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 \((x, y)\)
  - 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 focusing 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 a digital image with \( M \) rows and \( N \) columns
- Values of \( x \) & \( y \) become discrete quantities

\[ f(x,y) \text{ is sampled producing digital image with } M \text{ rows and } N \text{ columns} \]

Values of \( x \) & \( y \) become discrete quantities

\[ f(x,y) \]

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Values of \( x \) & \( y \) become discrete quantities

\[ f(x,y) \]

Representing Digital Images

\[ M \times N \text{ image can be written in matrix form:} \]

\[
\begin{bmatrix}
f(0,0) & f(0,1) & \cdots & f(0,M-1) \\
f(1,0) & \ddots & \ddots & \vdots \\
\vdots & \ddots & \ddots & \ddots \\
f(N-1,0) & \cdots & f(N-1,M-1)
\end{bmatrix}
\]

Digital Image

Image Elements (Pixels)

\[ f(x,y) \]

\[ f(x,y) \text{ is sampled producing digital image with } M \text{ rows and } N \text{ columns} \]

Values of \( x \) & \( y \) become discrete quantities

\[ f(x,y) \]

Representing Digital Images

\[ f(x,y) \text{ is a digital image if:} \]

- \( (x,y) \) 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

\[ f(x,y) \]

\[ f(x,y) \text{ is sampled producing digital image with } M \text{ rows and } N \text{ columns} \]

Values of \( x \) & \( y \) become discrete quantities

\[ f(x,y) \]
Representing Digital Images

- These quantities are usually integer powers of two: 
  \[ N = 2^n \quad M = 2^m \quad G = 2^k \]
  
  \( G \) = 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

Calculating number of storage bits

\[ \text{number of bits} = N \times M \times k \]

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

- Greater number of bits \( \Rightarrow \) higher image quality

Spatial Resolution

- Smallest discernible detail in an image
- Sampling is the principle factor
- Often defined by 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

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- 1024 X 1024 image subsampled down to 32 X 32
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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

- Spatial Resolution Test Pattern

Summary

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