دانشگاه
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Computer Vision

Lecture 4: Image Filtering

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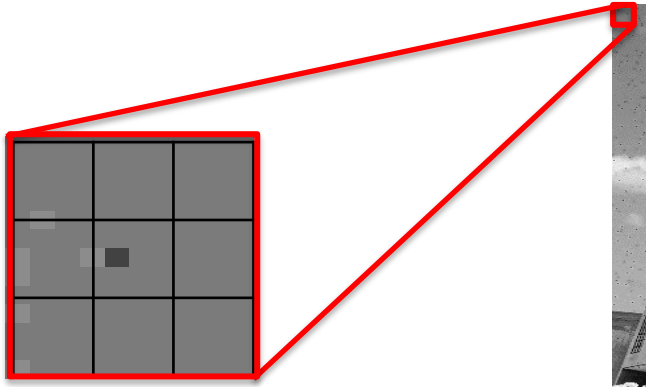
How can we reduce effect of noise on an image?

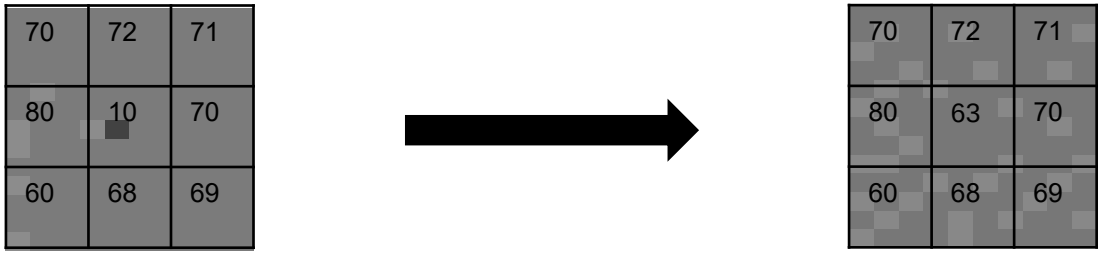
Let’s have a closer look



The pixel at the center of this small area is noisy, but the neighbors are not. So, what if we use the information from neighbors to reduce the effect of the noise?

How do we do that?

- By averaging!

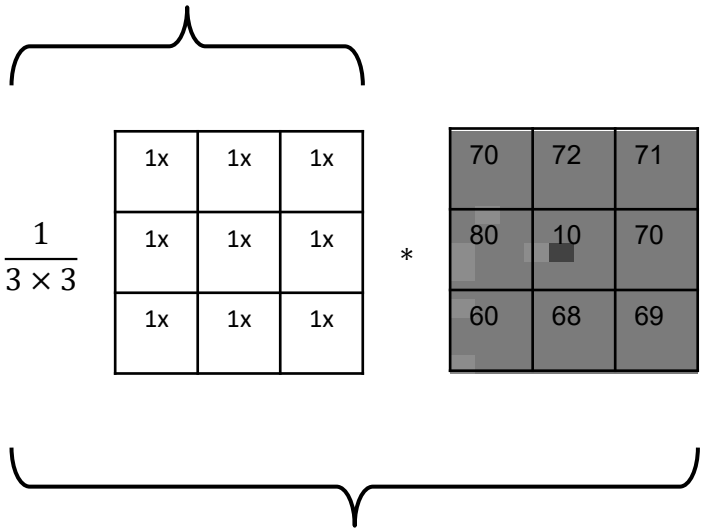


$$middle\ pixel = 10$$

$$middle\ pixel = \frac{(70 + 72 + 71 + 80 + 10 + 70 + 60 + 68 + 69)}{9} = 63$$

Convolution

Filter (also called kernel)

