ECE 472/572 - Digital Image Processing

Lecture 4 - Image Enhancement - Spatial Filter

09/06/11

Roadmap

- Introduction
  - Image format (vector vs. bitmap)
  - IP vs. CV vs. CG
  - HLIP vs. LLIP
  - Image acquisition
- Perception
  - Structure of human eye
    - rods vs. conss (Scotopic vision vs. photopic vision)
    - Fovea and blind spot
    - Flexible lens (near-sighted vs. far-sighted)
  - Brightness adaptation and Discrimination
    - Weber ratio
    - Dynamic range
  - Image resolution
    - Sampling vs. quantization
- Image enhancement
  - Enhancement vs. restoration
  - Spatial domain methods
    - Point-based methods
      - Negative
      - Log transformation
      - Power-law
      - Contrast stretching
      - Gray-level slicing
      - Bit plane slicing
      - Histogram
      - Averaging
    - Mask-based (neighborhood-based) methods - spatial filter
  - Frequency domain methods

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Questions

- Smoothing vs. Sharpening filters
  - Characteristics of the masks
  - Visual effect
- Linear vs. Nonlinear smoothing filters
- Averaging vs. Weighted averaging
- Unsharp masking
- 1st vs. 2nd derivative
  - Principle
  - Design

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Spatial filtering

- Use spatial filters (masks) for linear and nonlinear image enhancement
- How to use mask?
  - 1D (the mask is 3 2 1)
  - 2D

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

mask

f_1	f_2	f_3
f_4	f_5	f_6
f_7	f_8	f_9

image

$$g_1 = z_5 f_1 + z_6 f_2 + z_8 f_4 + z_9 f_5$$

$$g_5 = \sum_{i=1}^{9} z_i f_i$$

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Spatial filters

- Purpose:
  - Blur or noise reduction
- Lowpass/Smoothing spatial filtering
  - Sum of the mask coefficients is 1
  - Visual effect: reduced noise but blurred edge as well
- Smoothing linear filters
  - Averaging filter
  - Weighted average (e.g., Gaussian)
- Smoothing nonlinear filters
  - Order statistics filters (e.g., median filter)
- Purpose
  - Highlight fine detail or enhance detail blurred
- Highpass/Sharpening spatial filter
  - Sum of the mask coefficients is 0
  - Visual effect: enhanced edges on a dark background
- High-boost filtering and unsharp masking
- Derivative filters
  - 1st
  - 2nd

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Smoothing filters

1/9 x

1	1	1
1	1	1
1	1	1

1/16

1	2	1
2	4	2
1	2	1

- Purpose:
  - Blur or noise reduction
- Smoothing linear filtering (lowpass spatial filter)
  - Neighborhood (weighted) averaging
  - Can use different size of masks
  - Sum of the mask coefficients is 1
  - Drawback:
- Order-statistic nonlinear filters
  - Response is determined by ordering the pixels contained in the image area covered by the mask
  - Median filtering
    - The gray level of each pixel is replaced by the median of its neighbor.
    - Good at denoising (salt-and-pepper noise/impulse noise)
  - Max filter
  - Min filter

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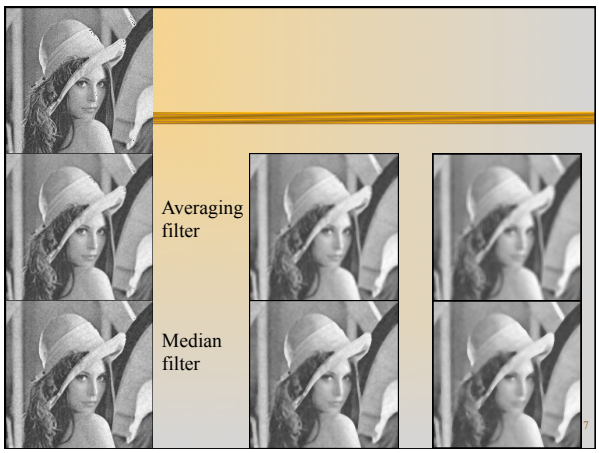

