Computer Image Processing

Lecture 7

Digital filters

Digital filters

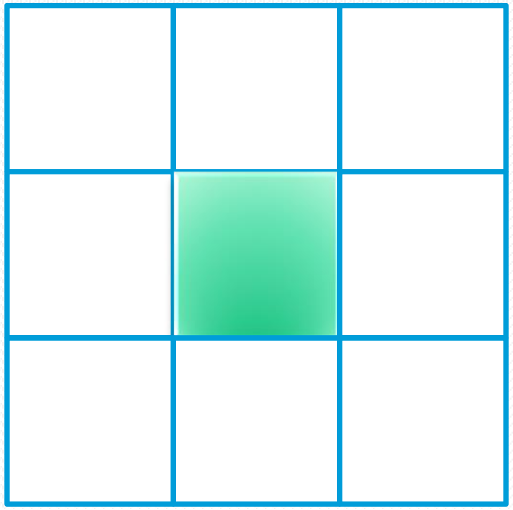
Sample goals of image filtering:

- reduction of undesirable noise,
- improving the quality of blurry images, moved or with little contrast,
- removing of specific image defects,
- strengthening certain elements of the image,
- image reconstruction in case of partial damage,
- detection of edges, corners,
- …

Digital filters

Filtering – complex, contextual transformation. Calculations are performed not only on a single pixel, but also on the pixels in the neighbourhood.

The problem with calculations appears in case of edge pixels.



Digital filters

Filter types:

- linear (filtering based on a linear combination of pixels of the source image)
- nonlinear (logical, median, minimum, maximum, adaptive).

Linear filters are usually simpler in operation, while nonlinear filters give wider possibilities.

From the mathematical point of view, the filter is a multi-argument function that transforms the source image into a new image using the "pixel by pixel" method.

Digital filters

Filter is called **linear,** if function φ fulfills following conditions:

$$\varphi(A+B)=\varphi(A)+\varphi(B)$$
$$\varphi(\alpha A)=\alpha\varphi(A)$$

where
$\alpha > 0$
A, B – filtered images

Digital filters

In the image analysis, the brightness function is two-dimensional and discrete. It is called **discrete convolution**, having the form:

$$J_o(x, y) = \sum_{i,j \in K} J(x - i, y - j) w(i, j)$$

where

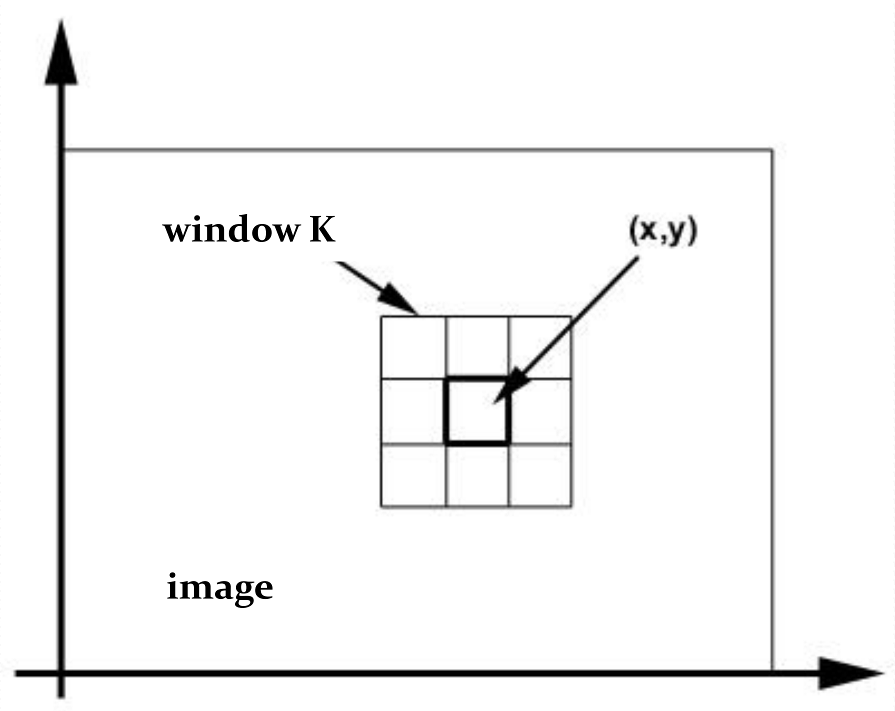
K – neighbourhood of given pixel

$w(i, j)$ – weights of neighbouring pixels (x, y)

Digital filters

Filter – array (kernel, mask, matrix) of the coefficients $w(i, j)$.

