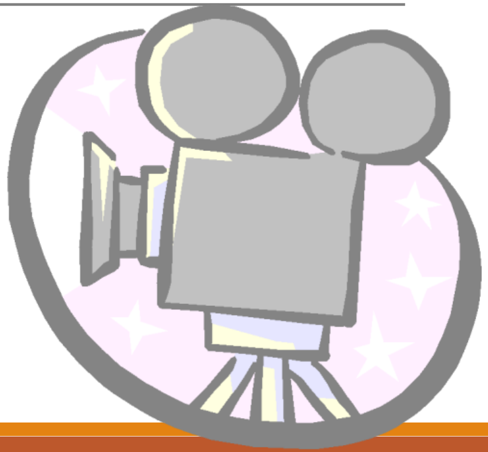
Image Processing

CS-317/CS-341



Outline

- Image Sampling and Quantization
- Digital Image Representation
- Spatial and Gray -Level Resolution

Light and electromagnetic Spectrum

Frequency (ν) and **wavelength** (λ) are joined by the equation $\lambda = c/\nu$, where c is the speed of light.

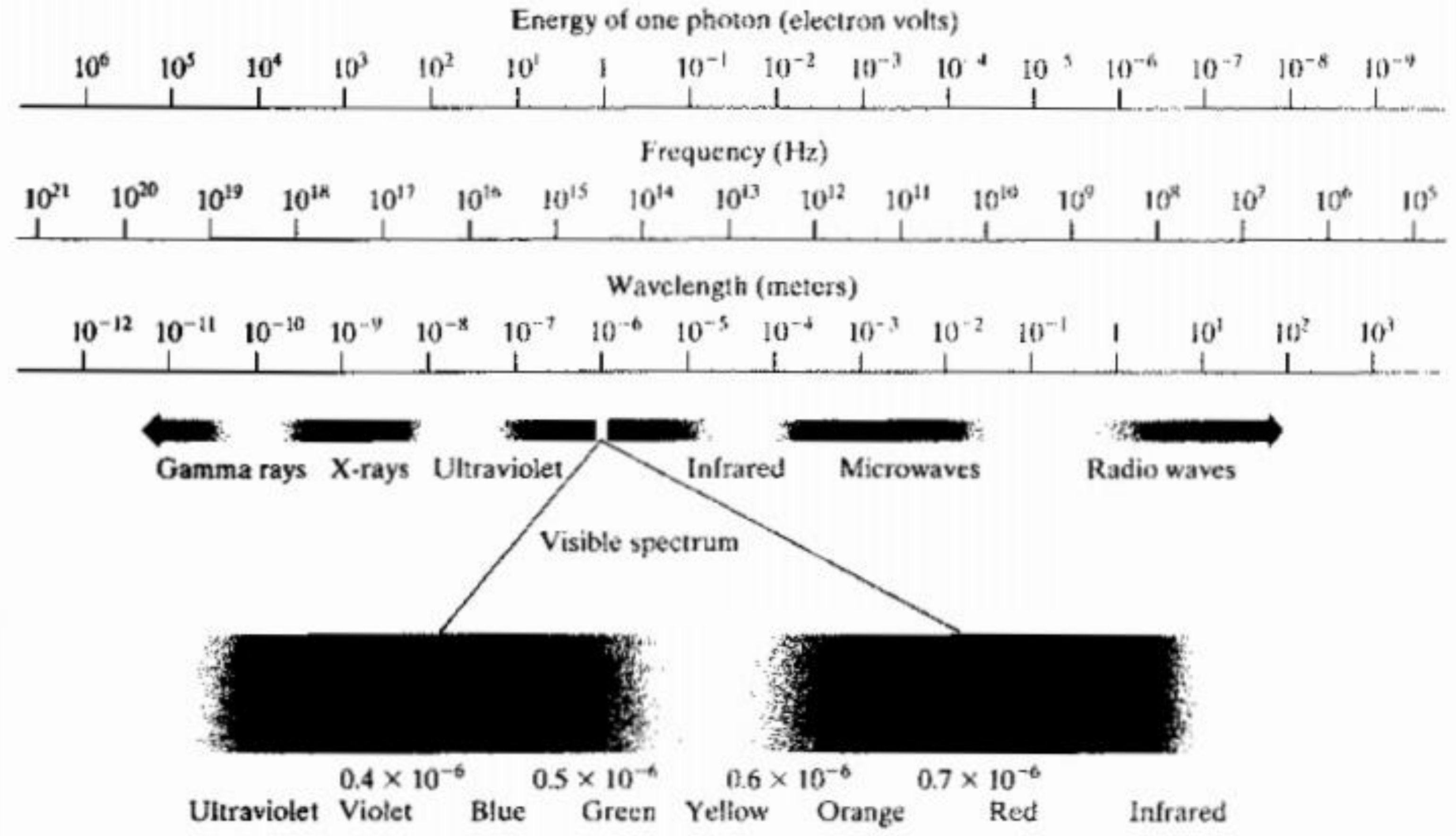


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

The energy of various Components of electromagnetic Spectrum is given by

$E=h\nu$

Where, h is Plank's constant

Image Sampling And Quantization

For computer processing, an image function needs to be digitized both ***spatially and in amplitude***.

