

영상의 증강 : Image Enhancement

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II. Spatial-Domain Methods

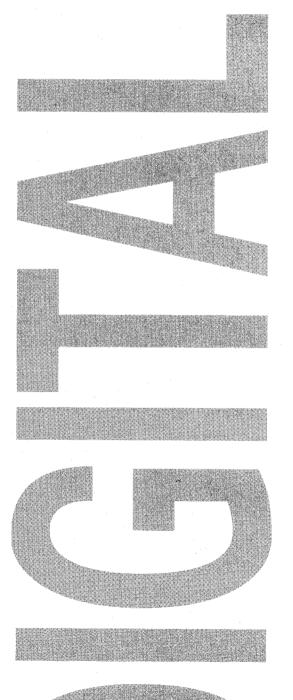
III. Frequency-Domain Methods

IV. Histogram Modification

V. Image Smoothing

VI. Image Sharpening

VII. Detection of Discontinuity and Similarity

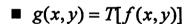


I. Introduction

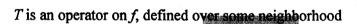
- Process a given image so that the result is more suitable than the original image for a specific application
- Enhancement techniques are very much problem-oriented
- Visual evaluation of image quality is a highly subjective process
- **Enhancement Technique**
 - 1. Spatial-domain methods (Direct manipulation of the pixels in an image)
 - 2. Frequency-domain methods (Fourier transformation)
 - 3. Global and Local Methods







where f(x,y) is the input image, g(x,y) is the processed image, and



■ Notation: Mask Operation

$$w_1$$
 w_2 w_3 w_4 w_5 w_6 w_7 w_8 w_9

'3x3 Mask:
$$\begin{bmatrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{bmatrix}$$
 Pixel Coordinates $\begin{bmatrix} (x-1,y-1) & (x-1,y) & (x-1,y+1) \\ (x,y-1) & (x,y) & (x,y+1) \\ (x+1,y-1) & (x+1,y) & (x-1,y+1) \end{bmatrix}$

$$T[f(x,y)] = w_1 f(x-1,y-1) + w_2 f(x-1,y)$$

$$+ w_3 f(x-1,y+1) + w_4 f(x,y-1)$$

$$+ w_5 f(x,y) + w_6 f(x,y+1) + w_7 f(x+1,y-1)$$

$$+ w_8 f(x+1,y) + w_9 f(x+1,y+1)$$

III. Frequency-Domain Method

■
$$g(x,y) = h(x,y) * f(x,y) \leftrightarrow G(u,v) = H(u,v)F(u,v)$$

where G, H , and F are the FT of g, h , and f

Find H(u, v) and Compute

$$g(x,y) = \mathcal{F}^{-1}[H(u,v)H(u,v)]$$

IV. Histogram Modification

■ Histogram of gray-level contents provides a global description of the appearance of an image.

1. Grav-level transformation

1x1 mask (neighborhood)

$$s = T(r)$$
 where $r = f(x,y)$ and $s = g(x,y)$

2. Histogram Equalization

- Increase the dynamic range of the pixels
- Force the resulting histogram to be uniformly distributed
- For each gray level j, the new assigned value k is given by

$$k = \sum_{i=0}^{j} N_i / T$$
 where $N_i = \sum_{f(x,y) \le j} pt(x,y)$ and T is the total number of points

V. Image Smoothing

■ Reduce noise, spurious effect, but does not get rid of them

1. Neighborhood Averaging

• $g(x,y) = \frac{1}{M} \sum_{(n,m) \in S} f(n,m)$ where S is the set of coordinates of points in the

neighborhood of the point (x,y)

Degree of blurring is strongly proportional to the size of the neighborhood

•
$$g(x,y) = \begin{cases} \frac{1}{M} \sum_{(m,n) \in S} f(m,n) & \text{if } \left| f(x,y) - \frac{1}{M} \sum_{(m,n) \in S} f(m,n) \right| < T \\ f(x,y) & \text{otherwise} \end{cases}$$

Reduce blurring by leaving unchanged regions of an image with large (compared to T) variations in gray level(may be an edge)

2. Median Filtering

- Smoothing blurs edges and other sharp details
- Replace the gray level of each pixel by the median of the gray levels in neighborhood of that pixel
- Advantage:

Effective when spikelike noise patterns are present and preserve the edge sharpness

Disadvantage:

Computationally very expensive and not good for corners of an object

3. Lowpass Filtering

 Edges and other sharp transitions (such as noise) in the gray levels of an image contribute heavily to the high-frequency contents of this Fourier Transformation

$$G(u,v) = H(u,v)F(u,v)$$
 where $F(u,v) = \mathcal{F}[f(x,y)]$
Find $G(u,v)$ and $g(x,y) = \mathcal{F}^{-1}[G(u,v)]$

a) ILPF(Ideal Lowpass Filter)

$$H(u,v) = \begin{cases} 1 & \text{if } D(u,v) \le D_o \\ 0 & \text{if } D(u,v) > D_o \end{cases}$$

