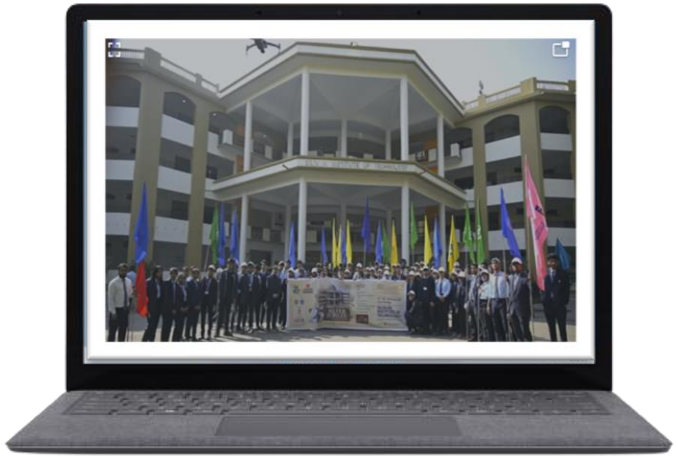  

Digital Image Fundamentals

Image Sensing, Image Acquisition, Sampling, Quantization, Résolutions

Visual Perception

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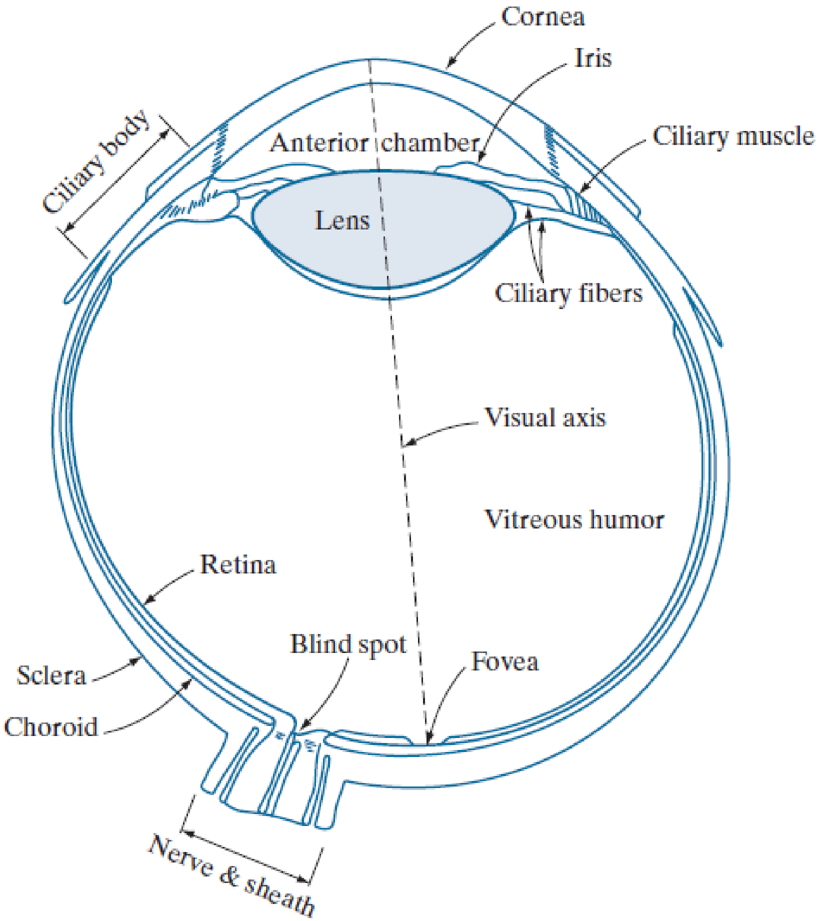
- The field of digital image processing is built on a foundation of mathematics, human intuition and analysis.
- Developing an understanding of the basic characteristics of human visual perception is the first step of digital image processing.