- ***Image Sampling*** – Digitization of the spatial coordinates ***(x,y)***
- ***Gray-level quantization*** – Digitization of Amplitude
- For sampling for 2-D sensor array is needless

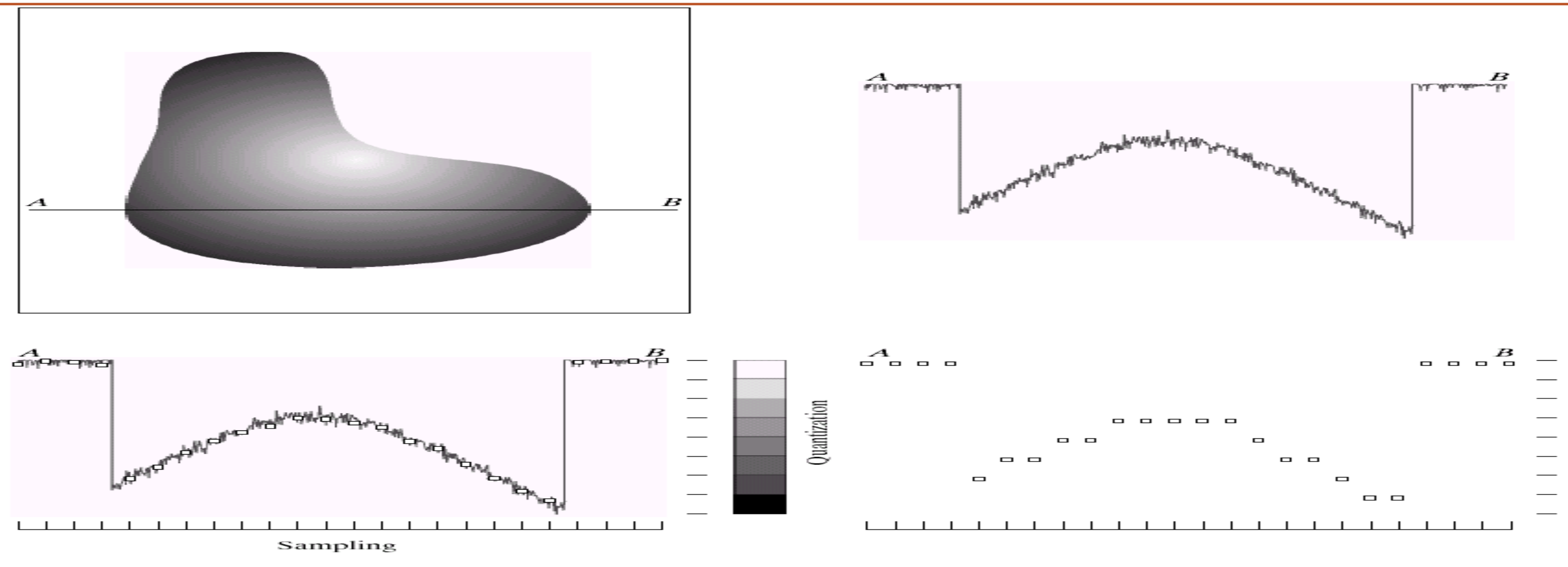


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image Sampling And Quantization