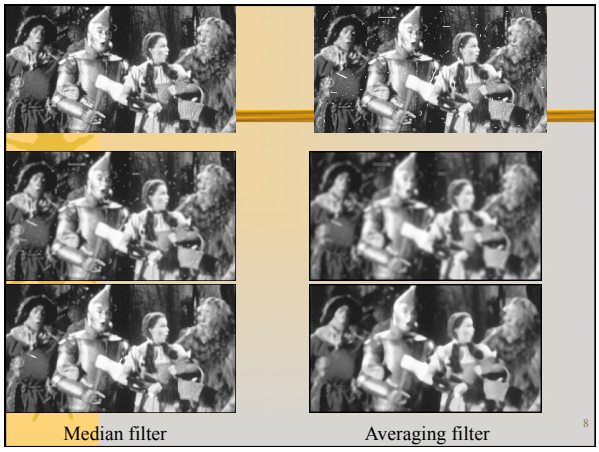

Sharpening filters

$$\frac{1}{9}\times\begin{bmatrix}-1 & -1 & -1\\ -1 & 8 & -1\\ -1 & -1 & -1\end{bmatrix}$$

- Purpose
  - Highlight fine detail or enhance detail that has been blurred
- Basic highpass spatial filter
  - Sum of the mask coefficients is 0
  - Visual effect: enhanced edges on a dark background
- Unsharp masking and High-boost filtering
- Derivatives
  - 1st derivative
  - 2nd derivative

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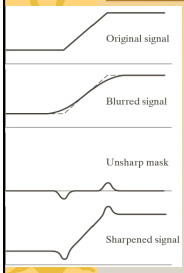
Unsharp masking and high-boost filters



- Unsharp masking
  - To generate the mask: Subtract a blurred version of the image from itself
  - Add the mask to the original

$$g_{mask}(x,y) = f(x,y) - \bar{f}(x,y)$$
$$g(x,y) = f(x,y) + k*g_{mask}(x,y)$$

- Highboost:
  - k>1
  - Application: input image is very dark

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Derivative filters

$$\nabla f = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}, \qquad |\nabla f| = \left[\left(\frac{\partial f}{\partial x} \right)^2 + \left(\frac{\partial f}{\partial y} \right)^2 \right]^{1/2}$$

$$|\nabla f| \approx \left| \frac{\partial f}{\partial x} \right| + \left| \frac{\partial f}{\partial y} \right|$$

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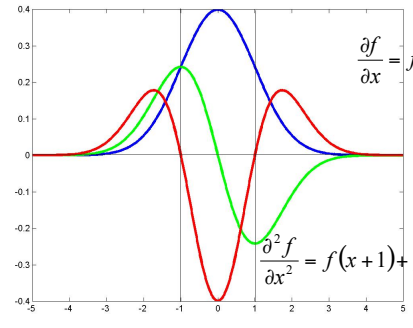
Derivative filters



$$\frac{\partial f}{\partial x} = f(x+1) - f(x)$$

$$\frac{\partial^2 f}{\partial x^2} = f(x+1) + f(x-1) - 2f(x)$$

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Filters - 1st derivative

- Roberts filter

1	0
0	-1

0	1
-1	0

- Prewitt filter

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	0	1

- Sobel filter

-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

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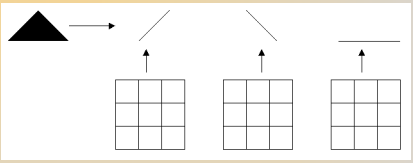
Spatial filters



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2nd Derivatives – The Laplacian

$$\partial^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

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

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

$$\partial^2 f = f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1) - 4f(x, y)$$

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The Laplacian - Masks

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

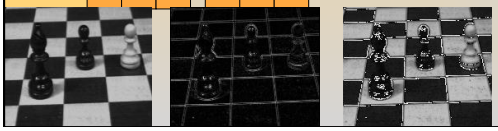
To recover the image:

$$g(x,y) = f(x,y) + \nabla^2 f(x,y)$$

0	-1	0
-1	4	-1
0	-1	0

-1	-1	-1
-1	8	1
-1	-1	-1

$$g(x,y) = f(x,y) - \nabla^2 f(x,y)$$



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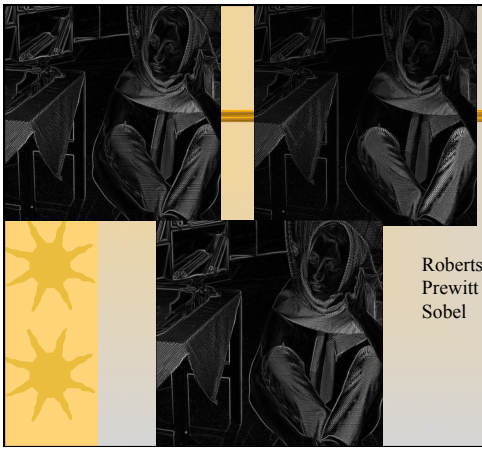