Structure of the human eye

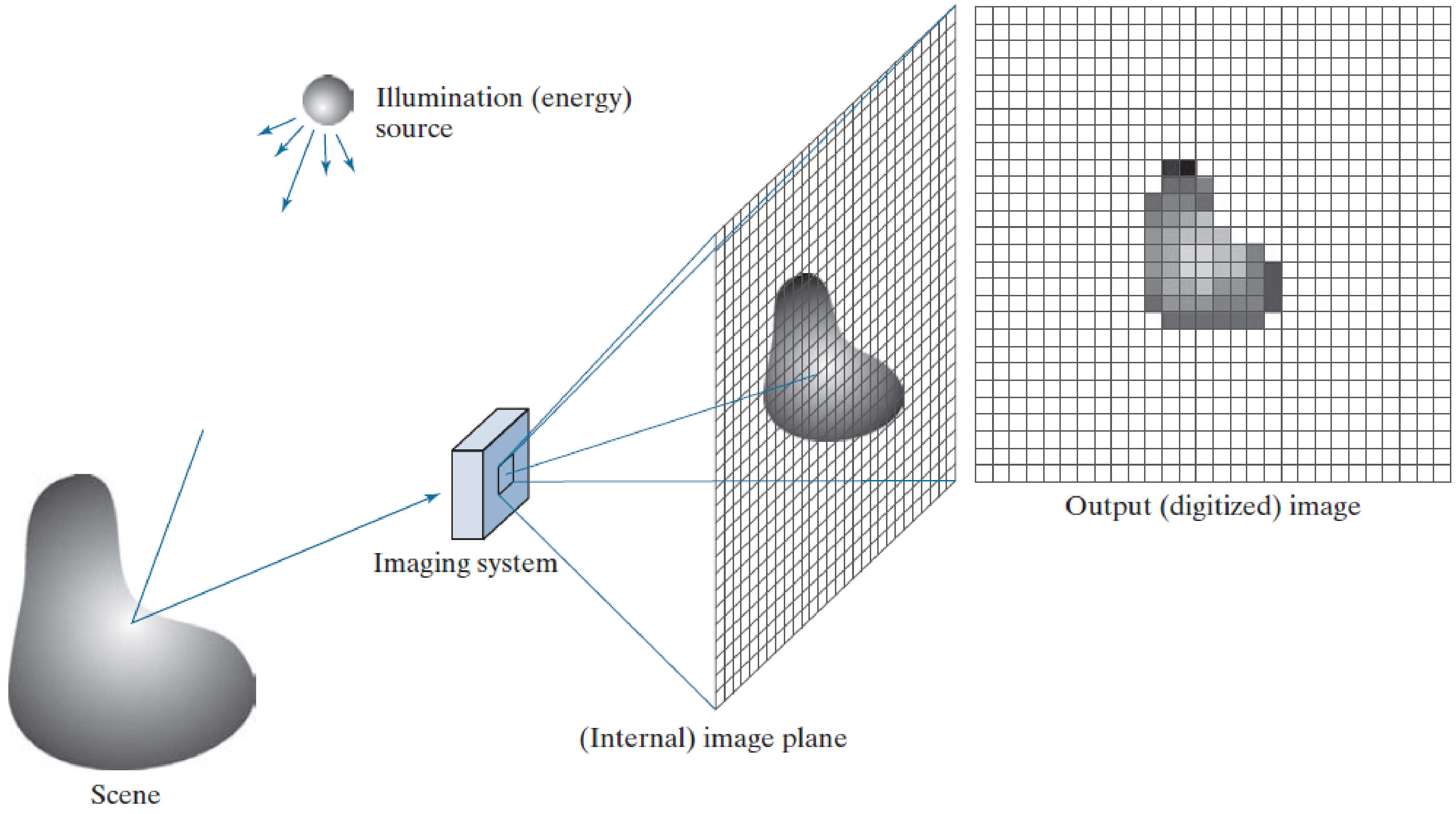


- The eye is nearly a sphere, with an average diameter of approximately 20 mm
- Three membranes enclose the eye
- the cornea and sclera outer cover
- the choroid
- the retina

Image Formation Model

- We denote images by two dimensional functions of the form $f(x, y)$.
- The value of f at spatial coordinates (x, y) is a scaler quantity whose physical meaning is determined by the source of the image, and whose values are proportional to energy radiated by a physical source.
- $f(x, y)$ nonnegative and finite.
- $0 \leq f(x, y) < \infty$

Image Formation Model



- Function f(x,y) is characterized by two components
- the amount of source illumination incident on the scene being viewed
- the amount of illumination reflected by the objects in the scene.
- The two function combined as a product to form f(x,y)
- $f(x, y) = i(x, y).r(x, y)$
- $0 < i(x, y) < \infty$
- $0 < r(x, y) < 1$

Image Sampling and Quantization

- To create a digital image, continuous sensed data is converted into a digital format. This requires two processes: Sampling and Quantization.
- Digitizing the coordinate values is called sampling.
- Digitizing the amplitude values is called quantization.