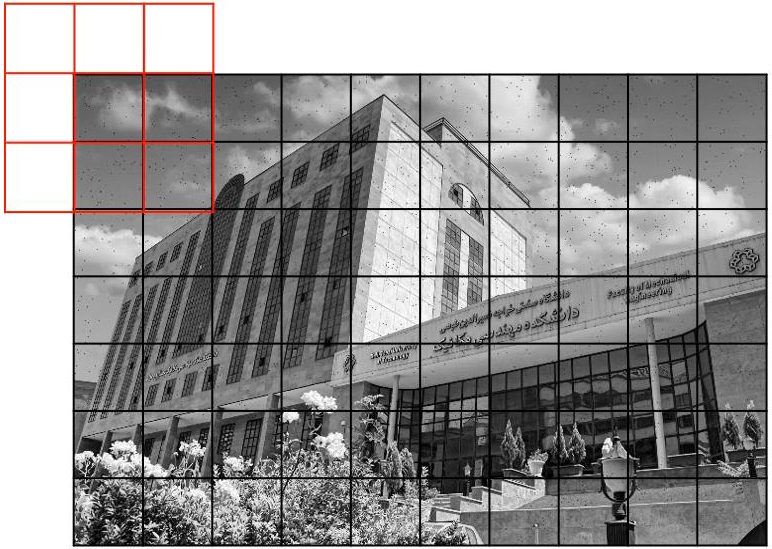


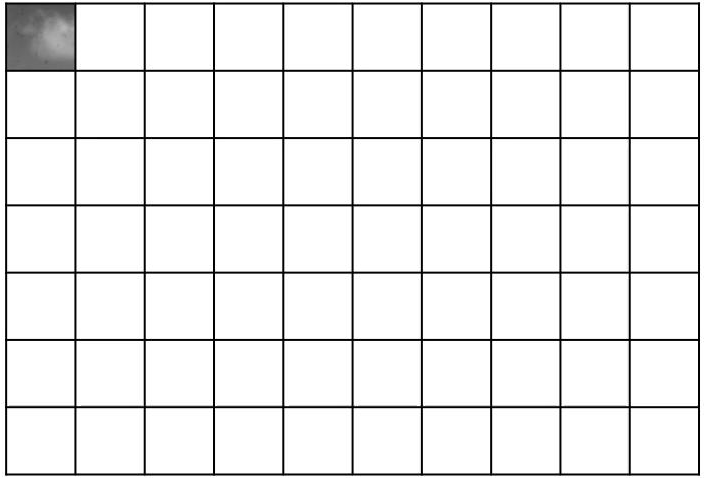
This is a linear operation.

$$= \frac{1}{9}(1 \times 70 + 1 \times 72 + 1 \times 71 + 1 \times 80 + 1 \times 10 + 1 \times 70 + 1 \times 60 + 1 \times 68 + 1 \times 69) = 63$$

The output of the convolution operation is a single number. This single number will be the new value for the middle pixel.

Filter slides across the image





When the filter is at the borders, elements outside the image can be assumed to be zero.

Convolution on the entire image

$$\frac{1}{3 \times 3}$$

1x	1x	1x
1x	1x	1x
1x	1x	1x

*

Filter Convolution Raw image

Filtered image
(Convolved with filter)

Filtered image

- Better, but still noisy!
- Let’s try bigger filters

Filtered image

- 5x5 filter

$$\frac{1}{5 \times 5}$$

1x	1x	1x	1x	1x
1x	1x	1x	1x	1x
1x	1x	1x	1x	1x
1x	1x	1x	1x	1x
1x	1x	1x	1x	1x

- Much better!

Filtered image

- 7x7 filter

$$\frac{1}{7 \times 7}$$

1x	1x	1x	1x	1x	1x	1x
1x	1x	1x	1x	1x	1x	1x
1x	1x	1x	1x	1x	1x	1x
1x	1x	1x	1x	1x	1x	1x
1x	1x	1x	1x	1x	1x	1x
1x	1x	1x	1x	1x	1x	1x
1x	1x	1x	1x	1x	1x	1x

- There is no noise, but the image looks very blurred.

