PAM3012
Digital Image Processing for Radiographers

Image Enhancement in the Spatial Domain (Part II)

In this lecture

- ★Histograms of Digital Images
- ★Histogram Processing
  - ★Histogram Equalisation
  - ★Histogram Specification
- ★Arithmetic Operations

Histogram Processing

- The histogram of a digital image with gray levels from 0 to L-1 is a discrete function

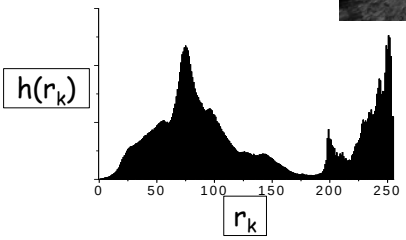
$$h(r_k) = n_k$$

  - r_k is the k^{th} gray level
  - n_k is the # pixels in the image with that gray level
  - n is the total number of pixels in the image
  - k = 0, 1, 2, …, L-1

- Normalized histogram $p(r_k) = \frac{n_k}{n}$
  - Sum of all components = 1

Image Histogram

Probability of pixel amplitude r_k occurring
(Probability Density Function)



$$h(r_k) = n_k$$

$$p(r_k) = \frac{n_k}{n}$$

Histogram Processing

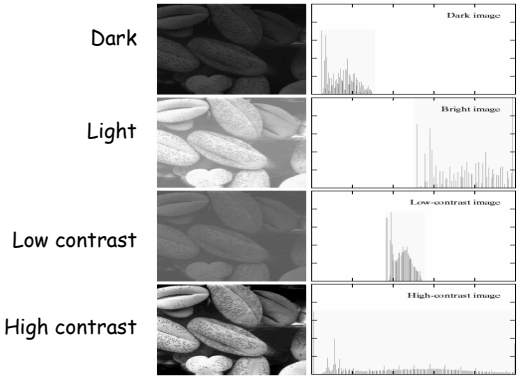
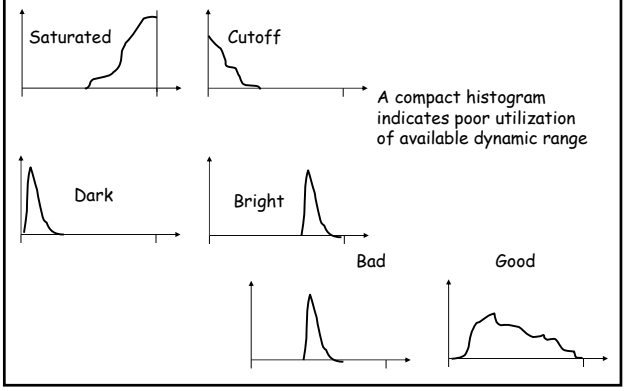


Image Histogram

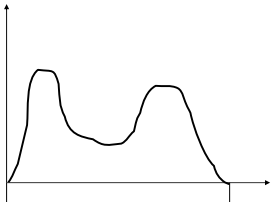
- The shape of the histogram of an image provides useful information about the possibility for contrast enhancement

Assessing Image Quality

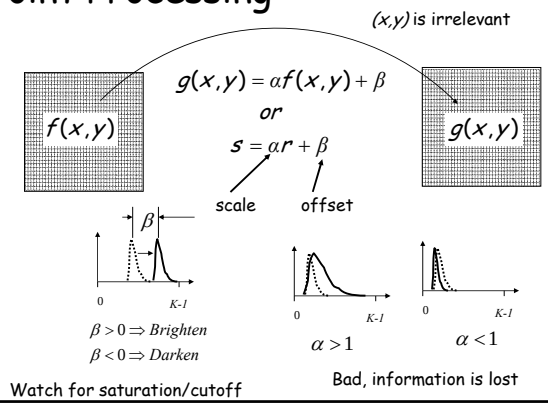


Assessing Image Properties

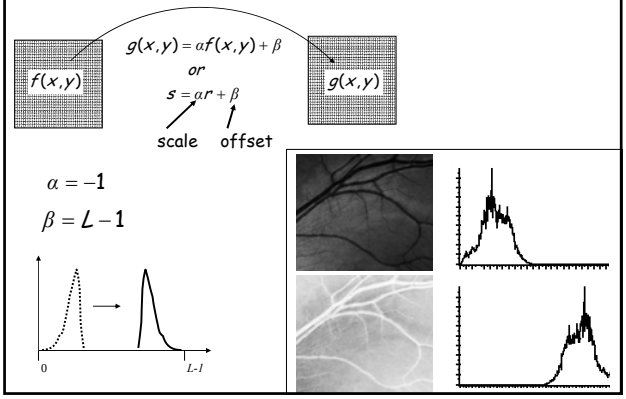
- "Bi-modal" histogram indicates that there are two major kinds of pixels in the image
- Two kinds of objects in scene – one kind brighter than the other