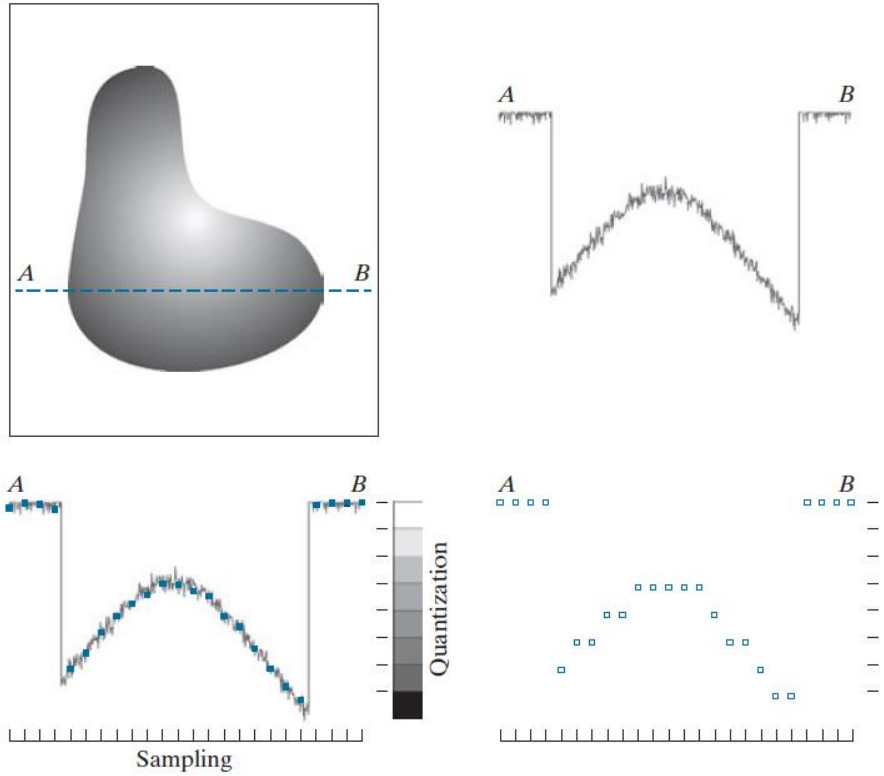


Image Sampling and Quantization

- The method of sampling is determined by the sensor arrangement used to generate the image.
- When an image is generated by a single sensing element combined with mechanical motion, the output of the sensor is quantized in the manner described earlier.

Representing Digital Images

- A digital image, $f(x, y)$, containing M rows and N columns, where (x, y) are discrete coordinates.
- For notational clarity and convenience integer values are used for these discrete coordinates: $x = 0, 1, 2,\dots,M - 1$ and $y = 0, 1, 2,\dots, N - 1$.
- The value of the digital image at the origin is $f(0,0)$, and its value at the next coordinates along the first row is $f(0,1)$.
- The value of a digital image at any coordinates (x, y) is denoted $f(x, y)$, where x and y are integers. The coordinates of an image is called the spatial domain

