DIGITAL IMAGE

영상의 증강 : Image Enhancement

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DIGITAL

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

II. Spatial-Domain Methods

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

  where $f(x,y)$ is the input image,
  $g(x,y)$ is the processed image, and
  T is an operator on f, defined over some neighborhood

- **Notation**: Mask Operation

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 : $\begin{bmatrix} (x-1,y-1) & (x-1,y) & (x-1,y+1) \\ (x,y-1) & (x,y) & (x,y+1) \\ (x+1,y-1) & (x+1,y) & (x-1,y+1) \end{bmatrix}$

$$\begin{aligned} T[f(x,y)] = {} & w_1 f(x-1,y-1) + w_2 f(x-1,y) \\ & + w_3 f(x-1,y+1) + w_4 f(x,y-1) \\ & + w_5 f(x,y) + w_6 f(x,y+1) + w_7 f(x+1,y-1) \\ & + w_8 f(x+1,y) + w_9 f(x+1,y+1) \end{aligned}$$

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. Gray-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

$$k = \sum_{i=0}^{j} N_i / T \quad \text{where } N_i = \sum_{f(x,y) \le j} pt(x,y)$$ 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

$$G(u,v) = H(u,v)F(u,v) \quad \text{where} \quad F(u,v) = \mathcal{F}[f(x,y)]$$

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

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

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 $|\nabla f| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$ equals the maximum rate of increase of *f*(*x*,*y*) per unit distance in the direction of ∇f

- **Discrete Approximation of Gradient**

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

$$\begin{aligned} \nabla[f(x,y)] &\cong [f(x+1,y) - f(x,y)]\vec{i} + [f(x,y+1) - f(x,y)]\vec{j} \\ &\cong \left\{[f(x,y) - f(x+1,y)]^2 + [f(x,y) - f(x,y+1)]^2\right\}^{1/2} \\ &\cong |f(x,y) - f(x+1,y)| + |f(x,y) - f(x,y+1)| \end{aligned}$$

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

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

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

- **Roberts' Gradient operator**

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

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

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)

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

- 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:

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

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

1. Point Detection

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \qquad \vec{w}^t \vec{x} = -x_1 - \cdots - x_4 + 8x_5 - x_6 - \cdots - x_9$$

$\left|\vec{w}^t \vec{x}\right| > T$ where T is nonnegative threshold

2. Line Detection

$$\begin{bmatrix} -1 & -1 & -1 \\ 2 & 2 & 2 \\ -1 & -1 & -1 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & 2 \\ -1 & 2 & -1 \\ 2 & -1 & -1 \end{bmatrix} \quad \begin{bmatrix} -1 & 2 & -1 \\ -1 & 2 & -1 \\ -1 & 2 & -1 \end{bmatrix} \quad \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix}$$

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)

$$G_x = (x_7 + 2x_8 + x_9) - (x_1 + 2x_2 + x_3)$$
$$G_y = (x_3 + 2x_6 + x_9) - (x_1 + 2x_4 + x_7)$$

$$G_x \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad G_y \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

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

$$L[f(x,y)] = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} \qquad \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$