DIGITAL IMAGE PROCESSING-1

Unit 1: Lecture 8-9

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Unit 1: Introduction to DIP

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Last Session

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

Today's Session

- Digital Image Fundamentals
  - Image Sampling and Quantization
  - Representation of Digital Image

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- 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)***

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

- 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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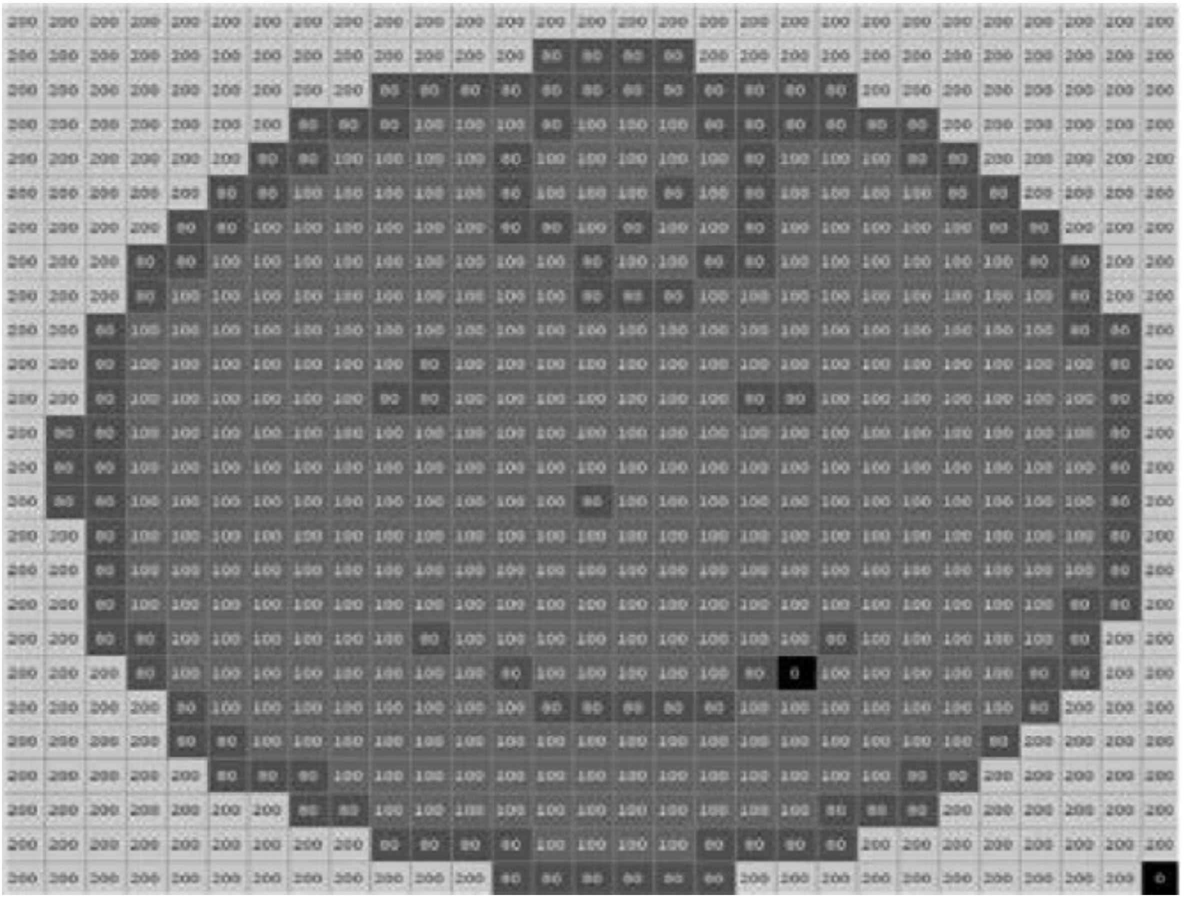
Simple Image

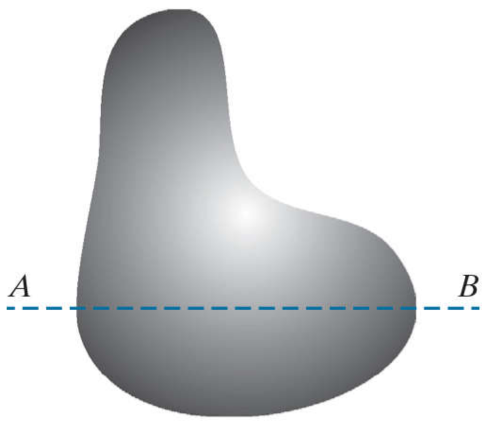


- Digital Image Fundamentals
  - ✓ Elements of visual perception
  - ✓ Image Sensing and acquisition
  - ✓ Image Formation Model
  - Image Sampling and Quantization
  - Representation of Digital Image

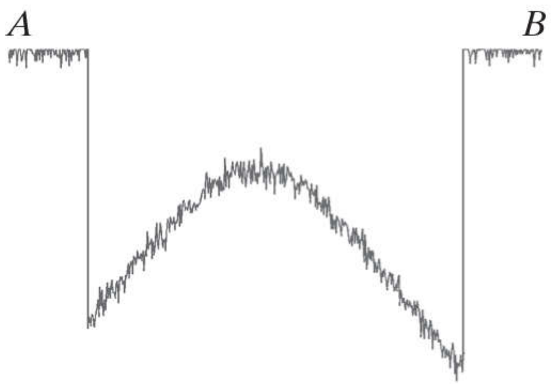
Image Sampling and Quantization

- An image may be continuous with respect to the x- and y-coordinates, and also in amplitude
- To convert it to digital form, we have to sample the function in both coordinates and in amplitude
- Digitizing the coordinate values is called ***sampling***
- Digitizing the amplitude values is called ***quantization***

