DIGITAL IMAGE PROCESSING

IMAGE ENHANCEMENT

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IMAGE ENHANCEMENT

- Image enhancement is the process of manipulating an image so that the result is more suitable than the original for a specific application. These techniques are problem oriented
- Image enhancement techniques basically are heuristic procedures designed to manipulate an image in order to take advantage of the psychophysical aspects of the human visual system
- Image enhancement is largely a subjective process, while image restoration is for the most part an objective process

IMAGE ENHANCEMENT

atmospheric disturbance

- The performance of imaging sensors is affected by a variety of factors(different environmental conditions/the quality of the sensing elements
- Images are corrupted during transmission principally due to interference in the channel used for transmission
- Improve an image in some predefined sense

IMAGE ENHANCEMENT

rice grains

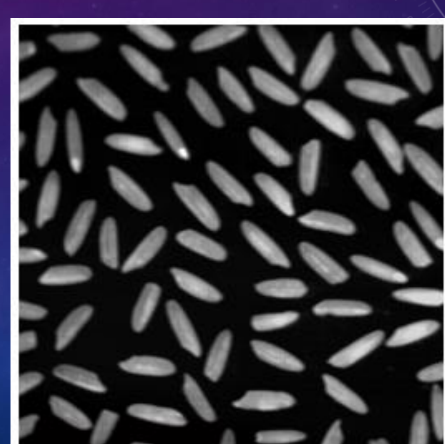

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IMAGE ENHANCEMENT

- Spatial domain processing

$$g(x,y) = T[f(x,y)]$$

  - Spatial filtering
    - E.g. image sharpening, smoothing
  - Intensity transformation
    - E.g. contrast manipulation, thresholding
- Frequency domain processing

$$f = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 5 & 2 & 3 & 3 & 8 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 10 & 0 \\ 0 & 0 & 5 & 2 & 1 & 5 & 0 & 0 \\ 0 & 3 & 4 & 0 & 7 & 6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$g(x,y) = F^{-1}\{T[F[f(x,y)]]\}$$

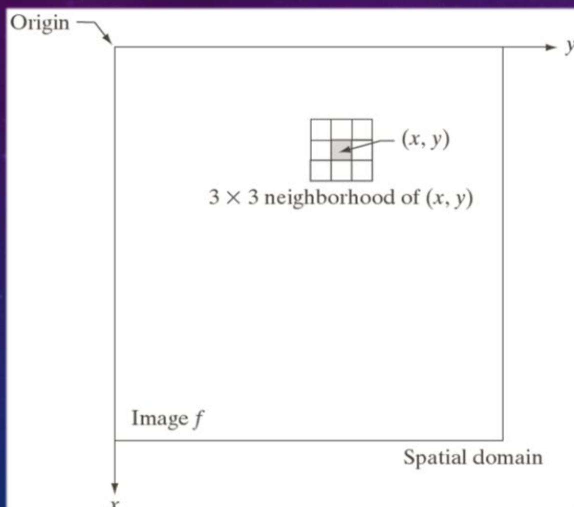
IMAGE ENHANCEMENT

- Spatial domain processing

$$g(x,y) = T[f(x,y)]$$

$$f = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 5 & 2 & 3 & 3 & 8 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 10 & 0 \\ 0 & 0 & 5 & 2 & 1 & 5 & 0 & 0 \\ 0 & 3 & 4 & 0 & 7 & 6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \longrightarrow g = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 4 & 1 & 6 & 6 & 7 & 0 \\ 0 & 0 & 0 & 2 & 2 & 2 & 9 & 0 \\ 0 & 0 & 4 & 1 & 2 & 8 & 0 & 0 \\ 0 & 9 & 6 & 0 & 4 & 8 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

