ $\Delta I_c/I$ is small.

Bad brightness discrimination

⇨ $\Delta I_c/I$ is large.

Importance of Visual Context



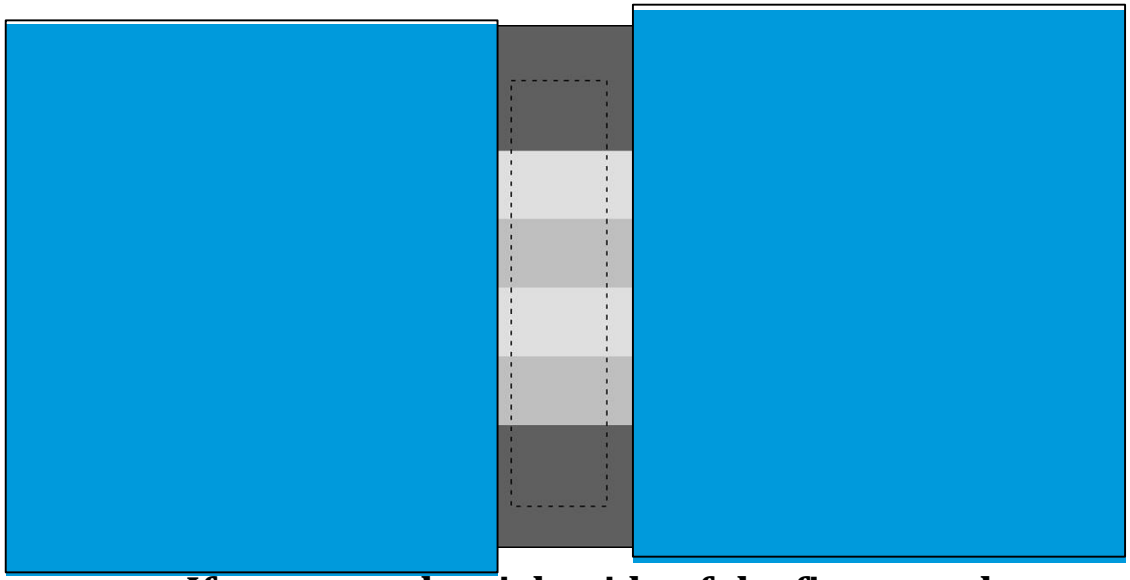


Patches p and q have the same reflectance, but different luminances.

Patches q and r have different reflectances and different luminances; they share the same illuminance.

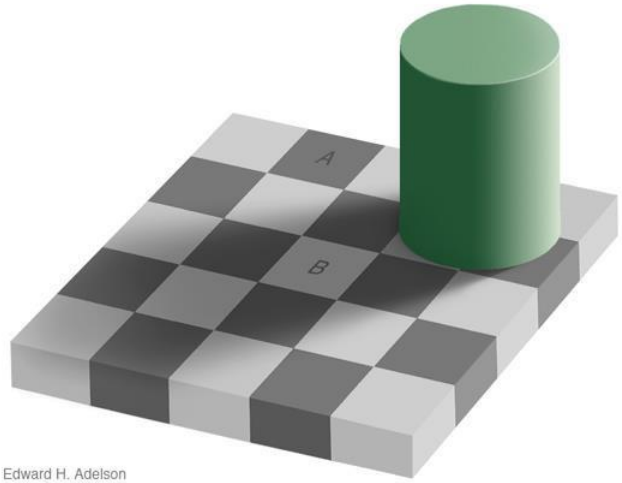
Patches p and r happen to have the same luminance, because the lower reflectance of p is counterbalanced by its higher illuminance.

Lightness Illusion



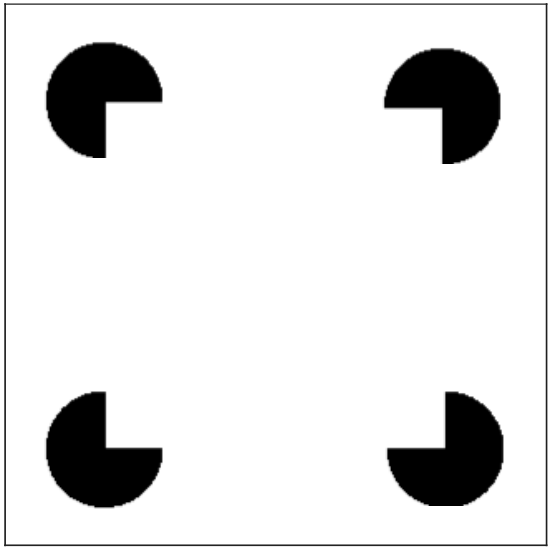
If we cover the right side of the figure and view the left side, it appears that the stripes are due to paint (reflectance). If we cover the left side and view the right, it appears that the stripes are due to different lighting on the stair steps (illumination).

