Summary

- Acquisition
  - Sampling and quantization
- Image representation
  - Matrix or function
- Image Manipulation
  - Point Processing Operators
    - Image Enhancement
    - Color transformations
Image acquisition

FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Acquisition

FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.
Function of two variables $f(x,y)$ is the pixel value

matrix $F$: entries are pixel values or pointers to a look-up-table (LUT)

Image: representation

- **Matrix $M \times N$**
  - Each element is an integer in the interval $[L_{\text{min}}, L_{\text{max}}]$
  - The number of required bits to represent the $L$ gray levels of the interval is $K$
    \[ L = 2^K, \quad L = L_{\text{max}} - L_{\text{min}} + 1 \]
  - The total number of bits to store the image is $K \times M \times N$
- **Spatial resolution**: the smallest visible element (pixel)
- **Gray Level resolution**: the smallest visible color change

An image has a spatial resolution of $M \times N$ pixels and a gray level resolution of $K$ bits or $L$ grey levels
Image representation: color

- A **(digital) color image** includes color information for each pixel.
- Color representation spaces
  - RGB (Red, Green and Blue)
  - YUV (*luma* (Y') and two *chrominance* (UV))
  - YCbCr in *digital encoding*
  - HSV, RGB variants, and so on.
- MATLAB true color images are represented by M xN x3 matrices: one matrix by component.
- Pseudo-color images: color represented the index to a table (color table).

Spatial versus Gray Level Resolution
Spatial Resolution

Manipulations with ImageJ (public domain, Java-based image processing program)

Example: resizing images

Original Color image (RGB): 1024x2048x3
Why?

Point Processing operations

- Given the pixel values they are transformed using a function
  \[ g(x) = af(x) + b, \]
  Where
  - \( x \equiv (i, j) \) denotes pixel localization
  - \( f(x) \) pixel value of original image
  - \( g(x) \) pixel value of the output image

Luminance (brightness) changes with \( b \)
Contrast changes with \( a \)
Example: Gray images

Example: color image

\[ g_c(x) = a f_c(x) + b, \]
\[ x \equiv (i, j) \quad c \equiv \{R, G, B\} \]

b=16

a=1.1
Point processing transformations

- Methods to change pixel values
  - Linear transforms
  - Linear transforms with saturation
  - Piecewise linear transformations
  - Non-linear transform
  - Histogram equalization

Example I: piecewise linear and threshold

![Graph showing piecewise linear transformation](image)
Example II: specific range of gray levels

FIGURE 3.11 (a) This transformation highlights intensity range \([A, B]\) and reduces all other levels to zero. Hence the lower level \(L = 1\). (b) This transformation highlights range \([A, B]\) and preserves all other intensity levels.

FIGURE 3.12 (a) Aortic angiogram. (b) Result of using a slicing transformation of the type illustrated in Fig. 3.11(a), with the range of intensities of interest selected in the upper end of the gray scale. (c) Result of using the transformation in Fig. 3.11(b), with the selected area set to black, so that grays in the area of the blood vessels and kidneys were preserved. (Original image courtesy of Dr. Thomas R. Fritz, University of Michigan Medical School.)

Histogram Equalization

An image whose gray levels have a uniform density function appears to have high contrast

Manipulations with MATLAB (see commands imhist and histeq)
Histogram equalization

• Image to be processed (ENHANCED)
  • \( r \) represent the gray levels
  • \( r \) is continuous and has been normalized to lie in the interval \([0, 1]\), \( r = 0 \) = black, \( r = 1 \) = white

• The following transformation \( s = T(r) \)
  • \( T(r) \) is single-valued and monotonically increasing in the interval \( 0 \leq r \leq 1 \),
  • and \( 0 \leq T(r) \leq 1 \) for \( 0 \leq r \leq 1 \)

• Goal: producing an image whose gray levels have a uniform density function

Histogram equalization: discrete approach

• With histogram compute a probability mass function (PMF)
• Compute the Cumulative Distribution Function (CDF)
• \( T(r) \) is related to CDF (de-normalized)

\[
s_k = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} P_r(k) \leq 1 \quad 0 \leq r_k \leq 1 \quad k = 0, 1, \cdots L-1
\]

**Figure 3.19** Illustration of histogram equalization of a 3-bit (8 intensity levels) image. (a) Original histogram. (b) Transformation function. (c) Equalized histogram.
Example I: PMF and CDF

Example I: transformation
Example: color images

Figure 3.7 Histogram analysis and equalization: (a) original image (b) color channel and intensity (luminance) histograms (c) cumulative distribution functions; (d) equalization (transfer) functions; (e) full histogram equalization; (f) partial histogram equalization.

Color space transformation: example

The color space YUV (TV in most countries of Europe)

- The luminance component \( Y \)
  \[ Y = 0.299R + 0.587G + 0.114B \]

- The chrominance components
  \[ U = -0.147R - 0.289G + 0.436B = 0.492(B - Y) \]
  \[ V = 0.615R - 0.515G - 0.100B = 0.877(R - Y) \]

The Gray scale version results from \( Y \) luminance component.

MATLAB color transformations: \textit{rgb2gray, rgb2ycbcr}, etc.
Bibliography

- Gonzalez and Woods- Digital Image Processing using MATLAB (part of the figures of slides).
  
  (available online: http://szeliski.org/Book/)