This is called “box filter”

- In box filter, all elements are equal to: $\frac{1}{No.of\ elements\ in\ filter}$

$\frac{1}{3 \times 3}$

1x	1x	1x
1x	1x	1x
1x	1x	1x

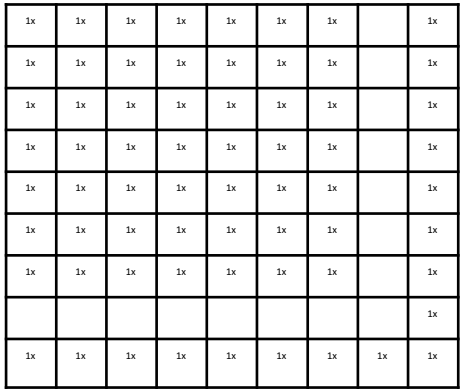
3x3 box filter

$\frac{1}{5 \times 5}$

1x	1x	1x	1x	1x
1x	1x	1x	1x	1x
1x	1x	1x	1x	1x
1x	1x	1x	1x	1x
1x	1x	1x	1x	1x

5x5 box filter

$\frac{1}{m \times n}$



m x n box filter

Box filter is also known as “Mean filter” and “Averaging”. The filter size is a design choice.

Box filters smooth image

Raw image

Filtered image

How about a color image?

- For color images, we can filter each channel separately, then merge them to get the final result

How about a color image?

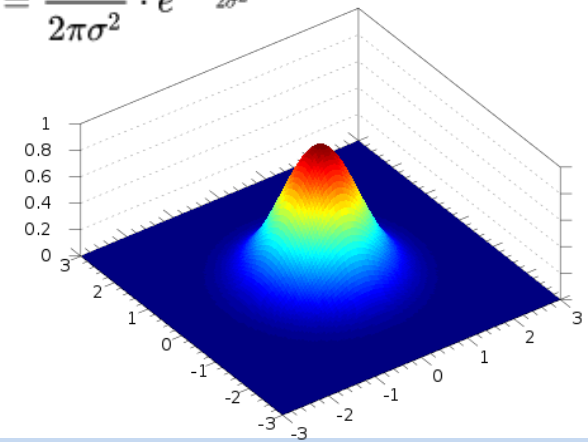
Raw image

Filtered image

Gaussian filter, a smoothly weighted filter

- 2d Gaussian filter
  - For gaussian filter, we have a formula based on a given variance.
  - Filter size is also a design choice.

$$g(x,y) = \frac{1}{2\pi\sigma^2} \cdot e^{-\frac{x^2+y^2}{2\sigma^2}}$$



$$\frac{1}{1023}$$

0	0	1	2	1	0	0
0	3	13	22	13	3	0
1	13	59	97	59	13	1
2	22	97	159	97	22	2
1	13	59	97	59	13	1
0	3	13	22	13	3	0
0	0	1	2	1	0	0

Visualized gaussian kernel. The elements in the middle have more weight than the corners; thus, we see them brighter.

2D Gaussian filter

The convolution is the same as before. This is a linear operation between the kernel and the image.

$$\frac{1}{1023}$$

0	0	1	2	1	0	0
0	3	13	22	13	3	0
1	13	59	97	59	13	1
2	22	97	159	97	22	2
1	13	59	97	59	13	1
0	3	13	22	13	3	0
0	0	1	2	1	0	0

$*$

Filter Convolution Raw image

Filtered image
(Convolved with Gaussian filter)

Gaussian filter also smoothens the image.

Guess the filter!

- What happens if we convolve the image with the given filter?

0	0	0
0	1	0
0	0	0

*

?

Filter Convolution Raw image Filtered image

Identity filter: Does nothing!

- What happens if we convolve the image with the given filter?