IMAGE ENHANCEMENT



$$T(f) = \frac{1}{9}\sum_{s=-1}^{1}\sum_{t=-1}^{1} f(x+s, y+t)$$

$$g(x_0, y_0) = T[f(x_0, y_0)]$$

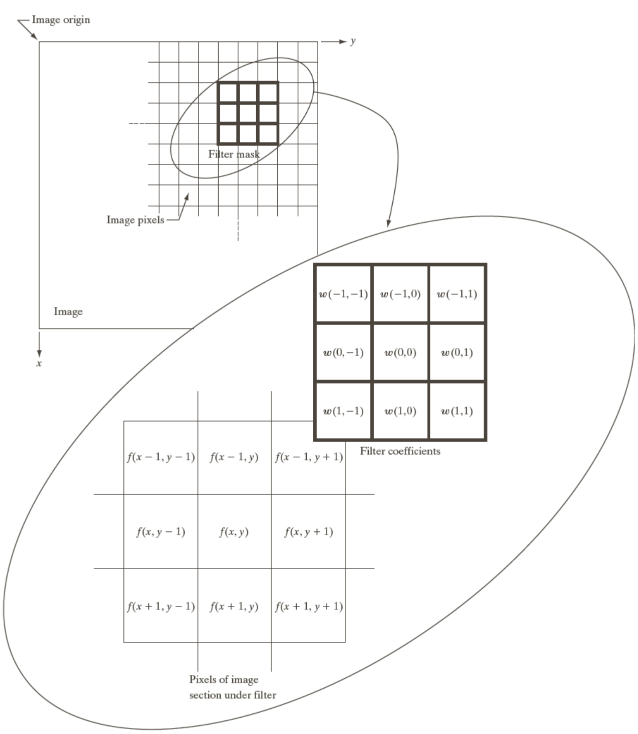


IMAGE ENHANCEMENT

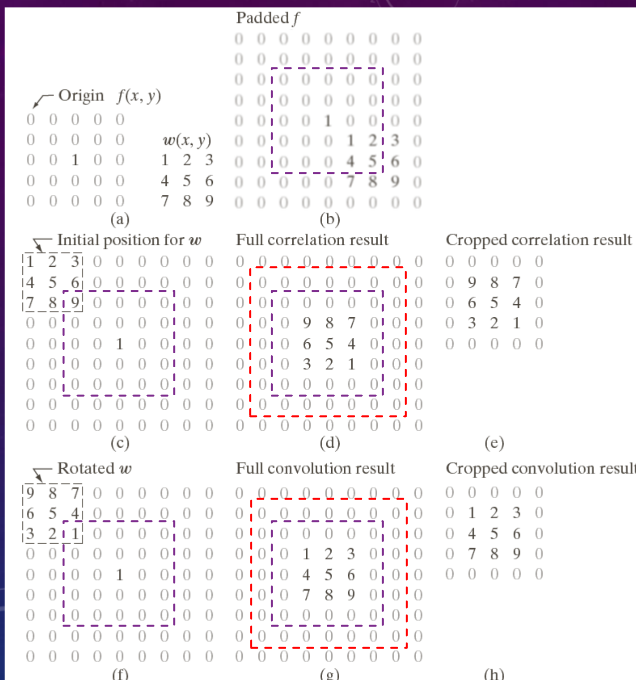
Correlation:

$$g(x, y) = \sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t) f(x+s, y+t)$$

Convolution:

$$g'(x, y) = \sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t) f(x-s, y-t)$$

IMAGE ENHANCEMENT



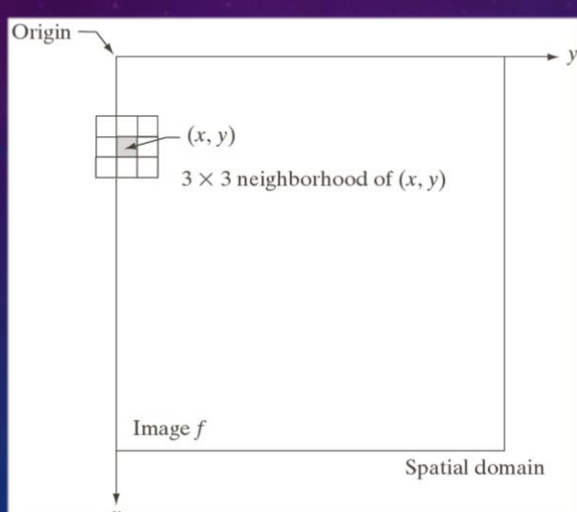
Correlation:

$$g(x,y)=\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)\,f(x+s,y+t)$$

Convolution:

$$g'(x,y)=\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)\,f(x-s,y-t)$$

IMAGE ENHANCEMENT



$$g'(x,y)=\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(-s,-t)\,f(x+s,y+t)$$