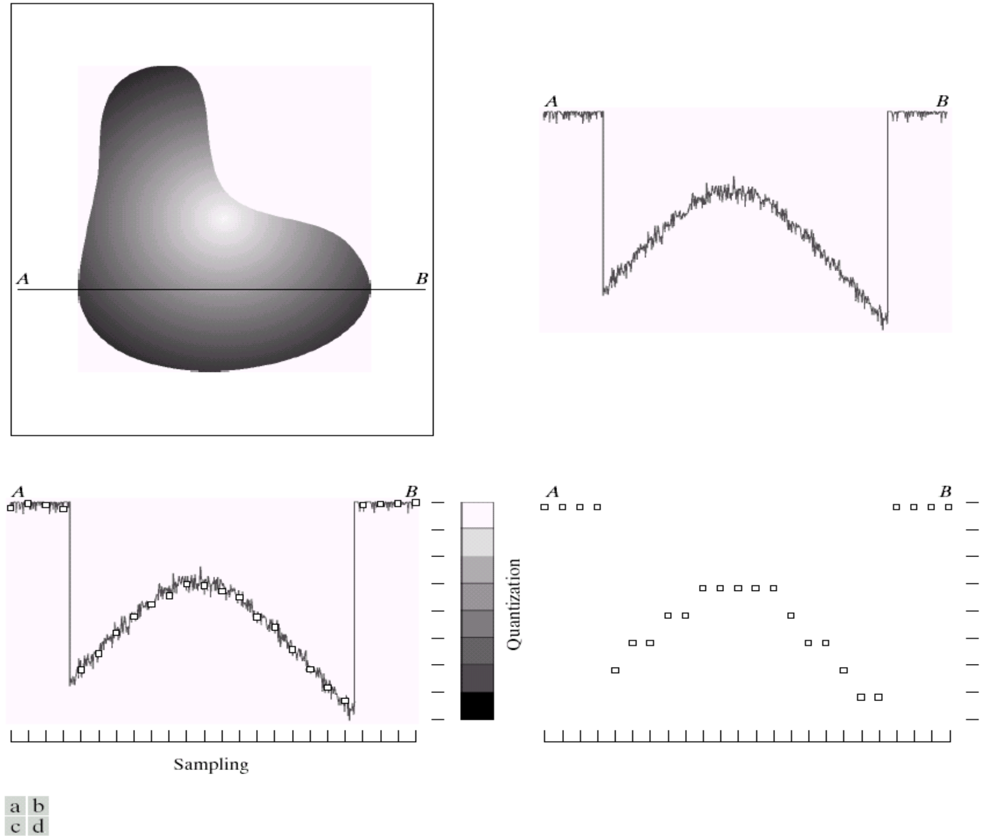


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

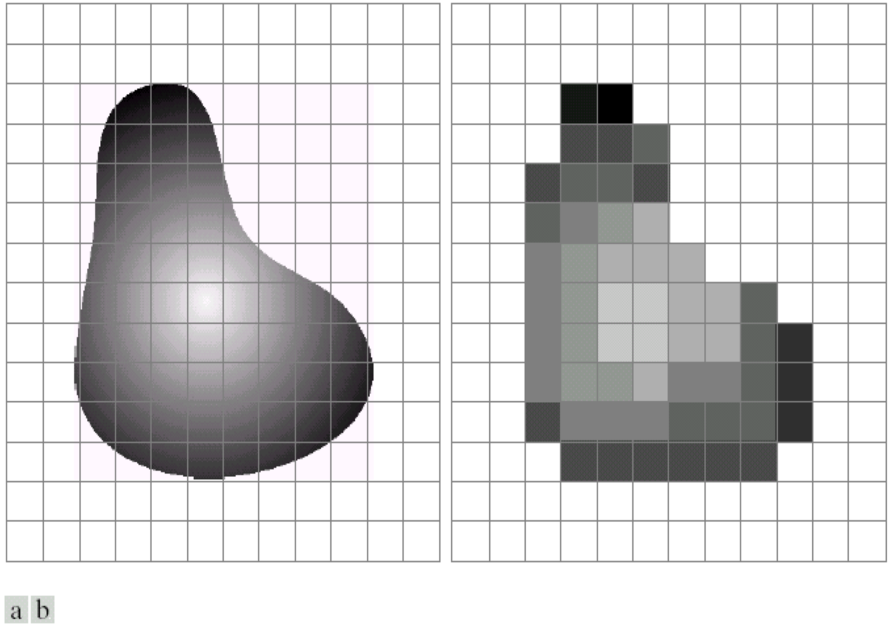


FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

A Simple Image Formation Model

Light Intensity Function

- **Image** - two dimensional light intensity function, denoted by ***f(x,y)*** , where the value or amplitude of ***f*** at spatial coordinates ***(x,y)*** gives the intensity (brightness) of the image at that point.

Perception of an object : Light reflected from that object

f(x,y) can be characterized by two components

1. The amount of source light incident on the scene being viewed

   Illumination component - *i(x,y)*

2. Amount of light reflected by the objects in the scene

   Reflectance component - *r(x,y)*

$$f(x,y) = i(x,y)r(x,y)$$
$$0 \leq i(x,y) < \infty$$
$$0 \leq r(x,y) \leq 1$$

- Physical meaning of *f* is determined by the source of the image i.e. *i(x,y).*
- *r(x,y)* is determine by the characteristics of the imaged object.

Image Formation Model

Light Intensity Function

- Reflectance is bounded by ***0 (total absorption)*** and ***1 (total reflectance)***

- The nature of ***i(x,y)*** is determined by the light source and ***r(x,y)*** is determined by the characteristics of the objects in a scene.

***i(x,y)*:**
Clear Day – 90,000 lm/m^2
Cloudy day - 10,000 lm/m^2
Full moon - 0.1 lm/m^2
commercial office - 1,000 lm/m^2

Typical values of ***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

Grey Level (l) at point (x,y)
- Intensity of monochrome image ***f*** at coordinates ***(x,y)***

Image Formation Model

Light Intensity Function

- we call the intensity of a monochrome image ***f at*** coordinate ***(x,y) the gray level (l) of the image*** at that point.

  thus, ***l*** lies in the range $L_{min} < l < L_{max}$
- L_{min} *is positive and* L_{max} *is finite.*

  gray scale = [L_{min}, L_{max}]
- common practice, shift the interval to [***0, L-1***]
- ***0 = black , L-1 = white***
- All intermediate values are shades of gray varying from black to white.

Digital Image Representation

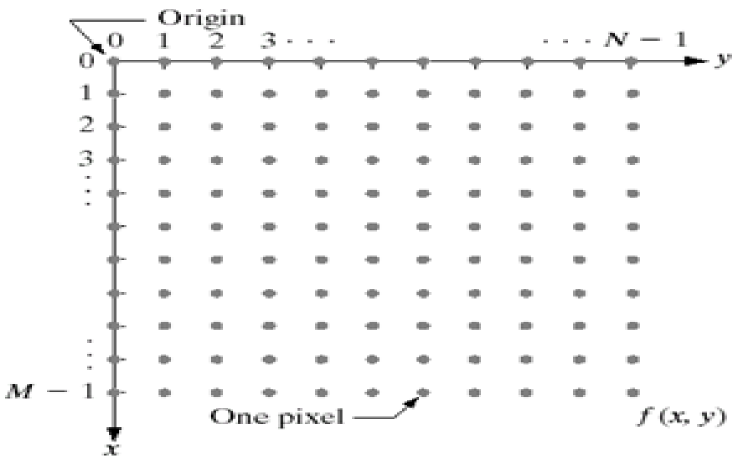
A ***digital image*** can be considered a ***matrix*** whose ***row and column indices*** identify a ***point*** in the image and the corresponding ***matrix element value*** identifies the ***gray level*** at that point.

- Definition of coordinate system
- Dynamic range of an image

  - the range of values spanned by the gray levels of existing pixels
- Spatial resolution (e.g., dpi, or 1024x1024)
- Gray-level resolution (8 (often visual), 10, 12 (e.g., thermal), or 16 bits / sample)

Digital Image Representation

Coordinate System & Matrix Representation



Continuous image *f(x,y)* – Equally spaced samples arranged as ***(N x M)*** array (matrix). ***Each element in the array is a discrete quantity***.