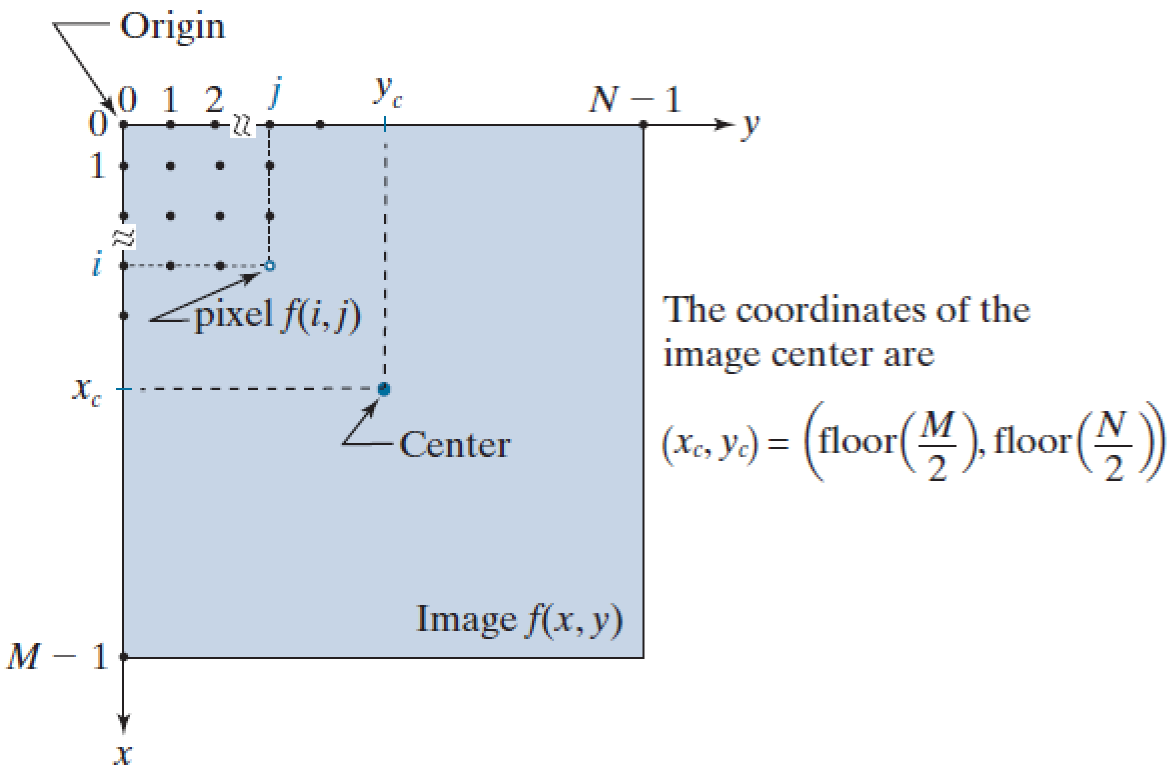
Representing Digital Images

- The right side of this equation is a digital image represented as an array of real numbers

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

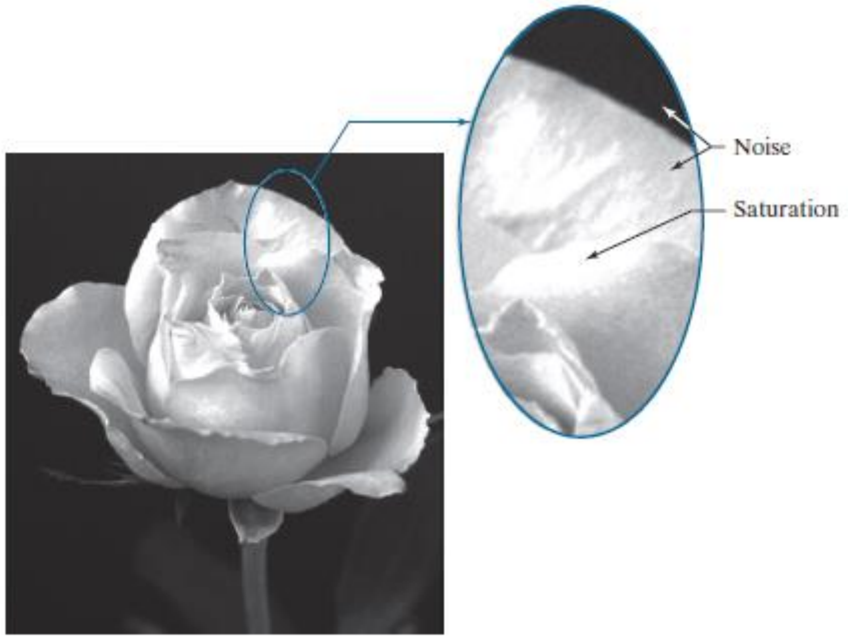
$$\mathbf{A} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

- A digital image is represented as $M \times N$ 2D array containing M rows and N columns.
- The number, b, of bits required to store a digital image is $b = M \times N \times k$, where 2^k intensity levels used for the pixels.