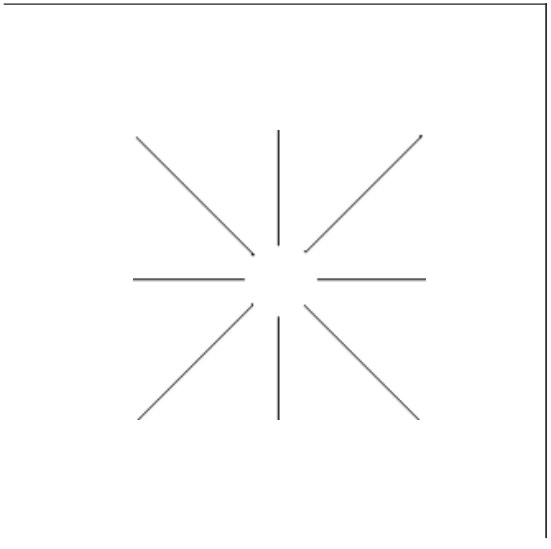
Another Lightness Illusion

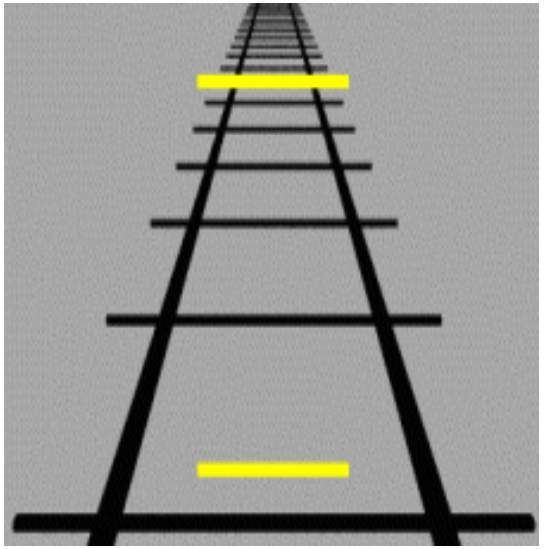


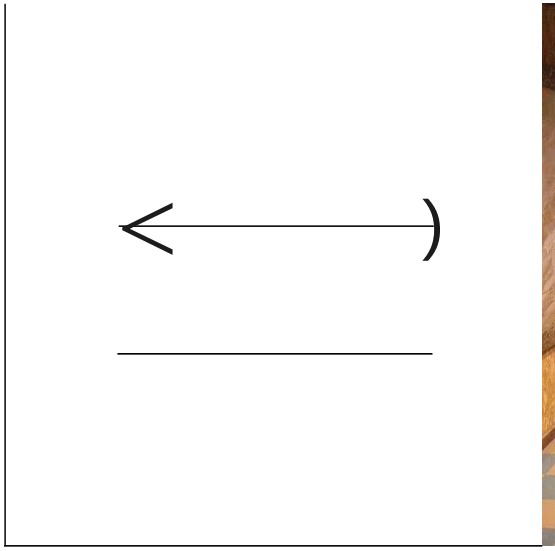
You will verify that A and B have exactly the same value.