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

Digital Image

Image Element (pixel)

Digital Image Representation …

Need to decide the values for **N, M** and number of discrete gray levels allowed for each pixel **(G).**

In Digital Image Processing only restriction on M, N is that they are positive integer, however due to processing, storage, and sampling hardware consideration we take them is an ***integer power of 2***:

$$N = 2^n$$

$$M = 2^k$$

$$G = 2^m$$

G: No. of gray levels and it is assumed that these levels are equally spaced between ***0 and L*** =G-1 in the gray scale.

Amount of storage required to store a digitized image

$$\mathbf{b = N \times M \times k} \quad \text{(bits)}$$

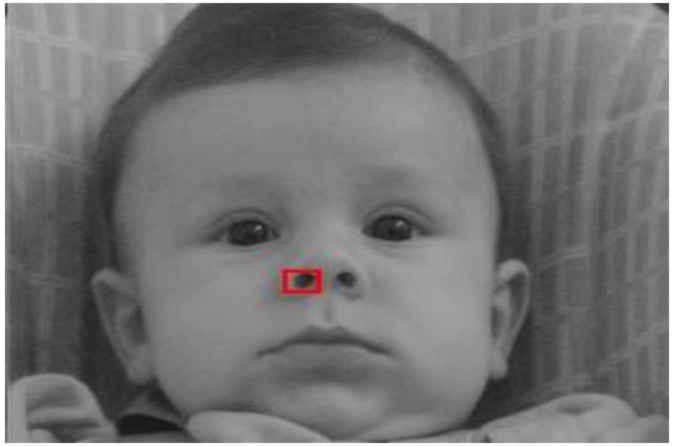
If **M=N, b = N^2k**

Digital Image Representation …

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

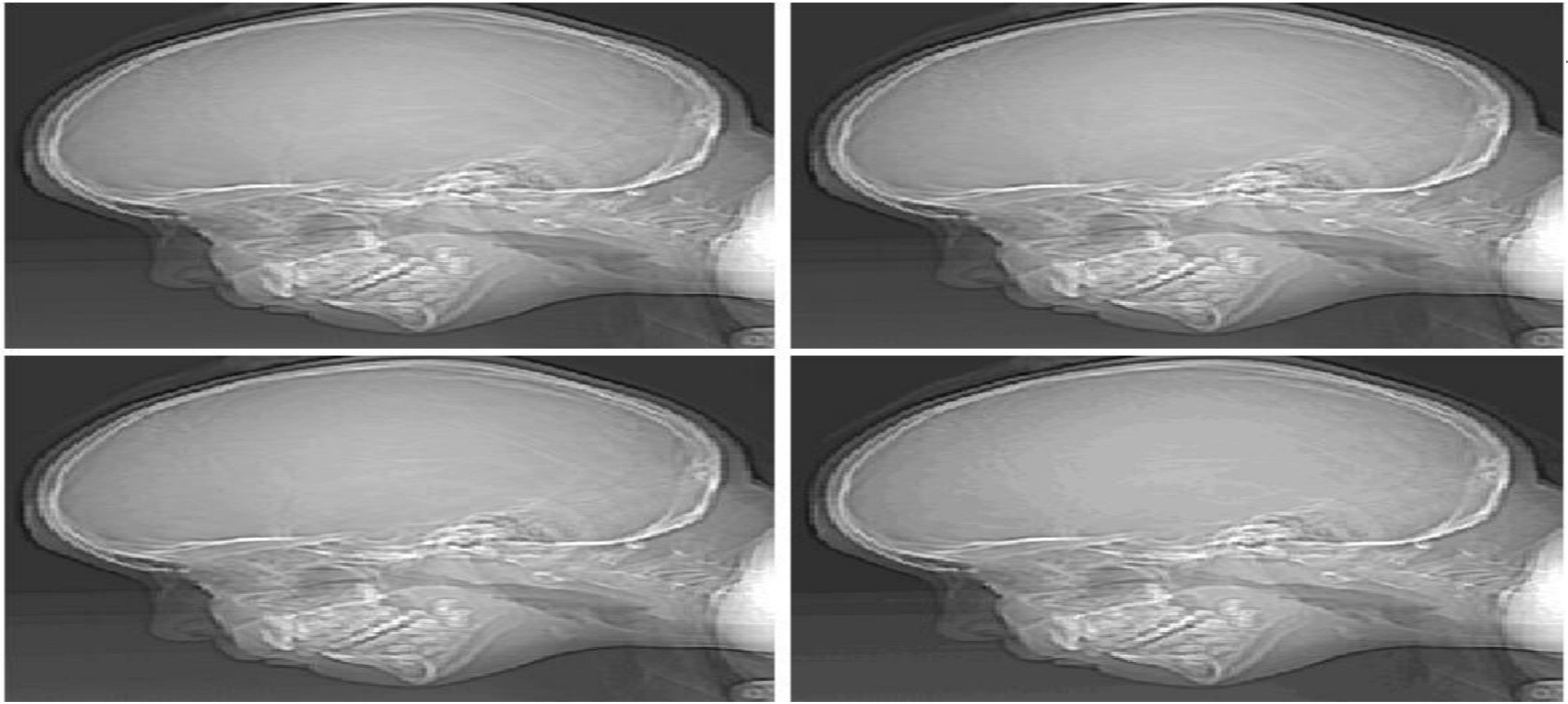
Pixel values in highlighted region:



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

Resolution (Gray -Level)

