

Edge Detection ( Turunan ke dua )

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# Using Second Derivatives for Image Enhancement

- The 2<sup>nd</sup> derivative is more useful for image enhancement than the 1<sup>st</sup> derivative
  - Stronger response to fine detail
  - Simpler implementation
  
- The first sharpening filter we will look at is the *Laplacian*
  - Isotropic
  - One of the simplest sharpening filters
  - We will look at a digital implementation

# The Laplacian

- The Laplacian is defined as follows:

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

- where the partial 1<sup>st</sup> order derivative in the  $x$  direction is defined as follows:

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

- and in the  $y$  direction as follows:

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

# The Laplacian (cont...)

- So, the Laplacian can be given as follows:

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

- We can easily build a filter based on this

0	1	0
1	-4	1
0	1	0

# The Laplacian (cont...)

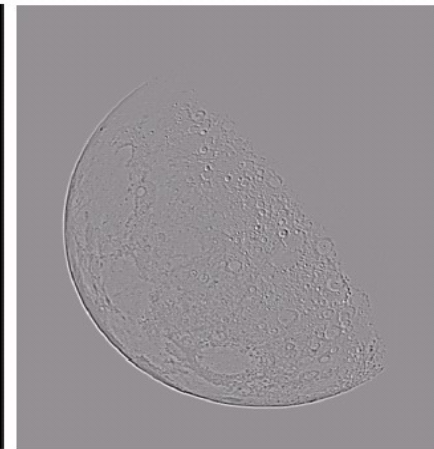
- Applying the Laplacian to an image we get a new image that highlights edges and other discontinuities



Original  
Image



Laplacian  
Filtered Image

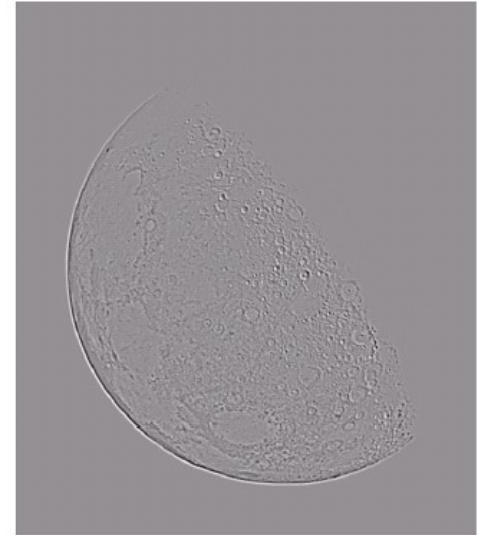


Laplacian  
Filtered Image  
Scaled for Display

# But That Is Not Very Enhanced!

- The result of a Laplacian filtering is not an enhanced image
- We have to do more work in order to get our final image
- Subtract the Laplacian result from the original image to generate our final sharpened enhanced image

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



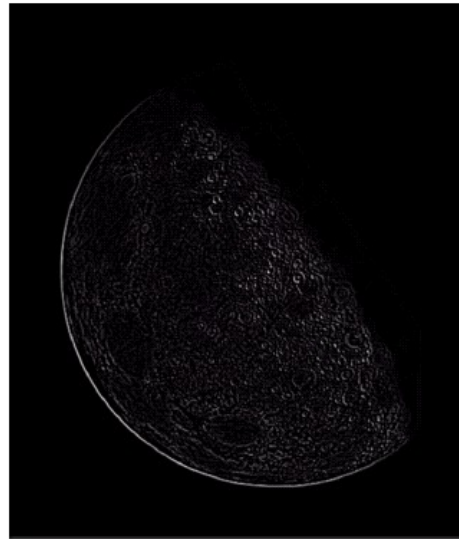
Laplacian  
Filtered Image  
Scaled for Display

# Laplacian Image Enhancement



Original  
Image

-



Laplacian  
Filtered Image

=



Sharpened  
Image

- In the final sharpened image edges and fine detail are much more obvious

# Simplified Image Enhancement

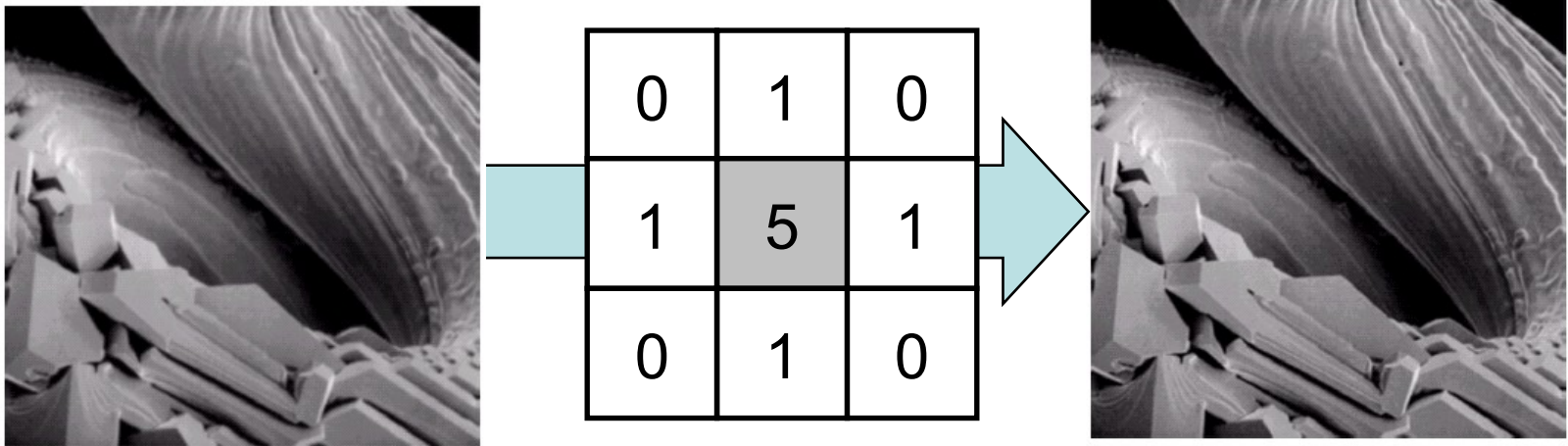
- The entire enhancement can be combined into a single filtering operation

$$\begin{aligned}g(x, y) &= f(x, y) - \nabla^2 f \\ &= f(x, y) - [f(x+1, y)f(x-1, y) \\ &\quad + f(x, y+1) + f(x, y-1)] \\ &\quad + 4f(x, y) \\ &= 5f(x, y) - [f(x+1, y)f(x-1, y) \\ &\quad + f(x, y+1) + f(x, y-1)]\end{aligned}$$



# Simplified Image Enhancement (cont...)

- This gives us a new filter which does the whole job for us in one step



# Variants on the Simple Laplacian

- There are lots of slightly different versions of the Laplacian that can be used:

0	1	0
1	-4	1
0	1	0

Simple  
Laplacian

1	1	1
1	-8	1
1	1	1

Variant of  
Laplacian