Image Sampling and Quantization



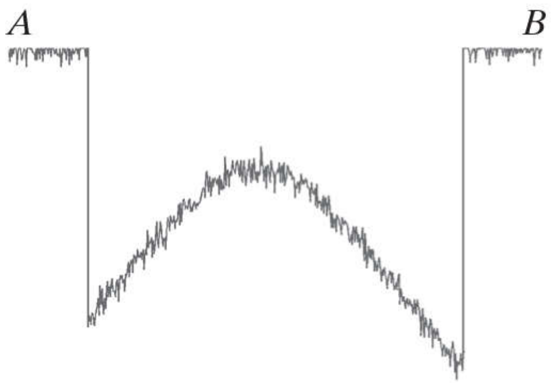
Continuous image

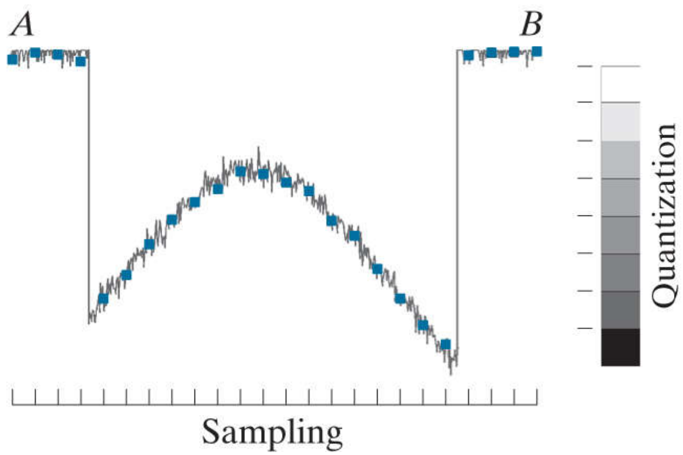


A scan line showing intensity variations along line AB in the continuous image

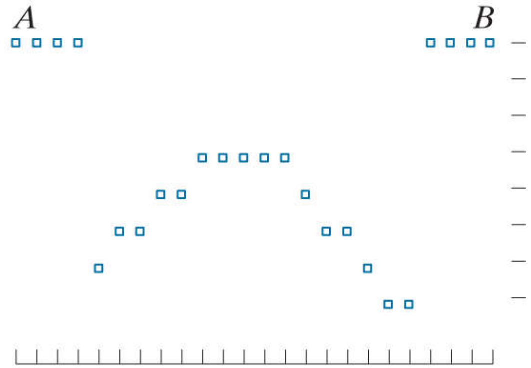
- The one-dimensional function shown in the figure above is a plot of amplitude (gray level) values of the continuous image along the line segment AB.
- The random variations are due to image noise.

Image Sampling and Quantization



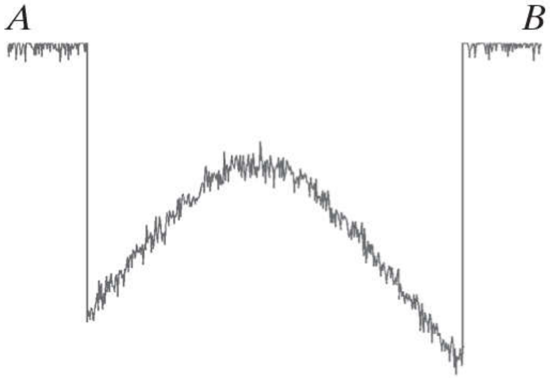


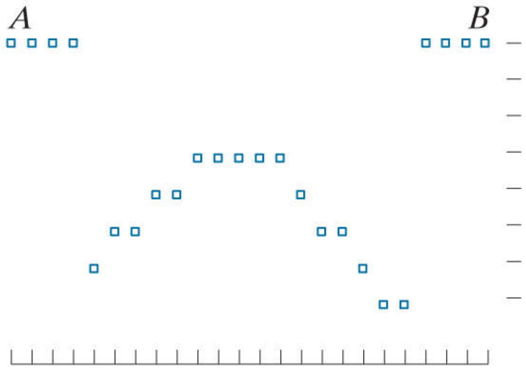
Sampling and quantization.