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- Question: please write down the correlation and convolution output image matrix for the given w and f:

$$g(x,y)=\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)\,f(x+s,y+t)$$

$$W=\begin{bmatrix}1&2&3\\4&5&6\\7&8&9\end{bmatrix}$$

$$f=\begin{bmatrix}0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0\\0&0&0&1&1&0&0&0\\0&0&0&2&1&0&0&0\\0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0\\0&0&0&0&0&0&0&0\end{bmatrix}$$

$$g'(x,y)=\sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)\,f(x-s,y-t)$$

IMAGE ENHANCEMENT

- Spatial domain processing

$$g(x,y)=T[f(x,y)]$$

  - Spatial filtering
    - E.g. image sharpening, smoothing
  - Intensity transformation
    - E.g. contrast manipulation, thresholding

spatial mask, kernel, template, window

$$s=T[r,n(r)]$$

$$s=T[r]$$

- Frequency domain processing

$$g(x,y)=F^{-1}\{T[F[f(x,y)]]\}$$

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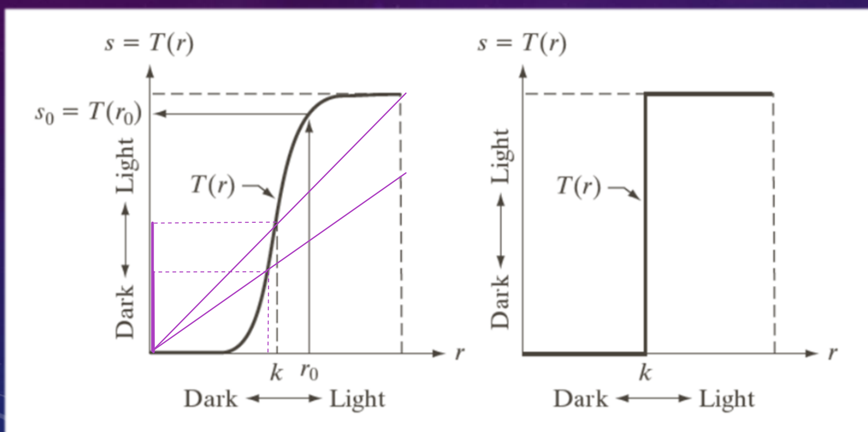
IMAGE ENHANCEMENT

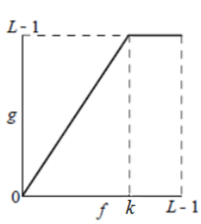


a b

FIGURE 3.2 Intensity transformation functions. (a) Contrast-stretching function. (b) Thresholding function.

IMAGE ENHANCEMENT

Q: The transformation function shown here produce an image



(A) **darkening the intensity levels below** k

(B) **darkening the intensity levels above** k

(C) **of higher contrast than the original for intensity levels below** k

(D) **of higher contrast than the original for intensity levels above** k

IMAGE ENHANCEMENT

- Spatial filtering
  - Neighborhood processing techniques

    $$g(x,y) = f(x,y) * h(x,y)$$

  - Point processing techniques

    $$g(x,y) = f(x,y) \cdot h(x,y)$$

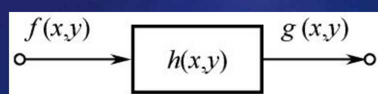
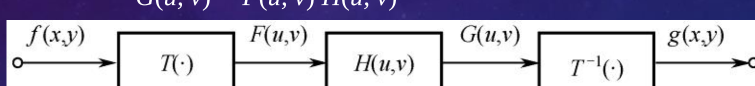