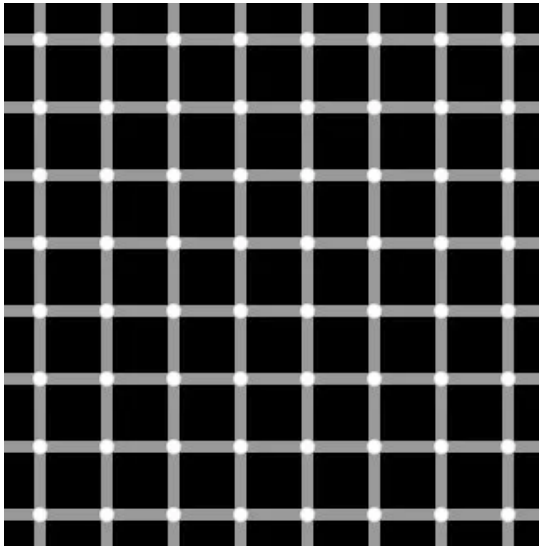
Optical Illusions



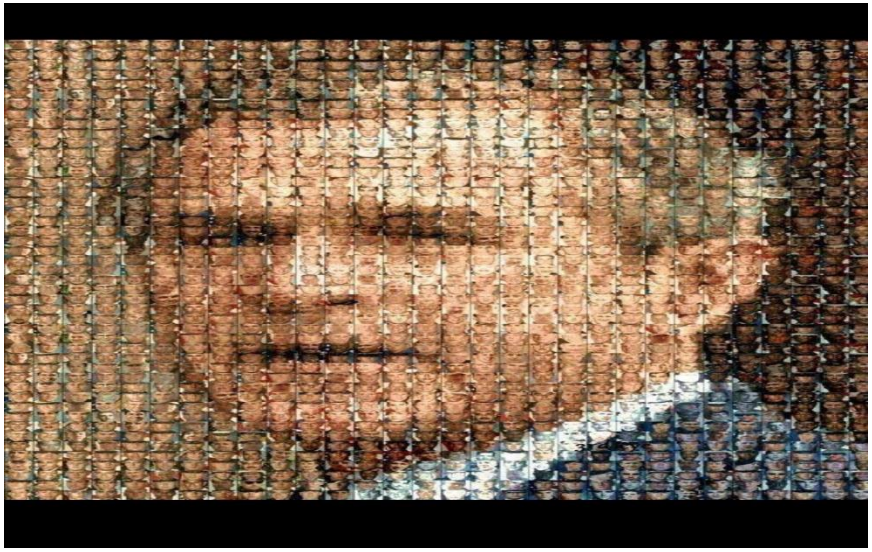








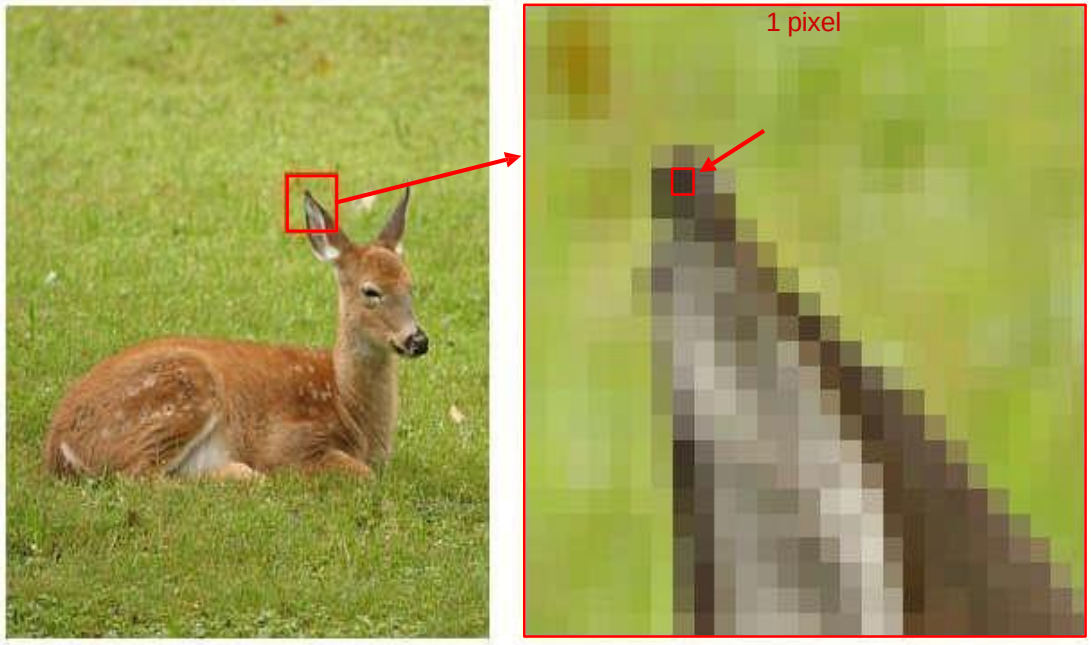
What is Digital Image?



Digital Image

a grid of squares, each of which contains a single color

each square is called a pixel (for *picture element*)

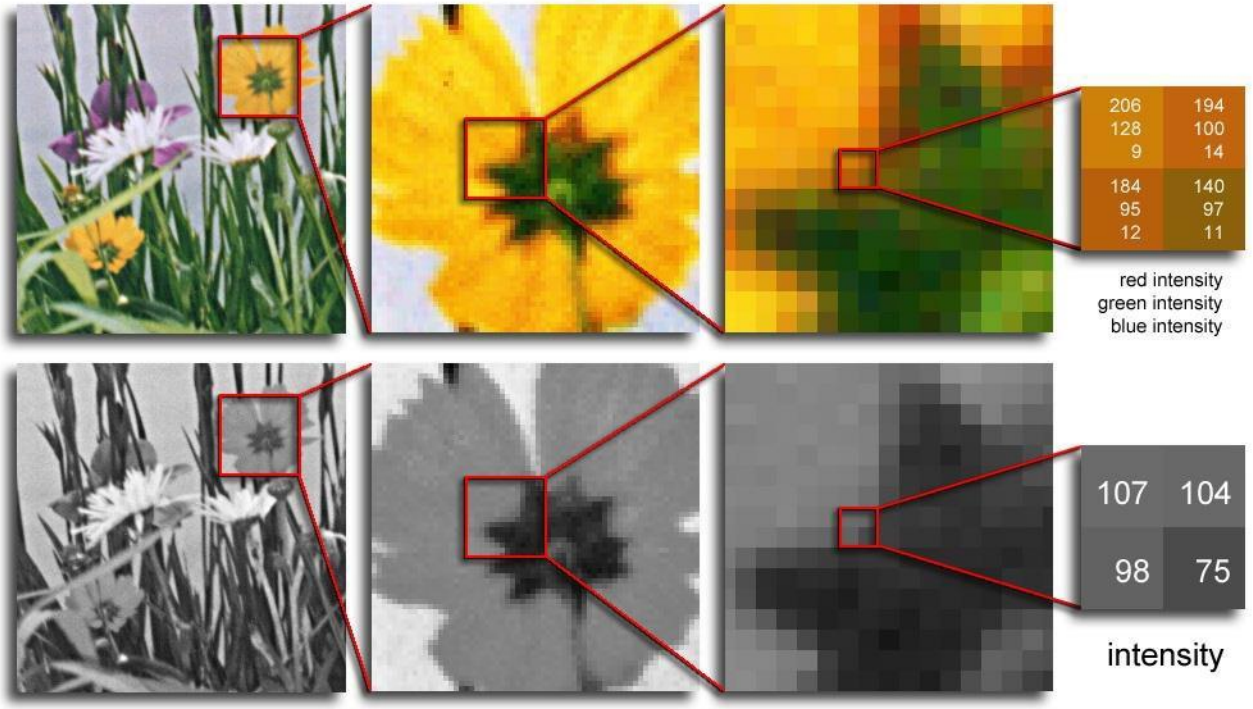


Digital Image

Color images have 3 values per pixel; monochrome images have 1 value per pixel.

a grid of squares, each of which contains a single color

each square is called a pixel (for *picture element*)