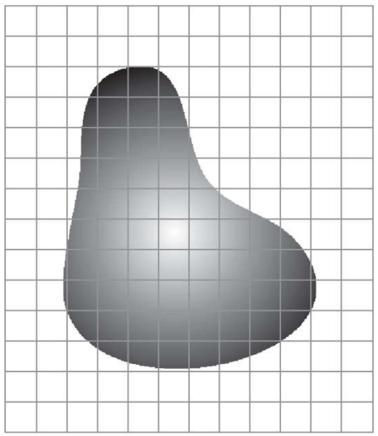


Digital scan line

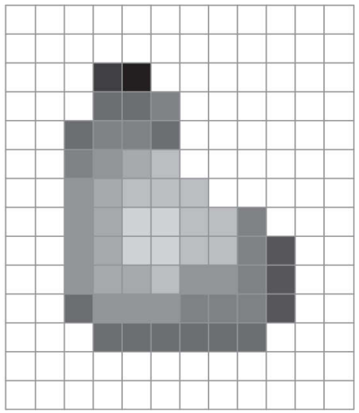
Image Sampling and Quantization





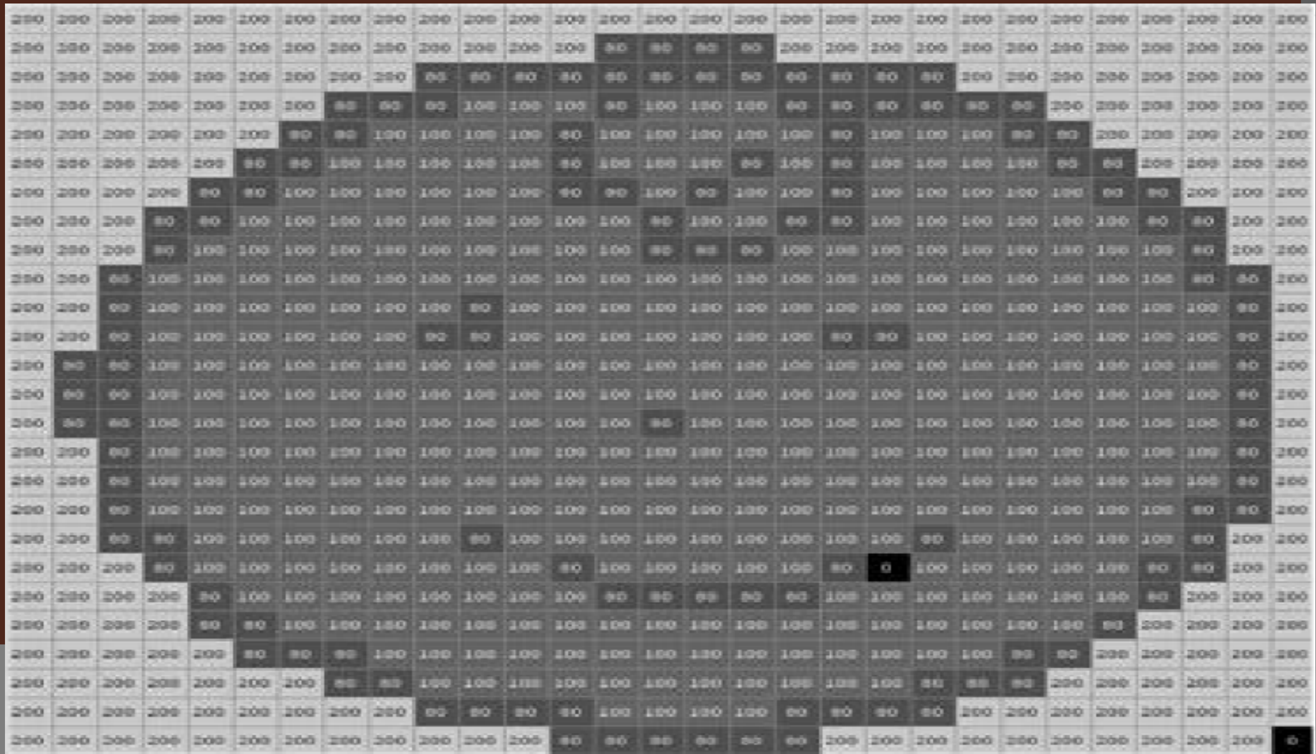


Continuous image projected onto a sensor array



Result of image sampling and quantization

Image Sampling and Quantization

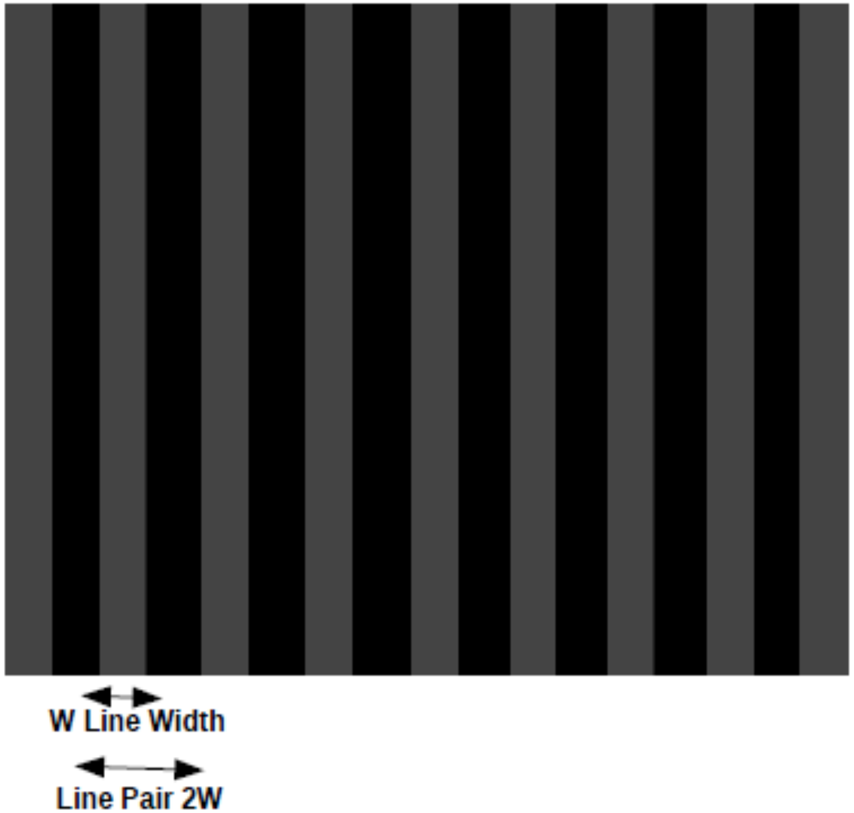


The result of sampling and quantization is a matrix of real numbers.