IMAGE ENHANCEMENT

- Frequency domain processing
  - 2D filter H(u,v)

    $$G(u, v) = F(u, v) \cdot H(u, v)$$



  - H(u,v) can be
    - Low-pass filter，smoothing
    - High-pass filter，sharpening

HISTOGRAM PROCESSING

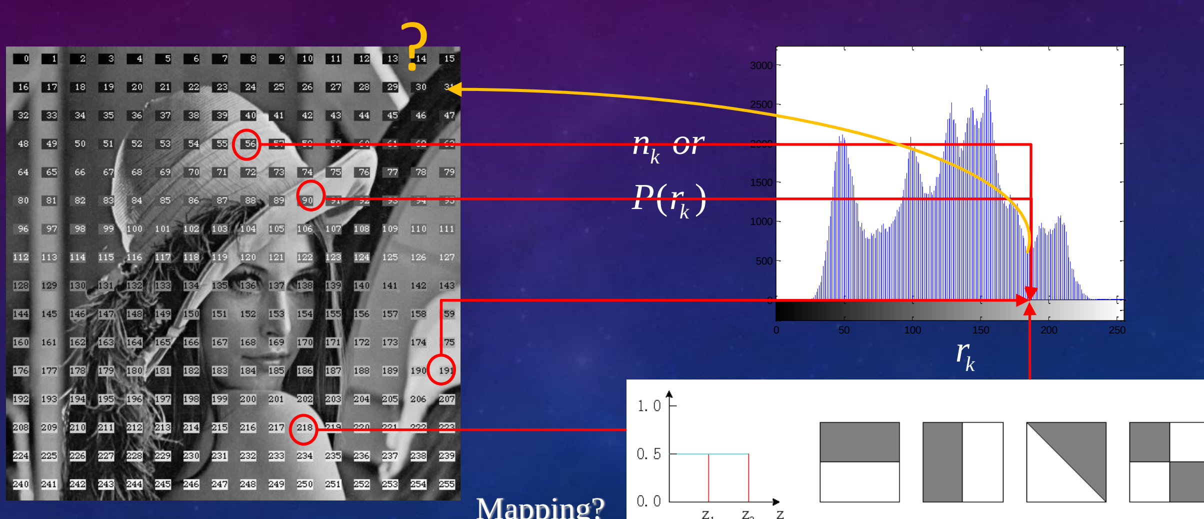
- Histogram
  - Histogram is an estimate of the probability of occurrence of each intensity level in an image
  - A normalized histogram of a $M \times N$ digital image with intensity levels in the range [0, L-1] is given by:

$$P(r_k) = \frac{n_k}{MN}, \quad k = 0, 1, \ldots, L-1$$

    - MN —— total # of pixels
    - r_k —— the kth intensity value
    - n_k —— # of pixels with intensity r_k

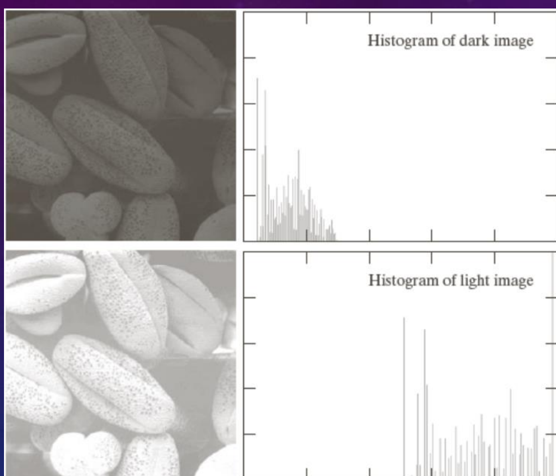
$$P(r_k) = \frac{n_k}{MN}, \quad k = 0, 1, \ldots, L-1$$

