
# Computer Vision and Image Processing (CSEL-393)

## Lecture 6

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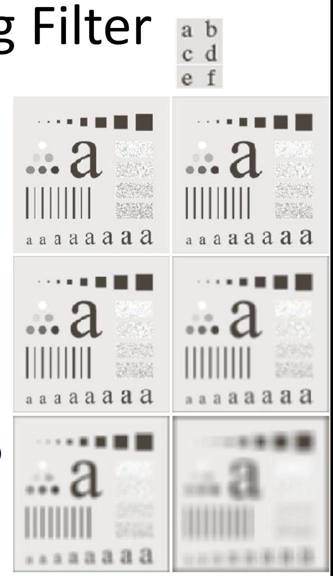
# Smoothing Spatial Filter

| | | |
|---|---|---|
| $^1/_9$ | $^1/_9$ | $^1/_9$ |
| $^1/_9$ | $^1/_9$ | $^1/_9$ |
| $^1/_9$ | $^1/_9$ | $^1/_9$ |

- One of the simplest spatial filtering operations we can perform is a smoothing operation
  - Simply average all of the pixels in a neighborhood around a central value
  - Especially useful in **removing noise from images**
  - Also useful for **highlighting overall details** of image
  - **Blur** the overall image

# Average Smoothing Filter




- (a)The image at the top left is an original image of size 500 * 500 pixels
- The subsequent images (b-f) show the image after filtering with an averaging filter of increasing sizes a 5. 9. 15 and 35
- Image gets blur as we increase size of an average filter unable to differentiate the objects

**Notice how detail begins to disappear**

## Weighted Smoothing filter

| | | |
|---|---|---|
| $^{1}/_{16}$ | $^{2}/_{16}$ | $^{1}/_{16}$ |
| $^{2}/_{16}$ | $^{4}/_{16}$ | $^{2}/_{16}$ |
| $^{1}/_{16}$ | $^{2}/_{16}$ | $^{1}/_{16}$ |

- More effective smoothing filters can be generated by allowing different pixels in the neighborhood **different weights** in the averaging function
  - We make high priority of the central pixel
  - No equal contribution works
  - Pixels closer to the central pixel are more important (giving second higher priority)
  - Referred to as a weighted averaging filter
  - Each weight is divided by sum of all weights

## Median Filter

- Write steps to apply median filter of size 3x3 on the image
- Steps:

# Median Filter

- Write steps to apply median filter of size 3x3 on the image
- Steps:

| | | | | |
|---|---|---|---|---|
| 123 | 125 | 126 | 130 | 140 |
| 122 | 124 | 126 | 127 | 135 |
| 118 | 120 | 150 | 125 | 134 |
| 119 | 115 | 119 | 123 | 133 |
| 111 | 116 | 110 | 120 | 130 |

Step1: List all pixel values surrounded by window

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 124 | 126 | 127 | 120 | 150 | 125 | 115 | 119 | 123 |

Step2: Sort All values

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 115 | 119 | 120 | 123 | 124 | 125 | 126 | 127 | 150 |

Step3: Pick middle value and replace with center pixel value

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 115 | 119 | 120 | 123 | **124** | 125 | 126 | 127 | 150 |

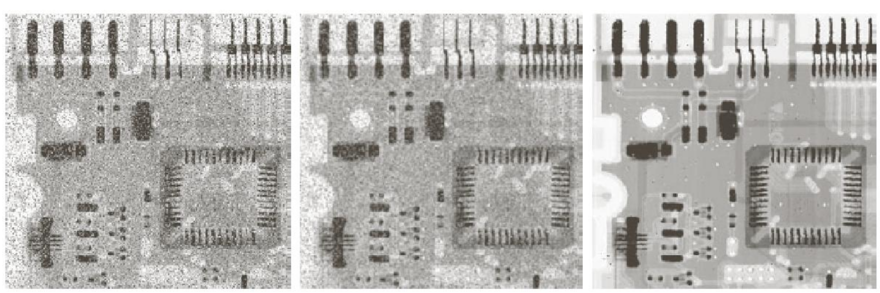
# Average Vs. Median Filter

•Median Filter is one of the most useful filter in image enhancement using spatial filter