- Spatial Resolution: Smallest discernible detail in an image
- Sampling : The principal factor determining the spatial resolution of an image

Spatial Resolution

- Consider a chart with vertical lines of width W, with space between lines also having width W
- Line pair consists of one line and its adjacent space
- Thus width of line pair is 2W and there are 1/2W line pairs per unit distance
- Resolution: The smallest discernible line pairs per unit distance
  - Ex: 100 line pairs per millimeter



Spatial and Intensity (Gray level) Resolution

- Gray–level Resolution: The smallest discernible change in gray level (highly subjective)
- Considerable discretion can be used regarding the number of samples used to generate the image, but this is not true for number of gray levels
- The most common number is 8 bits, with 16 bits used in some applications where enhancement of specific gray-level ranges is necessary

Gray Level Resolution

Subsampling of a Gray Level Image

Subsampling of a Gray-scale image

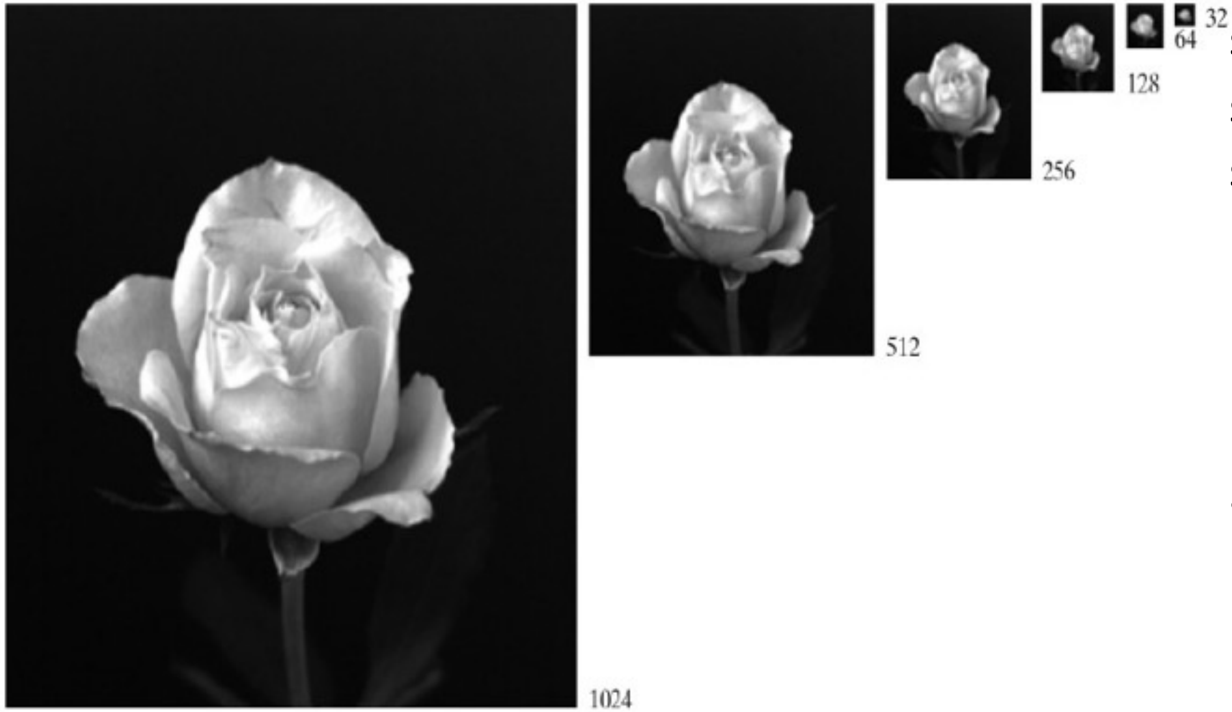


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

We subsample the 1024× 1024 image shown in the figure to obtain the image of size 512×512 pixels. The 512×512 is then subsampled to 256×256 image, and so on until 32×32 image

- Due to hardware considerations and simplicity, the number of gray levels is an integer power of 2.