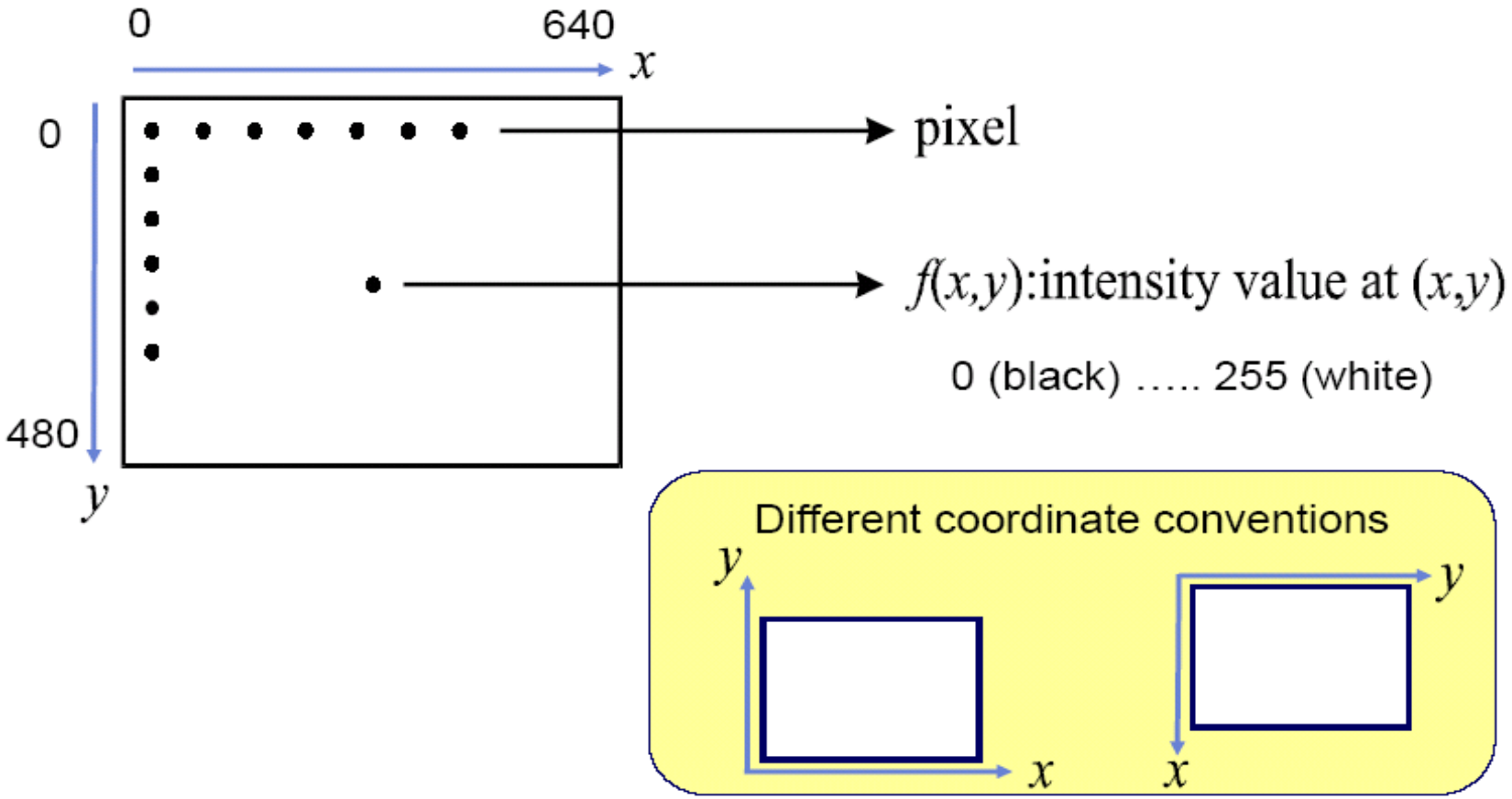


Digital Image

- **A set of pixels (picture elements, pels)**
- **Pixel means**
  - **pixel coordinate**
  - **pixel value**
  - **or both**
- **Both coordinates and value are discrete**

Example

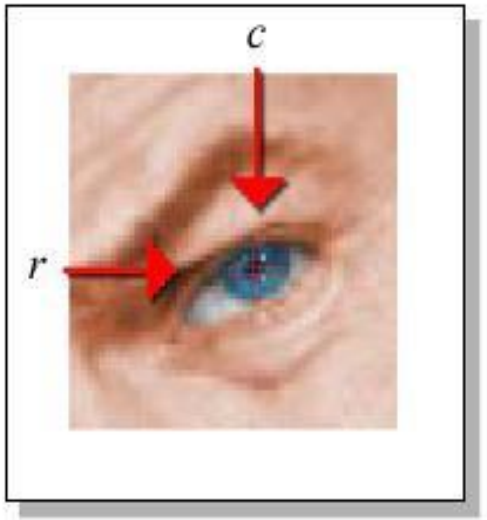
640 x 480 8-bit image

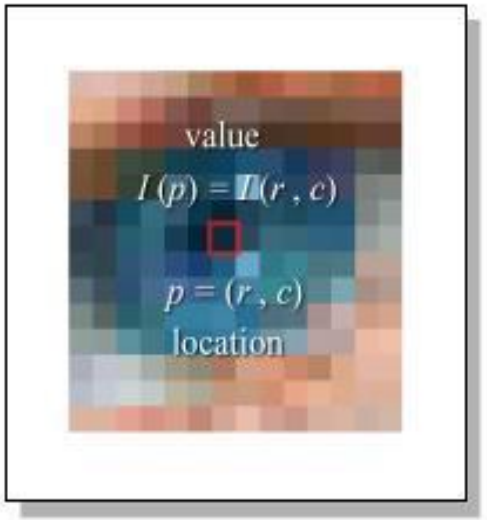


Pixels

- $p = (r,c)$ is the pixel location indexed by row, r, and column, c.
- $I(p) = I(r,c)$ is the value of the pixel at location p.
- If $I(p)$ is a single number then I is monochrome.
- If $I(p)$ is a vector (ordered list of numbers) then I has multiple bands (*e.g.*, a color image).