Due to the simplicity and speed of calculations, integer coefficients are usually used.



Digital filters

If

$\sum w(i,j) = 1$ image brightness remains unchanged

$\sum w(i,j) > 1$ brightening of the image

$\sum w(i,j) < 1$ darkening of the image

In most kernels, the sum of the coefficients is 0 or 1.

Digital filters

If the sum of coefficients exceeds 1 it is necessary to apply normalization of brightness so that the obtained results are reduced to the range of available brightness levels.

$$J_o(x,y) = \frac{\sum_{i,j \in K} J(x-i, y-j) w(i,j)}{\sum_{i,j \in K} w(i,j)}$$

The formula is used only for positive coefficients.

Digital filters

Convolution matrix (kernel)

1	1	1
1	1	1
1	1	1

24	35	16	21	42	65
25	30	14	13	28	11
47	51	16	14	39	10
67	82	73	78	91	65
78	35	21	17	19	25

(16+21+42+14+13+28+
+16+14+39)/9≈22,56≈23

24	35	16	21	42	65
25	30	14	23		

Digital filters

Convolution matrix (kernel)

1	1	1
1	1	1
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24	35	16	21	42	65
25	30	14	13	28	11
47	51	16	14	39	10
67	82	73	78	91	65
78	35	21	17	19	25

(21+42+65+13+28+11+
+14+39+10)/9=27

24	35	16	21	42	65
25	30	14	23	27	

Digital filters

If there are negative coefficients, negative values of the brightness attribute may appear in the resulting image.

This problem can be remedied in several ways:

- by cutting the values at the level of acceptable minimum,
- using the absolute value of the new brightness value,
- using normalization.

Digital filters

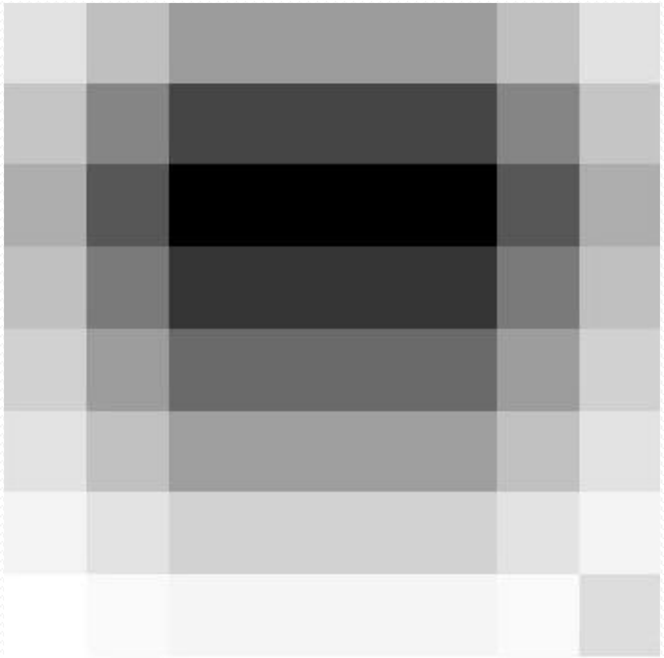
Coefficients for individual pixels from the neighbourhood of the point *(x, y)* can be chosen basically freely by the filter designer.
Due to the need to place the point *(x, y)* centrally, kernels with an odd number of pixels are usually used. The larger the size of the neighbourhood (K), the clearer the effect of the filter.
Kernels with a 3 x 3 size are used usually.