• Provides good noise reduction for certain types of noise such as impulse noise

• Considerably less blurring than weighted averaging filter

•Forces a pixel to be like its neighbors

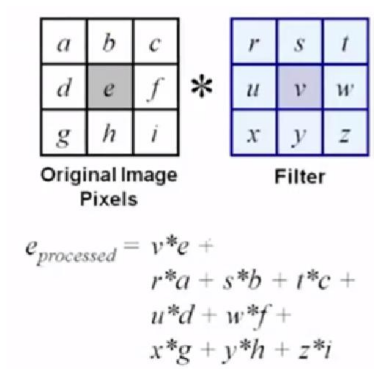


a b c

**FIGURE 3.35** (a) X-ray image of circuit board corrupted by salt-and-pepper noise. (b) Noise reduction with a 3 × 3 averaging mask. (c) Noise reduction with a 3 × 3 median filter. (Original image courtesy of Mr. Joseph E. Pascente, Lixi, Inc.)

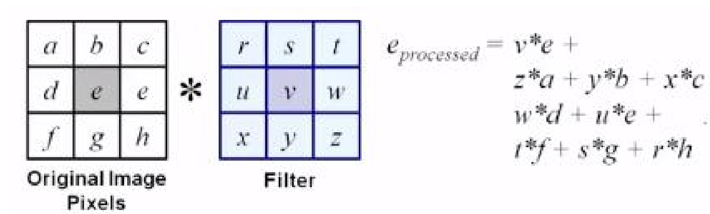
## Correlation Vs Convolution

- **Correlation:** Correlation is the process of moving a filter mask over the image and computing the sum of products at each location.




## Correlation Vs Convolution

- **Convolution:** Similar to the correlation operation but has a slight difference. In Convolution operation, the kernel is first flipped by an angle of 180 degrees and is then applied to the image.

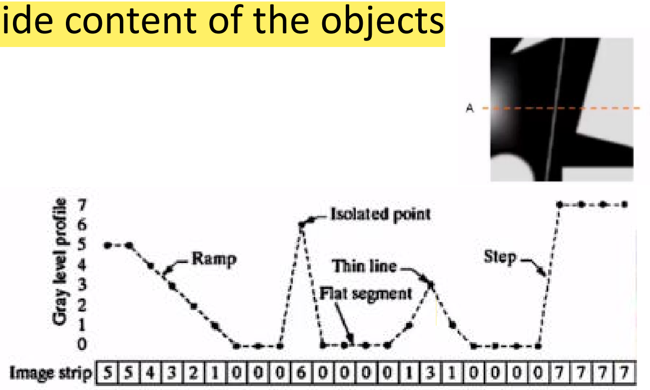


# Sharpening spatial Filters

- **Sharpening filter** highlights or enhances details of objects in images
- **Sharpening filter** enhances the quality to get clear/refined details of individual objects (either small or large)
- **Sharpening filter** removes blurring from images
- **Sharpening filter** highlights edges
- Sharpening filters are based on spatial differentiation i.e. processing the rate of change. Edge s are very effectively extracted using differentiation filters.

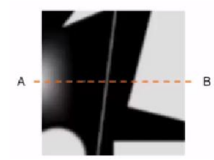
# Sharpening spatial Filters

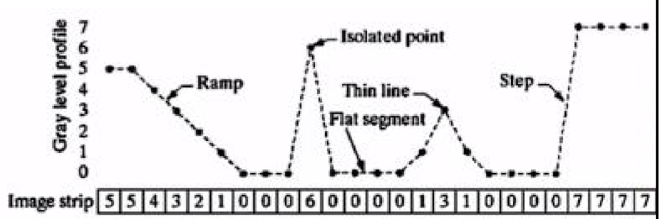
- Spatial Derivative: calculate rate of change of neighboring pixels intensities.
- Highlight inside content of the objects



# Spatial Differentiation

- 1 Dimensional Image: Lets consider the a simple 1-D example in x-direction
- Intensity levels are from 0-7
- **Terminologies**
- **Ramp**: Gradually change in intensity values
- **Isolated point:** only one pixel of black in white region or white pixel in black region
- **Thin line:** Appose to isolated point, more than one points are thin line
- **Flat Segment:** No change in the intensity values continuously for a specific period of time (either black or white)
- **Step**: Change from white to black or from black to white is called STEP