Pixels





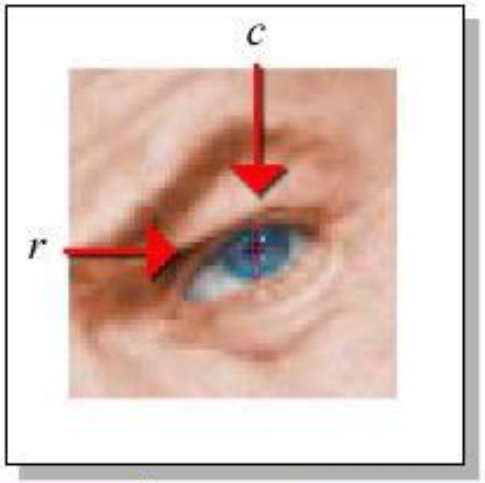
Pixel Location: $p = (r, c)$

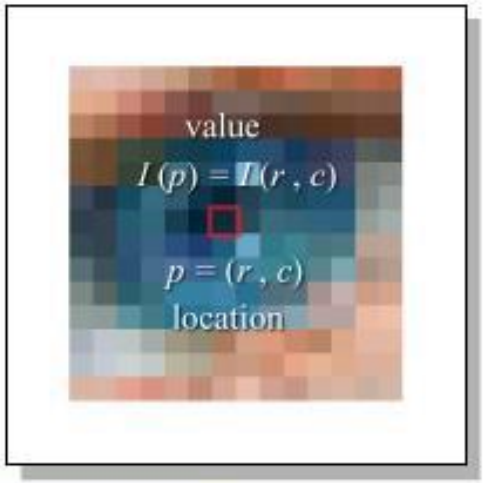
Pixel Value: $I(p) = I(r, c)$

Pixel : $[p, I(p)]$

Pixels

Pixel : $[p, I(p)]$

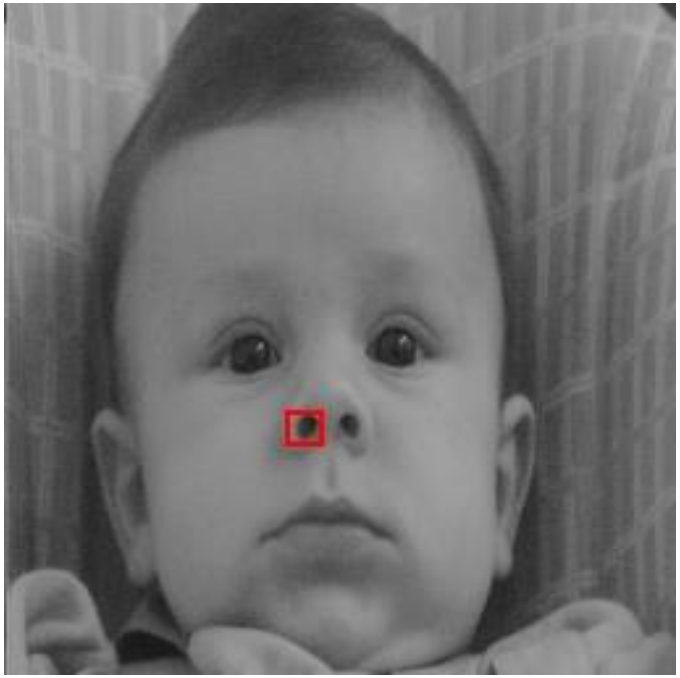




$$p = (r, c)$$
$$= (\text{row \#}, \text{col \#})$$
$$= (272, 277)$$

$$I(p) = \begin{bmatrix} \text{red} \\ \text{green} \\ \text{blue} \end{bmatrix} = \begin{bmatrix} 12 \\ 43 \\ 61 \end{bmatrix}$$