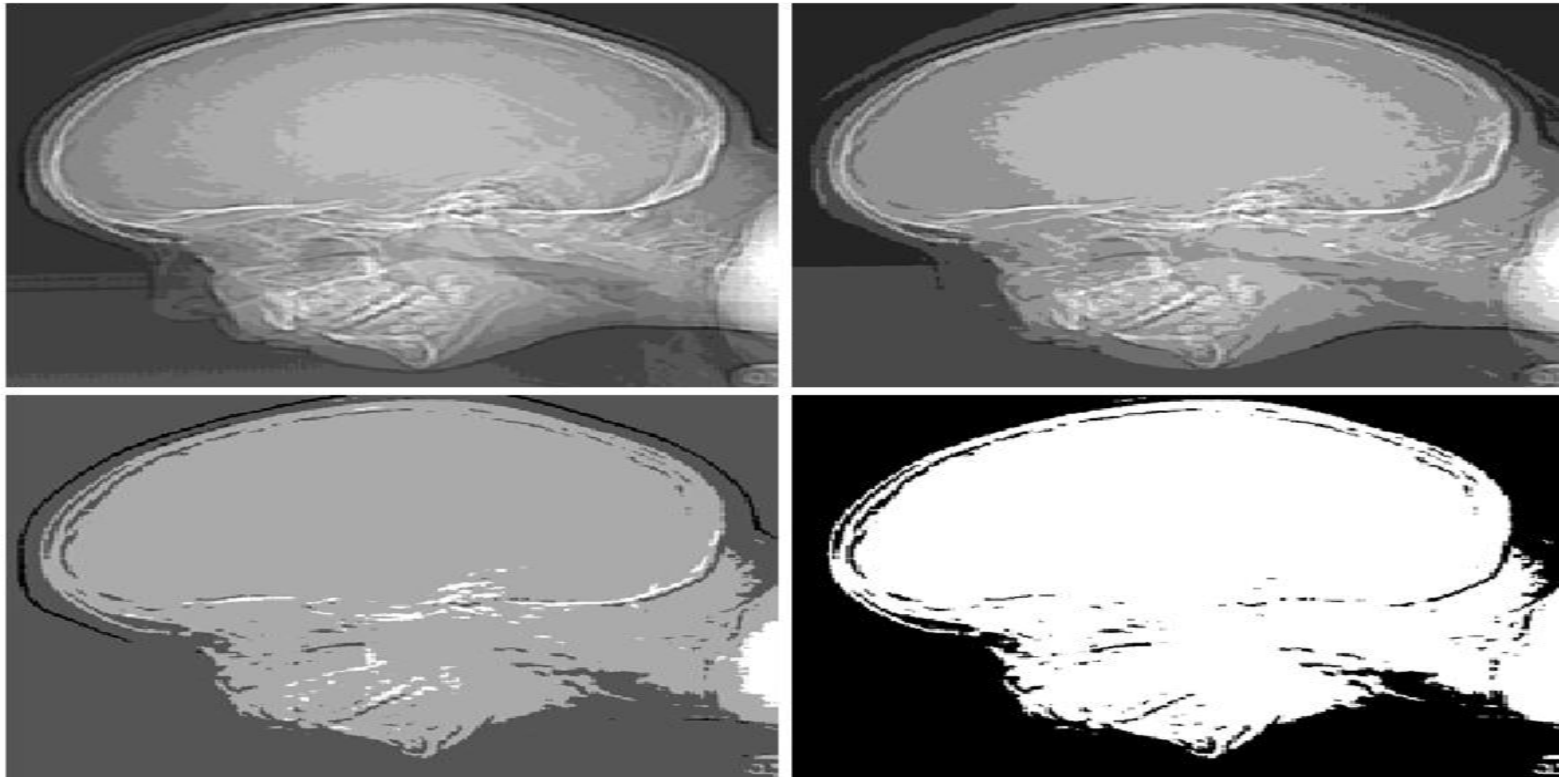
Keep the number of samples constant and reduce the number of gray levels from **256 to 32**.



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

Resolution (Gray -Level)

Keep the number of samples constant and reduce the number of gray levels from **16 to 2**.



(e)–(h) Image displayed in 16, 8, 4 and 2 gray levels, while keeping the spatial resolution constant.

False Contouring Effect: imperceptible set of very fine ridge like structure in areas of smooth gray level.

Non uniform Sampling and Quantization

Adaptive scheme of sampling can be used to improve the appearance of an image for a fixed spatial resolution.

Here sampling process depends on the characteristics of the image.

- Fine sampling in the neighborhood of sharp gray-level transitions.
- Coarse sampling in relatively smooth regions

E.g. A face superimposed in a uniform background.

Nonuniform quantization: Considering the relative frequency of gray levels

- Frequent gray levels (within a range) – finely spaced
- Gray levels outside this range – coarsely spaced.

Resolution

Resolution (how much you can see the detail of the image) depends on sampling and gray levels.

The bigger the sampling rate (n) and the gray scale (g), the better the approximation of the digitized image from the original.