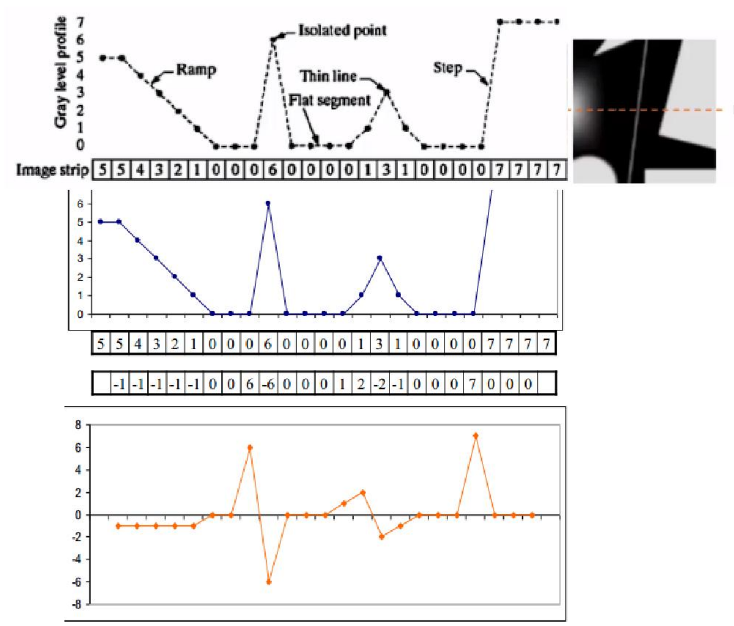

# First Order Derivative

- Rate of change
- The formula for the 1$^{st}$ derivative of a function is as follows:

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

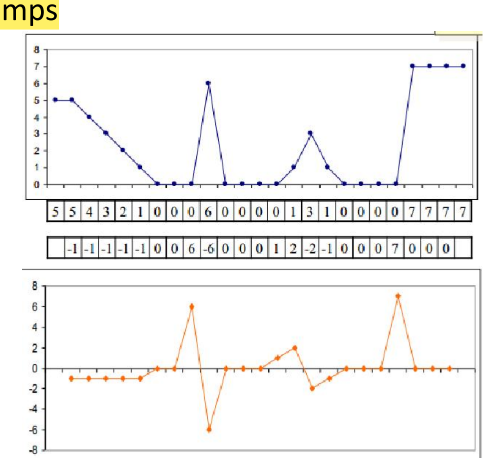
- Its just the difference between subsequent values and measures the rate of change of the function

# First Order Derivative




# 1st Derivative

- Observations
- Must be zero in flat segments(area of constant gray levels)
- Must be non-zero at the onset of a gray level step or ramp
- Must be non zero along ramps



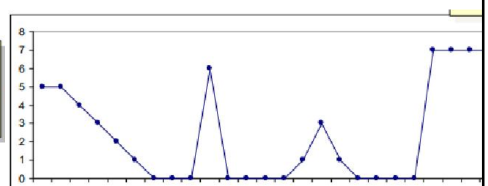
# $2^{nd}$ order derivative

- The 2nd derivative of a function is given by:

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

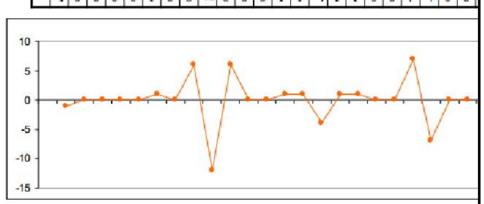
- Simply takes into account the values both before and after the current value

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



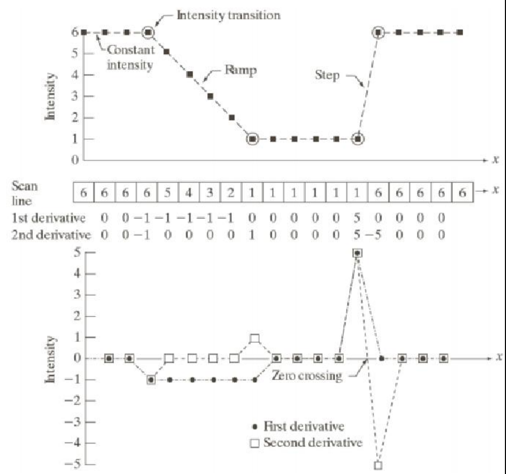
| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 5 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 7 | 7 | 7 |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -1 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | -12 | 6 | 0 | 0 | 1 | 1 | -4 | 1 | 1 | 0 | 0 | 7 | -7 | 0 | 0 |