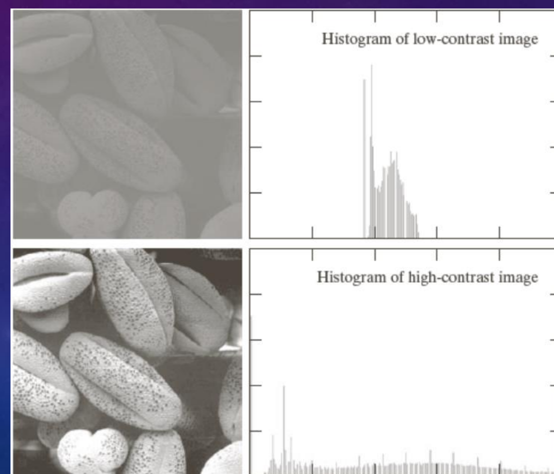
HISTOGRAM PROCESSING



Entropy熵

HISTOGRAM PROCESSING





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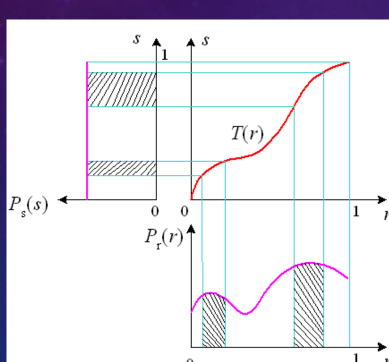
HISTOGRAM EQUALIZATION

Probability Density Function(PDF)



$s = T[r]$

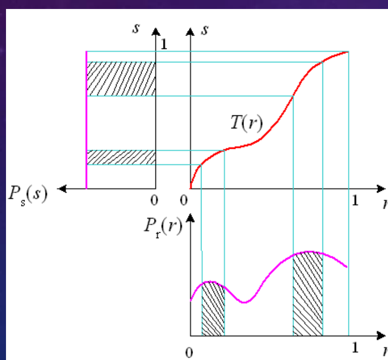
$T(r)$: Transformation function

r: Normalized intensity values

$0 \le r \le 1$

s: Output intensity levels

HISTOGRAM EQUALIZATION



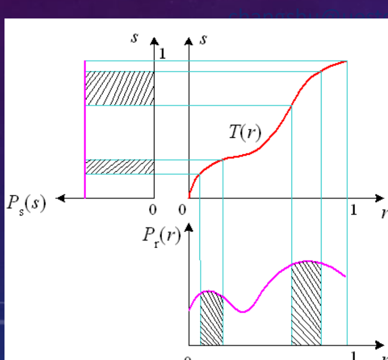
$$p_s(s) = p_r(r)\left|\frac{dr}{ds}\right| \qquad r = T^{-1}(s)$$

$$s = T(r) = \int_0^r p_r(\omega)d\omega$$

cumulative distribution function(CDF)

HISTOGRAM EQUALIZATION

definite integral



$$\frac{ds}{dr} = \frac{dT(r)}{dr} = \frac{d\left(\int_0^r p_r(\omega)d\omega\right)}{dr}$$

$$= p_r(r) - p_r(0) = p_r(r)$$

$$p_s(s) = p_r(r)\left|\frac{dr}{ds}\right| = \frac{p_r(r)}{p_r(r)} = 1 \qquad 0 \le s \le 1$$

$$s = T(r) = \int_0^r p_r(\omega)d\omega$$

HISTOGRAM EQUALIZATION

- Histogram equalization in discrete form
  - The normalized histogram of a $M\times N$ digital image with intensity levels in the range [0, L-1] is given by:

$$p_r(r_k)=\frac{n_k}{MN} \qquad 0\le r_k \le L-1, k=0,1,\ldots,L-1$$

  - The transformation(mapping) function is：

$$\underbrace{s_k=T(r_k)}_{\text{histogram equalization transformation}}=(L-1)\sum_{j=0}^{k}p_r(r_j)=(L-1)\underbrace{P_r'(k)}_{\text{CDF}}=\frac{L-1}{MN}\sum_{j=0}^{k}n_j$$