



## **Computer Vision and Image Processing (CSEL-393)**

### **Lecture 6**

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## Smoothing Spatial Filter

- 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

$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$
$1/9$	$1/9$	$1/9$

## 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

- 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

$\frac{1}{16}$	$\frac{2}{16}$	$\frac{1}{16}$
$\frac{2}{16}$	$\frac{4}{16}$	$\frac{2}{16}$
$\frac{1}{16}$	$\frac{2}{16}$	$\frac{1}{16}$

## 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:

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
-----	-----	-----	-----	-----	-----	-----	-----	-----

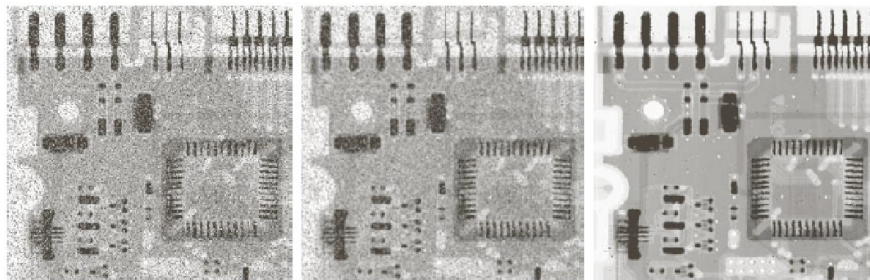
Step3: Pick middle value and replace with center pixel value

115	119	120	123	<b>124</b>	125	126	127	150
-----	-----	-----	-----	------------	-----	-----	-----	-----

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

## 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

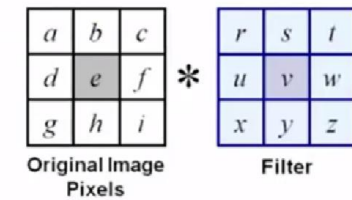


a b c

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

## Correlation Vs Convolution

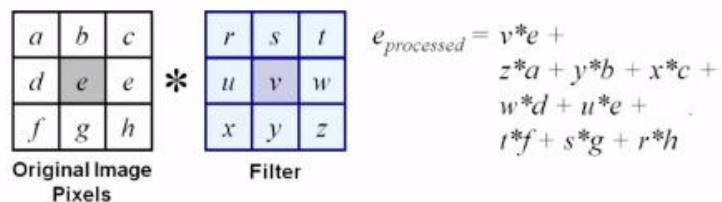
- **Correlation:** Correlation is the process of moving a filter mask over the image and computing the sum of products at each location.



$$e_{processed} = v * e + r * a + s * b + t * c + u * d + w * f + x * g + y * h + z * i$$

## 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.



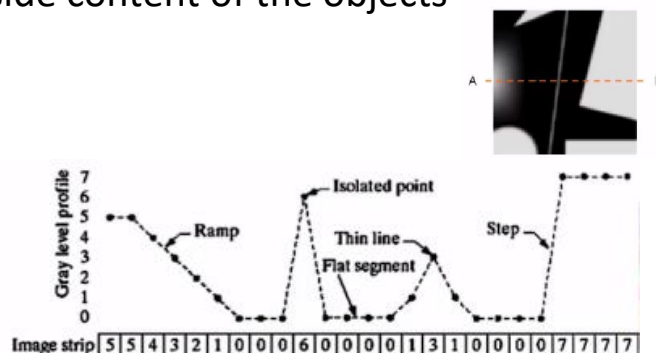
$$e_{processed} = v * e + z * a + y * b + x * c + w * d + u * e + t * f + s * g + r * h$$