Roberts
Prewitt
Sobel

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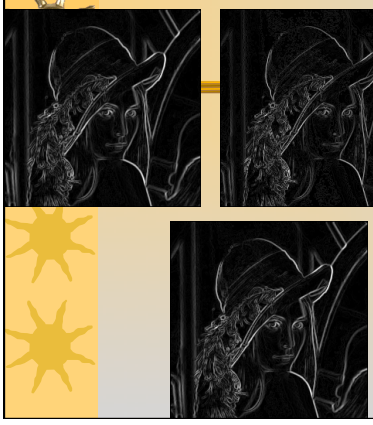

Roberts
Prewitt
Sobel

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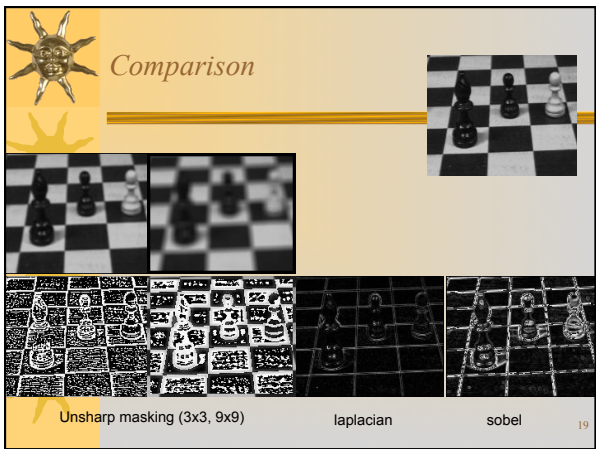
Comparison
Unsharp masking (3x3, 9x9)
laplacian
sobel
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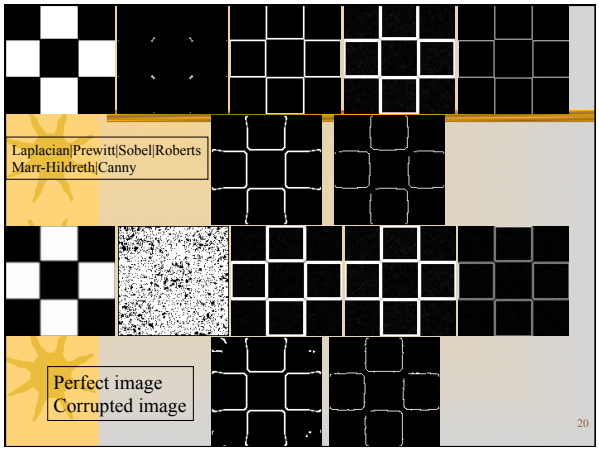
Laplacian|Prewitt|Sobel|Roberts
Marr-Hildreth|Canny
Perfect image
Corrupted image
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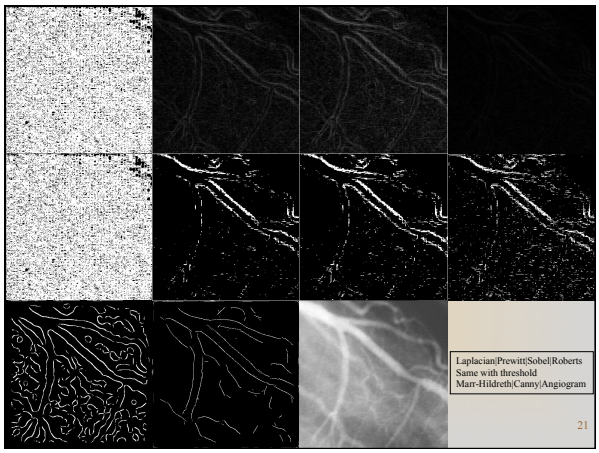
Laplacian|Prewitt|Sobel|Roberts
Same with threshold
Marr-Hildreth|Canny|Angiogram
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Example 1 - Unsharp Mask

Examples taken from http://www.2live4.com/photoshop-tips.asp

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Example 2 - Sharpening filter

Examples from http://www.mediacy.com/index.aspx?page=AH_ForensicImageEnhancement200001

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