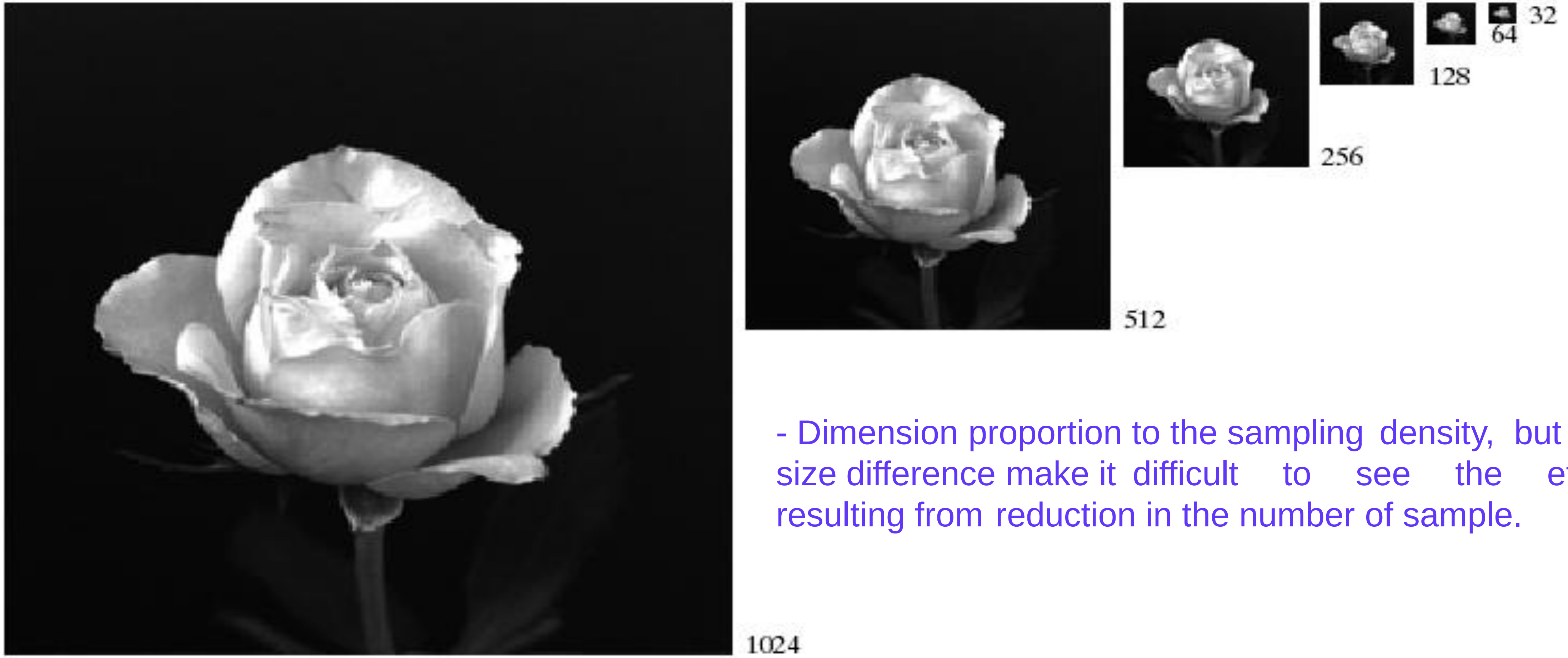
The more the quantization scale becomes, the bigger the size of the digitized image.

Resolution

Spatial Resolution: *Spatial resolution* is the smallest detectable detail in an image. Sampling is principle factor in determining the spatial resolution.

Grey level Resolution: *Gray-level resolution* similarly refers to the smallest detectable change in gray level.

Resolution (Spatial)



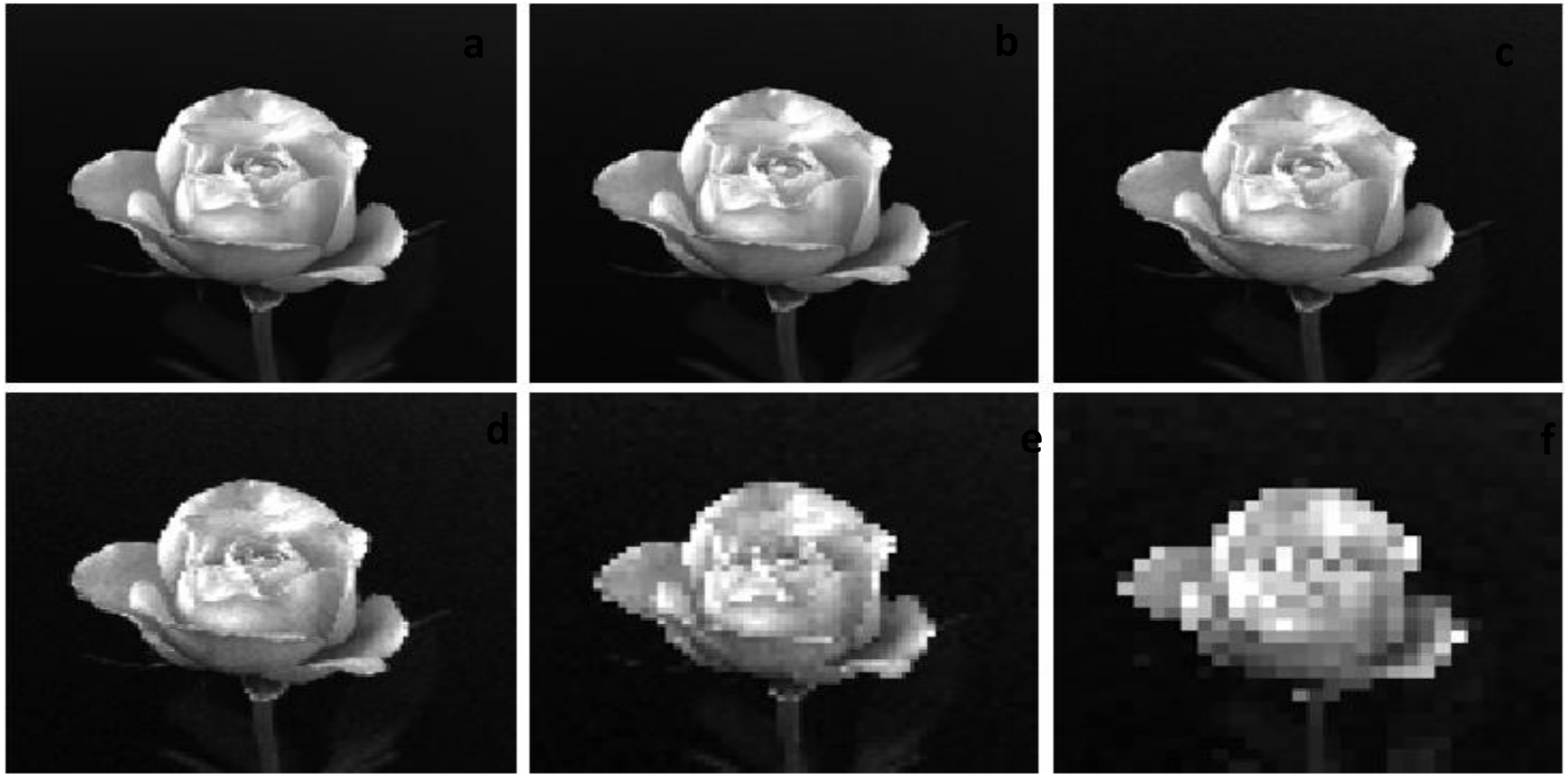
- Dimension proportion to the sampling density, but their size difference make it difficult to see the effects resulting from reduction in the number of sample.