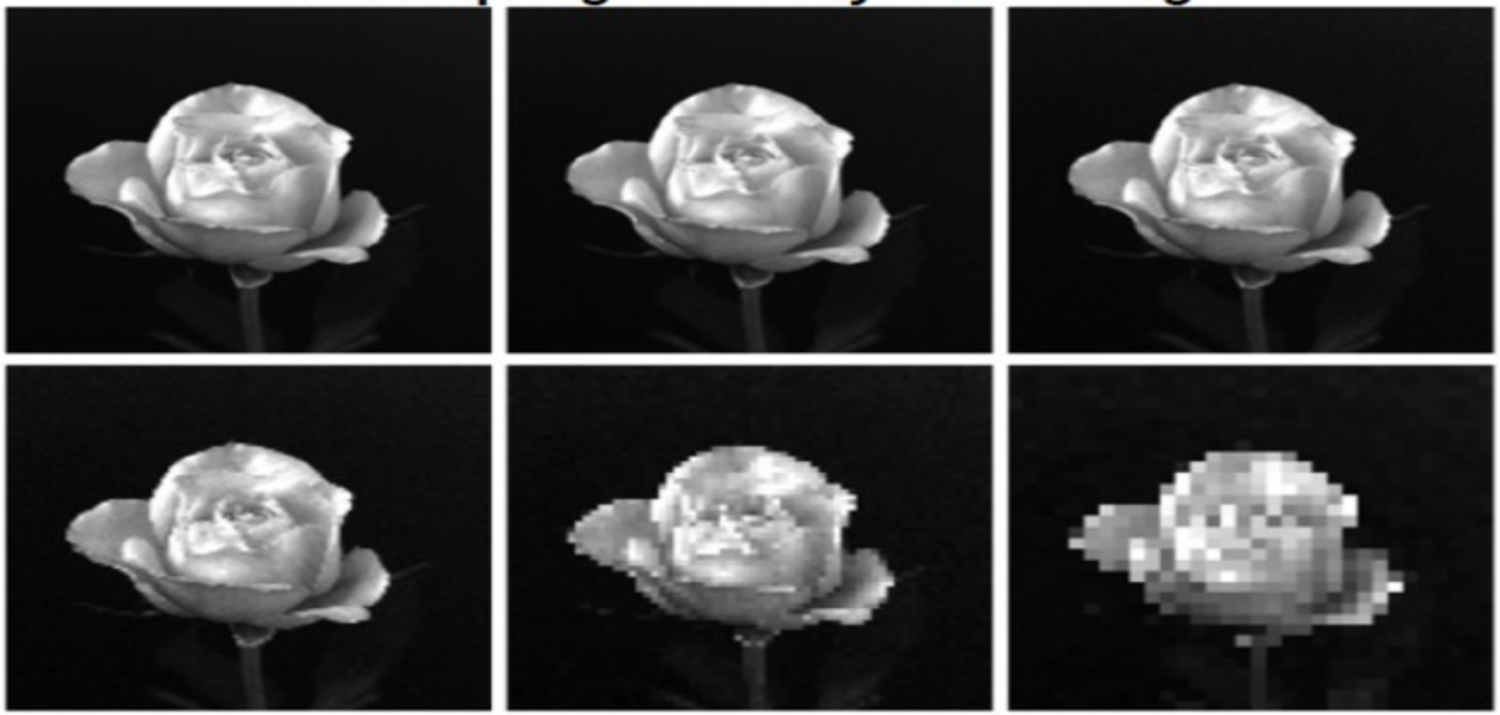
- The subsampling process means deleting the appropriate number of rows and columns from the original image.
- The number of allowed gray levels was kept at 256 in all the images.

Subsampling of a Gray Level Image

- To see the effects resulting from the reduction in the number of samples, we bring all the subsampled images up to size 1024×1024 by row and column pixel replication.
- The resulted images are shown in the figure

Resampling of a Gray-Scale Image

Resampling of a Gray-scale image

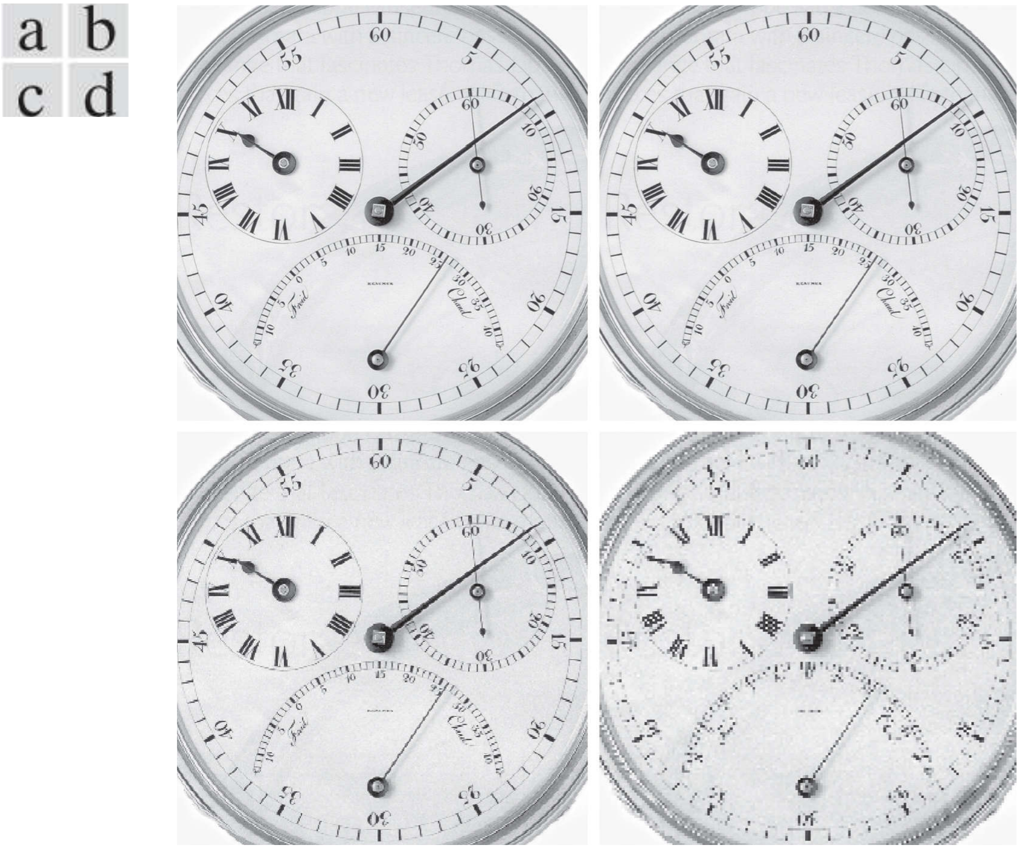


a b c
d e f

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.

Subsampling of a Gray Level Image

Effects of reducing the spatial resolution of a digital image.