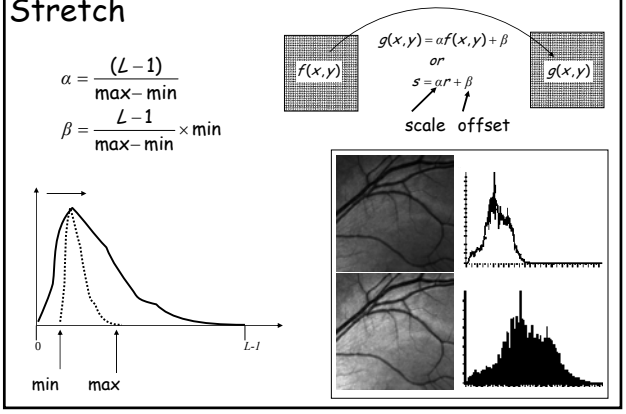
Point Processing



Point Processing: Image Inversion



Point Processing: Full-Scale Histogram Stretch



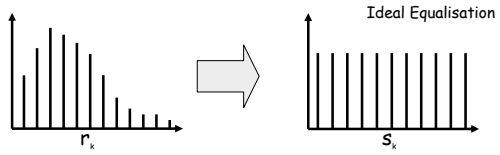
Histogram Equalization

- **Objective**:
  - Flatten the histogram
  - Each gray level occurs with equal probability
- **Application:**
  - Processing a large number of images
  - Minimizes variability
- Advantages: Automated

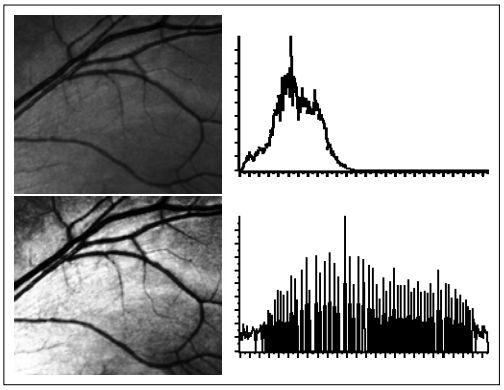
Histogram Equalisation

- $P(r_k)$ is the probability of occurrence of gray level r_k
- $P(r_k)$ can be re-distributed for enhancing the image

$h(r_k)$ or $P(r_k)=n_k/n$ $\quad$ $h(s_k)$ or $P(s_k)$



Example



Histogram Equalisation

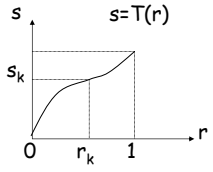
Computer 'designs' point processing function, s = T(r), to equalize histogram

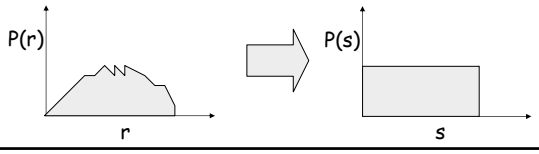
Over the range $0 \le r \le 1$ T(r) must…

(1) Be single valued over the range

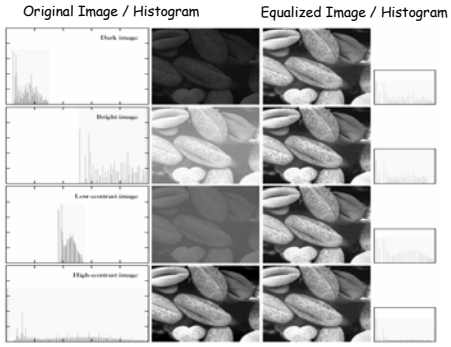
(2) Increase monotonically

(3) Have $0 \le T(r) \le 1$





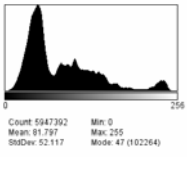
Histogram Equalisation



Practicalities

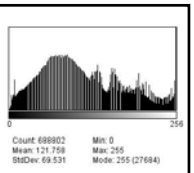
- Need to check if new pixel values will be out of the range 0 …K-1
  - Saturation or cutoff leads to information loss
- When scaling an image by a fractional number, the result needs to be rounded
- Processors often quote equalization with a % of saturated pixels

Examples



Examples

10% saturation



Histogram Specification

- Histogram equalization does not allow interactive image enhancement and generates only one result: an approximation to a uniform histogram.
- Sometimes useful to specify particular histogram shapes for highlighting certain gray-level ranges.

Arithmetic Operations

- Subtraction