PAM3012
Digital Image Processing for Radiographers

Image Sampling & Quantization

## In this lecture

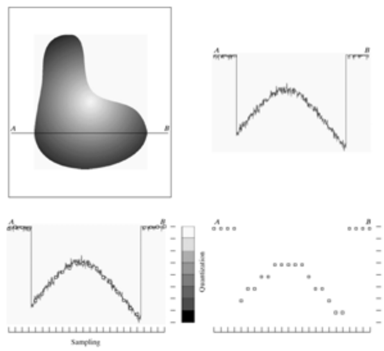
- ★Definitions of Sampling & Quantisation
- ★Representing Digital Images
- ★Spatial & Gray-level resolution
- ★Perceived Image Quality & Resolution
- ★Aliasing & Moire patterns

## Sampling & Quantisation

- The spatial and amplitude digitization of f(x,y) is called:
  - image sampling when it refers to spatial coordinates (x,y) and
  - gray-level quantization when it refers to the amplitude.

## Sampling & Quantisation

1D function is a plot of amplitude values of the continuous image along AB

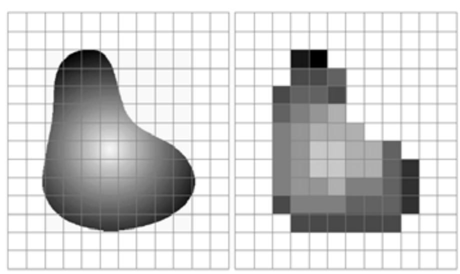


## Sampling & Quantisation

- Sampling limitations set by detector
- Single Sensor
  - Mechanical motion in x and y can be very precise
  - Limited by focussing optics
- Line Sensor
  - Number of elements in strip
- Array
  - Density of elements in array

## Sampling & Quantisation

Continuous image projected onto Array Sensor

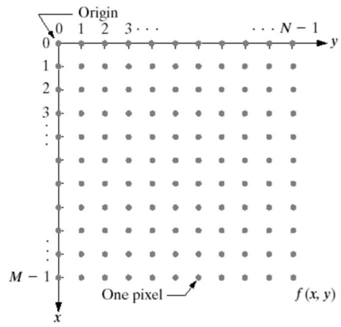


# Representing Digital Images

- Sampling & quantisation produces a matrix of numbers
- Image *f(x,y)* is sampled producing digital image with M rows and N columns
- Values of x & y become discrete quantities

# Representing Digital Images

- Coordinate convention used to represent digital images
- (0, 1) second sample in first row
- NOT the values of physical coordinates when image was sampled




# Representing Digital Images

M X N image can be written in matrix from:

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

Digital Image

Image Elements (Pixels)

# Representing Digital Images

Can also be written in traditional matrix form:

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

Digital Image

Image Elements (Pixels)

$$a_{ij} = f(x = i, y = j) = f(i, j)$$

# Representing Digital Images

- f(x,y) is a digital image if:
  - (x,y) are integers
  - f is a function that assigns a gray-level value (from R) to each distinct pair of coordinates (x,y) [quantization]
- Gray levels are usually integers

# Representing Digital Images

- The digitization process requires decisions about:
  - values for N, M
  - Where N x M: the image array

and

  - the number of discrete gray levels allowed for each pixel.

## Representing Digital Images

- These quantities are usually integer powers of two:

  $N=2^n$ $M=2^m$ and $G=2^k$

  G = number of gray levels

- Another assumption is that the discrete levels are equally spaced between 0 and L-1 in the gray scale.

## Sampling & Quantization

<u>Calculating number of storage bits</u>

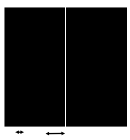
number of bits = N x M x k

- N & M = number of samples in vertical & horizontal direction
- k = bit depth

- *Greater number of bits => higher image quality*

## Spatial Resolution

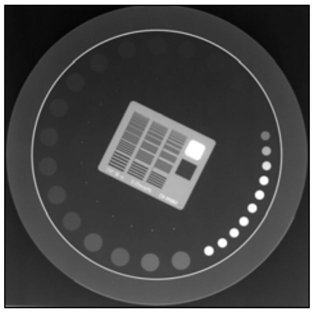
- Smallest discernible detail in an image
- Sampling is the principle factor
- Often defined by line pairs per mm



Width of line, W
Width of line pair, 2W
1/2W line pairs per mm

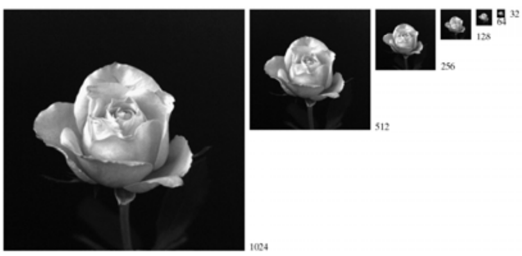
## Gray-Level Resolution

- Smallest discernible change in gray-level, L
- Number of gray-levels
- Determined by ADC