The images shown are at:
(a) 930 dpi, (b) 300 dpi, (c) 150 dpi, and (d) 72 dpi.

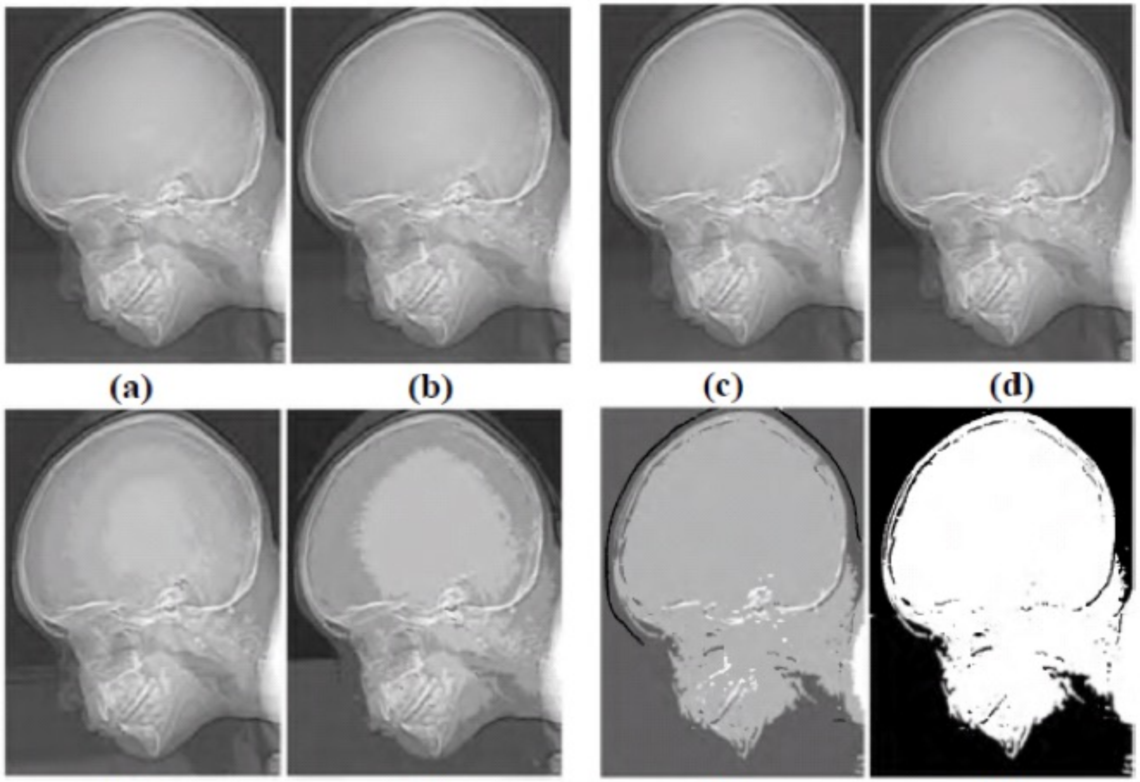
Original image is 2136 × 2140 pixels, but the 72 dpi image is an array of only 165 × 166 pixels

Effect of Reducing the Gray Level Resolution

- Decreasing the gray-level resolution of a digital image may result in what is known as false contouring.
  - This effect is caused by the use of an insufficient number of gray levels in smooth areas of a digital image.
- To illustrate the false contouring effect, we reduce the number of gray levels of the 256-level image shown in Figure from 256 to 2.

Effect of Reducing the Gray Level Resolution

- The resulted images are shown in the figures (b) through (h).



(a) (b) (c) (d)
(e) (f) (g) (h)

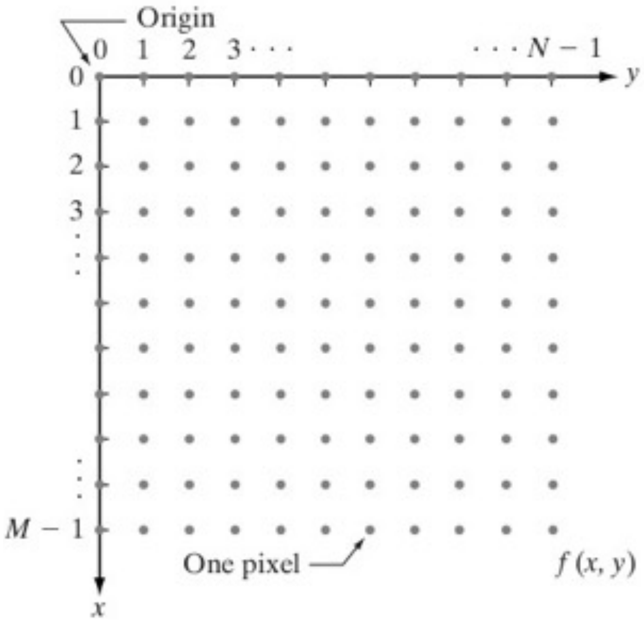
Figure 2.6 (a) 452×374, 256-level image. (b)-(h) Image displayed in 128, 64, 32, 16, 8, 4, and 2 gray levels, while keeping the spatial resolution constant.

Effect of reducing the number of gray levels from 256 to 2, in integer powers of 2.

- This can be achieved by reducing the number of bits from k = 8 to k = 1, while keeping the spatial resolution constant at 452×374 pixels.