Dynamic range

- the range of values spanned by the gray scale is referred to as the dynamic range
- the upper limit is determined by saturation and the lower limit by noise, although noise can be present also in lighter intensities
- Dynamic range determines contrast of an image
- For a good contrast image dynamic range will be more



Storing an image

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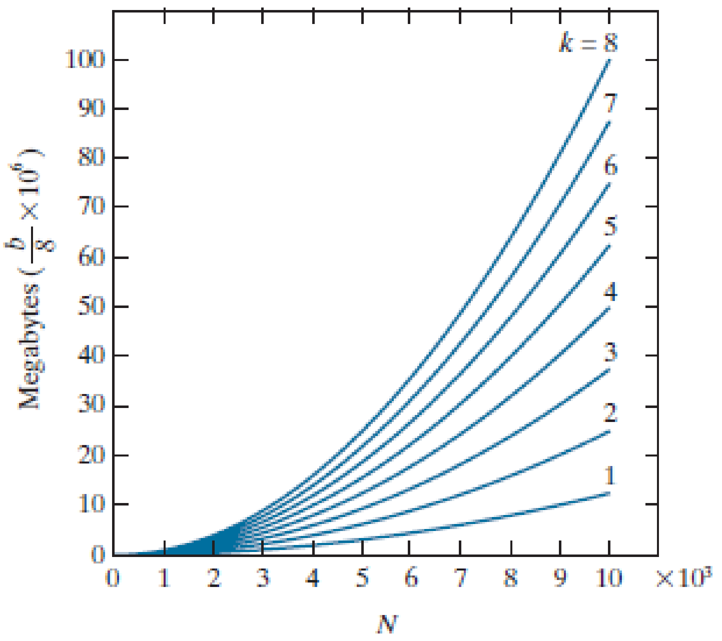
- The number, b, of bits required to store a digital image is $b = M \times N \times k$
- When $M = N$, this equation becomes $b = N^2 k$
- When an image can have 2^k possible intensity levels, it is common practice to refer to it as a "k-bit image," (e,g., a 256-level image is called an 8-bit image).
- Figure shows the number of megabytes required to store square images for various values of N and k