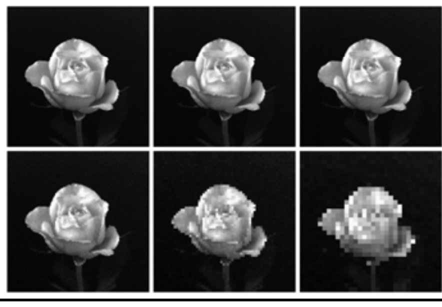
## Examples

- Reducing spatial resolution, constant Gray-level
- 1024 X 1024 image subsampled down to 32 X 32
- 8-bit image – 256 gray levels



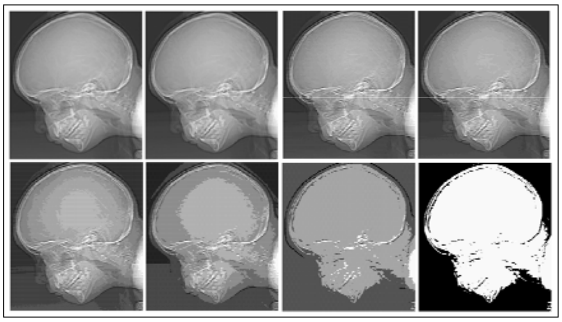

## Examples

- Reducing spatial resolution, constant Gray-level
- 1024 X 1024 image subsampled down to 32 X 32
- 8-bit image – 256 gray levels



## Examples

- Reducing Gray-level, constant spatial resolution (452 X 374)
- 8-bit (256 levels) to 1-bit (2 levels)



## Sampling & Quantization

- How many samples and gray levels are required for a good approximation?
  - Quality of an image depends on number of pixels and gray-level number
  - i.e. the more these parameters are increased, the closer the digitized array approximates the original image.
  - But: Storage & processing requirements increase rapidly as a function of N, M, and k

## Perceived Image Quality & Resolution

- Different versions (images) of the same object can be generated through:
  - Varying N, M numbers
  - Varying k (number of bits)
  - Varying both
- Huang 1965 – Isopreference Curves

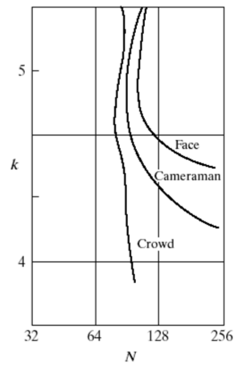
## Isopreference Curves

- Isopreference curves (in the N-k plane)
  - Each point: image having values of N and k equal to the coordinates of this point
  - Points lying on an isopreference curve correspond to images of equal subjective quality.

## Example

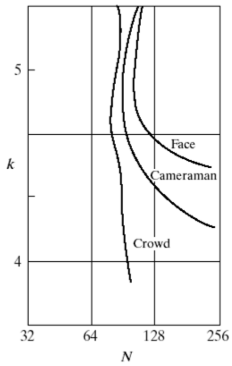
## Example

- Curves shift up & right with increasing quality
- Quality of images increases as N & k increase
- Similar shape in each category

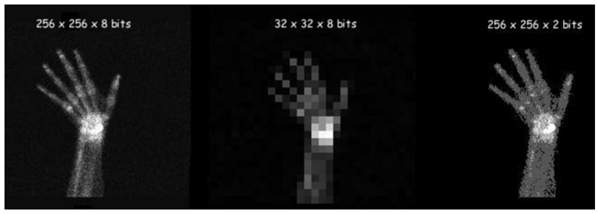


## Example

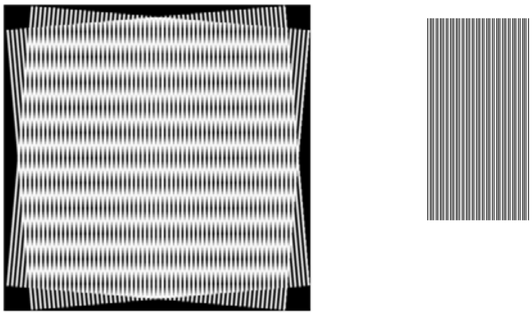
- Sometimes, for fixed N, the quality improved by decreasing k (increased contrast)
- More vertical for higher image detail
- Images with a large amount of detail require few gray-levels




## Example

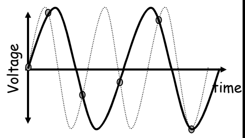


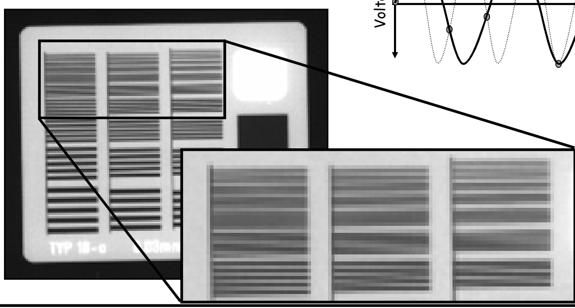

## Aliasing & Moiré Patterns



## Aliasing & Moiré Patterns

- Spatial Resolution Test Pattern



## Summary

★Definitions of Sampling & Quantisation
★Representing Digital Images
★Spatial & Gray-level resolution
★Perceived Image Quality & Resolution
★Aliasing & Moire patterns