- Crude Rule of thumb:
    - Assuming powers of 2 for convenience and hardware limitations, images of size 256*256 pixels and 64 gray levels are about the smallest images that can be expected to be reasonably free of objectionable sampling checkerboards and false contouring

- Different Notations



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

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

Digital Image Representation

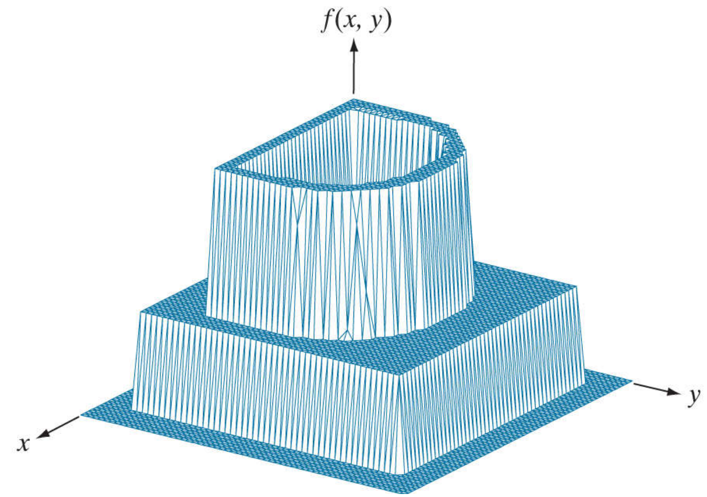


Image plotted as a surface.

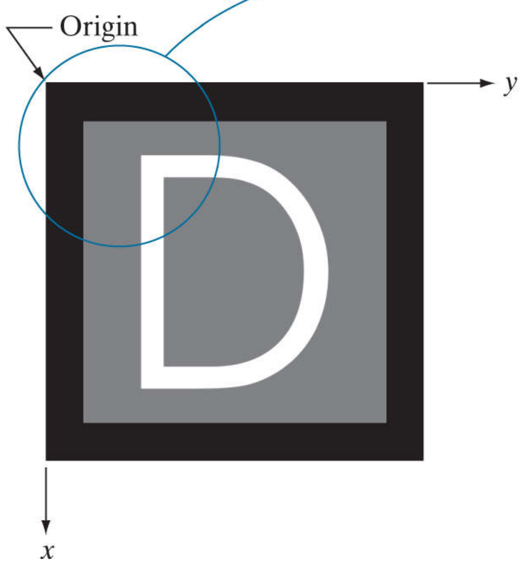


Image displayed as a visual intensity array

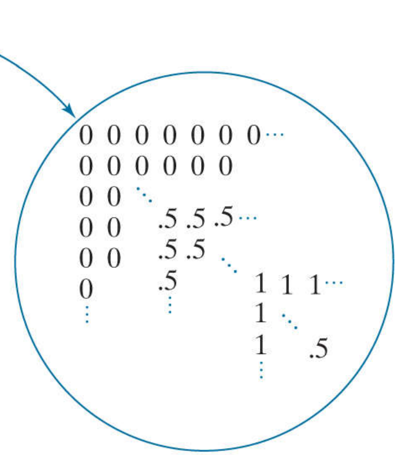


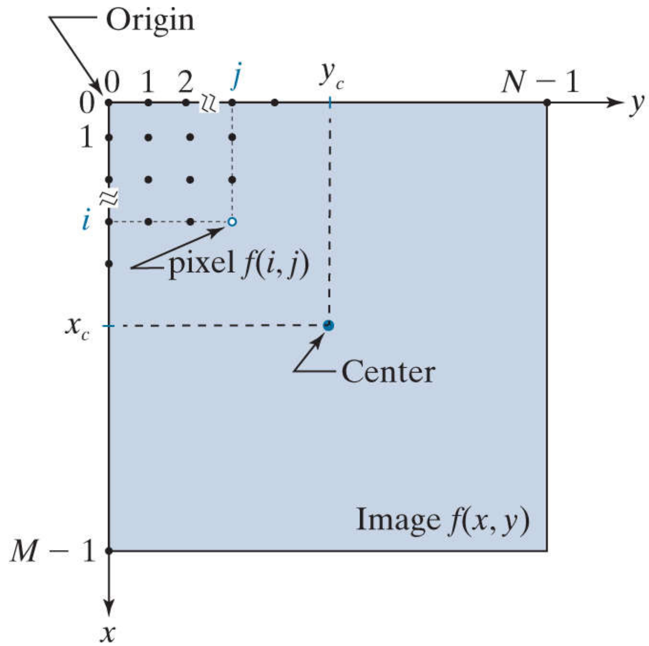
Image shown as a 2-D numerical array. (The numbers 0, 0.5, and 1 represent black, gray, and white, respectively.)

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

Digital Image Representation

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

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



For example, the center of an image of size 1023×1024 is at
Some programming languages (e.g., MATLAB) start indexing at 1 instead of at 0.
The center of an image in that case is found at
$(x_c, y_c) = (\text{floor}(M/2) + 1, \text{floor}(N/2) + 1)$.

Digital Image Representation

- If M = Number of row pixels

  N = Number of column pixels

  k = Number of bits used to represent each pixel

Then number of bits required to store a digital image is:

$b = M \times N \times k$

- If N = M then,

  $b = N^2k$

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

Varying N and k Simultaneously

- Consider Three types of images :
  - With little detail
  - Intermediate details and
  - large amount of detail

Test Images

Lena
(Low detail/frequency)

Barbara
(High detail/frequemcy)

Test Images

Cameraman
(Mid level detail /frequency))

Goldhill
(High detail /frequency))

Varying N and k Simultaneously: Isopreference Curve

- Varying N: Sampling, spatial resolution
- Varying k : quantization, gray level resolution

Varying N and k Simultaneously

- Huang [1965] attempted to quantify experimentally the effects on image quality produced by varying N and k simultaneously
- Three sets of images : With little, intermediate and large amount of detail
    - Sets of these three types of images were generated by varying N (number of samples) and k (number of levels)
    - Observers were then asked to rank them according to their subjective quality.