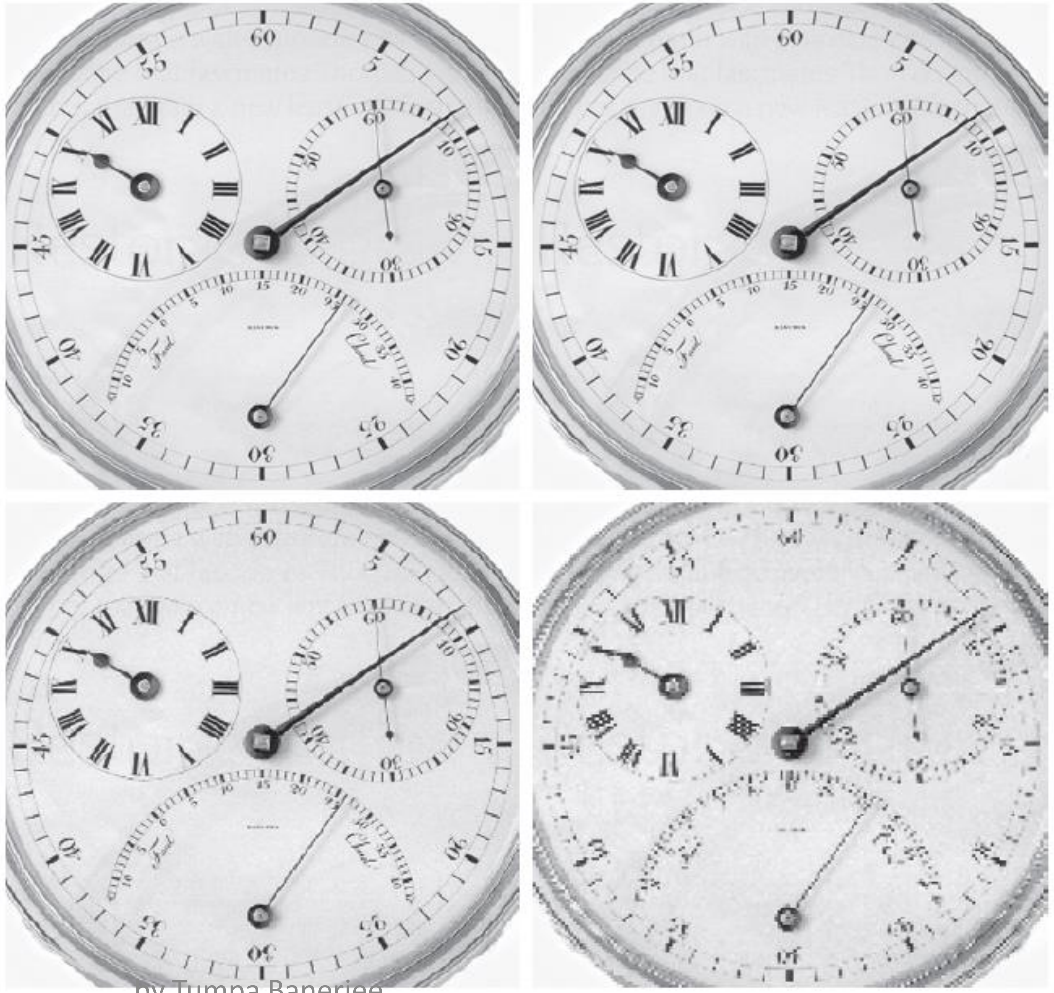


Resolution of an image

- Spatial resolution is a measure of the smallest discernible detail in an image. Quantitatively, spatial resolution can be stated in several ways, with line pairs per unit distance, and dots (pixels) per unit distance being common measures.
- Intensity resolution similarly refers to the smallest discernible change in intensity level.
- Temporal resolution defines number of frames per second, and is the property for video.

Effects of reducing spatial resolution.

- Dots per unit distance is a measure of image resolution used in the printing and publishing industry.