w_1	w_2	w_3
w_4	w_5	w_6
w_7	w_8	w_9

Digital filters

Problem with edge pixels

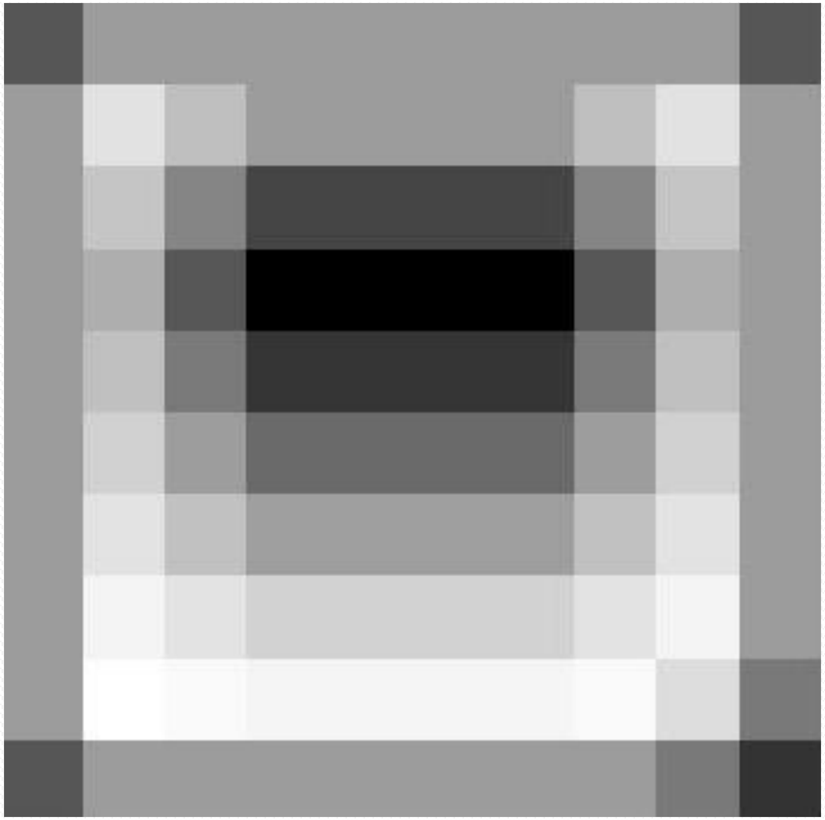
„valid" method



Digital filters

Problem with edge pixels

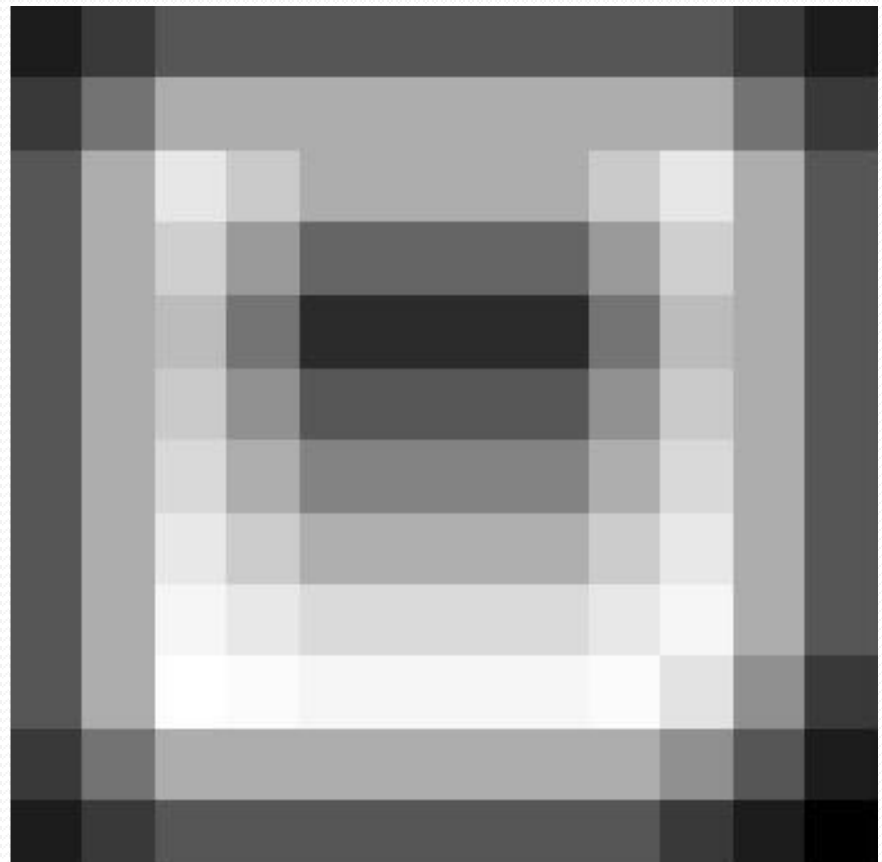
„same" method



Digital filters

Problem with edge pixels

„full” method



Lowpass filters

The lowpass filter suppresses the components of the spectrum at a higher frequency, leaving the lower frequency components unchanged.