DIGITAL IMAGE REPRESENTATION



PIXEL VALUES IN HIGHLIGHTED REGION

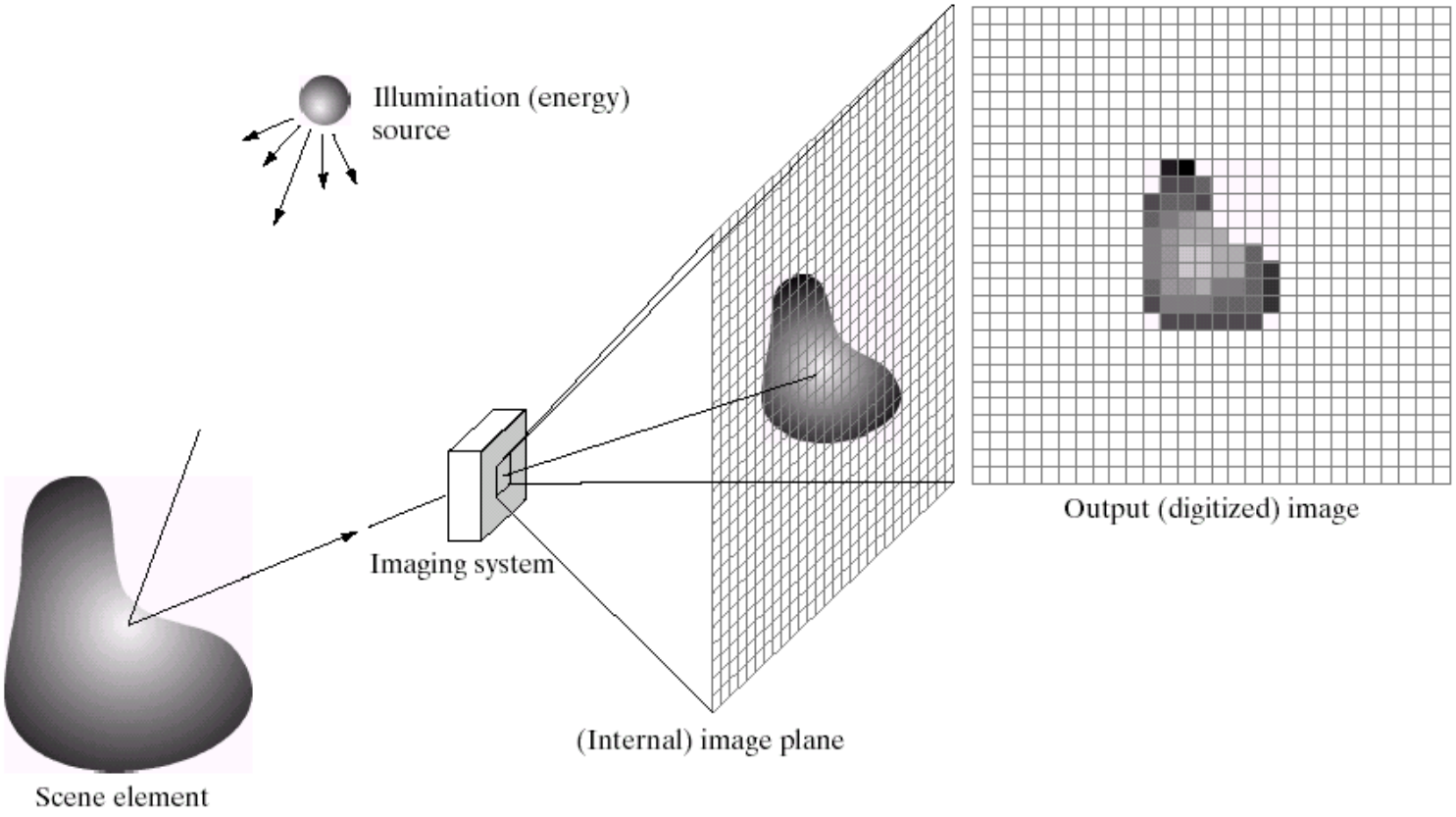
99	71	61	51	49	40	35	53	86	99
93	74	53	56	48	46	48	72	85	102
101	69	57	53	54	52	64	82	88	101
107	82	64	63	59	60	81	90	93	100
114	93	76	69	72	85	94	99	95	99
117	108	94	92	97	101	100	108	105	99
116	114	109	106	105	108	108	102	107	110
115	113	109	114	111	111	113	108	111	115
110	113	111	109	106	108	110	115	120	122
103	107	106	108	109	114	120	124	124	132

CAMERA ⇨ **DIGITIZER** ⇧ A set of number in 2D grid

Samples the analog data and digitizes it.

Image Acquisition & Formation

Image Acquisition



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.

Sampling and Quantization

- Sampling:
  - Digitization of the spatial coordinates (x,y)
  - Commonly used number of samples (resolution)
    - Digital still cameras: 640x480, 1024x1024, 4064 x 2704
    - Digital video cameras: 640x480 at 30 frames/second (fps)

- Quantization:
  - Digitization in amplitude (also known as gray level quantization)
  - 8 bit quantization: 2^8 =256 gray levels (0: black, 255: white)
  - 1 bit quantization: 2 gray levels (0: black, 1: white) – binary