ab

cd

(a) 930 dpi,

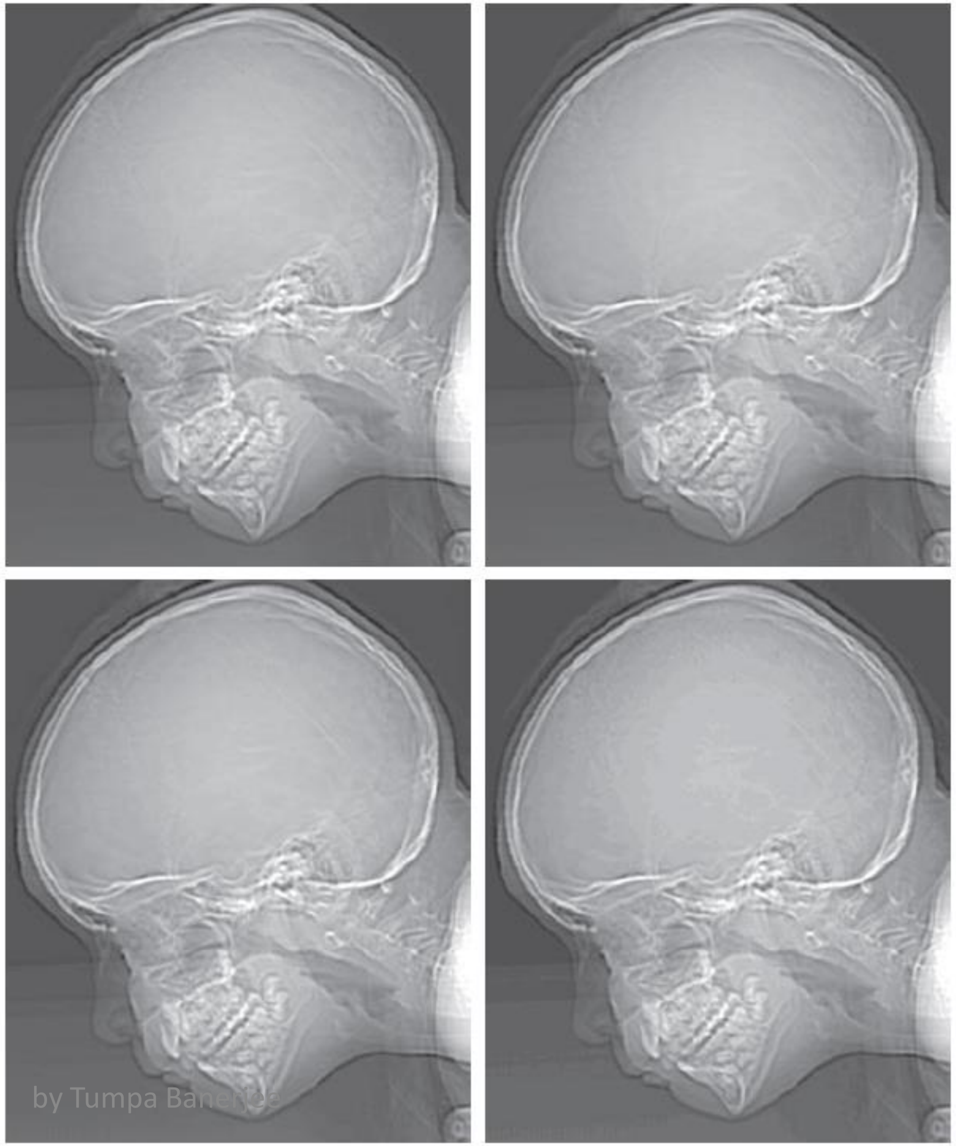
(b) 300 dpi,

(c) 150 dpi, and

(d) 72 dpi.

Effects of reducing Intensity resolution

- The 128- and 64-level images are visually identical for all practical purposes.
- The 32-level image in Fig (d) has a set of almost imperceptible, very fine ridge-like structures in areas of constant intensity. levels



ab

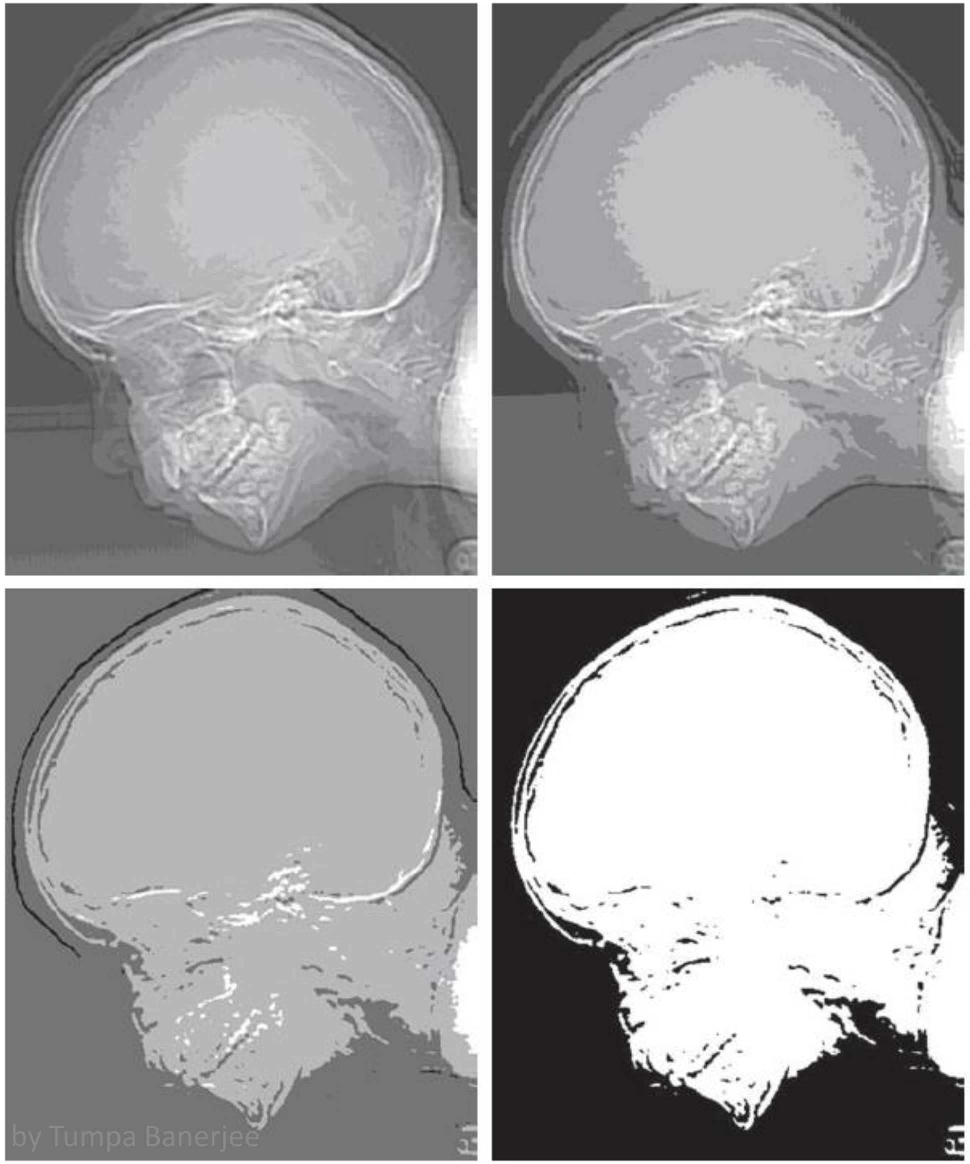
cd

(a) 774 × 640, 256-level image.