ILPF causes blurring and ringing

b) Butterworth Filter

$$H(u,v) = \frac{1}{1 + [D(u,v)/D_o]^{2n}}$$

Advantage

No evident ringing effect due to smooth transition between low and high

Preserve more of the edge compared to ILPF

VI. Image Sharpening

- Highlighting edges in an image
 - Averaging(Integration) ← Differentiation
 - Gradient:

Given a function f(x,y), the gradient of f at (x,y) is defined as the vector

$$\nabla [f(x,y)] = \begin{bmatrix} \underline{\underline{\mathcal{J}}} \\ \underline{\underline{\partial}} \\ \underline{\underline{\partial}} \\ \underline{\underline{\partial}} \end{bmatrix}$$

Properties

- 1. Vector $\nabla [f(x,y)]$ points in the direction of the maximum rate of increase of the function f(x,y)
- 2. Magnitude of $\nabla [f(x,y)]$ given by $|\nabla f| = \sqrt{\left(\frac{\mathcal{J}}{\partial x}\right)^2 + \left(\frac{\mathcal{J}}{\partial y}\right)^2}$ equals the maximum rate of increase of f(x,y) per unit distance in the direction of ∇f
- Discrete Approximation of Gradient

$$f(x,y) \qquad f(x,y+1)$$

$$f(x+1,y)$$

$$\nabla [f(x,y)] \cong [f(x+1,y) - f(x,y)]\hat{i} + [f(x,y+1) - f(x,y)]\hat{j}$$

$$\cong \{ [f(x,y) - f(x+1,y)]^2 + [f(x,y) - f(x,y+1)]^2 \}^{1/2}$$

$$\cong |f(x,y) - f(x+1,y)| + |f(x,y) - f(x,y+1)|$$

- Methods for generating a gradient image g(x,y)
- 1. $g(x,y) = \nabla f$ (Smooth regions in f(x,y) appear dark in g(x,y))

2.
$$g(x,y) = \begin{cases} \nabla f & \text{if } \nabla f \ge T \\ f(x,y) & \text{otherwise} \end{cases}$$

$$= \begin{cases} L_G & \text{if } \nabla f \geq T & \text{where } L_G \text{ is specified gray level for edge} \\ f(x,y) & \text{otherwise} \end{cases}$$

$$= \begin{cases} \nabla f & \text{if } \nabla f \geq T \\ L_B & \text{otherwise} & \text{where } L_B \text{ is specified gray level for background} \end{cases}$$

Roberts' Gradient operator

$$\frac{f(x,y) \qquad f(x,y+1)}{f(x+1,y) \qquad f(x+1,y+1)} = \frac{f(x,y) - f(x+1,y+1)}{(x^2 + 1, y + 1)^2 + [f(x+1,y) - f(x,y+1)]^2} = \frac{f(x,y) - f(x+1,y+1) + [f(x+1,y) - f(x,y+1)]^2}{(x^2 + 1, y + 1) + [f(x+1,y) - f(x,y+1)]^2}$$

2. Highpass Filter

- Edges and other abrupt changes in gray levels are associated with high frequency components
- Attenuates the low frequency without disturbing high frequency
- IHPF(Ideal Highpass Filter)

$$H(u,v) = \begin{cases} 0 & \text{if } D(u,v) \le D_o \\ 1 & \text{if } D(u,v) > D_o \end{cases}$$

Butterworth Filter

$$H(u,v) = \frac{1}{1 + [D_o / D(u,v)]^{2n}}$$

VII. Detection of Discontinuity and Similarity

- Used in image segmentation
- Most important step in automated image analysis (Description and Recognition)

Notation:

$$\begin{bmatrix} w_1 & w_2 & w_3 \\ w_4 & w_5 & w_6 \\ w_7 & w_8 & w_9 \end{bmatrix} \Longrightarrow \overline{w} = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

$$\overline{w}^{t} x = w_1 x_1 + w_2 x_2 + \cdots + w_9 x_9$$
 where $x_1, \dots x_9$ are gray level

1. Point Detection

 $\left| \frac{-t}{w} \right| > T$ where T is nonnegative threshold

2. Line Detection

Horizontal

Diagonal(45 Deg)

Vertical

Diagonal(-45 Deg)

3. Edge Detection

- Isolated points and thin lines are not frequently occurrence in most practical applications
- Regions in question are sufficiently homogeneous so that the transition between two regions can be determined on the basis of gray-level discontinuities alone.
- Gradient(Sobel operator)

$$G_{x} = (x_{7} + 2x_{8} + x_{9}) - (x_{1} + 2x_{2} + x_{3})$$

$$G_{y} = (x_{3} + 2x_{6} + x_{9}) - (x_{1} + 2x_{4} + x_{7})$$

$$G_{x} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

$$G_{y} \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Advantage: Using 3x3 area has the advantage of in creased smoothing over 2x2 operator, tending to make the derivative operations less sensitive to noise

Laplacian operator

Laplacian is a second-order derivative operator defined as

$$L[f(x,y)] = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$