A 1024*1024, 8-bit image sub-sampled down to size 32*32 pixels. The number of allowable gray levels was **kept at 256**. Sub-sampling is achieved by deleting every other row and column.

Resolution (Spatial)

Image re-sampled into 1024*1024 pixels by row and column duplication

Check Board Effect



(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.

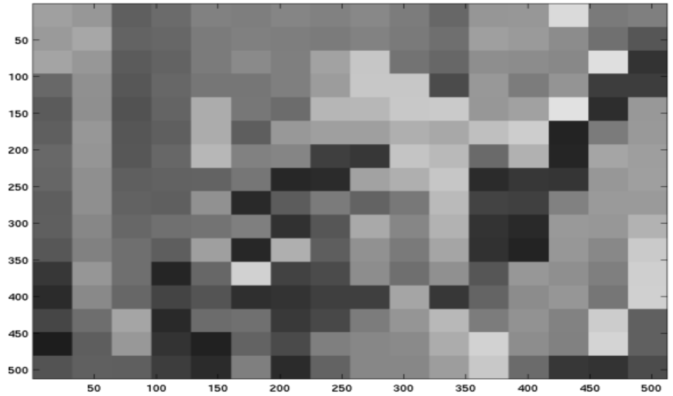
Resolution (Spatial)

Original

Reduced by 2 in each direction

Reduced by 8 in each direction

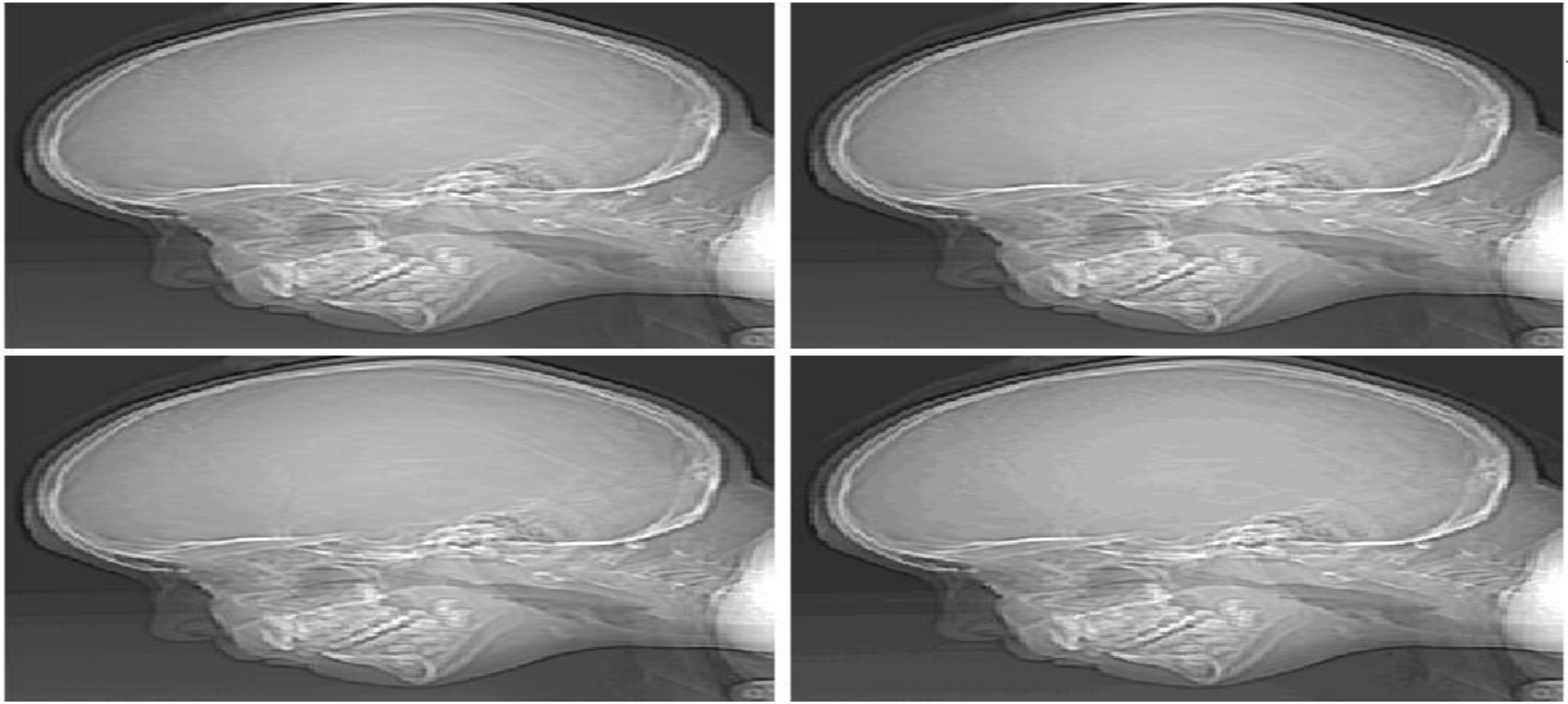
Reduced by 32 in each direction



Checkerboard Effect

Resolution (Gray -Level)