(b)-(d) Image displayed in 128, 64, and 32 intensity levels

Effects of reducing Intensity resolution

- These structures are clearly visible in the 16-level image in Fig. (e).
- This effect, caused by using an insufficient number of intensity levels in smooth areas of a digital image, is called false contouring, so named because the ridges resemble topographic contours in a map.



ef

gh

(e)-(h) Image displayed in 16, 8, 4, and 2 intensity levels.

Image Interpolation

- Interpolation is used in tasks such as zooming, shrinking, rotating, and geometrically correcting digital images.
- Interpolation is the process of using known data to estimate values at unknown locations.

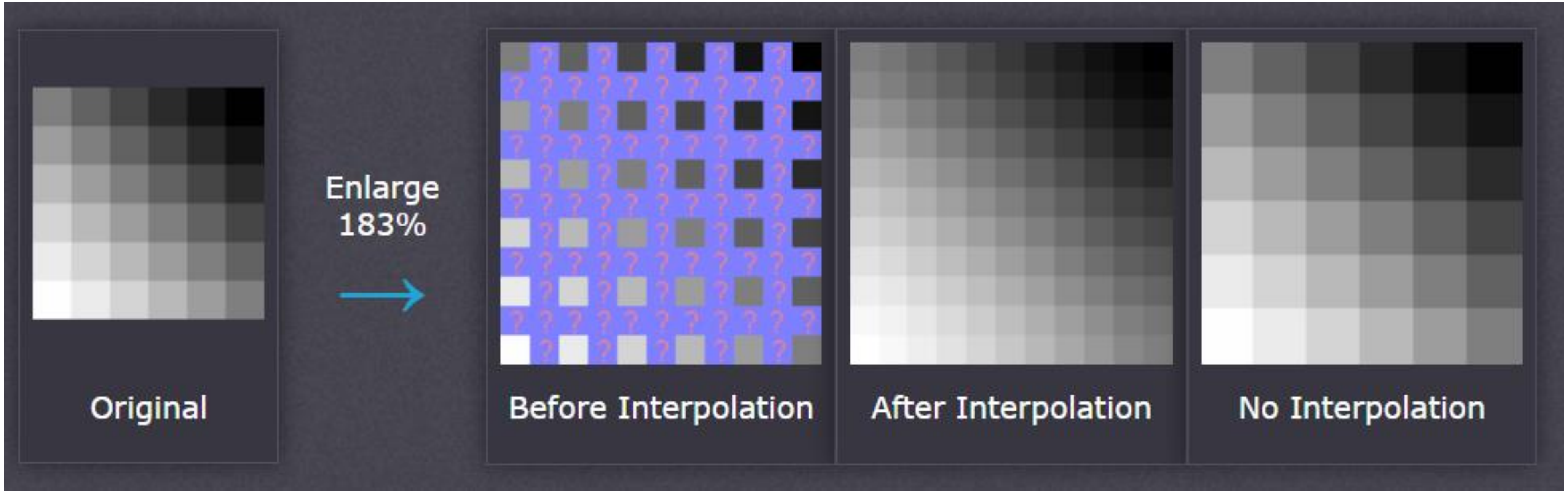


Image Interpolation

- nearest neighbor interpolation assigns the intensity of its nearest neighbor in the original image to each new location.
- This approach is simple but, it tends to produce undesirable artifacts, such as severe distortion of straight edges.
- bilinear interpolation uses the four nearest neighbors to estimate the intensity at a given location.
- takes the weighted average of these values to assign the unknown pixel.

Image Interpolation

- bicubic interpolation involves the sixteen nearest neighbors of a point.
- Since the known pixels are at various distances from the unknown pixel, closer pixels will give higher weighting.

Reference

- E Woods, Richard, and Rafael C Gonzalez. "Digital image processing." (2008).