0	0	0
0	1	0
0	0	0

*

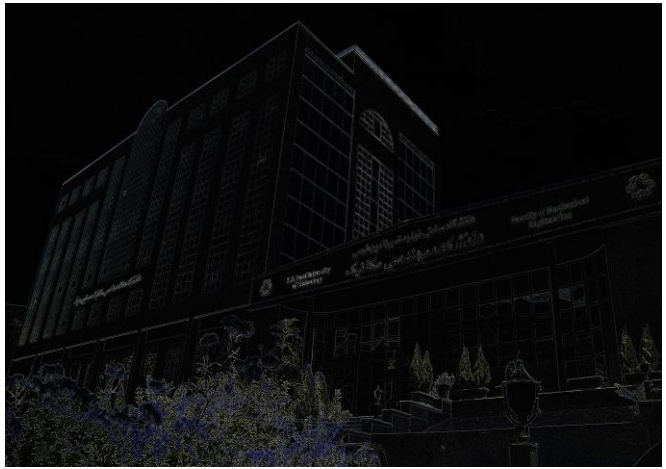
Filter Convolution Raw image Filtered image

Highpass filter: finds edges

This filter is called 2D Laplacian. It can be shown that this filter calculates the second derivative of the image.

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

*



Filter Convolution Raw image Filtered image

Sharpen filter: sharpens!

This filter is a combination of Laplacian and Identity filters.

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

*

Filter Convolution Raw image Filtered image

Emboss filter: stylin’

The artistic effect on the image is obvious!

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

*

Filter Convolution Raw image Filtered image

Sobel filters: edges and…

This is Sobel-X filter. This filter calculates the gradient of the image in X-direction.

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

*

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

This is Sobel-Y filter. This filter calculates the gradient of the image in Y-direction.

Filters

Convolution

Raw image

The Sobel-X mostly finds the vertical edges.

The Sobel-Y mostly finds the horizontal edges.

Filtered images

Sobel filters: edges and gradients

- With Sobel-X and Sobel-Y, we have the X & Y components of the gradient vector.

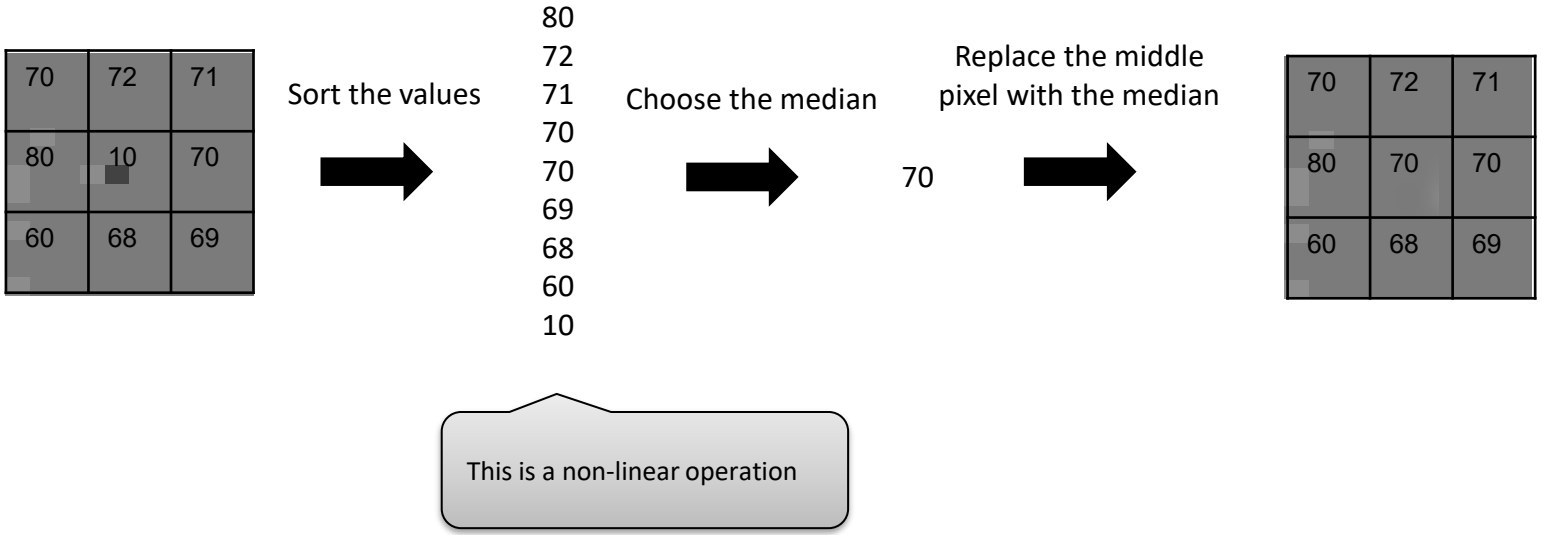
- Gradient Vector Magnitude:
  - $\sqrt{Grad_x^2 + Grad_y^2}$
  - Gradient magnitude shows location of edges in the image