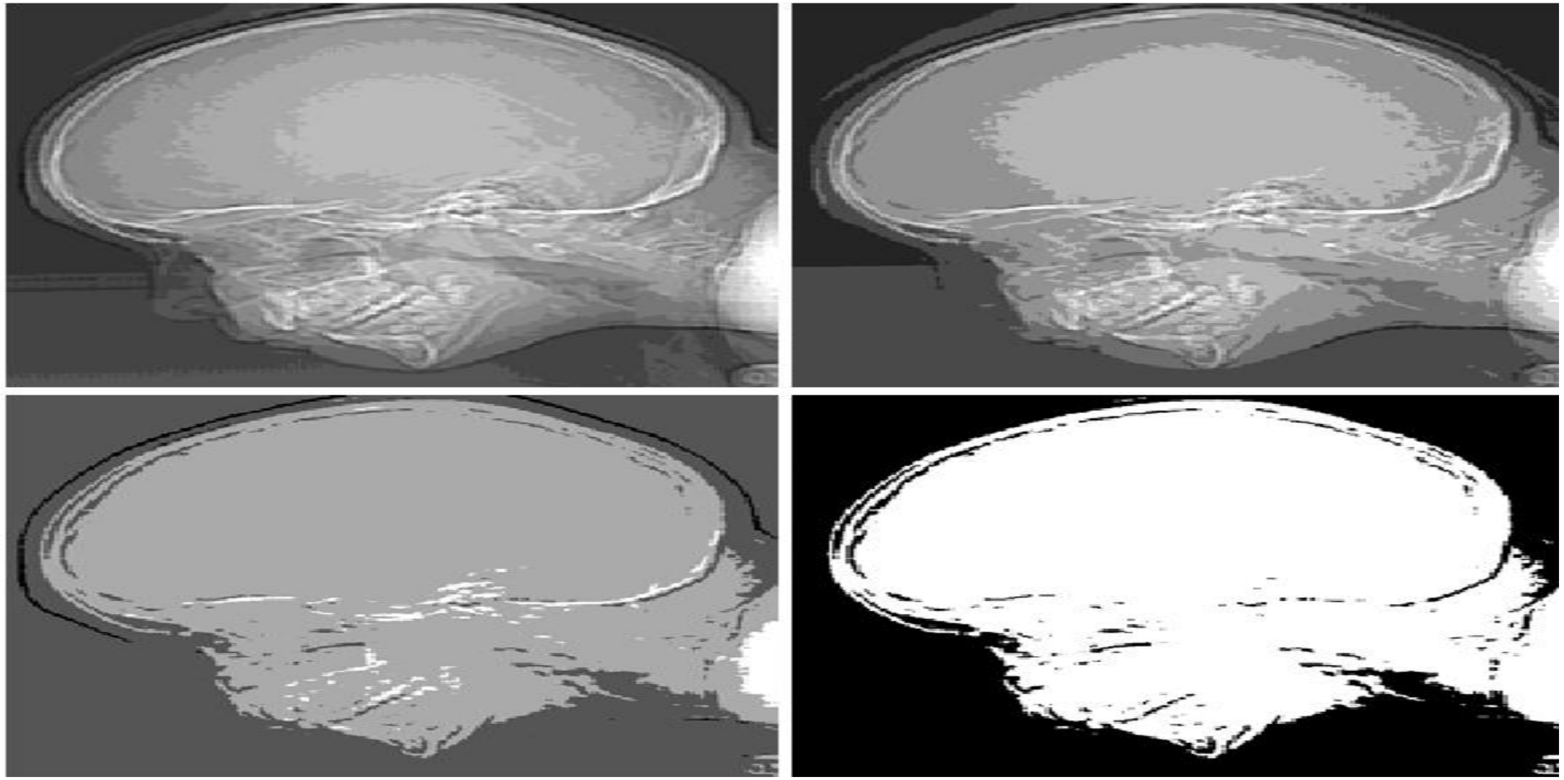
Keep the number of samples constant and reduce the number of gray levels from **256 to 32**.



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

Resolution (Gray -Level)

Keep the number of samples constant and reduce the number of gray levels from **16 to 2**.



(e)–(h) Image displayed in 16, 8, 4 and 2 gray levels, while keeping the spatial resolution constant.

False Contouring Effect: imperceptible set of very fine ridge like structure in areas of smooth gray level.

Resolution (Gray-Level)

Original (256 levels)

64 levels

4 levels

2 levels

Resolution (Gray-Level)

When the number of gray level values are reduced, very fine ridge like structures develop in the areas of gray levels.

This effect is known as ***false contouring*** and is caused by the insufficient number of gray levels in smooth areas of the image.

Suggested Readings

- **Digital Image Processing by Rafel Gonzalez, Richard Woods, Pearson Education India, 2017.**

- **Fundamental of Digital image processing by A. K Jain, Pearson Education India, 2015.**

Thank you