## $2^{nd}$ Order Derivative

- Observations
  - Must be zero in flat segments
  - Must be non-zero at the onset and end of a gray level step or ramp
  - Must be non zero along ramps of constant slope




## Filters for Derivatives to sharpen the image

- **Laplacian Filter**
- Finding of derivatives with respect to both directions x and y i.e.

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

- Where partial 1st derivative in x direction is defined as $$\frac{\partial^2 f}{\partial^2 x} = f(x+1, y) + f(x-1, y) - 2f(x, y)$$

- And in y direction is defined as

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

# Laplacian Filter

- By taking sum of both directions we have

$$\nabla^2 f = [f(x+1,y)+f(x-1,y)+f(x,y+1)+f(x,y-1)]-4f(x,y)$$

- Laplacian filter can be built as

| | | |
|---|---|---|
| | x-1,y | |
| x,y-1 | x,y | x,y+1 |
| | x+1,y | |

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

# Different types of Laplacian Filters

| | | |
|---|---|---|
| 0 | 1 | 0 |
| 1 | −4 | 1 |
| 0 | 1 | 0 |

| | | |
|---|---|---|
| 1 | 1 | 1 |
| 1 | −8 | 1 |
| 1 | 1 | 1 |

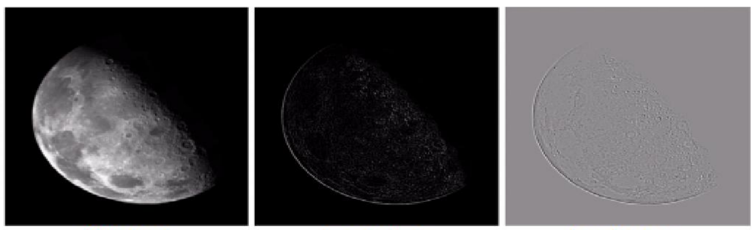
To give priority to the center pixels
and give less priority to neighboring pixels

| | | |
|---|---|---|
| 0 | −1 | 0 |
| −1 | 4 | −1 |
| 0 | −1 | 0 |

| | | |
|---|---|---|
| −1 | −1 | −1 |
| −1 | 8 | −1 |
| −1 | −1 | −1 |

# Sharpening using Laplacian Filter

- After applying Laplacian filter on an image
- The new image contains highlighted edges and discontinuities.
- However image is not giving an enhanced view

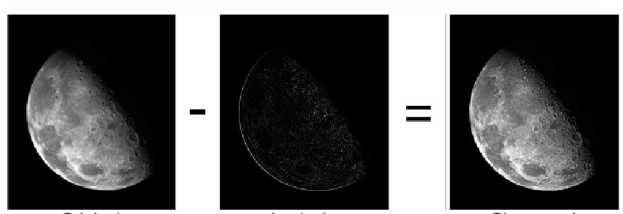


Original Image | Laplacian Filtered Image | Laplacian Filtered Image Scaled for Display

# Image Sharpening using Laplacian

- **Solution**
- Subtract the resultant image( after application of Laplacian filter) from the original Image
- Sharpe Image= Original Image- Resultant Image

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



Original Image - Laplacian Filtered Image = Sharpened Image

# Simplified Filter

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

$$= f(x,y) - [f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1) - 4f(x,y)]$$

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

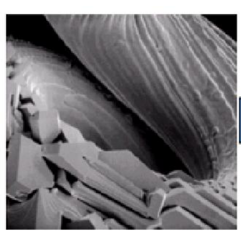
$$= 5f(x,y) - f(x+1,y) - f(x-1,y) - f(x,y+1) - f(x,y-1)$$

| | | |
|---|---|---|
| 0 | -1 | 0 |
| -1 | 5 | -1 |
| 0 | -1 | 0 |

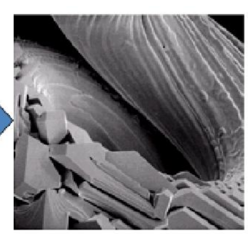
| | | |
|---|---|---|
| | x-1,y | |
| x,y-1 | x,y | x,y+1 |
| | x+1,y | |