Applications:

- reduction of noise and disruptions,
- smoothing of minor edge whirls,
- removing the effects of "waving" the brightness of objects and background.

Disadvantage:

- reducing the sharpness and clarity of the image.

Lowpass filters

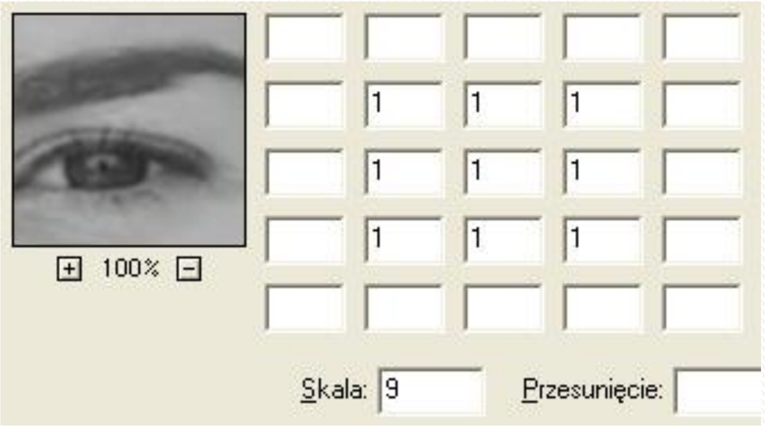
Source image

Image after lowpass filtering

Lowpass filters

Filter kernel

Calculation of new pixel values is performed according to the formula:



$$J_o(x,y) = \frac{1}{w}\sum_{i,j\in K} J(x-i, y-j)$$

where $w = 9$

Lowpass filters

The reduction of the blur effect can be achieved by using filters with a higher central point coefficient. The original brightness value of the pixel has a greater impact on the resulting image then.

1	1	1
1	a	1
1	1	1

$w = 8 + a,\quad a = 0, 1, 2, 4, 12$

1	b	1
b	b^2	b
1	b	1

$w = (b+2)^2 \quad b = 0, 1, 2, 4$

Lowpass filters

Source image

Image after Gauss filtering

Lowpass filters

Image after lowpass filtering

Image after Gauss filtering

Lowpass filters

Gauss filter with the coefficient $b = 3$

The brightness normality w factor is the sum of 'shares' from all pixels.

Lowpass filters

Averaging filter with the 5 x 5 kernel

Lowpass filters

3 x 3 kernel

5 x 5 kernel

Highpass filters

High pass filters are used primarily to enhance the high frequency details that occur in the image. However, they suppress parts of the low frequency image.

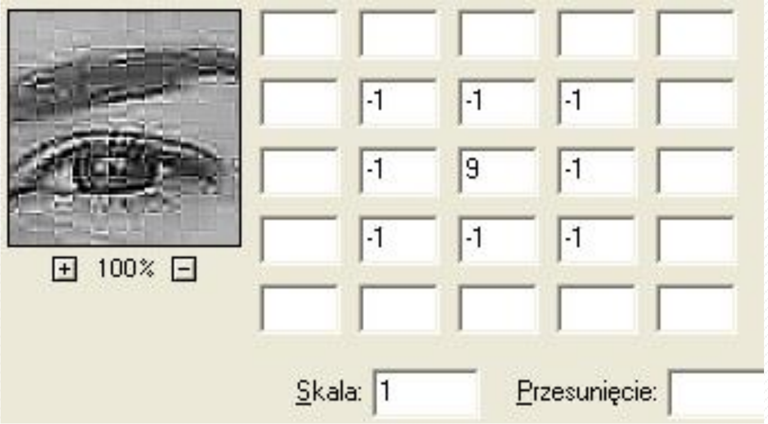
Applications:

- increasing the sharpness of the image,
- highlight elements characterized by fast change of brightness (edges, contours, contrasting textures)

Disadvantage:

- enhancement of noise.

Highpass filters



Sharpening filter

Enhancement filter

Its goal is to make the image looks like a relief.