Varying N and k Simultaneously

Images used in the experiment

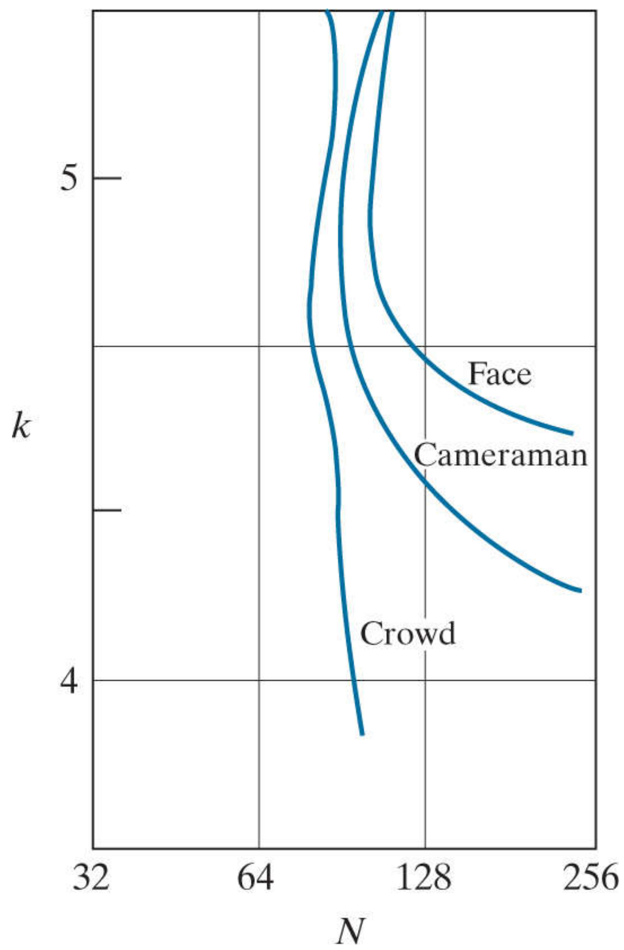
a. Image with a low level of detail.
b. Image with a medium level of detail.
c. Image with a relatively large amount of detail.

Varying N and k Simultaneously: Isopreference Curve

- Each point in the Nk-plane

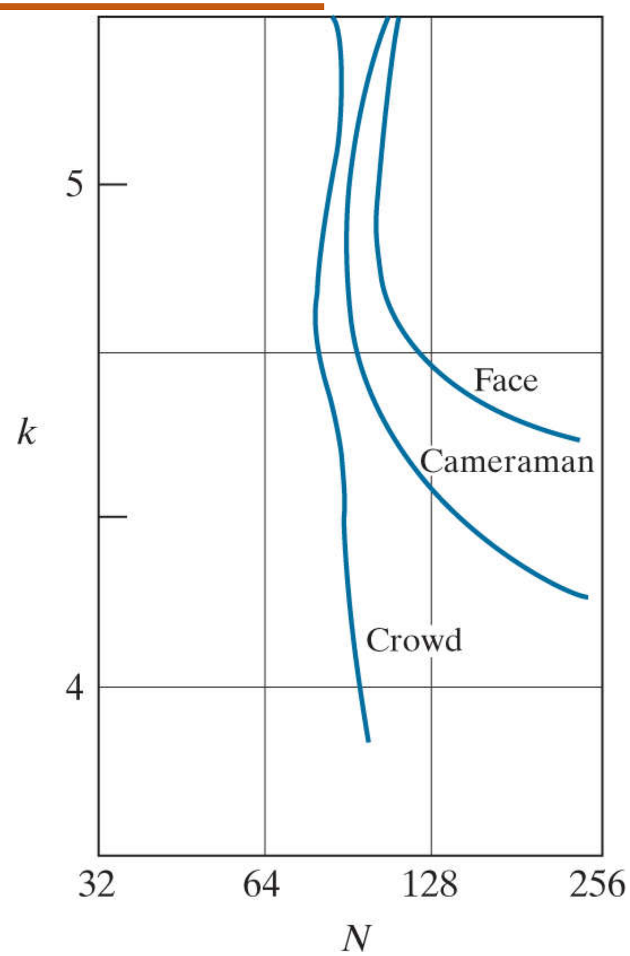
represents an image having values of N and k equal to the coordinates of that point

- Points lying on an isopreference curve correspond to images of equal subjective quality
- It was found that the *isopreference curves tended to shift right and upward, but their shapes in each of* the three image categories were *similar*



Analysis

- A shift up and right in the curves simply means larger values for N and k, which implies *better picture quality.*
- Curves tend to become more *vertical as the detail in the image increases.*
  - For images with a large amount of detail only a few gray levels may be needed
  - This indicates that, for a fixed value of N, the perceived quality for this type of image is nearly independent of the number of gray levels used
- Perceived quality in the other two image categories remained the same in some intervals in which the spatial resolution was increased, but the number of gray levels actually decreased.
  - A decrease in k tends to increase the apparent contrast of an image, a visual effect that humans often perceive as improved quality in an image



Representative isopreference curves for the three types of images

Next Session

- Zooming and Shrinking
- Basic relationship between pixels

THANK YOU

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