- Gradient Vector Angle:
  - $Arctan2(Grad_y, Grad_x)$
  - Gradient angle shows direction of edge.

Nonlinear filters

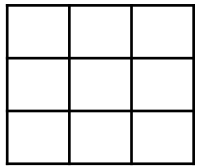
- We talked about filters and convolution operation.
- The operations done for filtering the image were linear.
- Image filtering can be non-linear.

Median filter



Median filter

- Just like linear filters, we slide the median filter on the entire image.
- This filter doesn’t have coefficients, instead we calculate the median.

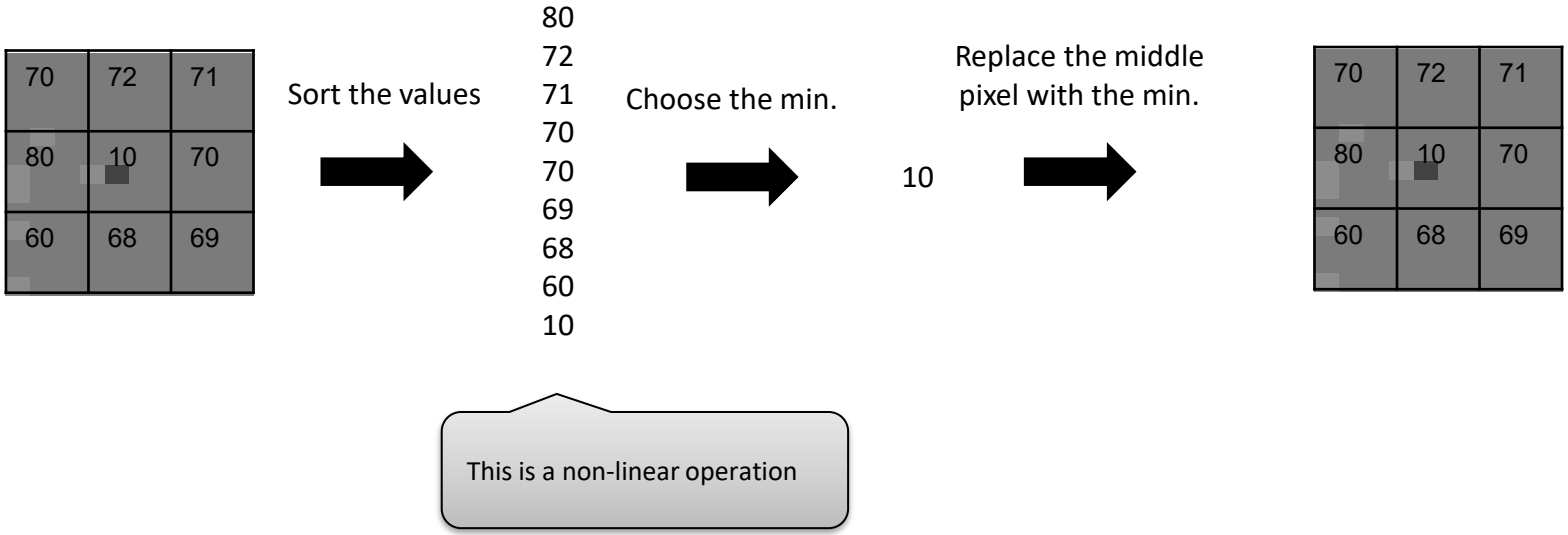


Filter

Raw image

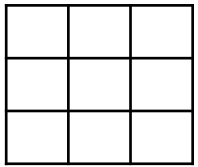
Filtered image

Erosion


70 72 71
80 10 70
60 68 69
Sort the values
80
72
71
70
70
69
68
60
10
Choose the min.
10
Replace the middle pixel with the min.
70 72 71
80 10 70
60 68 69
This is a non-linear operation