## 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.

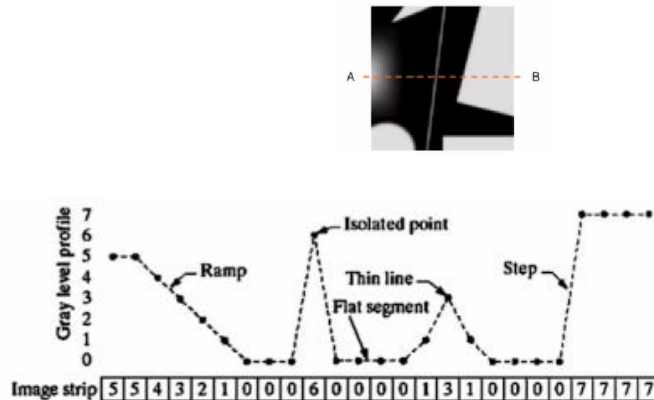
## Sharpening spatial Filters

- 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



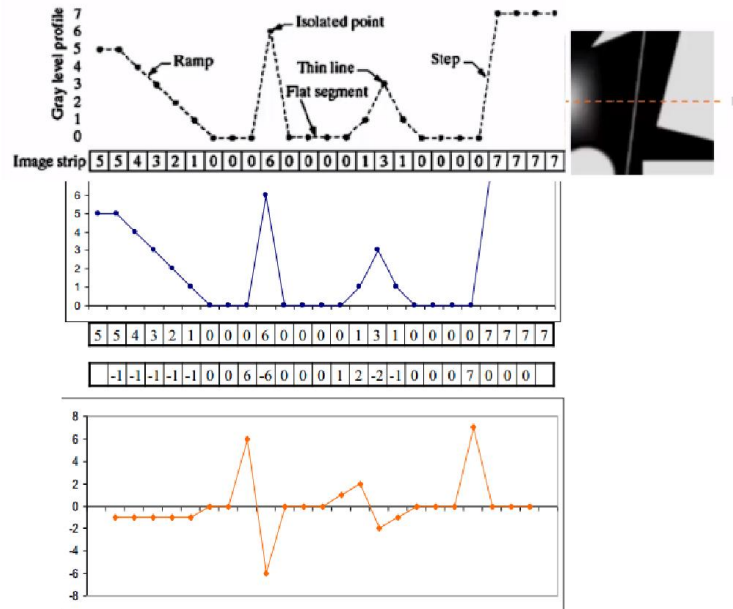
## First Order Derivative

- Rate of change
- The formula for the 1<sup>st</sup> derivative of a function is as follows:

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

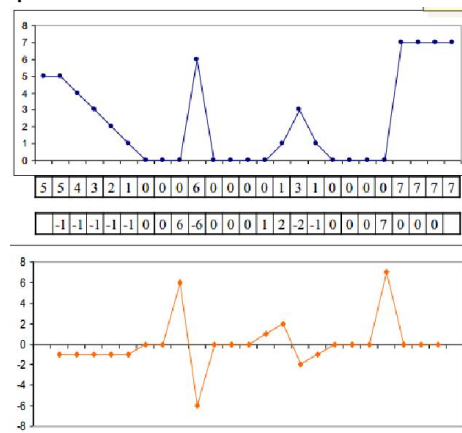
- Its just the difference between subsequent values and measures the rate of change of the function

## First Order Derivative



## 1<sup>st</sup> 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





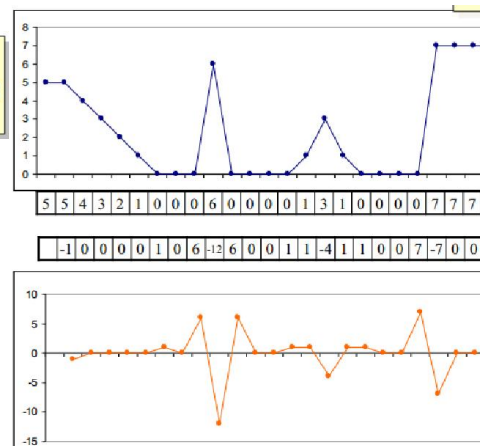
## 2<sup>nd</sup> order derivative

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

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

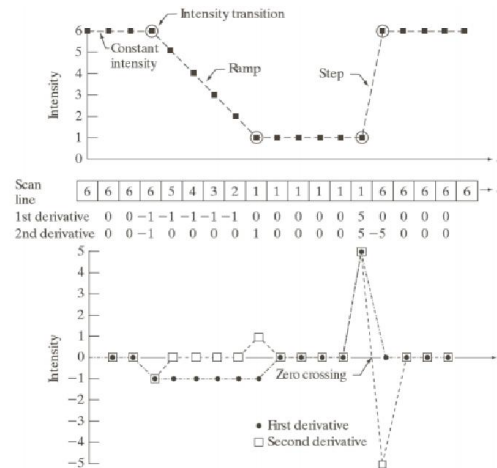
- Simply takes into account the values both before and after the current value

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



## 2<sup>nd</sup> 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 1<sup>st</sup> 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	1	1
1	-4	1	1	-8	1
0	1	0	1	1	1
0	-1	0	-1	-1	-1
-1	4	-1	-1	8	-1
0	-1	0	-1	-1	-1

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

## Sharpening using Laplacian Filter

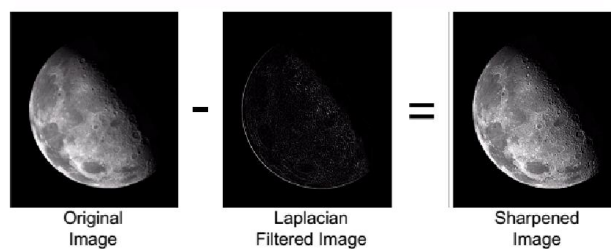
- After applying Laplacian filter on an image
- The new image contains highlighted edges and discontinuities.
- However image is not giving an enhanced view