Sampling and Quantization

- Digital Image is an approximation of a real world scene

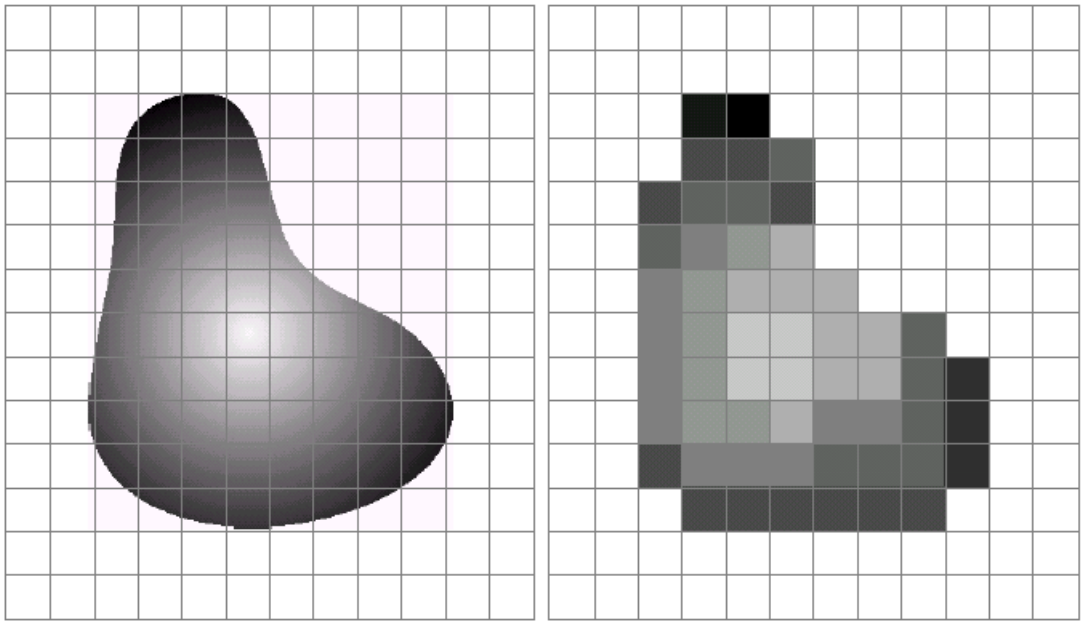


Image Formation

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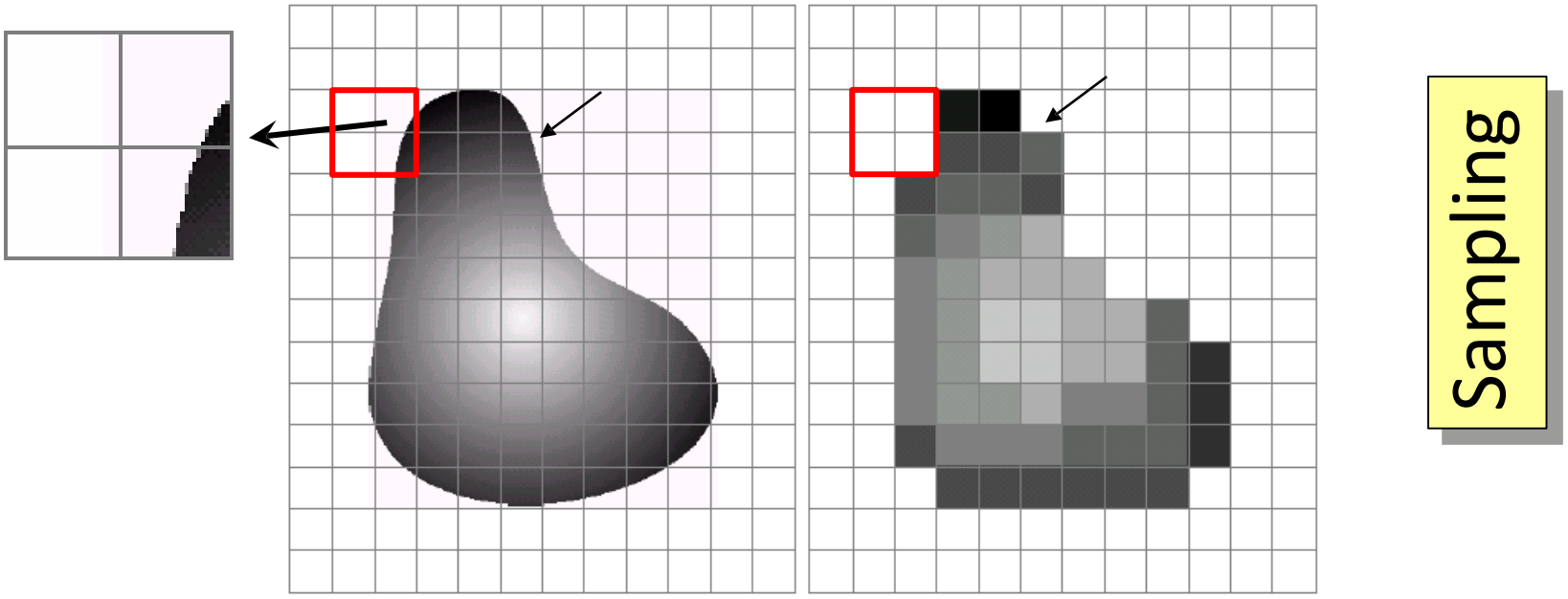
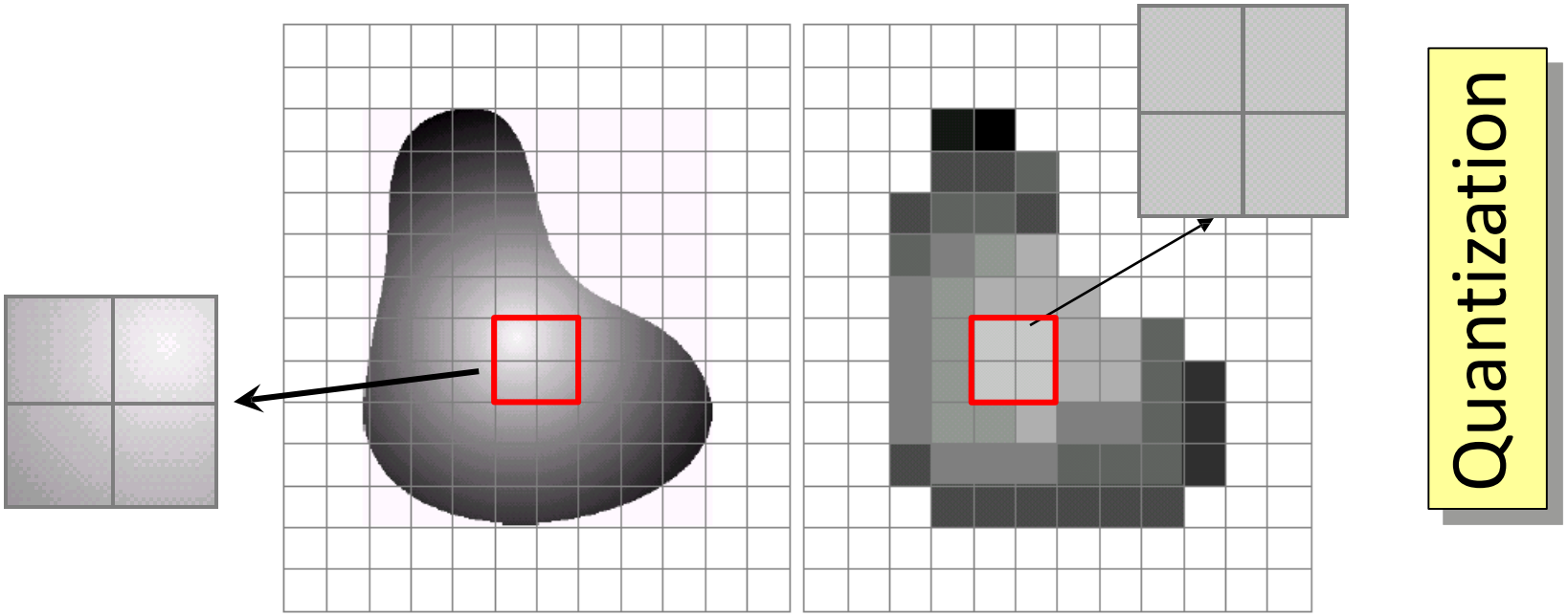
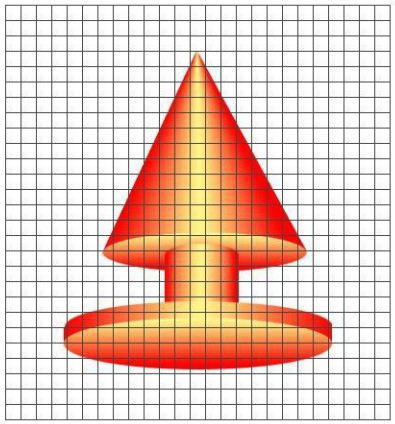