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

# Simplified Filter



| | | |
|---|---|---|
| 0 | -1 | 0 |
| -1 | 5 | -1 |
| 0 | -1 | 0 |



## Variants of Simplified Filter

$$\begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & -8 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array} \quad \Rightarrow \quad \begin{array}{|c|c|c|}\hline -1 & -1 & -1 \\ \hline -1 & 9 & -1 \\ \hline -1 & -1 & -1 \\ \hline \end{array}$$

## UnSharp Mask and Highboost

- Steps for highboost filtering:
- sequence of linear spatial filters in order to get sharpening effect.
  1. Blur
  2. Subtract from original image img with details
  3. Add resulting mask to original image sharpened image

## Sharpening using Highboost Filtering

- Subtract from original image to produce sharp image

$$g(x,y) = f(x,y) - \bar{f}(x,y)$$

- Generalized Formula of Unsharp Masking

$$g(x,y) = Af(x,y) - \bar{f}(x,y)$$

| | | |
|---|---|---|
| 0 | −1 | 0 |
| −1 | A + 4 | −1 |
| 0 | −1 | 0 |

| | | |
|---|---|---|
| −1 | −1 | −1 |
| −1 | A + 8 | −1 |
| −1 | −1 | −1 |

## First Order Derivative

- Implementation of $1^{st}$ derivative filters is difficult in practice
- For a function *f(x,y)* the gradient of *f* at coordinates (x. y) is given as the column vector:

$$\nabla \mathrm{f} = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix}$$

# First Order Derivative

- Magnitude of this vector is defined as:

$$\nabla f = mag(\nabla f) = \left[G_x^2 + G_y^2\right]^{1/2} = \left[\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2\right]^{1/2}$$

Simplified as

$$\nabla f \approx |G_x| + |G_y|$$

| | | |
|---|---|---|
| $z_1$ | $z_2$ | $z_3$ |
| $z_4$ | $z_5$ | $z_6$ |
| $z_7$ | $z_8$ | $z_9$ |

$$\nabla f \approx |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)|$$

Using coordinate system

# Sobel operations

for edge detection

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

*Extract horizontal edges*

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

*Extract vertical edges*

Emphasize more the current point (y direction)

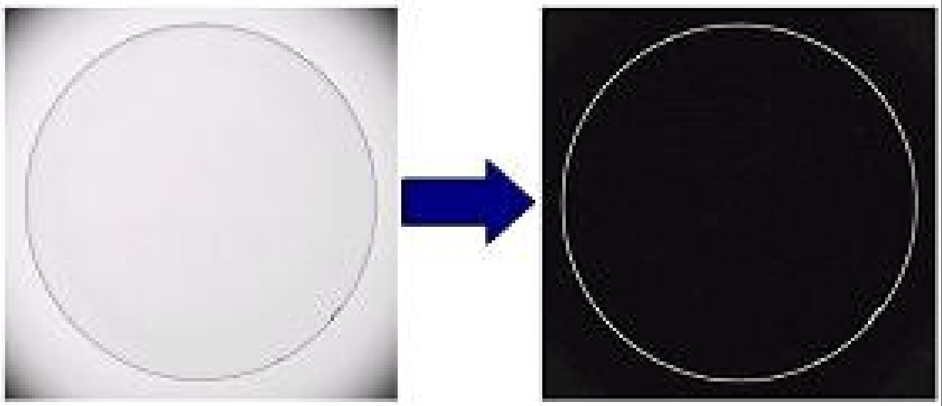
$$\nabla f \approx |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)|$$

Emphasize more the current point (x direction)

| | | |
|---|---|---|
| $z_1$ | $z_2$ | $z_3$ |
| $z_4$ | $z_5$ | $z_6$ |
| $z_7$ | $z_8$ | $z_9$ |

*Pixel Arrangement*

# Sobel operations



# Reading from book

- Chapter # 3 of book.
- Book:
- Gonzalez, R. C. and Woods, R. E., Digital Image Processing, Second Edition, Pearson-Prentice Hall, Inc., 2002. ISBN 81-7758-168-6

THANK YOU