Erosion

- Erosion uses the minimum value.
- Minimum values are closer to 0 (black).

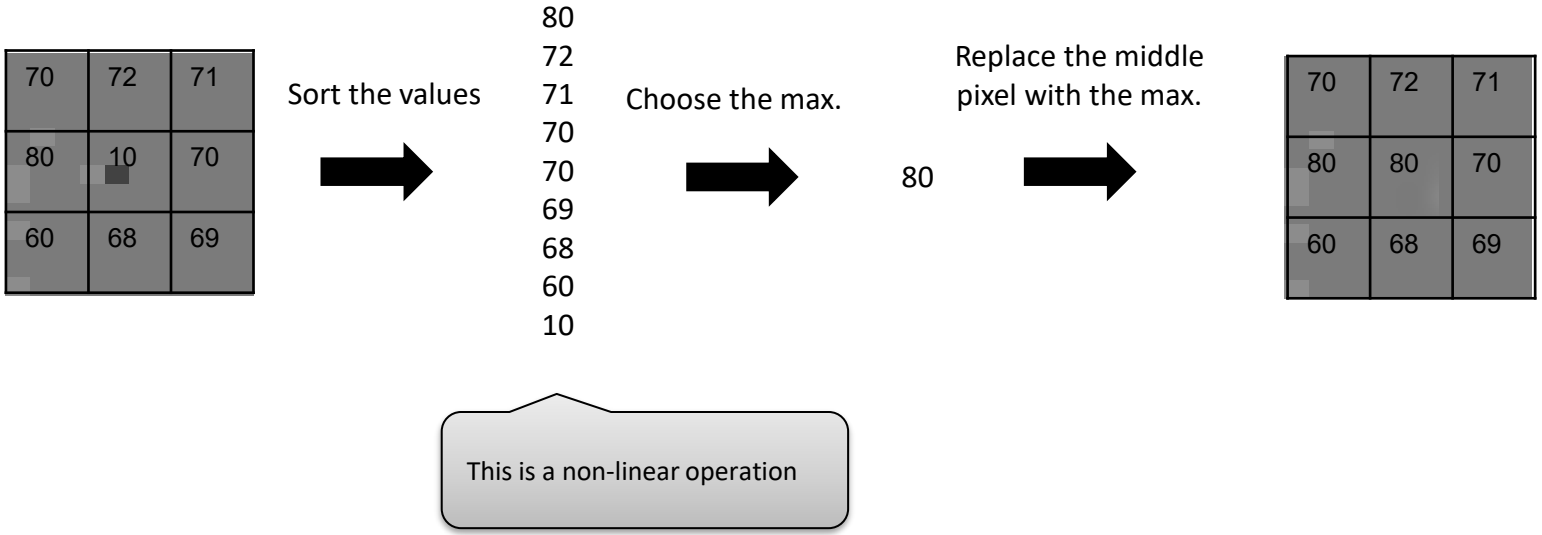


Filter

Raw image

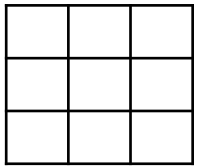
Filtered image

Dilation


70 72 71
80 10 70
60 68 69
Sort the values
80
72
71
70
70
69
68
60
10
Choose the max.
80
Replace the middle pixel with the max.
70 72 71
80 80 70
60 68 69
This is a non-linear operation

Dilation

- Dilation uses the maximum value.
- Maximum values are closer to 255 (white).



Filter

Raw image

Filtered image