Image Formation

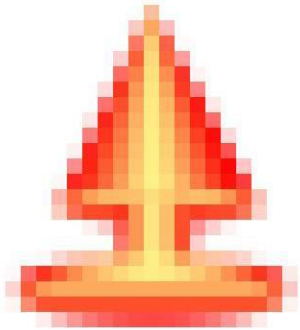
- Digital Image is an approximation of a real world scene



Sampling and Quantization



real image

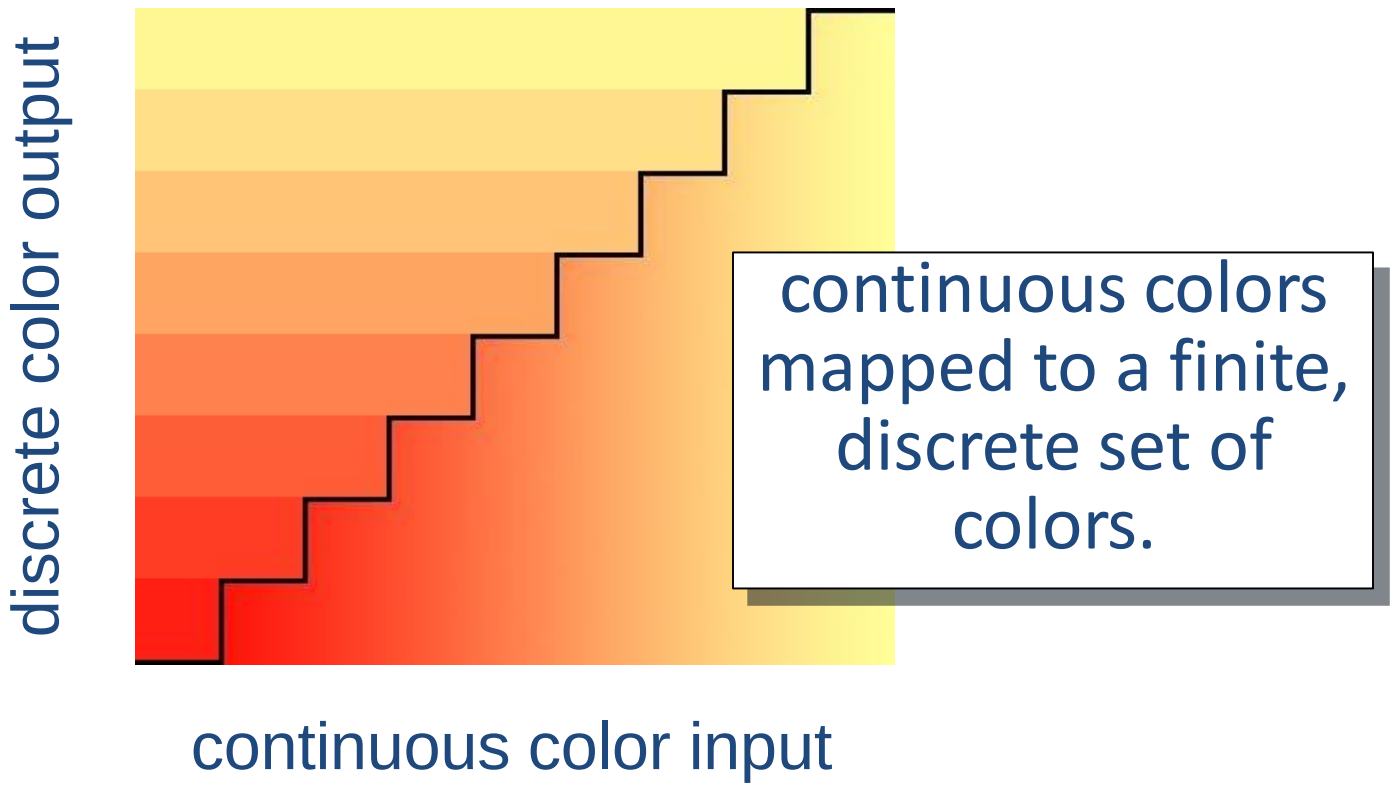


sampled

quantized

sampled & quantized

Image Formation - Quantization



References

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