## Image Sharpening using Laplacian

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

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



## Simplified Filter

$$\begin{aligned}
 g(x, y) &= f(x, y) - \nabla^2 f \\
 &= f(x, y) - [f(x+1, y) + f(x-1, y) \\
 &\quad + f(x, y+1) + f(x, y-1) \\
 &\quad - 4f(x, y)]
 \end{aligned}$$

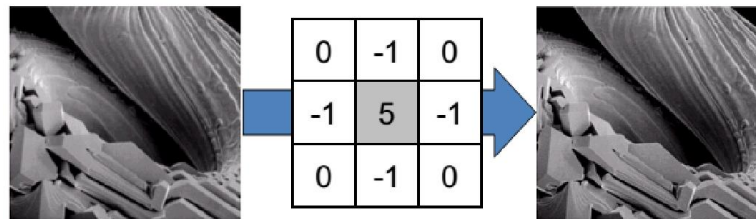
$$\begin{aligned}
 g(x, y) &= f(x, y) - \nabla^2 f \\
 &= 5f(x, y) - f(x+1, y) - f(x-1, y) \\
 &\quad - f(x, y+1) - f(x, y-1)
 \end{aligned}$$

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

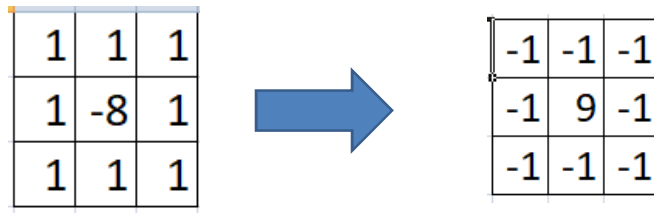
	$x-1, y$	
$x, y-1$	$x, y$	$x, y+1$
	$x+1, y$	

0	1	0
1	-4	1
0	1	0

## Simplified Filter



## Variants of Simplified Filter



## 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
  3. Add resulting mask to original 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	-1	-1
-1	$A + 4$	-1	-1	$A + 8$	-1
0	-1	0	-1	-1	-1

## First Order Derivative

- Implementation of 1<sup>st</sup> 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:

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

## First Order Derivative

- Magnitude of this vector is defined as:

$$\begin{aligned} \nabla f &= \text{mag}(\nabla f) \\ &= [G_x^2 + G_y^2]^{1/2} \\ &= \left[ \left( \frac{\partial f}{\partial x} \right)^2 + \left( \frac{\partial f}{\partial y} \right)^2 \right]^{1/2} \end{aligned} \quad \xrightarrow{\text{Simplified as}} \quad \nabla f \approx |G_x| + |G_y|$$

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

$$\begin{aligned} \nabla f &\approx |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| \\ &\quad + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)| \end{aligned}$$

Using coordinate system

## Sobel operations

<b>-1</b>	<b>-2</b>	<b>-1</b>
<b>0</b>	<b>0</b>	<b>0</b>
<b>1</b>	<b>2</b>	<b>1</b>

Extract horizontal edges

Emphasize more the current point  
(y direction)

$$\begin{aligned} \nabla f &\approx |(z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)| \\ &\quad + |(z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)| \end{aligned}$$

Emphasize more the current point (x  
direction)

<b>-1</b>	<b>0</b>	<b>1</b>
<b>-2</b>	<b>0</b>	<b>2</b>
<b>-1</b>	<b>0</b>	<b>1</b>

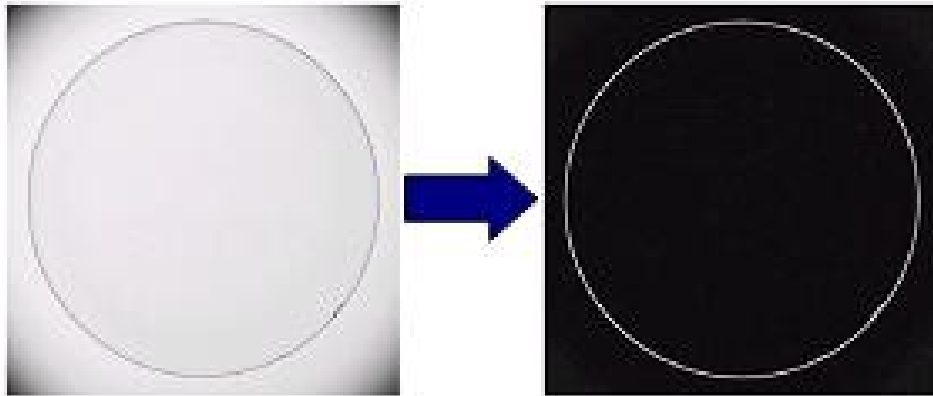
Extract vertical edges

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

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